Contents

Interagency Ecological Program--1998 Status and Trends Report

The Year in Review--Notes for Managers

Randall Brown, Department of Water Resources

This is the annual status and trends issue of the IEP Newsletter. I ask agency and university staff to prepare short articles on important components of the San Francisco Bay, Sacramento-San Joaquin Delta, and Central Valley system. As you will find, the important area of contaminants and their effects is not covered in this status review. I will be expanding the contact list for contaminant-related articles in the coming months.

Below I have given a few general comments and observations on material contained in this issue. Overall, most of the fish species of special concern fared reasonably well in 1998. However, there are exceptions, such as Pacific herring and striped bass, even the fall striped bass juvenile abundance was up a little over the past few years.

Flow and Pumping

As described by Roos (this issue, page 4), the 1998 water year was wet, the fourth wet year in a row. Net delta outflow (as calculated by DAYFLOW) during the environmentally important February-through-May period was the third highest observed during 1970 through 1998 (Figure 1).

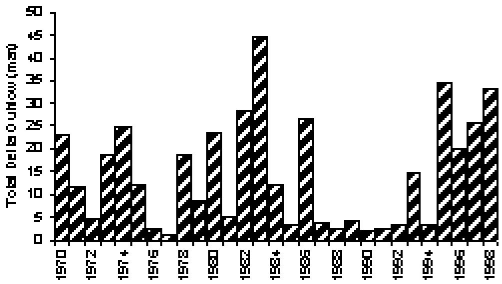

Figure 1 Total calculated delta outflow Jan through May, 1970-1998

Combined CVP and SWP exports for calendar year 1998 were less than 4,000,000 acre-feet, among the lowest in the past 19 years (Figure 2).

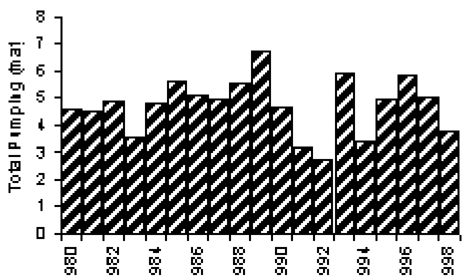

Figure 2 Total pumping (SWP + CVP) in acre-feet for calendar years 1980-1998

Introduced Aquatic Species

Several introduced nuisance species continued to cause problems and concerns in the estuary and watershed. I have commented on a few of the more important ones.

Egeria densa

A South American waterweed has become established in the delta, causing problems for boaters, marina owners, and water intakes (including fish screens). The California Department of Boating and Waterways is contracting with DWR for environmental documentation for a control program.

Potamocorbula amurensis

This clam, arriving from Asia in the mid-1980s, continues to exist in high numbers in the northern reaches of the estuary despite four high outflow years. Chlorophyll levels in Suisun Bay, an indicator of the amount of planktonic (floating) algae available for the aquatic food web, has remained below historic levels since the clam became established.

Late this summer the Chinese mitten crab, Eriocheir sinensis, almost stopped operation of fish salvage operation at the State and federal intake as thousands adult crabs moved down to the bay to spawn. The US Bureau of Reclamation and DWR are working to reduce mitten crab impacts to project operations and fish salvage.

Miscellaneous zooplankton

Kimmerer and others (this issue, page 16) and Orsi describe several species of zooplankton now commonly appearing in zooplankton hauls, some of which may have displaced native zooplankton. It is not yet clear if the introduced species are filling the same niches in the food web as the displaced species.

In 1998, there was considerable activity to reduce nuisance species introductions.

- Using CALFED funding, the US Fish and Wildlife Service is heading up an agency/stakeholder nuisance introduced species task force. Funding for prevention, control, and education projects is expected to be approved in 1999.

- The Regional Water Quality Control Board is considering using provisions of the Clean Water Act to eliminate introductions of new species via ballast water exchange in estuarine waters. (That is, introduced species are contaminants.)

- The Western Regional Panel of the National Nuisance Aquatic Species Task Force established a coastal committee to recommend education, prevention, and control strategies for Oregon, Washington, California, and Alaska. British Columbia has also been invited to participate.

The Interagency Ecological Program data are reported informally through the project work teams, the management team, and the agency coordinators and directors. The following are more formal means of conveying of data and information to interested staff, management, stakeholders, consultants, and general public.

Fish Species of Special Concern

The abundance estimates of several key species of fish will be used as indicators to determine the "health" of the bay and delta and its watershed. Put another way, if these species do not reach population levels that remove them from threat of extinction, restoration programs such as the ones being proposed by CALFED may be judged as failures.

The list of species of special concern include those fish already listed and native fish (and even a few introduced species) that have been in low abundance. For purposes of this discussion, the list includes the listed spring-run chinook, winter-run chinook, delta smelt, and splittail and non-listed longfin smelt, American shad, striped bass, fall-run chinook, surf perch (all species) and Pacific herring. I have included one invertebrate, the bay shrimp, as well.

Spring-run chinook

The 1998 spring run was the second best in the past three decades and by far the best in the past four decades to Butte Creek. Although most of the more than 20,000 spring-run chinook returned to Butte Creek, there were good runs to Mill and Deer creeks as well. Several million dollars of CALFED and CVPIA funds have been used to improve fish passage in Butte Creek, which may help explain the recent strong runs. The California Fish and Game Commission listed spring-run chinook as threatened in late 1998.

Winter-run chinook

As with spring-run chinook, the 1998 winter-run chinook escapement, at more than 2,600, was the best in the past several years. Escapements for the past four years have been encouraging when compared to about 200 fish returning to the upper Sacramento River in the years around 1990. Hatchery production, reduced ocean harvest, and improved early rearing conditions are likely contributors to increased abundance.

Delta smelt

IEP uses two indices to track annual variations in abundance of delta smelt and annual fish. The indices vary widely and a good summer index does not necessarily mean a good fall index. In 1998, both the summer and fall indices were moderately low compared to similar indices from the 1970s, 1991, and 1993. Because of population distribution and flows, the CVP and SWP intakes salvaged less than 1,000 delta smelt in 1998. Made clear at an October 1998 workshop, biologists do have a good understanding of the reasons for delta smelt abundance.

Splittail

The 1998 fall midwater trawl survey index was the highest for the period of record with most of the captured fish being from the 1998 spawn. Although splittail were more abundant in Suisun Marsh in 1998 than in the past decade; their numbers in the marsh are still much lower than seen in the early to mid-1980s.

Longfin smelt

Longfin smelt dropped to very low levels during the 1982-1992 drought and were considered for listing. As compared to 1997, longfin smelt abundance increased substantially in 1998; these fish are the progeny of the 1996 year class. Based on pre-drought data, abundance is correlated with flow conditions, when fish are larvae, 1998 numbers are lower than would be expected from 1998 flow levels.

American shad

American shad is an introduced species and an important game fish. The adults spawn in Sacramento streams and the young reside in these streams before moving into and through the delta. The American shad is somewhat of an anomaly in that their abundance, as indexed by the numbers of juveniles captured in the fall midwater trawl, has been increasing in the past decade. Although much more information is needed, American shad may be a useful indicator of changes in the environmental quality of this watershed and the bay-delta. (They use the entire Sacramento Valley and bay-delta system; there is no hatchery contribution and fishery impacts are minimal).

Striped bass

Striped bass is another introduced species that supports a valuable sports fishery. Before fish listings, striped bass abundance was an indicator of overall "health, productivity, and condition" of the upper estuary. In 1998, evidence on juvenile striped bass abundance was somewhat conflicting--the summer townet index was the lowest on record, whereas the fall midwater trawl index was above 1,000 for the first time since 1994 and was higher than the average for the past ten years. Estimates of adult abundance are made every other year and this was not the year.

Fall-run chinook

Fall-run chinook is the most abundant chinook salmon race in the Central Valley and is heavily supported by production from Coleman, Feather, Nimbus, Mokelumne and Merced hatcheries. The Pacific Fisheries Management Council has a target escapement of 122,000 to 180,000 fall-run chinook to the Sacramento Valley. Figure 3 shows a cohort escapement (in other words, the total number of adults returning from the brood year). The figure indicates that the goal was reached, and cohort escapement in 1998 was the third best in the past 28 years. A few notes about these data follow:

- Hatchery fish are those that are actually taken into a hatchery.
- Natural fish are those spawning in the streams and includes fish of hatchery origin that were not allowed in the hatchery.
- Actual numbers of fish leaving the ocean was probably about 25% higher than escapement, the difference going to an inland recreational harvest.
- High escapement is at least partly due to reduced ocean harvest, which was in turn due to less fishing effort and increased regulatory restrictions.

Surf perch

Several species of surf perch have shown long-term, severe declines in the lower estuary. Although not all species are shown in this status and trends report, the three species reported (shiner, walleye, and pile) continued in low abundance in 1998.

Pacific herring

Pacific herring are typically abundant in South, Central, and San Pablo bays from spring through summer and support the only large commercial fishery remaining in the bay. Abundance of age-0 fish (in other words, spawned in 1998) was again low in 1998, perhaps due to effects of El Niño and high winter flows, which may have transported larvae from the bay.

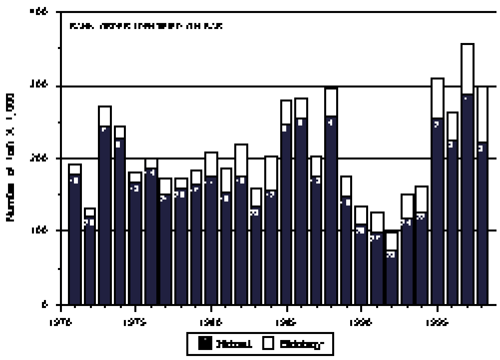

Figure 3 Annual fall-run chinook salmon cohort escapement to the Sacramento River and major tributaries

Crangon franciscorum

This is an ecologically important bay shrimp, which is often concentrated in San Pablo Bay in early summer. The distribution shifts upstream to Suisun Bay in the late summer and early fall. Abundance of juvenile C. franciscorum was highest for the 1980-1998 period of record. Juvenile abundance of this shrimp is tied closely to flow and the series of high flow years has likely increased the broodstock population.

