Public Water Agencies' Comments on the Tentative NPDES Permit Renewal for the Vallejo Sanitation and Flood Control District Wastewater Treatment Plant
November 23, 2011

The San Luis & Delta-Mendota Water Authority, the Metropolitan Water District of Southern California, Westlands Water District, Santa Clara Valley Water District, Tulare Lake Basin Water Storage District, Alameda County Flood Control and Water Conservation District, Zone 7, Coachella Valley Water District, and Alameda County Water District (collectively, "Public Water Agencies") appreciate the opportunity to comment on the tentative renewal of the National Pollutant Discharge Elimination System permit ("Tentative Permit") for the Vallejo Sanitation and Flood Control District's ("VSFCD") Wastewater Treatment Plant ("Treatment Plant").[1]

The VSFCD Treatment Plant provides secondary treatment of wastewater from domestic and commercial sources within the City of Vallejo, the former Mare Island Naval Facility, and an adjacent unincorporated area. The VSFCD discharges wastewater from two points: Discharge Point No. 001, which discharges wastewater into the Carquinez Strait, and Discharge Point No. 002, which discharges wastewater into the Mare Island Strait. The areas of discharge are important for aquatic resources.

The Carquinez and Mare Island Straits connect the Napa River to Suisun Bay and hence San Pablo Bay, a northern extension of San Francisco Bay. The greater San Francisco Bay/Sacramento-San Joaquin River Delta estuary system is referred to as the Bay-Delta estuary, the largest estuary on the United States' Pacific coast. The Bay-Delta estuary and specifically the Napa River provide important habitat to species protected under the federal and State Endangered Species Acts, including Delta smelt and longfin smelt.[2] It is well documented that water quality and aquatic resources within the Bay-Delta estuary are under stress. The populations of both pelagic and anadromous fish have suffered serious decline in recent years.

During wet weather conditions, only flows up to approximately 35 million gallons per day ("MGD") receive secondary treatment. The maximum wet weather capacity of the Treatment Plant, however, is 60 MGD. When wet weather flows exceed 30 MGD, treated effluent is discharged through Discharge Point No. 001 to Carquinez Strait and Discharge Point No. 002 to Mare Island Strait. The discharges to Carquinez Strait may consist of a disinfected blend of primary and secondary treated effluents, while discharges to Mare Island Strait consist of only secondary-treated and dechlorinated effluent. Included in the daily discharge are more than 1,500 pounds of "nutrients," in the form of ammonium (or "ammonia as nitrogen") that VSFCD does not remove or otherwise treat.[3]

[1] On or about November 23, 2011, the Public Water Agencies filed with the Regional Board a disc that contains copies of material referenced in this comment letter. The Public Water Agencies hereby incorporate into this letter by this reference the material on that disc.

[2] *See* Figures 1 to 4, attached. *See also* Federal Register 58:12854 (Delta smelt listing), Federal Register 59:65256 (Delta Smelt critical habitat designation); Federal Register 76:50447 (Winter-run listing); Federal Register 58:33212 (Winter-run critical habitat designation); Federal Register 76:50447 (Spring-run listing); Federal Register 70:52488 (Spring-run critical habitat designation); Federal Register 76:50447 (Steelhead listing); Federal Register 70:52488 (Steelhead critical habitat designation); Cal. Admin. Code tit. 14, § 670.5 (listing Longfin smelt as threatened).

[3] Pounds of nutrients was calculated based on the permitted Average Dry Weather Capacity of 15.5 MGD and average effluent ammonium-N concentration of 12 mg L-1.

The Public Water Agencies have a significant interest in how the Regional Board regulates the VSFCD. The members of the Public Water Agencies receive water through the California State Water Project ("SWP") and the federal Central Valley Project ("CVP"). The SWP and CVP collect and store water in large reservoirs in northern California for use throughout the State. After water is released from reservoirs, the water flows to the Delta. From there, water is pumped and conveyed for use by more than 2 million acres of prime farmland and some 25 million Californians living in two-thirds of the state's households. To date, regulators have largely responded to the stress to water quality and aquatic resources by regulating the SWP and CVP and restricting the water available to the members of the Public Water Agencies. These restrictions have had a direct and severe adverse impact on the ability of the members of the Water Agencies to serve the people who depend on SWP and CVP water.

Unfortunately, while the focus on water users has resulted in great hardship, it has not led to real improvements in either water quality or aquatic resources. To the Public Water Agencies, this has not been a surprise. Federal and state agencies have long recognized that nutrient loadings seriously impact water quality and aquatic life.[4] Although it has long been thought that the Bay-Delta Estuary was not vulnerable to nutrient impacts, that is no longer the case.

The VSFCD's discharge of more than 275 tons per year of nutrients (specifically ammonium) is significant. It discharges into areas inhabited by endangered and threatened species, including the Delta smelt and longfin smelt. In fact, as demonstrated in Figures 1 to 4, attached hereto, the VSFCD discharges into an area where a substantial portion of the Delta smelt and longfin smelt populations are found or travel through. The California Department of Fish and Game prepared Figures 1 to 4. Using the data from monitoring studies of postlarval-juvenile Delta and longfin smelt, the Figures depict the distribution and relative abundance of those species throughout the historical spring range, which includes portions of San Pablo Bay and Napa River. Overwhelming scientific literature, grounded in sound science, demonstrates the impact to the Delta smelt and longfin smelt caused by nutrient discharges from the VSFCD Treatment Plant, in concert with discharges from other publicly owned treatment works (including Sacramento Regional County Sanitation District ("SRCSD") and Central Contra Costa Sanitary District).

Indeed, writings by Regional Board staff have publically acknowledged the scientific evidence that establishes the nexus between nutrient discharges and impacts on aquatic life. On June 4, 2010, the Regional Board submitted a letter to the Central Valley Regional Water Quality Control Board citing published studies that document the impacts of ammonium in Suisun Bay and urging the Central Valley Regional Board to take all necessary actions to ensure beneficial uses in Suisun Bay are fully protected.[5] Since Carquinez and Mare Island Straits connect the Napa River to Suisun Bay and San Pablo Bay, nutrient discharges in the Carquinez and Mare Island Straits are also relevant to water quality in Suisun Bay and San Pablo Bay.

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[4] According to U.S. EPA: "Nutrient pollution, especially from nitrogen and phosphorus, has consistently ranked as one of the top causes of degradation in some U.S. waters for more than a decade. Excess nitrogen and phosphorus lead to significant water quality problems including harmful algal blooms, hypoxia and declines in wildlife and wildlife habitat. Excesses have also been linked to higher amounts of chemicals that make people sick." http://water.epa.gov/scitech/swguidance/standards/criterialnutrients/.

[5] San Francisco Bay Regional Water Quality Control Board letter from Bruce H. Wolfe, Executive Officer, to Kathy Harder, Central Valley Regional Water Quality Control Board re Comments on "Issue Paper - Aquatic Life and Wildlife Preservation Related Issues - Proposed NPDES Permit Renewal for Sacramento Regional County Sanitation District Sacramento Regional Wastewater Treatment Plant" June 4, 2010.

For all of these reasons, nutrient discharges are impairing water quality and designated beneficial uses of receiving waters. They are devastating the food web.

In spite of these harms, the Tentative Permit would allow the VSFCD to not only continue to discharge, but to increase its discharge by 48 percent from a current average dry weather flow of 10.5 million gallons per day, Tentative Permit at p. F-4, to a future average dry weather flow of 15.5 million gallons per day. Tentative Permit at 8. It would also effectively provide the VSFCD a new point source for discharge, by allowing the VSFCD to shift discharges during normal operations from the Carquinez Strait (Discharge Point No. 001) to Mare Island Strait (Discharge Point No. 002).[6] It is inconsistent with the law and good public policy to proceed in this manner. The Public Water Agencies urge the Regional Board to undertake a different course of action.

1. The Regional Board should revise the Tentative Permit to expeditiously provide for nitrification of the discharge to remove ammonium. Further interim limits should be set that restrict the discharge while treatment is designed and built. In addition, the Regional Board and VSFCD should conduct studies addressing the impact of nutrient discharges on the Napa River and Carquinez Strait and should evaluate whether denitrification should also be required.

2. In the alternative, if the Regional Board is convinced that further study is needed before requiring nutrient removal, the Public Water Agencies urge the Regional Board to expedite (consistent with good scientific practice) the completion of necessary studies, but defer issuing this Permit until that work is completed and published, so the Regional Board may consider those data and analyses. Further studies should include more comprehensive monitoring of ammonium and other nutrient constituents at the two discharge locations.

3. Lastly, if the Regional Board determines it must proceed with a permit now, the Public Water Agencies urge the Regional Board to include a detailed framework in the final permit that includes (a) a schedule for promptly conducting necessary studies, with a plan for funding, (b) a clear procedure for reconsideration of the ammonium issue, with full public participation in the process, and (c) interim limits consistent with the actual maximum concentrations of ammonium in VSFCD discharges.

I. The Tentative Permit Does Not Address the Significant Uncontrolled Discharge of Ammonia-Nitrogen From the VSFCD Wastewater Treatment Plant

The Public Water Agencies' concern with the Regional Board's Tentative Permit is grounded in one irrefutable fact well known to the Regional Board: On average the VSFCD Treatment Plant discharges more than 1,500 pounds of untreated ammonium in its wastewater every day.

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[6] The Regional Board, if it were to permit the discharge into Mare Island Strait (Discharge Point No. 002), would violate legal principles establish in *Friends of Pinto Creek v. United States Environmental Protection Agency,* 504 F.3d 1007 (9th Cir. 2007) (holding the NPDES regulations prohibit permitting of a new source to an impaired waterbody absent a TMDL with a very specific waste load allocation).

VSFCD discharges directly into the Carquinez and Mare Island Straits. Those Straits connect the Napa River to Suisun Bay and thence to San Pablo Bay, a northern extension of San Francisco Bay. The greater San Francisco Bay/Sacramento-San Joaquin River Delta estuary system is referred to as the Bay-Delta estuary, the largest estuary on the United States' Pacific coast. Species protected under the federal and state Endangered Species Acts inhabit those areas. *See* footnote 3; Tentative Permit, at 5. Given the expansive view of federal and state agencies of the need to protect listed species, one would expect the Tentative Permit to directly address the ammonium in VSFCD's discharge in its Tentative Permit.

Yet, the Regional Board's Tentative Permit would not limit the ammonium in the VSFCD's discharge. In contrast, many other municipal wastewater treatment plants in central California that discharge into waters that feed into the Bay-Delta estuary and its tributaries have stepped up and made the investments (or been required to make the investments) needed to install treatment technology that would remove ammonium. These plants are listed in Table 1 hereto.[7] Thus, if required to bring its treatment up to date, VSFCD would not be singled out to invest in new or unproven technology.

II. VSFCD's Significant Uncontrolled Discharge of Ammonium May Adversely Affect Beneficial Uses of Waters of this State and the United States

In the Tentative Permit, the Regional Board staff has not discussed the substantial available evidence linking nutrient discharges to significant impacts on aquatic life. The full body of research and scientific literature already available demonstrates that full ammonium removal should be applied to VSFCD. At a minimum, the Public Water Agencies request that the Regional Board carefully consider that evidence before deciding whether to allow the continued discharge of untreated "nutrients" into the Carquinez and Mare Island Straits.

In fact, the overwhelming data and scientific literature demonstrate that nutrients discharged directly to the Bay-Delta estuary, including areas of great importance to threatened and endangered species, such as Carquinez and Mare Island Straits, are likely causing toxic effects on aquatic species and contributing to the altering of the aquatic food web – the foundation of the entire Bay-Delta estuary. These impacts to the beneficial uses of waters of this State and the United States require a far more vigorous evaluation and response by the Regional Board than that proposed in the Tentative Permit.

