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Sampling and Analysis Plan for a Study of Lakes and Reservoirs with Low Concentrations of Contaminants in Sport Fish

May 2014

FINAL

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The Bioaccumulation Oversight Group (BOG)

Surface Water Ambient Monitoring Program

May 2014

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Bioaccumulation Oversight Group (BOG) Members
>   Terry Fleming, USEPA
>   Rich Fadness, Region 1 Water Board
>   Karen Taberski, Region 2 Water Board
>   Karen Worcester, Region 3 Water Board
>   Michael Lyons, Region 4 Water Board
>   Chris Foe, Region 5 Water Board
>   Stephen Louie, Region 5 Water Board
>   Tom Suk, Region 6 Water Board
>   Jeff Geraci, Region 7 Water Board
>   Chad Loflen, Region 9 Water Board
>   Lori Webber, State Water Board
>   Jennifer Salisbury, State Water Board
>   Jon Marshack, State Water Board
>   Bob Brodberg, OEHHA
>   Margy Gassel, OEHHA
>   Lori Lim, OEHHA
>   Tom Maurer, USFWS
>   Jay Davis, SFEI
>   Autumn Bonnema, MLML
>   Cassandra Lamerdin, MLML
>   Stacey Swenson, MLML
>   Gail Cho, CDFW
>   Gary Ichikawa, CDFW
>   Billy Jakl, MLML
>   Dylan Service, MLML
>   Steven Martenuk, MLML
>   Marco Sigala, MLML
>   Eric von der Geest, MLML

SWAMP Bioaccumulation Peer Review Panel
>   Jim Wiener, University of Wisconsin, La Crosse
>   Chris Schmitt, USGS, Columbia, Missouri
>   Harry Ohlendorf, CH2M Hill, Sacramento, CA

I.   INTRODUCTION

This document presents a plan for sampling and analysis of sport fish in a one-year effort to identify California lakes and reservoirs with low concentrations of contaminants in sport fish. This work will be performed as part of the State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP).

Oversight for this Project is being provided by the SWAMP Roundtable. The Roundtable is composed of State and Regional Water Board staff and representatives from other agencies and organizations including USEPA, the California Department of Fish and Wildlife, the California Office of Environmental Health Hazard Assessment, and the University of California. Interested parties, including members of other agencies, consultants, and other stakeholders are also welcome to participate.

The Roundtable has formed a subcommittee, the Bioaccumulation Oversight Group (BOG), which focuses on bioaccumulation monitoring. The BOG is composed of State and Regional Water Board staff and representatives from other agencies and organizations including USEPA, the Department of Fish and Wildlife, the Office of Environmental Health Hazard Assessment, and the San Francisco Estuary Institute. The members of the BOG individually and collectively possess extensive experience with bioaccumulation monitoring.

The BOG has also convened a Bioaccumulation Peer Review Panel that is providing programmatic evaluation and review of specific deliverables emanating from the Project, including this Sampling Plan. The members of the Panel are internationally recognized authorities on bioaccumulation monitoring.

The BOG was formed and began developing a strategy for designing and implementing a statewide bioaccumulation monitoring program in September 2006. To date the efforts of the BOG have included a two-year screening survey of bioaccumulation in sport fish of California lakes and reservoirs (2007 and 2008), a two-year screening survey of the California coast (2009 and 2010), a one-year survey of California rivers and streams (2011), and a two-year study of mercury accumulation in grebes on California lakes and reservoirs (2012-2013). Final reports on the sport fish surveys are available (Davis et al. 2010; Davis et al. 2012; Davis et al. 2013; http://www.mywaterquality.ca.gov/monitoring_council/bioaccumulation_oversight_group/#mpr).

II.   GENERAL ASPECTS OF THE SWAMP BIOACCUMULATION MONITORING PROGRAM

A.   Addressing Multiple Monitoring Objectives and Assessment Questions for the Fishing Beneficial Use

The BOG has developed a set of monitoring objectives and assessment questions for a statewide program evaluating the impacts of bioaccumulation (Table 1). This assessment framework is consistent with the frameworks developed for other components of SWAMP, and is intended to guide the bioaccumulation monitoring program over the long term. The four objectives can be summarized as 1) status; 2) trends; 3) sources and pathways; and 4) effectiveness of management actions.

Over the long term, the primary emphasis of the statewide bioaccumulation monitoring program will be on evaluating status and trends. Bioaccumulation monitoring is a very effective and essential tool for evaluating status, and is the most cost-effective tool for evaluating trends for many contaminants. Monitoring status and trends in bioaccumulation will provide information useful for identifying sources and pathways and for evaluating the effectiveness of management actions at a broader geographic scale. However, other types of monitoring (i.e., water and sediment monitoring) and other programs (regional TMDL programs) are also needed for addressing sources and pathways and effectiveness of management actions.

This workplan describes an effort to refine the characterization of the status of lakes and reservoirs with regard to impairment due to bioaccumulation. SWAMP surveys to date have focused on identifying water bodies with elevated concentrations of bioaccumulative contaminants so that managers could develop strategies for addressing problem areas. In contrast, this survey will aim to provide information on another facet of status: identification of lakes and reservoirs with relatively low levels of contamination. This information will be useful to managers in their efforts to protect these relatively high quality ecosystems and to replicate these conditions in other water bodies. The information will also be valuable to the fishing public, drawing attention to water bodies where beneficial uses can be enjoyed with reduced exposure to bioaccumulative contaminants.

III.   DESIGN OF THE CLEAN LAKES STUDY

A.   Management Questions for this Study

Three management questions (one primary question, and two secondary questions) have been articulated to guide the design of this study. The primary question is the main driver of the sampling design. The secondary questions will be addressed to the extent possible with the resources available for the study, after assuring that the primary question is appropriately addressed.

Management Question 1 (MQ1)

Which popular lakes in California can be confirmed to have relatively low concentrations of contaminants in sport fish?

Answering this question will address the critical need of managers and the public to know which water bodies can be considered relatively clean. With this information, the fishing public can be directed to water bodies where they can enjoy the benefits of fishing and fish consumption and have reduced exposure to contaminants.

The data needed to answer this question are repeated observations of low concentrations of all contaminants of concern (including methylmercury, PCBs, legacy pesticides, and selenium) in the species with the greatest tendency to accumulate high concentrations. For methylmercury, top predators such as black bass tend to accumulate relatively high concentrations. High-lipid, bottom-feeding species such as catfish, carp, and sucker have the greatest tendency to accumulate relatively high concentrations of organic contaminants of concern (PCBs and legacy pesticides). Selenium also biomagnifies primarily through accumulation in muscle, but past monitoring in the San Joaquin Valley (Beckon et al. 2010) suggests that bottom-feeders accumulate slightly higher concentrations. Measuring low concentrations of contaminants in both of these types of indicator species provides compelling evidence that a water body has a low overall degree of contamination. Given the variance associated with contaminant concentrations, the evidence becomes even more compelling if the low concentrations are observed on more than one occasion. This higher level of confidence obtained through repeated observation of low concentrations in both types of indicator species is desirable to be assured of providing reliable information to the public to guide their decisions on where to fish.

In some water bodies, it is not feasible to obtain both types of indicator species because they are not present in high enough abundance. Lakes at higher elevations with colder water where trout species predominate are a common example. For these lakes, repeated observation of the species that do occur there and are most likely to have high concentrations is the best basis that can be obtained for characterizing a lake as one with relatively low concentrations.

Management Question 2 (MQ2)

Why do some lakes have relatively low concentrations of methylmercury in sport fish?

A statewide control program for methylmercury is being developed by the State Water Resources Control Board: (http://www.waterboards.ca.gov/water_issues/programs/mercury/). Understanding the conditions associated with low concentrations of food web methylmercury is valuable to managers in their efforts to reduce concentrations in waters that are impaired. Supplemental measurements may provide valuable information on factors that drive methylmercury accumulation in lake food webs. Supplemental parameters that are expected to be very informative, based on data analysis conducted in support of the TMDL, include: mercury and selenium in prey fish; total mercury, methylmercury, sulfate, DOC, and chlorophyll in water; and total mercury and organic carbon in sediment.

Management Question 3 (MQ3)

Did the 2007-8 survey accurately characterize the status of lakes in which only rainbow trout were collected?

Many of the lakes found to have low concentrations of contaminants in the 2007-8 survey were lakes where only rainbow trout were collected. Rainbow trout generally had low concentrations of methylmercury, with a statewide average of 0.05 ppm. Concentrations of organics in trout were also generally low. To some degree, this was due to lower concentrations of contaminants in these lakes, but other factors also likely played a role. Trout generally occupy a lower trophic position and accumulate lower concentrations of methylmercury and other pollutants than black bass. However, a factor that probably contributed to lower observed concentrations in trout is that, in many lakes, recently planted hatchery fish are part of the catch. A previous study found that hatchery trout consistently had very low concentrations of methylmercury (rainbow trout from four hatcheries all had less than 0.023 ppm – Grenier et al. 2007).

With the level of effort that could be expended in the statewide survey of 2007-8 it is possible that other resident species with a potential to have higher concentrations were missed, such as resident populations of trout or small populations of warmwater predators like black bass or bottom feeders like sucker. With the greater effort planned for the present study, it is anticipated that information will be obtained that will allow for some evaluation of the accuracy of the 2007-8 assessment for lakes where only one species was obtained.

B. **Overall Approach**

The overall approach to be taken to answer these three questions is to re-sample a select subset of lakes that were identified as having relatively low concentrations of contaminants in the 2007-8 survey. The same basic design used in the 2007-8 survey will be repeated, as the goal is to obtain confirmation of the earlier results.

C. **Coordination**

The BOG is coordinating with other efforts to significantly leverage the funds for this survey and achieve a more thorough evaluation of California lakes with relatively low levels of contamination. These coordinated efforts are adding approximately $169,000 worth of work to the BOG funds available for sampling and analysis in this study ($240,000).

The Colorado River Basin Regional Water Quality Control Board (Region 7) will be conducting a survey of contaminants in sport fish in Region 7 lakes this summer. Region 7 has a relatively large proportion of lakes that meet the criteria for having low concentrations, including 10 of the 16 lakes that will be sampled in the Region. Resources for this statewide effort will be pooled with Region 7 resources to allow a more thorough and definitive assessment of the lakes in this region. The data from the Region 7 effort will be processed and reported along with the data from the statewide effort.

The Los Angeles Regional Water Quality Control Board (Region 4) will partner to expand this study in their region. Region 4 is covering the cost of all of the work in their region, including an extra lake (Castaic Lake) to complement sampling of Castaic Lagoon.

The San Diego Regional Water Quality Control Board (Region 9) is planning a study of cyanotoxins in reservoirs for this summer. One of the lakes to be sampled in that effort (Lake Henshaw) is also a candidate for inclusion in this study. If Lake Henshaw is selected for this study, the work will be coordinated with the cyanotoxin study. Effort will be made to collect Lake Henshaw at a similar time the other lakes from the Region 9 study are being collected.

Several U.S. Geological Survey (USGS) research labs are partnering with this study as an opportunity to provide improved understanding of mercury cycling in the western US. The USGS Wisconsin Water Science Center's Mercury Research Team will partner with SWAMP on this study by performing chemical analysis of water and sediment samples for total mercury, methylmercury, and related parameters. The MRT operates one of the premier mercury labs in the country, and frequently contributes to mercury studies at regional and national scales.

The Corvallis Research Group of the USGS Forest and Rangeland Ecosystem Science Center in Corvallis OR will partner with SWAMP on this study by performing chemical analysis of small fish samples for total mercury.