Outreach and Communication

IEP Newsletter

The four 1998 issues numbered about 200 pages and contained more than 50 articles written or coauthored by 77 authors. Each issue also contained quarterly highlights. The spring issue covered the status and trends of key species, assemblages, flow, pumping, and fish salvage at the State and federal fish facilities. IEP distributes about 1,000 copies of the newsletter each quarter.

IEP web site

As described in the fall 1998 newsletter, visitors from 63 countries accessed 116,000 pages at the IEP web site (www.iep.water.ca.gov). Data management staff continues to upload IEP data sets.

Annual workshop

About 300 IEP staff, managers, and guests attended the three-day 1998 workshop held at the Asilomar conference center (see also article on page 58).

Technical reports

IEP published three interagency technical reports in 1998: "1998 Entrapment Zone Study," "Proceedings of 14th Annual PACLIM Workshop," and "Recommendations Regarding Comprehensive Aquatic Monitoring in the Estuary."

- ## Water Year 1998-1999

Maurice Roos, Department of Water Resources

Most of the rainy season is now over. Water year 1998-1999 is a classic example of the La Niña effect on California winter weather. A La Niña event occurs when the equatorial surface temperatures in the eastern Pacific are cooler than normal. In contrast, water year 1997-1998 had much warmer than average eastern tropical Pacific water temperatures (a strong El Niño). The generalized, winter season, western US rainfall relationship for La Niña (cold water event) is a dry American Southwest and a wet Pacific Northwest. Southern California tends to be dry like the Southwest, while northern California is in between and can be either wet or dry. This past winter the north Pacific storm track was vigorous and the wetness extended into northern California, especially the mountains, with the exception of a month long dry spell centered around New Year's Day. Many storms seemed to run out of energy between Stockton and Fresno; as a result, the southern Sierra was quite dry, although not as dry as many of the drought years. Figure 1 shows the percentages of average seasonal precipitation (as of 1 April) since 1 October for California's ten hydrologic regions.

The drop off in precipitation in the southern Sierra showed up in the 1 April snowpack. The snow water content from the Tuolumne River watershed north was above average, whereas from the Merced River south amounts were progressively below average. The range was from about 140% of average on the upper Sacramento River (above Shasta Lake) and 130% on the Yuba and American rivers to slightly over 50% on the Kern River. The statewide average snowpack was 110% of average. Spring snowmelt runoff forecasts varied accordingly, with a statewide average forecast to be about 110% of average.

For the Sacramento River system the 1 April forecast of water year runoff was about 22 million acre-feet, about 120% of average. This makes 1999 the fifth consecutive wet year in a row. This extended run of wet years has not occurred since before this century, and based on rainfall records probably not since 1850. Previous extended wet year runs happened twice and lasted four years in succession. A review of the tree ring reconstruction of Sacramento River runoff to 1560 revealed three other five-year or longer wet runs: 1601-1606 (6 years); 1801-1806 (6 years); and 1808-1812 (5 years). Just a decade ago we were in the throes of drought (Figure 2).

Figure 1 Seasonal precipitation in percent of average, 1 Oct through 31 Mar 1998. Water year is 1 Oct through 30 Sep.

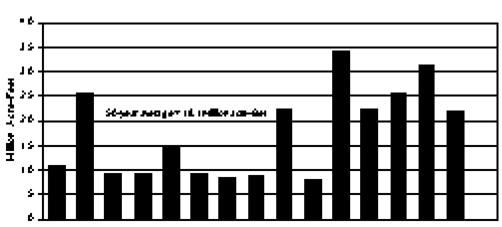

Figure 2 Sacramento River system water year runoff. Sum of the Sacramento River above Bend Bridge near Red Bluff, Feather River at Oroville, Yuba River at Smartville, and the American River at Folsom.

Runoff so far this year has been good as of 31 March, about 115% of average compared to 165% last year. The following table shows estimated statewide runoff by month in percent of average.

Month	Estimated Statewide Runoff (Percent of Average)
October	110
November	130
December	85
January	80
February	165
March	120

Seasonal runoff mirrors the pattern of precipitation with about 120% of average in the Sacramento River region to around 90% in the Tulare Lake region and around half the average in southern California. (The southern region numbers look as good as they do partly because of the residual base flow from a very wet 1998. This carryover effect will fade as we progress into the 1999 dry season.)

Reservoir storage has been excellent all season. Amounts on major reservoirs has been limited by flood control requirements, with considerable excess water being released during the winter months. Statewide storage as of 1 April was 115% of average, virtually the same as one year ago. With a good snowpack in most of the State, water supplies should be average or better for most areas. Some deficiencies are expected in the Central Valley Project service area on the west side of the San Joaquin Valley and in the areas of the southern half of California that have little storage and are dependent on local runoff.

There were some periods of high water in Central Valley rivers this winter, but no large floods. In that sense, water year 1998-1999 was fairly benign. The only extreme event was temperature related--a severe freeze the week before Christmas.

1998 Fall Dissolved Oxygen Conditions in the Stockton Ship Channel

Stephen P. Hayes and Jeannie S. Lee
Department of Water Resources

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

As part of a 1969 Memorandum of Understanding between the Department of Water Resources (DWR), the US Fish and Wildlife Service, the US Bureau of Reclamation, and the Department of Fish and Game, the Department of Water Resources usually closes the head of Old River by installing a temporary rock barrier during periods of projected low fall outflow. The barrier increases net flows down the San Joaquin River past Stockton, and may contribute to the alleviation of low dissolved oxygen levels in the eastern Stockton Ship Channel. In 1998, however, DWR did not install the barrier because water year 1998 [1] was classified as wet, and late summer and early fall (August through October) flows in the San Joaquin River were much higher than normal [2] . Average daily flows in the San Joaquin River past Vernalis ranged from 4,753 to 6,708 cfs from August through October, and average daily flows past Stockton ranged from 1,020 to 2,011 cfs. The average daily flows past Vernalis in 1998 were two to three times the flow (about 2,000 cfs) observed in the late summer and early fall of 1997, which far exceeded the average daily flows of 1,000 cfs or less observed in this area during the fall seasons of previous drought years. During previous years, intermittent reverse flow conditions were also present in the late summer and early fall in the San Joaquin River past Stockton.

Monitoring of dissolved oxygen levels in the Stockton Ship Channel was conducted six times by vessel between 7 August and 20 October 1998 [3] . During each of the monitoring runs, fourteen sites were sampled from Prisoner's Point in the central delta (Station 1) to the Stockton Turning Basin (Station 14) at the terminus of the ship channel (Figure 1). For each site, Dissolved oxygen and water temperature data were collected near the surface and bottom of the water column during ebb slack tide using a Hydrolab Model DS-3 Multiparameter Surveyor.

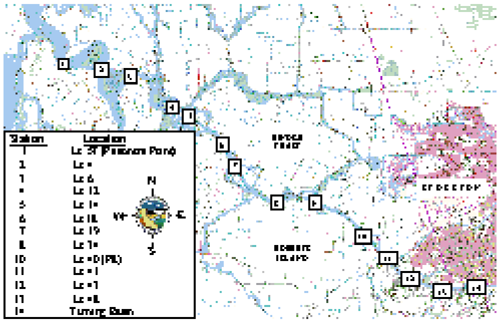

Figure 1 Dissolved oxygen monitoring sites in the Stockton Ship Channel

In 1998, all surface and bottom dissolved oxygen levels measured in the channel exceeded 5.0 mg/L and a dissolved oxygen sag (where dissolved oxygen levels were less than 5.0 mg/L) was not observed (Figure 2). In previous years, an oxygen sag developed in and immediately west of the Rough and Ready Island area (the Station 10 to 13 area) within the eastern channel during August and September. In 1998, however, San Joaquin River inflows into the eastern channel appear to have been sufficiently high to push the potential sag area from its historic location westward to where tidal fluctuations and mixing maintained higher dissolved oxygen levels. The higher flows from the San Joaquin River into the channel immediately east of Rough and Ready Island also resulted in reduced residence times in this area, and potentially permitted greater dissolved oxygen saturation within the extreme eastern channel.

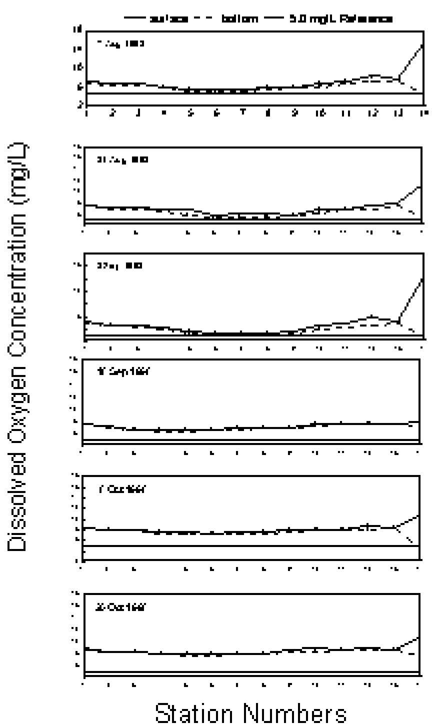

Figure 2 Dissolved oxygen concentrations in the Stockton Ship Channel in 1998

Despite improved flow conditions within the channel, a dissolved oxygen depression (an area within the channel where dissolved oxygen levels ranged from 5.0 to 6.0 mg/L) did exist within the system in 1998. Monitoring from August through early September 1998 showed a depression existed from Columbia Cut (Station 5) to Fourteen Mile Slough (Station 9). On 7 August, the lowest dissolved oxygen levels in the channel were measured from Columbia Cut to the west of Turner Cut (Station 7). On 21 August and 8 September, the dissolved oxygen depression shifted eastward to the area from the eastern end of Columbia Cut (Station 6) to Fourteen Mile Slough. These areas are consistently west of the historic sag area described previously.