That untreated nutrients cause serious impacts on aquatic life is not a novel proposition, as detailed here and in the enclosed Technical Memorandum collecting and summarizing the recent nutrient research. See Water Agencies' Technical Memorandum (November 22, 2011), Attachment 1 hereto. Indeed, among other work, the Memorandum highlights the most recent work done by Dr. Patricia Glibert, et al.[8] Dr. Glibert's latest paper analyzes comparable

[7] *See also* West Yost Associates, Wastewater Control Measures Study (March 2011), available at http://www.swrcb.ca.gov/rwgcbSlwaterissues/drinkingwaterpolicy/dwpwastewtrcntrlmeasstdy.pdf. This report, prepared for the Central Valley Regional Board, lists 26 treatment plants that are currently achieving nutrient removal and nine additional plants that are required by current NPDES permits to achieve this standard of treatment.

[8] Dr. Glibert is an aquatic ecologist and nutrient bio-geochemist with over 30 years of experience working on issues related to nutrient loading, nutrient ratios, eutrophication, changes in trophic dynamics, harmful algae, and management implications of nutrients loading all over the world. She has a Ph.D. from Harvard University and was awarded an honorary doctorate degree from Linnaeus University, Sweden earlier this year. She has studied and published widely on nutrients and food web dynamics in systems covering phytoplankton nutrient uptake and

ecosystems and demonstrates that the fact that nutrient loadings materially impact the food web is well established by stoichiometric analysis of data from systems across the United States and around the world. This and other existing literature provide ample support for the Regional Board to take action now to restrict the discharge of untreated nutrients.

Indeed, in addition to the literature and research outlined in the Technical Memorandum, the Public Water Agencies and/or their members have previously provided comments in other proceedings which further detail how ammonium is harming aquatic species in the Bay-Delta estuary and altering the aquatic food web including the following:

1. Water Agencies' Response to Discharger's Petition For Review, In the Matter of the Sacramento Regional County Sanitation District's Petition for Review SWRCB/OCC File Nos. A-2144(a) and A-2144(b) (Consolidated) (May 4 and 6, 2011);

2. San Luis & Delta-Mendota Water Authority and State Water Contractors Comments on U.S. Environmental Protection Agency ("U.S. EPA") Advanced Notice of Proposed Rulemaking Regarding Water Quality Challenges in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, Docket No. EPAR09-0W-210-0976, 76 Federal Register 9709, February 22, 2011 (April 21, 2011);

3. Westlands Water District's Comments on EPA Advanced Notice of Proposed Rulemaking Regarding the Water Quality Challenges in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary 76 Federal Register 9709 (February 22, 2011) Docket Number: EPA-R09-0W-201O-0976 (April 25, 2011);[9]

4. Proposed NPDES Permit Renewal and TSO, Sacramento Regional County Sanitation District, Water Agencies' Testimony before Central Valley Regional Water Quality Control Board Meeting (December 9, 2010) (Water Agencies' Testimony);

5. Comments of the Water Agencies on the Tentative Waste Discharge Requirements Renewal for the Sacramento Regional County Sanitation District Sacramento Regional Wastewater Treatment Plant (Oct. 8. 2010);

6. Comments of Westlands Water District (Westlands) and the San Luis & Delta-Mendota Water Authority (Authority) on Tentative Waste Discharge Requirements Renewal (NPDES Permit No. CA0077682) for Sacramento

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photosynthesis, nutrient excretion by zooplankton, harmful algal physiology, nutrient preferential use by phytoplankton taxa, eutrophication, and global nutrient modeling. Her field investigations span the globe - including the Chesapeake Bay, Long Island Sound, Florida Bay, Australia, Brazil, the Baltic Sea, East China Sea, Kuwait Bay, Gulf of Oman, and Hong Kong coastal waters, as well as many other sites, including San Francisco Bay Delta. She serves as the co-chair of the U.S. National HAB Committee, chair of the committee on eutrophication for the international GEOHAB Programme, and co-chair of the international SCORILOICZ Working Group on HABs and Eutrophication. She has consulted with the governments of Kuwait and Oman on issues related to nutrient pollution, served as an independent advisor to the Chinese Academy of Sciences on their studies of eutrophication, served on numerous panels and advisory boards related to nutrient management for the federal government and the states of Florida and Maryland.

[9] http://www.regulations.gov/#!documentDetail:D=EPA-R09-0W -2010-0976-0037.

Regional County Sanitation District, Sacramento Regional Wastewater Treatment Plant (Oct. 8, 2010);

7. San Luis & Delta-Mendota Water Authority and State Water Contractors Comments on Draft Report Titled "Nutrient Concentrations and Biological Effects in the Sacramento-San Joaquin Delta" (June 14, 2010);[10]

8. Water Agencies' Comments on Aquatic Life and Wildlife Preservation Issues Concerning the Sacramento Regional Wastewater Treatment Plant NPDES Permit Renewal (June 1, 2010).[11]

The Public Water Agencies hereby incorporate by reference into this letter the arguments, analysis, data and scientific literature cited and described in those comments. *See* footnote 2 above.

Among other things, the research outlines four basic scientific propositions:

1. <u>Excessive ammonium has been shown to be toxic to copepods</u>

Recent studies indicate that ammonium at concentrations present in the Bay-Delta estuary is acutely toxic to copepods central to the food web that supports aquatic life, including the threatened Delta smelt. See Technical Memorandum at 7. Specifically, Dr. Swee Teh (and colleagues) at the University of California at Davis[12] have completed a variety of studies on the effects of ammonium on the native copepods *Eurytemora affinis* and *Pseudodiaptomus forbesi.*[13] Dr. Teh found ten percent mortality occurred in invertebrate species exposed to ammonia

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[10] San Luis & Delta Mendota Water Authority and State Water Contractors letter to Dr. Chris Foe, Central Valley Regional Water Quality Control Board re Comments on Draft Report Titled "Nutrient Concentrations and Biological Effects in the Sacramento-San Joaquin Delta." June 14,2010.

[11] Water Agencies letter to Ms. Kathleen Harder, Central Valley Regional Water Quality Control Board re Comments on Aquatic Life and Wildlife Preservation Issues Concerning the Sacramento Regional Wastewater Treatment Plant NPDES Permit Renewal. June 1, 2010.

[12] Dr. Teh is a Ph.D in Comparative Pathology and a Research Toxicologist and Pathologist in the Department of Anatomy, Physiology, and Cell Biology at the University of California - Davis. He serves as the Interim Director of the Aquatic Toxicology Laboratory at the UC-Davis School of Veterinary Medicine, and is a UC-Davis Faculty Member for the Graduate Group in Ecology, the Center for Aquatic Biology and Aquaculture, the Center for Health and the Environment, and the John Muir Institute of Environment. Dr. Teh conducted his work under the auspices of the Central Valley Regional Water Quality Control Board.

[13] The relevant research and related writings include Dr. Teh's presentation at the Ammonia Summit sponsored by Central Valley Regional Water Board http://www.waterboards.ca.gov/centralvalley!water issues/delta water quality/ambient ammonia concentrationslindex.shtml (August 18-19,2009) ("Teh Presentation") {also provided with these comments as an attachment to the Declaration of Dr. Swee Teh (May 4, 2011) ("Teh Decl."); Werner, et al., Pelagic Organism Decline (POD): Acute and Chronic Invertebrate and Fish Toxicity Testing in the Sacramento San Joaquin Delta 2008-2011, Final Report Submitted to the California Department of Water Resources (July 24, 2010), (http://www.science.calwater.ca.gov/pdf/workshopsiPOD/ Werner'l1020et%20al 2010 POD2008-2010 Final%20Report.pdf) (also at Teh Decl. Exhibit 3); Full Life-Cycle Bioassay Approach to Assess Chronic Exposure of P. forbesi to Ammonia/Ammonium to the Delta Pelagic Organism Decline Contaminants Work Team (July 6, 2010) Teh Decl. Exhibit 4; Letter from S. Teh to C. Foe (November 10, 2010) Teh Decl. Exhibit 5; S. Teh, et al., Final Report, Full Life-Cycle Bioassay Approach to Assess Chronic Exposure of *Pseudodiaptomusforbesi* to Ammonia/Ammonium - Submitted to C. Foe and M. Gowdy (March 4, 2011) Teh Decl. Exhibit 6.

concentrations present in the Sacramento River using a 96-hour toxicity test.[14] Dr. Teh has likewise conducted life cycle tests to assess the impacts of different concentrations of ammonium on the ability of the copepod to reproduce and thrive. Dr. Teh found that total ammonia impacted adult *P. forbesi* reproduction at concentrations greater than or equal to 0.79 mg L^{-1}, while nauplii and juveniles are affected at concentrations as low as 0.36 mg L^{-1}.[15] This level of ammonium is exceeded all the time in VSFCD effluent samples. *See* Figure 5. Dr. Teh repeated the life cycle testing and confirmed his results, which he provided to the Central Valley Regional Board.[16] The toxic effect of total ammonia is a major stressor on aquatic life that has a pervasive impact across the Bay-Delta estuary.

2. <u>The excess ammonium is inhibiting nitrogen uptake by diatoms and reducing diatom primary production in the Bay-Delta</u>

In addition to toxic effects, the ammonium loadings are disrupting the food supply by inhibiting nitrogen uptake by diatoms in the Bay-Delta estuary. The phytoplankton that form the base of the food web are essential to a healthy aquatic ecosystem. Primary consumers, including copepods (such as *P. forbesi*) rely on that primary production by phytoplankton as their main source of food, which, in turn, serves as a food source for other aquatic life. In recent research, Dr. Richard Dugdale and others have found that excessive ammonium from wastewater treatment plant discharges is inhibiting nitrogen uptake by diatoms and contributing to reduced diatom production in the Bay-Delta estuary.[17] *See* Technical Memorandum at 1; Taberski, Dugdale, et al., SWAMP Monitoring Plan 2011-2012, *San Francisco Bay Region Work Plan; Monitoring Spring Phytoplankton Bloom Progression in Suisun Bay* at 1 (Dec. 2010) ("Work Plan"). at 1-3.[18]

Indeed, as the Work Plan acknowledges, Dr. Dugdale has found that at an ammonium concentration of 4 μmol L^{-1},[19] nitrate uptake is fully inhibited. Work Plan at 2-3. This level of ammonium is exceeded nearly all the time in Carquinez Strait, at the VSFCD receiving water monitoring location in the lower Napa River, and in VSFCD effluent samples, as demonstrated in Figures 5, 6 and 7 presenting ammonium monitoring data for the three locations. The

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[14] Werner, et al., *supra;* Teh Presentation, *supra.* Dr. Teh was unfairly criticized that his initial testing did not apply a representative average pH. This criticism was not valid, as Dr. Teh's first test was within the range found in the River 20 percent of the time. Nonetheless, Dr. Teh repeated his analysis and again observed that comparable toxic effects occurred at a pH of 7.8. Teh, S. et al., August 31, 2011 Final Report to C. Foe, *supra.*

[15] Teh, S. Full Life-Cycle Bioassay Approach, *supra* (Teh Decl. Exhibit 4).

[16] Teh, S. et al., Final Report to C. Foe, *supra* (August 31, 2011 Report).

