■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER

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Of Interest to Managers

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Salt Marsh Harvest Mouse Surveys in Suisun Marsh

Patty Finfrock reports on results of the 2000 salt marsh harvest mouse (SMHM) surveys in eight Suisun Marsh conservation areas totaling over 1,300 acres (see page 18). The SMHM is a threatened species and these surveys are regularly completed to determine the status of the SMHM in Suisun Marsh. Results from 2000 suggest the SMHM is well distributed throughout the conservation areas, but SMHM abundance declined from 1999 levels. These declines are attributed to "the natural cyclic rhythm of rodent populations." In 1999 and 2000, DWR staff also collected hair follicle samples from captured mice. These samples will be used to develop genetic markers to allow for more definitive identification of SMHM and the co-occurring common western harvest mouse. Genetic markers will also be used to test the validity of morphological characteristics now used in species identification and to determine if inbreeding is occurring.

Long-term Changes in Grizzly Bay Benthos

Heather Peterson is analyzing benthic community data and physical data from the DWR Environmental Monitoring Program to understand the factors responsible for changes in the benthos of Grizzly Bay (see page 21). Results show the introduction of the Asian clam had a profound effect on the composition of the benthic community. Establishment of the Asian clam has also affected how the community changes in response to physical factors associated with water year type and X_2. Heather's work, along with the work of other researchers, clearly show the dramatic effects introduced species can have on the biota in San Francisco Estuary.

Suisun Marsh Habitat Mapping

Todd Keeler-Wolf and others report on an 18-month survey to document and classify habitats in the Suisun Marsh (see page 20). Accurate information of this type is essential to the management and conservation of this special management area. This latest survey was completed using new GIS technology and satellite imagery. Results will be used to answer habitat-based questions as well as facilitate future project planning. Comparisons with earlier surveys will provide information on how marsh vegetation has changed with time.

Delta Smelt Culture Progresses

Bradd Baskerville-Bridges and others report on the progress in successfully mass-culturing delta smelt (see page 23). Several physical improvements in the culture facility along with results of experiments aimed at optimizing culture conditions and delta smelt survival highlight year 2000 accomplishments. Developing sound methods for the mass culture of this threatened species is an ideal way to provide delta smelt for research without further diminishing the natural stock. In addition, the results of this work have provided important information about the life history and reproductive biology of delta smelt.

Development of a Dissolved Oxygen TMDL for the San Joaquin River

G. Fred Lee and Anne Jones-Lee provide a synopsis of the situation and issues important to developing a total maximum daily load (TMDL) for the San Joaquin River (see page 29). This stakeholder driven process is required by the Central Valley Regional Water Quality Control Board, which classified the San Joaquin River Deep Water Ship Channel as impaired in 1994 due to the chronic reoccurrence of low dissolved oxygen levels in this stretch of the river. The process described in this article exemplifies the type of approach that is necessary to resolve many of the long-standing concerns in the Sacramento-San Joaquin Delta.

CALFED SCIENCE CONFERENCE SUMMARY REPORT

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A summary of the October 3-5, 2000 CALFED Science Conference is available at http://www.iep.water.ca.gov/calfed/sciconf/. A very limited supply of hard copies is also available. For those without web access, a hard copy can be obtained by calling Lynda Parrish at (916) 227-7533, or contacting her by e-mail at parrish@water.ca.gov.

The 50-page report, written by Randy Brown, Fred Nichols, and Larry Smith, provides conference planning details, recommendations about future conferences, conference highlights, and brief summaries of individual presentations. The website also includes abstracts of oral and poster presentations, the affiliation of the 800 plus attendees and rapporteurs' notes from individual technical sessions.

BAY-DELTA SCIENCE CONSORTIUM

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For the past several months a small group of scientists has met about every four to six weeks to discuss science coordination in the Bay-Delta and the merits of some infrastructure changes. The impetus for these discussions came from IEP's need to consider new office and laboratory space for Stockton and Sacramento scientists and administrators and CALFED's need for science coordination to support adaptively managed restoration. Initially CALFED asked Perry Herrgesell and me to develop a proposal to acquire a Delta site that would house what we initially called the CALFED Science Center. We established a small advisory committee to help evaluate various sites and provide guidance as to facilities needed to house staff, laboratories, storage, maintenance, etc.

The science center discussions evolved into exploring ways to achieve better science coordination, with new facilities in the Delta and on the UC Davis campus being part of the mix. We agreed on the tentative consortium title, suggested by Jeff Mount of UC Davis, and also agreed to limit our scope to the Bay-Delta. Finally, we thought it appropriate to include outreach as an essential program element. At our January meeting, Steve Barbata (Delta Science Center at Big Break) and John Cain (Natural Heritage Institute) described their vision for the Delta Science Center at Big Break—a center with integrated education, science, and restoration goals. This center, with secured funding from Propositions 12 and 13 and other sources, will complement the proposed consortium's science and outreach efforts.

The advisory committee has expanded in recent months and now includes representatives from the Romberg Tiburon Center, the San Francisco Estuary Institute, the Point Reyes Bird Observatory, the Delta Science Center at Big Break, CALFED, USGS, UCD, DWR, and the USFWS. Stakeholder members are from the Natural Heritage Institute and the Metropolitan Water District of Southern California.

The group's present activities center around developing plans for new facilities in the Delta (mainly field elements) and on campus at Davis (senior scientists and managers) and stimulation of working partnerships. Chuck Armor, Zach Hymanson, and Brian Cole are working with USGS, DFG, USFWS and DWR managers to assess staff assignments to the two locations and facilities needed at each site. Jeff Mount drafted a Memorandum of Understanding intended to foster communications and coordination among Bay-Delta science organizations. Kim Taylor of CALFED drafted core principles for the consortium. The team is also learning more about activities of watershed groups, such as the Sacramento River Watershed Program, to help determine how watershed programs can be closely linked with those in the Bay and Delta. Although not a direct group responsibility, Kim Taylor is working with the UC Sea Grant Program to establish a fellowship program for graduate students and post-doctoral associates to help agency and other scientists analyze historical databases, approach questions of mutual interest to agencies, the academic community and stakeholders, and publish the results.

I need to emphasize that the discussions are in the conceptual stage, but there is mutual good will and momentum to move forward on this process. Although some IEP and agency staff are likely to move in the next few years, there are numerous economic and institutional issues to be resolved before anyone actually moves into new facilities of the Science Consortium. Science coordination through something like the Bay-Delta Science Consortium is more promising. There is general agreement that it is needed and CALFED can help make it a reality by providing some of the necessary incentives (aka money).

CALFED Non-native Invasive Species Program

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The CALFED Bay-Delta Program was established to develop a long-term solution to the problems affecting the Bay-Delta system. The CALFED Ecosystem Restoration Program's (ERP) goal is to restore ecological processes and to increase and improve aquatic and terrestrial habitats to support stable, self-sustaining populations of diverse and valuable species.

We have come to recognize the threat nonnative invasive species represent to healthy ecosystems and restoration efforts. As part of the ERP, the U.S. Fish and Wildlife Service has accepted the responsibility of developing, implementing, and coordinating a Nonnative Invasive Species (NIS) Program in the San Francisco Bay-Delta estuary which includes terrestrial as well as aquatic species. This program, with the coordination of CALFED staff, agencies and interested stakeholders, focuses on the San Francisco Bay-Delta, the Sacramento and San Joaquin rivers, and associated watersheds. The program has three objectives:

1. Develop a long-term strategy to manage NIS in the Bay-Delta estuary and watersheds.
2. Support prevention-oriented management and research projects to prevent or minimize additional NIS from being introduced into the Bay-Delta estuary and watersheds.
3. Support control-oriented management and research projects to eradicate or manage NIS once they have arrived and prevent or delay their proliferation.

The NIS Program has already accomplished many tasks, including the formation of Agency and Technical Work Teams, the development of NIS Strategic and Implementation Plans, and the implementation of several NIS prevention and control projects. Several agencies and organizations are represented on the teams:

<u>Local or Academic Affiliates</u>

- University of California, Davis
- University of California, Berkeley
- Bodega Marine Lab
- Delta Protection Commission
- The Bay Institute
- East Bay Regional Parks

<u>California State Agencies</u>

- Department of Fish and Game
- Department of Water Resources
- Department of Food and Agriculture
- San Francisco Regional Water Quality Control Board
- Department of Boating and Waterways

<u>Federal Agencies</u>

- Environmental Protection Agency
- Fish and Wildlife Service
- Department of Agriculture
- Geological Survey
- Bureau of Reclamation

Approved projects include control of purple loosestrife (a flowering wetland plant), *Spartina* species (cord grasses), and *Arundo donax* (a bamboo-like plant). Prevention projects include outreach and education to the pet, aquarium, and nursery industries, an invasive plant guidebook for restoration projects, and a zebra mussel detection and education project. Research projects will be focusing on ballast water and *Potamocorbula amurensis* (an Asian clam). Additional articles on specific NIS issues and projects will follow in future editions of this newsletter. For further information, contact Kim Webb at (209) 946-6400, ext. 311, or kwebb@delta.dfg.ca.gov.

IEP Quarterly Highlights—Winter 2001

San Francisco Bay Fisheries Monitoring

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We continued to sample fish and invertebrates monthly with midwater and otter trawls in the last quarter of 2000. Newsworthy information included a record catch of the introduced goby, *Tridentiger barbatus*, in October 2000. We collected 59 fish, with the majority of fish in the lower Sacramento River (salinity <2.5‰). Most of the fish collected were less than 22 mm TL. We collected four *T. barbatus* in November and 27 in December. This three-month total of 90 fish is substantially higher than the 66 collected since November 1997.

We have also noticed a significant overlap in the distributions of *Cancer magister* (Dungeness crab) and *Eriocheir sinensis* (Chinese mitten crab) in fall and winter. For example, in December 2000, *C. magister* were common in the upper San Pablo Bay channel and Carquinez Strait (bottom salinity 22.5‰ to 25.8‰) while *E. sinensis* were most common from the western end of the Strait to Chipps Island (bottom salinity 9.2‰ to 24.5‰). From late fall through winter, *C. magister* stage for their emigration from the bay, as they move from the shoals to the channel. Meanwhile, *E. sinensis* migrates from the rivers and Delta to brackish water to reproduce. Through the winter, the center of the *E. sinensis* distribution moves slightly downstream, as ovigerous females are found at higher salinities (mean = 16.9‰) than either adult males (mean = 10.2‰) or non-ovigerous females (mean = 10.9‰). Although most *C. magister* are >85 mm carapace width by December (which is larger than most *E. sinensis*), it is not known if this distributional overlap affects *C. magister*. Also, *E. sinensis* is reported to die soon after reproduction, with males dying soon after mating and females dying after the eggs hatch.

Preliminary 2001 abundance indices for selected estuarine species, including the shrimp *Crangon franciscorum*, Dungeness crab, longfin smelt, and starry flounder will be reported in the status and trends (spring 2001) issue of the *IEP Newsletter*.

Delta Flow Measurement

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Eleven of the 12 continuous flow-monitoring stations successfully collected data throughout the quarter without extended periods of missing data. Unfortunately, the station on the Sacramento River downstream of Georgiana Slough was down for approximately a month during the IEP DCC-PWT Delta Cross Channel (DCC) study. The station failed due to a fatigued underwater transducer cable; the cable was replaced on December 11.

Cathy Ruhl became the Delta flows contact person for the USGS in January. Cathy has been working for the USGS on various Bay-Delta sediment projects for the last three years with Dave Schoellhamer. Cathy will continue to keep everyone informed of Delta flow measurement activities via this quarterly update.

Delta Cross Channel Study

The six UL-ADCPs that were deployed on September 5 in the vicinity of the DCC as part of the DCC study (refer to last quarters report) were recovered during the week of December 18. Numerous flow measurements were made during the deployment period at the DCC, and North Fork and South Fork Mokelumne UL-ADCP sites. These measurements will be used to flow calibrate the UL-ADCPs. Because the Sacramento River flow was fairly constant over the three-month deployment period, the DCC UL-ADCP was redeployed in the hope that the Sacramento River flows will increase, but will remain less than 25,000 cfs (triggers the closure of the DCC gates) so the flow splits in the vicinity of the DCC can be further investigated at slightly higher flow levels than those that occurred during the previous three months.

Several fish movement studies were conducted over a two-week period during the middle of November that included the release and recapture of spray-dyed salmon smolts, the tracking of radio tagged salmon, and the use of acoustics to determine fish distribution. Additional hydrodynamic data were collected during these fish movement studies, including velocity profile measurements at various fish locations, the tracking of drogues released at the same time and location as the fish, and high density velocity profile mapping at the junction of the DCC and the Sacramento River. The velocity profile mapping data will be used in conjunction with the velocity profile data collected by the three UL-ADCPs deployed in the Sacramento River at the junction with the DCC. These three UL-ADCPs will not be flow calibrated but will provide continuous velocity-profile data to monitor the hydrodynamics at the junction during DCC gate operation, and give information about how the velocity variations might affect fish passage.

The DCC hydrodynamic work described was done jointly by USGS and DWR Central District staff with funding provided by CALFED and the IEP.

NEOMYSIS AND ZOOPLANKTON

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The most abundant copepod over the last quarter was, as usual, *Limnoithona tetraspina*. This small cyclopoid copepod reached a maximum density of 91,645 m^{-3} in the entrapment zone in October. Another similar cyclopoid copepod, *Oithona davisae*, was more abundant than usual, reaching 6,957 m^{-3}at Martinez. High salinity intrusion probably brought *O. davisae* upstream, as it is a lower bay species that had an abundance of 26,021 m^{-3} in San Pablo Bay in October. The large predatory copepod, *Tortanus dextrilobatus*, was also more abundant than usual in Suisun Bay due to the same cause.

The second most abundant copepod was *Pseudodiaptomus forbesi*, a calanoid that is an important fish food. Its peak abundance was 16,121 m^{-3} in the Sacramento River at Sherman Island; however, it was generally much less abundant than this. *Eurytemora affinis* made its seasonal reappearance in November at several stations from the entrapment zone to Stockton on the San Joaquin River and Sherman Island on the Sacramento River. *Sinocalanus doerrii* was not abundant but did show an annual peak in September. *Acartiella sinensis* looked like it might have disappeared from the system, but “reappeared” in October and November. The native *Diaptomus* and *Cyclops* copepods were rare.

Cladocerans were also unusually rare. No *Daphnia* were taken in October and few were caught in September and November. Rotifers were less abundant than usual.

No *Neomysis mercedis* were seen. However, *Acanthomysis bowmani* was fairly abundant with a peak of 74 m^{-3} in the Sacramento River at Sherman Island in October. This mysid was present from San Pablo Bay where three individuals were taken in September, to Stockton. Its peak abundance was in the entrapment zone in September. It is not known why *A. bowmani* can thrive in fall when *N. mercedis* disappears. *Neomysis mercedis* was once common in fall, but declining phytoplankton abundance resulted in its disappearance in that season.

JUVENILE SALMON MONITORING

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Monitoring efforts increased in October for the fall sampling period. Lower Sacramento River seining collected one adult chinook (at Wards Landing), 11 winter-run sized, and two late fall-run sized chinook in November and December. The Sacramento area beach seine began on October 17, with five fall/spring, two late fall, and three winter-run chinook captured for the quarter. All sites on the San Joaquin River were sampled with the beach seine in September, but no chinook were captured this season. A new seine site on the San Joaquin River, four miles upstream from the mouth of the Tuolumne River, has been added to better understand the contribution from the Merced River.

To better target larger less abundant races, Kodiak trawling replaced midwater trawling at Sacramento on October 4, with four late-fall sized chinook salmon captured in December. Due to very low flows on the San Joaquin River, Kodiak trawling has not been possible at Mossdale. Trawling at Chipps Island collected 14 adult chinook, 19 fall-run and 13 late fall-run chinook juveniles between September and December.

Similar to last year, significant storms that tend to bring juvenile chinook down into the Delta did not materialize in the fall. A minor fish trigger in which the Knights Landing Catch Index and Sacramento Catch Index both exceeded 3.0 occurred on December 21, and the Delta Cross Channel (DCC) gates were closed for a few days. Otherwise the DCC gates were open most of the quarter since the bulk of the fish have not been seen yet.