The August and early September dissolved oxygen depression within the channel appears to be partly due to warm water temperatures. Water temperatures throughout the channel ranged from 24-26 °C on 7 August, 22-24 °C on 21 August, and 23-25 °C on 8 September. The well-established inverse relationship between dissolved oxygen level and water temperature (higher water temperature, lower dissolved oxygen level 4) applies here. At the range of water temperature values recorded in the late summer of 1998 (22-26 °C), dissolved oxygen levels have been low (less than 5.0 mg/L) in the eastern channel during the late summer in previous years.

In past years, intermittent reverse flow conditions past Stockton appeared to contribute to low summer and fall dissolved oxygen conditions in the eastern channel. In late summer and early fall 1998, however, reverse flow conditions past Stockton were absent because of the high San Joaquin River flows described previously. In fact, average daily flows past Stockton ranged from 1,003 to 1,979 cfs from August through mid-September. Thus, reverse flow conditions in the San Joaquin River past Stockton did not contribute to low dissolved oxygen conditions in the eastern channel in 1998.

By 18 September 1998, the late summer dissolved oxygen depression present in the channel had been eliminated. Surface and bottom dissolved oxygen levels measured on 18 September exceeded 6.5 mg/L throughout the channel. By 20 October, these levels had improved to 8.0 mg/L or greater throughout the channel. Because of the full recovery of dissolved oxygen conditions in October, monitoring was not conducted in November.

Cooler water temperatures appear to have contributed to the improved fall dissolved oxygen conditions in the channel. Surface and bottom water temperatures within the channel ranged from 20-22 °C on 18 September, 17-18 °C on 8 October, and 15-16 °C on 20 October. The significant decrease in water temperature in the fall contributed to the elimination of the late summer dissolved oxygen depression within the channel, and the ultimate elevation of dissolved oxygen to the high levels historically measured in November in previous years.

Average daily San Joaquin River flows past Vernalis from mid-September through the end of October ranged from 5,058 cfs to 6,694 cfs, and average daily San Joaquin flows past Stockton ranged from 1,113 to 2,011 cfs. These fall flows are similar to the late summer (August through mid-September) flows and show that flow conditions were consistently high and essentially constant throughout the entire study period.

Exceptionally high surface and low bottom dissolved oxygen levels were periodically measured in the Stockton Turning Basin throughout the study period. Sampling on 7 August, 21 August, and 8 September 1998 showed surface dissolved oxygen levels ranging from 11.4 to 15.4 mg/L and bottom dissolved oxygen levels ranging from 4.4 to 5.6 mg/L. On 18 September, the distinct dissolved oxygen stratification subsided, and surface and bottom dissolved oxygen levels were 7.9 and 7.3 mg/L, respectively. On 8 and 20 October 1998, however, a lesser dissolved oxygen stratification returned. Surface dissolved oxygen levels ranged from 10.5 to 10.7 mg/L and bottom dissolved oxygen levels ranged from 4.2 to 7.8 mg/L.

The highly stratified dissolved oxygen conditions detected in the basin throughout much of the 1998 study period appear to be the result of localized biological and water quality conditions occurring in the basin. The basin is at the eastern, dead-end terminus of the ship channel and is subject to reduced tidal activity, restricted water circulation, and increased residence times when compared to the remainder of the channel. As a result, water quality and biological conditions within the basin have historically differed from those within the main downstream channel and have led to extensive late summer and fall algal blooms and dieoffs. The late summer and early fall of 1998 were no exception, and a series of intense algal blooms composed primarily of crytomonads, diatoms, flagellates, and blue-green and green algae were detected. Blooms appear to produce stratified dissolved oxygen conditions in the water column of the basin in the following way: high algal productivity at the surface of the basin produces elevated surface dissolved oxygen levels and dead or dying bloom algae settle out of the water column and sink to the bottom to contribute to high BOD. Bottom dissolved oxygen levels in the basin are further degraded by additional BOD loadings in the area such as regulated discharges into the San Joaquin River and from recreational activities adjacent to the basin. When bloom activity subsides, the dissolved oxygen stratification is reduced, and basin surface and bottom dissolved oxygen levels become less diverse.

Bacteria and the Microbial Loop in Northern San Francisco Bay and the Sacramento-San Joaquin Delta

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Why should the IEP or CALFED care about bacteria? After all, most people only think of them when they are sick or have an infected cut--then bacteria are something to be killed. The rare individual might remember them in connection with yogurt, vinegar, or pharmaceuticals manufacturing--then they are part of an industrial process. Yes, alas, it is true: bacteria are not as charismatic as some of the other organisms with which they share the earth, "Johnny-come-latelys" like sea otters, whales, great white sharks or delta smelt. But they are every bit as important (if not more so) in maintaining the flow of nutrients and organic matter that make an ecosystem function. For example, in our 1996 paper (Hollibaugh and Wong 1996), we reported that our estimate of the biomass of bacteria in San Francisco Bay (0.2 g C/m2) was 57.5 times that of "Humphrey" the humpback whale. Using standard techniques, we also estimated that the bacterial biomass of the bay doubles in about 1.2 days (it is much longer for humpback whales). The bay would rapidly become as thick as yogurt if this production kept up and wasn't consumed by something else. The broader implication is that there is a large flux of carbon and energy through this compartment of the bay's food web (baywide annual average production is estimated to be 50 g C/m2/yr).

But biomass doesn't tell the whole story. Because bacteria are very small, their surface area in the bay is very large, about 20 times the surface area of the bay at high tide. And unlike the surface of a sediment particle (where you will also find bacteria), the surface of a bacterial cell is a veritable biochemical factory, capable of adsorbing, absorbing, decomposing, or transforming organic matter and substances like selenium, mercury, PAHs, pesticides and other poisons.

1988-1991 Surveys

These conclusions are based on information collected during an intense study of the spatial and temporal variation of bacterioplankton biomass and production in the San Francisco Bay Estuary conducted between 1988 and 1991. In addition to these surveys, other studies (Hollibaugh 1988, 1994) have examined the physiology of bacteria in San Francisco Bay. Two conclusions have emerged from this work. First, bacterial production in San Francisco Bay appears to be lower than in other estuaries. I have attributed this to food limitation, inferred from limited phytoplankton production in San Francisco Bay. Second, the physiology of San Francisco Bay bacterioplankton differs significantly from the physiology of bacteria in other estuaries in at least one regard; the metabolic fate of the DNA precursor thymidine. Exogenously supplied thymidine is extensively degraded by San Francisco Bay microbial assemblages, whereas it is assimilated directly into DNA without modification in many other estuaries.

I believe that this difference in thymidine metabolism also points to food limitation. In other estuaries (Chesapeake Bay, Tomales Bay) or coastal waters (Monterey Bay), fresh organic matter derived from phytoplankton is the most important source of food fueling the microbial loop food web (Figure 1). This organic matter is composed of simple molecules that bacteria can easily assimilate. In San Francisco Bay, especially northern San Francisco Bay, partially degraded, detrital organic matter appears to be more important. Because it is partially degraded, the readily assimilable molecules have been removed, leaving behind material that requires more extensive metabolic processing by the bacteria before they can assimilate it into biomass. This difference in metabolism then affects the way bacteria process thymidine (and probably other compounds).

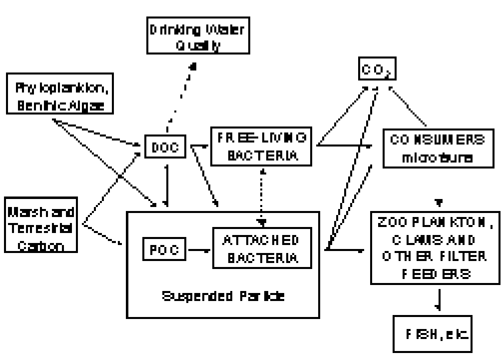

Figure 1 Conceptual model of the "microbial loop" (Pomeroy 1974; Azam and others 1983) that has emerged from our studies of San Francisco Bay. Detrital organic matter originating from algae and

higher plants as well as soil is broken down by converted to bacterial biomass. In the process, the chemical characteristics of the organic matter are altered in ways that may affect drinking water quality. The bacterial biomass, in turn, is consumed by microfauna or zooplankton and other large filter feeders and enters the "classical" food chain (algae ! zooplankton ! fish) (Steele 1974).

Recent Research

Between 1991 and 1996, our work focused on processes affecting the distribution and fate of bacterioplankton biomass in San Francisco Bay. One area of research compared populations of bacteria closely associated with particles with populations of cells that float freely in the water. This distinction is important because particle-associated bacteria are more likely to be retained in the estuary and, most importantly, because they are more available as food for zooplankton or filter-feeding benthic organisms (for example, clams) (Werner and Hollibaugh 1993). We found that when care is taken to minimize disruption of the fragile particles and aggregates found in the bay, especially in the region of the entrapment zone, over half of the bacteria were associated with particles (Hollibaugh and Wong, forthcoming). This aggregation appears to be strictly physical, as there was little metabolic differentiation between the two populations (Murrell 1998; Murrell and others 1999) and the phylogenetic composition of the two populations was very similar (Figures 2 and 3) (Hollibaugh and others, submitted for publication), though composition changed along the salinity gradient and through time (Murray and others 1996; Hollibaugh and others, submitted for publication).