[17] *See e.g.,* Parker, A.E., A.M. Marchi, J. Drexel-Davidson, R.C. Dugdale, and F.P. Wilkerson. " Effect of ammonium and wastewater effluent on riverine phytoplankton in the Sacramento River, CA. Final Report to the State Water Resources Control Board; Wilkerson, F.P., R.C. Dugdale, V.E. Hogue and A. Marchi, 2006. Phytoplankton blooms and nitrogen productivity in San Francisco Bay, Estuaries and Coasts 29(3): 401-416; Dugdale, R.C., F.P. Wilkerson, V.E. Hogue and A. Marchi. 2007. The Role of ammonium and nitrate in spring bloom development in San Francisco Bay. *Estuarine, Coast and Shelf Science* 73: 17-29 ; Sommer, T., C. Armor, R. Baxter, R. Bruer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga and K. Souza. 2007. The Collapse of Pelagic Fishes in the Upper San Francisco Estuary, *Fisheries* 32(6):270-277; Glibert, P. 2010a. "Long-term changes in nutrient loading and stoichiometry and their relationships with changes in the food web and dominant pelagic fish species in the San Francisco Estuary, California," *Reviews in Fisheries Science.* 18(2):211 - 232.

[18] http://www.swrcb.ca.gov/water_issues/programs/swamp/docs/workplans/1112rb2wp.pdf.

[19] An ammonium concentration of 4 μmol L^{-1} is equivalent to 0.056 mg L^{-1}.

monitoring locations are indicated on the map in Figure 8. *See* Figures 5-8, attached hereto. While the additional research by Ms. Taberski and Dr. Dugdale outlined in the Work Plan will provide additional useful information to supplement the body of knowledge of how ammonium inhibits primary productivity, existing data amply document the effects of nutrient discharges like those from VSFCD sufficient to require nutrient removal. At a minimum, as noted, the Regional Board should consider carefully these recent studies, before deciding whether to allow VSFCD to continue to discharge more than 1,500 pounds of nutrients into Carquinez Strait every day.

3. Nutrient discharges into the Bay-Delta estuary are contributing to a shift in algal communities by changing the nutrient ratios to favor harmful, invasive species

Further, the research of Dr. Glibert and others demonstrates that ammonium discharges have adversely impacted aquatic life in the Bay-Delta estuary by increasing the ratio of nitrogen to phosphorus in the receiving water which triggers impacts to the food web on which aquatic life depends. Increasing ammonium discharges, particularly when phosphorus discharges have been declining, degrades water quality by changing the ratio between dissolved inorganic nitrogen and phosphorus, as well as the total nitrogen to total phosphorus ratio. These ratios are known to have profound influences on food webs.[20] Dr. Glibert's research strongly suggests that changes in Delta smelt and several other fish species' abundance are ultimately related to changes in ammonium load from wastewater discharges. Dr. Glibert concluded that "[r]emediation of pelagic fish populations should be centered on reduction of nitrogen loads and reestablishment of balanced nutrient ratios delivered from point source discharges."[21] *See* Technical Memorandum at 3-4.

4. Where implemented in impacted ecosystems, nutrient removal has improved the natural ecosystem and aquatic life

Requiring nitrification and denitrification of wastewater treatment plant effluent would help restore the health of the ecosystem and aquatic life in the Bay-Delta estuary. Again, the literature is clear that requiring nutrient removal on wastewater treatment plants has proven to be effective at reversing the harmful effects of previously undertreated discharges and restoring native ecosystems. As just one example that is discussed in Dr. Glibert's work, nutrient removal at the Blue Plains treatment plant in Washington D.C. has reduced the invasive species and begun to restore the native vegetation in the Potomac River, which flows into the Atlantic coast's largest estuary, Chesapeake Bay. Once nutrient removal was implemented at Blue Plains in the 1990s, within several years, the abundance of the invasive *Hydrilla* began to decline and the abundance of native grasses increased. There are many other examples in other systems. *See* Technical Memorandum at 4-5.

To reiterate: The Public Water Agencies submit that the existing literature amply documents the effects of nutrient discharges like those from VSFCD sufficient to require treatment. At a minimum, before issuing any permit to VSFCD, the Regional Board should consider carefully

[20] Sterner, R. W. and J.J. Elser. 2002. Ecological stoichiometry: The biology of elements from molecules to the biosphere. Princeton University Press, Princeton, N.J. Sterner and Elser (2002), state that, "Stoichiometry can either constrain trophic cascades by diminishing the chances of success of key species, or be a critical aspect of spectacular trophic cascades with large shifts in primary producer species and major shifts in ecosystem nutrient cycling."

[21] Glibert, P. 2010a.

these studies, as the Central Valley Regional Board did in deciding to impose full nutrient removal on the SRCSD Treatment Plant.

III. The Regional Board's Consideration of Ammonium in the Tentative Permit is Incomplete and Contrary to Law

The Regional Board considers ammonium (referred to as total ammonia as N) essentially in two ways. First, the Regional Board evaluates whether the ammonium in VSFCD's discharge has the reasonable potential to exceed a water quality objective and if so, whether a water quality based effluent limit is required. Second, after setting the limits, the Regional Board determined that state and federal Antidegradation Policy and anti-backsliding requirements are met, because no previous permit included any limits. Neither analysis appears to be correct.

A. The Regional Board's application of a dilution factor is flawed and should be reconsidered

The Public Water Agencies are concerned that the Regional Board staff has erred in its application of a dilution factor to set effluent limits for ammonium. As the Tentative Permit acknowledges, the applicable Basin Plan has Water Quality Objectives for un-ionized ammonia of 0.025 mg/L (annual median) and 0.16 mg/L (maximum). Tentative Permit, Attachment F at F-25. As the un-ionized component of total ammonia is only a small fraction of the total discharge, these are then converted to total ammonia objectives of 4.9 mg/L (acute) and 1.7 mg/L (chronic). Tentative Permit, Attachment F at F-26. Given that the measured effluent concentration for ammonium consistently exceeds these levels, there unquestionably is a reasonable potential to exceed these objectives. *See* Figure 5. However, the Tentative Permit proceeds to allow a substantial dilution for total ammonia to set the effluent limits by apparently relying on the "Mixing Zone Study." If so, that would be inappropriate for several reasons:

First, the staff acknowledges the inability to set a Mixing Zone.

> Because of the complex hydrology of San Francisco Bay, a mixing zone has not been established. There are uncertainties in accurately determining an appropriate mixing zone. The models used to predict dilution have not considered the three dimensional nature of San Francisco Bay currents resulting from the interaction of tidal flushes and seasonal fresh water outflows. Being heavier and colder than fresh water, ocean salt water enters San Francisco Bay on a twice-daily tidal cycle, generally beneath the warmer fresh water that flows seaward. When these waters mix and interact, complex circulation patterns occur due to the varying densities of the fresh and ocean waters. The complex patterns occur throughout San Francisco Bay, but are most prevalent in the San Pablo, Carquinez Straight, and Suisun Bay areas. The locations of this mixing and interaction change, depending on the strength of each tide. Additionally, sediment loads from the Central Valley change on a long-term basis, affecting the depth of different parts of San Francisco Bay, resulting in alteration of flow patterns, mixing, and dilution at the outfall.

Tentative Permit, Attachment F, at F-23 to F-24. In fact, the Mixing Zone Study specifically emphasizes that the complexities are greatest in the vicinity of the VSFCD discharge to the Carquinez Straight. Given that, it would be wholly illogical for the Regional Board to then go ahead and apply a full dilution factor for ammonia to the VSFCD discharge and establish limits substantially greater than the maximum concentration observed.

Nonetheless, second, the staff proposes that dilution be applied to ammonia. However, in doing so, the staff relies on a provision of the Basin Plan that may apply to *ammonia* but that is not applicable to the more than 275 tons of *ammonium* that are present in the discharge from the VSFCD each year. Specifically, the staff asserts as follows:

> For *ammonia*, a conservative estimated actual initial dilution was used to calculate the effluent limitations. This is justified because *ammonia*, a non-persistent pollutant, quickly disperses and degrades to a non-toxic state, and cumulative toxicity effects are unlikely. In the Mixing Zone Study Report (Vallejo Sanitation and Flood Control District, 2011), the Discharger developed dilution estimates for the Facility's discharges from Discharge Point Nos. 001 and 002....[T]his Order establishes the more conservative dilution of 26:1 to achieve compliance with water quality objectives.

Tentative Order, Attachment F at F-24 (emphases added). However, the Basin Plan discussion that the staff has relied on in the Tentative Order is referring to the small *"un-ionized"* fraction of ammonia, *not* the *ammonium* that is the nutrient of concern in the VSFCD discharge. *See* Basin Plan, § 3.3.20 at 3-7. As the literature demonstrates – including the work by Dr. Glibert and by Dr. Dugdale and others – it is the *ammonium* that is causing real, demonstrable impacts on primary productivity in the Bay-Delta environment. Unlike un-ionized ammonia, ammonium does not quickly disperse and degrade to a non-toxic state. As such, and consistent with the clear direction in the Basin Plan that the "complex patterns" near the discharge point are not appropriate to establish a mixing zone, no dilution should be applied to ammonium.

Third, the Basin Plan cautions against application of dilution in light of various concerns, including the difficulty in measuring the discharge in a tidal zone, Basin Plan, § 4.6.1.1 at 4-18, precisely where the VSFCD discharge is located. It further states that it would "consider inclusion of an effluent limitation greater than that calculated from water quality objectives when the increase in concentration is caused by implementation of significant water reclamation or water reuse programs at the facility; the increase in the effluent limitations does not result in an increase in the mass loading; and the water quality objectives will not be exceeded outside the zone of initial dilution." Basin Plan, § 4.6.1.1 at 4-18. But no such findings or analyses have been completed here.

Further, fourth, the Basin Plan also cautions against relying on modeling when evaluating a discharge in an estuarine environment because models are limited to the initial dilution analysis. This includes U.S. EPA models like that relied on by the discharger here. *See* Mixing Zone Study Report, Vallejo Sanitation and Flood Control District, Prepared For: RMC Water and Environment Oakley Water Strategies, Prepared By: LimnoTech Ann Arbor, Michigan (March 22, 2011) (uses U.S. EPA "Visual Plumes" model). Specifically, according to the Basin Plan, "the direction of waste transport varies over the course of the tidal cycle, so it is difficult to determine the fraction of new water versus recirculated water mixing with the discharge. U.S. EPA has developed several models of initial dilution for discharge plumes, *but none takes into account transport due to tidal currents.*" Basin Plan, § 4.6.1.1 at 4-18. Indeed, here, while the Mixing Zone Study Report claims to use an equation (the "Brooks algorithm") to assess far-field dilution, no specific data or calculations are presented in the Report showing those results; only the "initial dilution" is described, precisely the concern raised in the Basin Plan.

Finally, fifth, regardless, the analysis of ammonia and dilution is entirely divorced from the overwhelming body of literature and data outlined in and provided with these comments. In fact, as outlined, the data demonstrate that the concentration of ammonium (or total ammonia as N) is consistently exceeding the inhibitory threshold for primary productivity and contributing to the exceedance of toxicity levels for copepods. That suggests the proposed dilution is not the "conservative approach to calculating effluent limitations" required by the Basin Plan. Basin Plan, § 4.6.1.1 at 4-18. Instead, those data must be considered carefully and fully by the Regional Board before deciding that the tons of "nutrients" that the VSFCD and other point sources discharge into the Bay-Delta and habitat used by endangered and threatened species will simply be "diluted" away.

