From: Michael Lozeau [michael@lozeaudrury.com]
Sent: Monday, September 27, 2010 4:12 PM
To: ILRP Comments; Pamela Creedon; Adam Laputz
Cc: Joe Karkoski; Bill Jennings; Richard Drury
Subject: CSPA Comments on ILRP PEIR and Related Documents - E-mail 2 of 2
Attachments: 2000 Community Effects of Hyacinth toft_ms.pdf; 2004 DFG Report hazasm04_03.pdf; 18554034 Report re Stunted Striped Bass.pdf; BDCP_Status_Update_3_June_2010[1].pdf; Central Coast ag_preliminary_report.pdf; Executive_summary_to_NMFS'_CVP-SWP_operations_BO_RPA.pdf; G. Fred Lee Delta-WQ-IssuesRpt.pdf; March%202010%20NAS%20Study%20Report.pdf; Mulcahy Declaration.pdf; NeedsAssessmentDF.pdf; NMFS_Biological_and_Conference_Opinion_on_the_Long-Term_Operations_of_the_CVP_and_SWP.pdf; pesticide_biop[1].pdf; 2010.9.25 Barrigan email.pdf; 2010.9.26 Kari Burr e-mail.pdf; 2010.9.26 Rauzi e-mail.pdf; 2010.24.2010 Forbes e-mail.pdf

Dear Ms. Smith, Ms. Creedon and Mr. Laputz,

Please find attached 16 documents that accompany CSPA's and CWIN's comments on the Irrigated Lands Regulatory Program EIR and related documents. Please include the attached documents in the administrative record. If you could confirm receipt of this e-mail would be apreciated.

Sincerely,

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Community Effects of the Non-Indigenous Aquatic Plant Water Hyacinth (*Eichhornia crassipes*) in the Sacramento/San Joaquin Delta, California

Jason David Toft

A thesis submitted in partial fulfillment of the requirements for the degree of

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University of Washington
Graduate School

This is to certify that I have examined this copy of a master's thesis by

Jason David Toft

And have found that it is complete and satisfactory in all respects,
and that any and all revisions required by the final
examining committee have been made.

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Abstract

Community Effects of the Non-Indigenous Aquatic Plant
Water Hyacinth (*Eichhornia crassipes*) in the
Sacramento/San Joaquin Delta, California

Jason David Toft

Chairperson of the Supervisory Committee:
Professor, David A. Armstrong
School of Fisheries

Biological invaders are widespread and can alter population dynamics and community structure of native ecosystems. Substantial habitat alteration by non-indigenous species can additionally affect the surrounding community. Aquatic plants are particularly invasive, especially in areas that are modified by humans. Water hyacinth (*Eichhornia crassipes*) is a floating aquatic plant that is non-indigenous to the Sacramento/San Joaquin Delta, California. Hyacinth is native to Brazil, and has a history of worldwide invasions. A common native that functionally occupies similar habitats as hyacinth is pennywort (*Hydrocotyle umbellata*). Based on the utilization of such habitats by invertebrates and fish, my main scientific question was: Has hyacinth modified the invertebrate assemblage structure and fish-invertebrate food web as compared to pennywort? To assess this, I sampled invertebrates in hyacinth and pennywort and analyzed fish diets in the surrounding area at three sites in the Delta during 1998 and 1999. I also took measurements of leaf density, root structure, dissolved oxygen and temperature.

Ecological differences between hyacinth and pennywort were linked to habitat architecture. Insects had higher densities in pennywort, and there were significant differences in the composition of insect assemblages. Leaf density was higher in pennywort, although hyacinth formed taller canopies. Taxa richness and diversity of invertebrates were usually higher in pennywort early in the summer, but were higher in hyacinth during later months. Hyacinth roots had more surface area and biomass, and dissolved oxygen levels were lower. Overall densities of epibenthic and benthic macroinvertebrates were usually greater in pennywort, and taxonomic compositions of aquatic invertebrate assemblages did show significant differences. Amphipods and isopods were particularly abundant living epiphytically in the root masses, including several new introduced species: the amphipod *Crangonyx floridanus*, and the isopods *Caecidotea racovitzai* and *Asellus hilgendorfii*. In general, *C. floridanus* was significantly more abundant in hyacinth and was not prevalent in fish diets, presumably due to the greater refuge value of hyacinth roots. The native amphipod *Hyalella azteca* was often significantly more abundant in pennywort, and was heavily preyed upon by fish. Coupled with the management challenges of hyacinth, such ecological modifications make it an even more influential invader.

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Acknowledgements

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Introduction

Biological invaders such as water hyacinth (*Eichhornia crassipes*) have become widespread on a global level (Drake and Mooney 1989). Although policy to control the spread of invasive species is becoming more common, the congruent ecological impacts of specific organisms are less well known. Exotic species can alter the population dynamics and community structure of native ecosystems (Elton 1958, Mooney and Drake 1986, Luken and Thieret 1997). They tend to be most successful in disturbed habitats (Drake and Mooney 1989), consistent with the intermediate-disturbance hypothesis (Connel 1978, Moyle and Light 1996). Ecological concern over non-indigenous species is especially applicable to the Sacramento/San Joaquin Delta, CA, as this estuary is considered one of the most modified by human activity in the United States (Nichols et al. 1986), and may be the most invaded estuary in the world (Cohen and Carlton 1998).

Aquatic plant invasions are a nuisance worldwide, especially in environments that have been extensively modified by humans (Barret 1989). Invasive plant theory predicts that a release from environmental constraints due to altered hydrology can often lead to a successful invasion (Galatowitsch et al. 1999). As a result, disruptions of wetland ecosystems involving irrigation canals, hydroelectric projects and construction of artificial lakes make such areas particularly susceptible to invasions (Barret 1989). The rapidly colonizing nature of many aquatic plants coupled with modified hydrological regimes often produces conditions for successful invasions (Crawley 1987, Ashton and Mitchell 1989, Rejmanek and Richardson 1996). Such a combination is exemplified to the extreme for worldwide invasions of hyacinth, as hyacinth is often termed a ‘perfect invader’ (Ashton and Mitchell 1989).

Non-indigenous species such as hyacinth can be particularly influential in the surrounding community due to habitat alteration. Studies on habitat-modifying organisms, or 'ecosystem engineers', have increased in recent years (Jones et al. 1994, 1997, Bertness et al. 1999) and are beginning to be applied more to non-indigenous species (Bertness 1984, Posey 1988, Vitousek 1990, Richardson et al. 1995, Ricciardi et al. 1997, Schmitz et al. 1997, Woods 1997, Crooks 1998, Crooks and Khim 1999). Crooks and Khim (1999) provide detailed examples of biogenic structures in many different aquatic habitats. Hyacinth can be labeled as such an invasive habitat modifier, as it provides a structurally complex canopy. In addition to the effects of forming a dense vegetative mat, the physical structure of the roots hanging in the water column and the leaves above water provide habitat for other species. Furthermore, organic fallout from the canopy can influence the benthic zone.

Introduced populations of hyacinth are the focus of controversy over issues of control and management all over the world (Gopal 1987). The plants are valued by ornamental pond enthusiasts for their beautiful flowers, which is how most introductions of hyacinth are initiated (Gopal 1987). It is remarkably easy to order hyacinth, even in locations where non-indigenous wild populations are established. Once the plants are introduced into the natural environment they rapidly increase in coverage, as hyacinth has the highest growth rate of any saltwater, freshwater or terrestrial vascular macrophyte (Wolverton and McDonald 1979). Doubling times range between 6-18 days (Gopal

1987, Schmitz et al. 1993). For these reasons, hyacinth has earned such nicknames as 'the weed from hell' and 'the beautiful devil' (Gopal 1987).

Hyacinth is native to Brazil and was first introduced to North America at the Cotton Centennial Exposition in New Orleans in 1884 (Gopal 1987). Thereafter, it rapidly became established in Florida by 1890. The first record in California is from 1904 when it was found in Yolo County around Clarksburg (Bock 1966, USCOE 1985, Gopal 1987). By 1947 it started to become a problem in the Sacramento/San Joaquin Delta, and by 1972 there were requests to control its abundance (USCOE 1985). Its early distribution in California was documented in detail by Bock (1966). In the 1980's, its prevalence in the Delta reached high enough levels that it became a hindrance to boat traffic. There are several reasons why hyacinth may have taken so long to prosper in the Delta, including: (1) An increase in stable freshwater flows in the area due to dams, reducing the severity of floods and high flows in the winter that can flush hyacinth out of the system. Such an abiotic factor associated with the altered hydrologic regime has also been attributed to the success of invasive fish in the Delta (Moyle and Light 1996); and (2) Hyacinth is a tropical plant, so it may have taken awhile for it to adapt to the temperate climate of central California (Finlayson 1983). In any case, 506 hectares of hyacinth covered the Delta in 1981, or 241 of the 1094 kilometers of waterways (Finlayson 1983). This was the spark to initiate an extensive biological and chemical control program headed by the California Department of Boating and Waterways (DBW), which actively controls coverage of hyacinth with spraying of the chemical 2,4-D. 202 hectares of hyacinth were treated with 2,4-D in 1983 with an annual budget of $200,000.

Although the abundance of hyacinth has drastically decreased in the Delta, control efforts have steadily increased, as 985 hectares of hyacinth were chemically treated during 1998-99 with an annual budget of approximately $1,000,000 (CDBW 1998, Pat Thalken, pers. com.). The weevils *Neochetina bruchi* and *N. eichhorniae* and the moth *Samaodes albiguttalis* were released as biological control agents in 1982 and 1983, without much success (USCOE 1985). Further control with biological agents has not been pursued.

Despite all the focus by society and management on the problems and control of hyacinth, the ecological processes associated with hyacinth have not been researched adequately in the Delta. Effects of hyacinth on community dynamics as compared to its native functional counterparts are particularly unknown. Pennywort (*Hydrocotyle umbellata*) is the predominant native floating aquatic vegetation (FAV) in the Delta. Pennywort tends to occupy similar habitats as hyacinth, but again, research has not been done to see how fish and invertebrates use these habitat types. One would expect a modification in community dynamics in response to changes in: spatial complexity of the vegetative structure, shading effects of dense canopies, amount and location of plant biomass, densities of vegetation patches, plant detritus deposition rate, growth rates, dissolved oxygen levels, and rates of evapotranspiration (Penfound and Earle 1948, McVea and Boyd 1975, Wolverton and McDonald 1978, Center and Spencer 1981, Crowder and Cooper 1982, Reddy 1984, Gopal 1987, Jantrarotai 1990, Schmitz et al. 1993, Madsen 1997). Research specific to hyacinth and pennywort in Florida has shown that overall dry biomass of hyacinth is 259% greater than pennywort (Reddy 1984). Other research in Florida on hyacinth and a different species of pennywort (*Hydrocotyle* *ranunculodies*) has shown that overall dry biomass of hyacinth is 161% greater, and the maximum root length of hyacinth is 164% greater (Jantrarotai 1990).

The roots of hyacinth can be important habitat for epiphytic macroinvertebrates (aquatic invertebrates living on macrophytes; Hutchinson 1967, Schramm et al. 1987), especially amphipods (Schramm et al. 1987, Bailey et al. 1993, Bryan 1993). Epiphytic invertebrates can be much more abundant than benthic invertebrates and are positively correlated to the amount of colonizable surface area available (Marcheck 1966, Crowder and Cooper 1982, Dvorak and Best 1982, Schramm et al. 1987). Furthermore, fish such as bluegills (*Lepomis macrochirus*) selectively feed on epiphytic invertebrates over other sources of prey (Werner and Hall 1976, 1979, Keast 1978, Mittelbach 1984, Schramm and Jirka 1989). FAV can also be beneficial as a nursery habitat for juvenile fishes and many invertebrates (Sazima 1985, Gopal 1987, Werner and Hall 1988, Schramm and Jirka 1989, Dibble 1996). Effects of hyacinth on the fish-invertebrate food web in the Delta are unknown, and could be important due to the prominence of hyacinth as a major habitat zone in shallow water areas. This is all dependent on patch size, as large patches of hyacinth can cause low dissolved oxygen levels, high input of plant detritus, and senescence of submerged vegetation (Lynch et al. 1947, Gopal 1987). However, with the onslaught of chemical control against hyacinth in the Delta, canopies of hyacinth usually remain constrained to small patches fringing the marsh edge. Back channels in the marsh can also become overrun with hyacinth due to limited access by chemical control methods.

A comprehensive ecosystem study in the Sacramento/San Joaquin Delta provided the opportunity to address gaps in the knowledge of hyacinth (BREACH; Simenstad et al. 1999). BREACH focused on predicting the rates and patterns of restoration of breached-levee wetlands. Research on hyacinth fit into the overall BREACH study objectives, as hyacinth canopies form on the marsh fringe and may be influential in the development of the adjacent marsh community. In warmer climates where hyacinth grows throughout the year, permanent floating islands are created, which deposit large amounts of organic matter. These floating islands can greatly accelerate pathways of succession, allowing emergent and eventually riparian vegetation to colonize (Penfound and Earle 1948, Trivedy et al. 1978, Gopal 1987, Woods 1997). Although such patterns of succession have been reported in Louisiana (Penfound and Earle 1948), this pathway is abbreviated in central California, as low winter temperatures inhibit growth of hyacinth, usually preventing formation of such permanent floating islands.

Based on the previous statements involving the utilization of FAV by invertebrates and fish, the main scientific question for my research is: Has hyacinth modified the invertebrate assemblage structure and the associated fish-invertebrate food web as compared to its native functional counterpart pennywort? Within this broad question, my research has five main objectives:

(1) Determine whether there are significant differences between hyacinth and pennywort in the physical parameters of leaf density, surface area and biomass of roots, dissolved oxygen and water temperature.

(2) Determine whether there are significant differences in epiphytic macroinvertebrate assemblage composition and abundance between hyacinth and pennywort.

(3) Determine whether there are significant differences in epibenthic and benthic macroinvertebrate assemblage composition and abundance between hyacinth and pennywort.

(4) Determine whether there are significant differences in insect assemblage composition and abundance between hyacinth and pennywort.

(5) Determine whether the diets of resident fishes are different surrounding patches of hyacinth and pennywort.

Materials and Methods

Study Area

All study sites were located in the Sacramento/San Joaquin Delta, California, USA (~38.0° N, 121.5° W). Three study sites were utilized in this project, hereafter referred to as Site A (Mandeville Tip), Site B (Brown's Island), and Site C (Mildred island) (Fig. 1). These three sites were a subset of the study sites used for the BREACH research program (Simenstad et al. 1999). This area has a mild temperate climate, and represents one of the most northern established populations of hyacinth in the world (Bock 1966, Finlayson 1983, Gopal 1987). The Delta is heavily influenced by human activity, including agricultural, recreational and industrial activities (Nichols 1986). Historically, the Delta was almost all wetlands characterized by the tule grass (*Scirpus* spp., hereafter referred to as 'tule') with some natural levees and riparian habitat (woody vegetation, mostly *Salix* spp.; Atwater et al. 1979, TBI 1998). Approximately 97% of these wetlands have been leveed and drained predominantly for agricultural purposes (Atwater and Belknap 1980, Herbold and Moyle 1989, SFEP 1991). Consequently, the majority of channels are now rip-rapped and constrained and deep water ship channels are regularly dredged. Although salinity wedges have historically entered the Delta, current water management has prevented this from happening, mainly due to controlled water flows that increase freshwater inflow during summer months (Kelley 1966, Nichols et al. 1986, CDWR 1993). Such water management maintains freshwater available for irrigation and drinking purposes. Due to freshwater usage, the overall flow into San Francisco Bay is less than 40 percent of historic levels (Nichols et al. 1986). Benthic sediments in the Delta are soft-bottom, consisting of a mixture of sand, silt and clay (Hazel 1966, Siegfried et al. 1980, Hymanson et al. 1994). Tidal range is approximately one to two meters (Kelley 1966, CDWR 1993).

Sampled FAV patches were located on the marsh fringe. FAV patches were not utilized if they did not look healthy, since this could indicate recent chemical control with 2,4-D. Five patches of both hyacinth and pennywort were randomly sampled at each site. These patches occupied indentations in the marsh fringe and were separated by clumps of tule. The exception to this was the pennywort patches at Site A where patches were not clearly delineated by tule separation. For this reason, a transect line was deployed through this site and five random points along the transect were sampled.

Site A was studied in the months of April, June and July 1998, and June 1999. Chemical control at Site A exterminated all patches of hyacinth in August 1998. Therefore, sampling was conducted at Sites B and C in the months of August 1998 and June 1999.

Physical Sampling

Intensive sampling of the physical structure of the FAV canopies was done in June 1998 at Site A, and August 1998 at Sites B and C. This was congruent with epiphytic invertebrate sampling described below. Leaf density was determined by counting the number of leaves in a 0.5-m^2 quadrat. Surface area of the canopies was roughly determined by measuring the length and width of each patch. The roots from the epiphytic invertebrate sampling were analyzed for biomass and surface area. Biomass was determined by measuring preserved wet weight of the roots. The roots were blotted dry with a towel, allowed to air dry for 10 minutes, and weighed to nearest milligram. Surface area of the roots was measured using a surfactant technique (Harrod and Hall 1962, Hicks 1977). A soapy solution was mixed in a bucket, containing 60 ml of Liquinox soap in 6 liters of water. This soapy solution was left overnight so that the bubbles dispersed. For each root sample, five 1 gram dried samples (as above) were taken and dipped in the soapy solution. The excess soap was shaken off, so that a monolayer of soapy solution was retained around the root surface. Each sample was then reweighed. The difference in weight can be standardized to the weight difference from known surface areas, allowing calculations of surface area for the root samples. Known surface areas of 25, 100, 225, 400, 625, and 900 cm^2 for tinfoil were utilized to calculate these weight differences as above, five samples for each surface area. A regression was fit to this data and the model was used to calculate surface area of the root samples from their weight differences. All weight differences from the root samples fell within those of the known surface areas.

Measurements of dissolved oxygen and temperature were taken at each FAV patch congruent with sampling of epiphytic invertebrates in August of 1998 at Sites B and C. These measurements were taken with a YSI model handheld meter, with the probe directly underneath the FAV canopies.

Biological Sampling

Epiphytic Macroinvertebrates

Epiphytic macroinvertebrates living in association with the root masses of the vegetation were sampled by manually collecting plant samples (Schramm et al. 1987, 1989). Amount of canopy surface area sampled was determined by correlating the number of leaves in each plant sample to the number of leaves in a 0.5-m^2 quadrat. Samples were taken in the middle of the FAV canopies, with five replications for each month of sampling. All macroinvertebrates were then separated from the collected root mass by vigorously shaking each root sample in a bucket containing 10% isopropyl alcohol, causing the macroinvertebrates to detach from the roots. The alcohol-solution was then sieved at 0.5 mm to collect only the macroinvertebrates and fixed in 5% buffered formaldehyde solution. These samples were later preserved in 70% isopropanol in the laboratory. Roots from each sample were retained separately in 70% isopropanol and brought to the laboratory, in order to take measurements of surface area and biomass (as above). Any additional macroinvertebrates that were not detached from the roots in the alcohol-solution were later separated in the laboratory. Invertebrates were counted and identified to the lowest practical taxonomic level with light microscopy. Standing stock was estimated by measuring the preserved wet weight of each taxon. Excess liquid was toweled-off, and each taxonomic group weighed to nearest 0.1 mg. Numbers and standing stock of invertebrates were standardized to 1 m^2 surface area of the canopy, allowing for comparisons between strata and with other invertebrate sampling as density (number/m^2) and standing stock (g/m^2), respectively.

Epibenthic/Benthic Macroinvertebrates

Benthic cores were used to sample epibenthic and benthic macroinvertebrates beneath FAV canopies at sites A and B. Cores were taken to 10 cm depth beneath the sediment surface with a core area of 0.0024 m^2. The core was made of metal pipe with sharp edges so that it was able to cut through the organic material underneath the canopies. Samples were taken in the middle of the FAV canopies, with five replications for each month of sampling. The core was inserted into a hole in each patch, sampling both epibenthic macroinvertebrates in the water column (approximately 1 m depth) and benthic macroinvertebrates in the sediment. Samples were immediately fixed in 5% buffered formaldehyde solution containing rose bengal dye. The samples were sieved at 0.5 mm in the laboratory in order to clean the samples of sediment and retain only macroinvertebrates. The samples were then transferred and preserved in 70% isopropanol. Invertebrates were counted and identified to the lowest practical taxonomic level with light microscopy. As with the epiphytic invertebrate sampling, numbers of invertebrates were standardized to 1 m^2 surface area of the canopy, allowing for comparisons between strata and with other invertebrate sampling as density (number/m^2).

Insects

Passive insect fallout traps were used to sample insects living in association with the FAV canopies at sites A and B. These traps consisted of a rectangular tray (0.0782 m^2) partly filled with soapy water. The soap disrupts the surface tension of the water, trapping insects that come into contact with the water (Sutherland 1996). Samples were taken in the middle of the FAV canopies, with five replications for each month of sampling. The trays were nestled into the canopy, so that they floated on the water surface with the leaves of the canopy surrounding the tray. These traps were tethered with PVC poles to the specific site, allowing vertical movement with the tides. The trays were deployed for 24 hours after which the soapy water was sieved at 0.106 mm and the insects preserved in 70% isopropanol. Invertebrates were counted and identified to the lowest practical taxonomic level with light microscopy. As with the other invertebrate sampling, numbers of insects were standardized to 1 m^2 surface area of the canopy, allowing for comparisons between strata and with other invertebrate sampling as density (number/m^2).

Fish

At Site A, fish were sampled in nearshore habitat adjacent to FAV during June and July 1998. The California Department of Water Resources (DWR) directed this sampling as part of the BREACH study (Simenstad et al. 1999). Depletion beach seine sampling (7.6 m x 1.2 m, 3.2 mm mesh) inside block-net enclosures (range 30-48 m^2) under 1.5 meters water depth was used to capture fish along the marsh edge. FAV patches were located on the same marsh edge. Perimeter stakes were set at least 24 hours in advance to minimize disturbance in the area. The following day the area was surrounded with block nets (25 m x 1.2 m, 3.2 mm mesh). The enclosure was repeatedly swept with a beach seine to remove fish. At least four hauls in alternating directions were conducted until juvenile fish catch decreased for two consecutive hauls. Fish species were counted and the first twenty of each species measured in fork length (mm). A subset of bluegills (*Lepomis macrochirus*) were preserved in 5% buffered formaldehyde solution and saved for fish diet analysis. Bluegills were chosen for diet analysis because they are omniverous fish that have been shown to feed on macroinvertebrates in FAV habitats (Werner and Hall 1979, McGinnis 1984, Schramm and Jirka 1989), are opportunistic feeders, and were present in substantial abundance to guarantee sufficient sample size. Bluegills are also non-indigenous to the Delta.

DWR did not conduct fish sampling directly adjacent to FAV at Sites B and C. However, they did sample fish in many areas surrounding sites A, B, and C using the same methodology as above. Representative fish of common species from these areas were saved for diet analysis.

The density of the FAV canopies and steep incline of the channels made it near impossible to use seine nets to sample fish directly underneath FAV. Seining (7.6 m x 1.2 m, 3.2 mm mesh) was only successful in directly sampling five patches of hyacinth at Site C. The net was pulled underneath the canopy, during which the entire patch of hyacinth was thrown behind the net allowing the net to be hauled onto the shore. Because this method is destructive, it was not used on the native pennywort patches. All fish sampled from the hyacinth patches were preserved in 5% buffered formaldehyde solution and saved for fish diet analysis. This enabled comparisons with DWR sampling adjacent to FAV to ensure that fish diets between adjacent habitat and underneath FAV were comparable, and that bluegills actively utilize FAV habitat. Various other techniques of sampling fish directly underneath FAV were attempted without much success. Other techniques were found either not to be cost effective (pop-nets), and/or not to have sufficient sample size (minnow traps).

Fish saved for diet analysis were measured (fork length in mm, preserved wet weight in g). The stomachs were then dissected from the fish and the gut contents removed. Overall gut contents were blotted dry and weighed. Taxa were then separated and identified to the lowest possible taxonomic level with light microscopy. Each taxonomic group was then counted, blotted dry and weighed. Levels of stomach content digestion and stomach fullness were estimated. Prey items were then ranked based on modified Index of Relative Importance values (IRI; Pinkas 1971, Cailliet 1977, Simenstad et al. 1991, Shreffler et al. 1992):

$$\text{IRI} = \begin{matrix}\text{\% frequency}\\ \text{of occurrence}\end{matrix} \times \left[\begin{matrix}\text{\% numerical}\\ \text{composition}\end{matrix} + \begin{matrix}\text{\% gravimetric}\\ \text{composition}\end{matrix} \right]$$

Diet overlap with sampled aquatic prey resources was calculated using a modified Percent Similarity Index (PSI; Hulbert 1978):

$$\text{PSI} = \sum_{i=1}^{n} \text{minimum} \, (p_{xi}, p_{yi})$$

where p_{xi} = percentage of prey i in predator x, and p_{yi} = percentage of prey i in sampled aquatic prey resources. Ivlev's electivity index was used to compare differences in fish selectivity of the major amphipod taxa present in the sampled invertebrates (Ivlev 1961):

$$E_i = (r_i - p_i)/(r_i + p_i)$$

where E_i is the index of electivity, r_i is the percent of a prey item in the fish diet, and p_i is the percent of a prey item in the environment. Values fall between a range of -1 to 1, with positive values indicating positive selectivity, negative values indicating negative selectivity, and values around 0 indicating neutral selectivity. The Ivlev electivity index was chosen as it is easy to interpret, and gives similar results to other indices (Lechowicz 1982, Kline 1996).

Data Interpretation and Statistical Tests

Measurements of density (number/m^2), taxa richness, and the Shannon-Weiner diversity index were calculated for all invertebrate sampling. Similar measurements of standing stock (g preserved wet/m^2) were calculated only for epiphytic macroinvertebrates. Mean numbers and standard errors for each taxon were calculated. Parametric two sample t-tests were used to statistically compare means for biological and physical sampling between hyacinth and pennywort at each study site ($\alpha = 0.05$). Therefore, for all measurements between hyacinth and pennywort, H_o: $u_1 = u_2$ and H_a: $u_1 \neq u_2$. The parametric t-test is a robust statistic, meaning it can withstand considerable departures from its underlying assumptions of normality and homogeneity of variance, especially if $n_1 = n_2$ and the test is two-tailed, as is the case with our study design (Simenstad et al. 1991, Zar 1996).

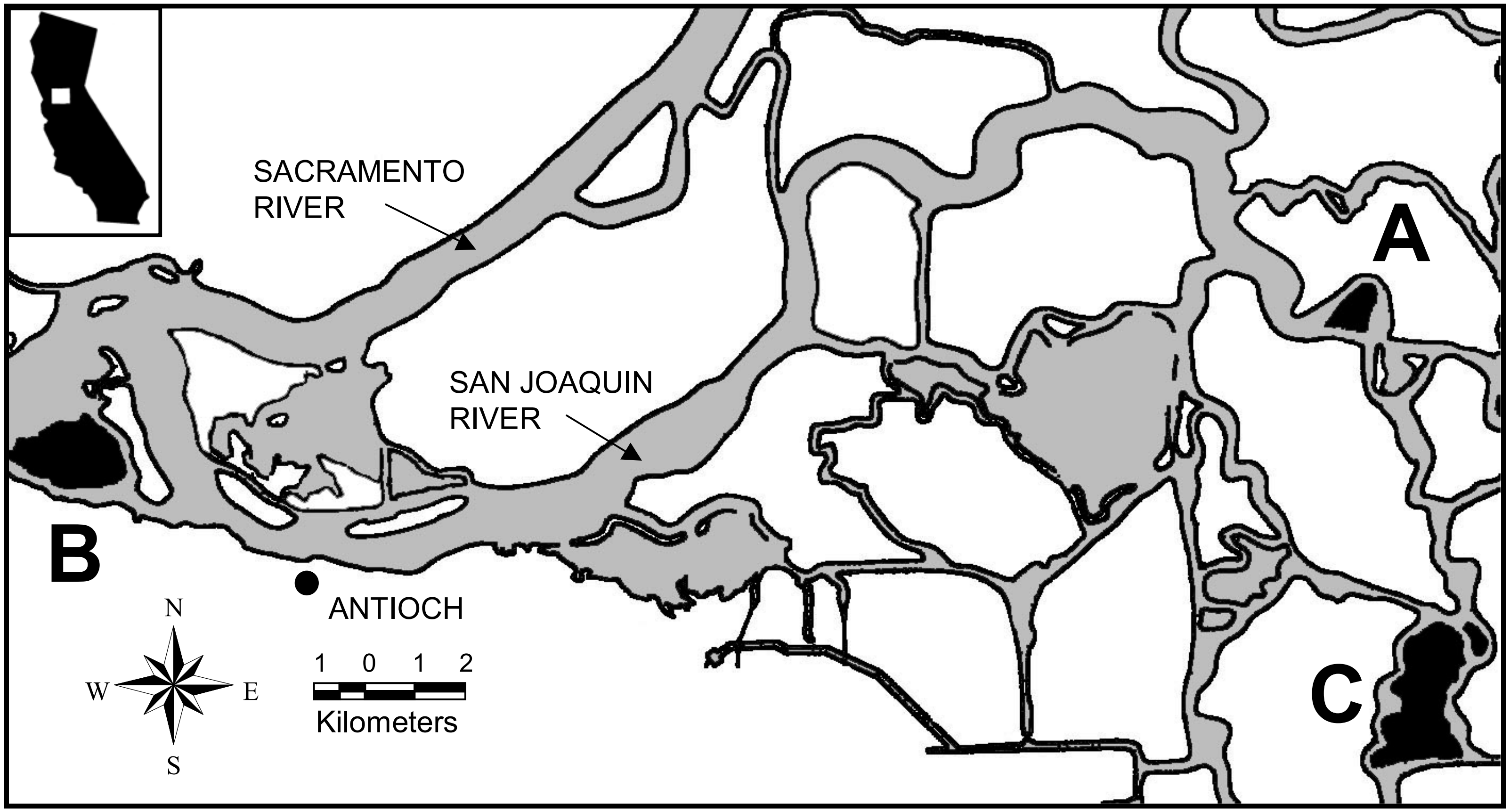

Figure 1. Map of Study Sites. Water is shaded grey, land is white, and study sites are black. Inset is the state of California. Site A = Mandeville Tip, Site B = Brown's Island, Site C = Mildred island.

Results

General Characteristics

Pennywort and hyacinth occurred in separate patches, sometimes directly bordering each other. Small amounts of the semi-aquatic plant *Ludwigia* spp. were found to grow occasionally with both hyacinth and pennywort. Hyacinth was absent at our study sites in June 1999, although residual patches remained in back channels of wetlands and marinas in the surrounding area. The lack of hyacinth in 1999 was due to the following: (1) DBW intensively sprayed 2,4-D throughout the summer months and into mid-December; (2) There were several heavy freezes during the winter, which caused high mortality of carry-over plant material; (3) It was a wet winter, which created a high flow flushing plant material out of the Delta into San Francisco Bay; and (4) DBW started 2,4-D spraying early in spring 1999 with more crews than ever before (Pat Thalken, pers. com.). Pennywort was still sampled in June 1999 so that interannual variation could be measured, as well as to determine if the invertebrate community changed with the absence of hyacinth.

Physical Sampling

All patches were of the same magnitude in size, and occupied similar habitats fringing the marsh edge. The average canopy surface area was 30.96 m^2, ranging from 8.69-50.90 m^2. Water depth was approximately 1 m for all invertebrate sampling. Pennywort always had a higher density of leaves than hyacinth, significantly higher at Sites A and C (Fig. 2).

Weight differences of known surface areas produced an extremely tight regression model for calculating the surface area of roots (R^2=0.99; Fig. 3). Hyacinth always had a greater root surface area than pennywort, significantly higher at Site B (Fig. 4). Similarly, hyacinth tended to have a greater root biomass than pennywort (Fig. 5), although no significant differences were detected.

Dissolved oxygen levels directly underneath the FAV canopies were significantly lower in hyacinth than pennywort at Site C, and slightly lower at Site B (Fig. 6). These spot values were taken during the same time period, and indicate that hyacinth can have significantly lower dissolved oxygen levels than pennywort. Concurrent water temperatures showed no significant differences (Fig. 7).

Biological Sampling

Epiphytic Macroinvertebrates

There were no consistent trends in total overall density and standing stock of epiphytic macroinvertebrates at any of the sites (Fig. 8). However, there were taxonomic differences between hyacinth and pennywort specific to each study site (Tables 1, 2). At Site A in June 1998, there was a dramatic contrast in assemblage composition, with the amphipod *Crangonyx floridanus* being the most abundant taxon in hyacinth in terms of both density and standing stock, and the amphipod *Hyalella azteca* being most abundant in pennywort (Figs. 9, 10). *C. floridanus* had not been previously reported in the Delta. These amphipods had different contributions numerically and gravimetrically, as *C. floridanus* density in hyacinth was 187% that of *H. azteca* in pennywort, but only 62.5%

in terms of standing stock. The amphipods *C. floridanus* and *Corophium spinicorne* were significantly more abundant in terms of density and standing stock in hyacinth. The amphipod *H. azteca*, the isopod *Caecidotea racovitzai*, and the oligochaete *Stylaria lacustris* were significantly more abundant in terms of density and standing stock in pennywort, and turbellarians were more abundant in terms of standing stock. *C. racovitzai* had also not been previously reported in the Delta. Pennywort was slightly higher than hyacinth in taxa richness, and much higher in diversity (Table 3).

Sites B and C in August 1998 did not show the same dramatic contrasts in epiphytic macroinvertebrate assemblages as in Site A. At Site B, the amphipod *Gammarus daiberi* was the most abundant species in both hyacinth and pennywort (Figs. 9, 10). *G. daiberi* is a large amphipod, which accounts for the high levels of standing stock at Site B. The only significant difference was that the standing stock of the oligochaete *S. lacustris* was higher in pennywort. At Site C, the amphipod *H. azteca* was the most abundant species in patches of both hyacinth and pennywort. The only significant difference was that the density of chironomid larvae was higher in pennywort. Hyacinth was higher than pennywort in taxa richness and diversity at both sites (Table 3).

Results of the June 1999 sampling indicated that there was minimal interannual variation in invertebrate assemblages, as the most abundant taxon present at each site was the same between 1998 and 1999 (Fig. 11). In patches of pennywort at Site A, *H. azteca* was 50% of the overall density in June 1998 and 65% in June 1999. At Site B, *G. daiberi* was 84% of the overall density in August 1998 and 61% in June 1999. At Site C, *H. azteca* was 86% of the overall density in August 1998 and 57% in June 1999.

C. floridanus almost completely vanished in June 1999 when hyacinth was absent from the study sites (Fig. 11). At all sites during 1998, *C. floridanus* was denser in hyacinth than pennywort. When the sites were devoid of hyacinth patches in June 1999, *C. floridanus* was completely absent from pennywort patches at Sites A and B, and was only 0.23% of overall invertebrate density at Site C.

Epibenthic/Benthic Macroinvertebrates

Overall densities of epibenthic and benthic macroinvertebrates were greater underneath patches of pennywort than hyacinth at Site A during all months of sampling, but were significantly more abundant in pennywort only during June (Fig. 12). Oligochaetes were the predominant benthic invertebrate under both hyacinth and pennywort. Species-specific trends in the epibenthic macroinvertebrates were similar to those in the epiphytic macroinvertebrates (Fig. 13, Table 4). *C. floridanus* was the predominant epibenthic taxon under hyacinth, and *H. azteca* was the predominant epibenthic taxon under pennywort. *C. racovitzai* was also always more dense under pennywort. H. *azteca* was significantly more dense under pennywort during June and July, and *C. racovitzai* and turbellarians were significantly more dense under pennywort during June. Pennywort was higher in taxa richness and diversity in April, while hyacinth was higher in June and July (Table 3).

Overall densities were almost equal in hyacinth and pennywort at Site B during August 1998 (Fig. 12). Oligochaetes were once again the most abundant benthic invertebrate (Fig. 13). The most striking difference was that there were no amphipods or isopods underneath hyacinth patches at all, therefore overall densities of amphipods and isopods were significantly higher under pennywort ($p < 0.015$; Table 4). *G. daiberi* was the major epibenthic taxon under pennywort, as was the case with the epiphytic macroinvertebrates. Pennywort was much higher in taxa richness and diversity (Table 3) because hyacinth was almost devoid of epibenthic invertebrates.

As was the case with the epiphytic macroinvertebrates, there was minimal interannual variation in invertebrate assemblages, as the most abundant taxon present at each site was the same between 1998 and 1999 (Fig. 14). Under patches of pennywort at Site A, *H. azteca* was 76% of the overall epibenthic density in June 1998, and 53% in June 1999. At Site B, *G. daiberi* was 50% of the overall epibenthic density in August 1998, and 83% in June 1999.

When hyacinth was absent in June 1999, *C. floridanus* almost completely vanished from the epibenthic community, as it did in the epiphytic community (Fig. 14). *C. floridanus* was more abundant in hyacinth than pennywort at Site A during all months in 1998. When the sites were devoid of hyacinth patches in June 1999, *C. floridanus* in turn was completely absent from epibenthic samples in pennywort at Site A. *C. floridanus* was not found in the epibenthos at either hyacinth or pennywort at Site B in 1998, but it must be remembered that no epibenthic amphipods were found at all in these hyacinth patches. At Site B, *C. floridanus* only accounted for 0.63% of the overall density in June 1999.

Insects

Overall densities of terrestrial insects were significantly greater in pennywort than hyacinth at Site A during all months of sampling (Fig. 15). FAV differences and seasonal differences were apparent (Fig. 16; Table 5). In April, Ephydridae were significantly more abundant in hyacinth, and Psychodidae were significantly more abundant in pennywort. Ephidridae and Psychodidae both decreased in June and July, with Collembola becoming significantly more abundant in hyacinth by July, and Cicadellidae significantly more abundant in pennywort in both June and July. Chironomidae were significantly more abundant in hyacinth during April, but were significantly more abundant in pennywort during June and July. Other significant findings were higher values in pennywort of Aphididae and Sphaeroceridae in April, Dolichopodidae, Sphaeroceridae, and Staphylinidae in June, and Araneae, Delphacidae, Hymenoptera, and Mymaridae in July. Aphididae and Hemiptera were significantly greater in hyacinth in July. Pennywort was higher in taxa richness, while hyacinth was higher in diversity throughout all months (Table 3).

Overall densities were also greater in pennywort than hyacinth at Site B in August 1998, but differences were not statistically significant (Fig. 15). Pennywort did have significantly greater densities of Chironomidae and Araneae (Fig. 16; Table 5). Cicadellidae were very abundant, more so in pennywort, although the differences were not significant. These trends were similar to those found at Site A in July 1998. Hyacinth was higher in both taxa richness and diversity (Table 3).

There was minimal interannual variation, the main difference being more Collembolans in pennywort during June 1999 (Figs. 17). However, specific taxonomic differences could not be determined, as Collembolans were only identified to Order.

Fish

Most of the fish captured adjacent to patches of hyacinth and pennywort at Site A during June and July of 1998 were juveniles (Table 6). The majority of these fish were non-indigenous to the Delta. The native species splittail (*Pogonichthys macrolepidotus*), tule perch (*Hysterocarpus traski*) and prickly sculpin (*Cottus asper*) accounted for only 24% of the numerical catch in June and 3% in July.

Diet analysis of bluegills indicated differences among the major prey items between fish caught adjacent to hyacinth and pennywort (Fig. 18). Based on IRI values, the predominant prey item for bluegills adjacent to pennywort in both June and July was *H. azteca*, which was also the most common epiphytic and epibenthic macroinvertebrate found in those pennywort patches. Adjacent to hyacinth patches, the major prey items of bluegills in June were the amphipod *G. daiberi*, the isopod *Asellus hilgendorfiii,* and insects of the family Aphididae. *A. hilgendorfii* had not been previously reported in the Delta. In July, the major prey items were chironomid larvae, gastropods, *G. daiberi*, and the copepod *Pseudodiaptomus forbesi*. These prey items did not directly coincide with the major aquatic macroinvertebrates found in hyacinth. *C. floridanus* was the major epiphytic and epibenthic macroinvertebrate found in hyacinth, which was the ninth ranked prey item in June, and was not found in the prey items at all in July. Ivlev

Electivity Index values between *C. floridanus* in hyacinth and *H. azteca* in pennywort also suggest differences in preference for these two major prey resources, as *C. floridanus* always had lower values (Table 7).

Overlap between prey items and potential macroinvertebrate prey was also higher in pennywort (Fig. 18). PSI with the prey resources in pennywort was 23.7% for epiphytic and 23.4% for epibenthic macroinvertebrates during June, and 69.5% for epibenthic macroinvertebrates in July. Overlap with prey resources in hyacinth was 4.9% for epiphytic and 11.1% for epibenthic macroinvertebrates during June, and 10.7% for epibenthic macroinvertebrates in July. Most of the overlap between macroinvertebrate prey items and resources was due to amphipods, isopods, gastropods, and chironomid larvae. Discrepancies were due to either differences in species of amphipods and isopods, as was the case with hyacinth, or due to the presence of planktonic organisms such as cladocerans, ostracods, and copepods in the diet.

Most of the fish captured directly underneath 5 patches of hyacinth at Site C during August 1998 were juveniles (Table 8). The majority of these fish were non-indigenous to the Delta, the only native fish caught was one prickly sculpin accounting for 2% of the numerical catch. Other common captured organisms included the non-indigenous crayfish *Procambarus clarkii* and the giant water bug (family Belostomatidae).

Diet analysis of the fish living directly underneath the hyacinth canopy indicated that they were utilizing the prey resources in the canopy (Fig. 19). The most abundant amphipod in the prey was *H. azteca*, which was also the most abundant epiphytic and epibenthic macroinvertebrate. *H. azteca* was the predominant prey item for larger bluegills (size 2) and juvenile largemouth bass (*Micropterus salmoides*). Other common prey items for these fish were zygoptera nymphs and chironomid larvae, which were also found as prey resources in hyacinth. *H. azteca* was still in the top three or four prey items of smaller fish such as bluegills (size 1) and rainwater killifish (*Luciana parva*). The diets of these smaller fish were composed mainly of planktonic organisms, such as the copepod *P. forbesi* and the cladoceran *Ceriodaphnia* spp. For this reason, PSI with epiphytic and epibenthic macroinvertebrates for larger bluegills and juvenile largemouth bass was approximately 40%, and approximately 10% for smaller bluegills and rainwater killifish.

Ivlev Electivity Index values between *C. floridanus* and *H. azteca* in hyacinth further demonstrated the differences in preference for these two potential prey items (Table 7). Both amphipods were found in the diets of larger bluegills and juvenile largemouth bass, and *C. floridanus* always had lower Ivlev Electivity Indices than *H. azteca*.

The top five prey items based on IRI values of common nearshore juvenile fish in the area surrounding the study sites are illustrated in Fig. 20. Bluegills and largemouth bass are established non-indigenous species, while chinook salmon (*Oncorhynchus tshawytscha*), splittail, tule perch and prickly sculpin are natives. It is apparent that the amphipods *H. azteca* and *G. daiberi* were major prey items in almost all of these species. *C. floridanus* was absent from the major prey items, which was the amphipod found to be prevalent in hyacinth canopies. Other common prey items included chironomids, copepods, cladocera, the isopod *Caecidotea racovitzai*, and the amphipod *Corophium spinicorne*.

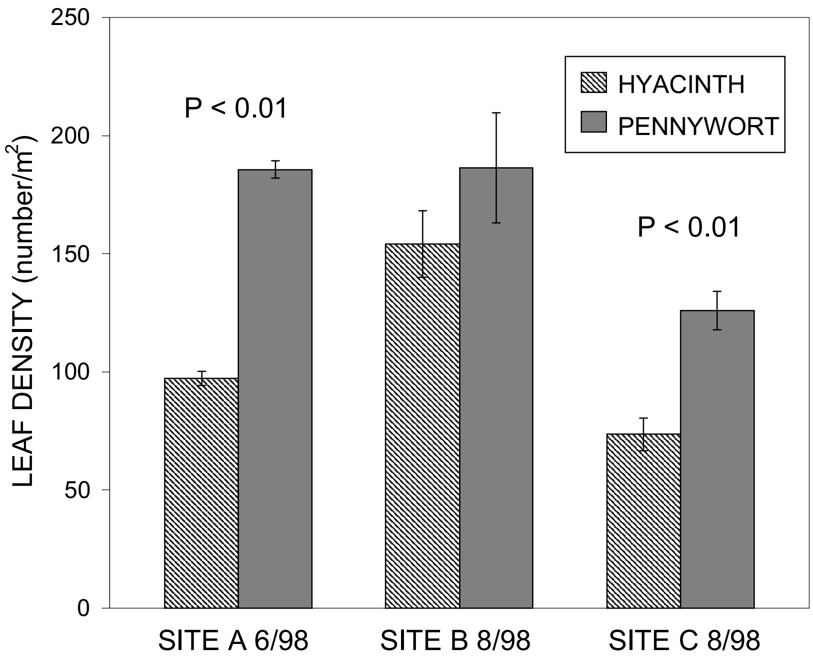

Figure 2. Leaf density of hyacinth and pennywort. P-values show significant results from two sample t-tests, error bars are ± standard error, n = 5 for each bar.

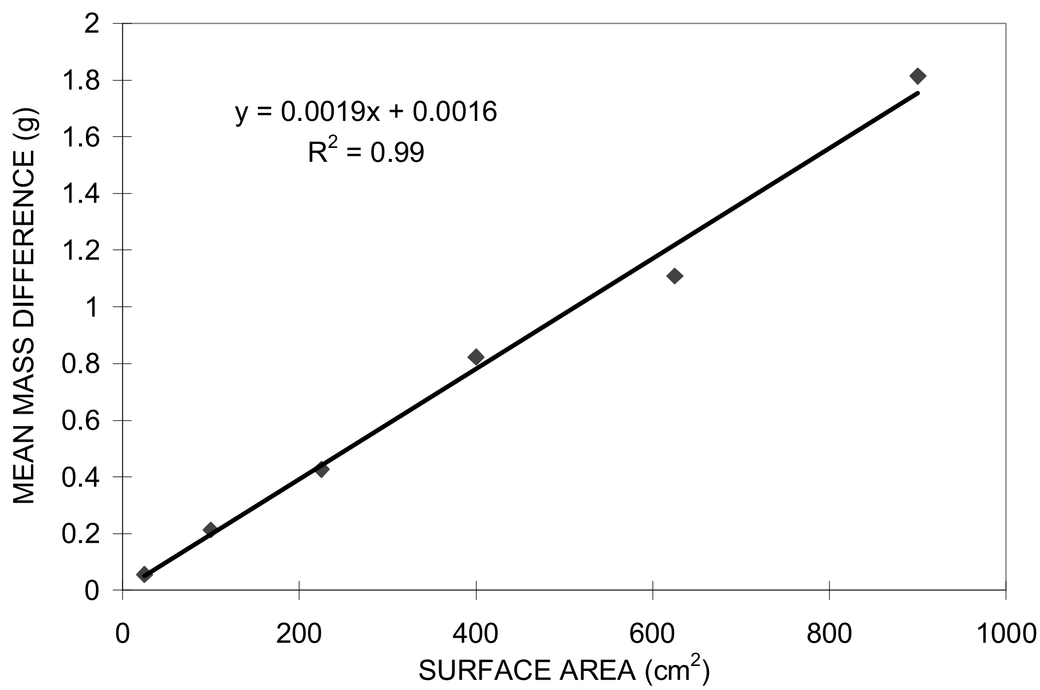

Figure 3. Regression of mass differences for known surface areas used for calculating the surface area of roots. Each point represents 5 samples.

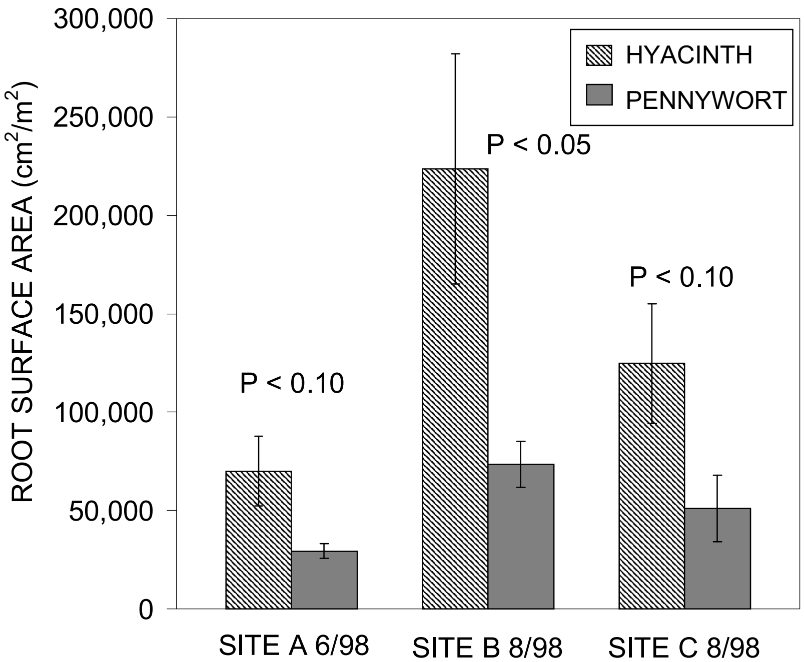

Figure 4. Surface area of roots (cm^2/m^2 of canopy). P-values show results from two sample t-tests, error bars are ± standard error, n = 5 for each bar.

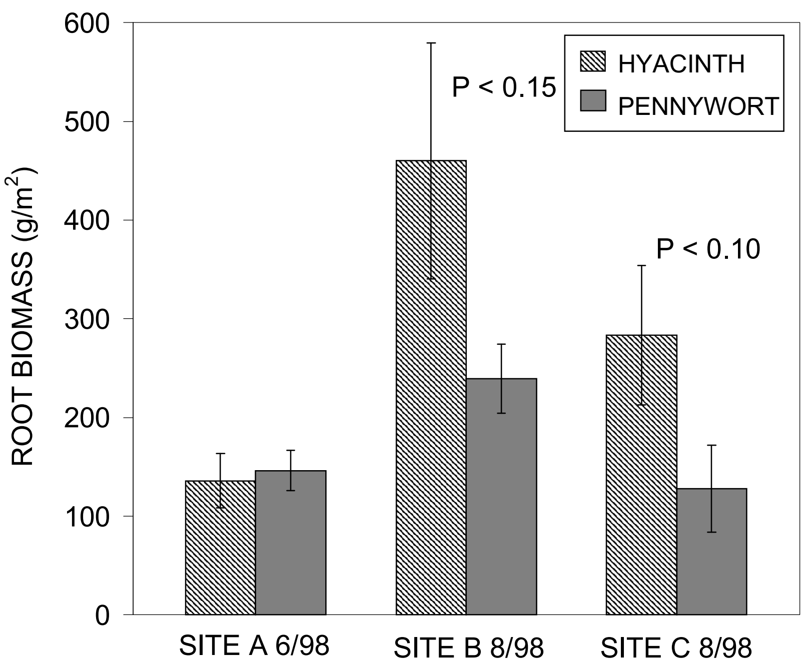

Figure 5. Biomass of roots (g wet/m^2 of canopy). P-values show results from two sample t-tests, error bars are ± standard error, n = 5 for each bar.

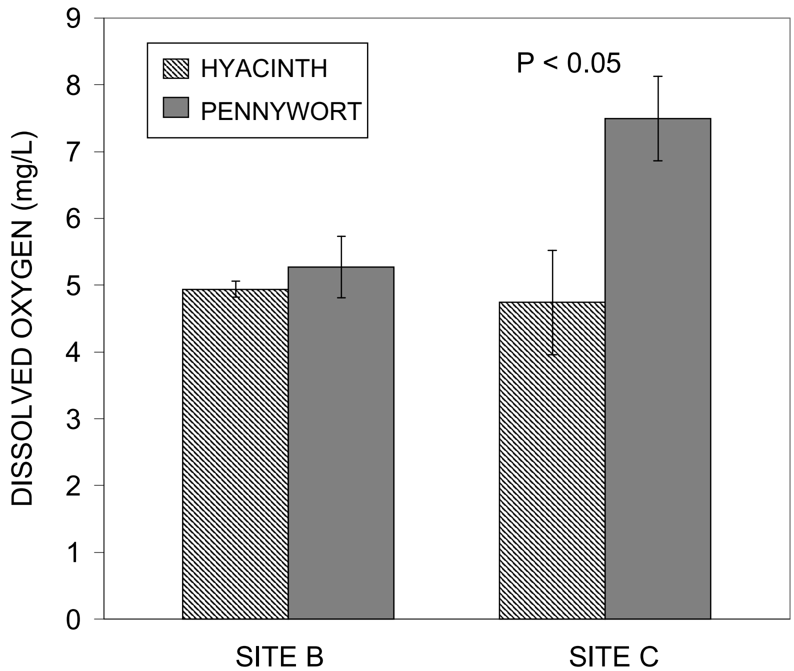

Figure 6. Dissolved oxygen levels (mg/L) from 8/98. P-values show results from two sample t-tests, error bars are ± standard error, n = 5 for each bar.

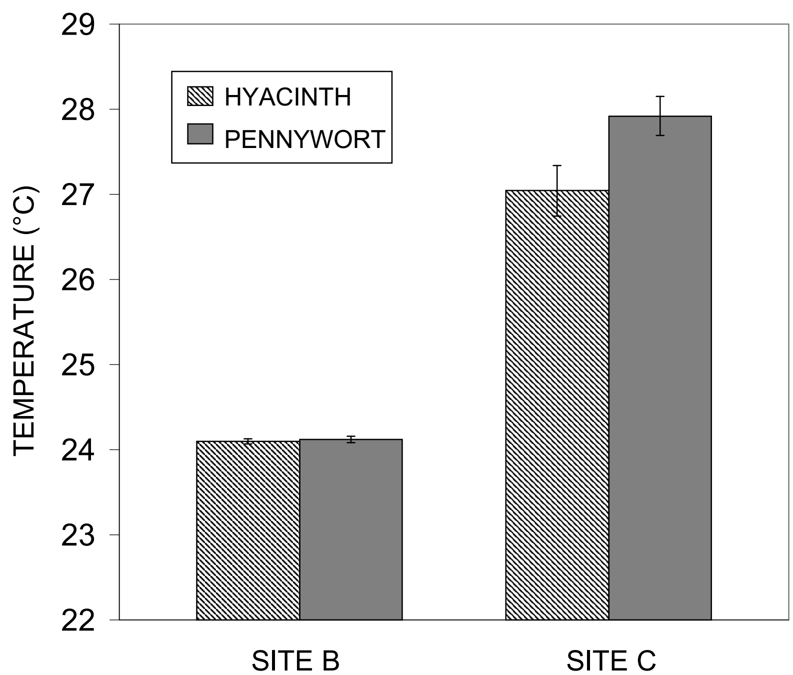

Figure 7. Water temperature in °C from 8/98. Error bars are ± standard error, n = 5 for each bar.

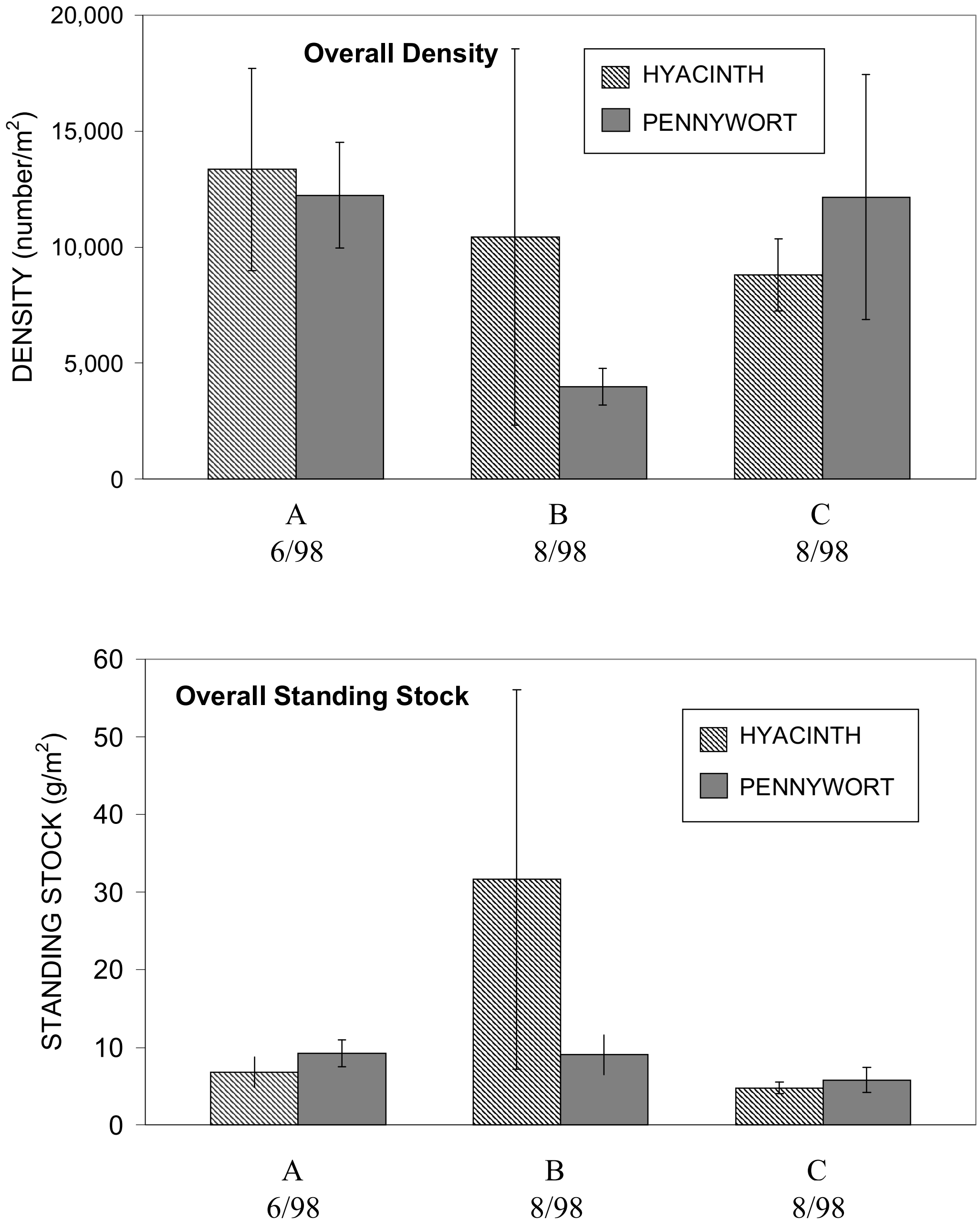

Figure 8. Overall density and standing stock of epiphytic macroinvertebrates per m^2 of canopy at Sites A, B, and C. Error bars are ± standard error, n = 5 for each bar.

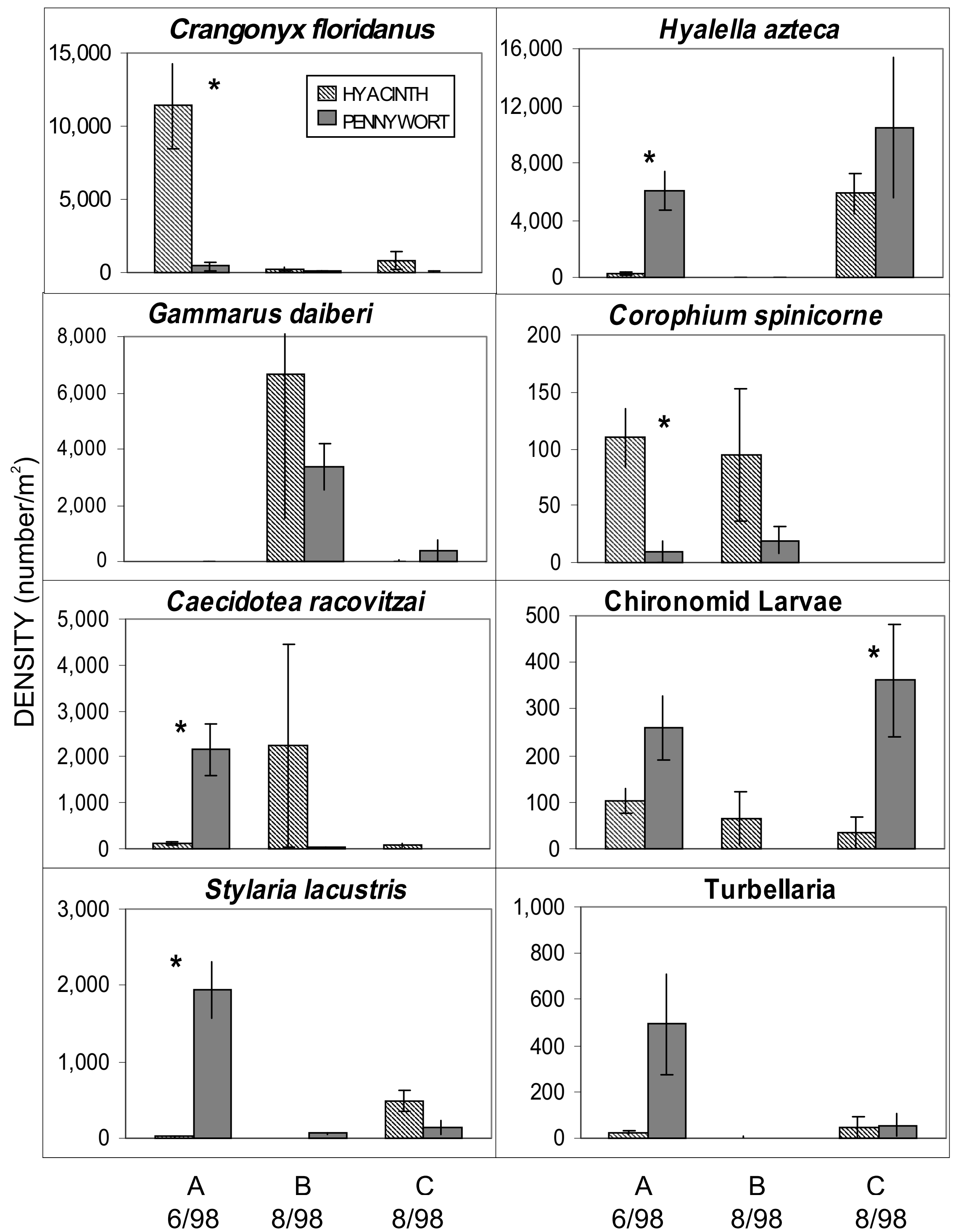

Figure 9. Density of common epiphytic macroinvertebrates per m^2 of canopy at Sites A, B, and C. * $P < 0.05$, error bars are ± standard error.

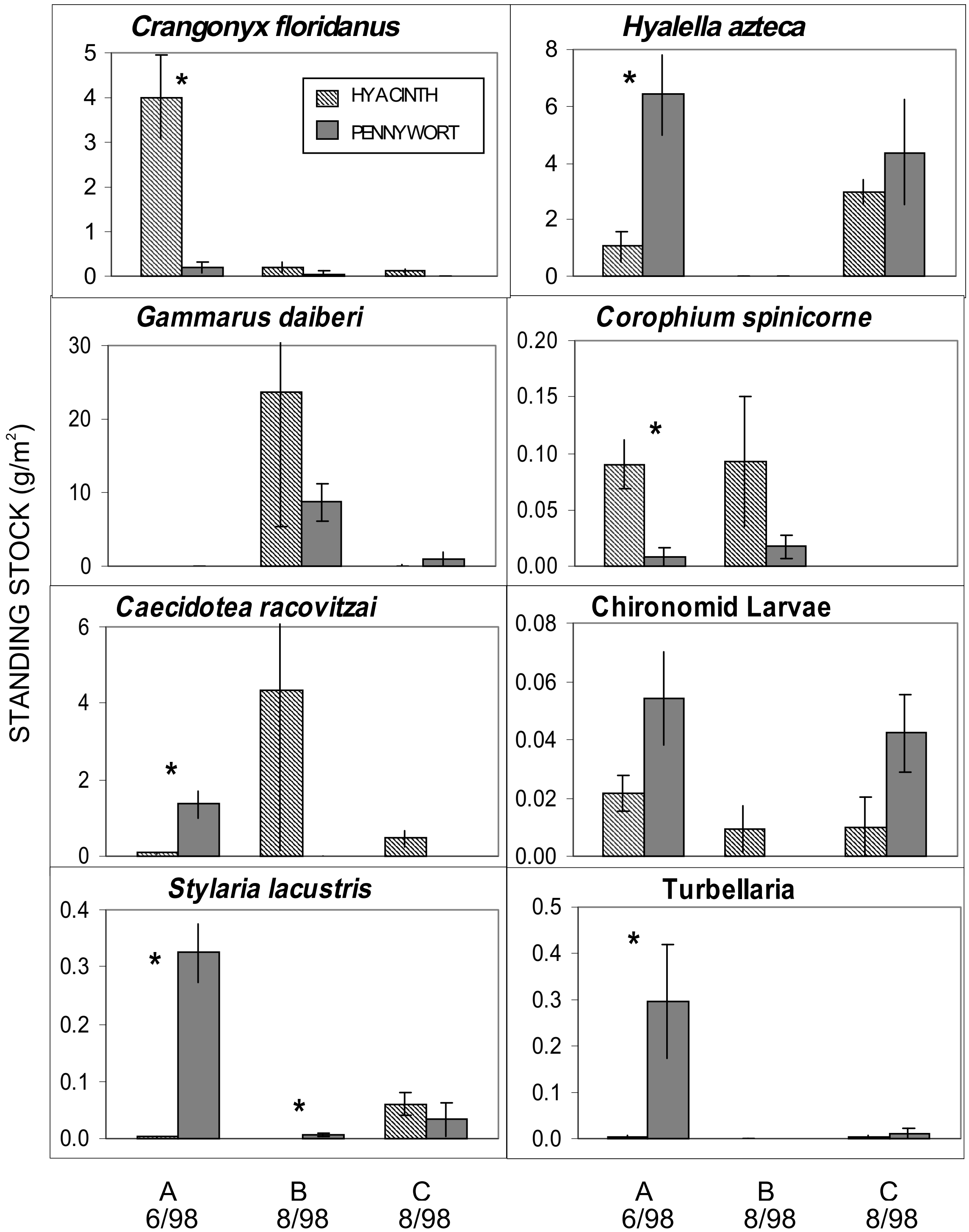

Figure 10. Standing stock of common epiphytic macroinvertebrates per m^2 of canopy at Sites A, B, and C. * $P < 0.05$, error bars are ± standard error.

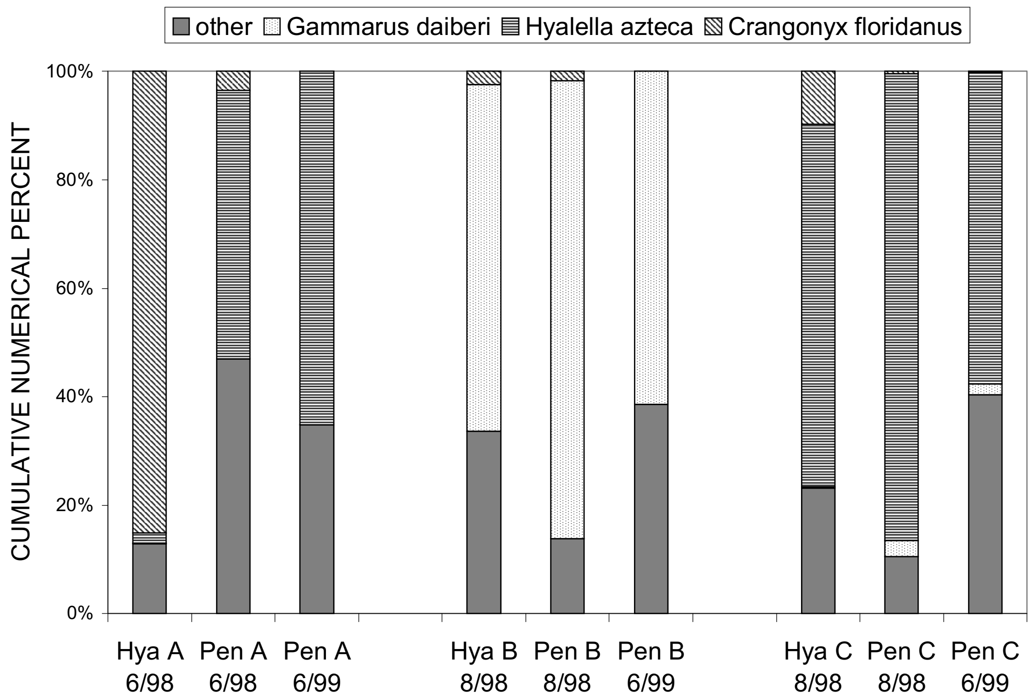

Figure 11. Cumulative numerical percent of dominant epiphytic macroinvertebrates in 1998 and 1999 at Sites A, B, and C. Hya = Hyacinth, Pen = Pennywort.

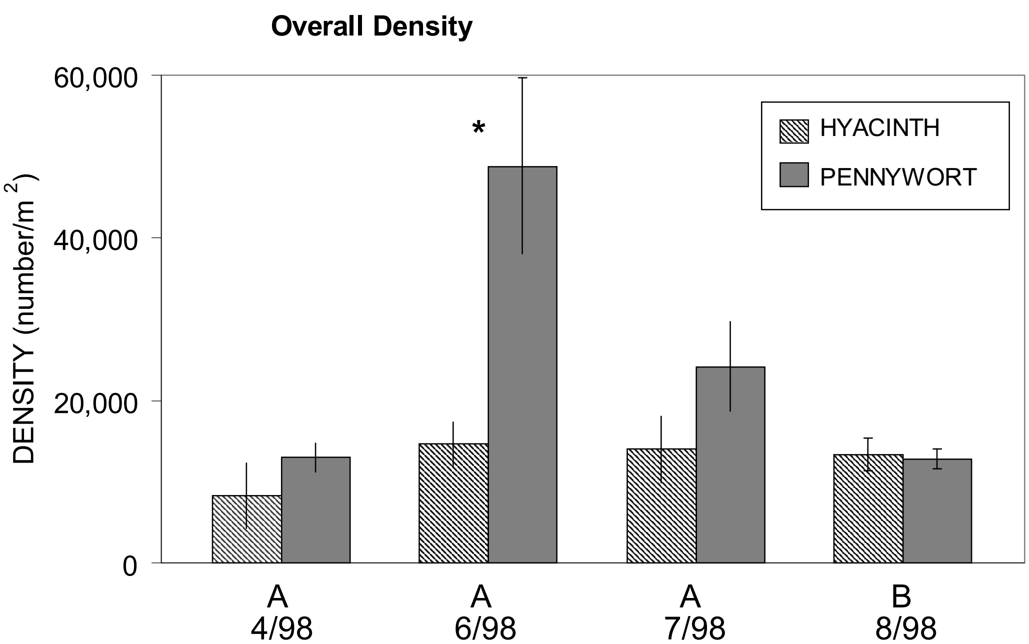

Figure 12. Overall density of epibenthic/benthic macroinvertebrates per m^2 of canopy at Sites A and B. * $P < 0.05$, error bars are ± standard error.

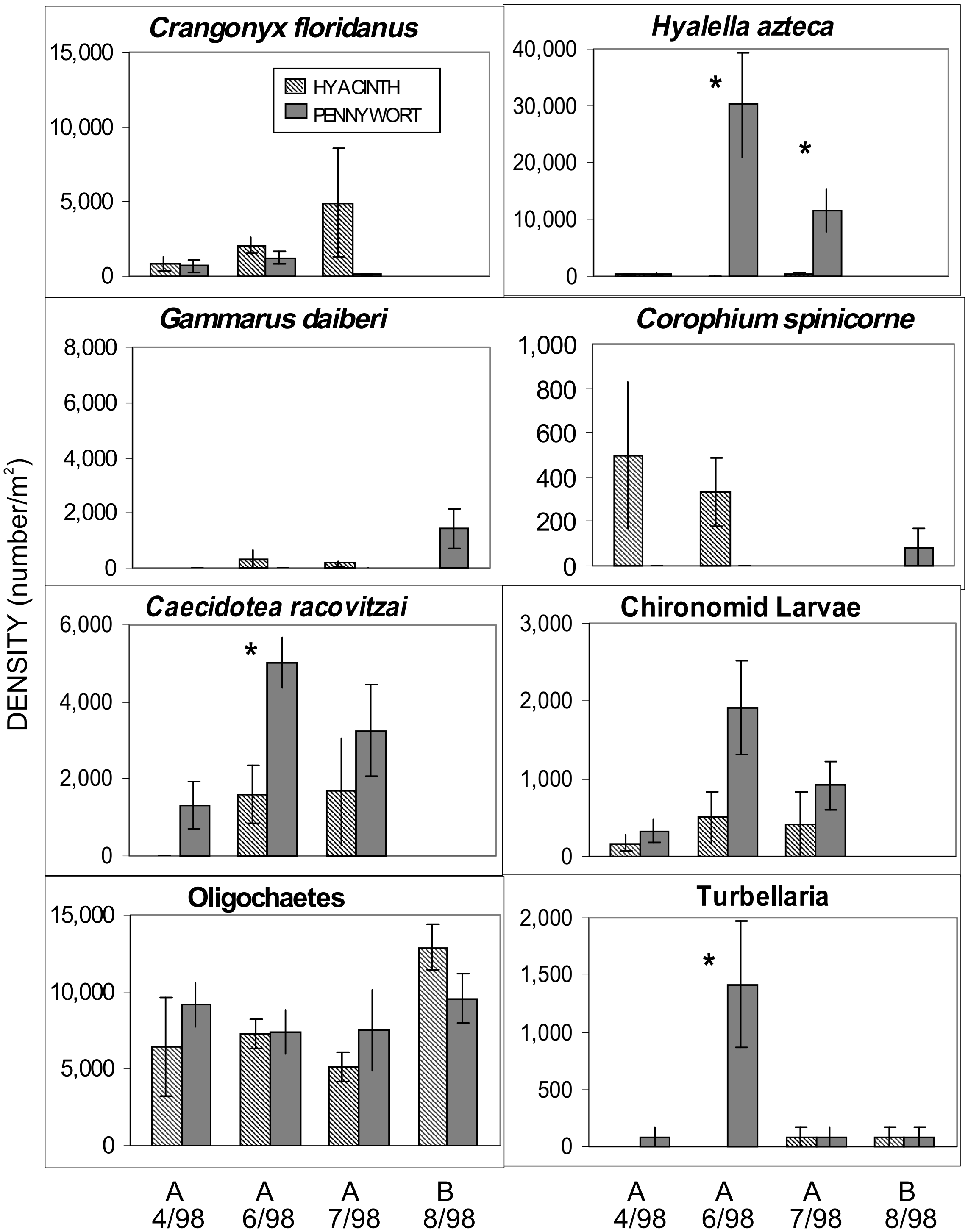

Figure 13. Density of common epibenthic/benthic macroinvertebrates per m^2 of canopy at Sites A and B. * $P < 0.05$, error bars are ± standard error.

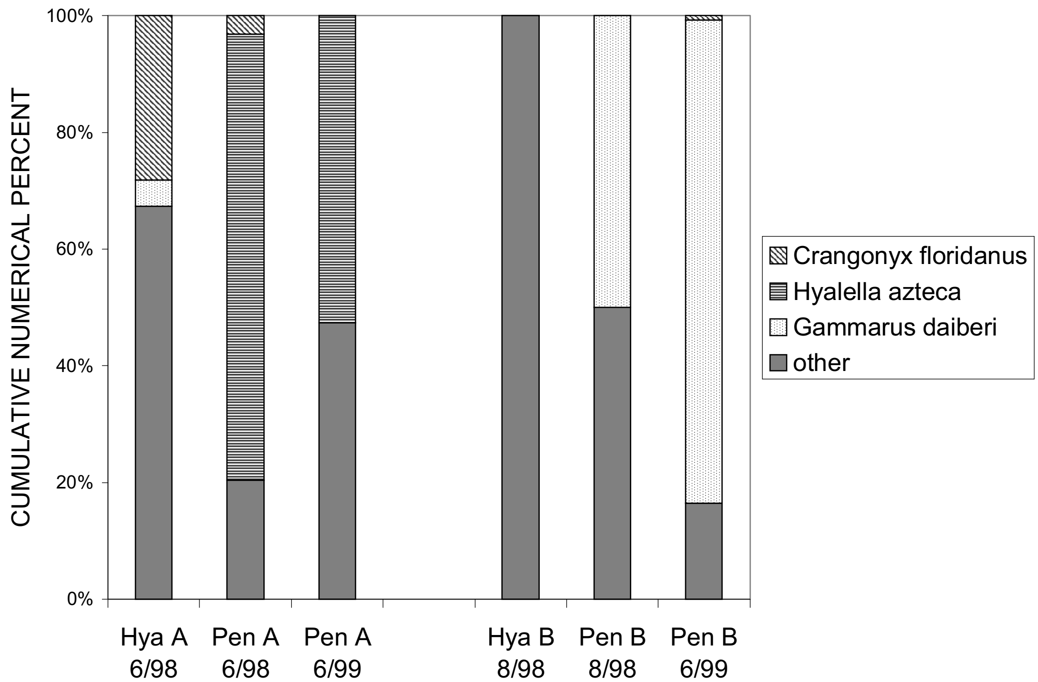

Figure 14. Cumulative numerical percent of dominant epibenthic/benthic macroinvertebrates 1998-99 at Sites A and B. Hya = Hyacinth, Pen = Pennywort.

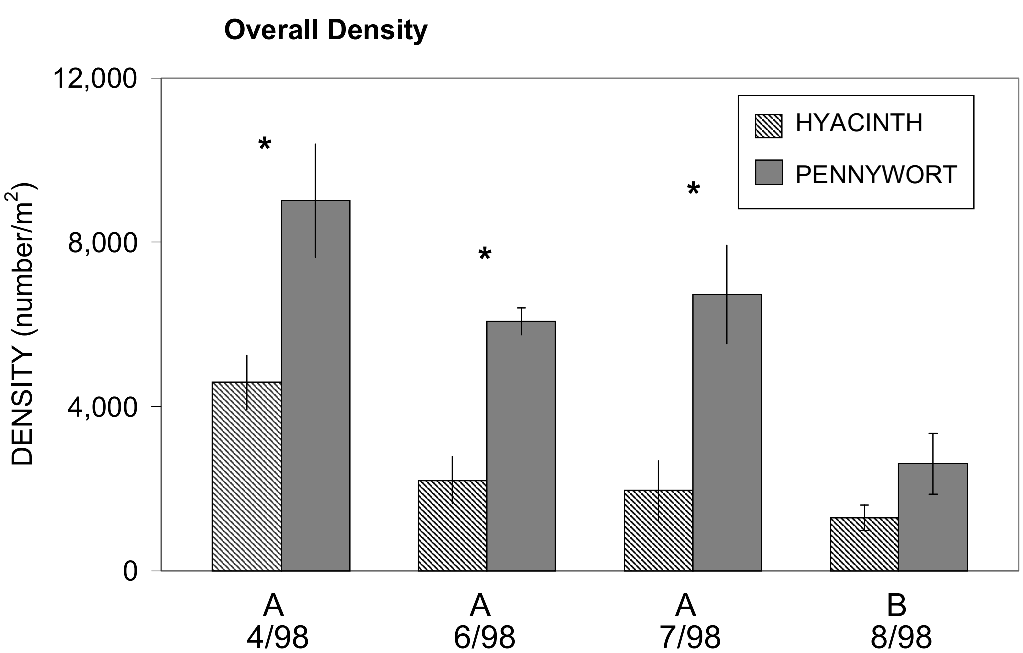

Figure 15. Overall density of insects per m^2 of canopy at Sites A and B. * $P < 0.05$, error bars are ± standard error.

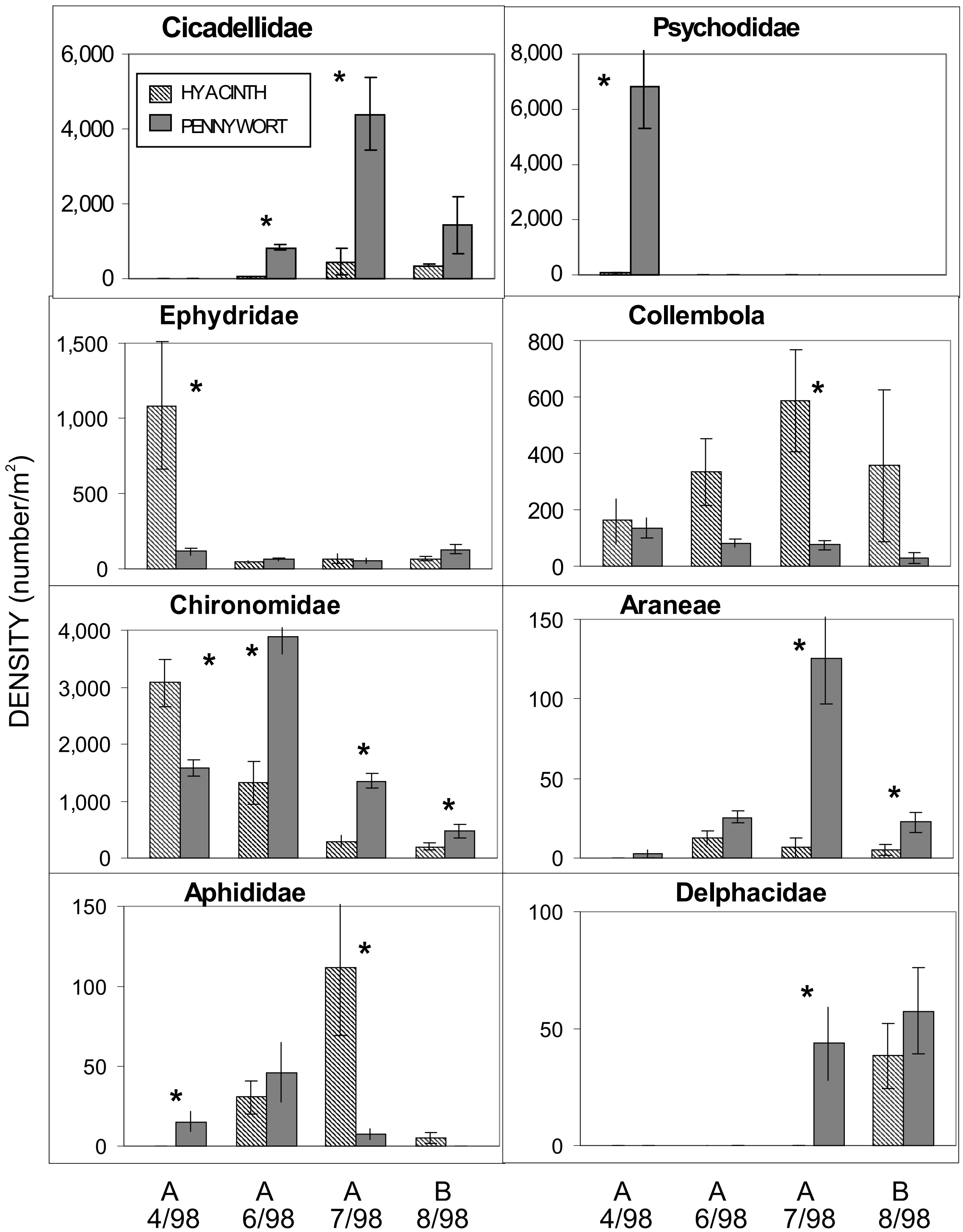

Figure 16. Density of common insects per m^2 of canopy at Sites A and B. * $P < 0.05$, error bars are ± standard error.

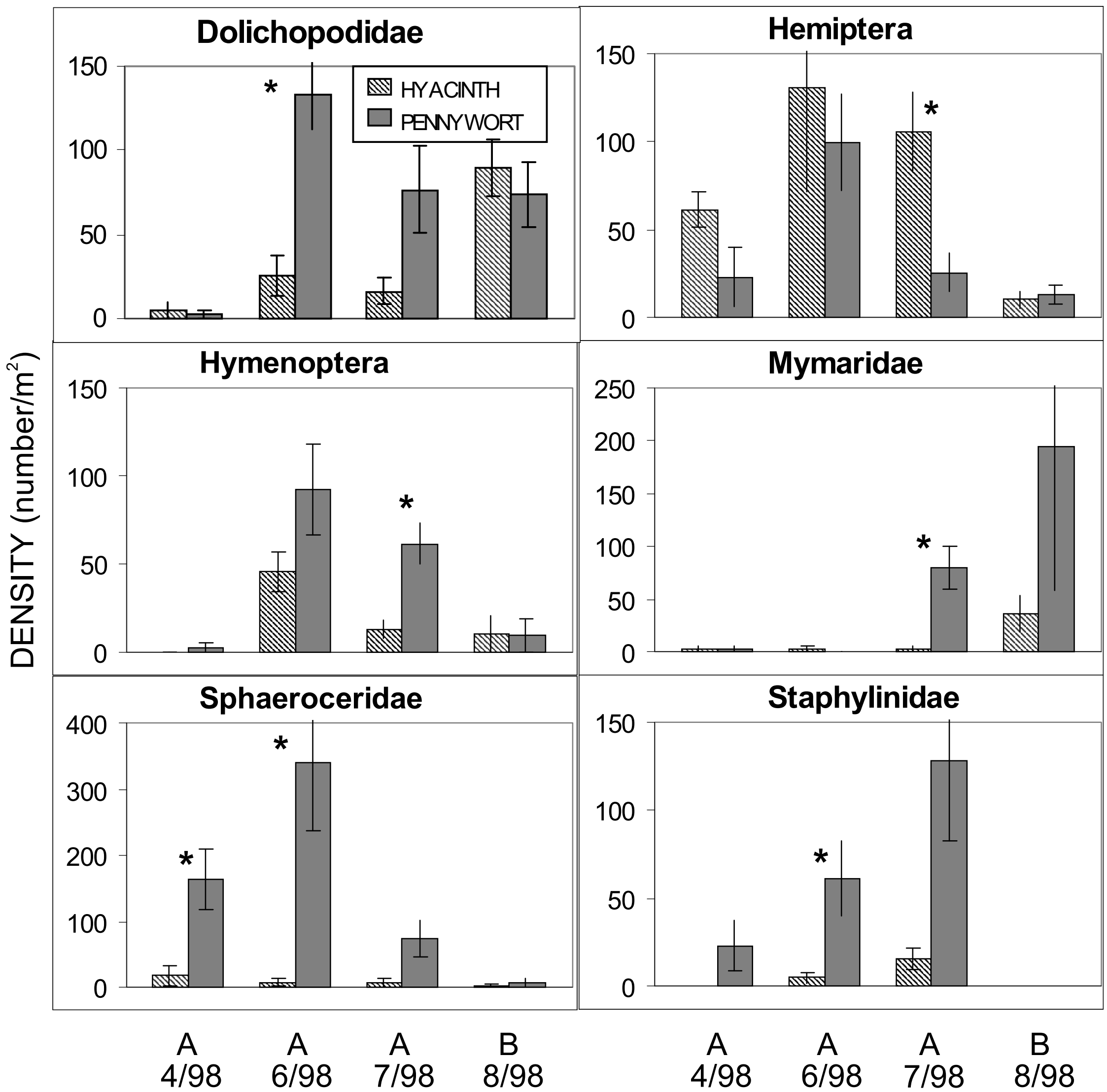

Figure 16 (continued). Density of common insects per m^2 of canopy at Sites A and B. * $P < 0.05$, error bars are ± standard error.

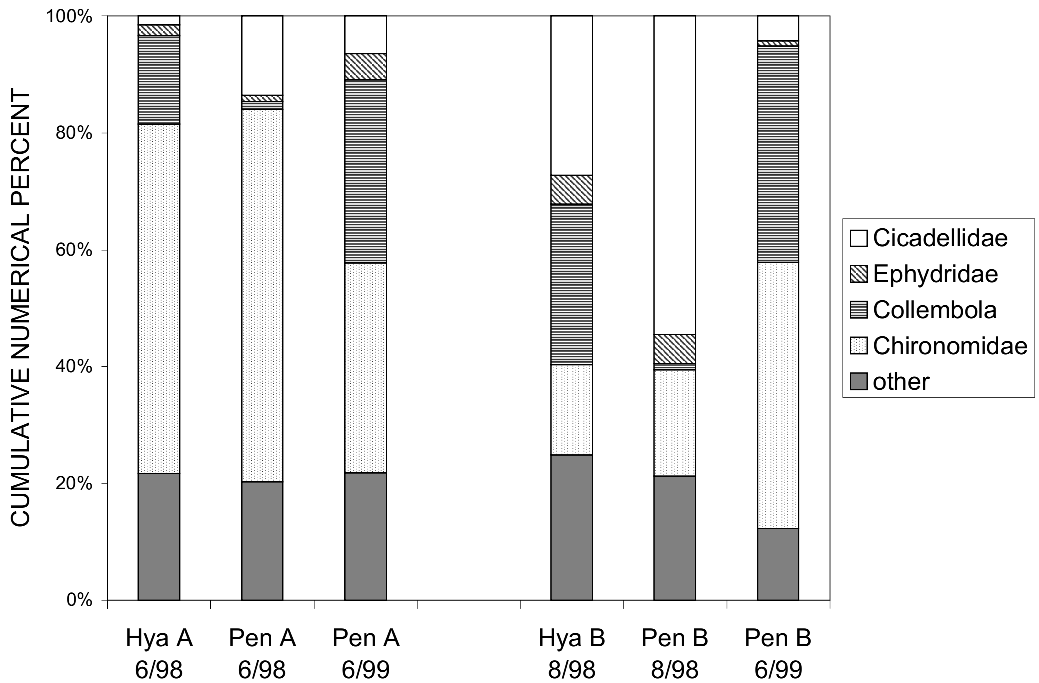

Figure 17. Cumulative numerical percent of dominant insects in 1998 and 1999 at Sites A and B.

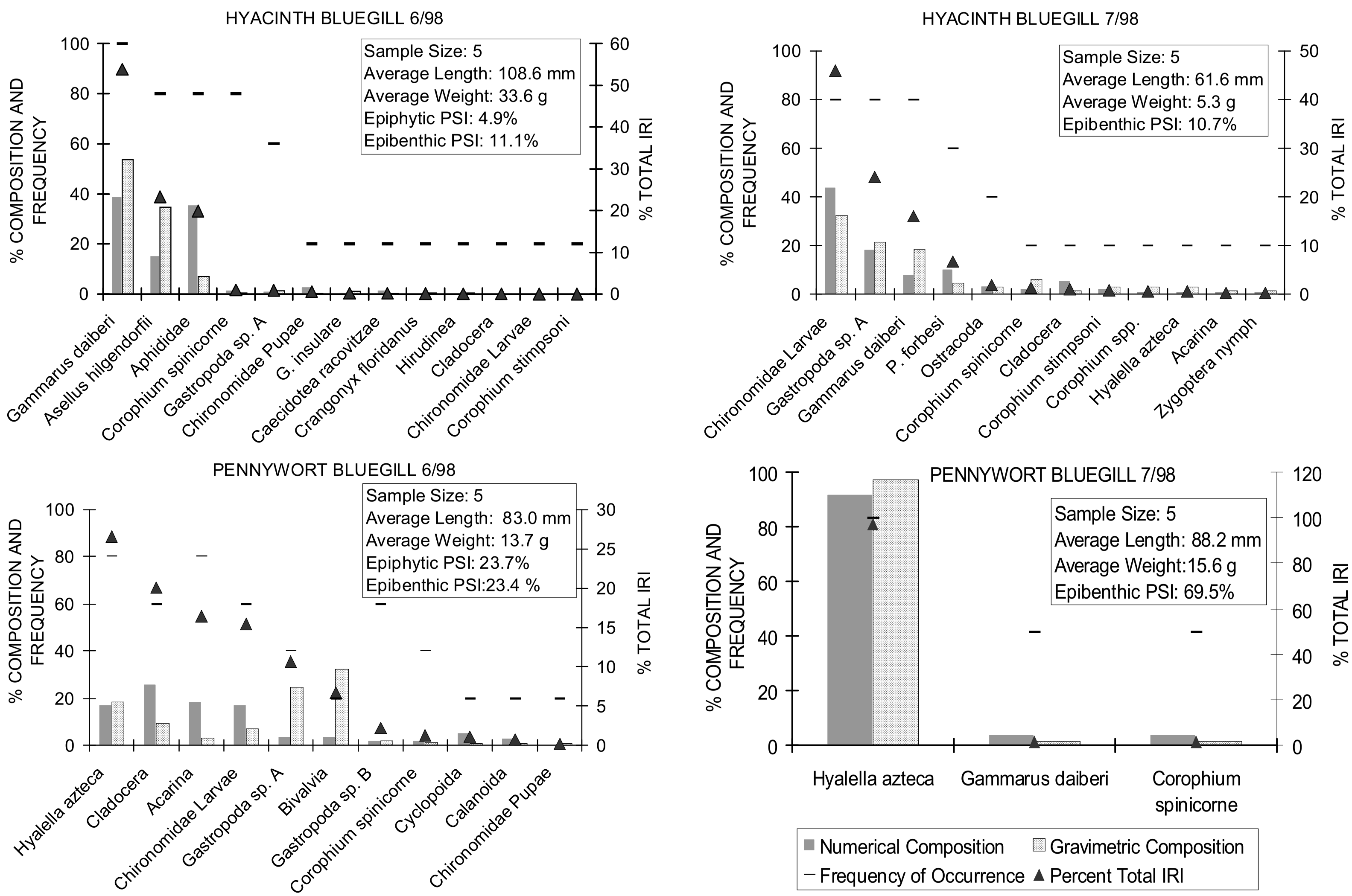

Figure 18. Fish diets for bluegills caught adjacent to hyacinth and pennywort at Site A in June and July 1998. Prey are ranked in declining values of percent total IRI.

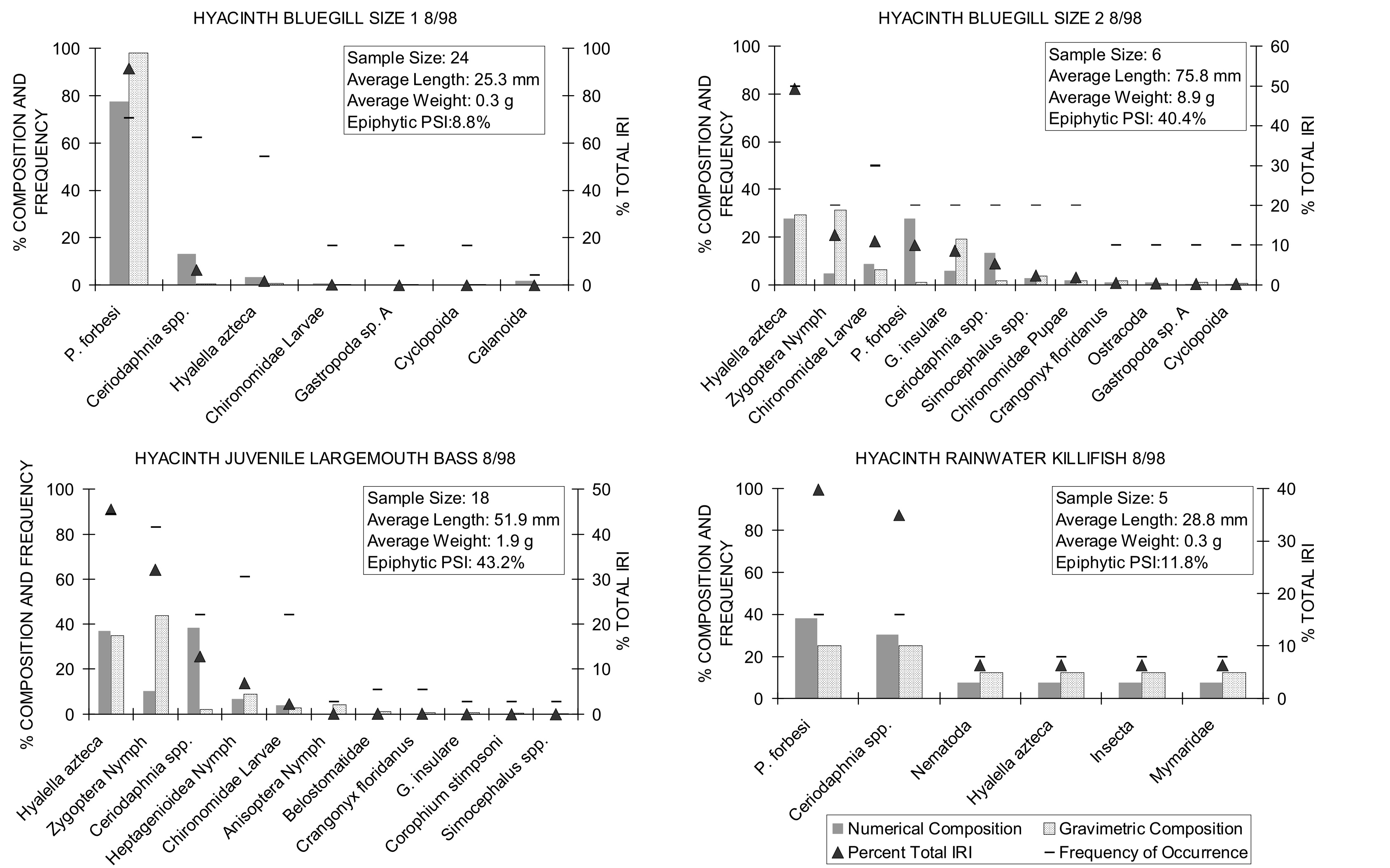

Figure 19. IRI graphs of diets of fish caught directly underneath hyacinth at Site C during August 1998. Prey are ranked in declining values of percent total IRI.

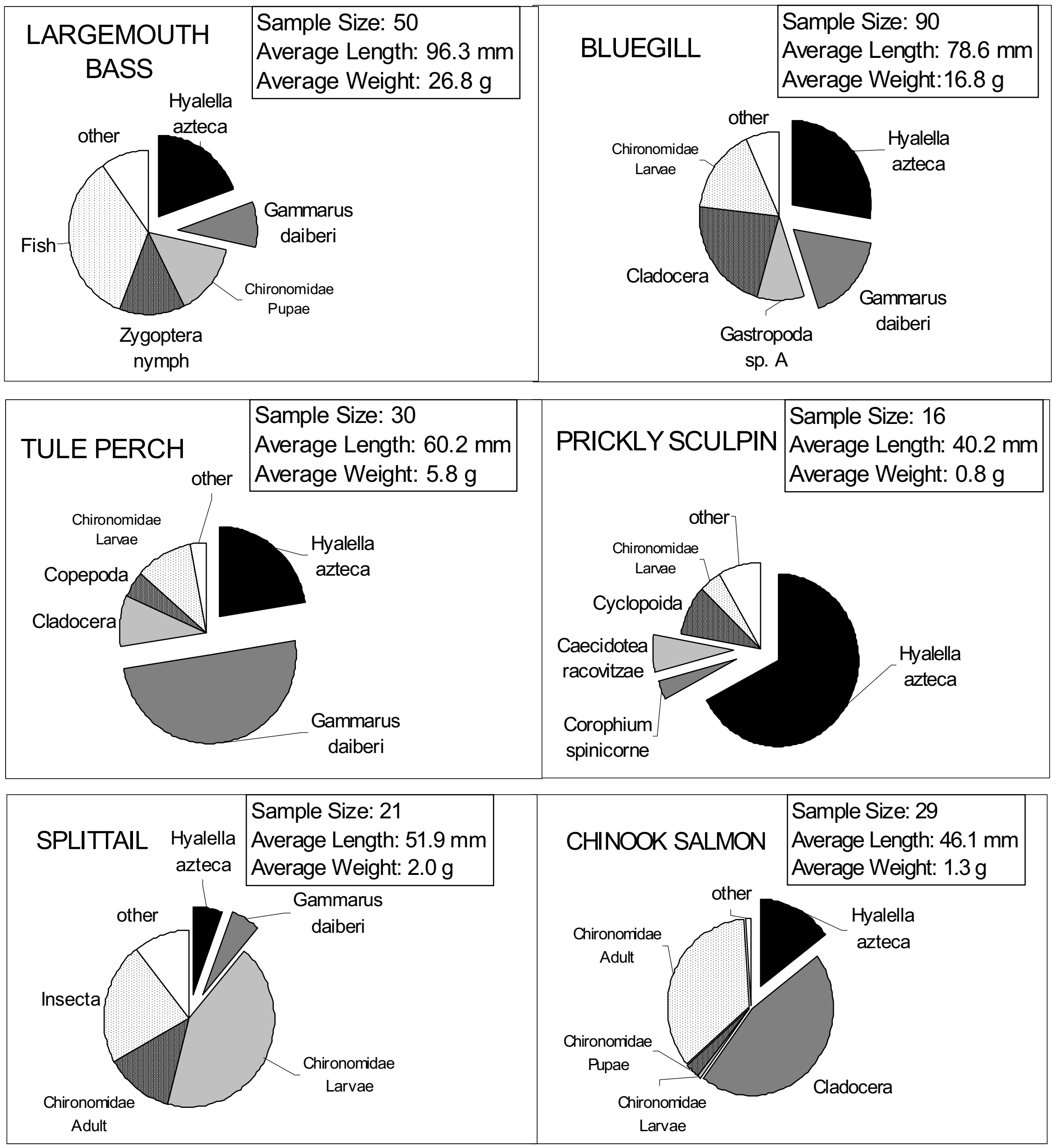

Figure 20. Top five prey items based on IRI values of common nearshore juvenile fish in the area surrounding the study sites. Separated pie slices represent amphipods and isopods.

Table 1. Average densities (number/m^2 of canopy) of all epiphytic macroinvertebrates at Sites A, B, and C (n=5). Significant differences from two sample t-tests are highlighted. H = Hyacinth, P = Pennywort.

	Site A			Site B			Site C		
	6/98		6/99	8/98		6/99	8/98		6/99
taxa	H	P	P	H	P	P	H	P	P
Hydrozoa	-	28.9	-	-	-	6.2	11.6	-	-
Turbellaria	22.2	494.1	-	2.4	-	-	49.2	55.2	-
Polychaeta	-	-	-	-	-	8.5	-	-	-
Oligochaeta	-	-	-	15.1	-	-	-	-	-
Oligochaete bud	2.3	65.8	-	-	-	-	-	-	-
Stylaria lacustris	**13.0**	**1938**	6.3	-	58.1	106.8	485.9	128.8	75.3
Hirudinea	-	-	-	2.4	-	-	-	-	-
Helobdella fusca	6.8	13.8	8.1	-	-	-	13.0	6.1	-
Gastropod sp. A	186.9	322.8	341.5	60.4	48.4	126.9	95.4	21.5	1260
Gastropod sp. B	824.1	135.7	16.3	66.5	-	30.9	-	3.1	58.9
Ancylidae (limpet)	14.7	25.4	-	-	-	11.2	-	6.1	-
Araneae	7.0	3.7	5.4	4.4	9.7	-	1.4	24.5	-
Acarina	4.6	9.1	-	-	-	-	1.4	-	-
Ostracoda	-	-	-	7.3	-	-	57.8	30.7	-
Cladocera-*Eurycercus lamellatus*	150.9	58.4	-	69.1	19.4	-	312.4	98.1	13.1
Copepoda	3.4	6.4	-	16.5	58.1	-	360.1	15.3	-
Cyclopoida	-	-	-	-	-	6.2	-	-	-
Isopoda-*Caecidotea racovitzai*	**115.2**	**2153**	20.9	2246	29.0	11.2	72.3	-	196.1
Gnorimosphaeroma insulare	106.6	32.1	85.3	797.5	222.6	1025	-	3.1	5.5
Munna spp.	-	-	-	-	19.4	-	-	-	-
Amphipoda-*Corophium spinicorne*	**109.8**	**9.1**	-	94.5	19.4	254.9	-	-	5.5
Crangonyx floridanus	**11371**	**422**	-	259.9	67.8	-	856.1	49.1	9.8
Gammarus daiberi	6.8	-	-	6676	3359	2576	23.1	368.0	82.5
Hyalella azteca	**252**	**6072**	1033	-	-	-	5889	10463	2417
Astacidae (crayfish)	-	-	-	3.7	-	-	-	-	-
Procambarus clarki	-	-	-	-	-	-	4.3	-	-
Insecta larvae-unknown	-	-	-	2.0	-	-	92.6	3.1	-
Collembola-Isotomidae	20.7	7.4	17.6	-	-	-	-	-	-
Sminthuridae	4.6	7.4	6.8	2.4	-	-	-	-	-
Anisoptera nymph	-	-	-	-	-	-	-	3.1	-
Zygoptera nymph	-	-	-	53.3	19.4	8.5	428.1	490.7	81.7
Thysanoptera	-	-	-	-	19.4	-	-	-	-
Hemiptera	1.6	-	-	-	-	-	-	-	-
Hydrometra	3.3	7.4	-	-	-	-	-	-	-
Homoptera-Aphididae	-	-	12.2	-	-	14.1	2.9	-	-
Cicadellidae larvae	-	-	6.3	-	19.4	-	1.4	24.5	-
Coleoptera larvae-unknown	0.4	12.9	-	1.9	9.7	-	-	-	-
Dytiscidae	-	-	-	1.9	-	-	-	-	-
Staphylinidae	-	-	-	-	-	-	-	3.1	-
Diptera adult-unknown	-	-	5.9	-	-	-	-	-	-
Chironomid larvae	102.2	259.6	12.7	65.0	-	11.2	**34.7**	**361.9**	6.6
Chironomid pupae	2.7	-	-	-	-	-	11.6	-	-
Chironomid adult	1.0	22.0	8.1	3.9	-	-	-	-	-
Sciaridae	1.0	-	-	-	-	-	-	-	-
Tipulidae larvae	16.2	-	-	-	-	-	-	-	-
Tipulidae pupae	0.4	-	-	-	-	-	-	-	-
Hymenoptera	2.3	-	-	-	-	-	-	-	-
Fish eggs	-	129.3	-	-	-	-	-	-	-
Overall	13354	12237	1587	10452	3978	4198	8804	12159	4212

Table 2. Average standing stock (g/m^2 of canopy) of all epiphytic macroinvertebrates at Sites A, B, and C (n=5). Significant differences from two sample t-tests are highlighted. H = Hyacinth, P = Pennywort.

	Site A			Site B			Site C		
	6/98		6/99	8/98		6/99	8/98		6/99
taxa	**H**	**P**	**P**	**H**	**P**	**P**	**H**	**P**	**P**
Hydrozoa	-	0.0054	-	-	-	0.0012	0.0020	-	-
Turbellaria	**0.0046**	**0.2959**	-	0.0005	-	-	0.0045	0.0119	-
Polychaeta	-	-	-	-	-	0.0017	-	-	-
Oligochaeta	-	-	-	0.0023	-	-	-	-	-
Oligochaete bud	0.0005	0.0045	-	-	-	-	-	-	-
Stylaria lacustris	**0.0017**	**0.3248**	0.0013	**-**	**0.0068**	0.0096	0.0601	0.0339	0.0111
Hirudinea	-	-	-	0.0034	-	-	-	-	-
Helobdella fusca	0.0745	0.1449	0.0675	-	-	-	0.1755	0.0976	-
Gastropod sp. A	0.0935	0.1906	1.5672	0.0178	0.0072	1.0813	0.0191	0.0099	0.5900
Gastropod sp. B	0.3108	0.0358	0.0049	0.0180	-	0.0051	-	0.0014	0.0262
Ancylidae (limpet)	0.0040	0.0038	-	-	-	0.0034	-	0.0022	-
Araneae	0.0188	0.0089	0.0076	0.0134	0.0375	-	0.0030	0.0640	-
Acarina	0.0008	0.0018	-	-	-	-	0.0004	-	-
Ostracoda	-	-	-	0.0005	-	-	0.0107	0.0033	-
Cladocera-*Eurycercus lamellatus*	0.0184	0.0080	-	0.0087	0.0013	-	0.0338	0.0071	0.0026
Copepoda	0.0002	0.0006	-	0.0014	0.0066	-	0.0719	0.0025	-
Cyclopoida	-	-	-	-	-	0.0006	-	-	-
Isopoda-*Caecidotea racovitzai*	**0.2695**	**1.3657**	0.0181	4.3298	0.0069	0.0045	0.4544	-	0.1150
Gnorimosphaeroma insulare	0.7523	0.0823	0.0717	3.2376	0.1143	1.5196	-	0.0052	0.0017
Munna spp.	-	-	-	-	0.0087	-	-	-	-
Amphipoda-*Corophium spinicorne*	**0.0902**	**0.0082**	-	0.0932	0.0169	0.2328	-	-	0.0039
Crangonyx floridanus	**4.0133**	**0.1961**	-	0.2060	0.0513	-	0.1016	0.0066	0.0029
Gammarus daiberi	0.0341	-	-	23.5620	8.7466	7.3128	0.0895	1.0108	0.3146
Hyalella azteca	**1.0446**	**6.4105**	1.6821	-	-	-	2.9652	4.3685	3.7087
Astacidae (crayfish)	-	-	-	0.0730	-	-	-	-	-
Procambarus clarki	-	-	-	-	-	-	0.6917	-	-
Insecta larvae-unknown	-	-	-	0.0016	-	-	0.0137	0.0024	-
Collembola-Isotomidae	0.0031	0.0011	0.0036	-	-	-	-	-	-
Sminthuridae	0.0010	0.0019	0.0034	0.0007	-	-	-	-	-
Anisoptera nymph	-	-	-	-	-	-	-	0.0012	-
Zygoptera nymph	-	-	-	0.0236	0.0119	0.0051	0.0581	0.1084	0.0294
Thysanoptera	-	-	-	-	0.0059	-	-	-	-
Hemiptera	0.0022	-	-	-	-	-	-	-	-
Hydrometra	0.0007	0.0015	-	-	-	-	-	-	-
Homoptera-Aphididae	-	-	0.0043	-	-	0.0042	0.0007	-	-
Cicadellidae larvae	-	-	0.0038	-	0.0099	-	0.0008	0.0052	-
Coleoptera larvae-unknown	0.0019	0.0660	-	0.0080	0.0378	-	-	-	-
Dytiscidae	-	-	-	0.0026	-	-	-	-	-
Staphylinidae	-	-	-	-	-	-	-	0.0028	-
Diptera adult-unknown	-	-	0.0071	-	-	-	-	-	-
Chironomid larvae	0.0215	0.0541	0.0025	0.0093	-	0.0034	0.0101	0.0422	0.0013
Chironomid pupae	0.0010	-	-	-	-	-	0.0078	-	-
Chironomid adult	0.0005	0.0092	0.0065	0.0023	-	-	-	-	-
Sciaridae	0.0003	-	-	-	-	-	-	-	-
Tipulidae larvae	0.0162	-	-	-	-	-	-	-	-
Tipulidae pupae	0.0014	-	-	-	-	-	-	-	-
Hymenoptera	0.0006	-	-	-	-	-	-	-	-
Fish eggs	-	0.0142	-	-	-	-	-	-	-
Overall	6.7823	9.2358	3.4516	31.6156	9.0696	10.1851	4.7746	5.7873	4.8074

Table 3. Measurements of taxa richness and the Shannon-Weiner diversity index for epiphytic macroinvertebrates, terrestrial insects, and epibenthic/benthic macroinvertebrates at Sites A, B, and C. Hyacinth samples are shaded.

EPIPHYTIC MACROINVERTEBRATES	TAXA RICHNESS	SHANNON-WEINER DIVERSITY INDEX
HYACINTH A 6/98	26	1.04
PENNYWORT A 6/98	28	2.34
HYACINTH B 8/98	20	1.65
PENNYWORT B 8/98	16	1.18
HYACINTH C 8/98	21	2.00
PENNYWORT C 8/98	20	1.02
INSECTS		
HYACINTH A 4/98	14	1.45
PENNYWORT A 4/98	21	1.24
HYACINTH A 6/98	24	2.29
PENNYWORT A 6/98	25	2.12
HYACINTH A 7/98	21	3.07
PENNYWORT A 7/98	25	1.85
HYACINTH B 8/98	21	2.97
PENNYWORT B 8/98	20	2.32
EPIBENTHIC/BENTHIC MACROINVERTEBRATES		
HYACINTH A 4/98	7	1.26
PENNYWORT A 4/98	12	1.72
HYACINTH A 6/98	16	2.61
PENNYWORT A 6/98	13	1.92
HYACINTH A 7/98	15	2.39
PENNYWORT A 7/98	12	1.89
HYACINTH B 8/98	5	0.26
PENNYWORT B 8/98	12	1.47

Table 4. Average densities (number/m^2 of canopy) of all epibenthic/benthic macroinvertebrates at Sites A and B (n=5). Significant differences from two sample t-tests are highlighted. Significant differences at Site B represent a combination of all amphipods and isopods. H = Hyacinth, P = Pennywort.