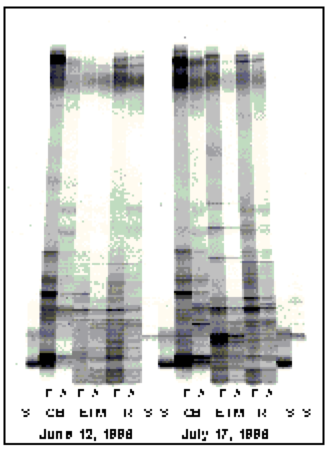

Figure 2 Denaturing gradient gel electrophoretic resolution of v3 (341-534) rDNA PCR products of mixed template amplifications from samples collected in San Francisco Bay on 12 June and 17 July 1996. Lane designations: F, free-living bacteria; A, attached or particle-associated bacteria; S, Standards; CB, Central Bay; ETM, estuarine turbidity maximum; R, River (Rio Vista). Dark bands indicate the presence of DNA characteristic of a given kind of bacteria, visual comparison of banding patterns between samples reveals differences in the composition of the microbial assemblages in the samples. These differences can be tested statistically using a regression-based cluster analysis of the banding patterns (see Figure 3).

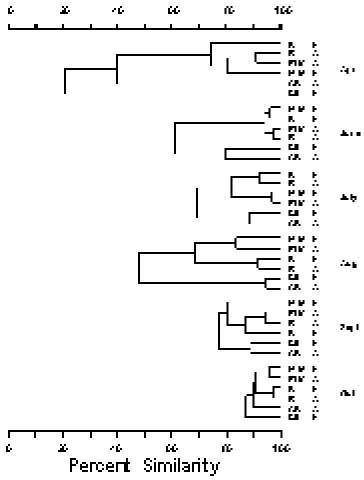

Figure 3 Dendrograms from cluster analyses of the similarity of PCR/DGGE profiles of samples collected on 1996 cruises to northern San Francisco Bay. Abbreviations as in the Figure 2 caption.

In our efforts to elucidate the microbial loop food web in San Francisco Bay, we have also attempted to measure grazing by microzooplankton on bacteria using a standard technique that involves following changes in population growth rate when grazing pressure is reduced by dilution of the sample (Murrell and Hollibaugh 1998). This approach yielded limited success in northern San Francisco Bay, though it worked well in south San Francisco Bay and Tomales Bay. If taken at face value, these results would suggest that microzooplankton grazing is not important to the mortality of bacterioplankton in the north bay; however, alternative interpretations are also possible. For example, the model upon which this technique is based assumes that microzooplankton feed upon bacteria as a result of random encounters between randomly distributed predators and prey. The high particle load and high percentage of bacteria associated with particles in the North Bay may foster a microzooplankton-feeding mechanism that is more like a cow grazing in a pasture--the predator grazes across the surface of the particle consuming attached cells. If this is the case, dilution of the sample would simply reduce the number of pastures in a sample, not the relative densities of cows and grass, and thus specific mortality rates, in a given pasture.

We have recently begun looking at potential sources of the carbon fueling the microbial loop in northern San Francisco Bay. Budgeting efforts (Jassby and others 1993) and our own work (Hollibaugh and Wong 1996, forthcoming) suggest that carbon exported from the delta is important in the north bay. We measured the concentrations and microbial consumption of dissolved organic carbon (DOC) found in different types of wetlands in the delta in a preliminary study, conducted in collaboration with a CALFED-funded study by USGS scientists (J.E. Cloern and colleagues) of particulate organic carbon (POC) sources and sinks in the delta. DOC concentrations ranged from 3 to 8 mg C/L (Figure 4). This is much higher than the POC concentrations typically found in the delta, except during floods (0.5-1.2 mg C/L). Decay coefficients for this DOC ranged from 0.01 to 0.02 per day and did not depend on the amount of DOC initially present (Figure 5). This suggests that the elevated concentrations of DOC in the delta result from dynamic balances between production and consumption instead of the accumulation of recalcitrant material. Seventeen to fifty-four percent of the DOC originally present was consumed in 16 days (0.5-1.0 mg C/L, 31.3-62.5 mg C/L/d). If this result is typical, DOC produced in the delta could provide much of the carbon required for bacterial production in northern San Francisco Bay (an average of 28 mg C/L/d) (Hollibaugh and Wong 1996), but not all of it. Since some of the carbon is respired to provide the energy needed for biosynthesis, osmoregulation, and other aspects of metabolism, the bacterial carbon demand is three to five times the actual production value, depending on growth efficiency (Hollibaugh and Wong 1996).

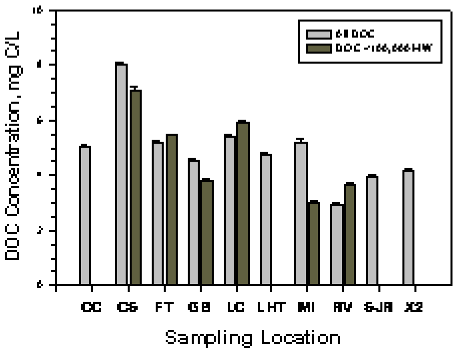

Figure 4 DOC concentrations in the delta and northern San Francisco Bay waters and wetlands. Organic carbon was measured by high temperature, Pt-catalyzed combustion. "All DOC" is organic carbon passing a GF/C glass fiber filter (nominal pore size 1 Fm); "DOC <100,000 MW" is organic carbon passing a 100,000 MW cutoff ultrafilter. Sampling location abbreviations: CC Clifton Court, west canal; CS Cutoff Slough; FT Frank's Tract; GB Grizzly Bay; LC Liberty Cut; LHT Little Holland Tract; MI Mildred Island; RV Sacramento River at Rio Vista; SJR San Joaquin River at Mossdale; X2 2 psu surface salinity in Suisun Bay.

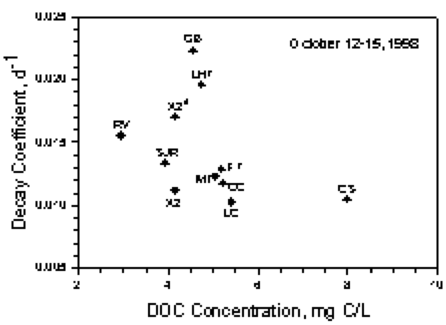

Figure 5 Exponential decay coefficients for DOC (DOCt = DOCi H
e-kt) in samples from the delta and northern San Francisco Bay. Sampling location abbreviations as in Figure 1. X2A is the decay coefficient from regression, with an outlier excluded.

What next? There are two general areas where more study of the microbial loop and its role in San Francisco Bay and delta productivity is needed. The first is to identify the sources of organic matter fueling bacterial production. The study discussed above was preliminary. It did not address bacterial production directly because we do not know the growth efficiency of bacteria on this DOC (production was not measured). It did not address seasonality; samples were taken during October when flows were low and water residence times were high (! elevated DOC), phytoplankton primary production was low (! low DOC), and marsh and riparian vegetation was just beginning to senesce and decay (! high DOC). We need to look at organic carbon sources in the delta over a seasonal cycle.

As stated earlier, we do not know the growth efficiency of bacteria on this DOC; moreover, we do not know the actual source of the DOC used by the bacteria. DOC is a mixture of compounds from many sources. Some of the compounds and compounds from some sources are used more readily than others. We need to characterize the organic matter from a variety of sources (growing marsh vegetation, rotting marsh vegetation, phytoplankton growth in delta channels, and so on) and use more sophisticated methods to trace the carbon actually used by bacteria. It is conceivable that CALFED restoration efforts could result in the production of organic matter that is not used by bacteria and thus would be lost to the delta food chain. This would be acceptable if there were other overriding habitat values or if the wetland produced more food of a different type (for example, POC that could be used directly by the classic food chain). However, the residual DOC might have undesirable properties; for example, it might create taste and odor problems or form toxic by-products during drinking water disinfection. Unlike POC, which can be removed by filtration or settling, DOC is difficult to remove from drinking water.

The second area that needs more research is elucidating the fate of bacterial production in the bay and delta. While bacteria appear to be a nutritious food source for organisms that can eat them (Werner and Hollibaugh 1993), their significance to the classic food chain is highly dependent on the number of trophic interactions required to transfer their biomass to species of concern (see Pomeroy 1979 or Ducklow and others 1986). Our work on this topic has just begun. We are reasonably certain that bacteria are grazed because we can measure production and yet their biomass is constrained within a narrow range, implying that the production is cropped.

We suspect that the trophic transfer efficiency is high because much of the bacterial biomass is associated with particles and is directly available to filter feeders. Free-living bacteria are too small to be consumed directly by most filter feeders and must first be consumed by microzooplankton grazers before their biomass can be transferred up the food chain. We know very little about the role of microzooplankton in the San Francisco Bay and delta microbial loop. Our data suggests that microzooplankton grazing on bacteria is not important in northern San Francisco Bay (Murrell and Hollibaugh 1998); however, this would be very unusual and our results were not conclusive. These measurements should be repeated using another approach.

Acknowledgments

My work on the ecology of San Francisco Bay bacteria would not have been possible without continued funding from the IEP and, particularly, DWR. I thank Dr. Randy Brown for his role supporting these studies. I have also received funding for San Francisco Bay studies from the San Francisco Foundation and the Ocean Sciences Program of the National Science Foundation. Finally, most of our field work was conducted in collaboration with the USGS San Francisco Bay Program. The work may have been possible without them, but it certainly wouldn't have been as much fun.