B. The Regional Board's analysis of Anti-degradation Policy compliance with regard to ammonia is contrary to established principles of law

California's Antidegradation Policy is summarized by a 1990 Administrative Procedures Update ("APU") from the State Board, which was meant to "provide guidance for the Regional Boards for implementing State Board Resolution No. 68-16...and the Federal Antidegradation Policy, as set forth in 40 C.F.R. § 131.12." APU 90-04, (July 1, 1990) at p. 1. As such, the APU is designed to help the Regional Boards implement both federal policy, 40 C.F.R. § 131.12, and the State Board's Antidegradation Policy, Resolution No. 68-16.

For high quality waters, Resolution 68-16 mandates that the water quality must be maintained unless the discharger can prove that lowering the water quality: (1) will provide "maximum benefit" to the state; (2) will not impair present or anticipated beneficial uses of the receiving water; and (3) will not violate water quality objectives. Additionally, discharges that increase the volume or concentration of waste in high quality waters must comply with discharge limits based on the "best practicable treatment or control" ("BPTC") which ensures that no pollution or nuisance will occur and that the highest water quality will be maintained.

If approved, the Tentative Permit would violate federal and state Antidegradation Policy by allowing degradation of receiving waters due to ammonium discharge. The Treatment Plant's actual current discharge is 10.5 MGD.[22] The Tentative Permit would allow that discharge to physically increase by nearly 48 percent to 15.5 MGD.[23] Although the Treatment Plant's existing discharge already has violated its permit due to ammonia toxicity,[24] the Tentative Permit has not proposed ammonium removal. By allowing at least a 48 percent increase in the discharge of ammonia, the Tentative Permit would allow increasing degradation of receiving waters. Those receiving waters are habitat occupied by threatened Delta smelt, other pelagic organisms and the plankton community comprising the foundation of the food web sustaining all these species. *See* Figures 1 to 4. If VSFCD's requested Permit were granted, VSFCD would not just further degrade listed species habitat and harm Delta smelt and other pelagic species. In so doing, it would also further jeopardize the largest single source of fresh water supply in all California.

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[22] Average dry weather flow. *See* Tentative Permit at p. F-4.

[23] See Tentative Permit at 8.

[24] *See* Tentative Permit at F-7 (describing acute toxicity violations resulting in Notice of Violation).

Before the Regional Board can issue, reissue, amend, or revise such a discharge permit, however federal and state Antidegradation Policy requires the Regional Board to determine that permit conditions result in BPTC and to determine whether any water quality degradation that will result is permissible when balanced against the benefit to the public from issuing the permit. Here, the Tentative Permit makes no findings with respect to BPTC and the balancing of water quality degradation against any public benefit from allowing degradation.[25] The Tentative Permit discloses no analysis showing how the degradation of receiving water quality from the continuation of the existing 10.5 MGD discharge level, and how the additional degradation from allowing a 48 percent increase in that discharge to 15.5 MGD complies with the Antidegradation Policy. Nowhere does the Tentative Permit show a complete and legally adequate analysis of compliance with the Antidegradation Policy for this discharge.

To the extent that VSFCD might contend that some aspect of the required analysis is addressed in some unspecified, prior discharge permit or California Environmental Quality Act ("CEQA") documentation approved by the VSFCD, it is important to understand that substantially changed circumstances and significant new information prevent reliance on any prior permit or CEQA review to support the Tentative Permit. The pelagic organism decline and scientific evidence that ammonium discharges harm the Bay-Delta estuary and its food web would prevent reliance on any prior permit or CEQA document to help support the analysis and determination of compliance with the Antidegradation Policy that is required before VSFCD's new discharge permit may be approved.

The Regional Board must work with VSFCD to complete a legally adequate analysis and then circulate a revised Tentative Permit which demonstrates compliance with the Antidegradation policy, including ammonium effluent limits that achieve BPTC. Failure to do so will result in approval of an unlawful permit that degrades receiving water quality, violates water quality objectives, impairs designated beneficial uses – all in violation of state and federal water quality protection law.

IV. The Regional Board Should Take Affirmative Steps to Control the Ammonium in the VSFCD Discharge

A. The Regional Board should require VSFCD to install nitrification treatment

In view of the scientific evidence, the Regional Board should require VSFCD to reduce to acceptable levels the nutrients in its discharge. The Regional Board should set final effluent limits that are achievable with full nitrification treatment, as well as a reasonable schedule for designing and building the treatment system. Further, daily and monthly interim effluent limits for ammonium (ammonia as N) should be set that reflect the real daily and monthly maximum effluent concentrations that have been observed in the discharge, with a modest margin for compliance. The Regional Board and VSFCD should also conduct studies addressing the impacts of nutrient discharges on the Napa River and Carquinez Strait and evaluate whether denitrification should also be required.

[25] *See* Tentative Permit at F-31.

There are well established technologies available to VSFCD to remove nutrients, as evidenced by the many other municipalities in California and across the country that have implemented ammonium removal through the "nitrification" of the wastewater. *See* discussion, *supra.*

Unquestionably, this is a feasible technology that has previously been determined to satisfy BPTC under California law.[26]

B. <u>The Regional Board should defer issuing the Tentative Permit until studies on the effects of nutrients in VSFCD's discharge are completed</u>

In the alternative, if the Regional Board is convinced that further study is needed before requiring nutrient removal, the Public Water Agencies urge the Regional Board to expedite (consistent with good scientific practice) the completion of necessary studies. This would include completing the Work Plan and its examination of water quality issues in Suisun Bay and expanding that work to encompass the Carquinez and Mare Island Straits. However, the Regional Board should defer issuing this Permit until that work is completed and published, so the Regional Board may consider those data and analyses. Further studies should include more comprehensive monitoring of ammonium and other nutrient constituents at the two discharge locations.

Given the focus of recent studies and the recognized concerns about how the ammonium discharge can impair the primary productivity in the Bay-Delta estuary, proceeding to finalize the permit without either nitrification or considering fully the latest analyses is unreasonable. Specifically, among other objectives, the Regional Board Work Plan is designed to further assess whether "high ammonium concentrations in Suisun Bay correlate with low primary production." Work Plan, Attachment at 2. As the Work Plan acknowledges, the data gathered to date has found that "an additional ammonium signal was detected in the western part of Suisun that may play a role in controlling phytoplankton blooms in Suisun Bay." Work Plan at 4. Thus, these additional data may inform necessary steps to protect Carquinez and Mare Island Straits and Suisun Bay.

C. <u>Alternatively, if the Regional Board is intent on finalizing a permit now, the final permit should at a minimum be revised to address ammonium more effectively</u>

If the Regional Board determines it must proceed with a permit now and is not prepared to require full nitrification, then the Public Water Agencies urge the Regional Board to include a detailed framework in the final permit to address ammonium. The framework should include three components:

<u>First</u>: The Regional Board should make specific findings in the permit regarding its concern that the ammonium in VSFCD's discharge may be contributing to nutrient impairment in the Napa River and to impacts below Suisun Bay in Carquinez and Mare Island Straits, and that therefore it is in the process of implementing studies to evaluate those concerns. The permit should then

[26] A number of municipal sanitations districts have also been required to install "denitrification" treatment which follows nitrification to further treat the wastewater by removing the nitrates from the discharge. In the case of Sacramento Regional, the Water Agencies believe the evidence strongly supported the Central Valley Board's decision to require that additional treatment given the available data concerning that discharge. Here, as the Regional Board develops additional data regarding VSFCD's discharge, it should consider whether denitrification should also be included.

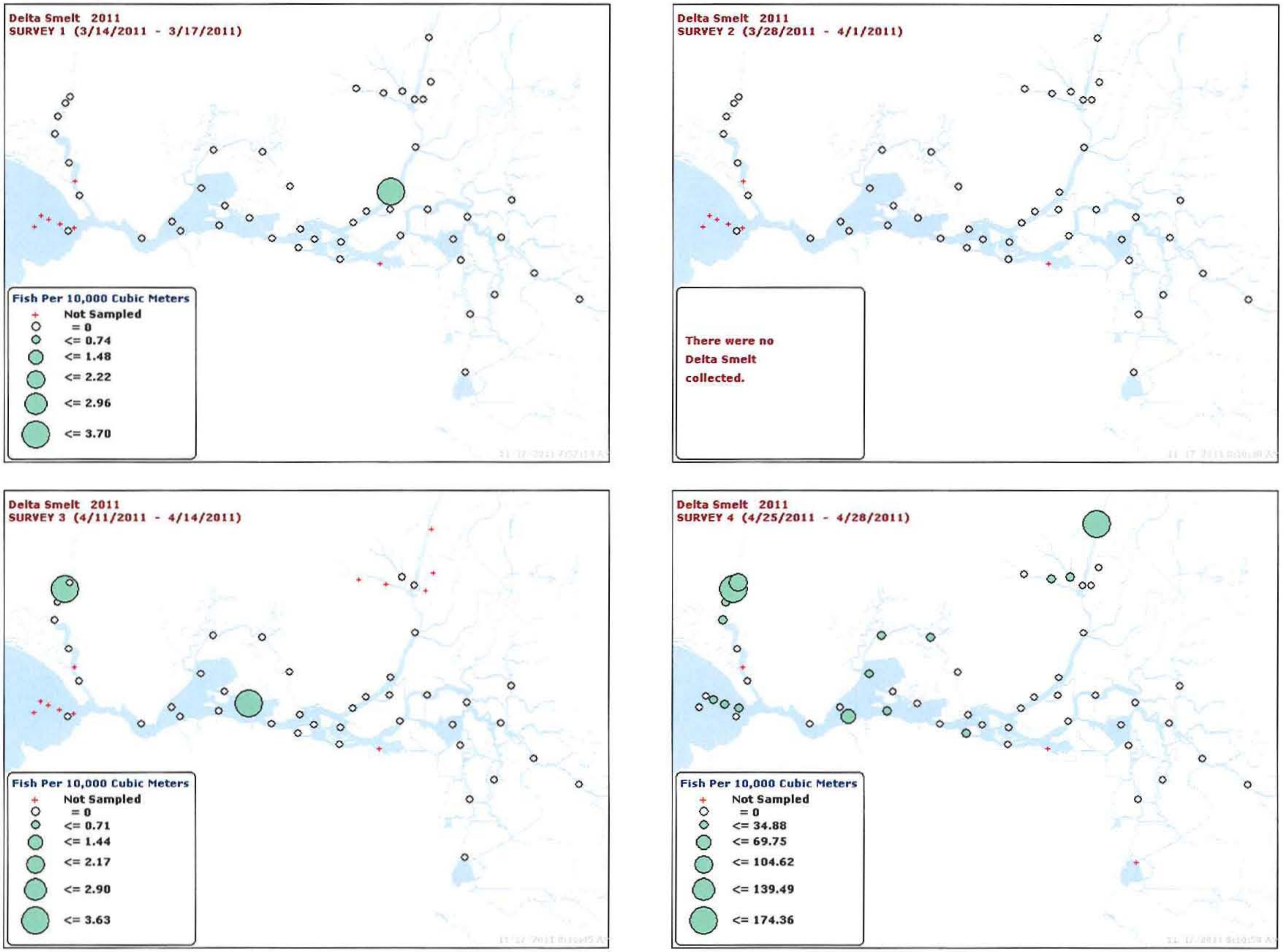
include a schedule for surface water ambient monitoring program sampling and associated studies, including sampling in Carquinez and Mare Island Straits and Suisun Bay.

Second: The Regional Board should set a clear procedure for reconsideration of the ammonium issue, with full public participation in the process, after the studies are completed and the data are published. The Regional Board should include deadlines to ensure the ammonium limits are reconsidered no later than 12 months after the Regional Board issues a final permit.