The Water Resources Division of USGS in Menlo Park CA will partner with SWAMP on this study by performing chemical analysis of small fish samples for selenium. They will also be analyzing mercury and selenium in sport fish livers from select lakes.

In addition, the Department of Fish and Wildlife will provide assistance in collecting fish from the Tahoe Keys.

D.   Selection of Lakes to Be Sampled

The pool of lakes considered for sampling consisted primarily of those included in the 2007-8 SWAMP lakes survey, with the addition of a few others sampled from 2002-2012 for which data were placed in the California Environmental Data Exchange Network (CEDEN), a centralized repository of data on California's water bodies, including streams, lakes, rivers, and the coastal ocean.

Selection of the lakes to sample in this study was not straightforward because few lakes meet all of the standards that are under consideration for California use in assessing impairment for the purpose of 303(d) listing. Ideally, it would be good to avoid classifying a lake as having low concentrations and having that same lake appear on the 303(d) list of impaired waters. 303(d) listing determinations are based on the proportion of samples available that exceed the relevant threshold. When more than 10% of the samples exceed the threshold, the water body is classified as impaired.

The state is in the process of developing a statewide tissue objective for mercury that is anticipated to be 0.2 ppm wet weight (all concentrations mentioned in this document are presented on a wet weight basis). This threshold will be used for the next round of listing. Through BOG discussion, the 0.2 ppm objective and listing threshold was selected as the criterion for classifying lakes as having relatively low concentrations of mercury. To be confident that a lake truly has fish mercury concentrations below 0.2 ppm, it is desirable to have measured concentrations in species such as black bass that are known to accumulate high concentrations.

The California Office of Environmental Health Hazard Assessment (OEHHA) has established two sets of thresholds - fish contaminant goals and advisory tissue levels - that are relevant as selection criteria for lakes to be included in this study (Klasing and Brodberg [2008], Table 2). Fish contaminant goals (FCGs) are health protective values for lifetime exposure and consider only the toxicity of the contaminants. They were developed by OEHHA to assist other agencies to establish fish tissue-based criteria for cleanup. For the two main chemicals of concern in this study, the FCGs are 0.22 ppm for mercury and 3.6 ppb for PCBs. The FCG for mercury (0.22 ppm) is of the same

magnitude as the statewide tissue objective of 0.2 ppm, based only on toxicity and one serving per week of consumption. FCGs are being used by the Water Boards in the latest round of 303(d) listing determinations.

Advisory Tissue Levels (ATLs) consider both the toxicity of contaminants and the health benefits of fish consumption. They are used to develop sport fish consumption advice for the public. OEHHA has developed ATL ranges for one to seven servings per week. A comparison of the same consumption frequency (one serving per week), shows that, for mercury, the low end of the ATL range (150 to 440 ppb) for the sensitive population (children and women of child-bearing age) encompasses the statewide tissue objective (200 ppb).   For PCBs, the low end of the ATL range (21 ppb) for a 2 servings per week consumption rate was also considered as a lake selection criterion.

For organics, given their use in 303(d) listing determinations, the FCGs are a relevant benchmark to use in assessing the degree of contamination. To be confident that a lake truly has organics concentrations below FCGs, it is desirable to have measured concentrations in species such as catfish, carp, or sucker that are known to accumulate high concentrations.

Only five lakes met these criteria for both mercury and organics, qualifying for Tier 1 of the list of candidate lakes for the study (Tables 3-5, Figure 1).

Given this outcome, slightly less stringent criteria were considered.

Since the FCGs for organics are much lower than the ATLs used to develop advisories, and OEHHA's advisories are the most important means of communicating information on fish contamination to the public, the use of the lowest ATLs for organics was considered. An additional six lakes had concentrations of mercury below the listing criterion and concentrations of organics below the lowest ATLs (Tier 2 in Table 5).

Another way in which the listing criteria are stringent is that they require 90% of the samples measured to be below the threshold. This leads to the fairly common occurrence that a lake has a mean mercury concentration below 0.2 ppm, but gets classified as impaired. The sampling approach employed in the SWAMP survey, which targets a wide range of sizes of black bass to provide a basis for ANCOVA that yields an accurate estimate of a size-standardized mean, has the unintended consequence of tending to trigger impairment listings because of the inclusion of large fish that tend to have relatively high mercury concentrations. Seven lakes had bass with size-standardized mean concentrations below 0.2 ppm and with organics means below the lowest ATLs (Tier 3 in Table 5). Many of the lakes included in Tier 3 are expected to be included on the next 303(d) list for mercury because while the means were below 0.2 ppm, 10% or more of the observations in individual fish were above this level due to the wide size ranges targeted for bass.

The last tier, Tier 4, is a more numerous category consisting of lakes where both indicator types were not sampled, but concentrations in the fish that were sampled were

below the 303(d) listing criteria for mercury and organics. This category is more numerous because it includes many lakes where only rainbow trout were sampled, and this species generally has low concentrations, in large part due to the origin of the fish at hatcheries.

Other criteria that were considered in selection of lakes for all tiers were having at least a moderate degree of fishing activity and a goal of having some lakes included from each of the Water Board regions.

E.   Sampling Design At Each Lake

The general goal of this study is to replicate and expand upon the observations of low concentrations observed in some lakes in the 2007-8 survey. Given this, the sampling design for sport fish at each location will generally match that of the prior survey (BOG 2007). Another aspect of this goal is to generate information that can be communicated to the public to raise awareness of locations with relatively low concentrations and promote exposure reduction. In accordance with this, OEHHA has provided detailed input on the data needed to support development of consumption advice for each lake targeted in this study. OEHHA's guidance will be followed to the extent possible. In some cases, additional fish will be collected beyond OEHHA's specifications, most notably to support estimation of average mercury in largemouth bass at a standard size of 350 mm.

This study will also aim to understand factors that may contribute to the low concentrations of mercury in the food webs of these lakes (MQ2). Detailed statistical evaluation of available data on sport fish mercury and related parameters has been conducted in development of the forthcoming TMDL for mercury in California reservoirs. Key parameters identified in the TMDL analysis will also be measured in this study.

1.   Sport Fish

a.   Sport Fish Species Targeted

Given the focus of the study on the fishing beneficial use, the species to be sampled, as in prior sampling, will be those that are commonly caught and consumed by anglers. Other factors considered include abundance, geographic distribution, and value as indicators for the contaminants of concern. The abundance and geographic distribution of species are factors that facilitate sample collection and assessment of spatial and temporal patterns in contamination. For example, largemouth bass are very common and widely distributed, and these factors contribute to making this an appropriate indicator species even though it is less popular for consumption than some other species.

The goal of this study is to identify lakes and reservoirs with relatively low concentrations of contaminants. Given this goal, the study is focusing on indicator

species that tend to accumulate the highest concentrations of the contaminants of concern - if these species have low concentrations, then it is likely that the food web in general has a low degree of contamination. Different contaminants tend to reach their highest concentrations in different species. Methylmercury biomagnifies primarily through its accumulation in muscle tissue, so top predators such as largemouth bass tend to have the highest concentrations. In contrast, although the organic contaminants of concern biomagnify, they do so primarily through accumulation in lipid. Concentrations of organics are therefore influenced by the lipid content of the species, with species that are higher in lipid having higher concentrations. Bottom-feeding species such as channel catfish and common carp tend to have the highest lipid concentrations in their muscle tissue, and therefore usually have the highest concentrations of organics.

Consequently, this study will target, where possible, two indicator species at each location: 1) a top predator (e.g., largemouth bass) as a mercury indicator, and 2) a high-lipid, bottom-feeding species (e.g., channel catfish, common carp) as an organics indicator.

Some lakes, particularly high elevation lakes, may have only one abundant top trophic level species (e.g., rainbow trout, and frequently these are stocked fish). In these cases in the 2007-8 survey, the one species present was often sampled as an indicator of all the target analytes. In contrast, in this study a greater effort (more hours spent fishing per lake) will be made to collect both mercury and organics indicator species.

In addition to the indicator species, species that are popular and accumulate lower concentrations have been identified for each lake by OEHHA and the Water Boards will be targeted for sampling (Table 6). Sampling of these species will allow for more comprehensive advice for each lake.

If the species recommended by OEHHA are not available, other potential targets will be considered (Table 7). Fish species are distributed unevenly across the State, with different assemblages in different regions (e.g., high Sierra Nevada, Sierra Nevada foothills, and Central Valley) and a variable distribution within each region. To cope with this, the sampling crew will have a prioritized menu of several potential target species. Primary target species will be given the highest priority. If primary targets are not available in sufficient numbers, secondary targets have been identified.

Other species will also be observed in the process of electroshocking. This "bycatch" will not be collected, but the sampling crew will record estimates of the numbers of each species observed. This information may be useful if additional follow-up studies are needed at any of the sampled lakes.

b.   Sport Fish Sampling Locations Within Each Lake

Lakes and reservoirs in California vary tremendously in size, from hundreds of small ponds less than 10 ha to Lake Tahoe at 50,000 ha. As lakes increase in size it becomes necessary to sample more than one location to obtain a representative

characterization of the water body. As much as possible, the same sampling locations visited in 2007-8 will be visited again for this survey.

In sport fish sampling using an electroshocking boat, it is frequently necessary to sample over a linear course of 0.5 – 1 mi to obtain an adequate number of fish. A sampling location in this study can therefore be thought of as a circle with a diameter of 1 mile. For small lakes less than 500 ha in size, one sampling location covers a significant fraction of the surface area of the lake. Therefore, for lakes less than 500 ha, one location will be sampled. For lakes of medium size (500 – 1000 ha), two locations will generally be sampled. For lakes in the large (1000 – 5000 ha) and very large categories (>5000 ha), two to four locations will be sampled. Since the goal of the study is to characterize human exposure, the existing locations have been established near centers of fishing activity.

Decisions regarding the number and placement of any new locations will be made in consultation with Regional Board staff with local knowledge of the lakes. Criteria to be considered in determining the placement of sampling locations will include the existence of discrete centers of fishing activity, known patterns of spatial variation in contamination or other factors influencing bioaccumulation, road or boat ramp access, and possibly other factors.

c.   Sport Fish Compositing and Size Ranges for Each Species

Chemical analysis of trace organics is relatively expensive, and the management questions established for the 2007-8 survey and this study can be addressed with good information on average concentrations. Therefore the compositing strategy employed in the 2007-8 survey will again be employed for these chemicals (Figures 2 and 3).

Chemical analysis of mercury is much less expensive, and SWAMP partners would like to be able to answer additional questions related to trends over time and differences among lakes. Consequently, the sampling design for the mercury indicator species includes analysis of mercury in individual fish. For the mercury indicator species, an analysis of covariance approach will be employed where possible, in which the size:mercury relationship will be established for each location and an ANCOVA will be performed. The ANCOVA will allow evaluation of differences in slope among the locations and comparison of mean concentrations and confidence intervals at a standardized total length, following the approach of Tremblay (1998). Experience applying this approach in the Central Valley indicates that to provide robust regressions, 11 fish spanning a broad range in size are needed (Davis et al. 2003, Melwani et al. 2007).

