■ Interagency Ecological Program for the Sacramento-San Joaquin Estuary ■

IEP NEWSLETTER

VOLUME 12, NUMBER 4, FALL 1999

CONTENTS

Of Interest to Managers

Randall L. Brown, Department of Water Resources

- **Fish Abundance Indices**

Pages 4 and 5. DFG reports summer and early fall indices of abundance of several fish of special interest including delta smelt, splittail, longfin smelt and striped bass. It appears that 1999 is a moderate to good year for most of these fish and a very good year for longfin smelt. Juvenile striped bass did well in comparison with recent years, but not as well as predicted by flow and pumping and much worse than in the 1960s and early 1970s.

- **Blue-green Algae Bloom**

Pages 11 and 12. In the past few weeks, DWR field sampling has identified a significant and persistent bloom of a noxious blue-green alga in the central and southern Delta. This bloom is unusual in its areal extent and its dominance by an alga that is commonly associated with eutrophic conditions. The alga can cause taste and odor and filter clogging problems for municipal water supplies.

- **Shallow Water Habitat**

Pages 15–21. Simenstad and others present preliminary results of a CALFED-IEP funded study to test the hypothesis that shallow water habitat created by island flooding can help restore populations of some native fish. They also provide an emerging conceptual model of geomorphologic processes and food web linkages in the Delta.

- **Juvenile Fall-run Chinook Salmon Emigration from the Feather River**

Pages 21–28. McEwan presents the results of three years of fish trapping on the Feather River. The results indicate that most of the juvenile salmon leave the river as fry, with the majority gone by the end of March. This is consistent with findings from other Central Valley streams with fall-run chinook. DWR staff are tagging significant numbers of the naturally spawned emigrants to help determine where they rear and their subsequent contribution to catch and escapement.

- **Multi-dimensional Modeling in the Delta**

Pages 28–35. Monsen and Monismith report on the calibration and verification of a depth-averaged two-dimensional model of the Delta and Suisun Bay. The model looks promising and can readily be converted to a full three-dimensional model—TRIM3D. With increasing computer technology, it may soon be feasible to make seasonal 3-D model runs of the Delta and Suisun Bay on desktop computers.

- **New Introduced Species**

Pages 35–38. Toft and others report on three new introduced invertebrates, one amphipod and two isopods, from the Delta. The ballast water discharge legislation recently signed by the Governor should help slow the rate of introductions.

- **Feather River Temperature Model**

Pages 42–46. Cook, Orlob, and Sommer describe the application of a one-dimensional, finite element, hydrodynamics and water quality model to the Feather River below Oroville Dam. The model will be used to help DWR, DFG, and NMFS determine feasible water temperature to protect spring-run chinook salmon and steelhead.

- **Vegetation Mapping in Suisun Marsh**

Pages 54–57. DWR has contracted with DFG for new mapping of Suisun Marsh vegetation using a combination of quantitative ground truthing and analysis of aerial photography. The system is based on a National Park Service standard and will be periodically updated for use by managers and regulatory agencies to determine vegetative patterns in the marsh.

DELTA SMELT UPDATE

Heather McIntire, Department of Fish and Game

The delta smelt 20-mm Survey was completed in July; 96,518 fish larvae were collected and identified. Most fish were processed within 24 hours of collection. This year delta smelt spawned primarily in the Sacramento-San Joaquin Delta and remained there until early July. Delta smelt take at the State Water Project and Central Valley Project exceeded the “red light” take limit by six fold in May and June, and two fold in July. Exports were reduced in all three months and resumed to near normal levels by early July.

Several mechanisms working individually or synergistically may explain why delta smelt numbers remained high in the Delta during May, June, and July: (1) the 1999 delta smelt population was much larger than it has been in the past, (2) low water temperatures and low specific conductance (SC, µs/cm) may have provided suitable environmental conditions such that delta smelt did not need to move, or (3) a high percentage of food organisms commonly found in the delta smelt’s diet was present.

The delta smelt population does not appear to be larger than in previous years. Total delta smelt catch was similar to previous years and average densities were similar to 1996 and 1997 and were lower than the 1995 and 1998 densities, suggesting that hypothesis one was not a factor.

The 20-mm Survey SC and temperature data were evaluated looking only at South Delta stations by survey. Average temperatures in April and early May were the coolest measured in the five years of the 20-mm Survey. By mid-May average temperatures increased from 12 to 16 °C to 19 °C. Average SC readings were the second highest recorded during the five years of survey. Normally, when delta smelt reach about 30 mm, they move to brackish water. In June, 30-mm and 40-mm delta smelt remained in the South Delta, where SC readings were around 300 µs/cm.

Zooplankton samples are still being processed. These data will be used to evaluate the hypothesis that higher concentrations of food may have influenced the downstream movement of delta smelt. We intend to further explore potential reasons for delta smelt remaining in the South Delta.

Two annual abundance indices are calculated for delta smelt. Delta smelt catch from the first two Summer Townet surveys are combined to calculate the 1999 delta smelt index of 11.9, an increase from last year’s 3.9. The September Fall Midwater Trawl (FMWT) index is 198; last year it was 238. Initial FMWT data show delta smelt were present near the Sacramento-San Joaquin River confluence, in Montezuma Slough, and Grizzly Bay.

STRIPED BASS ABUNDANCE: MIDSUMMER TOWNET SURVEY

Stephen Foss, Department of Fish and Game

The young striped bass 38-mm index for 1999 is 2.2, the highest annual index since 1995. This year’s striped bass index is lower than predicted based on water exports by State and federal water projects, river flow, and the abundance and egg production of adults. Thus, 1999 continues a trend of lower-than-predicted indices over the previous four years.

The final abundance indices for the Suisun Bay and Sacramento-San Joaquin Delta areas were 1.5 and 0.7, respectively, reflecting a higher concentration of striped bass in the area west of the Delta. About 64% of young striped bass were found in the Suisun Bay area this year.

The young striped bass index is set when the mean length of the sample is 38.1 mm, which typically occurs sometime in July. This year the 38-mm mean length was reached on 6 August (the last day of the third survey), the fifth latest in the 41-year history of the survey. The late 38-mm date resulted from a delay in striped bass spawning and probably slower growth due to abnormally cool spring and summer water temperatures.

Fall Midwater Trawl Survey

Russ Gartz, Department of Fish and Game

On 7 September 1999, the Department of Fish and Game began its 1999 Fall Midwater Trawl Survey (FMWT). The FMWT runs from September to December, with a monthly abundance index and a fall abundance index calculated for various species. The monthly index is the sum of the weighted average catches from 17 areas that encompass San Pablo Bay, Suisun Bay, Montezuma Slough, the lower Sacramento and San Joaquin rivers, and the eastern Sacramento-San Joaquin Delta. The FMWT samples 100 stations that are used in the monthly index and an additional 16 stations that are used to monitor the migration and distribution of delta smelt, *Hypomesus transpacificus*, beyond the survey area. The fall index is the sum of the four monthly indices.

During the September survey, seven stations in the Sacramento River could not be sampled due to gear problems (stations 716, 717, 72, 725, 73, 735, and 74). However, these stations are not used to monitor delta smelt (see above) and do not affect that species' monthly index.

In September 1999 most species of concern were less numerous (Table 1) and distributed in the eastern part of the San Francisco Estuary compared to the western part of the estuary in September 1998. The exception was longfin smelt, *Spirinchus thaleichthys*, which in September 1999 was more numerous (see Table 1), with the majority of the catch located in San Pablo Bay, in contrast to western Suisun Bay in 1998.

Currently the FMWT is assisting the University of California, Davis, in its collection of samples for a histological study of longfin smelt and delta smelt.

Table 1 September 1998 and 1999 monthly indices and fall 1998 indices for various species caught in the FMWT [a]

Species	*September 1998 Index*	*September 1999 Index*	*Fall 1998 Index*
striped bass (*Morone saxatilis*), young-of-the-year	234	154	1,224
delta smelt (*Hypomesus transpacificus*)	239	198	421
longfin smelt (*Spirinchus thaleichthys*)	149	1,953	6,654
Sacramento splittail (*Pogonichthys macrolepidotus*)	127	24	281
American shad (*Alosa sapidissima*)	1,318	346	4,140

[a] 1998 indices may vary slightly from previously published results due to minor corrections in the Midwater Trawl Database.

Juvenile Salmon Monitoring

Rick Burmester, US Fish and Wildlife Service

The US Fish and Wildlife Service, Sacramento-San Joaquin Estuary Fishery Resource Office (SSJEFRO) scaled back monitoring efforts in response to the summer salmon lull (July through September). San Joaquin River beach seining was completed for the season on 30 June. The last chinook salmon detected on this beach seine survey were two apparent fall-run chinook (77 and 80 mm) on 2 June. Lower Sacramento River and Sacramento-San Joaquin Delta area seining continued three days per week with three fall-run-sized chinook captured on 14 and 15 July (80 to 84 mm). Juvenile chinook have not been detected in the San Francisco Bay area seine since 26 May, when one spring-run-sized chinook (105 mm) was captured. Winter-run fry began showing up at Red Bluff Diversion Dam on 7 July, but none were detected in the SSJEFRO monitoring efforts in the Delta for the quarter.

Midwater trawling at Sacramento continued with 14 fall-run-sized chinook captured between 2 July and 25 August (77 to 98 mm). One late-fall-sized chinook was captured on 23 August (84 mm).

Trawling effort at Chipps Island decreased below scheduled summer sampling due to delta smelt take and needed repairs to the *Whitesel*. Of 11 sampling days conducted, nine were shortened due to delta smelt catches. Captures since 1 July include one late-fall-sized chinook on 7 July (56 mm), two fall-run-sized chinook on 7 and 27 July (66 and 104 mm), and four adult chinook (three on 16 August and one on 1 September).

Sampling efforts increased starting 1 October. Kodiak trawling at Sacramento is being conducted five days per week. When the Delta Cross Channel gates at Walnut Grove close, sampling will be reduced to three or four days per week. Chipps Island trawling is being conducted three days per week, and effort will increase to seven days per week during coded-wire tag studies in December and January. Trawling near Benicia is planned this year to establish a baseline of data for comparison to the Chipps Island trawl. The Benicia trawl may be needed to avoid excessive incidental take of delta smelt at Chipps Island.

On 15 October, the Sacramento area beach seine began. This seine route increases our ability to detect juvenile spring-run and winter-run chinook entering the Delta. Kodiak trawling at Mossdale also started on 15 October, to detect the Delta entry of San Joaquin River chinook, which can provide supporting data to help identify the origin of juvenile chinook captured in the South Delta and at the facilities.

For a thorough review of the season's salmon data, visit the IEP/USFWS-Stockton Internet site at http://165.235.108.8/usfws.

ROCK SLOUGH MONITORING PROGRAM

Jerry Morinaka, Department of Fish and Game

We used a sieve net to sample fish entrainment once a week at the Rock Slough intake of the Contra Costa Canal in July, August, and September. Adult white catfish, *Ictaluras catus*, (mean = 273 mm FL), was the predominant fish species captured in the sieve net in July. Juvenile threadfin shad, *Dorosoma petenense*, (mean = 34 mm FL), was the predominant fish species captured in August and September. Egg and larval net sampling was conducted at the Rock Slough intake until the end of July. Threadfin shad, (mean = 10 mm FL), was the predominant fish species captured in the egg and larval net. No delta smelt were captured in the sieve net or the egg and larval net.

OLD RIVER FISH SCREEN FACILITY (LOS VAQUEROS) MONITORING PROGRAM

Jerry Morinaka, Department of Fish and Game

Fish entrainment sampling was not conducted at the Old River Fish Screen Facility between 14 June and 12 August due to inspection and maintenance work. We used a sieve net once a week to sample fish entrained behind the fish screens at the Old River Fish Screen Facility for the remainder of August and in September. The sieve net caught 12 different fish species behind the fish screens in August and September. Inland silverside, *Menidia beryllina*, (mean = 28 mm FL), was the predominant fish species captured in the sieve net. No delta smelt were captured behind the fish screens during any of the sampling efforts.

SAN FRANCISCO BAY FISH MONITORING

Kathy Hieb, Department of Fish and Game

Based on age-0 longfin smelt catches from May through September, the 1999 year class appears to be relatively strong. For the study period (1980 through 1999), catches were higher only in 1980, 1982, and 1995. By September, fish were widely distributed from Central Bay to the lower Sacramento River, with the highest catches in northern Central Bay, San Pablo Bay, and Carquinez Strait.

Age-0 Pacific herring catches remained relatively low from July through September, which confirms another poor year class from the San Francisco Estuary. San Francisco Bay age-0 Pacific herring indices have been low since 1987. Age-0 fish begin to emigrate from the bay in late summer, and by August or September catches are usually low relative to earlier months. This year was no exception, with only 14 age-0 Pacific herring collected in August and 35 in September.

Predicting from raw, unweighted catches, the 1999 Dungeness crab index will probably be slightly smaller than the 1997 index. Smaller crabs (<20 mm carapace width) continued to be collected through August, indicating that several cohorts immigrated to the estuary in 1999. By September, age-0 Dungeness crabs were distributed from South Bay to Carquinez Strait, with the highest catches in Central Bay and upper San Pablo Bay and Carquinez Strait. The crabs collected in Central Bay were significantly smaller than those collected upstream.

As reported in the previous *IEP Newsletter*, we are still seeing the effects of the 1997-1998 El Niño. For example, our California halibut catches continued to be relatively high, with most fish now age 1 and age 2 (1997 and 1998 year classes, respectively). Halibut have been concentrated over the shoals of South and Central bays in recent months. Pacific sardine catches continued to be high, but sporadic, with record monthly catches for the study period in July and August 1999. Interestingly, we have collected about twice as many Pacific sardines as Pacific herring in 1999.

We have been collecting juvenile flatfish for Jennifer Brown, a UC Santa Cruz graduate student who is attempting to identify a San Francisco Bay chemical signature for English sole, California halibut, and speckled sanddab otoliths. Preliminary analyses of fish collected from the bay in 1998 indicated such a signature might be present. Sampling in 1999 will address interannual and within-estuary variability of this signature. If successful, this technique may be used to identify the bay contribution to the offshore trawl catch of English sole.

Several of the recently introduced shokohaze goby (*Tridentiger barbatus*) we collected in 1999 successfully spawned in an aquarium this summer. Although none of the larvae survived for more than two or three days, we now have eggs and newly hatched larvae in the DFG reference collection.

TIDAL MARSH STUDY

Suzanne DeLeón, Department of Fish and Game

1999 is the last year of the IEP Tidal Marsh Study. We continue to sample a variety of tidal marsh habitats in northern Napa-Sonoma Marsh and the lower Petaluma River (see *IEP Newsletter*, winter 1998 "Quarterly Highlights"), as well as new sites on Browns Island in the western Sacramento-San Joaquin Delta. Two gear types, an otter trawl and experimental gill nets, were added to our sampling regime. The otter trawl has a 3.18-mm mesh cod-end and a 1.83-m head rope and was fished in the fourth and fifth-order channels and in open water. The gill nets were fished in emergent vegetation. They are 6 m long and 1.25 m high and each net is divided into two panels of variable mesh ranging from 6.35 mm to 38.1 mm. We also plan to conduct mark-recapture studies for the mini-fykes, fyke net, throw cage, and block net-beach seine in September and October to estimate capture efficiency.

In the lower Petaluma River, fish were not collected in the first- and second-order channels until late June and July, about two months later than in 1997 and 1998. The yellowfin goby, *Acanthogobius flavimanus*, an introduced species, was present in all habitats sampled, but in very few numbers compared to previous years. In 1999, only yellowfin goby and longjaw mudsucker, *Gillichthys mirabilis*, were collected in the first- and second-order channels. In previous years, threespine stickleback, *Gasterosteus aculeatus*, was abundant also in these channels. In emergent vegetation adjacent to open water, Pacific staghorn sculpin, *Leptocottus armatus*, was most abundant, while topsmelt, *Atherinops affinis*, and yellowfin goby were most common in open water.

In northern Napa-Sonoma Marsh, only Pacific staghorn sculpin and threespine stickleback were collected in the first- and second-order channels. This community is much different than last year when prickly sculpin, *Cottus asper*, and shimofuri goby, *Tridentiger bifasciatus*, were most common in the marsh plain. In the larger, third-order channels, Pacific staghorn sculpin and inland silverside, *Menidia beryllina*, dominated the catch. In emergent vegetation, Pacific staghorn sculpin and shimofuri goby were most abundant. In a shallow water pond controlled by a tide gate, the catch was dominated by inland silverside and rainwater killifish, *Lucania parva*. This habitat has constantly produced the highest average densities for the Napa-Sonoma Marsh. In open water adjacent to the marsh, inland silverside dominated the catch, which also included yellowfin goby, striped bass, *Morone saxatilus*, splittail, *Pogonichthys macrolepidotus*, and tule perch, *Hysterocapus traski*.

Splittail Investigations

Gayle Garman and Randy Baxter
Department of Fish and Game

Splittail project activity during this quarter has centered on compilation and analysis of winter 1998-1999 data. The following are a few highlights from the data.

Angling data indicate adult splittail migrated upstream to spawn in groups or pulses. Angling at Meaders Beach, Sacramento River (river mile 24.5) represented an intensive sampling effort extending from late November to early April, a period covering the splittail spawning run. There were four peaks in the splittail capture rate during the season. The largest peak occurred during late February, with 36 splittail captured over three angling days. The three minor peaks occurred in early February (21 fish in two days), late January (19 fish in three days), and mid-December (16 fish in three days).

Angling success tended to be highest at moderate water temperatures, relatively low water clarity, and declining river stage. Water temperatures at the start of angling during the peaks in splittail capture ranged from 10 to 12 °C, water clarity ranged from 33 to 46 cm Secchi depth (except during the December peak when the Secchi depth was about 55 cm). No splittail were caught during the period of lowest water temperatures (7 to 8 °C) and highest water clarity (128 to 133 cm Secchi depth). More than twice as many splittail (n = 66) were captured during periods of declining river stage as compared to periods of rising stage (n = 23) or during hours of transition between declining and rising stage (n = 23).

Larger splittail were moving upstream early in the season. Length-frequency histograms of adult splittail caught by angling revealed a difference in the size distribution of fish captured from November to January compared to February to March. More large fish were captured early, contributing to a median size of 293.5 mm FL (n = 45). Later in the season there were more small fish with a median size of 273 mm FL (n = 64). This observation supports Caywood's (1974)—older fish may be moving upriver and spawning earlier than younger fish.

In contrast to 1998, few larval splittail were caught by light trapping on the Sutter Bypass, most were caught in late April 1999 by hand net sampling. To identify spawning locations, light traps were set on the Sutter Bypass in areas near vegetation or in areas where larvae were found in the previous season. This year only one splittail post-yolk larva was captured in four different sampling dates from mid-February through early April.

By mid-April of this year, flooded area on the Sutter Bypass was reduced to small pools in rice cells. Hand net sampling of these pools and the nearby toe drains produced several splittail larvae. In late April, yolk-sac larvae were captured in partially re-flooded rice cells nearest to East Canal. The presence of yolk-sac larvae suggests adult splittail spawned in or near the rice cell during re-flooding.

References

Caywood ML. 1974. Contributions to the life history of the splittail *Pogonichthys macrolepidotus* (Ayres) [MSc thesis]. Sacramento (CA): California State University, Sacramento. Available from: California State University, Sacramento.

Neomysis and Zooplankton

Jim Orsi, Department of Fish and Game

The introduced mysid, *Acanthomysis bowmani*, had a population explosion in the Suisun Marsh in August. Abundance reached an unprecedented 596/m^3 in Suisun Slough and 101/m^3 in Montezuma Slough. On the other hand, the native mysid, *Neomysis mercedis*, showed its usual summer decline in July and August.

Among the copepods, the introduced *Acartiella sinensis* was very rare, although it usually becomes abundant in August. *Eurytemora* was still present, albeit in very low abundance in July and August when it usually has disappeared. The most abundant copepod was *Limnoithona tetraspina*, which reached concentrations greater than 50,000/m^3 in Suisun Slough and near Chipps Island. These are normal summer levels for this species, which is very small and predacious. The native freshwater copepods, *Diaptomus* and *Cyclops*, were not abundant, nor was *Sinocalanus doerrii*, which has been at low levels since *Pseudodiaptomus forbesi* entered the San Francisco Estuary in the late 1980s. The latter species showed a strange pattern of abundance in summer. It peaked in July in Disappointment Slough at 7,244/m^3 but declined to only 255/m^3 there in August, when peak abundance shifted to Suisun Slough.

Cladocerans were considerably more abundant in the San Joaquin River at Stockton and in Disappointment Slough in July than they have been in recent years. Minor cladoceran species grouped together reached 12,023/m^3: *Bosmina* (8,849/m^3) and *Diaphanosoma* (6,579/m^3) at Stockton. In Disappointment Slough, *Diaphanosoma* abundance was an unprecedented 36,218/m^3. On the other hand, rotifer abundance was considerably lower than last year.

DELTA FLOW MEASUREMENT

Richard N. Oltmann, US Geological Survey

Two UVM flow monitoring stations required significant repair during the quarter. During mid-July, the San Joaquin River at Jersey Point UVM began providing “noisy” velocity data. After various tests, it was concluded that the 2,000-ft transducer cable that crosses the channel was the problem; on 10 August the cable was replaced. On 30 July, a transducer pile was again destroyed by a passing barge at the Threemile Slough UVM station. About a year ago, a favorable index velocity comparison test was conducted at this station between a side-looking ADCP (SL-ADCP) and the UVM. Therefore, instead of replacing the transducer pile (the frequency of destroyed piles has been about one per year), the use of the UVM was discontinued, and on 25 August a SL-ADCP was installed. The index velocity measured by the SL-ADCP will be calibrated and used to provide 15-minute tidal-flow data in the same manner as was done for the UVM.

Two new continuous tidal flow monitoring stations were recently established in the south Sacramento-San Joaquin Delta. On 25 June, a SL-ADCP was installed at Old River at the Highway 4 crossing, and on 7 September, a SL-ADCP was installed at Old River just east of the temporary barrier location near Delta Mendota Canal. The funding for these two new stations, along with the Grant Line Canal SL-ADCP station that was installed on 6 May, was provided by the US Geological Survey and Department of Water Resources. Several flow calibration measurements have been collected at these three new sites, but the stations have not yet been flow calibrated. These new stations now provide us with 13 continuous tidal flow monitoring stations in the Delta.

The five upward-looking ADCPs (UL-ADCP) that were deployed in the Delta during the spring were successfully retrieved on 12 July. We are currently computing tidal-flow time series for the three-month deployment for each of the five sites. The sites include Turner Cut, Middle River south of Columbia Cut, False River, Connection Slough, and Old River at San Joaquin River at Webb Tract. The computed tidal flow time series for these sites may be very beneficial for investigating the delta smelt crisis that occurred this spring.

During 30 and 31 August, a large hydrodynamic study of the Grizzly Bay area (principle investigator is Jon Burau, USGS) was initiated with the deployment of numerous hydrographic monitoring sensors that included several UL-ADCPs. We will attempt to flow calibrate several of these UL-ADCPs; flow calibration measurements have already been made at five sites. The location of the UL-ADCPs that we will attempt to flow calibrate are Suisun Slough south of Hunter Cut, Hunter Cut, Montezuma Slough south of Hunter Cut, Montezuma Slough at the Sacramento River, Suisun Cutoff, between Roe and Ryer islands, and the mothball fleet channel.

SALMON PASSAGE STUDY AT THE SUISUN MARSH SALINITY CONTROL GATES

Leslie Millett, Department of Water Resources,
George Edwards and Bob Fujimura,
Department of Fish and Game

Under the direction of the Suisun Marsh Salinity Control Gates Steering Group, the Department of Water Resources and the US Bureau of Reclamation modified the Suisun Marsh Salinity Control Gates (SMSCG) flashboards to provide continuous passage for adult chinook salmon in Montezuma Slough in 1998. The modification consists of two 3-foot by 40-foot slots in the flashboard portion of the structure. Department of Fish and Game staff are leading the three-year evaluation of the modification. Previous studies indicate the SMSCG potentially block and delay the upstream migration of adult salmon, therefore the objectives of the current evaluation are to compare the following:

- Chinook salmon passage rates with and without the flashboard modification.
- Time of passage with and without the modification in place.

The second year of the three-year study is underway. One hundred and ninety-eight fall-run chinook salmon will be tagged with regular and depth sensitive sonic tags and their movement will be tracked during three phases of the study. Table 1 shows the schedule for the 1999 evaluation.

Table 1 Schedule for the 1999 salmon passage evaluation at the SMSCG

Dates	*SMSCG Configuration*
14 to 26 September	Modified flashboards installed, gates operating, boat lock operating
27 September to 13 October	Regular flashboards installed, gates operating, boat lock operating
14 October to 4 November	Flashboards and gates out of the water, boat lock operating

We installed nine continuous monitoring stations near the SMSCG to track the tagged salmon passing the structure. In 1998, the hydrophones picked up unidentified noise at several of the stations. The noise has hampered our data analysis. To reduce the chances of noise interference in the 1999 evaluation, we made the following changes to our methods:

- Moved two monitoring stations further upstream and downstream of the structure.
- Installed real time pingers at various locations to provide regular verification that the hydrophones are working.
- Reduced the number of depth tags to 24 (eight per phase). (The noise interference overlapped with signals sent from the depth tags.)

The modified flashboards will be reinstalled at the end of the evaluation if SMSCG operation is needed to lower salinity in Suisun Marsh in subsequent months.