Third: As outlined for the recommended interim limits, the Regional Board should set effluent limits consistent with the actual daily and monthly average maximum concentrations of ammonium in the VSFCD discharge, with a modest margin for compliance. With the maximum observed concentration of ammonium according to the Regional Board in the range of 32 mg/L, there is no rational basis in the record to set limits of 43 mg/L (monthly) and 85 mg/L (daily maximum). Tentative Permit, Attachment F, F-21; Tentative Permit, at 9.

FIGURE 1

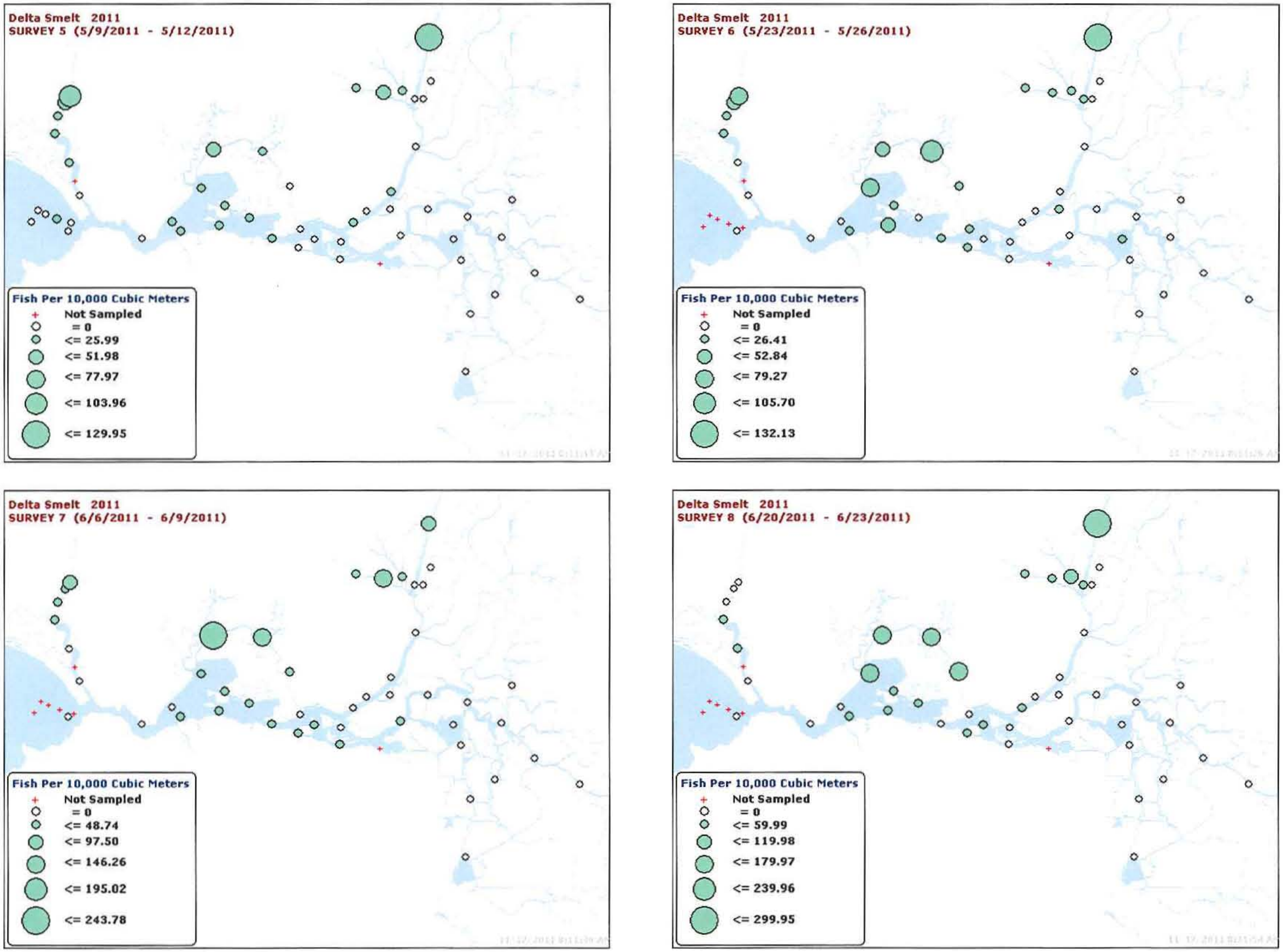
Figure 1. Delta Smelt 2011 20 mm Surveys 1-4.



Survey maps and underlying data from Cal. Dept. of Fish & Game, available at http://www.dfg.ca.gov/delta/projects.asp?ProjectID=20mm.

FIGURE 2

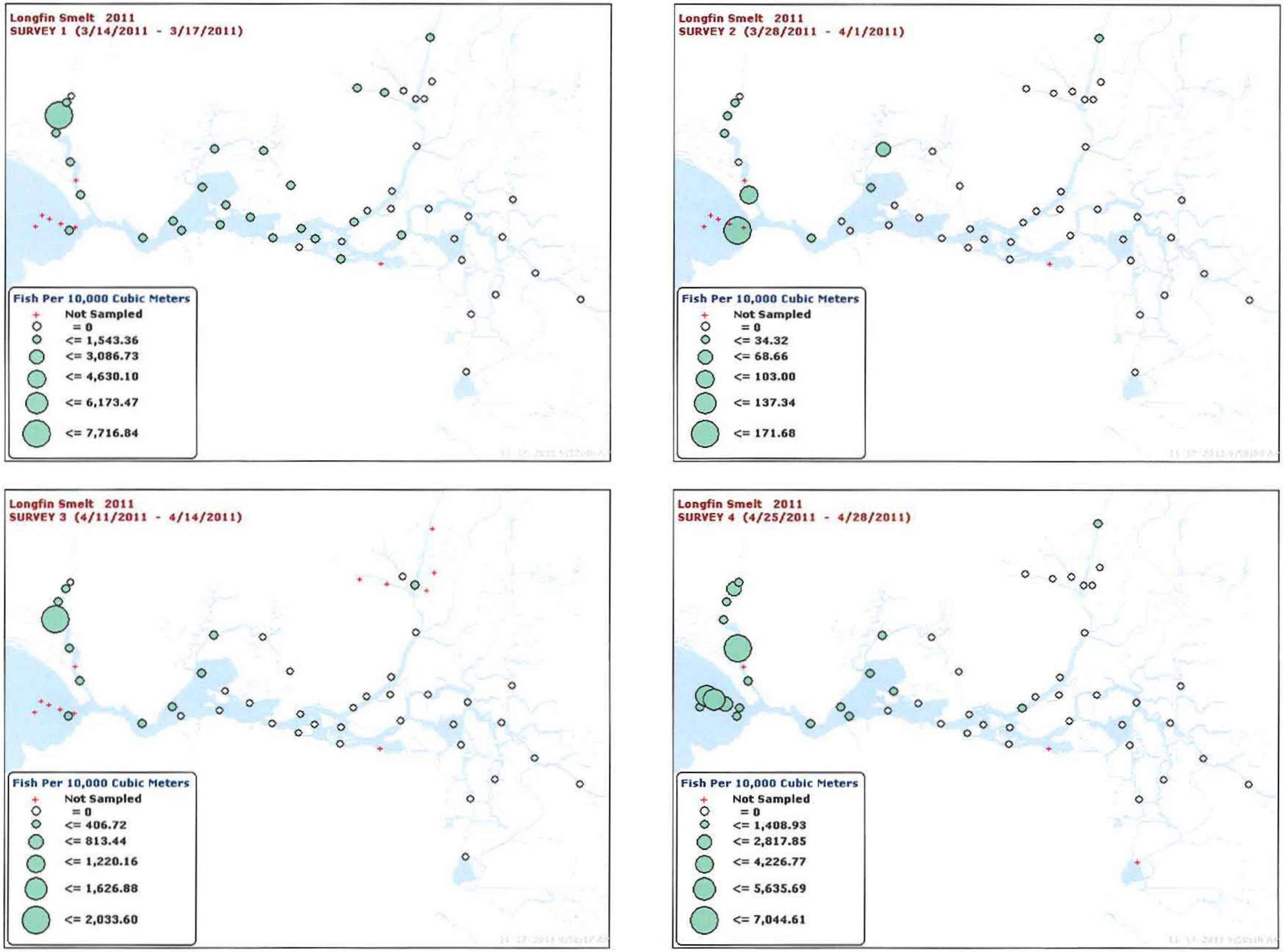
Figure 2. Delta Smelt 2011 20 mm Surveys 5-8.



Survey maps and underlying data from Cal. Dept. of Fish & Game, available at http://www.dfg.ca.gov/delta/projects.asp?ProjectID=20mm.

FIGURE 3

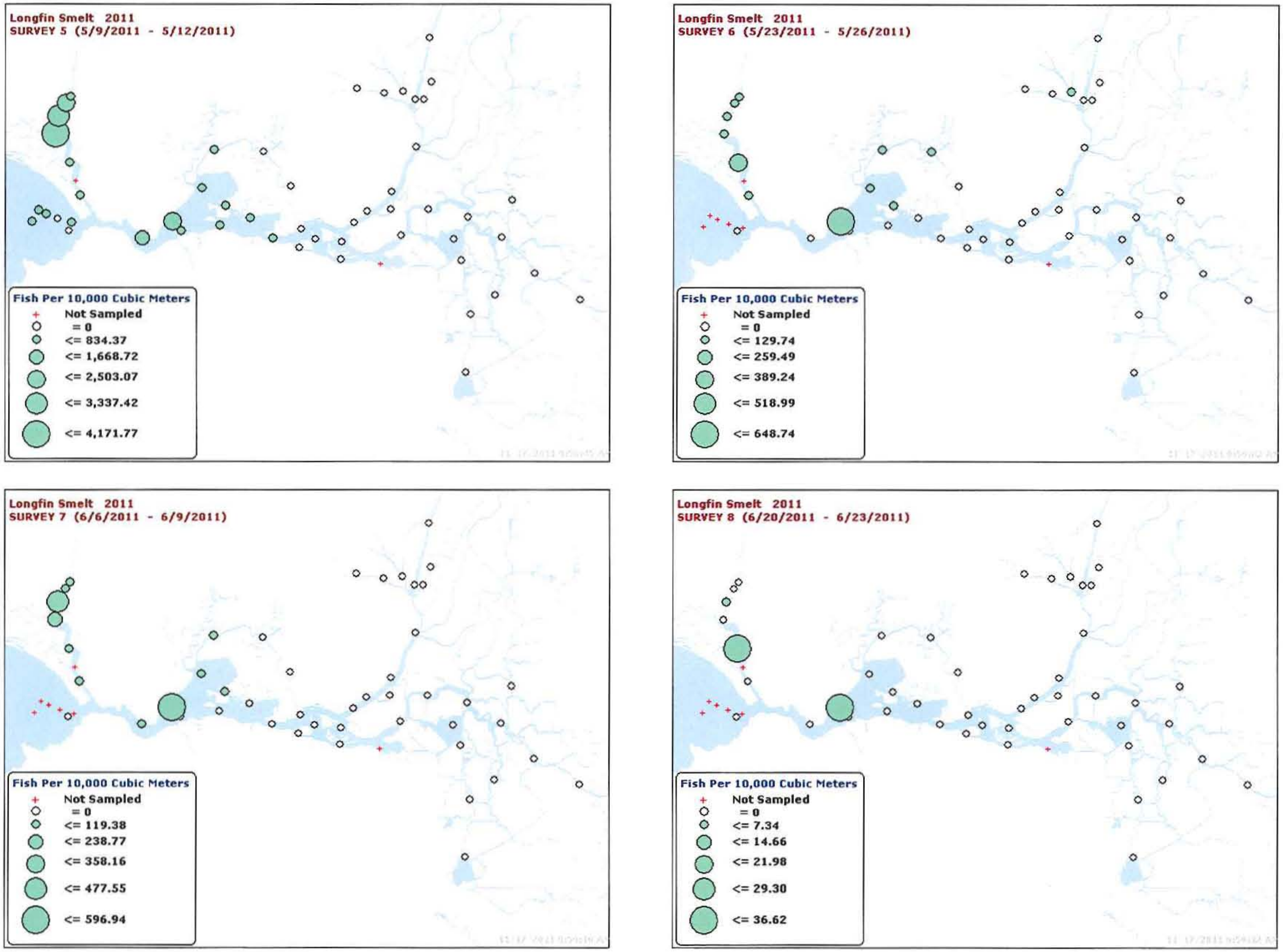
Figure 3. Longfin Smelt 2011 20 mm Surveys 1-4.