Specific size ranges to be targeted for each species are listed in Table 8. Black bass (including largemouth, smallmouth, and spotted bass), Sacramento pikeminnow (included in Group 1) and brown trout are the key mercury indicators. These species have a high trophic position and a strong size:mercury relationship. These species will be analyzed for mercury only (unless a bottom-feeding species is not present), and will be

analyzed individually. The numbers and sizes indicated for these species will provide the size range needed to support ANCOVA. In addition, the size range for black bass takes the legal limit for these species (305 mm, or 12 inches) into account. The goal for black bass is to have a size distribution that encompasses the standardized total length (350 mm) to be used in statistical comparisons. This length is near the center of the distribution of legal-sized fish encountered in past studies (Davis et al. 2003, Melwani et al. 2007). In past sampling, brown trout have been observed to accumulate high concentrations in some lakes, due to the existence in some cases of resident, self-sustaining populations and a switch to piscivory for larger fish. Brown trout will therefore have a similar target as black bass - 11 fish analyzed as individuals with the data analyzed through ANCOVA.

In many high elevation lakes, trout species predominate, especially rainbow trout. Trout will be sampled again in this study, though a greater effort will be made to obtain resident predators and bottom-feeders in trout lakes. Past sampling of rainbow trout in the Bay-Delta watershed has found low concentrations and a weak size:mercury relationship. Therefore, for rainbow trout the ANCOVA approach will not be used. Mercury will be analyzed in individuals, but a specified size range will be targeted to control for size rather than a wide span to support a regression-based analysis. Trout species will also be analyzed as composites for organics. The size ranges established for trout are based on a combination of sizes prevalent in past sampling (Melwani et al. 2007) and the 75% rule recommended by USEPA (2000) for composite samples.

Catfish, carp, bullhead, and sucker are the primary targets for high lipid bottom-feeders. These species will be analyzed for organics and mercury. Organics are expected to be highest in these species based on past monitoring in the Toxic Substances Monitoring Program and other studies (Davis et al. 2007). Mercury is expected to be highest in the pelagic predators, but concentrations may also be above thresholds for concern in the bottom-feeders, so mercury will be analyzed in these samples as well. Samples for these species will be analyzed as composites.

Secondary targets have been identified (Table 8) that will be collected if the primary targets are not available. These species would be processed for potential analysis of mercury and organics. The samples would be analyzed as composites. The size ranges established for bottom-feeders are based on a combination of sizes prevalent in past sampling (Melwani et al. 2007) and the 75% rule recommended by USEPA (2000) for composite samples.

The sampling crew will be reporting their catch back to the BOG on a weekly basis to make sure that the appropriate samples are collected and to address any unanticipated complications.

d.   Sport Fish Compositing and Archiving Strategies

Strategies for compositing and archiving will vary somewhat for lakes of different size. The overall strategy will be described first for small lakes, followed by a discussion of the differences for larger lakes.

Small Lakes

Figure 2 illustrates the approach to be taken for the predator and bottom-feeding species in small lakes (<500 ha). As described above, the predator species will be analyzed for mercury only and as individual fish. All samples of the predator species will be analyzed. Small lakes will be treated as one sampling location, so fish from anywhere in the lake will be counted toward meeting the targets for each size range listed in Table 8. For ANCOVA, one common regression line will be developed to describe the size:mercury relationship for the lake as a whole. Aliquots from these samples will also be archived after they are analyzed in case of any problems or other circumstances calling for reanalysis at a later time.

The bottom-feeding species will be analyzed as composites for organics and mercury (Figure 2). These composite samples will be analyzed and processed in a stepwise fashion. One representative composite sample will be analyzed first. Another composite sample will also be collected but analyzed only in the unanticipated event that the first composite sample has problematic concentrations. Aliquots from all composites will be archived, whether they are analyzed or not, in case of any problems or other circumstances calling for analysis or reanalysis at a later time.

Larger Lakes

For lakes in the medium, large, and very large categories the basic approach will be similar, with a couple of modifications. Figure 3 illustrates the approach using a medium lake as the example. The first difference from the small lake approach is that sampling locations will be treated discretely. For the predator species, this means that 11 fish spanning a wide range of sizes will be targeted for each location to support the development of a size:mercury regression and an estimated mean concentration at standardized total length for each location. From these location means a lakewide mean will be calculated.

For the bottom-feeder species, discrete composites will be prepared for each location. These composites will be homogenized and archived. Aliquots of homogenate from each location composite will be pooled to form a lakewide composite. The lakewide composite will be analyzed first. If the lakewide composite concentrations of any of the organics are problematic, then all the discrete location composites can be analyzed if that is desired by the Regional Board responsible for that lake. Since the goal of this study is to identify relatively clean lakes, these additional composites will not be automatically analyzed as part of this study. Aliquots from all composites will also be

archived, whether they are analyzed or not, in case of any problems or other circumstances calling for analysis or reanalysis at a later time.

2.   Prey Fish

Prey fish (25-100 mm) will be sampled using traps, seines, and dip nets from shoreline areas adjacent to the locations where sport fish are collected. Ten individuals each from three different prey fish species will be sampled from each lake. We will target the following primary prey fish target species at all lakes: Inland silversides, young-of-the-year largemouth bass, young-of-the-year bluegill, and threadfin shad. Other species that are within the target size range may be collected if the primary targets are not available.   Efforts will be made to sample the same species across all lakes, and when not possible fish that overlap in trophic guild will be sampled. Extra species of fish in the correct size ranges will be retained, and decisions on species to analyze for mercury will be made after all fish are collected each year.

Prey fish will be composited by species in each lake and analyzed for mercury and selenium.

3.   Water

Sampling locations for water will be selected with the aim of obtaining information that is representative of the lake and where the sport fish are accumulating their mercury. Three locations will be sampled in each lake.
1. Near dam at deepest part of lake (deepest part of lake could be in middle, if a natural lake), top and bottom (less than 1 m above the bottom) sample.
2. In a location where the water is <100 ft deep (likely off-thalweg), top and bottom sample.
3. Various, top and bottom sample.

If the lake has major tributary arms, then the arms will be sampled, if possible. If the lake has coves where the majority of the fish reside, these will be sampled. At each location, subsurface (0.1 m depth) and near-bottom grab samples will be collected and analyzed for unfiltered total mercury, unfiltered methylmercury, DOC, sulfate, and chlorophyll a. Depth profiles for Dissolved Oxygen, pH, temperature, Specific Conductivity and chlorophyll a will be conducted using a YSI EXO2 multiparameter water quality sonde.

4.   Sediment

Three sediment grab samples (top 2 cm) will be collected where waters are collected in each lake using a Van Veen grab sampler (0.5 m^2). Sediment samples will be analyzed for total mercury and total organic carbon loss on ignition (LOI).

F.   **Sample Processing and Analysis**

1.   **Sport Fish**

Fish will be collected in accordance with MPSL-102a, Section 7.4. Whenever possible an electro-fishing boat will be used; however, it may be necessary to employ another method also described in Section 7.4.

The following adaptation to MPSL-102a, Section 7.4.5 (Appendix II) has been made for this study: at the dock, all fish collected will be placed on a measuring board covered with a clean plastic bag; fork and total length will be recorded. Weight will be recorded with a digital spring scale. Large fish will be partially dissected in the field using the following protocol: fish will be placed on a cutting board covered with a clean plastic bag where the head, tail, and guts are removed using a clean (laboratory detergent, DI) cleaver. The cleaver and cutting board are re-cleaned between fish species, per site if multiple stations are sampled.

Upon collection, each fish collected will be tagged with a unique ID. Each fish collected will be linked to the latitude/longitude where it was collected. Several parameters will be measured in the field, including total length (longest length from tip of tail fin to tip of nose/mouth), fork length (longest length from fork to tip of nose/mouth), and weight. Total length changes with freezing and thawing and is best noted in the field for greatest accuracy and because it is the measure used by fishers and wardens to determine whether a fish is legal size. Determining fork length at the same time simplifies matters, and might help with IDs later to sort out freezer mishaps. For large fish (e.g., carp, which can be greater than 40 lb) there will be times when it is necessary to process fish in the field.

Whole fish or field-processed fish will be wrapped in aluminum foil and placed in a clean labeled zipper-style bag.   All samples will be kept cold on ice until frozen in a freezer or on dry ice within 24 hours of collection. Samples will be stored at -20°C at the laboratory until dissection and homogenization. Homogenates will also be frozen until analysis is performed. Frozen tissue samples have a 12-month hold time from the date of collection (USEPA 2000); however, the scientific advisory board has stated that samples kept frozen, with minimal thaw-freeze cycles, for several years have no appreciable degradation of organic contaminants.

All sport fish will be dissected "skin off". This is inconsistent with the guidance of USEPA (2000) that recommends that fish with scales have the scales removed and be processed with skin on, and skin is only removed from scaleless fish (e.g., catfish). The BOG is aware of this difference, but favors skin removal. Skin removal has been repeatedly used in past California monitoring. All fish (with limited exceptions) in Toxic Substances Monitoring Program, the Coastal Fish Contamination Program, and the Fish Mercury Project have also been analyzed skin-off. Processing fish with the skin on is very tedious and results in lower precision because the skin is virtually impossible to homogenize thoroughly and achieving a homogenous sample is difficult. Also, skin-on

preparation actually dilutes the measured concentration of mercury because there is less mercury in skin than in muscle tissue. The most ubiquitous contaminant in fish in California that leads to most of our advisories is mercury. By doing all preparation skin off we will be getting more homogeneous samples, better precision for all chemicals, and definitely a better measure of mercury concentrations, which are our largest concern. The analysis of axial fillets without skin was also advised by a bi-national workgroup concerning the monitoring and analysis of mercury in fish (Wiener et al. 2007).

Fish are filleted to expose the flesh. It is important to maintain the cleanliness of the tissue for analysis; therefore any flesh that has been in direct contact with the skin, with instruments in contact with skin, or with any potential contaminant surface such as foil or a plastic bag, must be eliminated from the analyzed sample. The exposed edges of the fillet should be trimmed by 1/4 inch with a clean scalpel or fillet knife to remove this contaminated tissue.

How a sample is dissected is greatly dependent on the types of analyses being conducted. Tissue from individual fish for mercury analysis only will be dissected from the fillet above the lateral line. When composites must be created, equal tissue weights are taken from 5 individual fish following the 75% size rule recommended by USEPA (2000) and homogenized into a Location Composite with a target weight of 200g or greater. Tissue for composites will be taken from the fillet of each fish above the lateral line and from the belly to include areas of higher lipid content. A subsequent lakewide composite will be created from equal portions of each contributing Location Composite within each lake. Figures 2 and 3 diagram compositing strategies and target weights for predator and bottom species. Post-homogenization aliquots will be taken from the lakewide composite for mercury, selenium and organics analyses.

Livers from selected fish will be preserved and processed for analysis of total mercury and selenium by USGS. Methods for these analyses are described in the "Prey Fish" section below.

Mercury will be analyzed by the Moss Landing Marine Laboratory Marine Pollution Studies Lab according to EPA 7473, "Mercury in Solids and Solutions by Thermal Decomposition, Amalgamation, and Atomic Absorption Spectrophotometry" using a Direct Mercury Analyzer. Samples, blanks, and standards will be prepared using clean techniques. ASTM Type II water and analytical grade chemicals will be used for all standard preparations. A continuing calibration verification (CCV) will be performed after every 10 samples. Initial and continuing calibration verification values must be within ±20% of the true value, or the previous 10 samples must be reanalyzed. Three blanks, a standard reference material (such as IAEA-407 or NRCC DORM-3), as well as a method duplicate and a matrix spike pair will be run with each set of samples.