Fyke trapping for adult fish was conducted between October 11 and November 15 to evaluate the potential effect of a through-Delta facility, connecting the Sacramento River with Snodgrass Slough, on adult anadromous fish. Two traps, ten foot in diameter by 20 feet long, were set in both Georgiana Slough and in the DCC. Captures in Georgiana Slough included 21 chinook, one adipose-clipped steelhead, and 28 striped bass. Although lower in numbers, fish were captured in the DCC, with three chinook salmon, one adipose-clipped steelhead, and one striped bass taken. Other resident fish were captured in both the Georgiana Slough and DCC traps.

To evaluate the potential fish protection benefits of a tidal gate operation of the DCC, some coded-wire tagged late fall-run chinook were used as part of a juvenile chinook diversion study. Modeling has shown that opening the DCC only on a flood tide could provide nearly all of the water quality benefits that continuous opening would provide. The study was designed to determine if such an operation strategy might also provide fish protection. Fish were released in mid-November, upstream of the DCC on different tides and recovered continuously for two days via midwater trawling in the DCC and on the Sacramento River just downstream from the DCC. The experiment was repeated one week later.

Recovery patterns from the DCC-Sacramento River study will be examined with respect to tide and day-night cycle. Preliminary results show that no fish were recovered during the day at either trawl site, most likely due to high water clarity. These results, along with hydroacoustic (USBR) and hydrodynamic (USGS) data collected will also be analyzed. A session on this work is scheduled for the IEP workshop at Asilomar.

For a thorough review of the season's catches, see the monitoring summary report at http://165.235.108.8/usfws/monitoring/report.asp.

HYDRODYNAMICS OF NORTH BAY

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Two major field efforts were concluded during this reporting period. The first involved the recovery of a large network of self-contained oceanographic equipment deployed in the Grizzly Bay area. This equipment was deployed in September 1999 to study shallow-channel exchange processes by continuously monitoring water levels, current speeds, temperatures, salinities, and turbidities. The equipment was recovered June 2000. The primary objective for this nine-month data set was to monitor the exchange of water, salt, and suspended sediment between Grizzly Bay and the channels of Suisun Bay. Secondary objectives were (1) to quantify Suisun Marsh-Grizzly Bay exchange, including the effects of Suisun Marsh Salinity Control Gate operation on this exchange, and (2) to document a possible bathymetrically controlled estuarine turbidity maximum (ETM) near the northern tip of Ryer Island (Garnet Point). This study was funded through the IEP and the Department of Interior's Place-Based program and was conducted in collaboration with Dave Schoellhamer, USGS. The data from this large effort have been processed and preliminary analyses have begun. Draft reports are expected sometime this fall.

Personnel and equipment associated with the hydrodynamics of North Bay study element also significantly contributed to the design and execution of the Delta Cross Channel fish passage study described in the "Delta Flows" study element (see page 3). Finally, we've continued to operate 12 self-contained salinity sensors that are deployed on the estuary bed in the channels of North Bay. Since December 1997, these sensors have continuously monitored the temporal evolution of the spatial structure in the near-bed salt and temperature fields from a site adjacent to the city of San Francisco to a site in the Sacramento River near Collinsville. Two additional sites were added to this network in June 2000 to study the tidal timescale compression and dilation of the near-bed salt field on the seaward side of Pinole Shoal and on the seaward side of the Benicia Bridge.

This IEP study element has also continued a strong collaborative relationship with academic colleagues at Stanford University, UC Berkeley and UC Davis. These collaborations have leveraged small IEP investments in field resources towards greatly increasing our understanding of a wide range of physical processes. For example, two Ph.D. theses from this collaboration were recently completed. Jessica Lacy published work on Honker Bay entitled "Circulation and transport in a semi-enclosed estuarine subembayment" at Stanford University under the direction of Stephen Monismith. John Warner published work on the Napa-Sonoma marsh complex entitled

"Barotropic and baroclinic convergence zones in tidal channels" at UC Davis under the direction of Geoff Schladow. In addition, results from these collaborations were also presented at a series of scientific conferences this fall.

Two talks were presented at the 6th International Conference on Nearshore and Estuarine Cohesive Sediment Transport Processes on September 4-8, 2000, in Delft, the Netherlands. They were titled, "Tidal asymmetry of erodibility at a site in San Francisco Bay, USA" by M.L. Brennan[1], D.H. Schoellhamer[2], J.R. Burau[2], and S.G. Monismith[1], and "Transfer of cohesive sediment between the bed and water column at a site in San Francisco Bay, USA" by D.H. Schoellhamer[2], J.R. Burau[2], M.L. Brennan[1], S.G. Monismith[1]. The conference proceedings will be published as a series of peer reviewed papers in book form. Additionally, the "Effects of Tidal Current Phase at the Junction of Two Straits" by J.C. Warner[3], S.G. Schladow[3], D.H. Schoellhamer[2], and J.R. Burau[2] was presented at the 10th International Biennial Conference on Physics of Estuaries and Coastal Seas on October 7-11, 2000, in Norfolk, Virginia. Both papers will appear in a peer-reviewed special issue of *Continental Shelf Research and Journal of Marine Systems*.

Finally, three of the 15 posters presented at the Estuarine Circulation, Mixing, and Modeling session of the American Geophysical Union's 1999 fall meeting, held December 13-17, 1999, in San Francisco, California, were at least partially funded by the IEP. These included "Effects of tidal current phase at the junction of two straits" by J.C. Warner[3], D.H. Schoellhamer[2], J.R. Burau[2], and S.G. Schladow[3]; "Lateral variability and secondary currents in Suisun Cutoff, San Francisco Bay" by J.R. Lacy[1], J.R. Burau[2], M.T. Stacey[4], S.G. Monismith[1]; and "The vertical structure of the turbulent kinetic energy balance in a stratified estuary" by M.T. Stacey[4], S.G. Monismith[1], J.R. Burau[2], J.R. Brennan[1], J.R. Lacy[1].

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Knights Landing Juvenile Salmonid Monitoring

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Juvenile salmonid emigration monitoring at Knights Landing continued from October through December 2000. Very few salmon have been collected apparently due to minimal changes in flow in the Sacramento River. Only 41salmon were collected between November 6 and the end of December. Twenty-one of the 41 were collected on December 20; 34 were collected between December 20 and 26.

This year's catch is comparable to that observed in the fall and winter of 1999. Within this period, less than 40 fish were collected until mid-January when storm induced flow increases eventually occurred. Since 1995, a majority of the late-fall- (>90%), winter-run- (>75%) and spring-run-sized salmon (>70%) catches at Knights Landing typically occurred during this first phase of emigration (November through early January). So far in 2000, only 12 late-fall, 21 winter- and two spring-run-sized salmon have been caught through December 31.

Fall Midwater Trawl

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The Fall Midwater Trawl Survey (FMWT) began in mid-September and was successfully completed in mid-December 2000. Four monthly surveys were conducted at the following areas: San Pablo Bay, the Carquinez Strait, Suisun Bay, the lower Sacramento and the lower San Joaquin rivers, and the eastern Delta. Some data are still subject to Quality Assurance and Quality Control procedures and so all indices (Table 1) and discussions of distribution are preliminary.

Table 1 Monthly and fall indices of abundance for various species caught in the 2000 and 1999 Fall Midwater Trawl Surveys[a]

Species and year	*Sep*	*Oct*	*Nov*	*Dec*	*Fall index*
Striped bass					
2000	93	156	90	50	389
1999	154	68	134	185	541
Delta smelt					
2000	430	128	56	143	757
1999	198	380	114	172	864
Longfin smelt					
2000	1,635	48	940	815	3,438
1999	1,953	2,736	330	223	5,242
Sacramento splittail					
2000	0	4	1	0	5
1999	24	3	12	0	39
American shad					
2000	253	326	125	57	761
1999	346	155	145	69	715

[a] Indices for 2000 are preliminary and subject to change.

Young-of-the-Year Striped Bass

The fall index for striped bass decreased by 28% from 541 in 1999 to 389 in 2000. Striped bass were widely distributed in the estuary with the exception of San Pablo Bay, where they were only caught during the October Survey. Striped bass were only caught in the Carquinez Strait during the November and December Surveys. The majority of catches were made in Suisun Bay, the Sacramento and San Joaquin rivers, and the eastern Delta.

Delta Smelt

The fall index for delta smelt decreased by 12% from 864 in 1999 to 757 in 2000. The distribution for delta smelt was more constrained than it was for striped bass. Delta smelt were only caught in the Carquinez Strait during the September survey and were not caught in San Pablo Bay or the eastern Delta in any of the surveys. Delta smelt were consistently caught in Suisun Bay and the Sacramento and San Joaquin rivers during all four surveys with the following exceptions. Delta smelt were not caught in the Sacramento River during the September survey and were not caught in the San Joaquin River during the October survey.

Young-of-the-Year Sacramento Splittail

The fall index for Sacramento splittail decreased by 87% from 39 in 1999 to 5 in 2000. The FMWT only caught six young-of-the year (YOY); descriptions of their relative distribution are inappropriate.

Longfin Smelt

The fall index for longfin smelt decreased by 34% from 5,242 in 1999 to 3, 438 in 2000. The highest concentrations of longfin smelt were in Suisun Bay during all four surveys and they were consistently caught in San Pablo Bay, the Carquinez Strait, and the Sacramento River. Only during the November and December Surveys were longfin smelt caught in small numbers in the San Joaquin River. No longfin smelt were caught in the eastern Delta.

American Shad

The fall index for American shad increased by 6% from 715 in 1999 to 761 in 2000. American shad distribution was wide and highly variable in the estuary during the 2000 FMWT, with American shad being caught in all areas during the September, October, and November surveys. American shad were not caught in the San Joaquin River during the December survey.

Developing a Diagnostic Key for Identifying Larval Osmerids

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We have identified several distinct characteristics believed to be unique to delta smelt and wakasagi at various life stages (yolk sac to 14 mm standard length). We are now in the process of measuring the variability among these characteristics from wild larvae (verified to species with genetic analysis) and larvae reared at the culture facilities. The specimens are being photographed using ImagePro Plus. To date, we have completed a morphometric analysis on approximately 60 photographed larvae from three different stages of interest (4 to 6 mm, 6.1 to 10 mm and 10.1 to 12 mm and larger). We will complete an inventory of preserved specimens from DFG and the

CVP to determine how many additional samples we will need to collect from the wild this spring. We plan to collect wakasagi from Folsom Lake during January and February 2001. We also will attempt to collect delta smelt from the field this spring. Through genetic analysis, we will verify the stock of osmerids collected in the Delta and use these collections as voucher specimens for key development and validation.

Splittail Investigations

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Field sampling to identify juvenile splittail riverine habitat ended abruptly September 25. Sampling ended early on the last day of the study phase before implementation of selective sampling. So we could not determine if juvenile splittail could still captured in the area or were concentrated in a few select locations. As mentioned in the summer quarterly highlights, only two juvenile splittail were captured during the study phase of this year's sampling, whereas over 300 juveniles were captured in the same area during the training period earlier in the summer. A suitable alternate boat was not available, so we did not determine if our limited splittail catch resulted from their low numbers and ability to avoid the net or because we missed sampling habitats where they were concentrated.

Sherman Island Agricultural Diversion Evaluation

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We are preparing a draft report of our 2000 sampling at side-by-side screened and unscreened diversion siphons in Horseshoe Bend. Our primary conclusions are that (1) entrainment through the screened diversion was significantly lower than through the unscreened diversion, and (2) there are very apparent tidal and diel (day-night) effects on fish entrainment, but different species respond in different ways to these cycles. The second conclusion has important implications for managing unscreened diversions to protect suites of species and for particle tracking modeling of small fishes.

Townet Survey

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We conducted four, biweekly surveys during the 2000 Townet Survey (TNS): survey 1 (June 23–27), survey 2 (July 7–11), survey 3 (July 21–25), and survey 4 (August 4–8). Each survey lasted five days and sampled 32 stations with up to three, ten-minute, oblique tows. Indices of abundance were calculated using 31 stations.

Results from surveys 1 through 4 are reported here and are restricted to young-of-the-year (YOY) fish. For striped bass, YOY includes all bass ≤99 mm FL. For delta smelt, YOY includes all smelt ≤69 mm FL. Only two striped bass >99 mm FL and only six delta smelt >69 mm FL were caught during the 2000 TNS. Index calculations for striped bass are described in Chadwick (1964) and Turner and Chadwick (1972); the same method was used for delta smelt.

As the 2000 TNS was a relatively "long" survey it is possible to detect spawning events. The following are hypothesized trends for a single spawning event: (1) consistently decreasing abundance, (2) consistently increasing size (FL), and (3) a constant growth rate (given constant conditions). Growth rates were calculated as [(mean length$_{\text{survey n+1}}$) – (mean length$_{\text{survey n}}$)]/14 days. Other observed trends could indicate multiple spawning events.

The distribution of striped bass and delta smelt is described by partitioning the 31 stations used in the index into six areas and calculating the percentage of survey index for that area/survey. The areas are Montezuma Slough, Suisun Bay, the Sacramento River, the San Joaquin River, the East Delta, and the South Delta.

Striped Bass

The 2000 TNS detected one spawning event of striped bass. Mean length of striped bass increased with each survey in a relatively smooth progression while the survey index consistently decreased (Table 1). The resulting growth rates are surveys 1–2, 0.58 mm/day; surveys 2–3, 0.92 mm/day; and surveys 3–4, 0.66 mm/day. Although not constant, the growth rates are reasonable for striped bass observed by the TNS. A visual inspection of length-frequency plots (Figure 1) gives further indication of a single spawning event.

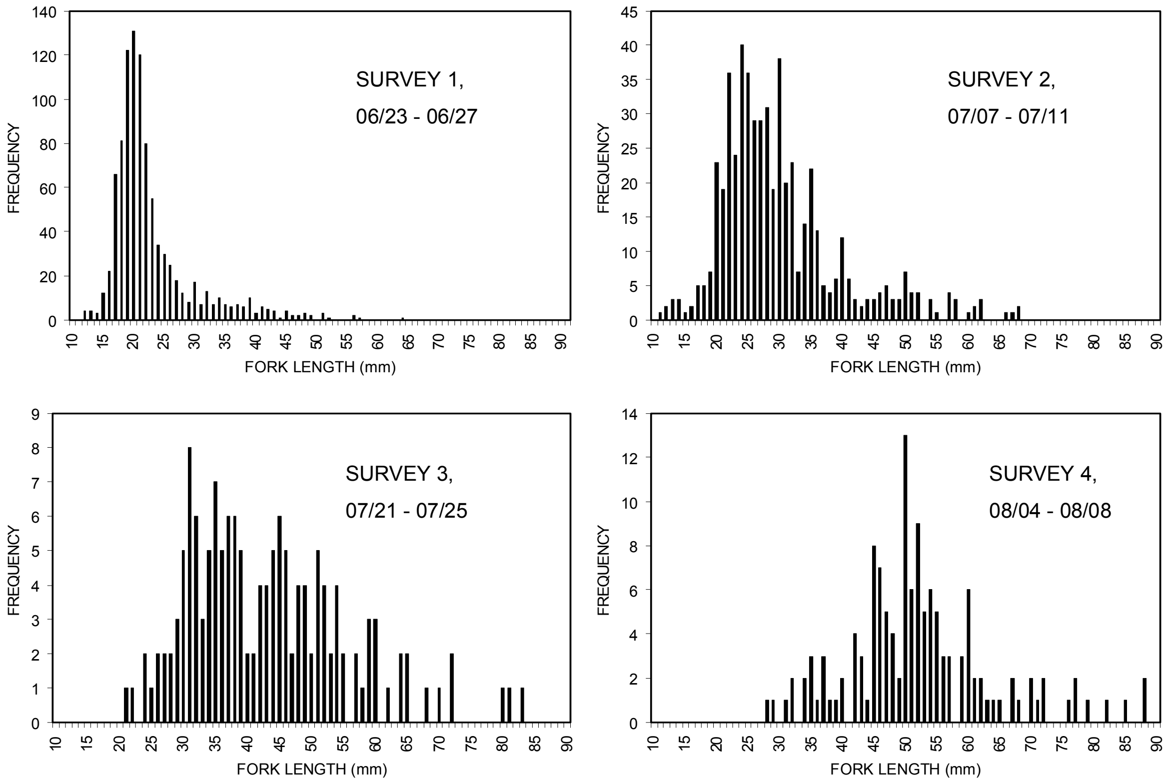

Figure 1 Length-frequency plots for YOY striped bass for townet surveys 1–4, 2000

Table 1 Mean length, standard deviation, sample size, and survey indices for striped bass and delta smelt during townet surveys 1–4, 2000

	Survey 1	*Survey 2*	*Survey 3*	*Survey 4*
Striped bass				
Mean length (mm FL)	21.9	30.0	42.9	52.1
SD (mm)	7.0	9.8	12.5	11.7
N	958	547	149	134
Survey index	15.5	13.1	3.3	2.9
Delta smelt				
Mean length (mm FL)	31.7	33.2	41.0	42.0
SD (mm)	7.3	8.3	8.0	8.8
N	186	227	213	159
Survey index	7.8	8.1	7.8	4.3

The distribution of striped bass showed little variation during the 2000 TNS with the exception of the large change in percentage of index occurring between surveys 3 and 4 in Montezuma Slough (Table 2). Striped bass were mainly distributed in Montezuma Slough, Suisun Bay, and the Sacramento and San Joaquin rivers (Table 2). The fraction of index set in the East Delta was never more than 10% for any survey and only during Survey 1 were striped bass caught in the South Delta (Table 2). The large change in percentage of index in Montezuma Slough could indicate a shift in distribution. However, the absolute catch during survey 4 was only 15 fish less than for survey 3 (Table 1), hinting at the possibility of better survival for YOY striped bass in Montezuma Slough than in other parts of the estuary.