SUISUN ECOLOGICAL WORKGROUP ANTICIPATES RELEASE OF FINAL REPORT

Eliza Sater, Department of Water Resources

The Suisun Ecological Workgroup (SEW) will submit its final report to the State Water Resources Control Board in October 1999. The final report includes recommendations for salinity objectives from four of SEW's five technical subcommittees: Brackish Marsh Vegetation, Waterfowl, Wildlife, and Aquatic Habitat. Also included in the report are discussions of the differences between various subcommittee recommendations and lists of research needs and recommendations for a comprehensive monitoring program.

SWRCB will use the report as part of its triennial review of the water quality standards in the 1995 Water Quality Control Plan. SWRCB is currently writing a draft decision on the first seven phases of the Bay-Delta hearings. Following adoption of a decision, SWRCB will hold a public workshop to discuss SEW's final report.

The final report will be available in late October in electronic format from SEW's Internet site:
http://www.iep.ca.gov/suisun_eco_workgroup/.

DSM2 PWT MODEL CALIBRATION UPDATE

Chris Enright, Department of Water Resources

The Delta Simulation Model 2 (DSM2) Project Work Team (PWT) has begun a cooperative effort to recalibrate the DSM2 model. Activities to date have included collection of new Bay-Delta channel geometry data, collection of flow data at strategic Sacramento-San Joaquin Delta locations, model testing and sensitivity analysis, and preparation for calibration by the team. Calibration preparation includes facilities for running the model and organizing complex outputs. PWT participation in the calibration is facilitated by an e-mail reflector (dsm2@osp.water.ca.gov) and an Internet site (http://www.iep.water.ca.gov/dsm2pwt/). The web site contains near real-time access to daily calibration run output and a facility for interactive comments on each calibration run. The team is using morning conference calls to discuss current calibration output and decide on future steps. Participants in the calibration effort include staff from the Department of Water Resources (DWR) Environmental Services Office, DWR Planning, DWR Operations & Maintenance, US Bureau of Reclamation, US Geological Survey, UC Berkeley, Stanford University, Contra Costa Water District, and Metropolitan Water District.

The DSM2 PWT intends to complete an enhanced calibration for both the DSM2 hydrodynamics and water quality model. The PWT process will be completely documented. The team will also prepare a white paper on model accuracy and error bounds under various modes and time-space scales of application. It is intended to provide model users and decision makers an indicator of model efficacy for different kinds of modeling analysis.

The PWT has begun a unique process—an interagency collaboration on the calibration of a complex hydrodynamics and water quality model. The potential benefits are great both in terms of creating an accurate model and generating trust and understanding about the cooperative process that created it. The PWT is working to complete the calibration by January 2000.

UC Davis Fish Treadmill Research Program and Fish Collection

Ted Frink, Department of Water Resources
Bob Fujimura, Department of Fish and Game

The treadmill research on fish behavior, performance, and physiology near simulated large screens has progressed “swimmingly” through 1998-1999. The research evaluates fish performance and behavior under night and daylight conditions, two water temperatures (12 °C, winter and spring, and 19 °C, fall and summer), and 16 different flow combinations centered around delta smelt and salmon screen approach velocity criteria. As of 15 October 1999, experiments with splittail (young-of-the-year) and chinook salmon (parr and smolts) are complete and final analyses are underway.

Delta smelt tests continue as fish become available from renewed field collections this fall. Department of Fish and Game staff started field collection of live delta smelt in late September. Fishing effort will be increased this season to ensure adequate numbers of smelt for testing. The total numbers of smelt allowed for capture has been increased up to 3,500 fish in 1999. Live American shad have also been obtained from the fish salvage operations at the Skinner Fish Facility this fall. In the absence of available delta smelt in late summer 1999, juvenile green sturgeon and American shad have been the focus of testing.

New funds ($1.04 million) for 1999-2001 were awarded to the Treadmill Program this summer through CALFED, with the new contract to be administered by the National Fish and Wildlife Foundation. In addition, the US Bureau of Reclamation (USBR) awarded a grant of $400,000 in September to augment the existing Department of Water Resources (DWR) contract to continue the research (“bridge funds”) until the CALFED award is dispersed.

Research results, including discussions of fish screen criteria applications, will be presented in the next annual report (November 1999) and at the January 2000 quarterly meeting. Preliminary results with delta smelt have been presented in previous reports and meetings and will be updated in the November report and quarterly meeting. The Fish Treadmill Project is scheduled to continue through 30 April 2001, with support from DWR, USBR, and CALFED.

Pilot Ultrasonic Telemetry Study of Chinese Mitten Crab Movement within the South Delta

Maureen McGee and Robert Fujimura
Department of Fish and Game

Annual entrainment of Chinese mitten crabs (*Eriocheir sinensis*) is a growing concern for the US Bureau of Reclamation (USBR), Central Valley Project, and State Water Project operators. In 1998, from September through November, thousands of migrating adult mitten crabs clogged the fish facilities, making fish salvage operations impossible. Little is known about the habits of mitten crabs within the Sacramento-San Joaquin Delta area. The Department of Fish and Game is performing a pilot ultrasonic telemetry study to examine the movement of mitten crabs. The investigation is funded by the USBR, and Maureen McGee is the lead biologist for the laboratory and field studies.

Initial investigations will examine whether we can collect appropriate size crabs in the field, attach ultrasonic tags without causing adverse effects, and track these animals successfully in the Delta channels. Later field studies will focus on obtaining crab movement information, such as the direction and speed of travel, channel and habitat associations, and the response to physical factors, such as channel splits, water flows, and diel periods. Initial trials of various sampling gears (ring traps, modified fyke traps, crab pots, modified crayfish traps, beach seines, and hook and line) have not successfully caught suitable numbers of crabs at locations of interest. Crabs of the right size are available from salvage collections at the Tracy Fish Facility (TFF). Several tag attachment methods have been evaluated. Nonfunctional (dummy) tags have been attached to the carapace using an adhesive and using rubber or coated-wire harasses. Crabs fitted with dummy tags will be held at the TFF for observation during early October. We will eventually use miniature ultrasonic transmitters designed for tracking juvenile chinook salmon in the field trials. The field trials are scheduled in three phases tentatively starting in mid-October and continuing through November. Day and night monitoring will be included in the field trials.

AN EXTENSIVE, PATCHY *MICROCYSTIS AERUGINOSA* BLOOM DETECTED IN THE DELTA

Stephen P. Hayes and Scott Waller
Department of Water Resources

A notorious taste and odor and filter-clogging blue-green alga, *Microcystis aeruginosa* (also known as *Anacystis cyanea*), was detected in the eastern Stockton Ship Channel on 27 September 1999 by DWR's Bay-Delta Monitoring and Analysis Section staff. This alga had not been detected in phytoplankton samples collected from the Delta in previous years. The bloom was composed of irregular, thumbnail-sized, flat bits of green algae floating exclusively on the surface, which looked like chopped or blended lettuce. Samples were collected for identification only (Figures 1 and 2).

Figure 1 ***Microcystis aeruginosa*** **(side view in solution)**

Figure 2 ***Microcystis aeruginosa*** **(top view in solution)**

Because the alga could adversely affect water supply and water treatment facilities, Bay-Delta Section staff conducted an emergency follow-up study of the central and southern Delta (the area leading to Clifton Court Forebay and ultimately to the Harvey O. Banks Pumping Plant) (Figure 3) on 30 September. Phytoplankton samples were collected for identification only, and visual estimates were made of surface algal density. *Microcystis aeruginosa* was present in all collection samples. A dense distribution (aggregated flakes) of *M. aeruginosa* was observed in the central and southern Delta in the area between Empire Cut at Latham Slough (Station 6) and Middle River at Columbia Cut (Station 7). A less dense distribution (dispersed flakes) was observed at Old River at Sand Mound Slough (Station 2) and at the San Joaquin River at Twitchell Island (Station 13). The least dense distribution (widely dispersed flakes) of this alga was detected in the Old River at the Railroad Bridge adjacent to Santa Fe Cut (Station 4) and at the Middle River at Santa Fe Cut (Station 5). Limited water quality measurements were also taken during the study. Water temperature ranged from 20.9 °C at the San Joaquin River at Jersey Point (Station 1) to 22.4 °C at Empire Cut at Latham Slough, and specific conductance ranged from 176 FS/cm at Potato Slough and Little Connection Slough (Station 11) to 1,202 FS/cm at the San Joaquin River at Jersey Point.

Water quality in the central and southern Delta is typically influenced by low summer and fall stream inflow. The southern Delta, in particular, has longer water residence times than regions adjoining the Sacramento and San Joaquin Rivers, and historically high phytoplankton biomass levels. Since blooms of *M. aeruginosa* in freshwater lakes, stock ponds, and lagoons have been associated with low flows, warm water temperatures, increased water clarity, and high nutrient inputs, it may be that the stimulus for this bloom was a duplication of these conditions within the central and southern Delta during the exceptionally warm and dry fall of 1999. As a result of the preliminary findings of this special study, DWR's Delta Field Division staff were immediately notified. They have since modified State Water Project operations to accommodate for the presence of the bloom. An additional special study to further evaluate the extent and quantify the intensity of the bloom using nutrient analysis, fluorometry, timed tows, and chlorophyll extractions is anticipated.

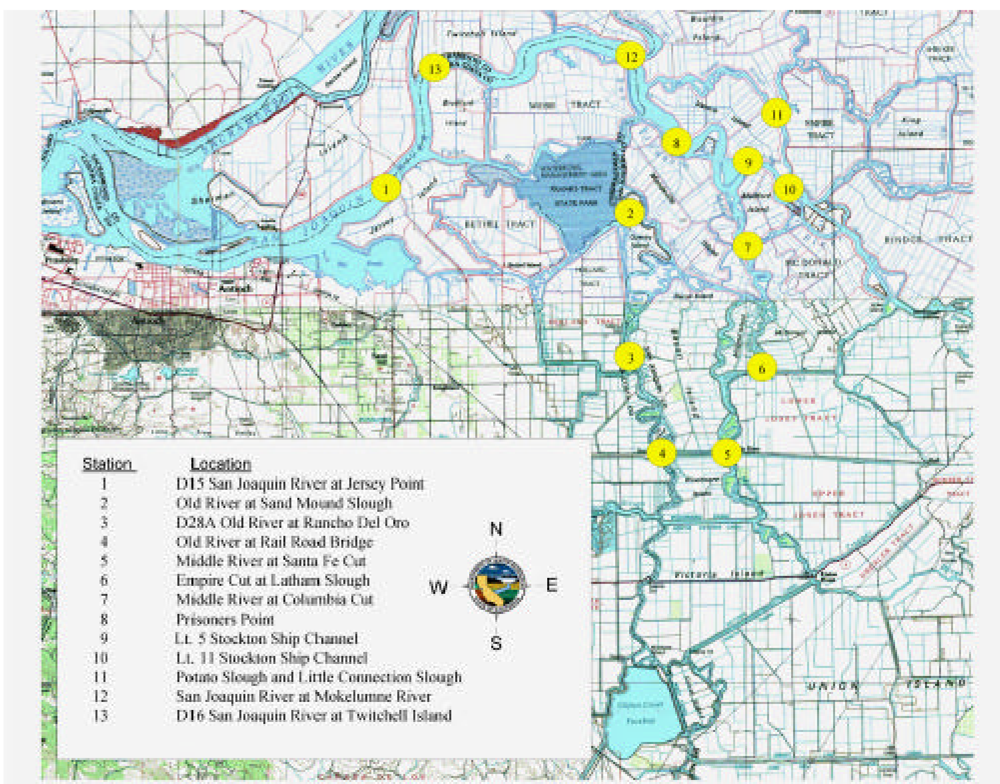

Figure 3 Algal bloom survey sites, 30 September 1999

Comprehensive Monitoring, Assessment and Research Program Update

Leo Winternitz, Department of Water Resources

The goal of the CMARP program is to provide data and scientific interpretations necessary to implement the CALFED program so that its success can be evaluated. Program managers recognize the importance of monitoring, research, and assessment in CALFED programs. Consequently, CALFED has provided a budget, resources, and a draft governance structure within which CMARP would be an integral part.

In March 1999, CMARP staff completed a document titled, "Recommendations for the Implementation and Continued Refinement of a Comprehensive Monitoring, Assessment and Research Program." (See the Internet site at http://calfed.ca.gov/programs.html). This document, now a technical appendix of the CALFED EIR/EIS, is a summary of 50 technical appendices produced by CMARP work teams during approximately one year. The appendices discuss critical aquatic resources issues (biological, water quality, and physical processes) with conceptual models. They also identify research priorities and recommend monitoring variables and assessment methods for CALFED programs.

The following paragraphs describe some of CMARP's major efforts to implement recommendations and refine the program.

Strategy for Enabling Research, Monitoring, and Assessment in the Context of Adaptive Management for Ecosystem Restoration Program and Water Quality Actions in the Delta. CALFED and stakeholders are reviewing a proposal to implement this strategy. Elements of the strategy have already been approved.

Baseline Status and Trends Monitoring Report. A draft report describing the baseline monitoring elements (status and trends monitoring) of major programs in the estuary is due this fall. The report will discuss the ability of the present monitoring network to meet CALFED Stage I needs and provide recommendations.

Science Conference. A CALFED science conference is planned for fall 2000. Conference participants will review information from the science activities sponsored and funded by CALFED and will provide a forum to present and exchange scientific information from other areas.

Research Program. A process for initiating, selecting, and conducting research is described in the March 1999, CMARP recommendation document. The process will be used to sponsor research addressing scientific questions critical to CALFED.

Data Management. CALFED is using the Bay-Delta Tributary Relational Database to manage Category III project-related data. The IEP, CAMP, and several other programs are also using the data management system.

Category III Monitoring and Assessment.
A process is being developed to ensure that appropriate Category III and Ecosystem Restoration Plan projects contain monitoring elements that provide an assessment of project performance. The process would also synthesize information from related subjects to foster implementation of adaptive management principles.

Management Level Indicators. A CMARP-sponsored workgroup is developing "management level" indicators to assess CALFED actions. A draft report is due by December 1999.

Drinking Water Quality Workshop. CALFED'S Water Quality Program held a workshop on August 26 and 27. Proceedings, including a summary of major points and recommendations for research and monitoring and development of information are available.

Geographic Information Systems. CMARP and CALFED are working to identify GIS needs and recommend a system to meet those needs.

Inventory of Monitoring Programs. An inventory of major Bay-Delta monitoring programs is being completed. The inventory will provide a simple method for sorting through many programs, as well as contact information and Internet sites of interest.

If you have any questions about these activities, please contact Leo Winternitz at (916) 227-7548 or by e-mail at lwintern@water.ca.gov.

ANNUAL INTERAGENCY ECOLOGICAL PROGRAM WORKSHOP

Zach Hymanson, Department of Water Resources

The 2000 IEP workshop will be 1–3 March, at the Asilomar Conference Center in Pacific Grove. The IEP workshop will provide information on a number of projects via talks, posters, and panel discussions. As in years past, the IEP workshop will overlap with the Bay-Delta Modeling Forum annual workshop, held 29 February through 1 March, so you can attend all or part of both workshops.

The planning committee is now formulating an agenda for the IEP workshop, with the intent of having a final agenda in December. The final agenda will be included in the winter edition of the *IEP Newsletter*. However, due to procedural changes at Asilomar the deadline for workshop registration is 1 December 1999. Registration forms will be available by the end of October. Check the IEP Internet site (http://www.iep.ca.gov) for registration forms and the latest information about the workshop agenda.

Poster presentations will again be an important part of the workshop. Titles for all poster presentations will be included in the 2000 workshop agenda and a formal evening poster session is planned. If you plan to present a poster at the workshop please contact Peggy Lehman (plehman@water.ca.gov) with the title of your poster. Please contact Zach Hymanson (zachary@water.ca.gov) for additional information about the IEP workshop. Please contact John Williams (jgwill@dcn.davis.ca.us) for additional information about the Modeling Forum workshop.

IEP TECHNICAL REPORT 63 AVAILABLE IN NOVEMBER 1999

Jim Orsi, Department of Fish and Game

The long-awaited "Report on the 1980-1995 Fish, Shrimp, and Crab Sampling in the San Francisco Estuary, California," will be published in November as IEP Technical Report 63. This report describes the abundance and distribution of 38 fishes, 4 *Cancer* crabs, and 6 caridean shrimps taken by the Bay Study from South San Francisco Bay to the west Delta from 1980 to 1995 (1996 in the case of crabs and shrimps). Abundance trends for some species are related to freshwater outflow and temperature. The report was written by Randy Baxter, Kathy Hieb, Suzanne DeLeón, Kevin Fleming, and Jim Orsi, who also served as editor.

CONTRIBUTED PAPERS

PRELIMINARY RESULTS FROM THE SACRAMENTO-SAN JOAQUIN DELTA BREACHED LEVEE WETLAND STUDY (BREACH)

BREACH Interdisciplinary Research Team:

Charles Simenstad, Jason Toft, Heather Higgins, and Jeff Cordell, University of Washington

Michelle Orr and Philip Williams, Philip Williams and Associates, Inc.

Lenny Grimaldo and Zachary Hymanson, Department of Water Resources

Denise Reed, University of New Orleans

INTRODUCTION

Over 90% of the once vast tidal-freshwater wetlands of the Sacramento-San Joaquin Delta have been diked, leveed, and removed from tidal and floodwater inundation. The CALFED Bay-Delta Program has developed an Ecosystem Restoration Plan (ERP) that provides strategies and actions for reverting many of these diked lands in the Delta to tidal wetland habitat (a.k.a. shallow water habitat). One of the strategies under consideration is the breaching or partial removal of levees surrounding diked islands in the Delta. It is anticipated that reflooded islands will provide ecosystem functions important to aquatic resources dependent on the Delta. Furthermore, it is hypothesized that restored tidal wetland habitats will promote the recovery of many native fish species that have declined in abundance over the last couple decades. The objectives of our BREACH research project are to test the underlying assumptions upon which this restoration strategy is based, as well as generate scientific information that provides some quantitative predictions of the patterns and rates of tidal wetland habitat in the Delta. In this article we discuss preliminary results from data collected in 1998 and 1999. We also provide some insights into our emerging conceptual model describing the patterns and rates of geomorphological processes, sediment dynamics, macroinvertebrate and fish community structure and food web linkages in the Delta. For more information, see the web site at http://depts.washington.edu/calfed/calfed.htm.

In 1997, we assembled our team of coastal ecologists (University of Washington), geomorphologists (University of New Orleans), hydrologists (Philip Williams and Associates) and fish biologists (California Department of Water Resources) to examine historically breached-levee wetlands as a means to predict the feasibility, patterns, and rates of restoration to natural ecological function. Breached-levee sites are former freshwater tidal wetland areas that were diked and drained and have now reverted to tidal action either accidentally (by way of levee failure) or purposefully, often with the addition of dredge material. We compared physical and ecological indicators of wetland status at six breached-levee sites to four reference wetland sites (Figure 1, Table 1). For the purposes of this study, reference sites are defined as continuously inundated areas within the study regions. These reference wetlands provide templates of habitat complexes (tule marsh, woody riparian vegetation, submerged and floating aquatic vegetation, tidal channel geomorphology, and so on) that we hypothesize the modern Delta ecosystem can sustain; many of these wetlands have been previously classified for their geomorphic features by Atwater (1980).

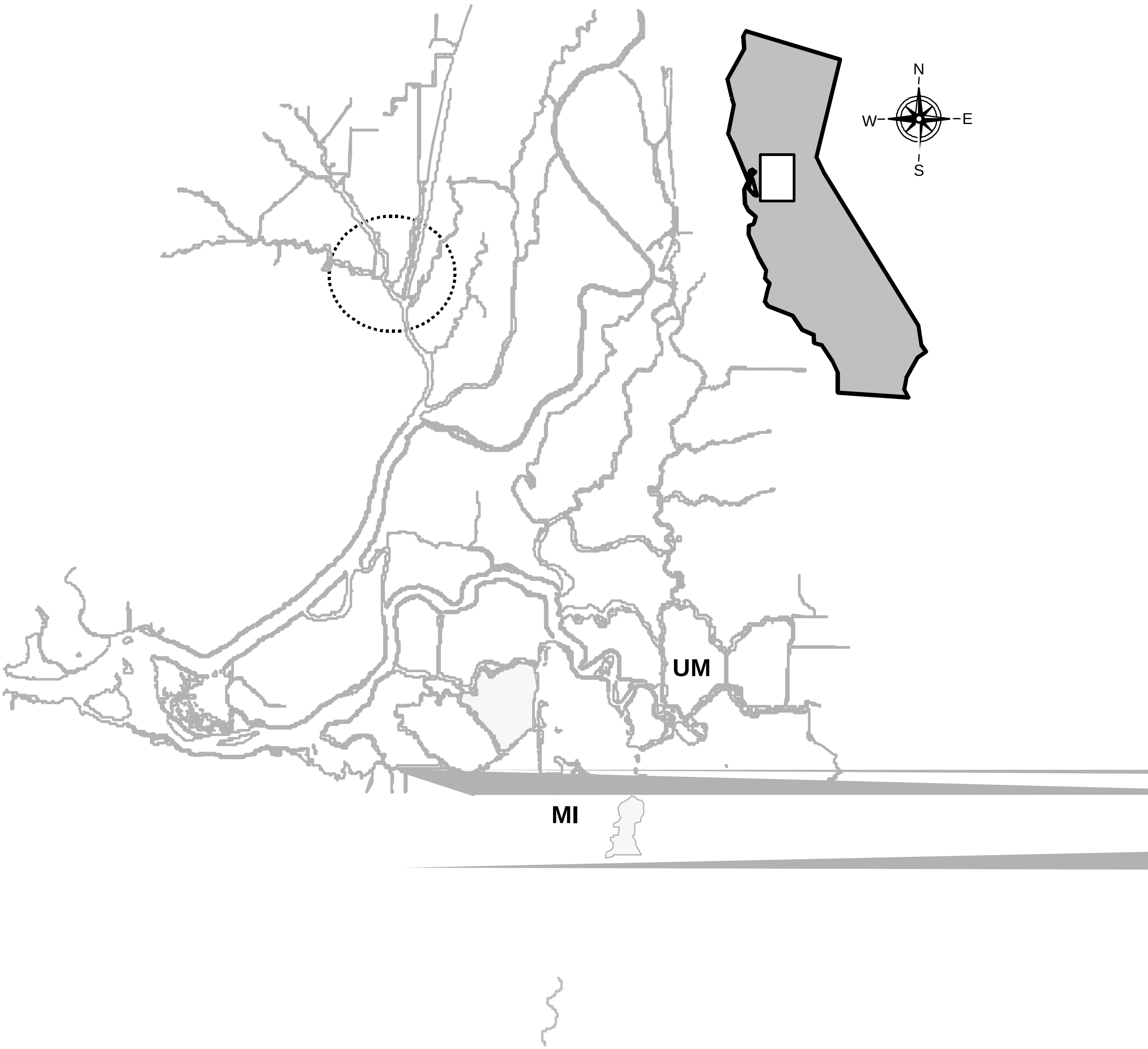

Figure 1 BREACH study regions and site locations. Wetland geomorphology, sedimentology, vegetation and invertebrate studies took place in all regions although fish were sampled only in the central Delta.

Table 1 BREACH research study sites at breached dike islands in the Sacramento-San Joaquin Delta [a]

Site	*Area (Acres)*	*Hydrogeomorphic Region*	*Date(s) Leveed*	*Date(s) Breached*	*Number of Years Leveed*	*Number of Years Since Breach*	*Active Restoration Actions*	*Previous Study*	*Prevalent Habitat*	*Comments*
Donlan	234	West Delta	1910-1920 (possibly 1870-80)	1937	17 - 27 (possibly 57 - 67)	61 (13)	USFWS and USACE restoration site. Dredged material islands created in 1985.	USFWS and USACE (1990)	open water and vegetated dredged material islands	
Lower Mandeville Tip	75	San Joaquin River Delta	1918	1933?	15?	65?	none		tidal wetland	Briefly used as county park. Breached during construction of Stockton Ship Channel.
Mildred	1,004	San Joaquin River Delta	1921	1983	62	15	none		open water	
Prospect West	230	Sacramento River Delta	1914-1918	1963?	45-49	35?	none		open water and fringe wetland	Breached during construction of Sacramento Ship Channel
Sherman Lake	3,278	West Delta	1869, 1894?	1925 ?	31?, 56?	73?	Some dredged material placement along the Sacramento River side.		open water and tidal wetland	
Venice Cut	205	Sacramento River Delta	1906	1933?	27?	65 (14)	USFWS and USACE restoration site. Dredged material islands created in 1986.	USFWS and USACE (1990)	open water and tidal wetland	Breached during construction of Stockton Ship Channel

[a] Breached levee sites are previously leveed areas currently subject to tidal action. May or may not be the site of active restoration efforts. Date leveed reflects the most recent reclamation only.

RESULTS

Geomorphology

Our conceptual model focuses on the patterns and rates of geomorphological processes driving the development of tule marsh plain because this was the predominant historic habitat type and is currently the dominant habitat type at the reference sites. The key factor in restoring marsh plain elevation is the generation of intertidal habitat that can then be colonized by tule vegetation. Our examination of breached-levee sites in the Delta indicates that freshwater-tidal marsh vegetation colonizes bare ground at intertidal elevations within several years. However, many of the breached-levee sites have undergone subsidence, some as much as six meters, during the diked phase. Vegetation establishment through natural processes on deeply subsided, subtidal sites is predicated to take significantly longer, as long as several hundred years, as a consequence of slow accretion of sediments and organic matter. Artificial means of raising substrate elevations, such as deposition of dredged materials, accelerates establishment of intertidal habitat and the colonization of tule marsh. Although the processes involved in marsh vegetation establishment in intertidal areas are evident, there is considerable uncertainty in our understanding of mechanisms and rates of transition between subtidal and intertidal habitats and the role of submerged and floating aquatic vegetation, SAV and FAV respectively, in this process.