Selenium will be analyzed by the Moss Landing Marine Laboratory Marine Pollution Studies Lab. Selenium will be digested according to EPA 3052M, "Microwave Assisted Acid Digestion of Siliceous and Organically Based Matrices", modified, and analyzed according to EPA 200.8, "Determination of Trace Elements in Waters and

Wastes by Inductively Coupled Plasma-Mass Spectrometry". Samples, blanks, and standards will be prepared using clean techniques. ASTM Type II water and analytical grade chemicals will be used for all standard preparations. A CCV will be performed after every 10 samples. Initial and continuing calibration verification values must be within ±20% of the true value, or the previous 10 samples must be reanalyzed. Two blanks, a standard reference material (2976 or NRCC DORM-3), as well as a method duplicate and a matrix spike pair will be run with each set of samples.

Organics analyses will be performed by the California Department of Fish and Game Water Pollution Control Lab in Rancho Cordova, CA. Organochlorine pesticides and PCBs will be analyzed according to WPCL-GC-006 "Analysis of Extractable Synthetic Organic Compounds in Tissues and Sediment (including Organochlorine Pesticides, Polychlorinated Biphenyls (PCBs) and PBDEs) by GC/ECD or Gas Chromatography with detection and quantitation by tandem mass spectrometry (MSMS)." Microcystins and microcystin metabolites will be analyzed according to WPCL-LC-065, "Determination of Microcystins and Microcystin Metabolites in Water and Tissue by Enhanced LC/MS/MS." Samples, blanks, and standards will be prepared using clean techniques. ASTM Type II water and analytical grade chemicals will be used for all standard preparations. A CCV will be performed after every 10 samples. Initial and continuing calibration verification values must be within ±25% of the true value, or the previous 10 samples must be reanalyzed. One blank, a laboratory control spike (LCS), a CRM (if available), and a method duplicate and a matrix spike pair will be run with each set of samples.

2.   Prey Fish

Inserting tags into small fish is not always possible, therefore upon collection, each prey fish will be individually bagged in well labeled zipper-style bag and placed in a larger zipper bag clearly labeled with the lake and species. Each fish will be linked to the latitude/longitude or UTM where it was collected. Several parameters will be measured in the field for each fish, including total length (longest length from tip of tail fin to tip of nose/mouth), fork length (longest length from fork to tip of nose/mouth), standard length, and weight. Once measurements have been recorded, prey fish will be frozen on dry ice in the field.

Prey fish will be analyzed as composites of whole fish for total mercury and total selenium only.

Analysis of total mercury in prey fish will be conducted by the Corvallis Research Group of the USGS Forest and Rangeland Ecosystem Science Center in Corvallis OR using the same analytical method as for the sport fish (EPA 7473).

Analysis of selenium in prey fish will be conducted by the Water Resources Division of USGS in Menlo Park CA. Selenium digested and analyzed by Isotope Dilution Hydride Generation Inductively Coupled mass Spectrometry. An ^{82}Se enriched isotope spike is used to measure isotope dilution. Calibration of the enriched ^{82}Se spike

is achieved by reverse spike isotope dilution. The digestates are mixed with concentrated hydrochloric acid to reduce the selenium to the most favorable valence for hydride generation. The solutions are then analyzed by inductively coupled plasma mass spectrometry coupled with hydride generation (ID HGICP-MS). Polyatomic and isobaric interferences are removed through the use of hydride generation and background correction using [82]Se enriched isotope spike. Samples, blanks, and standards will be prepared using clean techniques. ASTM Type II water and analytical grade chemicals will be used for all standard preparations. A continuing calibration verification (CCV) will be performed after every 4-5 samples. Initial and continuing calibration verification values must be within ±20% of the true value, or the previous samples must be reanalyzed. Two blanks, two certified reference materials (NIST 2976, NRCC DORM-3 or similar), as well as two method duplicates and a matrix spike pair will be run with each set of samples.

3.   Water

Water samples will be collected after fish are collected, but before sediment is collected at the site. Samples will be collected according to MPSL Field SOP v1.1 and the clean-hands dirty-hands collection methods where appropriate. It is important to follow the clean-hands dirty-hands collection method when collecting total and methylmercury samples to avoid sample contamination. One sub-surface water grab will be collected each for unfiltered total and methyl mercury in a clear glass 250 mL bottle, demonstrated to be free of contaminants, at 0.1 m below the water surface. Mercury and methylmercury samples will be preserved in the field with 2.5 ml 50 percent HCl. A sulfate sample will be collected at the same depth using a 125 mL HDPE bottle. Sample collection will occur in an area where the boat does not interfere with the sample, with the collector wearing clean polyethylene gloves. Containers will be opened and recapped under water to avoid surface water contamination of the sub-surface sample. Near-bottom water will be collected utilizing a 2L capacity Kemmerer. Each analyte will be dispensed into the appropriate bottle for analysis. Chlorophyll A up to 1000 ml may be filtered depending upon the turbidity of the water.

Total and methylmercury samples will be stored in the dark, on ice or refrigeration (4±2 ºC) until transfer to the laboratory within 48 hr of collection. When necessary, samples may be shipped on ice via freight carrier in a well-sealed ice chest. Ice will be double bagged to prevent water leakage into the samples. Glass bottles will be wrapped in bubble wrap to prevent breakage during shipment. Appropriate chain of custody records (COCs) will accompany each shipment. Samples collected will have the salinity (in parts per thousand) or specific conductivity (µS/cm), depth of collection, and date/time collected for each station on every COC.

Total mercury and methylmercury analysis will be performed by the U.S. Geological Survey Wisconsin Water Science Center's Mercury Research Team (MRT). Total mercury will be analyzed by oxidation, purge and trap, and cold vapor atomic fluorescence spectrometry following EPA Method 1631, Rev. E. Bromine Monochloride (BrCl) is added to the sample container to oxidize all forms of Hg to the HgII oxidation

state. After 5 days at 50 deg C, the BrCl is neutralized by the addition of Hydroxylamine Hydrochloride (NH2OH*HCl). Following neutralization, Stannous Chloride (SnCl2) is added to the sample to reduce the Hg from HgII to Hg0. The Hg0 is purged onto gold-coated glass bead traps (sample). The mercury vapor is thermally desorbed to a second gold trap (analytical) and from that detected by cold vapor atomic fluorescence spectrometry (CVAFS). Samples high in organic matter may require initial pretreatment in an ultra violet (UV) digester to remove the organic color from the sample.

Methymercury analysis will be performed by aqueous phase ethylation, followed by gas chromatography separation with speciated isotope dilution mass spectrometry (USGS 2002: Open-File Report 01-445). Water samples are spiked with isotopically enriched standard and distilled to remove potential interferences. The pH of the distillate is adjusted to 4.9 using acetate buffer. The distillate is then ethylated using sodium tetraethyl borate (NaTEB4) and allowed to react for 15 minutes. Following reaction with NaTEB the distillate is purged with grade 5 Argon gas (Ar) for 20 minutes and the ethylated mercury species are collected on a Carbotrap. The ethylated mercury species are thermally desorbed from the Carbotrap, separated using a gas chromatography (GC) column, reduced and ionized using the ICP-MS, and detected using Speciated Isotope Dilution Mass Spectrometry (SIDMS).

Sulfate and chlorophyll *a* analyses will be performed by the WPCL. Sulfate samples will be kept cold (<6 ºC) until transfer to and analysis at WPCL within 28 days of collection. Sulfate will be analyzed according to WPCL-AA-041: Inorganic Anions by Ion Chromatography, EPA Method 300. Samples, blanks, and standards will be prepared using clean techniques. ASTM Type II water and analytical grade chemicals will be used for all standard preparations. A CCV will be performed after every 10 samples. Initial and continuing calibration verification values must be within ±20% of the true value, or the previous 10 samples must be reanalyzed. A blank, laboratory control sample, certified reference material (NIST 1641d or similar), as well as a method duplicate and matrix spike pair will be run with each set of samples.

Chlorophyll a in water samples will be determined by USEPA Method 446, "In Vitro Determination of Chlorophylls *a, b, c_1+c_2* Pheopigments in Marine and Freshwater Algae by Visible Spectrophotometry." Periphyton are separated from water samples by filtering a measured volume of water through a glass fiber filter. The filter is wrapped to protect it from light then frozen for shipment to the laboratory. The filter is vortexed, sonicated, shaken, then steeped with a 90% acetone solution to extract the pigments from the periphyton. The UV spectrophotometer is zeroed using a blank, calibrated with standards, and the calibration verified with a certified reference standard. Absorbance of the blanks, standards, reference material, and sample extracts are recorded before and after acidification. Resultant readings are entered into "Lorenzen's Equation" as described in the method. A method blank, certified reference standard, and extract replicate are extracted with every batch of 20 or fewer samples. The mid-point calibration extract is reanalyzed after every 10 samples and end of analysis to monitor for drift (CCV). The acceptance criteria for the CCV is + 20% of the true value and + reporting limit for the method blank. If any instrument or batch quality control samples

do not meet acceptance criteria, the corrective action is to investigate possible causes for the failure, correct the cause, and reanalyze the affected samples. No certified reference material is available for chlorophyll a, therefore one will not be analyzed, and neither will a matrix spike/ duplicate pair.

DOC analysis will be performed by the USGS MRT using a catalytically-aided platinum 680°C combustion technique (http://wi.water.usgs.gov/mercury-lab/analysis-methods.html).

4.   Sediment

A stainless steel Young-modified Van Veen grab will be deployed to collect bed sediments at the 3 locations where water is collected (MPSL Field SOP v1.1). The grab will be slowly lowered to the bottom of the lake with a minimum of substrate disturbance, and the closed grab will be retrieved at a moderate sped (< 2 ft s^{-1}). Upon retrieval the lids of the grab will be opened and the material examined to ensure it is undisturbed and of sufficient quality (recently deposited fine sediment) for use in chemical analyses. Specific rejection criteria are found in MPSL Field SOP v1.1, p59.

Only the top 2 cm of the collected material will be transferred to a whirl pac bag, frozen in the field and shipped on dry ice.

Total mercury and LOI analysis will be performed by the USGS MRT. Total mercury will be analyzed by atomic adsorption following direct combustion with a Nippon MA-2 Mercury Analyzer (EPA Method 7473 [SW-846] Rev. 0). Solid sample is combusted at high temperature (850 deg C) in the presence of interference-reducing reagents, releasing mercury from the matrix as reduced gaseous mercury. In the resulting gas, matrix interference is further eliminated by catalytic treatment, adjusted to appropriate pH in a phosphate buffer, and then passed through a gold amalgam trap to quantitatively capture gaseous mercury. Lastly, the gold trap is heated, releasing the bound mercury into the sample stream, and detected by cold vapor atomic adsorption.

LOI will be analyzed following USGS Techniques of Water-Resources Investigations 5-A1, 3rd ed. Sample is weighed into aluminum boats and heated to 550ºC for two hours. The percent of sample mass lost following heating is reported as LOI. One sample per analysis is weighed in triplicate to assess method precision.

G.   Analytes in Sport Fish

Table 9 provides a summary list of sport fish analytes for the study. Since the study is focused on assessing the impacts of bioaccumulation on the fishing beneficial use, the list is driven by concerns over human exposure. Contaminants were included if they were considered likely to provide information that is needed to answer the management questions for the study. A detailed list of analytes is provided in Table 10.

Additional discussion of the analytes is provided below.

Ancillary Parameters

Ancillary parameters to be measured in the lab include moisture and lipid (Table 10). Fish sex will also be determined for all samples as it comes at no extra cost and can be valuable in interpreting the data. Each fish collected will be linked to the latitude/longitude where it was collected.

Scales will be collected from black bass species and analyzed for age.