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- ## 1998 Phytoplankton Biomass and Species Composition

Glenda Marsh, Department of Water Resources

Figures 1 through 5 show chlorophyll a concentration and percent chlorophyll measured in the lower delta, upper delta, downstream and two floating low salinity stations (2 ppt and 6 ppt salinity) during 1998 in the upper San Francisco Bay Estuary and Sacramento-San Joaquin Delta. Average monthly chlorophyll a concentrations were commonly below 4 Fg/L in most regions in 1998. Maximum chlorophyll a concentrations in the lower delta (stations C10, MD10, P8, D16, and D26 in the southern delta, eastern delta, and lower San Joaquin River, respectively) were below the 20-60 Fg/L maxima measured in 1997 (Figure 1), while concentrations in the downstream region (stations D41, D6, D7, D8, and D10 in San Pablo Bay and Suisun Bay, respectively) in the winter were higher than those in 1997 (Figure 2). Low chlorophyll concentrations in Suisun Bay were probably a function of grazing by Potamocorbula amurensis which has depressed chlorophyll biomass in this region since 1987. The low chlorophyll a concentrations in the upper delta (stations C3, D12, D4, and D22 in the northern delta, western delta and lower Sacramento River, respectively) were similar to those of 1997 (Figure 3), but in all regions chlorophyll a concentrations were lower than those measured before 1980.

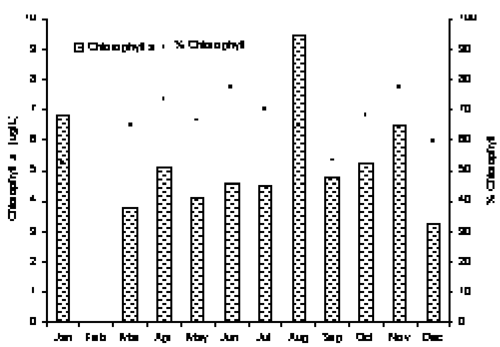

Figure 1 Chlorophyll a and percent chlorophyll a concentration in the lower delta

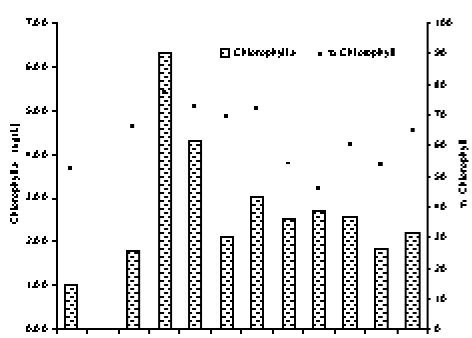

Figure 2 Chlorophyll a and percent chlorophyll a concentration in the downstream region

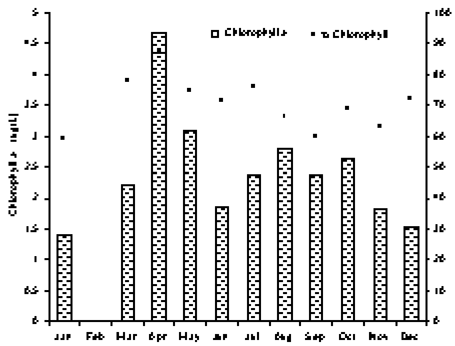

Figure 3 Chlorophyll a and percent chlorophyll a concentration in the upper delta

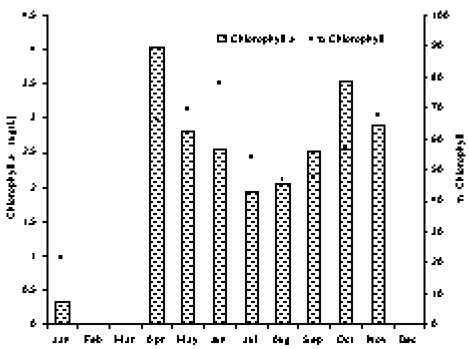

Figure 4 Chlorophyll a and percent chlorophyll a concentration at the 2 FS/cm station

A chlorophyll a maximum occurred in April or May for most regions and was followed by a peak in late summer or early fall. In contrast, the maximum concentration in the lower delta occurred during August when water residence times are high in that region. The high chlorophyll a concentrations in the spring were accompanied by percent chlorophyll a concentrations above 50%, which suggests phytoplankton were growing well throughout the estuary. Percent chlorophyll a concentration is the proportion of chlorophyll a in total chlorophyll pigment, a sum of chlorophyll a and pheophytin a. Pheophytin a is a breakdown product of chlorophyll a. The 6 ppt station had concentrations below 50% in the fall, but exceeded 50% more months than in 1997 (Figure 5).

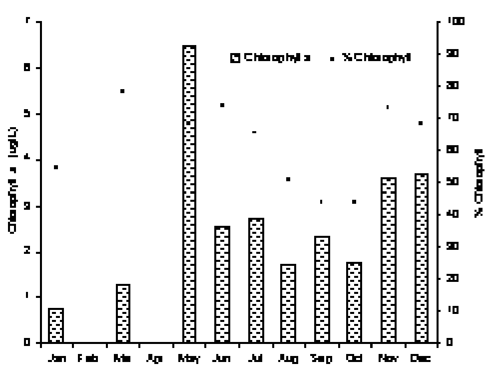

Figure 5 Chlorophyll a and percent chlorophyll a concentration at the 6 FS/cm station

Cryptomonas species and miscellaneous flagellates were common phytoplankton species in the lower and upper delta, but the chlorophyll maximum was associated with Cyclotella species in the lower delta and Cryptomonas species in the upper delta. Cryptomonas species, Skeletonema costatum, and miscellaneous flagellates were the most common species in the downstream region, but Skeletonema costatum was the most common species during the April bloom maximum.

Long-term Trends in Mysid Shrimp and Zooplankton

James J. Orsi, Department of Fish and Game

Data from 1969 for mysid shrimp and 1972 for several zooplankton groups enables us to examine the long-term abundance trends. Zooplankton can be divided into copepods, cladocerans, and rotifers. A number of exotic copepods and mysids have been introduced to the estuary but no exotic cladocerans or rotifers have been found.

Past analyses have found that exotic copepods are most abundant in summer and fall. Therefore, long-term trends were graphed for spring and for summer and fall combined. Native copepods (Cyclops and Diaptomus species) showed similar long-term declines in both periods, but from 1990 to 1998, their abundance was much lower in summer and fall (Figure 1A and 1B). An exotic copepod, Sinocalanus doerrii, first became abundant in 1979 and was more abundant in summer and fall than in spring. Another exotic copepod, Pseudodiaptomus forbesi, became abundant in 1988 and was also more abundant in summer and fall. As a result of these introductions, the long-term trend in the exotic copepods has been upward, although the peak came in 1992 (Figure 2A and 2B). Most of the copepods in the Suisun Bay and the delta during summer and fall are exotic species.

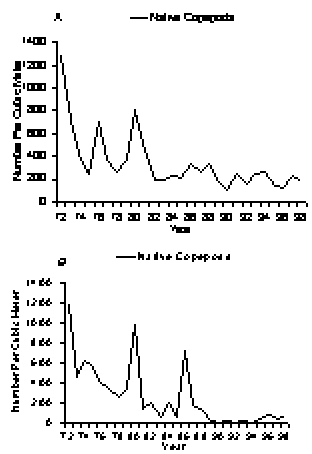

Figure 1 Mean annual abundance of native copepods from 1972 to 1998 (A) in spring and (B) in summer and fall

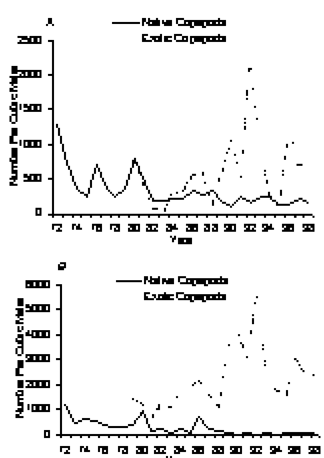

Figure 2 Mean annual abundance of native and exotic copepods from 1972 to 1998 (A) in spring and (B) in summer and fall

The origin of Eurytemora affinis is cryptic; it could be native or it could have been introduced prior to the Department of Fish and Game's delta study zooplankton sampling from 1963 to 1965. E. affinis has undergone a long-term decline, which has been more severe in summer and fall than in spring, especially since 1988 (Figure 3A and 3B).

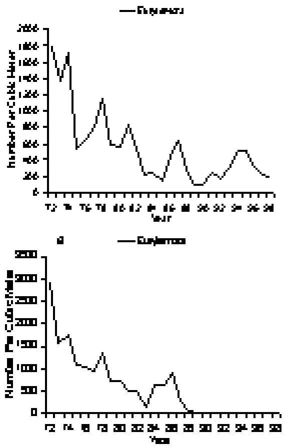

Figure 3 Mean annual abundance of Eurytemora affinis from 1972 to 1998 (A) in spring and (B) in summer and fall

The above copepods are all >1 mm total length, and have all been found in the stomachs of larval and small fish in this estuary. Two other introduced copepods, Limnoithona sinensis and L. tetraspina, are <1 mm total length and are much less common in the diet of larval fish. Limnoithona sinensis became abundant in 1980 but abruptly disappeared in 1993 (Figure 4A and 4B). Its congener, L. tetraspina, appeared in fall 1993 and became very abundant in 1994. It is now the most abundant copepod in Suisun Bay and the delta, and is more abundant than any copepod has ever been. It is also much more abundant in spring than L. sinensis was.