Delta Smelt

The 2000 TNS detected at least two major spawning events for delta smelt. Although mean length did increase with each survey, there was an abrupt change between surveys 2 and 3 (Table 1). The corresponding growth rates are surveys 1–2, 0.11 mm/day; surveys 2–3, 0.56 mm/day; and surveys 3–4, 0.07 mm/day. Abundance was relatively stable until survey 4 when it decreased by 45% from the survey index set during survey 3 (Table 1). These observed trends are inconsistent for a single, spawning event. An inspection of the length-frequency plots indicates at least two spawning events (Figure 2).

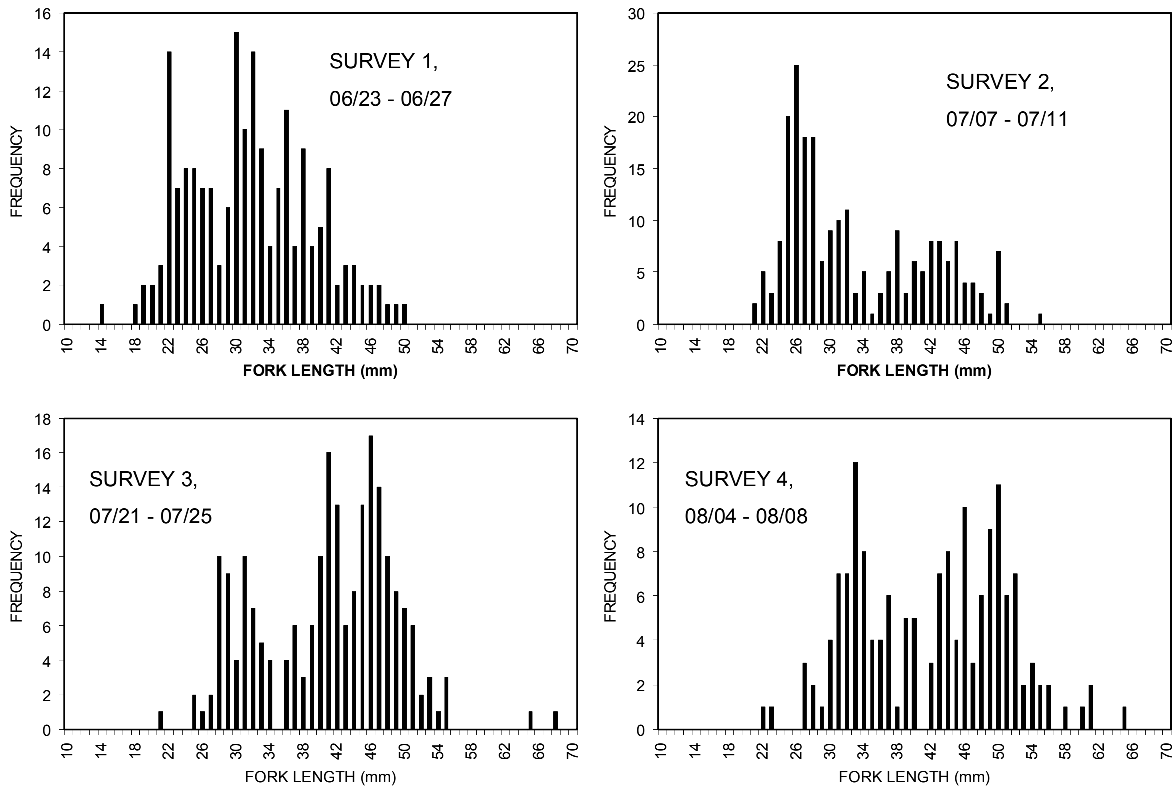

Figure 2 Length-frequency plots for YOY delta smelt for townet surveys 1–4, 2000

Table 2 Percentage of survey index for striped bass and delta smelt for townet surveys 1–4, 2000

Species and area	*Survey 1*	*Survey 2*	*Survey 3*	*Survey 4*
Striped bass				
Montezuma Slough	27.2	29.9	35.2	53.5
Suisun Bay	24.6	18.1	15.6	11.6
Sacramento River	18.4	24.0	20.8	14.0
San Joaquin River	18.2	26.3	24.3	18.2
East Delta	9.3	1.8	4.2	2.6
South Delta	2.2	0.0	0.0	0.0
Delta smelt				
Montezuma Slough	0.8	1.4	1.2	21.3
Suisun Bay	24.6	28.4	77.0	58.2
Sacramento River	68.6	68.6	17.5	19.3
San Joaquin River	5.8	1.6	4.4	1.2
East Delta	0.2	0.0	0.0	0.0
South Delta	0.0	0.0	0.0	0.0

Distribution of delta smelt shifted from the Sacramento River into Suisun Bay and Montezuma Slough as the 2000 TNS progressed (Table 2). Catches in the San Joaquin River never accounted for more than 5.8% of the index (Table 2). Only during survey 1 were delta smelt caught in the East Delta and no delta smelt were caught in the South Delta (Table 2).

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DISSOLVED OXYGEN LEVELS IN THE STOCKTON SHIP CHANNEL

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Dissolved oxygen concentrations in the Stockton Ship Channel (channel) are closely monitored during the late summer and early fall of each year because levels can drop below 5.0 mg/L, especially in the eastern portion of the channel. Several factors are thought to contribute to dissolved oxygen decrease in this area including low San Joaquin River inflows, warm water temperatures, high biochemical oxygen demand (BOD), reduced tidal circulation, and intermittent reverse flow conditions in the San Joaquin River past Stockton. Low dissolved oxygen levels can cause physiological stress to fish and inhibit upstream migration of salmon.

Monitoring of dissolved oxygen levels in the Channel was conducted seven times by vessel between August 14 and November 14, 2000. During each of the monitoring runs, 14 sites were sampled from Prisoner's Point in the central Delta to the Stockton Turning Basin. Dissolved oxygen and water temperature data were collected for each site at the top and bottom of the water column during ebb slack tide using traditional discrete (Winkler titration) and continuous monitoring (Hydrolab DS-3 multiparameter surveyor or Seabird 9/11 multiparameter sensor) instrumentation. Monitoring by vessel is supplemented by an automated multiparameter water quality recording station near Burns Cutoff at the western end of Rough and Ready Island. This site captures diel variation in dissolved oxygen levels, and indicated that early morning dissolved oxygen levels were often lower than values recorded later in the day throughout the fall monitoring period.

A dissolved oxygen sag (levels of 5.0 mg/L or less) rarely occurred in the Channel during the monitoring period, although depressed levels (between 5.1 and 6.0 mg/L) persisted in August and September. As in previous years, dissolved oxygen levels in the western portion of the channel from Prisoner's Point to Disappointment Slough were relatively high and stable throughout the study period, and ranged from 6.7 to 11.2 mg/L. Dissolved oxygen levels within the central channel from Columbia Cut to Fourteen Mile Slough ranged from 4.5 to 9.2 mg/L. Levels dropped below 5.0 mg/L on August 14 at Lights 28 and 34 and on September 26 at Lights 18 and 19. The lowest dissolved oxygen level (4.5 mg/L) occurred in August when temperatures were warmest (22.8 to 25.7 °C) and San Joaquin River flows were lowest (less than 2,000 cfs past Vernalis). In the eastern portion of the channel from Buckley Cove to the eastern end of Rough and Ready Island, the dissolved oxygen depression persisted in August and September, with levels improving to greater than 6.0 mg/L by early October. The dissolved oxygen levels in this region ranged from 5.0 to 10.3 mg/L.

By October 26, 2000, dissolved oxygen levels throughout the channel had recovered to 8.0 mg/L or greater. This sustained improvement was verified on November 14. Significantly cooler water temperatures (11.7 to 13.0 °C) and maintenance of adequate San Joaquin River inflows (average daily inflows past Vernalis of approximately 2,000 cfs) appear to have contributed to the maintenance of acceptable dissolved oxygen levels in the channel.

YOLO BYPASS FLOODPLAIN STUDY

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We began the fish sampling season for the Yolo Bypass Program with the installation of a fyke trap in the perennial Toe Drain channel in late September 2000. This will be the second season we tested this gear type for catching adult fish. Last year's sampling effort provided data on adult species composition, timing and duration of fish migration into the Yolo Bypass relative to different physical conditions. These results will be presented as a poster for the upcoming IEP Workshop (Asilomar, March 2001) and as a paper for the Riparian Habitat and Floodplain Conference (Sacramento, February 2001).

Native fish caught from October through December included five adult chinook salmon (mean fork length 729 mm), five Sacramento suckers (mean fork length 482 mm), and three Sacramento splittail (mean fork length 348 mm). As with last season, there has been a surprising number of adult striped bass: 117 striped bass (mean fork length 574 mm) have been captured since October. Other species include black crappie, carp, threadfin shad, and white catfish.

Similar to previous sampling years, the fish research component of the study will also include the use of a rotary screw trap and a number of beach seine stations. The screw trap was installed near the base of the Yolo Bypass in the Toe Drain in early January 2001 and will be operated 5 to 7 days per week, depending on catch and debris load. Beach seine sampling will be conducted at a number of locations in and around the perimeter of the floodplain on a monthly basis until floodplain inundation. During inundation beach seine stations will be sampled weekly.

In addition, we plan to release a total of 200,000 coded wire tagged salmon in groups of 50,000 into both the Yolo Bypass and the Sacramento River during February. These paired releases will provide additional information about floodplain salmon residence time, growth and survival.

Upper Estuary Chinese Mitten Crab Research Projects

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Two research projects are focused on Chinese mitten crabs in the Sacramento-San Joaquin Delta—one project (Chinese Mitten Crab Habitat Use Study) is evaluating mitten crab habitat use and the other (Mitten Crab Benthos Impact Study) is evaluating the effects of mitten crabs on the benthic invertebrate community.

For the Chinese Mitten Crab Habitat Use Study, we used “crab condos” and baited traps to collect mitten crabs in the Delta. Sampling with crab condos occurred primarily at Sherman Lake, Horseshoe Bend, and Frank’s Tract from July through December 2000. The crab condos were very successful at attracting juvenile crabs (total number of condos set = 496; total crab catch = 139). Mitten crab sizes ranged from 8 to 41 mm carapace width (CW), with an average size of 25 mm CW. Mitten crab catch increased in August (average number of crabs per condo or CPUE = 1.14, peaked in October (CPUE = 2.26, and declined sharply in December (CPUE = 0.08). Preliminary analysis indicates mitten crabs are more common in shallow (0.5 to 2 m) areas with submerged or emergent aquatic vegetation, followed by deep (over 5 m) channel areas. Mitten crabs were less common in shallow areas with no vegetation and in shallow riprapped areas.

Sampling with baited traps occurred February through December 2000. Baited traps were not successful at collecting mitten crabs (total number of baited traps set = 1,871, total crab catch = 8). We simultaneously fished baited traps and crab condos at Horseshoe Bend and Sherman Lake to confirm that local mitten crab density was not a factor in trapping success. On both sampling occasions, crabs were collected with crab condos but not with baited traps. Of the mitten crabs captured, four were collected in channels 3 to 5 m deep, two were collected in channels over 5 m deep, and two were collected in shallow areas with dense aquatic vegetation.

For the Mitten Crab Benthos Impact Study, we used otter trawls to conduct monthly sampling from April 2000 through November 2000. Sampling took place at DWR’s historical benthic monitoring sites. Originally, nine sites were sampled, but the number was reduced to seven (Suisun Bay, Grizzly Bay, Collinsville, Twitchell Island, Sherman Lake, Rio Vista, and Rock Slough) due to extensive debris and other safety hazards at two of the sites. Objectives of this first phase of the study were to determine crab presence at the benthic sites and the success rate of otter trawling as a sampling method. To date, 11 crabs have been collected at five of the sites. Two crabs have been collected in Suisun Bay near Martinez (D6), one female measuring 54 mm CW and one male measuring 46 mm CW. Five crabs have been collected in the Sacramento River at Collinsville (D4), two females (56 and 33 mm CW) and 3 males (57, 12, and 19 mm CW. One 50 mm CW male crab was collected in the San Joaquin River near Twitchell Island (D16) and a newly molted 60 mm CW male crab was collected in Rock Slough (D28A) near Holland Tract. Two crabs were also collected in the Sacramento River just below the Rio Vista Bridge (D24); both crabs were male measuring 27 and 66 mm CW.

In addition to otter trawling, a brief enclosure study was conducted during September. The purpose of this pilot study was to determine an appropriate enclosure design for mitten crab retention. This second phase of the Mitten Crab Benthos Impact Study will examine direct effects of the mitten crab on the benthic community and will commence in spring 2001.

SHALLOW WATER METHODS STUDY

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In 2000, we conducted preliminary field work for minnow seine, seine-depleted block net, and electrofishing methods. These are the primary technologies being investigated in this study. Most field time was expended on test-runs of the experiments we have selected for gear efficiency evaluation; the remaining time was spent exploring monitoring methodology issues, especially the selection of field protocol for the minnow seine in various situations. Six field sites on the Sacramento River (west bank 3 km south of Rio Vista; east shore of Decker Island), San Joaquin River (Venice Cut Island and adjacent ship channel), Mildred Island interior, and Liberty Island interior were adopted for the study. The project database, to date representing 300 seine hauls, 52 blocknet samples, and 30 electrofishing samples, is now complete and error-checked, thanks to the much-appreciated efforts of Randy Baxter.

Formal gear efficiency tests of seine, blocknet, and electrofishing technologies under likely use scenarios will be completed in 2001. We will also experiment with a channel-blocking fyke trap technique that may be useful in more saline tidal marshes around San Francisco Bay, and will investigate other technologies as time permits.

PREDATOR-PREY DYNAMICS STUDY

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This study relies in part on pairing prey samples collected during the course of the Shallow Water Methods Study with predator samples collected contemporaneously by gillnet in adjacent nearshore areas. In 2000, paired predator and prey samples were collected on 16 dates (June through October) at five stations: all the sites employed by the Shallow Water Methods Study except Liberty Island.

All predator stomach analyses and data entry for 2000 are complete, and the database is currently being error-checked. Sample sizes for the year are: 164 striped bass (53 to 512 mm SL), 102 largemouth bass (51 to 458 mm SL), 54 Sacramento pikeminnow (72 to 512 mm SL), 17 black crappie (52 to 265 mm SL), and 7 channel catfish (103 to 468 mm SL).