Methylmercury

Methylmercury is the contaminant of greatest concern with respect to bioaccumulation on a statewide basis (Davis et al. 2010). Methylmercury will be measured as total mercury. Nearly all of the mercury present in edible fish muscle is methylmercury, and analysis of fish tissue for total mercury provides a valid, cost-effective estimate of methylmercury concentration (Wiener et al. 2007). Mercury will be analyzed in all samples because it is possible that samples of each species will exceed thresholds of concern.

PCBs

PCBs are the contaminant of second greatest concern with respect to bioaccumulation on a statewide basis (Davis et al. 2010). PCBs will be analyzed using a congener-specific method. A total of 55 congeners will be analyzed (Table 10). PCBs will be analyzed in one composite sample from each lake. The species with the greatest expected concentrations (i.e., the organics indicator species where they are present) will be included.

Legacy Pesticides

Legacy pesticides may exceed FCGs in some locations. Individual compounds recommended by USEPA (2000) will be analyzed (Table 10). Legacy pesticides will be analyzed in one composite sample from selected lakes. The species with the greatest expected concentrations (i.e., the organics indicator species where they are present) will be analyzed.

Selenium

Past monitoring (Davis et al. 2010) indicates that selenium concentrations are generally not likely to be above thresholds in this study. Selenium analysis will be included for a select few lakes where selenium may approach thresholds.

Microcystins

Sampling of Lake Henshaw will be conducted in coordination with Region 9, which is conducting a regional study of cyanotoxins. Cyanotoxins will be analyzed in the fish samples collected from Lake Henshaw.

Other Contaminants

Assessment thresholds are essential in this study, and are not available for the other contaminant categories.

H. Quality Assurance

This effort will adhere to quality assurance requirements established for the SWAMP. A QAPP specific to this effort is in preparation (Bonnema 2014).

I. Archiving

1. Sport Fish

Samples will be stored in short-term archives. Samples in the short-term archive are stored at -20 °C and are intended for use in the identification of short-term time trends (i.e. < 5-10 years), the investigation of yet-unidentified chemical contaminants, and addressing quality assurance issues that may arise during the routine analyses of samples. These samples are intended for the analysis of chemicals that are not expected to degrade in five years of storage at -20 °C. The short-term archives will be located in an off-site freezer facility rented by Moss Landing Marine Laboratory. The facility is equipped with a backup generator in the event of a power outage.

A number of small-volume sub-samples, rather than one or two large-volume samples, are prepared for archiving to avoid subjecting the samples to several freeze-thaw cycles. Each sub-sample contains a sufficient amount of material for most chemical analysis, and when needed, can be removed from the freezer and sent to the appropriate laboratory without the need to sub-sample.

For each sampling location, up to three 40-50 g aliquots of each composite analyzed for organics will be archived. This will provide an integrative, representative sample for each location that can be reanalyzed in later years to confirm earlier analyses, look for new chemicals of concern, provide material for application of new analytical methods, provide material for other ecological research, and other purposes. Samples for the short-term archive will be stored in either glass jars with Teflon-lined lids for non-fluorinated organic chemical and trace metal analysis or in polyethylene or polypropylene for fluorinated chemical (i.e. PFCs) or trace metals analysis. Two of the three archive jars will be glass with a Teflon-lined lid (e.g., I-Chem 200 series glass jars). One

separate aliquot will be kept in a polypropylene jar for potential analysis of perfluorinated compounds. These archived samples will be stored at -20°C.

For storage of samples in the short-term archive, glass and plastic containers are pre-cleaned using appropriate acids or solvents by MPSL-DFG or purchased pre-cleaned commercially (e.g. from Fisher or ESS Vial). For containers purchased 'pre-cleaned' from ESS Vial or other companies, a minimum of two per shipment will not be opened and kept in storage with the other samples in case container contamination issues arise.

J.   Ancillary Data

In addition to the primary and secondary target species, other species will also be observed in the process of sample collection.   This "bycatch" will not be collected, but the sampling crew will record estimates of the numbers of each species observed. This information may be useful if follow-up studies are needed in any of the sampled locations.

K.   Timing

Sampling will be conducted from May 2014 through October 2014. Seasonal variation in body condition and reproductive physiology, as well as limnological characteristics, are recognized as factors that could affect contaminant concentrations. To the extent practical, the seasonal timing of sampling will replicate the timing of the previous round of sampling.

L.   Data Assessment

MQ1 will be assessed by comparing sport fish results from each location to the thresholds used for 303(d) listing determinations and to ATLs established by OEHHA (Klasing and Brodberg 2008) (Table 2). Data on water and sediment are being collected to address MQ2, and will not be compared to any assessment thresholds.

MQ2 will be assessed in collaboration with the Water Board staff working on the Reservoir TMDL. In addition to the parameters being measured in this study, other data that could help in addressing MQ2 include lake characteristics such as morphometry (surface area, shoreline length, bathymetry, volume), turnover, catchment area, water level fluctuation, fishing pressure, and landscape features such as wetlands (connected or adjoining), and agricultural land cover. If the budget allows, the influence of these parameters on concentrations of mercury in fish will be evaluated. If not covered by this study, it is likely that these factors will be evaluated by Water Board staff working on the statewide TMDL for reservoirs.

MQ3 will be assessed to the extent possible (depending on how many lakes are successfully sampled in a manner supporting this comparison) through a narrative summary of how the follow-up data compare to the previous results.

M.   Products and Timeline

A report on this 2014 sampling will be drafted by June 2015. The final report, incorporating revisions in response to reviewer comments, will be completed and released in September 2015.

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Table 1.   Bioaccumulation monitoring assessment framework for the fishing beneficial use.

D.1.   *Determine the status of the fishing beneficial use throughout the State with respect to bioaccumulation of toxic pollutants*

D.1.1 What are the extent and location of water bodies with sufficient evidence to indicate that the fishing beneficial use is at risk due to pollutant bioaccumulation?

D.1.2 What are the extent and location of water bodies with some evidence indicating the fishing beneficial use is at risk due to pollutant bioaccumulation?

D.1.3 What are the extent and location of water bodies with no evidence indicating the fishing beneficial use is at risk due to pollutant bioaccumulation?

D.1.4 What are the proportions of water bodies in the State and each region falling within the three categories defined in questions D.1.1, D.1.2, and D.1.3?

D.2.   *Assess trends in the impact of bioaccumulation on the fishing beneficial use throughout the State*

D.2.1 Are water bodies improving or deteriorating with respect to the impact of bioaccumulation on the fishing beneficial use?

D.2.1.1 Have water bodies fully supporting the fishing beneficial use become impaired?

D.2.1.2 Has full support of the fishing beneficial use been restored for previously impaired water bodies?

D.2.2 What are the trends in proportions of water bodies falling within the three categories defined in questions D.1.1, D.1.2, and D.1.3 regionally and statewide?

D.3.   *Evaluate sources and pathways of bioaccumulative pollutants impacting the fishing beneficial use*

D.3.1 What are the magnitude and relative importance of pollutants that bioaccumulate and indirect causes of bioaccumulation throughout each Region and the state as a whole?

D.3.2 How is the relative importance of different sources and pathways of bioaccumulative pollutants that impact the fishing beneficial use changing over time on a regional and statewide basis?

D.4.   *Provide the monitoring information needed to evaluate the effectiveness of management actions in reducing the impact of bioaccumulation on the fishing beneficial use*

D.4.1 What are the management actions that are being employed to reduce the impact of bioaccumulation on the fishing beneficial use regionally and statewide?

D.4.2 How has the impact of bioaccumulation on the fishing beneficial use been affected by management actions regionally and statewide?

Table 2a.   OEHHA Fish Contaminant Goals. From Klasing and Brodberg (2008).

Table 1. Fish Contaminant Goals (FCGs) for Selected Fish Contaminants Based on Cancer and Non-Cancer Risk* Using an 8-Ounce/Week (prior to cooking) Consumption Rate (32 g/day)**	
	FCGs (ppb, wet weight)
Contaminant Cancer Slope Factor (mg/kg/day)$^{-1}$	
Chlordane (1.3)	**5.6**
DDTs (0.34)	**21**
Dieldrin (16)	**0.46**
PCBs (2)	**3.6**
Toxaphene (1.2)	**6.1**
Contaminant Reference Dose (mg/kg-day)	
Chlordane (3.3×10^{-5})	100
DDTs (5×10^{-4})	1600
Dieldrin (5×10^{-5})	160
Methylmercury (1×10^{-4})[S]	**220**
PCBs (2×10^{-5})	63
Selenium (5×10^{-3})	**7400**
Toxaphene (3.5×10^{-4})	1100

*The most health protective Fish Contaminant Goal for each chemical (cancer slope factor- versus reference dose-derived) for each meal category is bolded.
**g/day represents the average amount of fish consumed daily, distributed over a 7-day period, using an 8-ounce serving size, prior to cooking.
[S]Fish Contaminant Goal for sensitive populations (i.e., women aged 18 to 45 years and children aged 1 to 17 years.)

Tabled values are rounded based on laboratory reporting of three significant digits in results, where the third reported digit is uncertain (estimated). Tabled values are rounded to the second digit, which is certain. When data are compared to this table they should also first be rounded to the second significant digit as in this table.

Table 2b.   OEHHA advisory tissue levels. From Klasing and Brodberg (2008).

Table 2. Advisory Tissue Levels (ATLs) for Selected Fish Contaminants Based on Cancer or Non-Cancer Risk Using an 8-Ounce Serving Size (Prior to Cooking) (ppb, wet weight)				
Contaminant	Three 8-ounce Servings* a Week	Two 8-ounce Servings* a Week	One 8-ounce Servings* a Week	No Consumption
Chlordane[c]	≤190	>190-280	>280-560	>560
DDTs[nc**]	≤520	>520-1,000	>1,000-2,100	>2,100
Dieldrin[c]	≤15	>15-23	>23-46	>46
Methylmercury (Women aged 18-45 years and children aged 1-17 years)[nc]	≤70	>70-150	>150-440	>440
Methylmercury (Women over 45 years and men)[nc]	≤220	>220-440	>440-1,310	>1,310
PCBs[nc]	≤21	>21-42	>42-120	>120
Selenium[nc]	≤2500	>2500-4,900	>4,900-15,000	>15,000
Toxaphene[c]	≤200	>200-300	>300-610	>610

[c]ATLs are based on cancer risk
[nc]ATLs are based on non-cancer risk
*Serving sizes are based on an average 160 pound person. Individuals weighing less than 160 pounds should eat proportionately smaller amounts (for example, individuals weighing 80 pounds should eat one 4-ounce serving a week when the table recommends eating one 8-ounce serving a week).
**ATLS for DDTs are based on non-cancer risk for two and three servings per week and cancer risk for one serving per week.

Tabled values are rounded based on laboratory reporting of three significant digits in results, where the third reported digit is uncertain (estimated). Tabled values are rounded to the second digit, which is certain. When data are compared to this table they should also first be rounded to the second significant digit as in this table.

Table 3. Criteria for assigning candidate lakes to tiers. Colors refer to shading in Table 4.

Tier 1 (blue)
Both indicator types sampled
Hg: Below 303(d) listing criterion (90% of samples below 0.2 ppm)
Organics: Below 303(d) listing criteria (90% of samples below FCGs)
At least some fishing activity

Tier 2 (green)
Both indicator types sampled
Hg: Below 303(d) listing criterion (90% of samples below 0.2 ppm)
Organics: means in the ATL range for three servings per week
At least some fishing activity

Tier 3 (purple)
Both indicator types sampled
Hg: mean below 0.2
Organics: means in the ATL range for three servings per week
At least some fishing activity

Tier 4 (yellow)
Both indicator types not sampled
Hg: Below 303(d) listing criterion (90% of samples below 0.2 ppm)
Organics: Below 303(d) listing criteria (90% of samples below FCGs)
The more fishing the better

Table 4.   Candidates for inclusion in the Clean Lakes Study.