Cladoceran abundance was high in spring from 1972 to 1976, then became much lower and has been consistently very low since 1994 (Figure 5A). The summer and fall trends are similar but the decline began in 1977 in that period (Figure 5B).

Rotifer abundance peaked in the early 1970s, then declined sharply until reaching a low point in the late 1980s or early 1990s (Figure 6A and 6B). Since then, a slight increase in abundance has occurred.

Neomysis mercedis showed highly variable abundance in both time periods, but no consistent decline until 1987 (Figure 7A and 7B). From 1987 to 1993 abundance was low and from 1994 to 1998 Neomysis was present only in trace numbers. Acanthomysis bowmani was introduced in 1993 and became more abundant than Neomysis but has not achieved the abundance shown by Neomysis in the 1970s and most of the 1980s (see Figure 7A and 7B).

In summary, cladoceran, rotifer, mysid, and native copepod abundances are much lower now than in the 1970s. Exotic copepods have replaced the natives and Eurytemora in summer and fall and provide a food source for larval fish. It is not clear what the exotic copepods feed on considering the low phytoplankton concentrations in Suisun Bay since the arrival of the Asian clam. The extremely high densities of L. tetraspina in the low salinity zone, where the clam is located, suggest that it does not feed solely on phytoplankton.

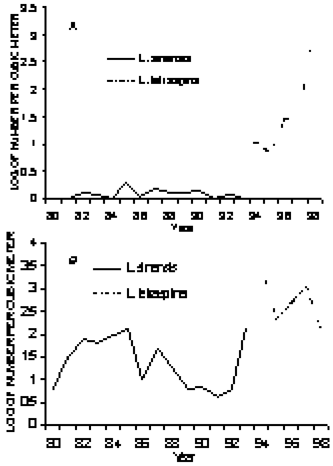

Figure 4 Mean annual abundance of L. sinensis from 1980 to 1998 and of L. tetraspina from 1994 to 1998 (A) in spring and (B) in summer and fall

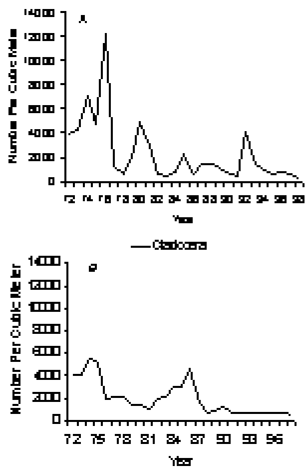

Figure 5 Mean annual abundance of all cladocerans from 1972 to 1998 (A) in spring and (B) in summer and fall

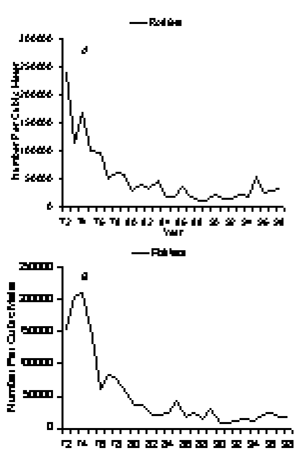

Figure 6 Mean annual abundance of all rotifers from 1972 to 1998 (A) in spring and (B) in summer and

fall

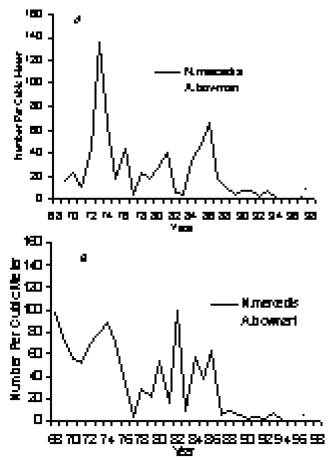

Figure 7 Mean annual abundance of N. mercedis from 1968 to 1998 and of A. bowmani from 1994 to 1998 (A) in spring and (B) in summer and fall

- **Zooplankton in the Lower San Francisco Estuary**

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2University of Washington

In 1997 we began an IEP-funded pilot study of zooplankton in the lower estuary, comprising San Pablo, Central, and South bays. The principal goal was to extend the current zooplankton monitoring into this previously undersampled region of the estuary (Wim Kimmerer, principal investigator). We also began sampling for zooplankton on the monthly USGS transects up the channel of the estuary to assess changes in the zooplankton community since the USGS sampled in 1978-1981 (Steve Bollens, principal investigator). This report presents the results to date of the IEP study, with species lists developed from both studies. Both studies are ongoing, with the IEP study expected to be completed and results of both studies submitted for publication by the end of 1999.

The objectives of this study are to answer the following questions.

1. What changes have occurred in the zooplankton of the lower estuary since the USGS survey conducted in 1978-1981?
2. What sampling design would represent the zooplankton of the lower estuary most cost effectively in a long-term monitoring program?
3. What species (or larger taxonomic groups) are important in the lower estuary and what is their distribution in space and time?

Answers to these questions are provisional, pending more complete analysis of the samples and the data set.

A previous report (Kimmerer 1998) presented the results of preliminary sampling and some of the key findings from the more intensive monthly sampling throughout the region. In this article, we focus on species identities, salinity, and seasonal distributions of common species, key differences from the 1978-1981 USGS study, and kilometer-scale spatial variability. Because our study used nets of a larger mesh size (150 m) than the USGS study (64 or 80 m), comparisons must be made on the basis of adult copepods or larger organisms that are collected efficiently by both mesh sizes. In this article, we compare the abundance of adult Acartia species, the most abundant copepod in the USGS study.

Methods

Monthly sampling has been conducted at the 30 stations used in the San Francisco Bay study: 10 in San Pablo Bay; 8 in Central Bay; and 12 in South Bay. Sampling took five days on the research vessel (R/V) Longfin (September 1997) and one and a half days on R/V Questuary (all other months). Stations were visited in an arbitrary order that differs on each survey. Sampling dates were scheduled to avoid sampling the same tidal stage each month and in different weeks from the sampling cruises of the USGS R/V Polaris. Stations were identified using a global positioning satellite (GPS) receiver.

The sampling design was based on simple methods, readily deployed from any research vessel. A Sea-Bird SBE19 CTD was used to obtain temperature and salinity profiles at each station; these data are generally reduced to water column mean values, surface values, and bottom values. At deep stations (>8 m depth) a vertical plankton sample was taken by hand from the bottom to the surface with a 0.5 m diameter, 150 m mesh net equipped with a flow meter. At all stations, a two-minute surface tow was taken at slow speed (about 2 m/s) with the same net. Samples were preserved in 5% formaldehyde. We also took samples at selected stations for mysids using a townet mounted on a sled (Orsi and Mecum 1986) and for small zooplankton with a pump sampler. Results of this sampling are not yet available. Additional samples were taken mainly in the north bay to assess between-sample variability and small-scale horizontal variability.

Subsamples were taken with a piston pipette and organisms counted under a dissecting microscope. Repeated subsamples were taken until counts of abundant organisms numbered about 100 and counts of less common species of interest numbered 10 to 20. Counts were converted to abundance based on volumes filtered determined from distance towed (for vertical samples) or flow meter readings (for surface tows).

Sampling on the monthly USGS cruises on R/V Polaris was comprised of vertical tows with an 80 m mesh net at each sampling station.

Results and Discussion

Table 1 lists the species and other higher taxonomic groups found to date in both studies. Most of these taxa have been reported before, either in the USGS study (Ambler and others 1985) or in the results of IEP sampling (Orsi and Mecum 1986; Orsi 1995; Kimmerer and Orsi 1996).

Most of the zooplankton collected in this program were copepods, which comprised 15% to 100% (median 92%) of the abundance in all samples. Most common copepods in these samples were small, generally around 1 mm or smaller. Meroplankton (larvae of benthic organisms or fish) made up 0% to 85% (median 5%) of abundance in all samples, and meroplankton and copepods combined made up 51% to 100% (median 99%). The remainder were predominantly other crustaceans (mainly cladocerans) and larvaceans (Oikopleura dioica).

Differences between results of the current sampling program and that conducted two decades ago by the USGS (Ambler and others 1985) are considerable. Among the copepods, the 13 most abundant species in the current study (Table 2) included four species introduced since that study. Abundant individual taxa are discussed below.

Among the six most common copepods, five have similar distributions with respect to salinity, with maxima near the maximum salinity of about 33 psu (practical salinity scale) (Figure 1). The copepod Tortanus dextrilobatus was most abundant at a salinity of about 15 psu. Most other taxa in the present study were most abundant at moderate to high salinity, except for freshwater or low salinity zone species (for example, Eurytemora affinis, Pseudodiaptomus forbesi) collected when X2 (Jassby and others 1995; Kimmerer and others 1998) was in San Pablo Bay. In addition, most species were generally more abundant in vertical than surface samples, probably because they avoid the surface (for example, see Figure 3 for Acartia species in Ambler and others 1985).

Seasonal distributions (based on residuals from salinity patterns above) are not striking, but most species were more abundant in fall than in spring or summer (Figure 2).

Table 1 List of species identified to date in both IEP and USGS-RTC sampling programsa

Copepods

Calanoids

Acartia californiensis

Acartia tonsa

Acartia (Acartiura)

Acartia danae

Acartiella sinensis

Epilabidocera longipedata

Labidocera trispinosa

Eurytemora affinis

Pseudodiaptomus forbesi

Pseudodiaptomus marinus

Diaptomus sp.

Paracalanus quasimodo

Sinocalanus doerrii

Tortanus dextrilobatus

Tortanus discaudatus

Calanus pacificus

Cyclopoids

Oithona davisae

Oithona similis

Limnoithona tetraspina

Acanthocyclops vernalis

Siphonostomes

Corycaeus anglicus

Harpacticoids

Euterpina acutifrons

Coullana canadensis

Copepod nauplius
Other crustaceans
Cladocera
Podon intermedius

Evadne sp.