2001 PROGRAMMATIC REVIEW OF THE IEP ENVIRONMENTAL MONITORING PROGRAM

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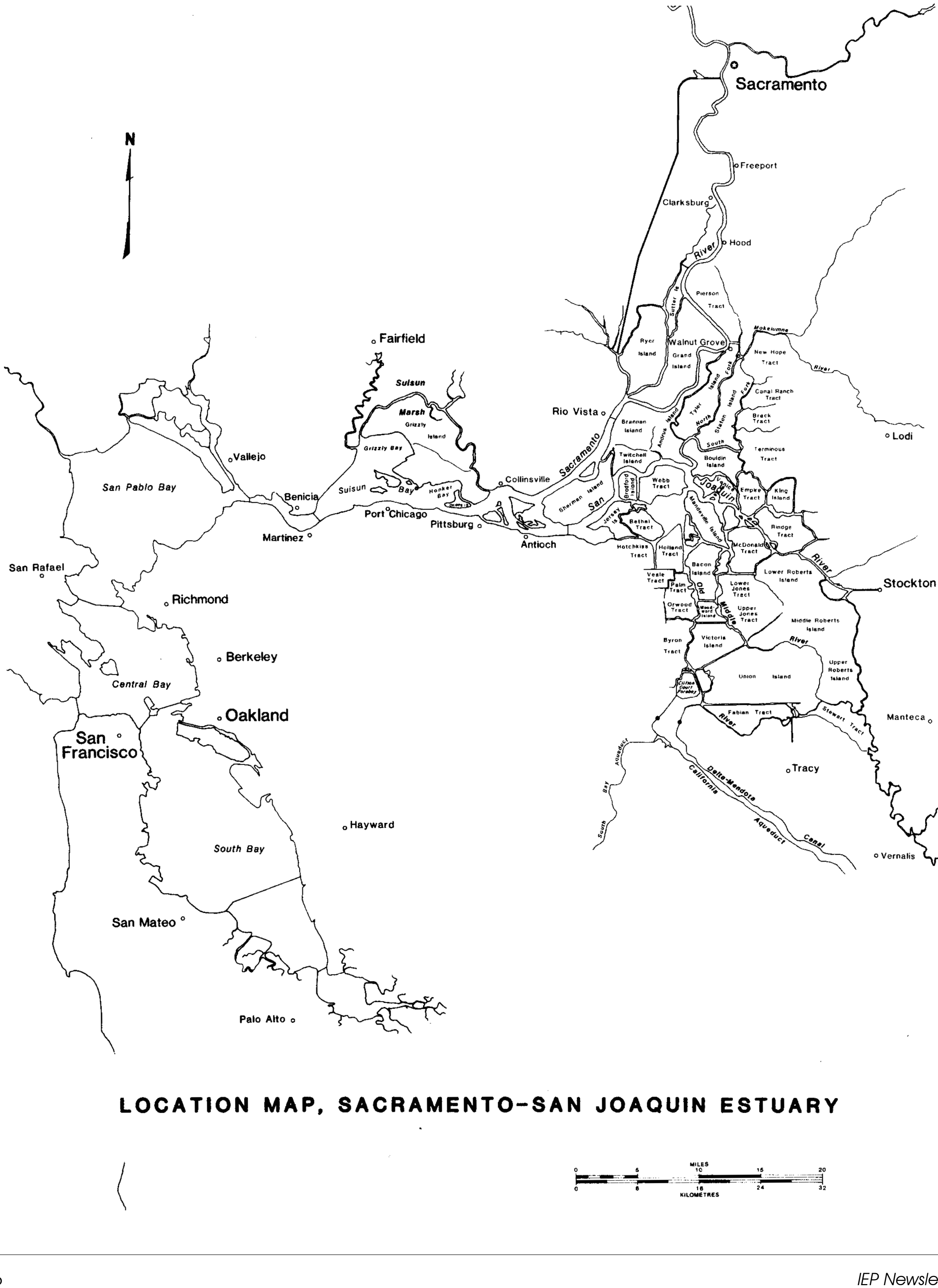
The IEP Environmental Monitoring Program (EMP) is undergoing a programmatic review under the direction of the IEP Water Quality Project Work Team. The EMP is carried out in compliance with State Water Right Decision D-1641 controlling exports and operations of the State Water Project and Central Valley Project. The main objective of the EMP is to monitor the effects of water project operation on water quality and lower trophic levels. For the past 30 years, the monitoring program has routinely collected data on traditional water quality constituents, phytoplankton, zooplankton, and benthos in the Delta, Suisun Bay, and San Pablo Bay. It provides long-term environmental information to IEP agencies as well as to other data users. Now beginning its fourth decade, the program is faced with many new challenges and opportunities such as its interaction with CALFED and the emergence of new technologies and information needs. The 2001 review offers a unique chance to launch a reinvigorated environmental monitoring program for the 21st century.

Participants in the 2001 review of the IEP EMP will include invited technical experts, stakeholder representatives, the IEP Science Advisory Group (SAG), and EMP staff. According to the current plan prepared by the Water Quality PWT, participants review the plan over the course of three to four large meetings and in small subject area teams starting in March 2001. The subject area teams will produce technical subject area reviews and monitoring plans. These will be synthesized into a comprehensive review summary and a draft monitoring plan which will then be discussed and finalized in follow-up meetings by all review participants and the SAG. EMP staff have prepared an information package for review participants that includes a historical overview of the IEP EMP and a description of its current design. The package will be distributed to review participants pending final IEP approval of the review process.



LOCATION MAP, SACRAMENTO–SAN JOAQUIN ESTUARY

SIMPLIFIED CONVERSIONS BETWEEN SPECIFIC CONDUCTANCE AND SALINITY UNITS FOR USE WITH DATA FROM MONITORING STATIONS

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The U.S. Geological Survey, Bureau of Reclamation, and the California Department of Water Resources maintain a large number of monitoring stations that record specific conductance, often referred to as "electrical conductivity," in San Francisco Bay Estuary and the Sacramento-San Joaquin Delta. Specific conductance units that have been normalized to a standard temperature are useful in fresh waters, but conversion to salinity units has some considerable advantages in brackish waters of the estuary and Delta. For example, salinity is linearly related to the mixing ratio of freshwater and seawater, which is not the case for specific conductance, even when values are normalized to a standard temperature. The Practical Salinity Scale 1978 is based on specific conductance, temperature, and pressure measurements of seawater and freshwater mixtures (Lewis 1980 and references therein). Equations and data that define the scale make possible conversions between specific conductance and salinity values.

This article presents a simplified conversion to salinity units for use with specific conductance data from monitoring stations that have been normalized to a standard temperature of 25 °C and an equation for the reverse calculation. Although these previously undocumented methods have been shared with many IEP agencies over the last two decades, the sources of the equations and data are identified here so that the original literature can be accessed.

Specific conductance is expressed in units of Siemens per centimeter at the temperature of the measurement (note that the term "specific" refers to 1 cm-cell geometry rather than a temperature of 25 °C, which is a common error). Rather than reporting specific conductance values at ambient water temperatures, values recorded by most instruments are normalized to a standard temperature of 25 °C using an average temperature coefficient of about two percent per degree Celsius. This procedure greatly facilitates interpretation of data, but it can be a potentially large source of error when ambient temperatures are much lower than 25 °C. In general, salinity values computed from normalized data are not as accurate as values computed from ambient measurements of specific conductance and temperature. The simplified conversions shown below assume that specific conductance values have been normalized to a temperature of 25 °C and that pressure corrections are unnecessary at shallow water depths.

SPECIFIC CONDUCTANCE AT 25 °C TO SALINITY CONVERSION

The general equations for the Practical Salinity Scale (PSS) are given by Lewis (1980) in a volume of the IEEE Journal of Oceanic Engineering dedicated to defining the details of the scale. The equation shown below is a simplification of equation 9 in Lewis' paper for the case of a single temperature, 25 °C.

$$S = K_1 + \left(K_2 \times R^{1/2}\right) + (K_3 \times R) + \left(K_4 \times R^{3/2}\right) + \left(K_5 \times R^2\right) + \left(K_6 \times R^{5/2}\right)$$

where,

$K_1 = 0.0120$ $K_2 = -0.2174$ $K_3 = 25.3283$ $K_4 = 13.7714$ $K_5 = -6.4788$ $K_6 = 2.5842$

Terms were combined to create the new set of coefficients, K_n. The R variable is the ratio of the sample specific conductance at 25 °C to that of standard seawater (salinity = 35) at the same temperature (53.087 milliSiemens per centimeter; Poisson [1980] and references therein). The first step in using the equation is to divide the sample values by the standard seawater value, producing conductivity ratios for each sample. Although this step could have been incorporated into the coefficients of the equation, the R values, which range from about 0 (freshwater) to 1 (standard seawater), provide a check that the sample data are in the correct units. Salinity values are unitless in this scale. However, since most scientists are used to seeing the parts per thousand (‰) unit for salinity, values for the PSS are often followed by "psu" (practical scale units) for clarity.

Salinity to Specific Conductance at 25 °C Conversion

Calibrations of field instruments often require the calculation of specific conductances from laboratory salinometer values. In some cases it is necessary to use the general equations for calculating specific conductance at ambient temperatures from salinity, as given by Poisson (1980). For the case where specific conductance at 25 °C is needed, Poisson's equation 15 can be simplified to the following expression.

$$X_{25,S} = (S/35) \times (53087) + S(S-35) \times \left[J_1 + \left(J_2 \times S^{1/2}\right) + (J_3 \times S) + \left(J_4 \times S^{3/2}\right)\right]$$

where,

$J_1 = -16.072$ $J_2 = 4.1495$ $J_3 = -0.5345$ $J_4 = 0.0261$

Terms were combined to create the new set of coefficients, J_n. Specific conductance at 25 °C, $X_{25,S}$, is calculated in microSiemens per centimeter. S is the practical salinity value.

Since both conversions require the input of several coefficients, it is most likely that the user will create a program or macro for multiple calculations. After doing this, the equations should be checked by using the data near 25 °C provided by Poisson (1980, Table 1, multiply conductivity ratio values by 53087 for specific conductance values at 25 °C in microSiemens per centimeter). The PSS 1978 was established for the salinity range of 2 to 42. Subsequent equations proposed by Hill and others (1986) that extend the scale to lower salinity values appear unnecessary for field studies, in part because most values are changed by less than 0.01 psu, which is beyond the resolution of most field instruments.

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Results of 2000 Salt Marsh Harvest Mouse Surveys in Suisun Marsh

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The California Department of Fish and Game and California Department of Water Resources have been conducting annual surveys of the endangered salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*, SMHM) in Suisun Marsh since 1998. The goal is to determine if the mice are present, and to make inferences about habitat suitability.

All surveys were conducted on DFG lands managed as SMHM habitat. These areas have either been designated as SMHM Conservation Areas to meet requirements of the Suisun Marsh Plan of Protection or mitigate for effects of DWR projects. There are currently eight conservation areas totaling more than 1,300 acres. Three areas are tidal marsh (Peytonia Slough, Joice Island, and Hill Slough East; 740 acres); the other five areas are diked managed ponds. An additional seven areas (1,400 acres) have been proposed as conservation areas. Six of these are diked managed marsh, one is tidal marsh (Hill Slough East Area 9, 430 acres). The two mitigation areas are located on Island Slough. Pond 7 (100 acres) is mitigation for construction of the physical facilities mandated in the Suisun Marsh Plan of Protection, and Pond 4 (57 acres) is mitigation for effects of the 1997 dredging of the Morrow Island Distribution System. Locations of the 17 areas are shown in Figure 1.

In 2000, nine areas of the marsh were surveyed: five existing conservation areas, two proposed conservation areas, and the two mitigation areas (Table 1). Survey methods were the same as those followed in 1998 and 1999 (Finfrock and Dorin 1999), except that we extended our survey period one additional day and set one hundred traps for four nights at each site (with the exceptions of five nights at Goodyear Slough and seven nights at Pond 15).

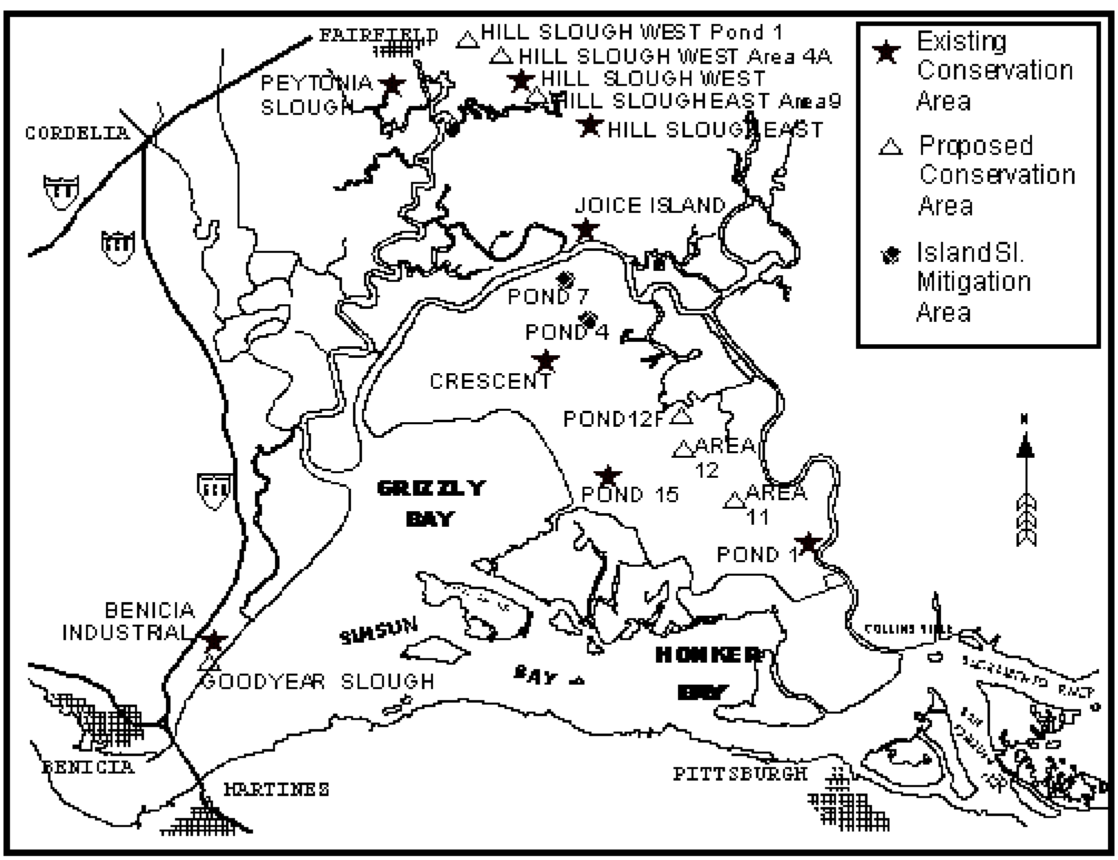

Figure 3 Areas of Suisun Marsh surveyed for presence of salt marsh harvest mice from 1998 to 2000

SMHM were captured in all areas surveyed except one mitigation area at Island Slough (Table 1). Six areas were surveyed in both 1999 and 2000, and trap success (total number of SMHM captured/total number of traps set) was lower at all six areas in 2000. This is not surprising given the large numbers of SMHM captured in 1999; populations were probably at their peak last year, and are now declining in the natural cyclic rhythm of rodent populations.