	Site A							**Site B**		
	4/98		**6/98**		**7/98**		**6/99**	**8/98**		**6/99**
taxa	**H**	**P**	**H**	**P**	**H**	**P**	**P**	**H**	**P**	**P**
Hydrozoa	-	-	-	83.3	-	-	-	-	-	416.7
Turbellaria	-	83.3	**-**	**1417**	83.3	83.3	-	83.3	83.3	83.3
Nematoda	-	166.7	83.3	-	166.7	-	-	83.3	333.3	166.7
Polychaeta-*Neanthes* spp.	-	-	-	-	-	-	-	83.3	-	-
Manayunkia speciosa	-	83.3	-	-	-	-	-	-	-	-
Fabriciola berkeleyi	-	-	-	-	-	-	-	-	83.3	-
Oligochaeta	6417	9167	7250	5917	5083	7500	8833	12917	9583	1917
Stylaria lacustris	-	-	-	1417	-	-	-	-	-	-
Hirudinea	-	-	-	-	-	-	83.3	-	-	-
Dina microstoma	-	250.0	83.3	-	-	83.3	-	-	83.3	83.3
Gastropod sp. A	-	333.3	166.7	416.7	83.3	-	250.0	-	-	166.7
Gastropod sp. B	-	-	250.0	-	-	-	-	-	-	-
Ancylidae (limpet)	83.3	-	-	-	-	-	-	-	-	-
Juvenile Bivalve	-	83.3	-	-	-	-	166.7	-	-	666.7
Corbicula fluminea	-	-	-	-	-	-	-	-	83.3	-
Acarina	-	-	-	-	-	83.3	-	-	-	-
Ostracoda	-	-	416.7	583.3	83.3	166.7	-	166.7	666.7	-
Cladocera	-	-	583.3	416.7	-	-	83.3	-	-	-
Calanoid Copepod	-	-	83.3	-	-	-	-	-	-	-
Pseudodiaptomus forbesi	-	-	-	-	-	-	83.3	-	83.3	-
Cyclopoid Copepod	-	-	750.0	-	83.3	-	-	-	83.3	-
Isopoda-*Caecidotea racovitzai*	-	1333	**1583**	**5000**	1667	3250	83.3	-	-	416.7
Gnorimosphaeroma insulare	83.3	83.3	83.3	-	-	83.3	83.3	**-**	**250.0**	250.0
Amphipoda-*Corophium spinicorne*	500.0	-	333.3	-	-	-	-	**-**	**83.3**	500.0
Crangonyx floridanus	833.3	666.7	2083	1250	4917	83.3	-	-	-	83.3
Gammarus daiberi	-	-	333.3	-	166.7	-	-	**-**	**1417**	10500
Hyalella azteca	166.7	416.7	**-**	**30167**	**333.3**	**11583**	833.3	-	-	-
Insect larvae-unknown	-	-	-	83.3	-	-	-	-	-	-
Collembola-Isotomidae	-	-	-	-	166.7	-	-	-	-	83.3
Onychiuridae	-	-	-	-	83.3	-	-	-	-	-
Hemiptera	-	-	-	83.3	-	-	-	-	-	-
Homoptera	-	-	-	-	83.3	-	-	-	-	-
Aphididae	-	-	-	-	500.0	-	-	-	-	-
Cicadellidae larvae	-	-	-	-	-	166.7	-	-	-	-
Diptera-Chironomid larvae	166.7	333.3	500.0	1917	416.7	916.7	-	-	-	83.3
Chironomid pupae	83.3	-	-	-	-	-	-	-	-	-
Chironomid adult	-	-	83.3	-	83.3	-	83.3	-	-	-
Hymenoptera	-	-	-	-	-	166.7	-	-	-	-
Mymaridae	-	-	-	83.3	-	-	-	-	-	-
Overall	8333	13000	**14667**	**48833**	14000	24167	10583	13333	12833	15417

Table 5. Average densities (number/m^2 of canopy) of all terrestrial insects at Sites A and B (sample size in parentheses at head of each column). Significant differences from two sample t-tests are highlighted. H = Hyacinth, P = Pennywort.

	Site A							**Site B**		
	4/98		**6/98**		**7/98**		**6/99**	**8/98**		**6/99**
	H	**P**	**H**	**P**	**H**	**P**	**P**	**H**	**P**	**P**
taxa	(5)	(5)	(5)	(5)	(4)	(5)	(5)	(5)	(4)	(5)
Araneae	-	2.6	12.8	25.6	**6.4**	**125.3**	15.3	**5.1**	**22.4**	12.8
Acarina	71.6	58.8	2.6	5.1	6.4	-	-	-	-	17.9
Aphididae	**-**	**15.3**	30.7	46.0	**111.9**	**7.7**	43.5	5.1	-	7.7
Collembola	161.1	135.5	332.5	79.3	**585.0**	**74.2**	337.6	355.5	28.8	555.0
Zygoptera	-	-	10.2	15.3	54.3	84.4	-	12.8	16.0	2.6
Terebrantia	5.1	2.6	5.1	7.7	-	5.1	12.8	-	3.2	2.6
Hemiptera	61.4	23.0	130.4	99.7	**105.5**	**25.6**	10.2	10.2	12.8	2.6
Hydrometra	-	-	-	5.1	-	2.6	-	-	-	-
Homoptera	-	-	-	-	-	2.6	5.1	5.1	-	2.6
Cicadellidae	-	-	**33.2**	**826.1**	**434.8**	**4396**	69.1	352.9	1423	63.9
Delphacidae	-	-	-	-	**-**	**43.5**	2.6	38.4	57.5	5.1
Coleoptera	2.6	10.2	2.6	10.2	12.8	33.2	5.1	2.6	-	2.6
Staphylinidae	-	23.0	**5.1**	**61.4**	16.0	127.9	2.6	-	-	-
Trichoptera	-	2.6	2.6	12.8	25.6	10.2	10.2	2.6	3.2	-
Diptera-unknown	23.0	5.1	**23.0**	**143.2**	**121.5**	**46.0**	15.3	51.2	95.9	7.7
Cecidomyiidae	-	-	20.5	2.6	-	5.1	-	-	-	-
Ceratopogonidae	12.8	28.1	12.8	15.3	-	17.9	-	25.6	28.8	17.9
Chironomidae	**3074**	**1568**	**1322**	**3875**	**294**	**1353**	386.2	**199.5**	**473.1**	685.4
Dolichopodidae	5.1	2.6	**25.6**	**133.0**	16.0	76.7	15.3	89.5	73.5	23.0
Ephydridae	**1084.4**	**112.5**	40.9	66.5	63.9	56.3	48.6	63.9	127.9	12.8
Phoridae	-	5.1	2.6	15.3	6.4	12.8	-	-	16.0	-
Psychodidae	**56.3**	**6798**	28.1	17.9	6.4	-	7.7	2.6	3.2	-
Sciaridae	-	28.1	35.8	143.2	19.2	12.8	-	-	3.2	2.6
Sphaeroceridae	**17.9**	**163.7**	**7.7**	**340.2**	6.4	74.2	23.0	2.6	6.4	12.8
Syrphidae	-	-	-	5.1	-	-	2.6	5.1	-	-
Tipulidae	12.8	20.5	71.6	38.4	51.2	2.6	2.6	-	-	10.2
Hymenoptera	-	2.6	46.0	92.1	**12.8**	**61.4**	12.8	10.2	9.6	40.9
Chalcidoidea	-	-	-	-	-	-	-	17.9	9.6	-
Mymaridae	2.6	2.6	2.6	-	**3.2**	**79.3**	48.6	35.8	195.0	12.8
Overall	**4591**	**9010**	**2207**	**6082**	**1960**	**6737**	1077	1294	2609	1501

Table 6. Species, number, and lengths of all fish caught adjacent to patches of hyacinth and pennywort at Site A during June and July 1998. Native species are in bold, sample size is at the head of each column. Hya = Hyacinth, Pen = Pennywort.

June		n=6	n=4	n=10		
Common Name	**Scientific Name**	**Hya**	**Pen**	**sum**	**Mean Forklength (mm)**	**Forklength Range**
Bigscale Logperch	*Percina macrolepida*	1	0	1	93	93
Black Crappie	*Pomoxis negromaculatus*	3	0	3	188	162-212
Bluegill	*Lepomis macrochirus*	24	39	63	100	43-171
Brown Bullhead	*Ictalarus nebulosus*	1	1	2	266	241-291
Golden Shiner	*Notemigonus crysoleucas*	3	34	37	51	26-114
Inland Silverside	*Menidia beryllina*	2	1	3	30	27-32
Largemouth Bass	*Micropterus salmoides*	5	6	11	110	25-290
Mitten Crab	*Eriocheir sinensis*	5	4	9	44	35-55
Prickly Sculpin	***Cottus asper***	**15**	**8**	**23**	**33**	**22-65**
Redear Sunfish	*Lepomis microlophus*	28	66	94	123	36-247
Splittail	***Pogonichthys macrolepidotus***	**4**	**1**	**5**	**52**	**41-59**
Spotted Bass	*Micropterus punctulatus*	2	1	3	100	98-102
Tule Perch	***Hysterocarpus traski***	**11**	**24**	**35**	**64**	**38-190**
Yellowfin Goby	*Acanthogobius flavimanus*	20	22	42	39	26-68
July		n=2	n=2	n=4		
Common Name	**Scientific Name**	**Hya**	**Pen**	**sum**	**Mean Forklength (mm)**	**Forklength Range**
Black Crappie	*Pomoxis negromaculatus*	1	1	2	35	34-35
Bluegill	*Lepomis macrochirus*	9	24	33	95	45-164
Common Carp	*Cyprinus carpio*	0	1	1	201	201
Golden Shiner	*Notemigonus crysoleucas*	1	20	21	39	30-86
Inland Silverside	*Menidia beryllina*	13	43	56	29	21-40
Largemouth Bass	*Micropterus salmoides*	9	452	461	43	21-502
Mitten Crab	*Eriocheir sinensis*	1	13	14	34	18780
Prickly Sculpin	***Cottus asper***	**0**	**6**	**6**	**47**	**35-62**
Redear Sunfish	*Lepomis microlophus*	2	31	33	96	49-192
Splittail	***Pogonichthys macrolepidotus***	**0**	**1**	**1**	**80**	**80**
Tule Perch	***Hysterocarpus traski***	**2**	**9**	**11**	**75**	**66-86**
Shad	*Dorosoma spp.*	4	0	4	-	-
Yellowfin Goby	*Acanthogobius flavimanus*	8	6	14	49	30-85

Table 7. Values for the Ivlev Electivity Index between *Crangonyx floridanus* and *Hyalella azteca*. Values are for bluegills adjacent to patches of hyacinth and pennywort at Site A during June and July 1998, and for bluegills and largemouth bass in patches of hyacinth at Site C during August 1998.

Site A Bluegills		
	Hyacinth	**Pennywort**
	Crangonyx floridanus	*Hyalella azteca*
June	-0.989	-0.487
July	-1.0	0.1393

Site C August		
	Crangonyx floridanus	*Hyalella azteca*
Bluegills	-0.730	-0.409
Largemouth Bass	-0.895	-0.284

Table 8. Species, number, and lengths of all fish caught directly underneath patches of hyacinth at Site C during August 1998. Native species are in bold, sample size is at the head of the column.

August		n=5		
Common Name	**Scientific Name**	**#**	**Mean Forklength (mm)**	**Forklength Range**
Bluegill size 1	*Lepomis macrochirus*	24	25.3	19-34
Bluegill size 2	*Lepomis macrochirus*	6	75.8	66-91
Largemouth Bass	*Micropterus salmoides*	19	51.9	39-66
Rainwater Killifish	*Luciana parva*	5	28.8	24-33
Brown Bullhead	*Ictalarus nebulosus*	3	35.0	34-37
Prickly Sculpin	***Cottus asper***	**1**	**95**	**95**

Discussion

Biological and Physical Differences

There are notable, significant differences between the FAV communities of the non-indigenous hyacinth and the native pennywort in the Sacramento/San Joaquin Delta. These differences range from physical structure to associated biological communities. Links between the physical structure and biological organisms of hyacinth and pennywort illustrate how a shift in the dominant FAV in the Delta has affected both the aquatic and terrestrial communities. The aquatic root mass of hyacinth has a more structurally complex surface area and more biomass than pennywort. Such a difference in root structure can explain the difference in macroinvertebrates that live in and around the roots of the two plants, as well as the lower levels of dissolved oxygen underneath the hyacinth canopy. Average spot measurements of dissolved oxygen were below 5 mg/L for hyacinth, and above 5 mg/L for pennywort. Other research has shown similar results. Hyacinth has the lowest dissolved oxygen levels as compared to milfoil, hydrilla, pondweed, and a native mix of submersed plants in Texas, and was the only plant to have averages below 5 mg/L (Madsen 1997). 5 mg/L represents the level at which fishes start to experience oxygen stress (Madsen 1997). Research specific to the Delta has shown that dissolved oxygen levels reached 0 mg/L three days out of a week in June, when measurements were taken every fifteen minutes underneath a large mat of hyacinth that completely covered a 15 meter wide slough (David Spencer, pers. com.). Lower levels of dissolved oxygen were likely the reason that hyacinth at Site B in August 1998 was completely devoid of epibenthic amphipods and isopods beneath the canopy. These hyacinth patches did have an abundance of amphipods and isopods living epiphytically amongst the roots, which suggests that these macroinvertebrates could potentially be taking refuge in the root mass from underlying hypoxia (Bryan 1993). Pennywort at the same site did have amphipods and isopods living both epibenthically and epiphytically. Overall densities of epibenthic and benthic macroinvertebrates were greater in pennywort than hyacinth during all sampling, except at Site B during August 1998 when values were approximately equal.

Patterns of taxa richness and diversity for all aquatic macroinvertebrates tend to fall along a seasonal gradient. Both taxa richness and Shannon-Weiner diversity indices were higher in pennywort during the first month of sampling (June for epiphytic, April for epibenthic/benthic), but were higher in hyacinth for all subsequent months (August for epiphytic, June and July for benthic/epibenthic; Table 3). The exception to this is pennywort having higher measurements for epibenthic/benthic macroinvertebrates at Site B in August. As discussed above, this is due to hyacinth being almost devoid of epibenthic invertebrates, presumably because of low dissolved oxygen levels. Such a pattern of values being higher in hyacinth in later months can be related to hyacinth reaching its maximum root growth later in the season (Figs. 4,5), thus providing more colonizable substrate. Similar data has been collected for hyacinth and a different species of pennywort (*Hydrocotyle ranunculodies*) in Florida, which shows that overall dry biomass of hyacinth is 161% greater, and that the difference in biomass is maximized in late summer (Jantrarotai 1990). The maximum root length of hyacinth in the same study was 164% greater than *H. ranunclodies* (Jantrarotai 1990).

The leaf structure of pennywort is denser than hyacinth, which may explain the greater overall density of insects in pennywort, as well as the taxonomic differences of the insects living in the two canopies. Pennywort was higher in taxa richness for all months and sites, except for August at Site B. However, the high leaf density of pennywort did not correspond to all indicators, since hyacinth had greater diversity throughout all months (Table 3). Hyacinth can grow a taller canopy, which may effect biological patterns of the insect assemblages as well.

Although there were site differences in aquatic invertebrate assemblages, these were consistent across years, as the most abundant taxon present at each site was the same between 1998 and 1999. There was also only minor interannual variation in insect assemblages, the main difference being more Collembolans in pennywort during June 1999. Collembolans were more abundant in hyacinth in 1998, so it is possible that with the absence of hyacinth in June 1999 Collembolans adequately relocated to living in pennywort.

It is clear that amphipods are the predominant aquatic macroinvertebrate in FAV communities as well as important fish prey. Numerous studies have shown that amphipods such as *H. azteca* are vulnerable to bluegill predation (Keast 1978, Crowder and Cooper 1982, Mittelbach 1984, Schramm and Jirka 1989). However, based on PSI values, amphipods were found to be proportionally more abundant in the FAV canopies than in the fish diets, presumably due to the refuge function of the root mass structure. This agrees with research conducted at lakes in Florida, USA, where Schramm and Jirka (1989) found that amphipods were most abundant epiphytically, and were less abundant both benthically and in fish diets. They also found that hyacinth roots provided a refuge for *H. azteca* from fish predation. *H. azteca* in hyacinth accounted between 69-86% of invertebrates in this system (Schramm et al. 1987), and was the most abundant taxon in south Florida canals (O'Hara 1968).

The major difference in amphipods between hyacinth and pennywort is the prevalence of *Crangonyx floridanus* in hyacinth. *C. floridanus* nearly vanished with the absence of hyacinth in 1999, lending even more credence that *C. floridanus* is preferably associated with hyacinth. *C. floridanus* is the smallest amphipod in this system, so it is possible that it prefers the branching network and larger surface area of the hyacinth roots. Furthermore, *C. floridanus* is not abundant in fish diets, as supported by both IRI and Ivlev Electivity Index values (Figs. 18-20; Table 7). This is in contrast to the amphipod *H. azteca* that was common in fish diets, and significantly more abundant in pennywort at Site A. There are a number of factors why *C. floridanus* may not be abundant in the fish diet, including: (1) Refuge function of hyacinth roots from fish predation; (2) Low caloric value and small size of *C. floridanus*; and (3) Poor taste of *C. floridanus*. The first scenario is the most likely, as research in Florida has shown that hyacinth roots can provide a refuge for invertebrates from fish predation (Schramm and Jirka 1989). Scenario two is also possible, as the standing stock of one *C. floridanus* is 0.000343 g, and one *H. azteca* 0.001056 g (Tables 1, 2). Therefore, *C. floridanus* is 33.43% smaller gravimetrically than *H. azteca*. With regards to the third scenario, it is not likely that *C. floridanus* is unpalatable to fish. Work has not been done specific to *C. floridanus*, but research has shown that a close congener, *Crangonyx richmondensis*, is eaten by chum, chinook, and sockeye salmon fry in freshwater tidal creeks of the lower Fraser River, British Columbia (Levings et al. 1995).

New Discoveries of Amphipods and Isopods

The results from the biological sampling and fish diet analysis illustrate both the prominence and trophic importance of amphipods and isopods in this system. Of even further importance is the fact that three of these species, the amphipod *Crangonyx floridanus* and the isopods *Caecidotea racovitzai* and *Asellus hilgendorfii*, are first records for the Delta. *A. hilgendorfii* was distinct from the other two species, as it was not found in FAV. All three species occurred to some degree in a variety of fish diets, and thus are being incorporated in the Delta food web. Other amphipods and isopods sampled in this study include the native amphipods *Hyalella azteca*, *Corophium spinicorne* and *Corophium stimpsoni*, the previously known introduced amphipod *Gammarus daiberi*, and the native isopod *Gnorimosphaeroma insulare*. Conspicuously absent were the native isopods *Caecidotea tomalensis* and *Caecidotea occidentalis*.

Current knowledge suggests that *C. floridanus*, *C. racovitzai* and *A. hilgendorfii* are non-indigenous to the Delta, as all of these species are native elsewhere and have never before been documented in the Delta (Table 9). Specific criteria have been developed to assign the newfound presence of species in locations outside of their described range into categories of non-indigenous, cryptogenic, or native (Carlton 1996). The application of these criteria to *C. floridanus, C. racovitzai* and *A. hilgendorfii* are presented in Appendix A, and support their status of non-indigenous to the Delta.

The newfound presence of these crustaceans could have significant ramifications apart from just adding their names to the already lengthy list of non-indigenous species in the Delta. Amphipods and isopods are known to be intermediate hosts of a number of parasites, including acanthocephalan parasites of fish (Nagasawa et al. 1983, Yasumoto and Nagasawa 1996). *Asellus hilgendorfii* has specifically been shown to serve as an intermediate host for numerous species of acanthocephalans that parasitize salmonids and other fish in waters of Japan (Nagasawa and Egusa 1981, Nagasawa et al. 1983, Mayama 1989). Infection occurs when fish prey upon *A. hilgendorfii* that contain acanthocephalan larvae. Adult acanthocephalans parasitize the intestinal tract of the definitive host fish (Nagasawa et al. 1983). Studies have shown that salmonids can have infection levels of 83-100% depending on the season, when *A. hilgendorfii* is only 2.1 % of the total wet weight of food items in the fish diet (Nagasawa et al. 1983). Thus, even though *A. hilgendorfii* occurs in low abundance in the diets of fish in the Sacramento/San Joaquin Delta, it could still potentially infect the entire population of salmonids with acanthocephalan parasites. It remains to be seen whether or not non-indigenous acanthocephalans were introduced along with *A. hilgendorfii* into the Delta, and if this is in turn infecting endangered native salmonids and other fish.

Introduced Species Theory

Despite the onslaught of non-indigenous species worldwide, it is often difficult to determine what the congruent ecological effects are of such invasions (Drake and Mooney 1989, Luken and Thieret 1997). Oftentimes, sufficient monitoring is not available to document changes caused by a specific invading organism. By comparing the community dominated by an exotic organism to that of an available native functional counterpart, it is possible to illuminate changes that may have arisen due to the establishment of that exotic organism. My research has shown that hyacinth can be characterized by a distinctly different invertebrate assemblage and associated fish-invertebrate food web as compared to its native functional counterpart, pennywort. The presence of hyacinth is associated with minor to major shifts in invertebrate assemblages depending on the site, and can alter the Delta fish-invertebrate food web. Such community-level effects can be typical of habitat-altering invaders such as hyacinth (Bertness 1984, Posey 1988, Vitousek 1990, Richardson et al. 1995, Ricciardi et al. 1997, Schmitz et al. 1997, Woods 1997, Crooks 1998, Crooks and Khim 1999) as hyacinth is not only widely abundant, but also provides structurally complex substrate to other organisms in both the aquatic and terrestrial zones.

The habitat-altering characteristic of hyacinth may also affect restoring wetlands in the area, as canopies of both hyacinth and pennywort form on the marsh fringe and may be influential in the development of the adjacent marsh community. There is vast interest in the Delta on predicting the rates and patterns of restoration of breached-levee wetlands, as exemplified by the BREACH research program (Simenstad et al. 1999). Succession in Louisiana follows a pathway of submerged aquatic vegetation, floating aquatic vegetation, emergent marsh vegetation, and willow forest (Penfound and Earle 1948). This pathway of succession is also supported in other warm climates where hyacinth grows throughout the year, as permanent floating islands are created which deposit large amounts of organic matter (Trivedy et al. 1978, Gopal 1987, Woods 1997). Although this pathway is abbreviated in central California due to low winter temperatures that inhibit continuous growth of FAV canopies, rates of wetland restoration could still be accelerated due to increased deposition of organic material. Growth of semi-aquatic plants such as *Ludwigia* spp. on canopies of both hyacinth and pennywort could also stabilize the canopies, allowing emergent marsh vegetation to obtain a foothold in colonization. Such pathways warrant more research in the Delta, as the current study focused primarily on ecological issues.

Hyacinth in the Delta has followed a predictable pathway of plant invasion theory, as once natural environmental constraints in the area were lifted due to an altered hydrological regime, its invasive nature was allowed to flourish (Finlayson 1983, Barret 1989, Galatowitsch et al. 1999). Such a combination of appropriate abiotic and biotic factors often turn hyacinth into a ‘perfect invader’ (Ashton and Mitchell 1989). Hyacinth is one of the most influential invaders in the current Delta, with an annual chemical control budget of approximately $1,000,000 (CDBW 1998, Pat Thalken, pers. com.). Its detrimental effects are comparable to other aquatic invaders in the area, such as the submerged aquatic plant *Egeria densa* (Obrebski et al. 1999), the clam *Corbicula fluminea* (Hymanson et al. 1994, Cohen and Carlton 1995), the Chinese mitten crab *Eriocheir sinensis* (Cohen and Carlton 1995), the Asian copepod *Pseudodiaptomus forbesi* (Cohen and Carlton 1995), and numerous species of non-indigenous fish (McGinnis 1984, Moyle and Light 1996).

It is noteworthy that in the process of studying one non-indigenous species, three more have been discovered. The amphipod *Crangonyx floridanus* and the isopods *Caecidotea racovitzai* and *Asellus hilgendorfii* are first records for the Delta, and have proven to be recent invaders into the system. This is not overly surprising, as the Delta is a highly human-modified system (Nichols et al. 1986), and may be the most invaded area in the world (Cohen and Carlton 1998). It is possible that hyacinth may have facilitated the invasions of these macroinvertebrates, as a function of its habitat-altering characteristics. Hyacinth does seem like a viable vector of introduction especially for *C. floridanus*, due to the prevalence of *C. floridanus* in the hyacinth community. The discovery of these three new species adds to the already lengthy list of 84 documented non-indigenous species in the Delta (Cohen and Carlton 1998). This keeps pace with the calculations of Cohen and Carlton (1998), as they determined that one new invasive species is currently established every 14 weeks in this system. No doubt future research will uncover still more invaders and their congruent ecological impacts, as has proven to be the case with hyacinth.

Table 9. Native range and non-indigenous populations of the amphipod *Crangonyx floridanus* and the isopods *Caecidotea racovitzai* and *Asellus hilgendorfii*, all first records for the Delta.

Species	Described Native Range	Non-Indigenous Populations
Crangonyx floridanus	Eastern and east-central United States (Holsinger 1972, Zhang 1997)	Colorado and Oregon USA, and Japan (Zhang 1997), California (this study)
Caecidotea racovitzai	Northeastern United States and southeastern Canada, Florida and Georgia USA (Williams 1970)	Washington and Utah USA (Bowman 1974, 1975, Williams 1970), California (this study)
Asellus hilgendorfii	Eastern Siberia, China, and Japan (Henry and Magniez 1995)	California (this study)

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Appendix A: Descriptions of Introduced Amphipods and Isopods

The amphipod *Crangonyx floridanus* and the isopods *Caecidotea racovitzai* and *Asellus hilgendorfii* are first records for the Delta. Samples, sites, and dates where the species occurred are summarized in Table 10. Additional sampling in habitats besides hyacinth and pennywort took place as part of the BREACH study (Simenstad et al. 1999). Brief descriptions of the species are outlined below, and in Figure 21.

Crangonyx floridanus Bousfield, 1963

Although species of the genus *Crangonyx* are often difficult to separate, it is relatively easy to distinguish *Crangonyx floridanus* from other amphipods in freshwater areas of the Delta. Two species that may be confused with *C. floridanus* are the native *Hyalella azteca*, and the non-indigenous *Gammarus daiberi* (Figure 21A-C). Adults of these species can be separated by differences in the lengths of antenna 1 and 2. *C. floridanus* has antenna 1 longer than antenna 2 (Figure 21A), *G. daiberi* has antenna 1 and 2 approximately the same length (Figure 21B), and *H. azteca* has antenna 1 shorter than antenna 2 (Figure 21C). Other distinguishing characteristics of *G. daiberi* include the presence of an accessory flagellum with 4-5 segments on antenna 1, as well as long setae specifically on the antennae and the extended uropod 3 (Figure 21B). *H. azteca* can be further identified by its large gnathopod 2 (Figure 21C). The three species can also be separated somewhat by size differences of adults, as relative sizes agree with published accounts documenting *C. floridanus* as the smallest (length 3.4-6.5 mm; Bousfield 1963), *G. daiberi* as the largest (8-12.5 mm; Bousfield 1969), and *H. azteca* as intermediate (4-8 mm; Pennak 1989). The taxonomic guides presented in Zhang (1997) or others

(Bousfield 1963, Holsinger 1972, Pennak 1989) should be used to key *C. floridanus* to species, as it is entirely possible that more than one species of the genus *Crangonyx* exists in the Delta.

Dr. John Holsinger identified *C. floridanus*, stating, "…we have a record of an introduction of *floridanus* in Japan…Presumably, the population you've sampled is also the result of an introduction." (pers. com.). Further details and definition of terms can be found in Pennak (1989) for *C. floridanus* and *H. azteca*, Bousfield (1963), Holsinger (1972), and Zhang (1997) for *C. floridanus*, and Bousfield (1969) for *G. daiberi*. *G. daiberi* is endemic to the Atlantic coast of North America, and was first detected in the Delta in 1983 (Hymanson et al. 1994, Cohen and Carlton 1995).

Caecidotea racovitzai Williams, 1970 and ***Asellus (Asellus) hilgendorfii*** Bovallius, 1886

The body shapes of these two species are extremely difficult to distinguish upon casual observation (Figure 21D), and will thus be treated together. Keys are currently only developed for adult males of the species. Two key distinguishing structures are located on gnathopod 1 and pleopod 2 (Figures 21E-H). *A. hilgendorfii* has 2 teeth-like spines located on the palm of the propodus of gnathopod 1 (Figure 21E), while *C. racovitzai* has a triangular process near the midpoint (Figure 21F). Also, *A. hilgendorfii* has a basal spur on the endopod of pleopod 2 (Figure 21G), which is not present on *C. racovitzai* (Figure 21H) or any other species in the genus *Caecidotea*. Size cannot be used to distinguish the two species, as published lengths for adults of *C. racovitzai* (4-15 mm; Williams 1972) and *A. hilgendorfii* (7-15 mm; Birstein 1964) overlap. The sizes of our specimens also fall into this range. The two recorded native isopods *Caecidotea occidentalis* and *Caecidotea tomalensis* were not found in this study, and are described in Bowman (1974).

Identification of *A. hilgendorfii* was confirmed by Dr. Guy Magniez, who has provisionally assigned the specimen as, "*Asellus (Asellus) hilgendorfii* forme de Californie…a species without doubt of human-mediated origin into the Delta" (Magniez and Toft, in prep). Dr. Noboru Nunomura has also examined samples of *A. hilgendorfii*, stating that the specimens are, "different from Japanese species of *A. hilgendorfii*" (pers. com.). Dr. Doug Smith confirmed the identification of *C. racovitzai*, saying, "Regarding the *Caecidotea*, they are certainly *racovitzai*. They may all be introduced, but I am not sure." (pers. com.). Dr. Julian J. Lewis has also confirmed the identification of *C. racovitzai* (pers. com.). Further details and definition of terms for *C. racovitzai* can be found in Pennak (1989) and Williams (1972), and for *A. hilgendorfii* in Henry and Magniez (1995) and Birstein (1964).

<u>Criteria for introduced species</u>

Current knowledge suggests that *C. floridanus*, *C. racovitzai* and *A. hilgendorfii* are non-indigenous to the Delta. Although this may be taken for granted based on the fact that they are native elsewhere and are new to the Delta, I used specific criteria that have been developed to assign the newfound presence of species in locations outside of their described range into categories of non-indigenous, cryptogenic, or native (Carlton 1996). Lindroth (1957) initially proposed five general criteria for the recognition of introduced terrestrial species. Carlton (1979) expanded these criteria into six sets, divided into thirteen categories. Chapman (1988) and Chapman and Carlton (1991, 1994) have further developed these criteria, applying them to temperate amphipods and isopods.

The following nine criteria presented by Chapman and Carlton (1994) were used to assess the likely invasions of *C. floridanus, C. racovitzai* and *A. hilgendorfii*: (1) Appearance in local regions where not found previously; (2) Expansion of local range subsequent to first appearance; (3) Access to human mechanisms of dispersal; (4) Association with known introductions; (5) Prevalence in or restriction to artificial or altered environments; (6) Discontinuous or restricted regional distribution; (7) Disjunct global distribution; (8) Insufficient life history adaptations for global dispersal; and (9) Exotic evolutionary origin. The degree to which each species met these nine attributes are summarized in Table 11 and as follows:

Attribute 1: Appearance in local regions where not found previously. All three species meet this criterion. A recent extensive review of the biological invasions of the San Francisco Bay and Delta did not document their presence (Cohen and Carlton 1995). Numerous studies have been conducted on the benthos of the Delta utilizing Ponar and Peterson dredges in channels, and none of these studies have reported their presence (Hazel 1966, Siegfried 1980, Herbold and Moyle 1989, Hymanson et al. 1994). These same studies have documented the native isopods *Asellus occidentalis*, *Asellus tomalensis*, *Gnorimosphaeroma insulare*, and *Asellus* spp., as well as the amphipods *Hyalella azteca*, *Corophium* spp., *Gammarus* spp., and the recent introduction of

Gammarus daiberi. However, a review of some of the isopods documented as *A. occidentalis* in Hymanson et al. (1994) has shown that these were actually *A. hilgendorfii*, the first specimen of which was collected in 1978 (Wayne Fields, pers. com.). Such initial misidentifications are common when exotic species first appear in a system. None of these reports have documented *Crangonyx* spp., although recent monitoring continual with that reported in Hymanson et al. (1994) has captured a few specimens starting in 1995, as well as a specimen of *Caecidotea racovitzai* in January 1999 (Wayne Fields, pers. com.). Other recent monitoring in submerged aquatic vegetation of the non-indigenous *Egeria densa* has documented only the amphipods *Hyalella azteca* and *Corophium* spp. (Obrebski et al. 1999). Historic reports on fish diets in the Delta have only documented *Corophium* spp. and *Gammarus* spp., as well as some isopods (Turner 1966).

Although the available data does support this criterion, it should be noted that most previous studies were conducted in deeper channels, not in shallow-water areas with dense aquatic vegetation. Such habitats have typically been undersampled in the Delta. However, as mentioned above, the sudden appearance of these three species in the ponar sampling continuous with that described in Hymanson et al. (1994) shows that these species can be found in such habitats. Coarse taxonomic resolution may also have obscured their initial discovery.

Attribute 2: Expansion of local range subsequent to first appearance. This criterion is not known for any of the species, as this is the first report of these three species in the

Delta and surrounding area. Only future monitoring will be able to adequately assess any such range expansions.

Attribute 3: Access to human mechanisms of dispersal. All three species meet this criterion. The San Francisco Bay estuary is considered one of the most modified by human activity in the United States (Nichols 1986), and may be the most invaded estuary in the world (Cohen and Carlton 1998). Such high levels of human modification and invasion rate make it clear that there are substantial human mechanisms for dispersal of organisms.

There are currently 84 established non-indigenous species in the freshwater Delta (Cohen and Carlton 1998). Ballast water and shipfouling have been associated with many of these species, including the invasion of the amphipod *Gammarus daiberi* (Cohen and Carlton 1995). Additionally, the introduction of *C. floridanus* into Japan and Oregon has been blamed on ballast water (Zhang 1997). Such a mechanism could also account for the presence of the three new species in the Delta, as a large port area encompassed the sampling locations. The Delta supports two major inland ports, Sacramento at the northern edge of the Delta and Stockton on the southeastern edge. These two ports account for the transport of 5 million tons of cargo annually (CDWR 1993). Most vessels are bulk carriers that arrive to port empty of cargo, subsequently loading grain and wood products (Carlton et al. 1990). Therefore, the majority of the vessels arrive with thousands of tons of ballast water taken up from their home port, which they release either in the ship channels upon approach or entirely at dockside (Carlton et al. 1990). Source regions for these species also have an abundance of shipping activity, as the described ranges of *C. racovitzai* and *C. floridanus* encompass numerous shipping centers in eastern North America (Williams 1970, Zhang 1997), as does *A. hilgendorfii* around the Sea of Japan (Henry and Magniez 1995).

Another viable human mechanism of dispersal is the transport of non-indigenous aquatic plants. As documented in this report, *C. floridanus* and *C. racovitzai* cling to the roots of the non-indigenous plant hyacinth, as well as parrot's feather (*Myriophyllum aquaticum*). Such attachment to pond plants on their removal from water has been attributed to the distribution of the non-indigenous *Crangonyx pseudogracilis* in Ireland (Costello 1993). Zhang (1997) has also attributed the presence of *C. floridanus* in Colorado and *C. pseudogracilis* in Arizona and Nevada as transported along with aquarium vegetation or fish containers from eastern localities. In addition, the described distributions of *C. floridanus* in Florida and Louisiana (Holsinger 1972) and *C. racovitzai* in Florida (Williams 1970) overlap with the distribution of hyacinth in those states. Although the exact vector of introduction of hyacinth into the Delta is unknown, it is extremely likely that it was transported as an ornamental pond plant shortly after its introduction into Louisiana and Florida (Bock 1966, Gopal 1987).

Other potential mechanisms of human dispersal that are of less prevalence include: (1) Fisheries stocking; (2) Releases or escapes from breeding and rearing facilities, and aquariums; (3) Introductions for biological control; (4) Plantings of exotic vegetation for marsh restoration and erosion control; and (5) Importation with shipments of live seafood and bait (Cohen and Carlton 1995, 1998). Cohen and Carlton (1995) give several examples of species released through these vectors.

Attribute 4: Association with known introductions. All three species meet this criterion. As previously mentioned, the San Francisco Bay and Delta is possibly the most invaded estuary in the world, and there are currently 84 established non-indigenous species in the freshwater Delta (Cohen and Carlton 1998). *C. floridanus* and *C. racovitzai* were found to live in association with the non-indigenous aquatic plants hyacinth and parrot's feather. Other abundant exotic organisms found to live in the same community as the three species include the amphipod *G. daiberi* and the clam *Corbicula fluminea*. All three species were also found with *G. daiberi* and the non-indigenous copepod *Pseudodiaptomus forbesi* in fish diets. Although the three new species are associated with known introductions in the Delta, species associations in their native described ranges are lacking.

Attribute 5: Prevalence in or restriction to artificial or altered environments. All three species meet this criterion. As mentioned earlier, the Delta is an extremely anthropogenically modified environment (Nichols 1986). Approximately 97% of the historic wetlands in the Delta have been leveed for agricultural purposes (Atwater and Belknap 1980, SFEP 1991). Of the eight sites where the species were found (Table 10; see Simenstad et al. 1999 for more information on sites), five of these are breached-levee restored wetlands (DO, LI, MI, SH, and VE). Two of these sites also have large depositions of dredged material (DO and VE). All sites are adjacent to rip-rapped levees, with the exception of one (BR). In addition, six of the sites directly border ship channels to Stockton and Sacramento (BR,DO,LI,SH,UM,VE), with the other two (MI and SM) being a few miles from the ship channel. There is also an abundance of recreational boat use and fishing in the area. As shown earlier, *C. floridanus* and *C. racovitzai* are found in the non-indigenous hyacinth community. Although the three new species are prevalent in artificial environments, current natural habitats are rare and undersampled in this area.

Attribute 6: Discontinuous or restricted regional distribution. All three species meet this criterion. *A. hilgendorfii* has never before been found in North America (Henry and Magniez 1995). The only report of *C. racovitzai* in western North America is from Washington and Utah (Williams 1970, Bowman 1975), but these populations are both probable introductions (Bowman 1974, 1975). The only reports of *C. floridanus* in western North America are from Colorado and Oregon, but as with *C. racovitzai* these populations are probable introductions (Zhang 1997). It should again be noted that habitats in which these species occur are generally poorly sampled on the West coast of North America, and coarse taxonomic resolution could have additionally obscured their presence.

Attribute 7: Disjunct global distribution. All three species meet this criterion. *C. floridanus* is widely distributed in the eastern and east-central United States (Zhang 1997), its native described range (Holsinger 1972). In addition to the new discovery of its presence in California, populations in Colorado and Oregon are likely to be introduced, and it has also been introduced into Japan (Zhang 1997). *C. racovitzai* has a fairly continuous distribution in the northeastern United States and southeastern Canada, and a subspecies occurs in Florida and Georgia (Williams 1970). As previously mentioned, there are populations in Washington and Utah (Williams 1970, Bowman 1975) which are probably introduced (Bowman 1974), in addition to its presence in

California. *A. hilgendorfii* has never before been documented in North America. The described native range of this species surrounds the Sea of Japan, in eastern Siberia, China, and the entire Japanese archipelago (Henry and Magniez 1995).

Attribute 8: *Insufficient life history adaptations for global dispersal.* All three species meet this criterion. Amphipods and isopods are brooders (Pennak 1989), and therefore do not have larval stages that are conducive for natural oceanic or intercontinental dispersal. This is especially significant because these species all occur in isolated freshwater systems as opposed to continuous marine coastlines.

Attribute 9: Exotic evolutionary origin. A. hilgendorfii fully meets this criterion, but it can not be completely satisfied for *C. floridanus* and *C. racovizai. A. hilgendorfii* definitely has exotic origins, as the genus *Asellus* consists solely of far-eastern species (Birstein 1964, Henry 1993, Henry and Magniez 1995). The only North American species of *Asellus* is *A. alaskensis*, which occurs north of the Arctic Circle in Alaska and has clear Asian affinities (Bowman 1975). There have also been reports of *A. aquaticus* from Greenland, although populations are not presently found and past populations have been attributed to temporary invasions via ballast water (Williams 1970).

Almost all species of the genus *Crangonyx* occur in eastern North America, east of the Rocky Mountains (Holsinger 1972, Zhang 1997). The ancestor of the genus *Crangonyx* might have evolved in the middle-western region of North America (Zhang 1997). Documented Pacific coast epigean species include: *C. richmondensis* in Oregon, Washington, British Columbia, and Alaska; probable introductions of *C. pseudogracilis* in Oregon, Arizona, and Nevada; and *C. floridanus* in Colorado and Oregon (Zhang 1997).

The genus *Caecidotea* also consists mostly of species in eastern North America (Williams 1970). Only two native species on the Pacific coast are known, *C. occidentalis* and *C. tomalensis* (Williams 1970, Bowman 1974). *C. communis* and *C. racovitzai* have both been documented in Washington, but these populations are probably introduced, as are populations of *C. communis* in Colorado and *C. racovitzai* in Utah (Bowman 1975).

Even though *C. floridanus* and *C. racovitzai* appear not to have originated on the Pacific coast of North America, the genera *Crangonyx* and *Caecidotea* are both common throughout North America, and therefore attribute 9 cannot be completely satisfied for these two species.

Summary of nine attributes. The three species satisfy almost all of the attributes of non-indigenous species for the Delta (Table 11). *C. floridanus* and *C. racovitzai* satisfy 7 of the 9 criteria, and *A. hilgendorfii* satisfies 8 of the criteria, with the remaining criteria not having enough evidence to either confirm or negate.

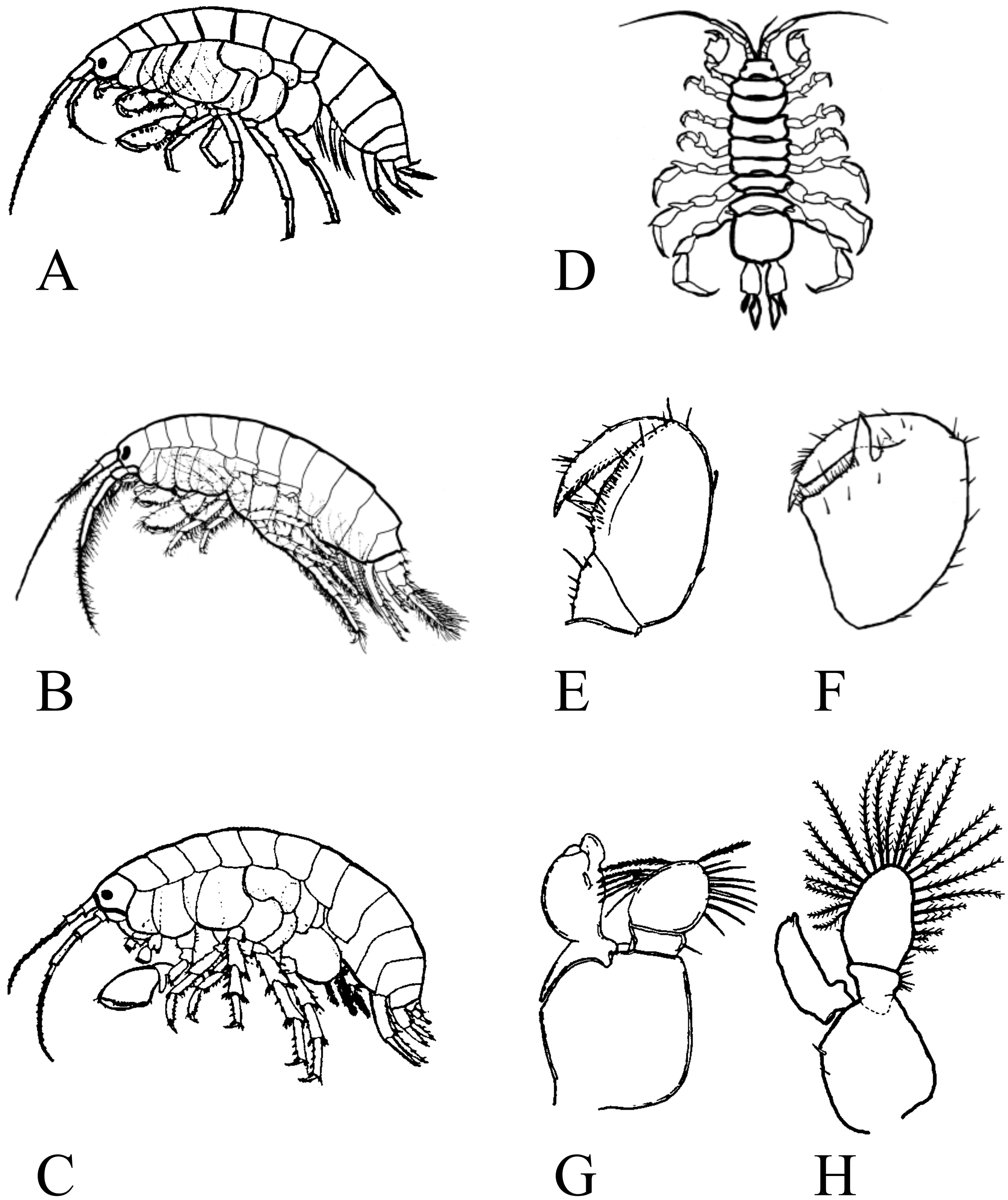

Figure 21. Descriptive diagrams of amphipods and isopods (A) *Crangonyx floridanus* (from Barnard and Barnard 1983). (B) *Gammarus daiberi* (from Bousfield 1969). (C) *Hyalella azteca* (from Pennak 1989). (D) Body morphology of *Caecidotea racovitzai* and *Asellus hilgendorfii* (from Pennak 1989). (E) Propodus of gnathopod 1 of *Asellus hilgendorfii* (from Birstein 1964). (F) Propodus of gnathopod 1 of *Caecidotea racovitzai* (from Williams 1972). (G) Pleopod 2 of *Asellus hilgendorfii* (from Birstein 1964). (H) Pleopod 2 of *Caecidotea racovitzai* (from Williams 1972).

Table 10. Samples, sites, and dates of occurrences of the amphipod *Crangonyx floridanus* and the isopods *Caecidotea racovitzai* and *Asellus hilgendorfii*. Sample codes: E = Emergent vegetation (*Scirpus* spp.), R = Riparian vegetation, H = Hyacinth, P = Pennywort, F = Parrot's Feather, B = Bluegill, L = Largemouth Bass, S = Sacramento Squawfish, T = Tule Perch. Site codes: BR = Brown's Island, DO = Donlon Island, LI = Lindsey Slough, LM = Lower Mandeville Tip, MI = Mildred island, SH = Sherman Island, SM = Sand Mound Slough, UM = Upper Mandeville Tip, VE = Venice Cut. Additional sampling in habitat besides hyacinth and pennywort was part of the BREACH study.

Species	Method	Samples	Sites	Dates
Crangonyx floridanus	Benthic Cores	E,R,H,P,F	BR,DO,LI,SH, SM,UM,VE	4/98, 6-7/98, 4/99, 6/99
	Floating Vegetation Roots	H,P,F	BR,LI,MI,UM	6/98, 8/98, 6/99
	Fish Diet	B,L	LM,VE	4/98, 9/98
Caecidotea racovitzai	Benthic Cores	E,R,H,P,F	BR,LI,MI,SH, SM,UM,VE	4/98, 6-8/98, 3-4/99, 6/99
	Floating Vegetation Roots	H,P,F	BR,LI,MI,UM	6/98, 8/98, 6/99
	Fish Diet	B	LM,VE	4/98, 6-7/98
Asellus hilgendorfii	Benthic Cores	E,R	UM,VE	6-7/98
	Fish Diet	B,L,S,T	LM,MI	5/98, 7-8/98

Table 11. Summary of the criteria for introduced species. Y = Yes, satisifies the attribute. ? = not enough evidence to confirm or negate the attribute.

	Attributes								
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Crangonyx floridanus	Y	?	Y	Y	Y	Y	Y	Y	?
Caecidotea racovitzai	Y	?	Y	Y	Y	Y	Y	Y	?
Asellus hilgendorfii	Y	?	Y	Y	Y	Y	Y	Y	Y

State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME

ACUTE TOXICITIES OF HERBICIDES USED TO CONTROL WATER HYACINTH AND BRAZILIAN ELODEA ON LARVAL DELTA SMELT AND SACRAMENTO SPLITTAIL

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ACUTE TOXICITIES OF HERBICIDES USED TO CONTROL WATER HYACINTH AND BRAZILIAN ELODEA ON LARVAL DELTA SMELT AND SACRAMENTO SPLITTAIL

by

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SUMMARY

The herbicides Reward® (diquat), Komeen® (copper ethylenediamine complex) and Sonar® (fluridone) are used to control Brazilian elodea *Egeria densa*. The herbicides Rodeo® (glyphosate) and Weedar 64® (dimethylamine salt of 2,4-dichlorophenoxyacetic acid) and spray surfactant R-11® (alkylphenolethoxylates) are used to control water hyacinth *Eichhornia crassipes*. These are two invasive, exotic aquatic weeds that infest the Sacramento-San Joaquin Delta. Concern exists over possible lethal and sub-lethal effects that the herbicides and spray surfactant may have on larval Delta smelt *Hypomesus transpacificus* and Sacramento splittail *Pogonichthys macrolepidotus*, two federally-listed threatened species. Acute toxicity tests were conducted on the herbicides and surfactant using larval Delta smelt and larval Sacramento splittail. The toxicity values were compared to those for larval fathead minnow *Pimephales promelas*, a surrogate species that is used in monitoring the impacts of the herbicides and surfactant in the Sacramento-San Joaquin Delta. Based on 96-h LC_{50} values, larval Delta smelt and larval fathead minnow were generally equally sensitive to the chemicals and larval Sacramento splittail were generally less sensitive. The surfactant R11® was more toxic than the herbicides, and Reward® and Komeen® were the most toxic herbicides tested. In herbicide/surfactant mixtures, acute toxicity was likely due to R-11®. Exposure levels of herbicides and surfactant in the Sacramento-San Joaquin Delta are several orders of magnitude less than the 96-h LC_{50} values with the exception of Reward® and Komeen®. Larval fathead minnow sensitivity to the herbicides and surfactant suggests that this species is a good surrogate for testing toxicity to Delta smelt and Sacramento splittail.

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ACKNOWLEDGEMENTS

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INTRODUCTION

The Sacramento-San Joaquin Delta is a heavily utilized recreational water way for boating in the Northern California region. Control of Brazilian elodea *Egeria densa* and water hyacinth *Eichhornia crassipes* has been a concern for the California Department of Boating and Waterways (DBW) in keeping these waterways clear of vegetation for boat passage. Both species of invasive aquatic weeds form dense growths that block waterways and destroy natural habitat by slowing water flow and drastically changing water quality. Brazilian elodea is controlled using Reward® (diquat), Komeen® (copper ethylenediamine complex), and Sonar® (fluridone) by the DBW Elodea Densa Control Program (EDCP). Water hyacinth is controlled using Rodeo® (glyphosate) and Weedar 64® (dimethylamine salt of 2,4-dichlorophenoxyacetic acid) with spray surfactant R-11® (alkylphenolethoxylates) by the DBW Water Hyacinth Control Program (WHCP).

Two federally-listed threatened fish species inhabit the Sacramento-San Joaquin Delta with Brazilian elodea and water hyacinth. Protection efforts for Delta smelt (*Hypomesus transpacificus* McAllister) and Sacramento splittail (*Pogonichthys macrolepidoyus* Ayres) appeared following drastic declines in Delta smelt populations in the early 1980's (Bennett and Moyle 1996). There has been a 60% decline in Sacramento splittail in the past 60 years (Moyle 2002). The U.S. Fish and Wildlife Service concerns for these threatened species precipitated the current study to generate toxicity values for the materials used to control the invasive weeds. The toxicity values for Delta smelt and Sacramento splittail were compared to those for larval fathead minnow, a surrogate species that is used in monitoring the impacts of the EDCP and WHCP in the Sacramento-San Joaquin Delta. The toxicity data were compared to the likely environmental concentrations of these chemicals to better assess the impacts of the control programs on these threatened species.

METHODS

Test Organisms

Delta smelt larvae were spawned and hatched in Tracy, California, at the Delta Smelt Project, University of California, Davis (UC Davis), Department of Animal Science (Bridges 2003). Larvae, 5 to10-d old, able to feed, were delivered to California Department of Fish and Game (DFG) Aquatic Toxicology Laboratory (ATL), in Elk Grove, California. The smelt were maintained in a black, flow-through circular tank (30-gallon) supplied with non-chlorinated, aerated and temperature controlled (17^{O} C) well water. Water quality was 68 mg/L $CaCO_3$ hardness, 84 mg/L $CaCO_3$ alkalinity, 8.2 pH and 255 µmho/cm conductivity. Smelt larvae were held for 96 h prior to testing under a simulated natural photoperiod regime (16-h light:8-h dark, 50-100 ft-c), fed (5-10/mL) rotifers (*Brachionus plicatilis*) during the holding period, and maintained in green water using algae paste (Nannochloropsis 3600- premium fresh, Reed Mariculture Inc). Due to the algae and turbidity requirements for feeding, no feeding was done during test periods (Bridges 2003). The smelt were 0.1 mg dry weight when tested.

Sacramento splittail larvae were spawned and hatched in UC Davis Aquatic Toxicology Program (Teh 2003). Larvae, 5 to 10-d old, able to feed, were delivered to DFG ATL. The splittail were maintained in a flow-through circular tank (30-gallon) supplied with non-chlorinated, aerated and temperature controlled well water (17^{O} C). Water quality was 69 mg/L $CaCO_3$ hardness, 92 mg/L $CaCO_3$ alkalinity, 8.1 pH and 198 μmho/cm conductivity. Splittail were held for 96 h prior to testing under a simulated natural photoperiod regime (16-h light:8-h dark, 50-100 ft-c). Fish were fed (0.2g/10 fish) brine shrimp (*Artemia*) nauplii (less than 24-h old) daily during holding time. No feeding was done during test period (Teh 2003). The splittail were 0.3 mg dry weight when tested.

Fathead minnow larvae *Pimephales promelas* came from Aquatic Bio Systems, Inc, Fort Collins, Colorado, and were shipped to the DFG ATL within 48 h of hatching. Fathead minnow larvae were utilized for testing upon arrival at the laboratory and no pretest maintenance was required. Fish were examined upon arrival to determine that no more than 20% mortality had occurred. Water temperature was adjusted to 25^{O} C at a rate of no more than 1^{O} C per hour and no more than 4^{O} C per day, and testing was performed under a simulated natural photoperiod regime (16-h light:8-h dark, 50-100 ft-c). Water quality was 78 mg/L $CaCO_3$ hardness, 81 mg/L $CaCO_3$ alkalinity, 8.2 pH and 206 μmho/cm conductivity. Fish were fed (0.1g/10 fish) brine shrimp nauplii (less than 24-h old) daily (U.S. EPA 1993). The minnow were 0.1 mg dry weight when tested.

Test Methods

The tests generally followed United States Environmental Protection Agency (USEPA) guidelines for larval fish testing (USEPA 1993; 1994). Delta smelt, Sacramento splittail and fathead minnow larvae were exposed to 5 concentrations of the chemicals in a dilution series (factor of 0.5) and a control (laboratory water).

Delta smelt and splittail were tested for 96-h using approved protocols (Appendix A). Forty fish were exposed per concentration, with four replicate test chambers per concentration (10 fish per chamber). Test temperatures were maintained at 17 ± 1^{O} C, and no feeding was done during the test. Test solutions were renewed at 48 h (USEPA 1993).

Fathead minnow were tested for 7-d using standard methods (Appendix A). Forty fish were exposed per concentration, with four replicate test chambers per each concentration (10 fish per chamber). Test temperatures were maintained at 25 ± 1^{O} C, and minnows were fed two to three times per day newly hatched *Artemia* nauplii. Test solutions were renewed daily (USEPA 1994).

Fish survival was recorded daily. Daily water quality (conductivity, dissolved oxygen, pH, and temperature) was measured for each treatment. Alkalinity and hardness were measured for each batch of test solution. At the start of a test, fish dry weight was determined. After completion of the test, all surviving fish (fathead minnows only) were weighed to determine average dry weight per test chamber. The difference in weight was used to determine growth in the fathead minnow tests.

Herbicide and Surfactant Exposure

Fish were exposed to the individual herbicides and surfactant and to mixtures of Weedar 64® and R-11® and Rodeo® and R-11®. All materials tested were commercially available products used in the EDCP and WHCP:

Reward® (EPA Reg. No. 10182-353) produced by Zeneca Incorporated (37.3 % diquat dibromide).

Komeen® (EPA Reg. No. 1812-312) produced by Griffin Corporation (8 % copper from copper-ethylenediamine complex and copper sulfate pentahydrate).

Sonar® (EPA Reg. No. 67690-4) produced by SePRO Corporation (41.7 % fluridone).

Rodeo® (EPA Reg. No. 524-343) produced by Monsanto (53.8 % glyphosate).

Weedar 64® (EPA Reg. No. 71368-1-264) produced by Nufarm Incorporated (46.8 % 2,4-Dichlorophenoxyacetic acid).

R-11® (California Reg. No. 2935-50142-AA) produced by Wilbur-Ellis Company (90 % alkylphenolethoxylates as 80 % nonylphenol polyethoxylate [NPE], compounded silicon and linear alcohol).

Exposure levels of each chemical were confirmed by analyses at the DFG Water Pollution Control Laboratory. Samples were analyzed by high performance liquid chromatography and mass spectrometry except that copper was analyzed by atomic absorption spectrophotometry. The LC_{50} values were based on concentrations of active ingredients in the commercial products. The active ingredient in R-11® was represented by the total concentration of nonylphenol polyethoxylate (NPE) and nonylphenol (NP). Percent recovery of spikes averaged 103 % for glyphosate, 100 % for NPE and NP, 104 % for 2, 4-D, 89 % for diquat, 99 % for fluridone, and 97 % for copper.

Statistics

The 96-h LC_{50} values were derived from survival counts during the 96-h tests with Delta smelt and Sacramento splittail. The herbicide concentration and mortality data were analyzed by the Comprehensive Environmental Toxicity Information System (CETIS) statistical package (Tidepool 2002). A variety of techniques were utilized to estimate LC_{50} values including Fisher's Exact T-test, two-point interpolation and linear interpolation. Herbicide and surfactant concentrations in the mixtures at the LC_{50} values were interpolated from least-squares regressions (mixture concentration versus herbicide and surfactant concentration). The toxicity of herbicides and surfactant in mixtures were expressed as toxic units (1 toxic unit of a chemical = 96-h LC_{50} concentration of that chemical):

$$H_m/H_i + S_m/S_i$$

Where H is the herbicide, S the surfactant, i is the LC_{50} value of an individual chemical tested separately, m is the LC_{50} value of an individual chemical tested in a herbicide/surfactant mixture (Marking 1977). The chemical with the highest toxic unit (TU) was likely responsible for causing toxicity.

Both 96-h and 7-d LC_{50} values were determined for the fathead minnow tests. Growth data from the 7-d tests were analyzed by unequal variance t (including Bartlett and Shapiro-Wilk W) to determine if significant effects occurred from the herbicides and the surfactant (Tidepool 2002).

The relative sensitivities of the three larval species to the herbicides and surfactant were assessed using fish sensitivity units. The lowest 96-h LC_{50} value for each chemical was assigned the value of 1.00 and the higher LC_{50} values were normalized as fractions (< 1.00) of the lowest LC_{50} value.

RESULTS

The surfactant R-11® was the most toxic and the herbicide Rodeo® the least toxic material to larval Delta smelt (Table 1).

Table 1. LC_{50} values (mg/L) and confidence limits (C.L.) of herbicides and surfactant (active ingredient) to larval Delta smelt.

Herbicides and Surfactant		LC_{50} (95 % lower and upper C.L.)
R-11® (NP & NPE)		0.7 (0.57-0.80)
Reward® (diquat)		1.1 (1.0-1.2)
Komeen® (copper)		1.4 (1.4-1.5)
Sonar® (fluridone)		6.1 (3.8-9.6)
Weedar 64® (2,4-D)		149 (72.1-185.6)
Rodeo® (glyphosate)		270 (186-324)
Rodeo®/R-11®	Rodeo® (glyphosate)	5.5 (5.3-5.7)
	R-11® (NP & NPE)	2.2 (2.17-2.3)
Weedar 64®/R-11®	Weedar 64® (2,4-D)	3.5 (2.5-4.0)
	R-11® (NP & NPE)	1.7 (1.3-1.9)

The herbicide Komeen® was the most toxic and the herbicide Rodeo® the least toxic material to larval fathead minnows (Table 2).

Table 2. LC_{50} values (mg/L) and confidence limits (C.L.) of herbicides and surfactant (active ingredient) to larval fathead minnow.

Herbicides and Surfactant		96-h LC_{50} (95 % lower and upper C.L.)	7-d LC_{50} (95 % lower and upper C.L.)
Komeen® (copper)		0.31(0.18-0.53)	0.19(0.16-0.23)
Reward® (diquat)		0.43(0.38-0.49)	0.40(0.38-0.42)
R-11® (NP & NPE)		1.1(0.99-1.2)	1.1(0.97-1.2)
Sonar® (fluridone)		5.7(5.0-6.1)	3.6(3.0-4.3)
Weedar 64® (2,4-D)		216(163-304)	211(163-293)
Rodeo® (glyphosate)		1154(903-1432)	652(484-967)
Rodeo®/R-11®	Rodeo® (glyphosate)	3.9(2.5-4.9)	2.8(2.2-4.8)
	R-11® (NP & NPE)	1.3(0.82-1.6)	0.9(0.7-1.6)
Weedar-64® / R-11®	Weedar 64® (2,4-D)	3.4(3.3-3.5)	3.4(3.3-3.5)
	R-11® (NP & NPE)	1.3(1.25-1.31)	1.3(1.25-1.31)

The herbicide Komeen® was the most toxic and the herbicide Rodeo® the least toxic material to larval Sacramento splittail (Table 3).

Table 3. LC_{50} values (mg/L) and confidence limits (C.L.) for herbicides and surfactant (active ingredient) to larval Sacramento splittail.

Herbicides and Surfactant		LC_{50} (95 % lower and upper C.L.)
Komeen® (copper)		0.51 (0.45-0.60)
Reward® (diquat)		3.7 (3.3-4.3)
R-11® (NP & NPE)		3.9 (3.0-4.4)
Sonar® (fluridone)		4.8 (3.8-5.9)
Weedar 64® (2,4-D)		446 (431-453)
Rodeo® (glyphosate)		1132 (814-1450)
Rodeo®/R-11®	Rodeo® (glyphosate)	5.5(5.3-5.8)
	R-11® (NP & NPE)	2.1(2.0-2.2)
Weedar-64® / R-11®	Weedar 64® (2,4-D)	3.0(3.0-3.0)
	R-11® (NP & NPE)	2.2(2.1-2.2)

Using a sensitivity unit of 1.00 to indicate the most sensitive species during a 96-h exposure, Delta smelt larvae had a mean rating of 0.82 followed by fathead minnow larvae with a rating of 0.73, and Sacramento splittail larvae with a rating of 0.36 (Table 4).

Table 4. Fish sensitivity units to herbicides and surfactant. A unit of 1.00 is the most sensitive LC_{50} value, with lesser values representing a fraction of the most sensitive LC_{50} value.

Herbicides and Surfactant	Delta Smelt	Fathead Minnow	Sacramento Splittail
Reward® (diquat)	0.28	1.00	0.08
Komeen® (copper)	0.84	1.00	0.31
R-11® (NP & NPE)	1.00	0.64	0.18
Sonar® (fluridone)	0.79	0.84	1.00
Weedar 64® (2,4-D)	1.00	0.69	0.33
Rodeo® (glyphosate)	1.00	0.23	0.24
Mean	0.82	0.73	0.36

The toxicity of the Rodeo®/R-11® and Weedar 64®/R-11® mixtures to aquatic life are largely determined by the concentration of R-11® (NPE and NP) present. Both herbicides are individually toxic at concentrations > 100 mg/L, and R-11® is toxic at approximately 0.7 to 4.0 mg/L (Table 1, 2 and 3). When the herbicides are tested with R-11® in mixtures, the LC_{50} values of R-11® change little while the LC_{50} values toxicity of Rodeo® and Weedar 64® are dramatically reduced. The surfactant R-11® comprises $\geq$ 99% of the Toxic Units in the mixtures (Tables 5 and 6).

Table 5. Number of Toxic Units (LC_{50m}/LC_{50i}) of Rodeo® and R-11® in mixture.

Fish Species	Rodeo® T.U. (% of total T.U.)	R-11® T.U. (% of total T.U.)
Delta smelt	0.02 (1%)	3.1 (99%)
Fathead minnow	0.003 (0%)	1.2 (100%)
Sacramento splittail	0.005 (1%)	0.54 (99%)

Table 6. Number of Toxic Units (LC_{50m}/LC_{50i}) of Weedar 64® and R-11® in mixture.

Fish Species	Weedar 64® T.U. (% of total T.U.)	R-11® T.U. (% of total T.U.)
Delta smelt	0.02 (1%)	2.4 (99%)
Fathead minnow	0.016 (1%)	1.2 (99%)
Sacramento splittail	0.008 (1%)	0.56 (99%)

DISCUSSION

Environmental monitoring for the WHCP and EDCP utilize water samples collected for herbicide and surfactant analyses and toxicity tests. To assess potential toxicity impacts that the WHCP and EDCP might have on fish, the maximum detected residue concentrations were compared to larval fish LC_{50} values (Table 7).

Table 7. Highest concentrations (mg/L) of herbicides and surfactant detected in 2002-2003 in the Sacramento-San Joaquin Delta from EDCP and WHCP and 96-h LC_{50} values (mg/L) for larval fish.

Herbicides and Surfactant	Highest Detected Concentration	Smelt LC_{50}	Fathead LC_{50}	Splittail LC_{50}
Weedar 64® (2,4-D)	0.260	149	216	446
Rodeo® (glyphosate)	0.037	270	1154	1132
R-11® (NP & NPE)	0.167	0.7	1.1	3.9
Sonar® (fluridone)	0.012	6.1	5.7	4.8
Reward® (diquat)	0.110	1.1	0.43	3.7
Komeen® (copper)	0.800	1.4	0.31	0.51

Rodeo®, Weedar 64® and Sonar® 96-h LC_{50} values for the three fish species are several orders of magnitude higher than detected concentrations in the environment. However, the LC_{50} values for Komeen®, Reward®, and R-11® are lower and approach the environmental concentrations.

Trial applications of Komeen® were made in the Sacramento-San Joaquin Delta with the highest concentration of copper detected of 0.8 mg/L at Frank's Tract. At Sandmound Slough, 0.2 mg/L copper was detected. Target application rates were 1.0 mg/L copper at Frank's Tract and 0.75 mg/L copper at Sandmound Slough; copper levels declined to background levels with in 24 hours (Anderson 2003). Highest concentration of copper detected was above the LC_{50} levels for larval fathead minnow and larval Sacramento splittail.

Reward® (diquat) LC_{50} values for the three larval fish species approximate the highest detected concentrations in the environment or the target application rate. Reward is used in the EDCP. Maximum application rate for diquat from the product label is 0.50 mg/L, and target application rate for the EDCP 2002-2003 season was 0.47 mg/L (Owens 2003). These rates are greater than the LC_{50} value for fathead minnow (Table 2) and approach the LC_{50} values for Delta smelt and Sacramento splittail larvae (Table 1 and 3). There have been several indications that Reward® is causing toxicity. It is very likely that Reward® cannot be used at these application rates without killing larval fish. If larval fish are in the application area, they likely will be killed. A possible mitigation measure would be to limit Reward® (diquat) use when larval fish are present during spring time. Applications could be made later in the year when juvenile fish can move away from application areas.

The WHCP uses R-11® as a surfactant for both Rodeo® and Weedar 64®. Throughout the WHCP for 2002-2003 season, R-11® was not detected in the Sacramento-San Joaquin Delta with one exception when it was detected at 0.167 mg/L NP and NPE. Applicators should be careful when applying mixtures containing R-11® so that the spray is on the emergent plants and not in the water column.

With the exception of Reward® and Komeen®, it is unlikely that acute toxicity from EDCP and WHCP is a problem to these larval fish. Sublethal effects from the

WHCP are unlikely since the exposure levels are so less than acute toxic levels and the materials are relatively nonpersistent in the environment. Sonar® should be further examined for sub-lethal effects due to its slow break down in the environment and repeated treatments in the same location.

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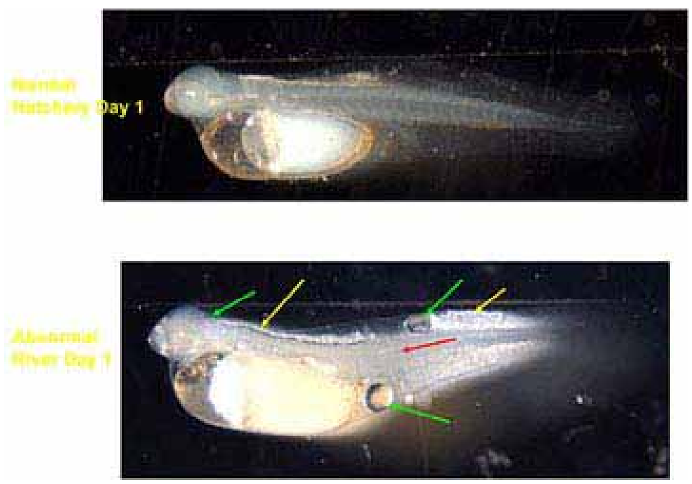
Delta Pollution Results in Stunted and Deformed Baby Striped Bass

by Dan Bacher
Monday Dec 8th, 2008 6:42 PM

An alarming report released by UC Davis Professor David Ostrach documents the maternal transfer of pollutants to striped bass fry in Central Valley rivers and the California Delta, resulting in stunted and deformed fry.

Photo: The top fish is a normal striped bass larva from a hatchery mother. The bottom fish is an abnormal striped bass larva from a river mother. The green arrows indicate areas of abnormal fluid accumulation, yellow areas indicate blistering and dead tissue, and red arrow indicates skeletal abnormality/curvature of the spinal cord. (David Ostrach/UC Davis)



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Delta Pollution Results in Stunted and Deformed Baby Striped Bass

by Dan Bacher

Pollution in the California Delta is contaminating the eggs of wild striped bass, resulting in stunting and deformation in baby striped bass, according to an alarming scientific report released by UC Davis Professor David Ostratch.

"Striped bass in the San Francisco Estuary are contaminated before birth with a toxic mix of pesticides, industrial chemicals and flame retardants that their mothers acquire from estuary waters and food sources and pass on to their eggs," according to a statement from the UC Davis researchers.

This report was released as Central Valley chinook salmon and Delta fish populations continue to crash, due to massive increases in water exports from the Sacramento-San Joaquin River Delta and an alarming decline in water quality in the estuary in recent years. State and federal scientists have documented a precipitous decline of juvenile striped bass and three other pelagic (open water) species - Delta smelt, longfin smelt and threadfin shad - since 2005.

"This is one of the first studies examining the effects of real-world contaminant mixtures on growth and development in wildlife," said study lead author David Ostrach, a research scientist at the UC Davis Center for Watershed Sciences. He said the findings have implications far beyond fish, because the estuary is the water source for two-thirds of the people and most of the farms in California, including drainage impaired land in the Westlands Water District of the San Joaquin Valley.

Using new analytical techniques, the researchers found that offspring of San Francisco Bay-Delta estuary fish had "underdeveloped brains, inadequate energy supplies and dysfunctional livers." They grew slower and were smaller than offspring of hatchery fish raised in clean, unpollluted water.

"If the fish living in this water are not healthy and are passing on contaminants to their young, what is happening to the people who use the water, are exposed to the same chemicals or eat the fish?" Ostrach emphasized. "We should be asking hard questions about the nature and source of these contaminants, as well as acting to stop the ongoing pollution and mitigate these current problems."

The new study, published online Nov. 24 by the journal Proceedings of the National Academy of Sciences, is one of a series of reports by Ostrach and UC Davis colleagues on investigations they began in 1988. Their goal is to better understand the reasons for plummeting fish populations in the imperiled estuary, the largest and most significant estuary on the West Coast.

"Biologically significant levels of polychlorinated biphenyls, polybrominated diphenyl ethers, and current-use/legacy pesticides were found in all egg samples from river-collected fish," the report abstract stated. "Developmental changes previously unseen with standard methods were detected with a technique using the principles of unbiased stereology. Abnormal yolk utilization, brain and liver development, and overall growth were observed in larvae from river-collected fish."

The full news release on the report can be read on the California Sportfishing Protection Alliance (CSPA) website, http://www.calsport.org.

The study is available at: http://www.pnas.org/search?fulltext=David+Ostrach&submit=yes. Unfortunately you'll have to pay to read the full report.

In an ironic twist, sources have informed CSPA that this project may be halted because the Department of Water Resources had the Pelagic Organism Decline (POD) Managers kill the funding for this program, according to Jerry Neuburger, CSPA Webmaster.

"These striped bass were the 'canary in the coal mine' for the Delta fisheries," said Neuburger. "An effort is being made to salvage the program and alternative funding is being sought so that the research may continue."

CSPA Sues Stockton and Davis over Water Pollution

Meanwhile, CSPA is suing the City of Stockton and the City of Davis and is pursuing correction of another 32 point pollution sources that feed into the rivers draining into the Delta. "These pollution sources and excessive agricultural runoff are the cause of this deformation and stunting of stripers," explained Neuburger. "These polluters are poisoning our rivers and the fish that live in them. CSPA will file suit against all of these polluters unless they fail to correct these violations, as well as ANY others identified as poisoning our waters and fisheries."

On December 1, the California Sportfishing Protection Alliance, California Water Impact Network (C-WIN) and Felix Smith, retired U.S. Fish and Wildlife Service biologist, filed an historic lawsuit against the State Water Resources Control Board, California Department of Water Resources and U.S. Bureau of Reclamation in Sacramento Superior Court over the "wasteful use" of Delta water.

The seven-count lawsuit alleges violations of the public trust, California Constitution, Porter-Cologne Water Quality Control Act, the Bay-Delta Water Quality Control Plan, Fish and Game Code 5937 and State Board Decision 1641 and asks the court to curtail water exports from the Delta. The lawsuit charges that the huge export pumps near Tracy in the south Delta kill thousands upon thousands of smelt and small salmon fry every year, at different times of year, and are the main threats to public trust resources in the Delta.

CSPA urgently needs the funds in order to force the federal, state and regional governments to take the necessary actions to restore our imperiled fish populations. Neuburger urged people concerned about the decline of Central Valley/Delta fish populations to join CSPA and donate at the level that you can afford! For more information and to donate, go to http://www.calsport.org

California Striped Bass Fishery Background

Striped bass are native to the waters of the East Coast of the U.S., including the Hudson River, Potomac River and Chesapeake Bay. The initial introduction to California occurred in 1879, when 132 small stripers were transported from the Navesink River in New Jersey via railray car and released into Carquinez Straits near Martinez. A second plant of 300 stripers into lower Suisun Bay took place in 1882.

The striped bass population grew quickly in the estuary's fertile water, with a commercial fishery developing within 10 years of the fish's introduction. The Department of Fish and Game closed commercial fishing for the bass in 1935, making the fishery solely a recreational one.

The striper population has varied widely in recent years. Abundance probably reached a peak of 3 to 4.5 million fish in the early 1960's. The population varied from 1.5 million to 1.9 million fish from the mid-1960's through 1976, but declined to an all time low of 600,000 fish in 1994, the result of increasing water exports, declining water quality and other factors.

Since that time, the population of legal-sized striped bass has increased to about 1.5 million. "The recent upturn in abundance is unexplained and is being investigated by DFG scientists," according to the DFG.

On the other hand, the juvenile striper population has declined precipitously over the past two decades. For example, in the fall 2005 trawl net survey in the Delta, DFG biologists documented the second lowest number of young-of-the-year stripers.

Add Your Comments

BDCP
Bay Delta Conservation Plan

A plan to restore the Delta's ecosystem and California's water supplies

What is new with the BDCP?

The Bay Delta Conservation Plan (BDCP) Steering Committee is preparing a Draft Habitat Conservation Plan (HCP) and Natural Communities Conservation Plan (NCCP) for the Sacramento San-Joaquin Delta (Delta), expected to be available for public comment by the end of 2010. The Plan is designed to provide for the conservation of sensitive species and their habitat in a way that will protect and restore water supplies.

PRELIMINARY DETAILS:

Habitat Restoration & Other Stressors

- Habitat restoration targets (up to 80,000 acres) for aquatic species
- Preserve and enhance approximately 45,000 acres of habitat for the needs of plant & wildlife species
- Refined list of measures to address water quality and other stressors on aquatic species

New Water Conveyance Facilities

- Up to five intakes along the Sacramento River from Freeport to Courtland
- Additional study of two underground 33-foot-diameter tunnels/pipelines designed for a combined capacity of up to 15,000 cubic feet per second (cfs). In addition, an above-ground canal is being considered as a conveyance option.

Flow Criteria (Operations Rules)

A range of potential new diversion rules for new North Delta water facilities in combination with continued operation of existing South Delta facilities (dual conveyance) and other key flow rules.

What are the Next Steps to Complete the Draft Plan?

In the coming months, the Steering Committee will address other important elements that need to be completed prior to the release of the Draft Plan, such as identifying terrestrial communities and species conservation measures, developing the adaptive management plan and implementation schedule, verifying covered activities, identifying funding mechanisms, refining biological goals, developing a governance structure, and further developing conservation measures.

Separately, a detailed analysis of impacts to water quality and other important aspects of the human environment will be conducted through the preparation of an Environmental Impact Report/Environmental Impact Statement (EIR/EIS) under the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA). The EIR/EIS will analyze BDCP-proposed actions and alternatives to those actions, including alternative water conveyance options.

What is in the Draft Conservation Strategy?

Below is an overview of the most recent draft conservation strategy measures:

Habitat Restoration Targets

- Restore up to 65,000 acres of freshwater and brackish tidal habitat within restoration opportunity areas.
- Restore 5,000 acres of riparian forest and scrub in restoration opportunity areas.
- Enhance channel banks along 20 to 40 linear miles with more natural riverbank features, such as overhanging shade, instream woody debris, and shallow benches.
- Restore 10,000 acres of seasonally inundated floodplain.
- Increase the frequency and duration of Yolo Bypass inundation via the modification of the Fremont or Sacramento Weirs to improve fish migration, food production, and spawning and rearing habitat.
- Preserve and enhance approximately 45,000 acres of terrestrial habitat. This target acreage is above and beyond the 75,000 acres of tidal marsh and riparian restoration in support of aquatic and terrestrial species. These targets can take place anywhere within the planning area where species may be present.

Water Facilities Rules

North Delta Diversion and Bypass Flows (1)*

- Construct diversion facilities to support flexibility in flow management, with a preliminary design capacity of up to 15,000 cfs, which is similar to existing south Delta facilities.
- Establish minimum river flows to ensure that Sacramento River flows are always greater than export diversions and that flows support the habitat needs of covered fish and the ecological needs of the Delta as a whole.

South Delta Channel Flows (2)*

- Minimize incidence and magnitude of reverse flow to acceptable levels during times of year most important to fish, and also to reduce entrainment.

Outflow (3)*

- Provide freshwater outflow necessary to maintain a desirable salinity regime and for fish health and survival.

Water Quality

- Maintain water quality standards set forth by the State Water Resources Control Board and other standards for quality throughout the Delta.

Other Controls

- Set new operating rules to better manage inflows, better manage flows through the Delta Cross Channel, and better manage flows at Rio Vista.

*Numbers refer to pull-out map.

Actions to Limit Other Stressors

- Minimize methyl mercury generation from restoration sites
- Control non-native aquatic plants that support predator habitat
- Reduce illegal harvest of Chinook salmon, Central Valley steelhead, green sturgeon, and white sturgeon
- Establish hatchery and genetic management plans
- Support Delta and longfin smelt propagation programs
- Reduce predators in high predator density locations
- Construct non-physical barriers to redirect outmigrating juvenile salmonids (e.g., bubbles, light, and sound barriers)
- Improve dissolved oxygen levels in the Stockton Deep Water Ship Channel

For a complete description of the proposed conservation measures, visit http://baydeltaconservationplan.com/BDCPPages/BDCPInfoCurrentDocs.aspx

What New Conveyance Facilities Are Currently Proposed?

A focused analysis is underway on an underground tunnel/pipeline conveyance system for potential inclusion into the Draft Plan. While the current pumping capacity proposed allows for a maximum diversion of up to 15,000 cfs, the Steering Committee is evaluating criteria based on a range of facility sizes, operations, and anticipated costs. The decision to further analyze a tunnel/pipeline is based on best available, preliminary information including cost estimates of $11.7 billion, as well as energy requirements, ongoing operations, maintenance needs, and anticipated environmental impacts at a 10 percent design stage. An above-ground canal is also being considered as a conveyance option. A decision on the proposed conveyance facility will be made after additional analysis has been completed.

In addition, five intake locations along the eastern bank of the Sacramento River between Freeport and Courtland are under consideration for the Draft Plan. Intake locations were identified, in part, to avoid and minimize impacts to important fish and wildlife species and their habitats, cultural and historical sites and housing, existing communities, and planned future land uses.

Under the current proposal, the conceptual tunnel/pipeline conveyance system would include:

- Up to 5 intakes, each at 3,000 cfs
- 6 pump stations
- 36 miles of tunnel (2 bores, 33 feet inside diameter)
- One 620-acre forebay near the existing Clifton Court Forebay
- One 750-acre forebay near Courtland

How will BDCP Water Operations Rules Help Recover Fish and Their HAbitat?

Separating California's water supply system from the fragile Delta estuary provides the ability to restore critical ecosystem functions – such as spawning and rearing habitat, production of food for fish, and fish migration patterns – throughout the Delta that are essential for species recovery. The Plan intends to restore these functions by:

- Establishing water flow rules that mimic natural seasonal flows in the estuary.
- Steering fish away from the existing state and federal water pumps.
- Restoring habitat areas throughout the Delta to support the natural ecological processes that are found in a properly functioning estuary.

How Will Water Diversions from the Sacramento River be Determined?

The Plan will propose water operations criteria that will determine how much water could be diverted from the Sacramento River via a new water conveyance facility. Currently, a range of operations is being studied that will limit the amount of water available for diversion depending on the time of the year and real-time flows. For instance, from December through April the proposed rules would require a base flow of 9,000 to 15,000 cfs in the Sacramento River before any water could be diverted at a North Delta diversion. These rules will be put in place to support the BDCP's goals of fish recovery and the restoration of natural seasonal flows.

What is the Role of Science in Developing the Draft Conservation Strategy?

The BDCP Conservation Strategy is built upon and reflects the extensive body of scientific investigation, study, and analysis of the Delta. The BDCP Steering Committee also undertook a rigorous process to develop new and updated information, including an evaluation of conservation options using the CALFED Bay-Delta Ecosystem Restoration Program's Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) evaluation process conducted by multiple teams of experts in early 2009. The BDCP Steering Committee sought and utilized independent scientific advice at several key stages of the planning process, enlisting well-recognized experts in ecological and biological sciences to produce recommendations on a range of relevant topics, including conservation planning for both aquatic and terrestrial species and to develop adaptive management and monitoring programs. Independent science input will continue as the plan is developed, and ongoing scientific input will be provided during plan implementation.

What Are the Benefits of Regional Conservation Planning?

The combination of an HCP/NCCP is the best available tool to develop a comprehensive plan that will contribute to the recovery of sensitive species and their habitats in a way that will protect and restore water supply reliability. This conservation plan will:

- Allow operations of state and federal water projects to proceed with a comprehensive ecosystem-focused approach that provides for the conservation of affected species and habitats and meets the standards of the NCCP Act.
- Eliminate more costly, often less effective piecemeal project-by-project, species-by-species permitting
- Provide flexibility in addressing those issues that are most effective for promoting the conservation of covered species.
- Are based on the best available science.
- Provide reliable funding sources for ecosystem restoration.




What Species Will Be Addressed by the BDCP?

"Covered Species" identified in the BDCP include both endangered or sensitive terrestrial and aquatic species whose conservation and management will be provided by the plan. The draft conservation strategy includes biological goals and objectives for approximately 50 sensitive wildlife and plant species, and also identifies conservation measures to help in their recovery. Species considered for coverage include:

- Delta smelt
- Longfin smelt
- Winter-run Chinook salmon
- Spring-run Chinook salmon
- Fall-run and late fall–run Chinook salmon
- Central Valley steelhead
- Green sturgeon
- White sturgeon
- Sacramento splittail
- River lamprey
- Pacific lamprey
- Approximately 50 terrestrial species (such as Giant garter snake, Swainson's hawk, and others)

Where feasible, BDCP conservation measures will be designed to complement other existing or planned terrestrial HCP/NCCPs in the Delta to enhance benefits to natural communities and species, and to support locally led conservation efforts and compatible existing land uses to the extent possible.

How Will Lands for Habitat Restoration Be Identified?

The following is a partial list of site selection criteria that will be used, along with local input, to identify lands for habitat restoration and enhancement.

FEASIBILITY

- Minimized effects on existing land uses
- Site availability
- Cost effectiveness in implementing restoration
- Potential effects on mosquito vector control

BIOLOGICAL ATTRIBUTES

- Ability to achieve multiple biological objectives for multiple species
- Proximity to channel systems that could benefit from restoration (e.g., increased tidal marsh restoration may help reduce bi-directional flows in upstream channels, or support greater mixing in channels, both of which are beneficial for native fish)
- Capacity to contribute to more natural transitions between habitats in the Delta (seasonal wetland, riparian, grassland)
- Proximity to existing habitats so that new restoration adds to and develops habitat corridors for fish and wildlife
- Minimal effects of other stressors (such as nearby water diversions or discharges of low-quality water) that could offset intended fish and wildlife benefits

How Will Restoration Sites Be Managed in the Long Term?

Individual habitat management plans will guide long-term management of BDCP restoration sites and will include:

- Biological goals and objectives to be met by the restoration activity
- Site-specific monitoring requirements and approach to adaptive management
- Controls for invasive plants
- Controls for non-native predators and competitor species
- Vegetation management and infrastructure maintenance
- Public access and other allowable uses

In addition, recent legislation created the Delta Conservancy to implement long-term restoration efforts.

What is the BDCP?

The BDCP is an HCP and NCCP under federal and state laws, respectively. When completed, the BDCP will provide the basis for the issuance of Endangered Species Act (ESA) authorizations for the operation of the state and federal water projects. The plan considers a 50-year planning period. The heart of the BDCP is a long-term conservation strategy that sets forth actions needed for a healthy Delta ecosystem.

Why is the Delta Important?

The Delta is home to half a million people and many historic communities. It is a key recreation destination and supports extensive infrastructure of statewide importance. Fresh water that reaches the Delta is the core of California's water system, which provides 25 million people throughout the Bay Area, the Central Valley, and southern California with a portion of their water supplies. Delta-conveyed water supports farms and ranches from the north Delta to the Mexican border. These agricultural resources are a major economic driver for the state, producing roughly half of the nation's domestically grown fresh produce. The Delta – the largest estuary on the West Coast – is also a vitally important ecosystem that is home to hundreds of aquatic and terrestrial species, many of which are unique to the area and several of which are threatened or endangered.

For More Information visit
www.BayDeltaConservationPlan.com
or call 1-866-924-9955

Contact Karla Nemeth
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Who Is Participating In the BDCP?

The BDCP is being prepared through a voluntary collaboration of state, federal, and local water agencies, state and federal fish and wildlife agencies, environmental organizations, and other interested parties. The BDCP Steering Committee consists of the following participants.

STATE AND FEDERAL AGENCIES

California Department of Water Resources
California Natural Resources Agency (chair)
California State Water Resources Control Board
US Bureau of Reclamation
US Army Corps of Engineers

FISH & WILDLIFE AGENCIES

California Department of Fish and Game
US Fish and Wildlife Service
US National Marine Fisheries Service

WATER AGENCIES

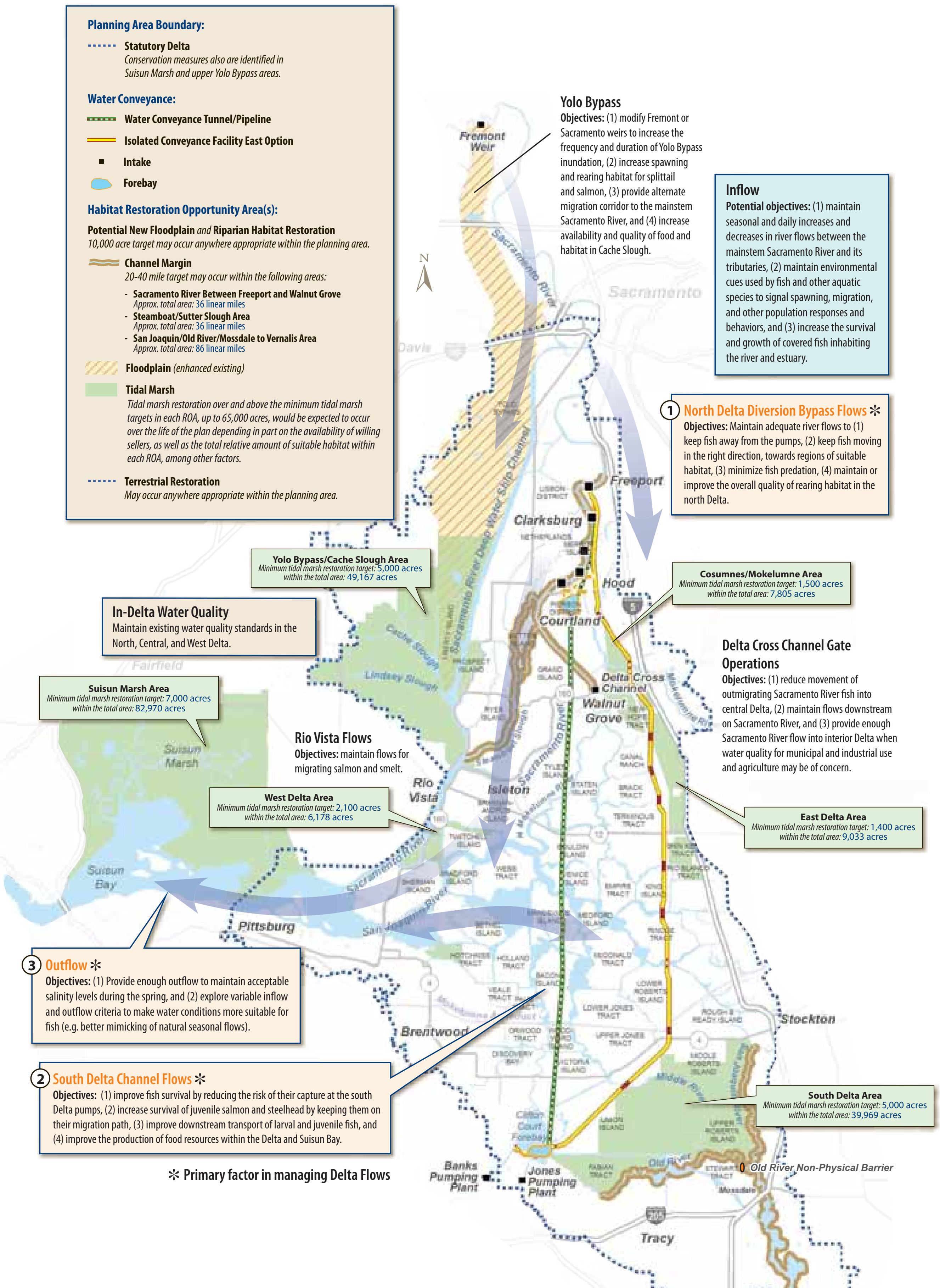
Kern County Water Agency
Metropolitan Water District of Southern California
San Luis & Delta-Mendota Water Authority
Santa Clara Valley Water District
Westlands Water District
Zone 7 Water Agency
Contra Costa Water District
Friant Water Authority
North Delta Water Agency

ENVIRONMENTAL ORGANIZATIONS

American Rivers
Defenders of Wildlife
Environmental Defense Fund
Natural Heritage Institute
The Bay Institute
The Nature Conservancy

OTHER ORGANIZATIONS

California Farm Bureau Federation
Mirant Delta



BDCP Habitat Restoration and Conveyance

PRELIMINARY DRAFT
STAFF RECOMMENDATIONS
FOR AN
AGRICULTURAL ORDER

CONDITIONALLY WAIVING INDIVIDUAL WASTE DISCHARGE REQUIREMENTS FOR DISCHARGES FROM IRRIGATED LANDS

Preliminary Draft Report

CENTRAL COAST REGIONAL
WATER QUALITY CONTROL BOARD

February 1, 2010

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1. Preliminary Draft Report on Water Quality Conditions
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3. Preliminary Draft Agricultural Order
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5. Preliminary Draft Initial Study and Environmental Checklist
6. List of References Consulted and/or Cited for Preliminary Draft Agricultural Order

1.0 Introduction

The Central Coast Water Board currently regulates discharges from irrigated lands with a Conditional Waiver of Waste Discharge Requirements (Order No. R3-2009-0050, hereafter current Order) that expires in July 2010. The Central Coast Water Board is beginning their process to consider conditions to be included in a new or revised Order that achieves desired water quality improvement.

1.1 What is the issue?

The Central Coast Water Board must determine how best to regulate agricultural discharges on the Central Coast to directly address the major water quality issues of toxicity, nitrates, pesticides and sediment in agricultural runoff and/or leaching to groundwater so that we achieve desired water quality outcomes that support all beneficial uses. Agricultural discharges (primarily due to contaminated irrigation runoff and percolation to groundwater) are a major cause of water quality impairment. The main problems are:

1. In the Central Coast Region, thousands of people are drinking water contaminated with unsafe levels of nitrate or are drinking replacement water to avoid drinking contaminated water. The cost to society for treating polluted drinking water is estimated to be in the hundreds of millions of dollars.
2. Aquatic organisms in large stretches of rivers in the entire region's major watersheds have been severely impaired or completely destroyed by severe toxicity from pesticides.

These impairments are well documented, severe, and widespread. Nearly all beneficial uses of water are impacted, and the discharges causing the impairments continue. Immediate and effective action is necessary to improve water quality protection and resolve the widespread and serious impacts on people and aquatic life.

1.2 Why is the issue important?

The Central Coast Region's coastal and inland water resources are unique, special, and in some areas still of relatively high quality. Millions of Central Coast residents depend on groundwater for nearly all their drinking water from both deep municipal supply wells and shallow domestic wells. In addition, the region supports some of the most significant biodiversity of any temperate region in the world and is home to many sensitive natural habitats and species of special concern. These resources and the beneficial uses of the Central Coast water resources are severely impacted or threatened by agricultural discharges. At the same time, the Central Coast Region is one of the most productive and profitable agricultural regions in the nation, reflecting a gross production value of more than six billion dollars in 2008, contributing 14 percent of California's agricultural economy. For example, agriculture in Monterey County supplies

80 percent of the nation's lettuces and nearly the same percentage of artichokes and sustains an economy of 3.4 billion dollars.[1]

Thousands of people rely on public supply wells with unsafe levels of nitrate and other pollutants. Excessive nitrate concentration in drinking water is a significant public health issue resulting in risk to infants for methemoglobinemia or "blue baby syndrome", and adverse health effects (i.e., increased risk of non-Hodgkin's, diabetes, Parkinson's disease, Alzheimers, endrocrine disruption, cancer of the organs) among adults as a result of long-term consumption exposure. Seventeen percent of public supply wells surveyed by the Department of Water Resources (DWR) showed contaminants above the drinking water standard, with nitrate as the most frequent chemical to exceed the drinking water standard. In a Monterey County study, in portions of the Salinas Valley, up to 50 percent of the wells surveyed had concentrations above the nitrate drinking water standard; with average concentrations nearly double the drinking water standard and the highest concentration of nitrate approximately nine times the drinking water standard. Water Board staff estimate several additional thousands of people are drinking from shallow private domestic wells. For these wells, water quality is not regulated, is often unknown, not treated, or treated at significant cost to the well owner.

Agricultural discharges of fertilizer are the main source of nitrate contamination to groundwater based on local nitrate loading studies. In some cases, up to 30 percent of applied nitrogen may have leached to groundwater in the form of nitrate. Due to elevated concentrations of nitrate in groundwater, many public water supply systems have abandoned wells and established new wells or sources of drinking water, or are required to remove nitrate before delivery to the drinking water consumer, often, at significant cost.

Agricultural discharges have impaired surface water quality in the Central Coast Region, such that some creeks are found toxic (lethal to aquatic life) every time the site is sampled and as a result many areas are devoid of aquatic organisms essential to ecological systems. Vertebrates, including fish, rely on invertebrates as a food source. Consequently, invertebrates are key indicators of stream health, and are commonly used for toxicity analyses and assessments of overall habitat condition. The majority of creeks, rivers and estuaries in the Central Coast Region are not meeting water quality standards. Most of these waterbodies are impacted by agriculture. These conditions were determined and documented on the Central Coast Water Board's 2008 Clean Water Act Section 303(d) List of Impaired Waterbodies. The three main forms of pollution from agriculture are excessive runoff of pesticides and toxicity, nutrients, and sediments. In a statewide study, the Central Coast Region had the highest percentage of sites with pyrethroid pesticides detected and the highest percentage of sites exceeding toxicity limits. In addition, there are more than 46 waterbodies that exceed the nitrate water quality standard and several waterbodies routinely exceed the nitrate water quality standard by five-fold or more. In addition to causing the human health impacts discussed previously, these high levels of nitrate are impacting sensitive fish

[1] Salinas Valley Chamber of Commerce http://atlantabrains.com/ag_industry.asp

species such as the threatened Steelhead, endangered Coho Salmon, by causing algae blooms that remove oxygen from water, creating conditions unsuitable for aquatic life.

The water quality conditions throughout the region are also impacting several other threatened and endangered species, including the marsh sandwort (arenaria paludicola), Gambel's watercress (nasturtium rorippa gambelii), California least tern (sterna antillarum browni), and red-legged frog (Rana aurora). The last remaining known populations of the two endangered plants, marsh sandwort and Gambel's watercress, occur in Oso Flaco Lake, are critically imperiled and depend upon the health of the Oso Flaco watershed to survive.

1.3 What is the Central Coast Water Board's regulatory role?

The California Regional Water Board's and State Water Resources Control Board's mission and regulatory responsibility *"is to preserve, enhance and restore the quality of California's water resources, and ensure their proper allocation and efficient use for the benefit of present and future generations."* The Central Coast Water Board is responsible for regulating discharges of waste to the region's waterbodies to protect beneficial uses of the water. In some cases, such as the discharge of nitrate to groundwater, the Water Board is the only agency with regulatory responsibility and authority for controlling the discharge to waters of the State. The Central Coast Water Board issues Orders that contain prohibitions on and requirements for discharging waste and enforces violations of the prohibitions and requirements in these Orders. The Central Coast Water Board also develops water quality standards and implements plans and programs. These activities are conducted to best protect the State's waters, recognizing the local differences in climate, topography, geology and hydrology. As the current Order expires in July 2010, The Central Coast Water Board must immediately determine how best to regulate agricultural discharges on the Central Coast to directly address the major water quality issues of toxicity, nitrates, pesticides and sediment in agricultural runoff and/or leaching to groundwater so that we achieve desired water quality outcomes that support all beneficial uses.

1.4 Why is the Central Coast Water Board changing the current Order?

The Central Coast Water Board and other stakeholders successfully developed an Order (in the form of a Conditional Waiver of Waste Discharge Requirements (2004 Conditional Waiver) through a stakeholder process and the Board adopted the Conditional Waiver on July 9, 2004 and renewed it for one year on July 10, 2009. Agricultural dischargers enrolled and established farm plans based on education and outreach, and created an industry-led, nonprofit, monitoring program. The current Conditional Waiver, however, lacks clarity and does not focus on accountability and verification of directly resolving the known water quality problems. The conditions of the 2004 Conditional Waiver address all common problems associated with all agricultural operations equally and without specific targets or timelines for compliance. Currently, the Water Board and the public have no direct evidence that water quality is improving due to the 2004 Conditional Waiver. The current watershed-scale monitoring program only indicates long-term (multi-year), receiving water changes without measuring : 1) if individual agricultural dischargers are in compliance with Conditional Waiver conditions or water quality standards, or 2) if short-term progress towards water quality improvements on farms or in agricultural discharges is occurring. We know that better on-site information assists growers in improving farming practices and some growers have advanced efforts toward water quality protection. Currently, information that provides evidence of on-farm improvements and reductions in pollution loading from farms is not required, and therefore probably does not exist for most farms. The public, including those who are directly impacted by farm discharges, and the Water Board, do not have the necessary evidence of compliance or improvements. This is unacceptable given the magnitude and scale of the documented water quality impacts and the number of people directly affected. At a minimum, we continue to observe that agricultural discharges continue to severely impact water quality. The Central Coast Water Board must determine how best to regulate agricultural discharges on the Central Coast to directly address the major water quality issues of toxicity, nitrates, pesticides and sediment in agricultural runoff and/or leaching to groundwater so that we achieve desired water quality outcomes that support all beneficial uses.

1.5 What actions are necessary to achieve water quality improvement?

The Central Coast Water Board must fulfill its regulatory responsibility to protect water quality. The Central Coast Water Board must determine how best to regulate agricultural discharges on the Central Coast to directly address and resolve the major water quality issues of toxicity, nitrates, pesticides and sediment in agricultural runoff and/or leaching to groundwater so that we achieve desired water quality outcomes that support all beneficial uses. The agricultural industry must be accountable for preventing and addressing the water quality issues caused by agriculture. Together, we must control agricultural discharges – especially contaminated irrigation runoff and percolation to groundwater. The Central Coast Water Board must focus on those areas of the Central Coast Region already known to have, or be at great risk for, severe water quality impairment. The agricultural industry must implement the most effective management practices (related to irrigation, nutrient, pesticide and sediment management) that will most likely yield the greatest amount of water quality protection, and verify their effectiveness with on-farm data. The Central Coast Water Board must establish a known and reasonable time schedule, with clear and direct methods of verifying compliance and monitoring progress over time so that agricultural dischargers understand when and if they are successfully reducing their contribution to the problems or maintaining adequate levels of protection. We all must adapt to what we learn from measures of progress, so we efficiently and effectively achieve water quality improvement over time. To prevent further water quality impairment and impact to beneficial uses, we must take action now.

1.6 A Dilemma:

Agricultural discharges continue to contribute to already significantly impaired water quality and impose certain risk and massive costs to public health, drinking water supplies, aquatic life, and valued water resources. If we do not protect water quality and beneficial uses, these costs and other impacts are likely to increase signficantly. Resolving agricultural water quality issues will greatly benefit public health, present and future drinking water supplies, aquatic life, aesthetic, recreational, and other beneficial uses. Resolving agricultural water quality issues will require changes in farming practices, will impose increasing costs to individual farmers and the agricultural industry at a time of competing demands on farm income, regulatory compliance efforts, and food safety challenges, and may impact the local economy.

Protecting water quality and the environment while protecting agricultural benefits and interests will require change and may shift who bears the costs and who reaps the benefits. There will be a spectrum of adaptation by individual farmers to any change in water quality requirements – some farmers will react by actively adapting to the change and find efficiencies and advantages to achieving compliance; and some farmers may be more resistant to change or otherwise have greater difficulty adapting, possibly resulting in negative impacts. These impacts can be reduced by the use of reasonable time schedules and by providing that individual farmers identify how they can best meet water quality standards in their individual Farm Plans.

However, continuing to operate in a mode that causes constant or increasingly severe receiving water problems is not a sustainable model. Change will be effected one way or another. Without proactive improvements in operation, a non-sustainable model will result in increasing changes such as increasingly impaired habitat, and reactive fixes such as additional costly water supply treatment, and additional cost for developing new supplies (example: northern Monterey County water supply on-going development costs due in part to groundwater overuse by Salinas Valley water users and seawater intrusion). There is no "new water" other than through desalinization which is expensive not only in terms of money but in energy costs.

To prevent further water quality impairment and impact to beneficial uses, the Central Coast Water Board must take action immediately to better regulate agricultural discharges on the Central Coast to directly address the major water quality issues of toxicity, nitrates, pesticides and sediment in agricultural runoff and/or leaching to groundwater so that we achieve desired water quality outcomes that support all beneficial uses.

2.0 Background

The California Regional Water Quality Control Board (Central Coast Water Board) Agricultural Regulatory Program was initiated in 2004, with the adoption of a Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands (2004 Conditional Waiver, Order No. R3-2004-0117). The 2004 Conditional Waiver expired on July 9, 2009 and the Central Coast Water Board extended it until July 10, 2010 (Order No. R3-2009-0050).

The intent of the 2004 Conditional Waiver was to regulate discharges from irrigated lands to ensure that such dischargers are not causing or contributing to exceedances of any Regional, State, or Federal numeric or narrative water quality standard. The requirements of the 2004 Conditional Waiver focused on enrollment, education and outreach, the development of Farm Water Quality Management Plans (Farm Plans), and receiving (watershed-scale) water quality monitoring. However, substantial evidence indicates discharges of waste are causing significant exceedances of numeric and narrative water quality standards resulting in negative impacts on beneficial uses.

Prior to the expiration of the current Conditional Waiver in July 2010, the Central Coast Water Board must consider the adoption of new or revised conditions to achieve desired water quality improvement. This report provides background and supporting information, and the terms and requirements for these Preliminary Staff Recommendations for an Agricultural Order for Discharges from Irrigated Lands (Preliminary Draft Agricultural Order). Specifically, this report contains:

1. an introduction explaining the context for considering a new Agricultural Order,
2. a description of the water quality impacts caused by agricultural discharges,
3. the Preliminary Draft Agricultural Order,
4. and a preliminary draft evaluation of environmental impacts from implementation of this Preliminary Draft Agricultural Order (initial study/environmental checklist).

3.0 The Preliminary Draft Agricultural Order

3.1 Summary

The Preliminary Draft Agricultural Order, like the 2004 Conditional Waiver, must regulate discharges of waste from irrigated lands to ensure that such dischargers are not causing or contributing to exceedances of any Regional, State, or Federal numeric or narrative water quality standard, such that all beneficial uses are protected. The Preliminary Draft Agricultural Order directly addresses agricultural discharges – especially contaminated irrigation runoff and percolation to groundwater causing widespread toxicity, unsafe levels of nitrate, unsafe levels of pesticides, and excessive sediment in surface waters and/or groundwaters. The Preliminary Draft Agricultural Order also focuses on those areas of the Central Coast Region already known to have, or at great risk for, severe water quality impairment. In addition, the Preliminary Draft

Agricultural Order requires the effective implementation of management practices (related to irrigation, nutrient, pesticide and sediment management) that will most likely yield the greatest amount of water quality protection. The Preliminary Draft Agricultural Order includes immediate requirements to eliminate or minimize the most severe or impactful agricultural discharges and additional requirements with specific and reasonable time schedules to eliminate or minimize degradation from all agricultural discharges. The Preliminary Draft Agricultural Order also includes clear and direct methods and indicators for verifying compliance and monitoring progress over time.

3.2 Public Input and Consideration of Additional Information

The Preliminary Draft Agricultural Order describes requirements for owners and operators (Dischargers) of irrigated lands that discharge or have the potential to discharge waste that could directly or indirectly reach waters of the State and affect the quality of any surface water or groundwater. The requirements described in the Preliminary Draft Agricultural Order were developed by Central Coast Water Board staff based upon information and data available, and public input received to date. At the December 2009 Board Meeting, the Central Coast Water Board invited interested persons to submit any alternative recommendations for regulating agricultural discharges for consideration by Board members and staff. Board members directed interested persons to submit alternative recommendations in writing by April 1, 2010. The Central Coast Water Board will review and consider all alternatives submitted for consistency with: 1) the program goals of resolving surface and groundwater water quality impairment and impacts to aquatic habitat over a reasonable time frame, and including milestones, and monitoring and reporting to verify compliance and measure progress over time; and 2) minimum statutory requirements (including Water Code sections 13263 and 13269 and relevant plans, policies, and regulations identified in Attachment A to the Preliminary Draft Agricultural Order). During the course of reviewing alternatives (including any specific comments on or recommendations for the Preliminary Draft Agricultural Order), Central Coast Water Board staff may modify proposed conditions or identify other feasible conditions, resulting in revisions to the Preliminary Draft Agricultural Order. Interested Persons will have an opportunity to review and provide comments on forthcoming versions of the Agricultural Order (e.g., during informal staff workshops or Board information workshops), and during future public comment periods associated with specific actions to be taken by the Central Coast Water Board (e.g., adoption of new Agricultural Order).

4.0 Water Quality Conditions

4.1 Summary of Surface Water Quality Conditions

Most waterbodies located in or near areas influenced by agriculture in the Central Coast Region have unsafe levels of nutrients, unsafe levels of pesticides/toxicity, and excessive levels of sediment/turbidity, evidenced by exceedances of surface water quality standards, and poor biological and physical conditions. Most surface waterbodies in agricultural watersheds are not suitable for drinking water, recreation (swimming or fishing), or aquatic life. Surface water quality data shows severe water quality impairment in most areas of the region with only minimal signs of improvement in a few areas.

To develop a comprehensive assessment of surface water quality in agricultural areas throughout the Region, staff evaluated data from the Cooperative Monitoring Program (CMP), the monitoring program established for compliance with the Conditional Waiver, and the Central Coast Water Board's Regional Monitoring Program, the Central Coast Ambient Monitoring Program (CCAMP). The CMP data focused monitoring in problem areas with agricultural sources and CCAMP data focused monitoring in all areas of the Region. Consequently, CMP data are biased toward more agricultural runoff influenced streams. Staff also evaluated (and will continue to evaluate) both sets of data for evidence of trends. Staff also completed an assessment of potential risk to Marine Protected Areas in the nearshore marine environment.

Surface water quality conditions are detailed in Attachment 1 to this staff report and summarized below.

Indicators of Surface Water Quality Impairment-

- Most of the same areas that showed serious contamination from agricultural pollutants five years ago are still seriously contaminated.
- The 2008 Clean Water Act Section 303(d) List of Impaired Waterbodies for the Central Coast Region (Impaired Waters List) identified surface water impairments for approximately 167 water quality limited segments related to a variety of pollutants (e.g., salts, nutrients, pesticides/toxicity, and sediment/turbidity). Sixty percent of the surface water listings identified agriculture as one of the potential sources of water quality impairment.
- Agricultural discharges most severely impact surface waterbodies in the lower Salinas and Santa Maria watersheds, both areas of intensive agricultural activity. Evaluated through a multi-metric of water quality, 82 percent of the most degraded sites in the Central Coast Region are in these agricultural areas.
- Nitrate concentrations in areas that are most heavily impacted are not improving in significantly or in any widespread manner and in a number of sites in the lower Salinas and Santa Maria watersheds appear to be getting worse in the last few years (from CCAMP and CMP data) .
- Thirty percent of all sites from CCAMP and CMP have average nitrate concentrations that exceed the drinking water standard, and approximately 57 percent exceed the level necessary to protect aquatic life. Several of these water bodies have average nitrate concentrations that exceed the drinking water standard by five-fold or more. Some of the most seriously polluted waterbodies include the Tembladero Slough system (including Old Salinas River, Alisal Creek, Alisal Slough, Espinosa Slough, Gabilan Creek and Natividad Creek), the Pajaro River (including Llagas Creek, San Juan Creek, and Furlong Creek), the

lower Salinas River (including Quail Creek, Chualar Creek and Blanco Drain), the lower Santa Maria River (including Orcutt-Soloman Creek, Green Valley Creek, and Bradley Channel), and the Oso Flaco watershed (including Oso Flaco Lake, Oso Flaco Creek, and Little Oso Flaco Creek).

- Discharges from some agricultural drains have shown toxicity every time the drains are sampled. Researchers collaborating with CCAMP have shown that these toxic discharges can cause toxic effects in river systems that damage benthic invertebrate communities.
- Agricultural use of pyrethroid pesticides in the Central Coast Region and associated toxicity are among the highest in the state. In a statewide study of four agricultural areas conducted by the Department of Pesticide Regulation (DPR), the Salinas study area had the highest percent of surface water sites with pyrethroid pesticides detected (85 percent), the highest percent of sites that exceeded levels expected to be toxic (42 percent), and the highest rate (by three-fold) of active ingredients applied (113 lbs/acre).
- Agricultural discharges contribute to sustained turbidity with many sites heavily influenced by agricultural discharges exceeding 100 NTUs as a median value. Most CCAMP sites have a median turbidity level of under 5 NTUs. Resulting turbidity greatly exceeds levels that impact the ability of salmonids to feed. Many of these sites are located in the lower Santa Maria and Salinas-Tembladero watersheds.
- Agricultural discharges result in water temperatures that exceed levels that are desirable for salmonids at some sites in areas dominated by agricultural activity. Several of these sites are in major river corridors that provide rearing and/or migration habitat for salmonids. These include the Salinas, Santa Maria, and Santa Ynez rivers.
- Bioassessment data shows that creeks in areas of intensive agricultural activity have impaired benthic communities. Aquatic habitat is often poorly shaded, high in temperature, and has in-stream substrate heavily covered with sediment.
- Several Marine Protected Areas (MPAs) along the Central Coast are at risk of pollution impacts from sediment and water discharges leaving river mouths. Three of the MPAs, Elkhorn Slough, Moro Cojo Slough and Morro Bay, are estuaries that receive runoff into relatively enclosed systems.
- For Moro Cojo Slough and Elkhorn Slough, nitrates, pesticides and toxicity are documented problems. These two watersheds have more intense irrigated agricultural activity than does the Morro Bay watershed.