Candidates for the Clean Lakes Study: Region 1. See Table 3 for tier and color scheme. Letters indicate priority of the Tier 4 lakes.

Region	Lake	Species	Tier	Comments
1	Kangaroo Lake	RBT		Remote back country lake.
1	Reservoir F	LMB		Remote back country lake.
1	Lewiston Lake	RBT	4a	Popular. More heavily fished than Cleone.
1	Trinity Lake	RBT		Listed for Hg. Do not eat LMB advisory.
1	Howard Lake	RBT		Remote back country lake.
1	Plaskett Lake	Hardhead		Remote back country lake.
1	Cleone Lake	RBT	4b	Popular.

Candidates for the Clean Lakes Study: Region 2. See Table 3 for tier and color scheme. Letters indicate priority of the Tier 4 lakes.

Region	Lake	Species	Tier	Comments
2	Horseshoe Lake, Quarry Lakes	CCAT		Not impaired for Hg. One of three PCB samples above FCG. Difficult to get bass.
2	Lago Los Osos	CCAT		No fishing allowed.
2	Lake Cunningham	CARP		Not popular. PCBs, DDTs, dieldrin, chlordanes above FCGs.
2	Lake Elizabeth	CARP		Not impaired for Hg. PCBs, DDTs, dieldrin above FCGs
2	Briones Reservoir	LMB		Fishing not allowed.
2	Lake Madigan	Bluegill		Only got bluegill.

Table 4.   Candidates for inclusion in the Clean Lakes Study (continued).

Candidates for the Clean Lakes Study: Region 3. See Table 3 for tier and color scheme. Letters indicate priority of the Tier 4 lakes.

Region	Lake	Species	Tier	Comments
3	Loch Lomond Reservoir	LMB, Bluegill		Impaired. Hg 0.11 at 350 mm.
3	Lopez Lake	LMB, Sucker	2	Not impaired. PCBs, dieldrin above FCGs

Table 4. Candidates for inclusion in the Clean Lakes Study (continued).

Candidates for the Clean Lakes Study: Region 4. See Table 3 for tier and color scheme. Letters indicate priority of the Tier 4 lakes.

Region	Lake	Species	Tier	Comments
4	Castaic Lagoon	LMB, CARP, RBT, Redear	3	Need repeat of low Hg, PCBs above FCG. New 303(d) Listing
4	Elizabeth Lake	Crappie, Bullhead, RBT		Hg 0.21 in 2007, under in 2010 - repeat? (Tier 4 based on 2010)
4	Lake Lindero	Carp		Not impaired. Hg low in 2007 and 2010. Organics above FCGs.
4	Malibou Lake	LMB, Carp, Bluegill	2	Not impaired. Hg low in 2007 & 2010. PCBs, dieldrin, chlordanes above FCGs.
4	Westlake Lake	LMB		Not impaired. PCBs, dieldrin above FCGs.
4	Cerritos Park Lake	LMB, Carp, RBT		Impaired. PCBs above ATL, DDTs, dieldrin above FCGs. New 303(d) Listing
4	Wilderness Park Lake	CCAT, Carp		Dieldrin above FCG.
4	Harbor Lake (Lake Machado)	Carp		Not impaired. PCBs above FCG.
4	Balboa Lake	Carp		DDTs, dieldrin above FCG.
4	Belvedere Park Lake	Carp	*	PCBs at 22 ppb (above ATL). Strong Region 4 interest in sampling this lake.
4	Lake Calabasas	LMB		Not impaired. PCBs above FCG.
4	Legg Lake	LMB, Carp, Redear, CCAT	3	Impaired. PCBs very high in 2005. Hg low in 2007 and 2010. PCBs above FCG in 2010. New 303(d) Listing.
4	Lincoln Park Lake	LMB, Carp	2	Not impaired. Hg low in 2007 & 2010. PCBs above FCG.
4	Sepulveda Lake	Carp		PCBs, DDTs, dieldrin above FCGs.
4	Toluca Lake	LMB		Not impaired. PCBs above FCG.
4	Echo Lake	LMB, Carp	*	PCBs above ATLs in past sampling, but cleanup and restocking have occurred. Expected to be clean now.

Table 4.   Candidates for inclusion in the Clean Lakes Study (continued).

Candidates for the Clean Lakes Study: Region 5. See Table 3 for tier and color scheme. Letters indicate priority of the Tier 4 lakes.

Region	Lake	Species	Tier	Comments
5	McCumber Reservoir	RBT		
5	North Battle Creek Reservoir	Brown Trout		
5	Blue Lakes	LMB		Tribes interested. Impaired.
5	Big Reservoir	RBT		
5	Caples Lake	Brown Trout	4b	Not impaired.
5	French Meadows Reservoir	RBT		Impaired.
5	Hell Hole Reservoir	Brown Trout		Impaired.
5	Ice House Reservoir	RBT	4e	
5	Union Valley Reservoir	RBT		Also SMB, 1 sample = 0.419
5	Lake of the Pines	LMB	4a	Not impaired.
5	Bowman Lake	Brown Trout		PCBs above FCG
5	Faucherie Lake	RBT		Impaired.
5	Jackson Meadow Reservoir	RBT		Impaired.
5	Lake Spaulding	RBT		Brown Tr(n=5) = 1.1, Chinook(n=3) = 0.58
5	Scotts Flat Reservoir	RBT		Impaired, BG, LMB, Brown Tr, Green Sunfish
5	Fuller Lake	Brown Trout		Not impaired.
5	Feeley Lake	Bullhead		
5	Kidd Lake	Bullhead		
5	Antelope Lake	LMB, Bullhead	1	Not impaired.
5	Bucks Lake	RBT		Not impaired. Brown Tr(n=10) = 0.069, Lake Tr(n=5) = 0.024
5	Butt Valley Reservoir	SMB		Impaired.
5	Frenchman Lake	RBT		
5	Gold Lake	RBT	4c	
5	Little Grass Valley Reservoir	RBT		
5	Lake Almanor	SMB		Impaired.
5	Lake Davis	RBT, Bullhead		

5	Lower Bucks Lake	Kokanee		
5	Paradise Lake	LMB		Impaired.
5	Whiskeytown Lake	LMB		Impaired.
5	Castle Lake	RBT		
5	Gumboot Lake	RBT		
5	Big Lake	RBT, Sucker		
5	Reservoir C	RBT		
5	Duncan Reservoir	RBT, Bullhead		
5	Iron Canyon Reservoir	RBT		
5	Lake Britton	SMB, Carp	3	Impaired. 303(d) Listed Sucker up to 0.5 in 2006. SMB 350 mean above 0.2 in 2008.
5	Medicine Lake	Brook Trout		
5	Cave Lake	Brook Trout		
5	Lily Lake	RBT		
5	Lower Bear River Reservoir	RBT		
5	Lower Blue Lake - Alpine County	RBT		Impaired. Dieldrin above FCG
5	Upper Blue Lake	RBT		
5	White Pines Lake	RBT		
5	Lake Alpine	RBT	4d	Nearby Spicer Meadow also possible, but Alpine had lower Hg.
5	Beardsley	RBT		
5	Pinecrest	RBT		
5	Spicer Meadow Reservoir	RBT		
5	La Grange Reservoir	RBT		
5	Bass Lake	LMB, Bullhead	1	Not impaired.
5	Florence Lake	Brown Trout		Not impaired.
5	Huntington Lake	RBT	4f	Kokanee(n=1) = 0.10
5	Mammoth Pool Reservoir	RBT		
5	Contra Loma Reservoir	LMB		Impaired.

5	545TU0164	LMB, Carp		Impaired. Would be Tier 3, but not popular for fishing. PCBs, DDTs, dieldrin above FCG, New 303(d) Listing
5	Marsh in Fresno Slough	LMB, Bullhead		Impaired. Would be Tier 3, but not popular for fishing. DDTs, dieldrin above FCG. New 303(d) Listing
5	Courtright Reservoir	RBT		Brown Tr(n=1) = 0.06
5	Hume Lake	RBT		
5	Wishon Reservoir	RBT		Brown Tr(n=1) = 0.29

Table 4. **Candidates for inclusion in the Clean Lakes Study (continued).**

Candidates for the Clean Lakes Study: Region 6. See Table 3 for tier and color scheme. Letters indicate priority of the Tier 4 lakes.

Region	Lake	Species	Tier	Comments
6	Ellery Lake	RBT		
6	Grant Lake	RBT		
6	Gull Lake	RBT		
6	June Lake	RBT		
6	Lundy Lake	RBT		Dieldrin above FCG.
6	Saddlebag Lake	RBT		Dieldrin above FCG.
6	Tioga Lake	RBT		
6	Convict Lake	RBT		
6	Lake Crowley	RBT		
6	Lake George	RBT		
6	Lake Mary	RBT		
6	Lake Mamie	RBT		
6	Pleasant Valley Reservoir	RBT		
6	Rock Creek Lake	RBT		
6	Lake Sabrina	RBT		
6	Twin Lakes	RBT		Dieldrin above FCG.
6	Apollo Lake	RBT		
6	Palmdale Lake	LMB, CCAT	3	PCBS, dieldrin above FCG. New 303(d) Listing
6	Lake Gregory	LMB, Carp	3	Dieldrin above FCG. New 303(d) Listing
6	Spring Valley Lake	RBT		PCBs above FCG.
6	Bridgeport Reservoir	RBT		
6	Virginia Lakes	RBT		
6	Topaz Lake	Sucker, RBT	4b	Very popular.
6	Indian Creek Reservoir	RBT	4d	Dieldrin above FCG. Wastewater was discharged into this reservoir for decades, Nutrient TMDL was done, and they are actively oxygenating the bottom to reduce nutrient mobilization. Due to all the waste discharged over the decades, i'm curious what any non-trout species may show. This reservoir is rather warm, and may not support trout

				long-term without continual physical manipulations, Probably will shift to warm-water species as climate warms).
6	Fallen Leaf Lake	Lake Trout	4c	Not impaired. PCBs, DDTs, dieldrin, chlordane above FCG. Suspect pesticides from numerous homes around the lake; however may not be able to capture any "bottom" species in this oligotrophic (cold) lake; if design requires multiple species, may kick this out of clean lakes study)
6	Lake Tahoe	RBT		
6	Lake Tahoe - Tahoe Keys		4a	Little/no data for non-trout species, which are caught & eaten by local people "of color" [potential EJ issue]; also, JRowan of DFW is actively shocking in the Keys Lagoons so costs could be modest compared to mobilizing a whole crew
6	Prosser Creek Reservoir	RBT		
6	Boca Reservoir	Sucker, RBT		
6	Stampede Reservoir	RBT		
6	Eagle Lake	Eagle Lk Trout		
6	Crater Lake	RBT		
6	Dodge Reservoir	RBT		

Table 4.   Candidates for inclusion in the Clean Lakes Study (continued).

Candidates for the Clean Lakes Study: Region 7. See Table 3 for tier and color scheme. Letters indicate priority of the Tier 4 lakes.

