■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER

VOLUME 14, NUMBER 2, SPRING 2001

CONTENTS

OF INTEREST TO MANAGERS

Chuck Armor, DFG
carmor@delta.dfg.ca.gov

This is the annual status and trends issue. Abundance and distribution data for many key estuary organisms are included, as well as a detailed description of the 2000 water project pumping and Delta hydrology. Included here are a few observations and high points.

A study designed to determine the distribution of mitten crabs in the San Joaquin River system and their habitat associations here found no mitten crabs in the San Joaquin River system upstream of Mossdale and only a few were found in the central Delta. This suggests that downstream migrating mitten crabs will not present a problem at the SWP and CVP as they have in the past.

Modified flashboards in the Suisun Marsh Salinity Control Structure did not work as anticipated in facilitating the passage of upstream migrant adult chinook salmon (Vincik, page 6). Four options to increase fish passage are under consideration for further study.

Sommer and Harrell (page 7) found that pulse flows from Putah and Cache creeks triggered upstream migration of native species including hundreds of splittail confirming the earlier finding that inundation of the Yolo Bypass by the Sacramento River is not required to attract large numbers of splittail to spawning areas. This shows that splittail move to spawning areas in years that do not have high flows or involve large-scale inundation of vegetated areas.

Souza (page 8) reports that the Spring Midwater Trawl collected a new species of freshwater shrimp belonging to the family Palaemonidae near Rough and Ready Island. The USFWS Beach Seine at Liberty Island and the Bay Study near Sherman Island have also collected this shrimp. These specimens have been sent to an expert in the Netherlands for identification. The distribution of this exotic species is upstream of other species found in the estuary and potentially includes the entire delta. The Spring Midwater Trawl is conducted to monitor the distribution and abundance of delta smelt. A total of 132 smelt was caught with a majority of the catch coming from Suisun Bay.

Le (page 10) reports that hydrologic conditions started off dry in January 2000, but precipitation began in late January and continued through March 2000. The greatest amount of precipitation resulted in high runoff between mid-February and mid-March. Adjustments to water project exports occurred throughout the year to address concerns for fish and water quality. 2000 Delta outflow was the eighteenth highest in the last 41 years. Annual water project exports were higher than the previous ten years and the second highest in the last 41 years.

Mecum and Orsi (page 12) summarize zooplankton abundances and trends for 2000. There were no major changes over 1999 (that is, the abundance of most native species remains low), but the good news is that no new introduced species were detected in the estuary in 2000.

Analysis of the USFWS beach seine data sets shows that some splittail reproduce (recruit) even in critically dry years (Baxter, page 16). It was previously thought that splittail did not reproduce in critically dry years when no flooding occurred. This suggests even in the worst of years there will be some reproduction of the splittail population.

In an analysis of the 2000 delta smelt 20-mm Survey data, Rockriver (page 19) reports that several spawning events occurred in 2000; furthermore, the one that occurred in late April and early May produced the largest cohort. However, this large cohort was not enough to raise the delta smelt indices above those seen in 1999, with both the summer townet index and the fall midwater trawl index indicating a slight decrease in the delta smelt population.

As in past years there was considerable variation in the response of fish, shrimp and crabs in San Francisco Bay (Hieb, page 21). The total shrimp index from the Bay Study was the fourth highest in twenty years. This was due to a record catch of *Crangon nigricauda*. The catch of *Crangon franciscorum* was up over 1999. Pacific herring catch was the highest since 1986 and was equal to that in 1989. Embiotocid (surfperch, sea perch, and perch) abundance remained much lower than levels observed in the early 1980s. For the flatfish, no age-0 or age-1+

California halibut were collected because ocean temperatures were too cool for reproduction in the San Francisco Bay area; however, these cooler ocean temperatures did result in record catches of English sole and speckled sanddabs. The starry flounder catch was the fourth lowest in twenty years.

Souza (page 27) reports the Fall Midwater Trawl index for striped bass (390) was the lowest on record and continues the overall declining trend in abundance in young striped bass. The Fall Midwater Trawl index for delta smelt fell 13%, reversing the pattern of increasing abundance observed since 1997. The abundance index for longfin smelt decreased by 35%, with a majority of the fish captured in Suisun Bay. Only five splittail were captured in the Fall Midwater Trawl resulting in a substantial (87%) decline in this annual abundance index compared to 1999. American shad were the exception to the declines in abundance indices, showing a 7% increase compared to the 1999 level. However, both 1999 and 2000 constitute the lowest index values for American shad since 1977.

Brown and Chappell (page 32) summarize the available information on Central Valley salmonid stocks for 2000. Central Valley chinook salmon abundance index was the fourth highest in thirty years, slightly more than 1,100,000, with fall-run having its highest index. Spring-run escapement also increased with a majority of the spawners (about 74%) observed in Butte Creek. Estimated winter-run escapement was 1,400, which is lower than observed in the last two years. Considering this run once numbered less than 200 fish, the results are still encouraging. Overall escapement was the best since the mid-1980s. In contrast, Burmester (page 29) reports that catch of emigrating juvenile chinook salmon declined from levels observed in 1999.

Fish salvage operations at the SWP and CVP continued in 2000 (Foss, page 37). An estimated 7.8 million fish were salvaged from the SWP. Striped bass was the predominant species salvaged (about 45%) at the SWP. An estimated 5.9 million fish were salvaged from the CVP. Threadfin shad was the predominant species salvage (about 54%) at the CVP. Salvage of delta smelt and chinook salmon declined somewhat from 1999 levels, but 2000 salvage levels of steelhead and splittail increased from levels observed in 1999.

Nobriga, Hymanson, Ruhl, and Fleming (page 42) present a review of the 2000 delta smelt salvage and south Delta hydrodynamics data. Comparisons of years with similar environmental conditions, but different VAMP related CVP and SWP operations show different results in terms of delta smelt salvage. The authors hypothesize that when spawning delta smelt are found in the central and southern Delta and the VAMP conditions result is a slightly negative to positive flow in that area, then delta smelt retention and growth is enhanced leading to increased salvage.

All managers should review Table 2 (page 45), the Delta Smelt Decision Tree. This table was developed by the Delta Smelt Working Group and summarizes the process for making decisions regarding actions to protect delta smelt. The table is divided by life stage and includes a description of what information will be used, questions that are asked, and possible recommendations. This table will be a critical tool for the Data Assessment Team this spring.

The article by Brandes (page 47) summarizes the results of the chinook salmon smolt survival experiments conducted in the Delta as part of the 2000 Vernalis Adaptive Management Plan (VAMP). These results are compared to other similar survival experiments to try and paint an overall picture of salmon survival through the south and central Delta.

Brown (page 55) presents a good summary of the CALFED splittail workshop held in January. This well-attended workshop helped develop consensus among researchers on what has been learned and what direction future work should take.

IEP Quarterly Highlights: January–March 2001

Delta Flow Measurement

Catherine Ruhl, U.S. Geological Survey
caruhl@usgs.gov

There were a few minor problems with the flow network during the last quarter. Problems with the transducer connection at Old River at Bacon Island caused approximately two weeks of bad data in early January. Flow data at Threemile Slough at San Joaquin River are currently unavailable until additional field discharge measurements can be made to complete the station's rating.

To minimize station outages, a new program was established to monitor raw data telemetered into the USGS office from each of the flow stations. This automated program generates e-mail and updates an internal web page daily. This tool allows our team to rapidly respond to any problems occurring in the field and has proven to be extremely effective in minimizing station downtime.

Three sideward-looking Acoustic Doppler Current Profilers (SL-ADCPs) were installed in the south Delta last year. Thanks to the help and cooperation of DWR, the USGS now has stage information directly integrated into our data collection platform, which will allow for more rapid calculation of flow at these stations.

A new SL-ADCP was installed in late February on the Sacramento River at Hood. Data are telemetered into the USGS office on a daily basis. Because the calibration process has just started, flow data are not yet available at this station. The stage record, measured with an upward-looking acoustic beam, appears to be working well. This is promising technology, which will allow us to deploy our equipment without requiring an external stage recorder.

Chinese Mitten Crab Surveys of the San Joaquin River Basin and Suisun Marsh

Jason May and Larry Brown, USGS
jasonmay@usgs.gov

Juvenile Chinese mitten crabs (*Eriocheir sinensis*) are thought to use riverine habitats as rearing areas. Thus, the initial objectives of our study were to examine habitat use and potential effects of mitten crabs in the San Joaquin River drainage upstream of the Sacramento-San Joaquin Delta. At the time we began our study, there was no clear indication of the efficacy of baited traps compared with the "crab condo" (used by other researchers in the Delta), so baited traps were chosen as the primary method for capturing crabs. After several unsuccessful attempts to catch or observe mitten crabs by trapping, electrofishing, and visual observations; we consulted with the IEP Management Team and redirected our efforts to determine the presence of crabs in the San Joaquin River (in the vicinity of Mossdale) and Suisun Marsh.

Monthly surveys using baited traps in the San Joaquin River were conducted from June through October 2000 and in the Suisun Marsh from August through October 2000. No mitten crabs were caught in the San Joaquin River basin and only one mitten crab was caught in Suisun Marsh. Ninety-two locations were surveyed by deploying 352 traps for 10,752 hours of trapping effort in the San Joaquin River basin. In Suisun Marsh, 34 locations were investigated by deploying 150 traps for 3,600 hours of trapping effort. The baited traps were successful at capturing a variety of organisms including catfish, yellowfin gobies, and crayfish. Data on specific trapping locations and organisms captured will be available soon in a web-based data report.

Migration Patterns of Adult Fall-Run Chinook Salmon in the Lower San Joaquin River, South Delta, and Delta Cross Channel

Derek Stein, DFG
dstein@delta.dfg.ca.gov

The Fish Facilities Research Unit investigated migration patterns of adult fall-run chinook salmon in the lower San Joaquin River using ultrasonic telemetry. This was a continuation of a study conducted during the falls of 1964 through 1967 by Hallock and others (1970). The primary objectives were to determine if the effect of low dissolved oxygen levels in the Stockton Deepwater Ship Channel, three temporary barriers in the south Delta, or the barrier at the head of Old River are impediments to upstream migration. In addition, we examined fish passage through the control gates at the Delta Cross Channel.

Tagging operations were conducted during fall 2000 on the San Joaquin River at Prisoners Point and Eddo's Boat Harbor. One hundred and twelve adult chinook salmon were tagged with ultrasonic transmitters and fitted with an external Floy tag to allow a quick visual identification by biologists, fishermen, and hatchery personnel. Eleven fixed hydrophone stations were placed at key locations throughout the Delta to monitor tagged fish movement. They were located on the San Joaquin, Mokelumne, Middle, Old, and Sacramento rivers, Georgiana Slough, and the Delta Cross Channel. In addition to using fixed monitors, we searched for salmon by boat on four routes encompassing most of the study area. Water quality data, including dissolved oxygen, conductivity, temperature, and water clarity, were collected at the tagging sites, during mobile monitoring, and at predetermined locations throughout the Delta.

Preliminary results indicate that 71 of the 112 tagged salmon were detected by fixed stations or mobile monitoring. Forty-seven salmon (66%) exited the study area through the Sacramento River at the Hood station and ten salmon (14%) exited through the San Joaquin River at Mossdale. Five tagged fish were detected at the Delta Cross Channel, two of which were tagged on the San Joaquin River.

Reference

Hallock RJ, Elwell RF, Fry DH, Jr. 1970. Migration of adult king salmon *Oncorhynchus tshawytscha* in the San Joaquin Delta as demonstrated by the use of sonic tags. Fish Bulletin 151. California Department of Fish and Game.

Upper Estuary Chinese Mitten Crab Research Projects

Tanya Veldhuizen and Cindy Messer, DWR
tanyav@water.ca.gov, cmesser@water.ca.gov

Two research projects focused on Chinese mitten crabs in the Sacramento-San Joaquin Delta are the Chinese Mitten Crab Habitat Use Study, which evaluates mitten crab habitat use, and the Chinese Mitten Crab Benthos Impact Study, which investigates the effects of mitten crabs on the benthic invertebrate community.

Sampling with "crab condos" for the Chinese Mitten Crab Habitat Use Study will continue through June 2001. The sample sites are Horseshoe Bend, Franks Tract/False River, Old River/Connection Slough, and Middle River at Five Fingers. Crab catch declined during winter months. During spring months, crab catch increased at the western Delta sites (Horseshoe Bend and Franks Tract/False River), but not at the interior Delta sites. Further investigation will be conducted on mitten crab distribution within the Delta, in addition to the main study objective of determining crab distribution among various habitat types.

For the Chinese Mitten Crab Benthos Impact Study, otter trawling was conducted monthly from April through November 2000. Sampling took place at seven of DWR's historical benthic monitoring sites (Suisun Bay, Grizzly Bay, Collinsville, Twitchell Island, Sherman Island, Rio Vista, and Rock Slough). The objectives of this first phase of study were to determine crab presence at the benthic sites and the success rate of otter trawling as a method of collecting mitten crabs. Eleven mitten crabs were collected at five of the benthic sites during this initial phase. In addition to monthly sampling in 2000, otter trawling was conducted in January and April 2001 in Suisun and San Pablo bays. The objective of additional sampling was to detect the presence of mature crabs migrating downstream. No mitten crabs were collected in January. Six mature crabs, four males (59 mm CW, 70 mm CW, 71 mm CW, 72 mm CW) and two gravid females

(55 mm CW, 61 mm CW) were collected in April from Suisun in the channel and on the shoal adjacent to the Mothball Fleet. No crabs were collected at DWR Benthic Monitoring Site D6.

The second phase of the benthos study is scheduled to begin in April and will consist of an enclosure study to detect the effects of juvenile mitten crabs on the benthic community. A survey of Sherman Lake was conducted to assess the availability of study sites. Site requirements include accessibility by boat, large shallow areas to set multiple enclosures, and hiding places for enclosures to minimize vandalism. Suitable study sites must also be located in the subtidal zone so that enclosures will not dewater during low tide. Crab condos will be used to collect crabs for the enclosures and provide presence and absence information for Sherman Lake. Benthic sampling within the enclosures will be conducted using a galvanized, 8-cm diameter, steel corer specifically designed for this study. Field testing of the corer was conducted in April.

Sherman Island Agricultural Diversion Evaluation

Matt Nobriga and Zoltan Matica, DWR
mnobriga@water.ca.gov

We are planning additional diversion sampling in the spring and summer of 2001. This element samples the relative abundance and species composition of fishes entrained in side-by-side diversion siphons in Horseshoe Bend on the lower Sacramento River. In particular, we are emphasizing the effects of tidal and diel cycles on fish entrainment. The Horseshoe Bend facility consists of two screened 24-inch diversion pipes and an unscreened 24-inch pipe. A screened and unscreened siphon will be sampled simultaneously using modified fyke nets (1,600 µm mesh) that fit completely over the outfall side of the pipes so that all water coming through the siphons is filtered before entering the irrigation canal.

Last year we completed one sampling “blitz”—a continuous sampling period of approximately 40 hours. This year we plan to complete three such blitzes. The first two will occur in May and will be timed to sample periods when peak nighttime high tides occur near sunset and midnight. Our third sampling blitz is planned for a crepuscular high tide period in July to compare with last year’s July sample.

Suisun Marsh Salinity Control Gates

Robert Vincik, DFG
rvincik@delta.dfg.ca.gov

The Suisun Marsh Salinity Control Gates Steering Group Technical Team analyzed data collected during the 1998–1999 salmon passage studies in Montezuma Slough. Several environmental factors were evaluated for their possible effects on salmon passage at the salinity control gates. This analysis was done in response to findings that adult salmon were not passing the structure when a set of modified flashboards were in place. The modified flashboards had two 3-ft by 66-ft slots placed below the water line to allow adult salmon passage while the radial gates were in operation.

The technical team evaluated environmental factors including tidal stage, flow, moon phase, day and night passage rates, salinity, water temperature, dissolved oxygen, and duration of gate openings. The team found no significant influences from the environmental factors and it was concluded that the low percentage of salmon passage was due to the modified flashboards.

Several options for improving fish passage at the SMSCG were considered for studies during fall 2001. Of these, the most feasible were

1. opening the existing boat lock to form a vertical passageway,
2. removing the top flashboard,
3. installing a fish ladder, and
4. creating a 6-ft by 66-ft gap in the existing flashboards

The Suisun Marsh Salinity Control Steering Group is examining each option and will recommend a study design for completion in fall 2001.

Delta Smelt and Splittail Transportation and Release

Virginia Afentoulis, DFG
vafentou@delta.dfg.ca.gov

This past year we began an extensive ongoing literature search, exploring all aspects of handling and transport including various alternative methods of handling and transport, aeration techniques, water circulation techniques, history of fish transport, and use of anesthetics to improve survival.

The literature review focuses on primary and secondary fish stress indicators such as cortisol, glucose, and lactate found in blood plasma after exposure to stressors. The literature review and research are currently being used to begin pilot experiments. These physiology experiments will evaluate the effect of the John E. Skinner fish protective facility in Byron, California, on fish stress indicator levels. Target species are delta smelt, splittail and other species that are endangered, threatened, or of special concern.

A series of pilot transport and handling mortality experiments was conducted from April through July 2000 at the Skinner fish protective facility. During the experiments juveniles of various species including splittail, American shad, delta smelt, and longfin smelt were used to test handling losses independently of transport losses. After the experiments, fish were placed into 300-gallon recovery tanks to observe mortality. Fish mortality counts for transport and handling experiments were recorded three times: immediately following the experiments, at 24 hours, and at 48 hours. The sample size of these experiments varied between 50 to 100 fish. Dissolved oxygen, water temperature, and visibility were also recorded. Data is currently being analyzed.

In May 2001 experiments on transport and handling will resume along with pilot experiments to sample fish stress indicators found in the blood plasma. The data collected will be used in future studies to improve fish survival during transport, handling and release at Skinner and other fish facilities.

UC Davis Fish Treadmill—Delta Smelt Collection

Virginia Afentoulis, DFG
vafentou@delta.dfg.ca.gov

Between November 2000 and January 2001, DFG and UCD staff conducted 17 sampling trips to capture wild delta smelt (*Hypomesus transpacificus*) by purse seining at Montezuma Slough, Chain Island, Sherman Island, and Horseshoe Bend. The delta smelt collected will be used for experiments in the UCD "Fish Treadmill," a facility used to test screens and water project flow effects on juvenile Delta fishes ranging in size from 4 to 8 cm. Of nearly 2,600 delta smelt collected (using strict, quality controlled methods) the total 24-hour collection survivorship averaged about 72% and the 48-hour total average survivorship was about 62%.

Yolo Bypass Floodplain Study

Ted Sommer and Bill Harrell, DWR
tsommer@water.ca.gov

Although 2001 hydrology has so far been relatively "dry," the Yolo Bypass floodplain study results have been more interesting than we expected. Wild fall run, winter run, spring run, and steelhead trout adults were all captured as part of autumn-winter fyke trap sampling in the Toe Drain, the Yolo Bypass' perennial channel. These results point to the need to improve upstream fish passage at Fremont Weir, which did not spill in 2001. Steelhead and fall run may have been migrating to Putah Creek, but we have no subsequent observations from the stream to validate this hypothesis. Substantial February flow pulses of >4,000 cfs[1] from Cache Creek triggered upstream migration of several native fish species including splittail, white sturgeon, suckers, and pikeminnow and inundated several thousand acres of floodplain. Hundreds of adult splittail were captured in the fyke trap, confirming our finding in 2000 that inundation from the Sacramento River is not required to attract large numbers of splittail into Yolo Bypass. Fourteen of the splittail were transferred to a demonstration floodplain wetland pond at the Yolo Basin Wildlife Area Headquarters, where we are doing an intensive study of spawning and rearing behavior.

Sampling by rotary screw trap began in January 2001. One notable result is that we captured three "wild" salmon fry in February. The most likely origin of these fish is Cache or Putah creeks, but we cannot rule out the possibility that these are Sacramento River salmon fry that entered the Toe Drain by swimming upstream through Cache or Prospect sloughs. Two paired coded-wire-tagged salmon releases were completed in February at Yolo Bypass (Toe Drain at I-5 Bridge) and Sacramento River (Elkhorn boat ramp). These releases are part of ongoing studies to examine growth and survival differences between river and floodplain habitats.

1. Cubic feet per second.

SPRING MIDWATER TRAWL SURVEY

Kelly Souza, DFG
ksouza@delta.dfg.ca.gov

The Spring Midwater Trawl Survey commenced in January 2001 and continued through March 2001. It is designed to monitor distribution and relative abundance of delta smelt (*Hypomesus transpacificus*). One hundred and thirty-two delta smelt were caught: 46 in both January and February, and 43 in March. In January, 82% of the delta smelt catch occurred in Suisun Bay near Freeman Island, the remainder were caught in the lower Sacramento River to the southeast corner of Horseshoe Bend. In February and March, Suisun Bay accounted for a smaller percentage of the total delta smelt catch, 57% and 35%, respectively. In March, 28% of the delta smelt catch was in the North and South Mokelumne rivers, mostly at the mouths of Sycamore and Hog sloughs.

In March 2001, the spring survey collected a new species of freshwater shrimp near Rough and Ready Island belonging to the family Palaemonidae. Preliminary analysis indicates that this shrimp is not one of the native North American palaemonids (Greg Jensen, personal communication). Identification to species may take several months, as the specimens may have to be sent to the Netherlands for additional confirmation. Other collections this year have been made by the USFWS Beach Seine Survey at Liberty Island (Jason Hanni, personal communication), and the DFG Bay Study near Sherman Island (Kathy Hieb, personal communication).

Notes

Greg Jensen. University of Washington. Personal communication with Kathy Hieb on March 20, 2001.

Jason Hanni. United States Fish and Wildlife Service. Conversation with author in March 2001.

Kathy Hieb. California Department of Fish and Game. Conversation with author in March 2001.

ROCK SLOUGH MONITORING PROGRAM

Jerry Morinaka, DFG
jmorinak@delta.dfg.ca.gov

The Contra Costa Water District used the Rock Slough intake intermittently from January through March 2001. Whenever the intake was used, the diverted water was either used for maintaining the water levels in the Contra Costa Canal or the water was blended with Los Vaqueros Reservoir water to supply the canal. A sieve-net was used to monitor fish entrainment on five occasions at the Rock Slough intake of the Contra Costa Canal from January through March. No sampling was conducted at the facility during Contra Costa Water District's 15-day no-diversion period, February 21 through March 7. Few fish were caught at the intake from January through March, and none of these fish were species of concern. Fish entrainment monitoring will continue once per week throughout the year.

The acquisition of land rights for the future screened facility at the Rock Slough intake has continued to be a problem. The start of construction for the facility has been postponed until 2002, and completion of the facility is extended to December 2003. Due to present problems with land acquisition, the site for the screened facility may have to be moved to a new location along Rock Slough.

OLD RIVER FISH SCREEN FACILITY (LOS VAQUEROS) MONITORING PROGRAM

Jerry Morinaka, DFG
jmorinak@delta.dfg.ca.gov

The Old River Fish Screen Facility was shut down from September 16, 2000, through the end of January 2001. A sieve-net was used to evaluate fish entrainment three times a week in front of the screens and behind the screens at the facility in February and March. No sampling was conducted at the facility during Contra Costa Water District's 15-day no-diversion period, February 21 through March 7. Few fish were captured in front of the facility and behind the fish screens, similar to entrainment in previous years during these months. No listed fish species were captured and the only fish captured behind the fish screens were large juvenile and adult fish residing within the facility. Monitoring in front of the facility and behind the screens will continue three times per week through June.

Mallard Slough Monitoring Program

Lee Mecum and Jerry Morinaka, DFG
lmecum@delta.dfg.ca.gov

The Contra Costa Water District did not start operating the Mallard Slough Pumping Plant in 2001 until March 12. The pumping plant was operated for a short time, then shut down on March 20. Only one sampling effort was conducted during this time. An egg and larval net was used to sub-sample approximately one-third of the water being diverted. Results have not been processed for the one sample taken before the sampling was halted due to heavy construction at the site. Construction is underway for the new pumping plant scheduled to be completed in 2002.

IEP Long-term Status and Trends for 2000

Delta hydrology

Kate Le, DWR
kle@water.ca.gov

During calendar year 2000, hydrologic conditions started off dry in January, however, some precipitation arrived by late January and continued through March. The greatest amount of precipitation resulted in high runoff from mid-February through mid-March. From April through the end of the year, outflow remained low, since very little precipitation occurred during this time. Near the end of October 2000 there was a storm event, but its duration was too short to result in a promising hydrology for the year. As a result of a dry fall, both State and federal water project staff anticipated water quality concerns due to the closure of the Delta Cross Channel (DCC) gates for fish protection and adjusted exports at both water projects to comply with water quality standards.

Net Delta Outflow

Figure 1 shows the calculated 2000 Net Delta Outflow Index (NDOI) and the 41-year (1959–1999) average Net Delta Outflow. Measurement of Delta outflow by USGS was not available this year.

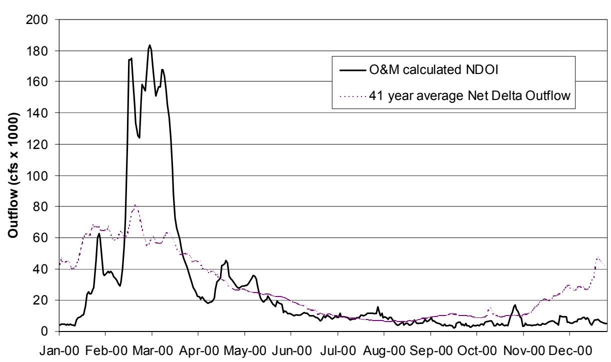


Figure 1 Calculated NDOI compared to measured Net Delta Outflow for January 1 through December 31, 2000, and average Net Delta Outflow

All outflow values are daily means. The 41-year average values were obtained from historical DAYFLOW data. The calculated values, provided by DWR's Division of Operations and Maintenance (O&M), are based on the mass balance of flows into and out of the Delta.

Comparing the O&M calculated NDOI to the 41-year average net outflow shows that February, March, mid-April through early May, and late July were higher than average in 2000 (Figure 1). From August on, the calculated outflow was lower than that of the 41-year average net outflow, except for the end of October, where a short storm raised outflow higher than that of the 41-year net outflow for that period (Figure 1).

Inflows and Exports

Figure 2 shows Sacramento and San Joaquin River mean daily flows along with precipitation for calendar year 2000. Flow in both rivers increased from February through mid-March due to runoff from storm events during that period. The maximum mean daily flow for Sacramento River peaked at about 87,000 cfs in late February, whereas San Joaquin River flow peaked at about 17,000 cfs in early March. Flow gradually decreased from mid-May through the end of the year. Despite variable export reductions in late November and on into December for water quality concerns, flow continued to decrease due to low precipitation from October through December 2000.

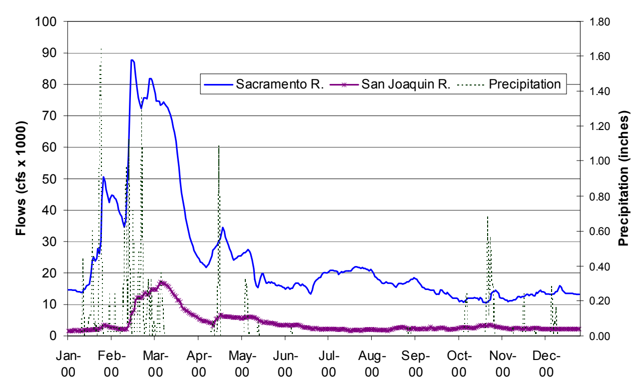
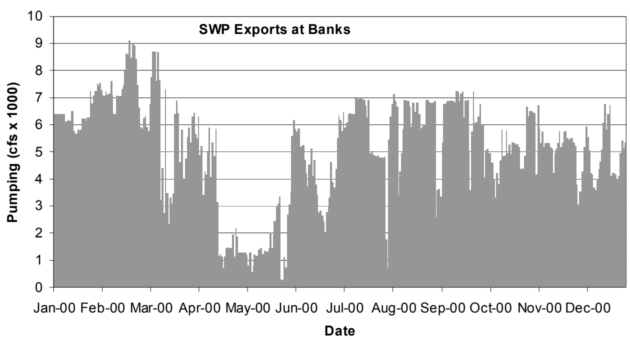


Figure 2 Mean daily Sacramento River and San Joaquin River flows for January 1 through December 31, 2000

Figure 3 shows the State Water Project (SWP) and Central Valley Project (CVP) mean daily export rates for calendar year 2000. Average SWP mean daily exports at Banks Pumping Plant averaged about 5,000 cfs over the year with peak pumping at about 9,000 cfs on February 20, 2000. CVP exports at Tracy Pumping Plant averaged about 4,000 cfs over the year with peak pumping slightly higher than 4,000 cfs on August 2, 2000.