Bosmina longirostris

Daphnia sp.

Ceriodaphnia sp.

Diaphonosoma sp.
Mysida
Neomysis mercedis

Acanthomysis spp.
Crangon sp.
Isopoda
Amphipoda
Nippoleucon hinumensis

Ampelisca abdita

Eogammarus confervicolus
Cumacean
Ostracod
Meroplankton

Barnacle nauplius

Barnacle cyprid

Crab zoea

Shrimp larvae

Snail veliger

Bivalve larva

Ctenophore

Polychaete larva

Trochophore larva

Echinopluteus larva

Asteroid larva

Medusa

Other taxa

Rotifer

Chaetognath: Sagitta sp.

Larvacean: Oikopleura dioica

Ascidian larva

Fish egg

Fish larva

a Although each specimen has been identified to the lowest practicable level, some are inevitably classified at a higher level either when they have been identified only to a coarse taxonomic resolution (for example, most meroplanktonic organisms) or when they are unsuitable for finer analysis (for example, juveniles of some species and damaged specimens)

Table 2 Summary of the most abundant copepod taxa in 225 samples counted to datea

Species	Geometric Mean Abundance	Frequency of Occurrence	Status	USGS Frequency
Oithona davisae	524	96	Introduced	20
Acartia spp.	412	95.1	Resident	~100
Pseudodiaptomus marinus	68	80.9	Introduced	0
Paracalanus quasimodo	50	77.3	Resident	28
Euterpina acutifrons	16	60.4	Unknown	0?
Tortanus dextrilobatus	11	57.3	Introduced	0
Harpacticoids	6	50.2	Various	70
Corycaeus anglicus	3	33.8	Neritic	15
Eurytemora affinis	1	9.8	Introduced?	13
Epilabidocera longipedata	1	9.3	Neritic	---
Oithona similis	1	8.9	Neritic	10
Acartiella sinensis	1	5.3	Introduced	0
Pseudodiaptomus forbesi	1	4.9	Introduced	0

aGeometric mean abundance was calculated as the antilog of the mean log (abundance + 10). Status is generally either resident (native), introduced resident, neritic (in other words, probably more abundant in coastal waters), or unknown. USGS frequency is the mean of the percent frequencies reported by Ambler and others (1985, Tables 1 and 2) from the same sampling regions as covered in this report.

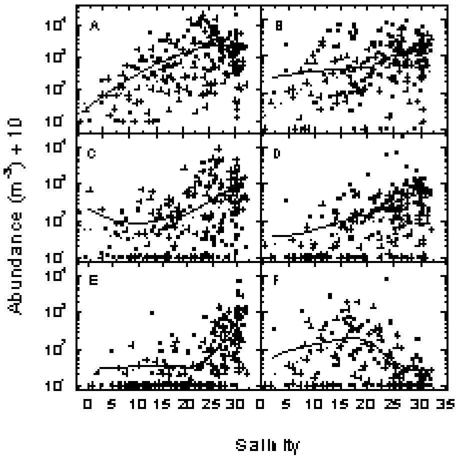

Figure 1 Salinity patterns of the most abundant copepod species: (A) Oithona davisae; (B) Acartia spp.; (C) Pseudodiaptomus marinus; (D) Paracalanus quasimodo; (E) Euterpina acutifrons; (F) Tortanus dextrilobatus. Solid squares and lines are vertically integrated samples; crosses and dotted lines are surface samples. Points are individual data values; lines are locally weighted least-squares regressions fit to the data.

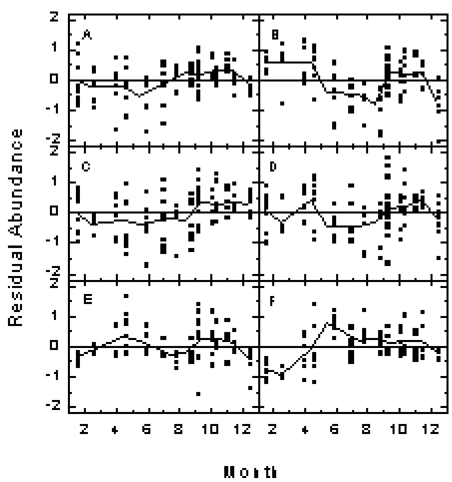

Figure 2 Seasonal patterns of the most abundant copepod species. Letters as in Figure 1. Data plotted are residuals from the curves in Figure 1 for vertical samples only. Solid squares are individual data points; lines are monthly means.

Oithona davisae

This small (0.5 mm) cyclopoid copepod, moderately abundant in the USGS samples from the South Bay, is now the most abundant copepod and was present in nearly every sample taken. Considering that in the present study only the adults have been collected effectively, the difference from the previous pattern is even more striking. In our study, O. davisae was most abundant at high salinity (see Figure 1A), somewhat more abundant in the South Bay than elsewhere, and more abundant in late summer and fall than other seasons (see Figure 2A).

This species feeds on motile prey (Uchima and Hirano 1986) and has a somewhat low population, reproductive and growth rate compared to other copepods (Uye and Sano 1995, 1998). O. davisae has proliferated in Tokyo Bay in apparent response to eutrophication (Uye 1994). Since eutrophication is not a major issue in San Francisco Bay, the reason for the proliferation of this species is unknown. In general Oithona species may become highly abundant in bays because their small size makes them less vulnerable than other species to predation (Ueda 1991; Kimmerer 1991). This same characteristic may make O. davisae less suitable as food for fish than other copepods (Uye 1994), reducing the rate of trophic transfer to higher levels.

Acartia species

Species of this genus are very abundant in most temperate estuaries and bays. We have not yet distinguished among the various species of this genus, mainly because we are not yet convinced that we can distinguish all of the species present. Species of this genus are notoriously difficult to identify (McKinnon and others 1992). Two subgenera are represented, Acanthacartia and Acartiura. In contrast to Ambler and others (1985), we have found Acanthacartia tonsa, a close congener of Acanthacartia californiensis, to be common at times in the bay. Two species of the subgenus Acartiura were identified in Tomales Bay (Kimmerer 1993), and it is possible that we have two in the San Francisco Estuary as well.

Although lumping Acartia species blurs the contrasting seasonal and salinity patterns observed by Ambler and others (1985) and by others for other estuaries, the results are still informative. For example, Figure 1B shows a similar pattern with regard to salinity to that of O. davisae. Seasonally, Acartia species were least abundant from June through September (see Figure 2B).

We compared abundance of Acartia adults from our study with raw data from the USGS study (Hutchinson 1991, 1982). We lumped data from stations by region and by month for comparisons, which are presented in Figure 3. For stations in the Central Bay, the patterns of abundance were very similar, with relatively little seasonal change. The similarity of abundance at these stations gives us confidence that the differences in methods did not overly bias the comparison. Results from San Pablo and South bays were quite different, with lower abundance particularly in summer in the present study than the USGS study. Data from previous IEP sampling in the northern estuary has also shown a decline in summer abundance of Acartia species, and this has been attributed to the clam Potamocorbula amurensis (Kimmerer and Orsi 1996). We do not know whether this interpretation applies to the South Bay.

Pseudodiaptomus marinus

This copepod has become the third most abundant copepod in the lower estuary since it was introduced in the late 1980s (Orsi and Walter 1991). Our estimates of its abundance may be low, since it tends to be epibenthic by day in other locations (Uye and others 1983). In contrast to its congener, P. forbesi, now the most abundant copepod of the low salinity zone (Kimmerer and Orsi 1996; Kimmerer and others 1998), P. marinus occupies the more saline reaches of the estuary (see Figure 1C) and the two species rarely co-occur. P. marinus was most abundant in fall (see Figure 2C).

Paracalanus quasimodo

This is probably the species referred to by Ambler and others (1985) as P. parvus. In contrast to the USGS results, we found this species to be quite abundant throughout the higher salinity regions of the estuary throughout the year (see Figure 1D), but somewhat less abundant in summer (see Figure 2D). Globally, species of this genus are common in coastal regions and higher salinity regions of temperate bays and estuaries (for example, Kimmerer 1991; Ueda 1991). Thus, we do not consider this a neritic species.

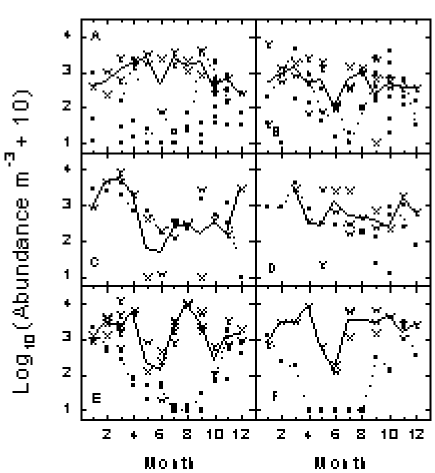

Figure 3 Abundance of Acartia spp. adults compared with previous USGS samples from 1978-1980: (A)

central San Pablo Bay; (B) southern San Pablo Bay to northern Central Bay; (C) Golden Gate (USGS) and Alcatraz (current study) stations; (D) south of Bay Bridge; (E) South Bay between San Mateo and Dumbarton bridges; (F) South Bay below Dumbarton Bridge. Solid squares and heavy lines are vertically integrated samples; open squares are surface samples; dotted lines and crosses are USGS data from channel stations.

Euterpina acutifrons

This small (about 0.6 mm) harpacticoid is common in coastal waters worldwide. We do not know whether it was introduced since the USGS study, but it is probably more abundant now than it was then. As with the other species discussed above it was abundant in the higher salinity regions of the estuary (see Figure 1E), but it did not have a strong seasonal pattern of abundance (see Figure 2E).