Region	Lake	Species	Tier	Comments
7	Lake Havasu	Carp		RB7 plans to sample in 2014
7	Gene Wash Reservoir	LMB, Carp	1	Not impaired. RB7 plans to sample in 2014
7	Ferguson Lake	LMB, Carp	1	Not impaired. RB7 plans to sample in 2014
7	Senator Wash Reservoir	LMB, Carp	1	Not impaired. RB7 plans to sample in 2014
7	Lake Cahuila	Carp		DDTs above FCG
7	Fig Lake	Tilapia, Carp		
7	Ramer Lake	Crappie, Carp		Not impaired. RB7 plans to sample in 2014
7	Wiest Lake	CCAT, Carp		Not impaired. RB7 plans to sample in 2014. PCBs, DDTs, dieldrin above FCG.
7	Sunbeam Lake	LMB, CCAT	2	Not impaired. RB7 plans to sample in 2014. PCBs, DDTs, dieldrin above FCG. Data from 2004 only.
7	Salton Sea	Tilapia		RB7 plans to sample in 2014

Table 4.   Candidates for inclusion in the Clean Lakes Study (continued).

Candidates for the Clean Lakes Study: Region 8. See Table 3 for tier and color scheme. Letters indicate priority of the Tier 4 lakes.

Region	Lake	Species	Tier	Comments
8	Lee Lake/Corona Lake	LMB		Impaired. PCBs above FCG.
8	Lake Evans	LMB, Carp	2	Not impaired. PCBs abo e FCG.
8	Prado Lake	LMB, Carp	2	Not impaired. PCBs above FCG.
8	Lake Hemet	RBT, Carp		Not impaired.
8	Perris Reservoir	LMB		Not impaired. PCBs and DDTs above FCG.

Table 4.   Candidates for inclusion in the Clean Lakes Study (continued).

Candidates for the Clean Lakes Study: Region 9. See Table 3 for tier and color scheme. Letters indicate priority of the Tier 4 lakes.

Region	Lake	Species	Tier	Comments
9	Lake Henshaw	LMB, Carp	3	Impaired. Popular. Sampled lots of large bass. Organics below FCGs. R9 Sampling in late summer for cyanotoxins in tissues. New 303(d) Listing
9	Dixon Lake	LMB	4a	Not impaired. In/close to urbanized areas. Lots of fishing for stocked species (catfish in summer and trout in winter). Popular for fishing. Newer Reservoir, dam built in 1960s? Storage for imported water treatment.
9	Lake Wohlford	LMB		Not impaired. Moderately popular. Private boats prohibited. Downstream from Henshaw…receives Henshaw water via canal
9	Lake Poway	LMB	4b	Not impaired. In/close to urbanized areas. Lots of fishing for stocked species (catfish in summer and trout in winter). Popular for fishing. Newer Reservoir, dam built in 1971. Storage for imported water treatment.
9	Lake Jennings	LMB, CCAT	3	Impaired. Dieldrin above FCG. New 303(d) Listing

Table 5.   Tier assignments for candidate lakes.

Tier 1 (blue)
1. Antelope Lake (R5)
2. Bass Lake (R5)
3. Gene Wash Reservoir (R7)
4. Senator Wash Reservoir (R7)

Tier 2 (green)
5. Lopez Lake (R3)
6. Lincoln Park Lake (R4)
7. Malibou Lake (R4)
8. Sunbeam Lake (R7)
9. Lake Evans (R8)
10. Prado Lake (R8)

Tier 3 (purple)
11. Castaic Lagoon (R4)
12. Legg Lake (R4)
13. Palmdale Lake (R6)
14. Lake Gregory (R6)
15. Lake Henshaw (R9)
16. Lake Jennings (R9)

Tier 4 (yellow - top choices for each region shown, in priority order)
17. Lewiston Lake (R1)
18. Lake Merced (R2)
19. Lake of the Pines (R5)
20. Caples Lake (R5)
21. Gold Lake (R5)
22. Lake Tahoe (Tahoe Keys) (R6)
23. Dixon Lake (R9)
24. Loch Lomond (R3) (not included due to budget limitations)
25. Huntington Lake (R5) (not included due to budget limitations)
26. Lake Alpine (R5) (not included due to budget limitations)
27. Ice House Reservoir (R5) (not included due to budget limitations)
28. Topaz Lake (R6) (not included due to budget limitations)
29. Fallen Leaf Lake (R6) (not included due to budget limitations)
30. Indian Creek Reservoir (R6) (not included due to budget limitations)

1   Table 6a.   OEHHA recommendations for sampling at each of the lakes to be included in the study. Species in **bold** are
2   especially important target species.
3

Water Body	BOG list #	County	Region	OEHHA recommendations-Hg	OEHHA PCBs	Comments
Antelope Lake	1	Plumas	5	bass (6 legal, indiv) resident brown trout (10 fish, 2 comps) Eagle Lake or rainbow trout (10 fish or 5 fish each species, 2 comps) catfish (10 fish, 2 comps)	brown trout catfish Eagle Lake trout or rainbow trout	
Bass Lake	2	Madera	5	bass (6 legal, indiv) **kokanee** (10 fish, 2 comps) bluegill (10 fish, 2 comps) crappie (10 fish, 2 comps) catfish (10 fish, 2 comps) rainbow trout (10 fish, 2 comps)	catfish kokanee Rainbow trout	
Gene Wash Reservoir	3	San Bernardino	7	bass (6-9 legal, indiv) channel catfish (10 fish, 2 comps) bluegill (10 fish, 2 comps) crappie (10 fish, 2 comps)	catfish	Also Se (all species) and OCs (catfish)
Senator Wash Reservoir	4	Imperial	7	bass (6-9 legal, indiv) channel catfish (10 fish, 2 comps) bluegill (10 fish, 2 comps) crappie (10 fish, 2 comps)		Also Se (all species) and OCs (catfish)
Lopez Lake	5	San Luis Obispo	3	crappie (10 fish, 2 comps) bluegill (10 fish, 2 comps) catfish (10 fish, 2 comps)	catfish	
Lincoln Park Lake	6	Los Angeles	4	bass (6 legal, indiv) catfish (10 fish, 2 comps) bluegill (10 fish, 2 comps) crappie (10 fish, 2 comps) rainbow trout (10 fish, 2 comps)	Catfish Rainbow trout	
Malibou Lake	7	Los Angeles	4	bass (6 legal, indiv.) catfish (10 fish, 2 comps) crappie (10 fish, 2 comps)	catfish	
Sunbeam Lake	8	Imperial	7	bass (9 legal, indiv.) rainbow trout (10 fish, 2 comps) catfish (15 fish, 3 comps) carp (15 fish, 3 comps) bluegill (15 fish, 3 comps)	catfish rainbow trout carp	Also Se (all species) and OCs (catfish, trout, carp)

4

Water Body	BOG list #	County	Region	OEHHA recommendations-Hg	OEHHA PCBs	Comments
Lake Evans	9	Riverside	8	bass (6 legal, indiv) catfish (10 fish, 2 comps) rainbow trout (10 fish, 2 comps) bluegill (10 fish, 2 comps)	Catfish Rainbow trout	
Prado Lake	10	Riverside, San Bernardino	8	bass (6 legal, indiv) catfish (10 fish, 2 comps) rainbow trout (10 fish, 2 comps)	Catfish Rainbow trout	
Castaic Lagoon	11	Los Angeles	4	bass (6 legal, indiv) catfish (10 fish, 2 comps) crappie (10 fish, 2 comps) rainbow trout (5 fish, 1 comp) carp (5 fish, 1 comp)	catfish (if no catfish or just one composite of catfish, do carp	Sampling the Lagoon without sampling Castaic Lake will cause communication problems
Castaic Lake	See comment	Los Angeles	4	Striped bass (10 indiv, 2 comps) catfish (10 fish, 2 comps) crappie (10 fish, 2 comps) rainbow trout (10 fish, 2 comps)	Striped bass and catfish and rainbow trout	Not sampled as part of the BOG study - to be sampled concurrently but separately for Region 4
Legg Lake	12	Los Angeles	4	bass (6-9 legal, indiv) crappie (10 fish, 2 comps) bluegill (10 fish, 2 comps) rainbow trout (10 fish, 2 comps)	Rainbow trout	high Hg mean, may not be good candidate for clean lake study
Palmdale Lake	13	Los Angeles	6	bass (6 legal, indiv) catfish (5 fish, 1 comp) rainbow trout (10 fish, 2 comps) bluegill (10 fish, 2 comps) crappie (10 fish, 2 comps)	Catfish Rainbow trout	private lake
Lake Gregory	14	San Bernardino	6	bass (6 legal, indiv) catfish (10 fish, 2 comps) brown trout if present, otherwise rainbow(10 fish, 2 comps) bullhead (5 fish, 1 comp)	catfish carp Rainbow trout carp (5 fish, 1 comp)	high Hg mean, may not be good candidate for clean lake study)
Lake Henshaw	15	San Diego	6	bass (6 legal, indiv) catfish (10 fish, 2 comps) **crappie** (10 fish, 2 comps) bluegill (10 fish, 2 comps) bullhead (10 fish, 2 comps)	catfish	high Hg mean, may not be good candidate for clean lake study)

1

Water Body	BOG list #	County	Region	OEHHA recommendations-Hg	OEHHA PCBs	Comments
Lake Jennings	16	San Diego	9	bass (6 legal, indiv, good size range) channel (large) or blue catfish (10 fish, 2 comps) bluegill (10 fish, 2 comps) rainbow trout (10 fish, 2 comps) "whipers" (9-10, indiv)	Catfish Rainbow trout "Whipers" (comp)	
Lewiston Lake	17	Trinity	1	brook trout (10 fish, 2 comps) brown trout (10 fish, 2 comps)	brown trout (or brook if don't get browns)	Do not expect warm water spp. But if there (bass, catfish), collect
Lake Merced	18	San Francisco	2	9 largemouth bass (individuals) Trout (2 comps) Carp (2 comps)—unless they catch catfish, which is better for PCBs Bluegill (2 comps)	Trout Carp or catfish	Not previously sampled, but included to have a lake in Region 2.
Lake of the Pines	19	Nevada	5	Bass (largemouth and smallmouth, 6 legal each, indiv) Sunfish (10 fish, 2 comps) Crappie (10 fish, 2 comps) Catfish (10 fish, 2 comps)	catfish	
Caples Lake	20	Alpine	6	rainbow trout (10 fish, 2 comps) brook trout (10 fish, 2 comps) lake trout (10 fish, 2 comps)	lake trout	
Gold Lake	21	Sierra	5	Brown trout (10 fish, 2 comps) Lake trout (10 fish, 2 comps)	Brown or lake	
Tahoe Keys	22	Placer, El Dorado	6	bass (6 legal, indiv); crappie (10 fish, 2 comps) bluegill (10 fish, 2 comps) bullhead (10 fish, 2 comps)	Bullhead	
Dixon Lake	23	San Diego	9	bass (6 legal, indiv) **crappie** (10 fish, 2 comps) rainbow trout (10 fish, 2 comps) channel (large) or blue catfish (10 fish, 2 comps)	Catfish Rainbow trout	

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3 Table 6b. OEHHA recommendations for sampling at other lakes that were considered for inclusion in the study. Species in
4 **bold** are especially important target species.
5

Water Body	BOG list #	County	Region	OEHHA recommendations-Hg	OEHHA PCBs	Comments
Lake Alpine	21	Alpine	6	Rainbow trout (large, 6-10 1-2 comps	none needed unless other species present	
Ice House Reservoir	22	El Dorado	5	Brown trout (large) (10 fish, 2 comps)	Brown trout	
Huntington Lake	23	Fresno	5	kokanee (10 fish, 2 comps) rainbow trout (large) (10 fish, 2 comps) brown trout (10 fish, 2 comps)	brown trout or kokanee and Rainbow trout	
Topaz Lake	26	Mono	6	Rainbow trout (10 fish, 2 comps)	Rainbow trout Sucker (10 fish, 1 comp)	
Fallen Leaf Lake	27	El Dorado	6	Lake trout (at least 16") (10 fish, 2 comps) Kokanee (10 fish, 2 comps)	Lake trout or kokanee	
Indian Creek Reservoir	28	Alpine	6	Eagle Lake trout (10 fish, 2 comps) Rainbow trout (5 fish, 1 comp, or if less than 2 comps of Eagle lake, then 10 fish, 2 comps Rainbow trout)	Eagle Lake (or rainbow trout if don't have Eagle Lake)	
Lake Tahoe	See comment	Placer, El Dorado	6	Lake trout (10 fish, 2 comps) Brown trout (10 fish, 2 comps) Kokanee (10 fish, 2 comps)	Brown, Lake, or kokanee and rainbow trout	Not included in this BOG study.

