Additional Scientific and Technical Information for the SWRCB Comprehensive (Phase 2) Review and Update to the Bay-Delta Plan

PREPARED FOR:	Linda Dorn/SRCSD Terrie Mitchell/SRCSD
PREPARED BY:	Cameron Irvine/CH2M HILL Christine Arenal/CH2M HILL
DATE:	August 16, 2012

The State Water Resource Control Board (SWRCB) asked for two types of information in its June 22, 2012, public notice informing stakeholders and interested parties about the pending Delta-Plan Information Review workshops: 1) scientific and technical information related to ecosystem changes in the low salinity zone (LSZ) of the Delta along with levels of uncertainty and recommended changes to the Delta Plan supported by the new information; and 2) comments on how to address uncertainty, change, and how to implement an adaptive management program (AMP). A response to the latter request for addressing uncertainty is presented here that will improve the quality of data used to inform AMPs and management decisions in the Delta, thus reducing uncertainty. This is presented in the first section as a lens to which all the following new information presented here can be viewed and lessons learned from those investigations.

1. Data Quality

Decision-makers should have sound environmental data. Debate over the validity of scientific studies generally arises 1) when data are of unknown or poor quality or 2) when scientists or decision makers do not agree on how data should be evaluated or applied. Poor quality data can misinform the public and decision makers and waste resources in debates, repeating studies, or in management decisions that do not have the desired effect because they are founded on incorrect information. These problems can be addressed to a large degree with only a moderately increased level of effort during investigation planning stages to develop clear Data Quality Objectives[1] (DQOs).

The DQO process is used to develop performance and acceptance criteria (or DQOs) that clarify study intent, define the appropriate type of data, and serve as the basis for designing a plan for collecting data of sufficient quality and quantity to support the goals of a study. The use of DQOs, typically in a Quality Assurance Project Plan (QAPP), is a requirement of the Data Quality Act for U.S. Environmental Protection Agency (EPA) projects to ensure that management decisions are based on data of known (and acceptable) quality (EPA Order CIO 2105.5 [preceded by EPA Order 5360.1 A2, EPA 2000, and 48CFR 46]).

This process allows for the decision-makers and planning teams to facilitate good communication and project documentation, concentrate on developing the appropriate requirements for collecting data of known quality, clarify vague objectives, and ensure the data will fulfill their intended use, all of which

[1] U.S. Environmental Protection Agency (EPA). 2006. “Guidance on Systematic Planning Using the Data Quality Objectives Process.” Office of Environmental Information. Washington, DC. EPA/240/B-06/001.

encourages more efficient peer review and acceptance. Scientific studies can be strengthened by clearly developing sound, comprehensive DQOs. As described by EPA, the DQO process defines criteria that will be used to establish the final data collection design, and consists of:

- The nature of the problem and a conceptual model
- The eventual decisions or estimates to be made
- The type of data needed
- How the data will be used to draw conclusions from the study findings
- Acceptable data quality criteria
- The investigation design that will collect data to meet stated objectives

Including the DQO process into planning documents will serve as an effective tool to help develop performance and acceptance criteria for the collection, evaluation, and use of environmental data in the Delta and to reduce uncertainty by generating data of known quality. The data can be validated and deemed acceptable if they meet the established data quality criteria or rejected if they do not. Validated data minimize uncertainties and help decision-makers develop well supported management approaches. Further, when stakeholders and regulators are included in the development of DQOs as part of planning documents for studies or monitoring programs, debates are less likely because the high-quality and validated data generated have reduced uncertainty and the data uses have already been agreed to by all parties.

In addition to generating high-quality data, the analyses and conclusions made from these data should be peer reviewed. Scientists produce work of varying quality and the confidence that resource managers have in data interpretations can be improved through peer review. However, not all peer reviews are created equal and the impact of peer review on document quality varies. Some peer reviews are very rigorous and have high standards for addressing reviewer comments, as determined by an editor or referee, but some reviews do not have any effect on the author's original conclusions if left to the discretion of the author. The most effective peer reviews solicit comments from peers with appropriate subject knowledge, referees validate the adequacy of responses to comments, and the comments/responses are included as appendices where readers can consider where disagreement exists.

A thorough and critical review of all information to develop a weight-of-evidence conclusion is further recommended to generate a balanced and weighted approach that accounts for differences in data quality, interpretations, and uncertainties. Such integration of data (preferably of known quality) will allows decision-makers to be confident that the foundations of their decisions can withstand technical scrutiny and helps them understand the level of confidence in achieving desired goals.

2. New Scientific and Technical Information Related to Ecosystem Changes in the LSZ

Summaries of new information are provided with brief descriptions of their associated uncertainties and positive attributes that reflect sound science and/or practices. Table 1 highlights the key points of each new study that is discussed.

TABLE 1
Highlights from Additional Scientific and Technical Information

Key Points	Uncertainties	Reference
Invasive Clams		
Grazing by invasive clams has contributed to the decline of phytoplankton biomass and annual phytoplankton blooms.	There is little consideration of this significant driver of ecosystem productivity and conceptual or empirical models that do not take bivalve grazing into account are highly uncertain.	Thompson and Parchaso. 2010. *Corbula amurensis* Conceptual Model. Prepared for the Delta Science Program. Greene et al. 2011. Grazing impact of the invasive clam Corbula amurensis on the microplankton assemblage of the northern San Francisco Estuary. Thompson et al. 2008. Shallow water processes govern system-wide phytoplankton bloom dynamics: A field study. Journal of Marine Systems. Winder and Jassby. 2011. Shifts in Zooplankton Community Structure: Implications for Food Web Processes in the Upper San Francisco Estuary.
Contaminants/Toxicity		
Guidance is provided for developing monitoring programs for contaminants of emerging concern.	The use of a Science Advisory Panel of experts to recommend a thoroughly vetted strategy for monitoring CECs limits uncertainty in these recommendations. However, there is little consideration of non-point sources, which remain an uncertainty.	Anderson et al. 2012. Monitoring Strategies for Chemicals of Emerging Concern (CECs) in California's Aquatic Ecosystems: Recommendations of a Science Advisory Panel.
Sources of pyrethroid pesticides are reported.	Evaluation of toxicity in effluent is not a relevant exposure when effluent is diluted in receiving waters. Therefore, toxicity data is not relevant for evaluating ecosystem impairment.	Weston and Lydy. 2010. Urban and agricultural sources of pyrethroid insecticides to the Sacramento-San Joaquin Delta of California.
Pyrethroids and organophosphates are reported in the Delta tributaries.	Uncertainties were managed in this study by sampling and testing over a large area to confirm that conclusions are broadly applicable.	Weston et al. in press. Identifying the cause of sediment toxicity in agricultural sediments: The role of pyrethroids and nine seldom-measured hydrophobic pesticides. Chemosphere.
This review article summarizes existing data and proposes a new approach for monitoring aquatic organisms health.	References are generic and may not describe studies or species relevant to the Delta. Greater impact from treated wastewater if portrayed than is warranted based on the available data.	Brooks et al. 2012. Life Histories, Salinity Zones, and Sublethal Contributions of Contaminants to Pelagic Fish Declines Illustrated with a Case Study of San Francisco Estuary.
The study concluded that sufficient high-quality chemical data are not available to make conclusions about the role of specific contaminants in the POD.	Care should be taken in drawing any conclusions about the effect of contaminants on the POD due to limited data.	Johnson et al. 2010. *Evaluation of Chemical, Toxicological, and Histopathologic Data to determine their Role in the Pelagic Organism Decline.*