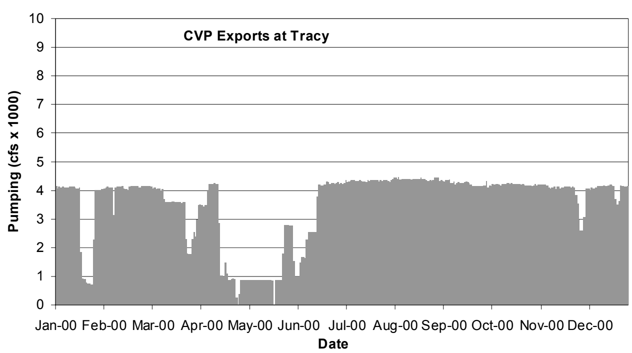


Figure 3 SWP and CVP mean daily export rates for January 1 through December 31, 2000

CVP export reduction in late January, as shown in Figure 3, was due to maintenance. There was more variability in SWP pumping than CVP due to fluctuating demands from March through mid-April. CVP reduced pumping only in late March because of low demands. From mid-April to mid-May, both projects reduced pumping in support of the Vernalis Adaptive Management Plan. From late May through July, both water projects adjusted pumping to deal with either water quality or delta smelt issues. Export reduction in August at the SWP afforded maintenance, whereas reduction in pumping at both projects in late fall alleviated water quality concerns from the fish protective action of the DCC closure.

Figure 4 shows the percent Delta inflow diverted by the SWP and CVP during calendar year 2000. Three-day and 14-day running averages are shown, along with the maximum allowable percent diversion for different times of the year. From February through June, diversions are limited to 35% of Delta inflow. For the rest of the year, diversions are limited to 65% of Delta inflow. Throughout the year, the percent diverted complies with the maximum allowed criterions. The percent diverted exceeded the 35% limit in late June through end of June because the export to inflow ratio was relaxed by the fishery agencies so that both projects could make up pumping curtailed in the early part of the year for fish protection.

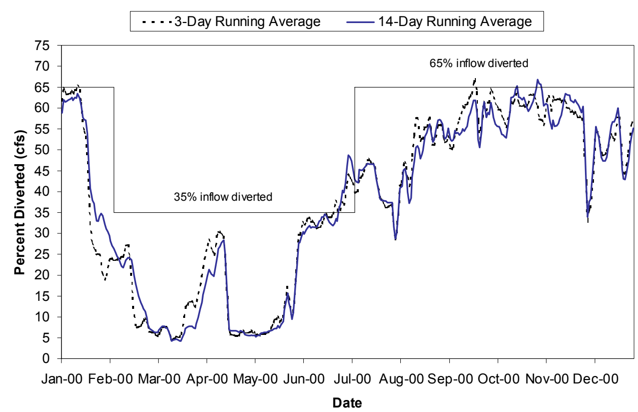


Figure 4 Total annual Delta outflow and annual exports for calendar years 1959 through 2000

Annual Totals

Figure 5 compares the 41-year record for total annual Delta outflow and total annual exports (SWP + CVP). The 2000 totals were calculated from DWR O&M data and the historical totals were calculated from DAYFLOW data. The annual Delta Outflow Index for 2000 was somewhat higher than 1999. 2000 Delta outflow represents the eighteenth highest in the last 41 years. The annual exports were higher than the previous ten years and the second highest in the last 41 years.

Figure 5 Total annual Delta outflow and annual exports for calendar years 1959–2000

Water Supply Forecast

Based on DWR's Bulletin 120 (dated March 1, 2001) water supply was forecasted to be below normal for the Delta watershed. Figure 6 shows water supply as a percent of average for the Sacramento and San Joaquin hydrologic regions.

Figure 6 Water supplies in percent of average for the Sacramento (Sac) and San Joaquin (SJR) hydrologic regions

Reservoir storage increased at about the normal pace during the month and is near average for this date statewide. Last year storage was higher at 120% of average. Lake Oroville gained about 0.1 maf[1] during February 2001 but remains much below average.

1. Million acre-feet.

Snow water content has improved to 85% of average for this date compared to 120% last year. The pack is about 70% of the April 1 average, the date of maximum accumulation. As noted last month, large snow amounts accumulated in the lower portion of the snow zone; amounts near the crest of the Sierra are considerably lighter.

The water year forecasts, assuming normal weather henceforth, are about 60% of average statewide compared to 95% actual runoff last year.

Zooplankton and Mysid Shrimp

W. Lee Mecum and James Orsi, DFG
lmecum@delta.dfg.ca.gov

Little change occurred in the abundance of zooplankton and mysid shrimp between 1999 and 2000. Except for *Limnoithona tetraspina* overall copepod abundance remained relatively low. *Sinocalanus doerrii* abundance continued at a depressed level but has shown signs of an increasing trend since 1996 (Figure 1). *Eurytemora affinis* abundance has been most heavily depressed in summer and fall (Figure 2). There was no change in 2000 in this pattern of relatively high abundance in spring and very low abundance in summer and fall. Abundance of *Pseudodiaptomus forbesi*, an important fish food organism, has oscillated without a trend since 1994 after declining sharply from its summer 1989 peak (Figure 2). The native freshwater genera *Diaptomus* and *Cyclops* continued to have low abundance (Figures 3 and 4). The greatest reduction for these species has been in summer and fall. A recently (1994) introduced copepod, *Acartiella sinensis* (Figure 5), almost disappeared from our catches in 1999, but its abundance increased slightly in 2000. A native lower-bay genus, *Acartia*, enters Suisun Bay when salinity is high. Its abundance has shown an increasing trend in spring since 1997 (Figure 6). The most abundant copepod in the upper estuary, the introduced *Limnoithona tetraspina*, showed continued high abundance in spring 2000 (Figure 7). In summer, its abundance has oscillated without trend since its introduction in fall 1993. No *L. sinensis* has been seen since 1994. *Limnoithona tetraspina* has probably replaced *L. sinensis* in the Delta.

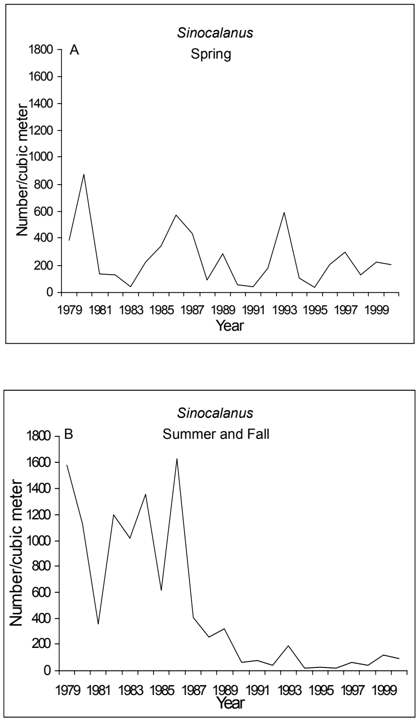


Figure 1 Mean abundance of the introduced copepod *Sinocalanus doerrii* in (A) spring and (B) summer and fall, 1979 through 2000

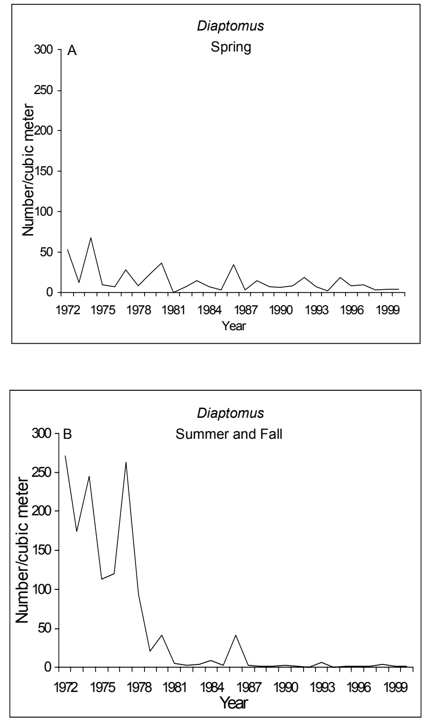


Figure 3 Mean abundance of all *Diaptomus* in (A) spring and (B) summer and fall, 1972 through 2000

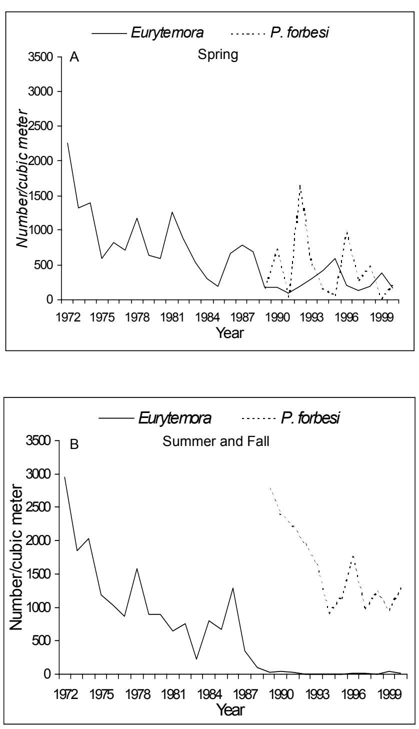


Figure 2 Mean abundance of *Eurytemora affinis* (of cryptic origin) and the introduced copepod *Pseudodiaptomus forbesi* in (A) spring and (B) summer and fall, 1972 through 2000

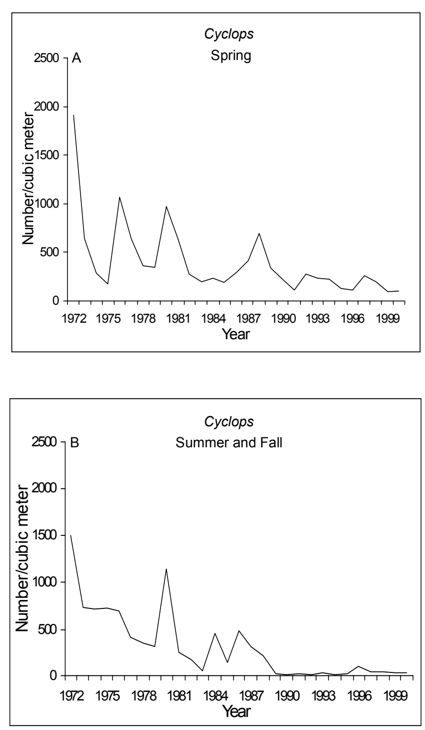


Figure 4 Mean abundance of *Cyclops* in (A) spring and (B) summer and fall, 1972 through 2000

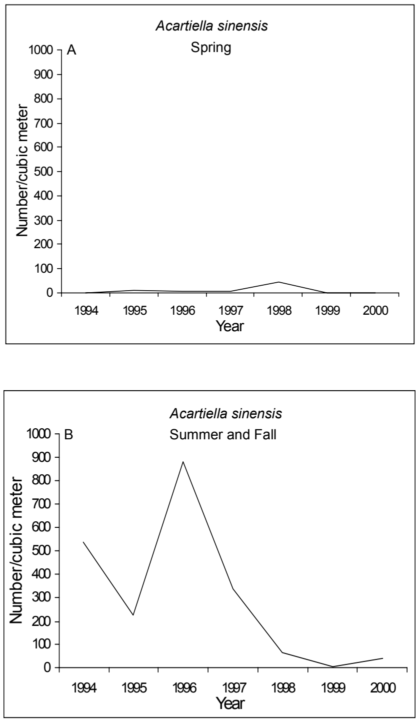


Figure 5 Mean abundance of the introduced copepod *Acartiella sinensis* in (A) spring and (B) summer and fall, 1994 through 2000

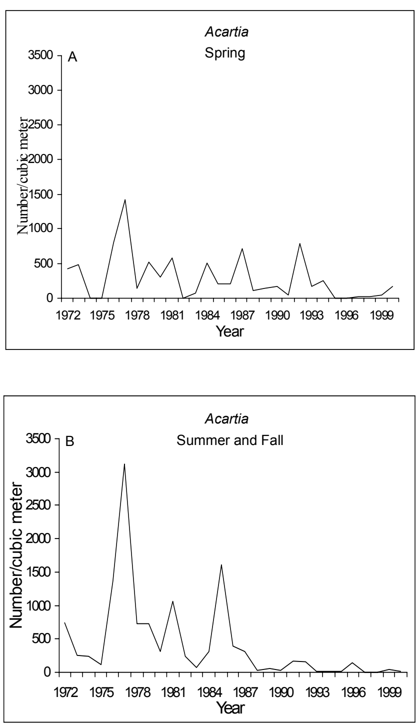


Figure 6 Mean abundance of *Acartia* in (A) spring and (B) summer and fall, 1972 through 2000

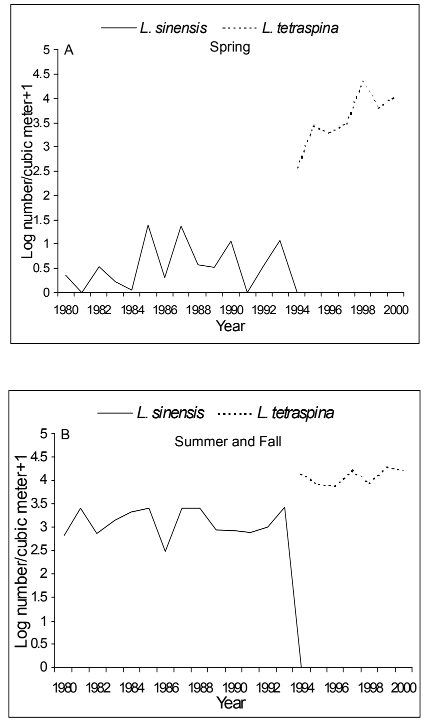


Figure 7 Mean abundance of the introduced *Limnoithona sinensis* and *L. tetraspina* in (A) spring and (B) summer and fall, 1980 to 2000

Cladocerans showed continued low abundance in all seasons, although abundance rose slightly in 2000 (Figure 8).

The estuarine rotifer, *Synchaeta bicornis*, had continued low abundance (Figure 9). Other rotifers also showed very low abundance in 2000 in all seasons (Figure 10).

The native mysid, *Neomysis mercedis*, has not recovered from its population crash, but the introduced mysid, *Acanthomysis bowmani*, has shown a trend of increasing abundance in summer and fall (Figure 11).

Competition for food with exotic copepods or mysids and the Asian clam *Potamocorbula,* as well as predation by *Potamocorbula,* probably prevent the recovery of native species. The diets of *P. forbesi*, *L. tetraspina*, *N. mercedis*, and *A. bowmani* should be investigated to determine the importance of these factors.

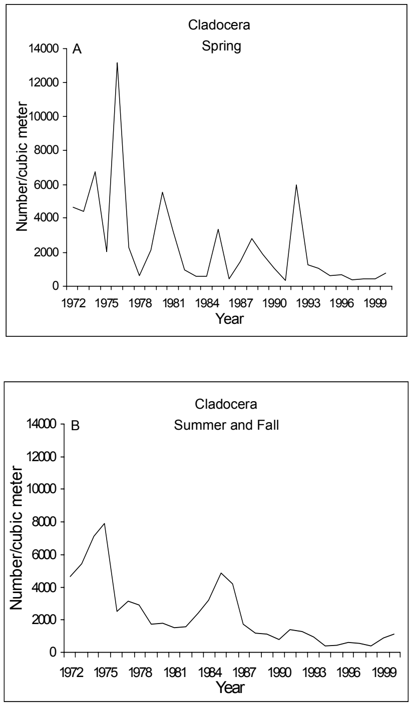


Figure 8 Mean abundance of all cladocera in (A) spring and (B) summer and fall, 1972 to 2000

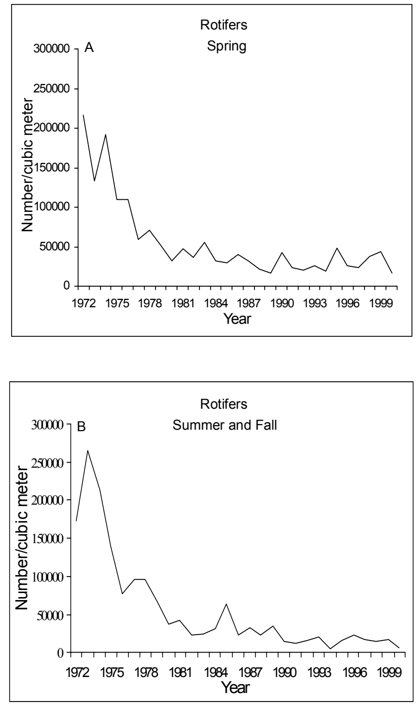


Figure 10 Mean abundance of all rotifers in (A) spring and (B) summer and fall, 1972 to 2000

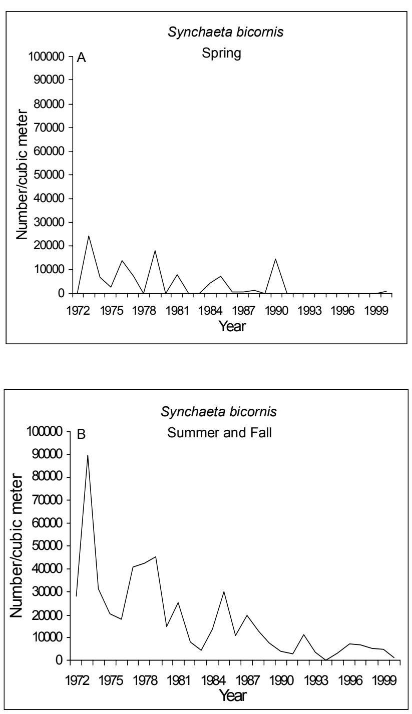


Figure 9 Mean abundance of the rotifer *Synchaeta bicornis* in (A) spring and (B) summer and fall, 1972 to 2000

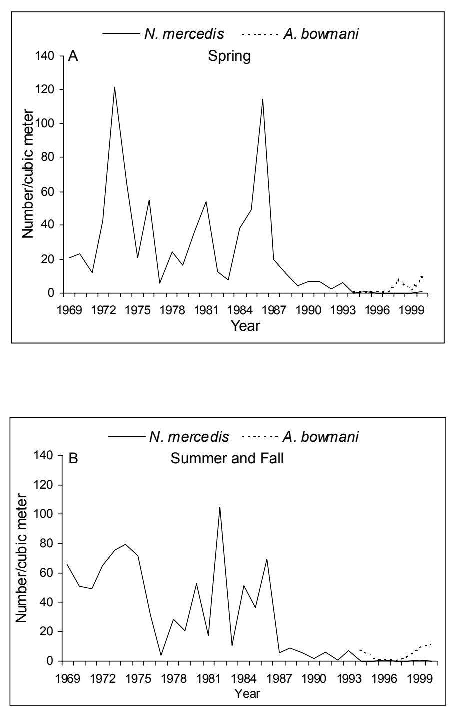


Figure 11 Mean abundance of the native *Neomysis mercedis* and the introduced *Acanthomysis bowmani* in (A) spring and (B) summer and fall, 1972 to 2000

Splittail and Longfin Smelt

Randall Baxter, DFG
rbaxter@delta.dfg.ca.gov

Splittail Abundance

Past status and trends articles reported total splittail abundance from the Fall Midwater Trawl Survey and age-specific abundance from Delta Outflow San Francisco Bay Study midwater and otter trawls. Here I update indices from these surveys and add two more indices: (1) young-of-the-year (age-0) abundance from the Fall Midwater Trawl Survey and (2) age-0 abundance from the U.S. Fish and Wildlife Beach Seine Survey. In 1975, the Fall Midwater Trawl Survey began recording splittail lengths as well as catch. These length data allowed separation of age-0 fish from older age groups and the calculation of an age-0 abundance index. The U.S. Fish and Wildlife Beach Seine Survey, which samples throughout the legal Delta and upstream in the Sacramento River to Colusa (and occasionally farther), has been very effective at capturing age-0 splittail, particularly when sampling continued through May and June, a period of dispersal and high vulnerability for young-of-the-year. The annual beach seine index was calculated as the sum across regions of mean May through June catch per haul by region. The index regions follow Sommer and others (1997) for the Delta, but three Sacramento River regions have been added. Trends in age-0 abundance from the beach seine survey provide a very different perspective on splittail recruitment than those garnered from trawl surveys.

Total splittail abundance (all ages combined) in the Fall Midwater Trawl Survey declined for a second consecutive year in 2000 (Figure 1, all ages). The decline resulted from low abundance of the 2000 year class (Figure 1, age 0) and better net avoidance with growth for the 1998 year class; the latter year class accounted for about 80% of the 1999 abundance index. There was only a slight decline in age-0 abundance between 1999 and 2000 (Figure 1, age 0). Neither year offered particularly good spawning conditions: flows peaked in February and declined rapidly in March of both years, so floodplain inundation did not persist through the principal spawning months of March and April.

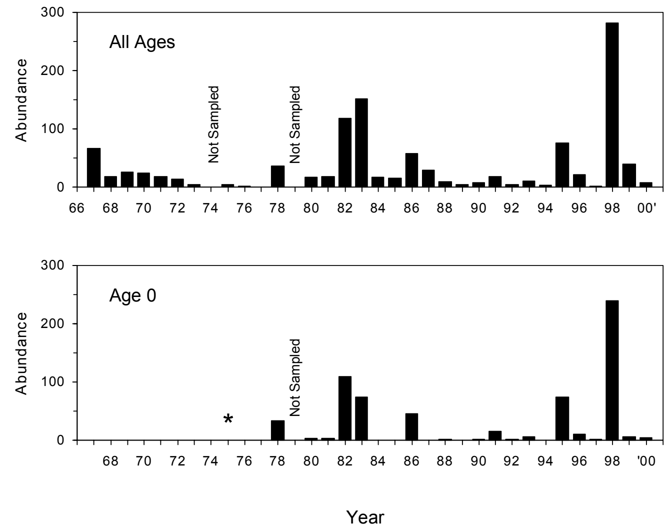


Figure 1 Splittail total annual and age-0 abundance indices from the DFG Fall Midwater Trawl Survey, 1967–2000. The length measurements for splittail were first recorded in 1975, allowing calculation of an age-0 abundance index from 1975 (asterisk) to present. The survey was not conducted in 1974 or 1979.

Bay Study sampling provided a more positive assessment of splittail production in 2000. The 2000 age-0 abundance index for the Bay Study midwater trawl increased substantially from 1999, but remained well below that of the two exceptionally strong year classes of 1995 and 1998 (Figure 2, age 0). Age-0 abundance in the Bay Study otter trawl exhibited a similar but more extreme pattern since 1995—no age-0 splittail were caught in 1996, 1997, or 1999; record and near-record abundance was recorded in 1995 and 1998; and moderate abundance was detected in 2000 (Figure 3, age 0). Age-0 catches for both Bay Study trawls came almost exclusively from May through August, before fall midwater trawl sampling began in September, suggesting splittail may not have been available to trawl capture later in the year.

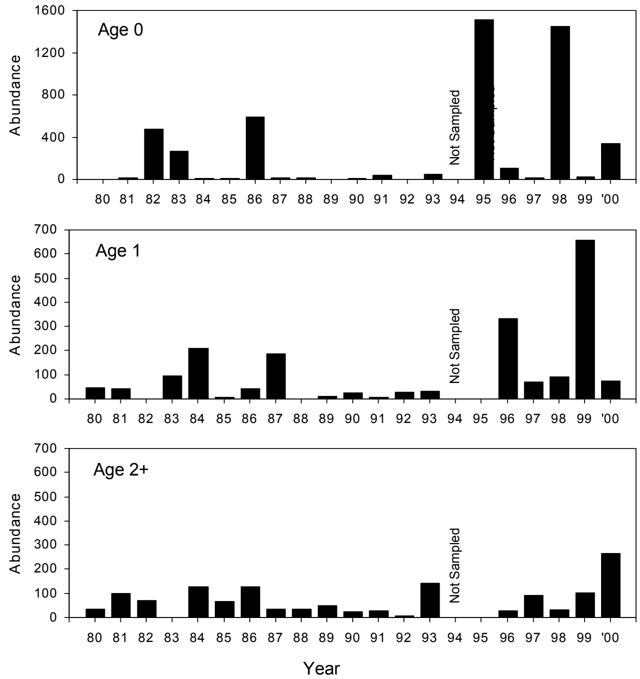


Figure 2 Splittail annual abundance indices for young of the year (age-0), age-1, and adult (age-2+) fish captured in the DFG Delta Outflow-San Francisco Bay Survey midwater trawl, 1980–2000. Sampling in 1994 was insufficient to calculate an index.

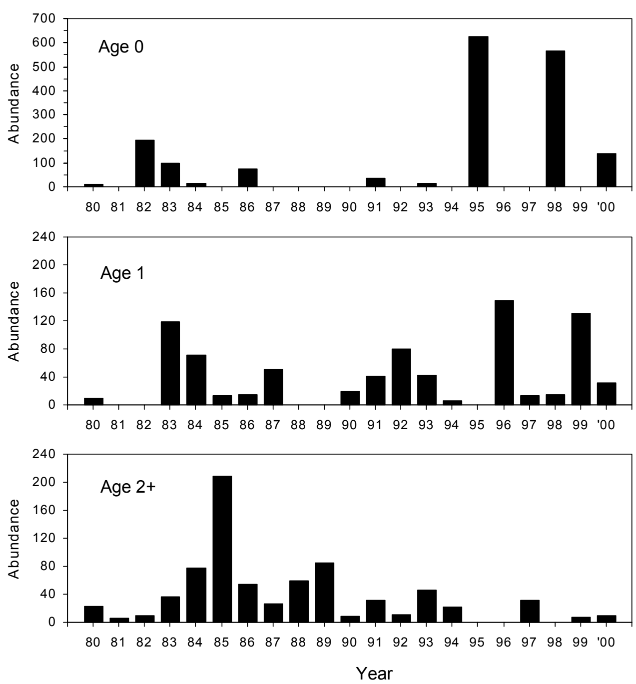


Figure 3 Splittail annual abundance indices for young of the year (age-0), age-1, and adult (age-2+ fish captured in the DFG Delta Outflow-San Francisco Bay Survey otter trawl, 1980-2000

In 2000, age-1 splittail indices declined for both Bay Study trawl surveys reflecting weaker recruitment in 1999 than in 1998 (Figures 2 and 3, age 1). As has often occurred in the past, substantially more 1999 year class fish were caught in 2000 at age 1 than in 1999 at age 0. This probably resulted from age-1 fish distributing themselves farther downstream and offshore than age-0 fish, making them more vulnerable to trawl capture.

The near-record 1998 splittail year class reached age 2 in 2000 and contributed to record age-2+ abundance for the Bay Study midwater trawl, but relatively low abundance for the otter trawl (Figures 2 and 3, age 2+). The 2000 midwater trawl index was strongly influenced by 15 adult splittail captured in April 2000, which resulted in a monthly index three times larger than the previous maximum for this survey. This high catch was probably composed of post-spawning adults returning to the Delta and Suisun Bay, and suggests a large spawning effort in 2000.

Age-0 abundance in the U.S. Fish and Wildlife Service Beach Seine Survey reached a near-record level in 2000 (Figure 4). Unlike trawl survey indices, the 2000 beach seine index was comparable to indices from recent high outflow years 1995 and 1998. Beach seine sampling also provided information on the distribution of age-0 splittail, which helped interpret patterns in other indices. In years of low spring outflow, such as 1992, 1994, and 1997, the largest catches of age-0 splittail occurred in Sacramento River regions, well upstream of traditional trawl survey sampling areas. This upstream distribution partially explains the limited detection of dry-year recruitment among trawl surveys. This survey also provided evidence of splittail recruitment even in critically dry years such as 1994.

Longfin Smelt Abundance

Longfin smelt abundance in the 2000 Fall Midwater Trawl Survey is described by Kelly Souza in this issue (page 27). Age-0 longfin smelt abundance declined sharply in 2000 in both Bay Study trawl surveys (Figures 5 and 6, age 0). The magnitude of the decline was unexpected because outflow conditions for 2000 were similar to 1999 and were assumed to produce similar abundance levels. Also, the abundance of spawners in 2000 (age-1 fish in 1999) reached its highest level in over a decade. In this case, December 1998 and early January 1999 flows may have made the difference. It is also possible that environmental factors other than freshwater outflow also affect reproduction.