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1   Table 7.   Target species and their characteristics.
2

Species	Foraging Type		Trophic Level	Distribution			Priority for Collection
	Water column	Bottom feeder		Low Eleva-tion	Foothi lls	High Elevat ion	
Largemouth bass	X		4	**X**	**X**		**A**
Smallmouth bass	X		4	x	**X**		**A**
Spotted bass	X		4	x	**X**		**A**
Sacramento pikeminnow	X		4	x	x		B
White catfish		X	4	x	x		**A**
Brown bullhead		X	3	x			B
Channel catfish		X	4	**X**	**X**		**A**
Carp		X	3	**X**	**X**		**A**
Sacramento sucker		X	3	x	x		B
Tilapia		X	3				B
Bluegill	X		3	**X**	**X**		B
Green sunfish	X		3	**X**	**X**		B
Crappie	X		3/4	x	x		B
Redear sunfish	X		3	**X**	**X**		B
Rainbow trout	X		3/4	x	x	**X**	**A**
Brown trout	X		3/4		x	x	**A**
Brook trout	X		3			x	**A**
Kokanee	X		3	?	x	x	B

3
4   Trophic levels are the hierarchical strata of a food web characterized by organisms that are the same number of steps removed
5   from the primary producers. The USEPA's 1997 Mercury Study Report to Congress used the following criteria to designate
6   trophic levels based on an organism's feeding habits:
7   Trophic level 1: Phytoplankton.
8   Trophic level 2: Zooplankton and benthic invertebrates.
9   Trophic level 3: Organisms that consume zooplankton, benthic invertebrates, and TL2 organisms.
10   Trophic level 4: Organisms that consume trophic level 3 organisms.
11   **X** widely abundant   x less widely abundant   "A" primary target for collection   "B" secondary target for collection

Table 8.   Target species, size ranges, and processing instructions.   I - process as individuals. C - process as composites.

	Process for Mercury	Process for Organics and Selenium	Numbers and Size Ranges (mm)
Primary Targets: stay on location until one of these targets from both Group 1 and 2 is obtained, or collect secondary targets if primary targets are not available			
Group 1) Predator			
Black bass	I		2X(200-249), 2X(250-304), 6X(305-407), 2X(>407)
Sacramento pikeminnow	I		3X(200-300), 5X(300-400), 3X(400-500)
Brown trout	I	C	3X(200-300), 5X(300-400), 3X(400-500)
Rainbow trout	C	C	5X(300-400)
Brook trout	C	C	5X(300-400)
Group 2) Bottom feeder			
White catfish	C	C	5X(229-305)
Channel catfish	C	C	5X(375-500)
Common carp	C	C	5X(450-600)
Brown bullhead	C		5X(262-350)
Sacramento sucker	C	C	5X(375-500)
Secondary Targets: collect these if primary targets are not available			
Bluegill	C	C	5X(127-170)
Redear sunfish	C	C	5X(165-220)
Black crappie	C	C	5X(187-250)
Tilapia	C	C	5X(235-314)
Green sunfish	C	C	Xx
Kokanee	C	C	5X(300-400)

Table 9.   Summary of sport fish analytes included in the study.

Analyte	Included in Study?
Methylmercury[1]	Some individuals, all composites
PCBs	Selected composites
DDTs	Selected composites
Dieldrin	Selected composites
Aldrin	Selected composites
Chlordanes	Selected composites
Selenium	Selected composites
Microcystins	Not included (except for work funded by Region 9)
PBDEs	Not included
Dioxins	Not included
Perfluorinated chemicals	Not included
Omega-3 fatty acids	Not included

[1] Measured as total mercury, which provides a direct estimate of methylmercury in fish muscle.

Table 10.   Parameters to be measured in sport fish.

FISH ATTRIBUTES
1.   Total length
2.   Fork length
3.   Standard length (small fish only)
4.   Weight
5.   Sex
6.   Moisture
7.   Lipid content
8.   Age (for black bass)

METALS AND METALLOIDS
1.   Total mercury
2.   Selenium

PESTICIDES

Chlordanes
1.   Chlordane, cis-
2.   Chlordane, trans-
3.   Heptachlor
4.   Heptachlor epoxide
5.   Nonachlor, cis-
6.   Nonachlor, trans-
7.   Oxychlordane

DDTs
1.   DDD(o,p')
2.   DDD(p,p')
3.   DDE(o,p')
4.   DDE(p,p')
5.   DDMU(p,p')
6.   DDT(o,p')
7.   DDT(p,p')

Cyclodienes
1.   Aldrin
2.   Dieldrin
3.   Endrin

HCHs
1.   HCH, alpha
2.   HCH, beta

Others

1. Dacthal
2. Endosulfan I
3. Hexachlorobenzene
4. Methoxychlor
5. Mirex
6. Oxadiazon

PCBs

1. PCB 008
2. PCB 011
3. PCB 018
4. PCB 027
5. PCB 028
6. PCB 029
7. PCB 031
8. PCB 033
9. PCB 044
10. PCB 049
11. PCB 052
12. PCB 056
13. PCB 060
14. PCB 064
15. PCB 066
16. PCB 070
17. PCB 074
18. PCB 077
19. PCB 087
20. PCB 095
21. PCB 097
22. PCB 099
23. PCB 101
24. PCB 105
25. PCB 110
26. PCB 114
27. PCB 118
28. PCB 126
29. PCB 128
30. PCB 137
31. PCB 138
32. PCB 141
33. PCB 146
34. PCB 149
35. PCB 151
36. PCB 153
37. PCB 156

38.   PCB 157
39.   PCB 158
40.   PCB 169
41.   PCB 170
42.   PCB 174
43.   PCB 177
44.   PCB 180
45.   PCB 183
46.   PCB 187
47.   PCB 189
48.   PCB 194
49.   PCB 195
50.   PCB 198/199
51.   PCB 200
52.   PCB 201
53.   PCB 203
54.   PCB 206
55.   PCB 209

Algal Toxins

Microcystins
1.   MCY-RR
2.   MCY-LR
3.   MCY-YR
4.   MCY-LA

MC metabolites
1.   Desmethyl-LR
2.   Desmethyl-RR

Cyanotoxins
1.   anatoxin a

Figure 1.   Map of sampling locations. Lake names are indicated in Table 5.

Figure 2.   Sampling design for a small lake.
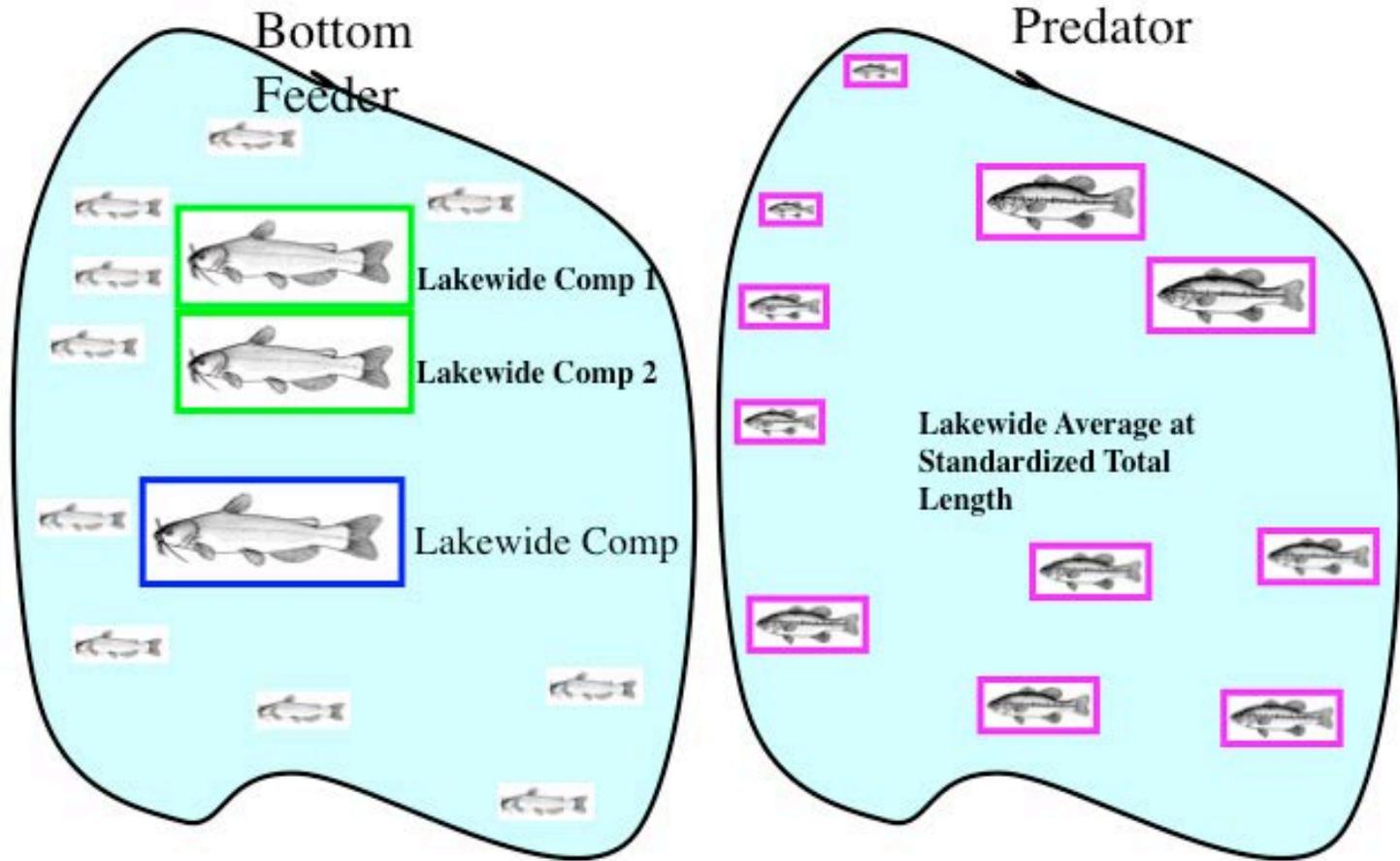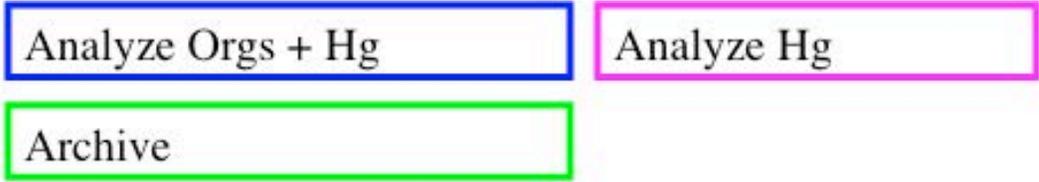
Figure 3.   Sampling design for a medium-sized lake.