Survey maps and underlying data from Cal. Dept. of Fish & Game, available at http://www.dfg.ca.gov/delta/projects.asp?ProjectID=20mm.

FIGURE 4

Figure 4. Longfin Smelt 2011 20 mm Surveys 5-8.



Survey maps and underlying data from Cal. Dept. of Fish & Game, available at http://www.dfg.ca.gov/delta/projects.asp?ProjectID=20mm.

TABLE 1

Table 1. Treatment Requirements for Select Wastewater Treatment Plants That Discharge Directly or Indirectly to the Bay-Delta Estuary.

Discharger	**Permitted Average Dry Weather Flow (mgd)**	**Treatment Requirements**
		Nitrification or Nitrification + Denitrification
Sacramento Regional WWTP	181	Yes
Stockton	55	Yes
Central Contra Costa Sanitary District	53.8	No
Fairfield	17.5	Yes
Manteca	17.5	Yes
Delta Diablo	16.5	No
Tracy	16	Yes
Vallejo	*15.5*	*No*
Vacaville Easterly WWTP	15	Yes
Woodland	10.4	Yes
Lodi	8.5	Yes
Davis	7.5	Yes
Mountain House	5.4	Yes
Benicia	4.5	No
Galt	4.5	Yes

ATTACHMENT 1

Attachment 1

Technical Memorandum

Summary of Nutrient Impacts

There is a large body of literature documenting the significant impacts of increased loading and changing forms, concentrations, and ratios of nitrogen and phosphorus both within the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta) and globally to the food web form and function. The form of nutrients matters. Wilkerson, *et al.* (2006) and Dugdale, *et al.* (2007) show that "bloom levels of chlorophyll are evident only when nitrate uptake occurs and that nitrate uptake only takes place at lower ambient ammonium concentrations." They conclude that ammonium concentrations greater than 4 $\mu mol\ L^{-1}$ inhibit nitrate uptake by diatoms and thus suppress bloom formation. This level of ammonium is exceeded a majority of the time in the Sacramento River and Suisun Bay.

In enclosure experiments with samples from Central Bay, Suisun Bay and the Sacramento River at Rio Vista, Wilkerson *et al.* (in preparation) observed "a gradient of decreasing phytoplankton physiological rates in the upstream direction as far as Rio Vista." Algal biomass accumulation was delayed in enclosures from Suisun Bay and was not observed within 96 hours in enclosures from Rio Vista. Also supporting this finding, Parker, *et al.* (in review) observed a 55% decline in primary production in the Sacramento River below the Sacramento Regional Wastewater Treatment Plant compared to production above the Treatment Plant's outfall. Parker, *et al.* (in review) conclude that "[t]he quantitative reduction in primary productivity and nitrogen uptake at various points in the river was predictable and strongly related with NH_4 concentrations."

These observations of ammonium suppression are not new or unique to the Bay-Delta. There is a large body of scientific research describing ammonium suppression of algae productivity, which was first observed as far back as the 1930s. Ludwig, 1938; Harvey, 1953. Some of the early field demonstrations of this phenomenon were by MacIsaac and Dugdale (1969, 1972), followed by research in the Chesapeake Bay by McCarthy, *et al.* (1975). Lomas and Glibert (1999a) describe the threshold for inhibition of nitrate uptake at ammonium levels of approximately 1 $\mu mol\ L^{-1}$. Ammonium suppression of nitrate uptake when both nutrients are in ample supply should not be confused with the preferential use of ammonium by phytoplankton when nitrogen is limiting. Under the latter conditions, phytoplankton will use ammonium preferentially because it requires less energy than nitrate. Under the former conditions, the cells must cope with an excess; and in doing so, their metabolism is altered away from an ability to assimilate nitrate. Total primary productivity is suppressed as a result. This is particularly problematic for the Bay-Delta as it is already a comparatively low producing estuary. Jassby *et al.,* 2002. Laboratory experiments suggest that Delta-wide chl-a levels are now low enough to limit zooplankton abundance. Müller -Solger *et al.*, 2002.

Nutrient form also affects phytoplankton species composition. Cyanobacteria have been shown to preferentially use chemically reduced forms of nitrogen over nitrate in many studies. Chemically reduced nitrogen not only includes ammonium, but also urea and dissolved organic nitrogen. This evidence comes from:

- Measurements of enzyme activities in the cells – enzymes that process these forms of nitrogen. Cyanobacteria have been shown to have some of the highest measured rates of urease, for example, relative to all phytoplankton species tested, and among cyanobacteria, *Microcystis* rates are the highest. Solomon et al., 2010.

- Directly determined rates of nitrogen uptake using isotope tracer techniques. These rates show that cyanobacteria use reduced nitrogen forms and, in many cases, avoid the chemically oxidized forms. Glibert *et al.,* 2004.

- Direct growth studies. These studies based on growth measurements in the laboratory demonstrate that growth rates of *Microcystis* can be significantly higher on urea than on nitrate. Berman and Chava, 1999. Meyer, *et al.* (2009) state: "Compared to NO_3- and N_2 (via fixation) as N sources, NH_4+ produces the highest growth and primary production rates for *Microcystis aeruginosa* and other cyanobacteria (*Aphanizomenon flos-aquae* and *Anabaena flos-aquae*) in laboratory studies [citations removed]." Meyer *et al.,* 2009.

Moreover, retrospective analysis of the data in the Bay-Delta system further demonstrates that at very high ammonium concentrations (*i.e.*, > 200 $\mu g\ L^{-1}$), phytoplankton functional groups such as flagellates, cryptophytes and diatoms are outcompeted by cyanobacteria. Glibert, P., Univ. of Maryland, personal communication. Thus, even though *Microcystis* may have a broad capability for using different forms of nitrogen to support their physiological demands for nitrogen, they have a greater capacity to take up and metabolize reduced forms of nitrogen compared to other functional groups and may have higher growth rates under reduced nitrogen compared to nitrate and thus may outcompete other phytoplankton groups at very high ammonium levels. Lehman et al. (2010) concedes: "Recent increases in ammonium concentration in the western delta may give a competitive advantage to *Microcystis* which rapidly assimilates ammonium over nitrate."

The physiological literature strongly supports the concept that different algal communities use different forms of nitrogen. Diatoms generally have a preference for nitrate; dinoflagellates and cyanobacteria generally prefer more chemically reduced forms of nitrogen (ammonium, urea, organic nitrogen). Berg, *et al*., 2001; Glibert, et al., 2004, 2006; Brown, 2009. It has long been recognized that diatoms may have a nutritional requirement for, and under some circumstances even a preference for, nitrate (Lomas and Glibert, 1999a; 1999b). Moreover, diatoms often show no evidence of nitrate uptake saturation under very high nitrate conditions, Collos et al. 1992, 1997, in contrast to the generally accepted saturating uptake kinetic relationships that are used to describe the relationship between nutrients and uptake rate. Thus, cyanobacteria may grow particularly well on ammonium while their competitors, such as diatoms, do not.

The shift in algal community composition in the Bay-Delta has been far more extensive than just the recent increase in annual blooms of *Microcystis*. The Delta's algal species composition has shifted from diatoms to smaller and lower quality food species such as flagellates, cryptophytes and cyanobacteria. Lehman, 2000; Lehman *et al*., 2005; Lehman et al., 2010; Jassby *et al*., 2002; Sommer *et al*., 2007; Glibert, 2010; Glibert et al., 2011; Winder and Jassby, 2010) and to invasive macrophytes such as *Egeria densa* (Sommer, *et al*., 2007; Nobriga et al., 2005; Glibert et al., 2011. Jassby (2008) states:

> *A decrease in percentage of diatom biovolume occurred during 1975–1989, caused by both a decrease in diatoms and an increase in green algae, cyanobacteria, and flagellate species biovolume (Kimmerer 2005; Lehman 1996), i.e., probably in the direction of declining nutritional value per unit biomass. In principle, the total nutritional value of a community could decrease even as its biomass increases. Moreover, changes in size, shape, and motility of species*

comprising the phytoplankton community could also affect their availability as food particles for crustacean zooplankton and other consumers.

In addition, the ratios of nitrogen to phosphorus are known to have profound influences on food webs. Sterner and Elser (2002) state: "[s]toichiometry can either constrain trophic cascades by diminishing the chances of success of key species, or be a critical aspect of spectacular trophic cascades with large shifts in primary producer species and major shifts in ecosystem nutrient cycling."

The N:P ratio has long been shown to influence phytoplankton community composition and the presence - or absence - of native species and vegetation, as extensive studies have repeatedly demonstrated in systems around the world including: Hong Kong, Tunisia, Germany, Florida, Spain, Korea, Japan, and Washington D.C. (Chesapeake Bay), to name just a few. The Potomac River (Chesapeake Bay) was invaded by submerged aquatic vegetation, *Hydrilla,* and clams, *Corbicula*, when the N:P ratio of effluent from the large Blue Plains sewage treatment facility increased after phosphorus was reduced in the 1980s. Ruhl and Rybicki 2010. In Spain's Ebro River estuary, *Hydrilla* and *Corbicula* invaded shortly after phosphorus was removed from effluent (Ibanez *et al.* 2008). In Tolo Harbor, Hong Kong, nutrient loading, particularly phosphorus loading, increased due to population increases in the late 1980's. The result was that a distinct shift from diatoms to dinoflagellates was observed in the harbor, coincident with a decrease in the N:P ratio. Hodgkiss and Ho 1997; Hodgkiss 2001. Once the phosphorus was removed from the sewage effluent that was being discharged into the harbor and stoichiometric proportions were re-established, there was a resurgence of diatoms and a decrease in dinoflagellates (Lam and Ho 1989). In Tunisian aquaculture lagoons, dinoflagellates have been shown to develop seasonally when N:P ratios decrease. Romdhane, et al. 1998. Comparable results have been observed in systems in Germany, Radach *et al.*, 1990, and along the coast of Florida. Glibert *et al.*, 2004; Heil *et al.*, 2007.

N:P ratios have also been shown to influence zooplankton community composition. Norwegian studies monitored lakes for many years and found that different zooplankton tend to dominate under different N:P ratios, due to the different phosphorus content of different species found in the lake. Hessen 1997. Hessen (1997), for example, showed that a shift from calanoid copepods to *Daphnia* tracked N:P; calanoid copepods retain proportionately more N, while *Daphnia* are proportionately more P rich. Studies from experimental whole lake ecosystems found that zooplankton size, composition and growth rates changed as the N:P ratio varied (*e.g.*, Schindler 1974, Sterner and Elser 2002).