Emerging information on vegetation change, marsh surface accretion and elevation change across the Delta between March 1998 and May 1999 indicates patterns that provide support for our conceptual model. As demonstrated at Lower Mandeville Tip, Donlon, and Venice Cut islands, tule marsh vegetation establishes quickly at intertidal elevations. However, subsequent colonization expansion is slow, with an estimated maximum rate of 1.5 to 3 lineal m/y, as observed at Sherman Island. Where wave energy is high, marsh erosion may further increase over time, as is evidenced at Lower Mandeville Tip. This is also consistent with observations of marsh erosion at other Delta islands, such as Northwest Quimby Island and previous unpublished documentation of in channel island marsh erosion.

Sediment Dynamics

Sediment dynamics directly affect the rebuilding and maintenance of marsh plain elevations. Patterns and rates of sediment accretion, erosion and changes in substrate elevation are particularly important factors to understand in the Delta, given that much of the area potentially available for restoration has undergone subsidence to some degree. Initial data on sediment dynamics show once vegetation has established, the current rate of sediment accretion is slow, supporting maintenance or a slow increase in marsh plain elevation. All sites where feldspar marker horizons were recovered show at least 10 mm, and sometimes >20 mm, of accretion during the approximately 13-month measurement period. Accretion was higher between March and August than between August and December. Between June and August all sites in the central and western Delta showed an increase in marsh plain elevation (as determined by Sediment Erosion Table [SET] measurements), which may be attributed to seasonal accumulation of below ground plant biomass.

Sites with high rates of accretion rarely show similarly high rates of elevation change. ^{210}Pb dating of shallow cores from the vegetation edges of our study sites indicates comparable long-term rates of between 8 and 9 mm/yr (Browns and Sherman islands) and 11 mm/yr (Sand Mound Slough)—these rates are of similar magnitude to the accretion data. Although current rates of sediment accretion imply that recovering intertidal habitat before vegetation colonization is the rate-limiting step in tule marsh restoration, our exploratory coring of subtidal habitats at Mildred Island indicated that approximately 0.64 m of sediment had accumulated in the intervening 15 years since breaching of the levee at this extensively-subsided island. If linear (obviously, an unlikely assumption given the accretion data), this rate (approximately 43 mm/yr) suggests return to high intertidal elevations will require a century or more.

Macroinvertebrates

We collected data on macroinvertebrate communities in all three-study regions as one biological measure of tidal wetland habitat development. Understanding the pattern of macroinvertebrate community development can provide insight into the potential for restored wetland habitat to contribute to secondary production in the Delta. Preliminary assessment of benthic macroinvertebrates and fall-out insects in shallow water habitats of the Delta indicates there are only subtle differences among sites, habitat types and seasons. Although nematodes and oligochaetes are the numerically dominant invertebrates in all benthic cores, the composition of crustaceans varied among amphipods (predominantly *Crangonyx floridanus*, *Hyallela azteca*, *Gammarus daiberi*), isopods (*Caecidotea racovitzae*) and cladocerans. Emergent insect (Chironomidae) larvae and pupae were well represented at a few sites (especially Venice Cut), and there was some evidence that they were more dominant at areas with supplemental dredge material. In the central Delta, we found that densities of benthic invertebrates were highest at the reference site, Upper Mandeville Tip, and lowest at the extensively subtidal Mildred Island. Macroinvertebrate assemblages in the emergent marsh habitat (in other words, tule vegetation) were typically less diverse than SAV and FAV habitats. Amphipods and isopods were more prominent in SAV and FAV habitats. Prominent amphipod species varied by SAV and FAV species and by site. Collembolans and chironomids numerically dominated the fall-out insect composition. There were no distinct trends in fall-out insect densities among sites or habitats but the composition of taxa did appear to be different between SAV and FAV (more collembolans, psychodids, and cicadellids) and emergent marsh habitats (greater proportion of chironomids).

Fishes

As mentioned previously, a primary purpose of tidal wetland restoration in the Delta is to promote the recovery of native fishes. Before this study we had only limited knowledge of the fish communities occupying shallow water areas within the Delta; however, several projects underway in the estuary are rapidly expanding our information base (Chotkowski 1999; Whitener and Kennedy 1999). In addition to describing the fish community and associated seasonal trends, we are interested in knowing what environmental factors help to shape the communities we observe.

To date, 35 fish species (8 native and 27 introduced) have been collected at all study sites in the central Delta. Over 98% of the total fish collected are non-migratory residents. Migratory and transitory species collected included chinook salmon (native), delta smelt (native), splittail (native), striped bass (introduced) and American shad (introduced). Approximately 98% of the total larval and juvenile catch (46,902 fishes) were introduced species. In 1998, the density of all native fish species combined was significantly higher (Kruskal Wallis, $P < 0.05$) at the reference site (Upper Mandeville Tip) compared to central Delta study sites. In contrast, the density of all introduced fish species was significantly higher (Kruskal Wallis, $P < 0.01$) at Mildred Island. These preliminary results suggest the habitat characteristics of the reference site (intertidal habitat) promote native fish use, whereas habitat features of the deeply subsided site (subtidal habitat) promote use by exotic fish.

Our preliminary results also show that the temporal residence and spatial distribution of fish is influenced by physical habitat attributes, specifically, water temperature and aquatic macrophyte type. Native fish spawned and reared during a constricted temporal window in the early spring months under a cool water temperature regime, ranging between 10 and 18 °C. In contrast, introduced fish spawned and reared from late spring into the early fall when water temperature was warmer, ranging between 15 and 25 °C. These data indicate shallow water habitats, independent of intertidal or subtidal habitat type, will favor introduced species during the late spring and summer months when water temperatures in the Delta are typically high. With respect to vegetation, initial results show densities of various fish larvae were different between inshore habitats vegetated by emergent and SAV macrophytes and offshore-open water habitats. Delta smelt larvae were found in significantly higher densities (Wilcoxon, $P < 0.05$) in the offshore-open water habitats, whereas larvae of centrarchid species were found in significantly higher (Wilcoxon, $P < 0.01$) densities along inshore vegetated habitats. Juvenile fish densities also differed between SAV densities (none, sparse, and dense) along the littoral zone. Juvenile chinook salmon were found in significantly higher (Kruskal Wallis, $P < 0.05$) densities in nearshore emergent habitats without SAV, whereas densities of juvenile tule perch, centrarchid and ictularid species were significantly higher (Kruskal Wallis, $P < 0.001$) in habitats with sparse or dense SAV. Based on this fish distribution data, we predict that intertidal or subtidal sites that promote colonization of SAV or FAV will provide increased habitat for most introduced species and some native species such as tule perch.

FOOD WEB LINKAGES

We are using descriptive data on macroinvertebrates and fishes combined with fish diet data to develop an understanding of the relationships between habitat structure and food web linkages. Understanding these types of relationships and ultimately the processes responsible for establishing these relationships are important to elucidating the biological benefits of wetland restoration in the Delta.

Food web linkages between invertebrates and fish indicated that both emergent and SAV/FAV habitats contributed prey resources important to fishes, with open-water prey entering into the diets of more planktivorous fishes during the spring. Juvenile chinook salmon fed predominantly on chironomid larvae and pupae (more typical of emergent marsh) as well as the amphipod *Hyallela azteca*. Both splittail and tule perch consumed prey items associated with open-water, SAV and emergent marsh habitats. These included cladocerans, amphipods (*Hyalella azteca*) and chironomid larvae and pupae. The diets of inland silverside collected in the open water habitats of Mildred Island during the spring included planktonic prey items, including numerous cladocerans (*Daphnia* sp., *Simocephalus expinosus*, and *Ceriodaphnia* sp.). In contrast, inland silverside collected at Upper Mandeville and Lower Mandeville (SAV or FAV) had more emergent marsh associated macroinvertebrates (chironomid larvae/pupae, ostracods) in their diets. Bluegill exhibited incredible diet diversity from all habitats, regardless of the site, indicative of a true opportunistic feeder. We also conducted field examinations of piscivorous largemouth bass, white catfish, and striped bass and found their gut contents to include several juvenile fish, including splittail (native), threadfin shad (introduced) and inland silverside (introduced).

We focused particular attention on food web linkages between invertebrate prey associated with introduced FAV, water hyacinth (*Eichhornia crassipes*) and the native FAV, pennywort (*Hydrocotyle umbellata*). We predict that macroinvertebrate taxa richness and density to be different between the two FAV species, due to distinct physical and biological characteristics of the FAV canopies. Preliminary results show that both types of FAV have diverse invertebrate assemblages in their root masses, dominated by amphipods. Fish diet analyses from fish collected underneath the FAV show amphipods provide an important source of food for these fishes. However, dissolved oxygen levels were lower beneath water hyacinth, as compared to beneath pennywort and adjacent emergent vegetation, suggesting a trade-off for fish foraging in hyacinth with the benefits being high amphipod densities and the risk being impairment by physiological conditions.

CONCEPTUAL MODEL

These preliminary results provide some intriguing interpretations about the physical and biological processes and expected benefits of restoring Delta wetlands by breaching levees:

- The process of rebuilding intertidal elevations to levels readily colonized by emergent marsh vegetation cannot be directly extrapolated from what we know about the historic formation of the Delta and depends greatly on the extent of leveed-island subsidence and the geomorphic region of the Delta.

- Based on our independent estimates from feldspar, SET, ^{210}Pb and core stratigraphy, we suggest sediment accretion rates of about 40 mm/yr might be predicted for subtidal habitats, and about 10 mm/yr for intertidal habitats, depending to a large degree on the extent of wave and current energy and the supply of fluvial sediment. Intervention through enhanced sediment input (dredge material disposal) offers one mechanism of shortening the subtidal habitat phase. Native tule marsh vegetation will rapidly colonize intertidal elevations.

- SAV and FAV, including introduced species such as *Egeria densa* and water hyacinth, will dominate subtidal habitats. How SAV and FAV affect the rate of evolution from subtidal phase to intertidal phase is unknown.

- The occurrence and abundance of introduced fishes will likely continue to exceed native fishes even with increased breach-levee restoration, due to the extensive subsidence and duration of the subtidal phase. In addition, the ability of introduced fishes to exploit these habitats for a greater proportion of the year gives introduced fishes an advantage.

- Although densities of macroinvertebrates were higher at the reference site, the composition of benthic macroinvertebrate and fall-out insect assemblages did not differ between reference and breached levee sites. It is predicated that breached levee restoration will provide habitat characteristics necessary for supporting emergent secondary producers.

- Our preliminary findings indicate that emergent marsh and SAV/FAV habitats are distinct in terms of benthic macroinvertebrate and insect contributions. Further, our preliminary findings indicate differences in fish densities among aquatic macrophytes and open water areas. This suggests there are implicit ecological “trade-offs” (for example, which fish are supported) to restoration strategies that result in deeply subsided areas and subsequent long periods of the subtidal phase.

- Food webs supporting both native and introduced fishes derive from SAV/FAV as well as emergent marsh habitats. Our data suggest that early stages of the subtidal breached-diked evolution support prey resources of more opportunistic fishes, while the later stages of predominantly intertidal habitats support more restricted habitat/food web specialists.

REFERENCES

Atwater BF. 1980. Attempts to correlate late Quaternary climatic records between San Francisco Bay, the Sacramento-San Joaquin Delta, and the Mokelumne River, California [dissertation]. Delaware: University of Delaware. Available from: University of Delaware. 212 p + maps.

Chotkowski M. 1999. List of fishes found in San Francisco Bay-Delta shallow water habitats. IEP Newsletter 12(3):12–8.

Whitener K, Kennedy T. 1999. Evaluation of fisheries relating to floodplain restoration on the Consumnes River preserve. IEP Newsletter 12(3):50–7.

FEATHER RIVER STUDY: HIGHLIGHTS OF THE SALMON EMIGRATION SURVEYS, 1996–1998

Debbie McEwan, Department of Water Resources

INTRODUCTION[1]

In 1991 the Department of Water Resources (DWR), in cooperation with the Department of Fish and Game (DFG), began the Feather River Study to examine the effects of temporary water transfers between the State Water Project and Yuba County Water Agency on chinook salmon and other fish. Initially, the study focused on determining the effect of flow on fish habitat. Study objectives included the development of a flow model using Instream Flow Incremental Methodology (IFIM) and a temperature model.

In 1995 study activities were expanded to gather fish data in support of the Federal Energy Regulatory Commission (FERC) relicensing of the State Water Project's Oroville Complex and to address issues raised by the Central Valley Project Improvement Act's (CVPIA) Anadromous Fish Restoration Program (USFWS 1997a). To this end, DWR initiated several studies on the lower Feather River consisting of five major elements: (1) chinook salmon spawning; (2) emigration; (3) chinook salmon spawning gravel evaluation; (4) hatchery tagging program; and (5) a Feather River literature database.

In 1997 DWR became a participant in the CVPIA's Comprehensive Assessment and Monitoring Program (CAMP) (USFWS 1997b) by contributing 1996 rotary screw trap data to the CAMP database. Study activities were also expanded to include water temperature monitoring throughout the lower river.

In 1998 the study was expanded again to estimate the survival of coded-wire tagged, in-channel produced salmon. Also added was a beach seining survey, a salmon egg survival and redd superimposition study, and water temperature monitoring in the Thermalito Complex. The study was expanded further in 1999 to include an intensive steelhead survey (seining, snorkeling, predator study, temperature tolerance study) and a salmon food habits element. DWR participation in the CAMP continued in 1998 and 1999.

The salmon emigration survey is a major element of the Feather River Study. This element examines the timing and magnitude of emigration of naturally produced salmon relative to different physical conditions and spawning population size. Although the element's main focus is salmon, data were also collected on steelhead, splittail, and other fish species.

The emigration of salmonids and other species has not been monitored in the Feather River since the 1970s (Painter and others 1977). The US Fish and Wildlife Service and the DFG have recently increased their fish monitoring activities (using rotary screw traps and other gear) in the Sacramento and San Joaquin River systems. Monitoring activities on the Feather River are consistent with the increased monitoring efforts in these other drainages.

1. This article summarizes the results from three recent Feather River Study salmon emigration surveys. More complete information is presented in three reports currently in production (DWR forthcoming). The reports are expected to be available for distribution by November 1999. For more information about the Feather River Study in general or to request copies of the reports, contact Debbie McEwan at dmcewan@water.ca.gov or (916) 227-7624.

METHODS

Study Area

The lower Feather River (Figure 1) is located within the Central Valley of California, draining an extensive area of the western slope of the Sierra Nevada. The reach between Oroville Dam and the confluence with the Sacramento River is of low gradient. Lake Oroville, created by the completion of Oroville Dam in 1967, has a capacity of approximately 3.5 million acre-feet of water and is a multi-use reservoir providing flood control, water supply, power generation, and recreation. Flow in the lower Feather River below the reservoir is regulated through releases from Oroville Dam, Thermalito Diversion Dam, and Thermalito Afterbay Outlet. Under normal operations, the majority of water released from Lake Oroville is diverted at Thermalito Diversion Dam into the Power Canal and Thermalito Forebay. The remainder of the flow, typically 600 ft^3/s (about 17 m^3/s), flows through the historical river channel, typically referred to as the "low flow channel." Water released from the forebay is used to generate power as it is discharged into Thermalito Afterbay. Water is returned to the Feather River through Thermalito Afterbay Outlet, then flows southward through the lower reach to the confluence with the Sacramento River at Verona. The Feather River study area (Figure 2) is 23 river miles (rm) long and consists of the low flow channel, which extends from the Fish Barrier Dam (rm 67.25) to Thermalito Outlet (rm 59), and a lower reach, which extends from Thermalito Outlet to Honcut Creek (rm 44). The study focuses on the upper 23 river miles (rm 44 to 67) of the lower river because it is the portion of the river where salmonid spawning occurs. River miles 0 to 44 are comprised mostly of flatwater habitat with substrata consisting mostly of fines.

The Fish Barrier Dam, just downstream of the Thermalito Diversion Dam, is the limit for upstream migrating fish. The base of the Fish Barrier Dam has a fish ladder that allows fish to enter the Feather River Hatchery. DWR built the hatchery to mitigate for loss of chinook salmon and steelhead spawning and rearing habitat resulting from the construction of Oroville Dam. DFG operates the hatchery under contract to DWR.

Data Collection

Salmon emigration is monitored primarily using rotary screw traps (RSTs). Two eight-foot RSTs are the main sampling devices used for the emigration survey. One RST was placed at the downstream end of the low flow channel at approximately rm 60, just upstream of the Thermalito Outlet (see Figure 2). The other was placed in the lower reach near the town of Live Oak (approximately rm 42) (see Figure 2). Separate RSTs are needed because operation of the Oroville Complex results in two substantially different flow regimes: flow in the low flow channel is more strictly regulated and is generally low and constant (600 ft^3/s); the lower reach (below Thermalito Outlet), is subject to flow fluctuations, which typically can range from 1,700 to more than 40,000 ft^3/s (about 48 to more than 1,133 m^3/s) during emigration. Therefore emigration cues and species composition may be different for the two reaches. The RST sites were selected based on the following criteria for RST installation, operation, and maintenance: (1) depth greater than 6 ft at minimum flow; (2) velocity greater than 2 ft^3/s at minimum flow; (3) suitable anchoring point(s); and (4) limited public access.

Normally, the RSTs were fished continuously for approximately six to eight months (approximately mid-December through June) except for short periods when river conditions became unsafe. Both RSTs were serviced at least once a day in the morning and more often when there was a high debris load. During servicing, trapped fish were removed from the livebox, identified to species and counted. Fork length to the nearest millimeter was measured for up to 50 individuals of each species. The fish were then released back to the river, except for salmon retained for coded-wire tagging. Other data such as water clarity (Secchi depth) and water temperature were also collected (daily) at each RST.

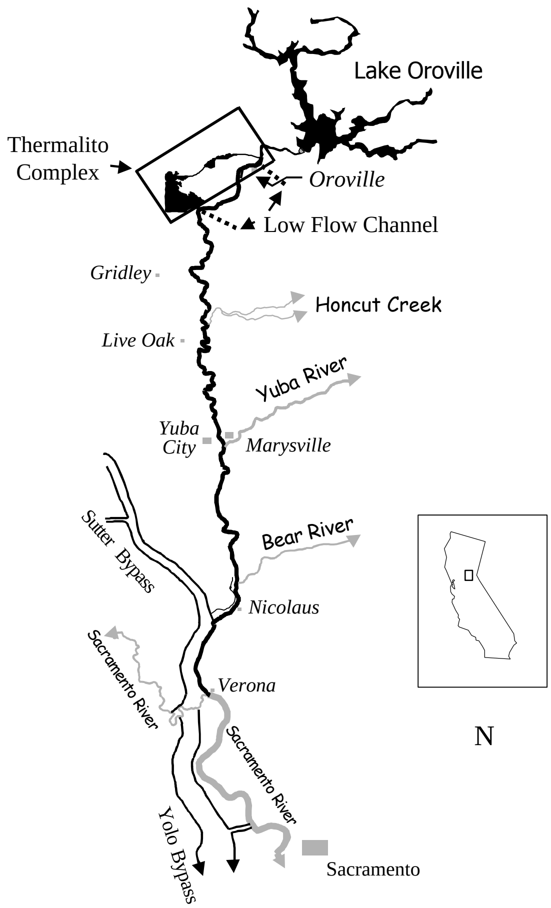

Figure 1 Lower Feather River and associated tributaries between Oroville Dam and the confluence with the Sacramento River

Chinook salmon individuals measured were also inspected for characters such as parr marks, silvery appearance, and deciduous scales to determine life stage and degree of smoltification. In addition, a simple life stage designation was determined for each salmon measured: clearly parr, intermediate, or clearly smolt. The percentages of each life stage in the daily subsamples were used to estimate numbers of each life stage captured each week at each RST.

During the December 1997 through June 1998 season, a salmon tagging station was set up at the Thermalito Afterbay Outlet to coded-wire tag (CWT) in-channel produced juvenile salmon. Juvenile salmon captured in the RSTs were transported and tagged by a contractor, Big Eagle and Associates.

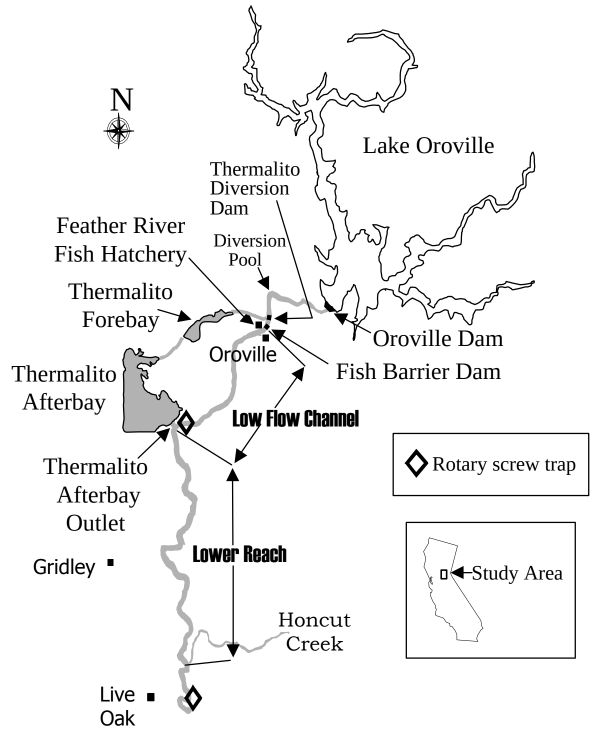

Figure 2 Feather River study area

Five lots of CWT half-tags (Northwest Marine Technology, Inc., Washington) were used. The tagged salmon were held overnight, checked for tag shedding, and then released just downstream of the Live Oak boat ramp, unless they were used for RST efficiency evaluations.

RST efficiency was evaluated using fish collected in the RSTs. Three evaluations were conducted using the CWT in-channel produced salmon. Marked fish were released approximately one-half mile upstream of each RST, and RST catch was monitored for recaptures over four days after marked fish were released. The average Thermalito RST efficiency value was used to calculate an estimate of the number of fish emigrating from the low flow channel. The average Live Oak RST efficiency value was used to calculate an estimate of the number of fish emigrating from the river. Total catch was estimated by summing the daily catch for the season. The emigration estimates were calculated by dividing the total salmon catch in a RST by the average RST efficiency value for that RST:

$$\text{Emigration Estimate} = \frac{\text{Total Catch in RST}}{\text{Average RST Efficiency Value}}$$

RESULTS

March through June 1996

March through June 1996 was the first season of the Feather River Study salmon emigration survey. This survey served as a pilot for sampling, operation, and mooring of the RSTs. The intent was to fish the RSTs from January through June 1996, but delivery delays from the RST manufacturer and high flow conditions in February prevented deployment until early March.

Twenty-four species of fish were caught (Table 1). A total of 17,078 juvenile salmon was caught between 3 March and 30 June 1996. Of the total catch, 14,514 salmon were caught in the Thermalito RST and 2,564 were caught in the Live Oak RST (Figure 3). Salmon size ranged from 25 to 121 mm FL, and most (78%) were 50 mm or less. Salmon emigration probably peaked sometime in January or February, but it could not be identified since RSTs were not deployed until early March. Average trap efficiency values were 1.1% for the Thermalito RST and 0.4% for the Live Oak RST. Seasonal emigration estimates could not be calculated because of lack of data for January and February. However, "partial" emigration estimates were calculated: 1.3 million fish for the low flow channel (Thermalito RST) and 641,000 fish for the lower reach (Live Oak RST). The estimates were consistent with the finding that approximately 70% of adult spawners were located in the low flow channel as opposed to the lower reach (Sommer and others forthcoming). Note that the actual production differences between the two reaches may have been even greater than estimated. The Live Oak estimate included fish from both the low flow channel and the lower reach, while it is assumed that the Thermalito estimate is based primarily on fish from the low flow channel. If a large proportion of the Live Oak catch was from the low flow channel, salmon production for the lower reach may have been substantially lower than the 641,000 estimate.

Totals of 83 young-of-the-year (<100 mm FL) and 15 juvenile steelhead of other age classes (100 to 300 mm FL) were captured between 8 March and 30 June 1996 (Figure 4). Capturing both of these life stages suggests the Feather River supports at least modest in-channel production of steelhead.

October through December 1996

In this season, the second salmon emigration survey, the upstream Thermalito RST was deployed in early October 1996 to determine whether an RST might capture emigrating steelhead smolts in the fall. The downstream RST at Live Oak was deployed as usual in December. Both RSTs were to be operated through the end of June 1997, but were lost during extreme flood control releases (peak was about 140,000 ft^3/s) that began the week of 29 December 1996. Although the RSTs were recovered, sampling was discontinued due to damage to the RSTs and the mooring sites, hence this survey produced minimal information.

Fifteen fish species were caught (see Table 1). A total of 1,945 juvenile salmon was caught between 15 November and 26 December 1996. Of the total catch, 1,755 salmon were captured in the Thermalito RST and 191 were captured in the Live Oak RST (Figure 5). Salmon size ranged from 27 to 39 mm FL at Thermalito and from 28 to 39 mm FL at Live Oak. No steelhead were caught. No emigration estimates were calculated because of the small data set.