Indicators of Surface Water Quality Improvement -

- Some drainages in the Santa Barbara area are improving in surface water quality (such as Bell Creek, which supports agricultural activities) and on Pacheco Creek in the Pajaro watershed. In the lower Salinas and Santa Maria watersheds, flow volumes are declining at some sites, so at these locations nitrate loads may not necessarily be getting worse in spite of trends in concentrations;
- Dry season flow volume appears to be declining in some areas of intensive agriculture;

- Detailed flow analysis by the CMP showed that 18 of 27 sites in the lower Salinas and Santa Maria watersheds had statistically significant decreases in dry season flow over the first five years of the program;
- Two sites in the lower Santa Maria area show significant improvements in nitrate concentration (Green Valley Creek (312GVS) and Oso Flaco Creek (312OFC);
- Four sites on the main stem of the Salinas River show improvements in turbidity during the dry season;
- Dry season turbidity is improving along a portion of the main stem of the Salinas River;
- CCAMP monitoring has detected declining flows at other sites elsewhere in the Region, likely because of drought;

Surface Water Quality Data and Information Gaps -

- The timeframe and frequency of data collection limit the evaluation of statistical trends for some water quality parameters in surface waterbodies;
- Flow data are not collected at all sites, making it difficult to identify patterns or trends in flow and loading of pollutants (compared to changes in concentration);
- Flow information and water quality data are not reported for agricultural discharges from individual farms, so correlations cannot be made between reductions in irrigation runoff or improvements in agricultural discharge quality vs. in-stream changes.
- In-stream water quality is an effective long-term measure of water quality improvement (especially for nutrients), and more time may be necessary to identify any significant change.
- There is no individual on-farm monitoring or reporting, and it is unknown how individual farms contribute to surface water quality improvement or impairment. In addition, it is unknown if individual Dischargers are in compliance with water quality standards (given the magnitude and scale of documented impacts, it is highly likely that most discharges are not in compliance).
- In Marine Protected Areas, there is no monitoring of sediments that carry pesticides in attached forms. Without this information it is difficult to determine if these pesticides, carried downstream in streamflow by sediments and discharged to the ocean, harm marine life.
- Additional research would increase understanding of the potential impacts of nutrient discharges in rivers in local ocean waters.

4.2 Groundwater Quality

Groundwater is severely impaired by nitrate contamination in many areas of the Central Coast Region. In many areas, nitrate concentration in groundwater is orders of magnitude above the drinking water standard, resulting in a significant threat to public health. This problem is critically important because much of the Central Coast Region is almost completely dependent on groundwater resources.

To develop a comprehensive assessment of groundwater quality in agricultural areas throughout the Region, staff evaluated available groundwater data collected by the California Department of Water Resources, California Department of Public Health (CDPH), Monterey County Water Resources Agency, and other researchers. Groundwater quality data generally represents conditions at the groundwater basin and sub-basin scale, and in particular, comprehensive impacts of agricultural land uses over a broad scale. Groundwater quality data for the purposes of characterizing specific individual agricultural discharges are not available and collection of this type of groundwater data is not required in the 2004 Conditional Waiver.

Groundwater quality conditions are detailed in Attachment 1 to this staff report and summarized below.

Indicators of Groundwater Quality Impairment -

- Groundwater contamination from nitrate severely impacts public drinking water supplies in the Central Coast Region. A Department of Water Resources (DWR) survey of groundwater quality data collected between 1994 and 2000 from 711 public supply wells in the Central Coast Region found that 17 percent of the wells (121 wells) detected a constituent at concentrations above one or more drinking water standards or primary maximum contaminant levels (MCLs). Nitrate caused the most frequent MCL exceedances (45 mg/L nitrate as nitrate or 10 mg/L nitrate as nitrogen), with approximately 9 percent of the wells (64 wells) exceeding the MCL for nitrate. According to data maintained in the GAMA-Geotracker database, recent impacts to public supply wells are greatest in portions of the Salinas Valley (up to 20 percent of wells impacted) and Santa Maria groundwater (approximately 17 percent) basins. In the Gilroy-Hollister Groundwater Basin, 11 percent are impacted, and the CDPH identified over half of the drinking water supply wells as vulnerable to discharges from agricultural-related activities. Due to these elevated concentrations of nitrate in groundwater, many public water supply systems are required to provide wellhead treatment, at significant cost, to remove nitrate before delivery to the drinking water consumer.
- Groundwater contamination from nitrate severely impacts shallow domestic drinking water supplies in the Central Coast Region. Domestic wells (wells supplying one to several households) are typically screened in shallower zones than public supply wells, and typically have higher nitrate concentrations as a result. Water quality monitoring of domestic wells is not generally required and water quality information is not readily available, however based on the limited data available, the number of domestic wells that exceed the nitrate drinking water standard is likely in the range of hundreds to thousands in the Central Coast Region.
- In Monterey County, 25 percent of 352 wells sampled (88 wells) had concentrations above the nitrate drinking water standard in the northern Salinas Valley. In portions of the Salinas Valley, up to approximately 50 percent of the wells surveyed had concentrations above the nitrate drinking water standard, with average concentrations nearly double the drinking water standard and the highest concentration of nitrate approximately nine times the drinking water

standard. Nitrate exceedences in the Gilroy-Hollister and Pajaro groundwater basins are similar, as reported by local agencies/districts for those basins.

- In many cases, whole communities relying on groundwater for drinking water purposes are affected. Local agencies have reported the shut down of domestic drinking water wells due to high nitrate concentrations. In addition, local agencies and consumers have reported impacts to human health resulting from nitrate contaminated groundwater likely due to agricultural land uses, and spent significant financial resources to ensure proper drinking water treatment and reliable sources of quality drinking water for the long-term. In the Central Coast Region, the Monterey County community of San Jerardo, the San Martin area of Santa Clara County, and the City of Morro Bay are among the local communities affected by nitrate.

Groundwater Quality Data and Information Gaps -

- Groundwater quality (especially in deeper parts of the aquifer) is an effective long-term measure of water quality improvement and long time periods are usually necessary to identify significant change in water quality.
- Shallow groundwater is generally more directly susceptible to pollution from overlying land use. Groundwater quality data collection from shallow wells (especially agricultural or domestic drinking water wells) is not required and data is only broadly available, thus limiting evaluations related to shorter term indications of water quality changes.
- Well construction data (e.g., depth and screened intervals) are generally available for public supply wells but are otherwise not collected on a broad scale in a common format. This data gap limits more precise evaluations of water quality and groundwater depth.
- Groundwater data from wells associated with individual farms or areas of intensive agriculture are not routinely collected, nor have data been collected for all such areas in the region. This data gap limits understanding of chemical contributions from individual farms or areas to the levels of chemicals found in groundwater wells.

4.3 Aquatic Habitat Conditions

Aquatic habitat is degraded in many areas of the region as evidenced by poor biological and physical conditions. Most surface waterbodies in agricultural watersheds are not suitable for safe recreational fishing or to support aquatic life.

To determine aquatic habitat conditions, staff reviewed data collected by CMP and CCAMP, and conducted a review of available riparian and wetland information for the Central Coast Region. While the 2004 Conditional Waiver did not specifically require aquatic habitat monitoring, it stated that cooperative monitoring of in-stream effects would enable the Central Coast Water Board to assess the overall impact of agricultural discharges to beneficial uses, such as aquatic life and habitat. The 2004 Conditional Waiver also requires protection of beneficial uses including aquatic and wildlife habitat.

The proposed 2010 order continues that requirement.

Aquatic habitat conditions are detailed in Attachment 1 to this staff report and summarized below.

Indicators of Aquatic Habitat Degradation -

- Agricultural activities result in the alteration of riparian and wetland areas, and continue to degrade the waters of the State and associated beneficial uses. Owners and operators of agricultural operations historically removed riparian and wetland areas to plant cultivated crops and in many areas continue to do so.
- As a result of aquatic habitat degradation, watershed functions that serve to maintain high water quality, aquatic habitat and wildlife - by filtering pollutants, recharging aquifers, providing flood storage capacity, have been disrupted.
- Data collected from CCAMP and CMP indicate that population characteristics of aquatic insects (benthic macroinvertebrates) important to ecological systems reflect poor water quality, degradation or lack of aquatic habitat, and poor overall watershed health at sites in areas with heavy agricultural land use. Aquatic habitat is often poorly shaded, high in temperature, and stream bottoms are heavily covered with sediment.
- The lower Salinas watershed and lower Santa Maria watersheds score low for common measures of benthic macroinvertebrate community health and aquatic habitat health.
- Unstable, bare dirt and tilled soils, highly vulnerable to erosion and stormwater runoff, are common directly adjacent to surface waterbodies in agricultural areas. Erosion and stormwater runoff from agricultural lands contributes sediment and sustained turbidity at levels that impact the ability of salmonids to feed. Many of these sites are located in the lower Santa Maria and Salinas-Tembladero watersheds.
- Degradation of aquatic habitat also results in water temperatures that exceed levels that are desirable for salmonids at some sites in areas dominated by agricultural activity. Several of these sites are in major river corridors that provide rearing and/or migration habitat for salmonids. These include the Salinas, Santa Maria, and Santa Ynez rivers.
- Real and/or perceived incompatible demands between food safety and environmental protection and subsequent actions taken by Dischargers to address food safety concerns associated with environmental features have resulted in the removal of aquatic habitat and related management practices.
- According to a Spring 2007 survey by the Resource Conservation District of Monterey County (RCDMC), 19 percent of 181 respondents said that their buyers or auditors had suggested they remove non-crop vegetation from their ranches. In response to pressures by auditors and/or buyers, approximately 15 percent of all growers surveyed indicated that they had removed or discontinued use of previously adopted management practices used for water quality protection. Grassed waterways, filter or buffer strips, and trees or shrubs were among the management practices removed.

Indicators of Aquatic Habitat Improvement -

- Protection, restoration and enhancement of aquatic habitat and watershed functions are demonstrated to be effective for improving water quality, aquatic and wildlife habitat, aquifer recharge, and flood storage capacity.
- Grant-funded projects in the Gabilan Watershed and surrounding Southern Monterey Bay Watersheds demonstrate that wetland restoration results in improved aquatic habitat conditions measured by changes in populations of native plants and birds, and establishment of macroinvertebrate populations. Restoration projects also resulted in water quality improvement by reducing sediment loads, removing large fractions of nitrate and suspended sediment inputs, and removal of ammonia, phosphate, and diazinon.
- Restoration projects implemented in the Moro Cojo Slough indicated that agricultural runoff that ran through wetland habitats can result in greatly reduced levels of nitrate. In addition, restoration resulted in better support of native plants and animals. Greater than 40 native plant species and 22 native vertebrates were observed throughout the project sites. In addition, the following protected species were documented throughout the Moro Cojo Watershed: California Red-legged Frog, California Tiger Salamander, Steelhead, Santa Cruz Long-toed Salamander, Tidewater Goby, and Saline Clover.
- Restoration projects in the Hansen Slough area near Watsonville resulted in decreases in stream turbidity by more than 50-fold, comparing sites above and below restoration. Nitrate concentrations also decreased as water passed through the restoration area – nitrate concentrations entering the site exceeded 140 mg/L and levels leaving the site never exceeded 40 mg/L, and were frequently below 5 mg/L.

Aquatic Habitat Data and Information Gaps -

- The success of aquatic habitat protection and restoration efforts is dependent on a variety of different parameters including scale, climate, topography, flow, water quality, and other site-specific variables.

4.4 Agricultural Discharge Water Quality

Water quality of agricultural discharges is often poor, carrying nitrates at concentrations above safe drinking water levels and pesticides at concentrations above toxic levels to waterbodies in the region. Agricultural discharges contribute significantly to water quality conditions. In some cases, agricultural discharges are the sole or primary source of pollution in impaired waterbodies. Even in areas where agricultural is not the only source of pollution, it is a primary contributor.

Numerous studies document the impact of agricultural discharges on water quality and specific pollutants contained in irrigation runoff. Research conducted by the Food and Agriculture Organization of the United Nations found that irrigation return flow resulted in a significant increase in nitrogen, phosphorous, pesticide residues, and sediments.

Agricultural research conducted by University of California Cooperative Extension (UCCE) found nitrate values in agricultural tailwater at 26, 53, and 75 mg/L NO3-N (up to 7.5 times the drinking water standard). UCCE researchers indicated that the high levels of nitrate at the site were likely caused by the grower injecting nitrogen fertilizer into the irrigation water during the 2nd and 3rd irrigation events. A UC Davis study of Salinas Valley farms found that by the second and third crop cycles, farm soils had begun to accumulate nitrogen, but that growers continued with the same fertilization schedule. In addition, soils are high enough in phosphorus that in some areas no added phosphorus is necessary; however, growers continue to add this chemical to their fields. These practices lead to excess fertilizer leaving the farm, which ultimately cause significant water quality impairment. Similar to tailwater, tile drain water with elevated nitrate levels has been found draining into surface water bodies. Nitrate concentrations in selected waterbodies in the Pajaro Valley Watershed have been found to range from 19 to 89.5 mg/l NO3 as N(compared to the drinking water standard, 10 mg/l).

Pesticides have been detected in agricultural tailwater and routinely exceed the toxicity water quality standard (lethal to aquatic life). Regionwide, CCAMP and the Cooperative Monitoring Program have conducted toxicity monitoring in 80 streams and rivers. Some measure of lethal effect (as opposed to growth or reproduction effect) has been observed at 65 percent of the water bodies monitored.

5.0 Preliminary Draft Staff Recommendations for an Agricultural Order

5.1 Background on Agricultural Regulatory Program Implementation (2004 – 2009)

On July 9, 2004, the Central Coast Water Board unanimously adopted the 2004 Conditional Waiver, and the associated Monitoring and Reporting Program, with the support of an Agricultural Advisory Panel (including agricultural and environmental interest group representatives), and overall public support. The goal of the 2004 Conditional Waiver was to improve agricultural water quality through the implementation of appropriate management practices. The requirements of the 2004 Conditional Waiver focused on enrollment, education and outreach, development of Farm Water Quality Management Plans (Farm Plans), and cooperative water quality monitoring.

During the term of the 2004 Conditional Waiver, Water Board staff worked with the agriculture community to develop an Agricultural Regulatory Program that would progress to protect and restore surface water quality, groundwater quality, and aquatic habitat to conditions that protect all designated beneficial uses of water in areas with irrigated agricultural lands. Major programmatic accomplishments of the first five years include the following:

- Enrollment of approximately 90 percent of the Central Coast Region’s total irrigated agricultural acreage under the 2004 Conditional Waiver;

- Development and Implementation of a region-wide monitoring program (CMP) to assess water quality conditions at the watershed-scale;
- Tracking program implementation for more than 1700 farming operations (including inspections at 59 farming operations, and various enforcement actions: more than 200 Notices of Violation, more than 20 water quality enforcement actions, and five Administrative Civil Liability complaints);
- Discharger development of Farm Water Quality Management Plans for over 1528 operations (72 percent of enrollees); and
- Discharger completion of water quality education courses (in total, more than 18,000 hours);

While the success of initial efforts of the Agricultural Regulatory Program to develop a Conditional Waiver with stakeholders and achieve enrollment through education and outreach is significant, the current Conditional Waiver lacks clarity and focus on water quality requirements and does not include adequate compliance and verification monitoring. Thus, desired water quality outcomes achievement is uncertain and unmeasured. At a minimum, agricultural discharges continue to severely impact water quality in most receiving waters. The Central Coast Water Board must determine how better to regulate agricultural discharges on the Central Coast to directly address the major water quality issues of toxicity, nitrates, pesticides and sediment in agricultural runoff and/or leaching to groundwater to achieve desired water quality outcomes that support all beneficial uses.

5.2 Preliminary Draft Agricultural Order – Summary of Staff Proposed Conditions

Conditions in the Preliminary Draft Agricultural Order and changes related to the 2004 Conditional Waiver are summarized in Attachment 2 and the Preliminary Draft Agricultural Order is contained in Attachment 3. Conditions in the Preliminary Draft Agricultural Order that are a clarification of conditions in the 2004 Conditional Waiver are notated as "<CLARIFICATION OF EXISTING>" in the Preliminary Draft Agricultural Order, Attachment B, Terms and Conditions. -. Conditions in the Preliminary Draft Agricultural Order that do not exist in the 2004 Conditional Waiver are notated as "<NEW>". Conditions in the Preliminary Draft Agricultural Order without a notation are the same as conditions contained in the 2004 Conditional Waiver.

Staff developed these preliminary recommendations for an Agricultural Order by building upon the 2004 Conditional Waiver to advance efforts to improve agricultural water quality and gain compliance with applicable water quality standards. Thus, staff recommends the same regulatory tool, a Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands, to regulate agricultural discharges. To ensure understanding of applicable water quality standards, staff included explicit clarification of water quality discharge and compliance requirements. In addition, to improve implementation actions directly addressing the specific priority water quality issues, the Preliminary Draft Agricultural Order builds upon the development and implementation of Farm Plans, including effective implementation of management practices (related to irrigation, nutrient, pesticide and sediment management) that will most likely yield the greatest amount of water quality protection. The Preliminary Draft Agricultural Order also builds upon the existing Cooperative Monitoring Program by retaining watershed-scale, receiving water monitoring, but adds individual monitoring and reporting to improve Water Board staff's ability to identify specific discharges loading pollutants or contributing to impacts, verify compliance with the requirements by dischargers and measure progress over time at the farm and watershed scales. The Preliminary Draft Agricultural Order focuses on reducing or eliminating agricultural discharges – especially contaminated irrigation runoff and percolation to groundwater in the most severely impaired areas. Due to the unique conditions related to irrigated lands and individual farming operations, the Preliminary Draft Agricultural Order includes multiple options for compliance to maximize Dischargers' flexibility in achieving desired water quality improvement according to a specific time schedule and specific milestones. Similar to the 2004 Conditional Waiver, the Preliminary Draft Agricultural Order also includes significantly reduced monitoring and reporting requirements for those agricultural discharges identified as having relatively low-risk for water quality impairment. The conditions for compliance, the monitoring and reporting requirements and the time schedule for compliance are summarized in the following paragraphs.

To demonstrate compliance with this Order, Dischargers must:

- Enroll to be covered by the Order
- Develop and implement a farm plan that includes management practices with certain conditions and specifications
- Eliminate non-storm water discharges, or use source control or treatment such that non-storm water discharges meet water quality standards
- Demonstrate through water quality monitoring that individual discharges meet certain basic water quality targets (that are or indicate water quality standards that protect beneficial uses). For example, non-storm water discharge monitoring should find:
    - No toxicity
    - Nitrate ≤ 10 mg/L NO_3 (N)
    - Turbidity ≤ 25 NTUs
    - Un-ionized Ammonia < 0.025 mg/L (N)
    - Temperature ≤ 68°F
- Demonstrate through water quality monitoring that receiving water is trending toward water quality standards that protect beneficial uses or is being maintained at existing levels for high quality water
- Farm operation must support a functional riparian system and associated beneficial uses (e.g., recreational uses like swimming, wading, or kayaking, fishing, wildlife habitat, etc.)

5.3 Preliminary Draft Monitoring and Reporting Requirements

Water quality monitoring for the Preliminary Draft Agricultural Order is required by California Water Code Section 13269. Monitoring requirements are designed to support the implementation of the Preliminary Draft Agricultural Order (specifically as a Conditional Waiver of Waste Discharges). Monitoring must verify the adequacy and effectiveness of the Order's conditions. Monitoring information and data must be reported to the Water Board. The reporting requirements that staff recommends with the Preliminary Draft Agricultural Order include all farm operations to report on management practice implementation at the time of enrollment, to report on management practices at least once during the period of the Order, to update their farm plans annually with monitoring and site evaluation results, and to update their plans annually with specific adjustments in response to any results that indicate unacceptable progress (e.g., do not meet interim milestones set forth in the Order).

The current monitoring program for the 2004 Conditional Waiver uses a third party for meeting all monitoring and reporting requirements (Preservation, Inc., the nonprofit organization that implements the Cooperative Monitoring Program). Under the current monitoring and reporting program, Dischargers are responsible for monitoring and reporting either individually or collectively, and they must comply with the requirements of the Board-approved Monitoring and Reporting Program. The preliminary draft monitoring and reporting requirements provide for Dischargers to continue to use a third party as long as the third party is approved by the Executive Officer.

The existing monitoring program does not collect sufficient information regarding:

- Groundwater quality
- Pollution source identification
- Individual compliance
- Terrestrial riparian conditions

To address the critical need for additional data for groundwater quality, source identification, source control and/or compliance and riparian condition, Water Board Staff considered various monitoring options.

In the Preliminary Draft Agricultural Order, Water Board staff recommends a monitoring program that requires four categories of monitoring: Individual Discharge Characterization Monitoring, Individual Discharge Monitoring, Watershed (receiving water) Monitoring, and Additional Monitoring if required by the Executive Officer (receiving water and/or discharge). Staff recommends this monitoring program because it:

- Addresses all surface water (tailwater, tile drain water, stormwater, etc) and groundwater
- Provides complete identification of individual operations responsible for discharge
- Allows for immediate management of known discharges with the potential to impact water quality

- Limits costs for farms that are in compliance
- Prioritizes further regulatory action on farms that are not progressing toward compliance
- Uniformly distributes costs for trend and stormwater monitoring across all growers resulting in similar costs for all growers based on acreage farmed
- Provides data for surface and groundwater trends, individual compliance, management practice implementation, riparian protection, and stormwater
- Allows data collection, analysis, and reporting to be performed by a non-regulatory single third party
- Provides follow up monitoring to identify and mitigate known discharges with the potential to impact water quality

The following paragraphs describe each of the four categories of monitoring recommended.

Individual Discharge Characterization Monitoring-
To establish the need for one time and/or continuous monitoring at an individual farm operation, farm operations (Dischargers) will be required to evaluate their farms individually. The first step under this option is a requirement that all farm operations conduct an "individual discharge characterization" of their farm operation. The characterization will require a farm operation to identify if they have non-stormwater discharge(s) to either surface or ground water. Examples of non-stormwater discharges include agriculture tailwater, irrigation runoff, tile drain water, pond water discharge, ponded furrows, and/or another intermittent agriculture water discharge.

If a farm operation verifies that it does not have any non-stormwater discharge, that farm operation is not required to conduct any individual discharge water quality monitoring. Each operation without an identified non-stormwater discharge must conduct watershed monitoring for stormwater and long-term in-stream trends.

If a farm operation has an identified non-stormwater discharge to either surface or ground water, that discharge must be sampled and analyzed for the following discharge characterization parameters:

- Flow
- Toxicity
- Total Nitrogen (mg/L)
- Nitrate-Nitrite (mg/L)
- Total Ammonia (mg/L)
- Ortho-Phosphosphate (mg/L)
- Turbidity (NTU)
- Water Temperature (degrees C)
- pH
- Total Dissolved Solids (mg/L)

The following parameter must be calculated (based on Ammonia and pH):

- Un-ionized Ammonia (mg/L)

Staff and the discharger will use this information to assess the discharge to surface and/or ground water. If the discharge characterization demonstrates the discharge is impairing or has potential to impair surface and/or groundwater (load pollutants at levels that would cause exceedance of water quality standards to protect beneficial uses), that pollutant discharge must be eliminated, If the discharge flow can not be eliminated, the discharge must be treated or controlled to meet water quality standards to be protective of ground and surface water beneficial uses (within a time-frame specified in the Order), and must be monitored as described under "individual discharge monitoring" below.

Individual Discharge Monitoring-
For a farm operation with continuous discharge(s), the discharge(s) must be monitored until the discharge(s) is terminated or controlled so that it meets water quality standards (within a time frame specified in the Order). Data collected through individual monitoring will be used to verify that individual operations are progressing towards or have succeeded to eliminate or adequately control discharges that are impacting waters of the state and associated beneficial uses. If individual discharge monitoring demonstrates discharges are loading significant amounts of pollutants to receiving waterbodies that are already impaired (exceed water quality standards that protect beneficial uses) or that have water quality conditions at or better than water quality standards currently supporting beneficial uses, the Discharger must use additional source control/pollutant reduction (compliance is defined by time frames specified in the Order).

A third-party monitoring group can fund or perform this monitoring on behalf of individual dischargers. Individual agriculture operations identified through Individual Discharge Characterization or Follow-up monitoring efforts as the source of pollution must implement additional management practices or improve implementation of current practices for the protection of water quality and associated beneficial uses.

If management practice implementation fails to eliminate a source of pollution or bring a discharge in compliance with applicable water quality standards, the Water Board may pursue enforcement to bring the discharge into compliance with water quality standards.

Watershed Monitoring Program-
Sites on main stems of rivers and tributaries in agricultural areas of the region must be monitored on a regular basis to evaluate in-stream stormwater trends and long-term trends in water quality and associated beneficial uses. All Dischargers must conduct watershed monitoring program.

The watershed monitoring program must collect samples at a core network of receiving water sites. For the watershed monitoring component of the monitoring requirements, Dischargers may recommend monitoring sites or constituents to best characterize potential agricultural impacts that the Executive Officer must approve to be effectuated. Similarly, the Executive Officer may require changes to the sites or waste constituents, or other aspects of the watershed monitoring program, to better characterize agricultural impacts, identify sources of pollution, or better characterize stream water quality (See discussion of Additional Monitoring below).

Surface Water
Representative surface water samples shall be collected and analyzed for the parameters listed in Attachment 4. Also, two stormwater events shall be monitored for the parameters listed in Attachment 4 during the rainy season (October 15 – March 15). Rainy season sampling is typically conducted during or shortly after runoff events, preferably including the first event that results in significant flow increase.

Groundwater
At a minimum, all Dischargers must sample their own irrigation wells and drinking water wells annually. Sampling must include collection and analyses of data for nitrate and TDS, at a minimum.

Additionally, individual Dischargers (or approved third party on their behalf) must develop a plan to monitor groundwater to characterize groundwater quality in agricultural areas including:

- current representative conditions of groundwater quality,
- more specific groundwater quality along general groundwater flow paths (where water is recharged to where it discharges, e.g., into streams or wells), and
- trends in groundwater quality
- impacts to beneficial uses (or protection of beneficial uses).

The proposed groundwater monitoring plan may rely on existing groundwater wells and may include existing monitoring efforts around the region to document groundwater quality. The proposed groundwater monitoring plan must be submitted to the Water Board Executive Officer by March 1, 2012.

To be an acceptable third-party, the monitoring group must:

- Be responsible for implementing monitoring and reporting program.
- Report names of participating dischargers.
- Report any dischargers who cease to comply with requirements.
- Comply with a Quality Assurance Program Plan and monitoring plan approved by the Water Board's quality assurance officer.
- Submit all data (daily, monthly, quarterly, etc.) to the Water Board; the data submission shall conform to criteria approved by the Central Coast Regional Water Quality Control Board Executive Officer.

Additional Monitoring required by the Executive Officer
At the direction of the Water Board Executive Officer, individual Dischargers or an approved third party must conduct Follow up monitoring in areas identified as problematic through Individual Discharge Monitoring, Watershed Monitoring, and the Central Coast Ambient Monitoring Program. This monitoring must be conducted to identify the source of pollution and monitor any identified discharges associated with

agriculture operations to surface or ground water, including discharges to streams, discharges to tail-water ponds, and stormwater runoff.

5.4 Proposed Time Schedule for Compliance

Water Board Staff considered a time schedule that would support timely and effective implementation. Under this Preliminary Draft Agricultural Order, either irrigation runoff will need to be eliminated within two years of adoption of the Order or the following pollutants in irrigation runoff will need to be eliminated and/or treated or controlled to meet applicable water quality standards by the dates specified:

- Toxicity – within two years of adoption of the Order
- Turbidity – within three years of adoption of the Order
- Nutrients – within four years of adoption of the Order
- Salts – within four years of adoption of the Order

Additionally, dischargers must implement management practices to reduce pollutant loading to groundwater.

Staff recommends the time-schedule in this Preliminary Draft Agricultural Order as a reasonable starting point to improve water quality. This schedule acknowledges that to fully control all discharges and achieve compliance will take longer than the five years of this Preliminary Draft Agricultural Order. In a separate, but related effort regarding regulation of agricultural discharges, staff is evaluating and developing a time schedule for actions and to meet interim milestones that extends out to 2025.

6.0 Preliminary Draft Environmental Analysis Pursuant to the California Environmental Quality Act (CEQA)

Consistent with CEQA, staff prepared a preliminary draft environmental impact analysis, currently in the form of an Initial Study, including an environmental checklist. See Attachment 5.

The project evaluated in this Initial Study/Environmental Checklist is the Preliminary Draft Irrigated Ag Order, which is a revised Conditional Waiver of Waste Discharge Requirements and the requirement to submit a report of waste discharge.

The preliminary draft environmental impact analysis contains the following information relating to the Preliminary Draft Irrigated Ag Order:

1. A description of proposed activity and proposed alternatives ,
2. An environmental checklist,
3. An initial evaluation of potentially significant environmental impacts.

7.0 References

Staff consulted several references in preparing the report on water quality conditions and the Preliminary Draft Agricultural Order. A list of those references is included as Attachment 6.

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11 REASONABLE AND PRUDENT ALTERNATIVE

11.1 OVERVIEW

11.1.1 Approach to the RPA

If NMFS finds that a proposed action is likely to jeopardize a listed species or adversely modify its critical habitat, the ESA requires NMFS to suggest those reasonable and prudent alternatives that it believes would enable the project to go forward in compliance with the ESA. By regulation, a RPA is defined as "alternative actions identified during formal consultation that can be implemented in a manner consistent with the intended purpose of the action, that can be implemented consistent with the scope of the Federal agency's legal authority and jurisdiction, that is economically and technologically feasible, and that the [NMFS] Director believes would avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat" (50 CFR 402.02).

Regulations also require that NMFS discuss its findings and any RPAs with the action agency and utilize the action agency's expertise in formulating the RPA, if requested (50 CFR 402.14(g)(5)). This RPA was developed through a thoughtful and reasoned analysis of the key causes of the jeopardy and adverse modification findings, and a consideration of alternative actions within the legal authority of Reclamation and DWR to alleviate those stressors. NMFS has worked closely with Reclamation and DWR staff and greatly appreciates the expertise contributed by these agencies.

Because this complex action takes place in a highly altered landscape subject to many environmental stresses, it has been difficult to formulate an RPA that is likely to avoid jeopardy to all listed species and meets all regulatory requirements. As detailed in this Opinion, the current status of the affected species is precarious, and future activities and conditions not within the control of Reclamation or DWR are likely to place substantial stress on the species. NMFS initially attempted to devise an RPA for each species and its critical habitat solely by modifying project operations (*e.g.*, timing/magnitude of releases from dams, closure of operable gates and barriers, and reductions in negative flows). In some cases, however, simply altering project operations was not sufficient to ensure that the projects were likely to avoid jeopardizing the species or adversely modifying critical habitat.

Consequently, NMFS developed focused actions designed to compensate for a particular stressor, considering the full range of authorities that Reclamation and DWR may use to implement these actions. These authorities are substantial. The CVPIA, in particular, provides Reclamation with ample authority to provide benefits for fish and wildlife through measures such as purchasing water to augment in-stream flow, implementing habitat restoration projects, and taking other beneficial actions (Cummins *et al.,* 2008). Some RPA actions, therefore, call for restoring habitat or providing fish passage above dams, even though the water projects are not directly responsible for the impaired habitat or the blocked passage.

NMFS concentrated on actions that have the highest likelihood of alleviating the stressors with the most significant effects on the species, rather than attempting to address every project stressor for each species or every PCE for critical habitat. For example, water temperatures lethal to incubating eggs often occur when the air is warm and flows are low. Fish cannot reach spawning habitat with colder water at higher elevations if it is above currently impassable dams. Accordingly, NMFS' near-term measures provide suitable water temperatures below dams in a higher percentage of years, and long-term measures provide passage to cooler habitat above dams as soon as practicable. Reducing egg mortality from high water temperatures is a critical step in slowing or halting the decline of Central Valley salmonids.

The effects analysis in this Opinion explains that the adverse effects of the proposed action on listed anadromous fish and their critical habitats are both direct and indirect. The USFWS stated in its biological opinion on effects of the projects on Delta smelt that in addition to direct adverse effects such as entrainment at the pumps, the water projects have affected smelt "by creating an altered environment in the Delta that has fostered both the establishment of non-indigenous species and habitat conditions that exacerbate their adverse influence on delta smelt population dynamics." (USFWS 2008a, p. 189) Similarly, NMFS concludes that the water projects have both directly altered the hydrodynamics of the Sacramento-San Joaquin River basins and have interacted with other activities affecting the Delta to create an altered environment that adversely influences salmonid and green sturgeon population dynamics. The altered environment includes changes in habitat formation, species composition, and water quality, among others. Consequently, NMFS must take a broad view of the ways in which the project agencies can improve the ecosystem to ameliorate the effects of their actions.

There are several ways in which water operations adversely affect listed species that are addressed in this RPA. We summarize the most significant here:

1) Water operations result in elevated water temperatures that have lethal and sub-lethal effects on egg incubation and juvenile rearing in the upper Sacramento River. The immediate operational cause is lack of sufficient cold water in storage to allow for cold water releases to reduce downstream temperatures at critical times and meet other project demands. This elevated temperature effect is particularly pronounced in the Upper Sacramento for winter-run and main-stem spring-run, and in the American River for steelhead. The RPA includes a new year-round storage and temperature management program for Shasta Reservoir and the Upper Sacramento River, as well as long-term passage prescriptions at Shasta Dam and re-introduction of winter-run into its native habitat in the McCloud and/or Upper Sacramento rivers.

2) In Clear Creek, recent project operations have led to increased abundance of Clear Creek spring-run, which is an essential population for the short-term and long-term survival of the species. Nonetheless, in the proposed action, continuation of these operations is uncertain. The RPA ensures that essential flows and temperatures for holding, egg incubation and juvenile survival will be maintained.

3) Red Bluff Diversion Dam (RBDD) on the Sacramento River impedes both upstream migration of adult fish to spawning habitat and downstream migration of juveniles. Effects are significant for winter-run and spring-run, but are particularly pronounced for green sturgeon and its proposed critical habitat in that a significant portion of the population is blocked from its spawning and holding habitat. The RPA mandates gate openings at critical times in the short term while an alternative pumping plant is built, and, by 2012, opening of the gates all year.

4) Both project and non-project effects have led to a significant reduction in necessary juvenile rearing habitat in the Sacramento River Basin and Delta. The project's flood control operations result in adverse effects through reduced frequency and magnitude of inundation of rearing habitat. To minimize these effects, the RPA contains both short-term and long-term actions for improving juvenile rearing habitat in the Lower Sacramento River and northern Delta.

5) Another major effect of water operations is diversion of out-migrating juveniles from the north Delta tributaries into the interior Delta through the open DCC gates. Instead of migrating directly to the outer estuary and then to sea, these juveniles are caught in the interior Delta and subjected to pollution, predators, and altered food webs that cause either direct mortality or impaired growth. The RPA mandates additional gate closures to minimize these adverse effects to winter-run, spring-run, and steelhead.

6) Similarly, water pumping causes reverse flows, leading to loss of juveniles migrating out from the Sacramento River system in the interior Delta and more juveniles being exposed to the State and Federal pumps, where they are salvaged at the facilities. The RPA prescribes Old and Middle River flow levels to reduce the number of juveniles exposed to the export facilities and prescribes additional measures at the facilities themselves to increase survival of fish.

7) The effects analysis shows that juvenile steelhead migrating out from the San Joaquin River Basin have a particularly high rate of loss due to both project and non-project related stressors. The RPA mandates additional measures to improve survival of San Joaquin steelhead smolts, including both increased San Joaquin River flows and export curtailments. Given the uncertainty of the relationship between flow and exports, the RPA also prescribes a significant new study of acoustic tagged fish in the San Joaquin Basin to evaluate the effectiveness of the RPA and refine it over the lifetime of the project.

8) On the American River, project-related effects on steelhead are pronounced due to the inability to consistently provide suitable temperatures for various life stages and flow-related effects caused by operations. The RPA prescribes a flow management standard, a temperature management plan, additional technological fixes to temperature control structures, and, in the long term, a passage at Nimbus and Folsom Dams to restore steelhead to native habitat.

9) On the Stanislaus River, project operations have led to significant degradation of floodplain and rearing habitat for steelhead. Low flows also distort cues associated with out-migration. The RPA proposes a year-round flow regime necessary to minimize project effects to each life-stage of steelhead, including new spring flows that will support rearing habitat formation and inundation, and will create pulses that cue out-migration.

10) Nimbus Fish Hatchery steelhead program contribute to both loss of genetic diversity and mixing of wild and hatchery stocks of steelhead, which reduces the viability of wild stocks. The Nimbus and Trinity River Hatchery programs for non-listed Fall-run Chinook also contribute to a loss of genetic diversity, and therefore, viability, for Fall-run. The RPA requires development of Hatchery Genetics Management Plans to improve genetic diversity of both steelhead and fall-run Chinook, an essential prey base of Southern Resident Killer Whale.

This RPA is composed of numerous elements for each of the various project divisions and associated stressors and must be implemented in its entirety in order to avoid jeopardy and adverse modification. There are several actions that allow the project agencies options for alleviating a particular stressor. Reclamation and DWR may select the option they deem most practical — NMFS cares only that the stressor be sufficiently reduced. There are several actions in which NMFS expressly solicits additional research and suggestions from the project agencies for alternative actions to achieve needed results.

NMFS recognizes that the RPA must be an alternative that is likely to avoid jeopardizing listed species or adversely modifying their critical habitats, rather than a plan that will achieve recovery. Both the jeopardy and adverse modification standards, however, include consideration of effects on an action on listed species' chances of recovery. NMFS believes that the RPA does not reduce the likelihood of recovery for any of the listed species. The RPA cannot and does not, however, include all steps that would be necessary to achieve recovery. NMFS is mindful of potential social and economic consequences of reducing water deliveries and has carefully avoided prescribing measures that are not necessary to meet section 7 requirements.

An RPA must avoid jeopardy to listed species in the short term, as well as the long term. Essential short-term actions are presented for each division and are summarized for each species to ensure that the likelihood of survival and recovery is not appreciably reduced in the short term (*i.e.*, one to five years). In addition, because the proposed action is operation of the CVP/SWP until 2030, this consultation also includes long-term actions that are necessary to address project-related adverse effects on the likelihood of survival and recovery of the species over the next two decades.

Some of these long-term actions will require evaluation, planning, permitting, and funding. These include:

1) Providing fish passage at Shasta, Nimbus, and Folsom Dams, which ultimately is the only means of counteracting the loss of habitat needed for egg incubation and emergence, and steelhead over-summering habitat at lower elevations. This habitat loss has already occurred and will be exacerbated by climate change and increased water demands.

2) Providing adequate rearing habitat on the lower Sacramento River and Yolo Bypass through alteration of operations, weirs, and restoration projects.

3) Engineering projects to further reduce hydrologic effects and indirect loss of juveniles in the interior Delta.

4) Technological modifications to improve temperature management in Folsom Reservoir.

NMFS considered economic and technological feasibility in several ways when developing initial actions in this RPA. The RPA also allows for tailored implementation of many actions in consideration of economic and technological feasibility without compromising the RPA's effectiveness in avoiding jeopardy and adverse modification of critical habitat. Examples include:

1) Providing reasonable time to develop technologically feasible alternatives where none are "ready to go" – *e.g.*, the Delta engineering action (Action IV.1.3), and lower Sacramento River rearing habitat action (Action I.6.1).

2) Calling for a stepped approach to fish passage at dams, including studies and pilot projects, prior to a significant commitment of resources to build a ladder or invest in a permanent trap and haul program.

3) Providing a health and safety exception for export curtailments.

4) Using monitoring for species presence to initiate actions when most needed.

NMFS examined water supply costs of the RPA as one aspect of considering economic feasibility. While only costs to the action agency are considered in determining whether a RPA meets the regulatory requirement of economic feasibility, NMFS is mindful of potential social and economic costs to the people and communities that historically have depended on the Delta for their water supply. Any water supply impact is undesirable. NMFS made many attempts through the iterative consultation process to avoid developing RPA actions that would result in high water costs, while still providing for the survival and recovery of listed species.

NMFS estimates the water costs associated with the RPA to be 5-7% of average annual combined exports: 5% for CVP, or 130 TAF/year, and 7% for SWP, or 200 TAF/year[1]. The combined estimated annual average export curtailment is 330 TAF/year. These estimates are over and above export curtailments associated with the FWS Smelt Opinion. The Old and Middle River flow restrictions in both Opinions tend to result in export curtailments of similar quantities at similar times of year. Therefore, in general, these 330 TAF export curtailments are associated with the NMFS San Joaquin River Ratio actions in the RPA. These water costs can be offset by application of CVPIA (b)(2) water resources, water conservation, groundwater use, water recycling and other processes currently underway.

The RPA includes collaborative research to enhance scientific understanding of the species and ecosystems, and to adapt actions to new scientific knowledge. This adaptive structure is important, given the long-term nature of the consultation and the scientific uncertainty inherent in a highly variable system. Monitoring and adaptive management are both built into many of the individual actions and are the subject of an annual program review. NMFS views both the CALFED Science Program and the NMFS Southwest Fisheries Science Center as essential partners in ensuring that the best scientific experts are brought together to assess the implementation and effectiveness of actions in this RPA. We will continue to pursue many of the long-term recommendations for improving science as recommended by the CALFED and CIE peer reviews, and we will seek to incorporate this new science as it becomes available through the adaptive management processes embedded in the RPA.

Finally, we note that the project agencies are currently developing and evaluating a plan to construct a diversion on the Sacramento River and a canal around the Delta, in the BDCP planning effort. Such a reconfiguration of the water conveyance system would take careful planning to avoid jeopardizing Sacramento River and north Delta species, as well as several years of environmental review and permitting, and would trigger a re-initiation of this Opinion. We expect that the collaborative research that is part of this RPA will inform this planning effort as it proceeds.

[1] The proportional share between the CVP and SWP is attributable to CalLite programming and may not represent the true share of export reductions that would be allocated to each facility under actual conditions.

Overview of Sacramento-San Joaquin River Delta Water Quality Issues

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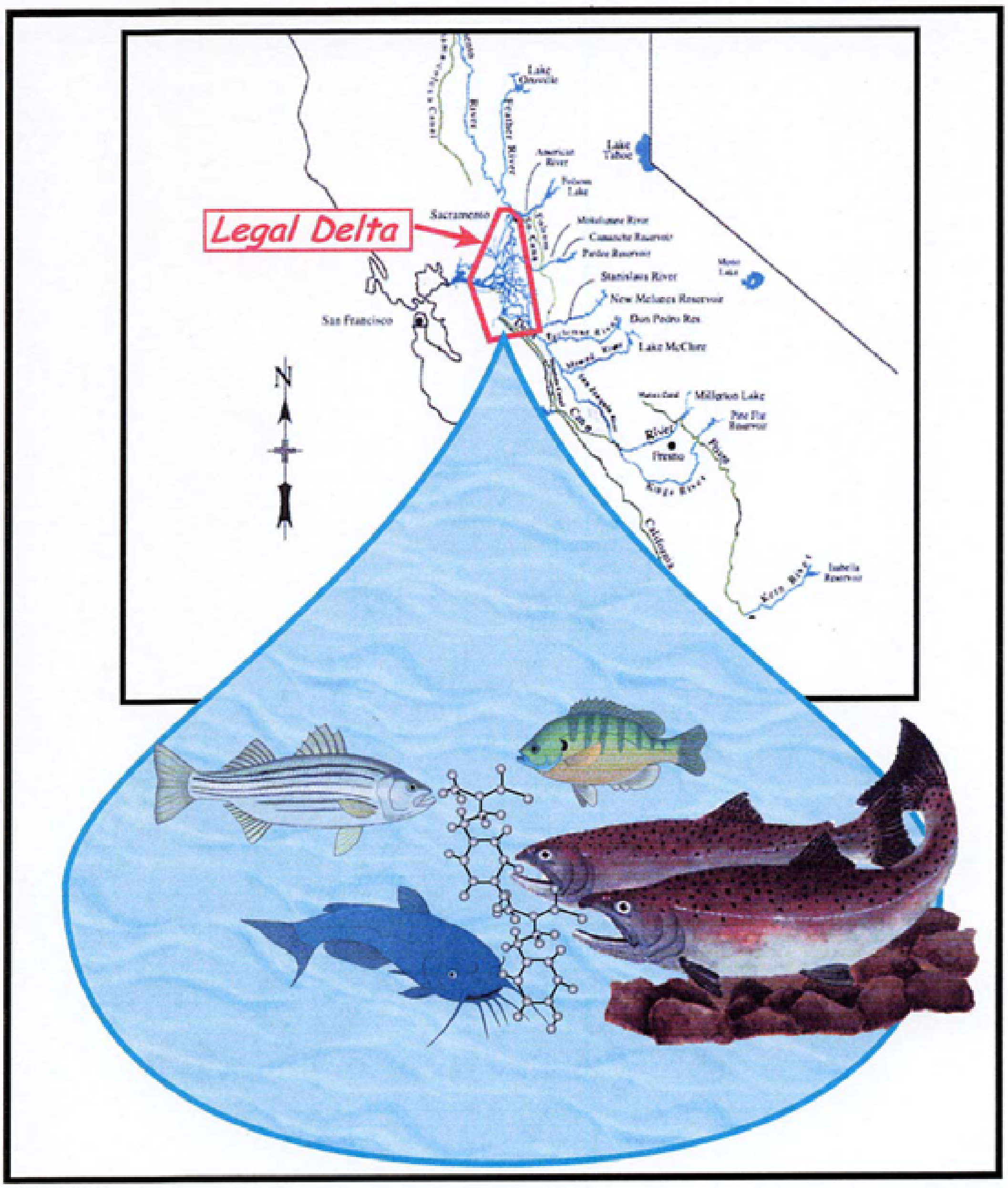


Adapted in part from images in SJRGA (2000)

June 22, 2004

Background on Report Development and Source of Additional Information

This report was originally develop as,

Lee, G. F. and Jones-Lee, A., "Overview of Sacramento-San Joaquin River Delta Water Quality Issues," Report of G. Fred Lee & Associates, El Macero, CA (2004). http://www.gfredlee.com/SJR-Delta/Delta-WQ-IssuesRpt.pdf

Subsequently it was presented in part with updated information as,

Lee, G. F., and Jones-Lee, A., "Overview—Sacramento/San Joaquin Delta Water Quality," Presented at CA/NV AWWA Fall Conference, Sacramento, CA, PowerPoint Slides, G. Fred Lee & Associates, El Macero, CA, October (2007). http://www.gfredlee.com/SJR-Delta/DeltaWQCANVAWWAOct07.pdf

Drs, G. Fred Lee and Anne Jones-Lee have developed several other reviews on Delta water quality issues. These reviews are available on their website www.gfredlee.com at http://www.gfredlee.com/psjriv2.htm.

Also a comprehensive review of Delta water quality issues was presented in their Stormwater Runoff Water Quality Newsletter, Volume 10 Numbers 10 & 11, October 18, 2007 Topic: Water Resource and Quality Crisis Issues in Sacramento San Joaquin Delta, CA available at, http://www.gfredlee/Newsletter/swnewsV10N10-11.pdf

The 2003 *CWA 303 (d) list that was used as the basis for this report is no longer on the SWRCB website.. It has been updated at, http://search.ca.gov/search?q=303+&output=xml_no_dtd&site=ca_swrcb&client=ca_swrcb&proxystylesheet=ca_swrcb)* .

Updated information on the current 303 (d) list is available in, http://www.gfredlee.com/SJR-delta/DeltaWQCANVAWWAOct07.pdf

Over the past approximately 10 years we have served as a volunteer technical resource to William Jennings on Delta and Delta tributary water quality management issues. Through discussions with William Jennings (DeltaKeeper) we have gained considerable insight into Delta water quality problems and issues that need to be addressed to manage these problems. This report has been prepared in support of the DeltaKeeper's efforts to improve and protect the Sacramento-San Joaquin River Delta water quality-beneficial uses.

Appendix D presents a summary of our background and expertise, which serves as a technical base for the development of this report.

Acknowledgments

We wish to thank all of those who took time to discuss with us, write about, organize conferences and workshops, and make presentations on Delta water quality issues, which has served as a basis for much of the information presented in this report.

William Jennings, Chair of the California Sportfishing Protection Alliance (CalSPA), arranged for our financial support during 1999 through 2001 from CalSPA litigation settlements with the cities of Turlock and Manteca, to serve as a technical resource to the San Joaquin River Deep Water Ship Channel DO TMDL Steering Committee. DeltaKeeper (William Jennings) also provided support through making a DeltaKeeper boat, boat crew and staff biologist Kari Burr available to conduct sampling tours of the Central and South Delta during the summer 2003. William Jennings has served as a significant source of information that has stimulated the development of this report.

The city of Stockton provided financial support during 2000 and 2001 which enabled G. F. Lee to serve as Chair of the Technical Advisory Committee for the SJR DO TMDL Steering Committee. CALFED provided support for G. F. Lee to serve as the coordinating PI for the Low-DO Directed Action Project during 2001, 2002 and 2003. We wish to thank the SJR DO TMDL Steering Committee for support of our work on the SJR DO TMDL, which allowed us to expand our understanding of Delta water quality problems. We also wish to acknowledge the efforts of Dr. Chris Foe in helping to educate us on Delta water quality issues. We appreciate the assistance of John Herrick and Alex Hildebrand for information on South Delta characteristics, and Curtis Creel and other DWR staff on Delta flow information.

We thank Barbara Marcotte, Sam Harader and Donna Podger of the CBDA staff for their assistance as a source of information and for their support of our activities. CALFED/CBDA Science Program's workshops and seminars where discussions were presented on issues related to Delta water quality have been an important source of information that is included in this review.

A draft of this report on Delta Water Quality Issues was made available to over 200 individuals to provide an opportunity for review and comments. Appropriate comments were included in the final version. This report is planned to be a living report of Delta water quality issues, where we plan to release addenda as additional information is developed.

The financial support for developing this report was primarily provided by Drs. G. Fred Lee and Anne Jones-Lee as part of their professional career-long efforts devoted to improving the quality of science and engineering used in water quality management.

G. Fred Lee, PhD, DEE and Anne Jones-Lee, PhD

Abstract

The Sacramento-San Joaquin River Delta is a unique and valuable resource and an integral part of California's water system. It is a tidal freshwater system, which receives runoff from over 40 percent of the State's area, including the Sacramento River and San Joaquin River watersheds. It covers 738,000 acres with hundreds of miles of interlaced waterways. Its land and waterways support communities, agriculture and recreation, and provide essential habitat for wildlife. The Delta also serves as a water supply source for about 23 million people in California. The legal Delta extends northward to just upstream of the city of Sacramento, eastward into the city of Stockton, southward to Vernalis, and westward to Chipps Island just downstream of Pittsburg (DWR, 1995).

Delta waters have been found to contain sufficient concentrations of various pollutants to be in violation of water quality objectives, and hence experience legal, as well as actual, impairments of beneficial uses. These violations of the US EPA Clean Water Act have led to the need to develop Total Maximum Daily Load (TMDL) programs in an effort to control the input of these pollutants from their sources, which include municipal, domestic, industrial and agricultural wastewater and stormwater.

For example, the water quality/beneficial use of Delta waters is impaired by excessive bioaccumulation in fish of organochlorine "legacy" pesticides (DDT, chlordane, dieldrin, etc.), PCBs, dioxins/furans, and mercury that is a threat to the health of those who use some types of Delta fish as food. Organophosphorus-based pesticides used in agriculture, such as diazinon and chlorpyrifos, are causing aquatic life toxicity to fish food organisms in the Delta. Further, pyrethroid-based pesticides are being found in aquatic sediments downstream of agricultural fields where these pesticides have been used. Some of those sediments have been found to be toxic to sediment organisms. Herbicides used to control roadside and other vegetation have been found to be present in Delta waters at sufficient concentrations to be toxic to algae. Also, Delta waters have been found to be toxic to aquatic life due to unidentified substances (i.e., exhibit toxicity of unknown cause). The current US EPA and California Department of Pesticide Regulation registration of pesticides does not ensure that following label restrictions for the use of a pesticide will prevent aquatic life toxicity in waters receiving runoff/discharges from areas of pesticide use.

An issue that is not being considered in regulating pesticides/herbicides in the Delta and elsewhere is the potential additive and synergistic toxicity of multiple pesticides and/or the interaction of pesticides with other chemicals in the water. Such interactions could cause adverse impacts to Delta aquatic life without there being an exceedance of current water quality objectives for the individual regulated pesticides.

Delta waters contain sufficient concentrations of total organic carbon (TOC) and nutrients (nitrogen and phosphorus compounds) to cause those water utilities that use Delta water as a domestic water supply source to have to provide additional treatment, at additional cost, to control excessive trihalomethanes (THMs) (carcinogens) in the treated waters. The nutrients in Delta waters stimulate algal growth which causes tastes and odors in the water supply.

The total salts (TDS/EC) in the San Joaquin River (SJR) as it enters the South Delta via Old River are at times in violation of the South Delta TDS/EC water quality objective (WQO). Several of the South Delta channels, such as Old River, Middle River and Grant Line Canal, have excessive levels of TDS/EC compared to water quality objectives. This situation has important and restrictive implications for South Delta agriculture. Further, the level of total salts in Delta waters restricts the ability of water management agencies to recharge domestic wastewaters to groundwater as part of wastewater reuse.

The nutrients in Delta waters cause excessive growths of water weeds such as water hyacinth that interfere with recreational use of Delta waters for boating, swimming, and water skiing. Further, the nutrients cause the growth of algae and aquatic weeds in Delta and Delta tributary waters that are used as agricultural water supply. Such growth requires the use of aquatic herbicides to prevent problems with water transport and the plugging of screens on irrigation canals and drip irrigation systems. There is concern about the toxicity of the aquatic herbicides to non-target aquatic life in the Delta and Delta tributary waters. The California State Water Resources Control Board (SWRCB) recently adopted a water quality order for a statewide general NPDES (National Pollutant Discharge and Elimination System) permit for the discharge of aquatic pesticides used for aquatic weed control. However, this permitting framework does not provide adequate protection of non-target organisms from toxicity caused by the aquatic pesticides alone or in combination with other chemicals in the water.

Excessive growth of algae in the San Joaquin River watershed waters and the South Delta channels also contribute to the problems of low dissolved oxygen in these waters. The decomposition of dead algae creates sufficient oxygen demand to cause or significantly contribute to violations of dissolved oxygen (DO) water quality objectives. At times the DO depletion is sufficient to cause fish kills. The export of South Delta water at the federal and state project pumps at Tracy and Banks greatly aggravates the low dissolved oxygen problem in the San Joaquin River (SJR) Deep Water Ship Channel (DWSC). Also, the export pumps at Tracy and Banks have altered the flow of South Delta channels so that low-DO problems and excessive salts are encountered in some of those channels as well. Another source of oxygen demand at times is the ammonia that is discharged in the city of Stockton domestic wastewater. This discharge to the SJR just upstream of the DWSC is a major source of oxygen demand that leads to low DO in the DWSC. The ammonia in the city of Stockton's wastewater discharges also has the potential to be toxic to aquatic life in the DWSC.

The fisheries and other aquatic life resources of the Delta have declined significantly over the past 20 years. This decline appears to be related to entrainment of fish at the export pumps and to the decline of fish food organisms (phytoplankton and zooplankton) in the Delta aquatic food web. The decline in phytoplankton in some parts of the Delta appears to be caused by the harvesting of algae by invasive species such as clams. The decline in zooplankton could be caused, in part, by aquatic life toxicity. The Delta water export projects may also contribute to these declines by drawing large amounts of low-nutrient Sacramento River water to the South Delta.

There is a lack of information on the significance of Delta sediments in causing aquatic life toxicity and contributing to excessive bioaccumulation of chemicals in edible organisms.

The SWRCB's current work toward development of sediment quality objectives should be expanded to cover Delta sediments, in accordance with the Bay Protection and Toxic Cleanup Program requirements.

The sanitary quality of Delta waters has been found to violate water quality objectives for contact recreation such as swimming, water skiing and wading. This means that those who have body contact with Delta waters are at increased risk of contracting disease. The sanitary quality of Delta waters is also of concern to the water utilities that use Delta waters as a water supply. The violations of the sanitary quality WQOs mean that without adequate treatment the use of Delta waters for domestic water supply poses a threat of disease for those who drink the water.

Heavy metals such as mercury, selenium, cadmium and nickel are potentially causing adverse impacts to Delta and San Francisco Bay organisms through food web bioaccumulation.

There is a variety of other potentially hazardous and deleterious chemicals discharged to Delta tributaries and the Delta channels. Several of the Delta tributaries are listed as 303(d) impaired due to heavy metals from former mining activities in the Delta watershed. Other hazardous and deleterious chemicals enter Delta tributaries and Delta channels via domestic and commercial wastewater discharges and stormwater runoff from Stockton, Tracy, Manteca, Sacramento, West Sacramento, etc., and from agricultural activities. These potentially hazardous and deleterious chemicals include pharmaceuticals and personal care products (PPCPs), pesticides, endocrine disruptors, etc., that have not been evaluated with respect to their impacts on Delta water beneficial uses. Further, current regulatory approaches do not adequately address the additive and synergistic impacts of multiple stressors on aquatic life and other beneficial uses of waterbodies.

There is also need for a more systematic and comprehensive approach to the examination of Delta waters and wastes discharged to the Delta for their implications for public health and aquatic life. The recent finding of perchlorate as a widespread water pollutant which is toxic to humans is an example of the inadequate approach for investigating potentially hazardous chemicals in water. Further, the finding of the polybrominated diphenyl ethers (PBDEs) (which bioaccumulate) as water contaminants in San Francisco Bay aquatic life demonstrates the inadequacy of the current approach for the protection of water quality. While both perchlorate and PBDEs have been in the aquatic environment for many years, they have only recently been discovered there.

The Delta water monitoring program associated with the State Water Resources Control Board (SWRCB) D-1641 water rights decision allowing Delta water export via the State Water Project (SWP) to Central and Southern California is substantially deficient compared to that which is needed to properly evaluate the impact of the water exports from the South Delta via the federal (Central Valley Project – CVP) and state export projects on Delta water quality-beneficial uses. Inadequate attention has been given to the water quality impacts of San Joaquin River water exports and the large amounts of Sacramento River water and its associated pollutants that are drawn to the South Delta by the federal project pumps at Tracy and the State Water Project pumps at Banks. The current water quality monitoring that focuses on TDS/EC is not an adequate surrogate for defining the full range of important Delta water quality problems.

There is an urgent need to significantly expand Delta water quality monitoring/evaluation to define the magnitude and extent of known and yet-to-be-defined water quality problems. This information is essential to developing water quality management programs to restore Delta water quality that has been degraded due to discharge of pollutants to the Delta channels, and the export of Delta waters by the federal and state projects. The funding for this program should be provided by the water exporters, those who discharge potential pollutants to the Delta and its tributaries, and those who use Delta aquatic resources. The current situation where decreasing funding is available for water quality monitoring is strongly contrary to protecting Delta water quality.

Summary of Existing Delta Water Quality Problems

This comprehensive review of the current understanding of Delta water quality issues has been developed in response to increased interest in Sacramento-San Joaquin River Delta water quality because of current South Delta water exports by the federal (Tracy) and state (Banks) water projects and proposed expanded Delta water exports by the State Water Project. This review discusses the currently recognized Delta water quality issues as assessed based on violations of Central Valley Regional Water Quality Control Board (CVRWQCB) Basin Plan water quality objectives (WQOs). These violations have resulted in the listing of Delta channels as US EPA Clean Water Act (CWA) 303(d) impaired. This means that chemicals and pathogen indicator organisms in Delta waters are at least legally impairing the beneficial uses of Delta waters. In accordance with the Clean Water Act, this listing requires that the CVRWQCB conduct TMDL programs to control the WQO violations.

As discussed below, in addition to the exceedances of WQOs, there are several known water quality problems – beneficial use impairments in Delta waters that are not listed by the CVRWQCB, State Water Resources Control Board (SWRCB) or US EPA as 303(d) impairments. These include excessive growth of aquatic weeds due to nutrients, TOC that leads to impairment of the use of Delta waters for domestic water supply, certain heavy metals that are toxic to aquatic life, and sediment accumulation that impairs the uses of Delta waters. These problems are primarily identified through the CVRWQCB Basin Plan "narrative" water quality objectives rather than by exceedances of numeric WQOs. There is need to conduct studies to implement the narrative water quality objectives for these and other constituents that are or potentially are causing beneficial use impairment.

This Delta water quality review also addresses deficiencies in current water quality monitoring programs that impede the ability to properly define the full range of Delta water quality problems-beneficial use impairments as well as to serve as the basis to begin to develop a TMDL program to control the WQO violations. This review also presents a summary of characteristics of current Delta water quality problems and suggests the approach that should be followed to control these problems. The current US EPA Clean Water Act and state of California water quality regulatory approach, which is based on defining violations of water quality standards/objectives and then developing a program to control those violations, fails to address the many thousands of chemicals that are present in urban and industrial wastewaters and stormwater runoff as well as discharges/runoff from agricultural areas, which can be adverse to the water quality-beneficial uses of waterbodies.

Periodically, significant environmental pollutants that have been in the environment for many years are discovered to represent a threat to water quality and/or public health. Two recent examples of this type of pollutant are perchlorate and the polybrominated diphenyl ethers (PBDEs). While these chemicals have been present in wastewaters and ambient waters for many years, they are now being recognized as widespread water pollutants. There are likely many other chemicals of this type which are a threat to water quality through adverse impacts to aquatic life or people who drink the water or who eat fish and other aquatic life derived from waterbodies, but which are not being adequately addressed in water quality evaluation and management programs. The issue of inadequate definition of water pollutants is discussed in more detail below.

Hazardous Chemicals in Edible Fish

A map of the Delta is presented in Figure S1. Various Delta channels/waterways are listed as CWA 303(d) impaired because of the excessive bioaccumulation in fish of mercury, organochlorine "legacy" pesticides (DDT, dieldrin, toxaphene, chlordane, etc.), PCBs, and, near Stockton, dioxins and furans. These organochlorine compounds can cause cancer and neurological damage in humans who eat Delta fish and other organisms that contain elevated levels. The organochlorine pesticides are called "legacy" pesticides because they had been used in agriculture and urban areas but have been banned for use for about 20 years because of their threat to human health. Since these chemicals are highly resistant to degradation in the environment, they are still present in soils and in water sediments downstream of areas where they were applied/used.

Even though excessive bioaccumulation of organochlorine compounds represents one of the most significant water quality problems in the Delta, at this time there are no funds available to the CVRWQCB or other agencies to evaluate the full extent of excessive bioaccumulation of the organochlorine chemicals that accumulate in Delta edible organisms. Further, no funds are available to define current sources of organochlorine hazardous chemicals or to begin to develop programs for control of the excessive bioaccumulation problem in Delta channels and near-Delta tributaries.

Also of concern is the excessive bioaccumulation of mercury in some types of Delta fish. Consuming mercury-contaminated fish can cause neurological damage in unborn and young children. The excessive bioaccumulation of mercury is also a threat to birds that feed on aquatic life. California Bay-Delta Authority (CBDA) is funding research to evaluate mercury bioaccumulation and its control in order to protect the CBDA Ecosystem Restoration Program's development of shallow water habitat to help restore Delta fisheries.

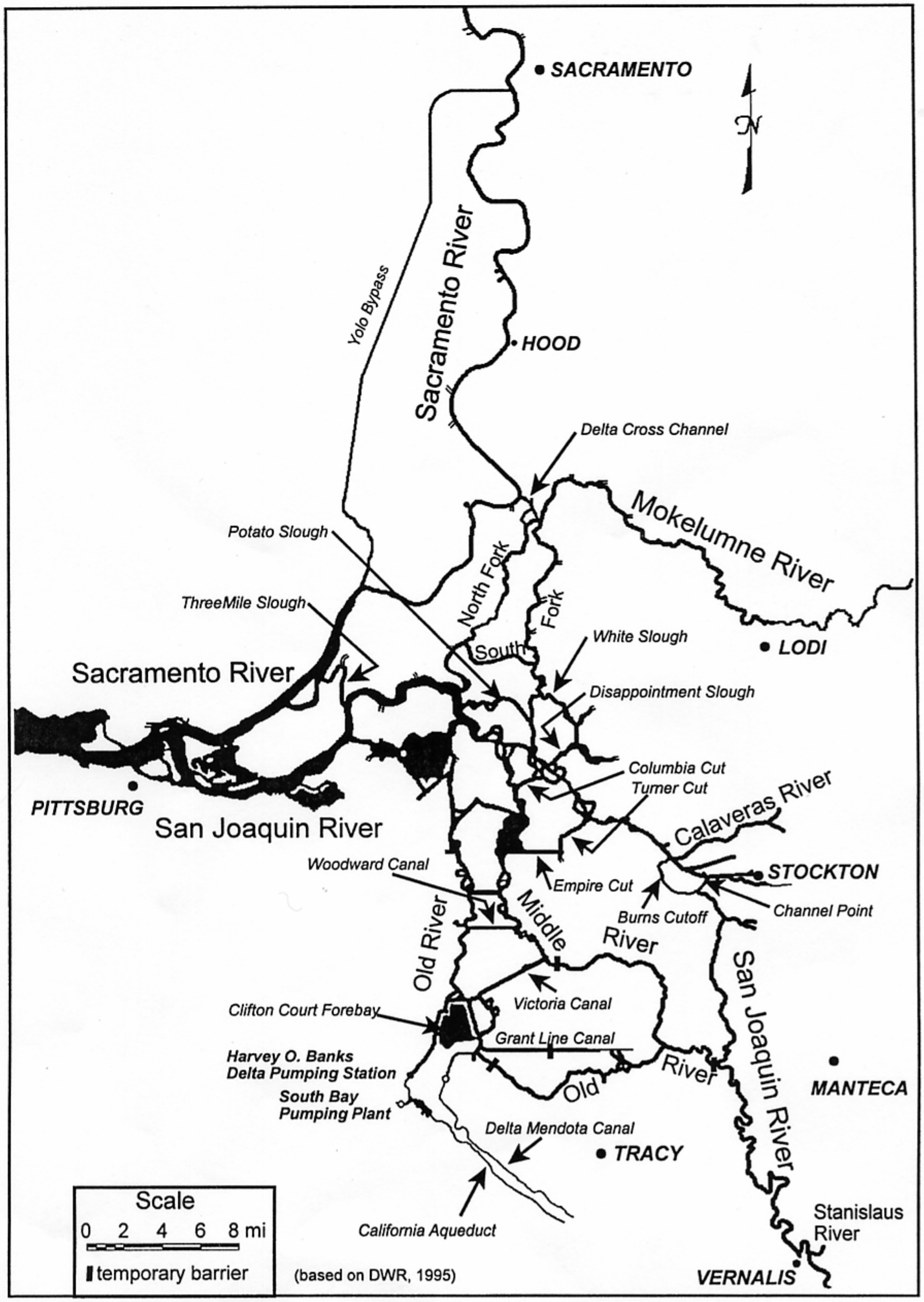
The chemicals that bioaccumulate to excessive levels in edible fish and other organisms tend to be associated with sediments. Therefore, work needs to be done to determine the role of Delta sediment-associated pollutants as a source of hazardous chemicals that bioaccumulate in edible organisms to levels that are a threat to the health of those who use Delta fish as food.

Overall, there are no funds available in CBDA or the State and Regional Water Boards to address several significant the human health problems of bioaccumulation of hazardous chemicals in Delta fish. This is a significant deficiency in the water pollution control programs in the Delta, Central Valley and California.

Toxicity of Currently Used Pesticides

With the banning of the organochlorine pesticides, new pesticides were developed to control agricultural and urban pests. Organophosphorus-based pesticides were developed and have been widely used in agriculture and in urban areas for about 20 years. The most commonly used organophosphorus pesticides are diazinon and chlorpyrifos. While the organophosphorus pesticides are less persistent in the environment than the organochlorine pesticides, they are

Figure S1
Map of the Delta



sufficiently persistent so that runoff from the areas where they have been applied can contain sufficient concentrations to be toxic to aquatic life in the receiving waters for this runoff.

Beginning in the late 1980s the CVRWQCB staff and University of California, Davis (UCD) faculty/staff found that diazinon and chlorpyrifos – two of the most commonly used organophosphorus pesticides – while not highly toxic to fish, are highly toxic to zooplankton (small water animals) that serve as food for young and small fish. This in turn can be detrimental to larger fish that are desirable to fishermen and are important to the Delta aquatic ecosystem. The CVRWQCB staff, with support of the UCD staff, found that waters in many areas of the Central Valley are toxic to zooplankton after organophosphorus pesticide application to agricultural and urban areas.

The presence of zooplankton toxicity in Central Valley waterbodies and Delta channels due to organophosphorus pesticides violates the CVRWQCB Basin Plan WQO controlling aquatic life toxicity. This has led to a CWA 303(d) listing for diazinon- and chlorpyrifos-caused aquatic life toxicity in the Delta channels. It is possible that this toxicity is in part responsible for the decline in the fisheries resources of the Delta. While the CVRWQCB is developing TMDLs to control organophosphorus pesticide toxicity in the Sacramento River and San Joaquin River watersheds, no work is being done to control the diazinon- and chlorpyrifos-caused toxicity in Delta channels. There are insufficient funds to enable the CVRWQCB to initiate work in this area.

With the reduced use of diazinon and chlorpyrifos, pyrethroid-based pesticides are being used increasingly in agricultural and urban areas. Some of these pesticides are as toxic or more toxic to zooplankton than the organophosphorus pesticides, and are also toxic to fish. One important difference between the organophosphorus and pyrethroid pesticides is that the pyrethroid pesticides tend to accumulate in aquatic sediments and are potentially toxic to sediment organisms. These sediment-associated organisms are important as fish food and to the aquatic ecosystem. At this time very little work is being done on investigating pyrethroid pesticide-caused water and sediment toxicity in the Central Valley and the Delta.

The current pesticide registration process used by the US EPA and the California Department of Pesticide Regulation (DPR) allows the use of pesticides that are highly toxic to aquatic organisms without evaluation of whether the pesticide can be present in stormwater runoff and irrigation water discharges at concentrations that are toxic to aquatic life in the receiving waters for the discharges/runoff. This is a significant deficiency in the federal and state of California pesticide registration process. Another deficiency in the current approach used for regulating pesticides is the failure to properly control aquatic life toxicity associated with additive or synergistic interactions among multiple pesticides in the water or between the pesticide and other chemicals in the water. It is well known that the toxicities of the organophosphorus pesticides diazinon and chlorpyrifos are additive. There is recent evidence that the combination of organophosphorus pesticides with triazine herbicides in water has a synergistic effect on aquatic life toxicity – i.e., the magnitude of the toxicity found is greater than the sum of the toxicities of the pesticide and herbicide. Additive or synergistic toxicity could lead to situations in which a pesticide could be present in concentrations below a water quality objective, yet be causing toxicity to aquatic life through interactions with other pesticides and/or other chemicals.

Sediment Toxicity

Organisms that live in or on aquatic sediments are important to the aquatic food web. A variety of chemicals can cause aquatic sediments to be toxic to aquatic organisms. While Delta sediments are known to contain several potential pollutants (heavy metals and organics) that have the potential to be toxic to aquatic life, there is limited information on the occurrence of toxicity in Delta sediments. This is an area that needs attention to determine where Delta sediments are toxic, and where toxic, the cause of the toxicity. This information is required to begin to remediate the polluted Delta sediments and to control the input of pollutants that accumulate in Delta sediments and cause the sediments to be toxic.

There is need to develop reliable sediment quality objectives to regulate real, significant water quality problems caused by sediment-associated pollutants. Recently the SWRCB staff responsible for developing sediment quality objectives has indicated that it has abandoned trying to use chemical concentration-based objectives in favor of a weight-of-evidence (WOE) approach. The WOE approach involves an integrated use of aquatic life toxicity, organism assemblage and appropriate chemical information to evaluate water quality impairment and causes, and remediation of the impairment. Sediment quality objectives should be based on biological effects, such as aquatic life toxicity, with the toxic substances properly identified through toxicity identification evaluations. Co-occurrence-based approaches, such as those that have been proposed in the past by the SWRCB staff, are well-known to be unreliable for this purpose. Adoption of a WOE approach by the SWRCB will be a significant advance toward properly regulating chemical pollutants in aquatic sediments. One of the major deficiencies of the current SWRCB sediment quality objectives development is the failure to include developing sediment quality objectives (SQOs) for Delta sediments, even though the Bay Protection and Toxic Cleanup Program (BPTCP) requires that SQOs be developed for Delta sediments.

Unknown-Caused Toxicity

Studies by the CVRWQCB staff, UCD Aquatic Toxicology Laboratory staff and others have found that many Central Valley waters, including the Delta, exhibit aquatic life toxicity for which the cause is unknown. The CVRWQCB staff, with support of others, has initiated a program to identify the cause of toxicity in such situations and develop management programs for this toxicity. A draft Strategy for Control of Toxicity of Unknown Cause is under development. This strategy will be used to support a proposal to CBDA to fund the implementation of a control program. Funding of this effort by CBDA would be in accord with the CALFED Record of Decision (ROD) which requires work to control the cause of unknown-caused toxicity in the Delta.

Heavy Metals

Several of the Delta tributaries are listed as 303(d) impaired due to heavy metals from former mining activities in the Delta watershed. Mercury from former Coast Range mercury mining operations and from gold mining operations in the Sierra-Nevada Mountains has been found to bioaccumulate in fish of the Delta and its tributaries. This accumulation is of sufficient magnitude to cause the fish to be hazardous to fetuses and young children when the contaminated fish are eaten by the mother or the child.

Selenium is another metal that is potentially causing water quality problems in the Delta. It bioaccumulates in the Delta food web and is potentially causing adverse impacts to certain higher trophic-level fish, notably sturgeon. This situation could cause even greater restrictions on the discharge of selenium to Delta tributaries in the San Joaquin River watershed than exist today.

There is a potential for food web accumulation of cadmium and nickel that is toxic to aquatic life. The bioaccumulation of these metals, as a cause of aquatic life toxicity, is not regulated under the current US EPA water quality criteria or CVRWQCB Basin Plan water quality objectives.

Some Delta sediments, such as in marinas, have been found to contain elevated concentrations of copper, possibly due to the use of copper in antifoulant paints on boat hulls.

In summary, past mining operations and current sources of heavy metals require that studies be conducted to determine the water quality significance of several heavy metals in Delta and Delta tributary water and sediments.

Drinking Water Quality Problems

From 10,000 to 13,000 cfs of Delta water is exported from the Central and South Delta for use for domestic water supplies in the San Francisco Bay area (Contra Costa and Santa Clara Water Districts) and Southern California (Metropolitan Water District of Southern California), and for agriculture in the Central Valley. About one-half of the exported water is used for domestic water supply. Delta water contains several constituents (TOC, bromide, nutrients and TDS/EC) that cause domestic water supply water quality problems that increase the cost of treatment. Of particular concern are the constituents – notably total organic carbon (TOC) and bromide – that form trihalomethanes (THMs) during water supply disinfection. THMs are chloroform and chloroform-like compounds that are regulated as carcinogens. The TOC is derived from runoff from agricultural and urban areas, wetlands, and Delta island peat soils; terrestrial plants and higher forms of aquatic plants. The bromide is derived from sea water intrusion into the Delta from San Francisco Bay.

The CBDA Drinking Water Subcommittee is developing a drinking water quality management strategy. The CVRWQCB is also reviewing drinking water quality problems in the Delta, associated with developing a Drinking Water Policy. There are major water quality management issues that will need to be addressed as part of developing a technically valid, cost-effective drinking water quality policy for the Delta, such as whether it is more appropriate to try to control TOC in agricultural runoff and urban stormwater and wastewater discharges at the source, or to treat the part of the export waters that are used for domestic water supply purposes to control the TOC/THM problem at the water treatment works.

The total salts (measured as total dissolved solids (TDS) and electrical conductivity (EC)) in Delta waters are of concern to the Southern California drinking water utilities, since elevated

TDS/EC in the water supply restricts the ability of water management agencies to recharge the treated wastewaters to groundwaters for future use as a domestic water supply.

Aquatic plant nutrients (nitrogen and phosphorus compounds) are derived from runoff and discharges from agricultural areas (including dairies and feedlots), wetlands discharges, urban wastewater discharges and stormwater runoff. The nutrients cause excessive growth of algae that cause tastes and odors in drinking water and decrease the length of filter runs for water utilities that use Delta waters as a water supply source. These water quality problems are controlled with increased water treatment at an increased cost. Efforts are being made by water utilities and regulatory agencies to control the constituents responsible for such impairments at their sources in the watershed. This could lead to significantly increased of cost of pollution control to agricultural and urban interests in the Delta watershed.

Impact of Salts on Agriculture in the South Delta

The San Joaquin River water that flows into the South Delta via Old River at times contains sufficient salts (TDS/EC) to cause violations of the CVRWQCB Basin Plan water quality objective for TDS/EC for the South Delta channels. The first phase of the currently proposed CVRWQCB Basin Plan Amendment to limit TDS discharges to the SJR upstream of Vernalis will not address this problem since the TDS/EC TMDL target that has been proposed by the CVRWQCB staff is the TDS/EC WQO for the South Delta channels. This means that South Delta irrigated agriculture tailwater discharges to the South Delta channels will at times cause violations of the WQO. These violations will be the result of the high salt loads to the Delta via the SJR that currently occur and are proposed to be allowed by the CVRWQCB as part of the initial phase of the San Joaquin River TDS/EC TMDL. There is need to control the TDS/EC discharges in the SJR watershed to a greater degree than that proposed by the CVRWQCB, so that the SJR waters that enter the South Delta will not be in violation of TDS/EC WQOs and will be suitable to South Delta agriculture that does not impair crop production and restrict tailwater discharges..

Nutrient Impact on Delta Aquatic Resources and Agricultural Water Supplies

Delta waters experience excessive growths of aquatic plants such as water hyacinth and *Egeria densa*. These water weeds interfere with recreational use of Delta waters for boating, swimming, water skiing, fishing, etc. The water weeds develop on nutrients added to Delta tributaries from urban, agricultural and wetlands sources in the Delta watershed, and from Delta island discharges. The California Department of Boating and Waterways spends several hundred thousand dollars per year to apply chemicals for controlling water weeds. There is concern about the potential toxic and other impacts of these chemicals on non-target organisms, such as fish food organisms, in the water column and sediments.

The excessive nutrients in Delta, Delta tributary and Delta export waters lead to the growth of sufficient algae and other aquatic plants to interfere with the transport of the waters in irrigation systems, including canals, by Delta watershed and in-Delta irrigation districts. The algae and water weeds plug irrigation system screens and drip-irrigation systems. Many irrigation districts treat these waters with herbicides to prevent aquatic plant growth in the irrigation water supply system. There is concern that the herbicides are toxic to non-target organisms and thereby impair aquatic life resources of the waters receiving the irrigation waters.

While, in the past, irrigation districts could apply aquatic herbicides without evaluating the potential for adverse impacts on non-target organisms, the SWRCB has been developing a permit system that could require monitoring of the treatment area for adverse impacts to aquatic resources in the area of treatment and downstream. However, the recently adopted Statewide General NPDES permit for application of aquatic herbicides falls short of providing adequate protection of non-target organisms from toxicity impacts of herbicides. It is essential that the NPDES permit covering aquatic herbicide application include comprehensive aquatic life toxicity testing and bioassessments to determine if the herbicides used and their transformation products, either alone or in combination with other chemicals in the water through additive or synergistic effects, are adverse to non-target organisms.

Low Dissolved Oxygen Problems

The nutrient-rich waters of the SJR upstream of the Deep Water Ship Channel (DWSC) lead to the development of sufficient algae in the SJR as it enters the DWSC to be a major contributor of oxygen demand that leads to the low-DO problem in the DWSC. The algae in the SJR do not cause low-DO water quality problems in the SJR upstream of the DWSC. However, the decomposition of algae that die in the DWSC is at times a major cause of oxygen depletion there which causes DO concentrations to fall below the WQO.

One of the recently documented problems caused by the export of South Delta water by the federal and state projects is the reduction of the flow of the SJR through the Deep Water Ship Channel near Stockton. The export pumping of South Delta water by the federal and state project pumps at Tracy and Banks causes most of the water in the SJR at Vernalis to be drawn into the South Delta via Old River, leaving little of the SJR flow to pass through the DWSC. This diversion of SJR flow into the South Delta is at times a major cause of severe low dissolved oxygen problems in the DWSC. If most of the SJR flow at Vernalis were allowed to pass through the DWSC before being exported to Central and Southern California, there would typically be sufficient flow to reduce/prevent the development of the low-DO problem in the DWSC.

The DeltaKeeper-supported studies conducted by the authors in the summer 2003 on South Delta channels showed severe DO depletion in Old River near the Tracy Boulevard bridge. At the time of the tour of this area on August 5, 2003, a fish kill had just occurred; many thousands of fish were seen floating on the water surface there. Data from DWR's continuous water quality monitoring station in the area of the fish kill showed that the DO there had been at or near zero for about six hours the previous night. Thus, the fish kill was likely due to low DO. A review of the DWR 2003 data obtained for Old River showed that there was a period of about six weeks beginning in late July when the DO in that channel was below the WQO. There were many days when the DO was less than 1.0 mg/L, compared to the 5 mg/L WQO. Similar situations have been recorded in that channel and some other South Delta channels over the past three years, and likely occurred before then as well. The severe low-DO problems in some of the South Delta channels are apparently the result of the decay of excessive algal growths.

The DeltaKeeper also supported two tours by the authors of Central Delta channels during the summer 2003 to investigate the mixing of Sacramento River water with San Joaquin River water that is present in the Deep Water Ship Channel. The SJR DWSC water enters the

Central Delta through Turner Cut and Columbia Cut where it mixes with Sacramento River water that is drawn to the South Delta via Middle River by the state and federal export projects. This mixing of Sacramento River water with SJR water in Turner Cut dilutes the oxygen demand, EC and other pollutants in the SJR DWSC waters, and thereby reduces the impact of introduction of SJR DWSC water into the Central Delta on Central Delta water quality. This is important because it means that the increased flow of the SJR through the DWSC which has been proposed as a means to help solve the low-DO problem will not in general have adverse impacts on Central Delta water quality. There may, however, be adverse impacts under certain flow and seasonal conditions. Specific studies need to be conducted to evaluate this situation.

Another major source of oxygen demand in the DWSC is the ammonia in the city of Stockton's domestic wastewater discharges. At times, the ammonia in the City's wastewater discharge to the SJR just upstream of the DWSC represents about 90 percent of the oxygen demand load to the DWSC. Under the revised CVRWQCB NPDES wastewater permit conditions designed to control ammonia toxicity to aquatic life, the city of Stockton's discharge of ammonia will need to be significantly reduced. This reduction will significantly reduce the oxygen demand load of Stockton's wastewater ammonia to the DWSC.

Delta fisheries have been declining over the past 20 years or so. Populations of lower trophic-level fish-food organisms (the zooplankton and phytoplankton that make up the lower level of the food web) have also declined one to two orders of magnitude since the 1980s. While the cause of this decline is not understood, it may be due in part to a decrease in algal populations in the Delta which could be caused by invasive species (Asian clams) that consume algae and zooplankton. Another potential cause of reduced algal growth in the Central Delta is the export pumps' drawing of large amounts of low-nutrient Sacramento River water through the Central Delta to the South Delta. Reductions in the algal input associated with nutrient control in the Delta watershed could lead to further reductions in the lower trophic-level food supply for zooplankton and larval and small fish. There is need to better understand the food web in the Delta to evaluate how manipulation of nutrients and algal loads to the Delta will impact Delta aquatic life resources.

Sediment Oxygen Demand

Studies of the bedded sediment oxygen demand (SOD) of the DWSC sediments have shown that it is not unusually high. It appears that the tidal currents cause the dead algae that would normally settle to the bottom and exert an SOD to be suspended in the water column near the bottom of the channel where the oxygen demand of the particulate matter (principally dead algae) is exerted.

Sanitary Quality of Delta Waters

The sanitary quality indicators in Delta waters have been found in some Delta waters to be in violation of water quality objectives for contact recreation, including swimming, water skiing, wading, etc. Studies on Delta waters have shown that they contain fecal coliforms at concentrations that have been associated with the presence of enteric (intestinal) pathogens (disease-causing organisms). As a result, those who have contact with some Delta waters are exposed to disease organisms that can cause a variety of enteric and other illnesses.

The sanitary quality of Delta waters is also of concern to the water utilities that use Delta waters as a water supply. The violations of the sanitary quality WQOs mean that the use of Delta waters for domestic water supply is a threat to cause diseases in those who drink the water without adequate treatment.

Sediment Accumulation

Some South Delta channels are experiencing shoaling (loss of water depth) due to the accumulation of sediment in the channels. The sediment accumulation is also detrimental to benthic (bottom-dwelling) organisms' habitat. The excessive sediments are apparently derived from erosion of agricultural lands in the watersheds of the westside tributaries of the San Joaquin River. Erosion in the San Joaquin River watershed also causes increased turbidity, which reduces light penetration and algal growth.

Managed Wetlands as a Source of Pollutants

The Delta watershed contains several federal and state wildlife refuges and private migratory waterfowl gun clubs. Many of these areas are managed to produce crops for wildlife. Runoff/discharges from managed wetlands contain several chemical constituents (TOC, salts and nutrients) that impair Delta water quality. As part of its agricultural waiver program, the CVRWQCB is requiring that the owners/managers of managed wetlands investigate the discharge of potential pollutants to Delta tributaries. This could lead to requirements for managing these discharges to protect Delta water quality.

Impact of Invasive Species

The Delta has been polluted by a variety of invasive species, such as the Asian clam, which are significantly adversely impacting the beneficial uses of Delta waters. It appears that the consumption of phytoplankton and zooplankton by this clam could be responsible for at least part of the decline in the lower trophic-level food web in the Delta.

Several types of aquatic plants (such as water hyacinth, *Elodea* and *Egeria densa*) are invasive plant species that are impairing the beneficial uses of Delta waters.

Impact of Export Projects on Chinook Salmon Home Stream Water Signal

The South Delta export projects that have changed the flow of Sacramento and San Joaquin River water through the Delta have also changed the transport of the home stream chemical signal which guides Chinook salmon to their spawning areas. Prior to the export projects, the San Joaquin River tributary home stream water chemical signal could be transported, during low-flow conditions, to San Francisco Bay, providing a home stream signal to fall-run Chinook salmon proceeding to their San Joaquin River tributary home stream. The export-project-caused drawing of large amounts of Sacramento River water to the South Delta has eliminated the San Joaquin River tributary home stream water signals from occurring in the Central and northern Delta, downstream of Columbia Cut. During the summer, fall and early winter the water in the San Joaquin River channel downstream of Columbia Cut is Sacramento River water, not San Joaquin River water. This means that when the fall-run Chinook salmon enter the Delta from San Francisco Bay during the fall and winter they have no home stream water signal to help them migrate through the Delta to their home stream waters.

Inadequate Water Quality Monitoring/Evaluation

As part of SWRCB water rights decision D-1641, several agencies, through the Interagency Ecological Program (IEP), conduct an Environmental Monitoring Program (EMP) that is to provide information on the impacts of Delta water exports to central and Southern California on Delta resources and water quality. A critical review of the IEP EMP shows that it falls short of adequately defining the full range of water quality impacts of the export of Delta water by the federal project (Central Valley Project – CVP) and state project (State Water Project – SWP). These exports are having major adverse impacts on DO concentrations in the SJR Deep Water Ship Channel and in several South Delta channels. They are also causing pollutants – such as mercury; organochlorine, organophosphorus and pyrethroid pesticides; and other pollutants such as TOC and heavy metals – that enter the Delta from tributary and in-Delta sources to be transported to areas of the Delta where they would not occur at the same concentrations if the South Delta exports did not occur.

The large amount of Sacramento River water that flows through the central Delta to the South Delta export pumps significantly changes the flow of water and pollutants in the Delta. For example, mercury present in Sacramento River water is transported to the central and South Delta via the Central Delta Old River and Middle River channels as a result of the export of South Delta water by the projects. This export changes the occurrence of mercury in Delta channels, which potentially impacts the excessive bioaccumulation of mercury in Delta fish. There has been essentially no evaluation of the impact of the export of South Delta waters at the Tracy and Banks pumps on a variety of Delta water quality problems. Particular attention should be given in an expanded monitoring/evaluation program to defining the full impact of the export of Delta waters by the federal and state projects.

There is need for a significant expansion of the water quality monitoring/evaluation program in the Delta. This expanded water quality monitoring should be focused on an evaluation of the current extent and magnitude of the 303(d) impairments in the currently listed Delta channels. Also, where the expanded monitoring/evaluation program shows a water quality use impairment, the sources of the pollutants responsible for the impairment should be defined. This information is essential to begin to develop a TMDL management program for the 303(d)-listed Delta channels.

The Clean Water Act of 1972 required that the US EPA develop a list of the Priority Pollutants and develop water quality criteria for them. The Agency was not given sufficient funding by Congress to accomplish this requirement, and therefore did not meet the congressionally established deadline. Litigation by an environmental group led to an agreement which established 129 Priority Pollutants. The list was developed by attorneys and was not peer-reviewed by the US EPA staff who were experts in this area or by professionals outside the Agency. It is recognized that the Priority Pollutant list did not and does not represent an appropriate listing of the wide variety of chemicals that are a threat to cause water pollution. It is also recognized that the currently regulated pollutants, such as the Priority Pollutants, represent a very small portion of the chemicals that are present in municipal, industrial and agricultural wastewaters and stormwater runoff that are a potential threat to water quality-beneficial uses of waterbodies. Unfortunately, however, the focus of water pollution control programs has been largely devoted to the Priority Pollutants, while ignoring many of the other chemicals used by urban populations, industry and agriculture that are a threat to cause water pollution. For example, more than 150 pesticides are used in the Central Valley, yet fewer than half a dozen receive any regulatory attention by the CVRWQCB. Even though there are significant problems with using the Priority Pollutant list as a primary list of hazardous chemicals of concern in the Delta and discharges to the Delta, there is inadequate monitoring of the Priority Pollutants in Delta waters.

There are more than 22 million organic and inorganic substances, with nearly 6 million commercially available. One hundred thousand of these are produced in large amounts. The current water quality regulatory approach addresses fewer than 200 of these chemicals. Another component of an expanded monitoring/evaluation program for the Delta should include a substantial program for searching for yet-unidentified water quality beneficial use impairments of Delta waters. Where found, the magnitude and extent of the impairment and the source of the pollutants should be defined. In addition to monitoring/evaluating potential water quality problems caused by conventional pollutants and Priority Pollutants, attention should be given to pharmaceuticals and personal care products (PPCPs) and endocrine disruptors that are present in domestic and other wastewaters and stormwater runoff that are discharged to the Delta and its tributaries, especially by the cities of Stockton, Tracy, Sacramento and West Sacramento. Also of potential concern are the wastewater discharges from Modesto, Merced and other San Joaquin River watershed municipalities and agricultural activities.

The PPCPs are a diverse group of chemicals, including human and veterinary drugs that are available over the counter and by prescription, food supplements, consumer chemicals such as fragrances and sunscreen agents, and the wastes from the manufacture of these and other materials. In general PPCPs and many other chemicals are not regulated with respect to causing water quality impairment. With increasing urban population and industrial activities in the Central Valley, there will be increasing significance of PPCPs and other pollutants derived from urban and industrial activities as a cause of water quality problems in the Delta. This is an area that needs attention in a Delta water quality monitoring/evaluation program. Additional information on PPCPs is available at www.epa.gov/nerlesd1/chemistry/pharma/index.htm.

Another significant deficiency in the current regulatory approach in defining water quality problems in the Delta and elsewhere is that chemical impacts are assessed based on individual chemicals without consideration of additive or synergistic effects. It is well established that the aquatic life toxicities of some combinations of pesticides are additive. Further, the toxicity of certain pesticide combinations show synergistic effects – i.e., the toxicity of a mixture of the pesticides is greater than the sum of the toxicities caused by the individual pesticides.

Another area that needs attention in an expanded water quality monitoring/evaluation program is the potential for various chemicals in domestic and commercial wastewater discharges and agricultural and urban stormwater runoff to be adverse to the migration of anadromous fish through the Delta to their home stream waters in the San Joaquin and Sacramento River watersheds. It is known that low concentrations, below those that are known to be toxic to fish and other forms of aquatic life, of a variety of chemicals – such as heavy metals, pesticides, PPCPs, etc. – can adversely impact the olfactory sensitivity and homing ability of anadromous fish such as Chinook salmon. There is need to determine if there are pollutants in Delta waters that are adverse to the homing of anadromous fish.

The funding for an expanded monitoring/evaluation program should be provided by the Delta water exporters, those who discharge wastewaters and contribute stormwater runoff to the Delta and its tributaries, and the users of Delta aquatic resources. The recent cuts in SWRCB water quality monitoring funding should be immediately reversed, and funding should be significantly expanded to cover defining current water quality problems, the sources of the constituents responsible for these problems, and the efficacy of water pollution control programs in controlling these problems, and to define yet-unidentified pollutants in the Delta and its tributaries.

The recently proposed CBDA Delta water exporters' "Delta Improvements Package" (DIP), in which additional Delta water would be exported to Central and Southern California by the State Water Project, is significantly deficient in defining the potential water quality impacts of additional Delta water exports. Before the proposed DIP is implemented with respect to increased Delta water exports, a comprehensive understanding of the current impacts of the existing exports should be developed. This information should then be used to predict the potential impacts of increased Delta water export, in order to provide a technically reliable basis upon which to establish appropriate mitigation measures for the Delta water quality problems caused by the export pumping of Delta water.

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Acronyms and Definitions

In this report, CALFED (California Federal Bay-Delta Program) is used to designate reports/activities prior to the 2003 reorganization and name change to the California Bay-Delta Authority (CBDA).

ac	acre
ac-ft	acre-feet
BOD	biochemical oxygen demand
BPTCP	Bay Protection & Toxic Cleanup Program
CALFED	California Federal Bay-Delta Program (former name of CBDA)
CBDA	California Bay-Delta Authority (formerly CALFED)
cf	cubic feet
cfs	cubic feet per second
CMARP	Comprehensive Monitoring, Assessment and Research Program
Corps/COE	US Army Corps of Engineers
CVP	Central Valley Project (Federal Project)
CVRWQCB	California Regional Water Quality Control Board, Central Valley Region (RWQCB)
CWA	Clean Water Act
DDT	dichlorodiphenyltrichloroethane (legacy pesticide)
DFG	California Department of Fish and Game
DHS	California Department of Health Services
DIP	Delta Improvements Package
DISC	Delta Issues Sub-Committee
DO	dissolved oxygen
DOC	dissolved organic carbon
DPR	California Department of Pesticide Regulation
DWQI	Delta Water Quality Issues (this report)
DWR	California Department of Water Resources
DWSC	Deep Water Ship Channel
EC	electrical conductivity
EMP	Environmental Monitoring Program
ft	feet
ft/sec	feet per second
g	grams
HOR	Head of Old River
IEP	Interagency Ecological Program
IMM	Iron Mountain Mine
lb/day	pounds per day
m^2	square meters
mgd	million gallons per day
mg/Kg	milligrams per kilogram
mg/L	milligrams per liter
mi	miles
MOU	Memorandum of Understanding
MRP	Monitoring Reporting Program

Acronyms (continued)

m/sec	meters per second
µg/L	micrograms per liter
µmhos/cm	micromhos (reciprocal ohms) per centimeter
µS/cm	microsiemens per centimeter
N	nitrogen
NPDES	National Pollutant Discharge Elimination System
O_2	oxygen
OCls	organochlorines, including organochlorine legacy pesticides (DDT, chlordane, dieldrin, toxaphene), PCBs and dioxins/furans
OEHHA	California Office of Environmental Health Hazard Assessment
OP	organophosphorus pesticide
OPP	US EPA Office of Pesticide Programs
P	phosphorus
PBDEs	polybrominated diphenyl ethers
PCBs	polychlorinated biphenyls
PPCPs	pharmaceuticals and personal care products
RMP	Regional Monitoring Program of San Francisco Bay and Estuary
ROD	Record of Decision
RRI	Rough and Ready Island (location of DWR continuous monitoring station)
RTAG	Regional Technical Assistance Group
SFEI	San Francisco Estuary Institute
SFEP	San Francisco Estuary Project
SJR	San Joaquin River
SOD	sediment oxygen demand
sq mi	square miles
SQO	sediment quality objective
storm sewer	Storm sewer is a separate storm drain that carries stormwater runoff from urban areas.
SWAMP	Statewide Ambient Monitoring Program
SWP	State Water Project (State Project)
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
THMs	trihalomethanes
TIEs	toxicity identification evaluations
TMDL	total maximum daily load
TOC	total organic carbon
UCD	University of California, Davis
USBR	US Bureau of Reclamation
US EPA	US Environmental Protection Agency
USGS	US Geological Survey
UVM	ultrasound velocity meter
VAMP	Vernalis Adaptive Management Plan
WOE	weight of evidence
WQC	water quality criteria
WQO	water quality objective

Conversion Factors

To Convert	Multiply By	To Obtain
acres	4.35×10^4	sq. ft.
acre-feet	3.26×10^5	gallons
cu ft/sec	4.49×10^2	gallons/min
feet	3.048×10^1	cm
inches	2.54	cm
miles (statute)	5.28×10^3	ft
miles (statute)	1.609	km
pounds	4.54×10^2	grams
mgd	1.55	cfs

Sacramento-San Joaquin River Delta Water Quality Issues

Introduction

The Sacramento-San Joaquin River Delta is formed by the confluence of the Sacramento and San Joaquin Rivers. It is one of the most important sportfishing and recreational areas in the state of California, yet there is a relatively poor understanding of water quality issues associated with the Delta that could affect the recreational, fishing and other beneficial uses of the Delta. The authors have been involved in investigating and evaluating Sacramento-San Joaquin River Delta water quality issues since 1989. They have found that there is a significant lack of understanding and considerable misinformation on Delta water quality issues. Further, there is little work being done to control the current, well known water quality problems in the Delta. Presented below is a discussion of the water quality issues in the Delta that need to be more adequately defined, through an improved monitoring program, and managed, to restore and protect the beneficial uses of the Delta and its resources. A map of the Delta and its major waterways and tributaries is provided in Figure 1. The legal Delta extends on the north from just upstream of the city of Sacramento, on the east into the city of Stockton, on the south to Vernalis, and on the west to Chipps Island just downstream of Pittsburg (DWR, 1995).

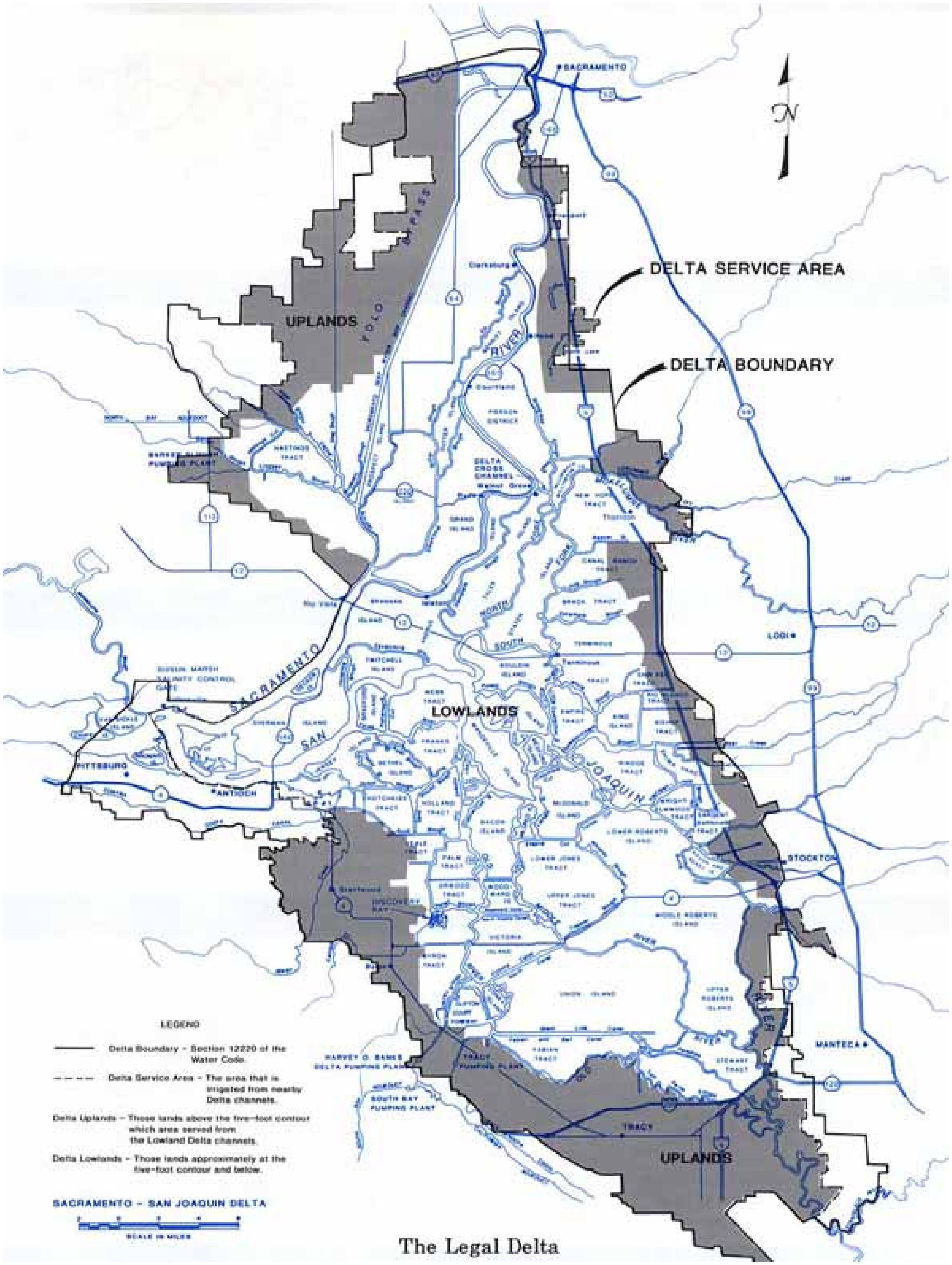
Delta Waterways and Channels 303(d) Listings

In July 2003 the US EPA (2003) Region 9 issued the final 2002 Clean Water Act (CWA) section 303(d) list of water quality limited ("impaired") segments of Central Valley Regional Water Quality Control Board (CVRWQCB) waterbodies. This listing is based on the recommendations of the CVRWQCB and the State Water Resources Control Board (SWRCB), with additions by the US EPA Region 9. The original list is based on information that was available in 2002 and is a source of information that should be used to evaluate some of the existing water quality problems in the Delta. However, it does not reflect all of the water quality problems, since it is dependent on there being a sufficient database of water quality monitoring on each of the Delta channels and tributaries to demonstrate that there have been violations of the CVRWQCB Basin Plan water quality objectives (WQOs) in the waterbody. As discussed below, there has been an inadequate monitoring program conducted on Delta channels and tributaries to determine the full extent of water quality objective violations that occur in the Delta. A summary of Delta waterbody and nearby tributary 303(d) listings as presented 2002 is presented below

Delta Waterways (eastern portion). Delta Waterways (eastern portion) is listed as impaired for chlorpyrifos from agriculture and urban runoff/storm sewers, DDT from agriculture, diazinon from agriculture and urban runoff/storm sewers, Group A pesticides from agriculture, mercury from resource extraction (mining), and unknown toxicity (source unknown). The Group A pesticides are the legacy pesticides that are no longer used, including aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan and toxaphene. All resource extraction sources are abandoned mines.

Delta Waterways (Stockton Ship Channel). Delta Waterways (Stockton Ship Channel) is listed as impaired for chlorpyrifos from agriculture and urban runoff/storm sewers, DDT from agriculture, diazinon from agriculture and urban runoff/storm sewers, Group A pesticides from agriculture, mercury from resource extraction (mining), organic enrichment/low dissolved

Figure 1
Map of the Legal Delta



From Delta Atlas (DWR, 1995)

oxygen from municipal point sources and urban runoff/storm sewers, and unknown toxicity (source unknown).

Stockton Deep Water Channel, Upper (Port Turning Basin) is listed for dioxins from a point source, furans from contaminated sediments, pathogens from urban runoff/storm sewers and recreational and tourism activities (non-boating), and PCBs from an unidentified point source.

Mormon Slough, Commerce Street to Stockton Deep Water Channel, is listed on the 303(d) list as impaired due to organic enrichment/low dissolved oxygen from urban runoff/storm sewers, and pathogens from urban runoff/storm sewers and recreational and tourism activities (non-boating).

Mormon Slough (Stockton Diverting Canal to Commerce Street) is listed for pathogens from urban runoff/storm sewers and recreational and tourism activities (non-boating).

Delta Waterways (western portion). Delta Waterways (western portion) is listed as impaired for chlorpyrifos from agriculture and urban runoff/storm sewers, DDT from agriculture, diazinon from agriculture and urban runoff/storm sewers, electrical conductivity (EC/TDS) from agriculture, Group A pesticides from agriculture, mercury from resource extraction (mining), and unknown toxicity (source unknown). From the information available, the Delta Waterways (western portion) includes the South Delta waterway of Old River. Old River (San Joaquin River to Delta-Mendota Canal) is listed for low dissolved oxygen due to hydromodifications (altered flows) and source unknown.

Middle River (in the South Delta) is listed for low dissolved oxygen due to hydromodifications (altered flows) and source unknown.

CWA 303(d) Listings of near-Delta Tributaries. Listed below are waterbodies that are tributaries to the Delta, which have been listed as 303(d) impaired in the reach that discharges to the Delta. These tributaries, therefore, are likely adding listed and unlisted pollutants to the Delta.

<u>City of Stockton Channels</u>**.** Several of the city of Stockton channels that are connected to the main body of the Delta have their own listing for specific constituents. Five Mile Slough in the city of Stockton is listed for chlorpyrifos from urban runoff/storm sewers, and diazinon from agriculture and urban runoff/storm sewers. The agricultural source of diazinon for this waterbody is indicated as being from aerial deposition. Five Mile Slough is also listed for organic enrichment/low dissolved oxygen from urban runoff/storm sewers and pathogens from other urban runoff and recreational and tourism activities (non-boating).

Mosher Slough downstream of I-5 is listed for chlorpyrifos from urban runoff/storm sewers, diazinon from agriculture and urban runoff/storm sewers (the agricultural source of diazinon for this waterbody is indicated as being from aerial deposition), organic enrichment/low DO and pathogens from urban runoff/storm sewers. Mosher Slough upstream of I-5 is listed for pathogens due to urban runoff/storm sewers.

Smith Canal in the city of Stockton is listed for organic enrichment/low dissolved oxygen and organophosphorus pesticides from urban runoff/storm sewers, and pathogens from urban runoff/storm sewers and recreational and tourism activities (non-boating).

Walker Slough is listed for pathogens from urban runoff/storm sewers and recreational and tourism activities (non-boating).

San Joaquin River Upstream of the Delta. The San Joaquin River (Merced River to South Delta Boundary) is listed for boron, chlorpyrifos, DDT, diazinon, electrical conductivity and Group A pesticides from agriculture, mercury from resource extraction (mining), and unknown toxicity, source unknown. This is the same water that, a few miles downstream, enters the South Delta.

Calaveras River Upstream of the Delta. The Calaveras River, Lower, is listed for diazinon from urban runoff/storm sewers, organic enrichment/low dissolved oxygen from urban runoff/storm sewers, and pathogens from urban runoff/storm sewers and recreational and tourism activities (non-boating).

Mokelumne River Upstream of the Delta. The Mokelumne River, Lower, is listed for copper and zinc from resource extraction (mining).

Sacramento River Upstream of the Delta. The Sacramento River (Knights Landing to the Delta) is listed for diazinon from agriculture, mercury from resource extraction (mining), and unknown toxicity (source unknown).

It is apparent from the 303(d) listings that there are significant known water quality problems in the Delta that require that the CVRWQCB develop total maximum daily loads (TMDLs) to control the sources of the pollutants responsible for violations of the WQOs. Unfortunately, however, little or no work has been or is being done to control several of these water quality problems.

Excessive Bioaccumulation of Organochlorine Compounds in Delta and near-Delta Tributary Fish

Excessive bioaccumulation of hazardous chemicals, such as the organochlorine legacy pesticides, PCBs and dioxins (collectively referred to herein as "OCls") and mercury, in edible fish and other organisms is one of the most significant water quality problems of the Delta and its nearby associated tributaries. While CALFED (now California Bay-Delta Authority – CBDA) has been devoting considerable funds to addressing the mercury excessive bioaccumulation problem in the Delta and its tributaries, as discussed by Lee (2003a), no funds have been made available by CALFED/CBDA to begin to address the excessive bioaccumulation of the organochlorine hazardous chemicals in Delta and near-Delta tributary fish. This situation appears to be related to the fact that CALFED/CBDA funding for mercury excessive bioaccumulation is related to the concern of the CALFED/CBDA ecosystem restoration program (devoted to developing shallow water habitat) that the development of this program may be inhibited by the created shallow water habitat contributing to excessive bioaccumulation of mercury in edible fish of the Delta. Shallow water habitats have been found to be areas that convert various forms of mercury into methylmercury, which bioaccumulates in fish.

The excessive bioaccumulation of the OCls and mercury should be supported as a high priority, independent of any shallow water habitat issues, since this is a significant public health problem. It is also a significant environmental justice problem that is not being adequately addressed. Appendix A of this report presents information developed by Lee and Jones-Lee (2002a) on the current excessive bioaccumulation problem in the Delta, as well as a discussion (Lee, 2003a) of the need for funding for the development of a management program for control of excessive bioaccumulation of OCls in Delta and near-Delta tributary fish, as well as elsewhere in the Central Valley.

Excessive Bioaccumulation of Mercury

The excessive bioaccumulation of mercury in edible fish is one of the most significant water quality problems in the Delta. The California Office of Environmental Health Hazard Assessment (OEHHA, 2004a) has issued a mercury health advisory for consumption of Delta fish. Based on this advisory, the California Department of Fish and Game (DFG, 2004) has published the following in its Sport Fishing Regulations booklet:

> *"**San Francisco Bay and Delta Region***
> *Because of elevated levels of mercury, PCBs, and other chemicals, the following interim advisory has been issued. A final advisory will be issued when the data have been completely evaluated.*
> - *Adults should eat no more than two meals per month of San Francisco Bay sport fish, including sturgeon and striped bass caught in the delta. (One meal for a 150 pound adult is about eight ounces.)*
> - *Adults should not eat any striped bass over 35 inches.*
> - *Women who are pregnant or may become pregnant, nursing mothers, and children under age six should not eat more than one meal of fish per month. In addition, they should not eat any striped bass over 27 inches or any shark over 24 inches.*
> - *This advisory does not apply to salmon, anchovies, herring, and smelt caught in the bay; other sport fish caught in the delta or ocean; or commercial fish.*
> - *Richmond Harbor Channel area: In addition to the above advice, no one should eat any croakers, surfperches, bullheads, gobies or shellfish taken within the Richmond Harbor Channel area because of high levels of chemicals detected there."*

The excessive bioaccumulation of mercury in fish has caused the Delta to be listed as a Clean Water Act 303(d) impaired waterbody because of excessive bioaccumulation of mercury. Delta Waterways (eastern portion), Delta Waterways (Stockton Ship Channel), Delta Waterways (western portion), Sacramento River (Knights Landing to the Delta), and San Joaquin River (Merced River to South Delta Boundary) have all been specifically listed for mercury impairment.

According to Foe (pers. comm., 2004), with CALFED/CBDA support, a major research effort is being conducted on methylmercury production and cycling in the San Francisco Bay estuary (which includes the Delta) and its bioaccumulation in aquatic organisms. The results developed thus far are available for review at http://loer.tamug.tamu.edu/calfed/DraftReports.htm (CBDA, 2002). Key findings are the development of a total and methylmercury mass balance for the estuary (Task 1) and determination of mercury concentrations in forage and sport fish (Task 2).

Of major concern is that CALFED/CBDA has purchased and is restoring many thousands of acres of wetlands in the estuary. Wetlands are known from the CALFED/CBDA studies and the peer-reviewed literature to be efficient sites for the methylation of mercury. The Clean Water Act requires TMDLs to reduce aqueous and biotic methylmercury levels in listed waterbodies such as the estuary and the major rivers in the Central Valley. It is unclear how the Regional Board will be able to issue US EPA Clean Water Act 401 permits for creation of wetlands in listed waterbodies. CALFED/CBDA and others need to begin to invest funds to determine how to create marshes that minimize the production and export of methylmercury.

San Joaquin River Watershed 303(d) Listings

Lee and Jones-Lee (2002b) developed an invited review on the existing and potential water quality problems in the San Joaquin River watershed with emphasis on the existing 303(d) listings/TMDLs and the constituents that are present at concentrations that could cause further 303(d) listings of water quality impairments of the SJR and some of its tributaries. Table 1 lists the current TMDLs and the constituents that could possibly lead to additional TMDLs in the SJR watershed.

Table 1
San Joaquin River Watershed TMDLs

Current TMDLs

- Selenium
- Salinity, Total Dissolved Solids
- Boron
- OP Pesticides (Diazinon, Chlorpyrifos)
- Oxygen Demanding Substances (BOD, Ammonia, Organic N)

Pending

- Organochlorine Pesticides, (DDT, Chlordane, Dieldrin, Toxaphene, etc.)
- PCBs
- Mercury
- Unknown-Caused Toxicity
- Toxicity to Algae (Herbicides)

Potential Future

- Nutrients, Excessive Fertilization (Nitrogen and Phosphorus Compounds)
- High pH, Low DO caused by Excessive Fertilization (Photosynthesis)
- Alternative Pesticides to OP Pesticides
- Total Organic Carbon, Trihalomethanes in Domestic Water Supplies
- Excessive Sediment, Erosion, Turbidity
- Pathogen-Indicator Organisms, *E. Coli*
- Sediment Toxicity, Pesticides, Nutrients/Algae/Sediment Ammonia
- Temperature (?)
- Dioxins/Furans, Combustion Residues (?)