TABLE 1
Highlights from Additional Scientific and Technical Information

Key Points	Uncertainties	Reference
Ammonia toxicity testing with a novel test species (*Pseudodiaptomus forbesi*) is reported .	There are significant concerns over the validity of these test data and the calculated effect levels. Uncertainties could be managed by retesting in accordance with well defined DQOs.	Teh, et al. 2011. Full Life-Cycle Bioassay Approach to Assess Chronic Exposure of *Pseudodiaptomus forbesi* to Ammonia/Ammonium.
Ambient surface water toxicity is reported.	This study contains good data, but some of the data analyses and conclusions are based on incomplete information.	Werner et al. 2010a. Pelagic Organism Decline (POD): Acute and Chronic Invertebrate and Fish Toxicity Testing in the Sacramento-San Joaquin Delta 2008-2010. Werner et al. 2010b. Monitoring acute and chronic water column toxicity in the northern Sacramento-San Joaquin Estuary, California, USA, using the euryhaline amphipod, *Hyalella azteca*: 2006-2007.
Sub-cellular effects in delta smelt exposed to ammonia are reported.	Linkages between biomarkers and adverse affects at the whole organism level that would affect survival, growth or reproduction are not clear.	Connon et al. 2011. Sublethal responses to ammonia in the endangered delta smelt

2.1 Invasive Clams

Thompson, J.K. and F. Parchaso. 2010. *Corbula amurensis* Conceptual Model. Prepared for the Delta Science Program.

This peer reviewed Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) conceptual model summarizes existing knowledge of invasive bivalves in the Sacramento-San Joaquin River Delta ecosystem and is an excellent source of information on this much neglected factor which has a potentially great effect on the Delta ecosystem. The Delta is described as a high nutrient, high turbidity estuary with low primary production due to a combination of light limitation and bivalve grazing[2, 3].

Corbula amurensis (Corbula), an invasive clam species now prevalent in portions of the San Francisco Estuary (SFE), is a suspension feeder that can filter and assimilate both phytoplankton and bacteria (<1.2 micrometers [µm]) from the water column.[4] *Corbula* can withstand a wide range of salinities (~2 to 30 practical salinity units [psu]),[5] and therefore maintains a high population year-round in the intertidal areas of the Delta (see Figure 1).

The northern part of the SFE has always had low primary production, but declines in primary production following the invasion of *Corbula* in 1986 lead researchers to conclude that suspension feeding by

---

2 Cloern, J.E., 2001. Our evolving conceptual model of coastal the eutrophication problem. Marine Ecology Progress Series, 210:223-253.

3 Thompson JK, Koseff JR, Monismith SG, Lucas LV, 2008 (in press). Shallow water processes govern system-wide phytoplankton bloom dynamics: A field study. Journal of Marine Systems. doi:10.1016/j.jmarsys.2007.12.006

4 Werner I, Hollibaugh, JT, 1993. *Potamocorbula amurensis*: comparison of clearance rates and assimilation efficiencies for phytoplankton and bacterioplankton. Limnology and Oceanography, 38:949-964.

5 Nicolini MH, Penry DL, 2000. Spawning, fertilization, and larval development of *Potamocorbula amurensis* (Mollusca: Bivalvia) from San Francisco Bay, California. Pacific Science, 54:377-388.

Corbula resulted in the decline in phytoplankton biomass (annual primary production[6,7] has been reduced from ≈100 grams of carbon per square meter per year [carbon/m^2/yr] to <20 grams of carbon/m^2/yr) and the elimination of an annual phytoplankton bloom in the estuary.[7,8] *Corbula* were reported to clear the water column up to once every 8-16 hours in Grizzly Bay and every 8-24 hours in the channel. High *Corbula* grazing rates in conjunction with relatively high water column vertical mixing rates continually challenge the potential for phytoplankton biomass increase in these shallow systems. This decline of phytoplankton biomass is also correlated with long-term declines of copepod and mysid shrimp populations.

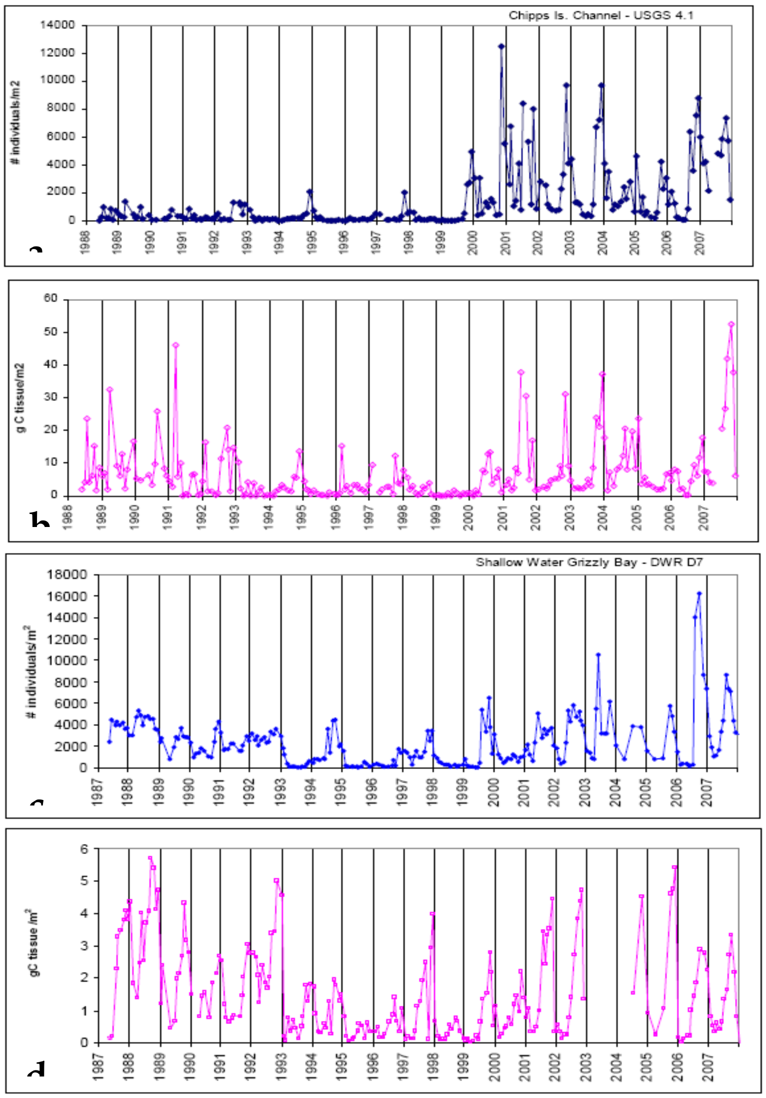

Figure 1: Density and biomass of *Corbula* at the western Delta (a, b) and in Grizzly Bay (c,d). Grizzly Bay data courtesy of DWR CALFED Biomass Study. (reproduced from Thompson and Parchaso, 2010)

---

6 Jassby, A.D., J.E. Cloern, and B.E. Cole. 2002. Annual primary production: patterns and mechanisms of change in a nutrient-rich tidal ecosystem. Limnology and Oceanography, 47(3):698-712.