December 1997 through June 1998

This was the first time that the RSTs were fished for the entire season. A total of 28 species of fish was caught (see Table 1), the highest diversity since the study was initiated. Native species were prevalent, representing 10 of the 15 most abundant fish. Catch was dominated by 336,377 juvenile salmon captured between 27 December 1997 and 30 June 1998. Of the total salmon catch, 248,962 fish (74%) were captured in the Thermalito RST and 87,415 (26%) were captured in the Live Oak RST (Figure 6). Average trap efficiency values were 0.8% for the Thermalito RST and 0.2% for the Live Oak RST. Emigration estimates were 31,120,250 for the low flow channel and 43,707,500 for the river. The majority of the juvenile salmon captured were parr (100% of the catch at the Thermalito RST and 99% of the catch at the Live Oak RST). Salmon size ranged from 27 to 113 mm FL, but most (83%) were 50 mm or less. Salmon emigration was observed as soon as the traps were installed in December, peaked the last week of January, and continued through June. Coded-wire tagging of naturally produced fish was successful (63,989 juvenile salmon tagged using five codes). A total of 155 young-of-the-year and ten juvenile steelhead of other age classes were captured between 4 January and 13 June 1998 (Figure 7).

Table 1 Summary of RST catch during the first three seasons of the lower Feather River chinook salmon emigration survey

Species or Group	*Origin*	*1995-1996 04 Mar to 30 Jun*	*1996-1997 02 Oct to 27 Dec*	*1997-1998 22 Dec to 30 Jun*
American shad	Introduced	✓		
black bullhead	Introduced		✓	
black crappie	Introduced			✓
bluegill	Introduced	✓	✓	✓
brown bullhead	Introduced	✓		✓
carp	Introduced	✓		✓
chinook salmon	Native	✓	✓	✓
golden shiner	Introduced	✓		✓
green sunfish	Introduced		✓	✓
hardhead	Native	✓		✓
hitch	Native	✓		✓
largemouth bass	Introduced	✓	✓	✓
logperch	Introduced			✓
mosquitofish	Introduced	✓	✓	✓
Pacific lamprey	Native	✓	✓	✓
prickly sculpin	Native	✓	✓	✓
red eye bass	Introduced			✓
redear sunfish	Introduced	✓	✓	✓
riffle sculpin	Native		✓	✓
river lamprey	Native	✓		✓
Sacramento splittail	Native	✓		✓
Sacramento squawfish	Native	✓	✓	✓
Sacramento sucker	Native	✓	✓	✓
smallmouth bass	Introduced	✓		✓
steelhead (young-of-the-year)	Native	✓		✓
steelhead (of other age classes)	Native	✓		✓
striped bass	Introduced	✓		
threadfin shad	Introduced	✓	✓	✓
tule perch	Native	✓		✓
wakasagi	Introduced	✓	✓	✓
warmouth	Introduced	✓	✓	✓
white crappie	Introduced	✓		✓
juvenile bass (*Micropterus* sp.) [a]	Introduced	✓		✓
juvenile centrarchid (non-*Micropterus* sp.) [a]	Introduced	✓	✓	✓
juvenile cyprinid [a]	Introduced/Native	✓	✓	✓
juvenile lamprey (ammocete) [a]	Native	✓	✓	✓
juvenile sculpin [a]	Native			
unidentified juvenile [b]	Introduced/Native	✓	✓	✓
Total Number of Species		24	15	28

[a] Individuals not identified to species (usually identified to genus or family).
[b] Small (less than 45 mm, often larval-sized) fish that could not be identified in the field.

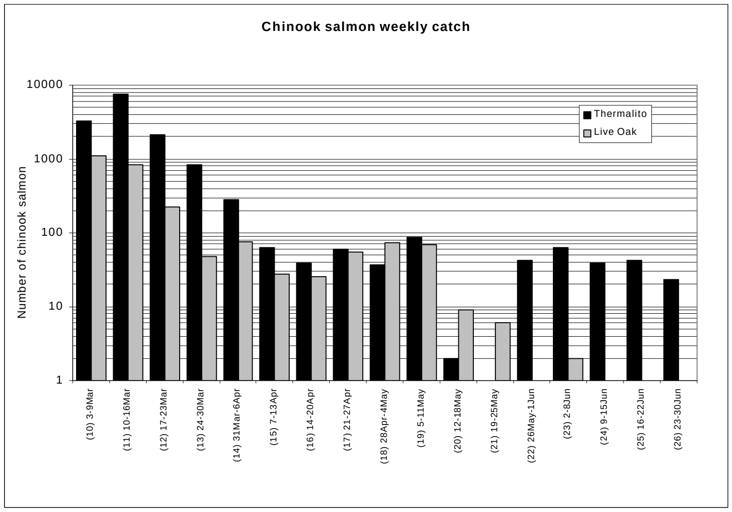

Figure 3 Weekly catch (March through June 1996) of chinook salmon caught by RSTs during the lower Feather River chinook salmon emigration survey. ( ) = Julian week number. The Thermalito RST was not fished from 17 to 24 May 1996 due to high flows (10,000 ft^3/s, about 283 m^3/s) in the low flow channel.

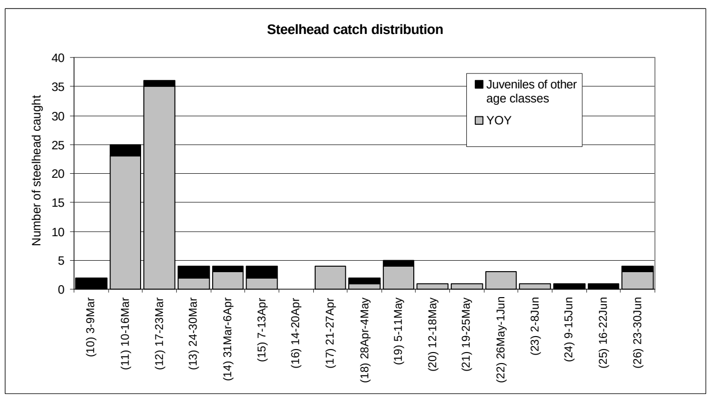

Figure 4 Catch distribution (March through June 1996) of juvenile steelhead caught by RSTs during the lower Feather River chinook salmon emigration survey. ( ) = Julian week number.

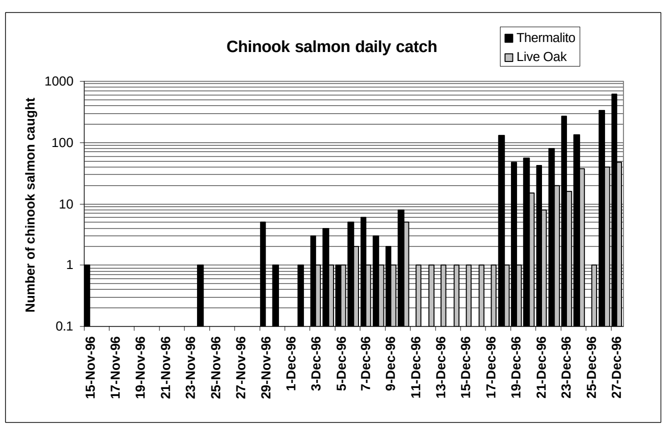

Figure 5 Daily catch (October through December 1996) of chinook salmon caught by RSTs during the lower Feather River chinook salmon emigration survey. The Thermalito RST was not fished from 10 to 17 December 1996 due to high flows in the low flow channel. The Thermalito RST was fished but not serviced on 25 December 1996.

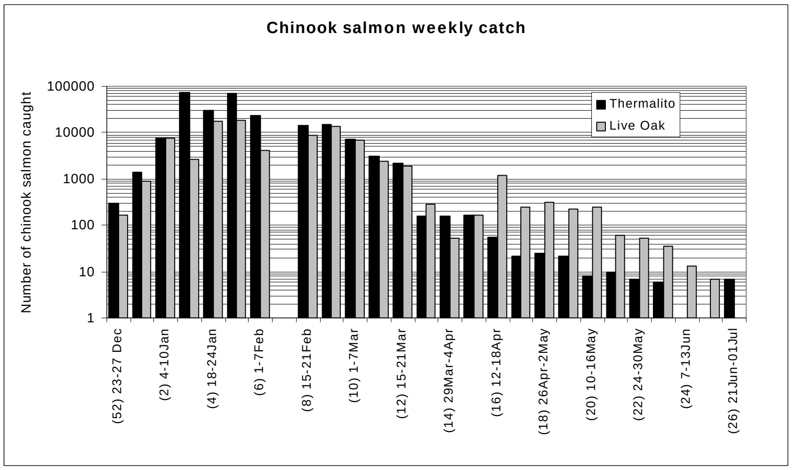

Figure 6 Weekly catch (December 1997 through June 1998) of chinook salmon caught by RSTs during the lower Feather River chinook salmon emigration survey. ( ) = Julian week number. RSTs were not fished from 4 to 17 February and 26 March through 1 April 1998.

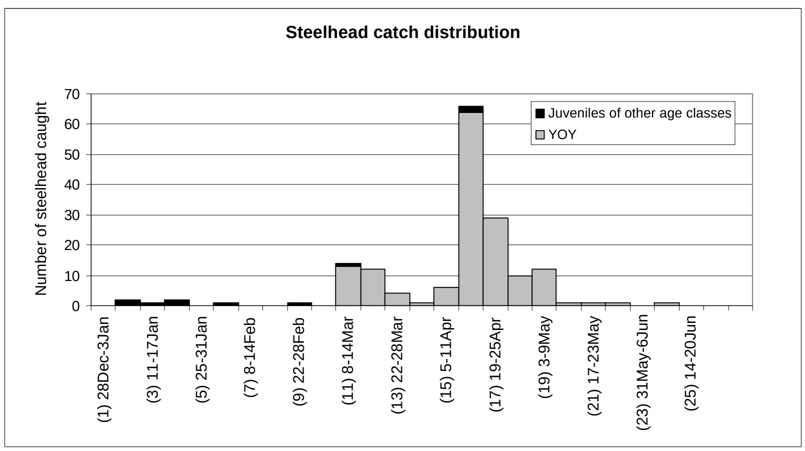

Figure 7 Catch distribution (December 1997 through June 1998) of juvenile steelhead caught by RSTs during the lower Feather River chinook salmon emigration survey. ( ) = Julian week number. RSTs were not fished from 4 to 17 February and 26 March through 1 April 1998.

DISCUSSION

In all three surveys, the Thermalito RST caught more fish than the Live Oak RST and species composition varied little among the surveys when effort is considered. Salmon emigration timing and size ranges were similar among all three surveys and similar to historical Feather River emigration survey data from 1955 (Warner 1955) and 1967 through 1975 (Painter and others 1977) and more recent (1994 through 1996) emigration surveys in the lower American River (Snider and others 1998). In all three surveys most of the emigrating salmon were pre-smolt, and greater than 76% of all emigrants were smaller than 50 mm, demonstrating that most Feather River salmon emigrate well before smoltification. Emigration estimates for the December 1997 through June 1998 survey suggest more salmon were produced in the low flow channel than in the lower reach.

There were more steelhead caught in the December 1997 through June 1998 survey than in the March through June 1996 survey, which suggests in-river steelhead production may have been greater in 1998 that in 1996.

REFERENCES

[DWR] California Department of Water Resources. Feather River Study, Chinook Salmon Emigration Survey, March through June 1996. Forthcoming.

[DWR] California Department of Water Resources. Feather River Study, Chinook Salmon Emigration Survey, October through December 1996. Forthcoming.

[DWR] California Department of Water Resources. Feather River Study, Chinook Salmon Emigration Survey, December 1997 through June 1998. Forthcoming.

Painter RE, Wixom LH, Taylor SN. 1977. An evaluation of fish populations and fisheries in the post-Oroville Project Feather River. California Department of Fish and Game, Anadromous Fisheries Branch. Report submitted to the California Department of Water Resources in accordance with Federal Power Commission License No. 2100. 56 p.

Snider B, Titus RG, Payne BA. 1998. Lower American River emigration survey. October 1995-September 1996 [unpublished report]. Available from: California Department of Fish and Game, Environmental Services Division. 56 p.

Sommer T, McEwan D, Brown R. Factors affecting chinook salmon spawning in the lower Feather River. California Fish and Game Fish Bulletin 179. Forthcoming.

[USFWS] US Fish and Wildlife Service. 1997a. Revised draft restoration plan for the Anadromous Fish Restoration Program. May 30, 1997. 112 p.

[USFWS] US Fish and Wildlife Service. 1997b. Comprehensive Assessment and Monitoring Program (CAMP) implementation plan. Sacramento (CA): US Fish and Wildlife Service, Central Valley Fish and Wildlife Restoration Program Office.

Warner GH. 1955. Studies on the downstream migration of young salmon in the Feather River [unpublished report]. Available from: California Department of Fish and Game, 4001 N. Wilson Way, Stockton, California 94205. 15 p.

CALIBRATION AND VERIFICATION OF DELTA TRIM

Nancy E. Monsen, Stephen G. Monismith, Stanford University

INTRODUCTION

Computer speed and memory have increased so dramatically in the last few years that it is now possible to run multi-dimensional hydrodynamic codes on a personal computer. Thus, it is now feasible to consider more complex problems that cannot be answered with the one-dimensional models currently in use.

There are several interesting questions that can potentially be addressed with multi-dimensional models.

- How do levy breaches in Suisun Marsh impact salinity intrusion (Enright and others 1998)?
- What is the impact of flooding islands in the Sacramento-San Joaquin Delta, and does the location of the breach influence system hydrodynamics?
- How do complex channel features and flows affect fish migration?
- What is the residence time in the flooded islands and how does residence time influence nutrient fluxes?
- How are contaminants tidally dispersed in complex junctions such as the confluence of the Sacramento and San Joaquin rivers?
- How do tidal friction and tidal waves influence the filling and emptying of the Delta during the fortnightly spring-neap tidal cycle?

Stanford University, under research grants from both the IEP and CALFED, has developed Delta TRIM, a depth-averaged two-dimensional model of the Sacramento-San Joaquin Delta (Delta), including Suisun Bay. The backbone of this code is TRIM3D (Tidal Residual Intertidal Mudflat Model), a hydrodynamic code developed by Vincenzo Casulli at the University of Trento in

Trento, Italy (Casulli and Cantini 1994). TRIM models have been previously applied to San Francisco Bay by Ralph Cheng at the US Geological Survey (Cheng and others 1993). TRIM3D calculates the free-surface elevation and velocity field at each grid element based on tidal and flow inputs into the system. TRIM3D also calculates salt transport based on the velocity field at each timestep. No horizontal diffusion coefficient is used. Ed Gross developed the transport scheme and has applied it to South San Francisco Bay (Gross and others 1999, forthcoming).

As the name implies, TRIM3D is a three-dimensional hydrodynamic code. For the series of calibration and verification runs discussed here, we assigned only one vertical layer to Delta TRIM. The TRIM3D is elegantly written such that the depth-averaged equations are solved if only one layer is specified. After the calibration and verification is complete, we will assign multiple layers in the vertical direction making this model fully three-dimensional. One of our main research goals is to compare the results of two-dimensional and three-dimensional model runs.

In Delta TRIM, the model calculates stage, velocity, and salt and passive scalar concentration on a 50-meter horizontal resolution with a 40-second timestep (Figure 1). There are approximately 150,000 computation cells calculated and stored in Delta TRIM. Code was added to incorporate flow from the Sacramento and San Joaquin rivers, export pump operations, agricultural diversions and returns, gate operations, and temporary barrier placement into the model. With a Pentium® III 550 MHz processor with 256 megabytes of memory, the model runs approximately four times faster than real time. That is, for every day of computer time, four days of simulation can be calculated.

This project has three main phases: development of the bathymetric grid, calibration and verification of the model, and addressing our research questions. This article will focus primarily on the second phase (calibration and verification of the model), which we are currently completing.

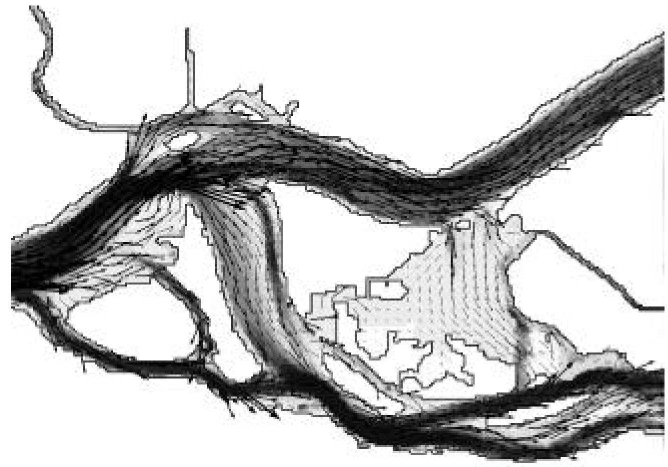

Figure 1 Sample velocity field at the confluence of the Sacramento and San Joaquin Rivers using Delta TRIM

CALIBRATION: MAY 1988 AND MAY 1994

Calibration of the model involved adjusting globally-valid, depth-dependent friction coefficients to match stage and flow throughout the system. That is, one friction coefficient was specified for a specified depth anywhere in the model domain. This eliminates the need to calibrate each region of the Delta separately. This also allows the model to remain calibrated if the model is used to evaluate changes to Delta bathymetry in the future.

For each period, the model was tidally forced with observed stage specified at the Martinez bridge (RSAC054)[1]. When we originally attempted the calibration, we forced this boundary using harmonic constants obtained from the US Geological Survey (USGS) for this station. The harmonic constant approach had worked well in previous studies in South Bay where there is minimal freshwater flow into the system. However, we discovered that the harmonic coefficients in the region near Martinez are dependent on flow conditions. Field studies have confirmed this finding (Lacy 1999).

The periods selected for initial calibration were May 1988 and May 1994. Because these periods were also used in the calibration of the DSM2 model, these data were more complete and accessible than other datasets available at the time calibration began.

1. All station numbers refer to the IEP database reference system.

During May 1988, flows at 18 stations throughout the Delta were measured in the field. Many of these stations were in channels that normally are not monitored. This set provided data needed to calibrate flow throughout the system. Because the flow records are for short periods, the dataset was used primarily for visual comparison of the model results and observed data.

The May 1994 period provided longer stage and flow time series information for the system. Flow was evaluated at the five Ultrasonic Velocity Meters (UVM) sites in operation at that time. Stage information was available at nine sites throughout the system.

In the first phase of the project, the bathymetric grid for the model was developed using the Department of Water Resources' bathymetry database. During the calibration process, errors in the bathymetry database and regions of missing or old data were identified. When possible, the grid was modified with National Oceanographic Survey (NOS) survey data or depths from National Oceanographic and Atmospheric Administration navigational maps.

VERIFICATION: APRIL 1997-DYE RELEASE

In the verification phase of the project, friction factors were no longer adjusted. Stage and flow at different stations were recorded and compared against observed values. To quantify the differences between model and observed values, we compared the differences in phase and amplitude of the major tidal frequencies using harmonic analysis. Since the harmonic analysis was done over a short period, we could assume that flow and the harmonic coefficients remained constant over that time. Because the model calculates passive scalar and salt transport using the surrounding velocity field and does not use horizontal diffusion coefficients to further adjust transport, model calibration was also verified based on how well the model evaluated the concentrations of dye or salt in the system.

The simulation period (26 April 1997 through 15 May 1997) was used to verify model calibration. This period was selected because of the large amounts of field data available. In April 1997, a dye release was conducted by the USGS in conjunction with the release of salmon smolts by the US Fish and Wildlife Service. As part of that experiment, automatic dye samplers were placed in nine locations throughout the Delta. Upward-looking, acoustic, Doppler current profilers (ADCPs) were also deployed at six locations (Oltmann 1999). In a second experiment, part of the Honker Bay study jointly conducted by the USGS and Stanford University, velocity and salinity measurements were made in Honker Bay, Suisun Cutoff, and near Snag Island (Lacy 1999). The UVM station information, as well as stage and EC data from the IEP database were also available.

Stage elevations at 14 sites and flow at 13 sites throughout Suisun Bay and the Delta were compared to field data. A harmonic analysis was performed on the data to quantify phase and amplitude deviations of the model against field data of major harmonic forcing signals. Overall, stage and flow compared well with observed data in Suisun Bay and the central and southern Delta. Stage and flow values on the Sacramento River are not as accurate partly due to sparse bathymetry data in this region.

In the past it has been difficult to evaluate model transport performance in the Delta because salinity differences in this area are very small during most years. Only in extremely dry years are salinities differences in the Delta significant enough to demonstrate model transport capabilities. However, the USGS dye study provided a dataset of passive scalar concentrations to compare with throughout the Delta. By simulating this dye release, we also provided some indication of how accurately the model would transport salt. Because we did not know the exact concentration of dye at the time of release, we simulated the dye release by initializing a concentration of 100 ppt at Mossdale Landing at the specified release time. We then scaled the concentration by the peak value at the first downstream observation location. The arrival time of the dye at stations throughout the Delta in the simulated dye release correlated well with observed values. There was a delay in arrival for the San Joaquin River west of Turner Cut (RSAN042). This could be due to islands within the channels in the eastern Delta that were not accounted for in the model (Figure 2). In the observed data, a concentration of 0.04 ppt is considered background level.

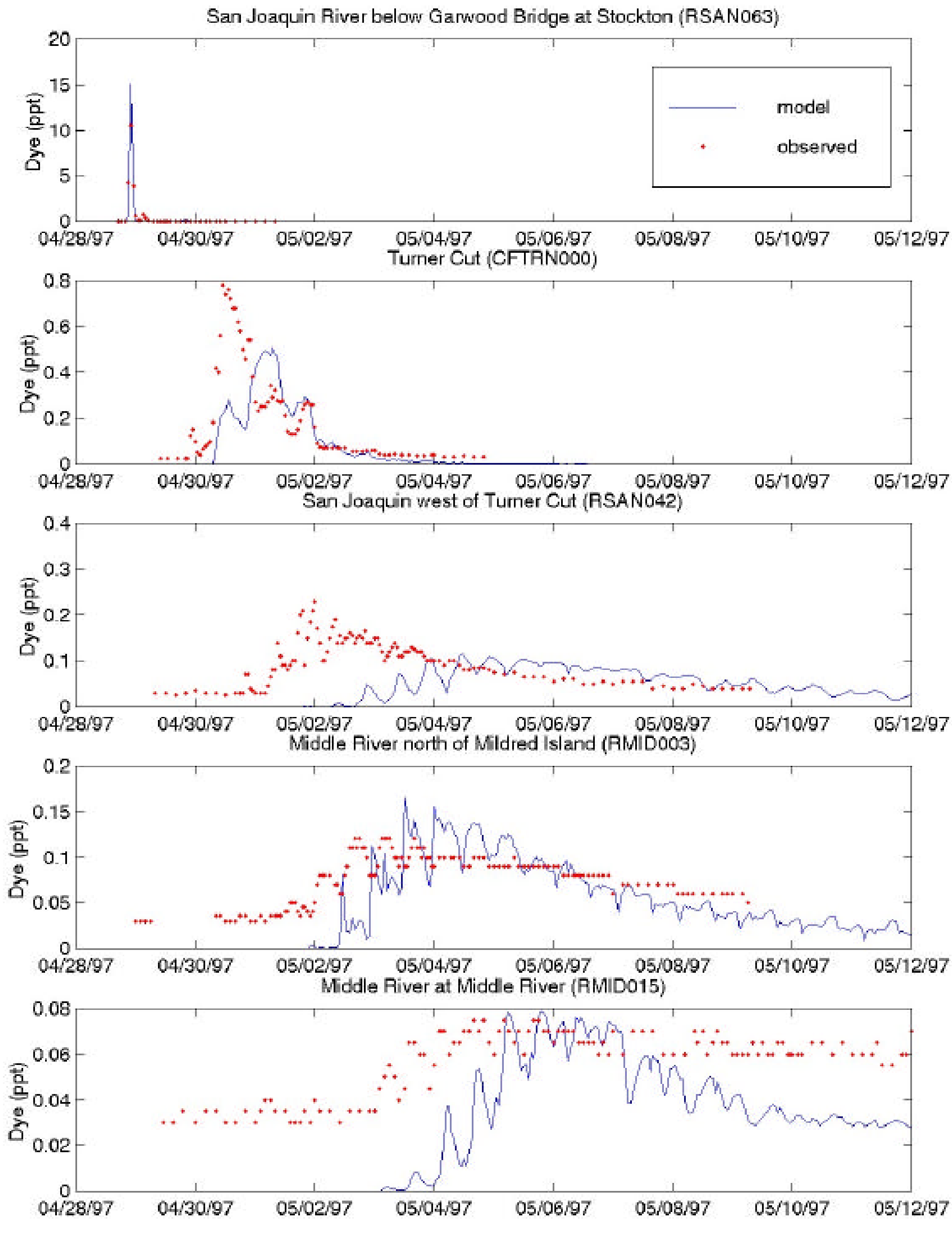

Figure 2 Dye results for April 1997

Salt transport was also evaluated during this simulation. Salt concentrations were recorded at five locations through Honker Bay, Suisun Cutoff, and near Snag Island. Salinity values throughout the Delta were also recorded. For these simulations, we considered salt to be a passive scalar rather than imposing baroclinic forcing because the equations do not accurately represent baroclinic forcing in the depth-averaged case. When we initially ran these simulations, the model was losing salt over time in Honker Bay. A 1992 NOS bathymetry dataset was located for Suisun Bay and portions of the San Joaquin River. This new bathymetry significantly improved the stage and flow calibration. After this bathymetry change, salinity concentrations agreed well with observed values over a one week period. This implies that it is critical to model Suisun Bay with the correct bathymetry to get accurate salinity results (Figure 3).