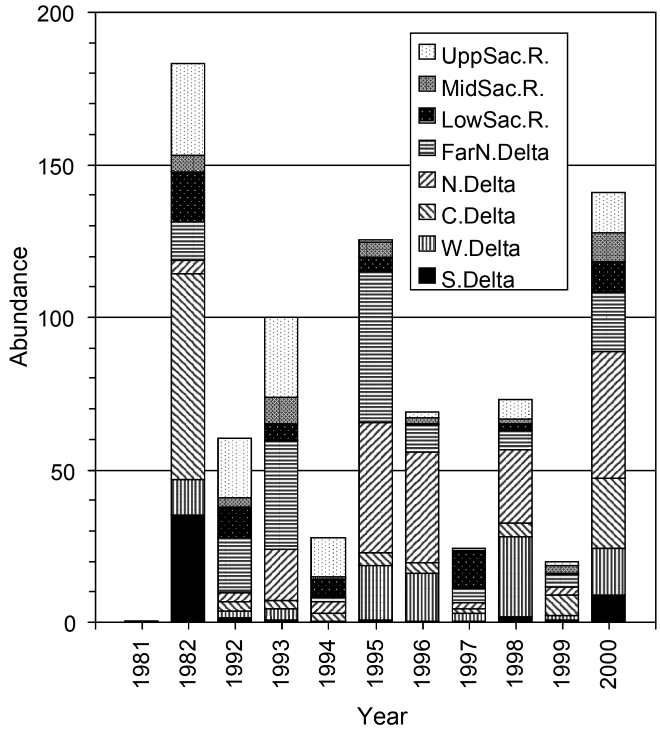


Figure 4 Splittail young-of-the-year (age-0) annual abundance indices for fish >24 mm FL from the USFWS Beach Seine Survey data for 1981, 1982, and 1992–2000. This index is still in draft form and will change. Regions follow Sommer and others (1997), except LowSac.R. (American River to Feather River), MidSac.R. (Knights Landing to Butte Creek) and UppSac.R. (Colusa State Park to Ord Bend).

Age-1 longfin smelt abundance also declined in 2000 in both trawl surveys (Figures 5 and 6, age 1). Little is known of the factors that influence survival between age 0 and age 1, but at least some of the apparent abundance decline results from a seasonal migration to the Gulf of the Farallones to cooler waters. After abundance declined to zero in August and September (midway through the index period), monthly abundance of age-1 longfin smelt increased in the fall as waters cooled, reaching over 3,500 in December 2000. Thus, shifts in distribution from the estuary to the coast might be interpreted as a decline in abundance.

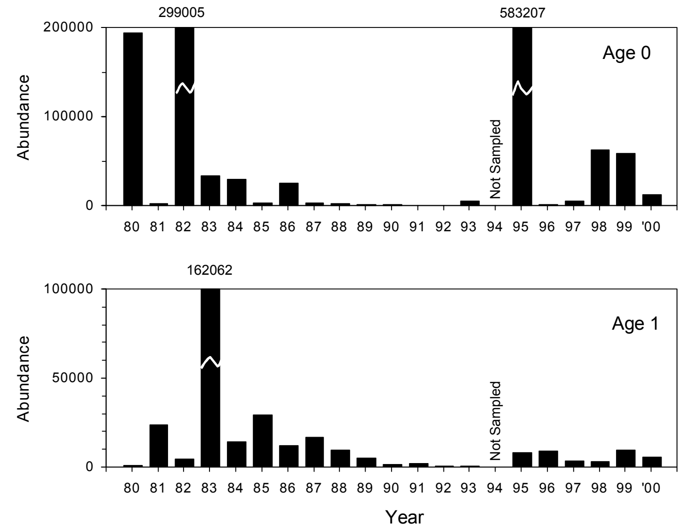


Figure 5 Longfin smelt young-of-the-year (age 0) and age-1 annual abundance indices from DFG Delta Outflow-San Francisco Bay Study midwater trawl sampling, 1980–2000. Sampling in 1994 was insufficient to calculate an index.

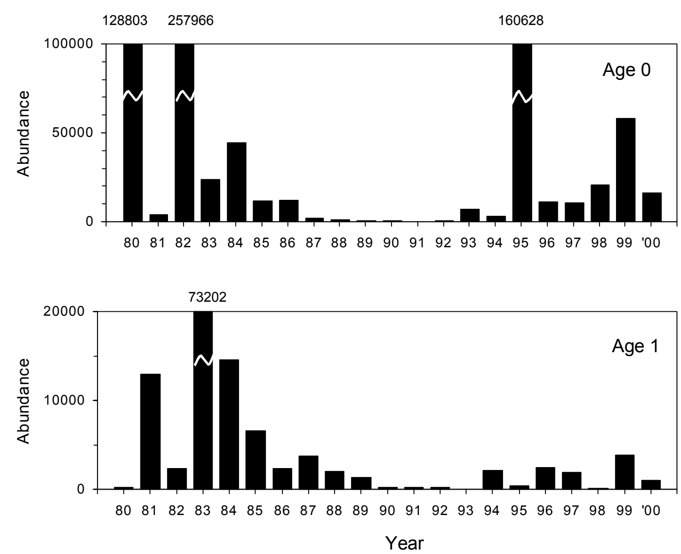


Figure 6 Longfin smelt young-of-the-year (age 0) and age-1 annual abundance indices from DFG Delta Outflow-San Francisco Bay Study otter trawl sampling, 1980-2000

References

Sommer T, Baxter R, Herbold B. 1997. Resilience of splittail in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 126:961–76.

Delta Smelt

Andy Rockriver, DFG
arockriv@delta.dfg.ca.gov

The spring Midwater Trawl Survey (MWT) is used to predict the general spawning location of delta smelt. In March 2000 some delta smelt began moving up the San Joaquin River, presumably to spawn (Figure 1A). The first 20-mm Survey at the end of March suggests the initial spawning took place in the western Delta (Figure 1B). Larval delta smelt (<15 mm TL) were caught on the lower Sacramento and San Joaquin rivers and down to Honker Bay. However, the length frequency data (Figure 2) indicate that it was the late spawners, in late April and early May, that produced the largest cohort of delta smelt. From April through May, larvae were caught throughout the system, from Cache Slough (North Bay Aqueduct egg and larval sampling program), in the central and south Delta (Figure 3A), down through Honker Bay, Montezuma Slough, and in the Napa River.

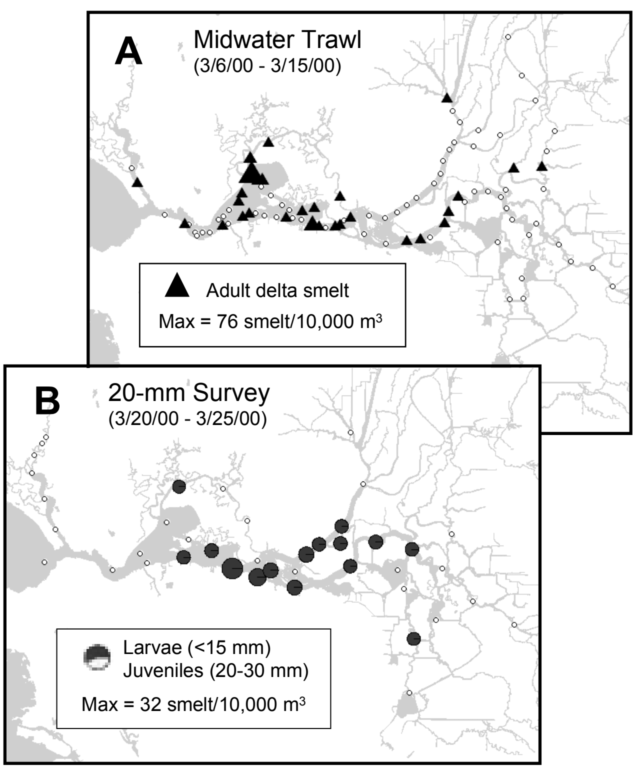


Figure 1 March 2000 distribution of adult delta smelt caught during the last Midwater Trawl Survey (A) and larval delta smelt caught during the first 20-mm Survey (B)

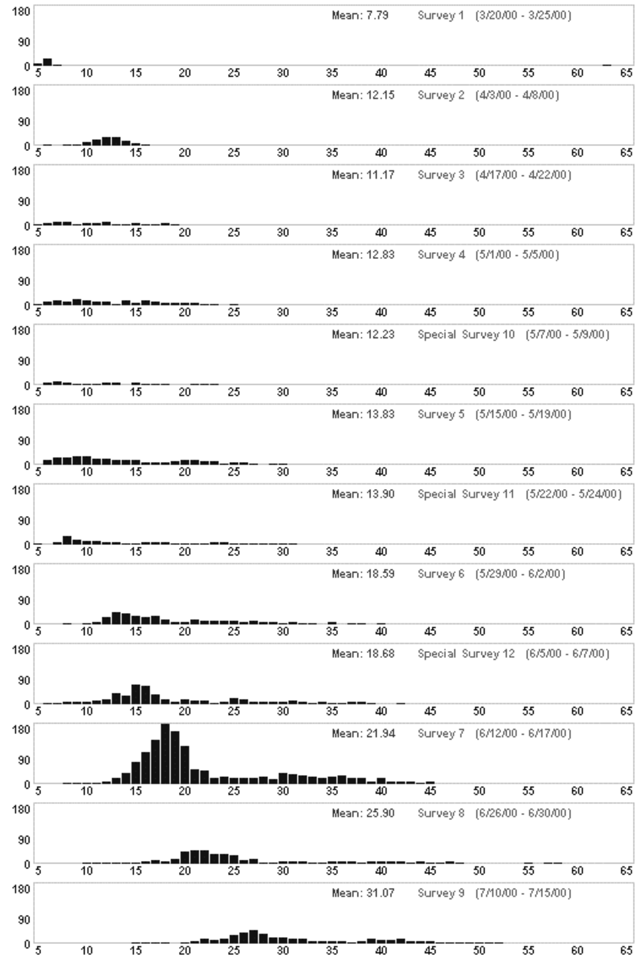


Figure 2 Delta smelt length frequencies, by survey, from the 20-mm Survey

In June, juvenile smelt began concentrating around the confluence and lower Sacramento River (Figure 3B). Average monthly water temperatures from April through June 2000 in the central and south Delta stations were about one to two degrees warmer than in 1999. Last June, the 20-mm Survey still caught larval and juvenile smelt in the central and south Delta. By July 2000, the summer Townet Survey (TNS) indicated the juvenile delta smelt distribution was shifting downstream toward Honker and Suisun bays (Figure 4A). In September, the late stage juveniles and adults were located just below the confluence. In October, the relative distribution shifted up into the lower Sacramento River (Figure 4B). In subsequent months, delta smelt were found in the lower Sacramento River and downstream into Suisun Bay.

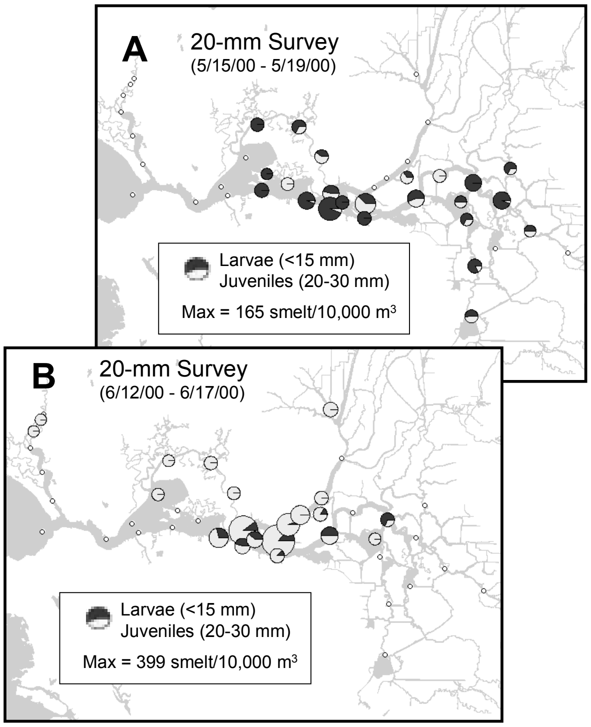


Figure 3 20-mm Survey larval and juvenile delta smelt distribution from May (A) and June (B) 2000

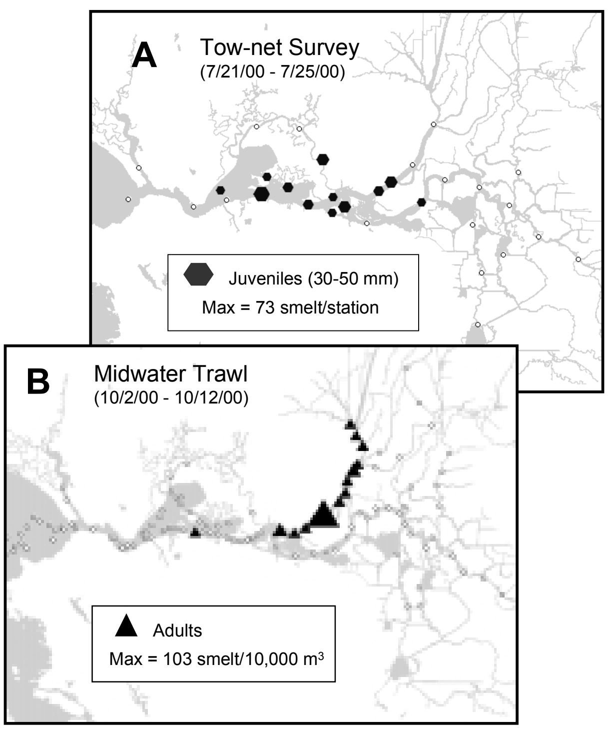


Figure 4 Juvenile delta smelt distribution from a July 2000 Townet Survey (A) and adult smelt distribution from the Fall Midwater Trawl Survey in October 2000 (B)

Although the relative delta smelt abundance calculated from the summer TNS and the fall MWT do not necessarily track one another, they both indicate a slight decrease in the population in 2000 (Figure 5). The 2000 TNS index (8.0) and the MWT index (757) were lower than last year's indices of 11.9 and 864, respectively. Interestingly, the 1999–2000 MWT two-year average index was the highest since 1981. Similarly, the TNS two-year average was the second highest since 1983. This pattern departs somewhat from the fluctuating abundance indices of the 1990s. Nevertheless, the current indices are definitely lower than the indices calculated from the 1970s. We still have a way to go before delta smelt reach their pre-decline levels.

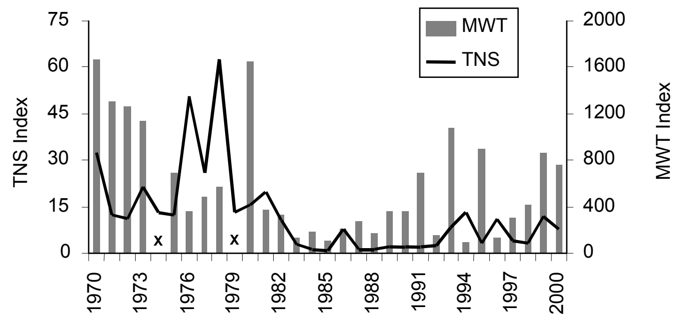


Figure 5 Delta smelt abundance indices (Townet Survey and Fall Midwater Trawl Survey) for the past 30 years. "X" indicates no sampling done in that year.

In 2000, approximately 113,000 delta smelt were salvaged from the State Water Project (SWP) and Central Valley Project (CVP). This is a decline from the approximately 152,000 smelt that were salvaged in 1999. Adult delta smelt salvage densities peaked in February and the juvenile densities peaked in late May (Figure 6). The red light take level was exceeded in May and June: 87% of the delta smelt salvaged in 2000 occurred during these two months. Although delta smelt salvage has been relatively high for the past two years, it is still less than the average SWP delta smelt salvage during the 1970s (564,146 ± 389,226 delta smelt per year). Of course, delta smelt were more abundant during the 1970s (Figure 5), which would partially explain the higher salvage numbers.

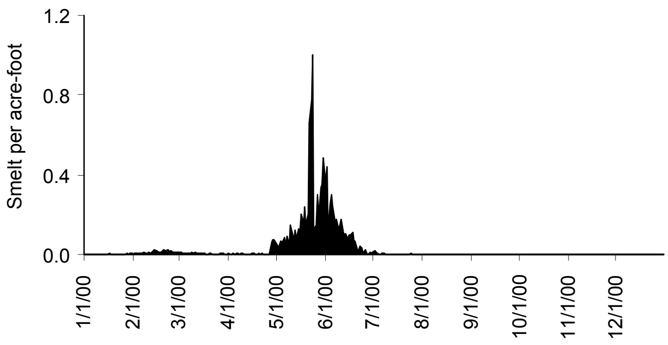


Figure 6 Combined (SWP and CVP) daily delta smelt salvage density for 2000

San Francisco Bay Species

Kathryn Hieb, DFG
khieb@delta.dfg.ca.gov

Annual abundance trends from 1980–2000 and distributional information for the most commonly collected species of shrimp, *Cancer* crabs, and fishes from San Francisco Bay are summarized in this article. Summary life history information was included in the 1997 status and trends reports for many of these species (DeLeón 1998; Hieb 1998). Additional life history information can be found in IEP Technical Report 63 (Orsi 1999).

Ocean temperature and freshwater outflow are two of the most important factors controlling abundance and distribution of species in the San Francisco Bay. Below average ocean temperatures continued in 2000, although it was not as cool as 1999. In the Gulf of the Farallones, the lowest monthly anomaly was –0.8 °C in July 2000, compared to 2.1 °C in June 1999. 2000 was classified as an "above normal" water year, with an average daily outflow of 50,164 cfs for January through May, followed by the usual low summer outflow (daily average of 6,682 cfs for July through September). These average values are very similar to those of 1999, although January and February 2000 outflow was lower than in 1999 and March 2000 outflow was slightly higher than in 1999. The major difference occurred before January, as outflow in late 1998 was much higher than outflow in late 1999.

Abundance of juvenile *Crangon franciscorum*, the California bay shrimp, increased in 2000 (Figure 1). The 2000 index was comparable to indices from many of the "wet" years of the 1980s and 1990s, although it was substantially lower than the very high indices of 1996–1998. Juvenile *C. franciscorum* were most common in Carquinez Strait and Suisun Bay during most of 2000, with a slow upstream movement in summer and fall. By December, the highest catches were in the lower Sacramento River and in South Bay at the station just south of the Dumbarton Bridge.

The 2000 abundance index of all sizes of *C. franciscorum* was almost identical to the 1999 index (Table 1). This index is comprised of adult shrimp from the previous and current year and several cohorts of juvenile shrimp, most from the current year. For example, in 2000, the "all sizes" index included adult shrimp hatched in 2000 and 1999 and juvenile shrimp, most hatched in 2000 (also from 1999). Although the juvenile *C. franciscorum* index increased in 2000, the all sizes index remained stable because the number of adult shrimp from the previous year decreased.

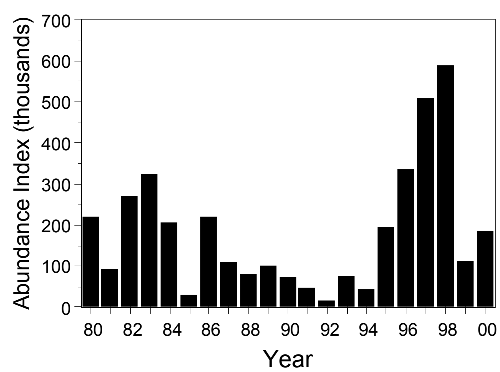


Figure 1 Annual abundance of juvenile *Crangon franciscorum* collected May through October with the otter trawl

The 2000 abundance of *C. nigricauda*, the blacktail bay shrimp, was a record high for the study period (Table 1). This species is found at higher salinities and cooler temperatures than *C. franciscorum*. In 2000, its distribution was centered in Central Bay, although it was also common in South Bay and throughout much of San Pablo Bay and collected as far upstream as Carquinez Strait. Abundance of *C. nigromaculata*, the blackspotted bay shrimp, decreased in 2000 from 1999 (Table 1). This species is found in more saline and cooler waters than *C. nigricauda*. In 2000 we collected it from South Bay to San Pablo Bay, but it was most common at our Central Bay channel stations. The abundance of the introduced shrimp *Palaemon macrodactylus*, the oriental shrimp, decreased slightly in 2000 from 1999 (Table 1). It is found in brackish and freshwater, being most commonly found in vegetated areas, around pilings, and other structured habitats (unlike the crangonids, it does not bury into the substrate). In 2000, *P. macrodactylus* was most common in Suisun Bay and at our station south of the Dumbarton Bridge. The abundance of *Heptacarpus stimpsoni*, the Stimpson coastal shrimp, increased in 2000 from 1999, although it remained a minor component (<10%) of the total shrimp index (Table 1). This is the smallest of the commonly collected shrimp species in the bay and is found in relatively saline, cool waters. In 2000, it was collected from South to San Pablo bays, but was most common in the Central Bay channels.

Total shrimp abundance (all species, all sizes) increased in 2000 from 1999 (Table 1), primarily due to increased *C. nigricauda* abundance. But CPUE (number per tow) did not consistently increase in all the regions of the San Francisco Bay in 2000 (Table 2). The largest increase in CPUE was in Central Bay, while CPUE declined slightly in Suisun Bay and the west Delta region. The CPUE differences are even more dramatic when compared to 1997 and 1998, when there was very high *C. franciscorum* abundance. From 1997–1998 to 2000, CPUE declined approximately 70% in San Pablo Bay and 50% in Suisun Bay. Note that the total index declined approximately 30% from 1997–1998 to 2000 (Table 1). Because of changes in species composition and distribution, regional shrimp CPUE does not change proportionally with the total shrimp index.

The 2000 abundance index of age-0 *Cancer magister*, the Dungeness crab, was similar to 1999 (Table 3). This was most likely a result of continued favorable ocean conditions in winter. Cool ocean temperatures and a relatively weak northward Davidson Current are thought to result in increased survival and retention of *C. magister* larvae in the Gulf of the Farallones, as well as increased nearshore settlement. Age-0 crabs were first collected in May in Central Bay and lower San Pablo Bay. They moved upstream over the next two months, and by July were common in upper San Pablo Bay and Carquinez Strait. There appeared to be a separate group of smaller *C. magister* in Central Bay from July to October; these crabs may have immigrated to the bay after spring and not migrated upstream or may have moved between the nearshore ocean area and Central Bay throughout summer and fall.

Table 1 Annual abundance indices (in thousands) of the five most common species of shrimp collected from San Francisco Bay from February through October with the otter trawl. Indices include all sizes for each species.

Year	*C. franciscorum*	*C. nigricauda*	*C. nigromaculata*	*Palaemon*	*Heptacarpus*	*All species*
1980	225.7	53.5	2.7	4.7	3.2	289.8
1981	119.2	22.1	0.5	5.1	0.5	147.3
1982	366.2	16.0	1.4	3.0	0.2	386.8
1983	328.3	38.8	16.0	1.3	0.6	385.0
1984	330.8	14.7	7.8	7.0	3.1	366.2
1985	57.8	19.7	3.1	3.9	3.1	88.3
1986	258.5	55.6	6.7	5.5	2.9	334.6
1987	142.9	75.5	9.6	2.4	6.8	239.0
1988	98.6	111.8	10.7	1.7	8.6	231.5
1989	100.2	118.6	22.1	4.6	27.4	273.1
1990	67.3	168.6	44.8	3.5	19.9	304.7
1991	51.4	190.3	63.0	4.7	41.1	350.7
1992	24.8	134.6	66.4	4.6	18.5	249.1
1993	70.5	128.0	78.6	4.0	25.4	308.3
1994	48.0	102.0	56.0	2.1	15.9	224.5
1995	180.6	78.8	33.1	3.7	4.3	302.3
1996	286.9	159.3	35.3	2.2	14.9	501.0
1997	444.4	163.9	43.4	4.9	9.1	667.8
1998	539.0	128.5	53.1	9.0	4.8	737.5
1999	159.4	134.6	42.0	4.1	13.2	353.3
2000	157.3	242.3	20.6	3.1	42.1	466.8

Table 2 Annual mean CPUE (number per tow) of all species and sizes of shrimp collected from February through October with the otter trawl, separated by region of San Francisco Estuary

Year	South Bay	Central Bay	San Pablo Bay	Suisun Bay	West Delta
1980	168	87	1143	851	124
1981	205	27	217	916	401
1982	174	70	1458	1944	3
1983	304	351	1291	679	0
1984	396	200	768	1821	195
1985	85	108	80	467	199
1986	273	190	867	1611	98
1987	225	311	147	1483	386
1988	272	248	416	459	775
1989	322	388	462	772	449
1990	336	577	371	382	640
1991	354	738	452	447	307
1992	232	625	262	178	206
1993	222	659	459	682	74
1994	215	446	286	409	279
1995	169	396	798	631	23
1996	658	530	970	1401	641
1997	663	872	1346	2054	604
1998	459	1302	1652	2109	1
1999	344	690	359	1008	207
2000	388	1048	509	983	200

Cancer gracilis, the graceful rock crab, is the smallest of the common *Cancer* species (most are <70 mm carapace width, CW) and is usually collected over open sandy or muddy substrates. Overall, it is the second most abundant *Cancer* crab in our otter trawl survey. Age-0 indices were low in 1999 and 2000, following the highest indices for the study period in 1997 and 1998 (Table 3). In 2000, *C. gracilis* was most common at several Central Bay channel stations and the Southampton Shoal station in Central Bay.

The brown rock crab, *Cancer antennarius*, reaches a maximum size of 160 mm CW, and is generally found in rocky areas and other structured habitats. It is the third most abundant Cancer crab in our otter trawl survey. Age-0 indices were low in the 1980s and increased sporadically in the 1990s to a peak in 1996 (Table 3). The 2000 index was the second highest for the study period. *Cancer antennarius* is somewhat tolerant of lower salinities and was collected from South Bay to upper San Pablo Bay in 2000. It was most common at our Alameda shoal station, where the catch accounted for 40% of our total annual catch. Note that this station is not used in calculation of our abundance indices, as it was added to the survey in 1988.

Table 3 Annual abundance indices of age-0 *Cancer* spp. collected with the otter trawl from May through July (*C. magister*) and May through October (*C. gracilis and C. antennarius*)

Year	C. magister	C. gracilis	C. antennarius
1980	45	17	99
1981	94	152	76
1982	268	87	0
1983	0	151	28
1984	2884	154	50
1985	3072	220	20
1986	5	59	0
1987	194	93	61
1988	11578	223	21
1989	263	204	29
1990	31	159	112
1991	796	656	171
1992	0	371	60
1993	54	616	398
1994	1097	1016	603
1995	58	227	367
1996	66	411	1126
1997	907	1131	351
1998	0	1624	718
1999	2862	221	89
2000	2176	251	849

The 2000 age-0 Pacific herring (*Clupea pallasi*) abundance index was almost identical to the 1989 index and the highest since 1986 (Figure 2). We collected the first age-0 fish in January 2000, which, based on daily aging of the otoliths, were from a late October and an early November 1999 spawn (Michael O'Farrell, personal communication). This was the earliest we collected a number of age-0 fish since the early 1980s. Juvenile Pacific herring were widely distributed from South to western Suisun bays through June, with relatively high catches in San Pablo Bay in May. By July, most fish were collected in Central Bay and by August most had emigrated from the bay.

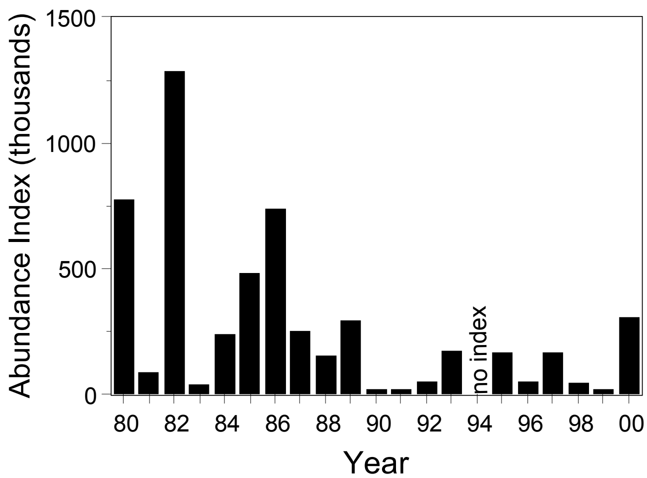


Figure 2 Annual abundance of age-0 Pacific herring collected April through September with the midwater trawl

Northern anchovy (*Engraulis mordax*) abundance indices have been relatively stable over the past six years (Figure 3). Predictably, we collected northern anchovy from South to Suisun bays in 2000, with the highest catches at South Bay channel stations and in Central Bay and lower San Pablo Bay.