There has been a measureable change in the N:P ratio in the Bay-Delta, an increase in total N loading, a decrease in total P loading, and a change in the dominant form of nitrogen from nitrate to ammonium. Glibert, 2010. In a retrospective analysis of 30 years of data from the Bay Delta, Glibert 2010; Glibert et al., 2011, found that the variation in these nutrient concentrations and ratios is highly correlated to variations in the base of the food web, primarily the composition of phytoplankton, to variations in the composition of zooplankton, to variations in the abundance of invasive clams, and to variations in the abundance of several fish species.

Winder and Jassby (2010) provide additional documentation of the shift that has occurred in the phytoplankton and zooplankton community.

The shift in the phytoplankton community has ripple effects through the food web. Cloern and Dufford (2005) state, "[t]he efficiency of energy transfer from phytoplankton to consumers and ultimate production at upper trophic levels vary with algal species composition: diatom-dominated marine upwelling systems sustain 50 times more fish biomass per unit of phytoplankton biomass than cyanobacteria-dominated lakes [citations removed]." Slaughter and Kimmerer (2010) provide further support. They observed lower reproductive rates and lower growth rates of the copepod, *Acartia* sp. in the low salinity zone compared to taxa in other areas of the estuary and conclude that "[t]he combination of low primary production, and the long and inefficient food web have likely contributed to the declines of pelagic fish."

There is also a growing body of literature documenting improvements in ecosystem functions in systems where nutrient loading is reduced. Reducing nutrient loading in the Chesapeake Bay, Tampa Bay, and coastal areas of Denmark has proven to be effective at reversing the harmful effects of previously undertreated discharges and restoring the native systems. For example, within several years of increasing nutrient removal at the Blue Plains treatment plant in Washington DC, N:P ratios in the Potomac River declined, the abundance of the invasive *Hydrilla verticillata* and *Corbicula fluminea* began to decline (Figure 1 immediately below), and the abundance of native grasses increased. Ruhl and Rybicki 2010.

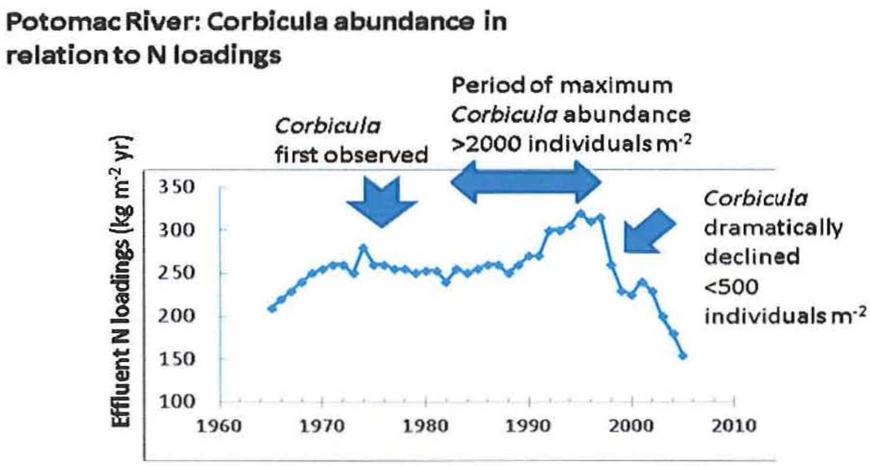


Figure 1. Comparative relationships for the Potomac River showing the change in effluent N loading and the relative abundance of the invasive clam, *Corbicula fluminea* clams. Data derived from Dresler and Cory (1980), Jaworski *et al.* (2007), and Cummins *et al.* (2010).

Tampa Bay provides another important example. Eutrophication problems in the Bay were severe in the 1970s, with N loads approximating 24 tons per day, about half of which was due to point source effluent. Greening and Janicki 2006. Several years after nitrogen and phosphorus reductions were achieved, native seagrass began to increase. Lower nutrient discharges also had positive effects on the coastal waters around the island of Funen, Denmark. Rask *et al.* 1999. Since the mid 1980s, there has been a roughly 50% reduction in the loading of N and P in the region due to point source reductions. Again, native grasses returned and low oxygen problems were reversed.

Moreover, there is recent evidence that diatom blooms can be restored in the Bay-Delta if ammonium loading were reduced. In Suisun Bay a diatom bloom reached chlorophyll concentrations of 30 μg L^{-1} during spring 2000 when ammonium concentrations declined to 1.9 μmol L^{-1}. Wilkerson *et al.* 2006. Similarly, chlorophyll concentrations in Suisun Bay reached 35 μg L^{-1} during spring 2010 when ammonium concentrations declined to 0.5 μmol L^{-1} Dugdale *et al.*, 2011. These blooms are comparable to spring chlorophyll levels from 1969-1977, Ball and Arthur, 1979, when ammonium concentrations were 1.8 μmol L^{-1} during summer and 4.0

$\mu mol\ L^{-1}$ during winter. Cloern and Cheng, 1981. If clam abundance declines, as has occurred in San Pablo Bay and South San Francisco Bay, Cloern *et al*., 2007, chlorophyll levels may also be restored during summer in Suisun Bay if ammonium loading were reduced.

Additionally, as Glibert (2010) reported, "[s]upporting the idea that correct balance of nutrients is important for restoration of delta smelt and other pelagic fish, there is a small but apparently successful subpopulation of delta smelt in a restored habitat, Liberty Island. Liberty Island is outside the immediate influence of Sacramento River nutrients. It has abundant diatoms among a mixed phytoplankton assemblage, as well as lower NH_4 levels and higher ratios of NO_3:NH_4 than the main Sacramento River [citations removed]."

The recent increase in *Microcystis* bloom frequency and size can also be explained by changes in Delta nutrients. Based on stable isotope analyses of particulate organic matter and nitrate, Kendall (2010) observed that ammonium, not nitrate, is the dominant source of nitrogen utilized by *Microcystis* at the Antioch and Mildred Island sites in the summer 2007 and 2008.

Nutrients affect more than *Microcystis* growth; nutrients may also affect its production of toxins. In Daechung Reservoir, Korea, researchers found that toxicity was related not only to an increase in N in the water, but to the cellular N content as well. Oh, *et al*. 2000. A very recent report by van de Waal (2010) demonstrated in chemostat experiments that under high CO_2 and high N conditions, microcystin production was enhanced in *Microcystis*. Similar relationships were reported for a field survey of the Hirosawa-no-ike fish pond in Kyoto, Japan, where the strongest correlations with microcystin were high concentrations of NO_3 and NH_4 and the seasonal peaks in *Microcystis* blooms were associated with extremely high N:P ratios. Ha *et al*. 2009. Thus, not only is *Microcystis* abundance enhanced under high N:P, but its toxicity is as well. Oh, *et al*. 2000.

Glibert *et al.* (2011) provides further support for the hypothesis that nutrient form and ratio is driving food web composition in the Delta. Using several different statistical approaches, Glibert *et al.* (2011) evaluated the relationships between approximately thirty different aquatic species and various nutrient ratios and found significant correlations for a majority of them. After comparing trends in the Bay-Delta estuary to those in Lake Washington, Potomac River, Hudson River and several European lakes and estuaries, they state,

> *Moreover, the physiology of the resident organisms and biogeochemical pathways lends support to the premise that similar trophic structure, including the appearance of* Microcystis, *in many of these systems has resulted from similar nutrient dynamics, biogeochemistry and food web interactions that resulted, in turn, from changes in stoichiometry and the relative abilities of different types of organisms to either sequester nutrients and/or to tolerate nutrients that are in excess (e.g., NH_4^+).*

They suggest that, "[r]eductions in N (especially NH_4^+) will allow organisms, from diatoms to fish, that cannot withstand high NH_4^+ (and/or that are outcompeted by NH_4^+ -tolerant organisms, such as various harmful dinoflagellates and cyanobacteria), to compete."

Glibert *et al.* (2011) found, "[f]or all organisms, with the exception of *Acartia*, for which strong correlations were observed with X2 (Table 9), *i.e.*, *Eurytemora*, *Pseudodiaptomus*, *Daphnia*, *Bosmina*, *Corbula*, *Crangon*, longfin smelt, splittail, striped bass, starry founder, crappie, sunfish and largemouth bass, equal or more significant correlations were observed with nutrients or nutrient ratios." This analysis determined pairwise relationships between biological parameters and nutrients and/or nutrient ratios using both the original data and data that were adjusted for autocorrelation. Glibert *et al.* (2011) also found that total phosphorus "explained at least as much of the variability in delta smelt as did the [Feyrer *et al.*, 2010] habitat index (Table 4), and dinoflagellate abundance explained even more (Table 6)." Unlike the X2 relationships whose mechanisms of effect are largely unknown, the nutrient relationships have a strong mechanistic explanation in ecological stoichiometry and stable state principles.

Ammonia Toxicity

Studies have been conducted by scientists at UC Davis investigating the effects of ammonia to the calanoid copepod *Pseudodiaptomus forbesi* using a full-life cycle bioassay approach. *P. forbesi* is an important food organism for the young of many fish species in the Bay-Delta including delta smelt and longfin smelt, two State listed species. Evidence of the toxic effects of ammonia on *P. forbesi* comes from life cycle tests conducted by Teh *et al.* (2011). Teh *et al.* (2011) found that total ammonia nitrogen at 0.36 ± 0.01 mg L^{-1} significantly affects the recruitment of new adult copepods and total ammonia nitrogen at 0.38 ± 0.01 mg L^{-1} significantly affects the number of newborn nauplii surviving to 3 days old.

Clam Invasion

There is no denying that the overbite clam has had a significant impact on the ecosystem since it took hold in the mid-1980s. Kimmerer (2002) and Kimmerer *et al.* (2009) found that many of the relationships between spring X2 and abundance changed in the mid-1980s, presumably due to the invasion by the overbite clam, *Corbula amurensis*. Phytoplankton biomass also declined significantly due to grazing pressure from the invasive clams. There is some scientific debate regarding the ability, or lack thereof, to manage clam populations by increasing freshwater outflows. However, this strategy fails to account for the potential consequences of an increased distribution in the freshwater clam, *Corbicula fluminea*, if freshwater flow is used to try to push the distribution of the brackish water clams further west of the Delta.

In addition, Glibert *et al.* (2011) found that "the change after 1987 also corresponds with the change in nutrient loading. X2 is strongly correlated with PO_4^{3-}, TP and NH_4^+." Glibert (2010) suggested that changes in nutrients created the environment in which these clams could dominate. Glibert (2010) found a strong correlation between the CUSUM trends in clam abundance and ammonium concentration and in the ratio of inorganic nitrogen to inorganic phosphorus (DIN:DIP).

Glibert *et al.* (2011) provides further support for nutrient effects on clam abundance as well as on the abundance of other invasive organisms such as non-native centrarchids and non-native invasive weeds. Using several statistical approaches, Glibert *et al.* (2011) found "a strong long-term correlation between water-column DIN:TP ratios (and DIN:PO_4^{3-} ratios) and abundance of the clam, *Corbula*…there is also a strong long-term positive relationship between pH and *Corbula* abundance." They explain,

> *Changes in external nutrient loads can drive changes in internal ecosystem biogeochemistry and, in turn, trophodynamics. This analysis suggests that increasing dominance over time of macrophytes, clams, and* Microcystis *along with more omnivorous fish that are fueled by a benthic food web, are not a result of stochastic events (random invasions) but, rather, are related to a cascade of changes in biogeochemistry resulting from changes in nutrient loading over time*

> *as a major driver. This analysis supports the premise that reductions in P loading from external sources drive aquatic systems toward increased importance of sediment dynamics, and toward the sediments as a major source of P. The food webs that are supported are different from those supported when the water column is the major source of P; they are benthic-dominated. Macrophytes such as* Egeria *and phytoplankton such as* Microcystis *are physiologically well adapted to these altered nutrient and pH regimes. The communities of bivalves and fish change accordingly.* (Glibert *et al*., 2011, pp. 389-399)

As discussed previously, and in more detail in Glibert *et al.* (2011), numerous examples exist where nutrient reductions in other ecosystems has led to the restoration of native sea grasses and to declines in invasive bivalve populations.