7 Alpine, A.E. and J.E. Cloern. 1992. Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary. Limnology and Oceanography, 37 (5):946-955

8 Kimmerer, W.J. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages. Marine Ecology Progress Series, 243:39-55.

Greene, V.E., L.J. Sullivan, J.K. Thompson, and W.J. Kimmerer. 2011. Grazing impact of the invasive clam *Corbula amurensis* on the microplankton assemblage of the northern San Francisco Estuary. Mar. Ecol. Prog. Ser. 431:183-193.

Grazing by the invasive overbite clam, *Corbula amurensis,* may be the cause of substantial declines in phytoplankton biomass and zooplankton in the SFE following its introduction in 1986. *Corbula* cleared 0.5 liters/individual/hour of microzooplankton (ciliates) and 0.2 liters/individual/hour of chlorophyll in this study. The authors conclude that the observed grazing rate may be sufficient for *Corbula* to alter food web dynamics through its predation and would disrupt the links between lower and higher trophic levels (see Figure 2).

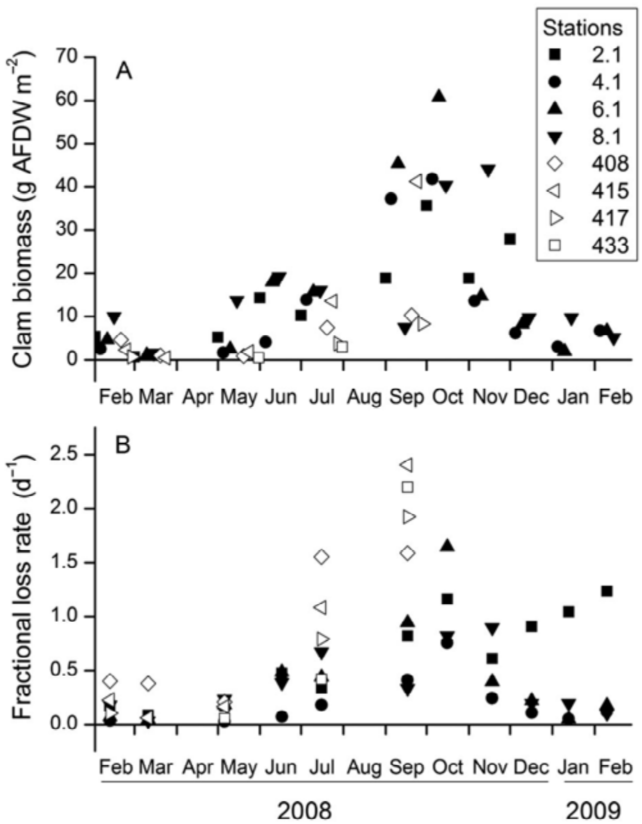

Figure 2: (A) Mean biomass from February 2008 to February 2009 in the low-salinity zone of SFE. (B) Estimated fractional loss rate (d-1) of microzooplankton resulting from grazing. (Note: Solid symbols indicate channel stations and open symbols indicate shoal stations.) (reproduced from Greene et al. 2011).

Thompson, J.K., J.R. Koseff, S.G. Monismith, and L.V. Lucas. 2008. Shallow water processes govern system-wide phytoplankton bloom dynamics: A field study. Journal of Marine Systems. 74:153-166.

This study found that phytoplankton bloom occurrence was dependent on shallow-water benthic filter-feeder grazing as well as surface water quality (i.e., turbidity and nutrients). These consumers have great potential to change the phytoplankton bloom dynamics in the Delta. One reason why benthic bivalves can effectively control phytoplankton biomass is that they are “always” present to some degree. Bivalves' long lives (relative to zooplankton) and large size allow them to survive periods of low food availability and to respond immediately to any increase in phytoplankton biomass. Shallow-water bivalves can be consumed by migratory birds and fish in the fall and winter.[9, 10] However, grazing rates can be high year-round (see Figure 3).

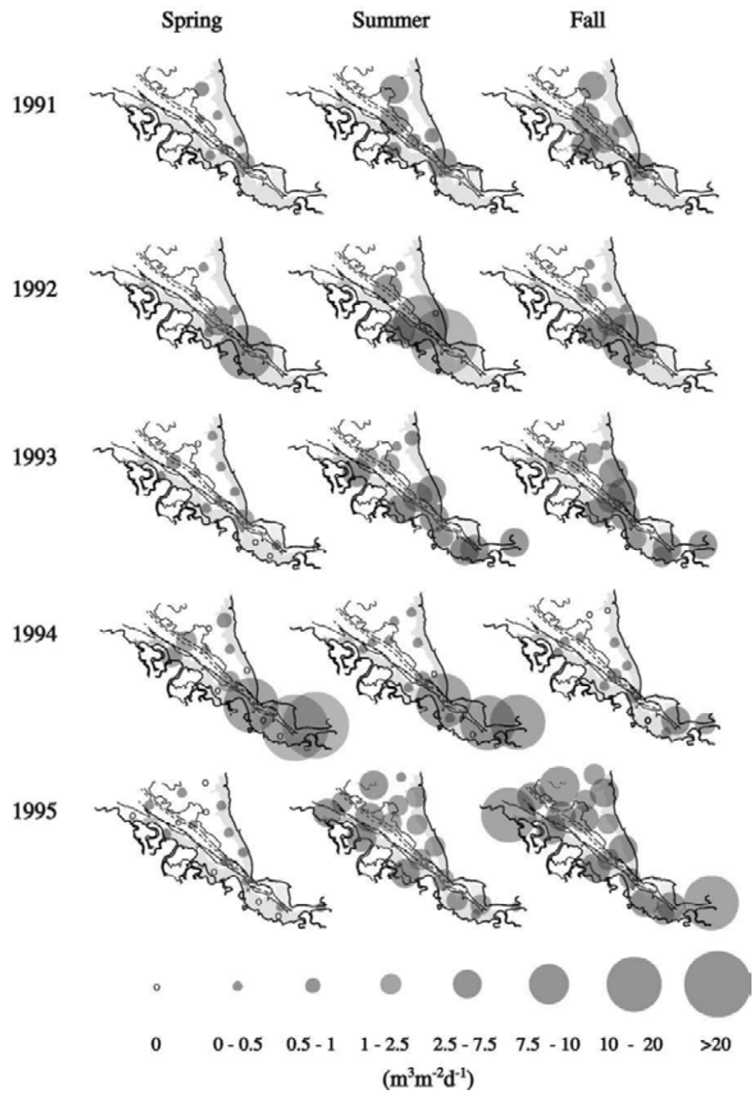

Figure 3: Bivalve grazing rates prior to spring bloom, in mid-summer, and in fall. (reproduced from Thompson et al. 2008)

9 Richman, S.E. and J.R. Lovvorn. 2004. Relative foraging value to Lesser Scaup ducks of native and exotic clams from San Francisco Bay. Ecological Applications 14 (4), 1217–1232.