This situation is of importance to Delta water quality since the SJR at Vernalis and downstream is in the Delta. Further, the SJR is a major source of constituents that cause 303(d) listings in the southern and eastern Delta.

Lee and Jones-Lee (2002b) have presented the characteristics of each of the parameters listed in Table 1 with information on the technical basis for the listing of constituents in Table 1 as constituents that could be found in the future to be in violation of a CVRWQCB WQO.

CVRWQCB Assessment of Delta Water Quality Problem Research Needs

In February 2004, CBDA Science Program held a Contaminant Stressors Workshop, at which K. Landau, Assistance Executive Officer for the CVRWQCB, presented a review of Delta water quality issue research needs from the Regional Board's perspective. This review, "Priorities, Data Gaps, and Research Needs," is presented in Appendix B. According to Landau, the CVRWQCB staff find that the water quality problems with the greatest research needs in the Delta are associated with mercury, selenium, legacy pesticides, agricultural and urban use pesticides, endocrine disrupters, dissolved oxygen demand, unknown toxicity, total organic carbon and salt. Landau's discussion of Delta water quality problem research needs emphasizes defining the extent and magnitude of the problems, identifying the sources of contaminants, determining how these sources interact in the environment to cause problems, and evaluating potential practices or actions that can be implemented to address the problems. Landau (Appendix B) has provided additional information on the research needs for the water quality problems he listed.

Unrecognized Environmental Pollutants

Periodically, previously unrecognized significant environmental pollutants are being found in aquatic systems. Two recent examples of this type of situation are perchlorate and the polybrominated diphenyl ethers (PBDEs). With respect to perchlorate as a widespread water pollutant, Silva (2003) of the Santa Clara Valley Water District, has discussed the potential for highway safety flares to be a significant source of perchlorate (ClO_4^-) contamination to water, even when the flares are 100-percent burned. According to Silva,

> *"A single unburned 20-minute flare can potentially contaminate up to 2.2 acre-feet* [726,000 gallons] *of drinking water to just above the California Department of Health Services' current Action Level of 4 μg/L* [for perchlorate].*"*

Silva points out that, *"More than 40 metric tons of flares were used/burned in 2002 alone in Santa Clara County."* Silva also indicates that fully burned flares can leach up to almost 2,000 μg of perchlorate per flare. California's Office of Environmental Health Hazard Assessment (OEHHA, 2004b) has recently conducted an evaluation of the hazards of perchlorate in drinking water. The 4 μg/L action level for perchlorate in drinking water was based on the detection limit; it has been revised to 6 μg/L based on the recent OEHHA evaluation. An issue that needs to be considered is whether perchlorate is present in Delta waters, especially those near urban areas and major highways. At this time there is no monitoring of Delta waters for perchlorate. Without monitoring for perchlorate, it is not possible to know if this is a problem in some areas of the Delta.

Another widespread "new" pollutant has been recently discussed by Dr. K. Hooper (2003) of the Hazardous Materials Laboratory, Department of Toxic Substances Control, California EPA. In his abstract, he states,

> *"Over the past 25 years, tens of thousands of new chemicals (7 chemicals per day) are introduced into commerce after evaluation by USEPA. Few (100-200) of the 85,000 chemicals presently in commerce are regulated. We have reasons to believe that a much larger number than 200 adversely affect human health and the environment."*

As an example of unidentified hazardous chemicals in the environment, Hooper discussed finding PBDE (polybrominated diphenyl ether) in human breast milk and in San Francisco Bay seals. Archived human breast milk shows that this is a problem that has been occurring for over 20 years. According to McDonald (2003) of California Environmental Protection Agency, Office of Environmental Health Hazard Assessment,

> *"Approximately 75 million pounds of PBDEs are used each year in the U.S. as flame retardant additives for plastics in computers, televisions, appliances, building materials and vehicle parts; and foams for furniture. PBDEs migrate out of these products and into the environment, where they bioaccumulate. PBDEs are now ubiquitous in the environment and have been measured in indoor and outdoor air, house dust, food, streams and lakes, terrestrial and aquatic biota, and human tissues. Concentrations of PBDE measured in fish, marine mammals and people from the San Francisco Bay region are among the highest in the world, and these levels appear to be increasing with each passing year."*

PBDEs are similar to PCBs and are considered carcinogens. Some of the PBDEs are being banned in the US and in other countries.

PPCPs as Environmental Pollutants

At the CBDA Contaminant Stressors Workshop, Dr. Christian Daughton, Chief, Environmental Chemistry Branch, US EPA National Exposure Research Laboratory, made a presentation, "Ubiquitous Pollution from Health and Cosmetic Care: Significance, Concern, Solutions, Stewardship – Pollution from Personal Actions." This presentation covered information on pharmaceuticals and personal care products (PPCPs) as environmental pollutants. He also discussed the relationship between endocrine disrupters and PPCPs. (A copy of Daughton's presentation at the CBDA workshop is available from gfredlee@aol.com.)

Daughton (2004) pointed out that there is a wide variety of chemicals that are introduced into domestic wastewaters which are being found in the environment. These include various chemicals (pharmaceuticals) that are derived from usage by individuals and pets, disposal of outdated medications in sewerage systems, release of treated and untreated hospital wastes to domestic sewerage systems, transfer of sewage solids ("biosolids") to land, industrial waste streams, landfill leachate, releases from aquaculture of medicated feeds, etc. Many of these chemicals are not new chemicals. They have been in wastewaters for some time, but are only now beginning to be recognized as potentially significant water pollutants. They are largely unregulated as water pollutants.

According to Daughton (2004),

"PPCPs are a diverse group of chemicals comprising all human and veterinary drugs (available by prescription or over-the-counter; including the new genre of "biologics"), diagnostic agents (e.g., X-ray contrast media), "nutraceuticals" (bioactive food supplements such as huperzine A), and other consumer chemicals, such as fragrances (e.g., musks) and sun-screen agents (e.g., methylbenzylidene camphor); also included are "excipients" (so-called "inert" ingredients used in PPCP manufacturing and formulation)."

* * *

"Since the 1970s, the impact of chemical pollution has focused almost exclusively on conventional "priority pollutants," especially on those collectively referred to as "persistent, bioaccumulative, toxic" (PBT) pollutants, "persistent organic pollutants" (POPs), or "bioaccumulative chemicals of concern (BCCs).

The "dirty dozen" is a ubiquitous, notorious subset of these, comprising highly halogenated organics (e.g., DDT, PCBs).

The conventional priority pollutants, however, are only one piece of the larger risk puzzle."

Daughton has indicated that there are over 22 million organic and inorganic substances, with nearly 6 million commercially available. The current water quality regulatory approach addresses less than 200 of these chemicals, where in general PPCPs are not regulated as potential water pollutants. According to Daughton, *"Regulated pollutants compose but a very small piece of the universe of chemical stressors to which organisms can be exposed on a continual basis."* Additional information on PPCPs is available at www.epa.gov/nerlesd1/chemistry/pharma/index.htm. With the increasing urban population and industrial activities in the Central Valley, the significance of PPCPs and other pollutants derived from urban and industrial activities, as a cause of water quality problems in the Delta, will increase. This is an area that needs attention in a Delta water quality monitoring/evaluation program.

While the full range of impacts of PPCPs is just beginning to be investigated, PPCPs are being found to have adverse impacts on aquatic ecosystems. For example, they are believed to be responsible for causing sex changes in fish. Eggen et al. (2004), in a feature article ("Challenges in Ecotoxicology: Mechanistic understanding will help overcome the newest challenges") in *Environmental Science and Technology,* have reviewed a number of the issues that are pertinent to understanding the impacts of PPCPs and other chemicals that can cause endocrine disruption, DNA damage/mutagenesis, deficiencies in immune system and neurological effects in fish and other aquatic life.

PPCPs may be particularly significant as a cause of water quality problems in the Delta, in the San Joaquin River near the city of Stockton's wastewater discharge, in Old River near the city of Tracy wastewater discharge, and in the Sacramento River near the Sacramento Regional County Sanitation District wastewater discharge and other communities such as West

Sacramento and Lodi. There is need to keep abreast of the latest developments in PPCP and endocrine disrupter research results, and apply these results to these areas of the Delta and near-Delta tributaries to ascertain whether significant water quality problems are being caused by these chemicals and other unrecognized pollutants.

The perchlorate, PBDE and PPCP situations are not atypical of what could be expected based on the approach that is normally used to define constituents of concern in water pollution control programs. As discussed by Kuivila (2000), there are approximately 150 pesticides used in the Central Valley that are a threat to cause water quality problems in the Delta. The CVRWQCB's current program to regulate pesticides considers only about half a dozen of these. Based on the vast arena of chemicals that are used in commerce, many of which could be present in aquatic systems through wastewater and stormwater runoff, it is likely that many other chemicals will be discovered in the future that are a threat to public health or aquatic ecosystems in the Delta. There is an obvious need to significantly expand the water quality monitoring program to specifically search for new, unrecognized water pollutants. As demonstrated by the perchlorate and PBDE situations, the current monitoring program, focusing on Priority Pollutants, is significantly deficient in properly defining constituents of concern with respect to impairing the beneficial uses of Delta waters.

Discussion of Delta Water Quality Problems

Presented below is a discussion of the major water quality problems in the Delta, their significance to the impairment of beneficial uses, and approaches that should be followed to address them.

Dissolved Oxygen. One of the most significant water quality problems in the Delta occurs in the first seven miles of the San Joaquin River (SJR) Deep Water Ship Channel (DWSC) below the Port of Stockton. In this reach of the Channel, dissolved oxygen (DO) concentrations can be 0 mg/L for extended periods of time. For at least 30 to 40 years there have been occurrences of DO concentrations below the water quality objective (WQO) which is 5 mg/L from December 1 through August 31, and 6 mg/L from September 1 through November 30. This situation has led to the CVRWQCB's listing this reach of the SJR DWSC as Clean Water Act 303(d) "impaired," which necessitates that the Regional Board develop a total maximum daily load (TMDL) of oxygen-demanding materials to control the DO WQO violations.

In 1999, with CALFED support, studies were initiated to define the causes of the low DO, the sources of constituents responsible and the factors influencing DO depletion in the DWSC. Lee and Jones-Lee (2000a) developed an "Issues" report, discussing many of the issues that need to be understood and addressed in order to begin to control the excessive DO depletion in the DWSC. In the spring of 2003, Lee and Jones-Lee (2003a) developed a Synthesis Report, which presents a summary and discusses the results of about four million dollars of principally CALFED-supported studies on the low-DO problem in the DWSC. It was found that the low-DO problem is the result of the development of the DWSC, where the SJR Channel was changed from 8 to 10 feet deep, to 35 feet deep, to accommodate ocean-going ships. This created a long, thin lake-like environment. Low flow conditions of the SJR through the DWSC leads to periods of several weeks to a month during which oxygen demand added to the DWSC at Channel Point (Port of Stockton) is exerted while traversing the first seven miles (critical reach) of the Channel.

One of the primary constituents responsible for the oxygen demand is the nutrients that develop into algae, which are discharged from agricultural sources in the headwaters of the San Joaquin River DWSC watershed from Mud and Salt Sloughs and the SJR at Lander Avenue (Highway 165). Another important source of oxygen demand for the DWSC is the city of Stockton's domestic wastewater discharge-associated ammonia. At times, especially under conditions of low SJR DWSC flow and high ammonia concentrations in the effluent, the City's oxygen demand load can represent on the order of 90 percent of the total oxygen demand load to the DWSC. However, under conditions of elevated flow and low effluent ammonia, the City's contribution of oxygen demand to the DWSC can be on the order of 15 percent of the total load.

As discussed by Lee and Jones-Lee (2003a) and Lee (2003b), coincident with fall stormwater runoff events the city of Stockton waterways (sloughs) experience fish kills which are associated with low dissolved oxygen in the sloughs. In November 2002 and August 2003, the DWSC at the Rough and Ready Island (RRI) monitoring station also experienced low DO following a rainfall runoff event. It appears, from the information available, that city of Stockton stormwater runoff has sufficient biochemical oxygen demand, as well as immediate oxygen demand, to cause low DO in the city of Stockton sloughs, which also may be impacting DO in the DWSC.

Another factor that greatly influences DO depletion in the DWSC is the flow of the SJR through the DWSC. Under low flow conditions of 100 cfs or so, the travel time for oxygen-demanding constituents, from the time they enter the DWSC at Channel Point until they reach Turner Cut seven miles downstream, can be on the order of 20 to 30 days. However, when the flows of the SJR through the DWSC are over about 1,500 cfs, the travel time between Channel Point and Turner Cut is a few days. In general during high flows, the DO water quality objective is not violated even though there are high oxygen demand loads added to the DWSC, because the amount of the demand that is exerted in the critical reach of the DWSC is small.

Ordinarily, higher flows in a river receiving an oxygen demand load will shift the point of maximum oxygen depletion (DO sag) further downstream. One of the unique aspects of the SJR DWSC low-DO problem is that higher flows do not cause the point of maximum DO depletion to shift downstream below Turner Cut. This arises from the situation where the state and federal project South Delta export pumps create a strong cross-Delta flow of the Sacramento River, which occurs to a considerable extent at Disappointment Slough/Columbia Cut and Turner Cut. The dilution of the residual SJR DWSC oxygen demand and its diversion into the Central Delta prevents DO problems from occurring in the SJR DWSC downstream of Turner Cut. Brown (2002) has provided information on the mixing of Sacramento River water with SJR DWSC water in the vicinity of Turner Cut and Columbia Cut.

From the information available now (see Gowdy and Grober, 2003), the solution of the low-DO problem in the SJR DWSC will be dependent on the use of aeration to add oxygen when needed, increased SJR DWSC flow, and, to the extent possible, reduction in the oxygen demand loads of nutrients/algae from upstream sources. As discussed by Lee (2003c) and Lee and Jones-Lee (2000a, 2003a), repeatedly over the period from 1999 through 2003, low SJR flows through the DWSC were accompanied by long hydraulic residence times in the first seven miles of the

DWSC below the Port of Stockton and severe DO depletion in the DWSC. The current practice of manipulating flows in the Delta and its tributaries without adequate regard to water quality impacts is strongly contrary to protecting the beneficial uses of the Delta's aquatic ecosystem. This issue is discussed further below in the Delta Improvements Package discussion.

Lee and Jones-Lee (2003a,b), as well as Lee (2003d) have presented the USGS-measured SJR DWSC flows for the period 1995 through September 2003. Figure 2 presents the complete 2003 SJR DWSC flow data. As shown in Figure 2, as well as in the previously reported data (Lee and Jones-Lee, 2003a), there are marked changes in the SJR DWSC flow over short periods of time. Many of the extreme low-flow events are associated with low DO in the SJR DWSC. As discussed by Lee and Jones-Lee (2003a,b) and Lee (2003d), the low flows of the SJR through the DWSC that have been occurring since at least 1995 are not the result of low flow of the SJR at Vernalis, but are related to the export of South Delta water by the state and federal projects and the associated manipulation of the current temporary South Delta barriers. Of particular concern is the Head of Old River (HOR) barrier. When it is present and operated so that most of the SJR Vernalis water is allowed to pass through the DWSC, there are few low-DO problems in the DWSC. It has also been found that the operation of the internal barriers within the South Delta (on Grant Line Canal, Middle River and Old River) influences the flow of the SJR through the DWSC. Based on barrier operation information provided by M. Holderman, Chief of the Temporary Barriers Project and Lower San Joaquin, Bay-Delta Office of the DWR, the removal of the South Delta internal barriers in the fall allows more SJR Vernalis water to pass into the South Delta at the Head of Old River. This in turn can even further aggravate the low-DO problem in the SJR DWSC.

<u>Impact of Vernalis Adaptive Management Program.</u> In 1999 the Vernalis Adaptive Management Program (VAMP) was initiated. This program was designed to assist the outmigration of juvenile salmon from the San Joaquin River eastside tributaries. Between about mid-April through mid-May, the operators of the water projects located on the eastside tributaries manage reservoir releases to provide a uniform flow of the San Joaquin River at Vernalis. At the same time, the Head of Old River barrier is closed so that the SJR flow at Vernalis primarily passes through the DWSC, rather than into the South Delta. The HOR culverts allow sufficient SJR Vernalis water to pass into the South Delta to protect South Delta channel water levels.

During VAMP operations in 2003 and projected for 2004, the SJR Vernalis flows were/are on the order of 3,200 cfs. Figure 2 shows the SJR DWSC flows during 2003, where the VAMP SJR DWSC flows during mid-April through mid-May were on the order of 2,500 to 2,700 cfs. During the 2003 VAMP, approximately 600 cfs of the 3,200 cfs VAMP flow at Vernalis passed through the Head of Old River barrier into the South Delta.

During 2003 VAMP, the state and federal projects averaged 1,446 cfs (SJRGA, 2004a). During the 2004 VAMP, the state and federal water projects will maintain an average pumping rate of 1,500 cfs (SJRGA, 2004b). As discussed elsewhere in this report, normally the combined export pumping by the state and federal projects is from 10,000 to 14,000 cfs. The greatly reduced export pumping during VAMP operations is designed to reduce the influence of the state and federal export projects' drawing of Sacramento River water and associated small fish to the South Delta.

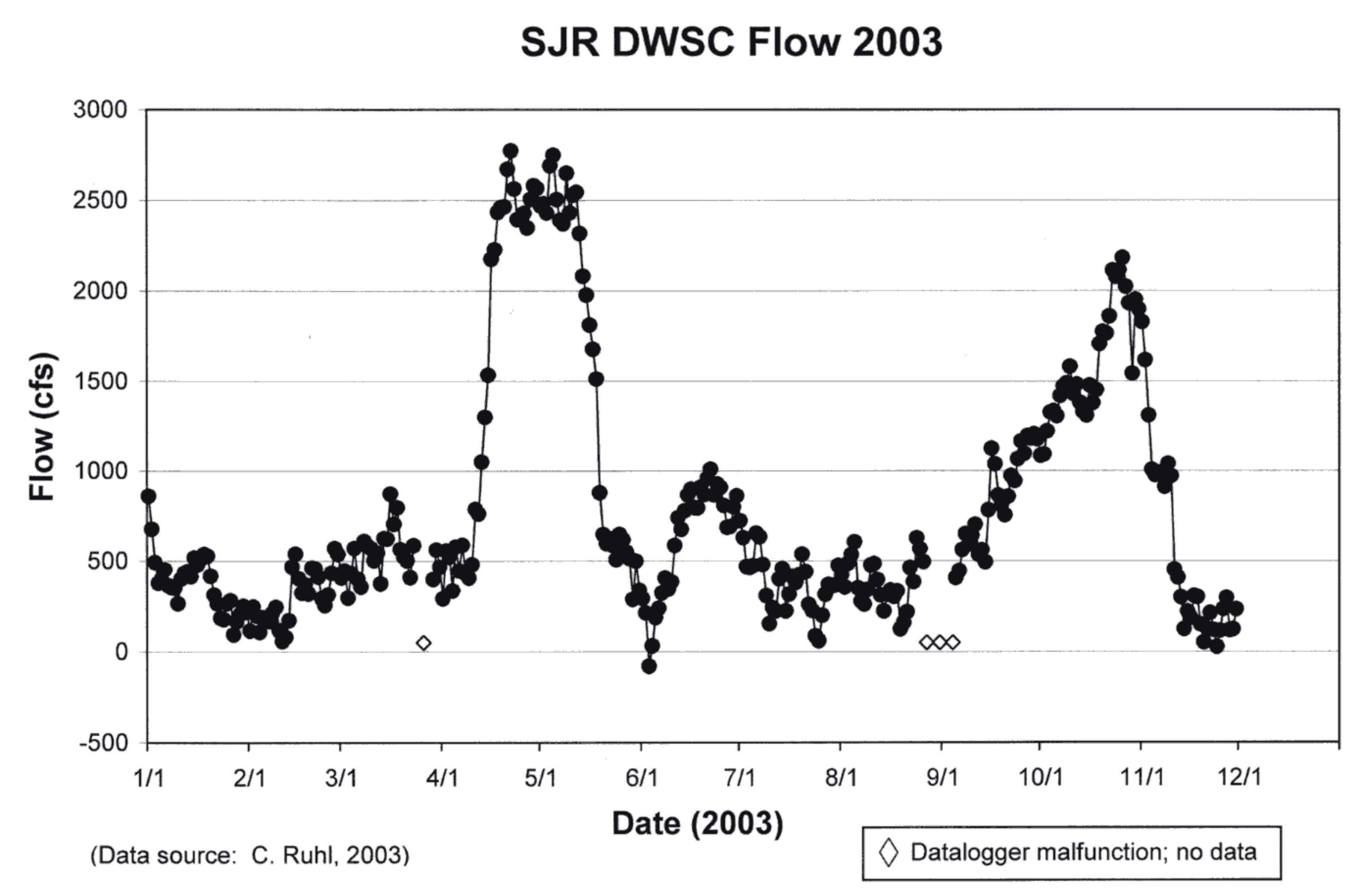

SJR DWSC Flow 2003
Flow (cfs)
3000
2500
2000
1500
1000
500
0
-500
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Date (2003)
(Data source: C. Ruhl, 2003)
Datalogger malfunction; no data

Figure 2

During the VAMP flows, studies are conducted by fisheries biologists from the California Department of Fish and Game, US Fish and Wildlife Service and the San Joaquin River Group Authority on salmon smolt responses and survival. These studies are designed to evaluate the survival of salmon smolt outmigrating the San Joaquin River watershed in relationship to flow and export conditions with the Head of Old River barrier in place.

By June 1, 2003, with the removal of the HOR barrier, the South Delta export project pumps took all of the SJR flow at Vernalis into the South Delta, with the result that on one day there was a negative (upstream) flow of the SJR to the Head of Old River. There was a several-week period following 2003 VAMP where the SJR DWSC flows were less than 500 cfs (see Figure 2).

During the VAMP flows of the SJR through the DWSC, there are no low-DO problems in the DWSC. However, as discussed by Lee and Jones-Lee (2003a), after the cessation of VAMP flow, the SJR flow through the DWSC can be a few hundred cfs. This has been accompanied by low-DO problems in the DWSC. Concern has been expressed by A. Hildebrand (pers. comm., 2004) about VAMP's contributing to the low-DO problem in the DWSC. The release of large amounts of flow during VAMP from the eastside reservoirs potentially reduces the amount of flow that could be present in the SJR DWSC during the summer months. The issue of the impact of VAMP on SJR DWSC flows needs to be evaluated.

The San Joaquin River Group Authority provides annual VAMP reports. Further information on VAMP is available at their website, www.sjrg.org.

Winter Low-DO Situations. Studies by Lee and Jones-Lee (2003a) on the low-DO episode that occurred in January, February and March 2003 show that it was caused by the extremely low flow of the SJR through the DWSC, with flows less than 100 cfs. Since there was over 2,000 cfs of flow in the SJR at Vernalis, this situation was the result of those responsible for manipulating flows in the SJR DWSC watershed (Bureau of Reclamation, Department of Water Resources) drawing essentially all of the water in the SJR at Vernalis down Old River to the federal and state projects' export pumps. This led to extended periods of time with DO concentrations in the early morning hours at the Rough and Ready Island monitoring station of 0 mg/L. By late afternoon on some days, the DO might have been as high as 0.25 to 0.5 mg/L. Concentrations less than about 3 mg/L are known to be lethal to many fish. As discussed by Lee (2003d), a similar situation occurred in July 2003, where very low DO was found in the surface waters of the DWSC near Rough and Ready Island. This occurred when there was low flow in the SJR DWSC resulting from the federal and state projects export pumps' drawing SJR water into the South Delta.

Sediment Oxygen Demand. One of the issues of concern with respect to sources of oxygen demand is the impact of Delta sediment oxygen demand (SOD) on the oxygen resources of the Delta channels. The death and decay of algae frequently lead to an accumulation of dead algal cells in sediments. This can lead to both biotic (biochemical) and abiotic (chemical) reactions between the constituents in the sediments and the oxygen content in the sediments and overlying waters. The depletion of the DO content of the water column is manifested as sediment oxygen demand. The abiotic sediment oxygen demand is due to the reduction of ferric iron to ferrous iron, sulfate to sulfide and manganese dioxide to manganous manganese. The ferrous iron and sulfide rapidly react with DO and therefore are an important source of oxygen demand in sediments and near-sediment overlying waters.

Studies by Litton (2003) on the SOD of the SJR DWSC near the Port of Stockton showed that the SOD of the DWSC was not unusually high considering the large amount of algal load to the DWSC. This situation is possibly due to the influence of tidal action on suspension of the bedded sediments. The tidal flow through the DWSC is on the order of 2,000 to about 4,000 cfs. The tidally influenced near-bottom currents in the DWSC are sufficient to suspend the settled sediments. There are elevated suspended solids in the near-bottom of the DWSC that are responsible for exertion of oxygen demand which impacts the DO concentrations in the water column. It appears that the normal SOD is manifested in the near-bottom DWSC water column rather than in the sediments or at the sediment water interface.

The zone of elevated suspended sediment near the DWSC sediment water interface is not due to density stratification. Salt (density) stratification does not occur in the central, eastern or southern Delta. It is limited to the northwestern Delta, where the Sacramento River enters the Delta near Chipps Island. Also, there is no permanent thermal stratification in the DWSC; however, there is temporary daily thermal stratification during the summer and fall that occurs on most days during the day but which is lost by late evening. With the cooling of the surface waters in late evening, much of the water column is mixed.

The Delta channel SOD may also be responsible for part of the low-DO conditions in the South Delta channels where DWR has found DO concentrations below the WQO. Of particular importance is the low-DO that occurs in Old River near the Tracy Boulevard bridge, which is discussed in this report.

<u>Managing Flows to Reduce Low-DO Problems</u>. As discussed by Lee (2003c,d) and Lee and Jones-Lee (2003a,b), a key aspect of an appropriate management approach for controlling the low-DO problem in the DWSC will be gaining control of the diversion of SJR flows at Vernalis down Old River to the federal and state projects' export pumps, as opposed to allowing these flows to proceed through the DWSC. To the extent that elimination of diversion of the SJR Vernalis water down Old River can be achieved to provide a minimum flow of 1,500 cfs through the DWSC, the magnitude of the low-DO problem in the DWSC can be significantly reduced. At this time, the CVRWQCB is initiating a Phase I TMDL designed to evaluate aeration and other approaches for controlling the low-DO problem. Lee (2003e) has reviewed various approaches that need to be evaluated with respect to solving the low-DO problem in the DWSC.

The South Delta currently has four temporary rock barriers that are installed each spring on South Delta channels and removed each fall. The export pumping of South Delta water by the federal and state projects exports water faster than it is replenished from the Central Delta and the San Joaquin River. This export used to lead to low water levels in South Delta channels. In order to address this problem, temporary rock barriers are constructed in order to maintain water levels in the South Delta. In accordance with the CALFED Record of Decision (ROD), these temporary rock barriers are to be replaced by permanent operable barriers by 2007. One of the potential approaches for gaining additional flow of the SJR through the DWSC suggested by Alex Hildebrand, involved reverse-flow low-head pumping of waters on the western side of the South Delta barriers into the South Delta. As part of the CALFED-supported 2001 Low-DO Directed Action Project, Rajbhandari et al. (2002) of DWR examined the feasibility of this approach as a means of supplementing the flow of the SJR into the DWSC. Lee and Jones-Lee (2003a) summarized the results of that study and concluded that it would be possible to reverse the flow of the South Delta from Old River into the SJR at the Head of Old River barrier through increasing the water levels in the South Delta through reverse-flow pumping over the western South Delta permanent barriers. This approach would introduce greater amounts of Sacramento River water into the South Delta than is occurring now, thereby improving South Delta water quality. Further, this approach would prevent low-quality water in the SJR at Vernalis from entering the South Delta. As discussed by Lee and Jones-Lee (2003a), there is, however, need to evaluate any potentially significant consequences of the reverse-flow low-head pumping over the permanent South Delta barriers on South Delta fisheries. Further, there may be need to obtain an NPDES discharge permit to pump South Delta water into the SJR.

Another approach for increasing the flow of the SJR through the DWSC is the recirculation of South Delta water through the Delta Mendota canal to allow the pumped water to flow into the SJR at the Newman Wasteway. This approach is possible since the federal project pumps at Tracy have excess pumping capacity during the summer months. This excess pumping capacity can be used to provide additional flow into the SJR that can then be allowed to pass into the DWSC before it is drawn to the export pumps in the South Delta. There are a number of biological/fisheries issues that need to be addressed/resolved before this approach can be approved, including the need for an NPDES permit to discharge Delta Mendota water into the SJR.

Another area where there is low DO in the Delta that is likely influenced by export project flow manipulations is the South Delta. Lee and Jones-Lee (2003a) reviewed the DWR monitoring data for the South Delta channel. They found that there are several South Delta channels (Old River, Grant Line Canal, and Middle River at some locations) where the dissolved oxygen at times can be below the water quality objective of 5 mg/L, and can be as low as 2 to 3 mg/L, especially in the early morning hours. On August 5, 2003, the senior author conducted a DeltaKeeper-supported tour of the South Delta channels. As reported by Lee et al. (2004a), during the tour they encountered a major fish kill in the Old River channel near where the Tracy Boulevard bridge crosses the channel. DWR maintains a water quality monitoring station near that location. The DO in the channel waters the night before was at or near 0 mg/L for several hours. The low DO likely caused the fish kill. The low DO was likely caused by excessive algal growth in the Old River channel, which, due to the limited flushing of that channel at that time, led to sufficient algal death and decay to lead to low DO.

<u>Low DO in the South and Central Delta</u>. Low DO in the South Delta channels is a significant water quality problem that deserves a high priority for defining the causes of the low DO, the role of flow manipulations in influencing low DO, and the sources of the oxygen-demanding constituents (which are likely the SJR watershed upstream of the Head of Old River split and local discharges from agricultural activities, as well as city of Tracy wastewaters). This situation is likely to change when CBDA (formerly CALFED) implements its Record of Decision (ROD)

commitment of installing operable barriers in the South Delta to replace the temporary barriers that are installed each year to help maintain water levels in South Delta channels, associated with the export pumping by the state and federal projects.

The Central Delta, Turner Cut and Columbia Cut are areas where there is a potential for low-DO problems at times. This can occur when elevated SJR flows through the DWSC bring large amounts of algae and ammonia into and through the critical reach of the DWSC under conditions where there is insufficient time in the critical reach for the algal-associated oxygen demand to be exerted and the ammonia to be nitrified. It is possible that low-DO situations may occur, especially along Turner Cut, under these conditions. During the summer 2003, Lee et al. (2004b) conducted two DeltaKeeper-supported tours of the Central Delta for the purpose of examining DO conditions in Turner Cut and Columbia Cut, as well as Old River and Middle River. These tours were conducted on July 17 and September 17, 2003. They showed that the SJR DWSC just upstream of Turner Cut had a high electrical conductivity (EC) which was not influenced by Sacramento River water. However, at Turner Cut on both occasions, the EC in Turner Cut channel was several hundred µmhos/cm (µS/cm) lower than the SJR DWSC water just upstream of Turner Cut. It was clear that Sacramento River water was being mixed with SJR DWSC water at Columbia Cut and Turner Cut, as a result of the state and federal projects' drawing Sacramento River water across the DWSC on its way to the export pumps.

There were no low-DO conditions found during these tours of the Central Delta. However, the tours were not conducted at times when the maximum likelihood for low-DO conditions would occur in Turner Cut or in its side channels, such as Whiskey Slough. Further studies of this situation are needed under conditions where there are greater oxygen demand loads to Turner Cut from the DWSC than occurred on the dates of the two tours.

As discussed below, pesticides, including herbicides, have been found in Central Valley waterbodies, including the Delta, at concentrations that are toxic to zooplankton and/or algae. This toxicity could influence the low-DO problem in the SJR DWSC.

Pesticide Toxicity. There are three types of pesticides of concern in potentially impacting water quality in the Delta. These include the organophosphorus (OP) pesticides such as diazinon and chlorpyrifos, as well as the carbamate pesticides, the pyrethroid pesticides and the organochlorine "legacy" pesticides. The CVRWQCB has listed Delta waterways (see above discussion) as impaired due to both the organophosphorus pesticides and the organochlorine pesticides. Pesticides are of concern because of their potential toxicity to various forms of aquatic life, which in turn can affect the aquatic ecosystem of the Delta, either directly through toxicity to aquatic life or indirectly through toxicity to zooplankton that serve as food for larval and juvenile fish. Some of the most severe pesticide-caused aquatic life toxicity occurs in Paradise Cut. This waterbody has no flow through it, and therefore limited dilution of the agricultural discharges of pesticides.

Recently, Spurlock (2004) reported on the current finding of chlorpyrifos in Central Valley waterbodies. According to Spurlock, *"Recent chlorpyrifos monitoring data were analyzed. In contrast to the previous analysis (Spurlock, 2002), these monitoring data reflect water quality in agriculturally-dominated waterways of the San Joaquin Valley, the Sacramento/San Joaquin Delta, and the Salinas River Basin under current use conditions throughout much of the year. The data demonstrate that chlorpyrifos has recently been observed in both rivers and tributaries of the San Joaquin Valley, the Sacramento/San Joaquin Delta, and Monterey County tributaries, frequently at levels that exceed DFG's WQC* [Department of Fish and Game's water quality criteria]*."*

One of the issues of particular concern is whether the OP pesticide toxicity to the zooplankter *Ceriodaphnia* measured in the laboratory represents toxicity that would be significantly adverse to larval or young fish. There are some who argue that, since the OP pesticide toxicity is restricted to certain types of zooplankton, toxicity to these types may not significantly affect fish populations, since there are other zooplankters that are not affected by OP pesticide toxicity which can serve as fish food. Werner et al. (2003a) reported that *Cladocerans* were found to be an important component of the diet of larval Chinook salmon. *Ceriodaphnia* is a *Cladoceran*. With respect to the impact of mixtures of pesticides on aquatic life, there is increasing evidence (Lydy, 2004) that mixtures of the triazine pesticides (herbicides) and the organophosphorus pesticides lead to an enhancement of toxicity.

There is also organophosphate pesticide toxicity associated with stormwater runoff from the city of Stockton into the Deep Water Ship Channel. As discussed by Lee and Jones-Lee (2001) and Lee and Jones-Lee (2002c), the water in the city of Stockton sloughs is toxic to zooplankton after each stormwater runoff event. This toxicity has been found to be caused primarily by diazinon used on urban properties, and also to some extent by chlorpyrifos.

With the termination of the use of diazinon and chlorpyrifos in urban areas because of the potential toxicity to children, there is increased use of the pyrethroid-based pesticides on home and commercial properties. At a CBDA salmon workshop, Inge Werner and Kai Eder, of the University of California, Davis, School of Veterinary Medicine, presented a discussion, "Sublethal Effects of Pesticides in Juvenile Chinook Salmon" (Werner and Eder, 2003), which included information on the relative 96-hour toxicities of diazinon, chlorpyrifos and esfenvalerate. Esfenvalerate is a pyrethroid-based pesticide. It is of interest to find that esfenvalerate has a 96-hour LC50 of about 0.25 µg/L to fathead minnow larvae, while diazinon's 96-hour LC50 toxicity to fathead minnow larvae is 6,000 µg/L and chlorpyrifos' is 331 µg/L. Similar toxicities were found for esfenvalerate to rainbow trout, with a 96-hour LC50 of 0.3 µg/L, while diazinon's 96-hour LC50 toxicity to rainbow trout is 400 µg/L and chlorpyrifos' is 9 µg/L. Esfenvalerate (and, for that matter, other pyrethroid-based pesticides) is much more toxic to fish than the OP pesticides diazinon and chlorpyrifos. With respect to toxicity to *Ceriodaphnia*, esfenvalerate's 96-hour LC50 is 0.28 µg/L, while diazinon's is 0.4 µg/L and chlorpyrifos' is 0.08 µg/L. Esfenvalerate is, therefore, also more toxic to *Ceriodaphnia* than diazinon.

While several of the pyrethroid-based pesticides are highly toxic to zooplankton and fish, it is unclear whether their strong sorption tendencies onto particulate matter reduce the magnitude of this toxicity sufficiently so that the amount of toxicity in the water column following a runoff event is small. However, this sorption can lead to the accumulation of the pyrethroid-based pesticides in sediments of the Stockton sloughs and the Deep Water Ship Channel, where there is a potential for aquatic life toxicity to benthic organisms. Weston et al. (2004) have found that sediments in some agricultural areas of the Central Valley contain pyrethroid-based pesticides and the sediments are toxic to benthic organisms. It is not clear, however, that this toxicity is due to the pyrethroid-based pesticides in the sediments. The current situation with respect to both water column and sediment toxicity in the city of Stockton sloughs and the Deep Water Ship Channel where the sloughs discharge needs to be investigated.

Another group of toxic chemicals that is of concern in the Delta is herbicides used in agricultural areas, as well as along roadways and other areas for weed control. Miller et al. (2002, 2003) reported finding diuron, a herbicide widely used along roads and in some agricultural areas, present in Central Valley waters at concentrations that are toxic to algae.

Lee (2003f) discussed the potential for the pesticide toxicity to zooplankton found within the SJR watershed and DWSC to possibly influence the DO depletion in the SJR DWSC. Toxicity to zooplankton could reduce the zooplankton grazing on algae and thereby increase the algae-caused oxygen demand load that enters the DWSC. Further, herbicide toxicity to algae upstream of Vernalis could reduce the amount of algae that enter the DWSC and thereby influence DO depletion in the DWSC. If the herbicide toxicity to algae was manifested near the DWSC, herbicides could increase the rate of death and decay of algae in the lower SJR and DWSC and thereby exacerbate the low-DO problem. The increased algae associated with pesticide toxicity to zooplankton and the decreased algae associated with herbicide toxicity to algae could be responsible for the patchiness of algae entering the DWSC and the DO "crashes" that occur at times (discussed by Lee and Jones-Lee, 2003a), where an abnormally high DO depletion will occur for a short period of time.

Lee and Jones-Lee (2004a) have discussed the deficiencies in the SWRCB's recent adoption of general aquatic herbicide NPDES permit. This permit does not require adequate monitoring of the waters that receive the herbicide to determine if its application leads to toxicity to non target organisms in the waters of the State. Since large amounts of aquatic herbicides are used in the Delta to control excessive growths of water hyacinth this could be an important issue impacting Delta water quality.

Adequacy of US EPA and DPR Registration of Pesticides for Control of Environmental Impacts. It is generally assumed by those not familiar with the US EPA Office of Pesticide Programs (OPP) and the California Department of Pesticide Regulation (DPR) that the pesticide registration process is designed to be protective of non-target organisms in the environment. However, a critical review of the US EPA OPP and California DPR registration processes shows that the use of registered pesticides in accordance with label restrictions can result in significant adverse impacts to non-target aquatic life.

Of particular concern with respect to water quality is that the US EPA OPP and California DPR do not restrict the use of pesticides that can be present in stormwater runoff or irrigation water discharges. However pesticides from those sources can be toxic to aquatic life in the receiving waters for the runoff/discharges. This situation is the origin of the widespread aquatic life toxicity that is occurring in California and other area surface waters due to the use of diazinon and chlorpyrifos in urban and agricultural areas. Jones-Lee and Lee (2000) and Lee (2001a) have recommended that regulatory agencies such as the CVRWQCB initiate a proactive approach for further evaluation of pesticide use in the Central Valley to determine if any of the 150 or so pesticides currently being used in this area are causing water column or sediment toxicity to aquatic life in the receiving waters for the runoff/discharges from the application areas. Further, as part of the proactive approach, with the beginning use of a new pesticide in an area, special-purpose studies should be conducted to determine if its use could cause aquatic life toxicity in the receiving waters for the runoff/discharges.

Organochlorine "Legacy" Pesticides. Lee and Jones-Lee (2002a) have reviewed the occurrence of excessive concentrations of the organochlorine "legacy" pesticides and PCBs in edible fish in the Central Valley. A summary of this information that is pertinent to the Delta and near-Delta tributaries is presented above and in Appendix A. The finding of excessive bioaccumulation of the OCls in Central Valley fish has led to the need to develop a TMDL to control the excessive bioaccumulation of these compounds in edible fish. The Lee and Jones-Lee (2002a) review also includes information on the approach that should be followed to define the relative significance of current runoff of OCls from areas where they have been applied, versus their presence in waterbody sediments, as a source of the OCls that are bioaccumulating in edible fish..

An area of increasing concern is the potential toxicity of mixtures of pesticides and other hazardous chemicals to aquatic life and human health. Carpenter et al. (2002) developed a review of this issue entitled, "Understanding the Human Health Effects of Chemical Mixtures." Additional information on this topic is provided in a book edited by Wilson and Suk (2002), entitled Biomarkers of Environmentally Associated Disease.

While the traditional approach for controlling excessive sediment-bound OCls is dredging of the sediments, increasing attention is being given to alternative approaches because of the high cost of dredging. One of the most promising is the addition of activated carbon to sediments, which would bind the OCls to the carbon particles, thereby preventing their uptake by benthic organisms. Luthy (2003) presented a review of his work on the use of activated carbon, in which he reported promising results for immobilizing organochlorine compounds in sediments. There is need to examine whether activated carbon addition to sediments could reduce bioaccumulation of OCls at various locations in the Delta and its tributaries, such as in city of Stockton Smith Canal Yosemite Lake sediments where, as discussed by Lee et al. (2002), PCBs and/or legacy pesticides are found in the sediments and are bioaccumulating to excessive levels in fish.

Sediment Toxicity. One of the issues that needs to be assessed for which there is little or no current information at this time is whether the sediments in various parts of the Delta are toxic to benthic and epibenthic organisms. Ogle et al. (2001) reported finding sediment toxicity in a number of the Delta channels in studies conducted in the mid-1990s. This work needs to be updated to evaluate the current situation. Also, further work needs to be done to define the cause of the toxicity, using sediment TIEs.

The US EPA (2000a) has developed a sediment toxicity test based on *Hyalella azteca,* which should be used to determine if there are sediments in the Delta that are toxic to benthic organisms. *Hyalella azteca* is an amphipod of moderate to high sensitivity to various types of pollutants. The finding of toxicity to *Hyalella* should be a trigger to conduct further studies to confirm that the toxicity is persistent (and, if not, its duration), the magnitude of the area that is toxic and whether there are gradients of toxicity which can identify "hot spots," whether the toxicity is accompanied by altered organism assemblages in the sediments of similar physical and chemical characteristics. Further, sediment TIE studies should be used to try to determine the chemical constituent(s) responsible for the toxicity. In time, following this approach, an understanding of the current situation with respect to sediment toxicity in the Delta will be obtained. Through ongoing periodic sampling of the sediments, it will be possible to determine whether the situation changes due to the introduction of new toxicants, such as a new or expanded-use pesticide that has not been used extensively, if at all, in the Delta and its tributaries.

Finlayson (pers. comm., 2004), as part of California Department of Fish and Game studies on water quality, has compiled Delta sediment toxicity data. These data are available from Finlayson on a CD ROM. This database also includes information on the chemical characteristics of the sediments in which toxicity measurements were made. Unfortunately, Finlayson included information on whether the concentrations of measured chemical parameters in the sediments exceeded the Long and Morgan co-occurrence-based so-called sediment quality guidelines. As discussed herein and by Lee and Jones-Lee (2002a), it is technically invalid to infer anything about the impact of a constituent in a sediment on beneficial uses of the waterbody on the basis of the concentration of a chemical constituent in sediment or whether that concentration exceeds or fails to exceed a co-occurrence-based sediment quality guideline. It has been known since the mid-1960s that the total concentration of a chemical in a sediment is not an indication of its potential impact on aquatic life or beneficial uses of the water.

Lee and Jones-Lee (2003c) presented a discussion of problems with the SWRCB's current efforts to develop sediment quality objectives (SQOs) as part of its complying with the state legislature's Bay Protection and Toxic Cleanup program's requirements for regulating contaminated sediments. They pointed out that the initial efforts of the SWRCB staff to develop chemical-specific numeric sediment quality objectives were not technically valid since they were based on a co-occurrence-based approach. As Lee and Jones-Lee discussed, a co-occurrence approach is not reliable for evaluating the water quality impacts of chemical constituents in sediments. Co-occurrence-based approaches for developing SQOs would lead to inappropriate regulation of the state's aquatic sediments. As a result of extensive comments it received on the unreliability of the initially proposed approach for developing SQOs, the SWRCB staff has recently indicated that a weight-of-evidence approach will now be used to develop SQOs for enclosed bays and estuaries of the state.

The SWRCB staff is still devoting considerable effort to trying to use the existing BPTCP database to relate the total concentration of a chemical in sediment and aquatic life toxicity. However, as Lee and Jones-Lee (2003c) discussed, the BPTCP database is significantly deficient in providing the information needed to properly relate sediment toxicity to a chemical(s) responsible for the toxicity, since toxicity identification evaluation (TIE) information was not collected in the BPTCP. There is no way to reliably evaluate the cause of the toxicity in the BPTCP studies without conducting TIE studies.

From a Delta water quality perspective, the SWRCB is not fulfilling the California legislature's requirements established in the BPTCP of developing sediment quality objectives for enclosed bays, estuaries and near-shore marine waters, including the Delta. The State Board staff and Board have indicated that they do not plan to develop sediment quality objectives for the Delta as part of their development of sediment quality objectives. If this current approach persists, the SWRCB will not fulfill the legislative requirements.

Finding sediment toxicity does not necessarily mean that the sediment is having a significant adverse impact on the overlying waters. As discussed by Lee and Jones-Lee (1996), many sediments are naturally toxic, due to low dissolved oxygen, and hydrogen sulfide and ammonia production arising from the decay of algae on or within the sediments. This decay leads to consumption of dissolved oxygen at the sediment-water interface and within the sediments. It is accompanied by a reduction of sulfate to sulfide and of ferric iron to ferrous iron. Also, any oxidized forms of manganese, such as MnO_2 are reduced to Mn^{2+}. Organic nitrogen is converted to ammonia, which in oxygen-free sediments remains in that form within the sediments, or slowly mixes, through sediment-water exchange reactions, into the overlying water column. The combination of low DO and ammonia causes many sediments to be unsuitable as habitat for a variety of forms of benthic and epibenthic organisms. However, the overlying waters in many eutrophic lakes where this situation is common produce outstanding warm water fisheries. This situation mandates that a proper evaluation be made of the water quality significance of sediment toxicity. This is why a combination of sediment toxicity, sediment TIEs to determine the cause of toxicity, and sediment organism assemblage information is essential to evaluating the significance of chemical constituents in aquatic sediments as they may impact the beneficial uses of the waterbody in which the sediments are located.

Lee and Jones-Lee (2002d) have recommended that a sediment quality triad involving a best-professional-judgment weight-of-evidence approach be used to evaluate sediment quality. As they discussed, it is important to properly use chemical information in this triad. Chemical concentration information should not be used in a co-occurrence-based approach like Long and Morgan's so-called "sediment quality guidelines," but rather should be evaluated through a TIE approach to identify the chemicals responsible for the toxicity. The sediment quality triad evaluation was advocated by a number of invited speakers at the Fifth International Symposium on Sediment Quality Assessment (SQA5) that was held in Chicago in October 2002 (Chapman, 2002; Burton et al., 2002). Those speakers and others, including DiToro (2002), discussed the inappropriateness of using co-occurrence-based sediment quality guidelines.

It is important, in evaluating the water quality significance of sediments, not to fall into the trap of trying to oversimplify the complexity of sediment - pollutant interactions. As discussed by Lee and Jones-Lee (2002a,d), there should be no attempt made to use chemical concentration-based sediment quality guidelines to judge excessive concentrations of constituents in sediments. Instead, a best-professional-judgment triad weight-of-evidence approach should be used.

Light Penetration and Turbidity/Color. Light penetration and, therefore, primary production in the Delta is limited by inorganic turbidity and/or color. The studies on the San Joaquin River Deep Water Ship Channel (Lee and Jones-Lee, 2003a) have shown that the light penetration in the San Joaquin River as it enters the Deep Water Ship Channel is severely limited by inorganic turbidity. Lee et al. (1995) conducted a survey of the world's literature of light penetration as measured by Secchi depth, where the focus of the results was on the Secchi depth that would occur based on light penetration's being inhibited only by phytoplankton. As phytoplankton numbers increase, light penetration (Secchi depth) decreases. It is possible to use the Lee et al. (1995) relationship to determine whether a waterbody has the light penetration expected based on the planktonic algal chlorophyll. Applying this approach to the San Joaquin River Deep Water Ship Channel and the Delta shows that the light penetration in the Deep Water Ship Channel and Delta is substantially less than what is predicted based on the planktonic algal chlorophyll. This decreased light penetration is due to erosion in the watershed, principally in the SJR westside tributary watersheds which transport large amounts of suspended sediment into the SJR and DWSC. Further, at times, there is sufficient release of highly colored water due to organics from the managed wetlands (refuges and duck clubs) in the Mud and Salt Slough watersheds to cause severe short-term decreases in light penetration. The inorganic turbidity and wetlands-derived color lead to lower DO than would be expected based on the photosynthesis that should be occurring by phytoplankton in the water column.

Also in the main part of the Delta the leaching of organics from peat soils on Delta islands introduces substantial amounts of color into the water. This in turn tends to lead to decreased phytoplankton growth. This may account in part for the deleterious growth of water hyacinth that occurs in some parts of the Delta, since hyacinth growth is on the surface of the water and therefore not inhibited by decreased light penetration. A review by Lee and Jones-Lee in the late 1980s and early 1990s (Lee and Jones, 1991a) showed that the planktonic algal chlorophyll present in the middle and south parts of the Delta near the export pumps is generally lower than would be expected based on the nutrient content of those waters. The reduced phytoplankton growth may also be due to a short hydraulic residence time between when nutrient-rich South Delta water mixes with nutrient-poor Sacramento River water that is drawn to the South Delta by the state and federal export projects.

Total Organic Carbon/Dissolved Organic Carbon. Total organic carbon (TOC) is an important water quality parameter for Delta waters, because those waters serve as a domestic water supply source for about 23 million people in California. TOC interacts with various disinfectants to produce trihalomethanes (THMs), which are low molecular weight organochlorine compounds like chloroform or chlorobromo compounds. THMs are regulated as carcinogens. This situation has caused the US EPA to propose to limit the TOC content of water supplies to about 2 mg/L.

TOC and dissolved organic carbon (DOC) have been measured in various Delta tributaries and at various locations in the Delta. From those studies it has been concluded that an appreciable part of the TOC that is exported from the Delta by the state and federal projects arises from the leaching of peat soils on Delta islands. The remainder is from sources upstream of the Delta. CBDA (2004a) discussed issues of TOC in Delta waters as it affects the use of those waters for domestic water supply purposes.

Recently Lee and Jones-Lee (2003d) introduced the concept of refractory and labile TOC in the Delta and its tributaries. Labile TOC is that part of the TOC measured concentration that will not persist from the point of measurement until it reaches a domestic water supply treatment works; i.e., it is the portion of the TOC that is degraded. Labile TOC is primarily composed of phytoplankton cells. As discussed by Lee and Jones-Lee (2003a), several investigators in the SJR DWSC low-DO studies have shown that there is a strong correlation between BOD and planktonic algal chlorophyll in the San Joaquin River and the DWSC. It is well established in the limnological literature (see Lee and Jones, 1991a) that the organic carbon in algal cells is largely mineralized during the decay of dead algal cells. The refractory (i.e., nondegradable) TOC is derived primarily from higher terrestrial and aquatic plants that contain lignin.

Recently, Dr. James T. Hollibaugh, Director of the School of Marine Programs at the University of Georgia, made a presentation at a CBDA luncheon seminar on work that he and his associates have done on the potential for shallow water habitat-developed vegetation to be a source of TOC that would contribute to the TOC problem for water utilities that utilize Delta waters as a water supply source. He reported that the TOC that develops in Delta shallow water habitat areas consists of refractory and labile (readily degradable) TOC. He concluded that the CBDA Ecosystem Restoration Program devoted to increasing shallow water habitat in the Delta as part of fisheries restoration will add refractory TOC to Delta waters. He indicated that, at this time, information is not available on the amount of TOC that would be exported from new shallow water habitat per unit area of new habitat. Without this information it is not possible to assess whether the creation of additional shallow water habitat in the Delta would represent a significant additional source of TOC compared to the existing concentrations.

From the studies that have been conducted on the SJR DWSC DO problems (Lee and Jones-Lee, 2003a), it is found that, at times, a substantial part of the TOC present in the San Joaquin River is in the form of algal cells. Depending on the flow of the SJR through the DWSC, much of the algae die and decompose in the first seven miles of the Deep Water Ship Channel below the Port of Stockton. Under elevated SJR DWSC flows above about 1,500 to 2,000 cfs, some of the algal cell TOC derived from San Joaquin River watershed sources is carried into the Central Delta via Turner Cut or Columbia Cut due to the cross-channel flow caused by the state and federal projects' export of water from the South Delta. This export creates a strong South Delta flow of Sacramento River water into the Central Delta, ultimately reaching the South Delta pumps.

Based on the studies by Lehman (2002), the death and decay of the planktonic algae that enter the DWSC from upstream SJR sources is compensated for by growth of algae in the DWSC. This means that even under conditions of low SJR DWSC flow, where much of the SJR DWSC watershed algae decompose in the first seven miles of the DWSC, there is still an appreciable planktonic algal chlorophyll load added to the Central Delta through Turner Cut and Columbia Cut.

Sacramento River water has low algal content and somewhat lower (although not insignificant) TOC, compared to San Joaquin River water. The fact that the planktonic algal chlorophyll at the Banks Pumping Station is normally found to be low compared to the SJR

DWSC TOC reflects the fact that the water pumped at Banks is primarily Sacramento River water. The high planktonic algal chlorophyll found in the San Joaquin River at Vernalis is either transported into the South Delta via Old River and then exported from the South Delta at the Tracy pumps, or is transported into the Central Delta via Turner Cut and Columbia Cut, where it is mixed with and diluted by the low planktonic algal chlorophyll water of the Sacramento River. It is expected that part of the planktonic algae that enter the Central Delta via Turner Cut and Columbia Cut will die and decompose in transport to the South Delta pumps at Tracy and Banks. It should be understood that much of the time, during the summer and fall, on the order of one-third to one-half of the water that is pumped by the Federal Project at Tracy is Sacramento River water and not San Joaquin River water.

As discussed in Lee and Jones-Lee (2003d), there are other sources of TOC for the Delta, such as urban stormwater runoff and domestic wastewaters, principally from the cities of Stockton and Sacramento and other communities in the Delta watershed. While wastewater discharges and stormwater runoff can cause elevated TOC in receiving waters, substantial parts of such TOC is labile and will not likely persist for a sufficient distance to reach a water supply treatment works in the Bay region or Southern California.

Woodard (2000) conducted a review of TOC concentrations and load data in Delta tributaries and at the export pumps. As discussed by Lee and Jones-Lee (2003d), it is important not to use the Woodard (2000) review of TOC data as an indication of sources of TOC that could affect water utilities that use Delta water as a water supply source. This is because Woodard's TOC data do not distinguish between the refractory and labile forms of TOC.

Lee and Jones-Lee (2003d) discuss the approach that should be followed to define the sources of labile and refractory TOC in Delta tributaries and within the Delta. They point to the importance of measuring not only TOC and DOC, but also planktonic algal chlorophyll *a,* pheophytin *a* and BOD in TOC source investigations.

In the late 1980s Delta Wetlands, Inc., proposed the development of in-Delta storage reservoirs. These reservoirs would be filled with water pumped from Delta channels during high flow periods and discharged back to Delta channels during the spring and summer. There is concern about the quality of water that would be discharged to the Delta channels. There have been several studies on this issue, the most comprehensive of which are the DWR studies conducted during the past year. These studies (DWR, 2004a) have investigated the potential for the peat soil of the Delta islands to release TOC that would contribute to the TOC problem for water utilities that use Delta waters as a water supply source. There is also a potential problem with adverse impacts of the Delta island storage reservoirs due to the conversion of the mercury in the island soils and in the waters added to the island reservoirs methylmercury and thereby contributing to the excessive mercury bioaccumulation problem that exists in the Delta. Since these islands have been used for agriculture, there may also be excessive bioaccumulation of legacy organochlorine pesticides derived from the soils when the soil-associated pesticides are mobilized in the waters added to these reservoirs. There is need for further studies to better define the water quality that will develop in the reservoirs and the impact of the discharge of the stored water on Delta channel water quality. CBDA (2003) has presented a discussion of these issues.

Algal Available Carbon Deficiency in the Central Delta. An issue that has emerged as important in managing Delta aquatic resources is the deficiency in available organic carbon to support the Delta aquatic food web. Jassby and Cloern (2000), Jassby et al. (2002), Jassby et al. (2003), Müller-Solger et al. (2002), Sobczak et al. (2002) have presented a series of papers on the importance of algal TOC added to the Delta as a component of the Delta aquatic food web. Jassby (pers. comm., 2003) has also supported the premise that algae are an important component of the aquatic food web in the Delta. As a result of their work, a different approach to managing the low-DO problem in the DWSC has evolved.

Lee (2003g) has suggested that rather than trying to reduce the algal oxygen demand load to the DWSC as one of the alternative approaches for solving the low-DO problem in the DWSC, it could be better to allow the algal load to the DWSC to pass into the Central Delta and thereby serve as a food source for the aquatic food web. As discussed herein, this can be accomplished by allowing the flows of the SJR through the DWSC to be above about 1,500 cfs. Under such flow conditions, the short residence time of the algal oxygen demand loads that enter the DWSC will transfer most of the algal oxygen demand loads to the Central Delta where they will not cause an oxygen demand problem and will serve as a source of assimilable carbon to the aquatic food web. Lee et al. (2004b) have investigated this situation and concluded that it would be rare that the addition of those algal oxygen demand loads to the Central Delta would lead to low-DO problems in that area. They suggested that any remaining oxygen depletion problems in the DWSC be controlled through aeration. The SJR upstream dischargers would still be held responsible for helping to pay for aeration to eliminate DO WQO violations that occur but that are not eliminated by the elevated flows of the SJR through the DWSC or the control of the city of Stockton ammonia loads.

One of the issues that needs to be considered is the benefit of nutrients to the Delta food web. Lee and Jones (1991b) have shown that there is a relationship between the normalized phosphorus loads to a waterbody and the fish biomass. The normalization is based on the Vollenweider approach of accounting for the waterbody's mean depth and hydraulic residence time. Lee and Jones-Lee (2004b) have discussed that the excessive nutrient loads to a waterbody which lead to high fish biomass tend to produce less desirable fish, such as carp.

Non-DO-Related Algal Impacts on Water Quality in the Delta. As discussed herein, algae are a major cause of low-DO problems in the Deep Water Ship Channel and in some South Delta channels. Excessively fertile waterbodies such as the Delta frequently experience blooms of bluegreen algae. This type of algae is notorious for causing water quality problems including floating algal scum, obnoxious tastes and odors in water supplies, airborne odors where the algal scum decomposes, and at times the production of toxins that kill animals and waterfowl. Further, bluegreen algae are known to a poor base to the food web since they are not readily grazed by zooplankton. Beginning in the 1960s most of the author's (Dr. G. F. Lee's) efforts devoted to excessive fertilization management were directed to waterbodies in which there were excessive growths of bluegreen algae. Lee (1971, 1973) published a comprehensive review of eutrophication which contains considerable information on bluegreen algae occurrence, water quality impact and control. For many waterbodies eutrophication (excessive fertilization) management focuses on the control of the excessive growth of bluegreen algae.

Until recently bluegreen algae were not the cause of water quality problems in the Delta. However, bluegreen algae have caused and continue to cause severe water quality problems in the city of Stockton Weber Point waterbody, McLeod Lake. This waterbody is connected to the Delta via a channel to the Port of Stockton. While this waterbody experiences Delta tides, it is a dead-end channel, where nutrients are derived from urban runoff. Stockton is devoting considerable effort toward controlling the impacts of bluegreen algae through aeration of the Weber Point waterbody to break up the algal scum (HDR, 2003).

Lehman and Waller (2003) have reported that,

> "*Blooms of the bluegreen algae* Microcystis aeruginosa *have occurred in the Delta from July through November since 1999 .... In 2002 these blooms occurred in the southern regions of the Delta in Middle and Old rivers and the lower San Joaquin River westward to Antioch."*

At about two-week intervals, as part of the DWR Delta D-1641 Compliance Monitoring, monitoring cruises are conducted along the SJR DWSC channel from about Prisoners Point to the Port of Stockton. The DWR (2003) September 24, 2003, and November 21, 2003, cruise reports state, "*Microcystis aeruginosa, a blue-green algae, was observed floating on or near the water surface from Station 1 (Prisoner's Point) to Station 8*." Station 8 is near Turner Cut. *Microcystis aeruginosa* is a classical bluegreen algae that is frequently associated with excessive fertilization of waterbodies.

While these water samples were taken from the SJR DWSC, the water in this channel at the time of the cruises in the late summer and fall is primarily a mixture of Sacramento River water with some Delta irrigation water returns. This is the result of the South Delta export pumping by the state and federal projects drawing all San Joaquin River water to the export pumps via Old River in the South Delta and through Turner Cut to the Central Delta/South Delta. As discussed in this report, typically the export pumping by the projects draws at least 8,000 cfs of Sacramento River water to the South Delta across the SJR DWSC downstream of Turner Cut and Columbia Cut.

Several members of the DWR Drinking Water staff made presentations on their studies at the California Lake Management Society (CALMS, 2003) annual meeting that was held in mid-November 2003. Information was provided at this meeting on the nature of the DWR Drinking Water monitoring program and some of the current water quality problems that are being experienced. The DWR presentations are posted at
http://wwwomwq.water.ca.gov/PublicationsPage/index.cfm.

At the California Lake Management Society annual meeting the DWR and the Santa Clara Valley Water District staff discussed problems with the growth of water weeds and algae in the Clifton Court Forebay and in San Luis Reservoir. San Luis Reservoir is located south of Clifton Court Forebay and is filled by California Aqueduct waters derived from the Banks Pumping Plant. Excessive growths of water weeds became a problem in Clifton Court Forebay beginning in 1994. There are 800 to 1,000 acres of water weeds in the Forebay. Also, weeds and attached algae are problems in the South Bay Aqueduct. According to the information provided, bluegreen algae are now developing in the Clifton Court Forebay which lead to excretion of taste- and odor-producing compounds. As far as is known, these algae are not developing to any significant extent in the northern, central or southern Delta. The tastes and odors produced by them can be a significant problem for water utilities that use Delta water as a water supply source.

This problem is not a new problem. The Metropolitan Water District of Southern California has experienced problems of this type, where algae develop in their water supply storage reservoirs that lead to taste and odor problems. These problems, in turn, lead to increased cost of treatment to control the tastes and odors. The algae that are causing tastes and odors are not the same type of algae that are contributed to the Central Delta through discharge of the SJR DWSC waters via Turner Cut and Columbia Cut. From the information available, it appears that those algae which make it through the DWSC die and decompose in the Central and South Delta. From the studies conducted in summer 2003 with DeltaKeeper's boat and staff support (Lee et al., 2004a,b), it appears that the algae in the DWSC that enter the Delta via Turner Cut and Columbia Cut do not lead to low-DO problems in the Central Delta. If there are problems of this type, they would be expected to be few and rare, and likely easily controlled. They would only occur under certain SJR DWSC flow regimes, and could be controlled through spot aeration in the Central Delta.

The excessive algae and weeds that develop in Clifton Court Forebay and San Luis Reservoir develop on nutrients (nitrogen and phosphorus compounds) primarily derived from the Sacramento River watershed and Delta island discharges. Both the San Joaquin River and the Sacramento River discharges to the Delta contain surplus nitrogen and phosphorus compared to the concentrations needed to limit algal growth rates. While the San Joaquin River at Mossdale and in the DWSC has a larger "surplus" algal available N and P than the Sacramento River, during the summer and fall essentially all of the SJR-derived surplus enters the South Delta and is exported by the federal water project at Tracy. Based on studies conducted in summer 2003 by Lee et al. (2004b) with DeltaKeeper support, DWR projects pumping records, DWR modeling of flows through the Central Delta and USGS flow measurements, the water and excess nutrients that enter Clifton Court Forebay and San Luis Reservoir are primarily derived from the Sacramento River watershed and from agricultural discharges to Middle River and Old River in the northern, central and southern Delta.

The US EPA, as part of a national program to develop chemical-specific numeric water quality criteria for nutrients (nitrogen and phosphorus compounds), has developed Regional Technical Assistance Groups (RTAGs) that work with US EPA Regional staff in developing nutrient criteria. Dr. G. F. Lee has been active since the 1960s in developing appropriate nutrient loads to waterbodies to protect the desired beneficial uses of the waterbody. He was an active participant in the US EPA Region 9 RTAG efforts to develop nutrient criteria for Central Valley waterbodies. Lee and Jones-Lee (2002e, 2004c) have discussed the problems with the approach that the US EPA (2000b) has adopted for developing the national default nutrient criteria, where they pointed out that this approach is not technically valid. This approach assumes that 25 percent of all waterbodies in an area contain excessive nitrogen and phosphorus. Adoption of the US EPA proposed national default nutrient criteria will result in overregulation of nutrients.

Lee and Jones-Lee (2004c) discussed the need to develop waterbody-specific nutrient criteria that consider the desirable nutrient-impacted water quality and the allowable nutrient loads/concentrations that can be added to the waterbody to achieve the desired level of algal and other aquatic plant productivity. Lee (2001b) has provided guidance on an approach for developing site-specific nutrient criteria for the Delta and Delta tributaries, as well as for the use of the Delta waters for domestic water supply purposes. This approach would involve the stakeholders and the regulatory agencies working together to develop a desired eutrophication-related water quality in the Delta tributaries, channels, and downstream water supply reservoirs. This evaluation would consider the desired amount of aquatic plants in each waterbody, considering their impacts on water quality beneficial uses and food web support. As part of this effort, studies would be conducted to determine the relationship between the nutrient loads/concentrations to and within a waterbody and the aquatic plant biomass-impacted water quality. Consideration would need to be given to the nutrients discharged from a waterbody on downstream waterbodies' eutrophication-related water quality.

Since domestic water utilities that use Delta water as a raw water source experience nutrient-related water quality problems such as algal caused tastes and odors, Lee (2001c) submitted a proposal to the CALFED Drinking Water Program to develop a framework for developing nutrient criteria for the Delta and water supply reservoirs that are filled with Delta water. CALFED was not interested in supporting this proposal, even though it was evaluated by several reviewers as a project that should be supported.

Sanitary Quality Issues. There are two aspects of sanitary quality in the Delta that need to be considered. One is the use of Delta water for domestic water supply purposes, such as by the Contra Costa Water District. The other is contact recreation, where those who use Delta water for recreational purposes incidentally ingest water, through swimming, boating, water skiing, etc. There are several types of organisms of concern with respect to causing human health problems associated with consumption of or contact with fecal contaminated waters.

Classical bacterial diseases are associated with the discharge of human fecal material to the water. These diseases range from gastroenteritis (upset stomach, diarrhea, vomiting, etc.) to severe diseases such as typhoid fever and cholera. There are also groups of bacteria that can cause a variety of "portal" diseases in the eyes, ears, nose and throat, such as staphylococcus and streptococcus. The sanitary quality of a water with respect to the group of enteric (intestinal) bacterial diseases is typically evaluated in terms of fecal indicator organisms of the coliform group. Since the 1940s, total coliforms, and then fecal coliforms, have been used as a measure of sanitary quality of a water, with respect to acquiring bacterial enteric diseases. While fecal coliforms are typically not pathogens, they are excreted in large numbers from human intestinal tracts and, therefore, are an indicator of fecal contamination of water. However, as discussed below, it has been well known for over 60 years that people can acquire diseases from waters that meet coliform standards.

Another group of intestinal disease organisms is protozoan (single-cell animal) parasites, such as amoebic dysentery. The protozoan intestinal parasites are of particular concern since they are cyst-forming organisms which are extremely resistant to death and decay. It has been known since the 1940s that the evaluation of the sanitary quality of a water based on coliforms is not a reliable indication of whether the water is safe with respect to enteric parasites. Waters can test free of fecal coliforms and still contain amoebic dysentery cysts and other protozoan parasites.

In recent years, the emphasis has shifted from amoebic dysentery to giardia and cryptosporidium. Both are protozoan parasites. Giardia became of importance through the finding that this organism inhabits the intestinal tracts of beavers and some other wild animals. It is for this reason that consuming what appears to be sparkling clear mountain stream water can lead to contracting giardia as a result of beavers defecating in the stream.

The protozoan intestinal parasite of greatest concern today is cryptosporidium. While it has been known for many years to be prevalent in water supplies, including those that meet the fecal coliform standards that have been used to judge the sanitary quality of drinking water, cryptosporidium gained national attention through the 1993 outbreak in Milwaukee, where 80 people died, and 400,000 people became ill through ingestion of the organism in drinking water. Ordinarily the ingestion of cryptosporidium may result in intestinal upset which will last for a couple of days. However, there are individuals with deficient immune systems (from AIDS, radiation therapy, etc.) who are extremely susceptible to severe illness, including death, caused by cryptosporidium.

The source of cryptosporidium can be human fecal waste, as well as some animal fecal waste, such as cattle. While for many enteric diseases, the parasitic organisms that inhabit the intestinal tract of animals are not pathogens for humans, there are situations, such as for some protozoan parasites, where there is the potential for fecal material discharged by animals to lead to human disease when consumed through a water supply or food.

The situation that developed in Milwaukee, where the municipal water supply was polluted by dairy wastes, brought to light what had been known since the 1940s – that the protozoan cyst pathogens are much more resistant to disinfection by chlorination than the coliforms. It is now well established that water supplies that meet the coliform drinking water standards, as well as the coliform-based contact recreation standards, can contain protozoan pathogens, such as cryptosporidium, at concentrations that are a threat to cause disease in people.

Another group of human pathogens of concern through drinking water supply or contact recreation is the viruses. There is a variety of human diseases caused by waterborne viruses. Their source is human fecal material. Generally, the viruses do not persist for long periods of time in water, although the persistence is sufficient so that they can cause human diseases. Viruses are a threat to cause disease in people through inadequately treated drinking water and through contact recreation. Viruses that can cause human disease also can be present in waters that meet the fecal coliform standard.

In the early 1990s, OEHHA conducted an environmental comparative risk project. The purpose of this project was to examine the human health and environmental risk associated with chemical and other stressors in the environment. This resulted in a report (OEHHA, 1994), which presented information on the comparative risk of various types of stressors to human health through water and air. Lee and Jones-Lee (1993) developed a section of this report devoted to a review of the comparative risk of pathogens to human health. They summarized the literature on this topic, pointing out that waterborne pathogens through drinking water, including waters that have been treated to meet the fecal coliform standard, represent a significant threat to cause disease in people through consumption of drinking water or contact recreation. From a comparative risk standpoint, humans in the US are far more likely to become ill and/or die from waterborne pathogens acquired through consumption of treated drinking water or contact recreation than from all of the highly regulated chemical stressors, such as the Priority Pollutants. This situation points to the inadequate regulation of water used for domestic water supply and contact recreation in protecting public health.

In an attempt to address the unreliability of the fecal coliform standard for protection of public health associated with contact recreation, in the 1980s the US EPA conducted several large-scale studies to examine the list of human diseases associated with contact recreation. This led to a recommendation that the fecal coliform standard be abandoned in favor of an *E. coli*, or fecal streptococcus, standard. It was found, through the US EPA studies, that there was a fairly direct relationship between *E. coli* concentrations in waters used for contact recreation, and intestinal illness. Based on this, the US EPA (1998) has adopted a policy that all states must adopt a contact recreation water quality standard based on *E. coli*. The CVRWQCB adopted this standard over a year ago and submitted it to the State Water Resources Control Board for review. Thus far the SWRCB has not acted on approval of this standard. One of the problems that has recently come to light is that Byappanahalli et al. (2002) have found that *E. coli* and *Enterococci* can reproduce in warm, moist soils. This finding could make the interpretation of an exceedance of an *E. coli* based contact recreation standard somewhat unreliable as an indicator of the potential for human enteric diseases.

As discussed in this report, the DeltaKeeper has focused part of its activities on evaluating sanitary quality of eastern and Central Delta waters. In general, it has been found that the sanitary quality of Delta waters based on *E. coli* is poor in the areas near Stockton and in areas near marinas and beaches. The water of the Delta outside of these areas meets the US EPA's suggested *E. coli* standard.

Unknown-Caused Toxicity. As discussed above, some of the Delta waterways are listed as impaired due to unknown-caused toxicity. Under the leadership of the Central Valley Regional Water Quality Control Board (originally Val Connor, now Karen Larsen), a group of scientists and engineers interested in this issue have developed a draft strategy for addressing the unknown-caused toxicity that occurs in Central Valley waterbodies. This strategy serves as the basis for developing a proposal to CBDA for Directed Action funding of its components. CBDA (CALFED, 2000) is committed, as part of its Record of Decision (ROD), to develop a program to control unknown-caused toxicity in Delta waters.

South Delta Salt Issues. The San Joaquin River as it enters the Delta and several Delta channels influenced by SJR waters contain excessive salts compared to the 700 µmhos/cm water quality objective for these waterbodies. The primary source for the excessive salts is the export of salts from agricultural areas, especially in the Mud and Salt Slough watersheds. These and other principally westside areas of the SJR watershed cause the SJR at Vernalis to be listed as 303(d) impaired because of excessive salts. Lee and Jones-Lee (2004d) and Lee et al (2004a) have recently reviewed the excessive salt situation in the SJR and South Delta. The total salt content of the waters is of concern because of its adverse impact on irrigated agriculture and the use of the water for domestic water supply. Montoya (DWR, 2004b) has recently reviewed the factors influencing the total salt content of the waters pumped by the state and federal projects. As discussed, the TDS/EC at the project pumping stations is influenced by a variety of factors, including the flow of the SJR, the amount of export pumping occurring, tide stage, position of South Delta barriers, etc.

A TMDL to control salt discharges to the level of the water quality objectives at Vernalis is being developed by the CVRWQCB. Since there are also excessive salts in several South Delta channels compared to the WQO for these waterbodies, there will be need to control salt discharges from SJR watershed sources so that the concentrations of salts in the SJR at Vernalis will not cause or contribute to violations of the EC water quality objective in South Delta channels.

As discussed by Lee et al. (2004a), Delta irrigated agriculture discharges EC in tailwater that is often three times that of the water taken from the channel. While the salt loads in the intake and discharge waters are on the average balanced, the concentrations in the tailwater discharges are greatly elevated due to the consumption of water by crop production. The net effect is to increase the salt concentration (EC) of Delta channels. If the waters taken by agriculture from a South Delta channel are already at the WQO of 700 µmhos/cm, the use of water from Delta channels by irrigated agriculture will lead to WQO violations when the tailwater is added back to the channels.

There is a major problem with the approach that the CVRWQCB has advocated to develop a Basin Plan amendment to begin to solve the violation of the salt (TDS, EC) water quality objective in the SJR watershed. The current focus of the TMDL is on meeting the salt WQO at Vernalis. This approach will not eliminate the violation of WQOs in the San Joaquin River upstream of Vernalis as well as in the South Delta. With respect to the latter, achieving the EC WQO at Vernalis will lead to continued EC WQO violations in the South Delta channels. As suggested by G. F. Lee at the CVRWQCB April 29, 2004, Salt and Boron TMDL workshop, the first step in this process should be to define TMDL goals for each reach of the SJR and its tributaries to meet the WQOs in all the waterbodies in the SJR watershed and in the South Delta. This will require that an understanding be developed of the EC that can be in the SJR at the Head of Old River and still allow irrigated agriculture to be practiced in the South Delta without causing violations of the summer irrigation season WQO of 700 µmhos/cm in South Delta channels at the location where the channel waters mix with irrigation tailwater.

As a possible approach for eliminating South Delta channel EC WQO violations, it has been suggested that the EC WQO for South Delta channels be raised from the current 700 µmhos/cm to a value that would allow South Delta irrigated agriculture tailwater discharges when the South Delta channels are at the WQO. It is unlikely that such an increase would be approved because of the adverse impact on crop production by irrigated agriculture. According to A. Hildebrand (pers. comm., 2004), *"In regard to water quality, there was extensive testimony that led to the need for a 700 µmhos/cm salinity standard to prevent losses in crop yield. The salinity was almost always better than 700 µmhos/cm pre CVP. Furthermore, even when the salinity standard is met at Vernalis it is not met downstream, particularly when flows are low and the salt load is high. Manteca, Tracy, Lathrop, and Mountain House wastewater enters the channel system. Furthermore, agricultural use of water necessarily concentrates whatever salt load is in the diverted water. The tributaries are not responsible for the salinity problem, but they aggravate the problem when they manipulate the time of flow from what it would be in the absence of VAMP."*

Depending on the operation of the permanent barriers that are to be installed in the South Delta by 2007, there is the potential to bring more low-salinity Sacramento River water into the South Delta and thereby reduce the EC in some, but not all, South Delta channels. This will not, however, eliminate the EC violations in some of the South Delta channels. From the information available, to eliminate these violations it will be necessary to reduce the EC concentrations of the SJR waters entering the South Delta at the Head of Old River below 700 µmhos/cm.

Heavy Metals. As discussed above, there is a major water quality problem in the Delta due to mercury. Lee (2003h) has presented a review of current and pending regulatory approaches for mercury in water and sediments. In addition to mercury, selenium is a metal that is potentially causing water quality problems in the Delta due to adverse impacts on certain fish (sturgeon) associated with its bioaccumulation in clams through the Delta food web. Linville et al. (2002) and Schlekat et al. (2000) have reported that particulate selenium can be taken up by clams, which are then consumed by sturgeon.

Brown et al. (2004) have discussed the potential for cadmium to be bioaccumulating in clams in the western Delta near Chipps Island to a sufficient extent to be potentially adverse to clam reproduction. Further, Thompson (1996) has found that diving ducks are gaining sufficient cadmium from eating clams to potentially adversely impact their reproduction.

Luoma (2004), at the CBDA contaminant stressor workshop, expressed the view that possibly the bioaccumulation of cadmium and nickel in aquatic life in Delta tributaries and the Delta could be adverse to Delta and San Francisco Bay aquatic life. The current water quality criteria for cadmium and nickel do not consider the potential for food web accumulation of these chemicals and the potential toxicity to host organisms. This is an area that needs study.

Former mining activities in the Delta watershed have resulted in large amounts of several heavy metals such as copper, zinc and cadmium being discharged to Delta tributaries which have then been transported to the Delta and have accumulated in Delta sediments. Of particular importance are the former discharges of the Iron Mountain Mine (IMM) near Shasta Lake to the upper Sacramento River. The US EPA (2004) has stated that its cleanup efforts at the Iron Mountain Mine

"… will lead to the control of over 95 percent of the copper, cadmium and zinc that historically discharged to the Sacramento River. Before Superfund cleanup actions, IMM discharged more than a ton per day of toxic metals into the Sacramento River."

While Keswick Reservoir will trap some of the particulate heavy metals from the IMM in its sediments, large amounts of the heavy metals that have been discharged to the Sacramento River from IMM and other mines are eventually transported to the Delta where they are to some extent deposited in Delta sediments.

According to A. Baillie (pers. comm., 2004) of the CVRWQCB, Delta marina sediments have been found to contain elevated copper concentrations compared to Delta channel sediments. Based on the Delta Dredging and Reuse database, Baillie reported that the average copper in marina sediments was 49.7 mg/Kg (dry weight) with a range of 5 to 300 mg/Kg. Delta river sediments had a mean copper concentration of 38 mg/Kg with a range of 1 to 90 mg/Kg. According to Dragun and Chiasson (1991) the USGS reported that the average copper in California soils was 49 mg/Kg with a range of 5 to 300 mg/Kg. It appears that Delta marina sediment copper is within the range of copper in California soils.

Baillie stated that some Delta marina sediments have also been found to contain tributyl tin (TBT). Both copper and TBT have been used in boat hull antifoulant paints. Copper is still being used for this purpose. Baillie also indicated that some Delta marina sediments are toxic to some aquatic life. It is not known whether the copper and other heavy metals in Delta sediments (including in marinas) is the cause of this toxicity. It will be necessary to conduct sediment toxicity tests and toxicity identification evaluations (TIEs) to determine which sediments are toxic and the cause of this toxicity. As discussed herein and by Lee and Jones-Lee (2002a,d), it is unreliable to try to use Long and Morgan ERLs and ERMs or MacDonald TELs (co-occurrence-based values) to determine the role of a constituent measured in sediments as the cause of sediment toxicity.

Urban street and highway stormwater runoff has been found to be a source of copper, zinc, cadmium and lead at concentrations above the US EPA CTR water quality criteria. However, Lee and Taylor (2001), as well as others (see review by Lee and Taylor, 2001), have found that the heavy metals in urban area and highway stormwater runoff are in nontoxic forms. While urban area stormwater runoff is toxic to *Ceriodaphnia*, TIEs have shown that the toxicity is due to the organophosphate pesticides diazinon and chlorpyrifos. It is likely that in Delta waterbodies, the heavy metals of potential concern in highway and street runoff will remain in nontoxic forms in Delta waters and sediments.

pH and Alkalinity. A review of the existing data for Delta channels shows that there are no excessive pH or extremely low alkalinity values in Delta waters. Even though there is marked algal photosynthesis in the surface waters of the San Joaquin River Deep Water Ship Channel that could cause elevated pH in the main channel in the late afternoon, which would violate the CVRWQCB Basin Plan objective, these problems have not been observed. There are situations, however, in some of the side channels, such as the Wine Slip in the Port of Stockton, where photosynthesis impacts diel pH sufficiently to cause violations. As discussed by Lee and Jones-Lee (2000a), Lee and Litton, in a study of the Port of Stockton Wine Slip conducted in August 1999, showed that pH values greater than 9 were experienced in late afternoon, which could be attributed to phytoplankton photosynthesis.

The CVRWQCB Basin Plan objective for maximum pH is 8.5. This value is considerably more restrictive than the US EPA Gold Book criterion of pH 9. Even a pH of 9 is not significantly adverse to a waterbody's fisheries, since many eutrophic waterbodies have excellent warm water fisheries and routinely have pH of 9.5 to 10 in the late afternoon.

The alkalinity levels in the San Joaquin River and in the Sacramento River are variable, depending on flow, but are sufficient to provide considerable pH buffering of Delta waters. This buffer capacity has not been recognized by the CVRWQCB as part of their permitting of the city of Stockton's wastewater discharges. Until recently, the Regional Board allowed the city of Stockton to add acid to its domestic wastewater effluent to a sufficient extent so that at times the pH in the effluent was on the order of 6. The purpose of the acid addition was to reduce the toxicity of ammonia present in the effluent. However, the acid was quickly neutralized in the San Joaquin River due to the buffering capacity of the water. The CVRWQCB no longer allows the city of Stockton to follow this approach.

Invasive Species. Cohen and Carlton (1995) have presented a comprehensive review of the occurrence and potential impacts of biological invasive species in San Francisco Bay and the Delta. Appendix C presents the Executive Summary from their report. They indicate that the San Francisco Estuary is recognized as the most invaded aquatic ecosystem in North America, with 212 introduced species (as of 1995). Since 1970, there has been at least one new species introduced every 24 weeks. They report that nonindigenous animals and plants in the Estuary have had a profound impact on the ecology of the system. One of the most important impacts is the introduced bivalves which, through filter feeding, are potentially altering the trophic dynamics of the Bay-Delta system. Cohen and Carlton point out that clams in the Suisun Bay area have the ability to filter essentially all of the water in the northern Estuary each day.

As discussed by Cloern et al. (2003), this filter-feeding (grazing) by clams appears to be having a significant adverse impact on the phytoplankton populations in the Suisun Bay area. The extent to which these impacts are occurring throughout the Delta is unknown and is an area that needs investigation. One of the major challenges of future water quality monitoring in the Delta is an assessment of the impacts of pollutants on the aquatic ecosystem, versus that of invasive species.

Biomarkers and Sublethal Effects

At a CBDA meeting in June 2003, Dr. Susan Anderson of the University of California, Davis, Bodega Marine Laboratory, presented a discussion (see Anderson, 2003) of some of her graduate students and her work on examining fish biomarker responses in the San Joaquin River and one of its tributaries. She reported that a caged fish in Orestimba Creek (one of the westside tributaries to the San Joaquin River, which has considerable runoff/discharges from irrigated agriculture) showed no cholinesterase inhibition during a February 2000-2001 stormwater runoff event when the concentrations of the OP pesticides diazinon and chlorpyrifos would be expected to be at their greatest. The measured concentrations of OP pesticides during this runoff event were in the low tens of nanograms per liter. The concentrations were below those that are known to be toxic to *Ceriodaphnia* and well below those that are known to be toxic to fish. Anderson (Whitehead et al., 2003) also made measurements of DNA strand breakage and Ames test mutations in the caged fish. There was evidence for positive responses in both tests, indicating that there may have been chemicals in the water that have the potential to be adverse to aquatic life. This type of testing is typically considered measurements of biomarkers – i.e., less than whole organism response to exposure to chemicals. It has been known since the 1960s that fish, under various exposure conditions, show biomarker responses to a variety of chemicals that have been investigated.

In 1996, the American Society for Testing and Materials held a biomarker symposium, at which the experts in the field presented the information they had on biomarkers in fish and other aquatic life in response to various types of chemicals or environmental settings. Bengston and Henshel (1996) edited the symposium proceedings. The overall conclusion from the experts at the symposium was that a properly conducted test of a biomarker response does indicate an organism exposure to a chemical or group of chemicals. In 1996 and, for that matter, today, there is still little understanding of what a biomarker response in fish means to fish populations. Since there is limited funding for work on this topic, the deficiency in understanding biomarker responses with respect to whole organism responses will likely prevail for considerable periods of time.

Werner and Eder (2003) conducted studies on the sublethal effects of chlorpyrifos and esfenvalerate on juvenile Chinook salmon, in which they measured acetylcholine esterase inhibition, stress proteins (indicators of cellular protein damage) and cytokine expression (immune system response). Four-month-old juvenile Chinook salmon were exposed for four days to chlorpyrifos and esfenvalerate, ranging in concentration for chlorpyrifos from 1.2 to 81 µg/L, and for esfenvalerate from 0.01 to 1 µg/L. They stated that,

> *"Exposure to sublethal concentrations of commonly used insecticides resulted in long-term alterations of cellular components of the immune system, nervous system (AChE inhibition), and the stress response."*

These responses are indicative of cellular alterations, which can be energetically costly to the organism. They also noted that the sensitivity of fish repeatedly exposed over the winter may be increased due to the increased exposure. This presentation was based on a paper that is in press (Eder et al., 2003a,b; 2004).

Werner et al. (2003b) have provided additional information on their work on sublethal effects of chemicals on aquatic life, focusing on impacts on cellular stress proteins in the freshwater fish medaka and examining the histopathology of Asian clams in the Delta. Further work is underway on these issues.

Delta Port and Navigation Channel Development

Ports that are used by ocean-going deep-draft ships have been developed in West Sacramento and Stockton. This development involved dredging channels from San Francisco Bay through to each of the ports. Since the dredged channels and associated port areas tend to accumulate sediments with a wide variety of potential pollutants, there is concern about maintenance dredging of these channels leading to the release of pollutants that are adverse to Delta water quality. Lee and Jones-Lee (2000b) and their associates have conducted extensive research on the water quality aspects of dredging in various waterbodies located throughout the

US and in some other countries. As they discuss, there is need to conduct comprehensive studies associated with each dredging project, especially those conducted in areas of poor water quality such as the Port of Stockton, to insure that the project does not cause significant adverse impacts to the beneficial uses of the waters in which the project is conducted, in areas where the dredged sediments are deposited and runoff/discharges from these areas, and in areas where dredged sediments are utilized for beneficial purposes, such as levee maintenance.

The CVRWQCB, as part of its permitting of dredging projects in the Delta, conducts comprehensive reviews of Delta channel maintenance projects for the purpose of working toward water quality protection associated with the dredging and dredged sediment disposal/utilization projects. While a wide variety of potential pollutants is investigated prior to and monitored associated with each dredging project, as discussed by Lee (2004a), there is the potential for unrecognized water quality impacts to be occurring by constituents that are not investigated/ monitored under the current regulatory program. There is need to continue to expand the comprehensive nature of these dredging project investigations to include evaluation of previously unrecognized and new pollutants that have accumulated in the sediments that are dredged.

The Port of Stockton is in the process of proposing to greatly expand the number of ocean-going ships that use the Port. According to the draft EIR (ESA, 2003), for the expansion project, *"The total number of annual port calls would increase from 20 to 150 as a result of the Proposed Project."* This expansion has a number of potentially significant ramifications for Delta water quality. These include significantly increasing the suspension of sediments that occurs associated with ship traffic. To the extent that chemical constituents are released during sediment suspension, the increased ship traffic could aggravate existing water quality problems associated with ship traffic. There is also the potential for increased shoreline erosion associated with ship traffic, caused by the ship's wake. There is need for a more comprehensive investigation of the impact of ship traffic on Delta water quality.

The Port of Stockton has proposed to change the navigation depth of the DWSC from the current 35 feet to 40 feet. This would further aggravate the low-DO problem that exists in the DWSC near the Port of Stockton. As discussed by Lee and Jones-Lee (2003a), the development of the Port of Stockton and its associated deep water navigation channel is one of the primary causes of the low-DO problem in the SJR DWSC near the Port of Stockton. The DWSC in this region has converted the SJR from a fast-flowing river that has a depth of 10 to 15 feet to a slow-moving, long, thin lake, with a depth of 35 feet. This change in the physical characteristics of the channel greatly increases the hydraulic residence time of water in the channel beginning at the Port, with the result that oxygen-demanding materials, such as ammonia discharged by the city of Stockton wastewater treatment plant and algae that develop on nutrients derived primarily from agricultural sources in the SJR DWSC watershed, exert oxygen demand to a greater degree in the SJR DWSC than would occur if the dredged navigation channel to the Port of Stockton did not exist. Increasing the navigation depth of this channel to 40 feet will further aggravate this situation.

The Corps of Engineers was required to mitigate the impact of the increased channel depth on the oxygen demand assimilative capacity associated with the past deepening of the channel from 30 feet to 35 feet that occurred in the late 1980s by installing an aeration device located at the Port of Stockton near Channel Point. A critical review of the approach that the Corps of Engineers was allowed to adopt with respect to evaluation of whether the aerator design would mitigate for the decreased oxygen demand assimilative capacity of the DWSC, and the required operation of this aerator, shows that the aerator is not achieving design specifications. This issue has been addressed by Brown (Jones & Stokes, 2003). Further and most importantly, the Corps' current approach for operating the aerator does not require the Corps to operate the aerator whenever the oxygen concentrations in the DWSC near the Port of Stockton are below the water quality objective for this reach of the Channel.

As discussed by Lee and Jones-Lee (2003a), there have been several periods over the last couple of years when the dissolved oxygen concentrations in the DWSC just downstream of the Port of Stockton were at or near zero mg/L. Associated with these periods were fish kills. However, in accordance with the current operations plan for the aerator adopted as part of mitigation for increasing the channel depth from 30 feet to 35 feet, the aerator was not operated during all times that the DO was below the water quality objective. Lee (2003i) has discussed the need to change the characteristics and operations of the aerator so that it more appropriately mitigates for the deepening of the channel that took place in the late 1980s from 30 feet to 35 feet. Further, associated with any additional deepening of the channel, such as that proposed by the Port of Stockton, more appropriate review of mitigation measures as they may impact the oxygen demand assimilative capacity of the SJR DWSC should be conducted than occurred for the late 1980s deepening of the channel.

Another aspect of increased ship traffic is the potential water quality impacts of ships discharging their ballast water at the Port of Stockton. Ballast water is notorious as a means of transporting invasive species to areas where they would not ordinarily be found. Further, since the ballast water for ocean-going ships that reach the Port of Stockton is likely marine water with a high salt content, the increased shipping could introduce substantial salt into the Port of Stockton area and thereby increase the TDS of the San Joaquin River water at the Port. Further, depending on the source of the ballast water and whether mid-ocean exchange of the ballast water from that which was acquired at the original port of embarkation has occurred, there is a potential for the introduction of a wide variety of chemical pollutants and pathogens into the Port of Stockton associated with the increased number of ships utilizing the Port.

Thermal Discharges

The pollution of Delta waters by thermal discharges is an issue that is not being adequately addressed. Part of the problem is that the California Thermal Plan is badly out of date and needs to be updated to more properly reflect current knowledge on how elevated temperatures impact aquatic life. All discharges that contain elevated temperatures in Delta waters should be investigated to determine if excessive thermal discharges are occurring that are detrimental to Delta aquatic life.

Impact of Urbanization on Delta Water Quality

The rapid urbanization of the Delta watershed is bringing ever-increasing amounts of potential pollutants into the Delta and its tributaries. In addition to urban stormwater runoff being a source of pesticide-caused aquatic life toxicity and oxygen demand, it is also a source of a wide variety of potential pollutants, such as heavy metals (including lead, cadmium, copper and zinc), petroleum hydrocarbons (including PAHs), dioxins, total suspended solids, etc. The Center for Watershed Protection (CWP, 2003) has recently issued a report, "Impacts of Impervious Cover on Aquatic Systems." This report provides information on the impacts of urbanization of areas on urban stream hydrology and stream aquatic life habitat, and includes information on the chemical characteristics of urban streams. Lee and Jones-Lee (2004e) have recently developed a review of urban stream water quality in which they discuss issues that need to be considered in evaluating the water quality impacts and the control of chemical constituents and pathogen indicator organisms.

Jones-Lee (2004) publishes a *Stormwater Runoff Water Quality Science/Engineering Newsletter* that discusses urban and rural stormwater runoff water quality issues. This *Newsletter* is in its seventh year of publication. It is distributed by email periodically at no cost to over 8,000 individuals. Past issues of this *Newsletter* are available at www.gfredlee.com. This *Newsletter* discusses the characteristics of urban stormwater runoff and the significant problems that exist today in regulating urban area stormwater runoff water quality impacts. Lee and Jones-Lee (2003e) have recently discussed these problems relative to urban stormwater runoff impacts to port and harbor water quality, and presented a recommended approach for evaluating and managing the water quality impacts of urban area and highway stormwater runoff-associated constituents.

The current regulatory approach at the federal and state level is not effective in defining and managing the real, significant water quality impacts of urban stormwater runoff-associated potential pollutants on receiving water quality. Jones-Lee and Lee (1998) have recommended that the current NPDES monitoring of stormwater runoff from urban areas and highways, in which a suite of potential pollutants is monitored in the runoff for a couple of storms each year, be changed to an Evaluation Monitoring approach. The current monitoring approach is patterned after typical wastewater discharge monitoring, in order to evaluate compliance with the NPDES permit conditions and water quality standards.

As discussed by Jones-Lee and Lee (1998) and Lee and Jones-Lee (2003e), the characteristics of urban stormwater runoff, where elevated concentrations of largely particulate (non-toxic, non-available) constituents are discharged over short periods of time, make the use of an exceedance of US EPA worst-case-based water quality criteria and state standards based on these criteria unreliable for evaluating water quality impacts. Rather than continuing to monitor discharge chemical characteristics, which are now well established, Jones-Lee and Lee (1998) recommend that the monitoring be shifted to studies of the receiving waters for the runoff, to determine the adverse impacts of the runoff-associated constituents on the beneficial uses of these waters. This approach will lead to the development of reliable wet-weather standards that can be used to more appropriately regulate the water quality impacts of urban area and highway stormwater runoff than the water quality standards that are being used today.

According to a May 5, 2004, editorial in the *Sacramento Bee*, 45,000 acres of Delta farmlands have been converted to urban areas in the last 10 years. Further, with the population of the Central Valley – and especially the Delta watershed – expected to increase significantly in the next decade or so, there will be substantial increases in the amount of stormwater runoff discharged to Delta tributaries and directly to the Delta. The current estimated urban population in the San Joaquin River watershed is approximately two million. Lee and Jones-Lee (2000a) report that the SJR watershed urban population is rapidly expanding with a rate of growth of 2 percent/yr and expected to double to about 4 million people by 2040. Increased attention needs to be given to evaluating the water quality impacts of Delta watershed urban stormwater runoff on Delta water quality-beneficial uses. This evaluation will require studies that specifically focus on the fate, transport and impacts of urban area and highway stormwater runoff on Delta tributaries and Delta waters. Particular attention should be given to stormwater runoff water quality impacts from Stockton, the greater Sacramento metropolitan area and upstream San Joaquin River watershed municipalities.

An issue of concern is the current stormwater management practice for Modesto's stormwater runoff, of discharging parts of it into dry wells without regard to whether this practice is causing groundwater pollution. Lee et al. (1998) and Taylor and Lee (1998) have provided information on the potential for infiltration of urban area and highway stormwater runoff-associated constituents to cause groundwater pollution. The current Modesto practice of infiltrating stormwater could – as a result of the investigations of the impacts of this practice, which are now being required by the CVRWQCB – be curtailed and result in even greater urban area stormwater potential pollutant loads to the San Joaquin River.

The recent SFEI Regional Monitoring for Trace Substances Annual Meeting included a discussion of the effects of the urbanization of the San Francisco Bay watershed on pollutant loadings to the Bay, by Davis et al. (2004). They conclude that, *"Urbanized portions of Bay Area watersheds are significant sources of most priority contaminants, including PCBs, mercury, copper, organochlorine pesticides, dioxins, diazinon, PAHs, and PBDEs."* In a presentation at the SFEI 2004 conference, Oros (2004) presented an expanded discussion of the current knowledge on the occurrence and sources of PAHs in the San Francisco Bay Estuary. A similar presentation was made by Yee (2004) for dioxins in the Bay sediments and aquatic life. Background information on Oros' presentation has been provided by Oros and Ross (2004). The Oros and Yee studies have shown that urban areas are significant sources of these potential pollutants. Based on the information provided, it is likely that similar kinds of problems, caused by PAHs, PCBs, PBDEs, organochlorine legacy pesticides and mercury, are occurring in waterbodies in the greater Sacramento area and the San Joaquin River Deep Water Ship Channel near Stockton. Both of these areas need to be specifically targeted for detailed studies on PAH, PCB and dioxin occurrence in water and sediments and for PCBs, PBDEs and dioxins in fish.

Impact of Export Projects on Chinook Salmon Home Stream Water Signal

At a CBDA Chinook/Steelhead Restoration workshop held in July 2003 several presentations were made on the lack of a well-defined genetic makeup of the Chinook salmon that return to San Joaquin River tributaries. This situation is related to the fish straying from their home stream water. It was pointed out that in other areas the Chinook salmon that return to a particular home stream normally have a well-defined genetic structure. It appears that something is causing the Chinook salmon that spawn in the SJR watershed tributaries to have problems finding their home stream for spawning. The South Delta export projects that have changed the flow of Sacramento and San Joaquin River water through the Delta have changed the transport of the home stream chemical signal for spawning of Chinook salmon. Prior to the export projects, the San Joaquin River tributary home stream water chemical signal which guides the fish to their spawning areas could be transported, during low-flow conditions, to San Francisco Bay, and thereby provide a home stream signal to fall-run Chinook salmon proceeding to their San Joaquin River tributary home stream. Lee and Jones-Lee (2003f) have discussed that the export-project-caused drawing of large amounts of Sacramento River water to the South Delta has eliminated any San Joaquin River tributary home stream water signals from occurring in the Central and northern Delta, downstream of Columbia Cut. The waters in the San Joaquin River channel downstream of Columbia Cut during the summer, fall and early winter are Sacramento River water, and not San Joaquin River water. This means that the fall-run Chinook salmon, upon entering the Delta from San Francisco Bay during the fall and winter have no home stream water signal to help them migrate through the Delta to their home stream waters. The consequences of this situation on the restoration of the Chinook salmon fishery need to be evaluated.

Delta Improvements Package

In the summer of 2003 the agencies/entities responsible for managing water exports from the Delta held a meeting in Napa, California, to discuss the implementation of the expanded exports of Delta water called for in the CALFED (2000) Record of Decision. The results of this meeting became known as the "Napa Agreement." Over the fall and early winter this has evolved into what is now called the Delta Improvements Package (DIP). Quinn (2004) of the Metropolitan Water District of Southern California presented a review of the "Delta Improvements Package: A 2004 CALFED Priority" at the January 2004 CBDA Drinking Water Subcommittee meeting. One of the components of the proposed Delta Improvements Package is additional monitoring of selected parameters (TOC and salt) of interest to those who export Delta waters for municipal and agricultural purposes, as well as Delta agricultural interests, especially the South Delta agricultural interests.

In February 2004 the CBDA (2004b) released the proposed Delta Improvements Package. Table 2 presents a listing of the components of the proposed DIP. In May 2004 CBDA (2004c) released for public comment a Draft Memorandum of Understanding (MOU) Regarding CALFED Bay Delta Program Activities in the Delta. In response to the request for comments on this draft MOU, Lee and Jones-Lee (2004d) provided an overall assessment and detailed comments on the proposed DIP and draft MOU covering its implementation.

> ***"Overall Assessment of the DIP***
>
> *It is our assessment that the California Bay-Delta Authority is not in a position to reliably pursue adopting and implementing the currently proposed Delta Improvements Package. The information base upon which to develop adequate reviews of the potential water quality impacts of increasing the Harvey O. Banks pumping station's flow to 8,500 cfs does not exist. Figure 1 presents a plot of the Department of Water Resources (DWR) measured flow at the Banks pumping station for the period 2001 through 2003. As shown, increasing the Banks pumping station flows to 8,500 cfs, as proposed in the DIP interim implementation, will, at times, represent a significant additional export of Delta water by the State Water Project.*

Table 2
Components of the Delta Improvements Package (DIP)

SUMMARY OF STATUS OF
ACTIVITIES UNDER CONSIDERATION[1]

WATER SUPPLY RELIABILITY
- Increase State Water Project (SWP) Pumping Capacity to 8,500 cfs
- Implement SWP/CVP Integration Plan
  - The SWP will convey CVP refuge water at the Banks Pumping Plant
  - The CVP will provide water to assist DWR in meeting the SWP's water quality responsibility
  - Water made available by Sacramento Valley water users pursuant to an Agreement known as "Phase 8" of the Bay-Delta water rights hearings by the State Water Resources Control Board (SWRCB) will be shared by the CVP and SWP
- Design and Construct CVP/SWP Aqueduct Intertie
- Operations Criteria and Plan Update

ENVIRONMENTAL WATER ACCOUNT
- Continue the Environmental Water Account (EWA)
  - Fixed Assets – Capital Assets and Water Purchases
  - Variable Operational Assets
    - SWP Pumping of (b)(2)/ERP Upstream Releases
    - EWA Use of SWP Excess Capacity
    - Export/Inflow Ratio Flexibility
  - Water Management Tools and Agreements
  - EWA Debt Carryover and Source Shifting
  - Wet/Dry Year Exchanges
  - Storage

ESA COMPLIANCE AND ECOSYSTEM RESTORATION
- Water project ESA consultation requirements
- Update of CALFED ROD programmatic ESA consultation – EWA and ERP

WATER QUALITY
- In-Delta Salinity Projects
  - Old River and Rock Slough Water Quality Improvement Projects
  - Develop Strategy for Franks Tract
  - Delta Cross Channel Reoperation
  - Through Delta Facility
  - Install Permanent Operable Barriers
- In-Delta Dissolved Oxygen Projects
  - Dissolved Oxygen Implementation Strategy

[1] From CBDA, February (2004b)
http://calwater.ca.gov/DeltaImprovements/DIP/DIP_CBDA_staff_report_Att_A_2-11-04.pdf

Table 2 (continued)

San Joaquin River Salinity
Basin Plan Amendment to Implement a Total Maximum Daily Load (TMDL) for Salinity
Implementation of Source Control Measures
San Joaquin River/CVP Recirculation Feasibility Study

SCIENCE
Environmental Water Account Technical Reviews
South Delta Hydrodynamics and Fish Investigations
Delta Smelt Fish Facility Survival
Addressing Critical Information Gaps and Uncertainties Regarding Water Operations and Biological Resources
RELATED ACTIONS
Trinity River
Freeport Regional Water Project

We have critically examined the current information base on the impacts of the State and federal export projects on Delta water quality. Our findings are presented in the DWQI report. It is found that CALFED, DWR, USBR and the State Water Resources Control Board (SWRCB) have not adequately and reliably evaluated the water quality impacts of the current exports of Delta water by the State and Federal export projects. Significantly increasing the amount of export, as proposed in the DIP, should not take place until an adequate evaluation of the current impacts of the export projects on Delta water quality has been conducted. Further, this evaluation of the current impacts should be conducted in such a way as to serve as a technical base for predicting the magnitude of the additional adverse impacts that will occur through increasing the Banks pumping station flows to a more consistent 8,500 cfs than has been occurring in the recent past. This information can then be used to develop appropriate mitigation measures to address the adverse impacts of further exports of Delta water through the State Water Project as proposed in the DIP."

(Figure 1 is presented in the Lee and Jones-Lee (2004d) comments on the MOU and proposed DIP.)

Lee and Jones-Lee (2004d) provided detailed comments on the deficiencies in information upon which to evaluate the water quality impacts of increasing Delta water exports on the water quality within the Delta. Of particular concern are the impacts of the current and proposed expanded exports on the transport and fate of pollutants added to the Delta from tributary and in-Delta sources. As they point out, the export projects have totally changed the flow of water through the Delta and therefore the impacts of pollutants in Delta waters on water quality-beneficial uses of the Delta.

Delta Water Quality Monitoring Programs

The key to reliably managing water quality in the Delta is a comprehensive water quality monitoring and evaluation program. There are several water quality monitoring programs being conducted in the Delta and its nearby tributaries. In general, these programs have specific objectives related to managing Delta resources. The most comprehensive of these programs is the Interagency Ecological Program (IEP) Environmental Monitoring Program (EMP). On March 25, 2003, Stephen Verigin of the Department of Water Resources (DWR) and Susan Ramos of the US Bureau of Reclamation (USBR) submitted a revised Delta water quality monitoring program to Celeste Cantú, Executive Director of the State Water Resources Control Board (available at http://iep.water.ca.gov/emp/EMP_Review_Final.html). This monitoring program is being conducted as part of implementing the State Water Resources Control Board's Water Rights Decision 1641 covering the export of water from the Delta by the state and federal projects. As stated in the cover letter for this submission,

> *"D-1641 specifies three goals for this monitoring program: (1) to ensure compliance with Bay-Delta water quality objectives; (2) to identify meaningful changes in any significant water quality parameters potentially related to operation of the State Water Project (SWP) or the Central Valley Project (CVP); and (3) to reveal trends in ecological changes potentially related to SWP/CVP operations. Condition 11 (e) requires DWR/USBR to evaluate the EMP and report their conclusions to the Executive Director of the State Water Resources Control Board every three years."*

The 2001-2002 Review of the Environmental Monitoring Program states that,

> *"The Environmental Monitoring Program (EMP) was initiated in 1971 and now monitors water quality and phytoplankton, zooplankton, and benthos abundance and distribution in the upper San Francisco Estuary."*

According to the report, the monitoring elements consist of

- *"'Continuous Recorder' monitoring of water temperature, electrical conductivity (EC), or dissolved oxygen,*
- *Continuous 'Multiparameter' monitoring,*
- *Discrete (monthly) physical and chemical water quality monitoring,*
- *Discrete (monthly) phytoplankton monitoring,*
- *Discrete (monthly) zooplankton monitoring, and*
- *Discrete (monthly) benthos monitoring.*

> *EMP monitoring is currently conducted at 22 of the 42 stations listed in D-1641, Table 5."*

The footnotes to Table 5 Water Quality Compliance and Baseline Monitoring list the following as the current parameters that are monitored:

- *"Continuous recording (every 15 minutes) of water temperatures, electrical conductivity (EC), and/or dissolved oxygen. For municipal and industrial intake chloride objectives, EC can be monitored and converted to chloride concentration.*
- *Continuous multi-parameter monitoring (recording every 1 to 15 minutes with telemetry capabilities) includes the following variables: water temperature, EC, pH, dissolved oxygen, turbidity, chlorophyll fluorescence, tidal elevation, and meteorological data (air temperature, wind speed and direction, solar radiation).*

- *Discrete physical/chemical monitoring is conducted near-monthly on alternating spring and neap tides and includes the following variables: macronutrients (inorganic forms of nitrogen, phosphorus, and silicon), total suspended solids, total dissolved solids, total, particulate and dissolved organic nitrogen and carbon, chlorophyll* a*, pH, dissolved oxygen (DO), EC (specific conductance), turbidity, Secchi depth, and water temperature. In addition, on-board continuous recording is conducted intermittently for the following variables: water temperature, dissolved oxygen, electrical conductivity, turbidity, and chlorophyll* a *fluorescence.*
- *Near-monthly discrete sampling on alternating spring and neap tides for phytoplankton enumeration or algal pigment analysis.*
- *Near-monthly tow or pump sampling for zooplankton, mysids, and amphipods.*
- *In 2003 and 2004, replicated benthos and sediment grab samples are taken quarterly (every three months) and during special studies; more frequent monitoring sampling resumes in 2005."*

There is also a monitoring program for fish in the Delta. However, it is not integrated with the EMP program.

Several years ago, those responsible for organizing the Interagency Ecological Program (IEP) monitoring terminated the pesticide monitoring. This is unfortunate. What should have been done was to shift the monitoring for organochlorine pesticides, from the water column to fish tissue. This is a much more reliable approach for determining whether there are excessive concentrations of organochlorine pesticides than attempting to measure these pesticides in the water column.

Dr. G. Fred Lee was part of an external advisory panel for the 2001-2002 review of the Environmental Monitoring Program, which served as a basis for the DWR/USBR (2003) submission to the SWRCB. As part of this effort it was found that those responsible for developing the D-1641 water quality monitoring program for the Delta assumed a narrow scope for the potential impacts of the export of Delta waters on Delta water quality compared to the water quality monitoring program that is needed to fully evaluate the impacts of the export projects on Delta water quality beneficial uses.

The state and federal export projects, which typically export about 10,000 to as much as 13,000 cfs of Delta water, significantly alter the impacts on Delta waters of a variety of pollutants, such as mercury, organochlorine pesticides, PCBs, organophosphorus and other pesticides, herbicides, aquatic plant nutrients, etc. As one example of this, the export of South Delta water by the two projects, which causes at least 8,000 cfs of Sacramento River water to be drawn through the Central Delta to the South Delta export pumps, carries mercury into regions of the Delta where it would not otherwise exist at the concentrations found, if the export projects did not occur. The same applies with respect to altering the location and impacts of a number of other constituents that are on the CVRWQCB 303(d) list of constituents causing impaired water quality in the Delta. Because of the limited scope that the DWR, USBR and SWRCB have assumed for potential impacts of the state and federal export projects, there has been no proper evaluation of the full range of water quality impacts of the export of Delta water by the state and federal projects.

One of the most striking examples of an impact of the state and federal export projects on Delta water quality occurs in the first seven miles of the Deep Water Ship Channel (DWSC) near Stockton. As documented by Lee and Jones-Lee (2003a,b) and Lee (2003c,d), the state and federal South Delta water export projects at times cause most (essentially all) of the San Joaquin River water at Vernalis to flow down Old River into the South Delta to the federal export project pump at Tracy. As discussed by Lee and Jones-Lee (2003a), this causes the hydraulic residence time (travel time) of water in the DWSC critical reach (between Channel Point and Turner Cut) to be increased from a few days to several weeks, to as much as a month. This, in turn, leads to much greater DO depletion in the DWSC than would occur if the San Joaquin River water at Vernalis were allowed to pass through the San Joaquin River DWSC. Lee and Jones-Lee, as part of developing the Issues Report (Lee and Jones-Lee, 2000a), found, through a review of the existing water quality data on the DO in the DWSC, that there was a direct relationship between low DO in the Channel and low flows of the SJR through the Channel. Further work on this issue by Lee and Jones-Lee is presented in the Synthesis Report (Lee and Jones-Lee, 2003a). Additional discussion of the low-DO problem in the SJR DWSC is presented herein. The low-DO problem in the DWSC is now recognized to be, in part, due to the export pumping of San Joaquin River Vernalis water that enters the South Delta via Old River.

A project proposal for continuation of the SJR DO TMDL monitoring program on the San Joaquin River and its tributaries was submitted to CALFED/CBDA by the agricultural interests in the SJR DWSC watershed. CBDA has approved this monitoring program with some modifications. Several individuals (Foe and Lee) have been critical of this program in providing the additional data needed to more adequately characterize the upstream discharges and their impacts on the low-DO problem in the DWSC. Their comments on the deficiencies in the proposed monitoring program are available from the SJR DO TMDL website (www.sjrtmdl.org). Those responsible for organizing this program chose not to correct the deficiencies in this program pointed out by Foe and Lee, and submitted it for approval by CALFED/CBDA. Lee and Jones-Lee (2003a) have commented on the continuing significant deficiencies in the proposal submitted to CALFED/CBDA for additional monitoring upstream of the SJR DWSC. Lee has provided additional comments (Lee, 2003j) on deficiencies in this monitoring program. CBDA chose to ignore many of these deficiencies and has approved the monitoring program for funding, with some changes that address, in part, some of the deficiencies raised by Foe and Lee. There are still significant problems with it, however, in providing the data needed to properly characterize upstream oxygen demand loads as they may impact DO in the DWSC.