Verification: September 1998—Confluence Study

The other verification period we are currently working with is September 1998. The USGS and others conducted a field study in the confluence of the Sacramento and San Joaquin rivers for three months beginning in September 1998. The period (21 September 1998 through 4 October 1998) will be used to evaluate the model representation of the confluence region. In addition, the operation of the Suisun Marsh Salinity Control Gates will be incorporated into the model using this period to evaluate performance.

An Application: Mixing in Frank's Tract

One of the first questions that we addressed using Delta TRIM was: "What are the circulation patterns in Frank's Tract, and how do these patterns influence mixing?" We assigned a passive scalar to a square region in Frank's Tract. We then recorded the movement of the tracer over a 24-hour period as it was transported with the 18 May 1994 hydrology (Figure 4).

The scalar was released at the tail end of an ebb tide. The western edge of the patch started exiting from the two main levy openings on the northwest side of Frank's Tract towards False River. The tides then reversed to flood and the patch moved in a southeasterly direction towards the Holland Cut and Old River junction. By noon, the tides had reversed again to ebb and the dye was again exiting through False River towards the San Joaquin. By 6:00 PM, flood tide has moved the patch back in the main part of Frank's Tract.

After 24 hours, the western side of the dye patch was significantly mixed by the interaction with the two levy breaks on the northwest side of the island and with False River. The eastern side of the patch, however, is still relatively intact. Because Frank's Tract is flooded farmland, the depth is uniform. Therefore, there are no significant velocity gradients that would cause substantial mixing in the central part of Frank's Tract. These results imply that the location of levy breaks and tides are important in mixing Frank's Tract and other flooded islands.

Conclusions

The initial evaluation of Delta TRIM is complete and the model is sufficiently calibrated and verified to justify using it to explore our research questions. We are planning several different modeling runs to investigate different hydrodynamic features of the Delta and to evaluate the limitations of the model. These runs include three-dimensional modeling runs, calculation of Eulerian and Lagrangian residuals, and longer simulations which will look at residual transport and the influence of the spring-neap cycle.

Delta TRIM has been criticized for being too slow to run seasonal or longer runs, which some people feel are necessary to evaluate alternative management actions in the Delta. Although the model is currently too slow to do seasonal runs, the computing technology is advancing so rapidly that longer runs will be feasible in only a few years. In April 1998 we started running simulations on a 300 MHz Pentium® II processor and the simulations ran two times faster than real time. Now, a year and a half later, 550 MHz Pentium® III processors are available which run the model four times faster than real time. And, even a couple months later, the 600 MHz machines are already available. This model should not be judged by the speed at which it can model the system today, but rather by the types of questions it can answer in the future.

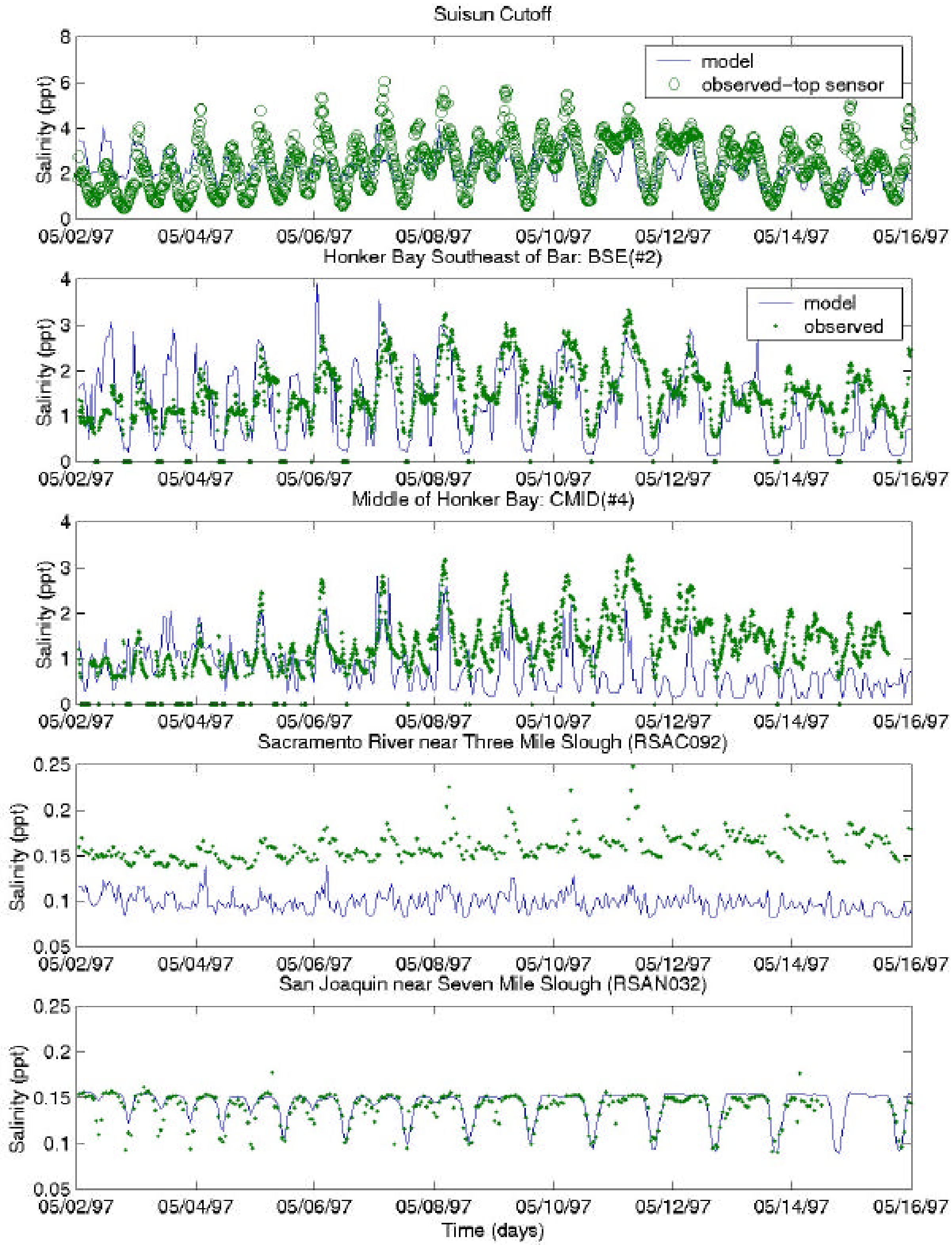

Figure 3 Salt results for April 1997

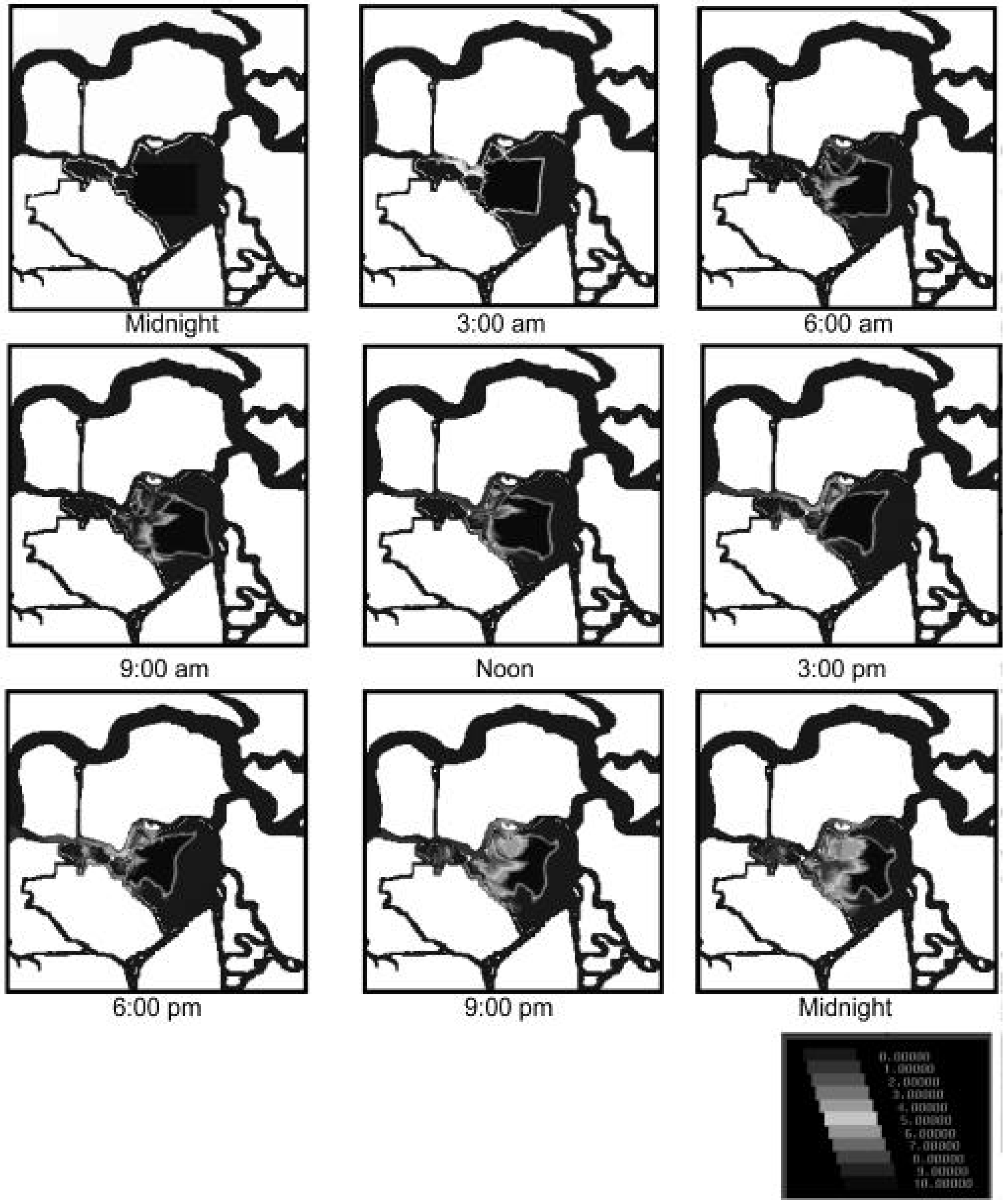

Figure 4 Tracer movement in Frank's Tract

REFERENCES

Casulli V, Cattani E. 1994. Stability, accuracy and efficiency of a semi-implicit method for three-dimensional shallow water flow. Computers and Mathematics with Applications 27(4):99–112.

Cheng RT, Casulli V, Gartner JW. 1993. Tidal, Residual, Intertidal Mudflat (TRIM) model and its applications to San Francisco Bay, California. Estuarine Coastal and Shelf Science 36:235–80.

Enright C, Le K, Guivetchi K. 1998. Progress in modeling salinity impacts of Suisun Marsh levee breaches. IEP Newsletter 11(4):34–7.

Gross ES, Koseff JR, Monismith SG. 1999. Evaluation of advective schemes for estuarine salinity simulations. Journal of Hydraulic Engineering 125(1):32–46.

Gross ES, Koseff JR, Monismith SG. November 1999. Three-dimensional salinity simulations of South San Francisco Bay. Journal of Hydraulic Engineering. Forthcoming.

Lacy J. 1999. Circulation and transport in a shallow semi-enclosed estuarine subembayment [DPhil thesis]. Stanford (CA): Stanford University. Available from: Stanford University.

Oltmann RN. 1999. Measured flow and tracer-dye data for spring 1997 and 1998 for the south Sacramento-San Joaquin Delta, California. IEP Newsletter 12(3):37–44.

MORE NON-INDIGENOUS SPECIES? FIRST RECORDS OF ONE AMPHIPOD AND TWO ISOPODS IN THE DELTA

Jason Toft, Jeffery Cordell, and Charles Simenstad
Wetland Ecosystem Team, University of Washington, Seattle

Amphipods and isopods are abundant aquatic crustaceans found in many different habitats in the Sacramento-San Joaquin Delta (Delta). As part of the CALFED-IEP funded research project, Predicting the Evolution of Ecological Functions of Restored Diked Wetlands in the Sacramento-San Joaquin Delta (BREACH), we have discovered one amphipod (*Crangonyx floridanus*) and two isopods (*Caecidotea racovitzai* and a species of *Asellus* strongly related to *A. hilgendorfii*) that are first records for the Delta. These species were discovered during our biological sampling of both breached-levee restored wetlands and natural wetlands in the Delta. Invertebrate sampling methods and strata included the following:

1. Benthic cores in shoreline emergent vegetation (*Scirpus* sp.), riparian vegetation, and below floating canopies of hyacinth (*Eichhornia crassipes*), pennywort (*Hydrocotyle umbellata*), and parrot's feather (*Myriophyllum aquaticum*) in shallow water.

2. Hand collection in the roots of floating canopies of hyacinth, pennywort, and parrot's feather.

3. Gut-content analysis of fish sampled in shallow water habitats (Grimaldo and others 1998).

For more information visit the Internet site at http://depts.washington.edu/calfed/calfed.htm.

Data on strata, sites, and dates of sampling are presented in Table 1. All three species occurred in a variety of samples from different strata, and at several sites throughout the sampling period. *Asellus* sp. was distinct from the other two species, as it was not found in any of the floating vegetation strata. All three species occurred in a variety of fish diets (see Table 1), and may be locally important in the Delta food web.

Table 1 Strata, sites, and dates of sampling where the three species occurred

Species	*Sample*	*Strata* [a]	*Sites* [b]	*Dates*
Crangonyx floridanus	Benthic Cores	E,R,H,P,F	L,U,V	4/98, 6-7/98, 4/99
	Floating Vegetation Roots	H,P,F	B,M,L,U	6/98, 8/98, 6/99
	Fish Diet	B,L	L,V	4/98, 9/98
Caecidotea racovitzai	Benthic Cores	E,R,H,P,F	L,M,U,V	4/98, 6-8/98, 3-4/99
	Floating Vegetation Roots	H,P,F	B,M,L,U	6/98, 8/98, 6/99
	Fish Diet	B	L,V	4/98, 6-7/98
Asellus sp.	Benthic Cores	E,R	U,V	6-7/98
	Fish Diet	B,L,S,T	L,M	5/98, 7-8/98

[a] Strata codes: E = emergent vegetation (*Scirpus* sp.), R = riparian vegetation, H = hyacinth (*Eichhornia crassipes*), P = pennywort (*Hydrocotyle umbellata*), F = parrot's feather (*Myriophyllum aquaticum*), B = bluegill (*Lepomis macrochirus*), L = largemouth bass (*Micropterus salmoides*), S = Sacramento squawfish (*Ptychocheilus grandis*), T = tule perch (*Hysterocarpus traski*). All strata were located in the nearshore zone.

[b] Site codes: B = Browns Island, L = Lower Mandeville, M = Mildred island, U = Upper Mandeville, V = Venice Cut.

Although the main purpose of this article is to describe the occurrence of these new species, current knowledge suggests they may be non-indigenous to the Delta. *Crangonyx floridanus* is endemic to Florida and Louisiana (Pennak 1989) and has also been introduced into Japan (J. Holsinger, personal communication, see "Notes"). *Caecidotea racovitzai* is endemic to the eastern United States and southeastern Canada, but has also been found in Washington and British Columbia (Williams 1972). The *A. hilgendorfii* complex is endemic to Asia (Henry and Magniez 1995). Although these species have not been recorded in previous studies of the area (for example, Cohen and Carlton 1995), a review of past samples shows that at least *C. floridanus* and *Asellus* sp. may have been present for several years (W. Fields, personal communication, see "Notes"). Certainly, there are many possible sources of invasion into the Delta, such as ballast water and ship-fouling, which have been associated with the invasion of the amphipod *Gammarus daiberi* (Cohen and Carlton 1995). Another vector could be invasive weeds such as hyacinth (*Eichhornia crassipes*) and *Egeria densa*. Chapman and Carlton (1994) are establishing criteria for the recognition of introduced species so that we can more accurately apply a title of non-indigenous, cryptogenic, or native to each species (Carlton 1996). Consequently, these new findings may add more taxa to the list of exotic species in the San Francisco Bay area, possibly the most invaded estuary in the world (Cohen and Carlton 1998).

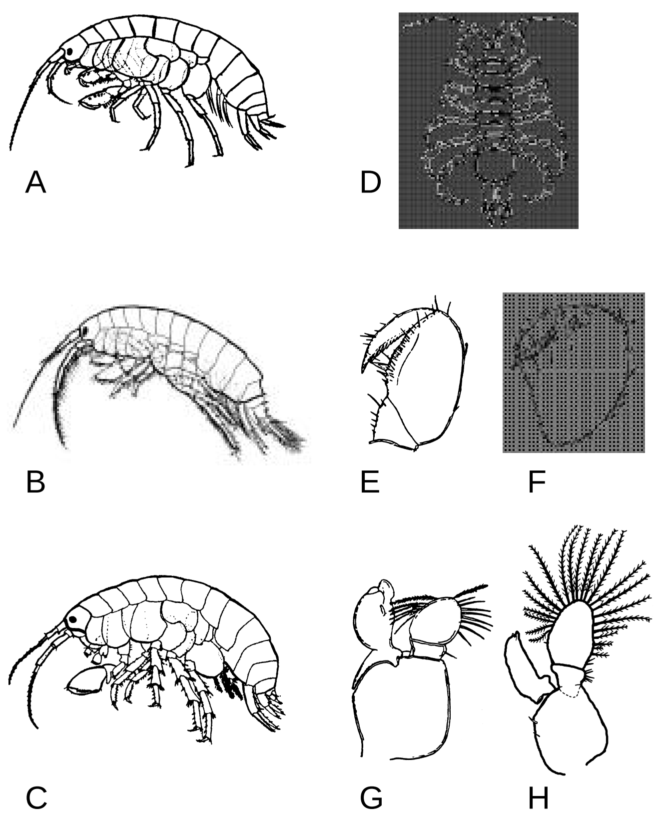

Figure 1 (A) *Crangonyx floridanus* (from Barnard and Barnard 1983). (B) *Gammarus daiberi* (from Bousfield 1969). (C) *Hyalella azteca* (from Pennak 1989). (D) *Caecidotea racovitzai* and *Asellus* sp. (from Pennak 1989). (E) Propodus of gnathopod 1 of *Asellus* sp. (from Birstein 1964). (F) Propodus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

Brief descriptions of the species occur in the following paragraphs along with illustrations in Figure 1.

CRANGONYX FLORIDANUS

Although members of the genus *Crangonyx* can be extremely difficult to identify to species, it is relatively easy to distinguish *Crangonyx floridanus* from other similar 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* (see Figure 1). Adults of these species can be separated by differences in the lengths of antenna 1 and 2. *Crangonyx floridanus* has antenna 1 longer than antenna 2 (Figure 1A); *G. daiberi* has antenna 1 and 2 approximately the same length (Figure 1B); and *H. azteca* has antenna 1 shorter than antenna 2 (Figure 1C). Other distinguishing characteristics of *G. daiberi* include the presence of an accessory flagellum with four to five segments on antenna 1, as well as long setae specifically on the antennae and the extended uropod 3 (Figure 1B). *Hyalella azteca* can be further identified by its large gnathopod 2 (Figure 1C). The three species can also be separated somewhat by size differences of adults, as *C. floridanus* is the smallest (length 3.4 to 6.5 mm, Bousfield 1963), *G. daiberi* is the largest (8 to 12.5 mm, Bousfield 1969), and *H. azteca* is in between (4 to 8 mm, Pennak 1989). We encourage use of the taxonomic guides presented in Pennak (1989) and Bousfield (1963) to key *C. floridanus* to species, as it is entirely possible that more than one species of the genus *Crangonyx* exist in the Delta.

Dr. John Holsinger identified *C. floridanus* (personal communication, see “Notes”). Further details and definition of terms can be found in Pennak (1989) for *C. floridanus* and *H. azteca*, in Bousfield (1963) for *C. floridanus*, and in Bousfield (1969) for *G. daiberi*. *Gammarus daiberi* is endemic to the Atlantic coast of North America, and was first detected in the Delta in 1983 (Cohen and Carlton 1995; Hymanson and others 1994).

CAECIDOTEA RACOVITZAI AND *ASELLUS* SPECIES

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

Identification of *Asellus* sp. was confirmed by Dr. Guy Magniez, who stated "[the specimen] belongs to the true genus *Asellus*, subgenus *Asellus*, strongly related to *Asellus* (*Asellus*) *hilgendorfii* (may be a member of this asiatic superspecies, but further examination is necessary)" (personal communication, see "Notes"). Dr. Noboru Nunomura has also examined our samples of *Asellus* sp., stating that the specimens are "different from Japanese species of *Asellus hilgendorfii*" (personal communication, see "Notes"). Dr. Doug Smith and Dr. Julian J. Lewis confirmed our identification of *C. racovitzai* (personal communication, see "Notes"). 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).

References

Barnard JL, Barnard CM. 1983. Freshwater amphipoda of the world. Volume 1: evolutionary patterns. Mt. Vernon (VA): Hayfield Associates. 259 p.

Birstein YA. 1964. Fauna of USSR, crustacea, freshwater isopods (Asellota). Washington, D.C.: The Smithsonian Institution, USA, and The National Science Foundation. 148 p.

Bousfield EL. 1963. New freshwater amphipod crustaceans from Florida. National Museum of Canada, Natural History Papers 18:1–9.

Bousfield EL. 1969. New records of *Gammarus* (crustacea: amphipoda) from the middle Atlantic region. Chesapeake Science 10(1):1–17.

Bowman TE. 1974. The California freshwater isopod, *Asellus tomalensis*, rediscovered and compared with *Asellus occidentalis*. Hydrobiologia 44(4):431–41.

Carlton JT. 1996. Biological invasions and cryptogenic species. Ecology 77(6):1653–5.

Chapman JW, Carlton JT. 1994. Predicted discoveries of the introduced isopod *Synidotea laevidorsalis* (Miers, 1881). Journal of Crustacean Biology 14(4):700–14.

Cohen AN, Carlton JT. 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. A report for the United States Fish and Wildlife Service, Washington, D.C. and the National Sea Grant College Program, Connecticut Sea Grant Program. 272 p.

Cohen AN, Carlton JT. 1998. Accelerating invasion rate in a highly invaded estuary. Science 279:555–8.

Grimaldo L, Harrell B, Miller R, Hymanson Z. 1998. Determining the importance of shallow water habitat in the Delta to resident and migratory fishes: a new challenge for IEP. IEP Newsletter 11(3):32–4.

Henry JP, Magniez G. 1995. *Nouvelles donnees sur les Asellidae epiges d'Extreme-Orient* (Crustacea, Isopoda, Asellota). Contributions to Zoology 65(2):101–22.

Hymanson Z, Mayer D, Steinbeck J. 1994. Long-term trends in benthos abundance and persistence in the upper Sacramento-San Joaquin Estuary, summary report: 1980-1990. Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 38. Sacramento (CA): California Department of Water Resources. 66 p.

Pennak RW. 1989. Freshwater invertebrates of the United States, Protozoa to mollusca. 3rd ed. New York: John Wiley & Sons, Inc. 628 p.

Williams WD. 1972. Biota of freshwater systems, identification manual nr. 7, freshwater isopods (Asellida) of North America. Environmental Protection Agency. 45 p.

NOTES

Wayne Fields (Hydrozoology). Numerous phone conversations and letters with J. Toft from 8 June 1998 to 9 September 1999.

John Holsinger (Old Dominion University). E-mail to J. Toft on 30 December 1998.

Julian J. Lewis. E-mail to J. Toft on 9 February 1999.

Guy Magniez (*Universite de Bourgogne*). E-mail to J. Toft on 27 April 1999.

Noboru Nunomura (Toyama Science Museum). E-mail to J. Toft on 18 December 1998.

Doug Smith (University of Massachusetts). E-mail to J. Toft on 11 December 1998.

LIFE ON THE BOTTOM: TRENDS IN SPECIES COMPOSITION OF THE IEP-DWR BENTHIC MONITORING PROGRAM

Wayne Fields, Hydrozoology
and Cindy Messer, Department of Water Resources

In 1975, as part of an environmental monitoring program mandated by the State Water Resources Control Board, the Department of Water Resources (DWR) began to collect data on the benthos of the Sacramento-San Joaquin Delta and Suisun and San Pablo bays. This benthic monitoring program is currently part of the larger, Interagency Ecological Program (IEP) environmental monitoring program. The Monitoring and Analysis Branch of the Environmental Services Office conducts the sampling. This program is designed to document the distribution, diversity, and abundance of benthic (bottom-dwelling) organisms and the substrate composition in the Sacramento-San Joaquin Delta and Suisun and San Pablo bays. The benthic community of the Delta and bays is a diverse assemblage of organisms some of which are large (macrobenthos) and familiar, such as clams, shrimp, crabs, a variety of worms, snails, and insects. Others are small (microbenthos), difficult to see, and generally not easily recognizable, such as bacteria, protozoa, and rotifers. All of these organisms spend at least part of their life on or in the bottom. This particular program monitors the macrobenthos, organisms larger than 0.5 mm (Markmann 1986). Substrate composition is also monitored and is used to evaluate changes in benthic fauna in response to changes in substrate.