10 Poulton, V.K., , J.R. Lovvorn, and J.Y. Takekawa. 2004. Spatial and overwinter changes in clam populations of San Pablo Bay, a semiarid estuary with highly variable freshwater inflow. Estuarine Coastal and Shelf Science 59 (3), 459–473.

Winder, M and A.D. Jassby. 2011. Shifts in Zooplankton Community Structure: Implications for Food Web Processes in the Upper San Francisco Estuary. Estuaries and Coasts. 34:675-690.

Zooplankton are an important trophic link and a key food source for many larval fish species in estuarine ecosystems. This study documents zooplankton dynamics in Suisun Bay and the Sacramento–San Joaquin Delta over a 37-year period (1972–2008). The zooplankton community experienced major changes in species composition during 1987–1994, largely associated with direct and indirect effects from the introduction of non-native bivalve species coupled with an extended drought period. A step decline in chl-a concentration in the mid 1980s coincided with the invasion of Corbula, and concentrations have remained at low levels (Figure 4).

Shifts in zooplankton species composition have also been accompanied by an observed decrease in zooplankton size and food quality as shown in Figure 5. These changes in the biomass, size, and possibly chemical composition of the zooplankton community imply major alterations in pelagic food web processes, including a drop in prey quantity and quality for foraging fish and an increase in the importance of the microbial food web for higher trophic levels.

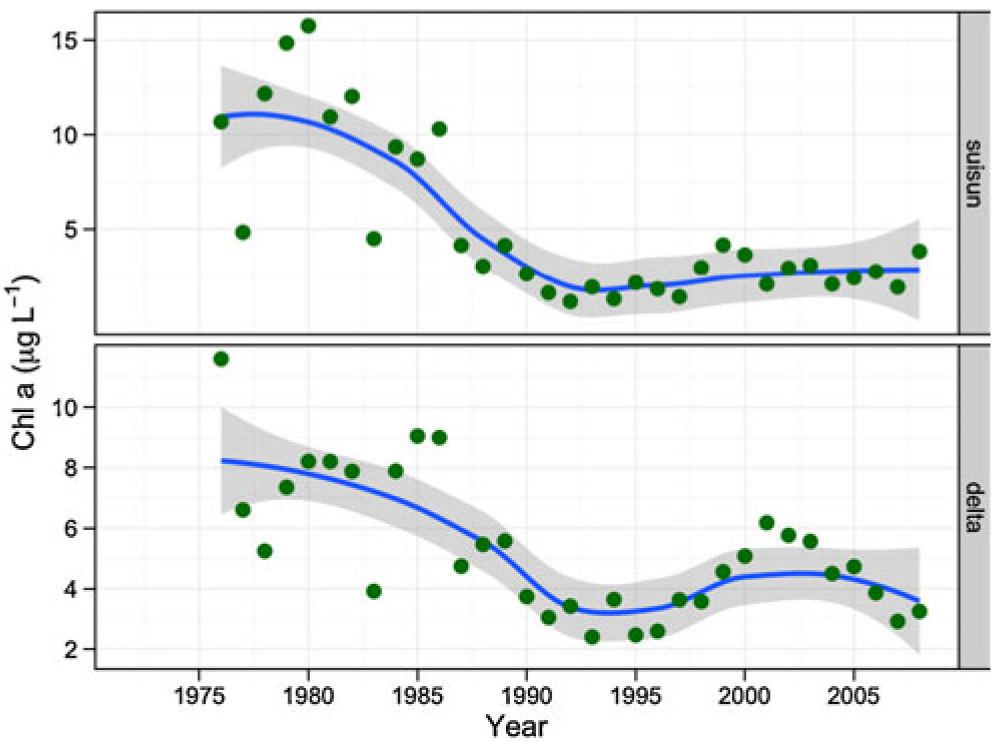

Figure 4: Annual average chlorophyll a concentration by subregion in the upper San Francisco Estuary between 1976 and 2008. Top panel represents the “suisun” and bottom panel the “delta” subregion. The blue line displays a loess fit ± standard error (shaded area) (reproduced from Winder and Jassby, 2011)

The study found large spatial and temporal changes of the zooplankton community in the Sacramento–San Joaquin Delta and Suisun Bay over the last four decades in both abundances and species composition. Major shifts in the zooplankton community composition coincided with the extended drought during 1987–1994 and explosive colonization of the invasive clam C. amurensis at the beginning of the drought.[11,12] Food limitation and predation after the population expansion of the overbite clam *C. amurensis* was the likely reason for the decline in the zooplankton community. Many zooplankton, including calanoids, rotifers, and mysids, compete with benthic suspension feeders for phytoplankton[13,14].