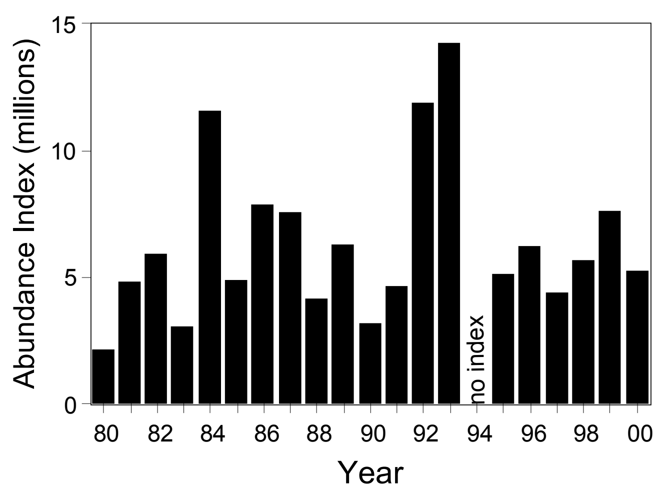


Figure 3 Annual abundance of northern anchovy (all sizes) collected April through October with the midwater trawl

Abundance of age-0 jacksmelt (*Atherinopsis californiensis*) increased slightly from 1999, but indices have been very low since 1996, and well below the highest indices of the mid-1980s since 1988 (Figure 4). Catches were again scattered from South to San Pablo bays.

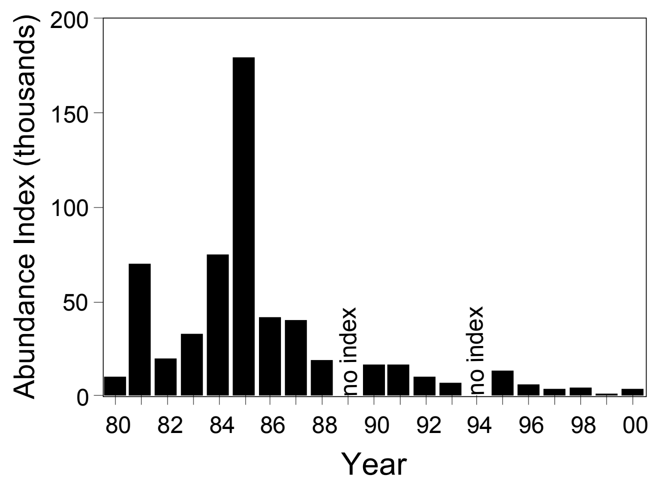


Figure 4 Annual abundance of age-0 jacksmelt collected July through October with the midwater trawl

Age-0 white croaker (*Genyonemus lineatus*) abundance increased in 2000 from 1999, which had a record low index for the study period (Figure 5). The age-1+ abundance index also increased in 2000 from a near record low index in 1999. In 2000, white croaker was most common in South and Central bays; a few fish were collected in upper San Pablo Bay and a single fish was collected in Suisun Bay.

The 2000 bay goby (*Lepidogobius lepidus*) index was almost identical to the 1999 index (Figure 6). The highest catches were over the Central Bay shoals, but it was also common in South and San Pablo bays.

Age-0 yellowfin goby (*Acanthogobius flavimanus*) abundance increased in 2000 to the highest index since 1995 (Figure 7). Similar to 1999, most fish were collected in Suisun Bay and the lower Sacramento River. The yellowfin goby is one of the most widely distributed species in the estuary. In 2000 we collected yellowfin gobies at all of our stations upstream of Central Bay and at most of our South and Central bay stations.

The 2000 age-0 staghorn sculpin (*Leptocottus armatus*) abundance index declined from a study period record level in 1999 (Figure 8). Fish were common from South Bay to Suisun Bay, with the highest catches in South Bay in March, Suisun Bay in April and May, and Central Bay from June through September.

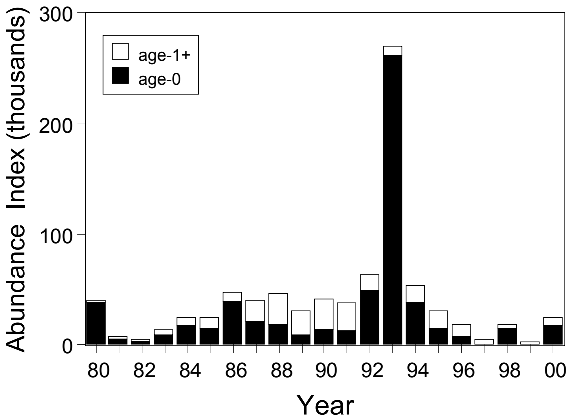


Figure 5 Annual abundance of age-0 and age-1+ white croaker collected February through October with the otter trawl

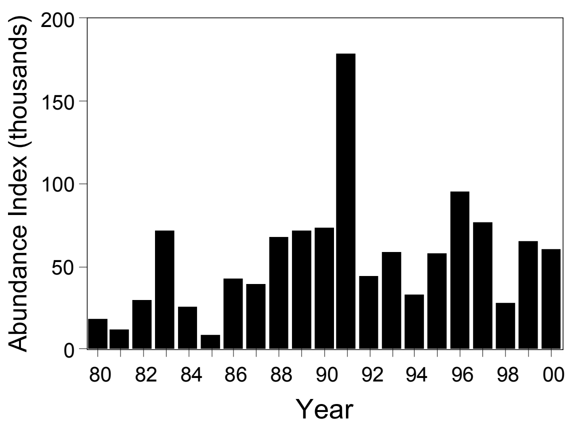


Figure 6 Annual abundance of bay goby (all sizes) collected February through October with the otter trawl

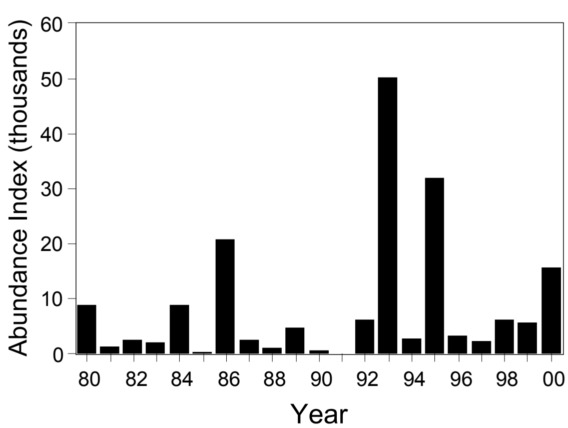


Figure 7 Annual abundance of age-0 yellowfin goby collected May through October with the otter trawl

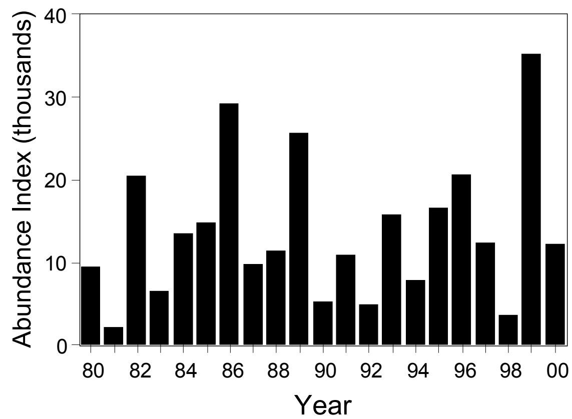


Figure 8 Annual abundance of age-0 staghorn sculpin collected February through September with the otter trawl

The 2000 age-0 shiner perch abundance index was again low (Table 4). With the exception of 1997, abundance has been relatively low since 1987. Most fish were collected in Central Bay in 2000 and surprisingly few were collected in South Bay. The age-0 walleye surfperch abundance index increased in 2000 to the highest level since 1989, but it was still much lower than the highest indices (Table 4). Most walleye surfperch were collected in Central Bay at the Southampton Shoal station (added to the survey in 1988 and not used for the index) and the Berkeley Pier station. Abundance of age-0 pile perch was increased in 2000 from an index of 0 in 1999 (Table 4). The 2000 index resulted from a single fish collected at our Treasure Island station in Central Bay. Like most other surfperches, barred perch abundance remained very low in 2000 (Table 4); in recent years the index resulted from a single fish collected each year. Most barred perch have been collected from South Bay and since 1996, all have been collected from our shoal station near Coyote Point. The white seaperch index was again 0 in 2000 (Table 4). Two fish were collected at Central Bay shoal stations, but these stations were added to the survey in 1988 and are not used to calculate the annual index.

Table 4 Annual abundance indices for the most common species of surfperches

Year	Shiner perch[a] Age-0	Walleye surfperch[c] Age-0	Pile perch[a] Age-0	Barred surfperch[b] All	White seaperch[a] All
1980	16673	1724	857	483	586
1981	42650	11672	998	942	1220
1982	43703	2460	472	335	348
1983	16147	994	778	1330	277
1984	14386	5589	110	673	872
1985	16616	543	301	73	137
1986	24582	454	289	0	311
1987	18069	2180	0	239	271
1988	7746	693	0	134	152
1989	6687	2046	153	101	47
1990	8181	681	0	79	95
1991	2724	32	0	84	0
1992	6142	665	0	41	0
1993	6341	925	0	43	0
1994	3241	no index	0	80	0
1995	6336	0	0	0	0
1996	4404	906	0	59	0
1997	23896	94	0	155	0
1998	4384	467	75	48	36
1999	6237	548	0	46	0
2000	4640	1843	31	43	0

[a] Indices are May through October from the otter trawl.
[b] Index is April through September from the otter trawl.
[c] Index is May through August from the midwater trawl.

No age-0 or age-1 California halibut were collected in 2000, but the age-2+ index remained high (Figure 9). The lack of juvenile fish was expected, as ocean temperatures were below the minimum reported for spawning (14 °C) for all but two months in 1999 and 2000. In contrast, ocean temperatures were >14 °C from November 1997 to May 1998. Most of the age-2+ fish were from the 1997 and 1998 year classes. In 2000, the majority of California halibut was again collected at South Bay and Central Bay shoal stations.

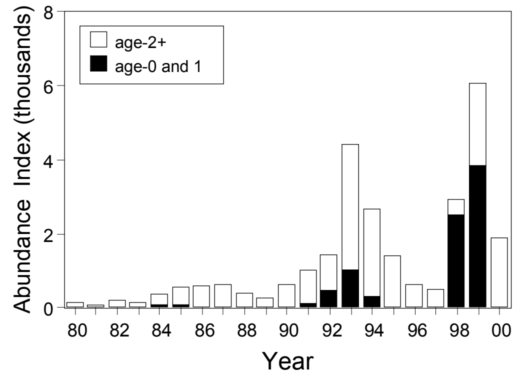


Figure 9 Annual abundance of juvenile (age-0 and age-1) and age-2+ California halibut collected February through October with the otter trawl

The abundance of age-0 English sole reached a record high for the study period in 2000, surpassing the previous record set in 1999 (Figure 10). It is believed that cooler ocean temperatures may have resulted in these strong year classes, but factors controlling recruitment of English sole to San Francisco Bay are not well understood. Age-0 fish were widely distributed over the shoals from South to San Pablo bays in late winter and spring. By July, they were concentrated in the Central Bay channels.

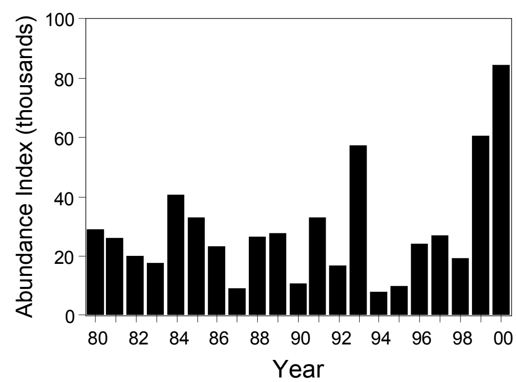


Figure 10 Annual abundance of age-0 English sole collected February through October with the otter trawl

In 2000, abundance of speckled sanddab was also a record high for the study period for the second year in a row (Figure 11). Speckled sanddab was again the most abundant species of flatfish collected in the Bay Study. It was most common in Central Bay during all months, but distribution was broadest from January to June and in November and December, with some fish collected as far upstream as Carquinez Strait.

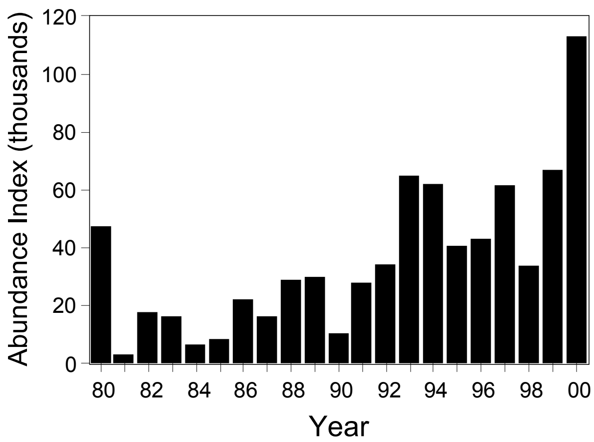


Figure 11 Annual abundance of speckled sanddab (all sizes) collected February through October with the otter trawl

The age-0 starry flounder abundance index was the fourth lowest for the study period (Figure 12A) and ended a series of moderate indices beginning in 1995. Only 11 age-0 fish were collected in 2000, with most from Suisun and Honker bays and a few from the lower San Joaquin River. The 2000 index of age-1 starry flounder (the 1999 year class) also declined (Figure 12B).

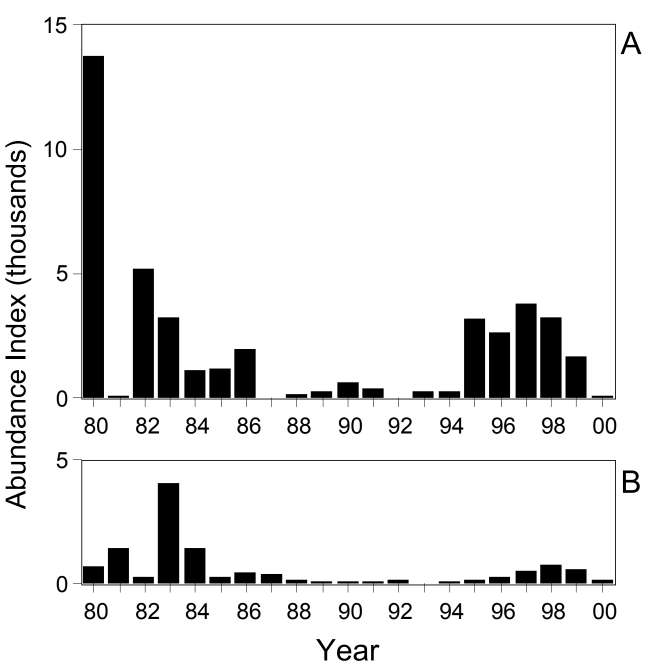


Figure 12 Annual abundance of starry flounder collected with the otter trawl: (A) Age-0, May through October, (B) Age-1, February through October

References

DeLeón S. 1998. Surfperch abundance trends in San Francisco Bay. Interagency Ecological Program for the San Francisco Estuary. IEP Newsletter 11(2):40–3.

Hieb K. 1998. Bay species. Interagency Ecological Program for the San Francisco Estuary. IEP Newsletter 11(2): 46–9.

Orsi J, editor. 1999. Report on the 1980–1995 fish, shrimp, and crab sampling in the San Francisco Estuary, California. Interagency Ecological Program for the San Francisco Estuary, IEP Technical Report 63. Sacramento (CA): Department of Water Resources. 503 p.

Notes

Michael O'Farrell, San Francisco State University, personal communication with author on June 21, 2000.

2000 Fall Midwater Trawl Survey

Kelly Souza, DFG
ksouza@delta.dfg.ca.gov

The Fall Midwater Trawl Survey (FMWT) is used to index young-of-the-year (YOY) striped bass (*Morone saxatilis*) and other fishes in the upper San Francisco Estuary. The survey has been conducted annually since 1967 (except in 1974 and 1979), and is the basis for evaluating abundance and distribution of young bass after the Townet Survey (TNS) 38-mm index is determined. Seasonal and monthly indices for the FMWT are calculated using catch data from 100 stations that are divided into 14 subareas. The mean monthly catch for each subarea is multiplied by a corresponding weight factor representing the volume of water sampled. The sum of these products is the monthly index. The sum of the four monthly indices constitutes the annual FMWT abundance index.

The 2000 FMWT striped bass index is the lowest of record (Figure 1). The 2000 index was 390, which is similar to the 1996 index of 392, continuing the overall declining trend in abundance. Although the current FMWT index does not follow the increasing TNS index (5.5, highest index since 1996), the two indices are still highly correlated ($r = 0.85$, $P < 0.0005$).

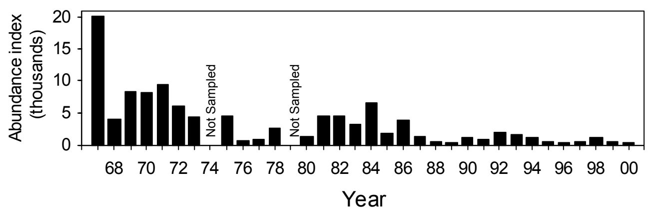


Figure 1 Annual abundance indices of YOY striped bass from the DFG Fall Midwater Trawl Survey, 1967–2000

Striped bass were widely distributed throughout the Delta with the majority of the catch occurring in Suisun Bay which is consistent with recent years (Figure 2). A higher than average percentage of the index, 24%, was set in the eastern Delta, near Vulcan and Rough and Ready islands. This contrasts 1998 and 1999 when only 1% and 10%, respectively, of the index was set in the eastern Delta. Striped bass were caught in San Pablo Bay only in October and the catch was only 8% of the total monthly index.

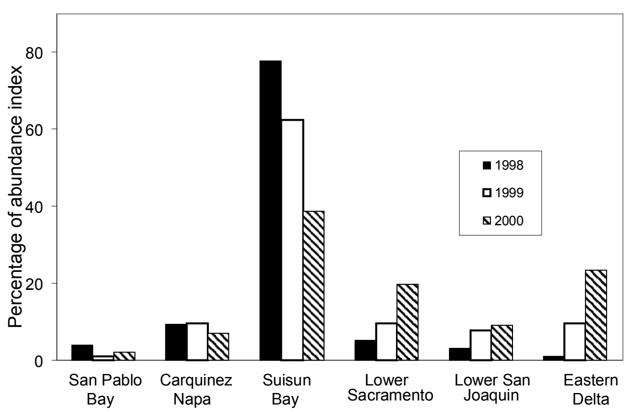


Figure 2 Percentage of annual YOY striped bass catch by area from the DFG Fall Midwater Trawl Survey, 1998–2000

The delta smelt (*Hypomesus transpacificus*) index fell from 864 in 1999 to 756 in 2000, reversing the pattern of increasing abundance since 1997 (Figure 3). The distribution of delta smelt was constrained in September and October. In September, 94% of the fish were caught in Suisun Bay and in October, 99% were caught in the lower Sacramento River. In November and December the distribution was more evenly dispersed between Suisun Bay, the lower Sacramento River, and the lower San Joaquin River. No delta smelt were caught in the eastern Delta or west of Benicia throughout the 2000 FMWT.

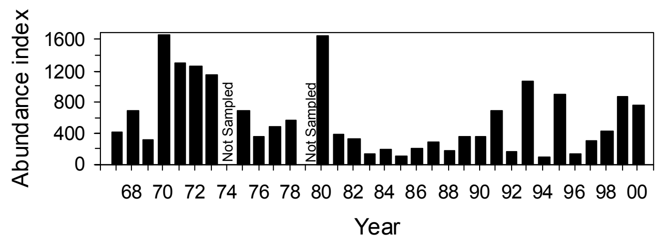


Figure 3 Annual abundance indices of delta smelt from the DFG Fall Midwater Trawl Survey, 1967–2000

In 1999 and 2000, Suisun Bay and the lower Sacramento River combined accounted for 87% and 91% of the total delta smelt index (Figure 4). This contrasts 1998, when Suisun Bay alone accounted for 91% of the delta smelt abundance index. 1998 was also the last year that delta smelt were caught in San Pablo Bay.

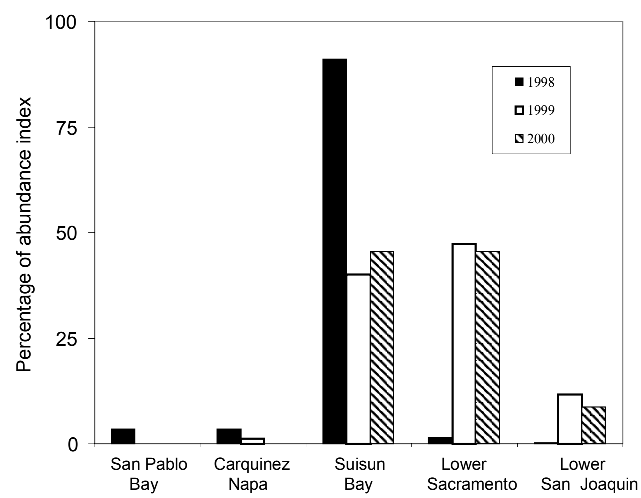


Figure 4 Percentage of annual delta smelt catch by area from the DFG Fall Midwater Trawl Survey, 1998–2000

The longfin smelt (*Spirinchus thaleichthys*) abundance index decreased from 5,242 in 1999 to 3,438 in 2000 (Figure 5). The majority of longfin smelt were caught in Suisun Bay during all months of the 2000 FMWT. Longfin were also caught consistently throughout the Delta with the exception of the eastern Delta, where no longfin smelt were caught, and the lower San Joaquin River, where an insignificant percentage (<2%) were caught in November and December.

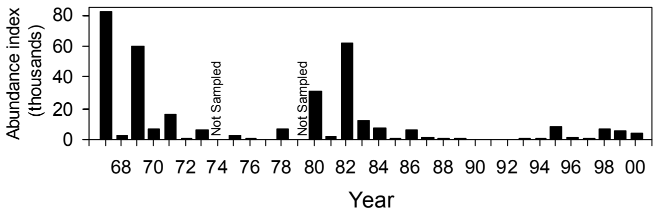


Figure 5 Annual abundance indices of longfin smelt from the DFG Fall Midwater Trawl Survey, 1967–2000

The 2000 American shad (*Alosa sapidissima*) index was 764 compared to the 1999 index of 715 (Figure 6). Both years constitute the lowest index values of American shad since 1977 when the index was 650. American shad were caught in all the subareas except in December, when no shad were caught in the lower San Joaquin River area.

Only nine YOY splittail (*Pogonichthys macrolepidotus*) were caught during the 2000 FMWT. The 2000 annual abundance index decreased compared to 1999 (Figure 7). Four of the splittail were caught in Suisun Bay.

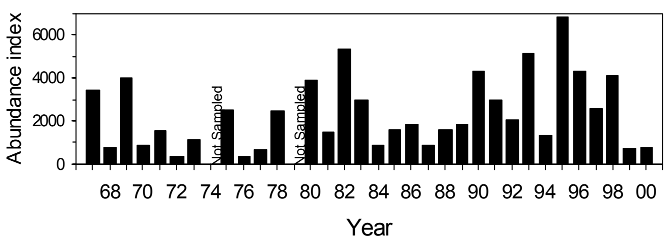


Figure 6 Annual abundance indices of American shad from the DFG Fall Midwater Trawl Survey, 1967–2000

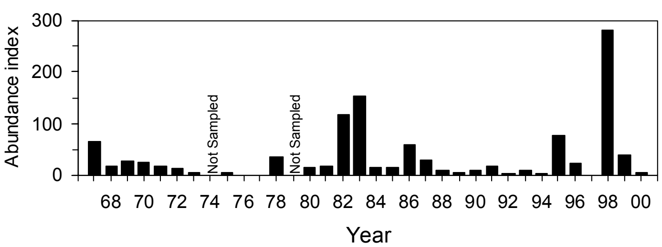


Figure 7 Annual abundance indices of splittail from the DFG Fall Midwater Trawl Survey, 1967–2000

JUVENILE CHINOOK SALMON ABUNDANCE

Rick Burmester, USFWS
rburmest@delta.dfg.ca.gov

Since the late 1970s, the USFWS Fish and Wildlife Office in Stockton has employed a number of sampling methods to monitor the abundance of juvenile chinook salmon in the San Francisco Estuary. Current methods include beach seines and midwater and Kodiak trawls. The current sampling area ranges from Colusa on the Sacramento River, south to the confluence of the Tuolumne and San Joaquin rivers, throughout the Delta, and west into San Francisco and San Pablo bays (Figure 1).

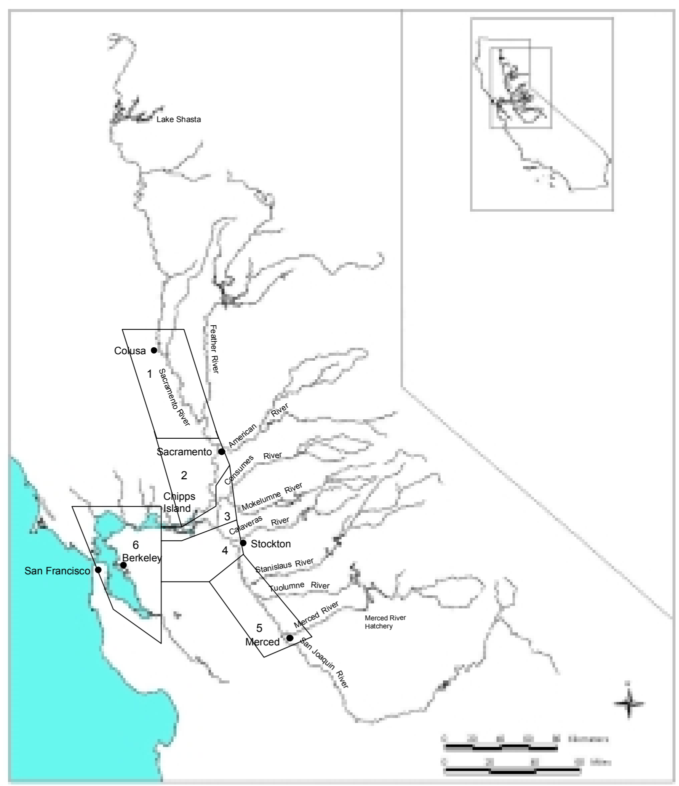


Figure 1 The San Francisco Estuary with biological areas sampled (boundaries indicated). 1 = lower Sacramento River, 2 = North Delta, 3 = Central Delta, 4 = South Delta, 5 = lower San Joaquin River, and 6 = San Francisco and San Pablo bays.

Lower Sacramento River Beach Seine

Beach seining is conducted on the Sacramento River between Elkhorn and Colusa (Figure 1, Area 1). Seven sites were sampled once per week throughout the year, except for periods when winter-run chinook salmon monitoring may increase the effort.

The mean salmon catch per cubic meter from January through March and mean February flow at Colusa are shown in Figure 2. The overall trend shows catches increasing as flows increase. The January through March mean salmon catch per cubic meter for the 2000 season was the third lowest and flows were the lowest for the years shown.

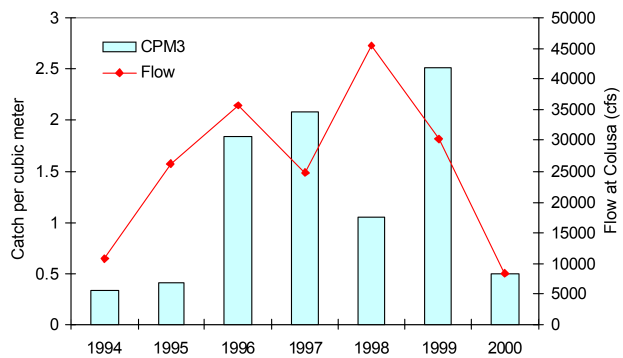


Figure 2 Mean salmon catch per cubic meter seined in the lower Sacramento River (January through March) and mean February flow on the Sacramento River at Colusa between 1994 and 2000

North, Central, and South Delta Beach Seines

Sampling was conducted from Discovery Park in Sacramento downstream on the Sacramento River into the Delta (Figure 1, Areas 2, 3, and 4). Twenty-nine sites were sampled once per week from October through June, and every other week during the summer months.