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FIGURE 5

Figure 5. This figure presents historical ammonium concentration data collected from 2006 to 2010 by the Vallejo Sanitation and Flood Control District (VSFCD). These data are for VSFCD effluent monitoring Station E-001. The Inhibition Threshold of 0.056 mg L^{-1} ammonium-N (equivalent to 4μmol L^{-1}) is the concentration that has been found to inhibit nitrogen uptake by diatoms and contribute to reduced diatom production in the Bay-Delta estuary. The Copepod Toxicity Threshold of 0.36 mg L^{-1} ammonium-N is the concentration that has been found to reduce the recruitment of new adult copepods and the number of newborn nauplii surviving to 3 days old. The Basin Plan Acute and Chronic Water Quality Objectives are 4.9 mg L^{-1} ammonium-N and 1.7 mg L^{-1} ammonium-N, respectively, as specified in the Tentative Permit, Attachment F at F-26.

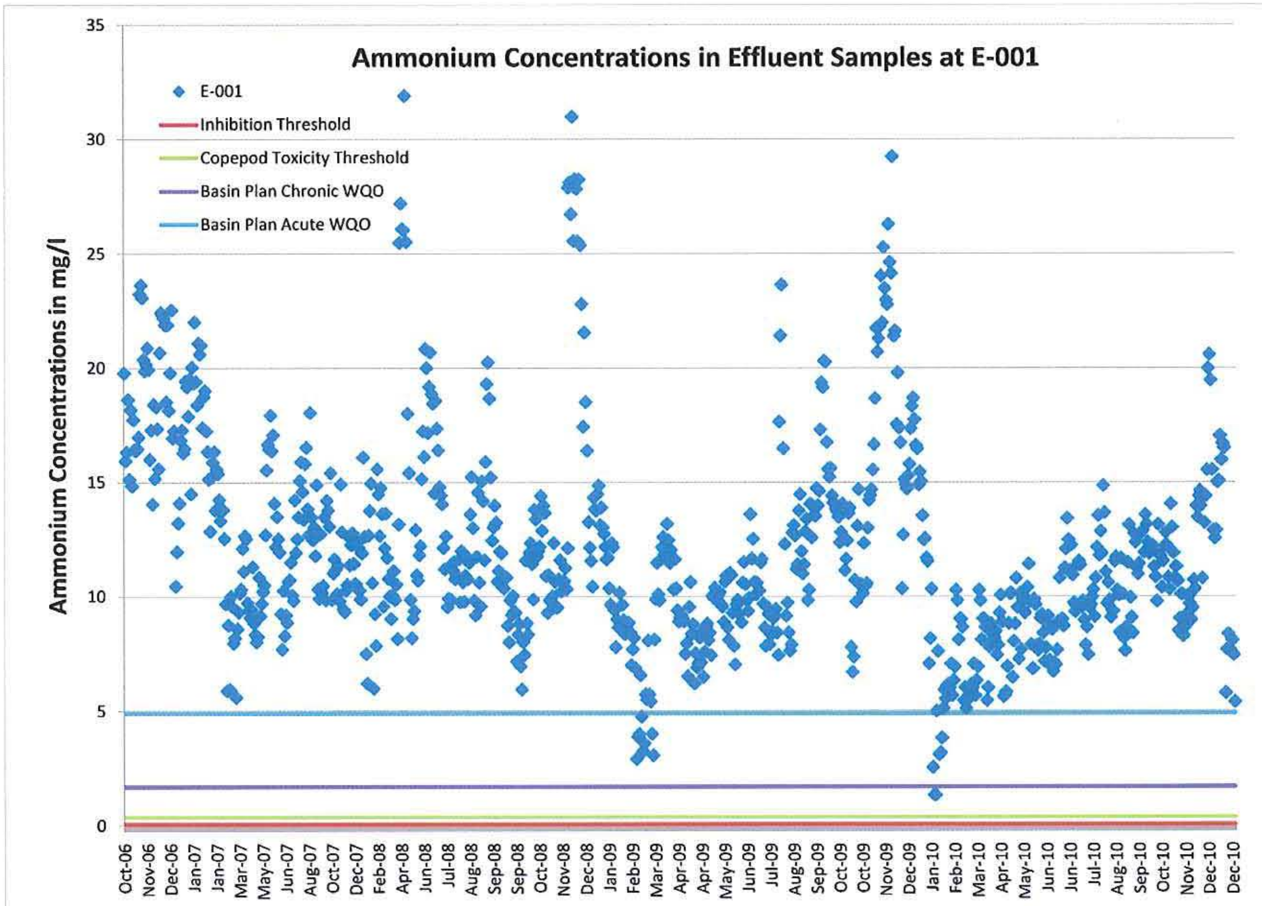

FIGURE 6

Figure 6. This figure presents historical ammonium concentration data collected from 1993 to 2010 by the U.S. Geological Survey (USGS). These data are for USGS monitoring stations 9, 10 and 11 located in Carquinez Strait. See Figure 7 for monitoring locations. The ammonium concentration of 0.056 mg L^{-1} (equivalent to 4μmol L^{-1}) is indicated on the graph. This ammonium level has been found to inhibit nitrogen uptake by diatoms and contribute to reduced diatom production in the Bay-Delta estuary. (Data source: http://sfbay.wr.usgs.gov/access/wqdata/index.html)

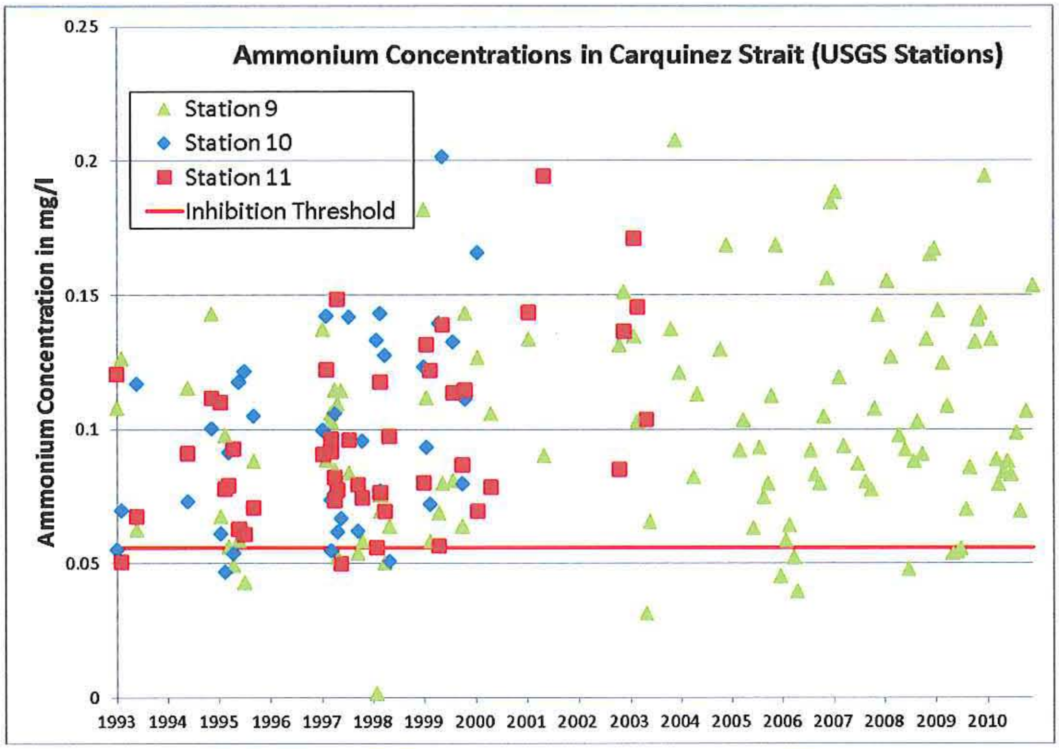

FIGURE 7

Figure 7. This figure presents historical ammonium concentration data collected from 1993 to 2001 by the Regional Monitoring Program (RMP). These data are for RMP Napa River Station BD50, a receiving water station for the Vallejo Sanitation and Flood Control District (VSFCD). See Figure 7 for monitoring location. The ammonium concentration of 0.056 mg L^{-1} (equivalent to 4μmol L^{-1}) is indicated on the graph. This ammonium concentration has been found to inhibit nitrogen uptake by diatoms and contribute to reduced diatom production in the Bay-Delta estuary. (Data Source: http://www.sfei.org/rmp)

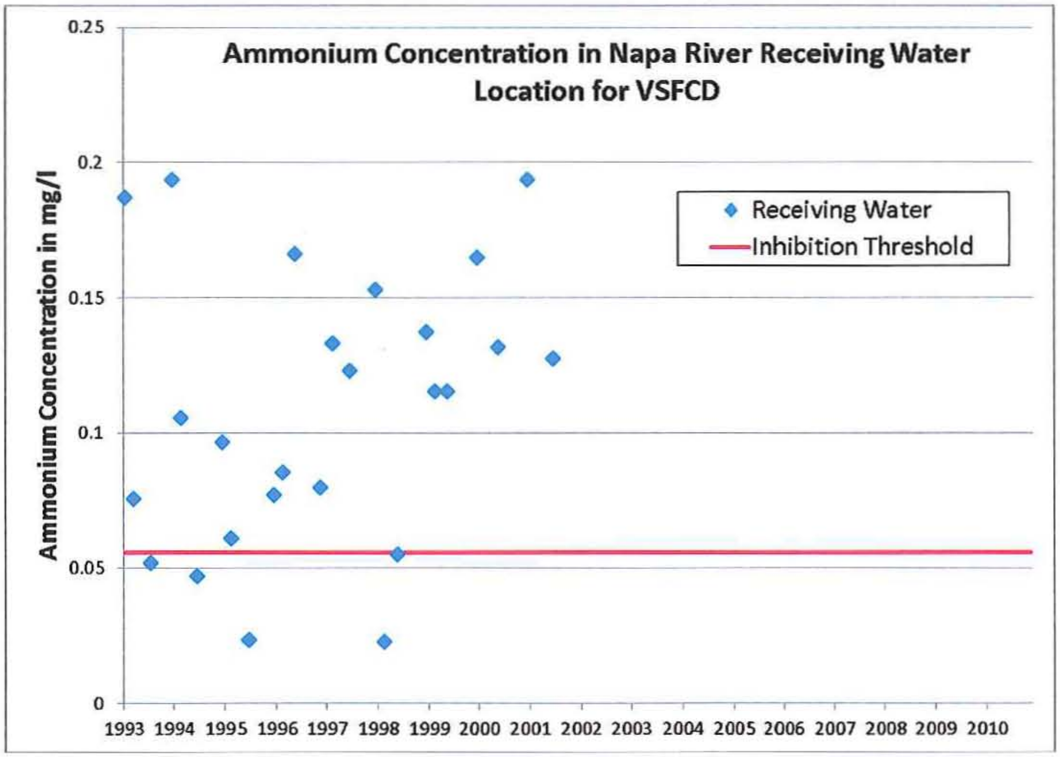

FIGURE 8

Figure 8. This figure shows the locations for the water quality monitoring stations that are referred to in Figures 6 and 7. The yellow dots labeled 9, 10 and 11 are USGS monitoring stations in Carquinez Strait, and the red dot is the RMP monitoring station BD50.