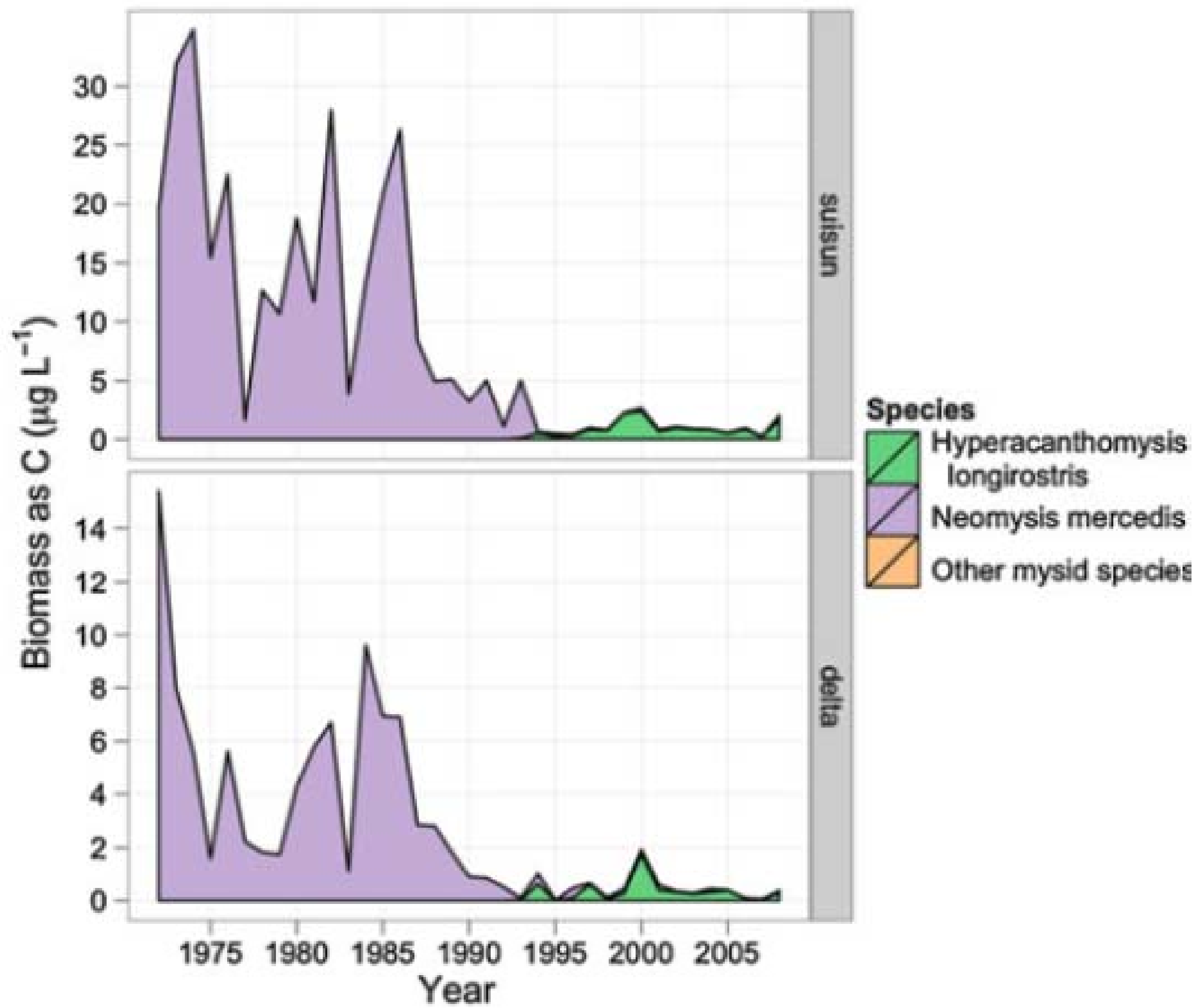

Figure 5: Annual average biomass of mysids species by subregion in the upper San Francisco Estuary between 1972 and 2008. *H.longirostris* was formerly classified as *A. canthomysis bowmani*; other mysids species include *A. aspera*, *A. hwanhaiensis*, *Alienacanthomysis macropsis, Deltamysis holmquistae, Neomysis kadiakensis*, and unidentified mysids. Top panel represents the "suisun" and bottom panel the "delta" subregion (reproduced from Winder and Jassby, 2011).

[11] Carlton, J.T., J.K. Thompson, L.E. Schemel, and F.H. Nichols. 1990. Remarkable invasion of San-Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis*. I. Introduction and dispersal. Marine Ecology Progress Series 66: 81–94.

[12] Alpine, A.E. and J.E. Cloern. 1992. Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary. Limnology and Oceanography 37: 946–955.

[13] Murrell, M.C. and J.T. Hollibaugh. 1998. Microzooplankton grazing in northern San Francisco Bay measured by the dilution method. Aquatic Microbial Ecology 15: 53–63.

[14] Irigoien, X., J. Titelman, R.P. Harris, D. Harbour, and C. Castellani. 2003. Feeding of *Calanus finmarchicus* nauplii in the Irminger Sea. Marine Ecology Progress Series 262: 193–200.

Uncertainties – Invasive Clams

Invasive clams have altered phytoplankton and zooplankton communities in the Delta and continue to consume incredible amounts of algae. It is unclear why there is relatively little discussion over how this has affected the POD, or what can be done to address it. Instead, the discussion has focused on whether or not there is a potential for one form of nitrogen to impair algae productivity over another form of nitrogen. Conceptual and empirical models that are being developed or considered should include the losses of phytoplankton due to grazing by invasive clams using known variables such as filtration rates, growth, abundance, and known preferred habitats (i.e., depth and salinity ranges where they occur). Uncertainty with phytoplankton growth models will be reduced when this significant factor is considered.

2.2 Contaminants/Toxicity

The 2009 staff report includes appropriate recommendations to allow the San Francisco Bay and Central Valley Regional Water Quality Control Boards to continue their efforts on ammonia and toxicity issues. However, the following information and discussion is presented in the event of renewed interest in these topics by the SWRCB.

Anderson, P.D., N.D. Denslow, J.E. Drewes, A.W. Olivieri, D. Schlenk, G.I. Scott and S.A. Snyder. 2012. Monitoring Strategies for Chemicals of Emerging Concern (CECs) in California's Aquatic Ecosystems: Recommendations of a Science Advisory Panel, Technical Report 692 - April 2012.

This technical report was prepared for the SWRCB by a selection of scientific experts charged with identifying potential sources, evaluating the fate and effects of chemicals of emerging concern (CECs), and ultimately providing guidance for developing monitoring programs to assess those chemicals with the highest potential of causing adverse effects in California surface waters. The following are the four products developed to help design a CEC monitoring process:

- A conceptual, risk-based approach to assess and identify CECs for monitoring in California receiving waters.
- Application of the risk-based screening framework to identify a list of CECs for initial monitoring.
- An adaptive, phased monitoring approach with interpretive guidelines that direct and update actions commensurate with potential risk.
- Identified research needs to develop bioanalytical screening methods, link molecular responses with higher order effects, and fill key data gaps.

Uncertainties

Data on CEC concentrations, analytical method development, and effect levels are continuing to improve; however, considerable uncertainty remains on these fronts, as identified by the report authors. This report was focused on treated wastewater point sources while "…agricultural sources were outside of the scope of this panel…" Non-point sources such as livestock facilities, which are known to contribute considerable CECs to receiving waters,[15,16] may be considered under other efforts, but

---

[15] Brander, S. 2010. From otoliths to oocytes: a three-tiered investigation into estrogenic and androgenic effects in a California estuary. Presented at the 20th Annual Meeting of the Northern California Regional Chapter of the Society of Environmental Toxicology and Chemistry. May 2010, Berkeley, CA.

should not be ignored. Understanding the uncertainties and formulating a plan to shed light on data gaps is an appropriate approach to move forward to the point where data are sufficient to inform management decisions.

Weston, D.P. and M.J. Lydy. 2010. Urban and agricultural sources of pyrethroid insecticides to the Sacramento-San Joaquin Delta of California. Environ. Sci. Tech. 44:1833-1840.