The January through March mean salmon catch per cubic meter and mean February flow on the Sacramento River at Freeport for 1985 through 2000 are significantly related (Figure 3). Both 1999, a wet year, and 2000, an above average year, fit the relationship. During below normal, dry, and critical years, catch per cubic meter/ mean cfs values are close. These values appear to be more variable during the higher flows of above normal or wet years.

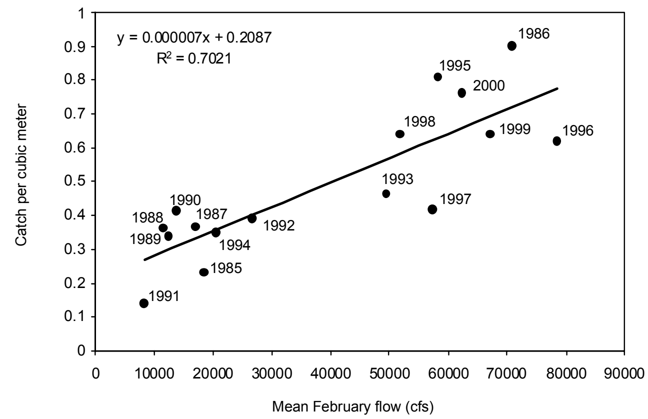


Figure 3 Mean salmon catch per cubic meter seined in the North Delta (January through March) and February mean flow on the Sacramento River at Freeport between 1985 and 2000

San Joaquin River Beach Seine

Eight sites were sampled weekly from January 1 through June 30 each year from Mossdale upstream to the mouth of the Tuolumne River (Figure 1, Area 5).

This beach seine route was added to the sampling program in 1994. Since this seine route was established, problems with both low flows, where sites could not be accessed by boat or land, and flood stage flows have caused gaps in sampling during the 1994, 1995, and 1997 field season. All chinook in the San Joaquin River system are considered to be fall run regardless of their classification by size criteria. In Figure 4, January through June mean catch per cubic meter of juvenile chinook and flow at Vernalis are shown. As in Figure 2, generally as flows increase, mean catch per cubic meter increases. Again, the 2000 season produced low mean catch per cubic meter values with similarly low flows.

San Francisco Bay Area Beach Seine

There are ten sites divided into two seine routes, with five sites sampled per week in San Francisco and San Pablo bays between November and April (Figure 1, Area 6). (The time of the year sampled has varied seasonally.)

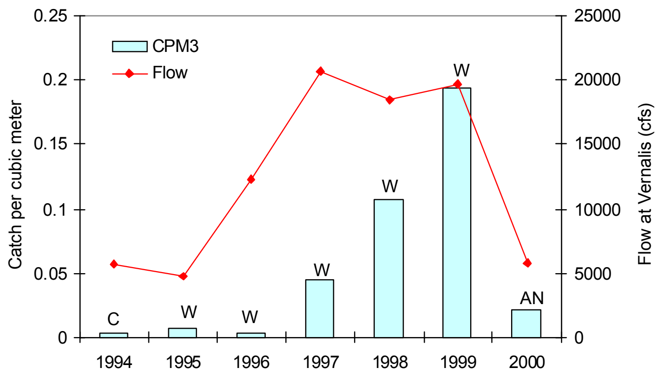


Figure 4 Mean catch per cubic meter of juvenile chinook from the San Joaquin River beach seine and mean flow at Vernalis between January and June 1994 through 2000. The water year type is included for each year (W = wet, AN = above normal, and C = critical). Due to high or low flow periods, no seining occurred in January and February of 1994, January 1995, and January, February, May and June of 1997.

When first started in 1976, the beach seine route captured one fall run for the season. In 1980, the seine route was started again, continuing through 1982. The seine route was discontinued until the 1997 season. According to the size criteria, all fish captured in the seine have been fall and spring run, except for one late-fall run. The mean fork length per year ranged from 39.4 to 47 mm. Although mean catch per cubic meter has declined, fry have moved into the bay during wet years, with the exception of 1981, a dry year (Figure 5).

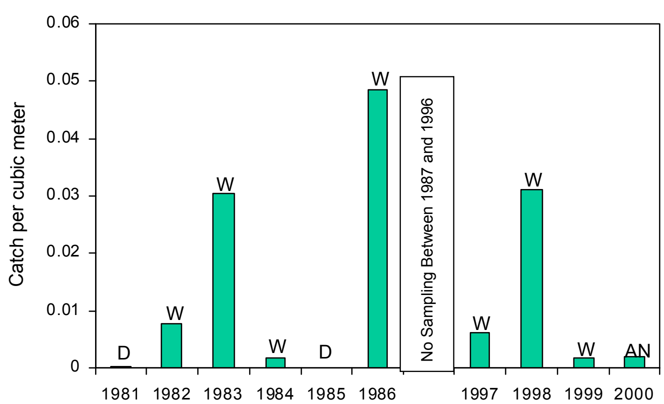


Figure 5 Mean catch per cubic meter of chinook salmon fry from the beach seine in San Francisco and San Pablo bays between 1981 and 2000 (data for 1976 and 1980 are not shown). Water year type is included for each year as in Figure 4.

Sacramento Midwater and Kodiak Trawls

Midwater and Kodiak trawling is conducted just downstream from Sacramento on the Sacramento River at Sherwood Harbor (Figure 1). Mean catch of salmon smolts per 20-minute midwater trawl tow in April, May, and June have continued to decline from 1988 through 2000 (Figure 6). The reason for this may not be so much a decrease in the run strength, but rather, a result of the fish being carried out with the flow earlier during the wet years 1995 through 2000. In the drier years, 1988–1994, the fish may have held upstream longer, and moved out later in the season. For most of the drier years, the highest catches were seen in May. In wetter years, April was usually the most productive month, but this is also the month when Coleman National Fish Hatchery released large numbers of juveniles.

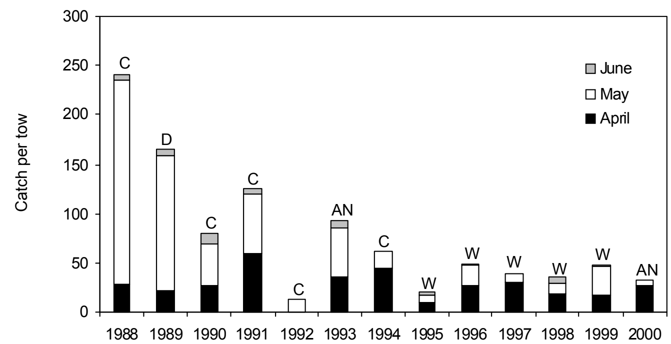


Figure 6 Mean catch of salmon smolts per 20-minute mid-water trawl tow at Sacramento in April, May, and June, 1988 through 2000. No sampling occurred in April of 1992. Water year type is included for each year as in Figure 4.

Mossdale Kodiak Trawl

Kodiak trawling is conducted just downstream from Mossdale on the San Joaquin River. This trawl has had problems similar to the San Joaquin River beach seine. Very low flows make it difficult to find areas with minimum trawling depths, and often larger boats cannot be launched. Flood stage flows have also restricted boat traffic due to pressures on the levees. These conditions have caused many gaps in the data set.

The January through June mean catch per cubic meter was lowest in 1997, when flood conditions existed in January. In 1998, mean catch per cubic meter and total catch were the highest, while the 1999 and 2000 field seasons were similar to 1997 (Figure 7). DFG's Region 4 has historically conducted sampling here from April through June.

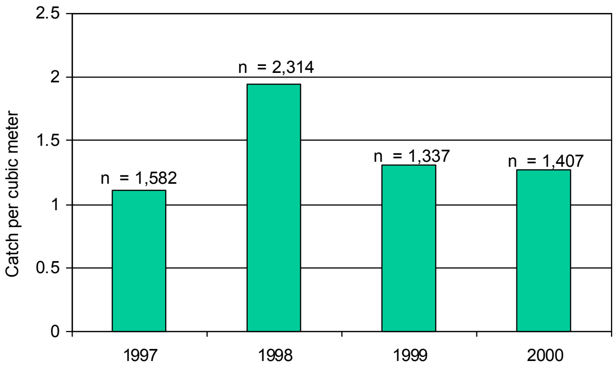


Figure 7 Mean catch per cubic meter and total catch (*n*) of chinook salmon fry between January 1 and June 30, 1997 through 2000

Chipps Island Midwater Trawl

Midwater trawling is conducted below the confluence of the Sacramento and San Joaquin rivers on the south side of Chipps Island (Figure 1). Mean catch of smolts per 20-minute tow for April through June, from 1978 through 2000, have also declined (Figure 8). Three out of the last four years reflect the fourth, third, and lowest catch for all years since the trawl began. Similar to the Sacramento trawl, the increased flows during wet years may have carried fry towards the bay earlier, making them unavailable for capture as smolts at Chipps Island.

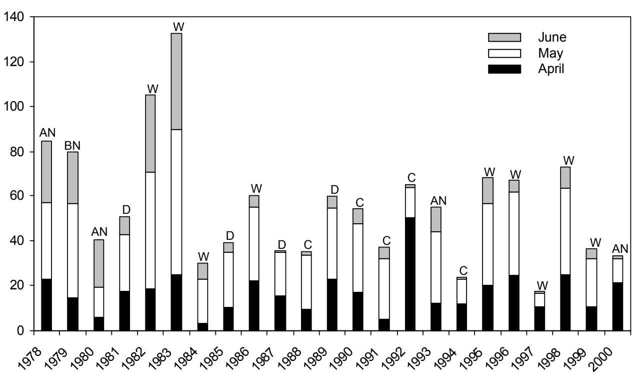


Figure 8 Mean catch of salmon smolts per 20-minute midwater trawl tow at Chipps Island in April, May, and June, 1978 through 2000. Water year type is included for each year (W = wet, AN = above normal, D = dry, and C = critical).

April through June mean catch per cubic meter of unmarked smolts is plotted against mean yearly flows at Rio Vista in Figure 9. There is a positive, significant relationship for values from April through June, demonstrating the importance of adequate flow for emigrating juveniles.

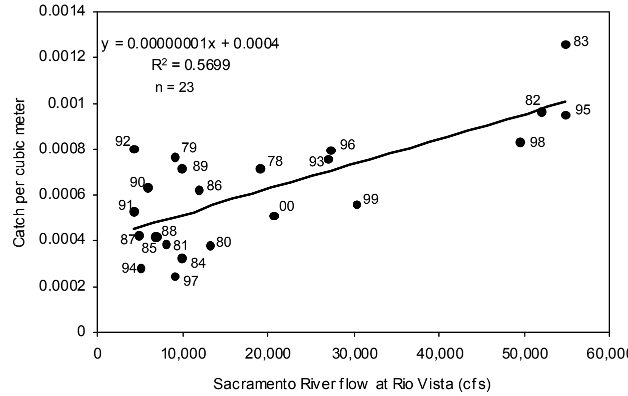


Figure 9 Mean catch of unmarked chinook salmon smolts per cubic meter in the midwater trawl at Chipps Island between April and June, 1978 through 2000 compared to mean daily Sacramento River flow at Rio Vista between April and June

Chinook Salmon Catch and Escapement

Randall L. Brown (retired) and Erin Chapell, DWR
rl_brown@pacbell.net

Much of the following information was taken from the February 2001 report, *Review of the 2000 Ocean Salmon Fisheries*, by the Pacific Marine Fisheries Council (PMFC). Copies of the report can be obtained by calling (503) 326-6352. Paul Ward, DFG, provided data on estimated spring chinook escapement to Mill, Big Chico, Deer and Butte creeks.

The PMFC continues to manage ocean fisheries to arrive at harvest levels that protect listed races including spring, winter, and other chinook runs to the Klamath River system. These seasonal and size restrictions affect not only harvest but subsequent escapement of non-target races of fall and late-fall chinook.

Central Valley Chinook Salmon Annual Abundance Index

The Central Valley chinook salmon abundance index consists of the estimated ocean harvest and escapement of all four chinook salmon races. The 2000 index, Figure 1, was slightly more than 1,100,000—the fourth highest in the 1970–2000 period of record. The long-term average is about 665,000 adults. The abundance index does not include inland harvest, which may take as many as 25% of those adults entering the Golden Gate on their way to the spawning grounds.

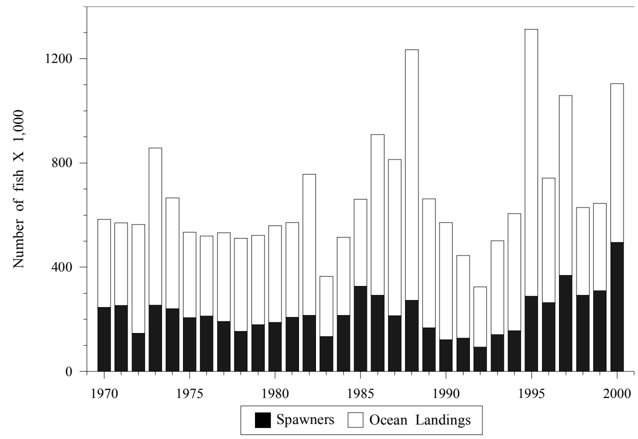


Figure 1 Central Valley chinook salmon annual abundance index, 1970–2000

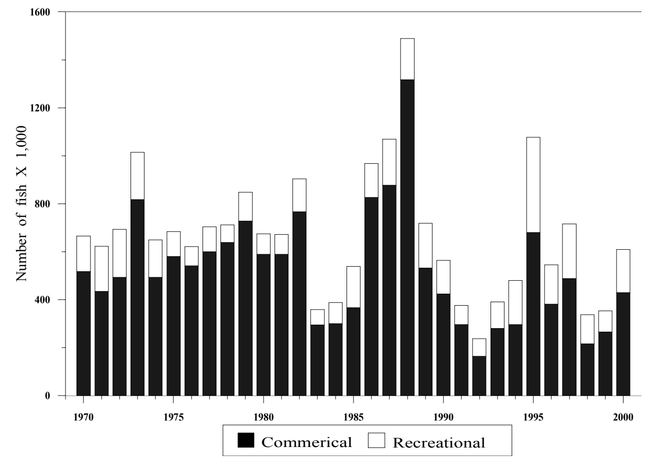


Figure 2 Annual California commercial and recreational chinook salmon ocean catch

Ocean Commercial and Recreational Catch

In 2000 the commercial fishery took an estimated 429,200 chinook salmon and the recreational anglers (party boats and skiffs) took an estimated 179,000 fish, Figure 2. These estimates do not include fish that were hooked and released but died after release. Fisheries managers are implementing fish size and hook regulations to minimize this so-called "shaker" mortality.

The ocean recreational effort off California in 2000 was about 209,000 angler trips, which is near the long-term average of 205,000 angler trips. Recreational anglers harvested about 30% of the total number of chinook taken in the ocean fishery. Commercial harvesters spent about 26,000 days on the ocean, taking about 70% of the total catch. On average, for the past three decades, commercial trollers spent about 41,000 days per year harvesting salmon in the ocean.

Ocean Harvest Index

The estimated 2000 harvest index was about 0.55, Figure 3. The index is calculated by dividing ocean catch by catch plus escapement and is often used as a rough approximation of harvest rate. The index does not include freshwater harvest.

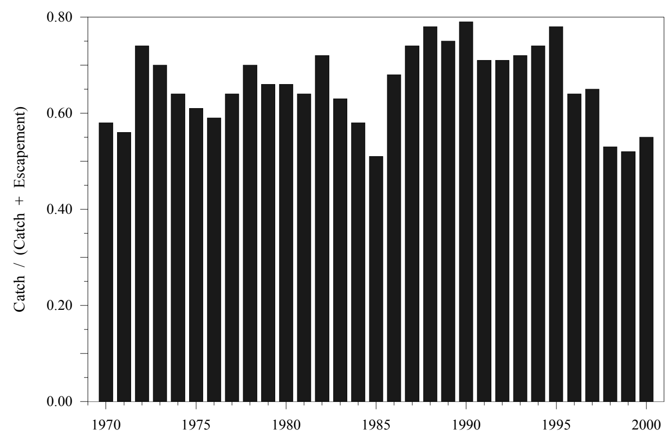


Figure 3 Central Valley chinook salmon ocean harvest index, 1970–2000

The 2000 index continues to reflect changes in ocean salmon management and economic factors causing a smaller fraction of the total potential escapement being taken in the ocean fisheries. This decline in harvest rate must be taken into consideration in hatchery management plans in that decreased ocean harvest can result in too many fish returning to their home streams.

Sacramento Valley Fall Chinook Escapement

The 2000 fall chinook escapement to the mainstem Sacramento River and its major tributaries was the highest in the 1970–2000 period of record, Figure 4. The approximately 400,000 estimated spawners far exceeded the management goal of 122,000 to 180,000 natural spawners in the Sacramento Valley system.

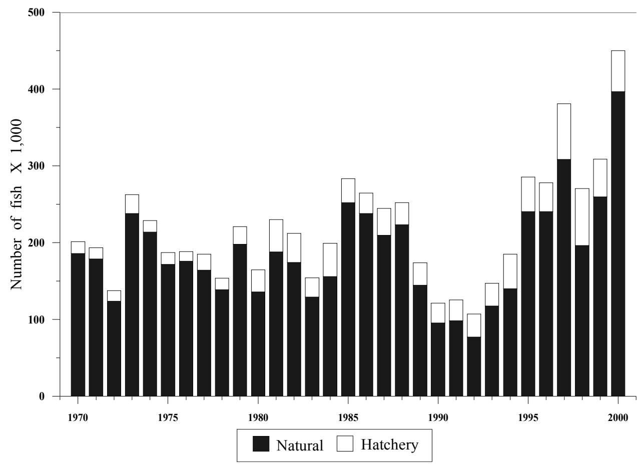


Figure 4 Annual fall-run escapement to Sacramento River and major tributaries, natural and hatchery contribution

The good 2000 fall-run escapement is further demonstrated in Figure 5, where escapement is based on cohorts by separating out the two-year olds (jacks) and three-year olds. The 2000 cohort escapement was, by far, the highest seen in the past three decades.

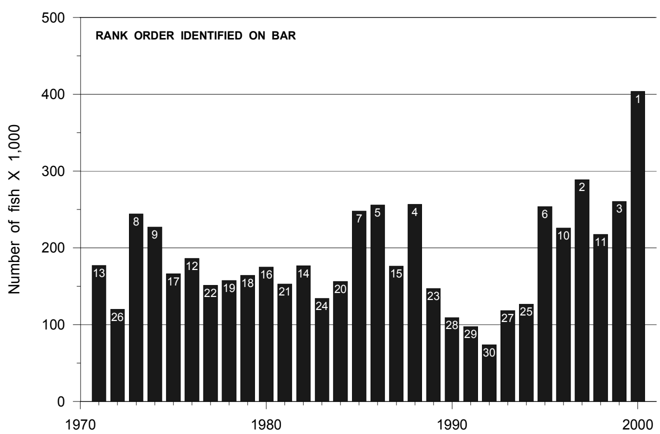


Figure 5 Annual natural fall-run cohort escapement to Sacramento River and major tributaries. Rank order identified by numbers at the top of each bar.

As mentioned in previous versions of the annual salmon status and trends articles, it is difficult to obtain accurate estimates of salmon escapement. Although not shown, the estimates given often have wide error bars. The IEP's Central Valley Salmonid Team has established an Escapement Project Work Team to help determine if there are more effective ways to estimate the numbers of spawners.

American River Fall Chinook Escapement

Consistent with the Sacramento Valley's good year, natural escapement of about 100,000 adult salmon to the American River was the highest seen in the past 30 years (Figure 6). Note that all the fall chinook production is transported to the San Pablo Bay area for release as smolts. It is not possible to determine how many of the fish returning to the river in 2000 resulted directly from hatchery production.

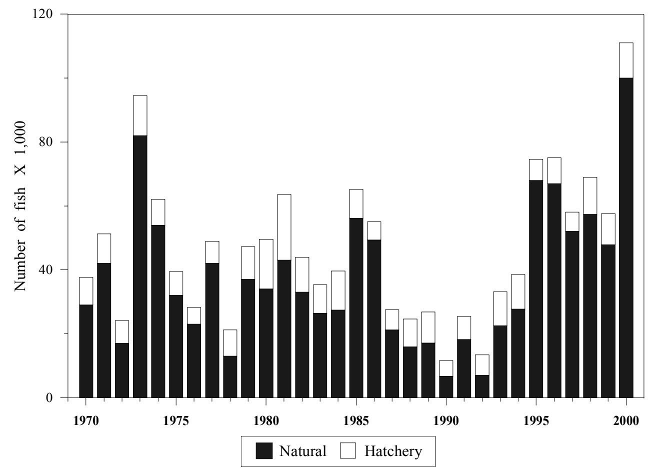


Figure 6 Annual fall-run escapement to American River, natural and hatchery contribution

Feather River Fall Chinook Escapement

The 2000 escapement of about 116,000 natural spawners was even more dramatic than that seen on the American River, with twice as many than any other year in the 30+ year period of record, Figure 7. On the Feather it will be more difficult to determine the relative strength of the 2000 run because DWR used labor intensive methods to derive the 2000 estimates, thus comparisons with previous years may not be appropriate.

It is clear that large numbers of adult fall chinook returned to the Feather River in fall 2000, with most of the fish attempting to spawn in the first few miles below the fish barrier dam. It is likely that superimposition (one or more females digging up redds of early spawners) reduced the effectiveness of the 2000 spawn.

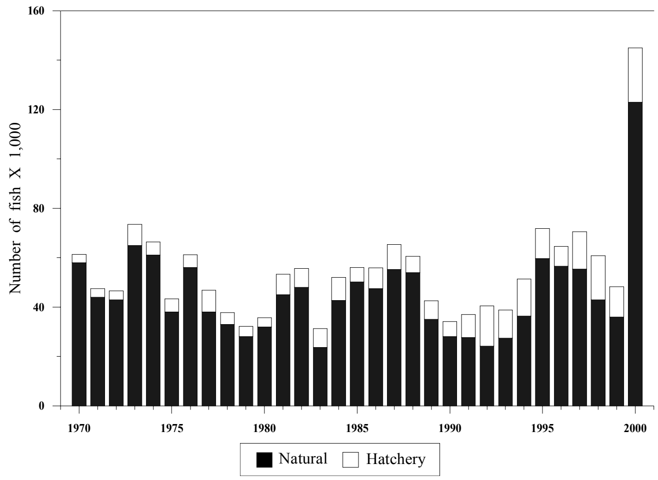


Figure 7 Annual fall-run escapement to Feather River, natural and hatchery contribution

For the first time in several years, the Feather River Hatchery experienced serious disease problems and lost a significant proportion of its production from the 1999 year class. Because of disease concerns, hatchery staff also destroyed several hundred thousand fish due to be planted in Oroville Reservoir. Early indications are that the disease problems continue with the 2000 production.

Disease concerns may affect the marking program being implemented to help estimate the fate of production releases from the hatchery—both for fall and spring chinook. The Central Valley Salmonid Team is sponsoring cohort analyses of hatchery releases from Feather, Nimbus, and Coleman hatcheries to help determine how many hatchery fish are caught in the ocean and inland fisheries, how many return to their home streams, and how many stray to other streams. The reports documenting the results of these analyses may be available later this year.

Yuba River Fall Chinook Escapement

Unlike the Feather and American rivers, the estimated 14,800 fall chinook escapement to the Yuba River was near the long-term average of about 14,000 adults and jacks (Figure 8). Once again the Yuba River escapement has demonstrated to be independent of those on the Feather River.

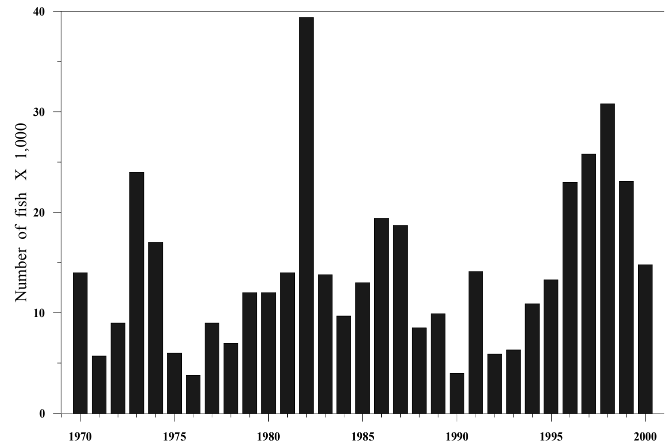


Figure 8 Annual natural fall-run escapement to Yuba River

Upper Sacramento River Fall Chinook Escapement

Although fall chinook returning to the upper Sacramento River system below Keswick Dam may spawn in the mainstem, or in a series of small tributaries such as Clear Creek, many of them are destined for Battle Creek below the Coleman National Fish Hatchery. Efforts underway to open Battle Creek above the hatchery will expand the amount of spawning habitat above the hatchery for fall, spring, and winter chinook. The role of the Coleman hatchery is being evaluated through a public review and consultation of the effects of hatchery operation and production on listed salmonids.

Escapement to the upper Sacramento River in 2000 was estimated to be about 158,000 adults and jacks, the second highest during the 31-year period of record. These data are not plotted.

San Joaquin River System Fall Chinook Escapement

These estimates, Figure 9, include data from the Mokelumne, Stanislaus, Tuolumne, and Merced rivers and two hatcheries—one on the Mokelumne and the other on the Merced. The San Joaquin system showed the best escapement since the mid-1980s, and if jacks are excluded, it was the third highest escapement for the period of record. On the Mokelumne River, an estimated 7,395 adult salmon passed the Woodbridge Dam on their way to the spawning grounds and the hatchery—about twice the long-term average of 3,434 adults (Suarez and Stout 2001).

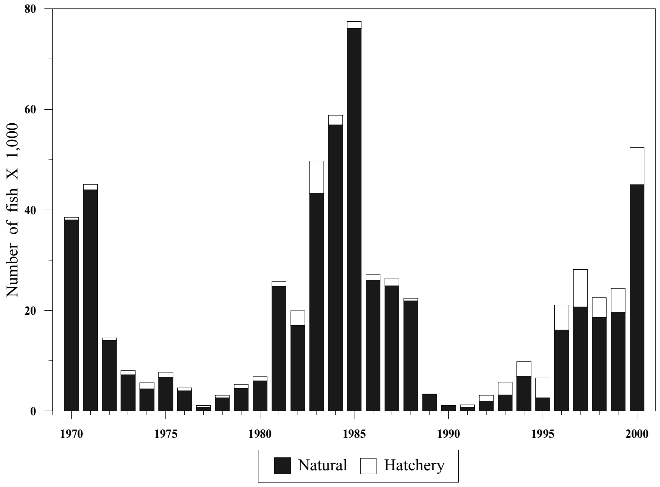


Figure 9 Annual fall-run escapement to the San Joaquin River system, natural and hatchery contribution

Spring Chinook Escapement to the Upper Sacramento River System

This escapement includes spring chinook spawning in the mainstem, Mill, Deer, and Butte creeks and some minor streams. The Feather River spring run data shown in the PMFC report are not included because of the uncertainty of their status. Preliminary genetic data indicate that these fish are not similar to spring run in Butte, Deer, and Mill creeks, but neither are they quite like Feather River fall chinook. They do exhibit spring chinook phenotypic characteristics of early arrival on the spawning grounds, holding over summer in the stream and early fall spawning. It does appear that a few thousand chinook salmon yearlings emigrate from the Feather River in the fall. (Brad Cavallo, personal communication)

The total escapement of about 5,600 adults to the upper Sacramento River system was better than seen during most of the 1990s but not exceptional. As shown in Figure 10, most of the spawners (an estimated 4,118) wound up in Butte Creek. Spawning estimates for other streams include 27 in Big Chico Creek, 637 in Deer Creek, and 544 in Mill Creek. The mainstem Sacramento River continues to play a minor role in spring-run spawning.