DWR Drinking Water Quality Program. The California Department of Water Resources (DWR) has a domestic water supply water quality monitoring program devoted to monitoring certain locations in the Delta. Information on this program is available from the DWR website (http://wq.water.ca.gov/mwq). The program includes monitoring for the following parameters at the Harvey O. Banks Pumping Plant:

- Electrical conductivity
- Chlorophyll fluorescence
- Water temperature
- UV 254

- pH
- Turbidity

These data are located at http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=HBP. The DWR water quality monitoring at Banks also includes periodic monitoring for a suite of potential toxicants (such as low molecular weight organic compounds, herbicides, pesticides, heavy metals, PCBs, etc.) of concern for use of the water as a domestic water supply. These data are available at http://wdl.water.ca.gov/wq/gst/wq_report_details_gst_asp. These monitoring data show that several potential toxicants with respect to use of the water for domestic water supply purposes are below critical concentrations for this use. They may not, however, be below critical concentrations for the impact of some of these constituents on aquatic-life-related beneficial uses of Delta waters. In addition, other DWR water quality data for other locations are available from http://www.wq.water.ca.gov/owq/Data/wqdata.htm.

DWR is now providing weekly water quality reports. Information on obtaining these reports is available from rich@water.ca.gov. Real Time Data and Forecasting Project Water Quality Weekly Reports are available for the Sacramento River and San Joaquin River precipitation, flow and electrical conductivity; flow, electrical conductivity and total organic carbon for in-Delta stations; chlorophyll fluorescence, turbidity and temperature on the South Bay Aqueduct; chlorophyll fluorescence, turbidity and UVA on the California Aqueduct; and information on Delta operations.

One of the problems with the DWR drinking water monitoring program (and, for that matter, other DWR monitoring programs) is that chlorophyll fluorescence is measured at a number of locations; however, the measurements are made in such a way that they cannot be translated to planktonic algal chlorophyll concentrations – i.e., the fluorometer measurements are not calibrated in terms of µg/L of chlorophyll *a*. This means that the chlorophyll data generated in this program are of little or no utility in examining the overall planktonic algal chlorophyll situation in the Delta. It is not possible to compare applicable chlorophyll measurements made using reliable analytical methods with the DWR data. This is a particularly significant deficiency, since one of the areas that needs attention in the Delta is a better understanding of phytoplankton growth dynamics and biomass. Without reliable, comparable planktonic algal chlorophyll data at various locations, it is not possible to use the existing DWR monitoring data as part of this evaluation.

Since there are a number of factors that influence chlorophyll measurements by fluorescence, it is extremely important that any fluorometric measurements of chlorophyll be frequently calibrated against water samples obtained from the same waters in which fluorescence measurements are made, which are extracted using the standard acetone extraction procedure for measuring planktonic algal chlorophyll (Standard Methods – APHA et al., 1998).

DWR South Delta Water Quality Monitoring. DWR maintains a set of monitoring stations in the South Delta associated with evaluating the operations of the South Delta temporary barriers. Lee and Jones-Lee (2003a) provide a summary of the characteristics of the monitoring and the data obtained from this monitoring program. As discussed herein, there are severe low-DO problems and excessive total salts in several of the South Delta channels.

DeltaKeeper Monitoring. The DeltaKeeper is conducting a monitoring program of the sanitary quality of selected areas in the Delta, such as near marinas, beaches, etc. The DeltaKeeper, in cooperation with local agencies, has established the Delta Issues Subcommittee (DISC), which is an interagency task force spearheaded by DeltaKeeper as part of their Delta Pathogen Project. The following agencies participate in this group: San Joaquin County Environmental Health Department, San Joaquin County Public Works Department, San Joaquin County Public Health Services, California Department of Health Services, and DeltaKeeper. Meetings are held approximately once every two months.

The purpose of the DISC is to provide outreach and education on public health issues associated with contact recreation in the Sacramento-San Joaquin River Delta. Its strategy is to combine resources and ideas and act in unison to produce and disseminate multilingual educational materials. Thus far, the San Joaquin County Environmental Health Department has produced a two-page laminated health advisory for recreational water use, and DeltaKeeper has distributed the notice to local marinas for posting. The next goal of the DISC is to post local waterways with warning/health advisory signs indicating that contact recreation water quality standards have not been met, and outlining precautionary steps for those who make contact with the water.

The DeltaKeeper also monitors dissolved oxygen in the city of Stockton sloughs that serve as drainage ways for city of Stockton stormwater runoff to the Delta. These sloughs have periodic fish kills associated with stormwater runoff events, which are caused by low DO and possibly other factors. Some of these data have been incorporated into the Lee and Jones-Lee (2003a) SJR DWSC Synthesis Report as part of the discussion of the impacts of city of Stockton stormwater runoff on the SJR DWSC low-DO problem. This issue has been discussed in another section of this report.

The DeltaKeeper has also been responsible for gaining funding for other water quality monitoring programs in the Delta, including the studies that were conducted by the San Francisco Estuary Institute (SFEI) on excessive bioaccumulation of organochlorine pesticides and PCBs in Delta fish. It also obtained funding from CALFED for a continuation of the monitoring program that the CVRWQCB staff had been conducting on the aquatic life toxicity of city of Stockton stormwater runoff to its sloughs. The CVRWQCB and DeltaKeeper data were written up by Lee and Jones-Lee (2001). These data cover the period from 1994 through 2000 and show that stormwater runoff from the city of Stockton was consistently toxic to *Ceriodaphnia*. This toxicity was due to diazinon and chlorpyrifos used on residential and commercial properties. The Mosher Slough and Five Mile Slough data from this study were used by Lee and Jones-Lee (2002c) as the basis for developing a draft TMDL technical report for the CVRWQCB.

City of Stockton. The city of Stockton conducts several water quality monitoring programs associated with its NPDES permits for domestic wastewater discharges and stormwater runoff. The stormwater runoff data are reported to the CVRWQCB in the annual NPDES permit report. In addition, as part of its NPDES MRP Order No. R5-2002-0083, the City conducts a monitoring program as part of its wastewater discharge impact evaluation on the SJR DWSC. The city conducts monitoring at eight stations, from the San Joaquin River at Bowman Road to just north of Turner Cut on the DWSC. A variety of conventional wastewater pollutants is monitored at each location at weekly, monthly and quarterly intervals, depending on the parameter and season.

City of Tracy. The city of Tracy also discharges wastewaters to Old River in the South Delta under an NPDES permit. Monitoring of the characteristics of these wastewaters is required by the CVRWQCB as part of this permit. The city of Tracy wastewater monitoring data are made available to the CVRWQCB in NPDES monitoring reports. The city of Tracy's wastewater discharge occurs to Old River just downstream of where Old River confluences with the San Joaquin River. The average monthly flow of the City's wastewater discharge is 8.1 mgd, which translates to 12 cfs (Kummer, pers. comm., 2003). Additional information on the characteristics of city of Tracy wastewaters is available in the Lee et al. (2004a) South Delta Tour report.

Special-Purpose Studies. There have been a number of special-purpose studies of a limited duration that have provided considerable data on Delta water quality issues. One of the most important of these is the CALFED-sponsored studies on the low-DO problem in the DWSC. A total of approximately four million dollars over a four-year period has been devoted to obtaining data and analysis on the occurrence, magnitude, extent and duration of dissolved oxygen concentrations less than the water quality objective in the DWSC between Channel Point and Columbia Cut. These studies have included detailed monitoring of many of the tributaries and the mainstem of the San Joaquin River to define the sources of oxygen demand and the factors influencing its transport to the DWSC. Approximately 20 reports have been generated by various investigators presenting the results of these studies. These are available from the SJR DO TMDL website (http://www.sjrtmdl.org). A summary and synthesis of the information obtained from these studies is presented in the Synthesis Report by Lee and Jones-Lee (2003a). Essentially all of the data generated as part of the CALFED-supported studies have been posted on the IEP database (http://iep.water.ca.gov/data.html).

Flow Monitoring. One of the key components of the monitoring that is being done in the Delta is the monitoring of flow of the various channels and SJR DWSC. This flow monitoring is difficult because of the tidal influence on flows in the Delta. The USGS UVM station (Garwood) located on the SJR just upstream of the DWSC is a key station, providing measurements of San Joaquin River flow through the DWSC. The USGS monitoring station at Vernalis is also a key station, providing measurements of total SJR flow into the Delta. Other flow measurements by DWR and the USGS are important in defining the total fluxes of various constituents of concern that impact Delta water quality. The flow data are available from the USGS and DWR websites.

SFEI. The San Francisco Estuary Institute has been conducting a monitoring program of San Francisco Bay for a number of years, which focuses on providing information related to the water quality characteristics of the Bay. In some years the SFEI monitoring studies have included monitoring stations located in the Delta. The SFEI data are available from the SFEI website (http://www.sfei.org).

Agricultural Waiver Monitoring. In July 2003 the CVRWQCB (2003) adopted Order No. R5-2003-0826, which included a requirement for a comprehensive monitoring program of agricultural discharges to Central Valley waterbodies. This monitoring program is applicable to agricultural discharges to Delta channels. The agricultural waiver monitoring program, if implemented as currently required, will eventually provide considerable additional data on the water quality characteristics of agricultural discharges to the Delta channels and their impacts on the beneficial uses of these channels. The objectives of this program are:

"a. Assess the impacts of waste discharges from irrigated lands to surface water;
b. Determine the degree of implementation of management practices to reduce discharge of specific wastes that impact water quality;
c. Determine the effectiveness of management practices and strategies to reduce discharges of wastes that impact water quality;
d. Determine concentration and load of waste in these discharges to surface waters; and
e. Evaluate compliance with existing narrative and numeric water quality objectives to determine if additional implementation of management practices are necessary to improve and/or protect water quality."

Lee has provided detailed comments on the deficiencies of the CVRWQCB (2003) agricultural waiver monitoring program (Lee, 2003j, 2004b; Lee and Jones-Lee, 2003g). Key deficiencies in this program were discussed in a *Stormwater Runoff Water Quality Science/Engineering Newsletter Volume* 6-10 (Jones-Lee, 2003). This Newsletter is available from www.gfredlee.com.

The Central Valley Regional Water Quality Control Board (CVRWQCB, 2003) has established, as part of Order No. R5-2003-0826, the following table (Table 3) as the minimum requirements for the constituents to be monitored by the agricultural watershed Coalition Groups. Each monitoring group or individual is to develop a Monitoring Reporting Program (MRP):

> *"The MRP Plan must include a sufficient number of monitoring sites and surface water flow monitoring for each location to allow calculation of the load discharged for every parameter monitored. Method detection limits and practical quantitation limits shall be reported. All peaks detected on chromatograms shall be reported, including those which cannot be quantified and/or specifically identified. The Coalition Group shall use US EPA approved methods, provided the method can achieve method detection limits equal to or lower than analytical method quantitation limits specified in this Order. At a minimum, the MRP Plan must clearly demonstrate (1) compliance with requirement of all phases of monitoring as described in this MRP; (2) sufficient number of monitoring sites based on acreages and watershed characteristics, flow monitoring, and frequency of sample collection to allow for the calculation of load discharged for every waste parameter monitored; and (3) the use of proper sampling techniques and laboratory procedures to ensure a sample is representative of the site and is performed in the laboratory using approved methodologies."*
>
> * * *
>
> *"Bioassessment monitoring protocols are at the developing phase, and there are no Basin Plan requirements or standards addressing the results of bioassessment monitoring. Coalition Groups are encouraged to conduct Bioassessments to collect data*

Table 3 Constituents to be Monitored[2]

Constituents	Quantitation Limit	Reporting Unit	Monitoring Phase
General Parameters			
Flow	N/A	cfs (ft^3/sec)	1, 2 & 3
pH	N/A	pH units	1, 2 & 3
Electrical Conductivity	N/A	µmhos/cm	1, 2 & 3
Dissolved Oxygen	N/A	mg O_2/L	1, 2 & 3
Temperature	N/A	Degrees Celsius	1, 2 & 3
Color	N/A	ADMI	1, 2 & 3
Turbidity	N/A	NTUs	1, 2 & 3
Total Dissolved Solids	N/A	mg/L	1, 2 & 3
Total Organic Carbon	N/A	mg/L	1, 2 & 3
Drinking Water			
E. coli	(b)	MPN	1
Total Organic Carbon	(b)	mg/L	1
Chloroform*	(b)	µg/L	1
Bromoform*	(b)	µg/L	1
Dibromochloromethane*	(b)	µg/L	1
Bromodichlormethane*	(b)	µg/L	1
Toxicity Tests			
Water Column Toxicity	-	-	1
Sediment Toxicity	-	-	1
Pesticides (a)			
Carbamates	(b)	µg/L	2
Organochlorines	(b)	µg/L	2
Organophosphorus	(b)	µg/L	2
Pyrethroids	(b)	µg/L	2
Herbicides	(b)	µg/L	2
Metals (a)			
Cadmium	(b)	µg/L	2
Copper	(b)	µg/L	2
Lead	(b)	µg/L	2
Nickel	(b)	µg/L	2
Zinc	(b)	µg/L	2
Selenium	(b)	µg/L	2
Arsenic	(b)	µg/L	2
Boron	(b)	µg/L	2
Nutrients (a)			
Total Kjeldahl Nitrogen	(b)	mg/L	2
Phosphorus	(b)	µg/L	2
Potassium	(b)	µg/L	2

a. In addition to Toxicity Investigation Evaluations (TIEs), sites identified as toxic in the initial screen shall be re-sampled to estimate the duration of the toxicant in the waterbody. Additional samples upstream of the original site should also be collected to determine the potential source(s) of the toxicant in the watershed.
b. Quantitation limits must be lower than LC50 or other applicable federal or state toxic or risk limits.
* Deleted from the required monitoring by the SWRCB, February 2004.

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[2] Adapted from CVRWQCB (2003)

that may be used as reference sites and provide information for scientific and policy decision making in the future. Bioassessments may serve monitoring needs through three primary functions: (1) screening or initial assessment of conditions; (2) characterization of impairment and diagnosis; and (3) trend monitoring to evaluate improvements through the implementation of management practices. Bioassessment data from all wadeable impaired waterbodies may serve as an excellent benchmark for measuring both current biological conditions and success of management practices."

Lee and Jones-Lee (2003g) discussed that a number of the monitoring parameters and the then-proposed approaches listed in Table 3 will lead to inadequate, unreliable, and in some cases, uninterpretable data on the characteristics of stormwater runoff and tailwater/subsurface drain water discharges from irrigated agricultural areas in the Central Valley. In order to use the funds spent on agricultural waiver water quality monitoring in a technically valid, cost-effective manner, Lee and Jones-Lee concluded that it is essential that revisions be made in the monitoring program parameters to work toward achieving reliable, meaningful data. Under the current regulatory agricultural waiver monitoring requirements, agricultural interests discharging to Delta channels must have defined the monitoring programs that they propose to use, by April 1, 2004. Many of the agricultural interests in the Central Valley failed to meet this deadline.

According to the CVRWQCB (2003) Order,

"The MRP Plan shall describe a phased monitoring approach and provide documentation to support the proposed monitoring program. The program shall not consist of more than three phases. Phase 1 monitoring shall, at a minimum, include analyses of physical parameters [labeled "General Parameters" in the above adaptation of Table 1]*, drinking water constituents, pesticide use evaluation, and toxicity testing. Phase 2 monitoring includes chemical analyses of constituents that were identified in toxicity testing in phase one that may include pesticides, metals, inorganic constituents and nutrients and, additional monitoring site in the watershed. Phase 3 monitoring includes management practice effectiveness and implementation tracking and additional water quality monitoring sites in the upper portions of the watershed."*

It was anticipated that the Phase 1 monitoring would begin in the spring 2004. Phase 2 monitoring is to begin no later than two years after the initiation of Phase 1, and Phase 3 will commence no later than two years after the initiation of Phase 2. Therefore, if implemented as proposed by the CVRWQCB, it will likely be three to four years before comprehensive data on discharges to Delta channels from Delta island agricultural activities will be available for Phase 2 parameters, which are the parameters of greatest interest in defining water quality issues.

Lee (2004b), in his comments to the SWRCB on the deficiencies in the CVRWQCB Order and the State Board staff's recommendations with respect to supporting this Order, pointed out that the proposed minimum monitoring program set forth in the Order will not achieve the Order's objectives defined above. These issues are discussed in detail in Lee (2004b). The State Board staff and Board chose to ignore these deficiencies, with the result that, unless the situation is changed, significant amounts of data will be generated as part of the agricultural waiver monitoring program that will be of little value in evaluating the water quality impacts of agricultural runoff/discharges to the Delta channels on channel water quality-beneficial uses.

An example of the significant deficiencies in the CVRWQCB (2003) Order is the approach that is recommended for monitoring for excessive fertilization problems arising from nutrient discharges from irrigated agriculture in the Central Valley. The minimum recommended monitoring program does not include monitoring for nitrate. Nitrate is the most common form of nitrogen in irrigated agricultural discharges that can lead to excessive fertilization of the receiving waters. Without monitoring for nitrate, it is not possible to evaluate the potential for irrigated agriculture to discharge excessive amounts of nitrogen compounds in stormwater runoff, tailwater and subsurface drain water discharges.

Other significant deficiencies in providing key data to properly evaluate the impact of pesticides, metals, organics and nutrients in agricultural stormwater runoff and tailwater discharges will not begin to become available until Phase 2 is initiated more than two years after Phase 1 is initiated. Since in many areas of the Central Valley, Phase 1 will not be initiated this year because of the failure of agricultural interests to submit their monitoring plans by the April 1 deadline, it will be three or more years before key data will be available on the characteristics of agricultural runoff/discharges.

Another problem with the proposed agricultural waiver monitoring is that there is no requirement for bioassessment monitoring of the impacts of agricultural discharges/stormwater runoff on macroinvertebrates in the waterbodies receiving this runoff. Further, there is no requirement for monitoring the tributary headwaters for agricultural drains and other small waterbodies that directly receive agricultural runoff/discharges. In addition, there are inadequate requirements for monitoring flow at the locations where the discharges occur. Without adequate flow measurements it will not be possible to estimate the loads of agriculturally derived pollutants that are being carried by various waterbodies.

During the summer 2003, on behalf of the CVRWQCB, the University of California, Davis, Aquatic Toxicology Laboratory conducted a monitoring program of selected agricultural drains and other waterbodies in the Central Valley that are likely to be impacted by agricultural runoff/discharges. It was found that several of the monitoring locations showed aquatic life toxicity in the water column and/or sediments, and concentrations of TOC and some other pollutants that are adverse to the beneficial uses of waterbodies.

SWAMP. The State Water Resources Control Board, in cooperation with the Central Valley Regional Water Quality Control Board, is developing a Statewide Ambient Monitoring Program (SWAMP). At this time the details of this program for the Central Valley have not been finalized. From the information available, it appears that there will be limited monitoring conducted in the Delta and near-Delta tributaries that would help better define the current water quality conditions in these waterbodies. Additional information on the SWAMP is available at http://www.swrcb.ca.gov/swamp.

DFG. The California Department of Fish and Game (DFG) conducts a fish monitoring program in the Delta and its tributaries. Associated with this program are physical and chemical data on the characteristics of the waters. These data are available from the IEP database. According to Finlayson (pers. comm., 2004), DFG does not conduct any routine water quality monitoring in the Delta.

Corps of Engineers Dredging of the SJR DWSC. Associated with obtaining permits for maintenance of navigation depth of the Deep Water Ship Channel, the US Army Corps of Engineers and public and private entities, such as the Port of Stockton and marina owners, must obtain CVRWQCB permits to dredge. These permits contain requirements for monitoring of the dredging projects. The data generated in these projects are made available to the CVRWQCB as project reports.

Other CALFED/CBDA Projects. CALFED/CBDA supports a number of individual research projects, which include collection of data on water quality characteristics of the Delta. The various CALFED/CBDA projects and their reports are made available through the CBDA website (http://calwater.ca.gov). Also, summaries of many of these projects are provided in the CBDA nearly annual Science Program reviews, where abstracts of the projects are presented.

San Francisco Bay-Delta Estuary Project (SFEP). The US EPA and several state of California agencies are active in the San Francisco Bay-Delta Estuary Project. According to the project's website,

> *"The S.F. Estuary Project is one of over 20 Estuary Projects established by the National Estuary Program to protect and improve the water quality and natural resources of estuaries nationwide.*
>
> *We were formed in 1987 as a cooperative federal/state/local program to promote effective management of the San Francisco Bay-Delta Estuary. In addition to spearheading and participating in a wide variety of projects, the Estuary Project also serves as a clearinghouse for information on the Bay-Delta ecosystem, including such topics as wetlands, wildlife, aquatic resources and land use."*

The SFEP holds biennial State of the Estuary conferences, in which the various investigators conducting studies on the estuary present summaries of their work. Abstracts of these projects are available in the books of abstracts for the State of the Estuary Conferences; the most recent report available is from October 2003. A description of the overall characteristics of this project is available from the SFEP website (http://www.abag.ca.gov/bayarea/sfep/).

Expanded CALFED/CBDA Science Program Delta Water Quality Activities. The CALFED/CBDA Science Program held a workshop on February 4-5, 2004, devoted to Contaminant Stressors in the Bay-Delta Watershed. Information on this workshop includes the following:

> *"**Contaminant Stressors in the Bay-Delta Watershed***
> *Populations of fish and other critical species in the Bay-Delta are in decline. Chemical contaminants are one of several key stressors on ecosystem health outlined by the CALFED Ecosystem Restoration Program Plan (ERPP, July 2000). Most metrics and*

indicators of xenobiotic effects focus on the level of the individual, however, cause-effect links to higher trophic orders (population, community, ecosystem) are poorly understood. How anthropogenic contaminants affect the recovery of populations is a critical unknown for ecosystem restoration. A major goal of the CBDA Science Program is to use the best available science to fill the gaps that critical unknowns leave in our understanding of ecosystem processes in the Bay-Delta."

(http://calwater.ca.gov/Programs/Science/adobe_pdf/Contaminant_Stressors_Public_Notice_2-4-5-03.pdf)

CBDA has posted a link to presenters and supplemental materials from this workshop at http://198.31.87.66/pdf/ContaminantStressorsSuppMat.pdf.

CMARP. The CALFED (2000) Bay-Delta Program August 28, 2000, Record of Decision, on page 75 states,

"The Science Program will be developed and directed by an interim lead scientist, who will also serve in the role of lead scientist during the initial years of program implementation. Implementation of the CALFED Science Program includes implementation of the Comprehensive Monitoring, Assessment and Research Program (CMARP), now under the direction of the interim lead scientist. The Science Program also has primary responsibility to establish the role of adaptive management in program implementation, implement strategies to reduce uncertainties that impede successful accomplishment of CALFED goals, provide programmatic review of overall implementation of mitigation measures and integrate the CALFED Science Program with existing/related agency science programs."

The CALFED/CBDA website contains the Comprehensive Monitoring, Assessment and Research Program (CMARP, 1999) report at http://calwater.ca.gov/programs/science/cmarp/contents.html. This report introduction states as "CALFED mission and principles,"

"The mission of the CALFED Bay-Delta Program is to develop a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta system. The CALFED Mission Statement is supported by a set of ***Primary Objectives*** *and* ***Solution Principles****, as cited in the Executive Summary of the CALFED Bay-Delta Program Programmatic EIS/EIR, March 1998.*

The ***Primary Objectives*** *are:*

- *Water Quality – Provide good water quality for all beneficial uses.*
- *..."*

The CMARP report represents the collective efforts of a number of Delta experts. The report includes Chapter 4- Part C. Water Quality. This Chapter states, *"The CALFED Bay-Delta Program's goal for water quality is to improve the quality of water of the Sacramento-San Joaquin Delta Estuary for all beneficial uses; including domestic, industrial, agricultural, recreation, and aquatic habitat. Providing good water quality for agricultural and industrial uses includes lowering mineral, nutrient, and metal concentrations in water such that the water is nontoxic and can be reused. The goal for drinking water quality is to reduce pathogens, nutrients, turbidity, and toxic substances in source waters to the Delta through watershed protection measures. In addition, bromide and organic carbon levels would be low enough to meet drinking water regulations. Good water quality for recreational use involves reduction of disease-causing organisms in the water and reduction in nuisance algal blooms."*

* * *

"The water-quality-monitoring program scope includes baseline, trend, effectiveness, compliance/mitigation and operations monitoring. The program addresses the programmatic water-quality actions outlined in the CALFED Phase II Report (11/98) (Table 4-2)."

"The goal of the water-quality-monitoring plan is to monitor water quality and associated physical and environmental variables to document the effects of CALFED Stage 1 actions on water quality and on the ecosystem (Table 4-3). A monitoring network will be established to evaluate the success of proposed CALFED Water-Quality Program Plan actions, to address or verify identified water-quality problems, and to assess trends, loads, and sources of important water-quality constituents. The major question, 'Is Delta water quality improving?', will be addressed through this monitoring program."

CMARP Chapter 4 Part C Water Quality lists in Table 4-2, **Water Quality Program Actions**,

Drinking Water,
Pesticides,
Organochlorine Pesticides,
Trace Metals,
Mercury,
Salinity,
Selenium,
Turbidity and Sedimentation,
Low Dissolved Oxygen and
Toxicity of Unknown Origin.

Table 4-3 lists as the **Water-Quality Monitoring Objectives**,

"1. Assess effects of CALFED activities (including Ecosystem Restoration, Storage and Conveyance, Water Transfers, Water Use Efficiency, Watershed Management Coordination, and Levee System Integrity Programs) on water quality
2. Determine sources, loads, and trends of water-quality constituents of concern
3. Assess system productivity of Bay/Delta waters
4. Monitor water and sediment quality as necessary to comply with CALFED actions

5. *Provide continuing data on water-quality constituents of concern, such as bromide, that may indicate the need for further CALFED actions to improve water quality.*
6. *Assess ecological and human-health related to water and sediment quality, including monitoring contaminant concentrations in biota."*

The CMARP report contains, as an appendix, the November 2, 1998, "Contaminants Monitoring in the Bay-Delta" report. This 23-page report was prepared by a workgroup consisting of experts from the San Francisco Estuary Institute, private aquatic life toxicity testing laboratories, representatives of the Central Valley and San Francisco Regional Water Quality Control Boards, the Department of Pesticide Regulation and the USGS. This appendix includes the following statements:

"Goals and Objectives
Water Quality is one of CALFED's Common Programs. The goal of the Water Quality Program is to improve the quality of the waters of the Sacramento-San Joaquin Delta Estuary for all beneficial uses. Because species dependent on the Bay and Delta are affected by upstream water quality conditions in some areas, the scope of the Water Quality Program also includes watershed actions to reduce water quality impacts on species dependent on the Delta (CALFED 1998a).

The specific CALFED goals and objectives addressed in this section are (CALFED 1998b):

- *Provide good Delta water quality for recreational use; Reduce health risks associated with consuming fish.*
- *Provide improved Delta water quality for environmental needs; Reduce concentrations of pesticide residues, hydrocarbons, heavy metals, and other pollutants in water and sediments.*

The CALFED Water Quality Technical Team (WQTT) has produced a Water Quality Program Plan that lists actions to improve water quality (CALFED 1998a). Monitoring will be needed to evaluate whether those actions are successful. Since many of the actions have not begun, monitoring cannot yet be designed. However, the monitoring recommendations included in this section provide for the determination of baseline conditions, and can be expanded in space or time to be used when needed."

This appendix includes discussion of the need for monitoring and research for a variety of known and potential pollutants in Delta waters, including trace elements (primarily metals), organochlorines (PCBs, dioxins and hexachlorocyclohexanes), polycyclic aromatic hydrocarbons (PAHs), pesticides and synthetic biocides, bivalve and fish tissue parameters, aquatic toxicity tests, sediment toxicity tests, exposure indicators (biomarkers, histopathology and physiology), as well as monitoring for system productivity for fish, phytoplankton, zooplankton and benthos.

The current CALFED's (now CBDA's) program for water quality monitoring, evaluation and management is falling far short of achieving the ROD commitment, since little of the

CMARP water quality monitoring program has been initiated since it was first formulated in 1998. This is a significant deficiency in CBDA's current water quality management program.

Recently, Patrick Wright, Director of the CBDA program, indicated that the CBDA agencies are conducting a review of the potential for an expanded water quality program in the Delta. The details of this proposed expanded program are not yet available. They could include substantial additional water quality monitoring in the Delta. In order for this program to be effective and produce needed and reliable results, it will be extremely important that a key component of the program include detailed review of past and current water quality data that exist on the Delta and near-Delta tributaries.

Overall. Even though there has been and continues to be considerable water quality monitoring in the Delta and its tributaries, there is still inadequate monitoring to provide the information needed to develop management programs for many of the constituents which cause the 303(d) listing of Delta channels as impaired. Further, the current 303(d) listing is likely limited compared to what would be needed based on a comprehensive, in-depth monitoring of the Delta channels.

Need for Expansion of the Delta Water Quality Monitoring/Evaluation Program

There is need to significantly expand the water quality monitoring/evaluation program for the Delta. This is a significantly neglected area. While there is an Interagency Ecological Program (IEP) monitoring program, it is not focused on water quality and is largely conducted with limited regard to providing information pertinent to water quality assessment. The current Delta water quality monitoring program needs to be expanded so that the focus is on an assessment of beneficial use impairment, rather than the current approach of monitoring algae, zooplankton, fish and sediment organisms. There is a variety of factors, such as invasive species, that can influence phytoplankton, zooplankton and benthic organism populations, which cause the IEP EMP to fail to provide the information needed on the impacts of chemical stressors on Delta aquatic-life-related beneficial uses.

As discussed above, the Delta and tributaries near the Delta have been found to be impaired under the Clean Water Act section 303(d). The monitoring program that is needed should specifically focus on assessing the current status of the impairment for each of the 303(d) listings. Particular reference should be given to whether the impairment, which is generally based on excessive concentrations of a chemical constituent, is a "real" impairment, or represents the application of worst-case-based water quality criteria/standards to Delta waters. Further, the monitoring program should specifically address the magnitude, area and duration of the impairment. With respect to duration, is it a pulse-type duration associated with and following pesticide application, or is the impairment year-round? This information can then be used to prioritize the second phase of the monitoring.

The second phase should be devoted to defining the constituents responsible, if not already defined (such as for toxicity), and the sources of these pollutants. The monitoring results can lead to the information base needed to begin to implement the TMDL that is needed to control the exceedance of an appropriately developed water quality standard/objective.

If it is found that the impairment represents an "administrative" impairment related to using worst-case generic water quality objectives rather than site-specific objectives that are appropriate for the Delta waters of concern, then work with the CVRWQCB should be initiated to develop the site-specific objectives that will be protective without spending large amounts of funds for constituent control that will have little or no impact on the beneficial uses of the waterbody in question.

The monitoring program should include both the water column and sediments. It should be integrated with the agricultural waiver monitoring program that is being developed. The application of that program to the Delta still must be defined. Once that is done, the deficiencies in that monitoring program in defining the amounts of potential pollutants in runoff/discharges from agricultural lands, as well as the amounts of pollutants entering the Delta from tributary sources, need to be investigated. Ultimately, the agricultural waiver program should include developing an understanding of the how the pesticides, fertilizers and other constituents added to agricultural lands and those that are discharged from agricultural lands in the form of tailwater or subsurface drain water impact water quality. Lee (2003j, 2004b) discussed the deficiencies in the current agricultural waiver monitoring program that was adopted by the CVRWQCB in July 2003. His recommendations should be incorporated into the agricultural waiver monitoring program that is being developed by Delta agriculture, in order to improve the utility of the data that are to be generated.

The monitoring should focus on measuring not only chemical constituents that are, at some times and locations, pollutants (i.e., impair beneficial uses of the waterbody), but also aquatic life toxicity in the water column and/or sediments. Further, the bioaccumulation of known hazardous chemicals, such as the organochlorine "legacy" pesticides (DDT, chlordane, dieldrin, toxaphene, etc.), PCBs, dioxins and furans, should be measured. Substantial monitoring funds should be available for toxicity identification evaluations (TIEs) to identify the cause of toxicity in the water column or sediment, wherever it is found. Lee and Jones-Lee (2002f) have developed a comprehensive discussion of the approach that should be used to conduct water quality monitoring programs in the Central Valley for nonpoint source discharges/runoff.

Unfortunately, there is no monitoring of the amount of water hyacinth and *Egeria densa* that develops in the Delta. This is a significant deficiency in the current Delta water quality monitoring program that should be immediately corrected, since this is one of the most significant water quality problems in the Delta. The magnitude of this problem can be judged by the fact that the California Boating and Waterways conducts extensive water hyacinth control through herbicide addition.

Over the past 10 years there has been comprehensive water quality monitoring of San Francisco Bay and its associated estuary. This effort was conducted under what is known as the Regional Monitoring Program (RMP). The San Francisco Estuary Institute held its annual conference on May 4, 2004, at which the results of the past year's RMP, as well as an overview review of the past five years' RMP were presented and discussed. This review and other information on this program is (or will shortly be) available from the SFEI website, www.sfei.org.

The focus of the RMP has been on those constituents that are causing the Bay to be on the 303(d) list, with emphasis on those constituents which are bioaccumulating to excessive levels in edible organisms, such as mercury, organochlorine legacy pesticides, PCBs and dioxins. Taberski (2004) has presented a review of the value of the RMP in helping the San Francisco Bay Regional Water Quality Control Board develop the kinds of information needed to begin to manage the water quality impacts of the constituents that cause the Bay to be on the 303(d) list. While aggressive monitoring/evaluation programs are being conducted in the San Francisco Bay area for mercury, PCBs, dioxins, PAHs, organochlorine legacy pesticides, aquatic life toxicity, etc., except for mercury, essentially no work is being done in the Delta to address these constituents which are a cause of Delta waters to be listed as 303(d) impaired. A similar kind of program to the San Francisco Bay RMP needs to be developed for the Delta to address the known water quality impairments that are occurring in Delta channels. Davis (pers. comm., 2004) has indicated that SFEI (2004) is developing a report that discusses the development and organization of the RMP. Davis indicated that he may be contacted for information on the availability of this report (jay@sfei.org).

Availability of Funding for Monitoring. In addition to the water quality monitoring programs' in the Delta having been deficient for many years, the current and especially the future situation is likely to be even bleaker because funding decreases are occurring associated with the current state of California budget shortfall. There is need to restore and greatly expand the funding available for Delta water quality monitoring.

While some take the position that it is the responsibility of the Central Valley Regional Water Quality Control Board to conduct monitoring of Delta water quality, this approach is not viable, since the Regional Board does not and will not likely have the funds to undertake this effort. As a result, it will be necessary for CBDA and those responsible for discharges/runoff to acquire the funds to fund this monitoring.

CALFED/CBDA's Activities in Addressing Water Quality Problems in the Delta

When CALFED first became active, there was a major effort to develop a water quality management program in the Delta and its tributaries. The consulting firm that had the initial contract to support CALFED activities assigned the responsibility for developing these programs to an individual(s) with limited understanding and experience in water quality issues. This person(s) made significant errors in evaluating water quality in the Delta, such as claiming that there were major heavy metal problems in the Delta due to stormwater runoff from urban areas that necessitated the collection and treatment of all urban stormwater runoff to remove heavy metals. Eventually, as a result of comments made by various individuals, including the senior author, on the unreliability of the proposed water quality management program, that effort was terminated and replaced by a new effort involving committees of interested experts advising CALFED on the water quality problems that exist in the Delta and its tributaries. This led to the development of a Water Quality Program Plan (CALFED, 1998). While this approach had considerable technical merit, CALFED management did not follow through, and all of the effort made by many individuals was lost several years ago. Since then, CALFED/CBDA's water quality management program has been essentially restricted to a major effort devoted to mercury and the low-DO problem in the first seven miles of the Deep Water Ship Channel below the Port of Stockton. There has been no effort devoted to many of the other well-documented water quality problems that exist in the Delta, such as those associated with the previous 303(d) list and the 2002 303(d) list of impaired Delta channels. CBDA needs to significantly expand its water quality investigation and management program to address the known water quality problems and to conduct studies to determine if there are other as yet undefined problems that are impairing the beneficial uses of Delta waters.

Delta Water Quality Research Needs

Presented in this report and for some issues discussed below is a summary of the areas of Delta water quality-related research needed to better define the known and potential water quality problems that are impacting the beneficial uses of Delta waters. The information gained from such research would be an important step in developing a technically valid, cost-effective program to manage Delta water quality. Additional information on each of the areas summarized below is provided in the above discussion.

Organochlorine Pesticides, PCBs and Dioxins. The finding of excessive bioaccumulation of the organochlorine legacy pesticides (such as DDT, chlordane, dieldrin, toxaphene, etc.), PCBs and dioxins in Delta and near-Delta tributary fish mandates that a substantial research effort be initiated on the current degree and extent of excessive bioaccumulation of OCls in edible Delta fish. Also the amount of these chemicals entering the Delta from tributary, agricultural, urban and wastewater sources needs to be defined. Studies need to be conducted on the role of Delta sediments as a source of OCls that are bioaccumulating to excessive levels in Delta channel fish. US EPA aquatic organism bioaccumulation testing should be conducted to determine whether the organochlorines are present in sediments at sufficient concentrations of bioavailable forms to bioaccumulate to excessive levels in Delta fish. Where this occurs studies need to be conducted to develop biota sediment accumulation factors which can be used to relate sediment concentrations to edible and other organism tissue residues. This approach is discussed in Lee and Jones-Lee (2002a).

It will also be important to determine whether the organochlorines are adverse to aquatic life. Particular attention should be given to dioxins in the vicinity of the Port of Stockton. It is now well-established that very low levels of dioxins can be adverse to fish and other aquatic life, below those concentrations that are known to cause cancer in people. The research on the organochlorines should include not only water column effects, but also benthic organism effects.

Where toxic hot spots are found in Delta and near-Delta tributary sediments of the OCls that are significant sources for excessive bioaccumulation in edible organisms, studies need to be done to determine if the addition of activated carbon is a potential remediation approach for controlling the bioavailability of sediment-associated OCls.

Currently Used Pesticides/Herbicides. Work needs to be done on the occurrence and water quality significance of the various pesticides/herbicides used in the Delta and in Delta tributaries, with respect to their potential to be adverse to aquatic life and other beneficial uses of Delta waters. Through DPR reporting, each of the pesticides/herbicides used in the Delta should be investigated to determine whether it is present in runoff/discharges from the areas of use in agricultural and urban areas at sufficient concentrations to be toxic or otherwise deleterious to various forms of aquatic life. Consideration should be given not only to toxicity in the water column but also to sediment toxicity and other adverse impacts cause by the currently used pesticides. Further, this should be an ongoing program, where if a new pesticide/herbicide is used in the Delta or near-Delta tributaries, studies would be conducted to determine whether its initial use is adverse to aquatic life and other beneficial uses of Delta waters. This effort should include the herbicides used for aquatic weed control, where studies independent of those conducted by those applying the herbicides are conducted to determine whether there are adverse water quality impacts caused by the use of the herbicides for aquatic weed control within the Delta and near-Delta waters.

Heavy Metals. Work needs to be done to define whether heavy metals are causing water quality problems-impairment of the beneficial uses for aquatic life, etc., in the Delta or near-Delta tributaries. Of particular concern is the potential for food web accumulation of cadmium or nickel, where concentrations of metals below the water quality objective can result in adverse effects to host organisms and higher trophic level organisms through accumulation of tissue residues of the metal. Further work needs to be done on whether selenium additions to the Delta are adverse to Delta aquatic life.

Impacts of the State and Federal Export Projects on Delta Water Quality. The state and federal export projects have the potential to cause significant adverse impacts on the water quality beneficial uses of the Delta. As discussed herein, the work that has been done under D-1641 to evaluate these impacts is deficient compared to that which is needed to define the impacts of Delta export projects on Delta water quality. A team of independent experts should work together to properly evaluate the potential adverse impacts of Delta water exports. Where this team finds potential problems with a particular type of pollutant, such as an organochlorine pesticide, mercury, currently used pesticides, heavy metal inputs from tributaries, etc., studies should be conducted to evaluate how the movement of water in the Delta caused by the export projects impacts the effects of these constituents on Delta water quality.

Phytoplankton Primary Production within the Delta. An assessment should be made of the factors controlling phytoplankton primary production within the Delta. Particular emphasis should be given to why, based on the nutrient content of Delta waters, there is not more primary production. It has been found that Delta waters, when allowed to stand, such as in a water supply reservoir, will produce substantial crops of phytoplankton. What is the role of light limitation due to inorganic turbidity and color on primary production? Is the export of water from the Delta creating insufficient time in Delta waters during the summer and fall months for the phytoplankton to develop before the water is exported from the Delta via the export pumps? What is the role of the export projects' drawing large amounts of low-nutrient Sacramento River water through the Delta in the limitation of algal production? Another area of concern is whether invasive species are significantly controlling phytoplankton biomass through harvesting of phytoplankton.

Another research area is an evaluation of the importance of phytoplankton derived from the San Joaquin River watershed as a source of assimilable organic carbon for the Delta food web. There is need to better understand the food web in the Delta and especially what controls the lowest trophic level biomass. Of concern is whether reducing the algal loads to the Central Delta would be detrimental to the food web.

Biomarkers, PPCPs, Endocrine Disrupters, Etc. A substantial research effort should be initiated on the occurrence of sublethal effects of various types of chemicals, such as PPCPs, endocrine disrupters and low levels of pesticides (at concentrations below those that are acutely toxic to aquatic life) on Delta water quality. Particular attention should be given to waters near the cities of Stockton and Tracy and downstream of the Sacramento Regional County Sanitation District discharges to the Delta, as well as other upstream communities that discharge wastewaters to Delta tributaries. Consideration should also be given to any discharges/runoff from dairies and other animal husbandry facilities as a source of PPCPs.

Delta Sediments. A comprehensive program of investigating the toxicity of Delta sediments should be initiated, using a variety of sensitive test organisms. Where toxicity is found, sediment-based toxicity investigation evaluations should be conducted to determine the cause of the toxicity and the sources of the constituents responsible for the toxicity. This work should include the development of biological effects-based sediment quality objectives for Delta sediments. Total chemical concentrations or co-occurrence-based sediment quality objectives should not be used in the Delta or other waterbodies that are tributary to the Delta (or, for that matter, elsewhere) as a basis for evaluating sediment quality, because of the unreliability of total concentrations in predicting bioavailable/toxic forms of potential pollutants.

Organism Assemblages. Surveys of Delta sediment benthic and epibenthic organisms should be conducted to determine where altered organism assemblages are occurring, compared to what would be expected based on an unimpacted sediment population.

Total and Dissolved Organic Carbon. Studies need to be conducted on the sources of total and dissolved organic carbon for the Delta from tributaries and within the Delta from aquatic vegetation. The organic carbon should be investigated in terms of the total labile and refractory carbon that can adversely impact domestic water supply water quality. Particular attention needs to be given to urban wastewater and stormwater runoff as a source of refractory TOC that can impact domestic water supply water quality. Studies need to be conducted on the potential for controlling refractory TOC from the various sources, including agricultural runoff, urban and industrial land runoff, wastewaters, etc. An evaluation needs to be made of the cost of controlling excess TOC in water utilities' raw water at the source, compared to the cost of controlling it at the water treatment works.

Pathogens. The monitoring that the DeltaKeeper has been doing in the eastern and Central Delta needs to be expanded to all parts of the Delta, to determine where pathogen indicator organisms, such as *E. coli*, are present at concentrations which are indicative of a public health threat for contact recreation in the waters of that area. In those areas where there are consistent violations of the *E. coli* water quality standard, there is need to conduct further studies to determine the specific sources of *E. coli* that are responsible for the violations.

Nutrients. Investigations need to be conducted to determine the degree of nutrient control needed from the Delta watershed and within the Delta to achieve desired water quality from the perspective of domestic water supply and aquatic weed growth, especially hyacinth and *Egeria densa* within the Delta.

Salts. There is need to determine the appropriate salt loads to the Delta from the San Joaquin River watershed, to protect the use of Delta waters for domestic water supply and the associated recharge of groundwaters from the wastewaters based on a Delta water supply, as well as to protect irrigated agriculture in the Delta.

Dissolved Oxygen. There is need to do further work on the relationship between various oxygen demand sources for the Deep Water Ship Channel, with particular reference to the interrelationship between the oxygen demand loads from the city of Stockton's domestic wastewaters, the city of Stockton's stormwater runoff, and the planktonic algae from the San Joaquin River watershed, to the DO depletion associated with the flow of the SJR through the DWSC. There is need to understand the impact of significantly reducing the flow of the SJR into the South Delta via Old River on water quality in the South Delta.

There is also need to understand the origin of the low DO that occurs in Old River near the Tracy Boulevard bridge, and what can be done to control it, as well as the low DO that occurs in Middle River within the South Delta.

There is need to investigate the potential occurrence of low DO in the Central Delta, especially Turner Cut and Whiskey Slough, under worst-case conditions of oxygen demand loads from the DWSC.

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Appendix A
Review of Excessive Bioaccumulation of
Organochlorine Pesticides and PCBs in Delta and Delta Tributary Fish

The following section is from the Lee and Jones-Lee (2002) report of excessive bioaccumulation of OCls in edible fish taken from the Delta and near-Delta tributaries. As discussed in this report, the data on the concentrations of legacy pesticides and PCBs in fish taken from some of the tributaries to the Delta indicate the current areas where excessive bioaccumulation of OCls has occurred and are useful in indicating the potential sources of these chemicals for the Delta, as well as for fish that may migrate into the Delta. The data presented in the following section uses the Office of Environmental Health Hazard Assessment (OEHHA) screening values to judge excessive concentrations of the legacy pesticides and PCBs in Delta and near-Delta tributary fish. The references for the following section are listed in the references for the main body of the report.

OEHHA Fish Tissue Criteria. Table 1 presents the US EPA and OEHHA fish tissue screening values for evaluation of excessive bioaccumulation of selected chemicals.

Table 1
US EPA and OEHHA Fish Tissue Screening Values

CHEMICAL	US EPA Value[1] (µg/kg wet weight)	OEHHA Value[2] (µg/kg wet weight)
Chlordane[3]	80	30
Total DDT[4]	300	100
Dieldrin	7	2
Total endosulfan[5]	60,000	20,000
Endrin	3000	1000
Heptachlor epoxide	10	4
γ-hexachlorocyclohexane (lindane)	80	30
Toxaphene	100	30
PCBs[6]	10	20
Dioxin TEQ[7]	0.7 ppt	0.3 ppt

Source: SARWQCB (2000)

1: USEPA SVs (US EPA, 1995) for carcinogens were calculated for a 70 kg adult using a cancer risk of 1x10-5. SVs for non-cancer effects were calculated for a 70 kg adult and exposure at the RfD (hazard quotient of 1). A fish consumption value of 6.5 g/day was used in both cases.

2: California OEHHA (1999) SVs (CLS-SVs) specifically for this study were calculated according to US EPA guidance (US EPA, 1995). CLS-SVs for carcinogens were calculated for a 70 kg adult using a cancer risk of 1x10-5. CLS-SVs for non-cancer effects were calculated for a 70 kg adult and exposure at the RfD (hazard quotient of 1). A fish consumption value of 21 g/day was used in both cases

3: Sum of alpha and gamma chlordane, cis- and trans-nonachlor and oxychlordane.

4: Sum of othro and para DDTs, DDDs and DDEs.

5: Sum of endosulfan I and II.

6: Expressed as the sum of Aroclor 1248, 1254 and 1260.

7: Expressed as the sum of TEQs for dibenzodioxin and dibenzofuran compounds which have an adopted TEF.

The values listed in Table 1 are based on an upper-bound estimated cancer risk of one additional cancer in a population of 100,000 people who consume, on the average, 6.5 g/day (about 1 meal/month) of the fish containing the screening value concentration over their lifetime. Additional information on critical concentrations of OCls in fish tissue is provided by Brodberg and Pollock (1999) and US EPA (1997).

The screening values listed in Table 1, when adjusted for appropriate consumption rates for people who use fish from the listed waterbodies as a regular part of their diet, are the recommended screening values that should be used as management goals in an OCl bioaccumulation management plan for a cancer risk of 10^{-5}.

Lee and Jones-Lee (2002) have discussed a significant problem with past excessive bioaccumulation studies associated with the detection limits used to measure the concentrations of the OCls in fish and other organism tissue. As they discuss, many of the previous studies have used analytical methods that did not have adequate sensitivity to measure the OCls at concentrations that are recognized as a potential threat to human health. This has resulted in substantial parts of the existing fish tissue OCl database not being adequate to determine whether there were excessive OCl concentrations in edible fish tissue, compared to the OEHHA screening values.

Excessive OCl Bioaccumulation in Delta Fish/Clams. There are two major sources of data on OCl bioaccumulation in the Delta and near-Delta tributaries. One of these is the study conducted by the San Francisco Estuary Institute (SFEI), with Jay Davis as the lead scientist (Davis et al., 2000). The planning and reporting of the data collected in this 1998 study was a joint effort between Dr. Chris Foe of the CVRWQCB, William Jennings (the DeltaKeeper) and Jay Davis of SFEI. The funding for this study was provided by the DeltaKeeper. The other major source of OCl excessive bioaccumulation data is the SWRCB's Toxic Substances Monitoring Program (TSMP) (SWRCB/TSMP, 2002). While that program provided substantial historical data, little recent OCl data have been gathered by the TSMP on the Delta since the funds available to the CVRWQCB have been devoted primarily to measuring mercury bioaccumulation in Central Valley fish. A summary of the data obtained on the OCl concentrations in fish taken from the Delta and near-Delta tributaries is presented below.

<u>Port of Stockton Turning Basin.</u> In 1998, largemouth bass and white catfish were collected by DeltaKeeper/SFEI from the Port of Stockton Turning Basin. Total DDT and total chlordane were present at concentrations below the OEHHA screening values in the largemouth bass sample. The white catfish sample contained total DDT above the OEHHA screening value. Total chlordane was not present in the white catfish at an excessive level. Dieldrin and toxaphene analyses were conducted with methods that did not have an adequate detection limit to determine if there were exceedances of the OEHHA screening value. However, total PCBs were present above the OEHHA screening value in several of the largemouth bass taken from the Port of Stockton Turning Basin.

White catfish and largemouth bass were collected from "Stockton Deep Water Channel" in 1986 and 1990. The only OCl measured with adequate detection limits was total DDT. It was found that total DDT was less than the OEHHA screening value in these fish.

Port of Stockton near Mormon Slough. DeltaKeeper/SFEI sampled *Corbicula fluminea* (freshwater clam) from the Port of Stockton near Mormon Slough in 1998. Mormon Slough enters the canal that connects McLeod Lake with the Turning Basin. Mormon Slough is of interest, since this is the area of the McCormick & Baxter Superfund site (US EPA, 2002), which has discharged sufficient PCBs and dioxins to cause the San Joaquin County Department of Health to post this area for excessive PCBs and dioxins in fish. Total DDT was less than the OEHHA screening value in fish taken from this area. Dieldrin and total PCBs were above the OEHHA screening values. The other OCls were not measured with adequate detection limits.

Smith Canal. Smith Canal is a freshwater tidal slough, located within the city of Stockton. It is one of the primary waterway conveyance systems of city of Stockton stormwater runoff. DeltaKeeper/SFEI sampled Smith Canal white catfish and largemouth bass at Yosemite Lake in 1998. Yosemite Lake is at the head of Smith Canal. It receives City storm sewer discharges. Total DDT and total chlordane were less than the OEHHA screening value in both kinds of fish. However, total PCBs were above the OEHHA screening value in both white catfish and largemouth bass taken from Smith Canal at Yosemite Lake. Dieldrin and toxaphene analyses were conducted with methods that did not have an adequate detection limit to determine if there were exceedances of the OEHHA screening value. As a followup to the finding of excessive PCBs in some Smith Canal fish, Lee et al. (2002), with DeltaKeeper and CVRWQCB support, conducted studies on Smith Canal sediments and found that the sediments in the Yosemite Lake area of Smith Canal contained elevated PCBs that were available for biouptake.

San Joaquin River near Turner Cut. In 1998, DeltaKeeper/SFEI sampled largemouth bass and white catfish from the San Joaquin River "around Turner Cut." This location is about seven miles downstream of the Port of Stockton Turning Basin within the Deep Water Ship Channel. Total DDT, total chlordane and total PCBs were all below OEHHA screening values in both types of fish analyzed. Again, inadequate detection limits were used for dieldrin and toxaphene.

White Slough downstream from Disappointment Slough. White Slough is on the eastern part of the mid-Delta. In 1998, DeltaKeeper/SFEI sampled largemouth bass and black bullhead at White Slough downstream from Disappointment Slough. Total DDT and total PCBs were less than the OEHHA screening values. Dieldrin, chlordane, and toxaphene were not measured with sufficiently sensitive analytical methods to determine if there were exceedances of the OEHHA screening values.

San Joaquin River at Potato Slough. In 1998, DeltaKeeper/SFEI sampled largemouth bass and white catfish from San Joaquin River at Potato Slough, which is between Disappointment Slough and Point Antioch. Total DDT and total chlordane were below OEHHA screening values for both types of fish. Total PCBs were found above the OEHHA screening value in the white catfish sample. Inadequate sensitivity was used in the PCB analysis of the largemouth bass sample. Dieldrin and toxaphene analyses were conducted with methods that did not have an adequate detection limit to determine if there were exceedances of the OEHHA screening value.

Lee (2003a) had reported that, except during high flood-flow conditions that occur in the spring, the water in the San Joaquin River Deep Water Ship Channel and its associated tributaries downstream of Disappointment Slough/Columbia Cut is predominantly Sacramento River water.

The state and federal export project pumps at Tracy and Banks cause all San Joaquin River water present in the Deep Water Ship Channel at Turner Cut to be drawn down to the South Delta via Turner Cut and Columbia Cut and Middle River. Therefore, the legacy pesticide/PCB content of the San Joaquin River Deep Water Ship Channel beginning at Turner Cut and downstream is influenced to a considerable extent by Sacramento River water and local sources.

San Joaquin River off Point Antioch. DeltaKeeper/SFEI collected largemouth bass in 1998 from the San Joaquin River off Point Antioch near the fishing pier. There were no exceedances of any of the OCls measured. The same problems occurred with this DeltaKeeper/SFEI study for detection limits for dieldrin, chlordane, and toxaphene. As discussed above, the San Joaquin River channel below Disappointment Slough is, during the summer, fall and early winter, primarily a mixture of Sacramento River water and releases from Delta islands. It would only be under high San Joaquin River flows, such as during the late winter/spring, that any significant amount of San Joaquin River water would reach Point Antioch.

Sycamore Slough near Mokelumne River. In 1998, DeltaKeeper/SFEI sampled largemouth bass and black bullhead from Sycamore Slough at Mokelumne River. One largemouth bass taken from this location had dieldrin above the OEHHA screening value. Total DDT was below the OEHHA screening value, while the analyses for the rest of the OCls were conducted with insufficiently sensitive analytical methods.

Mokelumne River between Beaver and Hog Sloughs. In 1998, DeltaKeeper/SFEI sampled largemouth bass and black bullhead from the Mokelumne River between Beaver and Hog Sloughs. Total DDT and total PCBs were less than the OEHHA screening values. Dieldrin, chlordane, and toxaphene were analyzed with insufficiently sensitive analytical methods to determine if there were exceedances of the OEHHA screening values.

Mokelumne River near Woodbridge. Various organisms were sampled from the Mokelumne River at Woodbridge in 1978-1981. Asiatic clam was the only organism that contained DDT above the OEHHA screening value in 1978. Total DDT was not above the OEHHA screening value in the 1979-1980 sampling for Asiatic clam and largemouth bass. Almost all other OCls at that sampling time and location were analyzed with insufficiently sensitive analytical methods.

In 1992, the USGS sampled Asiatic clam taken from the Mokelumne River near Woodbridge. The concentrations of total DDT were below the OEHHA screening value. The detection limits used for dieldrin, chlordane, toxaphene and total PCBs were inadequate to detect these chemicals at the screening value.

Middle River at Bullfrog. Middle River runs north to south through the middle of the Delta. It connects to the San Joaquin River Channel in the north and to Old River in the south. In 1998, DeltaKeeper/SFEI sampled largemouth bass and white catfish from Middle River at Bullfrog. Total DDT and total PCBs were less than the OEHHA screening values. The analytical methods used for dieldrin, chlordane and toxaphene were not sufficiently sensitive to determine if there were exceedances of the OEHHA screening values.

Old River. Old River connects to the San Joaquin River downstream of Vernalis. At times, appreciable San Joaquin River water is diverted into the South Delta via Old River. White catfish from Old River were sampled by DeltaKeeper/SFEI in 1998. Total DDT and total PCBs were found above the OEHHA screening value. Total chlordane was less then the screening value. Dieldrin and toxaphene were not measured with sufficiently sensitive analytical methods to determine if there were exceedances of the OEHHA screening values. Old River/Tracy fish were also sampled by the TSMP in the mid-1980s. Channel catfish collected in 1984 had excessive DDT concentrations. Total chlordane was less than the OEHHA screening value in channel catfish. The other fish sampled in the 1980s (golden shiner and redear sunfish) had total DDT below the OEHHA screening values. All of the other OCls measured in the fish taken from Old River in the 1980s were analyzed with insufficiently sensitive analytical methods.

Paradise Cut. Paradise Cut is an area of intensive agricultural drainage, located in the South Delta. It is a dead-end slough which connects to Old River. Carp, catfish and largemouth bass from Paradise Cut were obtained by the TSMP in the mid- to late 1980s. Excessive concentrations of DDT, dieldrin, chlordane, toxaphene, and PCBs were found in these fish. Largemouth bass were sampled by DeltaKeeper/SFEI from Paradise Cut in 1998. These fish did not contain total DDT, total chlordane and total PCBs above the OEHHA screening values. Insufficiently sensitive analytical procedures were used for dieldrin and toxaphene. In 1998, white catfish were also sampled by DeltaKeeper/SFEI from Paradise Cut and were found to have excessive total DDT above the OEHHA screening value.

Old River at Central Valley Project Pumps. White catfish were collected from Old River near the Central Valley Project pumps (Tracy) in 1998. While total DDT and toxaphene were above the OEHHA screening value, total chlordane was found to be at concentrations below the OEHHA screening value. Dieldrin and PCBs were not measured with sufficiently sensitive analytical methods to determine if there were exceedances above the OEHHA screening values.

O'Neill Forebay/California Aqueduct. In the early 1980s, the TSMP collected striped bass and white catfish from the O'Neill Forebay/California Aqueduct. Total DDT was found in all of these fish above the OEHHA screening value. Total chlordane was found at concentrations less than the OEHHA screening value. All but one of these fish had dieldrin above the OEHHA screening value. One of the fish had total PCBs above the OEHHA screening value. The other fish were analyzed with inadequate sensitivity to measure PCBs at screening-value concentrations. Also, some of the fish were analyzed for dieldrin and toxaphene with analytical methods that were not sufficiently sensitive.

Near-Delta Tributaries. It is of interest to examine the OCl bioaccumulation data for fish taken from near-Delta tributaries. This information could be an indication of fish with excessive OCls that have moved out of the Delta or could move into the Delta. Further, near-Delta tributaries that contain fish with excessive OCls could be an ongoing source of OCls that bioaccumulate to excessive levels in Delta fish.

Sacramento River at Mile 44. The Sacramento River at Mile 44 station was not sampled as part of the State Water Resources Control Board's TSMP from 1978 through the 1980s. It has been sampled from 1997 through 2000 by the Sacramento River Watershed Program (SRWP) (LWA, 2003). All but one set of white catfish, largemouth bass, Sacramento sucker and pike minnow obtained during 15 sampling events from 1997 through 2000 had a total DDT less than the OEHHA screening value for an allowable limit for the chemical in edible fish tissue. The white catfish sample collected in 1998 had a total DDT above the screening value. The dieldrin data, presented in Figure 1, show a couple of white catfish samples with concentrations above the OEHHA screening value. Most of the values were reported as less than the detection limit, which was below the screening value. Chlordane concentrations were below the OEHHA screening value. Toxaphene was not measured.

Figure 2 presents the total PCBs found in various types of fish taken from the Sacramento River at Mile 44 during the period 1997 through 2000. The Sacramento River downstream of Sacramento is part of the Delta, according to its legal definition. There were a number of white catfish, largemouth bass and Sacramento sucker with concentrations of total PCBs above the OEHHA screening value.

Sacramento River at Hood. Sacramento River at Hood station is located downstream of the city of Sacramento. This station is one of the primary monitoring stations for OCl bioaccumulation in fish in the lower Sacramento River. Figure 3 presents the total DDT concentrations found in fish from this location for the period 1978 through 1998. As shown, there are many values over the years with concentrations of total DDT in white catfish above the OEHHA screening value. Figure 4 shows that, in 1998, dieldrin was present above the OEHHA screening value in white catfish and largemouth bass taken from the Sacramento River at Hood. Some of the white catfish taken from this location in 1998 had excessive concentrations of total chlordane (Figure 5) and toxaphene (Figure 6). Total PCBs (Figure 7) in white catfish and largemouth bass taken from the Sacramento River at Hood station in 1998 had concentrations above OEHHA screening values.

Cache and Putah Creeks. Cache Creek and Putah Creek are important lower Sacramento River tributaries. They discharge to the Yolo Bypass. Historically, in 1978 through 1981, the concentrations of the OCls measured in the fish and other organisms taken from these creeks did not exceed OEHHA screening values.

TSMP data from 1999 show that sucker taken from Putah Creek had a DDT concentration below OEHHA screening values. However, largemouth bass had excessive DDT. In largemouth bass taken in 1999, chlordane was measured at a concentration below the OEHHA screening value. Inadequate detection limits were used for chlordane measured in the sucker. Both sucker and largemouth bass analytical methods had insufficient sensitivity for measurements of dieldrin. Largemouth bass were just under the OEHHA screening value for PCBs. Analytical methods used on the sucker had inadequate detection limits for chlordane, toxaphene and PCBs. In largemouth bass samples taken in 1999, chlordane and toxaphene were not measured with sufficiently sensitive analytical methods to determine if there were exceedances of the OEHHA screening values.

In 1995, the USGS sampled Sacramento sucker from Cache Creek at Guinda. Dieldrin, toxaphene, and total PCBs were less than the detection limits, which were above the OEHHA screening values. They found that total DDT and total chlordane were less than the OEHHA

Figure 1

Concentrations of Dieldrin in Aquatic Organisms
Sacramento River at Mile 44 1997 - 2000

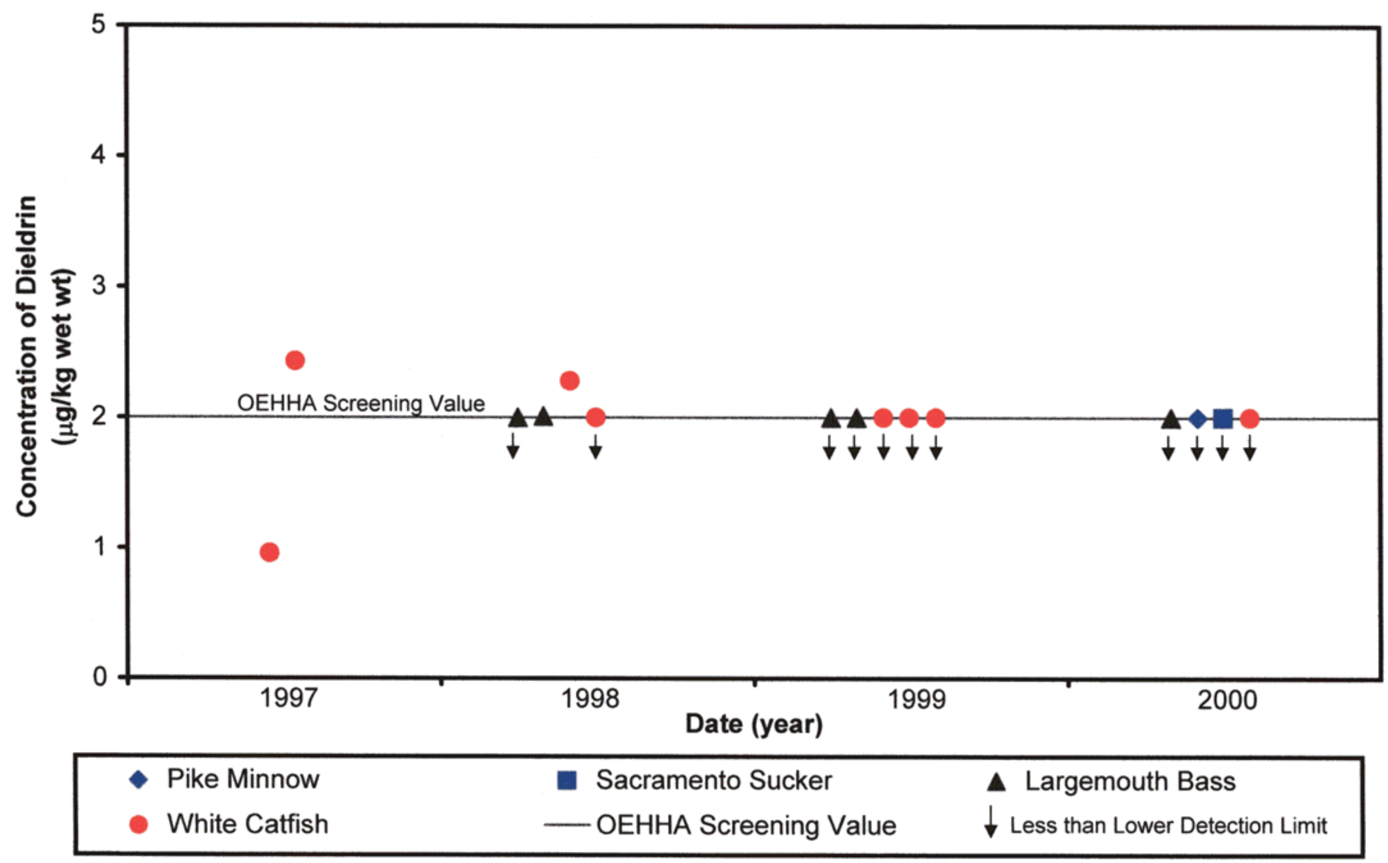


Figure 2

Concentrations of Total PCBs in Aquatic Organisms Sacramento River at Mile 44 1997 - 2000

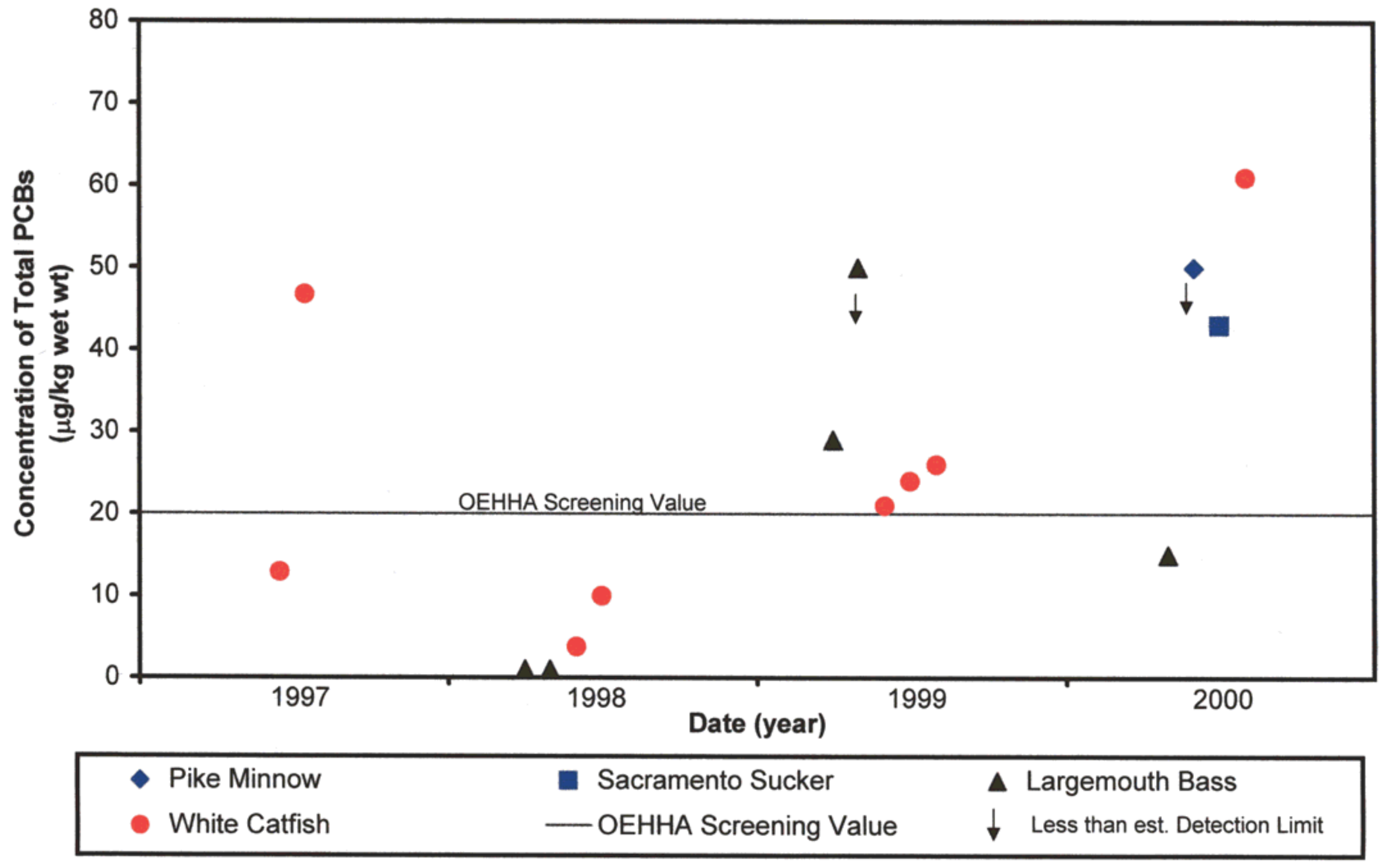


Figure 3

Concentrations of Total DDT in Aquatic Organisms
Sacramento River at Hood 1978 - 2000

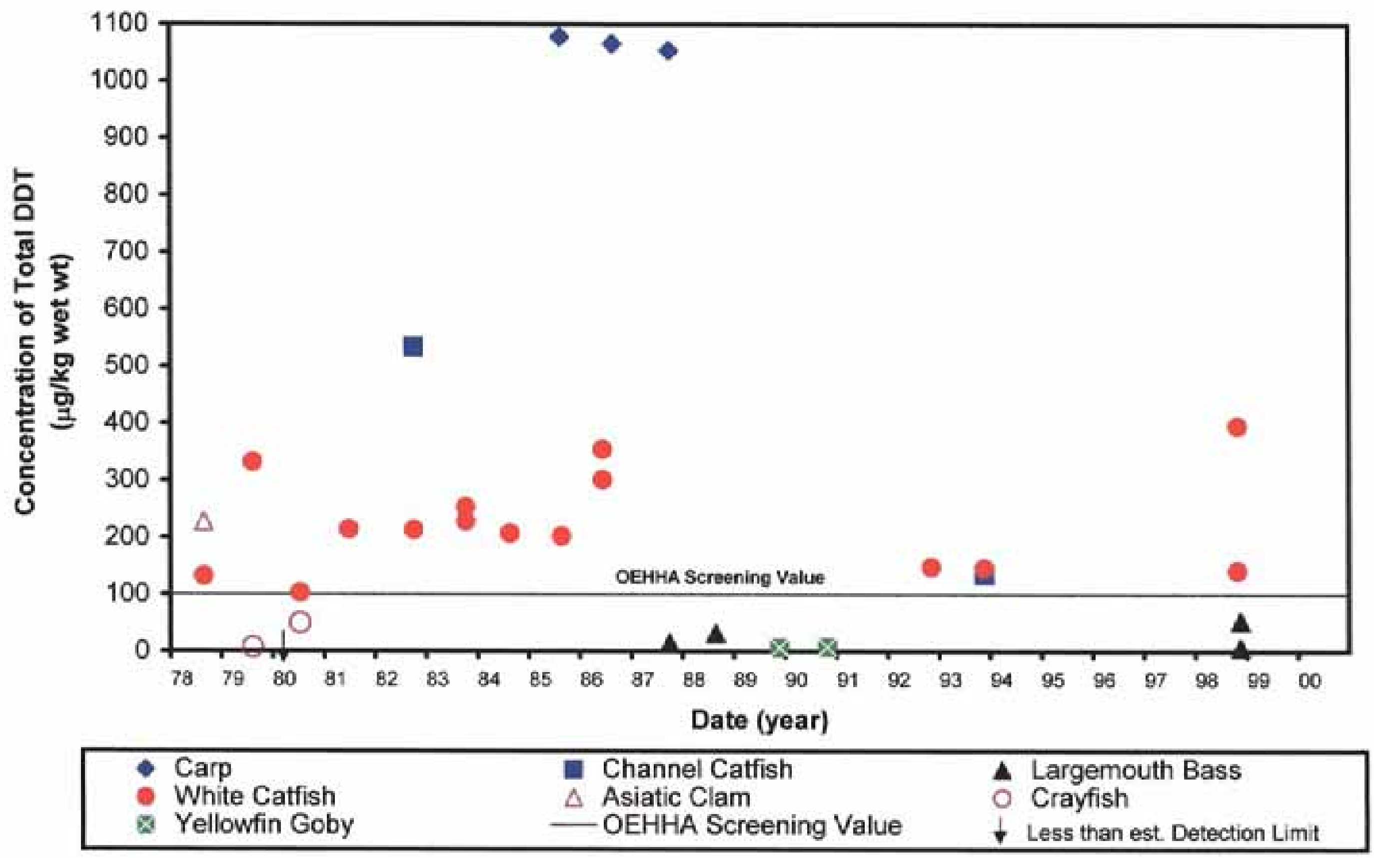


Figure 4

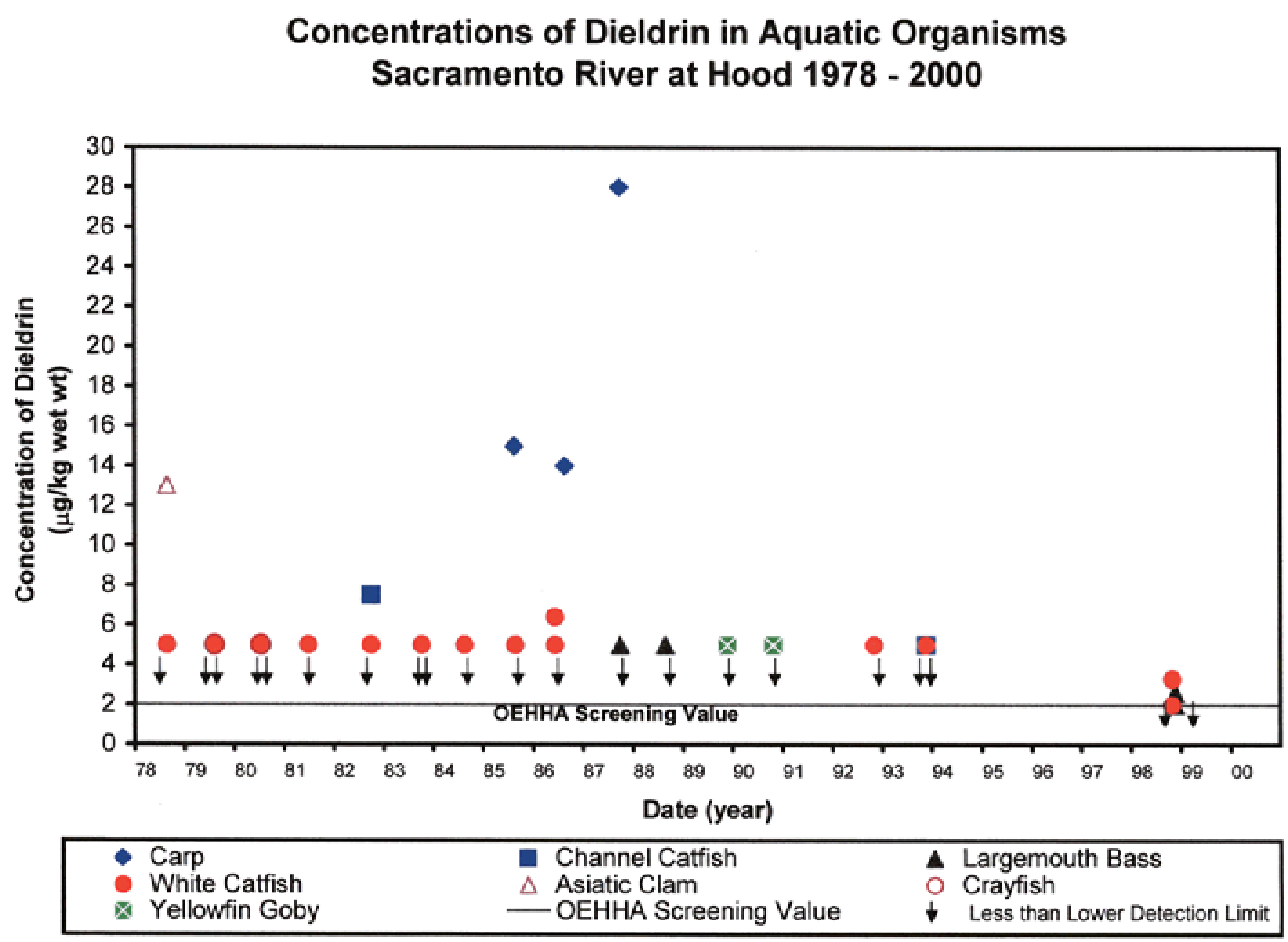

Concentrations of Dieldrin in Aquatic Organisms
Sacramento River at Hood 1978 - 2000
Concentration of Dieldrin (µg/kg wet wt)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
OEHHA Screening Value
78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00
Date (year)
Carp
White Catfish
Yellowfin Goby
Channel Catfish
Asiatic Clam
OEHHA Screening Value
Largemouth Bass
Crayfish
Less than Lower Detection Limit

Figure 5

Concentrations of Total Chlordane in Aquatic Organisms
Sacramento River at Hood 1978 - 2000

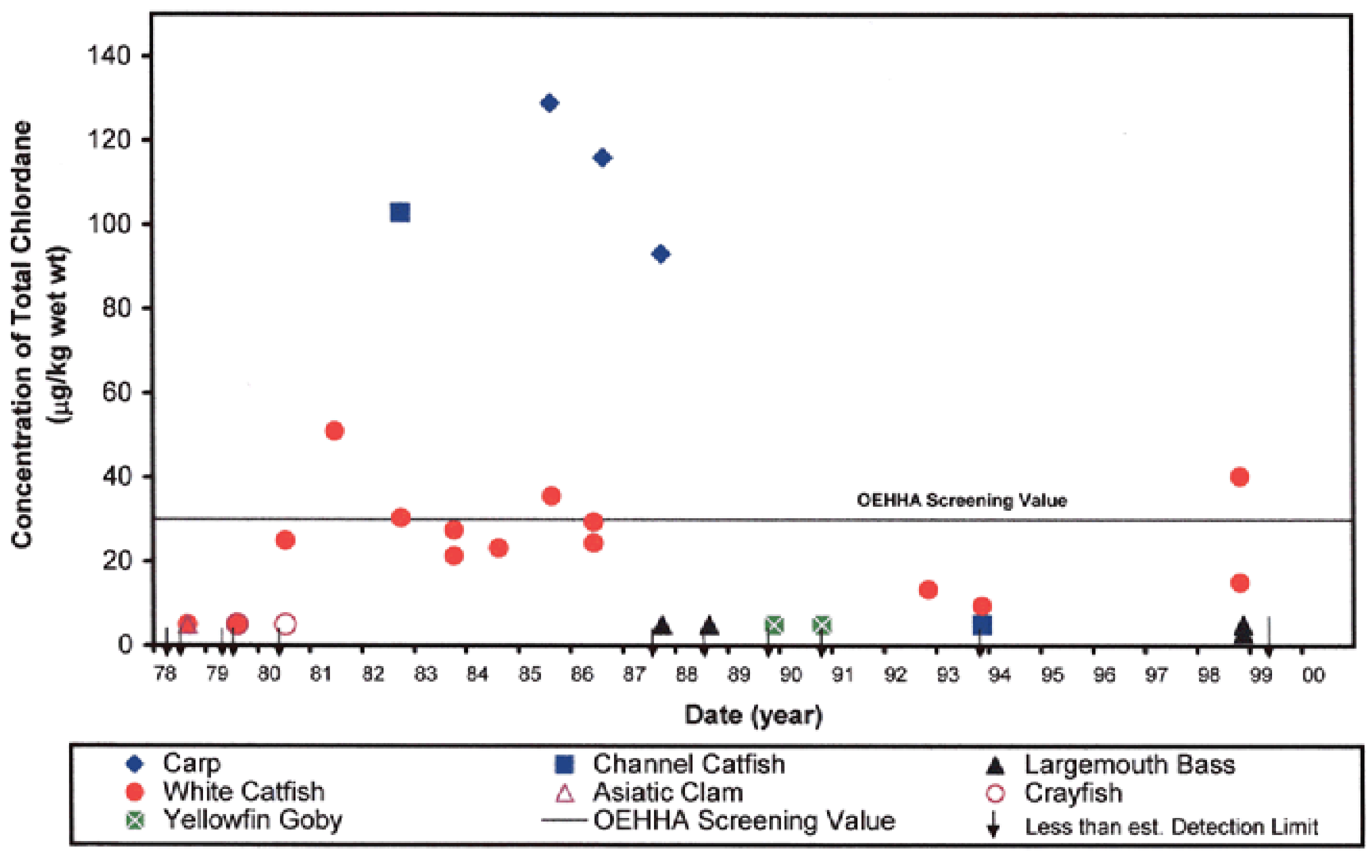


Figure 6

Concentrations of Toxaphene in Aquatic Organisms
Sacramento River at Hood 1978 - 2000

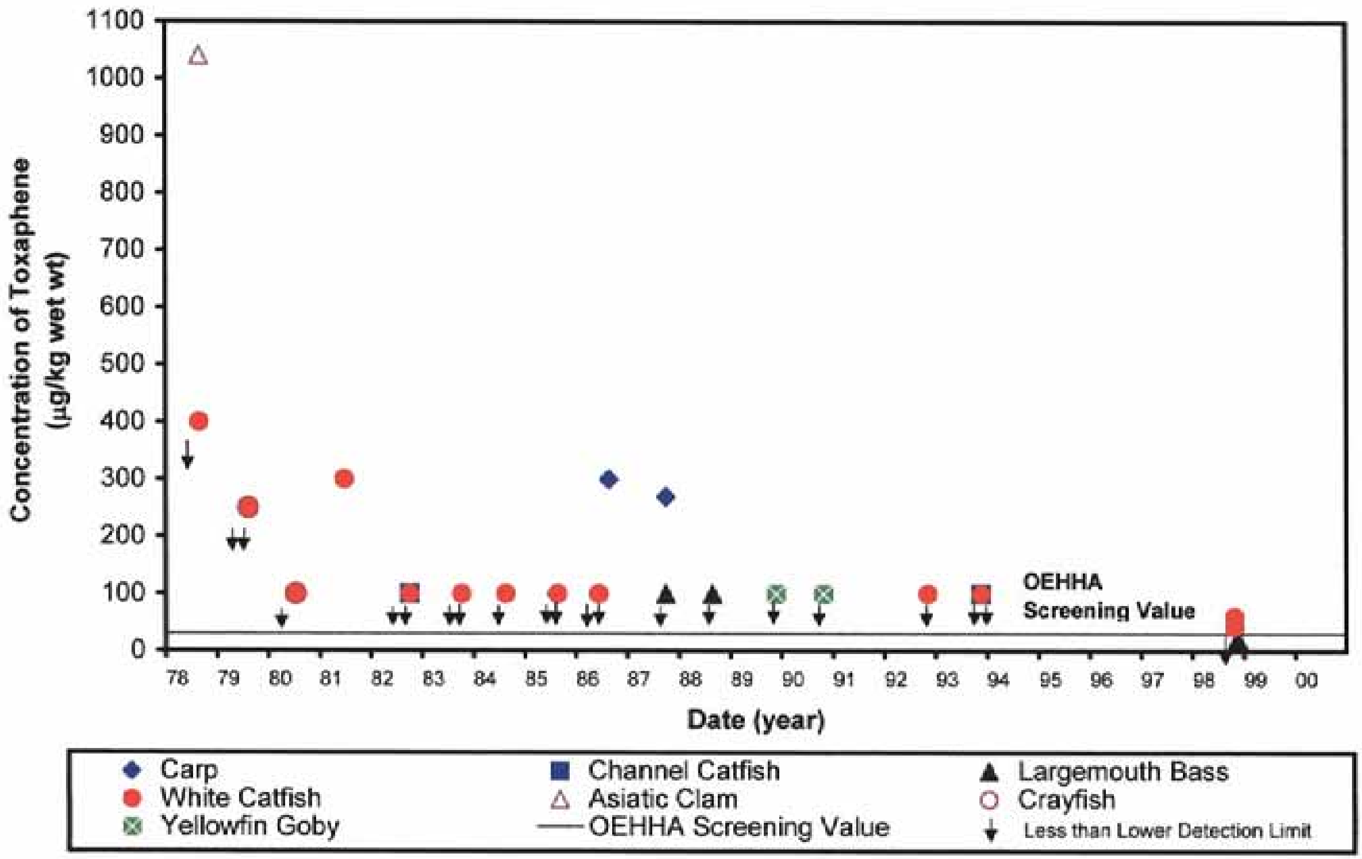
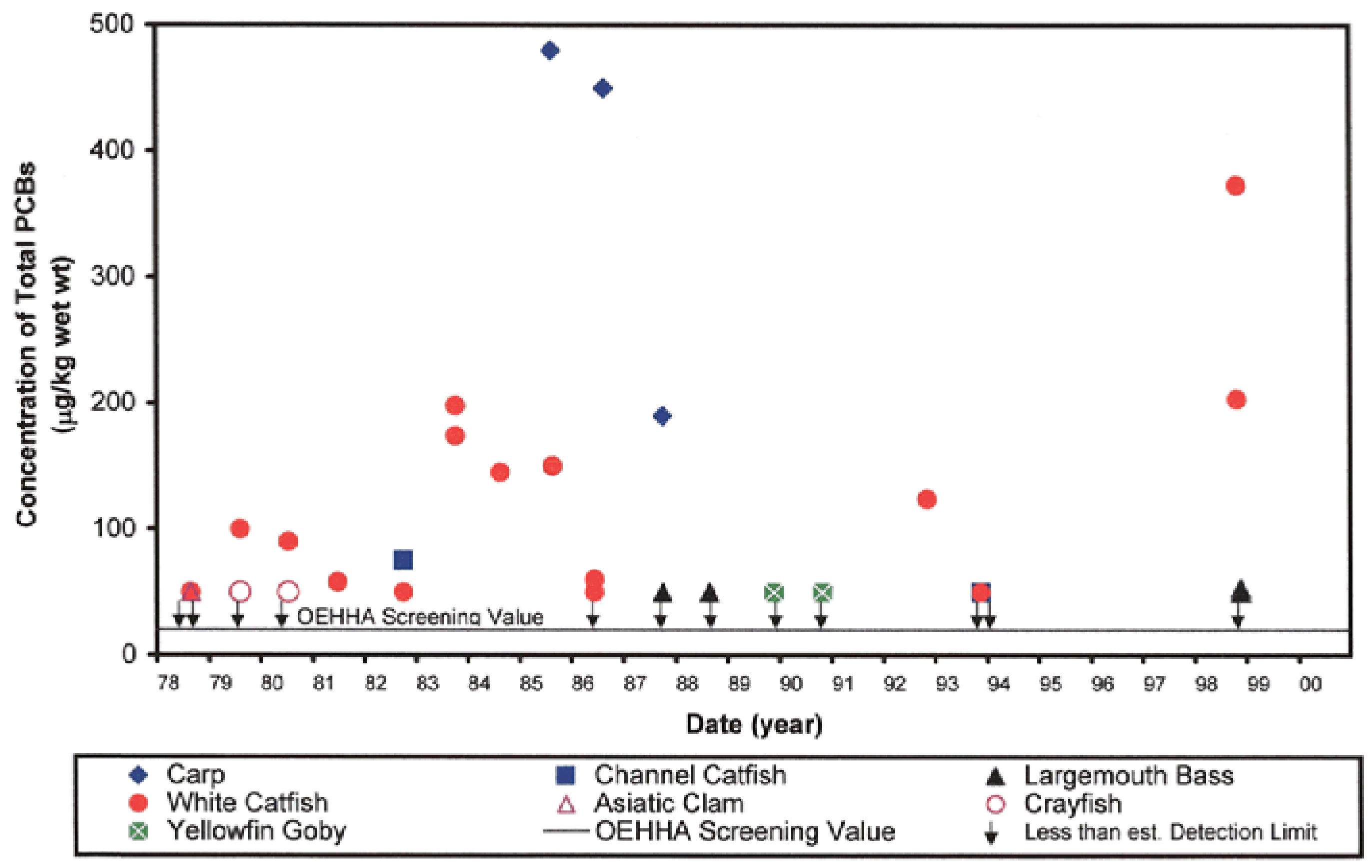


Figure 7

Concentrations of Total PCBs in Aquatic Organisms
Sacramento River at Hood 1978 - 2000



screening values. Overall, it can be concluded that, at this time, based on the limited sampling that has been done, except for DDT in Putah Creek, neither Cache nor Putah Creek fish have been found to contain excessive concentrations of OCls. However, a number of the OCls of particular concern, such as chlordane that is discharged from the University of California, Davis (UCD), Department of Energy (DOE) national LEHR Superfund Site, located on the UCD campus, have not been measured with sufficiently sensitive analytical methods. A review of the inadequacy of the studies that have been conducted thus far by UCD and DOE for the UCD/DOE LEHR Superfund site is provided in reports by Lee, which are available on the DSCSOC website, http://members.aol.com/dscsoc/ dscsoc.htm. Chlordane has been found to be discharged to Cache Creek from the LEHR site at concentrations above the US EPA water quality criterion that could bioaccumulate to excessive levels in Putah Creek fish.

Cache Slough. As part of the Sacramento River Watershed Program, Cache Slough fish were sampled in 1998, 1999 and 2000. In 1998, largemouth bass had measurements of DDT, chlordane, and PCBs below the OEHHA screening values. However, dieldrin exceeded the OEHHA screening value. Toxaphene was not measured. White catfish and largemouth bass were sampled from Cache Slough in 1999 and 2000. Largemouth bass were analyzed with inadequate detection limits for chlordane and PCBs, while the white catfish had concentrations of chlordane and PCBs below the OEHHA screening values. DDT concentrations were below the OEHHA screening values in both sets of fish sampled. Dieldrin was not measured with sufficiently sensitive analytical methods to determine if there were exceedances of the OEHHA screening values.

Sacramento River at Rio Vista. DeltaKeeper/SFEI sampled *Corbicula fluminea* from the Sacramento River at Rio Vista in 1998. They found that the total DDT and total PCBs were less than the screening values. Dieldrin, chlordane, and toxaphene analyses were conducted with methods that did not have an adequate detection limit to determine if there were exceedances of the OEHHA screening value.

Potential Future 303(d) Listings for Excessive OCl Bioaccumulation. While some of the Delta channels and near-Delta tributaries are listed on the 2002 303(d) list for excessive bioaccumulation of OCls, as discussed above, there are data from these areas for waterbodies which show excessive OCl bioaccumulation that has not caused the waterbody segment of concern to be listed on the current 303(d) list. It is possible that with the development of the updated list, additional Delta channels and near-Delta tributaries will be added to the Clean Water Act 303(d) list of OCl-impaired waterbodies. However, this situation is somewhat in doubt, since the approach that is being discussed at the SWRCB for establishing new 303(d) listings requires a substantial database to justify such listings, which in most instances is beyond the database available.

The problem with the State Board's proposed approach for establishing new 303(d) listings is that it is valid only if there are substantial monitoring funds and an appropriate monitoring program to investigate the waterbodies that have been found to have some fish with excessive bioaccumulation of OCls, to determine if there is a significant public health problem associated with eating fish from these waterbodies.

Under the current financial crisis that exists in California, the funds to properly implement the proposed approach for establishing new 303(d) listings may not be available. This could mean that the public who eat fish from these areas could be exposed to excessive concentrations of OCls without there being an appropriate regulatory program to evaluate the threat to their health. As discussed by Lee (2003b), there is an urgent need for funding of sufficient magnitude to determine the current status of OCl bioaccumulation in Delta channel and near-Delta tributary fish. The magnitude of this funding should be such that it will be possible to determine whether OEHHA should list a particular waterbody with a fish consumption advisory for having one or more OCls in edible fish tissue that are a threat to those who use the fish as food. The current situation, where there are a few fish taken in the past half a dozen years or so which show exceedances of OEHHA screening values for some OCls, should not be perpetuated.

There is also need to clearly define the fish consumption rates for those who are using Delta and near-Delta fish as a substantial part of their diet. It is believed that there are individuals who are subsistence fishermen in the Delta and near-Delta tributaries, who are consuming greater amounts of fish than are assumed by OEHHA in establishing its screening values. This situation could cause the screening values used for these waterbodies to have to be significantly lowered to protect the health of the subsistence fishermen in the area in order to avoid situations such as commonly occurred in the past, where a substantial amount of fish tissue analysis has been conducted with inadequate analytical methods. The regulatory agencies and the public should determine the appropriate screening value to protect the subsistence fishermen and then use analytical methods that will determine the concentrations of the OCls below these screening values.

Currently, there is a Delta Watershed Fish Project being conducted, which has a Local Advisory Group. The focus of this group's activities is on education of those who consume fish from the Delta on the potential hazards of these fish with respect to mercury. This group's activities need to be expanded to include the threat caused by organochlorine legacy pesticides and PCBs. Further, there is need to expand the work of Shilling (2003) on Background Information for a Central Valley Fish Consumption Study, which included some data on fish consumption in the Delta, to better define fish consumption rates in the Delta. There is also need to expand the work that is being done in the Sacramento River watershed by Alyce Ujihara and Sun H. Lee of the California Department of Health Services, Environmental Health Investigation Branch, to include assessing fish consumption rates in the Delta.

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Need for Funding to Support Studies to Control Excessive Bioaccumulation of Organochlorine "Legacy" Pesticides, PCBs and Dioxins in Edible Fish in the Central Valley of California[3]

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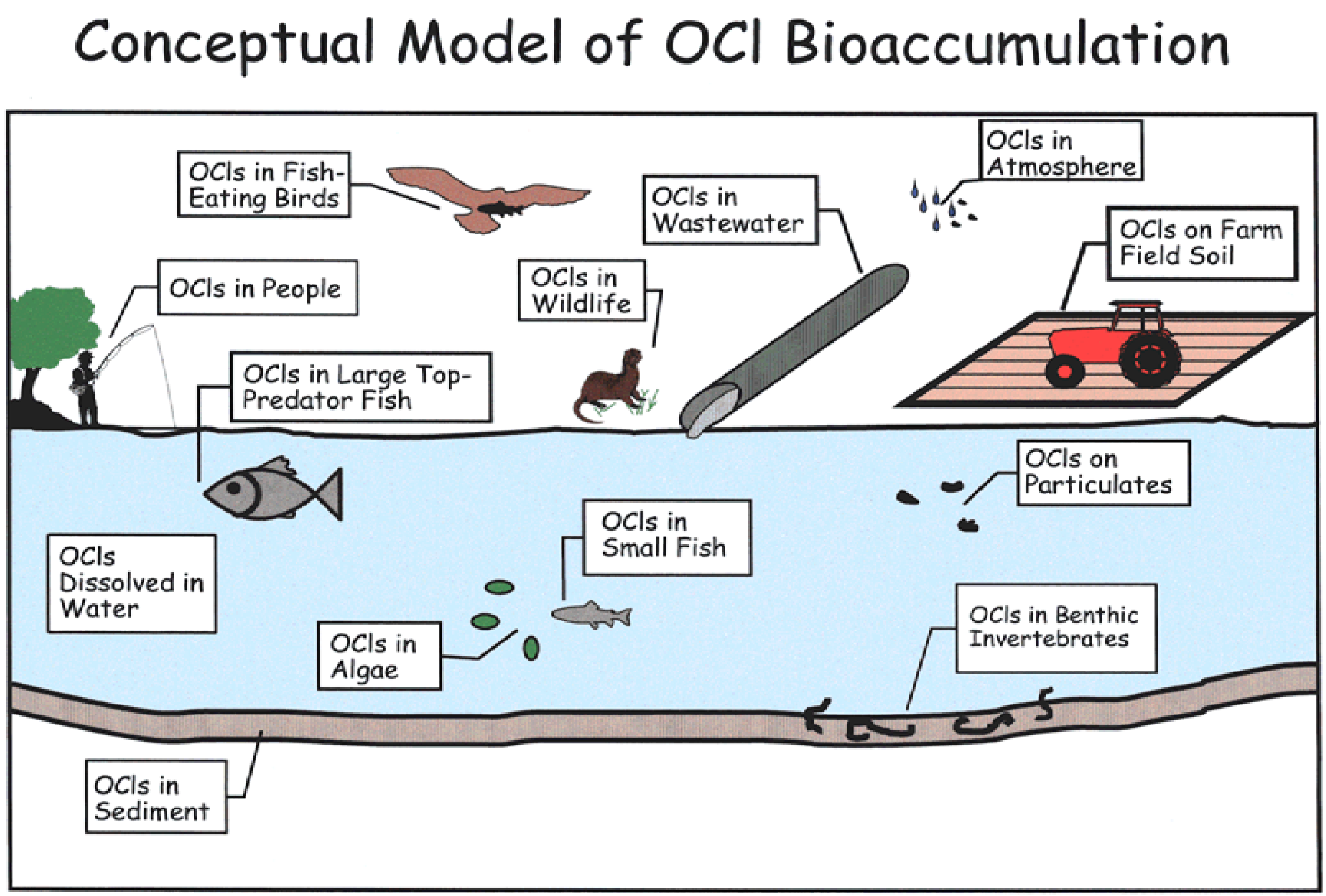
One of the most significant water quality problems that exist in the mainstems of the Sacramento and San Joaquin Rivers and many of their tributaries, as well as the Delta, is the excessive bioaccumulation of organochlorine "legacy" pesticides (DDT, dieldrin, chlordane, toxaphene), PCBs and possibly dioxins/furans. The excessive bioaccumulation of these organochlorines (OCls) causes many of the more desirable fish (such as largemouth bass, white catfish, etc.) to contain sufficient concentrations of these pesticides and/or PCBs so that their use as food represents a threat to cause cancer in those who eat them. This is an environmental justice problem, since the individuals who are most likely impacted to the greatest extent are those who must, because of economic reasons, use local fish as a major source of food in their diet.

Figure 1 shows the nature of the excessive bioaccumulation problem in Central Valley fish and other edible aquatic life. Basically, the problem is a food web accumulation problem, where the OCls are taken up by lower-trophic-level organisms, which ultimately results in elevated concentrations in fish and other organism tissue. Each of the waterbodies of concern has received in the past (and may receive, to some extent, today) sufficient concentrations of one or more OCls to lead to concentrations of these chemicals in some of the waterbodies' fish to be above the California Office of Environmental Health Hazard Assessment (OEHHA) guidelines for the use of the fish as food because of the potential for those who use these fish to acquire cancer.

The former use of one or more of the OCls (except dioxins/furans) in each of the waterbodies' watersheds for agricultural and/or urban purposes has led to stormwater runoff transport and, in some instances, wastewater discharges of the OCl(s) to a sufficient extent to lead to bioaccumulation to excessive levels in some of the edible fish in the waterbodies receiving the runoff/discharges. With respect to dioxins and furans, they may have been discharged to the waterbody or its tributary from former municipal and/or industrial wastewater discharges as well as in stormwater runoff from highways and streets and/or runoff/discharges from areas where low-temperature burning has taken place. They may also have been contaminants in the herbicide 2,4,5-T and could be derived from areas where this herbicide has been used.

[3] Reference as Lee, G. F., "Need for Funding to Support Studies to Control Excessive Bioaccumulation of Organochlorine "Legacy" Pesticides, PCBs and Dioxins in Edible Fish in the Central Valley of California," Report of G. Fred Lee & Associates, El Macero, CA, July (2003).

Figure 1


Conceptual Model of OCl Bioaccumulation
OCls in Fish-Eating Birds
OCls in People
OCls in Wildlife
OCls in Wastewater
OCls in Atmosphere
OCls on Farm Field Soil
OCls in Large Top-Predator Fish
OCls on Particulates
OCls Dissolved in Water
OCls in Small Fish
OCls in Algae
OCls in Benthic Invertebrates
OCls in Sediment

The Central Valley Regional Water Quality Control Board (CVRWQCB) has identified 11 waterbodies in the Central Valley, including the Sacramento and San Joaquin Rivers and the Delta, as well as a number of tributaries, as having excessive concentrations of the organochlorines in edible fish. This has resulted in these waterbodies being listed as Clean Water Act 303(d) "impaired" waterbodies. This listing results in the need for the CVRWQCB to develop a total maximum daily load (TMDL) to control the excessive bioaccumulation of the organochlorines in edible fish.

These waterbodies include the Delta Waterways, Lower American River, Colusa Basin Drain, Lower Feather River, Lower Merced River, Natomas East Main Drain, San Joaquin River, Lower Stanislaus River, Stockton Deep Water Ship Channel, Lower Tuolumne River and Lower Kings River. These waterbodies are listed on the federal Clean Water Act's 303(d) list as "impaired" for organochlorine (OCl) compounds including "Group A" pesticides (such as toxaphene, chlordane, dieldrin, aldrin, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane [including lindane], and endosulfan), DDT, DDE, DDD, and the non-pesticides polychlorinated biphenyls (PCBs) and dioxins/furans. The water quality problem caused by these chemicals is excessive bioaccumulation of one or more of the OCls in edible fish tissue compared to public health screening values established to protect humans from an increased risk of cancer associated with using the fish as food.

Table 10 from Lee and Jones-Lee (2002) (see attached) lists the Central Valley waterbodies that have been found to contain fish and other edible aquatic life with excessive OCls compared to OEHHA public health guidance for the use of fish as food. As shown, there are several other Central Valley waterbodies that have been found to contain excessive OCls that are not on the CVRWQCB 303(d) list of impaired waterbodies. The Central Valley waterbody OCl fish excessive bioaccumulation problem is likely much larger than indicated based on the 303(d) listing and the information presented in Table 10, since there have not been sufficient funds to conduct comprehensive surveys of Central Valley fish to fully define the extent of this problem.

In discussing this matter with the CVRWQCB staff (Jerry Bruns and others), it is found that the CVRWQCB does not have funds to develop the information needed to begin to address this problem, with the result that one of the most significant water quality problems in the Central Valley, which is directly affecting human health, is not being addressed.

This spring, it was decided that it would be appropriate for the DeltaKeeper to submit a proposal to try to gain funding to start the process of developing the information needed to effectively manage the excessive bioaccumulation of OCl chemicals in edible fish. Based on a review of the potential to gain funding under the SWRCB March 2003 Consolidated Request for Concept Proposals, this excessive bioaccumulation problem of the organochlorines is not eligible for support in any of the many tens of millions of dollars that the legislature has appropriated for studies. The Consolidated Request for Concept Proposals issued in March 2003 by the State Water Resources Control Board covers the California Bay-Delta Authority (CALFED), the US EPA, the California

Coastal Commission and the California Resources Agency. Grants would be made available through funding from Proposition 13, Federal Clean Water Act section 319, and Proposition 50. Based on discussions with CVRWQCB staff responsible for review of Concept Proposal submissions, none of these sources of funds could be used to address the excessive bioaccumulation of OCls.

About two years ago it was determined, with the concurrence of the Central Valley Regional Water Quality Control Board staff responsible for administration of a 319(h) project that had been awarded to the DeltaKeeper, that the project funds should be devoted to conducting a pilot study to determine whether the sediments in Smith Canal, a city of Stockton urban waterway, are the source of the PCBs that have been found in edible fish taken from Smith Canal. The situation is that the DeltaKeeper made settlement funds available to San Francisco Estuary Institute (SFEI) to do a survey of excessive bioaccumulation of organochlorine compounds in Central Valley fish. One of the locations where studies were conducted was in Smith Canal. The fish taken from Smith Canal were found to have some of the highest PCBs of any location in the Central Valley. Smith Canal at that time, and even today, is not on the CVRWQCB list of impaired waterbodies that have excessive bioaccumulation of PCBs. This situation exists for a number of other waterbodies in the Central Valley, where the current 11 waterbodies that are listed could readily be expanded to a much larger number, based on excessive bioaccumulation of organochlorines in edible fish.

The DeltaKeeper 319(h) project resulted in a report,

> Lee, G. F., Jones-Lee, A., and Ogle, R. S., "Preliminary Assessment of the Bioaccumulation of PCBs and Organochlorine Pesticides in *Lumbriculus variegatus* from City of Stockton Smith Canal Sediments, and Toxicity of City of Stockton Smith Canal Sediments to *Hyalella azteca*," Report to the DeltaKeeper and the Central Valley Regional Water Quality Control Board, G. Fred Lee & Associates, El Macero, CA, July (2002),

which demonstrated, using benthic organism uptake studies, that the PCBs in Smith Canal sediments are, at least in part, bioavailable, even though the sediments have a high organic carbon content. Organic carbon in sediments tends to reduce bioavailability of chemicals like the organochlorines. This was the first time that the US EPA's sediment bioaccumulation testing procedure had been used in the Central Valley. It is clear that there is need to conduct a large-scale sediment testing program using this approach to determine the location of the sediments in Central Valley waterbodies from which the organochlorines are being derived that are bioaccumulating to excessive levels in edible fish.

In the summer of 2000, Lee and Jones-Lee submitted a proposal to CALFED to develop the information that is needed to begin to define the sources of the organochlorines that are bioaccumulating to excessive levels in Central Valley waterbody fish. The reviews on the proposal indicated that one of the reasons it was not supported by CALFED was that it is devoted to a human health issue, rather than an ecological issue. As it turns out, there is no funding within CALFED, outside of the Drinking Water Program, for human health issues. The excessive bioaccumulation of organochlorines is not a drinking water problem. There were also questions by one of the reviewers about the practicality of defining sources of the organochlorines that are bioaccumulating to excessive levels, since this has not been undertaken in the Central Valley. However, as I pointed out, I have been working on organochlorine excessive bioaccumulation issues since the 1960s in other parts of the US, and I know from my experience and the literature that it is possible to define sources and to manage these sources.

At the May 6, 2003, CVRWQCB meeting, Board member Christopher Cabaldon indicated to the Board that the CALFED Environmental Justice Subcommittee had concluded that the excessive bioaccumulation of mercury in Delta and Delta tributary fish is an environmental justice issue, since the excessive bioaccumulation of mercury in edible fish is a threat to human health. Last winter, after I had completed a comprehensive review of the excessive OCl bioaccumulation problem for the CVRWQCB/SWRCB (see below), I contacted Sam Luoma, who directs the CALFED Science Program, indicating that the excessive OCl bioaccumulation problem is a well documented problem that is of significance to human health to people throughout the Central Valley who use Delta and its tributary fish as food. This is clearly an environmental justice issue. I pointed out that, as far as I could tell, there was no CALFED funding for this issue since this is a human health issue as opposed to an ecological issue. Dr. Luoma stated that he agreed that there was no funding to address this problem within CALFED, and that this is an environmental justice issue, but that the CALFED Environmental Justice Subcommittee has no funds to support work in this area.

Beginning about a year ago, the Central Valley Regional Water Quality Control Board, through funding from the State Water Resources Control Board and the US EPA, made funds available to the California Water Institute at California State University, Fresno, which provided support for Dr. Jones-Lee and me to develop a comprehensive report on the organochlorine excessive bioaccumulation issues. This report,

> Lee, G. F. and Jones-Lee, A., "Organochlorine Pesticide, PCB and Dioxin/Furan Excessive Bioaccumulation Management Guidance," California Water Institute Report TP 02-06 to the California Water Resources Control Board/Central Valley Regional Water Quality Control Board, 170 pp, California State University Fresno, Fresno, CA, December (2002)
> (http://www.gfredlee.com/OClTMDLRpt12-11-02.pdf),

was completed in December 2002. It provides detailed information on the current state of knowledge on excessive bioaccumulation of organochlorines in edible fish (see Table 10). Further, it defines the areas of needed study in order to begin to manage the problem. The principal issues of concern are those of the relative significance of aquatic sediments versus land runoff from agricultural and other areas as a source of organochlorines that are bioaccumulating to excessive levels. It is expected that aquatic sediments are the primary source; however, work in the early 1990s by the US Geological Survey showed that, at least in some areas, the "legacy" pesticides are still being discharged by agricultural lands at concentrations which could represent a significant source of organochlorines for excessive bioaccumulation in fish. Studies need to be conducted to determine, where excessive organochlorine bioaccumulation is found, whether the current terrestrial land runoff sources are a significant source for the excessive bioaccumulation.

Further, funds are needed to better define where excessive bioaccumulation is occurring. For example, an area of particular concern is excessive bioaccumulation of PCBs in the Sacramento River near Sacramento. This area, according to the data available, has excessive PCBs. It is not listed as a 303(d) "impaired" waterbody due to excessive PCB bioaccumulation. The Regional Board staff feels that there is need for additional studies to confirm the data; however, there are no funds available to do these studies. Lee and Jones-Lee conclude that there are sufficient data now to justify listing the Sacramento River near Sacramento as impaired due to excessive PCB bioaccumulation in fish. This approach would warn the public that many of the more desirable fish taken from the Sacramento River near Sacramento can contain excessive PCBs and, therefore, should not be consumed. It would also establish the need for studies to define the sources of these PCBs.

Recommended Approach for Establishing the OCl Management Program[4]

Lee and Jones-Lee (2002) have discussed a recommended approach for developing management programs for organochlorine pesticides and PCBs. The recommended approach for establishing the legacy pesticide, PCB and dioxin/furan excessive bioaccumulation management program is to first obtain sufficient funding so that a comprehensive study can be conducted on current OCl concentrations in edible fish from the 303(d) listed waterbodies. Particular attention should be given to sampling from various locations within the waterbodies to see if there are areas where fish and other organisms (such as clams) have higher concentrations.

At the same time that sampling is conducted for fish, samples of sediment from various locations in the listed waterbodies should also be taken and analyzed for OCls of concern. It would be highly desirable, although it may not be possible during the initial study, to do the sediment bioaccumulation evaluation using *Lumbriculus variegatus* (the oligochaete), following procedures similar to those used in the Smith Canal sediment PCB study (Lee et al., 2002).

For each of the listed waterbodies an advisory panel should be appointed to plan, implement and report on the needed studies. Suggested members of this panel include the CVRWQCB staff, DPR staff, county agriculture commissioners, CALFED, agricultural interests, Farm Bureau, county RCDs, irrigation districts, Department of Fish and Game and environmental groups. The results of this monitoring program could take several years to establish current degrees of excessive bioaccumulation for the OCls. This approach would also provide information that is needed to develop a site-specific sediment biota accumulation factor for each listed waterbody or parts thereof.

[2] From Lee and Jones-Lee (2002)

For some of the listed waterbodies − possibly most − there would be need to determine the external loads of OCls associated with summer irrigation season tailwater discharges and winter stormwater runoff. If substantial loads are found of excessive bioaccumulation at the point where the tributary discharges to the waterbody, then forensic studies would need to be conducted to determine the origin of these loads within the waterbody's watershed.

Ultimately, from studies of this type, it should be possible to determine whether current external loads of OCls represent a significant source of OCls that are bioaccumulating to excessive levels. This information could then be used to determine whether there is need to establish a control program from watershed sources of OCls for waterbodies that currently have excessive bioaccumulation of one or more OCls in one or more types of fish.

A list of specific topic areas of further study for OCl bioaccumulation management program development includes the following:

- Determine, for each of the listed waterbodies, as well as other Central Valley waterbodies, the current degree of edible fish tissue OCl residues. These residues should be compared to OEHHA screening values which have been adjusted for local fish consumption rates. This information is essential to defining the waterbodies within the Central Valley where OCls have bioaccumulated to excessive levels in edible fish.
- Determine for each of the listed waterbodies whether stormwater runoff and/or irrigation tailwater discharges and/or domestic and industrial wastewater discharges are currently contributing sufficient concentrations of the OCl(s) of concern in the waterbody to be contributing to the excessive bioaccumulation of this OCl(s) in edible fish tissue.
- Conduct a quantitative assessment of the current atmospheric loads of the OCls for several of the listed waterbodies to evaluate the potential significance of this source.
- Determine the concentrations of the OCls of concern in the listed waterbodies and the bioavailability of the sediment-associated OCl residues for food web accumulation that leads to excessive edible tissue residues.
- Determine the extent of edible fish tissue contamination by dioxins and furans within the Central Valley waterbodies. Where excessive concentrations are found in edible fish tissue, determine likely sources of the dioxins and furans that are bioaccumulating to excessive levels.
- Since the allowable OCl tissue residue for edible fish is dependent on local waterbody fish consumption rates, it is recommended that, as part of developing the management program for the OCl-listed waterbodies, representative fish consumption rates for each listed waterbody be developed.
- It is recommended that studies of the type conducted by USGS NAWQA in the early to mid-1990s be conducted again to verify that the continued transport of several organochlorine pesticides from agricultural and urban areas at potentially significant concentrations is occurring.