Weston and Lydy (2010) describe their assessment of potential pyrethroid sources in the Delta. Pyrethroids were found in treated wastewater and urban storm water at concentrations sufficient to cause toxicity to *Hyalella azteca*. Toxicity identification evaluation (TIE) methods confirmed the presence of pyrethroids in effluent and urban storm water. However, the reported toxicity in effluent is not a relevant exposure media for aquatic organisms that are exposed to effluent only after dilution by receiving waters. Further, the potential for pyrethroid loading into receiving waters should be interpreted with caution. For example, pyrethroid measurement errors are compounded by millions of gallons per day of treated wastewater that is discharged, and dilution in the Sacramento River reduces pyrethroids from Sacramento Regional Wastewater Treatment Plant (SRWTP) effluent to concentrations well below levels known to cause toxicity (EC50s range from 1.7-21.1 nanograms per liter [ng/L]). These low ambient concentration estimates are supported by the absence of toxicity in ambient samples from the Sacramento River by Weston and Lydy (2010) and by the lack of acute or chronic toxicity to *H. azteca* in 51 samples from Hood, a monitoring station located about 8 miles downstream of the SRWTP effluent discharge, reported by Werner et al. (2010a). Preliminary data from follow-up testing in 2011-2012 confirm the lack of detectable concentrations of pyrethroids in the Sacramento River downstream of SRWTP and the lack of toxicity to *H. azteca*[17]. It should also be noted that Weston and Lydy (2010) reported the highest concentrations of pyrethroids in urban storm drains[18] and surface water of tributaries receiving agricultural drainage.[19] Detailed calculations of pyrethroid loading from suspended sediments in agricultural drains and urban storm water have also been reported[20]. Likewise, recent work by Weston found that pyrethroids were present and causing toxicity to freshwater invertebrates in Delta tributaries affected by discharges from agricultural drains[21].

Uncertainties

Although this initial work by Weston and Lydy (2010) added value to the body of research on pyrethroid sources and toxicity in the Delta, there were uncertainties in the early study results and conclusions that need to be addressed to provide sound science for decision-making. For example, a “rough approximation” of pyrethroid loading into the Sacramento River from SRCSD discharge was based on a median concentration that overestimates loads when there were sampling days when no pyrethroids were detected. Detected pyrethroid concentrations reported in SRCSD effluent samples were variable

---

[16] Jeffries, K.M., E.R. Nelson, L.J. Jackson and H.R. Habibi. 2008. Basin-wide Impacts of Compounds with Estrogen-like Activity on Longnose Dace (*Rhinichthys cataractae*) in two Prairie Rivers of Alberta, Canada. Env. Tox. and Chem. 27:2042-2052.

[17] Ohlinger, K. 2011. Pyrethroid pesticides in municipal wastewater: early results. Presented to the Pelagic Organism Decline Contaminant Work Team (POD-CWT). June 22, 2011.

[18] Weston, D. and M. Lydy. 2012. Stormwater Input of Pyrethroid Insecticides to an Urban River. Env. Tox. and Chem. 31:1-8.

[19] Weston, D., S. Teh, S. Lesmeister and M. Lydy. 2011. T*he Role of Pyrethroid Insecticides in Limiting Prey Availability for Delta Smelt in the North Delta.* Presented to the POD-Contaminant Work Team, on June 22, 2011, Sacramento, CA.

[20] Domagalski, J.L., D.P. Weston, M. Zhang, and M. Hladik.. 2010. Pyrethroid insecticide concentrations and toxicity in streambed sediments and loads in surface waters of the San Joaquin Valley, California, USA. . Env. Toxicol. Chem. 29(4):813-823.

[21] Weston, D.P., Y. Ding, M. Zhang, and M.J. Lydy. in press. Identifying the cause of sediment toxicity in agricultural sediments: The role of pyrethroids and nine seldom-measured hydrophobic pesticides. Chemosphere.

among events and for individual pyrethroids during each event. Measured concentrations were also at or near reporting limits where the associated error is highest. Measurements were also based on single grab samples collected during each event. The load calculations compound these potential errors by multiplying them by the millions of liters discharged each day. However, these uncertainties surrounding initial load estimates have been mediated by repeated studies where sampling did not find detectable pyrethroids in surface water samples and there was no toxicity to *Hyalella*. Repeated analyses and specific DQOs to use serial dilutions of effluent samples to evaluate the potential for toxicity in receiving waters are appropriate methods for addressing uncertainty associated with initial results.

Weston, D.P., Y. Ding, M. Zhang, and M.J. Lydy. in press. Identifying the cause of sediment toxicity in agricultural sediments: The role of pyrethroids and nine seldom-measured hydrophobic pesticides. Chemosphere.

Seldom-analyzed but commonly used hydrophobic pesticides were analyzed in 69 sediment samples from Central Valley tributaries receiving agricultural irrigation runoff. Only a few of these pesticides were infrequently found to be present at concentrations contributing to *H. azteca* and *Chironomus dilutus* toxicity (abamectin, fenpropathrin, and methyl parathion), whereas pyrethroids (bifenthrin, lambda-cyhalothrin, cypermethrin, esfenvalerate, and permethrin) and the organophosphate chlorpyrifos were primarily responsible for observed toxicity.

Uncertainties

Uncertainty is managed in this study by reporting data from samples collected over a large area of the Delta. This work also builds upon previous studies that found pyrethroids in Delta tributaries.[22]

Brooks, M.L., E. Fleishman, L.R. Brown, P.W. Lehman, I. Werner. 2012. Life Histories, Salinity Zones, and Sublethal Contributions of Contaminants to Pelagic Fish Declines Illustrated with a Case Study of San Francisco Estuary.

This manuscript is largely a review article describing the POD. No new data or compelling data analyses are presented. The importance of organism life histories and environmental variables that affect exposures to contaminants are described as important considerations when evaluating possible adverse effects. Generic and brief conceptual models illustrating how these environmental variables may affect direct sublethal or indirect (i.e., through the food web) toxicity are discussed using the SFE as a case study. The stated goal is to “recast thinking about contaminant effects and criteria for identifying them, and to encourage development of suitable methods of assessment.”

The manuscript should only be considered to provide general information supporting the evaluation of energetic costs as a surrogate for chronic effects in Delta species. While the manuscript seems to focus on a case study of the SFE, many of the references are generic and may or may not describe studies or species relevant to the Delta/SFE. The authors discuss many factors that should be considered in any effects evaluation, but do not adequately describe the relative contributions from various sources and locations. The manuscript contains elements of bias, often framing study descriptions (for inorganic nitrogen, cyanobacterial blooms, and pyrethroids) in a way that implies greater impact from treated wastewater than indicated by the data. The lack of references to invasive clams affecting the POD,[23] or considering them as a confounding factor when interpreting Delta environmental data, is a major oversight. The authors discuss many factors that should be considered in an effects evaluation, but do

22 Amweg, E.L., D.P. Weston, and N.M. Ureda. 2005. Use and toxicity of pyrethroid pesticides in the Central Valley, California, USA. Environmental Toxicology and Chemistry 24, 966–972.

23 Kimmerer, W.J. 1994. Predation by an introduced clam as the likely cause of substantial declines in zooplankton of San Francisco Bay. Marine Ecology Progress Series, 113:81-93.

not differentiate toxicity that has been observed between tributaries and the main stem Sacramento River. The location of samples is a very important factor when describing study results and developing a conceptual model.

Uncertainties

Very general statements can be misleading if taken out of this very generic context. Many of the references describe studies or species not specific to the Delta/SFE. Further, it is not clear how developing new assessment methods, as suggested, would improve regulatory decision making. Toxicity tests are a well-proven assessment tool with benefits and limitations, and the debate about the environmental relevance of toxicity test data is ongoing and complex. This longstanding and proven tool should not be discarded in favor of an untested approach.