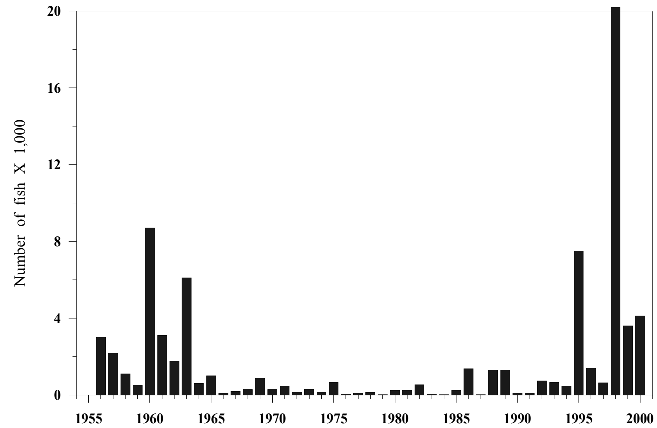


Figure 10 Annual spring-run escapement to Butte Creek

Winter Chinook Escapement to the Sacramento River Below Keswick Dam

The official winter-run escapement estimate is made by extrapolating counts of winter run moving up the ladders at the Red Bluff Diversion Dam. As the dam gates are now in the raised position during much of the period of upstream migration, the extrapolations are based on seeing a relatively low proportion of the population move up the ladders. DFG and others are looking into better ways to estimate the number of spawners.

The estimated winter-run escapement of 1,400 fish (more than one-half were jacks), is lower than in the last two years (Figure 11). However, considering this cohort was once less than 200 fish, these results are still encouraging.

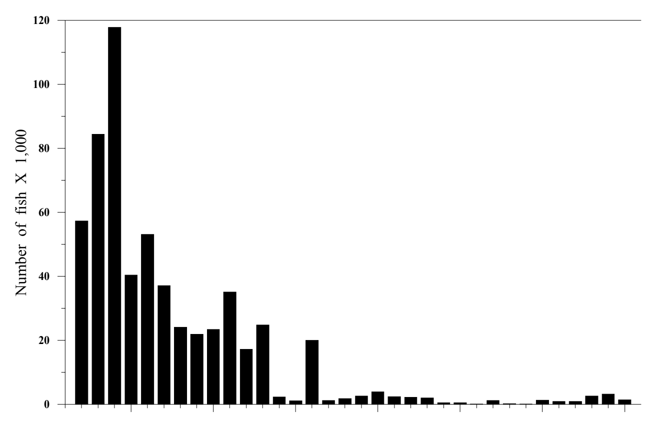


Figure 11 Annual winter-run escapement to Sacramento River below Keswick Dam

Reference

Suarez A, Stout C. 2001. The Mokelumne River Chinook Salmon Run and the Significance of Point Two. Special Science Report for the Toyon Middle School.

Notes

Brad Cavallo. California Department of Water Resources. Personal communication with author.

FISH SALVAGE AT THE STATE WATER PROJECT AND CENTRAL VALLEY PROJECT FACILITIES

Steve Foss, DFG
sfoss@delta.dfg.ca.gov

Introduction

Two large fish salvage facilities in the Sacramento-San Joaquin Delta, the Central Valley Project's Tracy Fish Collection Facility and the State Water Project's Skinner Delta Fish Protective Facility, remove (or salvage) fish from exported water. Both facilities use a louver-bypass system to collect entrained fish, which are then transported to release sites in the Delta. The Tracy facility began operation in 1957 and the Skinner facility in 1968. Salvage is estimated from sub-samples of fish collected at least every two hours while water is being pumped.

Salvage data can be obtained from DFG's Central Valley Bay Delta Branch FTP server: ftp://ftp.delta.dfg.ca.gov/salvage.

Exports

State Water Project (SWP) water exports totaled about 4.6 billion m^3 (3,739,000 acre-feet, af) in 2000, compared to about 3.3 billion m^3 (2,707,000 af) in 1999. During 2000, monthly water exports at the SWP ranged from a low of about 120 million m^3 (97,700 af) in May to a high of about 518 million m^3 (420,300 af) in February (Figure 1), higher than the 1999 range of about 6.5 million m^3 (52,300 af) to about 507 million m^3 (410,800 af). high exports in February 2000 contrasted with last year's amounts, when they were lowest.

Central Valley Project (CVP) water exports totaled about 3.2 billion m^3 (2,558,000 af) in 2000, compared to about 3.1 billion m^3 (2,534,000 af) in 1999. Monthly exports of water at the CVP in 2000 ranged from a low of about 102 million m^3 (83,000 af) in May to about 333 million m^3 (269,600 af) in August (Figure 1), similar to the 1999 range of about 124 million m^3 (100,700 af) to about 333 million m^3 (269,600 m^3).

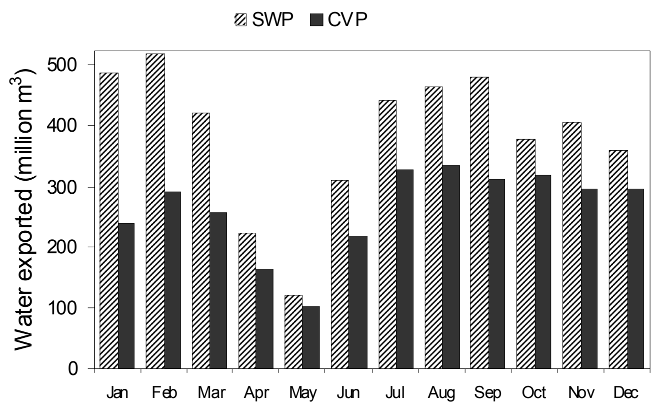


Figure 1 SWP and CVP monthly water exports in 2000

Fish Salvage

Almost 7.8 million fish were salvaged at the SWP in 2000, and over 5.9 million were salvaged at the CVP. At the SWP, striped bass was the predominant species salvaged (45.3% of the annual salvage) (Figure 2), whereas threadfin shad made up the majority of the annual salvage (54%) at the CVP (Figure 3).

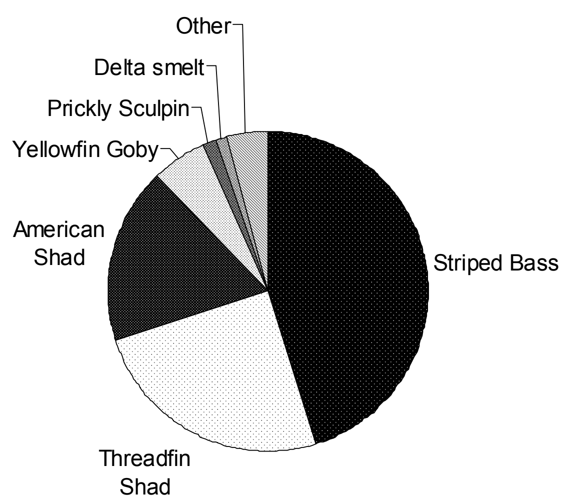


Figure 2 Relative species contribution to 2000 annual salvage at SWP

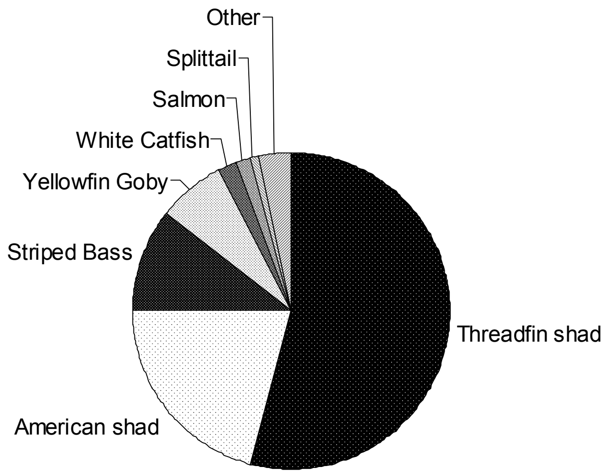


Figure 3 Relative species contribution to 2000 annual salvage at CVP

Density of fish (individuals salvaged per 10,000 m^3) was highest at the SWP in June (1.1) and at the CVP in October (1.0) (Figure 4). Striped bass accounted for most of the salvage in June at the SWP (81%) and threadfin shad comprised most of the CVP salvage during October (86.5%).

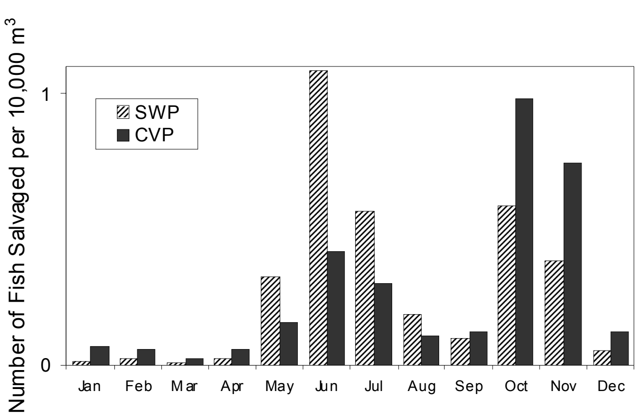


Figure 4 Fish salvage density at SWP and CVP in 2000

Delta Smelt

Estimated salvage of delta smelt at the CVP in 2000 was about 28,500, but more than 85,000 were salvaged at the SWP. Over the last 21 years, the 2000 SWP total was second only to 1999, when more than 107, 000 delta smelt were salvaged. More than 89% of the delta smelt at the SWP were salvaged during May and June (Figure 5) (See article by Nobriga and others on page 42 for further discussion of this observation).

Large numbers of adult delta smelt (almost 5,500) were salvaged at the SWP during February 2000, compared to the 1990–1999 mean February salvage of 645. Although it is not uncommon to salvage large numbers of delta smelt during January, this was the most salvaged during February since 1982, a phenomenon echoed at the CVP.

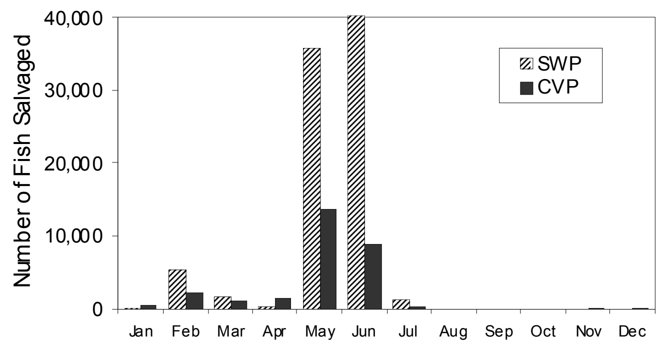


Figure 5 Monthly salvage of delta smelt at SWP and CVP in 2000

Chinook Salmon

Combined (SWP + CVP) salvage of chinook salmon was about 123,800, greater than the 1990–1999 average (78,000), but much lower than the 1980–1989 average (363,000). About 6% of the salmon salvaged last year were adipose fin clipped, indicating hatchery origin (Table 1). Most of the chinook salvage was fall-run sized and spring-run sized (Figure 6).

More chinook salmon were salvaged at the CVP in 2000 than at the SWP (Figure 7), and density of salmon (fish per acre-foot exported) at the CVP was more than double that of the SWP. Salmon salvage at the SWP peaked in April, exceeding 20,500, but at the CVP, salmon salvage was high in February and April, with about 27,500 and 30,000 salmon salvaged, respectively (Figure 8).

Salmon loss, an estimate of mortality resulting from entrainment at the export facilities, is based on pre-screen loss (predation), screen efficiency, and handling and trucking mortality. Total salmon loss (SWP + CVP) in 2000 was about 244,000, roughly twice the salmon salvage. Almost 10% of the salmon lost were adipose fin clipped (Table 2). SWP loss was much higher for all races than at the CVP, reflecting the high predation mortality rate (75%) in Clifton Court Forebay (Table 2).

Table 1 Chinook salmon salvage at CVP and SWP in 2000

	CVP salvage		SWP salvage		
Race	*Clipped*	*Unclipped*	*Clipped*	*Unclipped*	*Total*
Fall	1,488	49,448	2,570	21,394	74,900
Late fall	12	204	12	214	442
Winter	468	744	540	1,250	3,002
Spring	254	25,008	1,972	17,511	44,745
Total	2,222	75,404	5,094	40,369	123,089

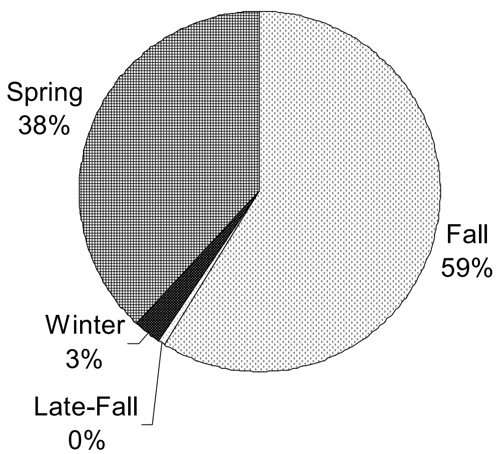


Figure 6 Percent of chinook salmon runs in 2000 salvage at SWP and CVP. Race determined solely by length at time of salvage.

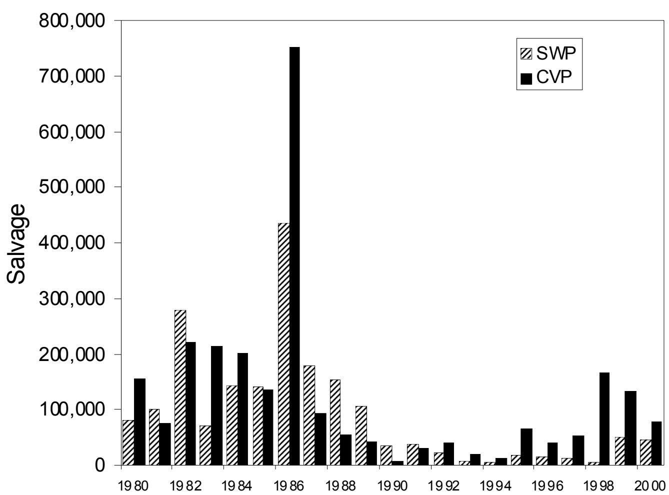


Figure 7 Annual chinook salmon salvage at SWP and CVP from 1980 through 2000

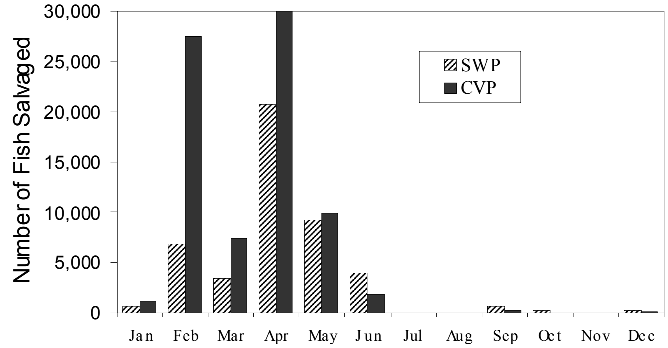


Figure 8 Monthly salvage of chinook salmon at SWP and CVP in 2000

Table 2 Chinook salmon loss at CVP and SWP in 2000

	CVP loss		SWP loss		
Race	*Clipped*	*Unclipped*	*Clipped*	*Unclipped*	*Total*
Fall	1,151	30,714	11,182	92,263	135,310
Late fall	8	138	55	941	1,142
Winter	305	516	2,358	5,481	8,660
Spring	206	15,913	8,452	74,232	98,803
Total	1,670	47,281	22,047	172,917	243,915

Steelhead Rainbow Trout

Steelhead salvage at both facilities in 2000 was the highest since 1993. The SWP salvaged 6,408 steelhead, more than the 1990–1999 mean of 4,082 and the CVP salvaged 2,957, slightly less than the 1990–1999 mean of 3,437. Steelhead salvage was highest during February at both facilities (Figure 9).

About 65% of the steelhead salvaged at the SWP and 44% of CVP steelhead were adipose fin-clipped fish, indicating hatchery origin. In 1999, a much lower percentage of salvaged steelhead were hatchery-reared—11% at the SWP and 5% at the CVP.

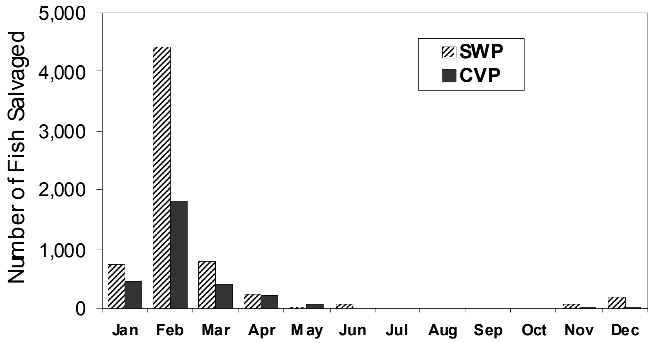


Figure 9 Monthly salvage of steelhead at SWP and CVP in 2000

Striped Bass

In 2000, the SWP salvaged more than 3.5 million striped bass, the most since 1993, but still below the 20-year average of 4.2 million. At the CVP, fewer striped bass were salvaged than in 1999 and salvage was less than one-fifth of the SWP 2000 annual total (Figure 10). Striped bass salvage peaked in June at both facilities. Almost 1.8 million young-of-the-year striped bass were salvaged in June at the SWP (Figure 11).

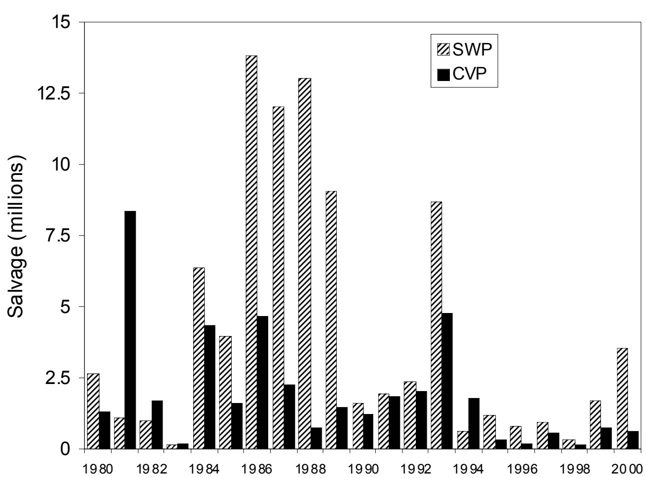


Figure 10 Annual striped bass salvage at SWP and CVP from 1980 through 2000

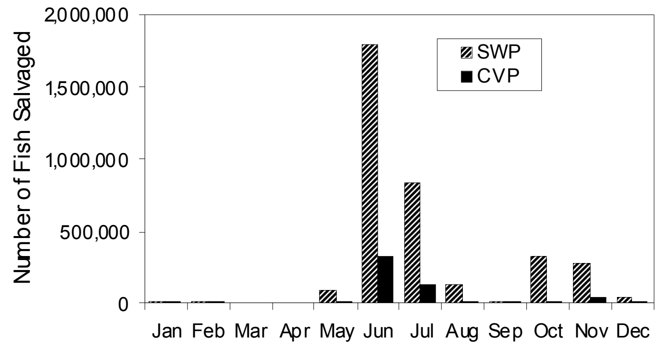


Figure 11 Monthly salvage of striped bass at SWP and CVP in 2000

American Shad

More American shad were salvaged in 2000 at the CVP than any other year during the past 21 years; SWP salvage was the second highest of the past 21 years (Figure 12). Salvage of American shad at the SWP peaked in July with almost a half million salvaged. At the CVP, salvage of American shad exceeded a half million in November. Most American shad salvaged were young of the year.

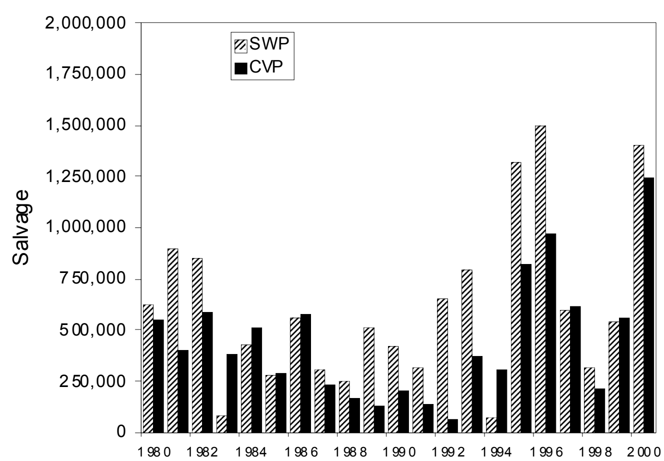


Figure 12 Annual American shad salvage at SWP and CVP from 1980 through 2000

Splittail

Combined splittail salvage (SWP + CVP) in 2000 was about four times the 1999 combined total, and was also greater than most other years after 1986, except 1995 and 1998 (Figure 13). Splittail salvage was greater at the SWP than the CVP for the first time since 1991.

Splittail salvage peaks occurred earlier in 2000 than in 1999; in 2000 salvage was greatest in May at the CVP and in June at the SWP; almost 35,000 were salvaged at each facility in those months (Figure 14). In 1999, splittail salvage peaked in July at both facilities.

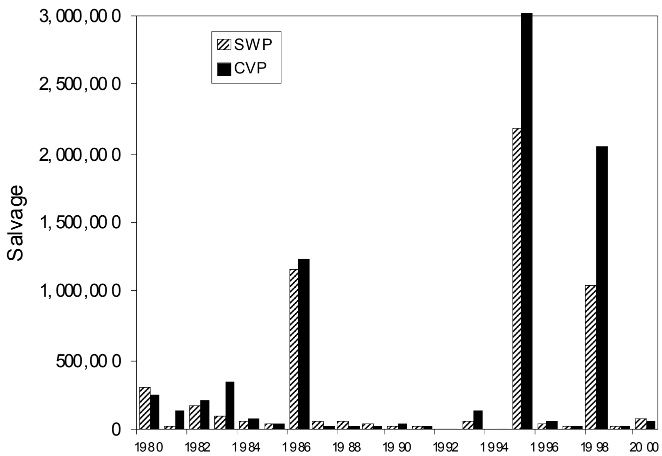


Figure 13 Annual splittail salvage at SWP and CVP from 1980 through 2000

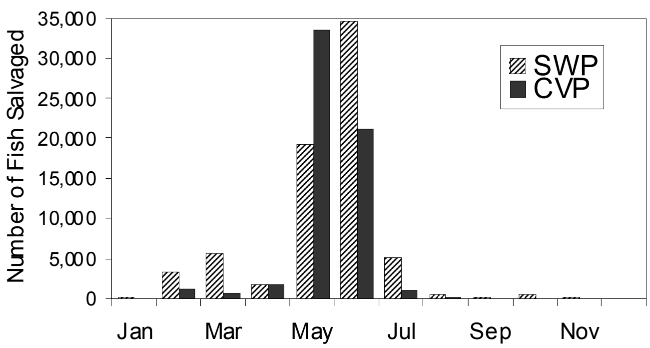


Figure 14 Monthly splittail salvage at SWP and CVP in 2000

Longfin Smelt

More longfin smelt were salvaged at both facilities in 2000 than in any year since 1994; 1,455 were salvaged at the SWP and 528 at the CVP. Most of the salvage occurred in April at both facilities.

Chinese Mitten Crab

The greatest numbers of adult Chinese mitten crabs at the fish facilities occur from September through December, during their downstream migration. From late August to late December 2000, an estimated 4,700 mitten crabs were entrained at the SWP and 2,556 at the CVP, fewer than in 1999 and far fewer than in 1998. The SWP total in 2000 was less than one-fifth the 1999 total (25,195). Mitten crabs did not significantly affect normal fish salvage operations as they did in 1998. Mitten crab numbers peaked around October 27 at the SWP. Most of the mitten crabs at the facilities were male, about 77% at the CVP and about 82% at the SWP.

Water Temperatures

Water temperatures were warmer, on average, at the CVP facility; the mean annual water temperature at the SWP facility was 15.9 °C and 17.6 °C at the CVP facility (Figure 15). Water temperatures peaked on August 1, at about 27 °C. The coolest temperatures occurred during the first week of January and reached about 7 °C at the SWP facility. The SWP experienced a precipitous water temperature increase from May 17 to May 23—water temperatures rose more than 7.4 °C during that week. Temperatures also rose steeply during the week of June 10 through 16, increasing about 6.7 °C in that period.

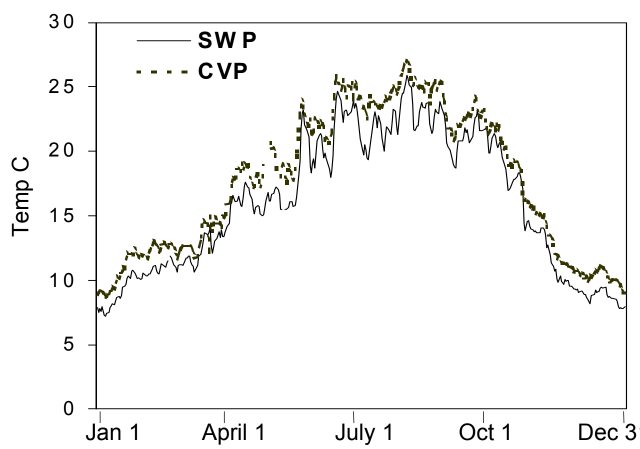


Figure 15 Daily water temperatures at SWP and CVP fish facilities in 2000

CONTRIBUTED PAPERS

SPRING 2000 DELTA SMELT SALVAGE AND DELTA HYDRODYNAMICS AND AN INTRODUCTION TO THE DELTA SMELT WORKING GROUP'S DECISION TREE

Matt Nobriga[1], Zach Hymanson[1], Kevin Fleming[2] and Cathy Ruhl[3]
[1]DWR, [2]DFG, [3]USGS

Introduction and Background

The delta smelt (*Hypomesus transpacificus*) is listed as a threatened species under both the Federal Endangered Species Act (FESA) and the California Endangered Species Act. Through formal consultation under Section 7 of the FESA, USBR and DWR received a biological opinion from USFWS, which allows for the incidental take of delta smelt arising through operation of the Central Valley Project (CVP) and the State Water Project (SWP). The incidental take of delta smelt is estimated as part of CVP and SWP fish salvage operations. Salvage levels of young delta smelt have exceeded incidental take levels every spring and summer since 1996, except in the very high spring outflow year of 1998 (Table 1). These high salvage levels have resulted in changes to project operations, often leading to the curtailment of water exports.

Nobriga and others (2000) reviewed data on delta smelt distribution, recruitment patterns and salvage, as well as Delta hydrodynamics during the moderately wet springs of 1996 and 1999 to provide hypotheses about why springtime delta smelt salvage has been consistently high. Based on their review, Nobriga and others (2000) suggested the following:

- Moderate winter-spring flows in the San Joaquin River may result in attraction of spawning delta smelt into the central Delta.
- Maintenance of moderate central Delta flows during the Vernalis Adaptive Management Plan (VAMP) provides good larval rearing habitat within the Delta[1].

Table 1 Estimated combined CVP and SWP salvage of delta smelt from April through August, 1994 through 2000[a]

Year	*Water year type[b]*	*Month*				
		Apr	*May*	*Jun*	*Jul*	*Aug*
1994	B	945	31,901	8,801	1,509	0
1995	A	24	0	0	0	0
1996	A	111	**30,099**	9,465	148	0
1997	A	1,159	**32,828**	7,876	228	0
1998	A	48	4	66	124	0
1999	A	410	**58,943**	**73,368**	**20,272**	48
2000	A	1,746	**49,401**	**49,124**	1,513	6

[a] Total salvage numbers that exceeded the red light take levels are shown in bold type. Red light take levels for above normal water years (1995–2000) are April = 2,378, May = 9,769, June = 10,709, July = 9,617, and August = 4,818. Red light take levels for below normal water years (1994) are April = 12,345, May = 55,277, June = 47,245, July = 35,550, and August = 25,889.
[b] B = below normal, A = above normal.

Although delta smelt salvage was very high in both 1996 and 1999, total salvage was much higher in 1999. Nobriga and others (2000) suggested two factors were primarily responsible for the higher salvage in 1999.

- The apparent recruitment of delta smelt, as inferred from the DFG 20-mm Survey, occurred for a longer period in 1999 than in 1996.
- Net flows in Old and Middle rivers at Bacon Island during the 1999 VAMP remained near zero much of the time, whereas they were typically positive during 1996. Presumably, positive net central Delta flows during the 1996 VAMP helped move larval delta smelt downstream away from the zone of influence of the south Delta facilities before they reached a size they could be observed in the salvage operations when exports were ramped up following the VAMP.

Based on data from 1996 and 1999, and forecasts of central Delta flows for spring 2000, Nobriga and others (2000) predicted delta smelt salvage would exceed the red light levels in 2000. As predicted, delta smelt salvage did

1. See also "Vernalis Adaptive Management Plan 2000 Salmon Smolt Survival Investigations" on page 47.

exceed red light levels in May and June 2000. In this article we review data on delta smelt salvage in conjunction with hydrodynamic data for spring and early summer 2000 to provide additional evidence that high spring salvage may result from VAMP operations. We also provide an overview of the Decision Tree Process used by the Delta Smelt Workgroup to help determine when changes to water project operations may be warranted.