Table 1 Results of salt marsh harvest mouse surveys in Suisun Marsh, 1998–2000

	Trap success (No. of SMHM captured/No. of traps set)		
Location	*1998*	*1999*	*2000*
Existing conservation areas			
Benicia Industrial	0.093	0.083	0.052
Peytonia Slough	0.040		0.030
Hill Slough West	0.020		
Joice Island	0.000	0.010	
Crescent	0.013	0.333	0.090
Pond 15	0.023		0.057
Pond 1	0.030	0.020	0.007
Hill Slough East	0.000	0.003	
Proposed conservation areas			
Goodyear Slough		0.060	0.040
Hill Slough West Pond 1		0.230	
Hill Slough West Area 4A		0.050	
Area 11		0.160	
Pond 12F		0.210	
Area 12		0.110	
Hill Slough East Area 9		0.080	0.037
Mitigation areas			
Island Slough Pond 4			0.010
Island Slough Pond 7		0.063	0.000

The SMHM looks very similar to the common western harvest mouse (*Reithrodontomys megalotis*), which inhabits both marsh and upland habitats. There are several characteristics that are used to distinguish between the two (Shellhammer 1984). However, during 1999 and 2000, many captured harvest mice displayed characteristics intermediate between the two species and were termed "unknown harvest mice." These results led DWR to contract with Dr. Francis Villablanca at Cal Poly San Luis Obispo to conduct a genetic study of harvest mice in the Suisun Marsh. This study will develop genetic markers to identify the two species, test the validity of the morphological characteristics currently used in species identification, and determine if the two species are interbreeding. The genetic material used in the study will be from hair follicles collected from captured mice; we collected samples in 1999 and 2000. Preliminary results of the genetics study are expected by fall 2001.

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SUISUN MARSH MAPPING

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Introduction

Suisun Marsh, one of the largest brackish marshes in the United States, has recently been intensely inventoried, and mapped for vegetation at a detailed scale, in keeping with national standards for mapping and classifying vegetation. The process is complete and the data are now available for distribution on compact disc.

This undertaking is the culmination of an 18 month survey to learn, document, and classify habitats in the marsh. The marsh has been inventoried before, roughly on a three year cycle since the mid-1980s. This effort, like the effort in 1991, produced a GIS dataset.

This latest inventory used new GIS technology. Satellite imagery was used to quickly create habitat strata in the marsh. Field samples were collected using a stratified random sampling. Global Positioning Satellites systems were used to document field sample locations. These field samples were used to develop a classification system and to provide ground truth for the map. Aerial photographs were digitized and registered to map projection and are part of the dataset. An accuracy assessment of interpreted vegetation types was also performed. Approximately 260 samples were tested by field verification.

The map data may be used by resource managers with a minimum of computer and software configuration. The data are designed to be used, analyzed, and displayed with ArcView GIS software (Trademark ESRI), but may also be viewed with free ArcExplorer software or Adobe's Acrobat Reader.

The data may be used to support general ecological understanding of the marsh. Questions such as "How many acres of pickleweed exist and where are they?" can be answered simply. The mapping classification can further break down the type of pickleweed and other vegetation to a number of sub-categories called vegetation associations. For example there are nine different categories of pickleweed based on the mixture of other plant species associated with pickleweed. Further detail on the average amount of vegetative cover in six categories and the height of the vegetation are also available for the more than 31,000 individual mapped polygons.

The map may be used with other spatial data collected in the field as well, such as salt marsh harvest mouse trapping locations. Project management planners may use the data to see how much habitat exists on particular parcel segments. Scientists may want to use habitat data has a spatial strata to decide where to conduct field samples in future studies. New habitat protection areas may be evaluated quickly using the information in this map. For example, where would be a good place to locate a new salt marsh harvest mouse set aside area? Can adverse effects be minimized by placing new projects strategically so that sensitive resources are not affected? Several invasive plants that dominate vegetation stands are mapped, including *Lepidium latifolium* (Perennial pepperweed), *Arundo donax* (giant reed), *Cortaderia jubatum* (pampas grass) and *Phragmites australis* (common reed). Maps can be produced showing the location of these vegetation types.

Future studies may add some temporal aspects to this data. How has vegetation distribution and abundance changed over time? Plans include evaluating newer aerial photography annually and incorporating change into the "living map" of the marsh. There are also plans to go back into the archives of aerial photos from previous missions and re-map vegetation from the 1980s to discover the amount and direction of change in vegetation over time. All of this information will provide more solid grounds for sustained management of the marsh. These types of assessment are made possible because of the standardized methods of mapping and classification that are being employed.

In spring 2001, a brown bag seminar will be held to demonstrate use of the map and its associated products. Contact Terri Gaines, DWR, at tgaines@water.ca.gov for details. In addition, a poster at the IEP Workshop in March will demonstrate the map.

PRELIMINARY ANALYSIS OF LONG-TERM BENTHIC COMMUNITY CHANGE IN GRIZZLY BAY

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Multivariate analyses of benthic community data from the DWR compliance monitoring site D7 in Grizzly Bay and physical data from the San Francisco Estuary show community change to be related to environmental variability and the introduction of *Potamocorbula amurensis* in the upper estuary. DWR site D7 has been consistently sampled since 1977 and provides a rare long-term benthic data set. These data chronicle the benthic assemblage in Grizzly Bay from 1977 through 1999. During this period there have been many environmental and biological changes including an extreme drought (1977), an extended drought (1987-1992), several El Niño cycles, and the introduction (fall 1986) of the clam *P. amurensis* to the estuary.

Cluster analysis, a method to represent the hierarchy of similarity of species composition between years, was used to determine if there were changes in the benthic community over time. A dissimilarity matrix for annual average species abundance (averaging monthly species abundance values) was generated using Bray-Curtis similarity coefficients. A dendrogram was then drawn using un-weighted pair group method clustering. The dendrogram (Figure 1) shows the patterns of benthic community change over the long term.

Clustering of yearly averaged abundance data indicates a clear contrast in community composition between the years before 1986 and after 1987, when *P. amurensis* was established in the upper estuary. Before 1987 the composition of the benthic community was relatively dissimilar from year to year and carries no strong separation between wet and dry year types. After *P. amurensis* was established in Grizzly Bay the species assemblage from all years are very similar and years cluster together by wet or dry types.

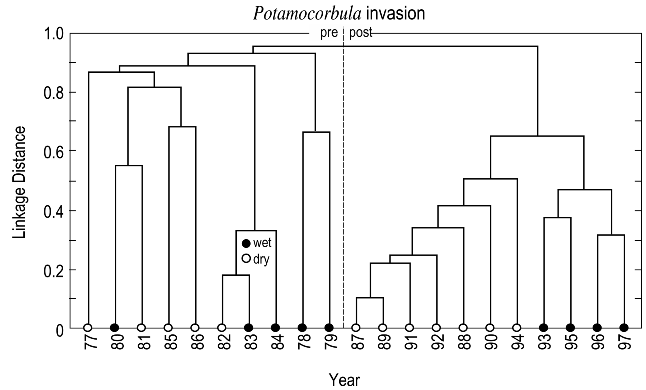

Figure 1 Cluster diagram of yearly averaged monthly benthic abundance data from 1977 to 1997 at DWR site D7 in Grizzly Bay. Clustering shows a clear contrast in community composition between the years before 1986 and after 1987, when P. amurensis was established in the upper estuary. Benthic community composition is compared between years using the Bray-Curtis similarity coefficient and un-weighted pair group clustering.

To further examine changes in community composition, trends in benthic organism abundance were compared with trends in X_2, the distance of the 2 psu isohaline relative to the Golden Gate (Jassby and others 1995). Because X_2 is an index of flow and salinity conditions, the response of a species to changes in these variables may be reflected in the relative trends of the species abundance and X_2. Thus, for example, the abundance of species that are favored in low flow, high salinity, or drought years show an increase in abundance when X_2 is high. Note that in the time series plots (Figure 2) species abundance values and X_2 are standardized ($X_i - X_{mean}$/standard deviation X) (Sokal and Rohlf 1995), allowing abundance data for several species to be plotted with X_2 on a common scale where each value is centered about its mean.

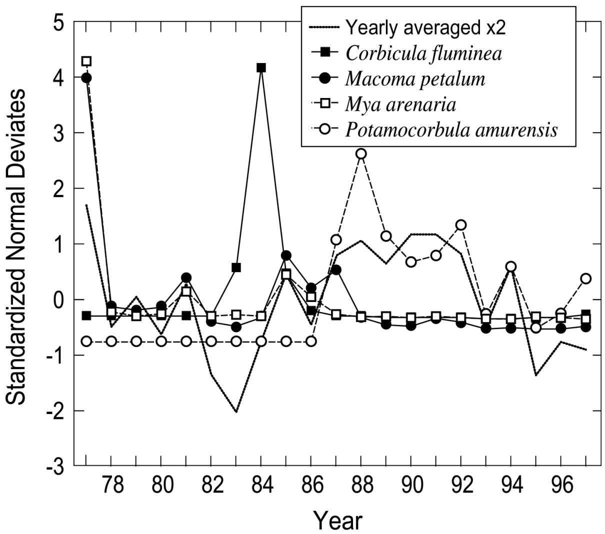

Figure 2 Standardized yearly averaged bivalve abundance plotted with X_2 from 1977 to 1997 at DWR site D7 in Grizzly Bay. Species abundance values and X_2 are standardized (X_i - X_{mean}/standard deviation X) and plotted on a common scale where each value is centered about its mean. Change in the response of the dominant bivalves to X_2 since the invasion of *P. amurensis* is evident.

One clear result of this time series analysis was the unmistakable change in the response of the dominant bivalves to X_2 since the invasion of *P. amurensis*. Before the invasion of *P. amurensis*, the dominant bivalves *Mya arenaria* and *Macoma petalum* showed a distinct pattern of increased abundance in Grizzly Bay during dry conditions (Figure 2), a finding also noted by Nichols and others (1990) during the late 1980s. *Corbicula fluminea* abundance increased during the wet years in 1982–1984. However, prolonged drought conditions beginning in 1987 did not bring about the increased *M. arenaria* and *M. petalum* abundances seen in previous dry periods. The return of wet conditions and high outflow in 1995–1997 did not bring an increase in *C. fluminea* abundance either. All three species have remained rare in Grizzly Bay since the invasion of *P. amurensis*.

Patterns of decreased variability in abundance and generally decreased abundance corresponding to the beginning of the 1987 drought and the invasion of *P. amurensis*, are similar for other groups of dominant benthic organisms including polychaetes and amphipods. Environmental factors that favor *P. amurensis* may act to exclude other species. The change in community response to X_2 since the invasion suggests other mechanisms may support the continued dominance of *P.amurensis* in the benthos of Grizzly Bay. Likely mechanisms include food limitation by *P. amurensis* (Alpine and Cloern 1992), predation by *P. amurensis* on larval forms of other members of the benthic community, and competition for space. These mechanisms, as well as the apparent correlation between clam abundance in Grizzly Bay and X_2, will be the focus of further research.

Based on these preliminary results with the long-term data set at the Grizzly Bay site, I plan to expand the analyses to include more specific environmental variables such as phytoplankton biomass, suspended sediment concentrations, and body burdens of trace elements. Similar analyses are also being done with benthic data from DWR site D41A in San Pablo Bay, where monthly benthic sampling began in 1991.

This work is being done as part of my Master's thesis and is funded by an EPA grant for development of ecological indicators of environmental stress. The ecological indicators project has several components that incorporate data from many projects at San Francisco State University and use data from many ongoing State and federal monitoring programs. Results from the project will examine the utility of a range of biological indicators of the condition of trophic components of the upper San Francisco Estuary, ranging from primary producers to fish.

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CONTRIBUTED PAPERS

PROGRESS AND DEVELOPMENT OF DELTA SMELT CULTURE: YEAR-END REPORT 2000

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INTRODUCTION

Delta smelt, *Hypomesus transpacificus*, are endemic to the Sacramento-San Joaquin Estuary in northern California. Due to decline of the wild population since the early 1980s, delta smelt were listed as threatened by both State and federal agencies by 1993. Factors contributing to the decline are thought to include one or more of the following: the prolonged drought in the 1970s, loss of shallow water habitat, entrainment into State and federal water diversion facilities, competition with non-native species, contaminant concentrations in the Delta, and changes in zooplankton species and abundance (Moyle and others 1992; USFWS 1996).

Developing a method for the culture of this environmentally sensitive species was considered and approved in 1992 as a way of providing a supply of smelt for research without further diminishing the natural stock. Initial progress was made at two different locations, the University of California Davis campus and the State Water Project's (SWP) Fish Facility near Byron, California; however, culture efforts were consolidated in 1998 at the SWP Fish Facility (Lindberg and others 1998). Funding has been intermittent since 1992, nevertheless the project has expanded to include a larger broodfish facility, three recirculating larval and juvenile systems and a facility to rear live prey for the larvae.

The interest in culturing delta smelt for experimental purposes is larger today than it was in 1993 and the natural stock has not rebounded to meet the demand. Research programs have been placed on hold, or have used surrogate species, until a sufficient supply of delta smelt could be provided. Researchers from a wide variety of disciplines have expressed interest in securing large numbers of delta smelt (100 to 5,000) to investigate fish screen design improvement and testing at water-diversion facilities, and for toxicology, morphometrics, genetics, and behavioral studies.

Our culture development program systematically tests methodologies each year and incorporates the best techniques. Over the past two years we have succeeded in developing methods to spawn and rear smelt from egg through the sensitive and prolonged larval period to the juvenile and adult phases. We have also tested for factors important to larval feeding behavior and report additional findings here. Further investigations of rearing temperature effects and weaning larvae to prepared diets, planned this spring and summer, will enable us to improve production of juveniles in 2002. Over the next two years we anticipate meeting the goal of developing a reliable and technically feasible method for culturing delta smelt in support of the research community.

COLLECTION AND REARING OF BROODFISH

Delta smelt broodfish were collected using a purse seine and a lampara net with the assistance of the Department of Fish and Game (DFG) and transported using techniques described by Swanson and others (1996). Fish were collected in the lower Sacramento River between Sherman Island and Chipps Island and taken to the culture facility at the State Water Project site, Byron CA. Fatalities within 72 hours of capture were attributed to handling stress. Mortality of broodfish (those surviving the first 72 hours) over the past four years has been low through winter months (1% to 5%), but increased with spring spawning (12% to 20%) (Table 1). Fatalities during the spawning season consisted largely of spent females.

The size of captured delta smelt ranged from 48.7 to 61.0 mm from 1997–2000. Average fork length and body weight over all collection years were 54.4 ± 2.6 mm and 1.16 ± 0.14 g, respectively (mean ± standard error of the mean) (Table 1).

Table 1 Size, survival, and collection fatalities of delta smelt broodfish from 1997–2000

Research year	*Mean fork length (mm)*[a]	*Mean body weight (g)*[a]	*Survival after capture (%)* 24 h	48 h	72 h	*Survival through winter*	*Survival through spawning*
1997[b]	48.7 ± 0.7	0.81 ± 0.40	93	92	91	98	81
1998[c]	52.0 ± 0.63	1.14 ± 0.04	79	78	77	96	80
1999[d]	56.0 ± 0.07	1.24 ± 0.04	84	82	81	95	88
2000[e]	61.0 ± 0.25	1.46 ± 0.02	55	51	51	99	80

[a] Values for fork length and weight are means ± standard error.
[b] Smelt were collected November and December 1996.
[c] Smelt were collected November 1997.
[d] Smelt were collected October 1998.
[e] Smelt were collected October through December 1999.

The broodfish were held in a flow-through facility with six 1000-L circular tanks. Intake pumps from the Delta-Mendota Canal provided water to a temperature-controlled head tank, which delivered water to each of the broodfish tanks. Water inflow was maintained at 8 to 10 L/min/tank. Three tanks were placed outdoors, covered with shade cloth, and were exposed to natural sunlight (10.5 mEinst/m^2sec). The remaining three tanks were located indoors and received light from a small window and two incandescent lights cycling with the natural photoperiod (0.21 mEinst/m^2sec). Fish in each tank were fed a mix of two dry diets: Kyowa 1000-C (BioKyowa™, Kyowa Hakko Kogyo Co., Ltd.) and Silver cup #2 crumble (Silvercup™, Nelson and Sons Inc.). These were delivered continuously during daylight hours using mechanical feeders.

Spawning, Egg Collection and Egg Incubation

Spawning began late February as the water temperature approached 12 °C. Delta smelt appeared to broadcast their eggs close to the substrate during the night. The eggs are adhesive and attach by inversion of the outer chorion (Wang 1986). Few spawning events have been witnessed, but eggs were always present in a single layer on the bottom and have never been observed along tank walls.