Johnson M., I. Werner, S. Teh, and F. Loge. 2010. Evaluation of Chemical, Toxicological, and Histopathologic Data to determine their Role in the Pelagic Organism Decline

The Central Valley Regional Water Quality Control Board (CVRWQCB) funded an evaluation to determine if there are sufficient water chemistry, toxicity, and histopathological (i.e., tissue) data "to characterize the extent and role of contaminants in the Pelagic Organism Decline (POD)." Experts representing several disciplines from the University of California, Davis, compiled these available data to make comparisons between pre- and post-POD chemical concentrations. They came to an overall conclusion that the available data do not indicate any links between ammonia, pyrethroids, or other chemical stressors and the POD. However, the limited data add uncertainty to these conclusions.

> "…*while contaminants are unlikely to be a major cause of the POD, they cannot be eliminated as a possible contributor to the decline*."

In general, the study found that there was insufficient high-quality data available to make conclusions about the potential role of specific contaminants in the POD. Data identified from the legal Delta proved to be very limited, leading to the inclusion of data from tributaries as far as 30 miles outside of the legally defined Delta. Therefore, and as stated in the conclusions of the report, care should be taken in drawing any specific conclusions about the effect of contaminants on the POD based on the data found and included in the report.

One conclusion was that delta smelt were not food-limited. This suggests that the food supply has not been reduced by exposure to contaminants or bottom-up effects and can support populations of POD species.

> *"Stomachs full of food upon capture suggest that delta smelt are not starving. This further suggests that the food supply has not been reduced by exposure to contaminants and can support populations of POD species*."

To the extent possible with the available data, the following conclusions were made:

- Chemicals with available data were not found in higher concentrations during the POD years compared to the pre-POD years.
- There was as much or more toxicity in water samples from the Delta in pre-POD years compared to the POD years.
- The percentage of toxic samples collected from Delta waters was lower than in tributaries (0-7 percent) and less frequent but could indicate a potential for toxicity to prey items utilized by POD species.

- Ammonia was not the focus of this review but there was no correlation between ammonia concentrations and larval delta smelt 7-d survival, where maximum unionized ammonia concentrations were < 0.016 milligrams per liter (mg/L).
- There appeared to be no difference in the percentage of toxic water samples to either *Ceriodaphnia dubia* or *Pimephales promelas* between the 2000-2002 step-decline years and the later POD years.
- There were no toxicity data available to determine if the threadfin shad was relatively less sensitive to chemicals present in the Delta compared to other POD species. Chemical data did not identify the cause of the step-decline in population of threadfin shad followed by the gradual increase in abundance in the subsequent years while other POD species were declining.
- It was considered unlikely that differential exposure of POD and non-POD species to contaminants would account for some species thriving (i.e., inland silverside, bluegill sunfish) in the Delta while POD species are not.
- Several non-POD species were present in the Delta at the same time as POD species. The cursory review of the relative sensitivity of POD and non-POD species to various chemicals found in the Delta during the POD years did not suggest that POD species are more sensitive to chemical toxicants.
- While direct toxicity to POD species was considered unlikely, indirect effects on POD species through toxicity to prey items could not be ruled out. A helpful evaluation of the prey items for POD and non-POD fish suggests different diets may contribute to differential food availability for POD and non-POD species; however, observations that smelt stomachs were full of food refute the potential for bottom-up effects.

The main conclusion drawn from the analyses was that contaminants did not seem to be a major cause of the POD, although they could not be eliminated as a possible contributor to the decline.

Uncertainties

Conclusions in this assessment were hindered by limited or unreliable data. Concentrations below detection limits could not inform risk evaluations when the detection limit exceeded the threshold toxicity effect concentrations. The data quality of other chemicals could not always be determined if collection records were incomplete or unavailable and if samples were improperly collected according to current standards (i.e., pyrethroids)—as expected when data was evaluated over an approximately 10-year period and detection limits have changed as new analytical methods have been developed and refined. This long-term data review emphasizes the importance of thinking ahead to possible data analyses when planning monitoring projects and using DQOs to ensure detection limits are adequate for the planned uses of the data – to the extent possible.

Teh, S., I. Flores, M. Kawaguchi, S. Lesmeister, and C. Teh. 2011. Full Life-Cycle Bioassay Approach to Assess Chronic Exposure of *Pseudodiaptomus forbesi* to Ammonia/Ammonium. Final Report. Submitted to Chris Foe of the Central Valley Regional Water Quality Control Board and Mark Gowdy of the State Water Resources Control Board. August.

This technical report presents the findings of multiple toxicity tests with a novel test organism—the copepod *Pseudodiaptomus forbesi (P. forbesi)*. Reported toxicity effect levels are presented for chronic reproduction effects and acute survival endpoints. Based on these results, the authors concluded that the concentrations of ammonia in the Sacramento River downstream of Hood are at levels potentially toxic to *P. forbesi.* However, significant concerns over the validity of these test results have been expressed by reviewers.

Uncertainties

An independent review of the final report by Pacific EcoRisk (PER)[24] found that the testing methods were flawed and results were calculated erroneously. For example, using the same statistical software as Teh et al., PER's independent analysis of 31-day reproduction toxicity data resulted in lowest observed effect levels of 1.62 mg/L total ammonia nitrogen (TAN) when the article reported 0.79 mg/L TAN for juveniles. Likewise, independent analyses found a LOEC of >3.23 mg/L TAN for adults when the study reported LOELs of 0.79 and 0.36 mg/L TAN. High variability within many of the test results sheds great uncertainty on the reported results, especially when significant effects are reported despite the lack of clear dose-response relationships. PER comments concluded that:

> *"The reviewer is troubled by the absence of any discussion by Teh et al. regarding the variability in their test response data, either between tests or within tests (i.e., inter-replicate variability). Without such acknowledgement, it is left for the non-scientist to assume that the data as presented are definitive. Moreover, it raises the question of whether the data from this study are adequate (or 'ready') for use in regulatory decision-making. However, it is important to note that this critical review is not intended to negate Teh et al.'s general observations that ammonia is toxic to naupliar, juvenile, and/or adult P. forbesi at elevated concentrations and that this toxicity is strongly influenced by pH. Indeed, the primary question of 'what are the effects of ammonia on P. forbesi' is relevant and Teh et al.'s study results certainly compel a more thorough examination of this. However, the problems associated with Teh et al.'s experimental methodology for Subtasks 3-3 and 3-4-1 and significant questions regarding the analysis of the resulting data do indicate that the quality of the work should preclude the resulting 'critical threshold' data (i.e., NOECs, LOECs, and point estimates [e.g., ECx, LCx, and ICx values]) from being used for regulatory purposes."*

Comments were provided to the CVRWQCB and Dr. Teh by SRCSD on May 17, 2011. Author responses to SRCSDs comments were provided in a letter to Ms. Linda Dorn of SRCSD on August 31 2011, but these responses did not adequately address SRCSD's comments and inconsistencies persist in the final report. It is recommended that this study be excluded from any SWRCB consideration pending further review and clarification of the reported effect levels. This study would have benefitted from developing DQOs and generating validated data of known quality, as the existing data are of uncertain quality and concerns exist that resource managers who rely on these data will be misinformed.