- There is need for studies to determine for each OCl-listed waterbody whether current transport of the OCls to the waterbody significantly contributes to the bioavailable OCl residues within the waterbody that lead to excessive bioaccumulation in edible organism tissue.
- Special-purpose studies need to be conducted using aquatic organism incubation to determine if domestic wastewaters are a significant source of OCls for certain Central Valley waterbodies.
- Studies should be conducted to determine if the bioaccumulation by the freshwater clam *Corbicula fluminea* could be used to evaluate the bioaccumulation that may be occurring in edible fish.
- All fish tissue analyses for the OCls should be conducted with an analytical method detection limit that is at least slightly below the OEHHA human health screening value.
- The fish samples that are currently stored frozen, taken from Smith Canal and a number of other locations, should be analyzed for OCl content in edible tissue.
- It is recommended that systematic studies of fish tissue OCl concentrations for the fish types of concern at a particular location be conducted to examine the variability in OCl composition at about the same time and location. This information is essential to understanding whether the apparent changes in OCl composition over time are related to real changes or simply reflect the variability of the data.
- It is also recommended that all OCl measurements of fish tissue include measurements of the lipid content. This information may be useful to normalize the OCl bioaccumulation based on fish edible tissue lipid content.

Additional information on these recommended studies is available in the Lee and Jones-Lee (2002) report.

The fact that none of the Consolidated funding sources have funds that could be used to support the needed organochlorine studies is a major gap in the approach that is being used today by the US EPA, CALFED, the State Water Resources Control Board and the Regional Water Quality Control Boards, where one of the most (if not the most) important water quality problems that affects human health in the Central Valley is not eligible for funding to develop the information base needed to begin to define the full magnitude of this problem, the sources of the organochlorines that are leading to excessive bioaccumulation, and approaches that could be used to potentially control the problem. It is for this reason that I recommend that the DeltaKeeper join with other environmental groups and request that the legislature provide funding to specifically address support for work on this topic. Another option would be to submit proposals to one or more foundations for support.

Discussion of Recent OCl Organism Tissue Data[5]

This section presents an overview discussion of the OCl fish and other aquatic organism recent (post-1997) data relative to exceedance of the OEHHA standard fish consumption screening values. As indicated, these values are based on a 21 g/day fish consumption rate, which translates to about 1 meal/week. They are based on an upper-bound cancer risk of one additional cancer in 100,000 people who consume fish at this rate over their lifetime. It is expected that there will be some individuals for some Central Valley Waterbodies who will consume fish from a listed Waterbody at a greater rate than the rate OEHHA used.

Table 10 presents a summary of all of the OCl aquatic organism tissue residue data that have been collected since 1997 compared to the OEHHA screening values. All data collected from 1997-2001 is, for the purposes of this report, termed "recent" data.

An "x" for an OCl and a location indicates that there are some recent OCl fish tissue or *Corbicula fluminea* (clam) data, where the concentrations of the OCl were above the OEHHA screening value. In situations where some fish had concentrations above the OEHHA screening value and others did not, an "x" was used to indicate that an exceedance of the value has recently occurred in at least one sampling of organisms at the location since 1997. An "o" means that there have been recent data collected with adequate analytical method sensitivity, which have shown that the concentrations of the OCl are below the OEHHA screening value. A "--" means that there have been no measurements made for this OCl at this location. A "?" indicates that the analytical methods used for the recent data have not had adequate sensitivity to determine the OCl at the OEHHA screening value. An "o?" indicates that the concentration of the OCl was just below the OEHHA screening value. An "x?" indicates that the concentration of the OCl in aquatic life tissue collected prior to 1997 was above the OEHHA screening value, but this OCl has not been measured at all, or with adequate sensitivity since 1997. An "*" indicates that organochlorine pesticides have been found in the water column at potentially significant concentrations; however, no data are available on the bioaccumulation of the OCls for this waterbody.

Based on past studies, the primary OCls of concern for excessive bioaccumulation in the Sacramento and San Joaquin River watersheds and the Delta are DDT, dieldrin, chlordane, toxaphene and PCBs. These are referred to herein as the primary OCls of concern.

Some of the past and recent studies have involved the use of analytical methods for certain of the OCls that did not have sufficient sensitivity to detect the OCl in fish tissue samples at the OEHHA screening values. Usually DDT and/or PCBs have been analyzed with sufficient sensitivity to detect exceedances. Unless previous studies showed exceedances of a certain OCl and there is no recent confirming data, the waterbody is not listed as a high priority for future studies.

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[5] From Lee and Jones-Lee (2002)

Table 10
Summary of Central Valley Waterbodies with Excessive OCl Residues
Based on 1997 - 2000 Organism Tissue Data and OEHHA Screening Values

Location	Total DDT	Dieldrin	Total Chlordane	Total Toxaphene	Total PCBs
San Joaquin River Watershed					
San Joaquin River at Highway 99	o	o	o	o	o
San Joaquin River at Lander Avenue	o	x	o	o	o
Mud Slough	x	x	?	x	x
Salt Slough	x?	x?	?	x?	?
Merced River	x	x	o	x	x
San Joaquin River at Crow's Landing	o	o	o	o	o
Orestimba Creek	x?	x?	?	x?	?
Spanish Grant Drain	x?	?	?	x?	x?
Olive Avenue Drain*	--	--	--	--	--
Turlock Irrigation District, Lateral #5	o	?	?	?	?
Del Puerto Creek	x?	?	?	?	?
Ingram Creek*	--	--	--	--	--
Hospital Creek*	--	--	--	--	--
Lower Tuolumne River	x	x	o	x	x
Stanislaus River	x	x?	?	x?	x
San Joaquin River at Vernalis	x	x	x	x	x
San Joaquin River "at Bowman Road"	x	?	o	?	x
San Joaquin River at Mossdale	x?	?	?	?	?
San Joaquin River "at Highway 4"	x	?	o	?	o
Sacramento River Watershed					
McCloud River	o	o	o	o	o
Clear Creek	o	o	o	o	o
Sacramento River at Keswick	o	?	o	--	x
Sacramento River at Bend Bridge, near Hamilton City	o	o	o	o	o
Mill Creek	o	o	o	o	o
Deer Creek	o	o	o	o	o
Big Chico Creek	o	o	o	o	o
Sacramento River at Colusa	o	?	o	--	x
Sutter Bypass	x?	x?	x?	x?	x?
Feather River near Nicolaus/Hwy 99	o	o	o	o	x
Feather River at Forbestown	--	--	--	--	x?
Yuba River	x?	?	?	?	?
East Canal near Nicolaus	x?	x?	?	?	?
Sacramento Slough	o	x	o	--	x
Colusa Basin Drain	x	x	x?	x?	o
Sacramento River at Veteran's Bridge	o	?	o	--	x
Natomas East Main Drain	o	?	o	?	x

Table 10 (Cont.)					
Sacramento River Watershed (Cont.)	**Total DDT**	**Dieldrin**	**Total Chlordane**	**Total Toxaphene**	**Total PCBs**
Arcade Creek	o	x?	x?	?	?
American River at Discovery Park	o	x	o	?	x
American River at Watt Avenue	x?	x?	x?	--	x?
American River at J Street	o	?	o	--	x
Sacramento River at Mile 44	x	x	o	--	x
Sacramento River at Hood	x	x	x	x	x
Cache Creek	o	?	?	?	o
Putah Creek	x	?	o	?	o?
Cache Slough	o	x	o	--	o
Sacramento River at Rio Vista	o	?	?	?	o
Delta					
Port of Stockton Turning Basin	x	?	o	?	x
Port of Stockton near Mormon Slough	o	x	?	?	x
Smith Canal	o	?	o	?	x
San Joaquin River around Turner Cut	o	?	o	?	o
White Slough downstream from Disappointment Slough	o	?	?	?	o
San Joaquin River at Potato Slough	o	?	o	?	x
San Joaquin River off Point Antioch	o	?	?	?	o
Sycamore Slough near Mokelumne River	o	x	?	?	?
Mokelumne River between Beaver and Hog Sloughs	o	?	?	?	o
Middle River at Bullfrog	o	?	?	?	o
Old River	x	?	o	?	x
Paradise Cut	x	?	o	?	o
Old River at Central Valley Pump	x	?	o	x	?
O'Neill Forebay/California Aqueduct	x?	?	x?	?	x?
Tulare Lake Basin					
King's River	o	?	o	?	o
Kern River	o?	?	?	?	--

x At least one fish sample taken in the late 1990s or 2000 was above the OEHHA screening value.
o None of the fish samples taken in the late 1990s or 2000 were above the OEHHA screening value.
? The analytical methods used were not sufficiently sensitive to measure the OCl at the OEHHA screening value.
o? The concentrations of an OCl were just below the OEHHA screening value.
x? The concentration of an OCl was above the screening value in the past but either has not been recently analyzed or the recent analytical methods used did not have sufficient sensitivity.
-- No measurements were made for this OCl.
* Organochlorine pesticides have been found in the water column at potentially significant concentrations. No data are available on the bioaccumulation of the OCls for this waterbody.

San Joaquin River Watershed. The uppermost point where fish have been recently collected and OCls have been measured with adequate sensitivity in the San Joaquin River watershed was at the San Joaquin River at Highway 99. The largemouth bass collected in 2000 did not show exceedances of the OEHHA screening value at this location for each of the primary OCls of concern. Further down the SJR at Lander Avenue, only dieldrin in white catfish collected in 1998 was above the OEHHA screening value. DDT, chlordane, toxaphene and PCBs were all below the OEHHA screening value.

Mud and Salt Sloughs are tributaries of the San Joaquin River that enter the River below Lander Avenue but above the Merced River. White catfish taken from Mud Slough in 1998 had concentrations of total DDT, dieldrin, toxaphene and total PCBs above OEHHA screening values. There have been no recent fish tissue data collected from Salt Slough. However, older data showed exceedances of total DDT, dieldrin and toxaphene.

Channel catfish and largemouth bass were collected from the Merced River at the Hatfield St. Recreation Area in 1998. These fish contained excessive concentrations of total DDT, dieldrin, chlordane, toxaphene and total PCBs above the OEHHA screening values. Future studies should include samples taken at several locations at and above the Hatfield St. Recreation Area.

The San Joaquin River at Crow's Landing receives the upstream discharges of Mud Slough, Salt Slough and the Merced River. The recent largemouth bass data collected at this location did not show exceedances for any of the OCls. It appears that Mud Slough, Salt Slough, and the Merced River, as well as the SJR at Lander Avenue, while having fish that show excessive OCls, are not contributing OCls to the San Joaquin River at sufficient concentrations to cause fish taken near Crow's Landing to have excessive OCls.

The westside tributaries to the SJR (Orestimba Creek, Spanish Grant Drain, Del Puerto Creek, Olive Avenue Drain, Ingram Creek and Hospital Creek) are major sources of OCls for the San Joaquin River. These waterbodies were found in the early 1990s to contain measurable concentrations of several of the OCls of concern in the water column that could bioaccumulate to excessive levels in aquatic organisms. There are no recent data on OCl concentrations in aquatic organisms taken from the westside tributaries. This is an area that should be a high priority for further study.

The mid- to lower eastside tributaries (Stanislaus River and Tuolumne River) of the San Joaquin River contain fish with excessive concentrations of several OCls. These tributaries are potentially contributing certain OCls to the San Joaquin River to cause fish taken from the San Joaquin River at Vernalis to show exceedances of the primary OCls of concern.

Fish taken recently from the San Joaquin River at Bowman Road and Highway 4 have had exceedances of one or more OCls. There has been no recent sampling of fish from the San Joaquin River at Mossdale. It would be expected, however, that they would also have an exceedance of total DDT.

Overall, with respect to the San Joaquin River watershed, the eastside and westside tributaries of the SJR contain fish with exceedances of one or more OCls. It also appears that these tributaries are discharging sufficient concentrations of some OCls to cause the fish taken from the San Joaquin River at Vernalis to contain excessive DDT, dieldrin, chlordane, toxaphene and PCBs.

Sacramento River Watershed. The Sacramento River and its tributaries above the Colusa Basin Drain (except at Keswick for PCBs), have been found, through recent fish collection, to have fish with OCls at less than the OEHHA screening value. While a 1997 sampling showed that there was an exceedance of PCBs in rainbow trout collected in the Sacramento River at Keswick, the subsequent samplings did not show this problem.

The Colusa Basin Drain is a main agricultural drain in the Central Sacramento Valley. Carp taken from the drain have been found to contain excessive DDT and dieldrin. White catfish did not contain excessive OCls. Previously, excessive chlordane and toxaphene have been found; however, there are no recently collected data with adequate sensitivity to ascertain the current situation with regard to toxaphene and chlordane in Colusa Basin Drain fish. The fish from this drain have recently been found to contain PCBs below the OEHHA screening value.

The recent white catfish and largemouth bass samplings from the Feather River near Nicolaus/Highway 99 have shown no exceedances of organochlorine pesticides. However, PCBs were found in pike minnow from the Feather River near Nicolaus/Highway 99 in excess of the OEHHA screening value.

In 1980, a variety of types of fish from the Feather River at Forbestown did show exceedances of PCBs. These exceedances relate to the use of PCB oils for road dust control. There has been no followup on this situation. It is suggested that this should be followed up to determine the current situation.

White catfish taken from the Sacramento Slough in 2000 contained excessive dieldrin and PCBs. Largemouth bass did not have excessive dieldrin, but did have excessive PCBs. DDT and chlordane were less than OEHHA screening values.

Sacramento River at Veteran’s Bridge had excessive PCBs in white catfish.

Natomas East Main Drain white catfish and largemouth bass contained excessive PCBs.

Recently sampled largemouth bass from the American River had exceedances of PCBs, while excessive dieldrin was found in pike minnow.

Sacramento River at Mile 44 had excessive DDT, dieldrin and PCBs in white catfish and excessive DDT and PCBs in largemouth bass.

Sacramento River at Hood had white catfish and largemouth bass showing exceedances of all of the primary OCls of concern.

Excessive DDT was found in largemouth bass obtained from Putah Creek.

Largemouth bass from Cache Slough had exceedances of dieldrin.

Delta. The Port of Stockton Turning Basin had excessive PCBs and DDT in largemouth bass.

Dieldrin and PCBs were found in *Corbicula fluminea* sampled from the Port of Stockton near Mormon Slough.

Largemouth bass and white catfish taken from the Smith Canal at Yosemite Lake contained excessive PCBs.

The San Joaquin River below Turner Cut and the Central Delta have not recently been found to contain excessive OCls (DDT and PCBs) in fish.

Sycamore Slough near Mokelumne River had an exceedance of dieldrin found in largemouth bass.

White catfish taken from Old River at several locations have been found to contain excessive DDT and, at one location, PCBs. Excessive DDT was found in largemouth bass from Paradise Cut.

Tulare Lake Basin. No problems were encountered with excessive OCls in recently sampled King's River fish.

References

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Appendix B

Priorities, Data Gaps, and Research Needs[6]

Kenneth D. Landau, Assistant Executive Officer
Central Valley Regional Water Quality Control Board

CALFED and the Regional Board have worked together over the past several years to develop approaches for addressing water quality problems that impact Delta watershed beneficial uses. The priority problems that are included in the ROD and other CALFED documents are consistent with Regional Board priorities. Regional Board staff is working with various federal, state and local agencies: discharger groups; watershed groups and other stakeholders to address contaminants of concern.

All the contaminants we are working on cause widespread impairments, but research and information is needed, in most cases,

- to define the extent and magnitude of the problems,
- to identify the sources of contaminants,
- to determine how these sources interact in the environment to cause problems and
- to evaluate potential practices or actions that can be implemented to address the problems.

The priority issues the Regional Board is facing with regard to contaminant issues are:

- mercury,
- selenium,
- legacy pesticides,
- agricultural and urban use pesticides,
- endocrine disrupters,
- dissolved oxygen demand,
- unknown toxicity,
- total organic carbon. and
- salt

I will be discussing the data gaps and research needs that must be filled to effectively address these problems.

Mercury – The Regional Board has identified sites throughout the Central Valley Region that are impacted because of elevated levels of mercury in fish. This includes the Delta, Cache Creek, Sacramento River and many lakes and reservoirs. We have been working

[6] Presentation at California Bay-Delta Authority Workshop, "Contaminant Stressors in the Bay-Delta Watershed" – Policy & Management Session, February 4, 2004.

with CALFED and others over the past several years to address the mercury problem in the Delta and key tributaries. Our efforts have focused on:

- identification of the sources of mercury,
- determining the factors that influence mercury uptake in organisms, and
- identification of preliminary actions to address the problems.

More work is still needed in all these areas. In addition, more information is needed on the distribution of fish with elevated levels of mercury in their tissue. We need to know where the hot spots are and why fish in those areas contain higher levels of mercury than in other places. We also need to know who is eating the fish and develop a system for alerting the public to the health risks.

Selenium –sources, controls and treatment measures for selenium-affected waterbodies tributary to the Delta are well understood. Regulations and control programs are in place, or are being developed, to implement solutions for these remaining impairments. There are, however, continuing selenium bioaccumulation problems in the Bay. Research is needed to determine whether Central Valley selenium contributes to problems in the Bay, and whether additional water quality objectives or control measures are needed to protect the Bay.

Legacy Pesticides – such as DDT and other organochlorines were banned from use over 25 years ago because of their highly toxic and bioaccumulative nature. Studies show that the amount of these pesticides present in the environment and in fish tissue is declining. However, levels in fish from many water bodies are still too high. In order to address the problem, we need to know where these pesticides have accumulated and at what rate they are degrading. Then we will need to determine whether we can rely on the natural rate of decline to address the problem or whether we should takes steps to accelerate it. In addition, there are some sites in the watershed that appear to be receiving inputs of essentially undegraded pesticides. We need to collect information to identify the sources of this material.

Agricultural and Urban Use Pesticides –impair many waterbodies in the Central Valley. The extent and magnitude of the problems and the sources of the pesticides are not well defined. The effectiveness of alternative management practices and other actions in keeping pesticides out of Delta waters and tributaries to the Delta have not been fully evaluated. Some of this information may be developed through TMDLs and the irrigated agricultural waiver program. However, determining the impacts of the mix of pesticides entering Delta waters from the different sources will continue to be a challenge. In addition, more information is needed on sediment toxicity. There is evidence that pyrethroid insecticides, which are coming into wider use as organo phosphate pesticides are being phased out, have the potential to cause widespread sediment toxicity.

Endocrine Disrupting Chemicals –are present in the environment at high enough concentrations to effect resident aquatic life. Sources of these chemicals include pharmaceuticals present in wastewater treatment plant effluent and pesticides in agricultural return flows and runoff. The Pesticide Action Network reports that over 2 million pounds of suspected endocrine disrupting pesticides are applied in California every year. Little is known about the levels of these chemicals present in Central Valley waterways and what their effects on aquatic life are.

Dissolved Oxygen Depletion – in the Stockton Deep Water Ship Channel effectively forms a barrier to fish migration in the San Joaquin near Stockton for weeks at a time in the spring and fall. Progress has been made in identifying the causes of the problem related to loading. Additional work, however, needs to be done to confirm the sources of loads and the linkage of causes to sources in the upper watershed. Additional data and research is also needed to determine the appropriate concentrations of dissolved oxygen needed to protect beneficial uses in various Delta waterways. Specifically, issues need to be resolved regarding averaging periods and where and how objectives are applied in the water column.

Unknown Toxicity – The Regional Board has employed toxicity testing to assess Central Valley water quality since the late 1980's. Toxicity from pesticides in urban and agricultural runoff, metals in abandoned mine drainage, and pathogens have been identified and programs to remove the toxicity have been established. Yet the cause and source of many instances of toxicity were never identified.

As such many Central Valley waterbodies are considered impaired due to "unknown toxicity". The major questions that need to be answered include:

- is the historic toxicity continuing today?
- if so, what is the cause and how can the problem be addressed?

In order to answer these questions, more extensive toxicity monitoring and research to develop advanced toxicity identification evaluation and chemical analysis tools needs to be conducted.

Total Organic Carbon – is a constituent of concern for drinking water uses because it causes the formation of carcinogenic disinfection byproducts when the water is chlorinated at the drinking water treatment plant. TOC also is a necessary component of the food web. The Regional Board must consider both drinking water and ecosystem beneficial uses when establishing objectives for constituents of concern. Research is needed to determine the levels of TOC allowable in source water to meet drinking water limits for Disinfection By Products while ensuring that ecosystem needs for TOC are still met.

Salt – Salinity is a major problem in the San Joaquin River, impacting agricultural and municipal use of water in the San Joaquin River and the Delta. Although salinity at these concentrations is not directly an ecological impact, potential control measures could involve changes in water management at the farm and regional level, which could impact flows and water quality of ecological significance. A major challenge is understanding the interrelations of these various control efforts so that improvements in one area do not exacerbate problems in another area.

Appendix C

BIOLOGICAL STUDY

NONINDIGENOUS AQUATIC SPECIES IN A UNITED STATES ESTUARY:

A CASE STUDY OF THE BIOLOGICAL INVASIONS OF THE SAN FRANCISCO BAY AND DELTA

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A Report for the

UNITED STATES FISH AND WILDLIFE SERVICE[2]
WASHINGTON, D. C.
December 1995

Copies may be obtained:

U.S. Fish & Wildlife Service
Division of Fish and Wildlife Management Assistance
4401 N. Fairfax Dr., Room 840
Arlington, VA 22203
(703) 358-2025
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National Technical Information Service
Springfield, VA 22161
(800) 553-6847 or (703)487-4650
Report No. PB96-166525
Cost: $49.00 plus $4.00 shipping

[1] Current address: San Francisco Estuary Institute, 180 Richmond Field Station, 1325 South 46th Street, Richmond, CA 94804.

[2] Funding provided to authors through Connecticut Sea Grant Program (National Oceanic and Atmospheric Administration Grant No. 36RG0467).

Executive Summary

1. THE SAN FRANCISCO BAY AND DELTA REGION IS A HIGHLY INVADED ECOSYSTEM

- The San Francisco Estuary can now be recognized as the most invaded aquatic ecosystem in North America. Now recognized in the Estuary are 212 introduced species: 69 percent of these are invertebrates, 15 percent are fish and other vertebrates, 12 percent are vascular plants and 4 percent are protists.

- In the period since 1850, the San Francisco Bay and Delta region has been invaded by an average of one new species every 36 weeks. Since 1970, the rate has been at least one new species every 24 weeks: the first collection records of over 50 non-native species in the Estuary since 1970 thus appear to reflect a significant new pulse of invasions.

- In addition to the 212 recognized introductions, 123 species are considered as cryptogenic (not clearly native or introduced), and the total number of cryptogenic taxa in the Estuary might well be twice that. Thus simply reporting the documented introductions and assuming that all other species in a region are native—as virtually all previous studies have done—severely underestimates the impact of marine and aquatic invasions on a region's biota.

  Nonindigenous aquatic animals and plants have had a profound impact on the ecology of this region. No shallow water habitat now remains uninvaded by exotic species and, in some regions, it is difficult to find any native species in abundance. In some regions of the Bay, 100% of the common species are introduced, creating "introduced communities." In locations ranging from freshwater sites in the Delta, through Suisun and San Pablo Bays and the shallower parts of the Central Bay to the South Bay, introduced species account for the majority of the species diversity.

2. A VAST AMOUNT OF ENERGY NOW PASSES THROUGH AND IS UTILIZED BY THE NONINDIGENOUS BIOTA OF THE ESTUARY. IN THE 1990s, INTRODUCED SPECIES DOMINATE MANY OF THE ESTUARY'S FOOD WEBS.

- The major bloom-creating, dominant phytoplankton species are cryptogenic. Because of the poor state of taxonomic and biogeographic knowledge, it remains possible that many of the Estuary's major primary producers that provide the phytoplankton-derived energy for zooplankton and filter feeders, are in fact introduced.

- Introduced species are abundant and dominant throughout the benthic and fouling communities of San Francisco Bay. These include 10 species of introduced bivalves, most of which are abundant to extremely abundant. Introduced filter-feeding polychaete worms and crustaceans may occur by the thousands per square meter. On sublittoral hard substrates, the Mediterranean mussel *Mytilus galloprovincialis* is abundant, while float fouling communities support large populations of introduced filter feeders, including bryozoans, sponges and seasquirts. The holistic role of the entire nonindigenous filter-feeding guild—including clams, mussels, bryozoans, barnacles, seasquirts, spionid worms, serpulid worms, sponges, hydroids, and sea anemones—in altering and controlling the trophic dynamics of the Bay-Delta system remains unknown. The potential role of just one species, the Atlantic ribbed marsh mussel *Arcuatula demissa,* as a biogeochemical agent in the economy of Bay salt marshes is striking.

- Introduced clams are capable of filtering the entire volume of the South Bay and the northern estuarine regions (Suisun Bay) once a day; indeed, it now appears that the primary mechanism controlling phytoplankton biomass during summer and fall in South San Francisco Bay is "grazing" (filter feeding) by the introduced Japanese clams *Venerupis* and *Musculista* and the Atlantic clam *Gemma*. This remarkable process has a significant impact on the standing phytoplankton stock in the South Bay, and since this plankton is now utilized almost entirely by introduced filter feeders, passing the energy through a non-native benthic fraction of the biota may have fundamentally altered the energy available for native biota.

- Drought year control of phytoplankton by introduced clams—resulting in the failure of the summer diatom bloom to appear in the northern reach of the Estuary—is a remarkable phenomenon. The introduced Atlantic soft-shell clams *(Mya)* alone were estimated to be capable at times of filtering all of the phytoplankton from the water column on the order of once per day. Phytoplankton blooms occurred only during higher flow years, when the populations of *Mya* and other introduced benthic filter feeders retreated downstream to saltier parts of the Estuary.

- Phytoplankton populations in the northern reaches of the Estuary may now be continuously and permanently controlled by introduced clams. Arriving by ballast water and first collected in the Estuary in 1986, by 1988 the Asian clam *Potamocorbula* reached and has since sustained average densities exceeding 2,000/m^2. Since the appearance of *Potamocorbula,* the summer diatom bloom has disappeared, presumably because of increased filter feeding by this new invasion. The *Potamocorbula* population in the northern reaches of the Estuary can filter the entire water column over the channels more than once per day and over the shallows almost 13 times per day, a rate of filtration which exceeds the phytoplankton's specific growth rate and approaches or exceeds the bacterioplankton's specific growth rate.

- Further, the Asian clam *Potamocorbula* feeds at multiple levels in the food chain, consuming bacterioplankton, phytoplankton, and zooplankton (copepods), and so may substantially reduce copepod populations both by depletion of the copepods' phytoplankton food source and by direct predation. In turn, under such conditions, the copepod-eating native opossum shrimp *Neomysis* may suffer a near-complete collapse in the northern reach. It was during one such pattern that mysid-eating juvenile striped bass suffered their lowest recorded abundance. This example and the linkages between introduced and native species may provide a direct and remarkable example of the potential impact of an introduced species on the Estuary's food webs.

- As with the guild of filter feeders, the overall picture of the impact of introduced surfacedwelling and shallow-burrowing grazers and deposit feeders in the Estuary is incompletely known. The Atlantic mudsnail *Ilyanassa* is likely playing a significant—if not the most important—role in altering the diversity, abundance, size distribution, and recruitment of many species on the intertidal mudflats of San Francisco Bay.

- The arrival and establishment in 1989-90 of the Atlantic green crab *Carcinus maenas* in San Francisco Bay signals a new level of trophic change and alteration. The green crab is a food and habitat generalist, capable of eating an extraordinarily wide variety of animals and plants, and capable of inhabiting marshes, rocky substrates, and fouling communities. European, South African, and recent Californian studies indicate a broad and striking potential for this crab to significantly alter the distribution, density, and abundance of prey species, and thus *to* profoundly alter community structure in the Bay.

- Nearly 30 species of introduced marine, brackish and freshwater fish are now important carnivores throughout the Bay and Delta. Eastern and central American fish — carp, mosquitofish, catfish, green sunfish, bluegills, inland silverside, largemouth and smallmouth bass, and striped bass—are among the most significant predators, competitors, and habitat disturbers throughout the brackish and freshwater reaches of the Delta, with often concomitant impacts on native fish communities. The introduced crayfish *Procambaras* and *Pacifastacus* may play an important role, when dense, in regulating their prey plant and animal populations.

- Native waterfowl in the Estuary consume some introduced aquatic plants (such as brass buttons) and native shorebirds feed extensively on introduced benthic invertebrates.

3. INTRODUCED SPECIES MAY BE CAUSING PROFOUND STRUCTURAL CHANGES TO SOME OF THE ESTUARY'S HABITATS.

- The Atlantic salt marsh cordgrass *Spartina alterniflora,* which has converted 100s of acres of mudflats in Willapa Bay, Washington, into grass islands, has become locally abundant in San Francisco Bay, and is competing with the native cordgrass. *Spartina alterniflora* has broad potential for ecosystem alteration. Its larger and more rigid stems, greater stem density, and higher root densities may decrease habitat for native wetland animals and infauna. Dense stands of *S. alterniflora* may cause changes in sediment dynamics, decreases in benthic algal production because of lower light levels below the cordgrass canopy, and loss of shorebird feeding habitat through colonization of mudflats.

- The Australian-New Zealand boring isopod *Sphaeroma quoyanum* creates characteristic "*Sphaeroma* topography" on many Bay shores, with many linear meters of fringing mud banks riddled with its half-centimeter diameter holes. This isopod may arguably play a major, if not the chief, role in erosion of intertidal soft rock terraces along the shore of San Pablo Bay, due to their boring activity that weakens the rock and facilitates its removal by wave action. *Sphaeroma* has been burrowing into Bay shores for over a century, and it thus may be that in certain regions the land/water margin has retreated by a distance of at least several meters due to this isopod's boring activities.

4. WHILE NO INTRODUCTION IN THE ESTUARY HAS UNAMBIGUOUSLY CAUSED THE EXTINCTION OF A NATIVE SPECIES, INTRODUCTIONS HAVE LED TO THE COMPLETE HABITAT OR REGIONAL EXTIRPATION OF SPECIES, HAVE CONTRIBUTED TO THE GLOBAL EXTINCTION OF A CALIFORNIA FRESHWATER FISH, AND ARE NOW STRONGLY CONTRIBUTING TO THE FURTHER DEMISE OF ENDANGERED MARSH BIRDS AND MAMMALS.

   - Introduced freshwater and anadromous fish have been directly implicated in the regional reduction and extinction, and the global extinction, of four native California fish. The bluegill, green sunfish, largemouth bass, striped bass, and black bass, through predation and through competition for food and breeding sites, have all been associated with the regional elimination of the native Sacramento perch from the Delta. The introduced inland silversides may be a significant predator on the larvae and eggs of the native Delta smelt. Expansion of the introduced smallmouth bass has been associated with the decline in the native hardhead. Predation by largemouth bass, smallmouth black bass and striped bass may have been a major factor in the global extinction of the thicktail chub in California.

   - The situation of the California clapper rail may serve as a model to assess how an endangered species may be affected by biological invasions. The rail suffers predation by introduced Norway rats and red fox; it may both feed on and be killed by introduced mussels; and it may find refuge in introduced cordgrass, although this same cordgrass may compete with native cordgrass, perhaps preferred by the rail. Other potential model study systems include introduced crayfish and their displacement of native crayfish; introduced gobies and their relationship to the tidewater goby; and the combined role that introduced green sunfish, bluegill, largemouth bass, and American bullfrog may have played in the dramatic decline of native red-legged and yellow-legged frogs.

5. THOUGH THE ECONOMIC IMPACTS OF INTRODUCED ORGANISMS IN THE SAN FRANCISCO ESTUARY ARE SUBSTANTIAL, THEY ARE POORLY QUANTIFIED.

   - Although some of the fish intentionally introduced into the Estuary by government agencies supported substantial commercial food fisheries, these fisheries all declined after a time and are now closed. The signal crayfish, *Pacifastacus,* from Oregon, whose exact means of introduction is unclear, supports the Estuary's only remaining commercial food fishery based on an introduced species.

   - The striped bass sport fishery has resulted in a substantial transfer of funds from anglers to those who supply anglers' needs, variously estimated, between 1962 and 1992, between $7 million and $45 million per year. However, striped bass populations and the striped bass sport fishery have declined dramatically in recent years.

   - Government introductions of organisms for sport fishing, as forage fish and for biocontrol have frequently not produced the intended benefits, and have sometimes had harmful "side effects," such as reducing the populations of economically important species.

- Few nonindigenous organisms that were introduced to the Estuary by other than government intent have produced economic benefits. The clams *Mya* and *Venerupis*, accidentally introduced with Atlantic oysters, have supported commercial harvesting in the Bay or elsewhere on the Pacific coast, and a small amount of recreational harvesting in the Bay (though these clams may have, to some extent, replaced edible native clams); the Asian clam *Corbicula* is commercially harvested for food and bait in California on a small scale; the Asian yellowfin goby is commercially harvested for bait; muskrat are trapped for furs; and the South African marsh plant brass buttons provides food for waterfowl. There do not appear to be any other significant economic benefits that derive from nongovernmental or accidental introductions to the Estuary.

- A single introduced organism, the shipworm *Teredo navalis*, caused $615 million (in 1992 dollars) of structural damage to maritime facilities in 3 years in the early part of the 20th century.

- The economic impacts of hull fouling and other ship fouling are clearly very large, but are not documented or quantified for the Estuary. Most of the fouling incurred in the Estuary is due to nonindigenous species. Indirect impacts due to the use of toxic anti-fouling coatings may also be substantial.

- Waterway fouling by introduced water hyacinth has become a problem in the Delta over the last fifteen years, with other introduced plants beginning to add to the problem in recent years. Hyacinth fouling has had significant economic impacts, including interference with navigation.

- Perhaps the greatest economic impacts may derive from the destabilizing of the Estuary's biota due to the introduction and establishment of an average of one new species every 24 weeks. This phenomenal rate of species additions has contributed to the failure of water users and regulatory agencies to manage the Estuary so as to sustain healthy populations of anadromous and native fish, resulting in increasing limitations and threats of limitations on water diversions, wastewater discharges, channel dredging, levee maintenance, construction and other economic activities in and near the Estuary, with implications for the whole of California's economy.

RESEARCH NEEDS

Much remains unknown in terms of the phenomena, patterns, and processes of invasions in the Bay and Delta, and thus large gaps remain in the knowledge needed to establish effective management plans. The following are examples of important research needs and directions:

1. EXPERIMENTAL ECOLOGY OF INVASIONS

Only a few of the hundreds of invaders in the Estuary have been the subject of quantitative experimental studies elucidating their roles in the Estuary’s ecosystem and their impacts on native biota. Such studies should receive the highest priority.

2. REGIONAL SHIPPING STUDY

Urgently required is a San Francisco Bay Shipping Study which both updates the 1991 data base available and expands that data base to all Bay and Delta ports. A biological and ecological study of the nature of ballast water biota arriving in the Bay/Delta system is urgently required. Equally pressing is a study of the fouling organisms entering the Estuary on ships' hulls and in ships' seachests, in order to assess whether this mechanism is now becoming of increasing importance and in order to more adequately define the unique role of ballast water. A Regional Shipping Study would provide critical data for management plans.

3. INTRAREGIONAL HUMAN-MEDIATED DISPERSAL VECTORS

Studies are required on the mechanisms and the temporal and spatial scales of the distribution of introduced species by human vectors after they have become established. Such studies will be of particular value in light of any future introductions of nuisance aquatic pests.

4. STUDY OF THE BAITWORM AND LOBSTER SHIPPING INDUSTRIES

This study has identified a major, unregulated vector for exotic species invasions in the Bay: the constant release of invertebrate-laden seaweeds from New England in association with bait worm (and lobster) importation. In addition a new trade in exotic bait has commenced, centered around the importation of living Vietnamese nereid worms, and both the worms and their substrate deserve detailed study. These studies are urgently needed to address the attendant precautionary management issues at hand.

5. MOLECULAR GENETIC STUDIES OF INVADERS

The application of modern molecular genetic techniques has already revealed the cryptic presence of previously unrecognized invaders in the Bay: the Atlantic clam *Macoma petalum,* the Mediterranean mussel *Mytilus galloprovincialis,* and the Japanese jellyfish *Amelia "aurita."* Molecular genetic studies of the Bay's new green crab (*Carcinus*) population may be of critical value in resolving the crab's geographic origins and thus the mechanism that brought it to California. Molecular genetic studies of worms of the genus *Glycera* and *Nereis* in the Bay may clarify if New England populations have or are becoming established in the region as a result of ongoing inoculations via the bait worm industry. Molecular analysis of other invasions will doubtless reveal, as with *Macoma* and *Mytilus*, a number of heretofore unrecognized species.

6. INCREASED UTILIZATION OF EXOTIC SPECIES

Fishery, bait, and other utilization studies should be conducted on developing or enlarging the scope of fisheries for introduced bivalves (such as *Mya, Venerupis,* and *Corbicula),* edible aquatic plants, smaller edible fish (such as *Acanthogobius),* and crabs (*Carcinus* and *Eriocheir).*

7. POTENTIAL ZEBRA MUSSEL INVASION

Studies are needed on the potential distribution, abundance and impacts of zebra mussels *(Dreissena polymorpha* and/or *D. bugensis*) in California, to support efforts to control their introduction and to design facilities (such as water intakes and fish screens) that will continue to function adequately should the mussels become established.

8. ECONOMIC IMPACTS OF WOOD BORERS AND FOULING ORGANISMS

The economic impacts of wood-boring organisms (shipworms and gribbles) and of fouling organisms (on commercial vessels, on recreational craft, in ports and marinas, and in water conduits) are clearly very large in the San Francisco Estuary, but remain largely undocumented and entirely unquantified. A modern economic study of this phenomenon, including the economic costs and ecological impacts of control measures now in place or forecast, is critically needed.

9. ECONOMIC, ECOLOGICAL AND GEOLOGICAL IMPACTS OF BIOERODING NONINDIGENOUS SPECIES

Largely qualitative data suggest that the economic, ecological, and geological impacts of the guild of burrowing organisms that have been historically and newly introduced have been or are forecast to potentially be extensive in the Estuary. Experimental, quantitative studies on the impacts of burrowing and bioeroding crustaceans and muskrats in the Estuary are clearly now needed to assess the extent of changes that have occurred or are now occurring, and to form the basis for predicting future alterations in the absence of control measures.

10. POST INVASION CONTROL MECHANISMS

While primary attention must be paid to preventing future invasions, studies should begin on examining the broad suite of potential post invasion control mechanisms, including biocontrol, physical containment, eradication, and related strategies. A Regional Control Mechanisms Workshop for past and anticipated invasions could set the foundation for future research directions.

Appendix D
Drs. G. Fred Lee and Anne Jones-Lee's Background
Pertinent to Assessment of Delta Water Quality

Dr. G. Fred Lee is President of G. Fred Lee & Associates, which consists of Drs. G. Fred Lee and Dr. Anne Jones-Lee (Vice President) as the principals in the firm. This discussion of Delta water quality is based on G. Fred Lee's academic background and professional experience, which includes a BA degree from San Jose State College in environmental health sciences in 1955, a Master of Science in Public Health focusing on water quality issues from the University of North Carolina in 1957 and a PhD in environmental engineering/environmental science from Harvard University in 1960. Beginning in 1960 for a period of 30 years he held university graduate-level professorial teaching and research positions at several major US universities, including the University of Wisconsin, Madison, the University of Texas system and Colorado State University. In 1989 he retired from university teaching and research as a Distinguished Professor of Civil and Environmental Engineering at the New Jersey Institute of Technology, where he also held the position of Director of the Site Assessment and Remediation division of a multi-university hazardous waste research center and, for a several-year period, Director of the Water Quality Program for the State of New Jersey Sea Grant Program. During his 30-year university teaching and research career he conducted in excess of five million dollars of research and published over 500 papers and reports on these efforts.

Dr. Anne Jones-Lee was a university professor for a period of 11 years in environmental engineering and environmental sciences. She has a BS degree in biology from Southern Methodist University and obtained a PhD in Environmental Sciences in 1978 from the University of Texas at Dallas focusing on water quality evaluation and management. At the New Jersey Institute of Technology she held the position of Associate Professor of Civil and Environmental Engineering with tenure. She and Dr. Lee have worked together as a team since the mid-1970s.

Dr Lee's areas of expertise include work on fate, effects and impacts of chemical constituents and pathogens on various aspects of water quality-beneficial uses of waterbodies. He has frequently served as an adviser to local, state, national and international governmental agencies and other entities on a variety of aspects of water quality, including water quality criteria and standards development and their appropriate implementation. This activity included serving as an invited peer reviewer for the National Academies of Science and Engineering "Blue Book" of water quality criteria in 1972, a member of the American Fisheries Society Water Quality Committee that reviewed the US EPA's "Red Book" water quality criteria of 1976, and a US EPA invited peer reviewer in the early 1980s for the approach that the Agency then proposed and finally adopted for developing water quality criteria for protection of aquatic life. This is the same criteria development approach that is in existence today. Further, Dr Lee was involved as a US EPA invited peer reviewer for several criteria documents. His work on water quality issues is somewhat unusual, in that, in addition to having a strong background in the chemical and biological sciences pertinent to water quality evaluation, he also has an engineering background in developing control programs for chemical constituents in point and nonpoint source discharges.

Overall, Dr. Lee is highly familiar with how water quality criteria have been developed, their strengths and weaknesses, and, most importantly, their proper application in water quality management programs. He and Dr. Jones-Lee published an invited paper, “Appropriate Use of Numeric Chemical Water Quality Criteria,” discussing how the US EPA criteria and state water quality standards based on these criteria should be implemented, considering the approach for their development and their appropriate use to regulate constituents in ambient waters from various sources.

In 1989, Dr Lee retired from university teaching and research and expanded his part-time consulting activities that he conducted while a university professor into a full-time activity. While living in New Jersey he became involved in three different consulting jobs in California, one of which was concerned with Delta water quality issues. Another was concerned with Lake Tahoe water quality, and the third was on behalf of the Metropolitan Water District of Southern California, on groundwater quality protection in the San Gabriel Basin. It was at that time that Dr. Anne Jones-Lee and he moved from New Jersey to El Macero, which is adjacent to Davis, about 11 miles from Sacramento. Since 1989 they have maintained a two-person specialty consulting firm, working on water supply water quality, water and wastewater treatment, water pollution control for both fresh and marine surface waters, and solid and hazardous waste impact evaluation and management, with particular emphasis on groundwater quality protection. They have continued to be active in publishing the results of their studies, where in the last 15 years they have added another 490 papers and reports covering work they have done in their various areas of activity. One of these areas is Delta water quality.

Dr Lee’s international work as a water quality adviser included serving as the US representative to the Organization of Economic Cooperation and Development (OECD) eutrophication studies. This was a 22-country, 200-waterbody, 50-million-dollar effort that was conducted in the 1970s, relating nutrient loads to eutrophication response for waterbodies located in western Europe, North America, Japan and Australia. Dr. Jones-Lee and Dr. Lee have been advisers to Spain on developing water quality management programs for Spain’s approximately 800 reservoirs, the USSR on developing water quality management programs for the Volga River Basin, Italy on developing management approaches for excessive fertilization of the Adriatic coast between Venice and Rimini, Israel (Sea of Galilee), Jordan on surface (King Talal Reservoir) and groundwater quality protection, Tunisia on its coastal marine waters, Japan on Seto Inland Sea water quality management issues, South Africa on managing water quality in reservoirs, Egypt on managing pesticide residues as they can impact water quality in the Nile River, the Netherlands on water quality management in the new waterbody then proposed to be created behind the Delta Works which was to be filled with Rhine River water, France on managing excessive fertilization of freshwater waterbodies, and Norway on lake water quality. Dr. Lee has also been adviser to the US-Canadian International Joint Commission for the Great Lakes, where he served on a number of advisory panels for investigating and managing Great Lakes water quality issues. His international work has included studies in Antarctica on nutrient load eutrophication response for an Antarctic lake. The best way to become familiar with Dr. Jones-Lee and Dr. Lee’s current activities is through their website, www.gfredlee.com, which lists the papers and reports that they have developed since they have been full-time consultants.

Dr. Lee's initial work on Delta water quality occurred in the summer of 1989, where he was asked to be a consultant to Delta Wetlands on water quality issues associated with the development of in-Delta storage reservoirs. As part of this effort he became familiar with Delta water quality issues. Dr. Lee's work on Delta water quality issues has included participating in various CALFED (now California Bay-Delta Authority – CBDA) committees, subcommittees, working groups, etc., concerned with water quality issues in the Delta and its tributaries. He is familiar with the various attempts by members of the CALFED administration to develop a credible water quality management program.

Beginning in the mid-1990s Dr. Lee became involved in the details of water quality issues in both the Sacramento and San Joaquin River watersheds. With respect to the Sacramento River, he worked with the Central Valley Regional Water Quality Control Board (CVRWQCB) staff in helping to develop the Sacramento River Watershed Program, with particular emphasis on the monitoring aspects of this program. Beginning in the 1990s he began to work with William Jennings (the DeltaKeeper) as a volunteer technical adviser to help the DeltaKeeper focus its activities on technically correct positions on water quality management. This approach has provided Dr. Lee with an opportunity to become involved in a variety of areas that are of particular significance to the DeltaKeeper's efforts to improve the quality of science and protection/enhancement of water quality of the Delta and its tributaries. Dr. Lee's work with the DeltaKeeper included addressing such issues as managing aquatic life toxicity in the Central Valley and Delta due to pesticide runoff/discharges from agricultural and urban areas, reviewing and managing excessive bioaccumulation of organochlorine legacy pesticides and PCBs in Central Valley waterbodies and the Delta, review of the potential environmental impacts of aquatic pesticides used for aquatic weed control in the Central Valley and Delta, impact of flow management in and from the South Delta on water quality, and providing guidance on environmental aspects of dredging and dredged sediment management in the Delta.

One of Dr. Lee's major areas of work has been on the San Joaquin River Deep Water Ship Channel low-DO problem. Through support provided from litigation settlements between the DeltaKeeper and various communities, where by mutual agreement part of the funds in the settlement were made available for Dr. Lee to support the Steering Committee for the San Joaquin River low-DO TMDL, beginning in 1999 Dr. Lee worked closely with the SJR DO TMDL Steering Committee as well as the Regional Board staff in helping to formulate and implement higher quality science and engineering in the San Joaquin River low-DO TMDL program. This included Dr. Lee being awarded a contract with the CVRWQCB, to develop an "Issues" report of the issues that need to be addressed as part of formulating a TMDL to control the low-DO problem in the San Joaquin River DWSC. This issues report is available as,

> Lee, G. F. and Jones-Lee, A., "Issues in Developing the San Joaquin River Deep Water Ship Channel DO TMDL," Report to Central Valley Regional Water Quality Board, Sacramento, CA, August (2000). http://www.gfredlee.com/sjrpt081600.pdf

A group of researchers submitted a proposal to CALFED in June 2000 that was a miscellaneous, unprioritized request for funds to support a group of projects that were, to some extent, related to the low-DO problem. CALFED did not support this proposal. Dr. Lee was asked by the Steering Committee to assume the leadership for developing the revised Directed

Action proposal to CALFED. With support from the DeltaKeeper through litigation settlements, Dr. Lee worked closely with the Central Valley Regional Water Quality Control Board lead staff (Dr. Chris Foe) in developing a coherent two-million-dollar proposal, which was funded by CALFED. Dr. Lee served as the coordinating PI for 12 projects that were conducted under this proposal. This work resulted in a synthesis report,

> Lee, G. F. and Jones-Lee, A., "Synthesis and Discussion of Findings on the Causes and Factors Influencing Low DO in the San Joaquin River Deep Water Ship Channel Near Stockton, CA: Including 2002 Data," Report Submitted to SJR DO TMDL Steering Committee and CALFED Bay-Delta Program, G. Fred Lee & Associates, El Macero, CA, March (2003). http://www.gfredlee.com/SynthesisRpt3-21-03.pdf

This report presents a summary/synthesis of approximately four years and four million dollars of studies on the SJR DWSC low-DO problem. Since completion of the synthesis report in March 2003, Drs. Lee and Jones-Lee have continued to be active in Delta water quality issues. They have developed a series of reports on these issues that are available from their website, www.gfredlee.com, in the San Joaquin River Watershed section. They are developing a synthesis report supplement that presents a review of the various studies that they have conducted over the past year that are pertinent to investigating and managing Delta water quality issues.

Further information on Drs. Lee and Jones-Lee's experience pertinent to assessment of Delta water quality issues is available on their website, www.gfredlee.com, or upon request.

A Scientific Assessment of Alternatives for Reducing Water Management Effects on Threatened and Endangered Fishes in Californiaâ€™s Bay Delta

Committee on Sustainable Water and Environmental Management in the California Bay-Delta; National Research Council

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Water Science and Technology Board

Ocean Studies Board

Division on Earth and Life Studies

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COMMITTEE ON SUSTAINABLE WATER AND ENVIRONMENTAL MANAGEMENT IN THE CALIFORNIA BAY-DELTA*

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* Biographical information for committee members is in Appendix E. This project was organized and overseen by the NRC's Water Science and Technology Board (lead) and Ocean Studies Board, whose rosters are in Appendixes B and C, respectively.

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Preface

California, like many states, faces challenges related to water. Much of the state is too dry to support many human activities, such as municipal and industrial water use and irrigated agriculture, without supplementing the natural water supply. It has done this through an extensive series of engineering projects that include reservoirs, canals, levees, and pumps, largely to move water from the more humid north to the more arid and densely populated south. Much of California's natural surface-water supply flows into and through the Sacramento and San Joaquin watersheds into California's Bay-Delta, and from there through San Francisco Bay into the ocean. The delta itself is a biologically diverse estuarine ecosystem, and is the main point of diversion for water that is transported to the south.

As California's population and economic activity have increased, along with water diversions from the delta, conflicts over various water uses have increased as well, especially surrounding the bay-delta. Those conflicts have been brought to a head by restrictions on water diversions that have been required by two biological opinions, one by the U.S. Fish and Wildlife Service, covering delta smelt, and one by the National Marine Fisheries Service, covering salmon, steelhead, and sturgeon, to protect those fishes, which are listed as threatened or endangered under the federal Endangered Species Act. In addition, several recent dry years have exacerbated the situation. Conflicts over water are not new in California, but the current conflicts over the bay-delta appear to be unprecedented in their scale. Few parts of the state are unaffected by what happens to delta water.

Protecting all the listed species and preserving existing and projected uses of the region's water is a serious challenge. The complexity of the problem and the difficulty of identifying solutions have been highlighted by a plethora of scientific publications and arguments, in which many qualified and distinguished experts have reached differing conclusions. Nobody disagrees that engineering changes; the introduction of many exotic species, the addition of contaminants to the system, and the general effects of an increasing human population have contributed to the fishes' declines. There are, however, disagreements about the relative contributions of those factors and the appropriate remedies for them. This is the context in which the National Research Council was asked by Congress and the Department of the Interior to help resolve the issue by evaluating the scientific bases of the biological opinions. In response, the NRC appointed a special committee of experts to carry out a complex and challenging study in two phases.

In its first phase, the committee was tasked to focus on the scientific bases of the reasonable and prudent alternatives (RPAs) in the two biological opinions. The committee also assessed whether the RPAs might be in conflict with one another, as well as whether other options might be available that would protect the fishes with lesser impacts on other water uses. Finally, we were asked to consider the effects of "other stressors" on the fishes if sufficient time were available. The results of this first-phase analysis are the subject of this report. The committee did consider other stressors, but it did not evaluate them in depth. They will be more thoroughly addressed in a second report, scheduled to be published late in 2011, which will focus on broader issues surrounding attempts to provide more sustainable water supplies and to improve the ecological sustainability of the delta, including consideration of what ecological goals might be attainable.

The committee met in Davis, California for five days in January 2010. The committee heard presentations from representatives of federal and state agencies and a variety of other experts, and from members of several stakeholder groups and the public (see Appendix D). The information gathering sessions of this meeting were open to the public and widely advertised. The committee sought to hear from as many groups and individuals as possible within the time constraints. All speakers, guests, and members of the public were encouraged to provide written comments during and after the meeting. All presentations and written materials submitted were considered by the committee as time allowed. The committee thanks all the individuals who provided information.

This report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise in accordance with the procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the NRC in making its published report as sound as possible, and to ensure that the report meets NRC institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We thank the following for their reviews of this report: Joan G. Ehrenfeld, Rutgers University; Mary C. Fabrizio, Virginia Institute of Marine Science; Peter Gleick, Pacific Institute; William P. Horn, Birch, Horton, Bittner & Cherot; D. Peter Loucks, Cornell University; Jay Lund, University of California, Davis; Tammy Newcomb, Michigan Department of Natural Resources; and Andrew A. Rosenberg, Conservation International.

Although these reviewers provided constructive comments and suggestions, they were not asked to endorse the report's conclusions and recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Michael Kavanaugh, Malcolm Pirnie, Inc., who was appointed by the NRC's Report Review Committee and by Leo Eisel, Brown and Caldwell, who was appointed by the NRC's Division on Earth and Life Studies. They were responsible for ensuring that an independent examination of this report was conducted in accordance with NRC institutional procedures and that all review comments received full consideration. Responsibility for this report's final contents rests entirely with the authoring committee and the NRC.

I am enormously grateful to my committee colleagues for their diligence, enthusiasm, persistence, and hard work. The schedule for the preparation of this report was short, and without everyone's engagement, it could not have been completed. I also am grateful to David Policansky, Stephen Parker, Laura Helsabeck, Heather Chiarello, Ellen De Guzman, and Susan Roberts of the NRC staff for their efforts in facilitating the committee's meeting and for their work in helping to get this report completed on schedule in the face of historic snowstorms.

California will continue to face great challenges in managing, allocating, and using water, including managing California's Bay Delta. We hope the committee's reports can help in that difficult process.

Robert J. Huggett
Chair

Contents

Acronyms and Abbreviations

AF	Acre-feet
BA	Biological Assessment
BO	Biological Opinion
(C)DFG	California Department of Fish and Game
(C)DWR	California Department of Water Resources
C.F.R.	Code of Federal Regulations
Cir	Circuit Court (federal system)
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DCC	Delta Cross Channel
DOI	(U.S.) Department of the Interior
DSM2	Delta Simulation Model II
EDT	Ecosystem Diagnosis and Treatment
ESA	Endangered Species Act
EWA	Environmental Water Account
FMT	Fall Midwater Trawl (survey)
FWS	(U.S.) Fish and Wildlife Service
HORB	Head of Old River Barrier
MAF	Million acre-feet
M&I	Municipal and Industrial
NAS	National Academy of Sciences
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
OCAP	Operations Criteria And Plan
OMR	Old and Middle River
OSB	Ocean Studies Board of the NRC
PTM	Particle-Tracking Model
RBDD	Red Bluff Diversion Dam
RPA	Reasonable and Prudent Alternative
SWP	State Water Project
TAF	Thousand acre-feet
USBR	United States Bureau of Reclamation
U.S.C.	United States Code
USGS	United States Geological Survey
VAMP	Vernalis Adaptive Management Plan
WSTB	Water Science and Technology Board of the NRC
X2	Contour line of salinity 2

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Summary

California's Bay-Delta estuary is a biologically diverse estuarine ecosystem that plays a central role in the distribution of California's water from the state's wetter northern regions to its southern, arid, and populous cities and agricultural areas. In addition to its ecological functioning and the ecosystem services it provides, there are numerous withdrawals of freshwater from the delta, the largest being pumping stations that divert water into the federal Central Valley Project (CVP) and the State Water Project (SWP), primarily for agriculture and metropolitan areas. Most former wetland and marsh areas of the delta have been drained for agriculture, and are protected by an aging collection of levees. Some of those areas also contain small urban settlements.

This hydrologic and engineered system has met the diverse water-related needs of Californians for decades. But operation of the engineered system, along with the effects of an increasing population of humans and their activities, has substantially altered the ecosystem. These ecosystem changes have contributed to changes in the abundance, distribution, and composition of species in the delta, including the decline of many native species and the successful establishment of many species not native to the region.

Recently, the Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS) issued biological opinions under the federal Endangered Species Act (ESA) that required changes ("reasonable and prudent alternatives," or RPAs) in water operations and related actions to avoid jeopardizing the continued existence and potential for recovery of delta smelt, winter-run and fall-run Chinook salmon, Central Valley steelhead, and green sturgeon. Those changes have reduced the amount of water available for other uses, and the tensions that resulted have been exacerbated by recent dry years.

The RPAs are divided into many separate actions. The RPA in the FWS opinion, divided into 6 actions, applies to delta smelt and thus focuses primarily on managing flow regimes to reduce entrainment of smelt and on extent of suitable water conditions in the delta, as well as on construction or restoration of habitat. The NMFS RPA, divided into 5 actions with a total of 72 subsidiary actions, applies to the requirements of Chinook salmon, steelhead, and green sturgeon in the delta and farther upstream. In addition to its focus on flow regimes and passage, it includes purchasing water to enhance in-stream flow, habitat restoration, a new study of acoustic-tagged steelhead, and development of hatchery genetics management plans. This committee did not evaluate all 78 actions and subsidiary actions in the two RPAs in detail. It spent most of its time on the elements of the RPAs that have the greatest potential to affect water diversions. It also spent time on elements whose scientific justifications appear to raise some questions.

Protecting all the listed species, as required by the ESA, while simultaneously trying to minimize impacts on existing and projected uses of the region's water, is a serious challenge. In addition, many anthropogenic and other factors, including pollutants; introduced species; and engineered structures such as dams, canals, levees, gates, and pumps adversely affect the fishes in the region, but they are not under the direct control of the CVP or the SWP, and thus are not subjects of the biological opinions.

The complexity of the problem of the decline of the listed species and the difficulty of identifying viable solutions have led to disagreements, including concerns that some of the actions in the RPAs might be ineffective and might cause harm and economic disruptions to water users, and that some of the actions specified in the RPAs to help one or more of the listed species might harm others. In addition, some have suggested that the agencies might be able to meet their legal obligation to protect species with less economic disruptions to other water users. Those concerns led the Department of the Interior and Congress to ask for advice from the National Research Council (NRC), which appointed a special committee of experts to carry out this study.

THE COMMITTEE'S CHARGE

The committee's charge includes the following tasks (the full statement of task is in Appendix A).

The committee was asked to undertake two main projects over a term of two years resulting in two reports. The first report, prepared on a very short timeline, was to address scientific questions, assumptions, and conclusions underlying water-management alternatives (i.e., the RPAs) in the two biological opinions mentioned above, and this is where the committee focused most of its attention. In addition, three specific issues were to be addressed. First, are there any "reasonable and prudent alternatives" (RPAs) that, based on the best available scientific data and analysis, would provide equal or greater protection for the listed species and their habitat while having lesser impacts to other water uses than those adopted in the biological opinions? Second, are there provisions in the biological opinions to resolve the potential for actions that would benefit one listed species while causing negative impacts on another? And finally, to the extent that time permits, the committee was asked to consider the effects of other stressors (e.g., pesticides, ammonia discharges, invasive species) on federally listed and other at-risk species in the Bay-Delta. The committee's second report, due in late 2011, will address how to most effectively incorporate science and adaptive management concepts into holistic programs for management and restoration of the Bay-Delta.

The committee's charge was to provide a scientific evaluation, not a legal one, and that is what the committee did. **Nothing in this report should be interpreted as a legal judgment as to whether the agencies have met their legal requirements under the ESA.** The committee's report is intended to provide a scientific evaluation of agency actions, to help refine them, and to help the general attempt to better understand the dynamics of the delta ecosystem, including the listed fishes.

THE COMMITTEE'S PRINCIPAL CONCLUSIONS

Context

The California Bay-Delta is a system that has undergone significant anthropogenic changes for more than a century. Those changes include water withdrawals; draining of wetlands; introduction of many nonnative species of plants and animals, some deliberate; construction of canals, gates, marinas, roads, levees, pumps, dams, and other structures that affect the hydrology of the system; the damming of almost all the major rivers and tributaries to the system, which also has altered the seasonal flow regime and other hydrologic aspects of the system; and the release of contaminants, pollutants, and nutrients into the system as a result of the above changes and the increase of agriculture, industrial and residential development, and other human activities. All these changes have affected the distribution, abundance, and composition of species in the delta, some of which have increased dramatically and some, including the species listed under the Endangered Species Act (Chinook salmon, delta smelt, steelhead, and green sturgeon), which have declined precipitously. The biological opinions with their associated RPAs that the committee has reviewed relate only to proposed changes in operations of the CVP and the SWP in the delta and methods to reduce the adverse effects on the listed species of those changes. Some restrictions on CVP and SWP water diversions have been initiated to protect the listed fish species, but so far have not produced measurable effects in slowing their declines.

The committee concludes that reversing or even slowing the declines of the listed species cannot be accomplished immediately. Even the best-targeted methods of reversing the fish declines will need time to take effect amid changing environmental conditions such as multi-year droughts and continued pressures on the system from other human-caused stresses. Especially for fishes whose populations are very low already, the effects of any actions will be difficult to detect at first, and detecting them will be made more difficult by the effects of other environmental changes and uncertainties inherent in sampling small populations.

The FWS Biological Opinion and RPA

The committee considered the six actions contained within the RPA, most of which were judged to have a sound conceptual basis. The committee then focused on the RPA actions that involved Old and Middle River (OMR) flows, the management of the mean position of the contour where salinity is 2[1] (X2), and the creation or restoration of tidal habitat for smelt. The first two actions involve significant requirements for water; the third does not.

The management of OMR flows is predicated on the concept that pumping of water for export from the south delta creates net negative (upstream) flows, averaged over the tidal cycle, that cause delta smelt (and some juvenile salmon) to be experience increased mortality in the south delta, especially in winter. The RPA action limits the net OMR flows to levels that depend on conditions during this period, with a variety of environmental triggers and adaptive-management procedures. **Although there are scientifically based arguments that raise legitimate questions about this action, the committee concludes that until better monitoring data and comprehensive life-cycle models are available, it is scientifically reasonable to conclude that high negative OMR flows in winter probably adversely affect smelt populations. Thus, the concept of reducing OMR negative flows to reduce mortality of smelt at the SWP and CVP facilities is scientifically justified.**

However, there is substantial uncertainty regarding the amount of flow that should trigger a reduction in exports. In other words, the specific choice of the negative flow threshold for initiating the RPA is less clearly supported by scientific analyses. The biological benefits and the water requirements of this action are likely to be sensitive to the precise values of trigger and threshold values. There clearly is a relationship between negative OMR flows and mortality of smelt at the pumps, but the data do not permit a confident identification of the threshold values to

[1] This is often expressed as a concentration, e.g., "2 parts per thousand," but more recently it has been expressed as a ratio of electrical conductivities, hence it has no units.

use in the action, and they do not permit a confident assessment of the benefits to the population of the action. As a result, the implementation of this action needs to be accompanied by careful monitoring, adaptive management, and additional analyses that permit regular review and adjustment of strategies as knowledge improves.

The management of the mean position of X2 during the fall (Action 4 of the FWS RPA) is based on observations that relate smelt use of spawning habitat with various salinity regimes. X2 is interpreted by the agencies not as a single line, but rather as an indicator of the spatial pattern of salinity in the delta and thus as indicative of the extent of habitat favorable for delta smelt.

The relationships among smelt abundance, habitat extent, and the mean position of X2 as an indicator of available habitat are complex. The controversy about the action arises from the poor and sometimes confounding relationship between indirect measures of delta smelt populations (indices) and X2. Although there is evidence that the position of X2 affects the distribution of smelt, the weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand. In addition, although the position of X2 is correlated with the distribution of salinity and turbidity regimes, the relationship of that distribution and smelt abundance indices is unclear. The X2 action is conceptually sound in that to the degree that the amount of habitat available for smelt limits their abundance, the provision of more or better habitat would be helpful. However, the derivation of the details of this action lacks rigor. The action is based on a series of linked statistical analyses (e.g., the relationship of presence/absence data to environmental variables, the relationship of environmental variables to habitat, the relationship of habitat to X2, the relationship of X2 to smelt abundance). Each step of this logical train of relationships is uncertain. The relationships are correlative with substantial variance left unexplained at each step, yet the analyses do not carry the uncertainty at each step to the next step. The action also may have high water requirements and may adversely affect salmon and steelhead under some conditions. **As a result, the committee concludes that how specific X2 targets were chosen and their likely beneficial effects need further clarification. It also is critical that the adaptive-management requirements included in the RPA be implemented in light of the uncertainty about the biological effectiveness of the action and its possibly high water requirements.**

The tidal habitat management action in the RPA requires creation or restoration of 8,000 acres of intertidal and subtidal habitat in the delta and in Suisun Marsh. This action has not been controversial because it does not affect other water users. **The committee finds that the conceptual foundation for this action (Action 6) is weak because the relationship between tidal habitats and food availability for smelt is poorly understood. The details of its implementation are not fully justified in the biological opinion. The committee recommends that this action be implemented in phases, with the first phase to include the development of an implementation and adaptive management plan (similar to the approach used for the floodplain habitat action in the NOAA biological opinion), but also to explicitly consider the sustainability of the resulting habitats, especially those dependent on emergent vegetation, in the face of expected sea-level rise.** In addition, there should be consideration of the types and amounts of tidal habitats necessary to produce the expected outcomes and how they can be achieved and sustained in the long term. The committee supports the monitoring program referred to in Action 6, and appropriate adaptive management triggers and actions.

The NMFS Biological Opinion and RPA

The NMFS RPA for salmon, steelhead, and green sturgeon is a broad complex of diverse actions spanning three habitat realms: tributary watersheds, the mainstem Sacramento and San Joaquin Rivers, and the delta. **On balance, the committee concludes that the actions, which are primarily crafted to improve life-stage-specific survival rates for salmon and steelhead, with the recognition that the benefits also will accrue to sturgeon, are scientifically justified.** The strategies underpinning many of the individual actions are generally well supported by more than a decade of conceptual model building about the requirements of salmonids in the region, although the extent to which the intended responses are likely to be realized is not always clearly addressed in the RPA. Given the absence of a transparent, quantitative framework for analyzing the effects of individual and collective actions, it is difficult to make definitive statements regarding the merits of such a complex RPA. Indeed, absent such an analysis, the controversial aspects of some of the RPA actions could detract from the merits of the rest of the RPA.

In general, as described in detail in Chapter 6, the committee concludes that although most, if not all, of the actions in this RPA had a sound conceptual basis, the biological benefits and water requirements of several of the actions are, as with the delta smelt actions, likely quite sensitive to the specific triggers, thresholds, and flows specified. As a result, the committee recommends that the specific triggers, thresholds, and flows receive additional evaluation that is integrated with the analyses of similar actions for delta smelt.

In particular, the committee concludes that it is difficult to ascertain to what extent the collective watershed and tributary actions will appreciably improve survival within the watershed or throughout the entire river system. The committee concludes that the actions to improve mainstem passage for salmonids and sturgeon, in particular those concerning the Red Bluff Diversion Dam, are well justified scientifically. The committee recommends some kind of quantitative assessment framework for assessing survival be developed and implemented.

The management of OMR flows to reduce entrainment mortality of salmon smolts is similar in concept to the smelt OMR action, and like that action, **the committee concludes that its conceptual basis is scientifically justified, but the scientific support for specific flow targets is less certain. Uncertainty in the effect of the triggers should be reduced, and more-flexible triggers that might require less water should be evaluated.**

Another set of actions in this RPA focuses on managing exports and flows in the San Joaquin River to benefit outmigrating steelhead smolts. The actions are intended to reduce the smolts' vulnerability to entrainment into the channels of the south delta and the pumps by increasing the inflow-to-export ratio of water in the San Joaquin River. It thus has two components: reducing exports and increasing San Joaquin River inflows into the delta. **The committee concludes that the rationale for increasing San Joaquin River flows has a stronger foundation than does the prescribed export action. We further conclude that the action involving a 6-year study of smolt survival would provide useful insight into the effectiveness of the actions as a long-term solution.**

The final two actions considered here were improving the migratory passage of salmon and sturgeon through the Yolo Bypass and the creation of additional floodplain lands to provide additional rearing habitat for juvenile salmon. **The committee concludes that both actions are scientifically justified, but the implications for the system as a whole of routing additional flows through the Yolo Bypass for the system were not clearly analyzed.** In particular, the consequences of the action for Sacramento River flows and for the potential mobilization of mercury were not clearly described.

Other Possible RPAs

The committee's charge requires the identification, if possible, of additional potential RPAs that might have the potential to provide equal or greater protection to the fishes than the current RPAs while costing less in terms of water availability for other uses. **The committee considered a variety of possible actions not in the RPAs (see Chapter 6), and concluded that none of them had received sufficient documentation or evaluation to be confident at present that any of them would have the potential to provide equal or greater protections for the species while requiring less disruption of delta water diversions.**

Other Stressors

Based on the evidence the committee has reviewed, the committee agreed that the adverse effects of all the other stressors on the listed fishes are potentially large. Time did not permit full exploration of the issue in this first report, but examples of how such stressors may affect the fishes are described. The committee will explore this issue more thoroughly in its second report.

Modeling

The committee reviewed the models the agencies used to understand the basis for the resource agencies' jeopardy opinion and to determine to what degree they used the models in developing the RPAs. **The committee concluded that as far as they went, despite flaws, the individual models were scientifically justified, but that they needed improvements and that they did not go far enough toward an integrated analysis of the RPAs. Thus the committee concluded that improving the models by making them more realistic and by better matching the scale of their outputs to the scale of the actions, and by extending the modeling framework to be more comprehensive and to include features such as fish life cycles would improve the agencies' abilities to assess risks to the fishes, to fine-tune various actions, and to predict the effects of the actions.**

Potential Conflicts Between RPAs and Integration of RPAs

The committee concludes that the RPAs lack an integrated quantitative analytical framework that ties the various actions together within species, between smelt and salmonid species, and across the watershed. This type of systematic, formalized analysis, although likely beyond the two agencies' legal obligations when rendering two separate biological opinions, is necessary to provide an objective determination of the net effect of all their actions on the listed species and on water users.

An additional overall, systematic, coordinated analysis of the effect of all actions taken together and a process for implementing the optimized, combined set of actions is required to establish the credibility of the effort overall. The committee is aware that instances of coordination among the agencies certainly exist, including modification of actions to reduce or eliminate conflicting effects on the species. Indeed, the committee did not find any clear example of an action in one of the RPAs causing significant harm to the species covered in the other RPA. But coordination is not integration. The lack of a systematic, well-framed overall analysis is a serious scientific deficiency, and it likely is related to the ESA's practical limitations as to the scope of actions that can or must be considered in a single biological opinion. The interagency effort to clearly reach consensus on implications of the combined RPAs for their effects on all the species and on water quality and quantity within the delta and on water operations and deliveries should use scientific principles and methods in a collaborative and integrative manner. Similarly, this committee's efforts to evaluate potential harmful effects of each RPA on the species covered in the other RPA were hampered by the lack of a systematic, integrated analysis covering all the species together. Full documentation of decisions should be part of such an effort, as should inclusion of the environmental water needs of specific actions and for the entire RPA.

It is clear that integrative tools that, for example, combine the effect over life stages into a population-level response would greatly help the development and evaluation of the combined actions. There has been significant investment in hydrological and hydrodynamic models for the system, which have been invaluable for understanding and managing the system. An investment in ecological models that complement and are integrated with the hydrological and hydrodynamics models is sorely needed. Clear and well-documented consideration of water requirements also would seem well advised because some of the actions have significant water requirements. Credible documentation of the water needed to implement each action and the combined actions, would enable an even clearer and more logical formulation of how the suite of actions might be coordinated to simultaneously benefit the species and ensure water efficiency. **This recommendation for integration of models and across species responds to the committee's broad charge of advising on how to most effectively incorporate scientific and adaptive-management concepts into holistic programs for managing the delta, and likely goes beyond the agencies' bare legal obligations under the ESA, and will be addressed more thoroughly in the committee's second report.**

1

Introduction

California's Bay-Delta estuary is a biologically diverse estuarine ecosystem that plays a central role in the distribution of California's water from the state's wetter northern regions to its southern, arid, and populous cities and agricultural areas (Figure 1-1). The Bay-Delta region receives water flows from the Sacramento and San Joaquin Rivers and their tributaries, which drain the east slopes of the Coast Range, the Trinity Alps and Trinity Mountains in northern California, and the west slopes of the Sierra Nevada Mountains. Outflows from the Bay-Delta, through San Francisco Bay and into the Pacific Ocean, are met by tidal inflows, resulting in a brackish water ecosystem in many reaches of the Bay-Delta. In addition to its ecological functioning and the ecosystem services it provides, there are numerous withdrawals of freshwater from the Bay-Delta, the largest being pumping stations that divert water into the federal Central Valley Project (CVP), primarily for Central Valley agriculture, and the State Water Project (SWP), primarily for southern California metropolitan areas. Other water is extracted from Bay-Delta waterways for consumptive use within the delta region itself, and for municipal and industrial use around the margins of the delta, and returned to its waterways diminished in quantity and quality. Most former wetland and marsh areas of the delta have been drained for agriculture, and are protected by an aging collection of levees (Moyle et al., 2010). Some of those areas also contain small urban settlements.

This hydrologic and engineered system has met the diverse water-related needs of Californians for decades. But construction and operation of the engineered system, along with the effects of an increasing population of humans and their activities, have substantially altered the ecosystem. Current conditions include altered water-quality and salinity regimes and the magnitude and direction of flows in the delta, with rigorous management of the location of the contour where salinity is 2[2] (known as X2) through flow releases from upstream reservoirs. Consequent changes in the abundance, distribution, and composition of species in the delta have been compounded by the introduction and invasion of many species not native to the region.

Recently, several species of native fishes have been listed as threatened or endangered under the federal Endangered Species Act (ESA) and the California Endangered Species Act. This study focuses only on the federal ESA. The federal listings have led to Section 7 (of the ESA) consultations between the operators of the CVP (the U.S. Bureau of Reclamation, or USBR) and of the SWP (the California Department of Water Resources, or DWR) and the Fish and Wildlife Service (FWS), the National Marine Fisheries Service (NMFS), and the California Department of Fish and Game (DFG). Those consultations led to the issuance of opinions by the Services that required changes ("reasonable and prudent alternatives," or RPAs) in water operations and related actions to avoid jeopardizing the continued existence and potential for recovery of delta smelt (*Hypomesus transpacificus*), winter-run and fall-run Chinook salmon (*Oncorhynchus*

[2] This is often expressed as a concentration, e.g., "2 parts per thousand," but more recently it has been expressed as a ratio of electrical conductivities, hence it has no units.

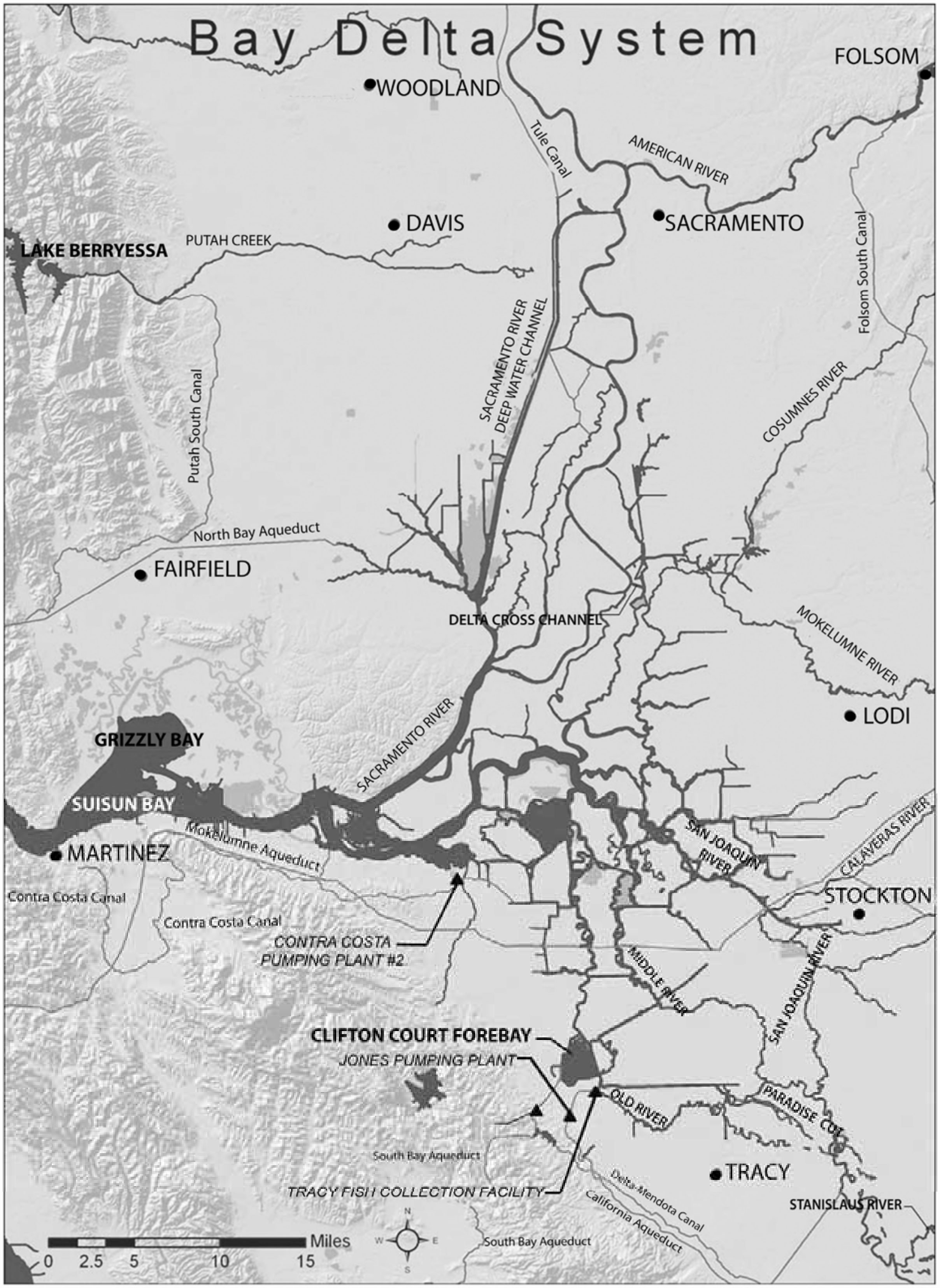

FIGURE 1-1 Map of the delta. Source: FWS, 2008.

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tshawytscha), Central Valley steelhead (*Oncorhynchus mykiss*), and green sturgeon (*Acipenser medirostris*). The impacts of the RPAs on water users and the tensions that resulted have been exacerbated recently by series of dry years. In the longer term, climate change presents uncertainties and challenges with its anticipated impact on precipitation, snowpack, streamflow, and rising sea level, which will affect not only salinity and riparian habitats in the delta but likely also will threaten the integrity of the extensive system of levees (1,100 miles in length).

The RPAs are divided into many separate actions. The RPA in the FWS opinion (FWS, 2008), divided into 6 actions, focuses primarily on the flow and storage regimes as affected by diversions (pumping water to the south) and on reducing entrainment, with some focus on habitat. The NMFS RPA (NMFS, 2009) is divided into 5 actions with a total of 72 subsidiary actions. In addition to its focus on flow regimes, storage, and passage, it includes purchasing water to enhance in-stream flow, habitat restoration, a new study of acoustic-tagged steelhead, and development of hatchery genetics management plans. This committee did not evaluate all 78 actions and subsidiary actions in the two RPAs in detail. It spent most of its time on the elements of the RPAs that have the greatest potential to affect water diversions. It also spent time on elements whose scientific justifications appear to raise some questions.

Protecting all the listed species and preserving existing and projected uses of the region's water is a serious challenge. As the NMFS biological opinion (NMFS 2009) says, "the current status of the affected species is precarious," and "it has been difficult to formulate an RPA that is likely to avoid jeopardy to all listed species and meets all regulatory requirements." Adding to this difficulty is the existence of the many anthropogenic and other factors that adversely affect the fishes in the region but which are not under the direct control of the CVP or the SWP, and thus are not subjects of the biological opinions[3]. These include other human modifications to the system, including pollutants; invasive species and altered species composition; and engineered structures such as dams, canals, gates, pumps, and levees.

The complexity of the problem of the decline of the listed species and the difficulty of identifying solutions to it have led to disagreements, including concerns that some of the actions in the RPAs might cause harm and economic disruptions to many water users, and that some of the actions specified in the RPAs to help one or more of the listed species might harm others.

SYSTEM OVERVIEW

Overview of System Hydrology

We briefly describe the Sacramento-San Joaquin delta (Figure 1) and the two massive water storage and delivery projects that affect the area. Several publications go into great detail describing the delta and the operations of the federal and state water systems (DWR, 2006, 2009a, 2009b; USBR, 2006).

The Central Valley Project (CVP) operated by the U.S. Bureau of Reclamation and the State Water Project operated by the California Department of Water Resources provide water to farms and cities in an area encompassing the majority of the land and population of California. The two projects constitute the largest agriculture and municipal water-supply system in the United States. Water supplying both projects ultimately comes mainly from California's two major

[3] Those other mainly adverse changes are considered as part of the "environmental baseline."

river systems—the Sacramento and the San Joaquin—with substantial imports from the Trinity River. Water also is stored in several major reservoirs as well, including Shasta (capacity 4.6 million acre-feet[4], or MAF), Oroville (3.4 MAF), Trinity (2.4 MAF), New Melones (2.4 MAF), San Luis (2 MAF), Don Pedro (2 MAF), McClure (Exchequer) (1 MAF), and Folsom (1 MAF), as well as many smaller ones. Releases from those reservoirs are used to help manage flows and salinity in the delta, as well as being used for agriculture, municipal and industrial uses, recreation, flood protection, and hydropower.

The CVP provides about 5 MAF of water to agriculture each year (about 70 percent of the CVP's supply), 0.6 MAF for municipal and industrial (M&I) use (serving about 2 million people) and 1.4 MAF to sustain fish, wildlife, and their habitats. The SWP provides about 70 percent of its water to M&I customers (about 20 million people) and 30 percent to agriculture (about 660,000 acres of irrigated farmland). The largest SWP contractor is the Metropolitan Water District of Southern California, which receives about 50 percent of SWP deliveries in any one year. At least two-thirds of the population of California depends on water delivered from these projects as a primary or supplemental source of supply. Other important functions provided by both projects include flood protection, recreation, power generation, and water quality to preserve fish and wildlife.

Both projects preceded and accommodated the explosive growth of California's economy and population. The CVP was begun in the mid to late 1930s and the SWP was begun in the 1960s. Dozens of reservoirs and lakes, pumping facilities, and over 1,200 miles of pipelines and canals make up the two interdependent water-supply and delivery systems.

The Sacramento-San Joaquin Delta

In the middle of both systems and connecting the northern water supply reservoirs and southern water demands is the Sacramento-San Joaquin Delta (Figure 1-1). Thus, the delta is an integral part of the water-delivery infrastructure for both the SWP and CVP. While the focus of this report is the determination of the effects of water allocations for fish, there are many other requirements that must be met in the delta to maintain flows and quality for the many uses of water delivered by the SWP and CVP projects.

Two major pumping plants draw water from the channels and rivers feeding the delta. The SWP pumping plant (Banks Pumping Plant) can deliver an average flow of nearly 6,700 cubic feet per second (cfs) to Clifton Court Forebay for transport to users south of the delta. The Jones Pumping Plant withdraws water primarily from Old River and has the capability of 4,600 cfs to contractors in southern California. Relatively small amounts of water are extracted for the Contra Costa canal (up to 195,000 af or 195 thousand acre-feet {TAF} per year) and the North Bay Aqueduct (up to 71 TAF per year) (FWS, 2008). In addition, diversions occur upstream of the delta. These diversions affect the location of X2, the amount of water that can be withdrawn at the pumps, the flow in the San Joaquin River, and other factors.

[4] An acre-foot is the amount of water required to cover an acre of land to a depth of one foot; it is equal to 43,560 cubic feet, 325,851 gallons, or 1,234 cubic meters of water.

THE PRESENT STUDY

The statement of task (Appendix A) charges the NRC committee to review the scientific basis of the Services' RPAs and advise on how to most effectively incorporate science and adaptive management concepts into holistic programs for management and restoration of the delta. To balance the need to inform near-term decisions with the need for an integrated view of water and environmental management challenges over the longer-term, the committee was tasked to produce two reports. This first report focuses on the scientific bases of the water-management alternatives (RPAs) in the two biological opinions and whether there might be possible alternative RPAs that would be as or more protective of the fishes with lesser impacts on other water uses. The committee also has considered "other stressors," as specified in its statement of task. These are stressors not necessarily directly associated with the water projects; they are part of the "environmental baseline," a concept related to the Endangered Species Act that refers to other anthropogenic modifications of the environment. As such, they are not addressed by the RPAs, because RPAs must address operations of the water projects.

In this first report, most of the committee's focus has been on the question of the scientific bases of the water-management alternatives (RPAs) in the biological opinions, with a smaller focus on potential conflicts between the RPAs, potential alternative RPAs, and other stressors. The committee's second report will focus on broader issues surrounding attempts to provide more sustainable water supplies and to improve the ecological sustainability of the delta, including consideration of what ecological goals might be attainable.

To prepare this report, the committee met in Davis, California for five days in January 2010. It heard presentations from representatives of federal and state agencies and a variety of other experts, and from members of the public, and began work on the report. The committee was able to consider information received by February 8. Additional writing and two teleconferences occurred in February, and the report was reviewed according to the NRC's report-review procedure (the reviewers are acknowledged in the preface).

2

The Legal Context of This Report

SCOPE OF THE COMMITTEE'S TASK

The committee was asked "to review the scientific basis of actions that have been and could be taken to simultaneously achieve both an environmentally sustainable Bay-Delta and a reliable water supply." While this committee's review is scientific, and not legal, the committee nonetheless recognizes the importance of the legal context within which its evaluation takes place. The standard of review applicable in legal challenges to the opinions and associated RPAs provides a useful reference. In such lawsuits, courts will invalidate the RPAs only if they are demonstrated to be "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law" (Administrative Procedure Act, 5 U.S.C. § 706(2)(A)). Courts are reluctant to second-guess technical agency judgments and may not substitute their judgment for that of the agency, particularly in cases where there are scientific uncertainty and differing scientific views. *See* Aluminum Co. of America v. Bonneville Power Administration, 175 F.3d 1156 (9th Cir. 1999); Trout Unlimited v. Lohn, 559 F.3d 946 (9th Cir. 2009). Thus, while the committee can come to different conclusions than the agencies did in their biological opinions, that would not be a *legal* justification for deeming them inadequate, as long as the agencies adequately considered the available scientific data and their conclusions are supportable by the evidence. Similarly, the RPAs should not be considered *legally* inadequate simply because different alternatives could be scientifically justified, as long as the agencies could reasonably believe that their RPAs would avoid the likelihood of jeopardy.

Some aspects of the committee's task require it to make determinations beyond the scope of the agencies' legal obligations or authority when issuing a biological opinion and RPAs. For example, the committee's charge includes consideration of the effects of stressors such as pesticides, ammonium, and invasive species on federally listed and other at-risk species in the Bay-Delta—stressors likely beyond the action agencies' legal authority to regulate, unless the effects are indirectly changed by the RPAs. Any such considerations by this committee in this or in its second report would have no bearing on the question of whether or not the biological opinions and RPAs are legally adequate. Instead, such considerations should be interpreted in contexts apart from the biological opinion and RPAs, such as the Bay-Delta Conservation Program (development of a habitat conservation plan); the State Water Resources Control Board's development of flow criteria for the delta; the Delta Stewardship Council's development of a delta plan; and others.

POTENTIAL VIOLATIONS OF ESA SECTION 7 AND SECTION 9

In each biological opinion, the relevant wildlife agency concluded that the proposed federal action—implementation of the water projects' operations plan—was likely to "jeopardize" the continued existence of species listed as endangered and to adversely modify their critical habitat. This would violate Section 7 of the Endangered Species Act (ESA), which requires agencies to "insure" that any actions they authorize, fund, or carry out are not likely to jeopardize endangered species or to destroy or adversely modify the species' critical habitat (16 U.S.C. § 1536 (a) (2)). As defined by agency regulations, "jeopardy" means that the proposed action "reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of [relevant endangered species] in the wild by reducing the reproduction, numbers, or distribution of that species" (50 C.F.R. § 402.02). As required by the ESA, the wildlife agencies suggested "reasonable and prudent alternatives" (RPAs) that would allow the action to go forward without violating Section 7 (16 U.S.C. § 1536 (B) (3) (A)).

In addition to the jeopardy determinations (generally, applying to species as a whole), both biological opinions found that the proposed action would "take" individual members of the endangered populations in violation of Section 9 of the ESA. By regulation, the "take" of an endangered species includes "an act which actually kills or injures wildlife" and may include "significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering" (Babbitt v. Sweet Home Chapter of Communities, 515 U.S. 687 (1995)).

The resource agencies, the National Marine Fisheries Service and the Fish and Wildlife Service, issued an "incidental take statement," in the present case, setting forth reasonable and prudent measures necessary and appropriate to minimize the effect of the proposed action on endangered species. If the action agencies (the Bureau of Reclamation and the California Department of Water Resources) comply with those measures, including monitoring and reporting requirements, then any "takes" that result from project operations will be deemed "incidental," and they will be exempt from the prohibitions of Section 9.

STANDARDS FOR THE PREPARATION OF BIOLOGICAL OPINIONS

Best Available Data

Under the ESA, the agencies must develop their biological opinions and associated RPAs using the "best scientific and commercial data available" (16 U.S.C. § 1536 (a) (2)). Courts have emphasized the qualifier *available,* explaining that perfect data are not required. Action can be taken based on imperfect data, so long as the data are the best available. In addition, the above requirement does not remove the agency's discretion to rely on the reasonable judgments of its own qualified experts, even if others, even a court, might find alternative views more persuasive (see Aluminum Co. v. Bonneville Power Admin., 175 F.3d 1156 (9th Cir. 1999).

Thus, the courts afford the agencies significant deference in determining the best data available for developing the RPAs. Therefore, even if this committee might have relied on different data or come to different conclusions than the agencies did, it does not follow that the RPAs are legally insufficient. Rather, this committee's conclusions and recommendations should be seen as applying to future work beyond the scope of the agencies' legal obligations.

Economic Considerations

Although the economic impact of species protections may be relevant under the ESA, its influence is limited. For example, economic concerns *may not* be part of the decision whether or not to list species as endangered or threatened, but *must be* considered when the agencies designate critical habitat (16 U.S.C. § 1533). When developing biological opinions and RPAs, the Ninth Circuit acknowledged that the wildlife agencies may go beyond "apolitical considerations" and that if two proposed RPAs would avoid jeopardy to the relevant species, the agencies "must be permitted to choose the one that best suits all of its interests, including political or business interests." Southwest Center for Biological Diversity v. U.S. Bureau of Reclamation, 143 F.3d 515 (9th Cir. 1998); *See also* Bennett v. Spear, 520 U.S. 154 (1997) (asserting that the "best scientific and commercial data" provision is . . . intended, at least in part, to prevent uneconomic [because erroneous] jeopardy determinations"). Nevertheless, the lower courts have been reluctant to second-guess agency opinions on the basis of economic arguments (Aluminum Co. cited above).

Effects of the Proposed Action and the Environmental Baseline

In preparing biological opinions, agencies must evaluate the "effects of the [proposed] action" on the species or its critical habitat. Other adverse modifications of the species' habitats or negative effects on their populations are considered part of the "environmental baseline." The agencies' analysis includes consideration of:

1) direct effects;
2) indirect effects ("those that are caused by the proposed action and are later in time, but still are reasonably certain to occur");
3) interrelated actions ("those that are part of a larger action and depend on the larger action for their justification");
4) interdependent actions ("those that have no independent utility apart from the action under consideration"); and
5) cumulative effects ("those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation") (50 C.F.R. §§ 402.02 and 402.14(g)(3-4)).

STANDARDS FOR THE PREPARATION OF REASONABLE AND PRUDENT ALTERNATIVES (RPAs)

Although RPAs are not binding on the action agency, adherence to the RPAs provides the agency with a safe harbor from claimed violations of the ESA. As the U.S. Supreme Court explained, "the action agency is technically free to disregard the Biological Opinion and proceed with its proposed action, but it does so at its own peril (and that of its employees), for 'any person' who knowingly 'takes' an endangered or threatened species is subject to substantial civil and criminal penalties, including imprisonment" (Bennett v. Spear, 520 U.S. 154 (1997)).

Under agency regulations, the RPAs must satisfy each of the following four requirements:

1) Project purpose: RPAs must be capable of implementation in a manner consistent with the intended purpose of the action.
2) Scope of agency authority: RPAs must be consistent with the scope of the action agencies' legal authority and jurisdiction.
3) Feasibility: RPAs must be economically and technologically feasible; and
4) Avoid jeopardy: The directors of FWS and NMFS must believe that the RPAs would avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat (50 C.F.R. § 402.02).

Although RPAs must avoid the likelihood of jeopardy, they are not required to promote recovery of the affected species. In other words, no RPA has the responsibility of mitigating all the adverse effects—the "environmental baseline"—that may be causing the decline of a listed species. They must only avoid the likelihood that the *proposed action* will cause jeopardy.

3

The Life Histories of The Fishes

INTRODUCTION

Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), and green sturgeon (*Acipenser medirostris*) are anadromous species; that is, they spawn in freshwater but spend a portion of their life in saltwater. Delta smelt (*Hypomesus transpacificus*) are resident within the brackish and freshwater habitats of the delta. In both anadromous and resident life-history strategies the fish migrate from their natal habitat into their adult habitat and then back to the spawning habitat, completing the life cycle. The fish do not simply drift between their habitats, but have evolved specific life-stage behaviors to meet the challenges they confront. These behaviors are cued by the fishes' physiology and by environmental conditions, which together drive the timing and movement of the individuals through their life cycle. Because all species spend time in the delta, they share some environmental conditions and challenges, but their different life histories cause them also to face unique challenges. Many of the challenges are the result of anthropogenic modifications to the delta and river habitats, and these challenges are of particular concern (see Chapter 5). Some, but not all, of them are addressed in the RPAs. The information on the fishes' life histories presented below illustrates the complexity of their interactions with their environments and the potential importance of apparently small changes in the timing, direction, and magnitude of variations in flow, salinity, turbidity, water temperature, and other environmental conditions.

FISHES OF THE SALMON FAMILY

The delta provides habitat for two species of Pacific salmon, Chinook salmon (hereafter "salmon") and the rainbow trout-steelhead complex. Pacific salmon typically are anadromous. There are many exceptions, however, such as rainbow trout, which although apparently genetically identical to steelhead, are not anadromous; and there is a great deal of variation in their life histories (Williams, 2006).

When adult salmon, steelhead, and sturgeon return from the ocean and begin their upriver migration, they experience several challenges, including physical and water-quality blockages. Here the delta water system has had a great impact on populations, for 80% of the historical spawning habitat for Chinook salmon (Clark, 1929) and much of it for the other species has been blocked by the storage reservoirs of the Central Valley (Lindley et al., 2006). Summer temperatures in the Central Valley waterways can reach potentially lethal levels for salmon, increasing their susceptibility to disease and decreasing metabolic efficiency (Myrick and Cech, 2001, 2004). The timing of adult salmon runs leads them to avoid most of the detrimental effects of high summer temperatures because they enter the delta and swim upriver to their spawning habitats and hatcheries in the spring, autumn, and winter. Wild spawning fish excavate redds in stream reaches with loose gravel in shallow riffles or along the margins of deeper runs (NMFS 2009), where temperatures are cooler and eggs buried in the gravel receive a sufficient flux of oxygenated water through interstitial flow. The eggs incubate for several months and after emerging the young fry either immediately begin their migration back to the ocean or spend several weeks to a year in freshwater before migrating. Because of this diversity, juvenile salmon and steelhead pass through the delta throughout the year; however, the timing and size of the migrants generally corresponds to specific runs (Williams, 2006, Lindley et al., 2006).

Salmon and steelhead undergo a complex set of physiological changes in preparation for their migration to the ocean known as "smoltification," after which the young fish are known as "smolts." The alteration of the fish's physiology to successfully osmoregulate in saltwater after beginning life in freshwater is a significant challenge that can be exacerbated by human-caused environmental changes (e.g., NRC, 2004b). Most Central Valley Chinook salmon migrate to the ocean within a few months of hatching and the smolts are less than 10 cm long, although some remain in freshwater for up to a year. Juvenile steelhead migrate to sea after one to three years in freshwater, and can be as large as 25 cm in length. Young migrating Chinook are much more vulnerable to entrainment in adverse flows than the stronger-swimming steelhead smolts.

Juvenile salmon migrants experience predation during their downstream migration through the Sacramento River or through the interior delta on their way to the sea. Fish that enter the central delta, driven by the strong tidal and pumping-induced flows, are moved through a labyrinth of channels, which further delays their migration and exposes them to additional predators (Perry et al., 2010). Finally, fish that enter the Old and Middle Rivers (OMR) can be drawn towards the SWP and CVP pumps (Kimmerer, 2008a). Juvenile salmon that successfully pass through the delta enter the ocean and spend one or more years there before returning to freshwater to spawn. Ocean survival is particularly dependent on the conditions the fish experience during the first few months they enter the saltwater (Lindley et al., 2009). Fish that are drawn into the central and southern delta by reverse flows are more vulnerable to predation than those that take a more direct path to the ocean, and other aspects of changed environmental conditions also expose them to predators (for more detail, see Chapter 5).

GREEN STURGEON

The Central Valley green sturgeon (*Acipenser medirostris*) is an anadromous fish that can reach 270 cm (nearly nine feet) in length with a maximum age of 60 to 70 years (Moyle et al. 2002). The historical distribution of green sturgeon is poorly documented, but they may have been distributed above the locations of present-day dams on the Sacramento and Feather Rivers (Beamesderfer et al., 2007). Information on the distribution of green sturgeon in the San Joaquin River is lacking. Mature green sturgeon enter the Sacramento River from the ocean in March and April. The Red Bluff Diversion Dam can impede their migrations (Heublein et al. 2009). After spawning, green sturgeon may immediately leave the river or hold over in deep pools until the onset of winter rains (Erikson et al., 2002, Heublein et al., 2009). Individuals then migrate back to the ocean and return to freshwater to spawn every two to four years (Erickson and Webb, 2007, Lindley et al., 2008)

Based on adult spawning behavior and the habitats required for green sturgeon embryo development, reproductive females likely select spawning areas with turbulent, high velocities near low-velocity resting areas. Green sturgeon spawning areas are presumed to be characterized by coarser substrates upstream of lower gradient reaches, which usually have slower velocities. Eggs and milt are released in turbulent water above deep, complex habitats; fertilized eggs drift into deeper areas and stick onto the substrate. Eggs require cool temperatures for development and hatch after approximately a week. Larval and juvenile green sturgeons are bottom-oriented and nocturnally active until a few months of age (Kynard et al., 2005). Juvenile green sturgeon migrate into seawater portions of natal estuaries as early as one and a half years old (Allen and Cech, 2007), and eventually emigrate to nearshore coastal waters by three years old. Subadults are migratory, spending their next 12 to16 years foraging in the coastal ocean and entering western estuaries during the summer (Moser and Lindley, 2007). In the ocean, green sturgeon inhabit the coastal shelf out to 100m depth with occasional, rapid vertical ascents near or to the surface (Erickson and Hightower, 2007).

DELTA SMELT

The delta smelt is a near-annual species; most individuals complete their life cycle in one year, but some survive for two years and reproduce again. Delta smelt reside in brackish waters around the western delta and Suisun Bay region of the estuary, being commonly found in salinities of 2 to 7, but the range they occupy extends from 0 (freshwater) to 15 or more (Moyle, 2002). In the winter (December to April), pre-spawning delta smelt migrate to tidal freshwater habitats for spawning, and larvae rear in these areas before emigrating down to the brackish water (Bennett, 2005). Delta smelt inhabit open waters away from the bottom and shore-associated structural features. Although delta smelt spawning has never been observed in the wild, information about related members of the smelt family suggests that delta smelt use bottom substrate and nearshore features during spawning. Juvenile and adult stages, 20-70 mm in length, are generally caught in the western delta and Suisun Bay in the landward margin of the brackish salinity zone, which may extend upstream of the confluence zone of the Sacramento and San Joaquin Rivers. Historically pre- and post-spawned fish were observed throughout the delta. In wet years, spawning adults often were observed in the channels and sloughs in Suisun Marsh and the lower Napa River.

In the brackish habitat of the western delta the flow is tidal with a net seaward movement, and so to maintain position, the juvenile fish appear to coordinate swimming behavior with the tides, occurring near the surface on the flood tides and at depth on the ebbs. However, in other regions, adaptive tidal behavior has not been observed and fish simply move with the tides, which may promote horizontal exchange to adjacent shallow water habitats. The FWS biological opinion emphasizes the complexity of this behavior (p. 651) and thus the above description is a general one that does not capture details that might be important.

The brackish zone also has higher densities of other fishes and zooplankton, suggesting that it may serve as a nursery habitat for delta smelt and other fishes (Bennett 2005). The spawning movement of adults from their brackish habitat in the western delta landward to the freshwater portions of the delta is triggered by high flows and turbidity pulses.

This diversity of paths from the low-salinity (brackish) zone to the freshwater spawning habitats suggests that delta smelt do not have fidelity to specific structural habitats as do salmon. Instead, their upstream movement is directed by a combination of physiological and environmental cues that involve salinity, turbidity, and both net and tidal flows through the channels of the delta and its tributaries. Additionally, since 2005, approximately 42% of the current delta smelt population is in the Cache Slough complex north of the delta, and may represent an alternative life-history strategy in which the fish remain upstream through maturity (Sommer et al., 2009).

Historically, the complete delta-smelt life cycle occurred unobstructed throughout the delta. Human-caused changes in delta water quality and hydrodynamics have disrupted the cycle and since 2005, delta-smelt population densities have been extremely low in the traditional habitats in the central and south delta (www.dfg.ca.gov/delta/data/), and pump salvage[5] also has been extremely low, about 4% of the 50-year average index (www.dfg.ca.gov/delta/data/townet/indices.asp?species=3). Analyses seeking causes for the declines to the present condition have focused on relationships between abundance, salvage, water exports, delta flows, turbidity, and food. Kimmerer (2008b) found that delta-smelt survival between summer (juvenile) and fall (adult) was related to zooplankton biomass, suggesting that high zooplankton abundances contributed to delta-smelt abundance and residence time in the southern delta, and thus increased entrainment risk at the pumps. Grimaldo et al. (2009) found that between 1995 and 2005 the inter-annual variation in adult delta-smelt salvage was best correlated with turbidity and the interaction of OMR[6] flows and X2[7]. The annual salvage of age-0 delta smelt (fish hatched in that year, around 27 mm in length) was best correlated with spring abundance of zooplankton, OMR flows, and turbidity. Additionally, Grimaldo et al. suggested that differences in temporal patterns of entrainment of delta smelt between years may be a measure of the degree to which their physical habitat overlapped with the hydrodynamic footprint of negative OMR flows towards the pumps. However, the year-class strength of adult delta smelt was not related to salvage, although the position of X2 was correlated with salvage at an intra-annual scale when OMR flows were negative. Other analyses showed a similar correlation (e.g., FWS, 2008).

While the correlation between OMR flows and salvage is substantial (Kimmerer, 2008b), their effect on population dynamics is not clear (Bennett, 2005; Grimaldo et al., 2009). Indirect factors could have contributed to population declines through a reduction in the size and abundance of food in the brackish zone. Overall zooplankton abundance is correlated with delta smelt survival (Feyrer et al., 2007; Kimmerer, 2008b; Grimaldo et al., 2009). Zooplankton abundance has been reduced through several factors, including the introduction of the overbite clam (*Corbula amurensis*), an efficient grazer of zooplankton in the low-salinity zone, and changes in nutrients that have altered the phytoplankton population so that cyanobacteria, which can reduce the food supply for zooplankton, have increased while diatoms have declined (FWS, 2008). The change in zooplankton species, associated with the success of invasive species in changed environmental conditions, also is probably important. It has been suggested that the position of X2 affects the size of delta smelt habitat and thus it affects the susceptibility of juvenile and adult delta smelt to pump entrainment (Feyrer et al., 2007, Kimmerer, 2008a). Furthermore, the mean position of X2 has moved inland about 10 km over the past 15 years (FWS 2008, p. 180). However, there is no direct evidence relating these indirect effects to population numbers of smelt

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[5] "Salvage" refers to fish caught in the pumps and retrieved alive to be released elsewhere in the system. It often is used as a surrogate estimate for "take" by the pumps.

[6] The term "OMR flows" refers to flows in the Old and Middle Rivers (see Figure 1-1), which are affected by the pumping of water for export. At high negative flows, that is, flows away from the sea towards the pumps in the south, the normal seaward flow associated with ebb tides can be completely eliminated.

[7] "X2" refers to the salinity isohaline of salinity 2 (a contour line of equal salinity). Sometimes X2 is used as shorthand for the mean position of that isohaline, measured in kilometers upstream from the Golden Gate Bridge over the outlet of San Francisco Bay. Managing the position of X2 is a major aspect of the delta smelt Biological Opinion and RPA; it is managed by adjusting flows of fresh water from delta reservoirs, as well as by adjusting pumping rates.

(Kimmerer, 2002; Bennett, 2005). In addition, delta smelt are now largely absent from the central and southern delta, while a significant portion of the remaining population exists in the Cache Slough complex to the north. These changes increase the uncertainty surrounding current estimates of delta smelt population changes in response to alterations in delta hydraulics.

4

Use of Models

MODELING SCENARIOS

Modeling of baselines and future project actions is a standard practice of evaluating impacts. Both biological opinions relied on the use of modeling scenarios (known as Studies) provided by the Operations Criteria and Plan (OCAP) biological assessment (BA) (http://www.usbr.gov/mp/cvo/ocap_page.html), although the extent to which such results were used in each biological opinion and in the formulation of RPAs varied significantly. The "proposed action" with reference to ESA is the continued operation of the CVP and SWP with additional operational and structural changes (Table 2-1 of USBR, 2008) to the system. The U.S. Bureau of Reclamation (USBR) and the California Department of Water Resources (DWR) provided the results of the modeling conducted for simulating baseline conditions, future system components, operational strategies, and the water supply demands. In addition to simulating the water-supply deliveries of the project, the modeling also attempted to mimic the project operations associated with the regulatory environments described in operating criteria described in D-1485, D-1641,CVPIA Section 3406 (b)(2) and the Environmental Water Account (EWA) (USBR 2008). A major difference in the current and future scenarios is the extent to which EWA is used. The purpose of EWA was to enable diversion of water by the SWP and CVP from the delta to be reduced at times to benefit fish species while minimizing uncompensated loss of water to SWP and CVP contractors (USBR, 2008, Chapter 2). The EWA is intended to replace the water loss due to pumping curtailments by purchasing surface water and groundwater from willing sellers and through increasing the flexibility of operations. The simulations include both a "full EWA" characterizing the full use of EWA assets as well as a "limited EWA" focusing only on a limited number of assets. The EWA is currently under review to determine its future (FWS 2008 p. 34) and the RPA actions were not based on it.

Another factor that changed from current to future conditions is the way water demand by CVP/SWP users is simulated. Demands have been pre-processed using either contractual amounts and/or level of development (existing versus future). Some demands were assumed to be fixed at contractual amounts whereas in other cases they varied according to the hydrologic conditions. This topic will be considered in the committee's second report.

While several study scenarios were developed for the OCAP biological assessment (USBR, 2008), the use of modeling results in the biological opinions was largely limited to a smaller set of scenarios (Table 4-1).

Study 7.0 describes the existing condition (circa 2005), whereas Study 7.1 presents the existing condition demands with near future facilities as well as the projected modification to EWA. Study 8 describes the future condition corresponding to the year 2030 (USBR, 2008, pp. 9-33, 9-53, 9-54). Study series 9 constitutes a future condition representing modified hydrology (warm and warmer, dry and wet) along with a projected sea level rise of one foot.

TABLE 4-1 Key scenarios used for biological opinions of FWS and NMFS

Study	Level of Development (Year)	Environmental Water Account (EWA)	Future project facilities[1]	Climate and Sea Level Rise
7.0	2005	Full EWA	No	No
7.1	2005	Limited EWA	Yes	No
8.0	2030	Limited EWA	Yes	No
9.0-9.5	2030	Same as in Study 8.0[2]	Yes	Yes

[1]Future project features include South Delta Improvement Program (Stage 1), Freeport Regional Water Project, California Aqueduct and Delta-Mendota Canal intertie
[2]According to the OCAP BA (USBR, 2008), Study suite 9 is identical to Study 8.0 except for climate change and sea-level rise

CENTRAL ISSUES CONCERNING MODEL USE IN THE BIOLOGICAL OPINIONS

The USFWS and NMFS supplemented the modeling results provided by USBR and DWR with their own modeling efforts and available science on the implications of management actions on species. The primary suite of models provided to FWS and NMFS include (Chapter 9, OCAP-BA):

(a) Operations and hydrodynamic models: CalSim-II, CalLite, the Delta Simulation Model II {DSM2}, including particle-tracking models (PTMs, which also are considered as surrogates for biological models)
(b) Temperature models: Reclamation Temperature, SRWQM, and Feather River Mode
(c) Biological models: Reclamation Mortality, and SALMOD

The modeling framework used by the agencies is diagrammed in Figure 4-1.

The USFWS, in its biological opinion, used available results from a combination of tools and data sources, including CalSim-II, DSM2-PTM, DAYFLOW historical flows, and statistical models based on observational data and particle-tracking simulations (FWS 2008 pg-204). NMFS analyses included results from coupled CalSim-II simulations with various water-quality and biological models for a few of the life stages (NMFS, 2009, page 64).

The CalSim-II model, the primary tool used to evaluate the water-resources implication of the proposed actions, was developed by the DWR and the USBR to simulate water storage and supply, streamflows, and delta export capability for the Central Valley Project (CVP) and the State Water Project (SWP). CalSim-II simulates water deliveries and the regulatory environment associated with the water-resources system north of the delta and south of the delta using a single time step (one month) optimization procedure based on a linear programming algorithm. CalSim-II represents the best available planning model for the CVP-SWP system, according to a CALFED Science Program peer review by Close et al. (2003) (USDI-USBR, 2008, p. 9-4). However, many users have suggested that its primary limitation is its monthly time step, and the model should be used primarily for comparative analysis between scenarios and discouraged its use for absolute predictions (Ferreira et al., 2005; USBR, 2008, Chapter 9). In response to the

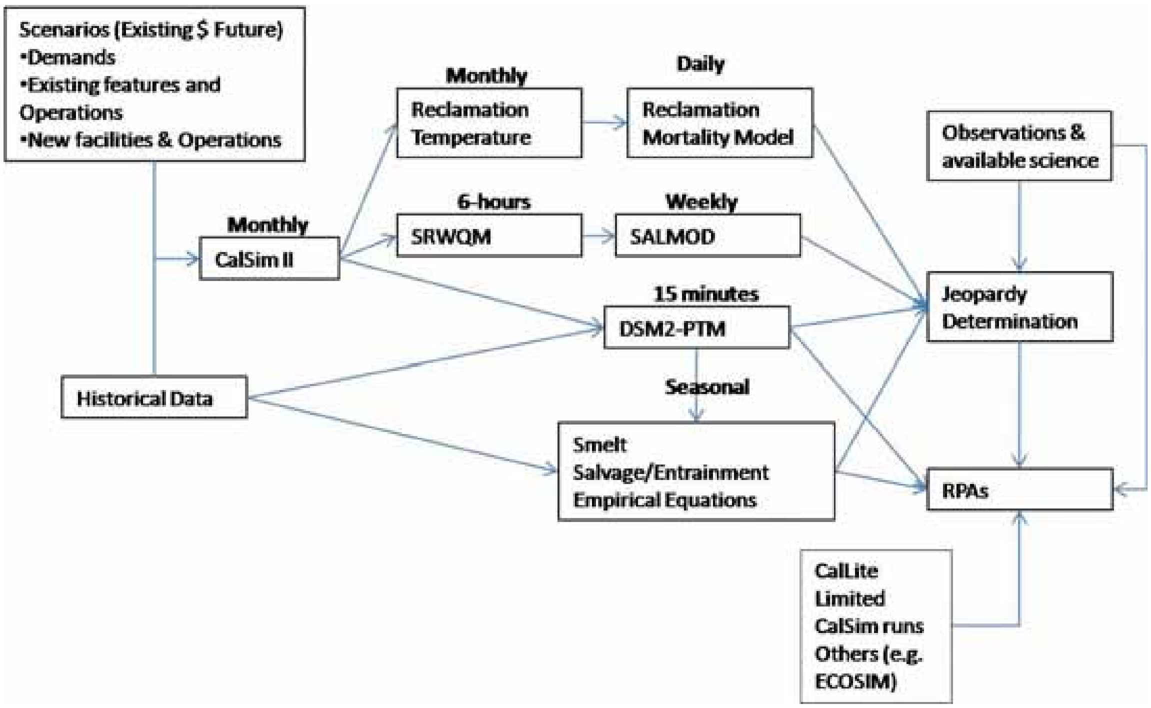

FIGURE 4-1 Modeling framework used in NMFS and USFWS biological opinions and RPAs.

peer review by Close et al. (2003), DWR and USBR provided a list of development priorities (Table 2, DWR/USBR, 2004), including the use of a daily time step, but it is not clear how many of such planned improvements have been incorporated into the version of CalSim-II used in the biological opinions.

Several other tools and models were central in effects analysis and developing RPAs, including hydrodynamic and water-quality (DSM2, USBR's temperature, SRWQM), habitat (SALMOD), and statistical and particle-tracking models (salvage, DSM2-PTM). Some of these models have already been evaluated in the literature for their individual strengths and limitations, though some (SALMOD and USBR's mortality models) have not yet been formally peer reviewed. We first review some of the challenges of applying these individual models in the determination of RPAs, and then focus on examining the modeling process, including how the models contributed to the development of RPAs, and where the uncertainties and vulnerabilities in that process lie.