Each morning tanks were examined for eggs by gently rubbing a hand over the bottom surface. An egg scraper was made by attaching a piece of sheet metal to the bottom edge of an aquarium net. We used it to cleave egg stalks and collect loosened eggs. The total number of eggs collected each day was estimated volumetrically (990 smelt eggs per/ml eggs) for all six tanks. Collected eggs were kept in special incubators. Incubators were cleaned daily and dead eggs were removed.

Smelt eggs hatched in 8 to 10 days at 15 to 17 °C. An air-lift was used to continuously circulate water over the eggs. Hatched larvae were carried out of the containment screen and into the incubator basin. Newly emerging larvae were removed, counted, and placed into 2-L beakers until five days post hatch, when they were added to the larval rearing tanks.

Over 115,000 eggs were collected in 2000, yielding more than 57,000 larvae (Table 2). Nearly two-thirds (64%) were collected from outdoor tanks. These were spawned earlier in the season in February. Fish reared in indoor tanks did not begin spawning until the end of March, when the ambient water temperature began to rise (15 °C). As the water temperature exceeded 18 °C, tank exchange rates were greatly reduced to minimize the load on the water chillers. On several occasions the chillers failed to cool the incoming water sufficiently. Flow to the tanks was turned off and ice was used to cool the tanks. Low flow rates and temperature disturbances may partially explain the lower egg production and poorer hatch rate from the indoor tanks (41,489 eggs, 32.5% hatch) compared to outdoor tanks (73,473 eggs, 59.7% hatch). A larger chiller was purchased this year to prevent future problems associated with insufficient chilling.

Table 2 Egg production from captive broodfish during the 2000 spawning season

Tank number	Spawning events[a]	Eggs collected	Eggs hatched
Indoor			
1	11	14,161	3,082
2	16	14,170	5,576
3	13	13,560	4,943
Outdoor			
4	22	19,313	12,658
5	33	44,849	26,034
6	7	9,311	5,157
Total	102	115,364	57,450
Egg production inside		41,891	13,601
% inside		36.3	23.7
Egg production outside		73,473	43,849
% outside		63.7	76.3

[a] Spawning event: number of days that eggs were collected from the broodfish tanks during the season.

LIVE FOOD PRODUCTION

Rotifers

Rotifers (*Brachionus plicatilis*) were cultured similarly to methods described by Baskerville-Bridges (1999) using a three-day batch cycle. This promoted high production with a stable population. Rotifers were cultured in 120-L tanks and were maintained at 23 to 24 °C and 15 g/L salinity. A "long term enrichment" (Olsen and others 1993) was administered, consisting of bakers yeast (36 g), DC Super-Selco (Inve Aquaculture, Inc.) (4 g), and water (2-L). This was fed to the rotifers four times per day (2-L food/tank/day). Three subsamples from each culture tank were analyzed daily to measure population growth. Rotifer density was calculated with a turbidity meter, prior to feeding, when the tanks were clear of food (Lindberg and others 1999). The rotifer cultures were started at 25 million rotifers and were harvested after three days at 40 to 50 million rotifers. Three rotifer cultures were staggered, so that a tank could be harvested each day. Twenty-five million rotifers were used to start a new tank while the remaining rotifers were harvested and fed to the larvae.

Artemia

Great Salt Lake brine shrimp (*Artemia*) were used for the next phase of live food production. Large quantities (50 to 100 g) of *Artemia* cysts were de-capsulated (Campton and Busack 1989) each week and stored in the refrigerator. Cysts were incubated in 15-L hatching vessels at 30 °C and 30 g/L salinity. De-capsulation of the cysts increased the hatch rate and prevented an accumulation of cyst shells in the larval tanks. After hatching (18 to 24 h), *Artemia* nauplii were transferred to enrichment vessels at 200,000 nauplii/L. They were enriched for 12 hours using DC Super-Selco (0.4 g/L). *Artemia* were harvested using a 150-mm sieve and were rinsed well to remove all lipid residues from their surface.

Rotifers and *Artemia* were harvested once per day as needed to meet the demands of the larvae. They were held in the lab with aeration (18 to 20 °C) and were fed to the larvae four times per day.

LARVAL REARING

Successful culture of delta smelt has not yet been achieved on a large scale. The major bottleneck is the production of juveniles, due to high mortality during the larval period (Mager and others 1996). One of the problems experienced in previous years was lack of a clean water source at our site. Water for the culture facility originates from Clifton Court Forebay, a regulatory reservoir at the beginning of the California Aqueduct. Wind mixing in the forebay results in a severely turbid water supply (20 to 250 nephalometric turbidity units, NTU) for our systems, which is unacceptable for larval culture and production of live prey organisms. The use of recirculation technology (Lindberg and other 1999) has overcome this problem and we are able to successfully culture smelt through the larval period.

Culture Methods

Larval Facility and Daily Maintenance

The larval facility was expanded last year with three recirculation systems to test temperature effects on growth and survival of smelt. Each system was equipped with four to six larval rearing tanks (100 L), a mechanical filter (filter bags and a canister filter), a chemical filter (charcoal), and a biological filter (bio-media). Water for each system was continuously chilled and passed through an ultraviolet sterilizer prior to entering the tanks.

Water quality (temperature, ammonia, nitrite, oxygen, pH, and salinity) was monitored and recorded daily to maintain safe and stable environmental conditions. The larvae were kept under conditions of continuous (24 h) light and a salinity of 1 to 3 g/L. The larval tanks were siphoned three to four times per week to remove uneaten food. A preventative treatment was administered each week using formalin (25 mg/L) or an anti-bacterial agent (10-mg/L nitrofurazone or 10-mg/L Chloramine-T) for one hour.

Feeding Regime

Algae paste (*Nannochloropsis oculata*; Marine Microalgae Cryopaste™, Reed Mariculture, Inc.) was routinely added to the tanks at each feeding to obtain a turbidity of 25 NTU (3 million algal cells/ml). At lower turbidity values, few rotifers were consumed. Rotifers and *Artemia* were enriched with DC Super Selco™ to improve their fatty acid composition. They were added to the tanks four times daily (at 0800, 1200, 1600, and 2000 h) to maintain sufficient prey densities (5 rotifers/ml, 3 *Artemia*/ml) within the tanks. Rotifers were fed to smelt larvae at first feeding (5 days post hatch); *Artemia* were fed to larvae when they attained a length of 10 mm. Rotifers and *Artemia* were fed to larvae for two weeks and then discontinued.

Larval Experiments

Stocking Density

The use of higher stocking densities was investigated in larger tanks this year to increase the production of juveniles. Last year we determined that delta smelt were good candidates for high-density culture using smaller tanks (20-L), as it did not have any adverse effects on survival or growth. This year larvae were placed into 80-L tanks at 20, 40, and 80 larvae/L for a 60-day feeding trial (15 °C). Three replicates of each treatment were evaluated. Twenty subsamples were removed from each tank every 10 days for length measurements. High stocking density had no effect on growth and survival during the feeding trial. Larvae from all treatments attained a length of 16 mm by the end of the study (Figure 1). The use of high stocking density can greatly improve production efforts by reducing the number of tanks that require daily maintenance.

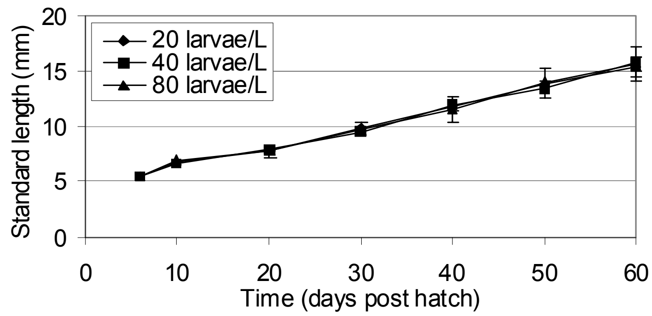

Figure 1 The effect of stocking density on length (mean ± SE) of delta smelt larvae from 6 to 60 days post hatch (3 replicates, 20 sub-samples per tank). There were no significant differences ($P > 0.05$) detected using analysis of variance.

Water Temperature

This past season a preliminary study was performed to investigate the effect of temperature on growth and survival of smelt larvae. A feeding trial was conducted for 60 days and larvae were maintained in six tanks at 14 °C, 17 °C and 20 °C. We evaluated two replicates per treatment. Twenty subsamples were removed from each tank every 10 days for length measurements. By day 60 post hatch, larvae at 17 °C were significantly larger (17.8 mm) than larvae reared at 14 °C (14.1 mm) (Figure 2). Larvae in warm water treatment (20 °C) experienced good growth for the first 30 days and were 14.4 mm by day 40. Larvae in 17 °C and 14 °C did not grow to this size until day 50 and 60, respectively. Unfortunately, equipment was not adequate for maintaining steady temperatures for the 20 °C treatment. Large daily temperature fluctuations resulted in high mortality and the treatment was discontinued due to lack of animals. We intend to repeat this experiment with new equipment that can maintain water temperatures.

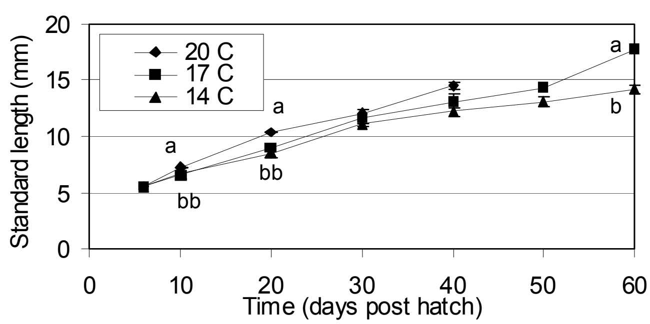

Figure 2 The effect of temperature on length (mean ± SE) of delta smelt larvae from 6 to 60 days post hatch (2 replicates, 20 subsamples per tank). Treatments with different letters at each time interval were significantly different ($P < 0.05$).

Feeding Behavior

Smelt larvae require a turbid environment to elicit a first feeding response and consume few rotifers in clear water (Mager and others 1996; Lindberg and others 1998, 1999). Addition of algae to rearing tanks, or "greenwater technique," has also been beneficial during the larval period for other species. This has been attributed to suppressing the development of harmful bacteria (Skjermo and Vadstein 1993), maintaining enrichment of zooplankton (Reitan and others 1993), increasing visual acuity for feeding (Boehlert and Morgan 1985; Naas and others 1992), and stabilizing water quality (Houde 1975).

Algal cells appear to play a physical role, which aid in feeding for smelt larvae. Turbid conditions provide better contrast between the prey and their background, allowing the larval predator to better capture its prey (Boehloert and Morgan 1985). In repeated trials we have observed an increase in feeding incidence (number of larvae eating) and intestinal fullness (number of prey/larvae) with increased turbidity (Lindberg and others 1999, 2000). This year three substrates (algae, silt, and bentonite) were used to investigate the effect of turbidity on feeding behavior.

Larvae (7 days old) were distributed (20 larvae/beaker) among 54 two-liter beakers with aeration and allowed to acclimate overnight. Treatments (algae, silt, or bentonite) were administered the following day to generate six levels of turbidity (0, 6.25, 12.5, 25, 50, and 100 NTU) for each treatment. Larvae were acclimated for two hours before addition of live prey (10 rotifers/ml) to the beakers. Larvae were fixed in 5% formalin after feeding for two hours. Feeding incidence then was compared for each substrate.

The number of larvae feeding increased with increasing turbidity level for all three substrates (Figure 3). Nearly 80% of the larvae initiated feeding at higher turbidity levels (>25 NTU) when algae or bentonite was used. A lower feeding response was observed with silt and clear water. The lower feeding response with silt was unexpected, due to its high abundance in the Delta. Too much silt may adversely effect some other aspect of the larvae's biology (for example, a negative effect on the gills), thereby decreasing their motivation to feed.

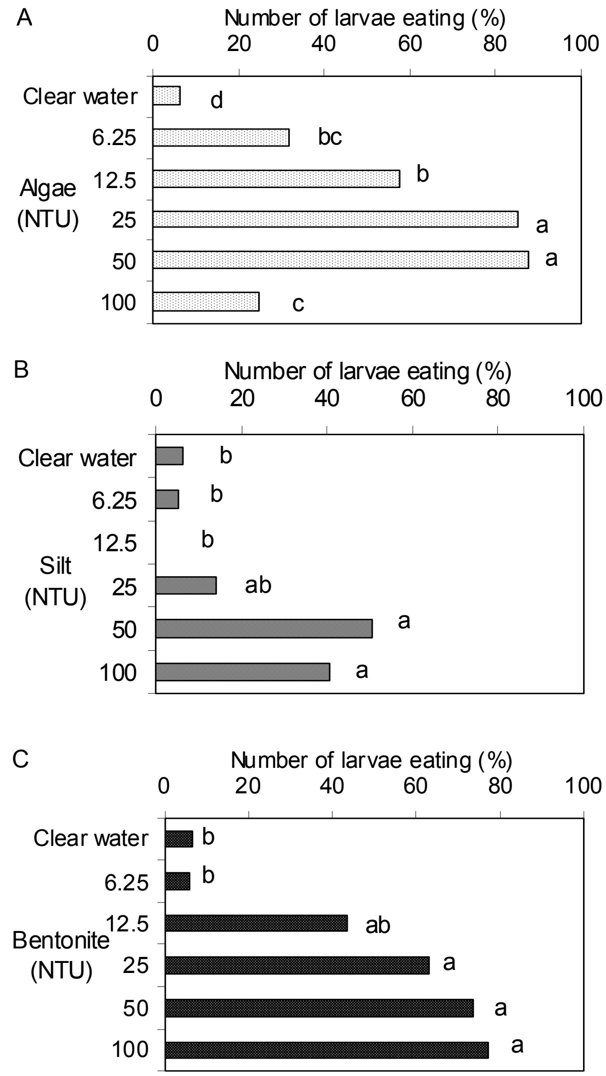

Figure 3 The effect of turbidity on feeding incidence (mean ± SE) of delta smelt larvae (3 replicates, 20 sub-samples per tank). Three substrates (algae, silt, and bentonite) were used to create turbid conditions. NTU: nepholometric turbidity units. Treatments with different letters were significantly different ($P < 0.05$).

Conclusions

We have made numerous improvements to our facility and are better able to culture all life stages of the delta smelt. Our broodfish facility was equipped with three additional tanks in an attempt to increase the production of eggs. Fish in the outdoor tanks began spawning earlier and produced considerably more eggs during the season. During the past season we successfully cultured 2,000 juveniles (20 to 40 mm).

Compromised water flow and temperature fluctuations appeared to have a negative effect on the broodfish, especially for the indoor tanks, and resulted in lower egg production compared to previous years. Many of the juveniles died due to inefficient water cooling, resulting in large daily fluctuations in tank temperature. New equipment is being installed to avoid similar problems and we anticipate much higher production this coming year.

Culture of delta smelt at high stocking densities with larger tanks has helped to increase production of juveniles. There were no negative effects of high stocking density on survival and growth and minimizing the number of tanks requiring daily maintenance has reduced workload.

Smelt larvae appear to be tolerant of a wide range of temperatures, but are not tolerant of high daily temperature fluctuations. During a 60-day feeding trial, larvae grew at a faster rate at 17 °C than at 14 °C and there appears to be further enhancement of growth at 20 °C.

Smelt larvae require turbid conditions to elicit a first feeding response. Particles appear to play a physical role, by providing contrast between prey and background. Feeding incidence increased with increasing turbidity using three substrate types (algae, silt and bentonite). Increased feeding response was not as great with silt compared to algae and bentonite. The reasons for this were not identified.

For spring 2001, we have purchased new equipment enabling better control over water temperature for the broodfish and larval tanks. We will continue to investigate differences in growth and survival of smelt larvae reared at three temperatures. We will also test larvae at various ages for their ability to wean to prepared food to improve the transition from larval to juvenile phases. In 2002, we plan to implement best rearing methods and develop a production protocol.