---

[24] Pacific EcoRisk, Inc (PER). 2011. *A Critical Review of: Full Life-Cycle Bioassay Approach to Assess Chronic Exposure of Pseudodiaptomus forbesi to Ammonia/Ammonium - Final Report Dated August 31, 2011.* Prepared for Larry Walker Associates and the Central Contra Costa County Sanitary District. December.

Werner, I. D. Markiewicz, L. Deanovic, R. Connon, S. Beggel, S. Teh, M. Stillway, and C. Reece. 2010a. Pelagic Organism Decline (POD): Acute and Chronic Invertebrate and Fish Toxicity Testing in the Sacramento-San Joaquin Delta 2008-2010. Final Report. Prepared by Aquatic Toxicology Laboratory, School of Veterinary Medicine, University of California, Davis, California. Submitted to the California Department of Water Resources.

Werner, I., L.A. Deanovic, D. Markiewicz, J. Khamphanh, C.K. Reece, M. Stillway, and C. Reece. 2010b. Monitoring acute and chronic water column toxicity in the northern Sacramento-San Joaquin Estuary, California, USA, using the euryhaline amphipod, *Hyalella azteca*: 2006-2007. Environ. Toxicol. Chem. 29:2190-2199.

Werner et al. (2010a,b) describe a toxicity monitoring program in the Sacramento-San Joaquin Delta from 2006-2009. This research focused on the toxicity of ambient waters to fish and aquatic invertebrates using laboratory and stream-side toxicity testing and used TIE methods to determine whether either pyrethroids or organophosphate insecticides were contributing to ambient toxicity. A total of 752 water samples were collected from 16 sites in the Northern Sacramento-San Joaquin Estuary during 2008-2009. Of these, acute *Hyalella azteca* toxicity (mortality measured over 10 days) was found in only 0.5 percent of samples (4 samples) and chronic toxicity to *Hyalella* (as measured by 10-day growth) was found in only 0.9 percent of samples (7 samples). There was no toxicity to delta smelt, *Hyalella,* or fathead minnows in streamside "*in situ*" tests. Although some areas within the Delta were identified as "*least favorable*"/" *at times unfavorable*" to delta smelt, the authors concluded that ammonia could not be implicated as a primary cause of smelt toxicity and in some cases, toxicity was partly attributable to low turbidity stress. In fact, good survival of larval smelt in water samples from some principal spawning and rearing grounds that had the highest concentrations of ammonia suggests that ammonia does not adversely affect juvenile smelt at these locations. Finally, pilot testing with water from several Delta sites identified low conductivity as a major factor determining survival of *Eurytemora affinis*. The low incidence of toxicity in these ambient samples supports a conclusion that contaminants are not a major driver of the POD.

Delta smelt toxicity from ammonia (lowest reported LD50 of 5.4 mg/L NH_4^+) were reported to be 1.8 times more sensitive to ammonium and 5-6 times more sensitive to ammonia than fathead minnows. However, current ambient water quality criteria for ammonia[12] are protective of delta smelt (acute criterion range of 3.19 to 5.25 mg N/L under conditions tested; pH of 7.9 and temperatures 20 to 25°C).

Uncertainties

Acute toxicity data do not provide a compelling argument that ammonia/ium is causing adverse effects in the Delta despite statements that there were "*Significant correlations between amphipod survival [and ammonia/ium]"* This statement applies to correlations of ambient surface water toxicity data from 2006-2009 at individual sites and the data were not compiled across all sites. Further, it does not adequately describe the results in which only one negative relationship (where ammonia/ium was associated with reduced survival) was observed (at Cache-Ulatis), but positive relationships between ammonia/ium and survival were observed at five sites (Sites 323, 504, 804, 915, and Cache-Lindsey). Werner et al. (2010a,b) report that growth measured in the *Hyalella* chronic toxicity tests was not a reliable toxicity endpoint due to variable organism size and effects related to water quality (i.e., conductivity). Therefore, any of the conclusions regarding chronic toxicity to *Hyalella* should be considered qualified due to this limitation, although no such qualification is stated. Despite these limitations, the authors make several conclusions based on the growth endpoint in these chronic tests.

Additionally, the analysis of ammonia discussed in both Werner et al. (2010a) and Werner et al. (2010b) was independent of pesticide analyses and did not consider interactions of contaminants. Ammonia was reported to have significant relationships with *Hyalella* survival and growth, but there was no consideration of the interactive effects from salinity/ions/hardness/conductivity[25] or the fact that measured concentrations of ammonia in the samples were below minimum concentrations reported to affect *Hyallela azteca* growth and survival (i.e., 4-day LC50 of 20 to 28 mg N/L; and growth was not reported to be affected by total ammonium concentrations up to 14 to 25 mg N/L[26]). Given these uncertainties, it would seem more likely that constituents/factors other than ammonia were greater contributors to the observed toxicity. Results for univariate correlations that ignore these other known stressors must be considered in context with other observations to draw conclusions and do not support conclusions about causal relationships.

Connon, R.E., L. Deanovic, E.B. Fritsch, L.S. D'Abronzo, and I. Werner. 2011. Sublethal responses to ammonia in the endangered delta smelt; *Hypomesus transpacificus* (Fam. Osmeridae). Aquatic Toxicol. 105(3-4):369-377.

Four-day exposures of 57-day old delta smelt to aqueous concentrations of ammonia (2.5-80 mg/L total ammonia; 0.023-0.439 mg/L unionized ammonia) were generally above actual (i.e., environmentally relevant) concentrations in the Delta. These tested concentrations were at or above the highest concentrations reported by Werner et al. (2010a) of 0.62 mg/L total ammonia and 0.025 mg/L unionized ammonia. This study demonstrated sub-cellular effects (e.g., cell membrane destabilization) from ammonia exposure (NOEC = 5 mg/L total ammonia/ium; 0.066 mg/L ammonia; LOEC = 9 mg/L total ammonia/ium; 0.105 mg/L ammonia), at concentrations above environmentally relevant exposures in the Delta.

Uncertainties

Biomarkers are typically only considered a measure of exposure—essentially where a gene is turned on/off in response to an exposure—but it is not clear what effect this change has on the whole organism (i.e., survival, growth, or reproduction) or population. Dose-responses for several biomarkers were varied and some of the associations between biomarkers and adverse effects were unclear. Organisms can also compensate metabolically and can recover from short-term chemical exposures. These uncertainties can be addressed to a degree by additional study to better understand the linkages between biomarkers and organism-level effects, as the authors recommend.

---

[25] Borgmann, U. 1994. Chronic toxicity of ammonia to the amphipod *Hyalella azteca*; importance of ammonium ion and water hardness. Environmental Pollution. 86:329-335.

[26] ibid