Model Scale and Management Implications

Very generally, the tiered modeling approach (Figure 4-1) applied the results of CalSim-II as input to various hydrodynamic and ecological models to predict impacts of project operations and, to a very limited extent, to explore RPAs. At one level, model simulations were also used or performed to investigate the feasibility of some proposed actions. For example, CalSim-II was used at the planning level to investigate whether the USBR could meet the 1.9MAF (at the end of

September) required by actions I.2.3 and I.2.4 (maintaining cold water supplies necessary for egg incubation for the following summer's cohort of winter-run), and to recommend storage conservation in severe and extended droughts (NMFS, 2009, page 596). Similarly, examination of CalSim results and hydrologic records demonstrated to the agencies that the first year of a drought sequence is particularly critical to storage and operations in the following drought year (NMFS 2009 page 596). The benefits of using models at this planning level, especially given the importance of water-year types, is clear, and there is little controversy about this application of the models.

At another level, model scenarios were examined to investigate the relationships between operations and impacts on various life stages of the fish across the water-year types and operations scenarios. For example, NMFS used DWR's Delta Survival Model (Greene, 2008) to estimate mortality of smolts associated with three CalSim-II Study scenarios (7.0, 7.1, 8.0). The USFWS used statistical models of salvage and total entrainment (Kimmerer, 2008; Grimaldo et al., 2009) to investigate the effects of proposed operations by comparing actual and predicted salvage and entrainment losses under modeled OMR flows (FWS, 2008, page 211).

While some challenges exist in linking models in this tiered approach (see next section), concerns and controversies appear to be largely directed at the various forms of statistical relationships of salvage versus OMR flows, extrapolation of these relationships that describe impacts on single life stages to assess the population impacts on species, and the use of biological models without full consideration of their underlying uncertainties. In particular, this nested sequence of statistical models does not allow for uncertainties at one step to influence predictions at the next step. As a result, some of the RPA actions, especially those involving X2 and OMR flow triggers, are based on less reliable scientific and modeling foundations than others. In these cases, the incomplete data and resolution of the models do not closely match the resolution of the actions.

Adequacy of Current Models

Life-cycle models

Both agencies have been criticized for the lack of adequate life-cycle models to address population level responses (e.g., Deriso, 2009; Hilborn, 2009; Manly, 2009). Nonlinear and compensatory relationships between different life-history stages are common in many fish species. Moreover, many life-history traits exhibit significant patterns of autocorrelation, such that changes in one life-history trait induce or cause related changes in others. These patterns can most effectively be understood through integrated analyses conducted in a modeling framework that represents the complete life cycle. However, complete life-cycle models were not used in either biological opinion to evaluate the effects of changes in operations. The agencies acknowledge that further model development is required, including the "cooperative development of a salmonid life-cycle model acceptable to NMFS, Reclamation [USBR], CDFG, and DWR" (NMSF biological opinion, page 584). While one life-cycle model (Interactive Object-Oriented Salmon simulation) was available for winter-run salmon from the OCAP BA (USBR, 2008), this model was rejected based on model resolution and data limitation issues (NMFS, 2009, page 65). Similarly, a better life-cycle model for delta smelt is critically needed (PBS&J 2008). Such life-cycle models for delta smelt are currently under development. The committee recommends that development of such models be given a high priority within the agencies. The committee also encourages the agencies to develop several different modeling approaches to enable the results of models with different structure and assumptions to be compared. When multiple models agree, the confidence in their predictions is increased.

Particle-Tracking Models (PTMs)

Particle-tracking models (PTMs) are models that treat eggs and larval fishes as if they were particles and simulate their movements based on hydraulic models of flows. Criticisms have applied to the use of PTMs, which rely on some key assumptions (e.g., neutral buoyancy, no active swimming) that have been challenged at least for some life stages (Kimmerer and Nobriga, 2008) on the basis that fish live and move in three dimensions. Other limitations of the use of PTMs in this case include the reliance on the one-dimensional DSM2, use of random-walks to simulate lateral movements, and the lack of simulation of fish behavior. In view of these limitations, PTMs as used in this case may not be suitable for predicting the movement of fish of some life stages (juvenile and adults) where behavior becomes relevant to the question of potential entrainment (Kimmerer and Nobriga, 2008). The NMFS acknowledges these limitations, noting that "The acoustic tagging studies also indicate that fish behavior is complex, with fish exhibiting behavior that is not captured by the 'tidal surfing' model utilized as one of the options in the PTM simulations. Fish made their way downstream in a way that was more complicated than simply riding the tide, and no discernable phase of the tide had greater net downstream movement than another" (NMFS, 2009, page 651).

However, while fish seldom behave like passive particles, results based on passive particles can provide insights. For example, the NMFS used a combination of models to simulate mortality rates of salmonids for three CalSim-II scenarios. The results were used to compare the inter- and intra-annual impacts of the three scenarios (NMFS, 2009, page 381). Further, the agencies advocate improving the model through further study, such as Action iV.2.2, which includes an acoustic tag experiment in part to evaluate action benefits and in part to improve PTM results (USBR, 2008, page 645). Thus, while there is uncertainty regarding the accuracy of the mortality losses, the use of the models in a comparative way is probably acceptable. However, it should be made clear how the model is used, and the explicit consideration of the PTM assumptions and uncertainties should be more clearly documented in the biological opinions.

Although there has not been an assessment of the degree to which these limitations affect the conclusions, PTM results were used for RPA development. Although the DSM2 has been calibrated adequately for OMR flows, there is no clear evidence concerning the accuracy of the PTM's ability to simulate smelt entrainment in relation to how the models are used for jeopardy determination and RPA development. This is particularly important because a number of actions driven by the RPAs recommend trigger values for OMR to curtail exports. As discussed in a later section, the science surrounding these OMR triggers is less clear than for many other aspects of the RPAs, and this trigger may result in significant water requirements. The committee's recommendations for improving the modeling and associated science are intended to improve the best science available to the agencies. The committee will address such improvements in greater detail in its second report.

Other Biological Models

The NMFS used other biological models to simulate the effects of operations on various life stages of salmon. These models involve several key assumptions and data limitations that influence the reliability of their results.

For example, SALMOD, developed by the USGS, was used by the NMFS to investigate the population level responses of the freshwater life stages to habitat changes caused by project operations (NMFS, 2009, page 269). A variety of weekly averaged inputs are required, including streamflow, water temperature, and number and distribution of adult spawners (USBR, 2008, page 9-25). This model provides some valuable insight, but requires greater consideration of the model assumptions (e.g., linear stream, habitat as primary limiting factor, independence of food resources on flow and temperature, density independence for some life stages) and uncertainties. Otherwise, the use of this model is limited to comparative, rather than absolute, analysis of RPA actions. Further, it would be important to investigate the sensitivity of the model to initial conditions and input data, particularly those prone to measurement error (e.g., number and distribution of spawners) to provide some indication of the reliability of model outputs. While SALMOD has not been thoroughly peer-reviewed, criticisms of similar modeling approaches (e.g., NRC, 2008) have highlighted some key issues with habitat-suitability models (e.g., the need for greater clarity concerning the assumption that habitat is a limiting factor and the need for a thorough assessment of the representativeness of the areas sampled) and have provided extensive discussions of the use of models in an adaptive-management approach, which is relevant to this committee's recommendations. Finally, the NMFS acknowledges that SALMOD is most appropriately applied to large populations that are not sensitive to individual variability and environmental stochasticity (NMFS 2009 page 270), which means that the predictions for the relatively small population in the delta river system are subject to considerable uncertainty. The uncertainties again highlight the need for an adaptive management approach.

The NMFS also used results from the USBR's salmon mortality model (Hydrologic Consultants, Inc., 1996) to examine daily salmon spawning losses for early life stages (pre-spawned eggs, fertilized eggs, and pre-emergent fry) due to exposure of high temperatures. Temperature-exposure mortality criteria for the three life stages are combined with modeled temperature predictions and spawning distribution data to compute percents of salmon spawning losses. Because simulations of river temperatures are run on a daily or shorter time step, downscaling of monthly CalSim-II data is required (Attachment H-1, USBR, 2008). Moreover, the monthly temperature models do not adequately capture the range of daily temperature variability (page 9-109, USBR 2008). In addition, several assumptions (e.g., density independence) and important data limitations (USBR, 2008, page L-6, L-7) challenge the reliability of this model. Finally, while this model has been applied in other systems, it is not thoroughly peer reviewed and no analysis of sensitivity or uncertainty has been performed. Addressing these model shortcomings would help increase confidence in the analyses.

Developing, Evaluating, and Applying Best Available Models

As the agencies work within the constraints of best available science, some recognition of the adequacy and reliability of the models should be reflected in the management decisions by making them adaptive. The following five factors, in particular, need better documentation.

1. *Incompatible temporal resolution and implications for management decisions.*

The individual models used in this tiered analysis approach have a broad range of temporal resolutions (Figure 4-1). Care must be exercised in such situations so that the linkages of models with different temporal and spatial resolutions do not result in propagation of large errors that may influence decisions derived from the modeling results. For example, CalSim-II uses a monthly time step whereas the DSM2 uses a 15-minute time step. Although the tidal boundary condition in DSM2 is pre-processed at 15-minutes, average monthly flow, simulated by CalSim-II, is provided as the upstream flow boundary condition at many delta inflow points. The linkage of CalSim-II and DSM2 attempts to smooth out the step change in monthly simulated flows (USBR, 2008, pages 9-14, 9-15), but this is not necessarily adequate to simulate the fluctuations of flows within the month. The use of the monthly time step certainly could have a significant influence on such performance measures as OMR flows, particularly when such flows are recommended in RPAs for triggering export curtailments. USFWS and NMFS should provide a comparison of daily versus monthly average simulations of DSM2 for a historical period to ascertain the reliability of using monthly CalSim output as input to DSM2.

The incompatibility of temporal resolutions is particularly important given that flows in the delta are strongly influenced by tides. The flows at such locations as Old River and Middle River are characterized by two flood-ebb cycles per day, with positive and negative values of much larger magnitude than the average net flow at these locations (Gartrell, 2010). In view of the fact that OMR flows have sub-hourly hydrodynamic components, averaging over a longer period such as 5 to 14 days to define the thresholds in the implementation of the RPAs could produce unnecessary changes in water exports. The use of monthly average flows produced by CalSim-II could further add to the concerns regarding the recommended thresholds of OMR flows. In view of these modeling uncertainties, further clarification as to how the modeled OMR flows were used for jeopardy determination and hence for the development and implementation of RPAs is needed.

2. *Inconsistent use of baselines.*

Both biological opinions use historical data along with modeling results of the CALSIM-II scenarios. Study 7.0, which represents the existing condition, is expected to be closest to historical conditions. However, important differences between the two (historical and existing conditions) could exist due to differences in demands and more importantly due to deviations in operations. Because of the simplifying assumptions used in CalSim-II historical simulations, the FWS BO opted to use actual historical data to develop their baseline (FWS, 2008, page 206) and continued to compare historical data with the modeling results of the numerous scenarios described above (see, for example, Figures E-3 through E-19).

The results suggest that often, actual data are very different in magnitude in comparison to Study 7.0 and furthermore, most scenarios (Studies 7, 7.1, 8, and study series 9) are clumped together with relatively small differences between them in relation to the magnitude of differences with the historical data. In view of these differences, the validation of Study 7.0 and consequently others, becomes even more important for the purpose of RPA development.

The use of historical data to make inferences is very typical and appropriate in the biological opinions. However, since the evaluation of project actions and the development of RPAs are based on the evaluation of modeling scenarios, which appear to greatly differ from historical data, a comparison of the two sets of data (historical and simulated) may incur errors in interpretation. The committee recommends that the biological opinions provide a better justification for the reasonableness of the baseline scenario, Study 7.0, as well as the comparison of scenario results with historical data.

3. *Challenges in calibrating and validating any of the models to historical observations and operations.*

It is a standard practice to ensure the appropriate use of models through the processes of calibration and testing (ASTM, 2008; NRC 2008). Validation of CalSim-II is described in Appendix U of the OCAP BA (USBR, 2008), which provides a comparison of Study 7.0 (existing condition) with the recent historical data. A review of those results shows that there are significant deviations of the historical data from the simulated storages and exports that may be of the same magnitude as the differences between the scenarios being evaluated. Thus, while the tool itself performs well, some questions remain regarding the gross nature of generalized rules used in CalSim-II to operate CVP and SWP systems, relative to actual variability of dynamic operations (USBR, 2008, pages 9-4). In their peer review of the CalSim-II model, Close et al. (2003) suggested that "Given present and anticipated uses of CalSim-II, the model should be calibrated, tested, and documented for "absolute" or non-comparative uses." It is not clear if the agencies that developed the model have responded to this suggestion in a comprehensive manner. As emphasized above, a clear presentation of the realism of Study 7.0 with respect to recent operations or observations would help avoid the criticism as to the results of Study 7.0 as well as other derivatives of it (Studies 7.1, 8.0 and series 9).

The OCAP BA (USBR, 2008) provides sufficient information on the calibration and testing of temperature models, and the time steps vary among models, although all used the monthly output of CalSim-II in predictions. Thus, they appear to be adequate for predicting temperature variation and making comparisons at the monthly time scale. Information on the calibration of DSM2 and PTM is provided in part by DWR, which has been posted online (http://modeling.water.ca.gov/delta/studies/validation2000/) results of the calibration of this 1-D, hydrodynamic model of the delta. Based on the information provided, it appears to adequately mimic the historical data at a daily time-scale. However, the DSM2 simulations should demonstrate that the range of negative OMR flows used for calibration covers the high negative flows simulated by CalSim-II for future scenarios. There has been an attempt to test PTM (Wilbur, 2001), but clearly this tool needs further improvements. Wilbur (2001) reports that the existing velocity profiles used in PTM consistently over-predict the field observations (i.e., the predicted velocities exceed the observed velocities).

In addition, with the potential for changes in the historical patterns of climate and hydrology, calibrating models with historical data alone may be less meaningful for projection of future operations. Thus, in addition to providing support for model improvement and adaptive management, a more robust monitoring program will also support calibration and testing of models with more relevant representation of the current and future system. For example, drought-induced low flows of the past several years provide opportunities to calibrate and test models under infrequent but foreseeable conditions. Realistic modeling of the system that incorporates what actually happens in an operational setting with climate outlook will be important in the future.

The biological models such as USBR's mortality model and SALMOD are essentially uncalibrated for the system, and further concerns about these models were addressed in previous sections.

4. Challenges of the Tiered Modeling Approach.

Temperature, OMR flows, and X2 performance measures are particularly challenged by the tiered modeling approach, with limitations related to data availability and inconsistency in model resolution (spatial and temporal) and complexity (USBR, 2008, page 9-31). However, the use of models may still be beneficial in planning and triggering adaptive management needs. For example, for NMFS implementation of Action II.2 (Lower American River Temperature Management), forecasts will be used to simulate operations and compliance with thermal criteria for specific life stages in months when salmon would be present (NMFS, 2009, page 614). However, if the USBR determines that it cannot meet the temperature requirement, and can demonstrate this through modeling of allocations and delivery schedules, consultation with the NMFS will occur. In this example, modeling results are used to evaluate the feasibility of meeting criteria, rather than trying to derive direct loss estimates. The RPA then leads to a process for adaptive management of the temperature operations based on updates to the hydrologic information. Thus, despite the particularly challenging example of managing temperature, the use of models appears to have allowed for flexibility.

However, no qualitative or quantitative analysis of the magnitude of errors across these model linkages and the resulting uncertainties are presented. While not required for the justification of RPAs, failing to consider error propagation across the models makes it difficult to evaluate the reliability of meeting the RPAs and their ability to provide the intended benefits.

5. Lack of an integrative analysis of RPAs

Numerous RPA actions proposed in both biological opinions cover new projects as well as operational changes. However, the information provided to the committee did not include a comprehensive analysis of all RPA actions, either individually or, more important, jointly, with respect to their ability to reduce the risks to the fish or to estimate system-wide water requirements. Clearly, the agencies lacked properly linked operations/hydrodynamic/biological models at the appropriate scales for RPA development. The agencies should be complimented for using historical data as well as best available science when modeling was not adequate. However, the proposed RPAs could incur significant water supply costs, and there should be an attempt to provide an integrative analysis of the RPAs with quantitative tools. The committee also acknowledges the challenges associated with estimating water requirements for some RPAs, particularly those based on adaptive management strategies, but explicit and transparent consideration of water requirements and biological benefits of specific actions and of subsets of actions would provide the basis for a smoother implementation of the RPAs.

The committee recommends that the agencies consider investigating the use of CalSim-II and other quantitative tools (e.g., PTM, life-cycle models) to simulate appropriate RPA actions of both biological opinions. These linked models would allow an integrated evaluation of the biological benefits and water requirements of individual actions and suites of actions, and the identification of potential species conflicts among the RPAs. Although not required by the ESA, such an integrative analysis would be helpful to all concerned to evaluate the degree to which the RPAs are likely to produce biological benefits and to quantify the water requirements to those who might be affected by the future actions of the two biological opinions. In addition to further model development, efforts to improve documentation of model use would be beneficial. Documentation should include a record of the decisions, assumptions, and limitations of the models (e.g., NRC, 2008).

Thus, we find that, while used appropriately in this analysis, the PTM and biological models for both salmon and smelt should be further developed, evaluated, and documented**.** The models show promise for being quantitative tools that would allow for examination of alternative ideas about key relationships underlying the RPAs. In addition, complete life-cycle models capable of being linked to these other models should be developed. Although developing, testing, and evaluating such models would require a significant investment, the committee judges that the investment would be worthwhile in the long term.

CONCLUSION

Modeling is useful for understanding the system as well as predicting future performance. As long as modelers understand and accurately convey the uncertainties of models, they can provide valuable information for making decisions. The committee reviewed the models the agencies used to determine to what degree they used the models in developing the RPAs. The biological opinions have used results of a variety of operations, hydrodynamic, and biological models currently available to them for RPA development. However, the agencies have not developed a comprehensive modeling strategy that includes the development of new models (e.g., life-cycle and movement models that link behavior and hydrology); such models may have provided important additional information for the development of RPAs. Nonetheless, the agencies should be complimented for combining the available modeling results with historical observations and peer-reviewed literature. The committee also compliments the agencies for the extensive discussion and presentation of the rationale for the particular types of actions proposed in the RPAs.

The committee concluded that as far as they went, despite flaws, the individual models were scientifically justified, but that they needed improvements and that they did not go far enough toward an integrated analysis of the RPAs. The committee has raised several important issues related to the modeling process used, including the model scale and management information; the adequacy of models, particularly the particle-tracking model and the lack of life-cycle models; incompatibilities in both temporal and spatial scales among the models and between model output and the scale of the RPA actions; the use of baselines; inadequate calibration and testing of modeling tools (in some cases); and inadequate model documentation. A more-thorough, integrative evaluation of RPA actions with respect to their likelihood of reducing adverse effects on the listed fishes and their likely economic consequences, coupled with clear documentation would improve the credibility and perhaps the acceptance of the RPAs. Thus the committee concluded that improving the models by making them more realistic and by better matching the scale of their outputs to the scale of the actions, and by extending the modeling to be more comprehensive and to include features such as fish life cycles would improve the agencies' abilities to assess risks to the fishes, to fine-tune various actions, and to predict the effects of the actions. Three-dimensional models are more expensive and time-consuming than simpler models, but they can contribute valuable understanding if used appropriately (e.g., Gross et al., 1999; Gross et al. 2009).

In addition, the committee concludes that opportunities exist for developing a framework to improve the credibility, accountability, and utility of models used in implementing the RPAs. The framework will be particularly important for some of the more-complex actions, such as those involving Shasta and San Joaquin storage and flows, which rely heavily on model predictions. The committee plans to address such issues, including the framework mentioned above, in more detail in its second report.

5

Other Stressors

INTRODUCTION

Declines in the listed species must be considered in the context of the many changes that are occurring in the "baseline" factors in the region. While the CVP and SWP pumps kill fish, no scientific study has demonstrated that pumping in the south delta is the most important or the only factor accounting for the delta-smelt population decline. Therefore, the multiple other stressors that are affecting fish in the delta environment as well as in the other environments they occupy during their lives must be considered, as well as their comparative importance with respect to the effects of export pumping. These factors and their impacts, only some of which originate within the delta itself, will be described in greater detail in the committee's second report. Some are described here to highlight their potential importance and to underscore that a holistic approach to managing the ecology of imperiled fishes in the delta will be required if species declines are to be reversed. The factors described here are not meant to be exhaustive, but are intended to demonstrate that the effects of these factors are numerous and, in some cases, not only potentially very important but also under-characterized. Moreover, while individual relationships with these stress factors are generally weakly understood, the cumulative or interactive effects of these factors with each other and with water exports are virtually unknown and unexplored (Sommer et al., 2007).

CONTAMINANTS

It has long been recognized that contaminants are present in the delta, have had impacts on the fishes, and may be increasing (Linville et al., 2002; Davis et al., 2003; Edmunds et al., 1999). Contamination of runoff from agricultural use of pesticides has been documented and has been shown to affect invertebrates and other prey, as well as on some life stages of fish (e.g., Kuivila and Foe, 1995; Giddings, 2000; Weston et al., 2004). Kuivila and Moon (2004) found that larval and juvenile delta smelt coincide with elevated levels of pesticides in the spring. Pyrethroid insecticide use has increased in recent years. Such insecticides have been found in higher concentrations in runoff, and may be toxic to macroinvertebrates in the sediment (Weston et al., 2004, 2005); it is toxic to the amphipod *Hyalella azteca*, which is found in the delta (Weston and Lydy, 2010). The use of pyrethroids increased substantially in the recent years during which the decline of pelagic organisms in the delta became a serious concern as compared to earlier decades (Oros and Werner, 2005). Among other identified contaminants that may also have effects are selenium and mercury. Histopathological studies have shown a range of effects, from little to no effect

(Foott et al., 2006) to significant evidence of impairment depending on species, timing, and contaminant biomarker.

ALTERED NUTRIENT LOADS

Nutrients have received recent attention as a potential stress factor for phytoplankton, zooplankton, and fish populations for several reasons. First, research by Wilkerson et al. (2006) and Dugdale et al. (2007) found that phytoplankton (diatom) growth in mesocosm experiments did not occur under *in situ* ammonium levels, and only increased when ammonium levels were reduced. They interpreted this finding to mean that diatom growth was suppressed under ambient ammonium levels, and only after ammonium concentrations began to be drawn down did diatoms begin to use nitrate, an alternate nitrogen form, and then proliferate.

With respect to nutrient loading effects, declines in phosphate loading may be related to declines in chlorophyll-*a* throughout the Sacramento-San Joaquin delta (Van Niewenhuyse, 2007). While these results show that chlorophyll-*a* in the water column declined coincident with the decline in phosphate in 1996, phosphate levels, both inorganic and organic, are not at extremely low concentrations in the water. Nevertheless, the effects of the rapid and substantial change in the ratio of inorganic nitrogen to inorganic phosphate in the system have yet to be adequately explored.

CHANGES IN FOOD AVAILABILITY AND QUALITY

Significant changes in the food web may have affected food abundance and food quality available to delta smelt. From changes in zooplankton to declines in chlorophyll to increases in submerged aquatic vegetation, these changes have enormous effects on the amount and quality of food potentially available for various fish species (e.g., Muller-Solger et al., 2006; Bouley and Kimmerer, 2006). The benthic community was significantly changed after the overbite clam, *Corbula amurense*, became dominant in the late 1980s; such changes have effects on food availability that may cascade through the food web to affect the abundance of delta smelt.

In addition to changes in food availability, other changes in the food web have had potentially large impacts on smelt. Since 1999, blooms of the cyanobacterium *Microcystis* have increased and are especially common in the central delta when water temperatures exceed 20^{o}C (Lehman et al., 2005). Although delta smelt may not be in the central delta during the period of maximum *Microcystis* abundance, during dry years the spread of *Microcystis* extends well into the western delta so that the zone of influence may be greater than previously thought (Lehman et al., 2008). Most recently it has been demonstrated that the *Microcystis* toxin, microcystin, not only is present in water and in zooplankton, but histopathological studies have shown liver tissue impacts on striped bass and silversides (Lehman et al., 2010).

INTRODUCED FISHES

The delta is a substantially altered ecosystem, and that applies to the fish species present as well. Some environmental changes likely enhance the spread of nonnative species (for example warm, irregularly flowing water around dams or diversions can favor warm-water species) (FWS 2008 p. 147), as can the presence of riprap to support banks (Michny and Hampton, 1984). Thus, the spread of nonnative species may be, at least in part, an effect of other ecosystem changes. Once nonnative species become established, they further alter the ecosystem. Some species, such as American shad (*Alosa sapidissima*) and striped bass (*Morone saxatilis*), native to the Atlantic and Gulf coasts of North America, have been present in the delta region since the late 19th century (Lampman, 1946; Moyle, 2002). Striped bass (along with the native Sacramento pikeminnow, *Ptychocheilus grandis*) have been implicated as predators on juvenile Chinook salmon, especially when they congregate below the Red Bluff Diversion Dam (Tucker et al., 2003) and other structures; at the Suisun Marsh Salinity Control Gates they were the dominant predator on juvenile Chinook salmon (Edwards et al., 1996; Tillman et al., 1996). Other introductions are more recent, and some might be more threatening to native species. For example, the silverside, *Menidia beryllina*, is becoming more widespread in the delta and likely preys on juvenile delta smelt (Moyle, 2002) or competes for similar copepod prey (Bennett and Moyle, 1996). Largemouth bass (*Micropterus salmoides*) and many other members of its family (Centrarchidae), along with various species of catfish (family Siluridae), native to the Mississippi and Atlantic drainages, also are increasing, while the lone member of the centrarchid family that was native to the region, the Sacramento perch (*Archoplites interruptus*), no longer occurs in the delta (Moyle 2002). All the above species include fish in their diets to a greater or lesser degree, including various life stages of delta smelt at times. In addition, other species, such as common carp (*Cyprinus carpio*) and threadfin shad (*Dorosoma petenense*), are not significant piscivores, but likely compete with delta smelt for food or otherwise affect their environment. Finally, the wakasagi (*Hypomesus nipponensis*), an introduced Japanese smelt very similar to the delta smelt, is becoming increasingly widespread in the delta. It interbreeds and competes with the delta smelt and might prey on it, and its presence in the delta complicates the assessment of delta smelt populations and salvage because it is so similar to the delta smelt that it is not easy to distinguish between the two species (Moyle, 2002). Delta smelt have co-existed with many of these alien fishes for more than 100 years before the recent declines, and so the decline of smelt cannot be attributed entirely to their presence, but some species have increased recently and their effects on smelt and salmonids—including on the potential for smelt populations to recover—have not been well studied.

IMPEDIMENTS TO PASSAGE, CHANGES IN OCEAN CONDITIONS, FISHING, AND HATCHERIES

Clark (1929) estimated that 80% of the original spawning habitat available to Chinook salmon in California's Central Valley had been made unavailable by blockages, mainly dams, by 1928. A similar loss of habitat has occurred for Central Valley steelhead as well (Lindley et al., 2006). Dams, diversion points, gates, and screens also affect green sturgeon. Ocean conditions vary, and in general they fluctuate between periods of relatively high productivity for salmon and lower productivity (Hare et al., 1999; Mantua and Hare, 2002). Lindley et al. (2009) concluded that ocean conditions have recently been poor for salmon, although there has been a long-term, steady deterioration in freshwater and estuarine environments as well. Sport and commercial fishing for salmon, sturgeon, and steelhead has been tightly regulated both at sea and in freshwater, and in 2008, there was a complete closure of the commercial and recreational fishery for

Chinook salmon (NMFS, 2009, page 145). However, Chinook salmon make very long oceanic migrations and their bycatch in other fisheries cannot be totally eliminated (NRC 2005). Hatchery operations have been controversial, but it is almost impossible to operate hatcheries without adverse genetic and even ecological effects on salmon (NRC, 2004b; NMFS, 2009, page 143) or steelhead (NMFS, 2009, page 143).

DISEASES

Histopathological studies have revealed a range of diseases of potential concern in the delta. For example, parasites have been found in threadfin shad gills, but not at a high enough infection rate to be of alarm, but evidence from endrocrine disruption analyses shows some degree of intersex delta smelt males, having immature oocytes in the testes (Teh et al., unpublished data). Other investigators have found myxosporean infections in yellowfin goby in Suisun Marsh (Baxa et al., unpublished data). These and other measures suggest that parasitic infections, viral infections, or other infections are affecting fish, and that interactions with other stressors, such as contaminants, may be having increasing effects on fish.

CLIMATE CHANGE

Climate change could have severe negative consequences for the listed fishes. There are at least three reasons why this is of concern. First, the recent meteorological trend has runoff from the Sierra Nevada shifting from spring to winter as more precipitation falls as rain rather than snow, and as snowmelt occurs earlier and faster because of warming, increasing the likelihood and frequency of winter floods and altered hydrographs, and thus changes in the salinity of delta water (Roos, 1987, 1991; Knowles and Cayan, 2002, 2004). Alteration of precipitation type and timing of runoff may affect patterns in reproduction of the smelt and migration of salmon and sturgeon (Moyle, 2002). Additionally, effects of sea-level rise will increase salinity intrusion further upstream, again impacting fish distributions that rely on salinity gradients to define habitat; their habitat will be reduced. Lastly, as climate warms, so too does the water. This will impact fish distributions in several ways. Temperature is a cue for many biological processes, so many stages of the life cycle are likely to be affected. Moreover, warmer water will mean proportionately more days in which the temperature is in the lethal range, ~25^{o}C (Swanson et al., 2000). The effects of these climate consequences are less suitable habitat for delta smelt in future years as well as threats to the migration of anadromous species like salmon and sturgeon.

CONCLUSION

Based on the evidence summarized above, the committee agreed that the adverse effects of all the other stressors on the listed fishes are potentially large. Time did not permit full exploration of this issue in this intense first phase of the committee's study. The committee will explore this issue more thoroughly in its second report.

6

Assessment of the RPAs

INTRODUCTION

The RPAs include many specific actions that fall into several categories for each species. The RPA in the FWS biological opinion for delta smelt focuses on limiting OMR negative flows in winter to protect migrating adults (Actions 1 and 2) and to protect larval smelt (Action 3) from entrainment at the export pumps. It also aims to protect estuarine habitat for smelt during the fall by managing the position of X2 (Action 4). Action 5 is to protect larval and juvenile smelt from entrainments by refraining from installing the Head of Old River Barrier (HORB) depending on conditions; if the HORB is installed, then the Temporary Barrier Project's gates would remain open. Finally, Action 6 calls for restoration and construction of 8,000 acres of intertidal and tidal habitat.

The RPA in the NMFS biological opinion for Chinook salmon, Central Valley steelhead, and green sturgeon is divided into far too many specific actions (72) to summarize here, but the biological opinion describes 10 major effects of the RPA on the listed species. They include management of storage and releases to manage temperature in the Sacramento River for steelhead and salmon; maintaining flows and temperatures in Clear Creek for spring-run Chinook salmon; opening gates at the Red Bluff Diversion Dam (RBDD) at critical times to promote passage for salmon and sturgeon; improving rearing habitat for salmon in the lower Sacramento River and in the northern delta; closure of the gates of the Delta Cross Channel (DCC) at critical times to keep juvenile salmon and steelhead out of the interior delta and instead allowing them to migrate out to sea; limiting OMR negative flows to avoid entrainment of juvenile salmon; increased flows in the San Joaquin River and curtailment of water exports to improve survival of San Joaquin steelhead smolts, along with an acoustic tagging program to evaluate the effectiveness of this action; flow and temperature management on the American River for steelhead; a year-round flow regime on the Stanislaus River to benefit steelhead; and the development of Hatchery Genetics Management Plans at the Nimbus (American River) and Trinity River hatcheries to benefit steelhead and fall-run Chinook salmon.

Rather than review every action and every detail, the committee comments on the broader concepts at issue and general categories of actions. Three important goals are to consider how well the RPAs are based on available scientific information; whether there are any potential RPAs not adopted that would have lesser impacts to other water uses as compared to those adopted in the biological opinions, and would provide equal or greater protection for the listed fishes; and whether there are provisions in the FWS and NMFS biological opinions to resolve potential incompatibilities between them. In addition we assess the integration of the RPAs within and across species and across all actions.

Addressing these goals requires explicitly recognizing the fundamental differences in the main conflicting arguments. There is concern, on one hand, that the increasing diversions of water from the delta over a period of many decades and the alteration of the seasonal flow regime have contributed to direct effects on populations of native species through mortality at the pumps, changes in habitat quality, and changes in water quality; and to indirect, long-term effects from alterations of food webs, biological communities, and delta-wide habitat changes. The RPAs propose that their collective effects will offset the impacts of the proposed operations of the SVP and the CWP by manipulating river flows and diversions, along with other actions. An alternative argument is that the effects of water diversions on the listed fishes are marginal. It is argued that the changes imposed by the RPAs would result, therefore, only in marginal benefits to the species, especially now that the delta environment and its biota have been altered (to a new ecological baseline) by multiple stressors. Those stressors obviously include water exports, but this argument suggests a smaller role for water exports in causing the fish declines and hence a smaller role for managing the exports to reduce or halt those declines. However, even with the copious amounts of data available, it is difficult to draw conclusions about what variable or variables are most important among the pervasive, irregular, multivariate changes in the system that have occurred over the past century.

The committee's charge was to provide a scientific evaluation, not a legal one, and that is what is presented below. Nothing in this report should be interpreted as a legal judgment as to whether the agencies have met their legal requirements under the ESA. The committee's report is intended to provide a scientific evaluation of agency actions, to help refine them, and to help the general attempt to better understand the dynamics of the delta ecosystem, including the listed fishes.

DELTA SMELT

Actions Related to Limiting Flow Reversal on the Old and Middle Rivers (OMR)

The general purpose of this set of actions is to limit the size of the zone of influence around the water-diversion points at critical times. The actions would limit negative OMR flows (i.e., toward the pumps) by controlling water exports during crucial periods in winter (December through March) when delta smelt are expected to be in the central delta (FWS, 2008). The data supporting this approach show an increase in salvage of delta smelt as OMR flows become more negative. However, there are important disagreements about how to express salvage and the choice of the trigger point or threshold in negative flows above which diversions should be limited.

An important issue is whether and how salvage numbers should be normalized to account for delta smelt population size. An increase in salvage could be due to an increase in the number of smelt at risk for entrainment, an increase in negative flows that bring smelt within range of the pumps, or both. Thus, an increase in salvage could reflect a recovery of the smelt population or it could reflect increasingly adverse flows toward the pumps for the remaining smelt population. The biological opinion (FWS, 2008) recognizes this relationship, and that is why salvage is used to calculate the percentage of the population entrained, rather than absolute numbers (FWS, 2008, Figures E-4 and E-5). However, the historical distribution of smelt on which the relationship with OMR flows was established no longer exists. Delta smelt are now sparsely distributed in the central and southern delta (www.dfg.ca.gov/delta/data), and pump salvage also has been extremely low, less than 4% of the 50-year average index. Since 2005, a significant portion of the remaining smelt population, 42% (Sommer et al., 2009), is in the Cache Slough complex to the north and is therefore largely isolated from the central delta. These changes in the distribution of delta smelt increase the uncertainty surrounding current estimates of the population and its likely response to alterations in delta hydraulics, and until the numbers of smelt rise closer towards the pre-2005 levels, they do not provide a reliable index for incorporation into models for the effects of pumping on smelt salvage.

Different authors have taken different statistical approaches to analyzing the data to interpret the relationship between OMR flows and effects on smelt, and thus chose different thresholds at which OMR flows should be limited. The choice of the limit to negative flows in the RPA gives the benefit of the doubt to the species. But there are important uncertainties in the choice. The different trigger points suggested by the different analyses have important implications for water users. The committee concludes that until better monitoring data and comprehensive life-cycle and fish-movement models are available, it is scientifically reasonable to conclude that high negative OMR flows in winter probably adversely affect smelt. We note as well that actions 1 and 2 of the FWS RPA are adaptive in that they depend for their implementation on a trigger related to measured turbidity and measured salvage numbers; they also may be suspended during three-day average flows of 90,000 cfs or greater in the Sacramento River at Rio Vista and 10,000 cfs or greater in the San Joaquin River at Vernalis. However, the portion of the existing smelt population in the Cache Slough complex appears not to move downstream towards the brackish areas (Sommer et al., 2009) and thus they should be largely insulated from the effects of the OMR flows and actions 1 and 2.

The biological benefits and the water requirements of this action are likely to be sensitive to the precise values of trigger and threshold values. There clearly is a relationship between OMR flows and salvage rates, but the available data do not permit a confident identification of the threshold values to use in the action, and they do not permit a confident assessment of the benefits to the population of the action. As a result, the implementation of this action needs to be accompanied by careful monitoring, adaptive management, and additional analyses.

Some monitoring and reporting is required in RPA component 5 (monitoring and reporting). However, more should be required, recognizing limits to the agencies' and operators' human and fiscal resources. Given the uncertainties in any choice of a trigger point, a carefully designed study that directly addresses measures of the performance (effectiveness) of the action is essential. This could include monitoring of variables like salvage at the pumps and numbers of delta smelt adults and larvae at the south ends of OMR channels during pumping actions, but it should also include other variables that might affect both salvage and populations. History shows that salvage and delta smelt indices have been insufficient for such an analysis alone, partly because the populations are small and partly because of the uncertainties in the salvage numbers (e.g., to what degree do they accurately reflect mortality, and to what degree are they affected by sampling error?). This deficiency in the data needs to be remedied. But other "proximate" measures such as monitoring of flows over the tidal cycle between and during the pumping limitations could help to understand the driving mechanism for the predicted entrainment mortality associated with pumping. Measuring mean daily discharges also is not sufficient. Temperature, salinity, turbidity, and possibly other environmental factors should also be monitored at appropriate scales as this action is implemented, to determine the availability of suitable habitat in the south delta during periods of reduced pumping. Information also is needed on how fish movement is affected by the immediate water-quality and hydraulic environment they experience. Because the effectiveness of the pumping needs to be expressed in terms of the population, the influence of pumping needs to be identified in more life-stage and area specific measures, In particular, the relevance of the Cache Slough complex needs to be resolved in assessing the effectiveness of pumping restrictions. In addition, because uncertainty is high regarding several aspects of this action, it would be helpful to include an accounting of the water requirements. Ongoing evaluation of performance measures could ultimately reduce the water requirements of actions and increase the benefits to the species. Addressing the effectiveness of the proposed actions on a long-term basis could also support consensus conclusions about the effectiveness of specific actions and increase public trust. To the degree that such studies could be jointly planned and conducted by the agencies and other interested parties, transparency and public trust would be enhanced.

X2 Management for Delta Smelt

Although the mean position of X2, the isohaline (contour line of equal salinity) of total salinity 2, is a measure of the location of a single salinity characteristic, it is used in this system to indicate the position and nature of the salinity gradient between the Sacramento River and San Francisco Bay. The position of X2 is measured in kilometers from the Golden Gate Bridge. In the RPA, it has been used by the agencies as a measure of the amount of smelt habitat—influenced by salinity as well as temperature and turbidity, which are also driven by the river-estuary interaction—and thus to approximate the seasonal extent and shifting of that habitat within the ecosystem. By this reasoning, the position of X2 affects the size of delta smelt habitat (Feyrer et al., 2007; Kimmerer, 2008a).

The RPA's action 4 (FWS, 2008, page 369) proposes to maintain X2 in the fall of wet years at 74 km east of the Golden Gate Bridge and in above-normal years at 81 km east. (The action was restricted to wetter years in response to consultation with the NMFS, which expressed concern that in drier years, this action could adversely affect salmon and steelhead [memorandum from FWS and NMFS to this committee on coordination, January 15, 2010].) The action is to be achieved primarily by releases from reservoirs. The objective of the component is to manage X2 to increase the quality and quantity of habitat for delta smelt growth and rearing.

The relationship between the position of X2 and habitat area for delta smelt, as defined by smelt presence, turbidity, temperature, and salinity (Nobriga et al, 2008; Feyrer et al., in review), is critical in designing this action. A habitat-area index was derived from the probability of occurrence estimates for delta smelt (fall mid-water trawl survey, FMT) when individuals are recruiting to the adult population. Presence/absence data were used because populations are so small that quantitative estimates of populations probably are unreliable. The authors show a broad relationship between the FMT index and salinity and turbidity, supporting the choice of these variables as habitat indicators. The statistical relationship is complex. When the area of highly suitable habitat as defined by the indicators is low, either high or low FMT indices can occur. In other words, delta smelt can be successful even when habitat is restricted. More important, however, is that the lowest abundances all occurred when the habitat-area index was less than 6,000 ha. This could mean that reduced habitat area is a necessary condition for the worst population collapses, but it is not the only cause of the collapse. Thus, the relationship between the habitat and FMT indexes is not strong or simple. Above a threshold on the x-axis it allows a response on the y-axis (allows very low FMT indices).

The controversy about the action arises from the poor and sometimes confounding relationship between indirect measures of delta smelt populations (indices) and X2. The weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand. In addition, although the position of X2 is correlated with the distribution of salinity and turbidity regimes (Feyrer et al., 2007), the relationship of that distribution and smelt abundance indices is unclear. The X2 action is conceptually sound in that to the degree that habitat for smelt limits their abundance, the provision of more or better habitat would be helpful. However, the examination of uncertainty in the derivation of the details of this action lacks rigor. The action is based on a series of linked statistical analyses (e.g., the relationship of presence/absence data to environmental variables, the relationship of environmental variables to habitat, the relationship of habitat to X2, the relationship of X2 to smelt abundance), with each step being uncertain. The relationships are correlative with substantial variance being left unexplained at each step. The action also may have high water requirements and may adversely affect salmon and steelhead under some conditions (memorandum from FWS and NMFS, January 15, 2010). As a result, how specific X2 targets were chosen and their likely beneficial effects need further clarification.

The X2 action for delta smelt includes a requirement for an adaptive management process that includes evaluation of other possible means of achieving the RPA's goal and it requires the establishment and peer review of performance measures and performance evaluation. It also requires "additional studies addressing elements of the habitat conceptual model" to be formulated as soon as possible and to be implemented promptly. Finally, it requires the FWS to "conduct a comprehensive review of the outcomes of the Action and the effectiveness of the adaptive management program ten years from the signing of the biological opinion, or sooner if circumstances warrant." This review is to include an independent peer review; the overall aim is to decide whether the action should be continued, modified, or terminated. It is critical that these requirements be implemented in light of the uncertainty about the biological effectiveness of the action and its high water requirements.

Tidal Habitat Action

The proposed RPA calls for the creation or restoration of 8,000 acres of intertidal and associated subtidal habitat in the delta and in Suisun Marsh. A separate planning effort also is under way for Suisun Marsh. The justification provided in the biological opinion is that the original amount of approximately 350,000 acres of tidal wetland has been reduced to less than 10,000 acres today, that the near-complete loss of tidal wetlands threatens delta smelt by reducing productivity at the base of the food web, and that delta smelt appear to benefit from the intertidal and subtidal habitat in Liberty Island, which includes tidal wetlands. This action has been less controversial than the others because it does not directly affect other water users.

However, although the concept of increasing and improving habitat to help offset other risks to smelt is conceptually sound, the scientific justification provided in the biological opinion is weak, because the relationship between tidal habitat and food availability for smelt is poorly understood, and it is inadequate to support the details of the implementation of this action. The opinion notes the importance of high-quality food sources to delta smelt and the association of these food resources with tidal habitats (including wetlands), and it references recent monitoring data from Liberty Island showing that such freshwater tidal habitats can be a source of high-quality phytoplankton that contribute to the pelagic food web downstream (p. 380). However, the specifics of which attributes of tidal habitat are essential to providing these food sources are not addressed.

In addition, the California Department of Fish and Game has raised questions about the details of this action (Wilcox, 2010). They include questions about the relative benefits of vegetated tidal marsh as opposed to open water; the extent to which invasive clams may divert new primary production; the amount of suitable productivity exported from restoration areas; the potential effect of the restored habitat on predation; the importance of productivity from vegetated tidal marsh directly or indirectly to the smelt; and the degree to which other fish species might use the habitat, possibly to the detriment of the smelt In briefings to the panel, the importance of ongoing studies in resolving these issues was identified. Identifying the characteristics of the "intertidal and associated subtidal habitat" that the action is expected to produce is needed to ensure that expectations of the outcomes, in terms of both habitat type and species benefits, are clear to all. The relative roles of areas of emergent vegetation, unvegetated intertidal and shallow, highly turbid subtidal habitat must be identified for the action to be effectively implemented.

The committee recommends that this action be implemented in phases, with the first phase to include the development of an implementation and adaptive management plan (similar to the approach used for the floodplain habitat action in the NOAA biological opinion), but also to explicitly consider the sustainability of the resulting habitats, especially those dependent on emergent vegetation, in the face of expected sea-level rise. In addition, there should be consideration of the types and amounts of tidal habitats necessary to produce the expected outcomes and how they can be achieved and sustained in the long term. More justification for the extent of the restoration is needed. The committee supports the monitoring program referred to in Action 6, and appropriate adaptive management triggers and actions.

SALMONIDS AND STURGEON

The NMFS RPA for salmon, steelhead, and green sturgeon is a broad complex of diverse actions spanning three habitat realms: tributary watersheds, the mainstem Sacramento and San Joaquin Rivers, and the delta. On balance, the actions are primarily crafted to improve life-stage-specific survival rates for salmon and steelhead, with the recognition that the benefits also will accrue to sturgeon. The committee agrees with this approach. The conceptual bases of the strategies underpinning many of the individual actions are generally well-founded, although the extent to which the intended responses are likely to be realized is not always clear. Given the absence of a clear, quantitative framework for analyzing the effects of individual and collective actions, it is difficult to make definitive statements regarding the merits of such a complex RPA. Indeed, absent such an analysis, the controversial aspects of some of the RPA actions could detract from the merits of the rest of the RPA.

The assortment of actions among the three habitat realms (watersheds, mainstem rivers, and delta) is designed to improve survival and to enhance connectivity throughout this system. This approach is consistent with the contemporary scientific consensus on improving ecosystem functioning as a means to improve productivity of anadromous and other migratory species (e.g., Williams 2005; NRC 1996, 2004a, 2004b). Watershed actions would be pointless if mainstem passage conditions connecting the tributaries to, and through, the delta were not made satisfactory.

Watershed and Mainstem River Actions

Watershed-level actions that are implemented in the tributaries are organized and formulated to meet the needs of specific listed populations in that system. The actions target limiting factors specific to those locales and populations. In general, the rationale for conducting the actions appears to be well-founded. However, it is difficult to ascertain to what extent, or even whether, the collective actions will appreciably reduce the risk to the fishes within the watershed or throughout the entire river system. We suggest that inclusion of some type of quantitative analysis using a tool like Ecosystem Diagnosis and Treatment (EDT) model during the planning process may have provided an even stronger justification for the set of actions selected (http://jonesandstokes.com/). We understand there is a recent application of EDT in the lower San Joaquin River, by Jones & Stokes, thus providing a precedent for its use in California's Central Valley. EDT is presented here as an example of a quantitative modeling approach that integrates the effects of various actions to produce relative changes in productivity and abundance. The committee emphasizes the need for a quantitative assessment framework, and does not necessarily specifically advocate the use of EDT.

The RPA also prescribes actions to improve mainstem passage conditions, most notably at the Red Bluff Diversion Dam (RBDD). The objective is to provide unobstructed upstream passage at the RBDD, to ensure more efficient access of adult salmonids to restored watersheds, and access for adult sturgeon to spawning grounds. Without such actions connectivity could not be fully realized. Furthermore, the passage improvement at the diversion dam, in combination with increased water delivery from storage reservoirs, is expected to improve smolt survival during downstream migration. This component is well justified scientifically, although the absence of a system-wide salmon survival model limits our ability to evaluate the extent to which this action contributes to improved survival for the populations in question.

Smolt Survival Near and Through the Delta

The net survival of salmonid smolts though the mainstem rivers and the delta under different water-management operations is of keen interest. Several RPA actions are intended to improve survival of the juveniles as they migrate seaward. Some of these actions have significant water requirements, and so they are controversial. The common goal of these actions is improve smolt survival by retaining a high proportion of the migrating smolt population in the mainstem Sacramento and San Joaquin Rivers. This involves two general approaches: block entrances to the interior delta, or manipulate currents in major channels to reduce the transport of smolt towards the pump facilities and possible entrainment or locations where they may be lost to predation, starvation, or disease. Here we focus on three pivotal actions: the closure of the Delta Cross Channel, the manipulation of OMR flows, and water-management actions in the lower San Joaquin River.

Delta Cross Channel (DCC)

As smolts migrate seaward from the upper Sacramento River they encounter the DCC near Walnut Grove. The DCC can at times draw large volumes of water from the Sacramento River, and some of the smolts follow that current toward the interior delta, where salmon mortality is high.

The objective of this action is to physically block the entrance of the DCC at strategic times during the smolt migration, thereby preventing access to the interior delta. This is a long-standing action that appears to be scientifically justified. However, Burau et al. (2007) estimated that when the DCC gates are open, approximately 45 percent of the Sacramento River flow measured at Freeport is redirected into the delta interior through the DCC and Georgiana Slough. The salmon action (Action Suite IV.1), which under certain triggers requires prolonged closure of the DCC gates from October 1 through June 15, must also consider the effects on delta smelt. The Smelt Working Group (notes from June 4, 2007 meeting) concluded that there could be a small beneficial effect on delta smelt from having the DCC gates open from late May until mid-June.

Although this action does not appear to constitute an important conflict between the needs of smelt and salmon, it illustrates the potential for conflict among the two opinions and the need for closer integration of the actions within the delta that have consequences for more than one of the listed species. This is an example where a systematic analysis of the implications for both species of actions would seem to be a scientific requirement.

Managing OMR Flows for Salmonids

This RPA action (IV.2.3, Old and Middle River Flow Management) also seeks to limit smolt excursion into part of the delta associated with high smolt mortality, but it does so by manipulating current direction and intensity within the Old and Middle River (OMR) drainages. The objective is to reduce current velocity toward the SWP and CVP facilities, thereby exposing fewer smolts to pump entrainment and being drawn into other unfavorable environments.

To accomplish the objective, the action calls for, reducing exports from January 1 through June 15, as necessary, to limit negative OMR flows to -2,500 to -5,000 cfs, depending on the presence of salmonids. The reverse flow will be managed within this range to reduce flows toward the pumps during periods of increased salmonid presence. The flow range was established through correlations of OMR flow and salmon entrainment indices at the pumps, and from entrainment proportions derived using the particle-tracking model (PTM). While the flow management strategy is conceptually sound, the threshold levels needed to protect fish is not definitively established. The response of loss at the pumps to OMR flow (e.g. figure 6-65 from NMFS, 2009) does not suggest a significant change in the vicinity of the flow triggers, but it does suggest that the loss rate increases exponentially above the triggers. The PTM suggests a gradual linear response in the vicinity of the trigger. However, no analysis was presented for the entrainment rate above the trigger (Figure 6-68 from NMFS, 2009), and it is not clear whether the salvage *rates* as well as salvage numbers were modeled. Therefore, the committee is unable to evaluate the validity of the exponential increase in loss rate above the trigger. Uncertainty in the effect of the flow triggers needs to be reduced, and more flexible triggers that might require less water should be evaluated.

The committee concludes that the strategy of limiting net tidal flows toward the pump facilities is sound, but the support for the specific flows targets is less certain. In the near-term telemetry-based smolt migration and survival studies (e.g, Perry and Skalski, 2009) should be used to improve our understanding of smolt responses to OMR flow levels. Reliance on salvage indices or the PTM results alone is not sufficient.

Additionally, there is little direct evidence to support the position that this action alone will benefit the San Joaquin salmon, unless it is combined with an increase in San Joaquin River flows. Furthermore, we understand this and other flow management actions are coordinated with the delta smelt actions. But we found no quantitative analysis that integrates across the actions to systematically evaluate their aggregate effects on both salmonids and smelt. Understanding those interactions will benefit from the development and use of multiple single-species models, including movement models.

Managing Exports and Flows in the San Joaquin River

The objective of this action (IV.2.1) is to reduce the vulnerability of emigrating Central Valley steelhead within the lower San Joaquin River to entrainment into the channels of the south delta and at the pumps by increasing the inflow-to-export ratio. It seeks to enhance the likelihood of salmonids' successfully exiting the delta at Chipps Island by creating more suitable hydraulic conditions in the mainstem of the San Joaquin River for emigrating fish, including greater net downstream flows.

The action has two components: reducing exports, and augmenting San Joaquin River flows at Vernalis. The rationale that increasing San Joaquin inflows to the delta will benefit smolt survival through this region of the delta is based on data from coded-wire tags on smolts. This statistical evidence provides only a coarse assessment of the action, but it indicates that increasing San Joaquin River flows can explain observed increases in escapement. Historical data indicate that high San Joaquin River flows in the spring result in higher survival of outmigrating Chinook salmon smolts and greater adult returns 2.5 years later (Kjelson et al., 1981; Kjelson and Brandes, 1989), and that when the ratio between spring flows and exports increase, Chinook salmon production increases (CDFG, 2005; SJRGA, 2007). In its biological opinion, NMFS therefore concludes that San Joaquin River Basin and Calaveras River steelhead would likewise benefit under higher spring flows in the San Joaquin River in much the same way as fall-run Chinook do. NMFS recognizes this assumption is critical, and thus the biological opinion calls for implementation of a 6-year smolt-survival study (acoustic tags) (Action IV.2.2), using hatchery steelhead and fall Chinook.

The controversy lies in the effectiveness of the component of this action that reduces water exports from the delta. The effectiveness of reducing exports to improve steelhead smolt survival is less certain, in part because within the VAMP (Vernalis Adaptive Management Plan) increased flows and reduced exports are combined, and in part because steelhead smolts are larger and stronger swimmers than Chinook salmon smolts. Furthermore, it is not clear in the biological opinion how managing exports for this purpose would be integrated with export management for other actions. The choice of a 4:1 ratio of net flows to exports appears to be the result of coordinated discussions among the interested parties. Given the weak influence of exports in all survival relationships (Newman, 2008), continued negotiation offers opportunities to reduce water use in this specific action without great risk to salmon. Further analysis of VAMP data also offers an opportunity to help clarify the issue.

The committee concludes that the rationale for increasing San Joaquin River flows has a stronger foundation than the prescribed action of concurrently managing inflows and exports. We further conclude that the implementation of the 6-year steelhead smolt survival study (action IV.2.2) could provide useful insight as to the actual effectiveness of the proposed flow management actions as a long-term solution.

Increase Passage through Yolo Bypass

This action would reduce migratory delays and loss of adult and juvenile salmon and green sturgeon at structures in the Yolo Bypass. For sturgeon there is substantial evidence that improved upstream passage at Yolo will be beneficial. For salmon, the purpose is to route salmon away from the interior delta and through a habitat that is favorable for growth. This action is scientifically justified and prudent, but its implications for the routing of flows through the system as a whole were not transparently evaluated. For example, moving water through the Yolo Bypass results in less water coming through the Sacramento River. Were the effects of less flow in the Sacramento River considered in the design of the action? Similarly, how were the possible negative consequences of increased flooding of the Yolo Bypass on mercury cycling considered? This exemplifies a general tendency throughout the discussion of the actions to focus on the biologically beneficial aspects but to not fully present how any conflicting consequences or potential for such consequences were considered.

Floodplain Habitat

The floodplain habitat actions (Actions I.6.1-4) involve increasing the inundation of private and public lands within the Sacramento River basin to increase the amount and quality of rearing habitat for juvenile salmon. This action suite appears scientifically justified on the basis of a number of studies (e.g., Sommer et al., 2001; Whitener and Kennedy, 1999; Moyle et al., 2007). Given the strong basis, the committee recommends early implementation of these actions providing the implications for releases and routing of flows on other actions, and any potential negative consequences, e.g., mobilization of mercury, are adequately considered. In addition, the committee suggests detailed studies of the outcome of these actions to provide important data for improved life cycle models for these species.

INTEGRATION OF RPAs

The RPAs lack a quantitative analytical framework that ties them together within species, between smelt and salmonid species, and across the watershed. This type of systematic, formalized analysis is necessary to provide an objective determination of the net effect of the actions on the listed species and on water users.

An additional overall, systematic, coordinated analysis of the effect of all actions taken together and a process for implementing the optimized, combined set of actions would help to establish the credibility of the effort overall. Instances of coordination certainly exist. For example, the analysis done by NMFS for the Action IV.2.1 (Appendix 5), is an example of coordination, where the water needs for the 4-to-1 flow-to-export ratio for steelhead were determined and used to refine the action. But coordination is not integration. The lack of a systematic, well framed overall analysis is a serious deficiency. The interagency effort to transparently reach consensus on implications of the combined RPAs for their effects on all the species and on water quality and quantity within the delta and on water operations and deliveries should use scientific principles and methods in a collaborative and integrative manner. Full documentation of decisions is an essential part of such an effort, as is inclusion of the environmental water needs of specific actions and for the entire RPA.

It is clear that integrative tools that, for example, combine the effect over life stages into a population-level response would greatly help the development and evaluation of the combined actions. This was acknowledged by the FWS and NMFS, as well by many of the other presenters during the two days of public session of the committee meeting. There has been significant investment in operations and hydrodynamic models for the system, which have been invaluable for understanding and managing the system. An investment in ecological models that complement the operations and hydrodynamics models is sorely needed. This issue has been raised repeatedly in peer reviews, but still has not been incorporated in the NMFS and FWS analyses. Without a quantitative integration tool, the expected effects of individual actions on the listed species will remain a matter of judgment based on the interpretation of many disparate studies. The NMFS and FWS had to therefore determine the cumulative effects of the multiple actions in each RPA in a qualitative manner. This leads to arguments and disputes that are extremely difficult to resolve and that can undermine the credibility of the biological opinions. Commitment to a long-term effort to develop a quantitative tool (or tools) should be part of the RPA, with the explicit goal of formalizing and focusing the sources of disagreement and allowing for the clear testing of alternative arguments.

Transparent consideration of the implications of water requirements also would seem well advised because some of the actions have significant water requirements. DWR and NMFS used CalSim-II and Calite to simulate a collection of actions to determine water needs associated with the NMFS RPA, and concluded that they would amount to 5-7% of total water allocations (NMFS, 2009). (Because the actions involving negative OMR flows were similar in timing and magnitude in both the NMFS and the FWS RPAs, all OMR flow management was included in this estimate.) Those, and complementary efforts, should be extended to as many of the actions in combination as feasible, recognizing that the adaptive nature of many aspects of the RPAs, along with variations in environmental conditions and in water demands, limit the degree of certainty associated with such estimates. Credible documentation of the water needed to implement each action and the combined actions, would enable an even clearer and more logical formulation of how the suite of actions might be coordinated to simultaneously benefit the species and ensure water efficiency.

OTHER POSSIBLE RPAs

The committee's charge included the task that the committee should identify, if possible, additional potential RPAs that would provide the potential to provide equal or greater protection to the fishes than the current RPAs while costing less in terms of water availability for other uses. The committee considered RPAs that had been considered and rejected by the agencies or that were recommended to the committee for its consideration (Hamilton 2010). They included using bubble-curtain technology instead of hard barriers to direct migration of salmon and steelhead smolts, use of weirs to protect wild steelhead from interbreeding and competition, use of weirs to reduce spring-run Chinook from inbreeding and competition with fall-run Chinook, habitat restoration and food-web enhancement, restoration of a more-natural hydrograph, reducing mortality caused by nonnative predators, reducing contaminants, reducing other sources of 'take," implementation of actions to reduce adverse effects of hatcheries, and ferrying San Joaquin River steelhead smolts through the delta.

Some of these are already included to some degree in the RPAs (e.g., reduction of adverse hatchery effects, habitat restoration), and some might not be within the agencies' authorities as RPA actions under the ESA (e.g., contaminant reduction and reduction of other sources of "take"). The committee did not attempt to evaluate whether these suggestions represent good actions to help reduce risks to the listed species in a general attempt at restoration, as that will be addressed in the committee's second report. The committee concludes that none of the above suggested alternative RPAs has received sufficient documentation or evaluation to be confident at present that any of them would have the potential to provide equal or greater protection for the listed species while requiring less disruption of delta water diversions.

Several long-term actions described above have the potential to increase protections for the species while requiring the use of less water for that purpose, because they will result in a better understanding of the system. That better understanding should allow for a better matching of water for species needs, thus potentially reducing the amount of water used in less-effective actions. However, no short-term measure was identified that would provide equal protection to the fishes while reducing restrictions on water diversions.

RESOLVING INCOMPATIBILITIES BETWEEN THE RPAs

The committee noted in its discussion of the Delta Cross Channel action for salmon that it has a small potential for conflict with the requirements for smelt, although the action itself includes a consideration of the effects on smelt. In addition, the agencies have coordinated, and in some cases changed, their actions to avoid or reduce such conflicts, including actions concerning the installation of a "non-physical" barrier at the Head of Old River and the possibility of constructing a barrier across Georgiana Slough (NMFS and FWS, 2010). However, as the committee has noted elsewhere, coordination is not integration, and while it commends the agencies for working together to avoid incompatibilities between the RPAs, it concludes that this coordination is not sufficient to achieve the best results or full evaluation of incompatibilities. To achieve those goals requires an integrated analysis, because without such an analysis it is difficult or impossible to properly evaluate potential conflicts among RPA actions. More important, such an analysis would help to produce more-effective actions. The lack of an integrated analysis also prevented the committee from a fuller evaluation of potential incompatibilities between the RPAs.

EXPECTATIONS AND PROXIMATE MEASURES

The committee heard several times at the public sessions that the RPA actions for delta smelt are not working as there has been no response in the standard annual abundance indices during the last 3 years when action-related restrictions have been imposed. Such comments are appropriate, but only if realistic expectations are used to judge effectiveness. In this case, it is unrealistic to expect immediate and proportional responses to actions in annual indices of delta smelt, especially within the first few years of implementation. There are several reasons for this. First, fish abundances are influenced by many factors not affected by the actions. This is true in all estuarine and marine systems, and is simply inherent in fish population dynamics. For example, in the case of the species here, three drought years coincided with the implementation of the actions. Other factors have also varied that would further mask any response in the annual indices.

Second, delta smelt populations are very small. The ability of the annual indices to show changes in response to actions is compromised due to the inherent lack of precision in sampling and constructing indices of abundance when populations are very small. Unlike salmon and steelhead, the adults of which can be counted with great precision as they migrate upstream, delta smelt are more difficult to count as well as being rare. While this is frustrating, little change in the annual indices over a few years neither invalidates the utility of the actions nor do they demonstrate that the actions are effective. Finally, there were no prior quantified estimates of response to calibrate expectations. Expectations would be better established if the RPA proposals more explicitly quantified the nature and the expected timescale of responses in the target species, and detailed exactly what would be done to assess the validity of those predictions.

RPA RECOMMENDATIONS

The committee concluded that the uncertainties and disagreements surrounding some of the RPA actions could be reduced by some additional activities. In general, the committee recommends that, within the limits the agencies face with respect to human and financial resources, a more-integrated approach to analyzing adverse effects of water operations and potential actions to reduce those effects would be helpful. The approach would include a broader examination of the life cycles of each fish species and where possible, integrating analyses across species. Although there is much general evidence that the profound reduction and altered timing of the delta water supply has been part of the reason for the degradation of these species' habitats, the marginal benefits of beginning to reverse the damage will be difficult to recognize for some time and there is much uncertainty about how to design attempts at the reversal. At this time, the best that can be done is to design a strategy of pumping limitations that uses the best available monitoring data and the best methods of statistical analysis to design an exploratory approach that could include enhanced field measurements to manage the pumping limitations adaptively while minimizing impacts on water users. Such an approach would include a more explicit and transparent consideration of water requirements, despite the variability in environmental conditions and water demand; and population models to evaluate the combined effects of the individual actions.

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Appendixes

PREPUBLICATION COPY

Appendix A

Committee on Sustainable Water and Environmental Management in the California Bay-Delta

STATEMENT OF TASK

At the request of Congress and the Departments of the Interior and Commerce, a committee of independent experts will be formed to review the scientific basis of actions that have been and could be taken to simultaneously achieve both an environmentally sustainable Bay-Delta and a reliable water supply. In order to balance the need to inform near-term decisions with the need for an integrated view of water and environmental management challenges over the longer-term, the committee will undertake two main projects over a term of two years resulting in two reports.

First, by approximately March 15, 2010, the committee will issue a report focusing on scientific questions, assumptions, and conclusions underlying water-management alternatives in the U.S. Fish and Wildlife Service's (FWS) Biological Opinion on Coordinated Operations of the Central Valley Project and State Water Project (Dec. 15, 2008) and the National Marine Fisheries Service's (NMFS) Biological Opinion on the Long-Term Central Valley Project and State Water Project Operations Criteria and Plan (June 4, 2009). This review will consider the following questions:

- Are there any "reasonable and prudent alternatives" (RPAs), including but not limited to alternatives considered but not adopted by FWS (e.g., potential entrainment index and the delta smelt behavioral model) and NMFS (e.g., bubble-curtain technology and engineering solutions to reduce diversion of emigrating juvenile salmonids to the interior and southern Delta instead of towards the sea), that, based on the best available scientific data and analysis, (1) would have lesser impacts to other water uses as compared to those adopted in the biological opinions, and (2) would provide equal or greater protection for the relevant fish species and their designated critical habitat given the uncertainties involved?
- Are there provisions in the FWS and NMFS biological opinions to resolve potential incompatibilities between the opinions with regard to actions that would benefit one listed species while causing negative impacts on another, including, but not limited to, prescriptions that: (1) provide spring flows in the Delta in dry years primarily to meet water quality and outflow objectives pursuant to Water Board Decision-1641 and conserve upstream storage for summertime cold water pool management for anadromous fish species; and (2) provide fall flows during wet years in the Delta to benefit Delta smelt, while also conserving carryover storage to benefit next year's winter-run cohort of salmon in the event that the next year is dry?
- To the extent that time permits, the committee would consider the effects of other stressors (e.g., pesticides, ammonia discharges, invasive species) on federally listed and other at-risk species in the Bay-Delta. Details of this task are the first item discussed as part of the committee's second report, below, and to the degree that they cannot be addressed in the first report they will be addressed in the second.

Second, in approximately November 2011, the committee will issue a second report on how to most effectively incorporate science and adaptive management concepts into holistic programs for management and restoration of the Bay-Delta. This advice, to the extent possible, should be coordinated in a way that best informs the Bay Delta Conservation Plan development process. The review will include tasks such as the following:

- Identify the factors that may be contributing to the decline of federally listed species, and as appropriate, other significant at-risk species in the Delta. To the extent practicable, rank the factors contributing to the decline of salmon, steelhead, delta smelt, and green sturgeon in order of their likely impact on the survival and recovery of the species, for the purpose of informing future conservation actions. This task would specifically seek to identify the effects of stressors other than those considered in the biological opinions and their RPAs (e.g., pesticides, ammonia discharges, invasive species) on federally listed and other at-risk species in the Delta, and their effects on baseline conditions. The committee would consider the extent to which addressing stressors other than water exports might result in lesser restrictions on water supply. The committee's review should include existing scientific information, such as that in the NMFS Southwest Fisheries Science Center's paper on decline of Central Valley fall-run Chinook salmon, and products developed through the Pelagic Organism Decline studies (including the National Center for Ecosystem Analysis and Synthesis reviews and analyses that are presently under way).
- Identify future water-supply and delivery options that reflect proper consideration of climate change and compatibility with objectives of maintaining a sustainable Bay-Delta ecosystem. To the extent that water flows through the Delta system contribute to ecosystem structure and functioning, explore flow options that would contribute to sustaining and restoring desired, attainable ecosystem attributes, while providing for urban, industrial, and agricultural uses of tributary, mainstem, and Delta waters, including for drinking water.
- Identify gaps in available scientific information and uncertainties that constrain an ability to identify the factors described above. This part of the activity should take into account the Draft Central Valley Salmon and Steelhead recovery plans (NOAA 2009b), particularly the scientific basis for identification of threats to the species, proposed recovery standards, and the actions identified to achieve recovery.
- Advise, based on scientific information and experience elsewhere, what degree of restoration of the Delta system is likely to be attainable, given adequate resources. Identify metrics that can be used by resource managers to measure progress toward restoration goals.

The specific details of the tasks to be addressed in this second report will likely be refined after consultation among the departments of the Interior and Commerce, Congress, and the National Research Council, considering stakeholder input, and with the goal of building on, rather than duplicating, efforts already being adequately undertaken by others.

Appendix B

Water Science and Technology Board

CLAIRE WELTY, *Chair*, University of Maryland, Baltimore County
YU-PING CHIN, Ohio State University, Columbus
OTTO C. DOERING, Purdue University, West Lafayette, Indiana
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ANITA A. HALL, Senior Program Associate
MICHAEL J. STOEVER, Research Associate
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Appendix C

Ocean Studies Board

DONALD F. BOESCH (Chair), University of Maryland Center for Environmental Science, Cambridge
EDWARD A. BOYLE, Massachusetts Institute of Technology, Cambridge
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ANDREW A. ROSENBERG, Science & Knowledge Conservation International, Arlington, Virginia
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HEATHER CHIARELLO, Senior Program Assistant
JEREMY JUSTICE, Senior Program Assistant

Appendix D

Speakers at Committee's Meeting
January 24-29, 2010
University of California, Davis

Ara Azhderian, San Luis and Delta Mendota Water Authority
Barbara Barrigan-Parilla, Restore the Delta
Brett Baker, Delta Resident
Letty Belin, U.S. Department of the Interior
Cheryl Bly-Chester, UC Berkeley
Dan Castleberry, U.S. Fish and Wildlife Service
Jim Costa, U.S. House of Representatives, California-District 20
DeeDee D'Adamo, Office of U.S. Representative Dennis Cardoza, California-District 18
Cliff Dahm, CALFED (Delta Science Program)
Stan Dean, Sacramento Regional County Sanitation District, Director of Policy
Rick Deriso, Inter-American Tropical Tuna Commission
Diana Engle, Larry Walker Associates
Fred Feyrer, Bureau of Reclamation
David Fullerton, Metropolitan Water District of Southern California
Greg Gartrell, Contra Costa Water District
Zeke Grader, Pacific Coast Federation of Fishermen's Association
Cay Goude, U.S. Fish and Wildlife Service
Scott Hamilton, Coalition for a Sustainable Delta
Ann Hayden, Environmental Defense Fund
Bruce Herbold, U.S. Environmental Protection Agency
John Herrick, South Delta Water Agency
Jerry Johns, California Department of Water Resources
Harold Johnson, Pacific Legal Institute
Linda Katehi, University of California, Davis
Jason Larroba, Tehama-Colusa Canal Authority
Tom Lindemuth, Delta Science Center, Big Break
Steve Lindley, National Marine Fisheries Service
Craig Manson, Council for Endangered Species Act Reliability
BJ Miller, Consultant
Ron Milligan, Bureau of Reclamation
Jeffrey Mount, University of California, Davis
Peter B. Moyle, University of California, Davis
Steve Murawski, National Oceanic and Atmospheric Administration
Eligio Nava, Central Valley Hispanic Chamber
Dante John Nemellini, Central Delta Water Agency

Matt Nobriga, California Department of Fish and Game
Doug Obegi, Natural Resources Defense Council
Tim O'Laughlin, O'Laughlin & Paris
Bruce Oppenheim, National Marine Fisheries Service
Richard Pool, Salmon fishing industry
Maria Rea , National Marine Fisheries Service
Rhonda Reed, National Marine Fisheries Service
Mark Renz, Association of California Water Agencies
Spreck Rosekrans, Environmental Defense Fund
Melanie Rowland, NOAA-General Counsel
Patricia Schuffon, Pacific Advocate Program
Jeff Stuart, National Marine Fisheries Service
Nicky Suard, Delta Land and Business owners
Christina Swanson, The Bay Institute
Robert Thornton, Nossaman
Mike Urkov, Tehama-Colusa Canal Authority
Jay Wells, North American Power Sweeping Association
Carl Wilcox, California Department of Fish and Game
Susan William, Pt. Lobos Marine Preserve
Mary Winfree, PoE/USANG
Phil Wyman, Former Central Valley Senator/Assemblyman
Paula Yang, Hmong Sisterhood
Garwin Yip, National Marine Fisheries Service

Appendix E

Biographical Sketches for Members of the Committee on Sustainable Water and Environmental Management in the California Bay-Delta

ROBERT J. HUGGETT, ***Chair***, is an independent consultant and professor emeritus and former chair of the Department of Environmental Sciences, Virginia Institute of Marine Sciences at the College of William and Mary, where he was on the faculty for over 20 years. He also served as Professor of Zoology and Vice President for Research and Graduate Studies at Michigan State University from 1997 to 2004. Dr. Huggett is an expert in aquatic biogeochemistry and ecosystem management whose research involved the fate and effects of hazardous substances in aquatic systems. From 1994 to 1997, he was the Assistant Administrator for Research and Development for the U.S. Environmental Protection Agency, where his responsibilities included planning and directing the agency's research program. During his time at the EPA, he served as Vice Chair of the Committee on Environment and Natural Resources and Chair of the Subcommittee on toxic substances and solid wastes, both of the White House Office of Science and Technology Policy. Dr. Huggett founded the EPA Star Competitive Research Grants program and the EPA Star Graduate Fellowship program. He has served on the National Research Council's (NRC) Board on Environmental Studies and Toxicology, the Water Science and Technology Board, and numerous study committees on wide ranging topics. Dr. Huggett earned an M.S. in Marine Chemistry from the Scripps Institution of Oceanography at the University of California at San Diego and completed his Ph.D. in Marine Science at the College of William and Mary.

JAMES J. ANDERSON is a research professor the School of Aquatic and Fisheries Sciences at the University of Washington, where he has been teaching since 1983, and Co-Director of Columbia Basin Research. Prior to joining the faculty at the University of Washington, he did research work at the University of Kyoto in Japan, the National Institute of Oceanography in Indonesia, and Institute of Oceanographic Sciences in Wormley, UK. Dr. Anderson's research focuses on models of ecological and biological processes from a mechanistic perspective, specifically: (1) migration of organisms, (2) decision processes, and (3) mortality processes. For three decades he has studied the effects of hydrosystems and water resource allocations on salmon and other fish species. He has developed computer models of the migration of juvenile and adult salmon through hydrosystems and heads the DART website, an internet database serving real-time environmental and fisheries data on the Columbia River. His other research interests include mathematical studies in ecosystems, biodemography, toxicology and animal behavior. He has served on a number of regional and national panels and has testified numerous times before Congress on the impacts of hydrosystems on fisheries resources. He received his B.S. and Ph.D. in oceanography from the University of Washington.

MICHAEL E. CAMPANA is Professor of Geosciences at Oregon State University, former Director of its Institute for Water and Watersheds, and Emeritus Professor of Earth and Planetary Sciences at the University of New Mexico. Prior to joining OSU in 2006 he held the Albert J. and Mary Jane Black Chair of Hydrogeology and directed the Water Resources Program at the University of New Mexico and was a research hydrologist at the Desert Research Institute and taught in the University of Nevada-Reno's Hydrologic Sciences Program. He has supervised 70 graduate students. His research and interests include hydrophilanthropy, water resources management and policy, communications, transboundary water resources, hydrogeology, and environmental fluid mechanics, and he has published on a variety of topics. Dr. Campana was a Fulbright Scholar to Belize and a Visiting Scientist at Research Institute for Groundwater (Egypt) and the IAEA in Vienna. Central America and the South Caucasus are the current foci of his international work. He has served on six NRC-NAS committees. Dr. Campana is founder, president, and treasurer of the Ann Campana Judge Foundation (www.acjfoundation.org), a 501(c)(3) charitable foundation that funds and undertakes projects related to water, sanitation, and hygiene (WASH) in Central America. He operates the WaterWired blog and Twitter. He earned a BS in geology from the College of William and Mary and MS and PhD degrees in hydrology from the University of Arizona.

THOMAS DUNNE is a professor in the Donald Bren School of Environmental Science and Management at the University of California at Santa Barbara. He is a hydrologist and a geomorphologist, with research interests that include alluvial processes; field and theoretical studies of drainage basin and hillslope evolution; sediment transport and floodplain sedimentation; debris flows and sediment budgets of drainage basins. He served as a member of the WSTB Committee on Water Resources Research and Committee on Opportunities in the Hydrologic Sciences and was elected to the National Academy of Sciences in 1988. He has acted as a scientific advisor to the United Nations, the governments of Brazil, Taiwan, Kenya, Spain, the Philippines, Washington, Oregon, several U.S. federal agencies, and The Environmental Defense Fund. He is a recipient of the American Geophysical Union Horton Award. Dr. Dunne holds a B.A. from Cambridge University and a Ph.D. in geography from the Johns Hopkins University.

ALBERT E. GIORGI is president and senior fisheries scientist at BioAnalysts, Inc in Redmond, WA. He has been conducting research on Pacific Northwest salmonid resources since 1982. Prior to 1982, he was a research scientist with NOAA in Seattle, WA. He specializes in fish passage migratory behavior, juvenile salmon survival studies, biological effects of hydroelectric facilities and operation. His research includes the use of radio telemetry, acoustic tags, and PIT-tag technologies. In addition to his research, he acts as a technical analyst and advisor to public agencies and private parties. He regularly teams with structural and hydraulic engineers in the design and evaluation of fishways and fish bypass systems. He served on the NRC Committee on Water Resources Management, Instream Flows, and Salmon Survival in the Columbia River. He received his B.A. and M.A. in biology from Humboldt State University and his Ph.D. in fisheries from the University of Washington.

PATRICIA M. GLIBERT is a professor at the University of Maryland Center for Environmental Science, Horn Point Laboratory, where she has been on the faculty since 1986. Prior to UMD-HPL, she was a postdoctoral scholar and an assistant scientist at the Woods Hole Oceanographic Institution. Her research areas are in transformations and fate of inorganic and organic nitrogen in marine and estuarine systems; ecology of phytoplankton in coastal and oceanic environments; stable isotope techniques; eutrophication and its effects; growth and physiology of marine cyanobacteria and harmful algal bloom species; "top-down" control of nitrogen cycling; primary productivity and its regulation by environmental factors; and impacts of harmful algae on oysters. Her current projects are in the Chesapeake and coastal bays of Maryland, Florida Bay, and the Arabian Sea. She received her B.S. in biology from Skidmore College; M.S. in earth science from the University of New Hampshire; and her Ph.D. in organismal and evolutionary biology from Harvard University.

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UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF CALIFORNIA
FRESNO DIVISION

CONSOLIDATED SALMON CASES	**Lead Case No. 1:09-cv-01053-OWW-DLB**
SAN LUIS & DELTA-MENDOTA WATER AUTHORITY, *et al.* v. LOCKE, *et al.*	Consolidated Cases: 1:09-cv-01090-OWW-DLB 1:09-cv-01378-OWW-DLB 1:09-cv-01520-OWW-SMS 1:09-cv-01580-OWW-DLB 1:09-cv-01625-OWW-SMS
STOCKTON EAST WATER DISTRICT v. NOAA, *et al.*	
STATE WATER CONTRACTORS v. LOCKE, *et al.*	**DECLARATION OF GARY HAYWARD SLAUGHTER MULCAHY IN SUPPORT OF DEFENDANT-INTERVENORS' OPPOSITION TO PLAINTIFFS' MOTIONS FOR TEMPORARY RESTRAINING ORDER AND PRELIMINARY INJUNCTION**
KERN COUNTY WATER AGENCY, *et al.* v. U.S. DEPARTMENT OF COMMERCE, *et al.*	
OAKDALE IRRIGATION DISTRICT, *et al.* v. U.S. DEPARTMENT OF COMMERCE, *et al.*	
THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA v. NATIONAL MARINE FISHERIES SERVICE, *et al.*	

I, GARY HAYWARD SLAUGHTER MULCAHY, hereby declare:

1. I am the Governmental Liaison for the Winnemem Wintu Tribe ("Winnemem Wintu" or "Tribe") and have served in that capacity for six years. I am also a Tribe member. My responsibilities for the Winnemem Wintu include advocating on behalf of the Tribe, which includes coordinating the Tribal delegation and representation in litigation efforts. Much of this advocacy work is in the area of protecting the natural resources upon which the Winnemem Wintu depend for their cultural and religious existence.

2. The Winnemem Wintu are an historic California Native Tribe recognized by the California Native American Heritage Commission. The Winnemem Wintu's historical territory included the east side of the upper Sacramento River watershed, the McCloud River watershed from origin to termination, the Squaw Creek watershed from origin to termination, and approximately 20 miles of the Pit River from the confluence of the McCloud River, Squaw Creek and Pit River up to Big Bend. The Tribe has members living, and Tribal concerns, in many parts of the area impacted by operations of the Central Valley Project and State Water Project, including Clear Creek from Whiskeytown Dam to the Sacramento River, the Sacramento River from Shasta Dam to the Delta, and Spring Creek from the Debris Dam to Keswick Dam. Our Tribal village is located on Bear Mountain Road just northeast of Redding, California, by Jones Valley. Our Tribe's historical territory and areas of concern are directly connected to the Sacramento River and the Delta Estuary due to their importance to the continued existence of the salmon.

3. For centuries, the Winnemem Wintu have had a deep cultural and spiritual relationship with the salmon that utilize the Sacramento River and its tributaries. We sing to the salmon and the waters that sustain them. Our history, traditions, ceremonies, and culture are filled with respect, reverence, appreciation, and dependence on the salmon and these waters. Salmon were the staple of the Winnemem Wintu. Salmon are the food necessary to complete and fulfill many of the Winnemen Wintu's very special sacred ceremonies. Salmon are the sustainer of health and life of the Winnemem Wintu. We believe that when the first spirits were choosing what form they would take (i.e., Salmon, Eagle, Bear, Human, etc.), when Human chose to be human, the Grandfather spirit said that these Humans will need lots of help, and each of the other spirits gave

something to Humans to help them through life. We believe that Salmon gave us speech and in return we promised to always speak for them. This is remembered and celebrated in ceremonies on the McCloud River, Sacramento River, Squaw Creek and at Mt. Shasta several times a year. We believe that if the salmon go, the Winnemem Wintu will also disappear.

4. The salmon are disappearing. As a youngster, and later teen, I used to catch salmon for my family in the Sacramento River just below Lake Redding Park and above the Posse Grounds in Redding. During the salmon runs in those days, the river seemed a moving dark ribbon that you could almost walk across, because there were so many salmon. But Winnemem Wintu children today might never experience a healthy salmon run. This year, we saw fewer salmon return to the river than ever before. At the salmon jump in Lake Redding Park, and the salmon viewing window, I waited for two hours this year just to see a salmon jump, but I did not see a single fish during that time. What a tragedy this has become. The salmon are going away, and all I can say is, “Why?”

5. Like the salmon, the Winnemem Wintu are also struggling to survive. There used to be tens of thousands of Winnemem Wintu, but now there are only a few hundred left. This decline is partly due to the loss of salmon in our homeland. For example, dietary changes resulting from the scarcity of native wild salmon have had devastating effects on the Tribe. From the time Shasta Dam was built, and the salmon were blocked from returning to their natural spawning grounds, the Winnemem Wintu have had to forego their historic salmon-based diet, which was low in saturated fat; rich in complex carbohydrates, protein and omega-3 fatty acids; and a natural source of vitamins and minerals (all of the things that modern doctors say are needed today for a healthy body and diet). The Tribe’s diet today is high in saturated fat, refined sugars, and carbohydrates. The effect on the Tribe has been disastrous: Higher death rates, higher cancer rates, blindness, kidney problems, strokes, and on and on. More than 23% of the Tribe’s members are diabetic, compared to a national average of 6.4%. Almost 80% of us, including our children, are overweight or obese, and the rate of heart disease is well above the national average.

6. But diet is not all that has been affected by the decline of the salmon. There are no more village salmon bakes where the elders taught the young, the dancers and singers danced and sang for the salmon, and the community celebrated the old and the young. These festivals would last

for days at a time, but there are almost no salmon in the river now, and declining natural populations have made market prices for salmon far too high to even think of a salmon bake for the Tribe. A great part of the social and cultural way of life was taken away when Shasta Dam and other components of the water projects, including the Delta pumps, were built, and future export pumping from the Delta without salmon protections would further devastate what remains of the Winnemem Wintu and could destroy any chance of ever reconnecting with our spiritual and cultural heritage.

7. I and the Winnemem Wintu were overjoyed when the decision by this Court to strike down the 2004 Biological Opinion paved the way for a new Biological Opinion, issued by the National Marine Fisheries Service ("NMFS") in 2009, that in our view offers far more protection for the last of our homeland's salmon. My personal interests and those of the Winnemem Wintu are now inextricably tied to the 2009 Biological Opinion and the crucial protective measures it offers, including Reasonable and Prudent Alternative Actions IV.2.1 and IV.2.3. It may be the last hope for the salmon that have sustained and defined the Tribe throughout history. Enjoining measures in the 2009 Biological Opinion that NMFS believes are needed to keep salmon alive would harm our centuries old cultural, spiritual, and tribal interests in Sacramento River salmon. We fear that the region's dwindling salmon populations, which fight against all odds to survive in these inland waters so altered by project operations, cannot withstand the loss of large numbers of young fish during their critical migration through the Delta to the ocean.

I declare under penalty of perjury that the foregoing is true and within my personal knowledge.

DATED: March ____, 2010

____

GARY HAYWARD SLAUGHTER MULCAHY

for days at a time, but there are almost no salmon in the river now, and declining natural populations have made market prices for salmon far too high to even think of a salmon bake for the Tribe. A great part of the social and cultural way of life was taken away when Shasta Dam and other components of the water projects, including the Delta pumps, were built, and future export pumping from the Delta without salmon protections would further devastate what remains of the Winnemem Wintu and could destroy any chance of ever reconnecting with our spiritual and cultural heritage.

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I declare under penalty of perjury that the foregoing is true and within my personal knowledge.

DATED: March 12, 2010

GARY HAYWARD SLAUGHTER MULCAHY

Research, Outreach, and Education on Fish Contamination in the Sacramento – San Joaquin Delta and Tributaries (AKA Delta Fish Project)

Phase I Needs Assessment Final Report

January 2004

Environmental Health Investigations Branch

California Department of Health Services

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EXECUTIVE SUMMARY

Mercury, a potent neurotoxin, bioaccumulates in fish in the Sacramento-San Joaquin Delta and tributaries watershed (hereafter referred to as the Delta watershed) at levels that may pose health risks to people who consume the fish. Mercury is prevalent in the Delta watershed due to human activities, such as historic mercury mining in the Coastal range and gold mining in the Sierra Nevada, and naturally occurring deposits. Mercury concentrations in several species of fish at many locations in the Delta watershed exceed the health-based screening values set by the U.S. Environmental Protection Agency. The Environmental Health Investigations Branch (EHIB) of the California Department of Health Services is the lead agency coordinating the Delta Fish Project, an interagency effort to reduce exposure to mercury in populations that consume fish caught in the Delta watershed. During August 2002-September 2003, EHIB conducted a needs assessment in five priority counties in the Delta watershed: Lake, Sacramento, San Joaquin, Placer, and Yolo. The counties were selected based primarily on the following criteria: (1) high levels of mercury in fish, and (2) high levels of fishing activity. The purpose of the assessment was to identify specific populations that consume fish caught in the Delta watershed, and to determine fish contamination awareness, concerns, and information needs of county health and environmental health departments, Native American tribes, and community-based organizations (CBOs) and health care providers that serve populations who consume fish from the watershed.

Needs assessment findings include the following: (1) while county health and environmental health departments believe that local fish contamination is a public health concern, they are not undertaking public outreach and education activities, in large part due to competing public health needs that are a higher priority for these counties, (2) Pomo Indian tribal members reported that some members fish in local waterbodies and consume their catch while others do not due, in large part, to a belief that the waters are polluted with mercury and other contaminants, (3) health care providers are not aware of any concern among their patients about mercury contamination of fish, and (4) members of Southeast Asian, Latino, African-American, and Russian communities regularly eat fish, especially striped bass and catfish, from local waters, and have generally low awareness of fish consumption advisories and the health risks of exposure to mercury in fish. EHIB recommends the following: (1) develop and disseminate outreach and education messages and materials in collaboration with local government agencies, tribes, and CBOs, (2) use visual images (e.g., pictures, posters, calendars, and videos) and mass media (e.g., television and radio) to effectively communicate messages to target populations, (3) collaborate with health care providers (i.e., family practice physicians, obstetricians, gynecologists, pediatricians, physicians assistants, and nurse practitioners) to inform target populations, especially women of childbearing age, and (4) evaluate outreach and education activities on an ongoing basis to ensure the effectiveness and appropriateness of messages, materials, and communication methods.

I. BACKGROUND

The Sacramento-San Joaquin River Delta and tributaries watershed (hereafter referred to as the Delta watershed) covers a vast area of the state (see Appendix A) and includes the Delta, the Sacramento and San Joaquin Rivers, and numerous tributaries and reservoirs. Mercury is prevalent in the Delta watershed due to human activities and naturally occurring deposits. Mercury was mined in the Coastal range and was used extensively in gold mining operations in the Sierra Nevada during the latter half of the 19th century. Liquid mercury was poured into sluices to recover gold. The U.S. Geological Survey estimates that several million pounds of mercury may have been lost to the environment in these processes. Mercury is present in the watershed due to atmospheric deposition resulting from natural sources such as weathering of mercury-containing rocks and human activities such as the combustion of fossil fuels.

Once elemental mercury enters an aquatic system, bacteria convert it into a highly toxic form that is readily accumulated by aquatic organisms. Through biomagnification, mercury can be found at high levels in upper trophic level fish species. At many locations in the watershed, mercury concentrations in certain species of fish exceed the health-based guidelines for fish tissues set by the U.S. Environmental Protection Agency (EPA). Fish species of particular concern include largemouth bass, striped bass, catfish, and sturgeon.

Fishing for food or recreation is a popular activity throughout the watershed. The U.S. Fish and Wildlife Service estimates that 2.4 million Californians, almost ten percent of the population 16 years of age and older, engaged in fishing activities during 2001, and the California Department of Fish and Game (CDFG) estimates that anglers spent over 2.2 million hours fishing on the Sacramento River alone. Based on preliminary data, high trophic species commonly are caught and consumed by many anglers and their families in the Delta watershed.

Exposure to mercury in fish is a public health concern because mercury is a potent neurotoxin. The developing fetus and children are especially sensitive to mercury. Pregnant females and nursing mothers can pass on mercury to their fetuses or infants through the placenta and through breast milk. Excessive exposure to mercury can cause damage to the nervous system in children, leading to subtle decreases in learning ability, language skills, attention, and memory. Children may be vulnerable throughout adolescence as the nervous system continues to develop. In adults, the most subtle symptoms of mercury toxicity are numbness and tingling sensations in the hands and feet or around the mouth. Other symptoms at higher levels of exposure could include loss of coordination and vision problems.

Currently, health advisories have been issued for only a few areas and species in the watershed. These advisories recommend limits on striped bass and sturgeon in the Delta, based on fish tissue data gathered from San Francisco Bay. In addition, health advisories recommend limits on consumption of black bass and catfish, among other fish species, caught in Clear Lake, Lake Berryessa, Black Butte Reservoir, and reservoirs and rivers in the Sierra Lakes region (Yuba, Nevada, and Placer Counties). These health advisories, however, may not adequately address the scope and magnitude of the mercury contamination problem in the watershed. Concerns about mercury contamination in fish have also been raised at the national level. In 2001, EPA issued a national advisory recommending that pregnant and nursing women, women who may become pregnant, and young children limit their consumption of freshwater fish caught by family and friends. This advice applies to all fish in freshwater areas of the state.

II. INTRODUCTION

In December 2001, California Bay-Delta Authority (CBDA) formed an interagency workgroup, the Delta Fish Consumption Planning Group (hereafter referred to as the Planning Group), to begin exploring ways to address fish contamination concerns in the Delta watershed. CBDA's initial goal was to plan a fish consumption study that would characterize angling populations and their fish consumption patterns. In 2002, the Environmental Health Investigations Branch (EHIB) of the California Department of Health Services (CDHS) began coordinating the Planning Group's activities and expanded the group's focus to include community outreach and education.

During August 2002-September 2003, with funding from the Delta Tributaries Mercury Council[1] of the Sacramento River Watershed Program, EHIB developed and implemented Phase I of *Research, Outreach, and Education on Fish Contamination in the Sacramento-San Joaquin Delta and its Tributaries* (hereafter referred to as the Delta Fish Project). Staff resources for project implementation were also provided by the Centers for Disease Control and Prevention. The project's overall goal is to reduce exposure to mercury in populations that consume fish caught in the Delta watershed. Phase I activities consisted of: (1) project planning, (2) a study by Dr. Fraser Shilling of the University of California at Davis in which fish tissue mercury data and fishing creel survey data from the watershed were compiled, analyzed, and mapped[2], and (3) a needs assessment conducted by EHIB in five of the 30 counties that are located in the watershed: Lake, Sacramento, San Joaquin, Placer, and Yolo. These five counties were selected by the Planning Group based primarily on the following criteria: (1) high levels of mercury in fish, and (2) high levels of fishing activity. Data pertaining to these criteria were obtained from the database created by Dr. Shilling. In addition, the Planning Group considered environmental justice concerns, existence of health advisories, and sociodemographic characteristics, and sought to include at least one lake or reservoir and one rural area when selecting the priority counties. Refer to Appendix B for profiles on these five counties. Additional counties will be phased in during the course of project implementation pending funding availability.

EHIB is coordinating with federal, state, and local agencies, Native American tribes, community-based organizations (CBOs), environmental advocacy groups, and health care providers, among others, to achieve the project's goal. Refer to Appendix C for a list of project collaborators and profiles of their organizations.

Pending funding availability, additional project activities related to outreach, education, and training will be conducted during Phase II of the project from September 2003-August 2004.

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[1]Delta Tributaries Mercury Council is a subcommittee of the Sacramento River Watershed Program that receives funding from the U.S. Environmental Protection Agency Region IX through the Sacramento Regional County Sanitation District.
[2]*Background Information for a Central Valley Fish Consumption Study, Geographic Information System and Relational Database for Fish Tissue Mercury and Creel Survey Data.*

Activities include the following: (1) develop an outreach, education, and training strategy, (2) design a project evaluation plan, (3) form regional and local stakeholder advisory groups and committees as appropriate, (4) develop, translate, and field test outreach, education, and training materials, (5) identify information gaps and conduct follow-up activities, and (6) conduct a needs assessment in up to four additional counties located in the Delta watershed.

The following is a description of the needs assessment conducted in Lake, Sacramento, San Joaquin, Placer, and Yolo Counties during Phase I of the Delta Fish Project.

III. NEEDS ASSESSMENT

The purpose of the needs assessment was to identify specific populations that consume fish caught in the Delta watershed, and to determine fish contamination awareness, concerns, and information needs of tribes, county health and environmental health departments, CBOs, and health care providers that serve populations who consume fish from the watershed. EHIB and project partners will use information obtained from the needs assessment to undertake the Phase II activities identified above.

A. Data Collection Methods and Process

Information was collected during October 2002-July 2003 from four Pomo Indian tribes and two tribal organizations, the health and environmental health departments in each of the five counties, seven CBOs, an environmental advocacy organization, two health care facilities, and two churches (see Appendix D). These organizations were selected to participate in the needs assessment because preliminary information indicated they represent or serve populations that eat fish caught in the Delta watershed.

1. Data Collection Methods

The following describes the three methods that were used to collect primary data for the needs assessment:

Key informant interviews are conducted with key leaders in the community, particularly within an organization, representatives of a population, or with people who are knowledgeable about the population and may be able to provide information on the needs of particular groups. During the needs assessment, interviews were conducted with tribal health and environmental health directors, county public health officers and environmental health directors, CBO and church leaders, and health care facility administrators. The interviews focused on six themes: fish contamination, community leaders and stakeholders, outreach and education, capacity building, future collaboration, and existing secondary information.

Surveys utilize structured questionnaires to obtain information. Collected data are analyzed to provide information about the surveyed group. The needs assessment survey was conducted using a self-administered questionnaire. The questionnaire focused on five main themes: fish contamination, community stakeholders, outreach and education, capacity building, and information needs. The questionnaire was completed by the following individuals: county health and environmental health staff, Council for Asian Pacific Islanders Together for Advocacy and Leadership (CAPITAL) members, and Pomo Indian participants at an Earth Day event in Lake County.

Focus groups are small groups of people representing a larger population that are brought together to discuss particular topics. Focus groups rely on group interaction to help bring out ideas and reactions. The purpose of the focus group is to provide more in-depth understanding about the needs, attitudes, opinions, experiences, and expectations of a population. During the needs assessment, focus group discussions were conducted with Pomo Indian tribal members and CBO constituents. The discussions focused on three themes: fishing practices and fish consumption habits, fish contamination awareness, and information needs.

2. Process

The following describes the needs assessment process:

a. County health and environmental health staff were important sources for identifying stakeholders who, in turn, identified other appropriate stakeholders. Also, resource directories were consulted to identify stakeholders.

b. A letter that introduced the project and requested collaboration with the needs assessment, and a one-page summary of the project, were sent first to county health officers and environmental health directors. Once the needs assessment was underway with the county agencies, similar letters and project summaries were sent to directors of CBOs, the program manager of the environmental advocacy organization, Pomo Indian tribal leaders, administrators of health care facilities, and church leaders.

c. One week after each mail out, follow-up telephone calls were made to these individuals to schedule meetings at their offices.

d. One and one half hour meetings were held with the individuals or their representatives. EHIB staff provided a brief overview of the Delta watershed fish contamination issue and the project. Subsequently, key informant interviews were conducted. Following the interviews, participants had the opportunity to ask questions. A thank you note was sent to the individuals participating in the interviews.

e. At the end of each meeting with individuals from county health and environmental health departments, EHIB staff provided survey questionnaires to be completed by appropriate field staff. The questionnaires were to be returned within two weeks.

f. At the end of each meeting with tribal leaders and CBO directors or representatives, their assistance was sought in identifying community members to participate in subsequent focus groups.

g. Focus groups were held at CBO or tribal offices, or at another convenient location in the community. Each session lasted approximately one hour. The focus groups were conducted in the language of the participants.

h. A brief presentation on the project was made at meetings of the California Council of Environmental Health Directors for Regions I and II.

i. Information from CAPITAL members was obtained via a survey questionnaire completed during a CAPITAL meeting in Sacramento.

j. Information from Pomo Indian tribal members was obtained via a survey questionnaire completed by participants at an Earth Day event in Lake County.

k. Additional information was obtained from Placer County Environmental Health Services staff via a survey questionnaire completed during a one-day staff retreat at Lake Tahoe.

l. Within two weeks following the meetings held with county health officers and environmental health directors, letters were sent to local elected officials and other community leaders recommended by the staff to inform them about the project and provide a contact name for further information.

m. Letters were sent to county health officers and environmental health directors in the 25 Delta watershed counties that were not included in the initial needs assessment. The purpose of the letter was to inform officials about the project and the possibility that the project could expand into their counties in the future pending funding availability.

n. The primary contact for each organization participating in the needs assessment was asked to review a summary written by EHIB staff of key needs assessment findings pertaining to their organization. The review was requested to confirm the accuracy and completeness of the information in the summary.

o. A copy of the needs assessment report will be sent to the primary contacts for the participating organizations. A letter will accompany the report briefly describing the next phase of the project and requesting their continued collaboration.

Refer to Appendices E and F for the communications sent to needs assessment participants and the data collection tools.

B. Findings

The following are the fndings of the needs assessment by organization within each county.

Lake County

1. **Pomo Indian Tribes: Big Valley Rancheria, Elem Colony/Sulphur Bank Rancheria, Habematol of Upper Lake Rancheria, Robinson Rancheria,**

Hinthil Environmental Resources Consortium, and Lake County Tribal Health Consortium, Inc.

A key informant interview was conducted on February 26, 2003, with Michael Icay, Executive Director of the Lake County Tribal Health Consortium, Inc., and Mike Schaver, Environmental Director of Big Valley Rancheria. Key findings include the following:

a. Lake County Tribal Health Consortium, Inc., has not received inquires about fish contamination in local water bodies and is not conducting outreach and education on this issue. However, Big Valley Rancheria has received some inquiries about local fish contamination and has responded with health advisory information.

b. Both informants reported that many local tribal members eat catfish, crayfish, and hitch regularly. The Pomo catch hitch in March and April and then dry it for consumption during the winter.

c. They believe outreach and education should be conducted to inform tribal members about fish contamination issues and ways to reduce exposure to mercury in fish. Also, they believe that these activities should pertain not only to Clear Lake but also Lake Pillsbury, Indian Valley Reservoir, Letts Lake, and Blue Lake.

d. With a grant from EPA, Big Valley Rancheria will monitor mercury in local waterbodies. The tribe also may conduct fish tissue sampling.

e. Both informants recommend that the Delta Fish Project coordinate with tribal community activities, such as Earth Day and Tule Boat Days, to get acquainted with tribal members and build partnerships for effective outreach and education. Additionally, the project should provide the Intertribal Council of California and tribal environmental and education departments with relevant fish contamination-related educational materials when they become available.

A meeting was held on February 26, 2003, in Clearlake Oaks with members of the Hinthil Environmental Resources Consortium (HERC). The Elem Indian Colony hosted the meeting. Participants included Sara Ryan, Environmental Outreach Coordinator, Big Valley Rancheria; Mike Umbrello, Environmental Director, Elem Indian Colony; Cheryl Steele, Environmental Projects Coordinator, Elem Indian Colony; and Meyo Marrufo, Native American Graves Protection and Repatriation Act (NAGPRA) Director and Cultural Resources Management (CRM) Tribal Representative, Robinson Rancheria. Key findings include the following:

a. HERC members believe that few tribal members still fish or eat fish that is caught in Clear Lake due, in large part, to an awareness that the lake is polluted. Some have replaced fish with fast food consumption.

b. They believe that some tribal members are unaware of the health advisory for Clear Lake.

c. They recommend that fish contamination-related outreach and education activities be conducted collaboratively with appropriate tribal departments.

During the meeting, information was provided on the protocol for collaborating with the tribes and their governing bodies.

A focus group was held on April 9, 2003, at Upper Lake Rancheria with John Hancock, Environmental Director of Upper Lake Rancheria, and four members of Upper Lake Rancheria. Key findings include the following:

a. Members of Upper Lake Rancheria indicated they no longer eat fish caught in Clear Lake or participate in recreational activities in the lake due, in large part, to a belief that the lake is polluted. Mercury is one of the contaminants of concern.

b. They reported that their healthier, traditional diet, consisting of vegetables, fruits, fish, and acorns, is being replaced in many cases by fast food. This dietary change may be responsible for an increased incidence of diabetes and other diseases in tribal members.

c. Traditionally, hitch caught locally in Middle Creek and Clear Lake has been the preferred fish for consumption among tribal members, especially during the winter. However, modern development, such as housing and sewers, and participation in other recreational activities have reduced traditional gathering of native grasses, fishing practices, and availability of hitch.

d. Other species of fish that are caught locally and consumed regularly include bass, catfish, salmon, trout, and crayfish. Some tribal members also reported eating canned tuna once or twice a week.

e. Tribal members still fish in Bodega Bay, Blue Lake, and the Pacific Ocean, where they catch trout, crappie, octopus, mussels, and oysters. They give their catch to family and friends.

f. They recommend that the Delta Fish Project coordinate with Native American youth and HERC to undertake outreach and education on fish contamination and other related issues.

g. They suggest that fish contamination-related information be provided to tribal members via educational materials, such as brochures. Also, they recommend that a documentary be produced on the history of Clear Lake from the Native American perspective that includes a discussion of local water quality and fish contamination issues.

Survey questionnaires were completed by 27 members of the following Pomo Indian tribes: Robinson Rancheria, Elem Indian Colony, Upper Lake Rancheria, and Bear River Band of Ronerville Rancheria, a non-Pomo Indian tribe. Tribal members completed the questionnaire during an Earth Day event in Lake County on June 7, 2003. Key findings include the following:

a. Most respondents indicated they eat fish, caught by themselves or someone they know, from Clear Lake, Blue Lake, the Klamath River, and the Sacramento River.

b. Fish species that are caught and consumed regularly, as often as two to three times per week, include hitch, striped bass, catfish, salmon, trout, and crayfish. Commercial fish consumed by tribal members include salmon, tuna, and striped bass.

c. Most respondents are unaware of the Clear Lake sportfish health advisory.

d. The respondents want information on the health risks of exposure to mercury and dioxins, safe areas to fish, safe fish to eat, and safe fish preparation methods. The preferred ways of providing information to tribal members are through workshops, television, posters, videos, and newsletters.

2. County Health and Environmental Health Departments

A key informant interview was conducted with Craig McMillan, M.D., Public Health Officer, and Raymond Ruminski, Director of the Environmental Health Division, in Lakeport on November 5, 2002. Key findings include the following:

a. Mercury contamination of local fish is a concern to the departments but not a high priority among the issues they are addressing.

b. The Public Health Division and Environmental Health Division receive few public inquiries about local fish contamination. Those received are primarily from tourists and people with summer homes in the area. Inquiries are directed to a website maintained by the Office of Environmental Health Hazard Assessment (OEHHA) in the California Environmental Protection Agency (Cal/EPA). Also, a multilingual fact sheet developed by OEHHA on the Clear Lake sportfish health advisory is made available to the public upon request.

c. Currently, the Public Health Division and Environmental Health Division do not have an outreach and education program that addresses local fish contamination issues. However, they do respond to requests for information on these issues from the County Board of Supervisors and local groups such as the Rotary Club and angler associations.

d. The Clear Lake sportfish health advisory is not posted at the lake's fishing access sites.

e. Activities to disseminate fish contamination-related information to target populations should be coordinated with local family planning and maternal and child health programs.

f. Training on mercury exposure and health risks would benefit some staff members.

3. Health Care Provider

Redbud Community Hospital of Adventist Health

A key informant interview was conducted with Dave Crunk, Administrative Director of Clinic Services at the Redbud Community Hospital of Adventist Health, in Clearlake on March 27, 2003. Key findings include the following:

a. Mr. Crunk is not aware of any concern among the hospital's patients about mercury contamination of fish.

b. Fish contamination-related information could be disseminated to target populations via the Healthy Start Program; the Women, Infants, and Children (WIC) Program; and the obstetrics department at local outpatient health clinics.

c. Continuing medical education on mercury exposure and associated health risks would be useful for appropriate hospital and clinic staff.

Placer County

1. County Health and Environmental Health Departments

A key informant interview was conducted with Michael Mulligan, M.D., Deputy Public Health Officer, and Brad Banner, Director of Environmental Health Services, in Auburn on November 19, 2002. Key findings include the following:

a. Contamination of fish is a concern but not a high priority among the issues they are addressing. Mercury is the primary contaminant of concern in fish, followed by pesticides.

b. Health Services and Environmental Health Services believe there is little awareness among county residents of local fish contamination issues. The few public inquiries received are directed to the CDFG.

c. Posting health advisories may not be the best way to inform people about local fish contamination.

d. Fish contamination-related information should be disseminated to target populations via local health care providers, especially obstetricians and pediatricians.

e. Health Services plans to establish a listserve in mid-2003 to provide information to health professionals and the public, and suggests that fish contamination-related information be disseminated via this mechanism.

A survey questionnaire was completed by 17 staff members of Placer County Environmental Health Services during a retreat and training held in Lake Tahoe on July 30, 2003. Key findings include the following:

a. Most staff do not receive inquiries from the public regarding fish contamination issues and believe that Placer County residents are unaware of these issues.

b. The most common fishing sites in the county are Folsom Lake, Sierra Lakes, American River, Truckee River, Lake Tahoe, Donner Lake, Rollins Lake, and Camp Far West.

c. The most common fish species caught in local waterbodies and consumed are striped bass, catfish, salmon, and rainbow trout.

d. Most staff are unaware of any health advisories for waterbodies in California. However, some staff are aware of a striped bass health advisory for the Sacramento River.

e. Populations that fish regularly in Placer County waterbodies include Latinos, Native Americans, Whites, and Southeast Asians.

f. The following stakeholders are suggested as possible contacts for the Delta Fish Project: Hispanic Enrichment Association of Roseville (HEAR), CDFG, and fishing retailers.

g. The best ways to inform county residents about fish contamination issues are through newspapers, television, posted signs at fishing sites, websites, brochures, and pamphlets.

h. The staff are interested in receiving information via written materials and the Internet on the following topics: overview of fish contamination in Placer County, health risks of mercury exposure and ways to reduce exposure, health advisories for Placer County waterbodies, and mercury in sport and commercial fish and other seafood.

Sacramento County

1. County Health and Environmental Health Departments

A key informant interview was conducted on October 16, 2002, with Cassius Lockett, Ph.D., Epidemiology Program Manager, Sacramento County Department of Health and Human Services; Richard Sanchez, Chief, Environmental Health Division, Sacramento County Environmental Management Department; and Robert Berger, Supervising Environmental Specialist, Environmental Health Division, Sacramento County Environmental Management Department. Key findings include the following:

a. The departments expressed minimal concern about fish contamination in Delta waterbodies. They receive few public inquiries regarding fish contamination and these are mainly related to concerns about paralytic shellfish poisoning (PSP). Refer to Appendix G for information on PSP.

b. The departments believe that county residents generally are not aware of fish and shellfish contamination issues. However, they believe that some populations may be at risk of exposure to mercury, biotoxins, and other contaminants.

c. Southeast Asian, especially Vietnamese, and Russian populations fish regularly in Delta waterbodies.

d. It is important to deliver an appropriate risk communication message to the public without creating excessive panic.

e. Effective public outreach and education methods include television, radio, posters and signs (at major launch and fishing areas), Internet, home visits, and brochures.

f. Staff want information (electronically, PDF file, or hard copy) on mercury, PSP, and *vibrio* (Refer to Appendix G). They also want training in the form of half-day workshops on the following topics: introduction to toxicology, overview of fish contamination in the Delta, safe fish handling practices, and commercial seafood issues.

2. Community-Based Organizations and Community Members

Center for Community Health and Well-being "The Birthing Project"

A focus group was conducted with Tchaka Muhammed, Ph.D., and three constituents of the Center for Community Health and Well-being "The Birthing Project" in Sacramento on March 20, 2003. Key findings include the following:

a. Focus group participants believe that the African-American community eats fish regularly (i.e., once a week) that are caught locally or purchased in stores or restaurants. The sportfish caught include catfish, bass, crappie, sturgeon, and carp. Commercial fish consumed include salmon, crab, shrimp, red snapper, perch, and bluegill.

b. The participants believe there is some level of awareness in the African-American community about the Delta sportfish health advisory and health risks from exposure to contaminants.

c. Information is requested on safe areas to fish, safe fish to eat, safe fish consumption levels, fish/shellfish contamination from mercury, pesticides, PSP, and selenium.

d. A saturation process should be used to disseminate information to the community using television, radio, posters, and brochures. However, the Center noted that many people never read information provided in brochures.

Council for Asian Pacific Islanders Together for Advocacy and Leadership (CAPITAL)

A meeting was held with Sonny Chong, CAPITAL Chairman, and members of CAPITAL on January 25, 2003, in Sacramento. Nine members completed a survey questionnaire. Key findings include the following:

a. Fish contamination issues are a concern to CAPITAL members. Mercury, polychlorinated biphenyls (PCBs), dioxins, and pesticides are the primary contaminants of concern in fish and shellfish.

b. There is no awareness of any organizations that are conducting outreach and education activities on fish contamination issues in the Delta watershed.

c. Most CAPITAL members indicated they would like to participate in the Delta Fish Project's future activities.

Galt Community Concilio, Inc.

A focus group was conducted in Spanish with five constituents of Galt Community Concilio, Inc., on May 13, 2003. Sonia Ornelas, Program Assistant with Galt

Community Concilio, Inc., provided translation services. Key findings include the following:

a. Many Latinos eat fish regularly (at least once a week) which they catch in local waterbodies or buy in local markets. The sportfish caught include striped bass, catfish, and sturgeon. Fish bought locally include salmon, tilapia, and shrimp. How often Latinos fish depends on the agricultural season and their work schedules.

b. The constituents believe that Latinos generally are unaware of the Delta sportfish health advisory and have little concern about mercury contamination in fish, but some concern about pesticide contamination.

c. Information should be provided on fish contamination issues related to mercury and pesticides, safe areas to fish, safe fish to eat, safe fish consumption levels, and safe ways to prepare fish.

d. Risk communication messages should be disseminated to Latinos in Spanish via television and radio spots and workshops.

Slavic Assistance Center, Inc.

A focus group was conducted in Russian with Roman Romaso, Executive Director of the Slavic Assistance Center, Inc., and 19 members of the Center in Sacramento on May 13, 2003. Mr. Romaso provided translation services. Key findings include the following:

a. Russians eat fish about once or twice per month. They obtain fish from markets, vendors who sell at the Russians' apartment complex, or local waterbodies. Sportfish caught and consumed include catfish, striped bass, salmon, and carp. Commercial fish consumed include salmon, tilapia, catfish, and shark.

b. Russians are unaware of any sportfish health advisories or fish contamination issues.

c. The best ways to disseminate information to the Russian community are through Russian radio and television, newsletters, workshops, and word-of-mouth. Visual images of fish are helpful in conveying information to this population.

d. Information should be provided on mercury contamination in fish, safe areas to fish, safe fish to eat, and safe ways to prepare fish.

3. Health Care Provider

Health For All Clinic, Inc.

A key informant interview was conducted with Dr. Richard Ikeda, Executive Director of the Health For All Clinics and Adult Day Health Centers, in Sacramento on April 8, 2003. Key findings include the following:

a. Dr. Ikeda is not concerned about mercury exposure in his patients since he has never seen a case of acute or chronic mercury poisoning in Sacramento.