In 1996, the number of benthic monitoring stations was increased from six to ten to sample more of the environmental diversity within the Delta and bays (Figure 1). At each station, five bottom grab samples are taken using a Ponar dredge with a sampling area of 0.053 m^2 (Markmann 1986). Four samples are used for macrofauna analysis and the fifth sample is taken for substrate analysis.

Nine phyla are represented in the benthic fauna collected. These phyla are Cnidaria (jellyfish, corals, sea anemones, and hydrozoans), Platyhelminthes (flatworms), Nemertea (ribbon worms), Nematoda (roundworms), Annelida (segmented worms, leeches), Arthropoda (crabs, shrimp, insects, mites, amphipods, isopods), Mollusca (snails, univalve molluscs, bivalves), Chordata (tunicates) and Echinodermata (sea star, sea urchin, sea cucumber). Of these phyla, Annelida, Arthropoda, and Mollusca make up the largest portion of the organisms collected: 92% in 1996 and 99% in 1997.

The total number of benthic species collected by this monitoring program is about 250. The total number of species collected for the entire Bay-Delta ecosystem is slightly over 500. Many of the benthic species collected in the Bay-Delta system are introduced species. Introduced species may comprise up to 95% of the benthic invertebrate biomass in the Bay-Delta (SF Estuary Project 1992). As more fauna invade the system, the number of species collected increases. From 1975 to 1980, a total of 140 invertebrate species were collected by the IEP-DWR program (Markmann 1986). This number increased to 196 between 1981 and 1990 (Hymanson 1994). Table 1 provides information on the average annual number of species collected at each station between 1996 and 1998.

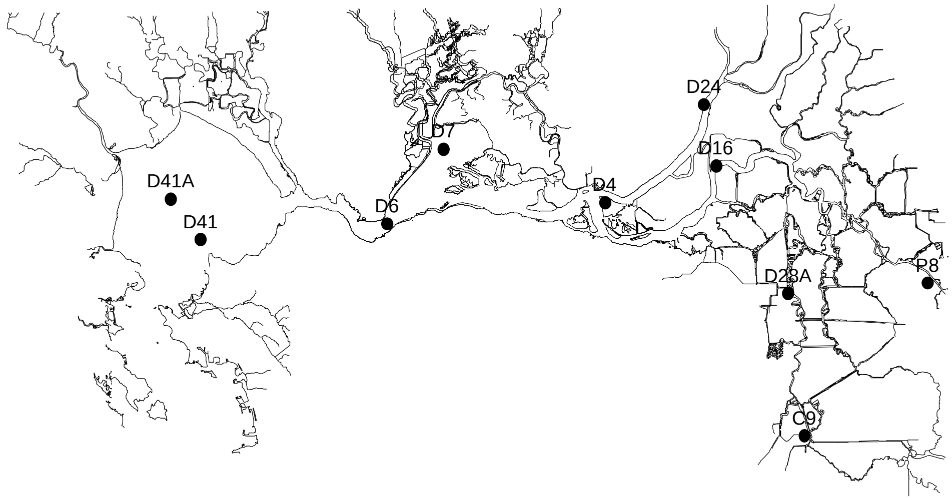

Figure 1 IEP-DWR benthic monitoring stations as of 1996

Table 1 Average number of benthic species collected per station between 1996 and 1998

Site	*1996*	*1997*	*1998*
D41	40	50	43
D41A	25	41	29
D7	24	26	27
D6	18	33	21
D4	45	48	65
D24	44	51	56
D28A	46	46	54
P8	45	51	47
C9	31	47	60
D16	18	25	36

Of all the organisms collected over the last 23 years, only 15 species represent the most common fauna in the monthly collections. This is typical for benthic communities where the total number of species is high but only a few species dominate in number and biomass (Reshetiloff 1995). In 1997, 14 of these species represented 70% of the annual catch, and in 1998, the 15 species together represented 66% of total organisms collected. These species are the nemertean *Prostoma graecense*; the oligochaetes *Aulodrilus limnobius*, *Limnodrilus hoffmeisteri*, and *Varichaetadrilus angustipenis*; the polychaete worm *Manayunkia speciosa*; the ostracod ("bean" or "seed" shrimp) *Isocypris* species A; the small crustacean *Nippoleucon hinumensis*; the amphipods *Ampelisca abdita*, *Corophium spinicorne*, *Corophium stimpsoni*, and *Gammarus daiberi*; the chironomid *Procladius* species A; the gastropod *Melanoides tuberculata*; and the molluscs *Corbicula fluminea* and *Potamocorbula amurensis*.

The following 13 benthic species collected by the IEP-DWR monitoring program have been selected for brief discussion. These organisms have been chosen both because they are abundant and because they illustrate the immense diversity of the benthic fauna collected.

- *Prostoma graecense* is an extremely soft bodied micropredator (6 to 8 mm in length) in the phylum Nemertea. Most of the species in this phylum are marine (the so called ribbon worms), but a handful of species are known from fresh water habitats in North America. *Prostoma graecense* is by far the commonest species. *Prostoma graecense* feeds by stabbing its prey with stylets (spear-like structures) at the end of an eversible proboscis after which, if the prey is small enough, it is drawn into the buccal (mouth) cavity using the proboscis and then digested in the elongated intestine.

- *Dorylaimus* species A is a tiny (about 3 mm in length) predatory member of the phylum Nematoda. This roundworm species has longitudinal ridges on the body, and the posterior end of the female is long and tapers to a point while that of the male is rounded. A spear-like structure in the mouth cavity is used to penetrate the body wall of prey species.

- *Limnodrilus hoffmeisteri* is an aquatic oligochaete (segmented worm, phylum Annelida) related and similar to an earthworm except much smaller (about 10 mm). It is one of 54 species of oligochaetes in seven families collected so far from the Delta. *Limnodrilus hoffmeisteri* is a member of the family Tubificidae, the numerically most abundant family of invertebrates in the IEP-DWR sampling area. *Limnodrilus hoffmeisteri* is the most common aquatic oligochaete in the world. Its food is organic detritus from bottom sediments which it ingests as it burrows.

- *Manayunkia speciosa* is, like *P. graecense*, a bit of an oddity. It is the only widespread freshwater polychaete worm (phylum Annelida) in North America. Only a handful of such species are known, the vast majority of polychaetes being marine. It is considered an introduced species. *Manayunkia speciosa* can be found at relatively high elevations: in 1993 it was the numerically dominant organism in samples from Cresta Reservoir, a mid-elevation impoundment on the North Fork of the Feather River. This small (4 mm) worm lives in a mud tube and passively collects organic detritus suspended in the water column on its sticky tentacles.

- *Nippoleucon hinumensis* is an introduced species of Japanese origin first seen in DWR benthic samples in 1986. It is a small (4 mm) crustacean (phylum Arthropoda, order Cumacea), part of a group whose members are almost exclusively marine. It has been collected by DWR only west of the Carquinez Strait, and sometimes in large numbers (a benthic sample taken at station D41, San Pablo Bay near Point Pinole, in May 1999 contained 1,772 specimens (33,668/m^2). Cumacea are odd-looking little animals, with the thoracic and anterior abdominal segments compressed into a teardrop shape in front and the posterior abdominal segments elongated into what appears to be a forked tail. *Nippoleucon hinumensis* is apparently a collector-gatherer by nature.

- *Isocypris* species A is probably common and widespread in Northern California. A species apparently identical to this has been collected sporadically in reservoirs, ponds, temporary water bodies in the Sacramento Valley, and in a few Sierra Nevada streams up to elevations of about 3,000 feet. *Isocypris* is a member of the subclass Ostracoda (phylum Arthropoda, class Crustacea), which are also known as “bean” shrimp or “seed” shrimp. These animals possess valves or “shells” which enclose and protect the body, resulting in a bean-like appearance. They are small (2 mm) collector-gatherers which swim well and also skip over the substrate using appendages which can be protruded ventrally.

- *Ampelisca abdita* is a small (6 mm) introduced tube building amphipod crustacean (phylum Arthropoda, order Amphipoda) native to the East Coast. Its date of introduction is not known but apparently precedes any comprehensive collections of invertebrates on the West Coast. It is a filter feeder and can be extremely abundant in San Francisco Bay, with densities up to 50,000 organisms/m^2. It is intolerant of fresh water and has rarely been collected in Suisun Bay.

- *Corophium spinicorne* and *Corophium stimpsoni* are native, mud dwelling, tube building amphipods often collected together in samples from the central and eastern Delta. *Corophium stimpsoni* has been consistently one of the most common and abundant species in the benthos. Both are sensitive to saline water and are rarely collected west of Grizzly Bay. Both sexes of *C. spinicorne* have similarly stout second antennae, but in *C. stimpsoni* they are strikingly dimorphic: mature males have second antennae longer than the body, while those of mature females are short. Their diet consists of detritus gathered from their surroundings or filtered from the water passing over them. Of the two, *C. spinicorne* is more likely to be a filter feeder, since its second antennae have numerous long hairs. These species grow to 8 or 10 mm.

- *Gammarus daiberi* was first collected in DWR benthic samples in December 1983 and may have been introduced from the East Coast. It is a large (up to 15 mm) vegetation and detritus feeding amphipod widespread and common in the central and eastern Delta, but is also occasionally collected west of Carquinez Strait. *Gammarus* *daiberi* is a strong swimmer and spends much of its time in the water column, particularly at night.

- *Procladius* species A is the only insect in this group and is a member of the family Chironomidae or non-biting midges (phylum Arthropoda, class Insecta, order Diptera), which is the largest, most widespread and successful group of invertebrates in fresh water. Of the nearly 250 species on the DWR benthic list, 40 are chironomids. These gnat-like flies exist for most of their brief lives as larvae and are about 5 mm long. *Procladius* species A is a predator, but many of the chironomids collected from the Delta are either collector-gathers or filterers. One species actually specializes as a miner by burrowing into the tissue of freshwater sponges.

- *Corbicula fluminea* is one of two Asian clam species that dominate the fauna of the Bay-Delta system. In samples for a typical month, *C. fluminea* can make up to 99% of the bio-mass collected from the freshwater part of the Delta. It reaches a maximum size of about 60 mm. *Corbicula fluminea* has apparently been present in the system since the 1940s. *Corbicula fluminea* apparently outcompetes freshwater mussels for food and space and is probably responsible for their rarity in the Delta. *Corbicula fluminea* is collected as far west as Grizzly Bay.

- *Potamocorbula amurensis*, the other Asian clam, dominates the benthos of the far western part of the Delta and San Francisco Bay. The largest specimens observed so far were 28 mm in length. It was introduced around 1986 and has been extremely successful, so much so that in wide ranging collections made in 1990, 1993, and 1995, few other clams species were taken.

In addition to the species regularly encountered in monthly sampling, there is an extensive list of organisms rarely seen. These are from almost all groups, but are mostly chironomids. They are not typical members of the fauna at the usual sampling sites and are almost certainly accidental collections of species that live in marshy areas adjacent to Delta channels or originate upstream.

Long-term monitoring programs such as this one are extremely useful because they provide a means of evaluating the spatial and temporal trends of the organisms under study. Several technical reports on such trends in the benthos of the Sacramento-San Joaquin Delta and Suisun and San Pablo bays have been generated from the data provided by the IEP-DWR benthic monitoring program. These data have also been used in conjunction with special studies both in the past (a spatially intensive survey for *Potamocorbula amurensis* conducted in the upper San Francisco Bay Estuary during 1990, 1993, and 1995) and for current projects (a study of the impacts of the Chinese mitten crab on the benthic community in the Delta and Suisun Bay). Ongoing evaluation of this program, incorporation of valid recommendations for improving the program, and uploading of the available data onto the IEP server will insure that good quality information is accessible to all interested parties.

References

Hymanson Z, Mayer D, Steinbeck J. 1994. Long-term trends in benthos abundance and persistence in the upper Sacramento-San Joaquin Estuary: summary report: 1980-1990. Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 38. Sacramento (CA): California Department of Water Resources. 66 p.

Markmann C. 1986. Benthic monitoring in the Sacramento-San Joaquin Delta: results from 1975 through 1981. Interagency Ecological Studies Program. Technical Report 12. Sacramento (CA): California Department of Water Resources. 55 p.

Reshetiloff K. 1995. Chesapeake Bay: introduction to an ecosystem [monograph online]. Available at: http://www.chesapeakebay.net via the Internet. Accessed 1999 June 2.

San Francisco Estuary Project. 1992. State of the estuary: a report on conditions and problems in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. 270 p.

MODELING TEMPERATURE FLUCTUATIONS IN THE LOWER FEATHER RIVER

Christopher B. Cook[1], Gerald T. Orlob[1], and Ted Sommer[2]
[1] Dept. of Civil and Environmental Engineering, University of California, Davis
[2] Department of Water Resources

INTRODUCTION

This article summarizes the application of a one-dimensional, finite element, hydrodynamic and water quality model of the lower Feather River in Northern California. The study was initiated to help understand the effects of water releases from Oroville Dam on chinook salmon and steelhead trout spawning and rearing habitat. Releases from Oroville Reservoir and the Thermalito Complex were shown to have a dramatic effect on downstream water temperatures. The exact degree to which these releases can affect diurnal downstream temperature fluctuations had not been determined before this study. Calibration and verification of the model was performed using field measurements of flow, meteorological conditions, and water temperatures obtained during intensive field monitoring between July and September 1998.

HYDROLOGY

Water flow to the lower Feather River is regulated by Oroville Dam and the Thermalito Complex. Under normal operations, the majority of Oroville Dam releases to the Feather River are diverted through the Thermalito Complex. Substantial seasonal warming occurs in the shallow Thermalito Afterbay Reservoir, before being released to the river at Thermalito Afterbay Outlet (river kilometer [rkm] 95.0). The remainder of the flow, typically 600 ft^3/s (17 m^3/s), passes through the historical river channel, the "low flow channel," a cool water reach extending from Oroville to Thermalito Afterbay Outlet. Below Thermalito Afterbay Outlet the river flows southward through the Central Valley joining the Yuba and Bear rivers before the confluence with the Sacramento River at Verona. The primary reach of interest for salmonid spawning and rearing is between the Fish Barrier Dam at Oroville and Live Oak (Figure 1).

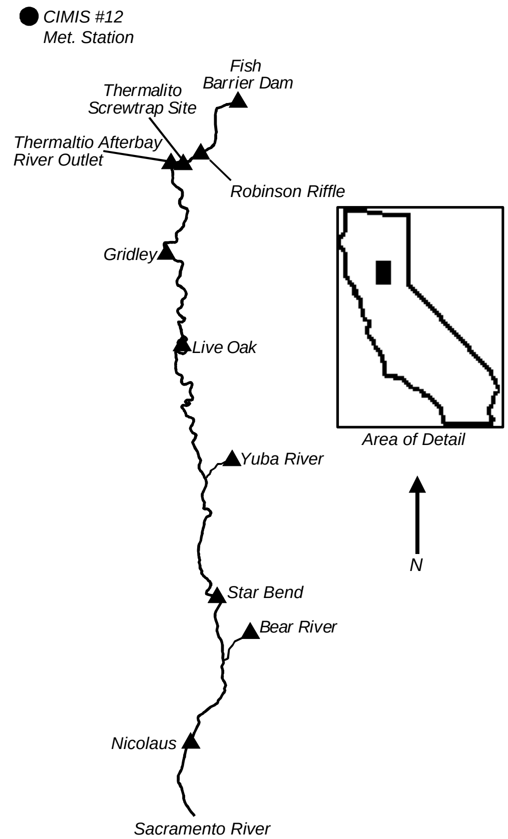

Figure 1 Feather River with data sites marked with triangles

FIELD DATA

Water temperatures in the Feather River vary dramatically from the relatively constant, below equilibrium temperatures near the Fish Barrier Dam to the diurnally varying temperatures near the confluence with the Sacramento River. To accurately calibrate and verify the model, the Department of Water Resources (DWR) collected water temperatures during summer 1998. Onset Optical StowAway® submersible temperature loggers were placed at ten locations (see Figure 1). These loggers have an accuracy of ±0.2 ºC, which was confirmed before logger deployment.

Model Implementation

The Feather River below Oroville Dam follows a meandering route, characterized by highly variable cross section, roughness, and bed slope. There are large variations in flows and water levels as a result of project operations. Water temperatures fluctuate greatly due to a combination of project effects and heat exchange along the air-water interface. To model the complex dynamics of the Feather River system, a multi-dimensional, hydrodynamic, finite element model, called RMA10, was applied. Though the model is capable of simulating one-, two-, or three-dimensional density varying current structures, the system was simplified and only one-dimensional, time-varying longitudinal variations in flow and temperature were calculated.

Adapting the model to the Feather River required construction of a one-dimensional grid of 274 elements to represent the morphological properties of the 108.5 km section of stream channel. Elements were generally 400 meters in length and of cross section determined from field surveys by DWR. Hydrodynamic boundary conditions for RMA10 were derived from time series of flows observed at the Fish Barrier Dam (rkm 108.5), the River Outlet of Thermalito Afterbay, and for the two principal tributaries, the Yuba (rkm 44.7) and Bear rivers (rkm 20.2). The downstream model boundary condition was defined by the observed water surface elevation of the Sacramento River, 1.4 km downstream of its confluence with the Feather River. Temperature boundary conditions for RMA10 were defined by observed water temperatures in the Feather River just below the Fish Barrier Dam and Thermalito Afterbay River Outlet, and in the Yuba and Bear rivers just before their confluence with the Feather River. Time series of meteorological conditions (air temperature, relative humidity, wind velocity, and incoming solar radiation) were taken from CIMIS Station #12, approximately 23.5 km from the upstream portion of the river. Atmospheric pressure measurements were obtained from CDEC Station Bryte, near Sacramento.

Computational stability for the model is governed by the Courant Number (C_o) defined as follows:

$$C_o = u(\Delta t)\Delta x^{-1}$$

where u is the water velocity, Δt is the time step, and Δx is the half-element grid size (distance between nodes). For the particular case of the Feather River model, with a Δx of 200 m and flows shown in Figure 2, Courant Number limitations dictated time steps of one-half hour.

Because of this detail and the magnitude of the resulting output files, input files were constructed such that only one month at a time was simulated, though output from the end of one month was used as input for the simulation of the next sequential month. The actual time it took to simulate an entire month was modest, about 10 to 15 minutes on a 400 MHz computer running Windows NT® operating system software.

Model Calibration: July 1998

The hydrodynamic component of the model for the reach above Gridley (rkm 50.8), was calibrated by comparing calculated and observed flows for the month of July 1998. Gridley is the only sampling location on the River where measured flows are not used as model boundary conditions (Figure 2). Observed flows at Gridley during the calibration period varied from 222 m^3/s (7,850 ft^3/s) to 140 m^3/s (4,960 ft^3/s). In applying RMA10 to simulate this flow regime, a Manning roughness of 0.05 was used. Observed flows at the upstream stations were specified as input to the model, and minor accretions and depletions were neglected. Results of the calibration run confirm the model's ability to replicate the historic experience, with local mass conservation errors less than 5%.

For portions of the river below Gridley, observed flows were not available. Flows near Nicolaus (Figure 2) were calculated by summing upstream flows and assuming zero accretions or depletions. In this downstream reach, an alternative approach for calibrating the model was adopted in which the hydrodynamic and water quality components were calibrated in tandem. Since the position of the predicted diurnal temperature cycle is dependent upon the flow velocity, adjustment of channel roughness (Manning's coefficient), which in turn affects velocities and travel times, were used to position the simulated diurnal water temperature cycles to coincide with observed. This approach was applied successfully to Feather River simulations for the reach between Gridley and Nicolaus (rkm 6.0), confirming again a Manning's n of 0.05. Model calibration errors based on the differences between observed and simulated results were low, ranging from 0.2 to 0.6 ºC.

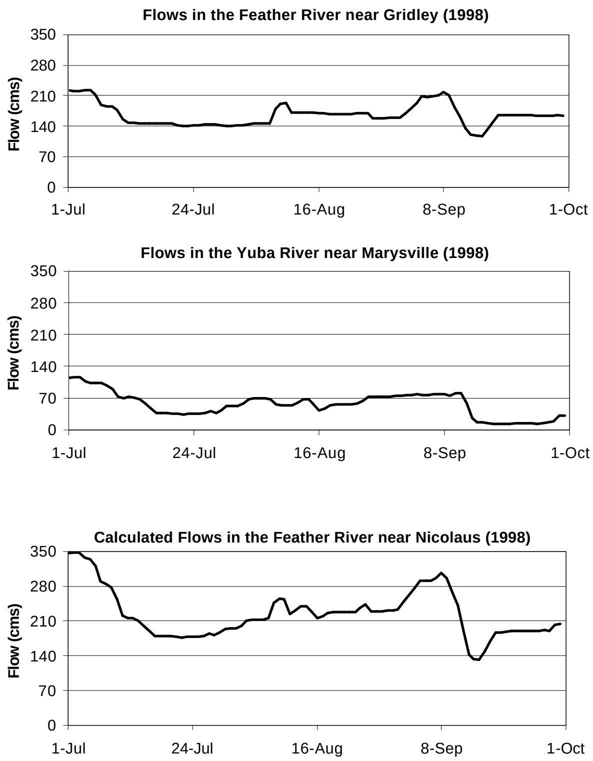

Figure 2 Flows in the Feather and Yuba rivers

Model Verification: August and September 1998

The calibrated hydrodynamic and water quality model was verified against alternative data sets for August and September 1998. Hydrodynamic results at Gridley again show that the model is capable of replicating the historical flows, with local mass conservation errors of less than 5% of observed.

Model results for water temperature at Robinson Riffle and Nicolaus are shown for August in Figures 3 and 4. The model accurately captures both the high frequency diurnal and lower frequency weekly oscillations in water temperature. Differences between observed and simulated results were small, ranging from 0.2 to 0.7 ºC for model locations.

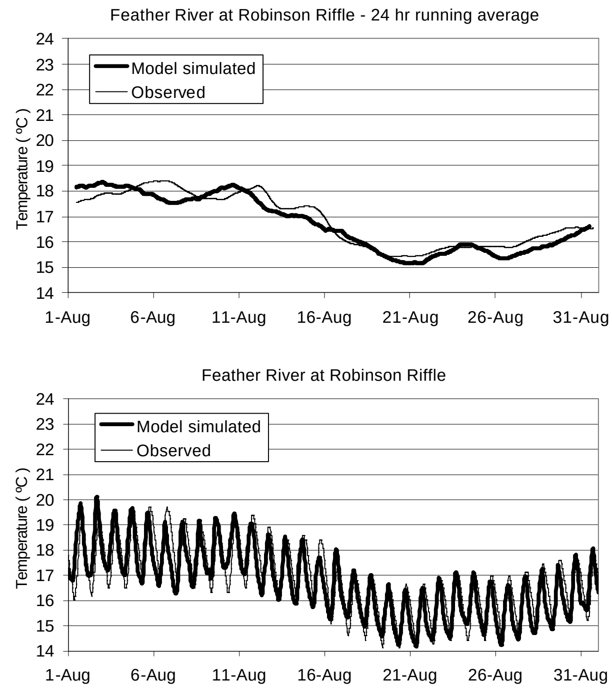

Figure 3 Simulated versus observed water temperatures near Robinson Riffle

Management Investigations

The calibrated and verified model is currently being applied to help understand the effects of various flow release scenarios on downstream water temperatures. The National Marine Fisheries Service has proposed a compliance point for water temperatures at Robinson Riffle (rkm 99.0) in the low flow channel.

To simulate various management alternatives, a base case was first chosen. Input boundary conditions at the Fish Barrier Dam were then altered from this base case. To demonstrate management capabilities of the model, a trial base case of August 1998 was chosen (verification period). For the management alternative, releases from the Fish Barrier Dam (approximately 17 m^3/s [600 ft^3/s]) and meteorological parameters were kept unchanged from the base case. Water temperatures, however, were lowered to a constant 10.3 ºC (50.5 ºF) (Figure 5), simulating releases from a deeper (and hence cooler) level in Oroville Reservoir. This is a plausible alternative since the release works for Oroville Reservoir are fitted with a multi-level intake structure capable of withdrawing water from virtually any reservoir depth.