Acknowledgements

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Synopsis of Issues in Developing the San Joaquin River Deep Water Ship Channel Dissolved Oxygen TMDL

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Abstract

In 1994, the Central Valley Regional Water Quality Control Board (Board) classified the San Joaquin River (SJR) Deep Water Ship Channel (DWSC) “impaired” because dissolved oxygen (DO) concentrations routinely fell below the water quality objective (standard or WQO) in the fall. This classification requires development of a total maximum daily load (TMDL) to control loads and conditions that cause violations of the DO WQO.

In 1998, the Board classified the dissolved oxygen impairment a high priority problem for correction. Staff committed to develop a TMDL plan for controlling the problem and submit it to the U.S. Environmental Protection Agency by June 2003. Furthermore, the Board, under the Bay Protection Plan, agreed to allow a Steering Committee of local vested interests help to develop the control plan if they committed to provide Board staff all the elements of the TMDL, including an implementation plan, by December 2002. If at any time the steering committee was unable to do so then staff would resume control over the development of the TMDL control plan.

This article presents an overview of the DWSC DO depletion problem and many of the issues that are in need of consideration by the Steering Committee and Board in developing a technically valid, cost-effective TMDL that will enable compliance with the DO WQO. This article is a synopsis of a more extensive report by Lee and Jones-Lee (2000), which presents the issues that need to be addressed in oxygen demand TMDL development and load allocation among stakeholders.

Background

As part of developing the Port of Stockton (Port), a navigation channel was dredged in the SJR through the Delta to Stockton (Figure 1). The SJR, just upstream of Stockton, is typically about 8 to 12 feet deep. It is a freshwater, tidally influenced river with a three-foot tidal range and flow that typically ranges between 2,000 and 4,000 cfs. The non-tidal flow during summer and fall is highly regulated with net flow at Stockton, ranging from negative (upstream) flow associated with upstream diversions at Old River to net downstream flow between 100 to 2,000 cfs. Beginning at the Port, the SJR DWSC is dredged to 35 feet deep to allow passage of ocean cargo ships bringing bulk materials to Stockton.This dredging greatly slows the net downstream transport rate of SJR water. The first 15 miles of the DWSC can have a hydraulic residence time that varies from about 5 days at a net downstream flow of 2,000 cfs to about 30 days at 100 cfs.

The relatively short hydraulic residence time of the DWSC has important implications for determining when oxygen demand loads to the DWSC may potentially lead to violations of the DO WQO. With hydraulic residence times of less than one month, high winter and spring SJR flows and associated oxygen demand and nutrient loads do not significantly contribute to DO depletion within the DWSC during summer and fall. All oxygen demand added during the winter and spring is flushed through the DWSC during this time.

Dredging the DWSC alters the oxygen demand assimilative capacity of the SJR for about 10 to 15 miles downstream of the Port (critical reach) by increasing the hydraulic residence time of the water and by decreasing the amount of re-aeration per unit volume of the channel. Also, greater water volume in the DWSC as a result of dredging dilutes the dissolved oxygen photosynthetically produced by algae. Further, the effect of sediment oxygen demand (SOD) is diluted for the same reason. These factors, coupled with diversions by the State and federal water projects (CVP and SWP) and other municipal and agricultural intakes, lead to DO concentrations below the WQO. The WQO is 6 mg/L from September through November and 5 mg/L from December through August. While DO depletions below the WQO is critical in summer and fall, there also can be violations at other times, such as during spring low flow.

Characteristics of the San Joaquin River Watershed

The San Joaquin River is one of California's primary rivers. It originates in the central Sierra Nevada, flows through the San Joaquin Valley and into the Delta, where it mixes with the Sacramento River before discharging into upper San Francisco Bay or being diverted by the CVP and SWP. The SJR drains the San Joaquin Valley between Fresno and Stockton. It has a 7,345 sq mi watershed that contains about one million acres of irrigated agriculture (Kratzer and Shelton 1998). The primary crops are fruits and nuts (almonds), corn, pasture, and cotton. The SJR watershed includes the metropolitan areas of Stockton, Modesto, Merced, and Fresno, and numerous dairies and feedlots. The current estimated urban population in this watershed is approximately two million and, at a growth rate of two percent per year, is expected to double to about four million people by 2040.

Upon entering the San Joaquin Valley floor, SJR water quality deteriorates due to agricultural, municipal, and industrial stormwater runoff; wastewater discharges; municipal, industrial, and husbandry activities; and natural and riparian runoff or drainage. In addition to adding oxygen requiring substances (carbonaceous and nitrogenous biochemical oxygen demand [BOD]), the discharges contribute substantial amounts of nutrients (N and P compounds), which can support algal growth. The dead algae are a source of oxygen demand in the DWSC where flows in the SJR at Vernalis represent a significant part of the flow into the DWSC. (Vernalis is located about 30 miles upstream of the DWSC.) Located between Vernalis and the DWSC, the Old River diversion can at times divert substantial flow into the South Delta.

Also, it is possible that detritus (dead plant and animal remains and waste products like manure) derived from the SJR watershed contributes to the oxygen demand present at Vernalis and, under certain SJR flow and diversion conditions, exerts oxygen demand in the DWSC. The SJR at Vernalis typically has several milligrams per liter of nitrate N and about 0.1 to 1 mg/L soluble orthophosphate P. These nutrients can support substantial algal biomass (20 to 100 µg/L chlorophyll *a*) in the SJR at Vernalis and the DWSC during summer.

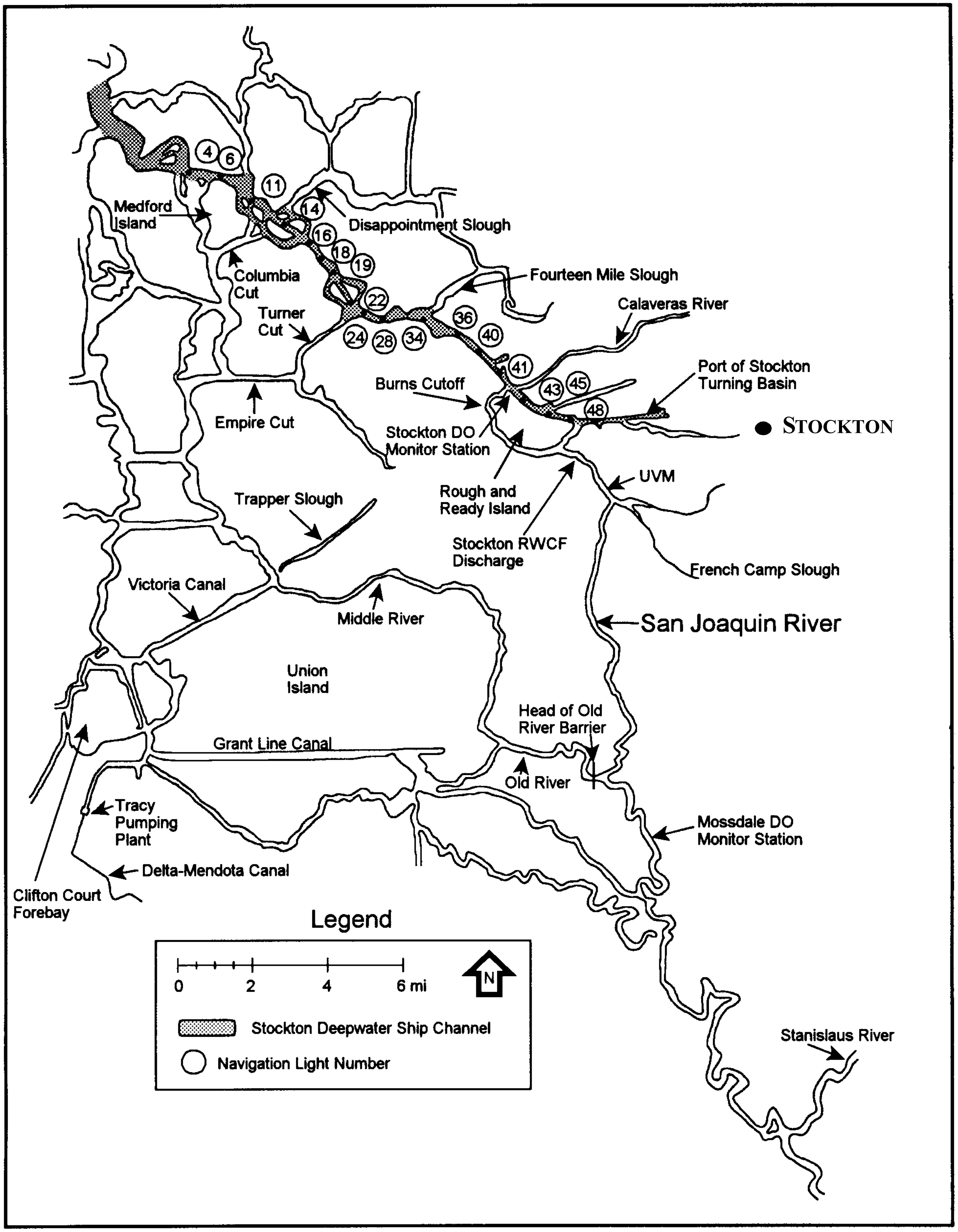

Figure 1 Location of water quality stations and navigation lights on the San Joaquin River in the vicinity of Stockton

DEEP WATER SHIP CHANNEL 1999 WATER QUALITY CHARACTERISTICS

A study was conducted of the oxygen demand sources and DO depletion in the DWSC by the SJR Technical Advisory Committee (TAC) during late summer and fall 1999. Some of the data from these studies are presented in Figure 2. Station 41 is near the downstream end of Rough and Ready Island, about two miles from the point where the SJR enters the DWSC at the Port. Station 18 is about 10 miles downstream of this point.

DO concentrations in the DWSC decreased below the WQO in August 1999 and September through early December 1999. During August and most of September, SJR flow into the DWSC was about 900 cfs. In late September through October, flow ranged from about 100 to 900 cfs as a result of upstream diversions into Old River. Under these low flow conditions, DO in some areas decreased to about 2 mg/L. Further, during November and early December 1999, concentrations of ammonia in the SJR just upstream of where it enters the DWSC were over 3 mg/L N. According to the EPA (1999), ammonia at these concentrations, combined with SJR DWSC temperature and pH, is toxic to many forms of aquatic life over a 30-day period and can be a significant source of oxygen demand. The ammonia was primarily derived from Stockton's domestic wastewater discharge just upstream of the DWSC.

Table 1 presents the results of box model calculations of the major sources of oxygen demand during summer and fall 1999. In general, they are based on measured concentrations of oxygen demand constituents and flow, summed to yield a total daily load of oxygen demand from each major source.

Box model calculations suggest the primary sources of DWSC oxygen demand during August and September 1999 were algae, detritus, and other organics in the SJR above Vernalis. During August and September, Stockton wastewater discharges were a small part of the oxygen demand load to the DWSC. However, in late September to early October, when SJR flow into the DWSC was about 150 cfs, SJR flow upstream of Vernalis and associated oxygen demand load was largely diverted down Old River. Under these conditions, Stockton wastewater flow (about 40 cfs) with a 20 mg/L N ammonia load was an important source of oxygen demand to the DWSC.

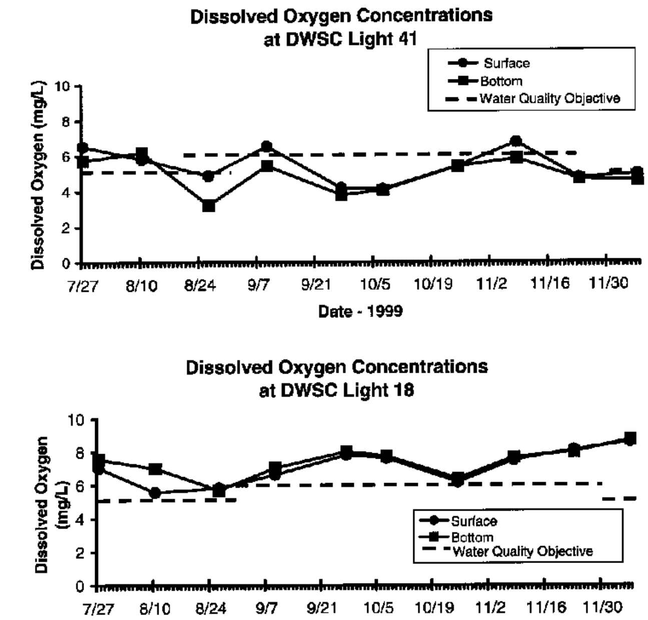

Figure 2 DWSC dissolved oxygen data, summer and fall 1999. Adapted from Lehman (2000).

Table 1 Summary of DWSC biochemical oxygen demand (BOD) sources during summer and fall 1999

	BOD_u (lbs/day)				
	Aug	*Sep*	*Oct*	*Oct*	*Oct*
SJR flow (cfs)	*900*[a]	*900*[a]	*150*	*400*	*1,000*
Upstream of Vernalis	61,000	70,000	6,300	14,130	35,325
City of Stockton	5,600	9,300	12,200	12,000	12,000
Local DWSC	?	?	1,750	1,750	1,750
SOD	6,000	6,000	6,000	6,000	6,000
Natural aeration	5,500	5,500	?	?	?
Mechanical aeration	2,000	2,000	?	?	?
DWSC algae	?	?	?	?	?
Export from DWSC	27,000	27,000	?	?	?

[a] Values are approximate.

These results suggest upstream diversions of SJR water are important in determining the source of the oxygen demand loads contributed to the DWSC. These results also indicate that it will be necessary to expand the TMDL load analysis to the SJR watershed upstream of Vernalis. Both carbonaceous and nitrogenous BOD and algal nutrients derived from irrigated agriculture are potentially important sources of oxygen demand that enter the DWSC.

The City of Stockton supported Chen and Tsai (1997) in the development of a mathematical model of oxygen demand and DO effects in the DWSC. This model, with appropriate modification, will be used to develop an oxygen demand TMDL as a function of SJR flow through the DWSC. In addition, another model is being developed to relate oxygen demand and nutrients discharged to the SJR and its tributaries upstream of Vernalis to oxygen demand in the DWSC.

TMDL Development and Allocation

A Technical Advisory Committee of the SJR DO TMDL Steering Committee is developing the SJR DWSC oxygen demand TMDL. Excessive DO depletion in the DWSC has been a long-standing problem. Brown & Caldwell (1970) determined that the DWSC could assimilate 40,000 lbs/day BOD_u. Since then, the SJR DWSC has been deepened by an additional five feet, which further reduces its oxygen demand assimilative capacity. Further, Brown & Caldwell's estimated allowable BOD_u load did not include the safety factor required in TMDL development. Work is underway as part of a "strawman" effort to develop preliminary estimates of the allowable oxygen demand load to the DWSC considering the effect of SJR flow through the DWSC on DO depletion for a given oxygen demand load.

Some relief from this oxygen demand load reduction may be achieved by increasing SJR flow through the DWSC. In summer and fall 1998, SJR flow through the DWSC was over 2,500 cfs and DO in the DWSC did not fall below the WQO. However, there is concern that these high SJR flows lead to DO depletion elsewhere in the central Delta. Similarly, the diversion of SJR flow down Old River could be causing low DO in the South Delta. Both of these issues will need to be examined in determining how SJR flows into the DWSC affect DO depletion.

Another important factor to consider in developing the TMDL is the population increase in the SJR DWSC. This population increase will increase the demand for water, wastewater discharges, and oxygen demand load to the SJR DWSC.

CALFED provided $866,000 during 2000 for the Technical Advisory Committee to conduct additional studies needed to define the relationship between oxygen demand load to the DWSC and DO depletion below the WQO. The Steering Committee is submitting a Directed Action proposal to CALFED in 2001 to continue field studies devoted to evaluating the relationships between discharge of oxygen demanding substances to the DWSC and the resulting DO depletion that occurs in the DWSC as a function of SJR flow through the DWSC.

Steering Committee Responsibilities

The Steering Committee is composed of stakeholders in the SJR watershed. The committee will need to resolve a variety of issues in developing and implementing the TMDL. The committee will need to establish an appropriate DO TMDL goal and evaluate how current standards should be interpreted. The EPA (1986, 1987) has indicated that DO depletion between 4 and 5 mg/L primarily affects the rate of fish growth; however, the effect of DO concentrations between 4 and 5 mg/L on fishes of the DWSC, San Joaquin River, and the Delta needs more study. There could be a large difference between a "worst case-based" DO goal versus an "average" daily water column DO goal.