Rather, he is more concerned about exposure to arsenic and asbestos, and the over-consumption of high calorie foods that lead to obesity.

b. The clinics' patients do not appear to be aware of fish contamination issues based on the lack of inquiries.

c. Public outreach and education messages should not scare the public away from eating fish. Instead, fish consumption should be encouraged and the public educated to the benefits of eating fish versus the disadvantages of beef, pork, and dairy products.

San Joaquin County

1. County Health and Environmental Health Departments

A key informant interview was conducted with Colleen Tracy, Deputy Director of Health Administration and Promotion, Public Health Services; Joan Mazzetti, Health Education Program Coordinator, Public Health Services; Donna Heran, Director, Environmental Health Department; Mark Barcellos, Supervising Registered Environmental Health Specialist, Environmental Health Department; and Al Olsen, Program Manager, Environmental Health Department, in Stockton on October 22, 2002. Key findings include the following:

a. Public Health Services and the Environmental Health Department are concerned about fish contamination and consumption in their county and believe it is an important issue. However, they receive few public inquiries. Phone calls received are mainly from anglers concerned about contamination in the San Joaquin River. Fish contamination and consumption information is provided based on studies conducted by CDHS, San Francisco Estuary Institute, and other organizations, and the sportfish health advisories developed by OEHHA. Inquiries are referred to OEHHA if additional information is requested.

b. Public Health Services has four bilingual outreach staff that work with Cambodian, Hmong, Latino, and Vietnamese populations.

c. Southeast Asian, Latino, and African-American populations residing in the county may be at greater health risk due to fish contamination because of their probable fish consumption practices.

d. Outreach and education activities should be coordinated with Health Access, WIC, the Maternal and Child Health Program, the Immunizations Program, Southeast Asian CBOs, the Striped Bass Association, and the sports editor of the Stockton Record newspaper.

e. The following were offered to enhance risk communication:

   1. Develop and disseminate an accurate message that avoids creating excessive panic. To achieve this, seek input and advice from community members.

2. Traditional health education methods that relay messages via the mass distribution of pamphlets often do not reach at-risk populations, particularly those with low literacy rates.
3. When translating risk communication messages, take into consideration that several language dialects are often spoken within some ethnic groups.
4. Pilot test all messages to avoid inappropriate translations.

f. Staff training on fish contamination-related issues is important.

g. It is essential to coordinate with Public Health Services and the Environmental Health Department prior to launching a public outreach and education campaign.

2. Community-Based Organizations and Community Members

Asian Pacific Self-Development and Residential Association (APSARA) and Cambodian Community Members

An initial key informant interview was conducted with Sovanna Koeurt, APSARA Executive Director, and Nim Ros, Social Services Coordinator, in Stockton on December 11, 2002. A follow-up interview with Ms. Koeurt was done via telephone on January 9, 2003. Key findings include the following:

a. Many Cambodians in Stockton eat catfish daily that is caught locally.

b. There appears to be a low level of awareness and concern among Cambodians about fish and shellfish contamination since APSARA has never received any inquiries.

c. Ms. Koeurt is collaborating with CDFG in the development of a video to educate the public on fish contamination issues.

d. Ms. Koeurt sent a letter to the San Joaquin County Health Officer on October 10, 2002, indicating that the Cambodian translation of the message on fish warning signs posted at the Port of Stockton was incorrect and could be interpreted by Cambodians to mean that fish caught in the Port are safe to eat. This translation error was corrected and the signs were reposted in January 2003 with the correct message, "fish caught here are not safe to eat."

A focus group was conducted in Cambodian with ten members of APSARA in Stockton on February 28, 2003. Lim Leang, a San Joaquin County Health Department staff person, provided translation services. Key findings include the following:

a. The participants indicated that fish and shellfish caught locally and consumed regularly (two-three times a week) by the Cambodian community include catfish, striped bass, bluegill, salmon, crawfish, and trout. Locally harvested clams are eaten during the summer. Also, many Cambodians commonly purchase fish and shellfish from vendors who sell door-to-door.

b. The participants were not aware of the health risks from consumption of contaminated fish.

c. Some of the participants indicated they have seen the "no fishing" sign at some locations in the Port of Stockton. However, they said the message on the sign was unclear and they do not know why they should not fish there.

d. Outreach and education materials should have a simple, clear message and include visual images. One suggestion is to develop a product that includes pictures of fish that are safe to eat as well as fish that should not be eaten.

e. The participants requested information on safe areas to fish, safe fish to eat, safe limits for fish and shellfish consumption, health risks of contaminants in fish, and sources of additional information.

Lao Khmu Association, Inc.

A key informant interview was conducted with Robert Khoonsrivong, Executive Director of Lao Khmu Association, Inc., in Stockton on February 6, 2003. Key findings include the following:

a. Mr. Khoonsrivong believes that 80-90 percent of Southeast Asians residing in San Joaquin County catch and/or eat fish caught in Delta waterbodies. Cambodian, Lao, Hmong, and Vietnamese are the groups that most often fish. People also buy fish caught locally from vendors who sell door-to-door.

b. Mr. Khoonsrivong believes that San Joaquin County residents, particularly the Southeast Asian community, are not aware of the fish contamination problem. He has never received any inquiries about this issue.

c. Visual methods and materials, such as videos, television, and calendars should be used for disseminating information. Printed materials should not be relied on exclusively to inform Southeast Asian populations.

d. An English language television show sponsored by the Central Asian Chamber of Commerce may be a good forum for disseminating information to a broad range of people.

e. Information dissemination should be coordinated with existing programs implemented by Southeast Asian organizations. Information could be posted on the Lao Khmu website: www.laokhmu.org.

Vietnamese Voluntary Foundation, Inc. (VIVO) and Vietnamese Community Members

A key informant interview was conducted with Ky Hoang, Program Manager, and Linda Hobson, Project Coordinator, in Stockton on February 6, 2003. Key findings include the following:

a. VIVO staff are very familiar with fish contamination issues. In 1996, VIVO collaborated with the Asian-Pacific Environmental Network (APEN) in producing educational materials about fish contamination in the Port of Stockton and safe fish preparation methods for consumption. VIVO distributed the materials to the Vietnamese community. The project ended due to lack of funding.

b. VIVO believes there is little knowledge or concern in the Vietnamese community about fish contamination, based on the lack of inquiries.

c. Approximately 70 percent of the Vietnamese community in Stockton are illiterate in English and about 30 percent are illiterate in their own language. Therefore, outreach and education materials should rely primarily on visual images (e.g., pictures, diagrams, photos) of fish that are safe to eat and those that should be avoided.

d. There are radio stations in Sacramento, but none in the Stockton area, that transmit in Asian languages.

e. VIVO and other similar organizations that are trusted within the community should disseminate information on fish contamination issues.

A focus group was conducted in Vietnamese with members of VIVO in Stockton on March 20, 2003. A San Joaquin County Health Department staff person provided translation services. Key findings include the following:

a. The Vietnamese community eats fish and shellfish regularly (approximately two to three times a week). Sportfish caught locally and consumed include striped bass and catfish. The Vietnamese community also buys fish at the local Asian Farmer's Market and from vendors who sell door-to-door. Commercial fish consumed include bluegill, trout, tilapia, tilefish, shrimp, herring, sardines, and crab.

b. The participants indicated there is some awareness in the Vietnamese community of the Port of Stockton health advisory sign and the health risks due to consumption of contaminated fish.

c. Some participants said that if a fish looks good, it is considered safe to eat. Since they do not see anyone getting sick from eating the fish, they are not concerned about fish contamination problems.

d. The best methods for communicating information are videos (most households have a VCR), the local Vietnamese newspaper, television, and brochures. Also, training should be provided to community service workers on this issue so that they can provide information to the community.

e. Focus group participants expressed an interest in receiving information on the health risks of mercury exposure, safe fish to eat, safe levels of fish consumption, and safe areas to fish.

3. Environmental Advocacy Organization

DeltaKeeper

A key informant interview was conducted with Bill Jennings, DeltaKeeper, and Kari Morgan, DeltaKeeper Volunteer and Monitoring Coordinator, in Stockton on October 22, 2002. Key findings include the following:

a. Two key issues for DeltaKeeper are: (1) consumption of chemical-contaminated fish, and (2) bacterial contamination of water and its impacts on recreational users in the Delta.

b. Sportfishing is practiced all year in the Delta. Southeast Asians, Latinos, and people who live on houseboats most commonly catch and consume catfish, largemouth bass, bluegill, and carp. Southeast Asians also harvest clams for consumption.

c. DeltaKeeper actively patrols the Delta by boat and conducts water quality monitoring for pathogens. They also have one-on-one contact with many people who live in the Delta.

d. The organization conducts outreach to high school and college environmental groups and maintains a telephone hotline.

e. Deltakeeper suggests the following actions:
    1. Develop and distribute a fact sheet on contamination of striped bass in the Delta.
    2. Develop and disseminate a general fish contamination message to ensure that everyone understands the fish contamination problem rather than directing the message only to pregnant women and children.
    3. Undertake a fish consumption study to better understand the health risks to those who eat fish caught in Delta waterbodies.
    4. Conduct comprehensive fish tissue monitoring in the Delta.

Yolo County

1. County Health and Environmental Health Departments

A key informant interview was conducted with Bette Hinton, M.D., Public Health Officer, and Thomas To, Director of the Environmental Health Division, in Woodland on November 14, 2002. Key findings include the following:

a. Public Health Services and the Environmental Health Division do not consider fish contamination as high a priority as other public health and environmental health issues in Yolo County.

b. Mercury contamination of fish in Putah Creek is a concern to Davis residents. However, in general, Public Health Services and the Environmental Health Division receive few public inquiries (one to two a year) regarding fish contamination unless there is a news release. The inquiries usually concern pesticide and mercury contamination of fish.

c. Staff believe that mercury, pesticides, PCBs, and dioxins are the contaminants that pose the greatest risks to public health.

d. Most staff are unaware of the Delta fish consumption advisory.

e. Dissemination of information on fish contamination-related issues should be coordinated with health care providers, organizations serving the Russian population, the County Social Services Department, and programs, such as WIC, that serve women of childbearing age, pregnant women, and young children.

f. Russians, Southeast Asians, and Latinos frequently consume fish caught in Delta waterbodies.

g. Public Health Services and the Environmental Health Division should be provided with information on fish consumption guidelines for pregnant women and on specific contaminants of concern during pregnancy (i.e., mercury, pesticides, PCBs, dioxins, *vibrio*, and PSP). The information should be provided in PDF file or electronic formats.

h. Training should be provided to staff on the following topics: overview of fish contamination in the Delta, health risks of exposure to contaminants of concern during pregnancy, fish consumption guidance for pregnant women to reduce their exposure to mercury, and risk assessment.

i. Staff should receive training through the Internet, videos, or a half-day teleconference or workshop.

j. Staff reported the following lessons learned from their outreach and education activities:
   1. Use existing resources and networks.
   2. Utilize someone "from the culture" to reach Latino, Russian, African-American, and Southeast Asian populations.
   3. Ensure that information is available in all major languages spoken by the target populations.
   4. Utilize elderly members of the population for disseminating messages to their communities.

2. Russian Churches of West Sacramento

A key informant interview was conducted with Ivan Kosuleki, Chief Executive Officer of the Holy Myrrhbearing Women Church, and Mikhail Avramenko, Assistant Pastor of the Russian Church of Evangelical Christian Baptists, in West Sacramento on February 4, 2003. Key findings include the following:

a. The Russian community fishes and eats fish caught in Delta waterbodies, primarily striped bass, catfish, and carp.

b. Church leaders believe that there is little awareness in the Russian community of fish contamination issues in Delta waterbodies and they are not aware of the Delta fish consumption advisory.

c. Dissemination of fish contamination-related information should be coordinated with the Russian hospital and clinic, and the Slavic Assistance Center.

C. Summary of Key Findings

The following summarizes the key findings of the needs assessment by category of participants. Among the *Pomo Indian* participants there appears to be little awareness of the Clear Lake sportfish health advisory. Some tribal members fish in local waterbodies and consume their catch while others do not due, in large part, to a belief that the waters are polluted with mercury and other contaminants. Traditionally, hitch has been the preferred fish for consumption among tribal members, especially during the winter. However, modern development in the area has contributed to a decreased availability of hitch in recent years. Some tribal members reported that the Pomo's traditional diet, consisting of vegetables, fruits, fish, and acorns, is being replaced, in many cases, by fast food. They believe this dietary change may be responsible for the increased incidence of diabetes and other diseases in tribal members. Fish contamination outreach and education activities should be coordinated with tribal events such as Earth Day and Tule Boat Days.

The *County Health and Environmental Health Departments* believe that local fish contamination is a public health concern, particularly for women of childbearing age and children under six years of age. However, the departments are not currently undertaking public outreach and education on this issue, in large part due to competing public health needs that are a higher priority for these counties. They receive few public inquiries regarding fish contamination, which may be related to a general lack of public awareness on this issue. The departments recommend collaborations with local programs aimed at target populations and dissemination of information through health care providers, especially family practitioners, pediatricians, and obstetricians. They believe that the use of mass media (e.g., television and radio), posters, and the Internet are effective methods for informing people about fish contamination issues. The departments support training for their staff on fish contamination-related topics to increase their knowledge about local fish contamination issues and associated human health risks, and better prepare them to respond to inquiries from the public that may be generated by the project's activities.

CBOs and their members representing African-American, Cambodian, Latino, Russian, and Vietnamese populations report that their communities regularly eat fish, especially striped bass and catfish. Also, carp is reported to be widely consumed in African-American and Russian communities. Sportfishing is practiced all year in the Delta watershed. Also, the CBOs and their members report that their communities have very low awareness of fish consumption advisories and the health risks of exposure to mercury in fish. They recommend that outreach and education activities focus on the use of visual materials (e.g., pictures, posters, calendars, and videos) rather than printed materials. CBOs and their members believe it is important to coordinate with existing programs serving their communities. Furthermore, some participants believe that local CBOs, rather than outside agencies and organizations, should disseminate information to the communities they serve because they are a trusted source. The CBOs and their members are interested in receiving information on safe areas to fish, safe fish to eat, safe levels of fish and shellfish consumption, and health risks of exposure to mercury and other contaminants in fish.

Health care providers participating in the needs assessment are not aware of any concern among their patients about mercury contamination of fish. However, one health care provider indicated that continuing medical education on mercury exposure and associated health risks would be useful for appropriate staff. He also suggested that public outreach and education on fish contamination-related issues should be coordinated with existing programs that reach the target populations (i.e., WIC and Healthy Start) and outpatient health clinics.

The *environmental advocacy organization* believes that public outreach and education on fish contamination issues are important to raise general awareness of the fish contamination problem in the Delta watershed. Also, the organization recommends that fish tissue monitoring and a fish consumption study be conducted to better understand the health risks to those who eat fish caught in the watershed.

IV. CONCLUSIONS

The needs assessment results provide a preliminary understanding of fish contamination awareness, fishing activities, and fish consumption practices among diverse populations in five Delta watershed counties. Although the findings are by no means exhaustive, they support the need for outreach, education, and training on fish contamination-related issues relevant to affected populations. Additional information will be collected from populations (e.g., tribes, Hmong, Filipinos, and anglers) and organizations serving these populations that were either underrepresented or not included in the needs assessment due to time and other resource constraints. The needs assessment results and the additional information collected will guide development of a strategy that aims to increase affected populations' awareness about mercury contamination in fish species, decrease their health risks from exposure to mercury in fish, and build local capacity to address these issues.

V. RECOMMENDATIONS

The following recommendations are based on the results of the needs assessment:

1. Convene a forum involving Pomo Indian tribes and state and local agencies to: (a) dialogue about tribal members' concerns about water quality, including fish contamination, in local waterbodies, and (b) plan a coordinated effort to respond to identified concerns.
2. Design and implement a comprehensive framework that focuses on priority water quality issues, including mercury, that are impacting Pomo Indian tribal members' lives and cultural traditions.
3. Collect additional information from populations (e.g., tribes, Hmong, Filipinos, and anglers) and organizations serving these populations that were either underrepresented or not included in the needs assessment due to time and other resource constraints. A fish consumption study is one method to accomplish this.
4. Develop fish contamination-related messages, in collaboration with tribes, local agencies, and CBOs that are appropriate to the languages and literacy levels of the target populations (women of childbearing age and anglers) and field test the messages prior to their dissemination.
5. Develop fish contamination-related materials that emphasize visual images (e.g., posters and calendars) and use mass media communication methods, particularly television and radio.

6. Identify and coordinate with local CBOs, tribes, health and social services programs (e.g., WIC, Maternal and Child Health, Healthy Start, and Family Planning), and health care providers, among others, to disseminate information to the target populations.
7. Develop and offer educational materials and training to appropriate health care providers (i.e., family practice physicians, obstetricians, gynecologists, pediatricians, physicians assistants, and nurse practitioners) and county health and environmental health staff on the health risks of exposure to mercury and other contaminants in fish and ways to reduce exposure.
8. Evaluate outreach and education activities on an ongoing basis to ensure the effectiveness of outreach and education messages, materials, and communication methods.

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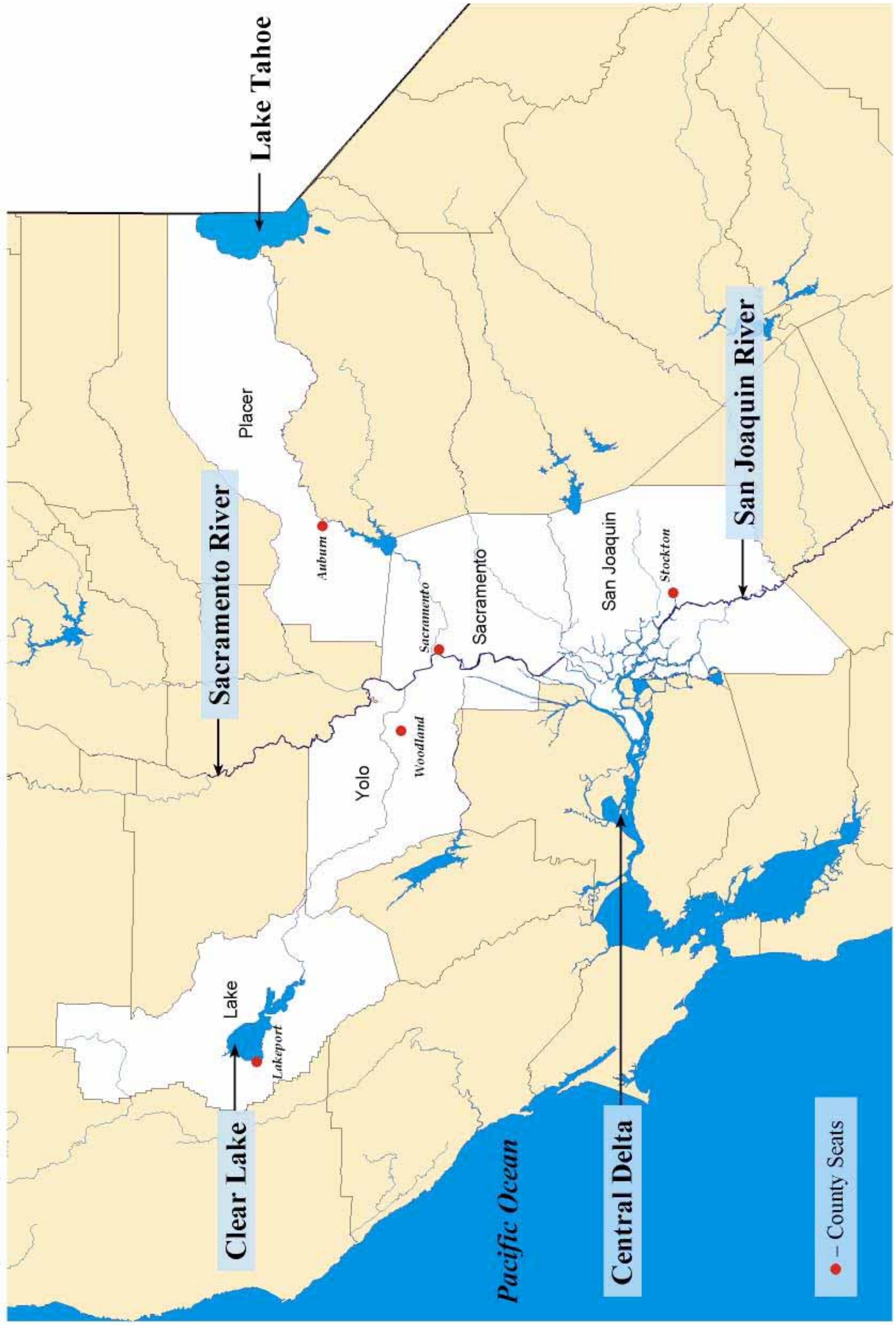
Appendices

Appendix A

Map: Delta Watershed Counties Participating in the Needs Assessment

Delta Watershed Counties Participating in the Needs Assessment



Appendix B

County Profiles

Lake County

Lake County is located 110 miles north of San Francisco and covers 1,327 square miles. The county is comprised largely of agricultural and national forest lands, recreational use areas, and several small towns. The county has five major waterbodies: Clear Lake, Upper Putah Creek, Lake Pillsbury, Blue Lakes, and Indian Valley Resevoir. The two cities in the county are Lakeport, the county seat, and Clearlake. In 2000, Lake County's population totaled 58,309 and was 81 percent White/Non-Hispanic, 11 percent Hispanic or Latino, 3 percent Native American or Alaska Native, 2 percent African-American, and 1 percent Asian. The Pomo Indians are the main Native American group in the county. In 2002, Lake County's unemployment rate was eight percent, the 23rd highest among the state's 58 counties. The principal industries in the county, based on number of employees, are government services and retail trade. Also, tourism and recreation are important components of the economy.

Placer County

Placer County is located 120 miles northeast of San Francisco and covers 1,507 square miles. The county is comprised largely of national forest lands, recreational use areas, and several small towns. There are several major waterbodies in Placer County, including the American and Bear Rivers, Lake Clementine, and the northwest portion of Lake Tahoe. The five cities in the county are Auburn (the county seat), Rocklin, Lincoln, Roseville, and Colfax. In 2000, Placer County's population totaled 248,399 and was 83 percent White/Non-Hispanic, 10 percent Hispanic or Latino, 3 percent Asian, 1 percent African-American, and 1 percent Native American or Alaska Native. In 2002, Placer County's unemployment rate was five percent, the 51st highest among the state's 58 counties. The principal industries in the county, based on number of employees, are services, retail trade, and government. Also, tourism is an important component of the economy.

Sacramento County

Sacramento County is located 90 miles northeast of San Francisco and covers 1,015 square miles. The county is in the middle of California's agricultural Central Valley region. There are several major waterbodies in Sacramento County including Lake Natoma, the southern portion of Folsom Lake, and the Cosumnes, American, and Sacramento Rivers. The six cities in the county are Sacramento (the state capital and county seat), Elk Grove, Citrus Heights, Folsom, Galt, and Isleton. In 2000, Sacramento County's population totaled 1,223,499 and was 58 percent White/Non-Hispanic, 16 percent Hispanic or Latino, 11 percent Asian, 10 percent African-American, and 1 percent Native American or Alaska Native. Sacramento County's unemployment rate was five percent in 2002, the 44th highest among the state's 58 counties. The principal industries in the county, based on number of employees, are government, services, and retail trade. Agriculture is an important component of the economy.

San Joaquin County

San Joaquin County is located 50 miles east of San Francisco and covers 1,436 square miles. The county is in California's agricultural Central Valley region. There are several major waterbodies in San Joaquin County including the Port of Stockton, the Stockton Deep Water Channel, and the San Joaquin, Old Paradise, and Middle Rivers. The seven cities in the county are Stockton, the county seat, Escalon, Lathrop, Lodi, Manteca, Ripon, and Tracy. In 2000, San Joaquin County's population totaled 563,598 and was 47 percent White/Non-Hispanic, 31 percent Hispanic or Latino, 11 percent Asian, 7 percent African-American, and 1 percent Native American or Alaska Native. San Joaquin County's unemployment rate was ten percent in 2002, the 16th highest among the state's 58 counties. The principal industries in the county, based on number of employees, are services, government, and retail trade. Agriculture is an important component of the economy.

Yolo County

Yolo County is located 50 miles northeast of San Francisco and covers 1,034 square miles. The county is comprised largely of agricultural land and small towns. There are several major waterbodies in Yolo County, including the Port of Sacramento, the Sacramento Deep Water Channel, and Cache Creek. The four cities in the county are Woodland, the county seat, Davis, West Sacramento, and Winters. In 2000, Yolo County's population totaled 168,660 and was 58 percent White/Non-Hispanic, 26 percent Hispanic or Latino, 10 percent Asian, 2 percent African-American, and 1 percent Native American or Alaska Native. The main Native American Tribe in the county is the Wintun Indians of Rumsey Rancheria. Yolo County's unemployment rate in 2002 was five percent, the 46th highest among the state's 58 counties. The principal industries in the county, based on number of employees, are government, services, and retail trade. Agriculture is an important component of the economy.

Appendix C

Project Collaborators

Contact List

Federal

Agency	Contact	Address	Phone #	E-mail	Website
US Environmental Protection Agency Region IX, Water Division	Gail Louis, Water Division	75 Hawthorne Street San Francisco, CA 94105-3901	415-947-3467	Louis.gail@epa.gov	www.epa.gov/region09/

Pomo Indian Tribes and Tribal Organizations

Agency	Contact	Address	Phone #	E-mail	Website
Big Valley Rancheria	Mike Schaver, Environmental Director	2726 Mission Rancheria Lakeport, CA 95453	707-263-3924	schaver@big-valley.net	www.big-valley.net
Elem Indian Colony/Sulphur Bank Rancheria	Cheryl Steele, Environmental Director	13300 E Hwy 20 Clear Lake Oaks, CA 95423	707-998-1058	epacs@pacific.net	N/A
Habematol of Upper Lake Rancheria	John Hancock, Environmental Director	375 E. Hwy 20, Suite 1 P.O. Box 516 Upper Lake, CA 95485	707-275-0737	han@saber.net	www.upperlakepomoindians.com
Robinson Rancheria	Meyo Marrufo, NAGRA Director & CRM Tribal Representative	1545 E. Highway 20 Nice, CA 95464	707-275-0205	rmmarrufo@hotmail.com	www.robinsonrancheria.org
Lake County Tribal Health Consortium, Inc.	Michael Icay, Executive Director	925 Bevins Court Lakeport, CA 95453	707-263-8382	N/A	N/A

State

Agency	Contact	Address	Phone #	E-mail	Website
California Bay-Delta Authority	Donna Podger, Water Resource Engineer	650 Capitol Mall, 5th Floor Sacramento, CA 95814	916-445-5511	dpodger@calwater.ca.gov	www.calwater.ca.gov/
California Department of Health Services, Environmental Health Investigations Branch	Samira Jones, MPH, Public Health Prevention Specialist	1515 Clay Street, Suite. 1700 Oakland, CA 94612	510-622-4500	Sjones1@dhs.ca.gov	www.ehib.org
California Environmental Protection Agency, Central Valley Regional Water Quality Control Board	Janice Cooke, PhD, Environmental Scientist	3443 Routier Road, Suite A Sacramento, CA 95827	916-255-3372	CookeJ@RB5S.swrcb.ca.gov	www.swrcb.ca.gov/rwqcb5
California Environmental Protection Agency, Office of Environmental Health Hazard Assessment	Robert Brodberg, PhD, Staff Toxicologist	1001 I Street, Sacramento, CA 95814	916-323-4763	rbrodber@oehha.ca.gov	www.oehha.ca.gov

Delta Tributaries Mercury Council	Carol Atkins, Senior Project Manager	P.O. Box 72237 Davis, CA 95617	530-758-0477	catkins@harriscompany.net	www.sacriver.org/subcommittees/dtmc
University of California at Davis, Department of Environmental Science and Policy	Fraser Shilling, PhD, Staff Research Associate IV	One Shields Avenue Davis, CA 95616	530-752-7859	fmshilling@ucdavis.edu	www.des.ucdavis.edu

County

<u>Lake County</u>

County Agencies:

Agency	Contact	Address	Phone #	E-mail	Website
Public Health Division	Craig McMillan, MD, Public Health Officer	922 Bevins Court Lakeport, CA 95453	707-263-1090	craigm@co.lake.ca.us	www.co.lake.us/countygovernment/departments.html
Environmental Health Division	Raymond Ruminski, Environmental Health Director	922 Bevins Court Lakeport, CA 95453	707-263-1164	rayr@co.lake.ca.us	www.co.lake.us/countygovernment/departments.html

Health Care Providers:

Agency	Contact	Address	Phone #	E-mail	Website
Redbud Community Hospital of Adventist Health	Dave Crunk, RN, Administrative Director of Clinic Services	15630 18th Avenue P.O. Box 6710 Clearlake, CA 95422	707-995-5846	N/A	www.adventisthealth.org

<u>Placer County</u>

County Agencies:

Agency	Contact	Address	Phone #	E-mail	Website
Health Services	Michael Mulligan, MD, Deputy Public Health Officer	11484 B Avenue Auburn, CA 95603	530-889-7119	mmulliga@placer.ca.gov	www.placer.ca.gov/hhs/hhs.htm.
Environmental Health Services	Brad Banner, Environmental Health Director	11484 B Avenue Auburn, CA 95603	530-889-7335	bbanner@placer.ca.gov	www.placer.ca.gov/hhs/enviro/enviro.htm

<u>Sacramento County</u>

County Agencies:

Agency	Contact	Address	Phone #	E-mail	Website
Department of Health and Human Services	Glenna Trochet, MD, Public Health Officer	7001 A East Parkway, Suite 600 Sacramento, CA 95826	916-875-5881	TrochetG@SacCounty.net	www.sacdhhs.com

Environmental Health Division	Richard Sanchez, MPH, Chief of Environmental Health	8475 Jackson Road, Suite 200 Sacramento, CA 95826	916-875-8409	SanchezRi@SacCounty.net	www.emd.saccounty.net
Sacramento Regional County Sanitation District	Vicki Fry, PE, Associate Civil Engineer	10545 Armstrong Avenue, Suite 101 Mather, CA 95655	916-876-6113	fryv@SacCounty.net	www.srcsd.com

Community Organizations:

Agency	Contact	Address	Phone #	E-mail	Website
Center for Community Health and Well-being, The Birthing Project	Tchaka Muhammed, PhD, Brother Friends Coordinator	1900 T Street Sacramento, CA 95814	916-558-4837	bpusa@earthlink.net	www.birthingprojectusa.com
Council for Asian Pacific Islanders for Advocacy and Leadership (CAPITAL)	Sonny Chong, DMD, Chairman	5665 Freeport Blvd., #2 Sacramento, CA 95822	916-392-6471	dachongs@worldnett.att.net	www.sactocapital.org
Galt Community Concilio, Inc.	Mary Lou, Executive Director	660 Chabolla Avenue Galt, CA 95632	209-745-9174	mlpowers@softcom.net	N/A
Slavic Assistance Center, Inc.	Roman Romaso, Executive Director	2117 Cottage Way Sacramento, CA 95825	916-925-1071	N/A	N/A

Health Care Provider:

Agency	Contact	Address	Phone #	E-mail	Website
Health For All, Inc.	Richard Ikeda, MD, MPA, Executive Director	2730 Florin Road Sacramento, CA 95822	916-393-4861	ikeda@health-forall.org	www.health-forall.org

San Joaquin County

County Agencies:

Agency	Contact	Address	Phone #	E-mail	Website
Public Health Services	Joan Mazzetti, MPH, Health Education Program Coordinator	1601 E. Hazelton Avenue Stockton, CA 95201	209-468-2293	jmazzetti@phs.hs.co.san-joaquin.ca.us	www.co.san-joaquin.ca.us/PHS/management
Environmental Health Department	Donna Heran, Environmental Health Director	304 E. Weber Avenue, Third Floor Stockton, CA 95202	209-468-3429	dheran@phs.hs.co.san-joaquin.ca.us	www.co.san-joaquin.ca.us/EHD

Community-Based Organizations:

Agency	Contact	Address	Phone #	E-mail	Website
Asian Pacific Islander Self-development and Residential Association (APSARA)	Sovanna Koeurt, Executive Director	3830 Alvarado Street, Suite C Stockton, CA 95204	209-944-1700	apsara@inreach.com	www.apsaraonline.org
Lao Khmu Association, Inc.	Robert Khoonsrivong, Executive Director	1044 N. El Dorado Street Stockton, CA 95202	209-463-3410	lka@laokhmu.org	www.laokhmu.com
Vietnamese Voluntary Foundation, Inc. (VIVO)	Linda Hobson, Project Coordinator	4410 N. Pershing Avenue, Suite C4-5 Stockton, CA 95202	209-475-9454	vivosjc@sbcglobal.net	N/A

Environmental Advocacy Organization:

Agency	Contact	Address	Phone #	E-mail	Website
DeltaKeeper	Bill Jennings, DeltaKeeper	3536 Ranier Avenue Stockton, CA 95204	209-464-5090	Deltakeep@aol.com	www.waterkeeper.com

Yolo County

County Agencies:

Agency	Contact	Address	Phone #	E-mail	Website
Public Health Services	Bette Hinton, MD, MPH, Public Health Officer	10 Cottonwood Avenue Woodland, CA 95605	530-666-8674	Bette.Hinton@yolocounty.org	www.yolocounty.org/org/health
Environmental Health Division	Thomas To, Environmental Health Director	10 Cottonwood Avenue Woodland, CA 95605	530-666-8646	Thom.To@yolocounty.org	www.yolocounty.org/org/health/eh/

Environmental Organization:

Agency	Contact	Address	Phone #	E-mail	Website
Larry Walker Associates	Tom Grovhoug, Vice President	509 4th Street Davis, CA 95616	530-753-6400	tomg@lwa.com	www.lwadavis.com

Faith-Based Organizations:

Agency	Contact	Address	Phone #	E-mail	Website
Holy Myrrhbearing Women Church	Ivan Kosuleki, Chief Executive Officer	833 Water Street, West Sacramento, CA 95605	916-371-1041	N/A	www.oca.org/pages/directory/listing.asp?KEY:OCA-WE-BRYHMW
Russian Church of Evangelical Christian Baptist	Assistant Reverend Mikhail Avramenko	828 Solano Street West Sacramento, CA 95605	916-375-1855	N/A	N/A

Organization Profiles

Federal

United States Environmental Protection Agency (EPA): EPA was created in 1970. Its mission is to protect human health and safeguard the natural environment. The agency develops and enforces regulations, provides financial assistance to states, nonprofit organizations and educational institutions, performs environmental research, sponsors voluntary partnerships and programs, and advances educational efforts. EPA is headquartered in Washington, D.C., and has ten regional offices and 16 laboratories. The Region IX office, which is collaborating with the Delta Fish Project, is located in San Francisco. The website is www.epa.gov/region09.

State

California Bay-Delta Authority (CBDA): CBDA was created in 1994 and has offices in Sacramento. It is a cooperative effort of more than 20 state and federal agencies working with local communities to improve the quality and reliability of California's water supplies and revive the San Francisco Bay-Delta ecosystem. The CBDA mission is to develop and implement a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta System. The website is www.calwater.ca.gov.

California Department of Health Services, Environmental Health Investigations Branch (EHIB): The EHIB mission is to protect the health of Californians by assessing the association between health outcomes and the environment, and collaborating with communities to address their environmental health concerns. To accomplish this, EHIB conducts health and exposure investigations, undertakes health and exposure surveillance, provides public health oversight, technical assistance and training, facilitates public participation and effective community relations, develops policy initiatives and recommendations, and maintains scientific preparedness. EHIB's offices are located in Oakland. The website is www.ehib.org.

California Environmental Protection Agency, Central Valley Regional Water Quality Control Board (CVRWQCB): CVRWQCB is one of nine Regional Boards that comprise the State Water Resources Control Board, which was created in 1967. It is responsible for protecting water resources in California's Central Valley. The mission of the Regional Boards is to preserve, enhance, and restore the quality of California's water resources, and ensure their proper allocation and efficient use for the benefit of present and future generations. The Regional Boards are semi-autonomous and comprised of up to nine part-time members appointed by the Governor. Regional boundaries are based on watersheds. Each Regional Board makes critical water quality decisions for its region. These decisions include setting standards, issuing waste discharge requirements, determining compliance with those requirements, and taking appropriate enforcement actions. The CVRWQCB website is www.swrcb.ca.gov/rwqcb5.

California Environmental Protection Agency, Office of Environmental Health Hazard Assessment (OEHHA): OEHHA was established in the Governor's Reorganization Plan of 1991. Its overall mission is to protect and enhance public health and the environment through scientific evaluation of risks posed by hazardous substances. OEHHA develops and provides risk managers in state and local agencies with information pertinent to decisions concerning public health, and collaborates with federal agencies, the scientific community, industry, and the public on environmental and public health issues. OEHHA has offices in Sacramento and Oakland. The website is www.oehha.ca.gov.

Delta Tributaries Mercury Council (DTMC): DTMC was created in 1999 as a subcommittee of the Sacramento River Watershed Program. Its offices are located in Sacramento. The DTMC mission is to bring together representatives of various federal, state, and county agencies, academic institutions, consulting firms, and citizen stakeholders to collaboratively develop and implement a strategic plan for the management of mercury in the Sacramento-San Joaquin Delta and its tributaries and monitor its effectiveness. The DTMC website is www.sacriver.org/subcommittees/dtmc.

University of California at Davis, Department of Environmental Sciences and Policy: The Department of Environmental Sciences and Policy at the University of California at Davis has academic and research programs. It offers a Bachelor of Science degree in two different undergraduate majors: Environmental Biology and Management and Environmental Policy and Analysis. Also, it has collaborated in the development of cross-disciplinary programs, such as integrated watershed-scale analyses of both environmental problems and public policy. The Department houses several research groups including two in watershed science and lake ecology (limnology). The website is www.des.ucdavis.edu.

County

Lake County

Pomo Indian Tribes: For nearly 10,000 years, the Pomo Indians, also known as Pomo, have lived in areas that are located primarily in what are now Mendocino, Sonoma, and Lake Counties. Traditionally, the Pomo engaged in hunting, fishing, and collecting native plants for subsistence. In 1990, the United States Census reported that approximately 5,000 Native Americans identified themselves as Pomo Indians. The following Pomo Indian tribes reside in Lake County:

Big Valley Rancheria: Big Valley Rancheria is a federally recognized Pomo Indian tribe that is governed by a five-member board. In 2002, Big Valley Rancheria had 726 members, making it one of the largest Pomo Indian tribes. Big Valley Rancheria is located west of Clearlake. Mike Schaver is the Environmental Director. The website is www.big-valley.net.

Elem Indian Colony/Sulphur Bank Rancheria: The Elem Indian Colony, also known as the Sulphur Bank Rancheria, is a federally recognized Pomo Indian tribe. The colony is located along the northwest side of Clearlake near Clearlake Oaks. In 2002, there were 350 members enrolled in the Elem Indian Colony. A general council composed of all eligible voters governs the colony. Cheryl Steele is the Environmental Director.

Habematol of Upper Lake Rancheria: Habematol, which means "We the people," of Upper Lake Rancheria is a federally recognized Pomo Indian tribe. Upper Lake Rancheria is located approximately five miles from Clearlake. The Rancheria is governed by a seven-member elected executive committee. In 2002, the tribe had approximately 150 members. John Hancock is the Environmental Director. The website is www.upperlakepomoindians.com.

Robinson Rancheria: The Robinson Rancheria is a federally recognized Pomo Indian tribe. There are two Robinson Rancheria sites: the older site is located approximately 2.5 miles northwest of Clearlake and the newer site is about seven miles northwest of Clearlake. A six-member elected business council governs Robinson Rancheria. In 2002, the tribe had 476 members. Robert Quitiquit is the Environmental Director. The website is www.robinsonrancheria.org.

Hinthil Environmental Resources Consortium (HERC): HERC was created in 2001. Its members include the environmental health directors from each Pomo Indian tribe in Lake County. HERC is chaired by an elected member and convenes monthly to discuss environmental projects and issues that affect the Pomo Indians.

Lake County Tribal Health Consortium, Inc.: The Lake County Tribal Health Consortium, Inc., created in 1983, is under the United States Indian Health Service and serves members of six tribes residing in Lake County: Big Valley Rancheria, Elem Indian Colony, Habematol of Upper Lake Rancheria, Middletown Rancheria, Robinson Rancheria, and Scott's Valley Rancheria. Its clinic is located in Lakeport and provides medical, dental, and counseling services. Michael Icay is the Executive Director.

Public Health Division: The Lake County Public Health Division is housed in the County Department of Health Services. The following programs and services are provided to county residents: family planning; HIV/AIDS case surveillance, education, and prevention; emergency preparedness; preventive health care for the aging; immunizations; counseling and referral for birth defects; and oral health education. Craig McMillan, M.D., is the Public Health Officer. The website is www.lake.ca.us/countygovernment/departments.html.

Environmental Health Division: The Lake County Environmental Health Division is housed in the County Department of Health Services. The following services are provided to county residents: solid waste management, public water systems treatment, emergency response and preparedness, nuisance complaints response, and special projects related to groundwater protection and environmental crime. The programs within the division include: food sanitation, the Certified Unified Program Agency handling of hazardous wastes and materials, onsite sewage disposal, and well water monitoring. Raymond Ruminski is Director of the Environmental Health Division. The website is www.co.lake.ca.us/countygovernment/departments.html.

Redbud Community Hospital of Adventist Health: Redbud Community Hospital was established in 1968 and is located in Clearlake. It served Lake County residents as a district hospital until 1997 when it joined Adventist Health. Adventist Health is a system of 20 hospitals in four western states that provides physical, mental, and spiritual care. The hospital offers a full range of inpatient and outpatient services. Outpatient primary care services are offered in five local health clinics. Dave Crunk is the Administrative Director of Clinic Services. The website is www.adventisthealth.org.

Placer County

Health Services: Placer County Health Services, which is housed in the County Health and Human Services Department, provides a wide variety of services throughout the county. The organization’s goals are to promote and sustain the public's health and safety by preventing serious problems and to provide a safety net of family-focused, locally accessible, nonbureaucratic and integrated services. Richard J. Burton, M.D., is the Public Health Officer. The website is www.placer.ca.gov/hhs/hhs.htm.

Environmental Health Services: Placer County Environmental Health Services provides preventive and corrective public health programs, and monitors the development of land uses to assure long-range and short-term community health. Services provided include: health inspections of retail food facilities, public swimming pools and spas; reviewing and inspecting land use applications filed with the county for a wide range of development; monitoring the proper use, storage, and disposal of hazardous materials; and the permitting of well drilling and septic systems to assure the integrity of the county's groundwater resources. Brad Banner is Director of Environmental Health Services. The website is www.placer.ca.gov/hhs/enviro/enviro.htm.

Sacramento County

Department of Health and Human Services: The mission of the Sacramento County Department of Health and Human Services is to: a) deliver health, social, and mental health services to the Sacramento community, b) direct resources toward creative strategies and programs which prevent problems, c) improve well-being, and d) increase access to services for individuals and families. The following are provided to all county residents: alcohol and drug abuse services; child protective services; emergency services; mental, primary and public health services; senior and adult services; shelter and homeless services; and trainings. Glenna Trochet, M.D., is the Public Health Officer. The website is www.sacdhhs.com.

Environmental Health Division: The Sacramento County Environmental Health Division is housed in the County Environmental Management Department. The Environmental Health Division provides regulatory services such as food and water protection and smoking control, and conducts lead illness investigations. Richard Sanchez is Chief of the Division. The website is www.emd.saccounty.net.

Sacramento Regional County Sanitation District: The Sacramento Regional County Sanitation District (SRCSD) serves the unincorporated area of Sacramento County and part of the following cities: Citrus Heights, Elk Grove, Folsom, Rancho Cordova, and Sacramento. SRCSD conveys wastewater to the Sacramento Regional Wastewater Treatment Plant which is owned and operated by SRCSD and located in Elk Grove. SRCSD operates a water recycling facility that treats, filters, and disinfects up to five million gallons of water per day to make it safe and suitable for nonpotable uses such as landscape irrigation. The website is www.srcsd.com.

Center for Community Health and Well-being "The Birthing Project": The Center is located in Sacramento and began as a smaller entity, "The Birthing Project," nearly 20 years ago to improve birth outcomes in the African-American community of Sacramento County. Subsequently, the Center for Community Health and Well-being was established to offer a broad array of community services to low-income women and other household members. Services include a comprehensive women's health care clinic, including substance abuse services; the Barber Shop, a fatherhood support project which provides assistance with employment, parenting education, and social support; and the Saturday Morning Beauty Salon which offers pregnancy prevention services for adolescents. African-Americans are the primary clientele served by the Center followed by Latinos, several Southeast Asian groups, and Caucasians. Kathryn Hall is the Director. The website is www.birthingprojectusa.com.

Council for Asian Pacific Islanders Together for Advocacy and Leadership (CAPITAL): CAPITAL is an umbrella organization located in Sacramento. It was established in 1995. CAPITAL has a membership of over 90 affiliate Southeast Asian professional organizations representing 200,000 to 400,000 people throughout Northern California. Its mission is civic awareness and empowerment of Sacramento's Asian and Pacific Islander member organizations. Sonny Chong is the Chairman. The website is www.sactocapital.org.

Galt Community Concilio, Inc.: The term "Concilio" refers to "Council for the Spanish-speaking." The Galt Community Concilio was founded in 1975 with a mission to facilitate the development of individual and family health, and self-sufficiency in the Hispanic community. It provides assistance for emergency needs (food, shelter, health insurance, and translations), immigration and legal services, job and life skills workshops, rural health services, an outpatient drug and alcohol program, senior assistance, and a volunteer center. The Galt Community Concilio has outreach offices in Walnut Grove and Isleton. Mary Lou is the Executive Director.

Health For All, Inc.: Health For All, Inc., is a community-based health, preventive medical, and social services provider that has served the most ethnically diverse and impoverished areas in Sacramento County since its incorporation in 1981. Its administrative offices are located in Sacramento. Health For All, Inc., operates four adult day health care centers and four community clinics in Northern California. The adult day health care centers provide medical and social programs that help patients maintain independence and prevent institutionalization in nursing homes. The four primary care clinics emphasize preventive medical care and health education. They have a Black Infant Health Program, an Infant and Toddler Immunization Program, and a Sickle Cell Anemia Trait Counseling Program. Dr. Richard Ikeda is the Executive Director. The website is www.health-forall.org.

Slavic Assistance Center, Inc.: The Slavic Assistance Center, Inc., was established in 2002 and is located in Sacramento. It offers immigration, naturalization, and citizenship services to Russian, Ukrainian, and other immigrants from the former Soviet Union. The Center also provides a variety of social services relating to employment, housing, and English language instruction. Roman Romaso is the Executive Director.

San Joaquin County

Public Health Services: Public Health Services is a division of the San Joaquin County Health Care Services Agency. The purpose of the organization is to protect, preserve, and promote the health of the San Joaquin community. Specific public health goals are to decrease preventable diseases, premature deaths and disability, and promote optimal physical, emotional, and social well-being. Some of the programs provided are childhood lead poisoning prevention, nutrition and physical activity, and comprehensive perinatal outreach and education. William Mitchell is the Director and Karen Furst, M.D., is the Public Health Officer. The website is www.co.san-joaquin.ca.us/PHS.

Environmental Health Department: The San Joaquin County Environmental Health Department (EHD) provides services that protect and enhance public health, well-being, and safety through prevention, education, inspection, and enforcement of state and local environmental laws and regulations. The EHD inspects restaurants, mobile food units, employee housing, hotels and motels, public water systems, dairies, wells, and underground storage tanks, and enforces environmental health regulations associated with many other business and construction activities. The EHD works with emergency response teams in the event of a hazardous waste incident. As the Certified Unified Program Agency, the EHD works with other agencies to coordinate hazardous materials program inspection and permitting activities. Donna Heran is the Environmental Health Director. The website is www.co.san-joaquin.ca.us/EHD/.

Asian Pacific Self-Development and Residential Association (APSARA): APSARA is a membership organization of more than 200 Cambodian refugee families who reside at Park Village in Stockton. Founded in 1989, its mission is to provide leadership for the residents by collaborating with the larger community to provide a safe, positive environment that promotes economic independence. Among the programs provided by APSARA are family support, citizenship, Head Start, Cambodian literacy, and English as a second language. Sovanna Koeurt is the Director. The website is www.apsaraonline.org.

DeltaKeeper: DeltaKeeper is one of several grassroots environmental advocacy organizations established in 1996 by the WaterKeepers of Northern California. WaterKeepers is a watchdog agency that was created in 1989 to protect the health of San Francisco Bay, the Delta, and surrounding waterways by taking action to locate pollution spills, illegal dredging, and other harmful activities. DeltaKeeper is located in Stockton. Its main objective is to monitor the Sacramento-San Joaquin Delta waterways for pollution and illegal dumping. DeltaKeeper activities include monitoring pathogen and pollutant levels in surface water, boat patrolling and land-based investigations, advocacy for water protection, enforcement of clean water laws, and field studies for young scientists. Bill Jennings is the Deltakeeper. The website is www.waterkeeper.org.

Lao Khmu Association, Inc.: Lao Khmu Association, Inc., was incorporated in 1983 as a nonprofit organization to provide Southeast Asian refugees and immigrants living in San Joaquin County with a variety of social services to assist their adjustment to life in the United States. The primary populations served are Laotian, Hmong, Khmu, Vietnamese, and Cambodian. Lao Khmu offers several social service programs including crisis intervention, emergency response, health care accessing services, child abuse counseling, youth delinquency counseling, vocational training, employment placement, and on-the-job training. The Lao Khmu office is in Stockton. Robert Khoonsrivong is the Executive Director. The website is www.laokhmu.org.

Vietnamese Voluntary Foundation, Inc. (VIVO): VIVO was established in San Jose in 1979. Its mission is to assist refugees/immigrants and low-income ethnic families to become productive members of the community and to value their multicultural diversity. VIVO provides employment services, youth and family services, child development information, gang prevention services, small business assistance, and citizenship assistance to its clients. VIVO also helps clients acquire new skills through English language instruction. Clients are primarily Vietnamese refugees but also include immigrants from Indochina, Bosnia, and other countries. VIVO is headquartered in San Jose and has a branch office in Stockton. Ky Hoang is Program Manager of the Stockton branch office.

Yolo County

Public Health Services: Yolo County Public Health Services, which is housed in the County Health Department, is responsible for protecting and improving the health of Yolo County residents and assuring that quality health services are available and accessible. Some of the services provided include detection and prevention of communicable diseases, health education, immunizations, and registration of births and deaths. Public Health Services also supports and monitors special programs for families with children, senior citizens and other populations with special health needs, and manages medical and dental care services for some children with chronic health problems, indigent populations, persons who are incarcerated, and residents receiving adult day health services. Some of the specific public health programs are the Yolo County Healthcare for Indigents Program; Lead Poisoning Prevention; Maternal, Child, and Adolescent Health; Refugee Health; Tobacco Prevention; and Women, Infants, and Children (WIC). Bette Hinton, M.D., is the Public Health Officer. The website is www.yolocounty.org/org/health/mission.asp.

Environmental Health Division: The Yolo County Environmental Health Division is housed in the County Health Department. The mission of the Environmental Health Division is to protect and enhance the quality of life of Yolo County residents by identifying, assessing, mitigating and preventing environmental hazards. Some of the programs and services pertain to food, housing, land use, pools and spas, and groundwater. Thomas To is the Director of the Environmental Health Division. The website is www.yolocounty.org/org/health/eh/.

Holy Myrrhbearing Women Church/Russian Orthodox Church and Russian Church of Evangelical Christian Baptists: Two churches located in West Sacramento serve approximately 12,000 Russian immigrants residing in the area. The Holy Myrrhbearing Women Church was founded in 1925. It was named for the many Russian women called “lady builders” who played a significant role in its construction by holding fundraisers and undertaking other activities. Today, the church is referred to as the Russian Orthodox Church. Its pastor is Reverend Gregory Szyrnski. The church’s website is www.oca.org/pages/directory/listing.asp?KEY=OCA-WE-BRYHMW. The Russian Church of Evangelical Christian Baptists has a congregation comprised primarily of former members of the Holy Myrrhbearing Women Church who wanted to form a new church based on the Christian Baptist philosophy. Reverend Pavel Khakimov is the Rector.

Private Sector

Larry Walker Associates: Larry Walker Associates is a company that works for public agencies in California that are responsible for wastewater and storm water management. The vision carried out by the company in services and approach is to promote environmental stewardship, sound science, effective public policy, and collaborative problem-solving. Services provided by Larry Walker Associates include National Pollutant Discharge Elimination System (NPDES) permit assistance to wastewater and storm water agencies; strategic planning; regulatory policy analysis; watershed studies; total maximum daily loads (TMDLs) and related studies; and wastewater treatment plant planning, design, and administration. The company has offices in Davis, Lafayette, and Thousand Oaks. The website is www.lwadavis.com.

Lake County

Pomo Indian Tribes and Tribal Organizations:

Big Valley Rancheria: Mike Schaver, Environmental Director; and Sara Ryan, Environmental Outreach Coordinator

Elem Indian Colony/Sulphur Bank Rancheria: Mike Umbrello, Environmental Director; and Cheryl Steele, Environmental Projects Coordinator

Habematol of Upper Lake Rancheria: John Hancock, Environmental Director

Hinthil Environmental Resources Consortium: Sara Ryan, Big Valley Rancheria; Mike Umbrello and Cheryl Steele, Elem Indian Colony/Sulphur Bank Rancheria; and Meyo Marrufo, Robinson Rancheria

Robinson Rancheria: Meyo Marrufo, NAGPRA Director and CRM Tribal Representative

County Agencies:

Public Health Division: Craig McMillan, MD, Public Health Officer

Environmental Health Division: Raymond Ruminski, Director

Health Care Providers:

Lake County Tribal Health Consortium, Inc.: Michael Icay, Executive Director

Redbud Community Hospital of Adventist Health: Dave Crunk, Administrative Director of Clinic Services

Placer County

County Agencies:

Health Services: Michael Mulligan, MD, Deputy Public Health Officer

Environmental Health Services: Brad Banner, Director

Sacramento County

County Agencies:

Department of Health and Human Services: Cassius Lockett, PhD, Epidemiology Program Manager

County Environmental Health Division: Richard Sanchez,Chief; and Robert Berger, Supervising Registered Environmental Health Specialist

Community-Based Organizations:

Center for Community Health & Well-Being "The Birthing Project": Tchaka Muhammed, PhD, Brother Friends Coordinator

Council for Asian Pacific Islanders Together for Advocacy and Leadership (CAPITAL): Sonny Chong, DMD, Chairman

Galt Community Concilio, Inc.: Sonia Ornelas, Program Assistant

Slavic Assistance Center, Inc.: Roman Romaso, Executive Director

Health Care Provider:

Health For All, Inc.: Richard Ikeda, MD, MPA, Executive Director

San Joaquin County

County Agencies:

Public Health Services: Colleen Tracy, Deputy Director of Health Administration and Promotion; Joan Mazzetti, Health Education Program Coordinator; and Lim Leang, Community Health Outreach Worker

County Environmental Health Department: Donna Heran, Director; Mark Barcellos, Supervising Registered Environmental Health Specialist; and Al Olsen, Program Manager

Community-Based Organizations:

Asian Pacific Self-Development and Residential Association (APSARA): Sovanna Koeurt, Director; and Nim Ros, Social Services Coordinator

Lao Khmu Association, Inc.: Robert Khoonsrivong, Executive Director

Vietnamese Voluntary Foundation, Inc. (VIVO): Ky Hoang, Program Manager; and Linda Hobson, Project Coordinator

Environmental Advocacy Organization:

DeltaKeeper: Bill Jennings, Deltakeeper; and Kari Morgan, Volunteer and Monitoring Coordinator

Yolo County

County Agencies:

Public Health Services: Bette Hinton, MD, Public Health Officer

Environmental Health Division: Thomas To, Director

Churches:

Holy Myrrhbearing Women Church: Ivan Kosuleki, Chief Executive Officer

Russian Church of Evangelical Christian Baptists: Mikhail Avramenko, Assistant Pastor

Appendix E

Communications

Appendix D

Needs Assessment Participants

Research, Outreach, and Education on Fish Contamination in the Sacramento-San Joaquin Delta and Tributaries (AKA *Delta Fish Project*)

Mercury bioaccumulates in fish in the Sacramento-San Joaquin Delta watershed at levels that may pose health risks to people who consume the fish. Mercury is prevalent in the Delta watershed due to naturally occurring deposits and human activities, such as historic mercury mining in the Coastal range and gold mining in the Sierra Nevada. Once mercury is in the aquatic environment, bacteria convert it into a form that bioaccumulates in fish and other aquatic biota. Mercury concentrations in fish at many locations in the Delta and its tributaries exceed the health-based screening values set by the U.S. Environmental Protection Agency. Several fish, such as largemouth bass, striped bass, catfish, and sturgeon are of particular concern. Based on preliminary data, these fish are caught and consumed by many anglers and their families in the Delta watershed. Pregnant and nursing women, infants, and young children need to be especially careful about limiting their exposure to mercury because the developing nervous system is the most sensitive health endpoint for mercury exposure.

The Delta Fish Project is an interagency effort to reduce exposure to mercury and other chemicals among populations that consume fish caught in the Delta watershed. The Environmental Health Investigations Branch (EHIB) of the California Department of Health Services (CDHS), in collaboration with other state and local agencies, tribes, and community-based organizations, began undertaking a number of activities to address this concern in the fall of 2002. The project is focusing initially on five counties: Sacramento, San Joaquin, Lake, Placer, and Yolo. The five counties were selected based primarily on the following criteria: (1) levels of chemicals of concern in fish; and (2) level of fishing activity. The project may be implemented in other counties in the Delta watershed if funding is available.

Project activities include:
*Conduct a needs assessment to identify information and training needs of county personnel, tribes, and community-based organizations serving populations consuming fish from the Delta watershed
*Create and convene a stakeholder advisory group to involve community members in determining fish sampling studies and developing outreach and education activities and materials
*Conduct public outreach and education to reduce exposure to mercury and other chemicals in fish
*Assess the feasibility of undertaking a fish consumption survey to assess the level of exposure to mercury and other contaminants among populations consuming fish caught in the Delta watershed

For more information about the Delta Fish Project or to identify ways to participate in this project, please contact Samira Jones at sjones@dhs.ca.gov ***or (510) 622-4470.***

State of California—Health and Human Services Agency
Department of Health Services

California
Department of
Health Services

DIANA M. BONTÁ, R.N., Dr. P.H.
Director

GRAY DAVIS
Governor

September 22, 2002

Dear Public Health Officer/Environmental Health Director:

The purpose of this letter is to request a brief meeting with you and/or appropriate member(s) of your staff in October 2002 to discuss your department's (1) collaboration with a new initiative: Research, Outreach, and Education on Fish Consumption in the Sacramento-San Joaquin Delta and its Tributaries (a.k.a. the Delta Fish Project); and (2) participation in a project-related needs assessment during the fall of 2002.

The Delta Fish Project is an interagency effort to gather information about populations that consume fish caught in the Delta watershed in order to reduce their exposure to mercury. Mercury is prevalent in the Delta watershed due to naturally occurring deposits and human activities, such as historic mercury mining in the Coastal range and gold mining in the Sierra Nevada. Once mercury is in the aquatic environment, bacteria convert it into a form that is bioaccumulated in fish and other aquatic biota. Mercury concentrations in fish at many locations in the Delta and its tributaries exceed the health-based limits set by the U.S. Environmental Protection Agency. Of particular concern are largemouth and striped bass. Based on preliminary data, these fish species are caught and consumed by many anglers and their families in the Delta. Because the developing fetus is most sensitive to the harmful effects of mercury, we are especially concerned about including women of childbearing age in our efforts.

The Environmental Health Investigations Branch (EHIB) of the California Department of Health Services (CDHS), in collaboration with other state and local agencies, proposes to undertake a number of activities to address this concern. One of the activities is to conduct a needs assessment with appropriate staff in your department to identify their information and training needs regarding mercury exposure and related issues. The information obtained during the assessment will help us to develop appropriate outreach and education materials, and, if interested, provide training for your staff on these issues.

I will contact your office during the week of September 28 as a follow up to this letter. In the meantime, please contact me at (510) 622-4414 or mmack@dhs.ca.gov should you have any questions in this regard. I hope we can count on your department's support and participation in this effort.

Sincerely,

Maura D. Mack, PhD, MPH
Chief, Community Participation and Education Section
Environmental Health Investigations Branch

Date

CBO Director
CBO
Address
City, CA 95826

Dear (Name of **CBO** Director):

The purpose of this letter is to inform you about a new initiative: Research, Outreach, and Education on Fish Consumption in the Sacramento-San Joaquin Delta and its Tributaries (AKA Delta Fish Project). We would also like to request a brief meeting with you in early 2003, to explore your organization's interest in collaborating with the initiative and to answer any questions you may have. I will contact you in January 2003 as a follow up to this letter.

The Delta Fish Project is an interagency effort coordinated by the Environmental Health Investigations Branch (EHIB) within the California Department of Health Services, in conjunction with local public health and environmental health departments, other state agencies, tribes, and community-based organizations. The goal of the project is to reduce exposure to mercury and other chemicals in populations that consume fish caught in the Delta waterbodies. Mercury is found in the Delta waterbodies due to naturally occurring deposits and human activities, such as historic mercury mining in the Coastal range and gold mining in the Sierra Nevada. The level of mercury in fish caught at many locations in the Delta is high and may harm the health of people who eat the fish regularly, especially pregnant women and children under six years of age.

EHIB plans to undertake a number of activities to address the issue of consumption of contaminated fish. One of the proposed activities is to meet with you and your staff to identify local populations who may be at risk of exposure to mercury. We also want to find out what information and training you and your staff may want on the health risks of exposure to mercury in fish and ways to reduce exposure. Later, in a separate meeting, we would like to speak with some members of the communities you serve. The purpose of this meeting would be to find out what people know about fish contamination issue, any questions or concerns they may have, and their information needs. The information provided during the meetings will help us plan a more effective community outreach and education project in the Delta Region.

Again, I will contact you in January 2003 as a follow up to this letter. Meanwhile, if you have any questions, please contact me at (510) 622-4473 or pandrese@dhs.ca.gov. I hope we can count on your organization's collaboration with this effort.

Sincerely,
Penny Andresen, MPH
Health Educator
Environmental Health Investigations Branch

Date

Blank
Address
City, State 95826

Dear (**Name of Local Elected Official)**:

The purpose of this letter is to inform you about a new initiative recently underway in XXX County: Research, Outreach, and Education on Fish Consumption in the Sacramento-San Joaquin Delta and its Tributaries (AKA Delta Fish Project).

The Delta Fish Project is an interagency effort coordinated by the Environmental Health Investigations Branch (EHIB) within the California Department of Health Services, in conjunction with local public health and environmental health departments, other state agencies, tribes, and community-based organizations. The goal of the project is to reduce exposure to mercury and other chemicals in populations that consume fish caught in the Delta waterbodies. Mercury is found in the Delta waterbodies due to naturally occurring deposits and human activities, such as historic mercury mining in the Coastal range and gold mining in the Sierra Nevada. The level of mercury in fish caught at many locations in the Delta is high and may harm the health of people who eat the fish regularly, especially pregnant women and children under six years of age. The project aims to inform people about the frequency and amount and of fish that can be eaten safely, recommended fish preparation practices, and fish species that should not be consumed at all (i.e., swordfish and shark).

At this time, we are undertaking a needs assessment with the XXX County Public Health and Environmental Health Departments to identify their information and training needs with respect to the public health risks of exposure to mercury and ways to reduce exposure. Subsequently, we plan to undertake a similar needs assessment with tribes and appropriate community-based organizations to determine their concerns and information needs on this issue. The information obtained during the needs assessment will help us plan and implement a more effective community outreach and education project in the Delta Region. It is anticipated that the project's outreach and education activities are expected to begin in the fall 2003.

We will keep you informed about the project. In the meantime, please contact me at (510) 622-4473 or pandrese@dhs.ca.gov should you have any questions in this regard.

Sincerely,

Penny Andresen, MPH
Health Educator
Environmental Health Investigations Branch

Date

Dear Public Health Officer and Environmental Health Director in Non-priority Counties:

The purpose of this letter is to inform you about a new initiative recently underway in your region: Research, Outreach, and Education on Fish Consumption in the Sacramento-San Joaquin Delta and its Tributaries (AKA Delta Fish Project). Initially, we are implementing the project in Sacramento, San Joaquin, Placer, Yolo, and Lake Counties. We selected these counties based on levels of mercury and other chemicals of concern in fish caught locally, and level of fishing activity in local waterbodies. If additional funding becomes available, we would like to implement the project in other counties in the Delta Region where significant exposure to mercury may be occurring from consumption of contaminated fish caught locally. We would contact you at that time if project expansion to other counties in the Delta Region becomes possible.

The Delta Fish Project is an interagency effort coordinated by the Environmental Health Investigations Branch (EHIB) within the California Department of Health Services, in conjunction with local public health and environmental health departments, other state agencies, tribes, and community-based organizations. The goal of the project is to reduce exposure to mercury and other chemicals in populations that consume fish caught in the Delta waterbodies. Mercury is found in the Delta waterbodies due to naturally occurring deposits and human activities, such as historic mercury mining in the Coastal range and gold mining in the Sierra Nevada. The level of mercury in fish caught at many locations in the Delta is high and may harm the health of people who eat the fish regularly, especially pregnant women and children under six years of age. The project aims to inform people about the frequency and amount and of fish that can be eaten safely, recommended fish preparation practices, and fish species that should not be consumed at all (i.e., shark, swordfish, king mackerel, and tilefish). The enclosed document will provide you additional information about the project.

Please contact me at (510) 622-4473 or email pandrese@dhs.ca.gov should you have any questions about the project.

Sincerely,

Penny Andresen, MPH
Health Educator
Environmental Health Investigations Branch

Appendix F

Tools

Key Informant Interview Questions
County Health and Environmental Health Departments

County: ________________________ Date _____________
Facilitator ______________

A. Fish Contamination

County Health and Environmental Health Departments

1. Is your department concerned about contamination of fish and/or shellfish caught in waterbodies located in your county?

   1a. If yes, what are the primary contaminants of concern in fish and/or shellfish?

   1b. Which of these contaminants do you believe pose the greatest risk to public health?

County Residents

1. Do you believe the residents of your county are concerned about contamination of the fish and/or shellfish in local waterbodies?

2. Does your department receive inquires from the public on fish and/or shellfish contamination?

   2a. If yes, what do the inquiries primarily focus on?

   2b. How does your department respond to these inquiries?

   2c. How often do the inquiries come in and how many did you received in the last year?

Fish or Shellfish Advisories

1. Are there any fish and/or shellfish advisories currently posted in your county?

   1a. If yes, what are the advisories?

   1b. Where are they posted?

B. Community Leaders and Stakeholders

1. Who are the community leaders in your county we should inform regarding the project?

2. Which community-based organizations in your county should we inform and request their participation in the project?

C. Outreach and Education

**The Delta Fish Project's outreach and education activities will target the following vulnerable populations: women of child-bearing age, pregnant or breastfeeding women, and children age six years and younger.*

1. What are the main programs in your department that conduct outreach and education targeted at the project's 'priority populations'? Who is the contact person in the department?

2. Is your department currently doing any outreach or education relating to fish and/or shellfish contamination in your local waterbodies?

   2a. If yes, who in your department is responsible for this outreach and education?

   2b. What is the focus of the outreach and education and who are the target populations?

3. How does your department inform the public about health alerts related to fishing or shellfish harvesting?

4. What are some key lessons learned from implementing outreach and education programs in your county?

E. Staff Capacity Building

1. How could we assist in building your staff's capacity to address health risks posed by fish and/or shellfish contamination in your county?

F. Collaboration

1. How else might our agencies work together in the future on issues related to fish and/or shellfish contamination?

G. Existing Secondary Information

1. Do you have any documents containing relevant secondary information that you could share with us?

Thank you!

Delta Fish Project

Field Staff
Needs Assessment Questionnaire

County: ____________________________ Date: ______________________
Job title: ____________________________ Program: _________________________

Please respond to the following questions to assist in planning outreach, education, and training on issues related to contaminated fish caught in the Sacramento-San Joaquin Delta and its tributaries.

Fish Contamination

1. In your opinion, how aware are people in your county about contamination of fish caught in Delta waterbodies?
   n No awareness n Some awareness n A lot of awareness n Don't know

2. How often do you receive inquiries about fish/shellfish contamination in your county?
   n Never n Once a year
   n Twice a year n Once a month
   n Once a week n Daily
   n Other: please specify _________________

   2a. If yes, how do you respond?

   2b. Which contaminants in fish/shellfish are people most concerned about? (Please check all that apply)
   n Mercury n Dioxins
   n Polychlorinated biphenyls (PCBs) n Pesticides
   n Biotoxins and bacteria (i.e. vibrio, Paralytic Shellfish Poisoning (PSP), scromboid fish poisoning)
   n Other: please specify ________________________________

3. Which contaminants in fish/shellfish do you believe pose the greatest risk to public health in your county? (Please check all that apply)
   n Mercury n Dioxins
   n PCBs n Pesticides
   n Biotoxins and bacteria
   n Other: please specify ________________________________

4. Are you aware of a fish advisory for the Delta?
   n Yes → If yes, what do these advisories address?
   n No

Community Stakeholder

5. Which community-based organizations in your county should we inform and request their participation in the project? (Please provide contact names and phone numbers).

Priority Populations

**The Delta Fish Project's outreach and education activities will target the following vulnerable populations: women of child-bearing age, pregnant or breastfeeding women, and children age six years and younger. Vulnerable populations may also include specific populations or groups whose intake of fish they catch themselves is high.*

6. Are you aware of particular groups (i.e. ethnic, angler, or other) in your county who regularly and frequently consume fish caught in the Delta waterbodies?

   n Yes → If Yes, please identify.
   n No

Outreach and Education

7. Do you address fish/shellfish contamination issues in your community outreach and education programs?

   n Yes → If yes, how do you address these issues?
   n No

8. What outreach and education methods have you found to be particularly effective in reaching your target populations (any issue, not only fish)? (Check all that apply)

Website	Radio spots	Videotapes
Workshops	Home visits	Comic books
TV spots	Brochures	Posters

   Other: please specify________________________

9. In what languages are your outreach and educational materials available? Please check all that apply.

Spanish	Lao
Cambodian	Chinese
Vietnamese	Hmong
Tagalog	Russian
Other: ________________________	Samoan

10. What are some of the main challenges you have encountered or lessons you have learned in carrying out outreach and education programs in your county?

Staff Capacity Building

Information Section

11. Please indicate if you would like to receive information on the following topics (Please check all that apply):

Mercury	Dioxins
PCBs	Pesticides
vibrio	Paralytic shellfish poisoning

Other: please specify __________________________________

12. In what format would you like to receive this information? (Please check all that apply.)

Hard copy	PDF file
Electronic copy	Video

Other: please specify ____

Training Section

13. Which of the following topics might you be interested in receiving training on? (Please check all that apply)

Health risks of PSP	Safe fish handling practices
Health risks of mercury exposure	Commercial seafood issues
Health risks of pesticides exposure	Health and nutritional benefits of fish
Health risks of dioxins exposure	Precautionary principle
Health risks of PCBs exposure	Risk assessment
Introduction to toxicology	Risk communication

Environmental Justice
Overview of fish contamination in Delta waterbodies
Not interested in training
Other: please specify____

14. What is your training style preference? Please check all that apply.

Workshop (half-day; full day) Web-based online training
Seminar (1 hour; 2 hours) Website
Teleconference Video
Other: please specify

____

15. When would you prefer that training be offered?

During work hours During lunch hour
Evening Saturday
Other: please specify ___________________

Please provide us with any additional comments or suggestions you may have.

Thank you very much for your assistance.

Name of Organization:
Contact Person:
Type of Organization:
Population(s) Served:

Date:
Interview Location:
Interviewer:
Translator:

Community-Based Organizations
Key Informant Interview Questions

A. Fish Contamination

Community-Based Organization

1. What is your organization's level of concern about contamination of fish and/or shellfish caught in waterbodies located in your county (i.e. on a scale from 1-10)?
   1a. What are the primary contaminants of concern in fish and/or shellfish?
   1b. Which of these contaminants do you believe are most harmful to the public?
   1c. What specific kinds of fish or shellfish are you most concerned about?

2. What is your organization's level of concern about contamination of fish and/or shellfish that you buy in stores or restaurants (i.e. on a scale from 1-10)?

Populations Served by Community-Based Organization

3. Are you aware of specific populations or groups you serve who fish and eat the fish they catch?
   3a. Which populations/groups are they?
   3b. How frequently do they eat fish they catch (daily, weekly, monthly)?
   3c. Where do they fish?
   3d. What types of fish do they catch?

4. Do you believe the populations you serve are concerned about contamination of the fish and/or shellfish?

5. Does your organization receive inquires from the populations you serve about fish and/or shellfish contamination?
   5a. What is the primary focus of these inquiries?
   5b. How does your organization respond to these inquires?
   5c. How often does your organization receive inquires and how many did you received in the last year?

6. Do people in your community buy fish or shellfish from fishers rather than from a store?

Fish or Shellfish Advisories

7. Are you aware of any fish or shellfish advisories in your county?
   7a. What are these?
   7b. Are you aware of specific locations where the advisories are posted?
   7c. Besides advisory signs, are you aware of other places where you can get fish advisory information?

Last updated 2/18/03 **Thank you!**

B. Community Leaders and Stakeholders

1. Which community leaders in your area should we inform about the project?

2. Besides your organization, which community-based organizations in your county should we inform and request their participation in the project?

C. Outreach and Education

**The Delta Fish Project's outreach and education activities will target the following populations: women of child-bearing age, pregnant or breastfeeding women, and children age six years and younger. These populations may also include specific populations or groups that consume high amounts of fish they catch.*

1. Does your organization conduct outreach and education activities targeted at women of childbearing age, pregnant or breastfeeding women, and children under six years?
   1a. What are these activities?

2. Does your organization conduct outreach and education activities targeted at other groups?
   2a. What are these groups?
   2b. What are these activities?

3. Is your organization currently doing any outreach or education relating to fish and/or shellfish contamination in your local waterbodies?
   3a. What is the focus of the outreach and education and who are the target populations?

4. What are some key lessons learned from implementing outreach and education programs in your community?

D. Organizational Capacity Building

1. How could we assist in building your organization's capacity to address health risks due to fish and/or shellfish contamination in your county?

E. Collaboration

1. How else might we work together in the future on issues related to fish and/or shellfish contamination?

F. Existing Information

1. Do you have any documents containing relevant information that you could share with us? (i.e. organizational publications, newsletters, etc.)

Delta Fish Project
Focus Group Script for CBOs

County: ______________________________ Date ____________________________
Organization:_________________________ No. attend __________ M ________F
Type of organization: _________________ Translator ________________________
Populations served: __________________ Facilitator ________________________
Language used for focus group _________

Language(s) represented at the focus group

Spanish	Lao
Cambodian	Chinese
Vietnamese	Hmong
Tagalog	Russian
Samoan	Other

Introduction:
The reason for our meeting is that the California Department of Health Services is working on a project about fish contamination issues. Some of the fish in the Delta are not healthy to eat because of high levels of pollutants. In our session today I would like to find out from all of you what would be the best way to get that information out to the population you represent. I would also like to find out more about the types of fish you and your family eat, where you get the fish, and if there are fish advisories that you know of around the area. After our discussion I will tell you more about what I know regarding the fish in the surrounding area.

Fishing Practices and Fish Consumption Habits

1. What are your fish eating habits?
   Prompts:
   a. How often do you eat fish?
   b. What types of fish or shellfish do you eat?
   c. Who in your household eats fish?
   d. Who in your house prepares the fish?

2. Where does your fish come from?
   Prompts:
   a. Do you fish or harvest shellfish?
      a1. Where do you fish?
      a2. What fish do you catch?

   b. Do any of your family members fish?
      b1. Where do they fish?
      b2. What fish do you catch?

   c. Do relatives or friends fish in nearby waters?
      c1. Where do they fish?

d. What fish do you buy from other anglers who fish in nearby waters?
   d1. Where do they fish?

e. Do you buy from the market?

Fish Contamination

3. What do you know about contamination of fish or shellfish in the Delta waterbodies?
   Prompts:
   - Awareness of fish signs
   - Awareness of fish advisory for the Delta waterbodies
   - Awareness of contaminants in fish or shellfish
   - Awareness of health risks
   - Awareness of how to reduce exposure to contaminants
   - Where did you learn about the advisory?

4. How concerned are you about contamination of fish or shellfish in the Delta waterbodies?
   Prompts:
   a. What contaminants in fish or shellfish are you most concerned about?
      n Mercury n Dioxins
      n Polychlorinated biphenyls (PCBs) n Pesticides
      n Biotoxins and bacteria (i.e. vibrio, Paralytic Shellfish Poisoning (PSP), scromboid fish poisoning)
      n None n Other:

   b. Why are you concerned/not concerned?

   c. What are you doing about your concern?

   d. How might we respond to your concerns?

C. Information Needs

5. What information would you like to receive on contamination of fish or shellfish in the Delta waterbodies?
   Prompts:

Mercury	Dioxins
PCBs	Pesticides
Vibrio	Safe areas to fish
Safe ways to prepare fish	Safe fish to eat
Safe limits to eat	Paralytic shellfish poisoning
Other	None

6. What are the best ways to inform your community about fish contamination in the Delta waterbodies?
   Prompts:

Website	Radio spots	Videotapes	Calendars
Workshops	Home visits	Comic books	Newspaper
TV spots	Brochures	Posters	Newsletter
Other:			

D. Other Comments or Suggestions from Focus Group Participants

Summary: (Explain the fish advisory and mercury contamination issue)
Thank you for you participation. I want to share with you some general information regarding fish contamination issues.

I. Introduction to the mercury problem
- A. Mercury comes from
  1. Mercury mining
  2. Gold mining
  3. Naturally occurring
- B. How it gets into fish (picture from Diana's presentation)
  1. Mercury changes to more dangerous methyl-mercury in the environment
  2. Starts in sediment and works its way to high accumulation predatory fish such as striped bass, largemouth bass, and catfish in the Delta
  3. Mercury stays in the flesh, so no easy way to reduce exposure
- C. Health effects in humans
  1. Most concern is women in their child-bearing years. If they become pregnant mercury can pass to the developing fetus through the placenta or breast milk
  2. Causes neural development problems
- D. Mercury advisories to reduce exposure to mercury
  1. Pregnant and nursing women are asked to reduce or eliminate certain types of fish from their diet
     - a. FDA suggests that women pregnant or breast feeding do not eat any king mackrel, tile fish, shark or sword fish commercial or otherwise
     - b. Local governments have issued other various warnings
       - i. Limited intake of striped bass, sturgeon
         - 1a. One meal a month for pregnant/nursing women
       - ii. NO FISH from the Port of Stockton (PCB, Dioxins)
       - iii. Largemouth bass and catfish should be limited
         - 1a. One meal per week for pregnant/nursing women

County: ___________________ Date: __________

Key Informant Interview Questions
Health Care Facility and Providers

A. Fish Contamination

Health Care Facility

1. Is your facility concerned about contamination of fish and/or shellfish caught in waterbodies located in your county?

   1a. If yes, what are the primary contaminants of concern in fish and/or shellfish?

   1b. Which of these contaminants do you believe pose the greatest risk to public health?

Health Care Facility Patients

1. Do you believe the patients of your facility are concerned about contamination of the fish and/or shellfish in local waterbodies?

2. Does your facility receive inquires from the public on fish and/or shellfish contamination?

   2a. If yes, on what do the inquiries primarily focus?

   2b. How does your agency respond to these inquiries?

   2c. How often do the inquiries come in and how many would you say were received in the last year?

Fish or Shellfish Advisories

1. Are there any fish and/or shellfish advisories currently posted in your county?

   1a. If yes, what are the advisories?

   1b. Where are they posted?

B. Community Leaders and Stakeholders

1. Who are the community leaders in your county we should inform regarding the project?

2. Which community-based organizations in your county should we inform and request their participation in the project?

C. Outreach and Education Methods

**The Delta Fish Project's outreach and education activities will target the following vulnerable populations: women of child-bearing age, pregnant or breastfeeding women, and children age six years and younger*.

1. What are the main programs in your facility that conduct outreach and education targeted at the project's 'priority populations'? Who would be a contact person in the department?

2. Is your facility currently doing any outreach or education relating to fish and/or shellfish contamination in your local waterbodies?

   2a. If yes, who is responsible for this outreach and education?

   2b. What is the focus of the outreach and education and who are the target populations?

3. How does your facility inform the public about health alerts related to fishing or shellfish harvesting?

4. What are some key lessons learned from implementing outreach and education programs in your county?

D. Staff Capacity Building

1. How could we assist in building your staff's capacity to address health risks posed by fish and/or shellfish contamination in your county?

E. Collaboration

1. How else might our agencies work together in the future on issues related to fish and/or shellfish contamination?

F. Existing Information

1. Do you have any documents containing relevant information that you could share with us?

Thank you!

Date: ___________ County: __________

Questionnaire for CAPITAL Members Regarding Fish Contamination in the Delta Watershed

Organization Contact information
Contact Person: ______________________________
Title: ______________________________
Address: ______________________________
Phone number: ______________ **Email or website:** ______________

Please respond to the following questions to assist the California Department of Health Services, Environmental Health Investigations Branch in planning outreach and education strategies on fish contamination for the Delta Fish Project.

1. Is the issue of fish contamination a concern to your organization or the people you represent?
   Yes (Go to 1a)
   No

   1a. If yes, what are the primary contaminants of concern in fish/shellfish?
   (Please check all that apply):
   - n Mercury
   - n Dioxins
   - n Polychlorinated biphenyls (PCBs)
   - n Pesticides
   - n Biotoxins and bacteria (i.e. Paralytic Shellfish Poisoning (PSP)
   - n Other *please specify* ______________________

2. Are you aware of any organizations that are conducting activities on fish contamination issues?
   Yes→ If yes, who are they?
   No

3. Please indicate if you would like for your organization to participate in the Delta fish project needs assessment activities including an informational meeting and a small focus group discussion with members of your organization.
   Yes
   No

* * * * * * * * * * * *

Please direct any further questions to Penny Andresen, EHIB/CDHS at (510) 622-4473 or Pandrese@ca.dhs.gov.

Thank you for your assistance.

HERC Earth Day Celebration

June 7, 2003
Robinson Rancheria
Lake County, CA

Tribal Affiliation: ________________________________ Gender :____ M ____F
Age: *(please Circle one)*: under 18 18-45 over 46

The California Department of Health Services is conducting this survey in connection with our fish contamination outreach and education project. We would like to find out about your fish eating habits and the best ways to get information to you and your community about fish contamination issues. Please answer the questions below.

Fishing Practices and Fish Eating Habits

<u>*Fish Caught Locally*</u>

1. Do you eat fish that you or someone you know catches in local lakes, streams, or other local waterbodies?
   Yes
   No → Go to Question 6

2. Where are these fish caught?
   Clear Lake Lake Pillsbury Thurston Lake
   Blue Lake Russian River Other *(where?)*______________________

3. What types of fish or shellfish do you or someone you know catch in local waters? (Circle all that apply)
   Hitch Crappie Catfish
   Trout Striped Bass Salmon
   Other *(please specify)*_________________ Crawdads/Crayfish

4. How often do you eat fish or shellfish that you or someone you know catches in local waters? (*Circle one*)
   More than once a day Once a week Once every few months
   Once a day Once a month Rarely
   2-3 times a week 2-3 times a month Never
   Other *(please specify)*____

5. Who in your household eats fish that you or someone you know catches locally? (*Circle all that apply*)
   You Mother Grandfather Grandmother
   Spouse Father Brother Sister
   Children Other *(who?)*____

Fish from Stores or Restaurants

6. How often do you eat fish from stores or restaurants? (*Circle one*)

More than once a day	Once a week	Once every few months
Once a day	Once a month	Rarely
2-3 times a week	2-3 times a month	Never

Other *(please specify)*______________________________

7. What types of fish do you buy at stores or eat at restaurants? (*Circle all that apply*)

Salmon	Striped Bass	Canned Tuna
Tuna	Catfish	Shark
None	King Mackerel	Swordfish
Tile fish	Other (*please specify*)______________	

Fish Contamination

8. Are you aware of any health advisories for fish caught in Lake County?

Yes → Please specify what the advisory says and what waters it covers.

____

____

____

No

Information Needs

9. Would you like to receive more information on contamination of fish or shellfish? (*Circle all that interest you)*

Mercury	PCBs	Safe ways to prepare fish
Dioxins	Safe fish to eat	Safe amounts of fish to eat
Pesticides	Safe areas to fish	Other *(please specify)*__________
None		

10. What are the best ways to get information to you and your community? (*Circle all that apply)*

Videotapes	Radio	Website	Calendars
Workshops	Newspapers	Comic books	Home visits
TV	Brochures	Posters	Newsletters

Other *(please specify)*__________

11. Do you have any Comments or Suggestions?

Thank you for your participation.

Placer County Environmental Health Staff Questionnaire Regarding *"Fish Contamination in Placer County "*

Name: ______________________________ **Title:** ________________________________
Phone number: ______________________ **Email:** ______________________________

Please respond to the following questions to help the California Department of Health Services, Environmental Health Investigations Branch, plan outreach, education, and training activities related to fish contamination in Placer County.

Fish Contamination

1. In your opinion, how aware are Placer County residents about fish contamination in local waterbodies?
   nNo awareness nSome awareness nA lot of awareness nDon't know

2. In your opinion, is fish contamination in local waterbodies a concern to Placer County residents?
   Yes (Answer 2a and 2b) No

   2a. How much of a concern is it?
   n Some concern n High concern nDon't know

   2b. About which contaminants in fish are Placer County residents primarily concerned with?
   ____

3. Do you receive inquiries from the public about fish contamination issues?
   Yes (Go to 4a) No
   3a. If yes, how many inquiries have you received in the last 6 months?
   nNone nLess than 5 n5-10 n10-20 nMore than 20

Fishing and Fish Advisories

4. What are the most popular fishing locations in Placer County? __________________
   ____

5. Which fish species are commonly caught and consumed from Placer County waterbodies? ____

6. Are you aware of any health advisories for fish caught in Placer County waterbodies?
   Yes (Go to 6a) No
   6a. If yes, for which waterbodies and fish species?________________________
   ____

7. Are you aware of any health advisories for fish caught in other waterbodies in California? ____
   Yes (Go to 6a) No
   7a. If yes, for which waterbodies and fish species?________________________
   ____

8. List specific populations or ethnic groups of which you are aware that fish regularly in Placer County waterbodies?

    ____

Community Stakeholders

9. Are there organizations in Placer County that you think we should contact about this project?

    Yes No Don't know

    9a. If yes, please give the name of the organization and a contact person. ______
    ____

Outreach and Education

10. What do you believe are the best ways to provide information to Placer County residents? (Please check all that apply)

Television	Newspaper
Radio	Calendar
Brochures, pamphlets	Fact sheets
Newsletters	Websites
Posters	Comic books
Posted signs at fishing sites	Other: __________

11. Are you interested in receiving information on topics related to fish contamination?

    Yes No

    11a. If yes, on what topics? (Please circle all that apply)

    Overview of fish contamination in Placer County
    Health risks of mercury exposure and ways to reduce exposure
    Health advisories for fish caught in Placer County waterbodies
    Mercury in sport and commercial fish and seafood
    Mercury in fish monitoring and remediation in the Bay-Delta watershed

Precautionary principle	Risk assessment methods
Risk communication methods	Environmental Justice

    Other: ______________________

    11b. How would you like to receive this information? Please circle all that apply.

Written materials	Seminar (1 hour or 2 hours)
Video	Teleconference
Website	Other: _________________________
Workshop (half day or full day)	

Please provide us with any additional comments or suggestions.

Please place your completed survey in the box on the table labeled "Fish Contamination Questionnaires" before 3 PM. Thank you!

Appendix G

Fact Sheets

University System of Maryland

Fish Health in the Chesapeake Bay

HARMFUL ALGAL BLOOMS

Extracted from:

Donald F. Boesch, Donald A. Anderson, Rita A. Horner, Sandra E. Shumway,Patricia A. Tester and Terry E. Whitledge. 1997. Harmful Algal Blooms in Coastal Waters: Options for Prevention, Control and Mitigation. NOAA Coastal Ocean Program, Decision Analysis Series No. 10, Special Joint Report with the National Fish and Wildlife Foundation, February 1997.

Site developer's note: genus and species names of algae are indicated in red, rather than standard underlining (not a webpage option unless a link...) or italics, in order to make the names easier to find and read.

[Harmful Algal Blooms - Main Page] | [Fish Heatlh in Chesapeake Bay - Main Page]

Paralytic Shellfish Poisoning

Paralytic shellfish poisoning (PSP) is a significant problem on both the east and west coasts of the U.S. Caused by several closely related species in the genus Alexandrium, PSP toxins are responsible for persistent problems due to their accumulation in filter feeding shellfish (e.g., Shumway et al. 1988), but they also move through the food chain, affecting zooplankton, fish larvae, adult fish, and even birds and marine mammals (Anderson and White 1992; Geraci et al. 1989; Shumway 1995). On the east coast, PSP is a serious and recurrent problem from Maine to Massachusetts. Connecticut, Long Island (New York) and New Jersey occasionally experience the toxin (or Alexandrium) at low levels, but these areas seem to define the southern extreme of this organism's geographic distribution. The offshore waters of George's Bank experienced a serious PSP outbreak several years ago, leading to the extended closure of the surfclam fisheries and the demise of a fledgling roe-on scallop fishery. On the west coast, PSP is a recurrent annual problem along the coasts of northern California, Oregon, Washington, and Alaska. Overall, PSP affects more coastline than any other HAB problem.

It is likely that seasonally recurring outbreaks of PSP are linked to the existence of a dormant cyst stage in the Alexandrium life history. This strategy allows the species to deposit dormant cells in sediments where they survive through harsh winter conditions and then germinate to initiate new outbreaks in subsequent years. Prior to 1972, for example, PSP was restricted to the far eastern sections of Maine ("down east") near the Canadian border. That year, however, a massive red tide causing high levels of toxicity in those areas for the first time recorded in history. Virtually every year since that event, this region has experienced PSP outbreaks, a result of the successful colonization of the area by Alexandrium spp. A similar expansion, with subsequent recurring outbreaks of Alexandrium, occurred in the Puget Sound region of Washington in the late 1970's an area with no prior history of shellfish poisoning (Nishitani and Chew 1988). Long-term climatic variability, which affects temperature, upwelling, and currents or allows cysts to survive in areas where they did not before, may be factors in such range extensions.

PSP occurs over a large geographic range, so a variety of physical mechanisms underlie the spreading of Alexandrium blooms. In southern New England , for example, localized blooms occur in small, isolated salt ponds and embayments, whereas in the southwestern Gulf of Maine, linkage has been documented between the abundance and distribution of Alexandrium and a buoyant coastal current that travels from north to south in that region (Franks and Anderson, 1992). Fresh water enters the Gulf of Maine from several large rivers in southern Maine, and the freshened coastal waters flow south in a manner that is influenced by the amount of rainfall and snowmelt, the local wind stress, and the underlying circulation of the Gulf of Maine. Toxic Alexandrium populations are closely associated with this buoyant water mass. The long distance transport of Alexandrium cells in this coastal current are responsible for PSP outbreaks in southern Maine and Massachusetts, and may even be linked to shellfish toxicity on George's Bank (Anderson and Keafer, 1992). The hydrographic mechanisms underlying PSP blooms in down-east Maine are more poorly understood than those described for the region to the southwest.

Similarly, on the west, blooms can be either localized in distribution (i.e., restricted to the inland waters of Puget Sound or the fjords of Alaska) or wide spread along the Pacific Ocean coast. In northern California, it is hypothesized that the onset of PSP toxicity is linked to the onshore movement of warm, stratified waters following the relaxation of coastal upwelling (Horner et al. in press). The relaxation events or downwelling, brought about by a change in wind speed or direction, carry established Alexandrium populations toward shore, resulting in rapid increases in toxicity in nearshore shellfish. There is currently no evidence that this also occurs in Washington or Alaska.

These are but a few of the physical mechanisms underlying PSP outbreaks in the U.S. Some areas are well-studied, and others are virtually unknown. Alexandrium blooms generally do not involve large cell accumulations that discolor the water and may be below the water surface where they are not visible. Low density populations can cause severe problems due to the high potency of the toxins produced by these species. Furthermore, Alexandrium species can grow in relatively pristine waters, and it is difficult to argue that anthropogenic nutrient inputs are stimulating the blooms. These characteristics are important when considering mitigation and control strategies.

The economic impact of these outbreaks is significant, though difficult to estimate in total. Most of the states listed above operate shellfish monitoring programs, each of which costs $100,00-200,000 per year. Estimates of the losses to shellfisheries and other seafood-related industries are few, but one listed the costs of a single PSP outbreak in Maine at $6 million (Shumway et al. 1988). Some estimates place the value of the quarantined surfclam resources on George's Bank at several million dollars per year. This resource has been closed to harvest since 1989. On the west coast, the shellfish industry in Alaska, which produced 5 million pounds of product in 1917, has been greatly reduced (except for aquaculture) as a direct result of persistent product contamination of butterclams by PSP (Neve and Reichart 1984). There is a highly restricted recreational shellfish industry since many if the state's resources remain permanently closed due to high costs associated with monitoring the state's vast coastline. The value of the sustainable, but presently unexploited, shellfish resource in Alaska is estimated to be $50 million per year (Neve and Reichart 1984). In addition to the risks of PSP from molluscs, there are PSP and domoic acid poisoning risks from consumption of Dungeness and other crabs.

[Harmful Algal Blooms - Main Page] | [Fish Heatlh in Chesapeake Bay - Main Page]

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UNIVERSITY OF MARYLAND
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CDC Home | Search | Health Topics A-Z

Division of Bacterial and Mycotic Diseases

Disease Information

Return to complete listing

Vibrio vulnificus

General Information | Technical Information | Additional Information

Frequently Asked Questions

- What is *Vibrio vulnificus*?
- What type of illness does *V. vulnificus* cause?
- How common is *V. vulnificus* infection?
- How do persons get infected with *V. vulnificus*?
- How can *V. vulnificus* be diagnosed?
- How is *V. vulnificus* infection treated?
- Are there long-term consequences of *V. vulnificus* infection?
- What can be done to improve the safety of oysters?
- How can I learn more about *V. vulnificus*?

What is *Vibrio vulnificus*?

Vibrio vulnificus is a bacterium in the same family as those that cause cholera. It normally lives in warm seawater and is part of a group of vibrios that are called "halophilic" because they require salt.

What type of illness does *V. vulnificus* cause?

V. vulnificus can cause disease in those who eat eat contaminated seafood or have an open wound that is exposed to seawater. Among healthy people, ingestion of *V. vulnificus* can cause vomiting, diarrhea, and abdominal pain. In immunocompromised persons, particularly those with chronic liver disease, *V. vulnificus* can infect the bloodstream, causing a severe and life-threatening illness characterized by fever and chills, decreased blood pressure (septic shock), and blistering skin lesions. *V. vulnificus* bloodstream infections are fatal about 50% of the time.

V. vulnificus can also cause an infection of the skin when open wounds are exposed to warm seawater; these infections may lead to skin breakdown and ulceration. Persons who are immunocompromised are at higher risk for invasion of the organism into the bloodstream and potentially fatal complications.

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How common is *V. vulnificus* infection?

V. vulnificus is a rare cause of disease, but it is also underreported. Between 1988 and 1995, CDC received reports of over 300 *V. vulnificus* infections from the Gulf Coast states, where the majority of cases occur. There is no national surveillance system for *V. vulnificus*, but CDC collaborates with the states of Alabama, Florida, Louisiana, Texas, and Mississippi to monitor the number of cases of *V. vulnificu*s infection in the Gulf Coast region.

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How do persons get infected with *V. vulnificus*?

Persons who are immunocompromised, especially those with chronic liver disease, are at risk for *V. vulnificus* when they eat raw seafood, particularly oysters. A recent study showed that people with these pre-existing medical conditions were 80 times more likely to develop *V. vulnificus* bloodstream infections than were healthy people. The bacterium is frequently isolated from oysters and other shellfish in warm coastal waters during the summer months. Since it is naturally found in warm marine waters, people with open wounds can be exposed to *V. vulnificus* through direct contact with seawater. There is no evidence for person-to-person transmission of *V. vulnificus*.

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How can *V. vulnificus* infection be diagnosed?

V. vulnificus infection is diagnosed by routine stool, wound, or blood cultures; the laboratory should be notified when this infection is suspected by the physician, since a special growth medium can be used to increase the diagnostic yield. Doctors should have a high suspicion for this organism when patients present with gastrointestinal illness, fever, or shock following the ingestion of raw seafood, especially oysters, or with a wound infection after exposure to seawater.

How is *V. vulnificus* infection treated?

V. vulnificus infection is treated with antibiotics. Doxycycline or a third-generation cephalosporin (e.g., ceftazidime) is appropriate.

Are there long-term consequences of *V. vulnificus* infection?

V. vulnificus infection is an acute illness, and those who recover should not expect any long-term consequences.

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What can be done to improve the safety of oysters?

Although oysters can be harvested legally only from waters free from fecal contamination, even legally harvested oysters can be contaminated with *V. vulnificus* because the bacterium is naturally present in marine environments. *V. vulnificus* does not alter the appearance, taste, or odor of oysters. Timely, voluntary reporting of *V. vulnificus* infections to CDC and to regional offices of the Food and Drug Administration (FDA) will help collaborative efforts to improve investigation of these infections. Regional FDA specialists with expert knowledge about shellfish assist state officials with tracebacks of shellfish and, when notified rapidly about cases, are able to sample harvest waters to discover possible sources of infection and to close oyster beds when problems are identified. Ongoing research may help us to predict environmental or other factors that increase the chance that oysters carry pathogens.

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How can I learn more about *V. vulnificus*?

You can discuss your medical concerns with your doctor or other health care provider. Your local city or county health department can provide information about this and other public health problems that are occurring in your area. Information about the potential dangers of raw oyster consumption is available 24 hours a day from the FDA's Seafood Hotline (telephone 1-800-332-4010); FDA public affairs specialists are available at this number between 12 and 4 p.m. Monday through Friday. Information is also available on the world wide web at: http://vm.cfsan.fda.gov.

Some tips for preventing *V. vulnificus* infections, particularly among immunocompromised patients, including those with underlying liver disease:

- Do not eat raw oysters or other raw shellfish.
- Cook shellfish (oysters, clams, mussels) thoroughly:
- For shellfish in the shell, either a) boil until the shells open and continue boiling for 5 more minutes, or b) steam until the shells open and then continue cooking for 9 more minutes. Do not eat those shellfish that do not open during cooking. Boil shucked oysters at least 3 minutes, or fry them in oil at least 10 minutes at 375°F.
- Avoid cross-contamination of cooked seafood and other foods with raw seafood and juices from raw seafood.
- Eat shellfish promptly after cooking and refrigerate leftovers.
- Avoid exposure of open wounds or broken skin to warm salt or brackish water, or to raw shellfish harvested from such waters.
- Wear protective clothing (e.g., gloves) when handling raw shellfish.

▲Top

Disease Listing | General Information | Technical Information | Additional Information

Arnold Schwarzenegger
Governor
State of California

S. Kimberly Belshé
Secretary
Health and Human Services

Thomas McCaffery
Chief Deputy Director
Department of Health Services

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213

In response reply to:
2008/09022

JUN - 4 2009

Mr. Donald Glaser
Regional Director
Mid-Pacific Region
U.S. Bureau of Reclamation
2800 Cottage Way, MP-3700
Sacramento, California 95825-1898

Dear Mr. Glaser:

This document transmits NOAA's National Marine Fisheries Service's (NMFS) final biological opinion and conference opinion (Opinion, enclosure 1) based on NMFS review of the proposed long-term operations of the Central Valley Project and State Water Project (hereafter referred to as CVP/SWP operations) in the Central Valley, California, and its effects on listed anadromous fishes and marine mammal species, and designated and proposed critical habitats, in accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*). This final Opinion is based on information provided in the Bureau of Reclamation's (Reclamation) October 1, 2008, transmittal letter and biological assessment (BA), discussions between NMFS and Reclamation staff, declarations filed pursuant to Pacific Coast Federation of Fishermen Association *et al. v.* Gutierrez *et al.* 1:06-cv-245-OWW-GSA (E.D. Cal. 2008), comments received from Reclamation, peer review reports from CALFED and the Center for Independent Experts, and an extensive literature review completed by NMFS staff. A complete administrative record of this consultation is on file at the NMFS Sacramento Area Office.

Based on the best available scientific and commercial information, NMFS' final Opinion concludes that the CVP/SWP operations are likely to jeopardize the continued existence of Federally listed:

- Endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*),
- Threatened Central Valley spring-run Chinook salmon (*O. tshawytscha*),
- Threatened Central Valley steelhead (*O. mykiss*),
- Threatened Southern Distinct Population Segment (DPS) of North American green sturgeon (*Acipenser medirostris*), and
- Southern Resident killer whales (*Orcinus orca*).

NMFS also concludes that the proposed action is likely to destroy or adversely modify the designated critical habitats of:

- Sacramento River winter-run Chinook salmon,

- Central Valley spring-run Chinook salmon, and
- Central Valley steelhead, and
- proposed critical habitat for the Southern DPS of North American green sturgeon.

The final Opinion concludes that the CVP/SWP operations are not likely to jeopardize the continued existence of Central California Coast steelhead (O. *mykiss*).

The conference opinion concerning proposed critical habitat for Southern DPS of North American green sturgeon does not take the place of a biological opinion under section 7(a)(2) of the ESA unless and until the conference opinion is adopted as a biological opinion when the proposed critical habitat designation for the Southern DPS of North American green sturgeon becomes final. Adoption may occur if no significant new information is developed, and no significant changes to the project are made that would alter the contents, analyses, or conclusions of this Opinion.

Take of threatened green sturgeon is currently not prohibited by Section 9 of the ESA. When the rule proposed on May 21, 2009 (74 FR 23822) under section 4(d) of the ESA becomes effective as a final rule, all take of threatened green sturgeon not in conformance with that rule will be prohibited under the ESA. Upon the effectiveness of the final green sturgeon take rule, compliance with this Incidental Take Statement provides exemption for take under section 7(o).

The ESA provides that if NMFS has reached a jeopardy or adverse modification conclusion, it must identify a reasonable and prudent alternative (RPA) to the proposed action that is expected to avoid the likelihood of jeopardy to the species and adverse modification of designated and proposed critical habitat, if such an alternative action can be offered. NMFS includes with this Opinion a RPA that we believe meets all four regulatory requirements, as set forth in 50 CFR 402.02. This has been a very challenging consultation for our agencies due to its complexity, long-term nature, and importance to the people of California and the resources we are required to manage. NMFS and Reclamation have had extensive discussions on the preparation of the BA, the draft Opinion, and the draft RPA, and while NMFS understands that Reclamation may have reservations with portions of the Opinion, NMFS understands that it is a package that Reclamation can accept. Because this is a jeopardy Opinion, Reclamation is required (402.15(b)) to notify NMFS "...of its final decision on the action." NMFS, therefore, requests that Reclamation provide NMFS with timely notification as to your agency's final decision.

Also enclosed are Essential Fish Habitat (EFH) Conservation Recommendations for Pacific Coast Salmon species, as required by the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) as amended (16 U.S.C. 1801 *et seq.*; enclosure 2). NMFS EFH analysis concludes that the CVP/SWP operations will adversely affect EFH for Pacific Coast Salmon species in the action area. The RPA that was developed for the ESA-listed salmon was designed to avoid jeopardy and adverse modification for those species but it also has substantial benefits to Pacific salmon EFH, and commercially valuable Central Valley fall-run Chinook salmon. Pursuant to the MSFCMA, Conservation Recommendations are also provided to further reduce adverse effects on EFH.

I want to express my sincere appreciation to you and to your staff for their professionalism and commitment to find a solution that comports with our various Federal mandates. You have my commitment that NMFS will continue to be close partner with Reclamation, CA Department of Water Resources, CA Fish and Game, and US Fish and Wildlife Service as we embark on implementation. I also look forward to continuing our participation with Reclamation, partner agencies and stakeholders in the Bay Delta Conservation Planning effort, a very important action to boost habitat improvements in the Delta and counterbalance some of the aging infrastructure limitations. If you have any questions regarding this consultation, please contact Mr. Garwin Yip, of my staff, at (916) 930-3611 or via e-mail at garwin.yip@noaa.gov.

Sincerely,

Rodney R. McInnis

Rodney R. McInnis
Regional Administrator

Enclosures:
- Enclosure 1: Biological and conference opinion on the long-term operations of the Central Valley Project and State Water Project
    - Appendix 1: Project Description
    - Appendix 2: Supporting documents for the RPA
    - Appendix 3: Fall-run and late fall-run Chinook salmon analysis
    - Appendix 4: Responses to CALFED peer review recommendations
    - Appendix 5: Technical memorandum for the San Joaquin actions
- Enclosure 2: EFH Conservation Recommendations

cc: Copy to file ARN: 151422SWR2004SA9116
NMFS-PRD, Long Beach, CA
Ron Milligan, Reclamation, 3310 El Camino Avenue, Suite 300, Sacramento, CA 95821
Lester Snow, CA DWR
Don Koch, CA DFG
Ren Lohoefener, FWS

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, MD 20910

NOV 1 8 2008

Ms. Debbie Edwards
Director, Office of Pesticide Programs
U.S. Environmental Protection Agency
One Potomac Yard
2777 S. Crystal Drive
Arlington, VA 22202

Dear Ms. Edwards:

Enclosed is the National Oceanic Atmospheric Administration National Marine Fisheries Service's (NMFS) final biological opinion (Opinion), issued under the authority of section 7(a)(2) of the Endangered Species Act (ESA), on the effects of the U.S. Environmental Protection Agency's (EPA) proposed registration of pesticide products containing the active ingredients chlorpyrifos, diazinon, and malathion on endangered species, threatened species, and critical habitat that has been designated for those species. This Opinion assesses the effects of all pesticides containing chlorpyrifos, diazinon, or malathion on 28 listed Pacific salmonids.

After considering the status of the listed resources, the environmental baseline, and the direct, indirect, and cumulative effects of EPA's proposed action on listed species, NMFS concludes that the proposed action is likely to jeopardize the continued existence of 27 listed Pacific salmonids as described in the attached Opinion. NMFS also concluded that the effects of chloropyrifos, diazinon and malathion may adversely affect Ozette Lake Sockeye salmon. We further conclude that the proposed action is likely to destroy or adversely modify critical habitat for 25 of 26 listed Pacific salmonids with designated critical habitat. The proposed action will not destroy or adversely modify designated critical habitat for Ozette Lake Sockeye salmon. As NMFS did not designate critical habitat for the Lower Columbia River coho salmon or Puget Sound steelhead, the Opinion presents no analysis of critical habitat pertaining to these species.

As required by section 7 of the ESA, NMFS provides an incidental take statement with the Opinion. The incidental take statement describes reasonable and prudent measures NMFS considers necessary or appropriate to minimize incidental take associated with this action. The incidental take statement also sets forth nondiscretionary terms and conditions, including reporting requirements that EPA and any person who performs the action must comply with to carry out the reasonable and prudent measures. Incidental take from actions by EPA and the applicants that meets these terms and conditions will be exempt from the ESA section 9 prohibitions for take.

This Opinion assesses effects to listed Pacific salmonids pursuant to the ESA. It does not address EPA's obligation under the Magnuson-Stevens Fishery Conservation and Management Act to consult on effects to essential fish habitat (EFH) for salmonids and other Federally-managed species. Please contact Mr. Tom Bigford or Ms. Susan-Marie Stedman in NMFS's Office of Habitat Conservation at 301-713-4300 regarding the EFH consultation process.

If you have questions regarding this Opinion please contact me or Ms. Angela Somma, Chief of our Endangered Species Division at (301) 713-1401.

Sincerely,

James H. Lecky
Director, Office of Protected Resources

National Marine Fisheries Service
Endangered Species Act Section 7 Consultation

Biological Opinion

Environmental Protection Agency Registration of Pesticides Containing Chlorpyrifos, Diazinon, and Malathion

Photograph: Tom Maurer, USFWS

From: "Linda June" <lindajunesmail@gmail.com>
To: <DeltaKeep@aol.com>
Sent: Friday, September 24, 2010 3:03 PM
Subject: Statement concerning Delta recreation

State Water Resources Control Boardâ€¨
P.=. Box 100 â€¨
Sacramento, CA 95812-0100
Â
Attention:=C2 Ag Waiver Staff
Â
September 24, 2010
Â
I was=a frequent visitor to the Delta region for five years, enjoying water ski=ng, camping, boating and swimming. I experienced several strange skin ras=es after weekends of recreation at the Delta, with the severity increasin= over time. Two summers ago I began to feel more and more uncomfortable=about the risks of pursuing my water sports passion there; I have not gon= swimming or skiing in Delta waters for over a year.
Â
Thank you,
Â
Linda Forbes

From: "Barbara" <Barbara@restorethedelta.org>
To: <DeltaKeep@aol.com>
Sent: Saturday, September 25, 2010 8:52 AM
Subject: statement on recreation

Dear Bill Jennings,

I am writing to share with you why our family no=longer enters the water in the Sacramento-San Joaquin Delta.

In July 2005, when my daughter Kate was three, we=took her out with some family friends on a Delta boating trip. It was qui=e a hot afternoon. We had been boating for some time and decided that it=was time for a swim. We were excited as it was time for Kate's firs= swim in a natural body of water, rather than a swimming pool. I cannot=remember exactly where we were, I know that we had launched from the Stockton=Sailing Club and motored into some sloughs about 1.5 hours from where we launched.<=:p>

My husband lowered her down to me, as I was alrea=y in the water, and we bobbed and played for some time. We had told Kate=to keep her mouth closed as we splashed and played. Like a normal presch=oler she kept sticking her face and head down into the water – only liste=ing to mom for a few minutes at a time. Consequently, she swallowed wat=r.

Half an hour after the swim we were rushing back=to the Stockton Sailing Club as she was having an intense intestinal reaction= That night we had her at Kaiser. She was given a course of antib=otics and other medicine to keep her from dehydrating.

This experience was one of a few events that prom=ted me to become involved in Delta work, becoming a member of CSPA and founding=Restore the Delta. My husband had water skied in the Delta for years.&nb=p; His grown daughters, my step-daughters, were raised on the Delta. Wh=le we go boating from time to time with friends, we will not swim in the Delta.=o:p>

Over the years, I have heard numerous stories fro= moms in the area who no longer take their children out on the Delta due to its=water quality. They won't even go boating. It's sad=that local urban residents have such an unfavorable view of this treasure=in their backyard. But, as a mom, I can understand the fear. A swim=isn't supposed to end in a trip to urgent care.

Sincerely yours,

Barbara Barrigan-Parrilla

Restore the Delta

Dear Bill, September 26, 2010

I have been working and recreating in the Delta since I arrived in Stockton 28 years ago. As a fisheries biologist and educator I enter the water frequently and have become more and more cautious over the years due to the continual degradation of water quality over time. I am often working in waters near farms, ranches and orchards where chemicals are applied regularly and water quality is impacted. When taking students in the water I must warn them to keep their mouths closed if in the water, to be careful not to swallow any and to wash thoroughly after working in the water.

Twenty years ago I may have done snorkel surveys and other work in a bathing suit, now after several rashes and a mean infection or two, I wear a wetsuit for added protection and check carefully for any sign of discharge pipes in the survey area. I still enjoy fishing and even do some hook and line surveys for work (which have become increasingly difficult due to low numbers of fish), but I will not eat fish reared or caught in the Delta or many of its tributaries because of their exposure to chemical contaminants, bacteria and parasites.

The decline of water quality in the Delta affects me very personally as it puts me at added risk while working, robs me of some of my favorite and most affordable recreational opportunities and even threatens my ability to stay in Stockton and make a living as a fish biologist.

Sincerely,
Kari Burr
Fishery Foundation of California

From: "Frank Rauzi" <franktrauzi@yahoo.com>
To: "DeltaKeeper keri burr" <deltakeeperus@yahoo.com>; <deltakeep@aol.com>
Sent: Sunday, September 26, 2010 9:41 AM
Subject: water quality

September 26, 2010 &n=sp;

Hey Bill,

We talked briefly yesterday after the Coastal Cleanup Day effo=t on the Calaveras River. My viewpoint on the condition of th= Delta water quality is from that of a lifelong resident and fisherman of=the Delta.

When I was a youngster we would catch perch,=catfish or stripped bass on an outing and enjoy them for dinner.&nbs=; We swam and played in the San Joaquin River at Hog Island.&nb=p; I still enjoy fishing the Delta today but I won't eat perch, catf=sh or any resident fish. I will eat stripper only if it is a f=esh run fish from the ocean that has not been in the Delta for more than=a couple of days.

Many fish now have fin-rot and sores on them. Several ti=es a year there are fish kills from water quality issues. The water=was so nasty yesterday during the clean-up that my neighbor who jumped&nb=p;off my boat briefly to grab items raced home to shower to get=the funky smell off before going to the barbecue after-wards.

I moved my family into a house that back ups to the=Calaveras River so that we could spend more time on the Delta. =nbsp;When my Father was young he caught salmon and steel-head on the =Calaveras. I didn't have that opportunity due to declining conditio=s. At this rate of decline the next generation may not even have pe=ch to catch.

Sincerely,
Frank T. Rauzi