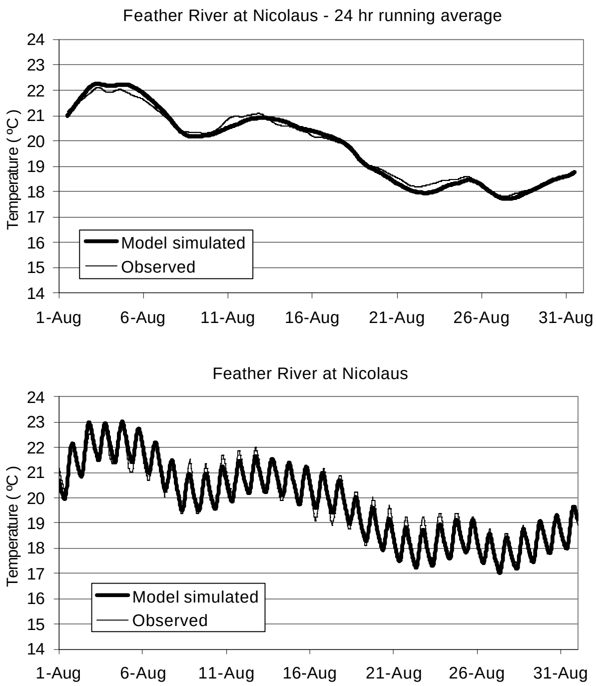

Figure 4 Simulated versus observed water temperatures near Nicolaus

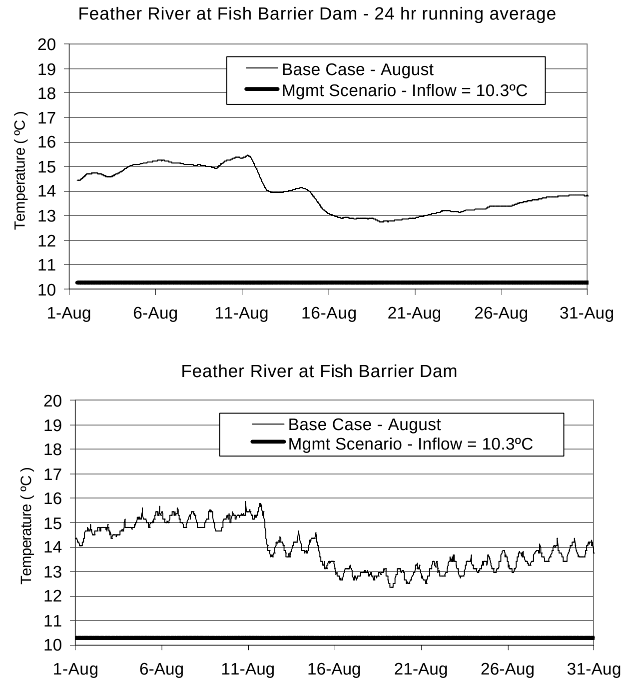

Figure 5 Upstream boundary conditions at the Fish Barrier Dam for the base case and management alternative

Results of these modifications (Figure 6) show a dramatic reduction of water temperature at Robinson Riffle. Average water temperatures for the month dropped from 16.7 ºC (original August 1998 value) to 15.2 ºC. A proposed management threshold for maximum water temperatures at Robinson Riffle is 15.5 ºC (60 ºF). In a mean monthly sense, the lower level releases from Oroville produced water temperatures at Robinson Riffle that satisfied this threshold. However, if one looks at the results on a daily scale, water temperatures during the early part of the month are much higher than the threshold. In fact, on 3 and 10 August, even the nighttime temperatures barely went below 15.5 ºC. During the later part of the month, when air temperatures were cooler, water temperatures dropped as well, with temperatures on some days remaining below the threshold, even during the warmest portion of the day.

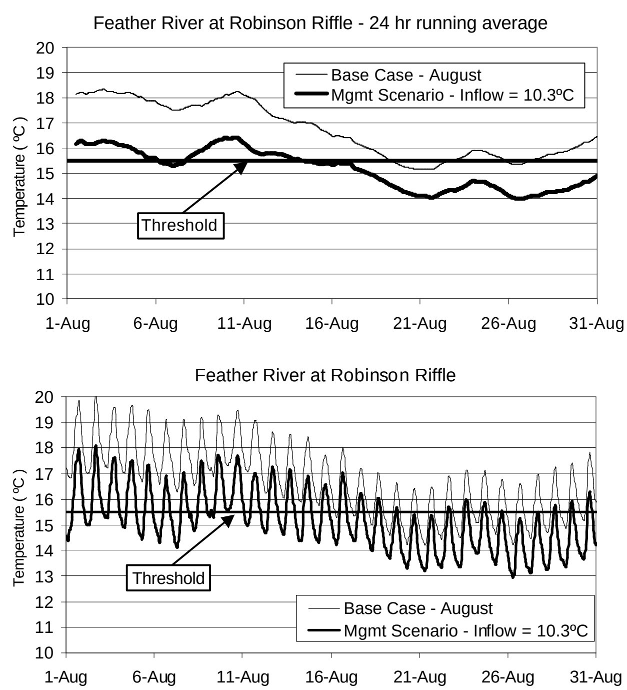

Figure 6 Base case versus management scenario at compliance point Robinson Riffle

Summary and Conclusions

Hydrodynamic and water quality models using the finite element method of numerical solution were developed and applied to simulate flow and temperature regimes of the Feather River below Oroville Dam. The model was calibrated and verified to observed field data during July through September 1998. Calibration and validation of the model indicate the capability to track diurnal fluctuations in water temperatures, as well as longer frequency weekly variations over a variety of flows (see Figure 2) and meteorological conditions affecting heat exchange at the air-water interface. Average errors were always less than 1.0 ºC, with typical errors less than 0.5 ºC and standard deviations less than 0.3 ºC.

A management scenario was investigated where inflow water temperatures at the Fish Barrier Dam were lowered below those actually observed. Although this particular management scenario assessed the effect of a single input parameter, the model is capable of investigating the effects of several variables. Future management scenarios will be designed to investigate the effects of both flow and temperature changes, as well as variations in meteorological conditions. Our immediate plans are to use the model to determine flow-temperature relationships between the Fish Barrier Dam and Robinson Riffle. Dam operators could then use these relationships in real time to alter release flows and temperatures to meet potential regulatory criteria at Robinson Riffle.

Acknowledgments

We would like to thank Debbie McEwan and Phil Huckobey of the Department of Water Resources for collecting water temperature data required for this investigation. We would also like to thank Dr. Ian King for his help and assistance with configuring RMA10 for application to the Feather River. A grant from the Department of Water Resources to the University of California, Davis, supported this research.

Specific Conductance, Water Temperature, and Water Level Data, San Francisco Bay, California, Water Year 1998

Paul A. Buchanan, US Geological Survey

Specific conductance and water temperature data are continuously recorded at four sites in San Francisco Bay, California: San Pablo Strait at Point San Pablo, Central San Francisco Bay at Presidio Military Reservation, Pier 24 at Bay Bridge, and South San Francisco Bay at San Mateo Bridge near Foster City (Figure 1). Water level data are recorded only at San Pablo Strait at Point San Pablo. These data were recorded by the Department of Water Resources (DWR) before 1988, by the US Geological Survey (USGS) National Research Program from 1988 to 1989, and by the USGS-DWR cooperative program since 1990. This article presents time-series plots of data from the four sites in San Francisco Bay during water year 1998 (1 October 1997 through 30 September 1998).

Specific conductance and water temperature data were collected at near-surface and near-bottom depths in the water column to define the vertical stratification. The mean lower-low water depth (the average of the lower-low water height of each tidal day observed during the National Tidal Datum Epoch) was about six feet below sea level at the more shallow Presidio site; therefore, data were collected only at near-bottom depths. Tidal variability (ebb and flood) affects specific conductance, water temperature, and water level. The degree of tidal variability corresponds with the vertical range of the “black bands” on Figures 2 through 4. Figure 5 shows the near-surface and near-bottom specific conductance and water levels at Point San Pablo for the 24 hours of 25 December 1997, which illustrates tidal variability. Tidal variability was greater at the Point San Pablo site than at the San Mateo Bridge site (Schoellhamer 1997).

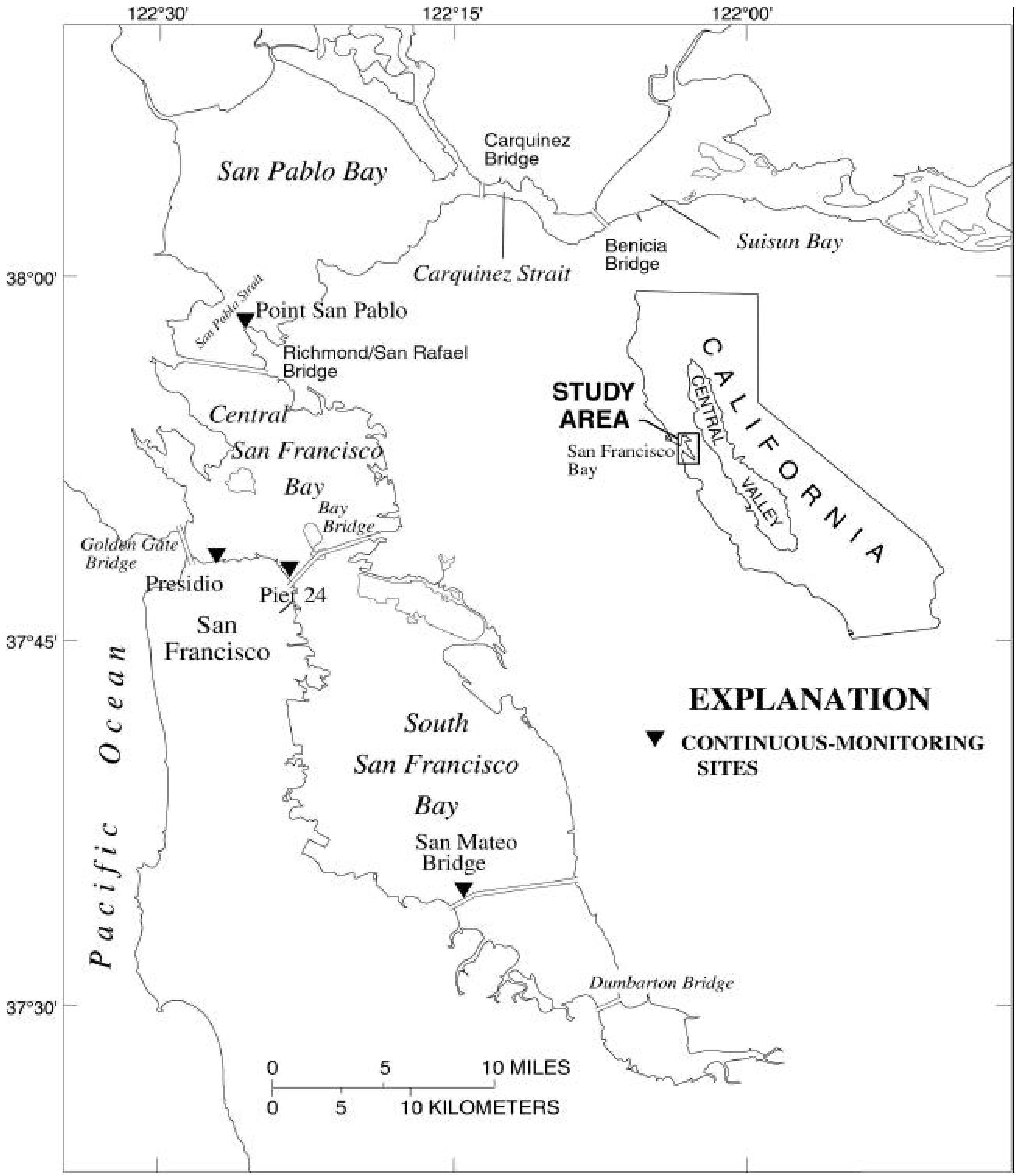

Figure 1 Location of specific conductance, water temperature, and water level data continuous monitoring sites in San Francisco Bay, California

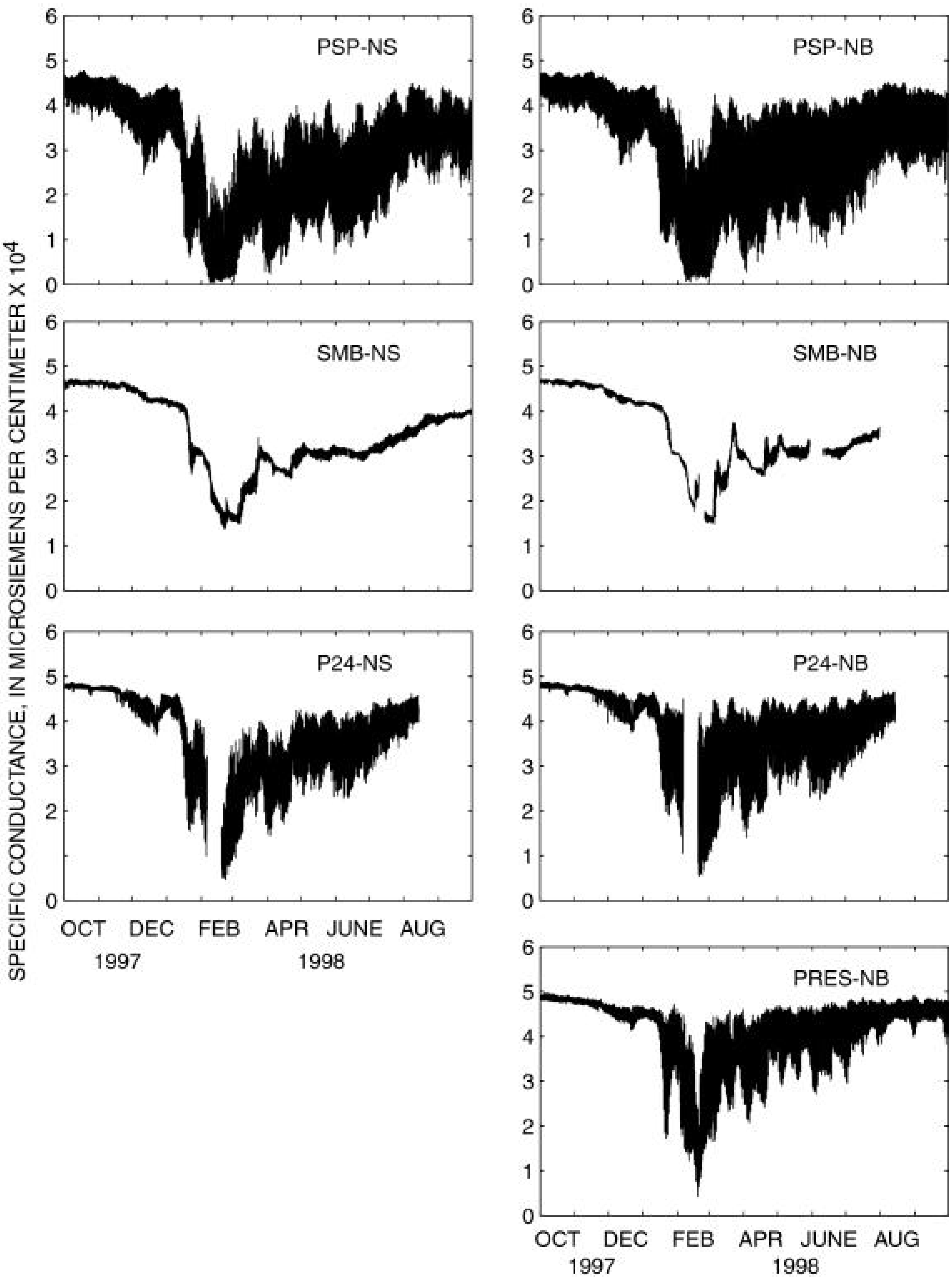

Figure 2 Near-surface (NS) and near-bottom (NB) depth measurements of specific conductance at Point San Pablo (PSP), San Mateo Bridge (SMB), Pier 24 (P24), and Presidio (PRES), San Francisco Bay, water year 1998. For reference, seawater has a specific conductance of 53,000 microsiemens per centimeter.

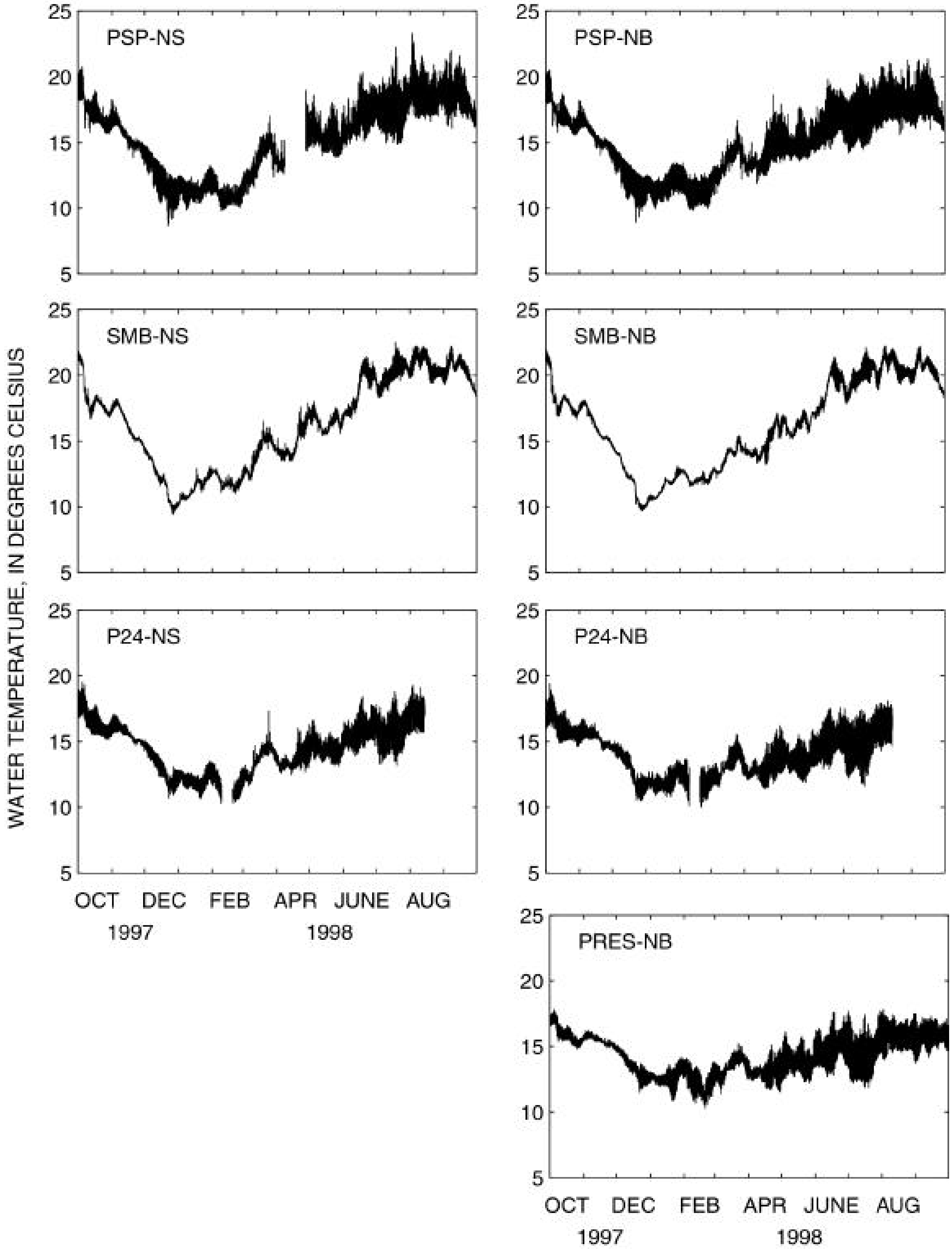

Figure 3 Near-surface (NS) and near-bottom (NB) depth measurements of water temperature at Point San Pablo (PSP), San Mateo Bridge (SMB), Pier 24 (P24), and Presidio (PRES), San Francisco Bay, water year 1998

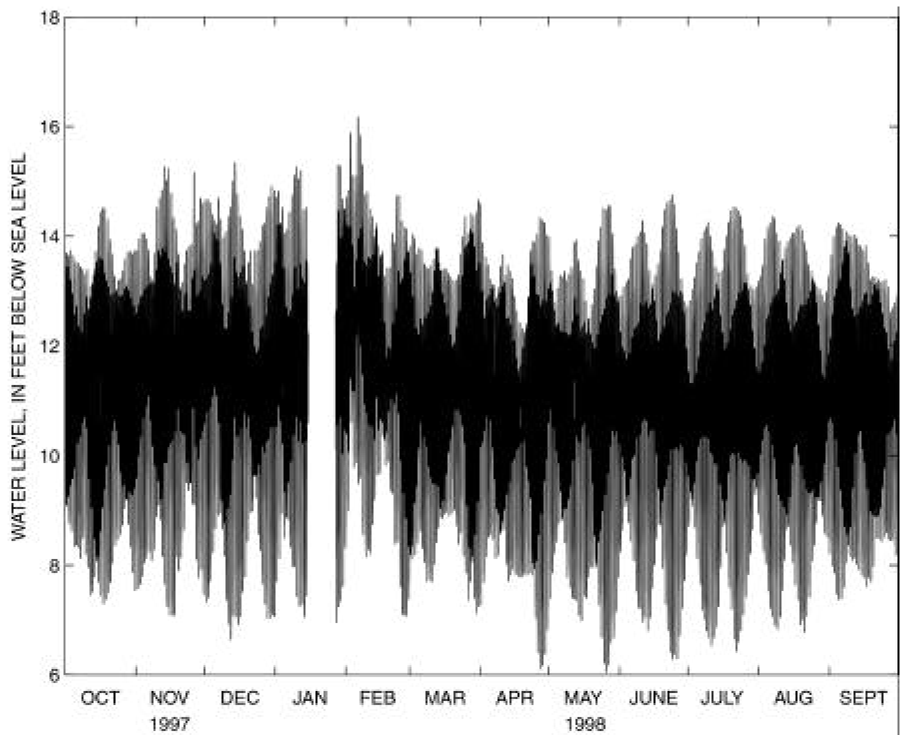

Figure 4 Water levels at Point San Pablo, San Francisco Bay, water year 1998. Vertical datum is 10 feet below sea level.

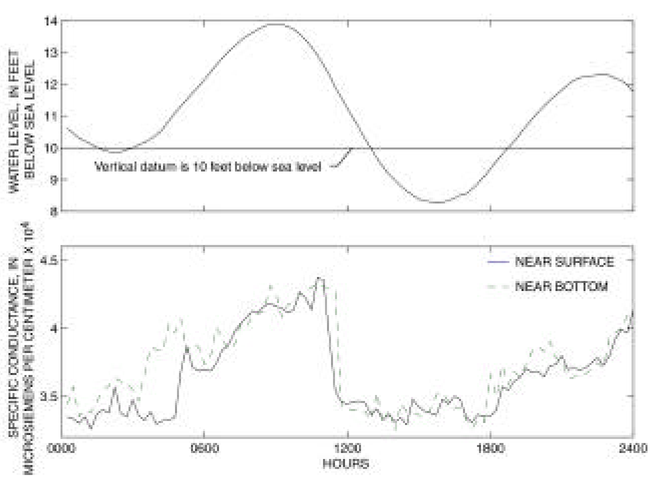

Figure 5 Near-surface and near-bottom depth measurements of specific conductance and water levels at Point San Pablo, San Francisco Bay on 25 December 1997. Vertical datum is 10 feet below sea level. For reference, seawater has a specific conductance of 53,000 microsiemens per centimeter.

Specific conductance (reported at 25 ºC) was measured using Foxboro® electrochemical analyzers (accuracy ±3%). Water temperature was measured using Campbell Scientific® thermisters (accuracy ±0.4 ºC). Water level was measured using a Handar incremental encoder with a float-driven, incremental stainless steel tape. Measurements were made and data were stored every 15 minutes using Campbell Scientific® CR10 data loggers. Gaps in the data usually were caused by equipment malfunctions.

Instrument calibrations were completed in the field every two to three weeks, depending on the season. Calibration of the continuous-recording instrument measuring specific conductance was done using an Orion® model 140 conductivity meter (accuracy ± 2%), calibrated to a known specific conductance standard. Calibration of the water-temperature instruments was done using a VWR Scientific® thermister (accuracy ± 0.2 ºC). Water level instruments were checked using a wire-weight gage mounted to the pier at the Point San Pablo site. Data corrections (shifts), based on differences between the continuous-recording instrument readings and the field-calibrated instrument readings (normally resulting from biological fouling), were applied to the record for final computation using the USGS Automated Data Processing System.

Maximum and minimum values of specific conductance, water temperature, and water level data for the four sites are published annually in volume 2 of the USGS California water data report series, which is available on the Internet at http://water.wr.usgs.gov.

REFERENCES

Schoellhamer DH. 1997. Time series of SSC, salinity, temperature, and total mercury concentration in San Francisco Bay during water year 1996: 1996 annual report of the Regional Monitoring Program for Trace Substances. p 65–77.

1999 MONITORING OF THE ENDANGERED SALT MARSH HARVEST MOUSE IN THE SUISUN MARSH

Patty Finfrock, Department of Water Resources, and Melinda Dorin, Department of Fish and Game

INTRODUCTION

The endangered salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*) (SMHM) inhabits the diked and tidal wetlands of the Suisun Marsh. Activities of the Department of Water Resources (DWR) and the US Bureau of Reclamation have affected SMHM habitat in the marsh. Mitigation efforts include the establishment of conservation areas and monitoring of SMHM populations.

An interagency monitoring effort between the Department of Fish and Game (DFG) and DWR has taken place in 1998 and 1999. In 1998 eight existing conservation areas were surveyed and SMHM were found at six of these areas (Finfrock 1999). In 1999 surveys were conducted at seven newly-proposed conservation areas and at two existing conservation areas where SMHM were not found in 1998 (Figure 1).

SMHM TRAPPING METHODOLOGY

The goal of trapping in 1999 was to determine whether SMHM were present in the areas surveyed. One-hundred Sherman live-traps were set for three consecutive nights at each area. Traps were set for less than three consecutive nights when trap success for SMHM was greater than 15% in one night. The traps are 3" x 3.5" x 9.25" aluminum boxes. The boxes close when a rodent enters and activates a pressure-sensitive treadle. Tail-to-body ratio, tail characteristics, and behavior were used to identify harvest mice (*Reithrodontomys* sp.) to the species level (Shellhammer 1984). All trapped rodents were released at the capture site.