Overview of Hydrodynamics Methods

The USGS collected tidal flow data on a 15-minute interval at Old and Middle rivers using ultrasonic velocity meters (UVM) (Oltmann 1998). These data were tidally averaged to provide net flow at each location. The net flow at Old and Middle rivers will be referred to as central Delta flows throughout this article.

Vernalis Flow and Delta Smelt

Nobriga and others (2000) hypothesized the occurrence of intermediate flows on the San Joaquin River in late winter 1996 and 1999 provided attractive conditions for adult delta smelt moving upstream to spawn. During winter and spring 2000, San Joaquin River flow at Vernalis was similar in timing and magnitude to the other recent moderately wet years reviewed by Nobriga and others (2000) (Figure 1). However, it is unknown what proportion of adult delta smelt spawned in any particular part of the Delta during any of these years. DFG is conducting a study designed to better characterize delta smelt spawning habitats. The results of this study may be very useful to forecasting high salvage events.

Since 1996, additional reservoir releases from the San Joaquin system have been provided for a 30-day period from mid-April to mid-May as part of the VAMP. This “pulse flow” was designed to provide transport flows for chinook salmon emigrating from the San Joaquin basin. The pulse flow is also thought to provide beneficial transport and habitat enhancement flows for delta smelt larvae spawned in the central and south Delta. However, by improving in-Delta habitat conditions and reducing net negative flows, VAMP may be responsible for the consistent exceedance of red light take levels in late spring and early summer. In years before the implementation of the VAMP, central Delta flows were typically negative throughout the spring. Presumably delta smelt spawned in the south Delta would have been entrained as larvae before they grew large enough to be salvaged at the facilities (see below). With the implementation of the VAMP pulse flow period, there is a window of time each spring during which central Delta flows range from only slightly negative to slightly positive. Nobriga and others (2000) hypothesized that the pulse flow allows delta smelt spawned in the central and south Delta to rear and grow large enough to be observed in the salvage (see below) once the pulse flow ends.

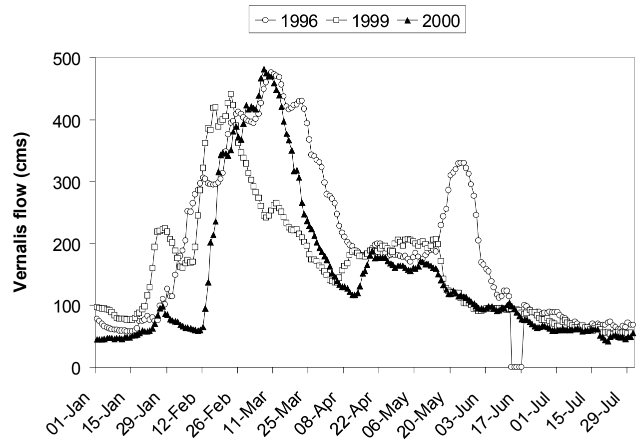


Figure 1 San Joaquin River flow at Vernalis (cubic meters per second) from January through July for moderately wet years 1996, 1999, and 2000

Overview of Salvage Patterns and Delta Hydrodynamics

Salvage of young delta smelt at the SWP and CVP Delta fish facilities begins to be quantified each spring when the smelt reach a length of about 25 mm. In terms of total delta smelt salvaged, 2000 was similar to recent years with high salvage occurring in May and June (Table 1). As in previous years (Nobriga and others 2000) delta smelt salvage began to increase, particularly at the SWP, at the end of the VAMP, about May 20 (Figure 2). Interestingly, the salvage increase was associated with only a very slight change in central Delta flows (Figure 3), suggesting the increase was triggered by smelt residing near the facilities. In response to the abrupt increase in delta smelt salvage, SWP exports were cut back and CVP exports were increased for a few days beginning about May 25 (see article by Le on page 9 for details about operations changes). Salvage densities decreased in response to this change in operations, but increased again when the SWP increased exports beginning about May 27. Despite a noticeable decrease in salvage density throughout June, the total number of delta smelt salvaged during June was about the same as in May (Table 1) due to the larger volume of water exported in June (Figure 4).

In conclusion, San Joaquin River flows during winter and early spring 2000 were similar to other years hypothesized by Nobriga and others (2000) to attract spawning delta smelt into the central Delta. Delta smelt salvage quickly exceeded red light levels following the VAMP in 2000 as it has in most recent years. This lends additional support to the hypothesis that the VAMP results in suitable larval rearing conditions within the central and south Delta, and therefore high salvage when CVP and SWP exports ramp up after VAMP. This should not be interpreted as meaning entrainment losses of delta smelt are higher now than they were historically. We believe the difference is that some of the fish that would historically have been “silently” entrained as larvae, now grow to a detectable size during the VAMP period and are therefore counted in salvage during late May and June.

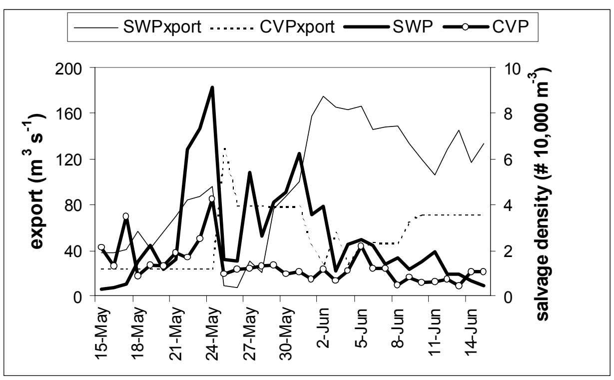


Figure 2 Daily CVP and SWP export rates and delta smelt salvage density for the 30-day period following the conclusion of the VAMP pulse flow in 2000

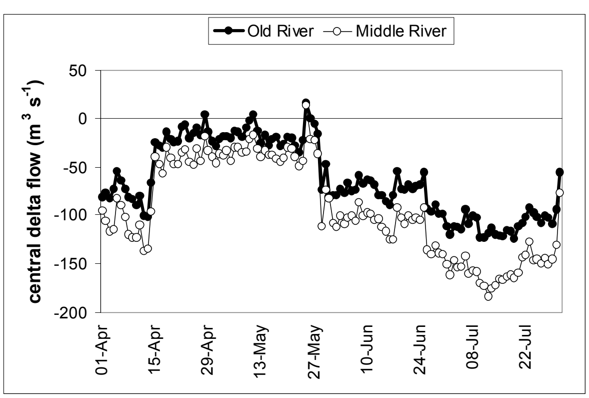


Figure 3 Tidally averaged (net) flow in Old and Middle rivers at Bacon Island from April through July as measured by ADCPs operated by USGS

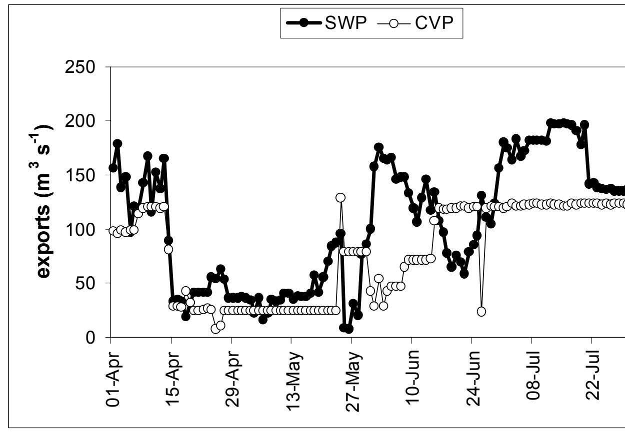


Figure 4 CVP and SWP daily export rates from April through July 2000

Delta Smelt Working Group Decision Tree Process

The Delta Smelt Working Group is a product of the 1995 delta smelt biological opinion. As defined in the opinion, the group’s purpose is “…to resolve biological and technical issues raised by this opinion and to develop recommendations for consideration by the management group.” Participants include agency personnel from USFWS, NMFS, DFG, USBR, EPA, DWR and SWRCB. The Delta Smelt Decision Tree (Table 2) is the written description of the types of information, questions, and thought processes the working group uses to determine if recommendations for operational changes are warranted. The decision tree is not intended to add any new requirements or criteria, but rather it is intended to inform other interested parties of the decision processes presently in use.

Reference

Oltmann RN. 19983 Measured flow and tracer-dye data showing anthropogenic effects on the hydrodynamics of south Sacramento-San Joaquin Delta, California, spring 1996 and 1997. USGS Open-File Report 98–285. Sacramento (CA): U.S. Geological Survey. 16 p.

Table 2 The Delta Smelt Decision Tree

Life stage	**Adults**
Timing	Pre-VAMP (February 1 through April 15)
Concerns	1) High relative densities of adults in the south Delta are a concern due to the potential for increase entrainment at the SWP and CVP. 2) High relative densities of delta smelt in the south Delta also suggest spawning may occur in the south Delta, increasing the chances for exceeding the red light level[a] of incidental take in the late spring and early summer.
Data of interest	Before pre-VAMP, consider fall midwater trawl indices Spring midwater trawl Salvage Beach seine Chipps Island trawl Hydrology (wet or dry year; placement of X2) Water quality conditions and water temperature Condition of the fish
Assessment of conditions	Adult distribution in Delta and downstream of the Delta Salvage levels/densities, yellow light Potential high numbers in juvenile salvage if high numbers of adults are concentrated in the south Delta
Tools for change	Reduction in exports, either concurrently at both facilities or at the facility that is salvaging the most fish
Biological questions using the available data	1) Is the adult distribution broad or not? 2) Is salvage elevated or not? 3) Is previous FMWT index high or low? 4) Are water quality conditions (e.g. water temperatures) conducive to spawning? 5) Are fish ripe for spawning? (Both of above may help determine if there will be a protracted spawn.)
Questions concerning operations	1) Is there a need to reduce exports at either or both facilities based on either the distribution of adults and/or an increase in the salvage of adult delta smelt? 2) Is it likely to be a difficult spring or summer? That is, do we expect high levels of delta smelt salvage in the spring or summer?
Assessment of concern	I. If the stated recovery criteria index is lower than 239, then concern is high. II. If distribution information shows adults delta smelt are concentrated in the south and central Delta, then concern is high. III. If the observed or predicted salvage of adults increases sharply, then concern is high. IV. If fish at the salvage facilities are on the verge of spawning and temperatures are conducive to spawning, then concern is high.
Recommendations	A) If concern is high and salvage increases abruptly, then recommendations for action is likely. B) If the observed or predicted salvage is at or approaching the red light or at the yellow light, then a recommendation for action is likely. C) If assessments II and I are true, then we expect a difficult spring or summer (June and July).
Life stage	**Larvae**
Timing	VAMP (April 15 through May 15)
Concerns	High numbers of larvae in the south Delta will likely result in higher numbers of fish rearing to juvenile stages and higher levels of entrainment.
Data of interest	Light traps surveys 20-mm survey[b] Water temperatures Salvage[c] Hydrology (wet or dry year; placement of X2)
Assessment of conditions	Spawning distribution Percent distribution

[a] Yellow light and red light as defined in the 1995 OCAP opinion.
[b] If fortnightly 20-mm survey is occurring and red light occurs, then effort will increase to weekly sampling.
[c] Salvage levels at this time will likely not reflect the number of delta smelt in the south Delta, since smelt begin to be counted at the salvage facilities at about 25 mm.
[d] The barriers shall be operated as stated in the USFWS biological opinion (1-1-96-F-53), April 26, 1996.
[e] Changes considered under "a" and "b" would aim to increase net positive flows in Old and Middle rivers downstream of the export facilities.

Table 2 The Delta Smelt Decision Tree (Continued)

Assessment of conditions (continued)	Timing: start and duration of spawning Implement model to predict future salvage (end of VAMP) Water quality conditions, water temperature
Tools for change	Change in San Joaquin River flows Change in export reductions (1–3 = net flow) Change in barrier operations
Biological questions using the available data	1) Is distribution of spawning broad or restricted? 2) Is larval distribution broad or restricted? 3) When does spawning start? 4) Do we expect punctuated or protracted spawning? 5) Do we expect SWP and CVP to reach red light salvage levels?
Questions concerning operations	Do we consider changing net flows in Old and Middle rivers?
Assessment of concern	I. If light trap results demonstrates that spawning has occurred in the south Delta, then concern is high II. If the 20-mm survey shows 50% of the delta smelt are in the zone of influence (e.g,. east of the confluence), then concern is high. III. If abundance in the 20-mm survey is low relative to other years, then concern is high. IV. If substantial larval recruitment is expected to occur in the south and central Delta post-VAMP, then concern is high
Recommendation	If concern is high and salvage is at or approaching red light or at yellow light, then recommendations to improve net flow in Old and Middle Rivers are likely. (This recommendation applies during VAMP and post-VAMP, although the tool used will vary.)
Life stage	**Juveniles**
Timing	Post-VAMP (May 15 through July 1)
Concerns	High numbers of delta smelt juveniles in the south and central Delta will likely result in increased entrainment when export levels increase at the end of VAMP
Data of interest	20-mm survey[b] Salvage Summer townet Hydrology (wet or dry year; placement of X2) Export rates
Assessment of conditions	Percent of the distribution outside the zone of influence (e.g., east and west of the confluence) Salvage level (number) Salvage density
Tools for change	Change in exports Change in agricultural barrier operations[d] Removal of HORB[d] Position of cross-channel gates Flow changes in San Joaquin, Old, and Middle rivers
Biological questions using the available data	1) What is the relative distribution in and outside the zone of influence (e.g. upstream and downstream of the confluence)? 2) Is abundance high? 3) Is salvage at or approaching red light or at yellow light? 4) Are fish migrating west from the Delta?
Questions concerning operations	1) Do we consider changing exports?[e] 2) Do we consider changing agricultural barrier/HORB operations?[e] 3) Do we consider changing the position of the cross channel gates after May 20?
Assessment of concern	I. If the 20-mm survey shows 50% of the delta smelt are in the zone of influence (e.g. east of the confluence), then concern is high. II. If abundance in the 20-mm survey is low, relative to other years, then concern is high.
Recommendation	If concern is high and salvage is at or near red light, then recommendation for action is likely.

[a] Yellow light and red light as defined in the 1995 OCAP opinion.
[b] If fortnightly 20-mm survey is occurring and red light occurs, then effort will increase to weekly sampling.
[c] Salvage levels at this time will likely not reflect the number of delta smelt in the south Delta, since smelt begin to be counted at the salvage facilities at about 25 mm.
[d] The barriers shall be operated as stated in the USFWS biological opinion (1-1-96-F-53), April 26, 1996.
[e] Changes considered under “a” and “b” would aim to increase net positive flows in Old and Middle rivers downstream of the export facilities.

VERNALIS ADAPTIVE MANAGEMENT PLAN 2000 SALMON SMOLT SURVIVAL INVESTIGATIONS

Pat Brandes, USFWS
pbrandes@delta.dfg.ca.gov

INTRODUCTION

The Vernalis Adaptive Management Plan (VAMP) is a key part of the San Joaquin River Agreement (SJRA). This agreement reflects a commitment to implement the State Water Resources Control Board's 1995 Water Quality Control Plan for the lower San Joaquin River and the San Francisco Estuary. VAMP is designed to protect juvenile chinook salmon migrating from the San Joaquin Basin through the Sacramento-San Joaquin Delta. VAMP also is an experiment to determine how salmon survival rates change in response to alterations in San Joaquin River flows, and State Water Project (SWP) and Central Valley Project (CVP) exports when a barrier is installed at the head of Old River. Although, not technically VAMP, similar, complementary experiments are also conducted in years when there is no barrier installed.

Specific experimental objectives of the VAMP in 2000 included

- Quantification of chinook salmon smolt survival between Durham Ferry and Jersey Point using recapture locations at Antioch and Chipps Island, under conditions of a San Joaquin River flow at Vernalis of 5,700 cfs, with a head of Old River Barrier, and SWP and CVP export rates of 2,250 cfs.
- Comparison of juvenile chinook salmon survival between releases of marked fish at Durham Ferry and at Mossdale for use in comparing results of VAMP 2000 with results from earlier survival studies where coded-wire-tagged salmon releases occurred only at Mossdale. The upstream release site was changed to Durham Ferry in 2000 to address the concern that smolts released at Mossdale could disperse into upper Old River (without a barrier) at a higher rate than those originating from the San Joaquin River tributaries. It was thought smolts released at Durham Ferry would better represent the juvenile salmon migrating through the Delta from upstream. To compare results from one year to the next, (with and without a barrier) the Durham Ferry site was chosen for use in all future VAMP and other complementary survival studies.
- Comparison of the survival of juvenile chinook salmon of Merced River and Mokelumne River hatcheries origin released at Jersey Point.

The VAMP 2000 experimental design included both multiple releases and multiple recapture locations. Groups of approximately 50,000 to 75,000 juvenile salmon smolts were coded wire tagged at Mercer River Fish Facility and released at Durham Ferry, Mossdale, and Jersey Point on April 17, 18, and 20, respectively (Figure 1). Replicate releases were made at Durham Ferry on April 28 and Jersey Point on May 1. Releases at Jersey Point on May 1 included groups from Merced River Fish Facility and Mokelumne River Hatchery. Between April 15 and May 15 exports and flows were near target levels (2,250 cfs exports and 5,700 cfs flows) and the barrier was in place at the head of Old River. Recoveries of marked fish were made by trawling at Antioch and Chipps Island and in the SWP and CVP salvage operations. Recoveries will also be made in future years in the ocean fishery.

Use of multiple releases and multiple recapture locations provides a stronger basis for evaluating juvenile chinook salmon smolt survival as part of the VAMP testing program, than reliance on recapture data from only one sampling location and only one series of releases per year.

Survival indices of marked salmon to Antioch and Chipps Island are generated based on the number of recoveries, corrected for the number of fish released, expanded by the percent of time and space sampled. The calculations of absolute survival estimates are based on the ratio of survival indices of marked salmon recaptured from upstream (Durham Ferry) and downstream (Jersey Point) release locations. Absolute survival represents actual survival rather than a relative index of survival. The use of survival estimates, as part of the VAMP study design, substantially reduces any bias associated with differential gear collection efficiency within and among years and strengthens the ability to detect differences in salmon smolt survival as a function of Vernalis flows and SWP and CVP exports.

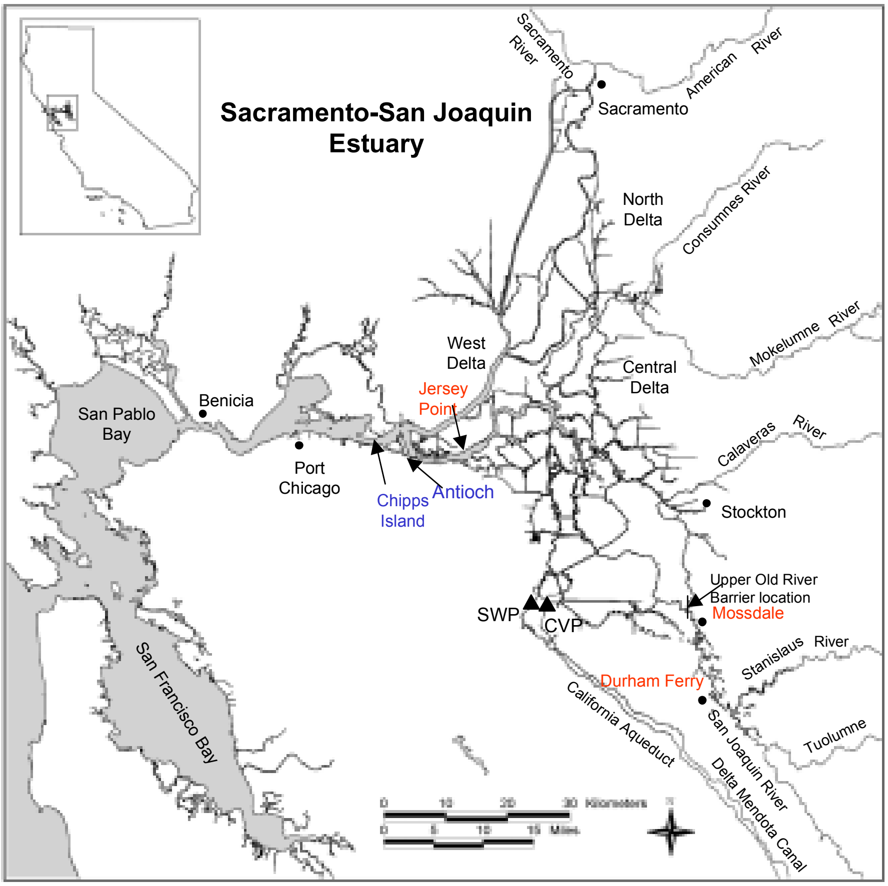


Figure 1 The Sacramento-San Joaquin Estuary, California

Survival Indices

The April 17 and April 28 Durham Ferry releases had survival indices to Antioch of 0.08 and 0.10, respectively (Table 1). Survival indices to Chipps Island were 0.19 and 0.15 (Table 1). The individual tag code survival indices to both recovery locations showed variability, such that there appeared to be no true difference between the two groups. Based on this information, it appears that the two Durham Ferry groups survived at similar rates.

The survival indices of the April 20 and May 1 releases at Jersey Point ranged from 0.42 to 0.69 at Antioch and 0.62 and 0.78 at Chipps Island (Table 1). The second group released at Jersey Point on May 1 appeared to survive at a higher rate than the first group, based on results from both recovery locations. However, the overlap in individual tag code survival indices to Chipps Island between the two Jersey Point groups suggests there may not be a true difference (Table 1). The wider difference in the Antioch survival indices suggests the second group did survive at a higher rate than the first group.

In 2000, releases were made at both Mossdale and Durham Ferry to determine if survival was different between these two locations. The results of the release at Durham Ferry on April 17 and Mossdale on April 18, using Antioch recoveries, indicated the survival index was higher from the release at Mossdale (0.14) than for Durham Ferry (0.08) (Table 1). This result would be expected considering the marked fish released at Durham Ferry had 11 more river miles to migrate through than fish released at Mossdale. By contrast, the survival indices generated based on the recoveries at Chipps Island indicated there was no substantial or detectable mortality between Durham Ferry (0.193) and Mossdale (0.195). Individual survival indices of the Durham Ferry and Mossdale groups did not overlap between groups using the Antioch recovery indices, but they did in the Chipps Island indices (Table 1). Further replication of these releases is required to determine if significant mortality occurs between the two sites.

The differences between the survival indices of the paired groups of Merced and Mokelumne hatchery fish released at Jersey Point on May 1 are not clear. The recoveries to Antioch appeared to show that the Jersey Point groups using Mokelumne River Hatchery stock had a lower survival (0.43) than the release using Merced River Fish Facility stock (0.69). By contrast, the recoveries at Chipps Island indicated that survival was higher for the Mokelumne group (0.85) than for the Merced group (0.78). Again there was greater variability among the Chipps Island indices than in the survival indices to Antioch (Table 1).

Table 1 Coded wire tag code, release site, date of release, number released, numbers recovered at Antioch, Chipps Island, and at CVP and SWP fish facilities, and survival indices to Antioch and Chipps Island

				At Antioch			*At Chipps*			*Expanded salvage*	
Tag code	*Release site*[a]	*Date*	*Number released*	*Number recovered*	*Survival index*	*Group survival*	*Number recovered*	*Survival index*	*Group survival*	*CVP*	*SWP*
06-04-01	Durham Ferry		23529	6	0.054		7	0.149		24	144
06-04-02	Durham Ferry		24177	10	0.088		10	0.206		24	132
06-45-63	Durham Ferry		24457	11	0.095		11	0.226		12	185
	Total	04/17/00	72163	27		0.08	28		0.193		
06-01-06-09-14	Durham Ferry		23698	8	0.059		7	0.15		12	75
06-01-06-09-15	Durham Ferry		26805	15	0.128		5	0.096		24	96
06-01-11-08-14	Durham Ferry		23889	8	0.069		10	0.206		12	60
	Total	04/28/00	74392	31		0.10	22		0.15		
06-44-03	Jersey Point		25527	50	0.433		24	0.463		0	0
06-44-04	Jersey Point		25824	47	0.401		41	0.782		0	0
	Total	04/20/00	51351	97		0.42	65		0.62		
06-01-06-10-01	Jersey Point		25572	76	0.606		48	0.949		0	3
06-01-06-10-02	Jersey Point		24661	76	0.704		30	0.623		0	3
	Total	05/01/00	50233	152		0.69	78		0.78		
06-02-53	Jersey Point[a]		50445	106	0.427		95	0.971		0	5
06-02-54	Jersey Point[a]		51167	110	0.439		74	0.734		0	0
	Total	05/01/00	101612	216		0.43	169		0.85		
06-44-01	Mossdale		23465	14	0.130		9	0.192		12	213
06-44-02	Mossdale		22784	16	0.149		9	0.199		12	220
	Total	04/18/00	46249	30		0.14	18		0.195		

[a] All stock were from the Merced River Fish Facility, except Jersey Point releases with tag codes 06-02-53 and 06-02-54, which used Mokelumne River Hatchery stock.

Absolute Survival Estimates

The absolute survival estimate in 2000 between Durham Ferry (April 17 release) and Jersey Point (April 20 release) was 0.19 based on recoveries at Antioch and 0.31 based on recoveries at Chipps Island (Table 2). The groups released at Durham Ferry on April 28 and Jersey Point on May 1 yielded survival estimates between Durham Ferry and Jersey Point of 0.14 for Antioch recoveries and 0.19 based on Chipps Island recoveries (Table 2). Using these absolute estimates of survival both sets of recovery information would indicate that the April 17 Durham Ferry group survived at a slightly higher rate than the April 28 group.

The absolute estimates of survival between Mossdale and Jersey Point were 0.33 based on the Antioch indices versus 0.31 based on the Chipps Island indices (Table 2), a very good agreement of the survival based on the two separate recovery locations.

The comparison between the Mossdale and April 17 Durham Ferry groups indicated absolute survival was lower for the Durham Ferry release than for the Mossdale group using the Antioch estimates whereas it was similar using the Chipps Island estimates (Table 2). The difference in absolute survival between the two recovery locations, is likely a reflection of typical imprecision seen in fish recovery data caused by a multitude of factors. Only through sample replication and efforts to limit bias can precision and accuracy be improved. Imprecision may limit our ability to see small survival differences even though they exist.

Evaluation of Flow on Smolt Survival with and without a Barrier

The survival estimates obtained using Chipps Island recovery information gathered in 2000 is relatively high compared to those measured since 1994 (Figure 2). Past absolute survival estimates between Mossdale and Jersey Point and estimates from VAMP 2000 are shown in relationship to Vernalis flow with and without the presence of an Old River barrier in Figure 2. Experience in 2000 revealed that the barrier as designed could only be used when target flows were less than 7,000 cfs. Two regression lines have been developed based on historical survival data with and without the Old River barrier. It appears that as flows increase survival increases both with and without the barrier at the head of Old River. Statistically, neither regression is significant, although prior to adding the data from 1999, the without barrier relationship was significant ($r^2 = 0.75$, $P = 0.025$, $n = 6$) (Figure 2).

Evaluation of Exports on Smolt Survival with a Barrier

Evaluating the role of SWP and CVP exports on salmon smolt survival through the south Delta and the effect of the Old River barrier is a key elements of VAMP. Presence of the Old River barrier affects both the emigration route of salmon smolts and hydraulic conditions in the lower San Joaquin River and Delta. While the barrier improves survival through the south Delta, some level of export effects may be experienced as the juvenile salmon migrate through Turner and Columbia cuts further downstream in the San Joaquin River.

The role of SWP and CVP exports with the Old River barrier in place is difficult to determine at this time, in part because of the few releases made with the barrier in place and the differing permeability of the barrier when it has been in place. Releases of test fish at both Mossdale and Jersey Point have only been made in three years when the Old River barrier was in place. In 1994, the Old River Barrier was installed without culverts, while in 1997 the Old River Barrier had two open culverts that passed approximately 300 cfs into upper Old River. In 2000, the Old River barrier had six gated culverts, with two open during the Mossdale and April 17 Durham Ferry release and four open during the April 28 Durham Ferry release.