The allocation of the oxygen demand load and responsibility among dischargers in the DWSC watershed will be a challenging task. The Steering Committee must complete this allocation by December 2002 to meet the Board's deadline. Failure to meet this deadline will result in the Board establishing the TMDL allocation.

Another important issue that will need to be addressed by the Steering Committee and stakeholders is how to balance the control of oxygen demand constituents, including aquatic plant nutrients that develop into algae that exert an oxygen demand in the DWSC, with the significantly reduced assimilative capacity of the DWSC associated with upstream of DWSC diversions of SJR water for the City of San Francisco, other communities and various irrigation districts, as well as the development and maintenance of the 35-foot navigation channel through the San Joaquin River to the Port of Stockton. The diversions of SJR water and the 35-foot navigation channel significantly adversely affect the ability of the DWSC to accept oxygen-demanding materials without violations of the DO water quality objective.

Some of the DO depletion problems in the DWSC could be achieved through aeration of the SJR DWSC. The Steering Committee and stakeholders will need to consider how the construction and operation of the aerators would be funded.

Below are issues that need to be further addressed or defined:

- Export and loss of BOD_u, CBOD, NBOD, algae, N and P between source-land runoff, discharges, and DWSC.
- Additional oxygen demand and nutrient loads to the SJR between Vernalis and Channel Point in the DWSC
- Effects of SJR flow at Vernalis and in the DWSC on DWSC DO depletion.
- Factors controlling SJR flow through the DWSC on DO depletion below WQOs.
- Significance of DWSC DO depletions below 5 mg/L on fish growth rates in the DWSC.
- Significance of DO depletions below 6 mg/L in serving as a inhibitor of chinook salmon immigration.
- Cost of controlling N, P, NBOD and CBOD from wastewater, stormwater runoff, and irrigation return (tail) water.
- Development of a reliable model for a given SJR DWSC flow to establish an oxygen demand TMDL?
- Management of increasing urbanization in the SJR DWSC watershed for potentially increased oxygen demand load.

Further information on the issues pertinent to the DO depletion problem in the DWSC is discussed by Lee and Jones-Lee (2000) and Jones & Stokes (1998).

Acknowledgment

The authors acknowledge the assistance provided by the SJR DO TMDL TAC in developing the SJR DO TMDL Issues report upon which this synopsis of issues is based. We also wish to acknowledge the reviewers of this report, especially Dr. Chris Foe, CVRWQCB; Dr. Gary Litton, University of the Pacific; Kevin Wolf of Kevin Wolf Associates and Dr. C. Kratzer of the USGS.

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Announcements

Rick Oltmann, Mr. Delta Flows, Retires

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After almost 31 years with the Geological Survey, Rick Oltmann retired in early January. After graduating from Sacramento State in 1971 with a degree in civil engineering, Rick honed his flow measurement skills in USGS assignments in Colorado and Oregon. Fortunately for us he returned to California in 1974 and began a long and fruitful career in the Sacramento-San Joaquin Delta.

Between 1974 and 1980 Rick worked on and developed the first mathematical flow model of the reach of the Sacramento River between Sacramento and Hood. During the 1976–1977 drought the model was used to calculate flows at Freeport.

In 1979 Rick and his colleagues installed the first continuous flow measuring station in the Delta. The station, located at Freeport, used state of the art Ultrasonic Velocity Meter (UVM) technology. This technology has become the standard continuous flow measuring technique at such key Delta stations as the Sacramento River at Rio Vista and the San Joaquin River near Jersey Point. Since 1985, Rick headed up the USGS-IEP hydrodynamic field program.

During his long career Rick had many outstanding technical accomplishments, perhaps foremost of which has been to provide a continuous (except when field monitoring sites are damaged by wayward barges and logs) indirect measurement of Delta outflow. However, his greatest contribution may have been to convey complex hydrodynamic information to audiences with widely varying technical backgrounds. This ability is of particular importance in the Delta where biologists, engineers and managers must use hydrodynamic and biological data to manage environmental resources and water supplies. I especially appreciate his frequent, well written and reader friendly contributions to this newsletter.

I am sure I speak for all IEP and others around the Bay-Delta in thanking Rick for all his hard work and in wishing him an enjoyable retirement.

Estuarine Research Federation

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As mentioned in the previous newsletter, Wim Kimmerer, Fred Nichols, and Randy Brown have been discussing formation of a California affiliate of the Estuarine Research Federation, tentatively called the California Estuarine Research Society or CAERS. Formation of a California chapter has been encouraged by ERF headquarters and by other local affiliates, including the Pacific Estuarine Research Society, which mostly serves Washington State estuarine scientists. To help us better understand how to establish and operate the new group, ERF headquarters has asked the affiliates to send us their bylaws and other relevant information. A scientist working for the Southern California Coastal Water Research Project is joining us in these discussions.

To facilitate discussion among affected scientists in the Bay area, Wim, Fred, and I will host an informal formation discussion at the upcoming IEP Workshop at Asilomar. We will select a time and location and will post an announcement on the conference center bulletin board. Although we are leaning towards forming a California affiliate, and scheduling meetings in conjunction with other conferences and workshops (such as IEP), there are some legal and administrative details we need to work out before taking this on. One of the key ingredients in forming a successful CAERS would be finding local coastal and estuarine scientists willing to help make it a productive and worthwhile effort.

If you have any questions, please contact Wim (kimmerer@sfsu.edu) or me (rl_brown@pacbell.net).

DON'T MISS THE UPCOMING AMERICAN FISHERIES SOCIETY ANNUAL MEETING

The Calfornia-Nevada Chapter and the Humboldt Chapter of the American Fisheries Society will be holding the 35th Annual Meeting March 29-31, 2001 in Santa Rosa, California. The meeting titled, "Progress and Continuing Challenges in Conservation and Restoration of Aquatic Species" will feature two symposia, a plenary session, ten technical sessions, and a poster session. The symposia and plenary session will provide information on habitat and fish restoration, fish passage, and facilities to reduce fish losses. The technical sessions will cover a range of topics including marine, estuarine, and freshwater fish ecology, abalone biology, conservation genetics, fluvial geomorphology, analytical tools for species restoration, and contaminant effects on aquatic species. Registration materials can be obtained from the AFS web page at http://www.afs-calneva.org or contact Lauren Buffaloe at (916) 227-1375 or buffaloe@water.ca.gov.

INTERNATIONAL CONFERENCE ON RESTORING NUTRIENTS TO SALMONID ECOSYSTEMS

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While you've got that 2001 planner handy, be sure to schedule in the "Nutrient Conference." This event will be held April 24–26, 2001, in Eugene, Oregon, and will define the cutting edge of information on the dynamics and application of nutrients in restoring salmon ecosystems. Interest has been exceptional, with more than 60 presentations submitted, addressing a diverse range of issues. Subjects include estimation of historic salmon escapements; dynamics among aquatic and terrestrial systems; nutrient contributions of carcasses, riparian vegetation, and artificial supplements; protocols for fertilizing lakes and streams in various Northwest ecotypes; methods for salmon carcass augmentation; water quality and primary production effects of carcass decomposition; etc.

Plenary speakers include Jim Lichatowich (WA, USA), Takeshi Murota (Kyoto, Japan), and John Stockner (BC, Canada). Session chairs include: C. Jeff Cederholm, Robert Bilby, and Hal Michael (WA), Robert Lackey and Bill Bakke (OR), Wayne Minshall (ID), Mark Wipfli (AK), Tom Reimchen (BC, Canada), and Lisa Thompson (CA). Besides interactive oral presentations, there will be a lively poster social featuring the Northwest's best microbrews. Student travel awards (up to $500) are available via a simple application process. The registration form, student award criteria, agenda, and further information are available on the conference web page. Or, you can contact me at 541-496-4580 or rgrost@compuserve.com.

A CONFERENCE ON SCIENCE, POLICY, AND CONSERVATION ACTION

Nicole Silk
nsilk@tnc.org

"Managing River Flows for Biodiversity: A Conference on Science, Policy, and Conservation Action" will be held July 30 through August 2, 2001, at Colorado State University, in Fort Collins, Colorado. Please contact Nicole Silk at nsilk@tnc.org for more details. Don't forget to visit the website at www.freshwaters.org/conference!

Paper Accepted for Journal Publication

Yolo Bypass Study Accepted for Publication in the Canadian Journal of Fisheries and Aquatic Sciences

Lauren Buffaloe, DWR
buffaloe@water.ca.gov

Publishing scientific work is no easy task. However, five IEP-affiliated scientists commemorate the real millennium by doing just that. Ted Sommer, Matt Nobriga, Bill Harrell, Wendy Batham, and Wim Kimmerer collaborated to report the results of the Yolo Bypass Study, initiated in 1997 as a product of an IEP project. The abstract and current reference appear below. The authors gratefully acknowledge funding from CALFED and assistance from IEP staff including DWR (R. Kurth, R. Brown, C. Messer, K. Malchow, F. Feyrer, L. Grimaldo, D. McEwan, R. Miller, C. Peregrin, Z. Hymanson and S. Ford); USFWS (P. Brandes, M. Pierce and R. Burmester); DFG (V. Johannsen and S. Kawasaki), and consultants (W. Fields and W. Shaul). Please contact Ted Sommer (tsommer@water.ca.gov) if you are interested in obtaining reprints.

Reference

Sommer, T.R., Nobriga, M., Harrell, B., Batham, W., and Kimmerer, W. 2001. Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival. Can. J. Fish. Aq. Sci. In press.

Abstract

In this study we provide evidence that the Yolo Bypass, the primary floodplain of the lower Sacramento River (California, USA), provides better rearing and migration habitat for juvenile chinook salmon (*Oncorhynchus tschawytscha*) than adjacent river channels. During 1998 and 1999 salmon size increased substantially faster in the seasonally-inundated agricultural floodplain than the river, suggesting better growth rates. Similarly, coded-wire-tagged juveniles released in the floodplain were significantly larger at recapture and had higher apparent growth rates than a group concurrently released in the river. Improved growth rates in the floodplain were in part a result of significantly higher prey consumption, reflecting greater availability of drift invertebrates. Bioenergetic modeling suggested that feeding success was greater in the floodplain than the river, despite increased metabolic costs of rearing in the significantly warmer floodplain. Survival indices for floodplain coded-wire-tagged release groups were somewhat higher than river groups, but the differences were not statistically significant. Growth, survival, feeding success and prey availability were higher in 1998 than 1999, a more moderate flow year, indicating that hydrology affects the quality of floodplain rearing habitat. These findings support the predictions of the flood pulse concept and provide new insight into the importance of floodplain for salmon.

DELTA INFLOW, OUTFLOW, AND WATER PROJECT OPERATIONS

Kate Le, DWR

From October through December 2000, San Joaquin River flow ranged between 2,000 cfs and 4,000 cfs, Sacramento flow ranged between 10,000 cfs to 16,000 cfs, and the Net Delta Outflow Index (NDOI) ranged between 2,000 cfs and 17,000 cfs (Figure 1). Precipitation in mid-October and mid-December resulted in increased Sacramento River flows and NDOI, also shown in Figure 1. The largest precipitation occurred at the end of October, causing NDOI to increase dramatically from about 3,000 cfs to about 17,000 cfs. This storm, which resulted in high flows in the Sacramento River, did not increase flows in the San Joaquin River. High tides and Delta Cross Channel closures in late November and late December caused the water projects to briefly reduce exports (Figure 2) to limit salinity intrusion in the South Delta. The late November 2000 increase in NDOI resulted from export reduction from both projects (Figures 1 and 2).

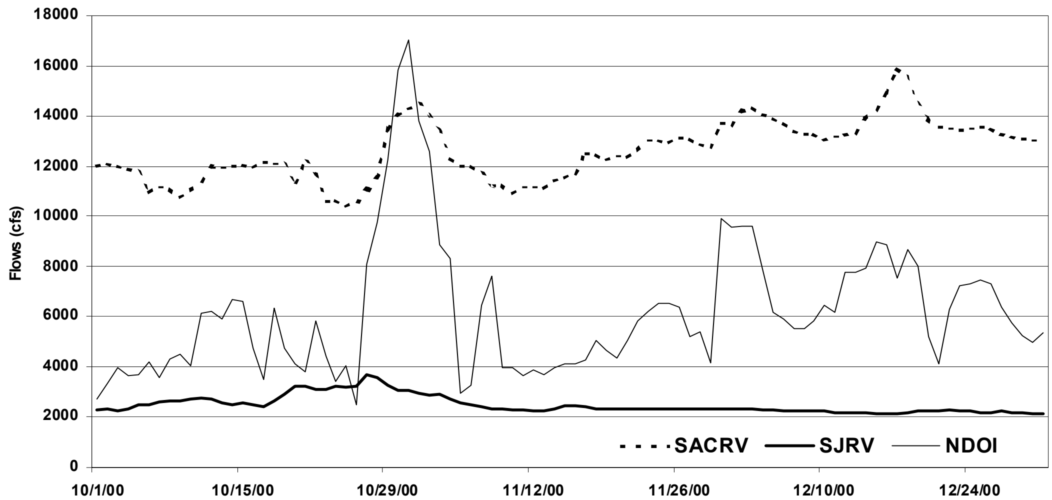

Figure 1 Flow in the San Joaquin (SJRV) and Sacramento (SACRV) rivers and Net Delta Outflow Index, Oct – Dec 2000

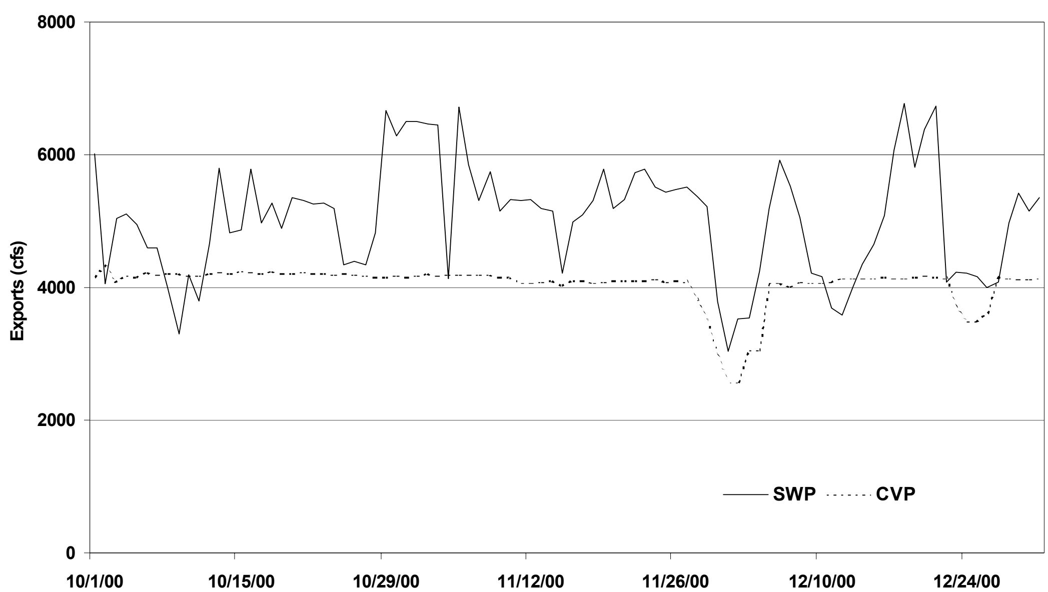

Figure 2 State Water Project (SWP) and Central Valley Project (CVP) exports, Oct – Dec 2000

■ Interagency Ecological Program for the San Francisco Estuary

IEP NEWSLETTER
3251 S Street
Sacramento, CA 95816-7017

For information about the Interagency Ecological Program, log on to our website at http://www.iep.water.ca.gov. Readers are encouraged to submit brief articles or ideas for articles. Correspondence, including submissions for publication, requests for copies, and mailing list changes should be addressed to Lauren Buffaloe, California Department of Water Resources, 3251 S Street, Sacramento, CA, 95816-7017.

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