RESULTS

SMHM were captured at all areas surveyed, although capture rates were widely divergent among areas. Trap success ([number of SMHM captured/total number of traps set] x 100) varied from 0.3% to 23%. Three areas had large numbers of SMHM (trap success >20%); all were managed wetlands with robust stands of pickleweed (*Salicornia virginica*). The two areas with the lowest trap success, Joice Island (1%) and Hill Slough East (0.3%), were the existing conservation areas in undiked tidal marsh where no SMHM were captured last year. All of the other areas trapped were proposed conservation areas. In most cases, the number of SMHM captured was inversely related to the number of house mice (*Mus musculus*) captured; indicating the two species may compete for resources (Table 1).

All harvest mice (*Reithrodontomys* sp.) were marked by hair-clipping so that recapture rates could be assessed. House mice were also marked at certain areas to determine if there were recaptures. However, not all house mice were marked, so totals in Table 1 include recaptures. With the exception of Area 12 at the Grizzly Island Wildlife Area, SMHM totals do not include recaptures. Not all mice at that site were marked the first day so recaptures cannot be determined (see Table 1).

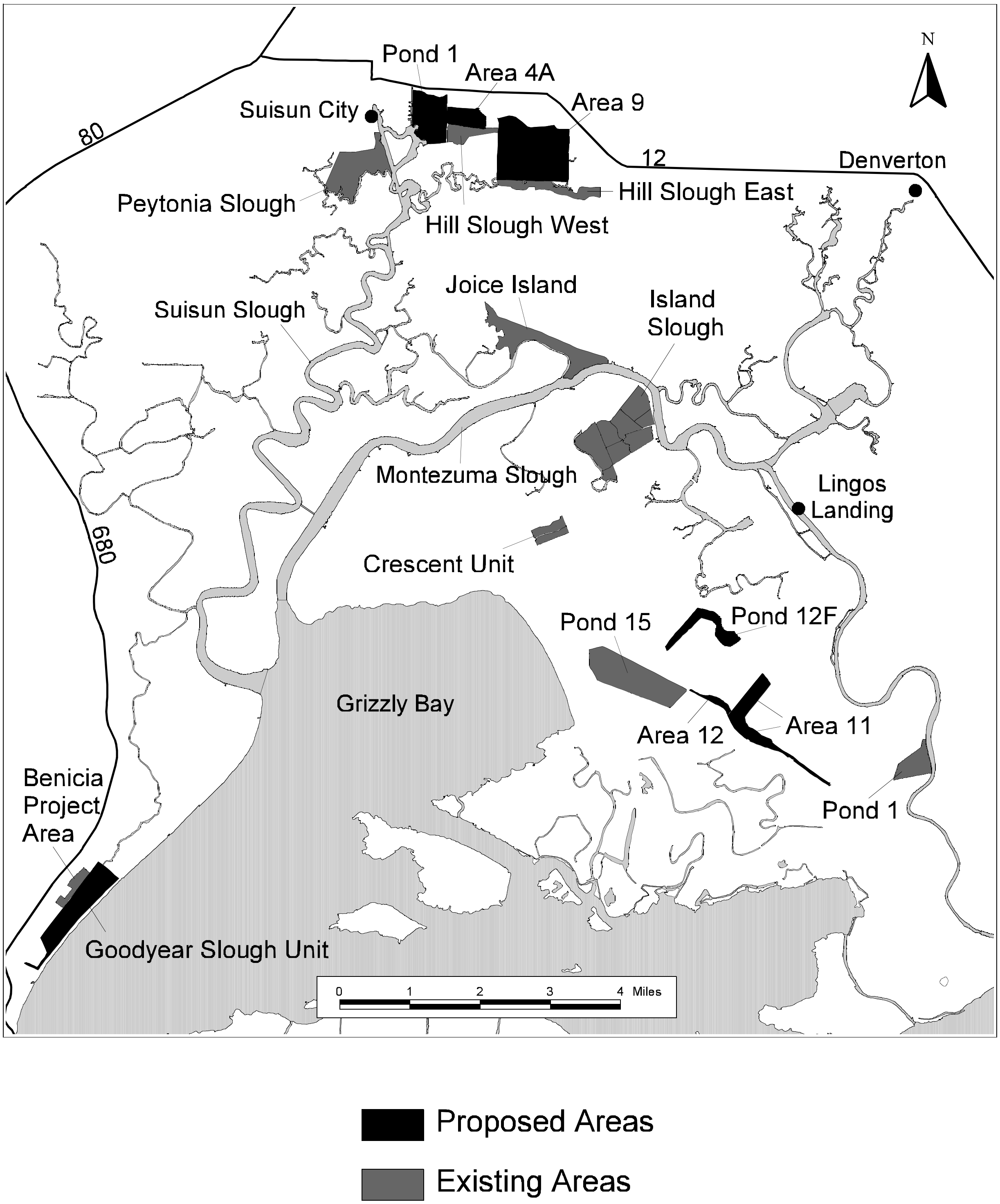

Figure 1 Department of Fish and Game lands existing and proposed conservation areas for SMHM.
(Source: Department of Fish and Game, Central Valley Bay-Delta Branch Special Water Projects, Suisun Marsh).

Table 1 Results of 1999 surveys for salt marsh harvest mice at existing and proposed conservation areas in Suisun Marsh

Locations Trapped	Species Caught: SMHM [a]	WHM [b]	UnkHM [c]	Mus [d]	Vole [e]	Trap Nights	SMHM Trap Success (%)
Hill Slough West, Pond 1	23	0	4	4	0	100	23
Hill Slough West, Area 4A	15	0	7	52	1	300	5
Grizzly Island Wildlife Area, Area 11	49	0	48	31	0	300	16
Grizzly Island Wildlife Area, Pond 12F	35	1	19	8	1	170	21
Grizzly Island Wildlife Area, Area 12	21	0	14	9	0	200	11
Hill Slough East	1	1	0	85	0	300	0.3
Hill Slough East, Area 9	23	3	18	32	3	300	8
Goodyear Slough Unit	18	0	11	30	3	288	6
Joice Island	5	25	11	156	1	500	1

[a] SMHM = salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*)
[b] WHM = western harvest mouse (*Reithrodontomys megalotis*)
[c] UnkHM = unknown harvest mouse (*Reithrodontomys* sp.); species could not be determined
[d] Mus = house mouse (*Mus musculus*)
[e] Vole = meadow mouse (*Microtus* sp.)

CONTINUING RESEARCH

The current survey protocol for the SMHM was written by DFG and DWR and approved by the Suisun Marsh Preservation Agreement Ecological Coordination Advisory Team (DFG 1999). The 1999 trapping was the second of these surveys. The next phase of the survey protocol will include mark-recapture trapping in sub-optimal habitat types, such as levee banks, upland grasslands, and wetland vegetation dominated by species other than pickleweed. This trapping effort will attempt to determine which habitats are used as refugia, how SMHM use sub-optimal habitats, and the population levels of selected populations.

REFERENCES

[DFG] California Department of Fish and Game. 1999. Salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*), monitoring and habitat management proposal for the Suisun Marsh. 11 p. Available from: DFG Central Valley Bay Delta Branch, Stockton CA.

Finfrock P. 1999. 1998 monitoring of the endangered salt marsh harvest mouse in Suisun Marsh. IEP Newsletter 12(1):36–9.

Shellhammer HS. 1984. Identification of salt marsh harvest mice, *Reithrodontomys raviventris*, in the field and with cranial characteristics. California Fish and Game 70(2):113–20.

THE SUISUN MARSH VEGETATION MAPPING PROJECT

Todd Keeler-Wolf, Department of Fish and Game

INTRODUCTION: WHY SHOULD WE HAVE A VEGETATION MAP?

When discussing the assessment of a landscape with valuable natural resources, managers often ask: “What kind of information do we need to collectively manage a large natural area?” Next, they usually ask for a vegetation or habitat map.

Vegetation or habitat mapping is usually the most effective means of depicting biological information at a scale that can be interpreted by land managers. Knowledge about the size, types, abundance, and location of vegetation, natural communities, or habitats facilitates synthesis of biological information to interpret and answer several questions:

- How can we best display critical habitat for rare species?
- How much habitat/vegetation of different types occurs in the area of interest?
- How can we track and quantify the changes in ecosystems or habitats over time?
- Where are the natural boundaries between major management areas?
- What are the rare vegetation types and ecosystems, where are they, and how should we manage them?
- What are the appropriate fire or other natural disturbance management responses for the area?
- Where are the suitable habitats for certain wildlife species and how much of each is there?
- Which vegetation types are likely to be conduits for weed invasion and where are they?
- What is the appropriate balance between managed, natural, and developed lands?

Mapping vegetation is both art and science. The art visually communicates the greatest biological and ecological information. The science collects and displays data so that the full range of biological variability of the area is represented. Vegetation maps can be based on simple or detailed classifications, cheap or expensive source information, coarse or fine spatial resolution, and produced with a little or a lot of field work.

Two fundamental things are needed to produce a map: a classification system and mapping technology. Classifications can be based on dominant or characteristic plant species, plant and vegetation morphology, and animal habitats. Most vegetation maps are produced using a Geographic Information System, which stores all information about the area and can produce various maps based on that information.

Before a vegetation or habitat map is produced, project proponents must decide what they really need to know and consider the underlying requirements and assumptions.

HOW THE SUISUN MARSH VEGETATION MAPPING PROJECT EVOLVED

When the salt marsh harvest mouse and California clapper rail were listed as federally endangered species in 1970, the State and federal agencies involved agreed to maintain habitat for the two species in Suisun Marsh. The US Fish and Wildlife Service and US Bureau of Reclamation asked the Department of Water Resources (DWR) and the Department of Fish and Game (DFG) to develop a monitoring and assessment program for the Suisun Marsh to ensure the species’ protection and population increase. The monitoring program included ground monitoring of populations and estimating the amount of suitable habitat. To estimate the amount of suitable habitat, vegetation mapping began in the early 1980s and was scheduled to recur every three years.

The first maps funded by DWR and produced by DFG were created manually, with relatively unsophisticated classification and cartographic standards. At the time, no quantitative rules for classification were in place in California. Although methodologies were developed for surveying and mapping, archiving and reproducing the information was difficult without formal standards. Therefore, reliable results were difficult to obtain every three years, and after 15 years of mapping and monitoring, the results were unsatisfactory. Consequently, the agencies and organizations that manage the Suisun Marsh agreed upon a new mapping protocol in 1998, based on a standard used by the US National Park Service.

THE PREMISE BEHIND THE US NATIONAL PARK SERVICE MAPPING PROTOCOL

The guiding principles behind the new protocol are as follows:

- There must be quantitative vegetation data collected within the mapping area.
- Field samples must be analyzed and processed into a classification.
- The classification must be quantitative and hierarchical with interpretable threshold values.
- The classification used should be standardized throughout the nation (a National Vegetation Classification).
- What you see on the ground is what you get in the map.
- Mapping units must be drawn from analysis of detailed, recent aerial photographs.
- Delineators must be trained in the classification and synthesis of information from the aerial photographs.
- Processing and production of the mapping information are done within a GIS environment.

THE NATIONAL VEGETATION CLASSIFICATION

The National Vegetation Classification is based on both floristic and physiognomic units. The two lower floristic units (defined by the plant species composition), are known as the alliance and the association. The alliance (the vegetation mapping equivalent of a genus), defines a group of related vegetation types by the same dominant or characteristic species. For example, all vegetation dominated by pickleweed (*Salicornica virginica*) is an <u>alliance</u>. Within the alliance, further variations of vegetation (defined by shifts in species composition) are known as associations. For example, stands of pickleweed alliance associated with fat hen (*Atriplex triangularis*) make up the pickleweed-fat hen <u>association</u>.

The two physiognomic units (defined by the morphology and hydrology of the vegetation), are known as formations and classes. For example, all cattail, tule, and giant reed alliances are a part of the tall, seasonally flooded graminoid <u>formation</u>. Because these tall graminoids (grass-like plants) are all non-woody, they are put within the herbaceous <u>class</u>.

DEVELOPING AN INITIAL CLASSIFICATION

The first step in developing a classification for an area is to accumulate all existing information. Information about California vegetation is summarized in *A Manual of California Vegetation* (Sawyer and Keeler-Wolf 1995). Although quantitative data describing the differences between vegetation types found in the Suisun Marsh exist for some alliances and associations, the majority of types has not been sampled and analyzed. Thus, a large amount of new data needs to be collected to differentiate vegetation types.

Depending on the scale of the map, there is an appropriate level of classification. For a very detailed map, the association level is appropriate. Because it is the smallest resolution of the classification, it should also be used to represent the smallest spatial resolution. Thus, with a fine-grained spatial scale a fine-grained classification unit should also be used.

COLLECTING DATA FOR THE CLASSIFICATION OF SUISUN MARSH VEGETATION

The field data used to classify the Suisun Marsh vegetation are simple and consists of the following parts:

- the cover values of all the vascular plant species in the sample plot;

- the correct identification of all the vascular plant species in the sample plot;
- the height of all vegetation strata in the sample plot;
- the precise location of the plot using a Global Positioning System; and
- the environmental data on soils, geology, slope, aspect, landform, wetland classification type, elevation, impacts and successional history.

This information is collected from a 400-m^2 plot shaped according to the characteristics of the stand of vegetation being sampled. A 400-m^2 plot was shown to capture the greatest amount of information from a stand of largely herbaceous or shrubby vegetation without re-sampling.

Cover data on species are estimated rather than measured because this approach saves time and produces results comparable to more labor-intensive methods. Depending on the complexity of the vegetation, plots can take from 20 to 60 minutes to complete.

HOW MANY SAMPLES ARE NEEDED?

The number of sample plots needed for the project depends on the number of vegetation types and the species composition within them. The National Classification for park mapping states a minimum of three plots per vegetation type. About 200 plots were needed to describe the vegetation in the Suisun Marsh (about 50 individual associations with four samples each). In some areas in the marsh, fewer plots were needed because some vegetation types were already well described. On the other hand, some types were not described previously and required more plots.

HOW ARE THE SAMPLES ALLOCATED?

We used a two-stage sampling process to answer this difficult question. During the process we wanted to achieve the following:

- allocate the most samples to the most diverse types of vegetation;
- ensure that all types of vegetation were sampled;
- stratify the entire marsh so that all portions of the marsh receive some samples; and
- assure that the samples are relatively accessible.

We used recent (June 1999) SPOT satellite imagery with an infared band component to select different reflectance values of vegetated and unvegetated terrain throughout Suisun Marsh. Our GIS analysts stratified the reflectance values into 40 classes. Since much of the marsh is privately owned, we requested that the GIS first locate as many different types of reflectance patterns on public lands as possible. We also requested that the areas considered be within 100 meters of a levee, road, or trail so we could access them. Then we asked the GIS to randomly select an equal number of locations within each of these areas. The selection resulted in about 145 random points within the 40 reflectance classes, which were assumed to represent different vegetation types.

In the field, crews collected samples from each of the reflectance patterns. The data showed that there were several types sampled, but that the most recent samples tended to be repeats. This was expected since satellite reflectance patterns are only a gross approximation of different vegetation types. Thus, the second sampling phase (opportunistic sampling) was implemented. Opportunistic sampling allows us to focus on vegetation types that may not be represented in the first sampling stage because of their rare or local nature or their similarity to other more widespread vegetation. We used the field crews' experience and the air-photo interpreters to locate examples of vegetation not yet sampled and selected examples from that subset to visit.

AERIAL PHOTOS VERSUS SATELLITE IMAGERY

Remote sensing usually includes aerial photography as well as satellite imagery. Most satellite imagery ranges from 10-m to 30-m resolution. For this project, we used 1:9600 scale aerial photography, which is below 1-m resolution. We chose aerial photography as the principal form of remote sensing because the information needed required a higher level of detail than could be provided by currently available satellite imagery. This allowed us to (1) define local-scale stands less than an acre, (2) define precise boundaries between vegetation types and vegetation and managed landscapes, (3) identify habitat features such as vegetation height and vegetation cover, and (4) define the species composition of stands more precisely.

PHOTO INTERPRETATION AND REGISTRATION

During the field sampling, GIS technicians and air photo delineators began delineating and attributing the 150 air photos that cover the marsh, scanning the photos into the GIS computer system, and “registering” the photos to real-world coordinates. All delineation is done based on a thorough understanding of the types of vegetation in the marsh. A preliminary label is attached to each polygon drawn indicating its preliminary vegetation type.

CLASSIFICATION OF THE VEGETATION

Following the fieldwork and delineation, the field data were entered into a database and downloaded into a statistical software package designed to classify vegetation sampling data. The data are grouped into similar sample sets. The most characteristic species of each group is identified and used to name the vegetation associations and alliances. This is a repeatable, quantitative technique.

By studying the characteristics of these sample sets, rules are established to define the threshold values between different vegetation types. Following the analysis, a key (with descriptions of each vegetation type defined in the data) is written. These keys allow the photo interpreters to place final labels on the map polygons and allow the field crews to assess the accuracy of the map by ground truthing.

DATE OF COMPLETION

We are currently finishing the fieldwork and have already finished scanning and registering all of the photographs. Next begins polygon labeling and photo mosaiking. We expect to have the first draft of the map finished in June 2000.

REPEATABILITY OF THE PROCESS

One of the major benefits of this mapping protocol is that all methodology is recorded and repeatable. Thus, when re-mapping is necessary, the protocol can be repeated with reliability. This will ensure comparable results and allow more certain conclusions and management decisions.

Although re-mapping was originally scheduled to occur every three years, a more flexible approach is possible. Using the new protocol, re-mapping will be less time consuming, less expensive, and more responsive to actual changes in the marsh for the following reasons:

- Much of the vegetation sampling has been done, so only newly discovered types will be sampled for the next iteration.
- The process is documented and no new methods will be employed, making the learning curve less steep for the re-mapping crew.
- Change detection methods will be employed, allowing re-mapping to be done only on sections of the marsh that have significantly changed.
- Although aerial photography will be conducted every year, re-mapping will only be done when the change detection suggests it is necessary. (For further detail see the article “New Vegetation Survey Methodology for the Suisun Marsh” on page 60 of the summer 1999 issue of the *IEP Newsletter*).

REFERENCES

Sawyer J, Keeler-Wolf T. 1995. A manual of California vegetation. Sacramento (CA): California Native Plant Society.

ERRATA

• In the "Contributed Papers" section of the previous issue of the *IEP Newsletter*, Mike Chotkowski's article, "List of Fishes Found in San Francisco Bay-Delta Shallow Water Habitats" contained a table listing the fishes observed during routine monitoring in Bay-Delta, near-shore, shallow water habitat. The table *did not* include keys to interpret the data in the table—and should have. The following two tables (directly below and in the right column) provide the missing information.

Proportional abundance (PA) categories for Table 1

Symbol	*Range*
–	not observed
I	0 < PA < 0.01
II	0.01 = PA < 0.05
III	0.05 = PA < 0.10
IV	0.10 = PA < 0.25
V	0.25 = PA

Column Legends for Table 1

Codes				
Substrate	*Vegetation*	*Description*	*Gear*	*Source*
SB		Bay seine	Minnow Seine	CDFG Bay Studies
TSM		Suisun shallow sloughs	Otter Trawl	UCD Suisun Marsh
SD		Delta seine	Minnow Seine	USFWS Beach Seine
EMS		mud bank + sand beach	Boat Electrofishing	CDFG Resident Fishes
EMF		mud flats / bare	Boat Electrofishing	CDFG Resident Fishes
EMS	EMGT	mud + sand / emergent vegetation	Boat Electrofishing	CDFG Resident Fishes
EMS	MIXED	mud + sand / mixed vegetation	Boat Electrofishing	CDFG Resident Fishes
EMS	RIPAR	mud + sand / riparian vegetation	Boat Electrofishing	CDFG Resident Fishes
EMS	SUBM	mud + sand / submergent vegetation	Boat Electrofishing	CDFG Resident Fishes
ER		rip-rap / bare	Boat Electrofishing	CDFG Resident Fishes
ER	EMGT	rip-rap / emergent vegetation	Boat Electrofishing	CDFG Resident Fishes
ER	FLOAT	rip-rap / floating vegetation	Boat Electrofishing	CDFG Resident Fishes
ER	MIXED	rip-rap / mixed vegetation	Boat Electrofishing	CDFG Resident Fishes
ER	RIPAR	rip-rap / riparian vegetation	Boat Electrofishing	CDFG Resident Fishes
ER	SUBM	rip-rap / submergent vegetation	Boat Electrofishing	CDFG Resident Fishes

• In "Of Interest To Managers" in the previous issue of the *IEP Newsletter*, a table was included that summarized the shallow water habitat data review. Some of those data were missing. Below is a reprint of the table, with the missing information in shaded cells.

Table 1 Summary of shallow water habitat data review[a]

Type of Habitat	*Data Set*	*Native Species (%)*	*Non-native Species (%)*	*Native Individuals (%)*	*Non-native Individuals (%)*
Bay	1980 to 1986	57	**43**	**88.2**	**11.8**
Delta and Lower Rivers	1994 to 1999	51	**49**	**40.7**	**59.3**
Delta	1995 to 1999				
Mud/Sand		48	52	77.4	22.6
Bare Mud Flat		24	76	5.1	94.9
Vegetated Mud/Sand		38	62	5.8	94.2
Rip-rap, bare		34	66	11.6	88.4
Vegetated Rip-rap		34	66	5.3	94.7
Suisun Marsh Shallow Sloughs	1994 to 1997	46	54	37.0	63.0

[a] Based on information developed by Mike Chotkowski, DFG, and IEP.

DELTA INFLOW, OUTFLOW, AND PUMPING

Dawn Friend, Department of Water Resources

Figures 1 and 2 (opposite page) contain plots of some important flow and pumping measurements for the third quarter of calendar year 1999 (1 July through 31 September).

A few notes:

- Sacramento River and San Joaquin River flows are measured. Delta Outflow is calculated by DWR's Division of Operations and Maintenance.
- 14-day running average Export/Import ratios are calculated by DWR's Division of Operations and Maintenance.

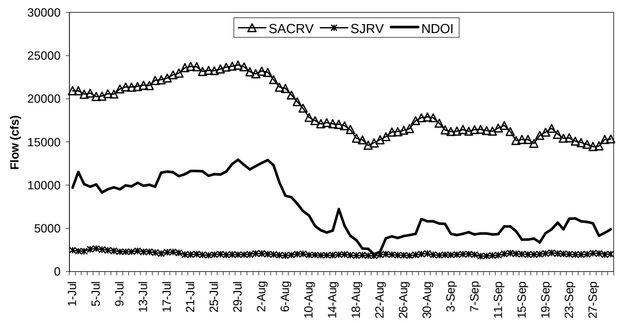

Figure 1 Sacramento and San Joaquin flows and Delta outflow for 1 July 1999 through 31 September 1999

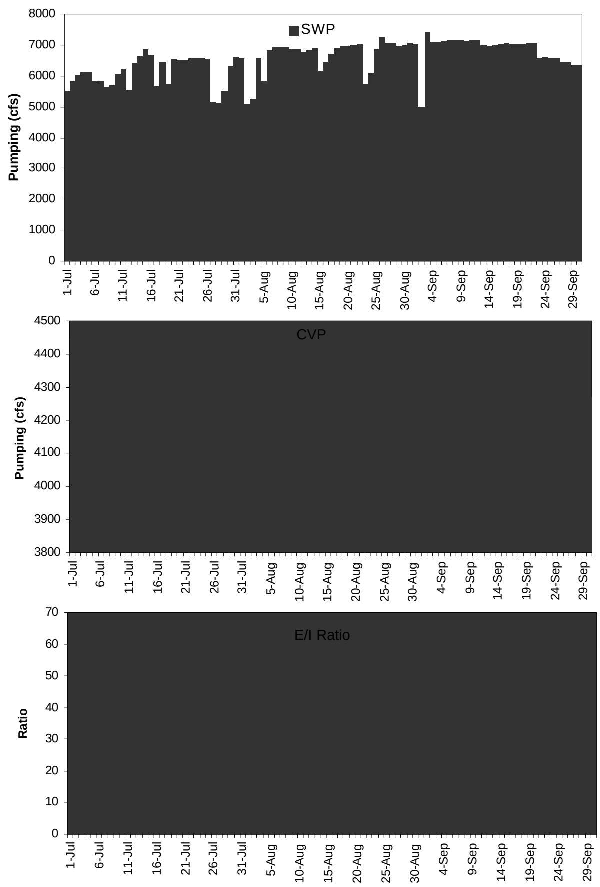

Figure 2 SWP exports, CVP exports, and 14-day running average E/I ratio

■ Interagency Ecological Program for the Sacramento–San Joaquin Estuary ■

IEP NEWSLETTER
3251 S Street
Sacramento, CA 95816-7017

For information about the Interagency Ecological Program, visit our Internet site (http://www.iep.water.ca.gov). Readers are encouraged to submit brief articles or ideas for articles. Correspondence, including submissions for publication, should be addressed to Dr. Randall L. Brown, California Department of Water Resources, 3251 S Street, Sacramento, California, 95816-7017.

■ Interagency Ecological Program for the Sacramento–San Joaquin Estuary ■

IEP NEWSLETTER

The Interagency Ecological Program for the Sacramento–San Joaquin Estuary
is a cooperative effort of the following agencies:

California Department of Water Resources
State Water Resources Control Board
US Bureau of Reclamation
US Army Corps of Engineers
California Department of Fish and Game
US Fish and Wildlife Service
US Geological Survey
US Environmental Protection Agency

National Marine Fisheries Service

BEFORE CITING INFORMATION HEREIN,
CONSIDER THAT ARTICLES HAVE NOT RECEIVED PEER REVIEW.