Changes in the permeability of the barrier add noise to the resulting data, making it more difficult to detect the potential effects of flow and export on salmon survival with the barrier in place. An additional problem identified in 2000, was that the design of the temporary barrier was not satisfactory to allow a target San Joaquin River flow of 7,000 cfs. The 2000 VAMP report recommends resolution of this concern as soon as possible to maintain the integrity of the original VAMP study design. Given this noise, however, the data to date appear to show that smolt survival between Mossdale/Durham Ferry and Jersey Point increases as exports increase from 1,600 to 2,300 cfs with the barrier in place (Figure 3). The relationship is not statistically significant, very likely because of the small sample size. Survival with the barrier has not yet been measured at the full range of targeted exports within the VAMP design (1,500 to 3,000 cfs).

Table 2 Survival indices and absolute survival estimates for marked fish released at Durham Ferry, Mossdale, and Jersey Point and recovered at Antioch and Chipps Island[a]

	Antioch			*Chipps Island*		
Release date	*Survival indices*	*Jersey Point*	*Absolute smolt survival*	*Survival indices*	*Jersey Point*	*Absolute smolt survival*
4/17, 4/20	0.08 (Durham Ferry)	0.42	0.19	0.19 (Durham Ferry)	0.62	0.31
4/28, 5/1	0.10 (Durham Ferry)	0.69	0.14	0.15 (Durham Ferry)	0.78	0.19
4/18, 4/20	0.14 (Mossdale)	0.42	0.33	0.19 (Mossdale)	0.62	0.31

[a] Absolute survival is calculated by dividing the Mossdale or Durham Ferry survival index by the corresponding Jersey Point survival index.

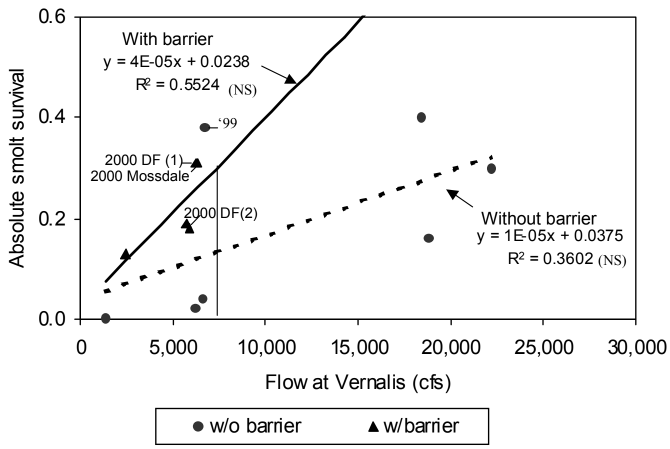


Figure 2 Absolute smolt survival between Mossdale or Durham Ferry (DF) and Jersey Point and river flow at Vernalis with and without the upper Old River barrier in place. 2000 DF(1) = 4/17 Durham Ferry and 4/20 Jersey Point release. 2000 DF(2) = 4/28 Durham Ferry and 5/1 Jersey Point release. 2000 Mossdale = 4/18 Mossdale and 4/20 Jersey Point release.

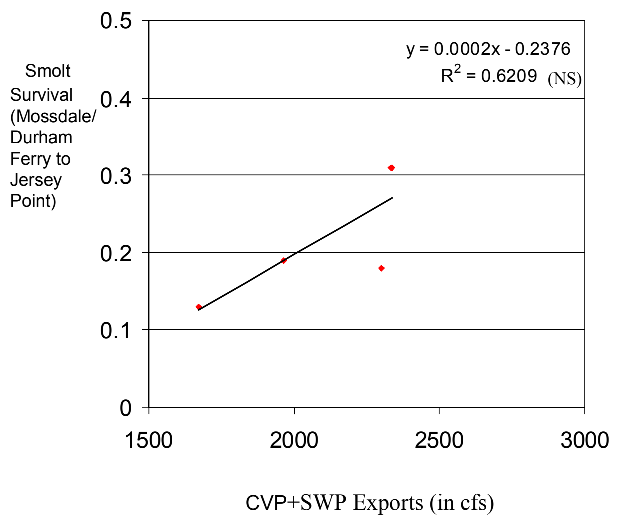


Figure 3 Absolute smolt survival between Mossdale or Durham Ferry and Jersey Point compared with CVP + SWP exports in years with a barrier in upper Old River

The Respective Roles of Flow and Exports with a Barrier

A multiple regression between survival, river flow (at Stockton) and exports with the barrier in place is shown in Figure 4. Flow at Stockton was selected for use in this analysis to account for flow diverted from the lower San Joaquin River through the operable culverts at the Old River barrier. The amount of flow into Old River when the barrier is in place varies with the flow in the river and the number of culverts opened. Water diverted through the Old River barrier reduces flows downstream within the lower San Joaquin River and needs to be taken into account when evaluating the flow-survival relationship for juvenile chinook salmon emigrating from the San Joaquin River and Delta.

As San Joaquin River flow at Stockton and exports increase, in the narrow range measured, survival between Mossdale and Jersey Point (with the barrier in place) appears to increase, although the multiple regression is not significant (Figure 4). It is difficult to separate the respective roles of the two factors since they are both increasing as survival increases. It is notable that typical river flow and exports have a much wider range of variability than those used in the VAMP experiment period. This limited range during the VAMP experiment makes it more difficult to identify the relative effects of flow and export due to data imprecision characteristic of smolt survival experiments.

Figure 4 The relationship between the absolute estimate of survival between Mossdale (or Durham Ferry) and Jersey Point and San Joaquin River flow at Stockton and CVP + SWP exports with a barrier in place

There have been several other mark-recapture studies conducted in the Sacramento-San Joaquin Delta to determine the effects of flow, export and migration route on smolt survival. These studies serve as a foundation for the VAMP. The results of these past studies have provided some insight on the roles of flow, exports and the barrier in upper Old River, but are clouded by imprecision and possible biases, which we hope to overcome in future studies.

One set of studies approximated the relative effects of flows and exports on smolt survival with a barrier in place, by using smolts released at Dos Reis (on the San Joaquin River downstream of the barrier) and Jersey Point. The effect of exports is likely underrepresented using this approximation, since the effects of exports are likely less in this reach of the river when there is no Barrier. (Only one release had been made at Dos Reis with the Barrier in place.) The results of this analysis indicated that there was a significant relationship of smolt survival from Dos Reis to Jersey Point with San Joaquin River flow at Stockton ($R^2 = 0.33$, $P < 0.03$, $n = 14$), even with an obvious outlier from data obtained in 1999 (Figure 5). There was not a significant relationship between survival and exports either alone (Figure 6) or in combination with flow (Figure 7), although survival did appear to decrease as exports increased (Figures 6 and 7). These data cover a wider range of flow and export values than the VAMP tests to date, although the experimental design only approximates the barrier effects. Although the conclusion of the role of exports differs using these data relative to the VAMP with barrier data, the results at lower exports show significant variability such that smolt survival may be increasing as exports increase from 1,500 to 4,000 cfs.

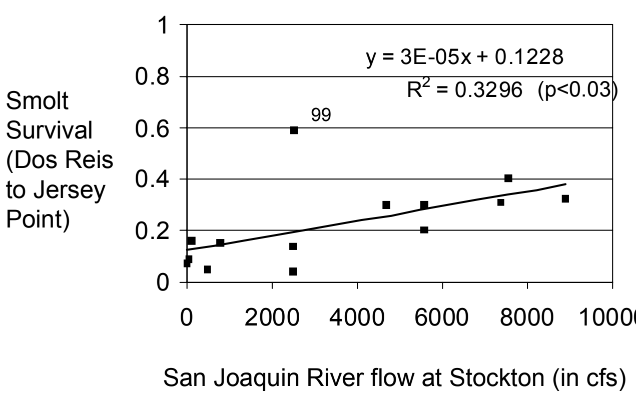


Figure 5 Absolute smolt survival (from Dos Reis to Jersey Point) and San Joaquin River flow at Stockton

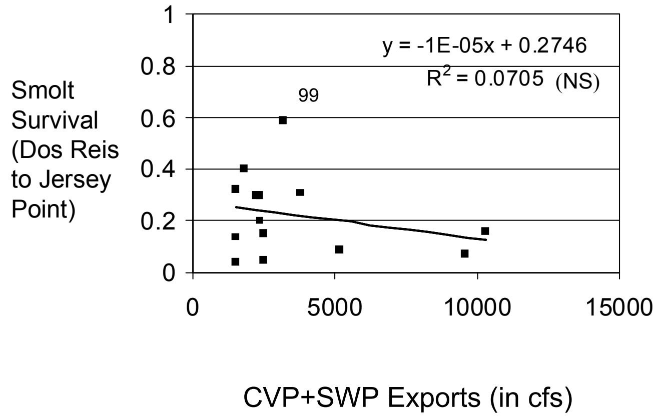


Figure 6 Absolute smolt survival (from Dos Reis to Jersey Point) and CVP + SWP exports

Figure 7 Absolute smolt survival (between Dos Reis and Jersey Point) and CVP + SWP exports (in cfs) and San Joaquin River flow at Stockton (in cfs)

THE RESPECTIVE ROLES OF FLOW AND EXPORTS WITHOUT A BARRIER

Other past studies allow evaluation of the role of exports on smolt survival, without a barrier. The data for releases made at Mossdale and Jersey Point (absolute survival), were regressed against flow at Vernalis and

CVP and SWP exports. The absolute survival estimate between Mossdale and Jersey Point was positively correlated to exports ($R^2 = 0.71$, $P = 0.017$, $n = 7$) (Figure 8) and flow and exports ($R^2 = 0.84$, $P = 0.025$, $n = 7$) (Figure 9) and were statistically significant. These data appear to show that as exports and flows increase, survival increases when there is no barrier in place. However, data have only been gathered at exports between approximately 1,500 and 4,000 cfs.

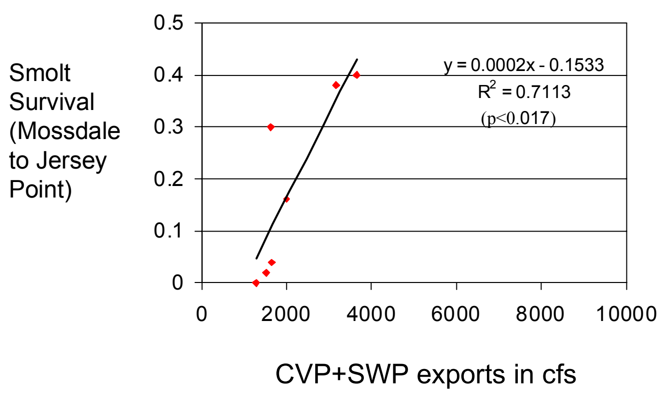


Figure 8 Relationship between absolute smolt survival (Mossdale to Jersey Point) and CVP + SWP exports when there is no upper Old River barrier in place

Figure 9 The relationship between absolute smolt survival between Mossdale and Jersey Point, San Joaquin River flow at Vernalis, and CVP + SWP exports

Some data gathered in 1989 and 1990 may support the conclusion that survival between Mossdale and Jersey Point, without a barrier in place, is greater at higher exports. These data appear to show that survival through upper Old River relative to that at Jersey Point was higher during the higher export period, but overall about half that of the survival of smolts released at Dos Reis (Brandes and McLain, forthcoming). Unfortunately, survival indices for the smolts released in upper Old River in these years were all low making conclusions based on these comparisons uncertain. However, if these differences are true, and many of the smolts migrate through upper Old River when there is no barrier in place, survival may be higher through this reach at higher exports. Residence time through upper Old River may be decreased as exports increase and thus increase survival due to less exposure time to predators or other mortality factors.

Confounding Aspects of Past Data

The confounding aspects of this past data limit our ability to draw conclusions on the relative importance of flow and exports on smolt survival. One confounding aspect is that both Feather River and Merced River Hatchery fish have been used in past experiments. Paired experiments with fish from Merced and Feather River hatcheries have shown that absolute survival is higher for fish originating from Merced River fish facility (Brandes and Pierce 1998), which may have affected our ability to detect the role of exports on survival due to added data imprecision. In addition, in 1998, 1999, and 2000 two shifts of sampling were conducted at Chipps Island instead of one. Although no major differences have been identified due to this change in sampling method, it does add additional noise to the survival indices and estimates. The 1999 data may be biased high due to the low recovery of the Jersey Point release due to boat problems during the sampling. In addition, the highest flow years are those with the highest relative export rates, making separation of the two variables on survival problematic. These confounding elements require additional information through the VAMP and complementary studies without the barrier to further define the relative roles of flow and exports, with and without a barrier in place at upper Old River, on juvenile salmon survival through the South Delta.

Additional variability in the data may occur from changing the upstream release location from Mossdale to Durham Ferry. Future investigations, using releases at both Durham Ferry and Mossdale are needed to determine if releases made at Mossdale and Durham Ferry result in similar survivals so that past data can be used in evaluating the effects of SWP and CVP exports on salmon survival. If the survivals between the two release locations are not similar and we cannot correct for the survival differences between the two sites, then using only Durham Ferry data will increase the number of years needed to complete the VAMP study.

Recommendations

Since definitive conclusions about the respective roles of flow and exports on salmon smolt survival are not possible with the data gathered to date, it is recommended that VAMP experiments continue. The most pressing need is to gather data at flows of 7,000 cfs and at export rates of 1,500 and 3,000 cfs with the barrier in place. This will help separate out the effects of flow from those of exports. Gathering data at the extremes of the target conditions will help focus the needs of future experiments. In addition, a small group of technical experts is working on further evaluating the results of the 2000 VAMP experiment to determine if changes in study design are needed to better determine the respective roles of flow and exports. As part of this evaluation, a variety of power analyses will be conducted with the present data to determine if it will be possible to identify the respective roles of flow and exports given the present VAMP design structure. These actions will improve future studies such that they will provide the necessary information needed to make the best management decisions possible regarding the protection of salmon smolts emigrating from the San Joaquin basin.

For a more detailed discussion on the results of the 2000 VAMP experiment and other aspects of VAMP, please refer to the 2000 VAMP Report and short errata sheet. To obtain copies contact Dan Felts, San Joaquin River Group Authority, at (916) 449-3957.

Acknowledgements

I would like to thank Marty Kjelson (U.S. Fish and Wildlife Service) and Dan Fults (San Joaquin River Group Authority) for their helpful suggestions and editorial comments on previous drafts of this article.

References

Brandes P, McLain J. forthcoming. Juvenile chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. In: Brown RL, editor. Fish bulletin 179: contributions to the biology of Central Valley salmonids. Sacramento (CA): California Department of Fish and Game.

Brandes P, Pierce M. 1998. 1997 salmon smolt survival studies in the South Delta. Interagency Ecological Program for the Sacramento-San Joaquin Estuary. IEP Newsletter 11(1):29–36.

A REVIEW OF THE CALFED SPONSORED SPLITTAIL WORKSHOP

Randall L. Brown, retired
rl_brown@pacbell.net

On January 29, 2001, CALFED convened a special workshop on the biology, life history, and environmental needs of the splittail. The splittail, a native minnow, has been listed as threatened by the U.S. Fish and Wildlife Service. CALFED had also asked Peter Moyle, Randy Baxter, Ted Sommer, and Robert Abbot to write a white paper on splittail. The splittail white paper is one of a series on species (including delta smelt and salmonids) or topics (for example, entrainment and open water processes) of special importance to the Bay-Delta Program. The draft white paper formed the technical basis for the workshop and the workshop provided additional information and perspectives that will be used in its completion.

Sam Luoma (CALFED Lead Scientist), Peter Moyle (UC Davis) and Paul Angermeier (USGS and member of the CALFED Science Board) organized the workshop around several important hypotheses found in the draft white paper and six technical presentations by scientists working directly on splittail. Peter Moyle, Ted Sommer, and Randy Baxter spoke about biology and life history, Tom Cannon on entrainment, Robin Stewart on selenium body burdens in splittail, and Ted Foin presented a new splittail life history simulation model.

In the morning Paul chaired a panel consisting of the speakers and Sam Luoma, Chuck Hanson, Tina Swanson, Larry Brown, and Kim Taylor. The general format was for the speakers to make a brief presentation, with panel members asking clarifying questions during or at the end of each presentation. Although much of the discussion about the technical material presented and its implications occurred among panel members, the audience (about 80 agency staff, representatives of environmental groups, and consultants) also became involved. In the afternoon Paul asked two breakout groups to examine assigned hypotheses, select the most important ones, and discuss information supporting or refuting them. An additional task was to suggest new monitoring and research efforts that would allow the hypotheses to be tested more rigorously.

Workshop products include this article, a technical summary prepared by Paul Angermeier, and a revised white paper. The technical summary can be found online at http://calfed.ca.gov/science.html.

Before discussing the specifics of the splittail workshop, a comment on CALFED workshops in general may be helpful. As Sam mentioned during the plenary session at the Fall 2000 CALFED Science Conference (see page 9 of the summary posted online at http://www.iep.water.ca.gov/calfed/sciconf/), he views workshops as a way to bring local experts and neutral parties together to help resolve complex technical issues. These workshops will be an integral part of the transparent and peer reviewed process necessary to ensure high quality CALFED science. The other white papers, floodplain processes, and fish effects of the south Delta barriers are among potential topics of future workshops.

The splittail presentations and the white paper demonstrated that our understanding of splittail biology has increased dramatically over the past few years and, conversely, that we have a long way to go before biologists can reliably quantify the effects of water operations and other factors on splittail abundance. Peter Moyle presented a conceptual model of the splittail life cycle (Figure 1)—an essential first step to help organize our thinking. Ted Foin took an equally important second step in developing and presenting a preliminary simulation model of the dynamics of splittail life history. The models, in particular the simulation model, are built around informed assumptions. These assumptions need to be validated by collection and analysis of additional field and laboratory data.

I believe a few key observations and conclusions can be drawn from the material presented at the workshop and contained in the white paper, and from discussions during breakout and plenary sessions.

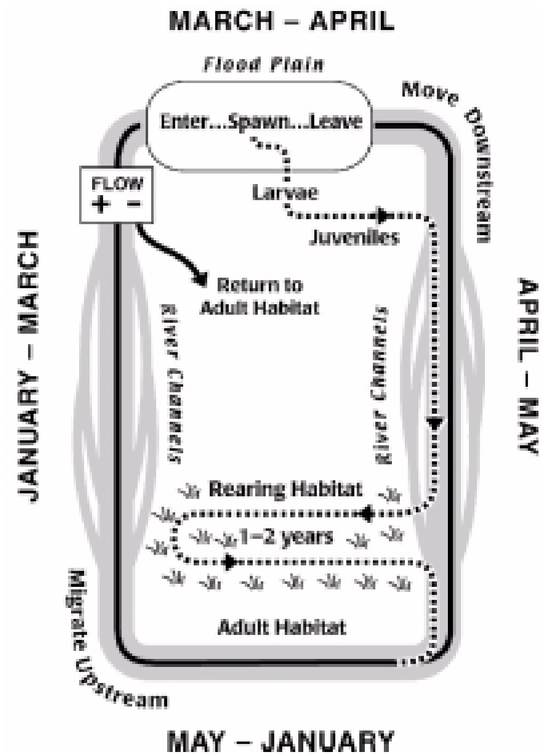


Figure 1 Conceptual model of the splittail lifecycle

Splittail Abundance Trends. Although historical abundance was not discussed extensively at the workshop, it is covered in the draft white paper. Unfortunately splittail have not been the specific target of IEP's numerous fish surveys, but most life stages have been incidentally captured. (See the white paper for a description of the indices.) As with all sampling efforts, there are specific limitations in capture efficiency that may bias the results. Further, at most the surveys provide data for the past three decades. In spite of the limitations, the abundance indices from the various surveys do provide useful trend information. A general observation is that splittail abundance demonstrates high inter-annual variability, but was generally higher before the 1987–1992 drought, was lower during the seven-year drought, and generally was at or near pre-drought levels from 1993–2000. The exception was Suisun Marsh, where post drought abundance remains low.

Splittail Abundance and Flow. If there is one consensus conclusion from the workshop and earlier splittail work, it is that splittail year class strength is closely correlated with river flow. This close correlation helps explain the high variability in many of the abundance indices. On the other hand, Randy Baxter used analysis of larval survey data to conclude that there is some splittail spawning in all water years.

Splittail and the Floodplain. It appears that the tight correlation between flow and splittail year class strength is due in large part to changes in availability of floodplain habitat (and submerged vegetation) during higher flow years. Data from the Sutter and Yolo bypasses and the Mokelumne–Consumnes floodplain indicate that adult splittail are adapted to move onto the floodplain to spawn and the juveniles can effectively move off as the flow recedes. Confirmed spawning in dry years indicates that small freshets can create suitable spawning habitat. This baseline, or river margin, habitat was the focus of considerable discussion. Although splittail biologists are not sure what constitutes this river margin habitat, it is important that it be defined and maintained.

Splittail and Salvage at the State and Federal Pumps. More than three decades of data demonstrate that all splittail life history stages are taken at federal and State water project pumps in the south Delta. Annual and seasonal take at the pumps varies considerably, both in absolute numbers and in life stage collected, with take generally highest in wet years when there are large numbers of young-of-the-year fish. We do not have the data to calculate numbers lost from numbers salvaged. That would require information on prescreen losses, screen efficiency, and predation, handling, and hauling losses. Nor are current data adequate to assess the population level effects of losses at the pumps.

Adult Population Age Structure and Abundance. Randy's data have shown that while splittail may live to be eight to ten years old, most adult splittail don't live longer than five years. Females dominate the older population. Unfortunately, sampling gear used by the IEP and others does not effectively sample adult splittail and we do not have reliable abundance estimates for the older fish. Workshop participants discussed mark-recapture and other techniques for estimating annual adult population abundance, but did not achieve consensus on a method.

Geographic Distribution. This was not discussed extensively at the workshop: however some data were presented to show that splittail are widely distributed in the Delta, Suisun Bay and Suisun Marsh, the Petaluma and Napa rivers, and the Sacramento and San Joaquin watersheds. As shown in the life cycle diagram, most splittail undergo annual spawning migrations and the young move downstream into the estuary. With the relatively few numbers of splittail captured in many of these sampling efforts, it is difficult to estimate annual variability in geographic distribution or trends in this distribution. Egg and larval data do indicate that some splittail move upstream of Sacramento each year and spawn. We do not know if there is some population fidelity among the Sacramento and San Joaquin populations. Workshop participants suggested genetic analyses to determine if there are distinct San Joaquin and Sacramento River populations, or if spawners opportunistically migrate with the flow.

Selenium and Splittail. Robin Stewart of the USGS presented new information on selenium levels in splittail and in their potential food sources. Selenium levels were high enough to pose some concern about physiological effects on the animal, including reproductive effects. Her data also demonstrated that a potential food source, the overbite clam (a common name suggested by SFEI's Andy Cohen), *Potamocorbula amurensis*, had relatively high selenium concentrations. Because of small sample sizes and limited geographic range in samples collected, more information is needed to determine if selenium poses a threat to splittail.

Splittail Simulation Model. Ted Foin described his new simulation model, developed specifically for the white paper. The model is an important tool in providing biologists a framework for thinking about the animal and the ability to run "what if" scenarios using various combinations of environmental variables. As with most biological models, many of the key assumptions driving the model need to be validated through collection and analysis of additional field and laboratory data.

In summary, the workshop provided a valuable forum for exchange of information among splittail biologists and others interested in this fish of concern. The attendees identified several research priorities including determining the possible presence of sub-populations, defining dry year habitat used for spawning and rearing, obtaining estimates of numbers of splittail in various life stages, and estimating survival from one life stage to the next. The population numbers and survival estimates could be used to assess the effects of such stressors as project pumping. Although biologists were generally optimistic that efforts to increase the amount of floodplain would benefit splittail, they expressed some concern that introduced fish and aquatic plants would reduce these benefits.

ANNOUNCEMENTS

BAY-DELTA MODELING FORUM PUBLISHES TWO LITERATURE REVIEWS ON WATER TEMPERATURE

John Williams
jgwill@wheel.dcn.davis.ca.us

A review of the literature on the effects of water temperature on chinook salmon and steelhead has been completed by Chris Myrick of Colorado State and Joe Cech of UC Davis. The review, "Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations," will be available soon on the web site of the Bay-Delta Modeling Forum (http://www.sfei.org/modelingforum/). The review was promoted by the Modeling Forum and funded by the California Department of Water Resources. Chapter titles include thermal tolerance, thermal preference, growth, smoltification, disease, predation, hooking mortality, and recommendations for future research. There is a five-page summary for the faint of heart.

A companion review of water temperature modeling, by Mike Deas of Watercourse Engineering and Cindy Lowney of Philip Williams & Associates, is ready for final review and should be posted on the web site within a few months. This review, which will be more a "users guide" to temperature models than an examination of particular models, has been funded by the Modeling Forum and the U.S. Bureau of Reclamation.

ENVIRONMENTAL WATER ACCOUNT SALMONID WORKSHOP

The EWA Science Advisors, Wim Kimmerer and Randy Brown, are convening a special workshop to explore the scientific underpinnings of processes leading to allocation of water for salmonid protection during the 2000-2001 emigration. The workshop will held on June 2, 2001, at the Putah Creek Lodge, located on the UC Davis campus. Wim and Randy will be preparing a workshop summary for distribution to attendees and other interested parties. The workshop itself will be limited to about 100 attendees. For more information, contact Randy at rl_brown@pacbell.net

FIFTH BIENNIAL STATE OF THE ESTUARY CONFERENCE: OCTOBER 9–11, 2001

CALL FOR POSTERS

The fifth State of the Estuary Conference will be held at the Palace of Fine Arts Theatre in San Francisco. The conference is sponsored by the San Francisco Estuary Project, CALFED Bay-Delta Program, and many other local state and federal agencies, programs and businesses. Poster sessions will be featured events at the late afternoon social gatherings that occur at the conclusion of the conference program on October 9 and 10. In addition to the technical posters, displays presenting information about species or habitat restoration, policy and management, socio/economic issues and environmental education related to the topics of the conference will also be accepted.

All poster topics must be relevant to the San Francisco Bay-Delta Estuary. Subjects of special interest include:

- Urban Challenges
- Airports and Ferries
- Climate Change
- Delta Islands
- Contaminants
- Land Use Changes
- Non-native Species
- River Restoration Projects
- Salmon Recovery
- Sediment Transport
- Species Studies
- Water Management
- Watershed and Restoration Beyond the Bay
- Agriculture
- Flood Control Monitoring Strategies/Design
- Conservation of Energy
- Conservation of Water
- Restoration/General
- Nonpoint Source Pollution
- Salt Ponds
- Urban Creeks
- Water Quality
- Status of Restoration Projects

Deadline for submission is June 30, 2001. For more information contact Cindy Brown, U.S. Geological Survey, at (650) 329-4477 or clbrown@usgs.gov.

CHINESE MITTEN CRAB REPORTING SYSTEM AND MONITORING PROGRAM

Ray von Flue, USFWS
ray_vonflue@fws.gov

With the support of IEP, the U.S. Fish and Wildlife Service is developing a reporting and monitoring program for the Chinese mitten crab (*Eriocheir sinensis*). This nonnative invasive species is widely distributed throughout the San Francisco Bay, the Sacramento-San Joaquin Delta and much of the Central Valley. While there is currently no formal monitoring survey or reporting program for the upstream crab populations, adults are collected at the fish salvage facilities and by trawl surveys during the downstream reproductive migration.

This new program will include the development of a reporting system for mitten crab collections and sightings. Reports may be made via a web page, e-mail, postage free mail, or phone. The contact information for reporting is included at the end of the article. Reports will be solicited from agency, university, and private sector scientists; water management and flood control districts; county agriculture offices; fishermen; and the public. The program will also include a summer monitoring program of various freshwater areas, primarily upstream of the Delta. This will provide information to help determine distribution and relative abundance of sub-adult mitten crabs. We will also work cooperatively with USFWS refuges and DFG wildlife areas to assist with the implementation of sampling programs on public lands. The sampling methods will be determined as an initial phase of the project, and will include a combination of "crab condos" and baited traps. This program will provide key information for the development of a predictive model of mitten crab year class strength and location of upstream rearing areas.

Your help is needed to make this reporting system a success. To report a sighting please go to the web site at http://www.delta.dfg.ca.gov/mittencrab/sighting.asp, e-mail at mcrabman@delta.dfg.ca.gov or call toll free at 1-888-321-8913. A brochure describing this program is nearing completion and will be available later this spring.

■ 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.

■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER

Chuck Armor, California Department of Fish and Game, IEP Program Manager & Editor
Zachary Hymanson, California Department of Water Resources, Editor
Lauren D. Buffaloe, California Department of Water Resources, Production Editor

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

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

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