Tortanus dextrilobatus

This moderately large (1.7 mm) copepod is of a genus that is predatory on smaller copepods (Mullin 1979; Ohtsuka and others 1987). Its congener, T. discaudatus, was occasionally collected at high salinity. Since it is also found in Tomales Bay (Kimmerer 1993), we assume it is native. The introduced T. dextrilobatus is most abundant at a salinity of about 15 psu (see Figure 1F) and abundant all year, except in late winter and early spring (see Figure 2F).

Other taxonomic groups

Several species or other taxonomic groups are noteworthy. The larvacean Oikopleura dioica was among the most abundant species in our samples, occurring in about 40% of all samples. It was not noted by Ambler and others (1985), although larvaceans were collected occasionally in the USGS survey (Hutchinson 1981, 1982). O. dioica was quite common in Tomales Bay (Kimmerer 1993). It is probably a native that was either less abundant from 1978 to 1981 than now, or was overlooked or misidentified in the earlier sampling.

Among the meroplankton, barnacle nauplii were overwhelmingly more abundant than others, occurring in 83% of the samples at a geometric mean abundance of 51 per cubic meter. Next in abundance was larvae of polychaete worms. Neither bivalve veligers nor crab zoeae were abundant enough to characterize their distributions, which might have been useful in setting up future studies of P. amurensis and mitten crabs, respectively.

A rather surprising result so far has been the lack of gelatinous plankton. In over 225 samples counted so far, we have found only three ctenophores and one medusa. This is in contrast with the plankton composition in many other estuaries, where ctenophores and medusae can be abundant enough to measurably reduce the abundance of crustacean zooplankton. Note that large medusae (Aurelia species and others) are collected often in bay study fish sampling at the same stations. Reasons for the lack of smaller gelatinous plankton might include the high particulate concentration in the water or the high level of tidally driven turbulence; however, both of these influences should be just as detrimental to larvaceans, which build delicate mucous structures for feeding. Thus, the cause of the low abundance of small gelatinous plankton remains unknown.

Sampling density

This study was designed partially to determine the number of stations needed to characterize the zooplankton. Spatial autocorrelation or similar analyses of the degree of similarity among data from different stations are useful in determining the appropriate number of stations (Jassby and others 1997). Since we have more samples to analyze, we have conducted only a preliminary analysis of relationships among stations.

Figure 4 shows the relationship between the geographic distance between pairs of stations and a measure of the difference between them in plankton species composition and abundance. Beyond about 30 km distance, the difference between pairs of stations in terms of total plankton or total Acartia species remains constant with geographic distance; thus, stations at least 30 km apart give information about regions of the bay with different plankton compositions. Within 30 km, the difference between samples decreases as stations get closer together; thus, these stations are providing partially redundant data. The limit of this process is in the expected difference between replicate samples taken at the same station at the same time, which was determined on one occasion for Acartia species (heavy bar in Figure 4). This limit appears to be approached in the sampling data, although Figure 4 suggests that the between-station differences may remain somewhat higher than within-station differences. This may be due to differences in depth, clarity, or wave action that can exist between neighboring stations.

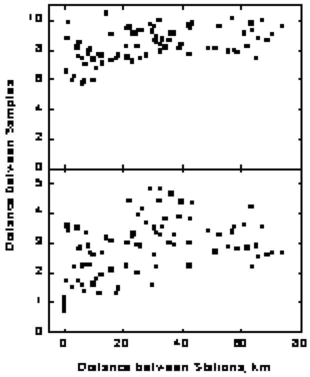

Figure 4 Geographic distance between paired stations against distance between zooplankton abundance data calculated as the Euclidean distance in log abundance (in other words, the square root of the sum of squared differences) for (top) all samples at each station for each species or (bottom) for Acartia spp. The heavy bar in the lower graph shows the 10th to 90th percentiles of the expected difference based on replicate sampling at a single station.

Conclusions

The zooplankton of the seaward reaches of the San Francisco Estuary comprise a community distinct from that in Suisun Bay and the delta, and presumably from that in the Gulf of the Farallones. Most of the species in this region occur in seawater salinity and values down to about half of seawater; relatively few species are most abundant at lower salinity values.

There is evidence that considerable change in the zooplankton of the lower estuary has occurred since the USGS samples were taken from 1978 to 1981, although perhaps less has changed than in the upper estuary (Orsi 1995; Kimmerer and Orsi 1996). Although some of the change can be attributed to the introduction of new species, other changes may be indirect, such as thorough grazing by P. amurensis. Some of these changes, especially the increase in abundance of O. davisae and the high abundance of the carnivorous T. dexrilobatus, suggest fundamental shifts in the functioning of the planktonic community.

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Potamocorbula amurensis

Cindy Messer, Glenda Marsh, and Heather Peterson, Department of Water Resources

In January 1996, the Department of Water Resources' benthic monitoring sampling program, originally mandated by Water Right Decision 1485, was expanded from six to ten sites in order to sample the abundance and distribution of bottom dwelling organisms over a wider range of benthic habitat types throughout the Sacramento-San Joaquin Delta and Suisun and San Pablo bays. Benthic data are currently collected at the following sites: C9 Clifton Court; D16 Twitchell Island; D24 Rio Vista; P8 Rough and Ready Island; D28A Old River; D4 Collinsville; D6 Bulls Head Point (near the mothball fleet); D7 Grizzly Bay; D41 Pinole Point and D41A at the mouth of the Petaluma River (Figure 1). Sites D28A, D4, D7, and D41 are remnants of the historical program [5] . Data from the western sites (D4, D7, D6, D41, and D41A) have provided monthly information on population trends of Potamocorbula amurensis.

Figure 1 D-1485 benthic monitoring sites

Average monthly flows for the Sacramento and San Joaquin rivers for water year 1997 are shown in Figures 2 and 3, respectively. The flow data are taken at Freeport in the Sacramento River and at Vernalis in the San Joaquin River and are included because flow throughout the delta and westerly bays can influence salinity at all benthic sites and impact distribution and density of P. amurensis populations. High inflow dominated the bay-delta system from December 1996 through March 1997.

Figures 4 and 5 summarize the data from all current benthic monitoring sites where P. amurensis occurs.

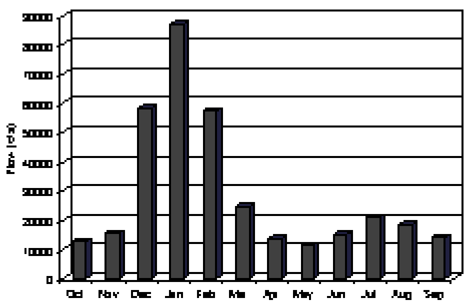

Figure 2 Sacramento River monthly average flow at Freeport during water year 1997 (Oct 1996 through Sep 1997)

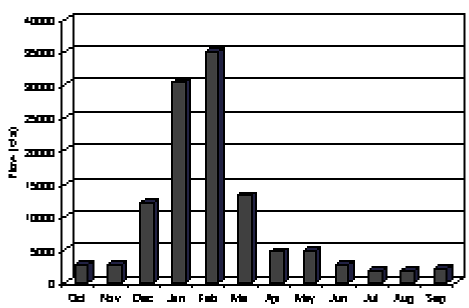

Figure 3 San Joaquin River monthly average flow near Vernalis, water year 1997 (Oct 1996 through Sep 1997)

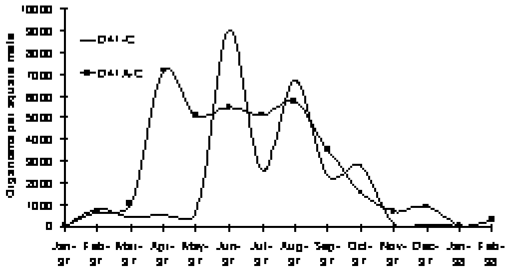

Figure 4 P. amurensis abundance at stations D41A-C and D41-C from January 1997 to February 1998

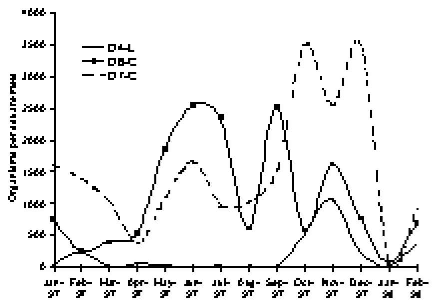

Figure 5 P. amurensis abundance at stations D6-C, D7-C, and D4-L from January 1997 to February 1998

Site D41A, located at the mouth of the Petaluma River, is the westernmost site sampled. In winter and early spring 1997, P. amurensis abundance was low, partly due to extremely high outflow in January 1997. Spring abundances grew steadily and peaked in April at 7,100 clams/m2. May through August abundances were lower, relatively stable, and ranged from 5,100 clams/m2 to 5,700 clams/m2. P. amurensis density declined steadily throughout the fall and reached a winter minimum of 300 clams/m2 by January 1998.

Site D41, located at Pinole Point in San Pablo Bay, has generally had the highest historical abundance of P. amurensis of all sites sampled. Winter and spring abundances were relatively low in 1997 ranging from 0 clams/m2 to 774 clams/m2 from January to mid-May. Abundances were highly variable in the summer, peaking in June (9,000 clams/m2), dropping in July (2,600 clams/m2), and rising again in August (6,900 clams/m2). As at site D41A, P. amurensis density declined in the fall with a slight rise to 2,800 clams/m2 in October 1997, possibly due to recruitment from late summer spawning. No clams were found at the site in January 1998.

Clam density at site D6, located at Bulls Head Point near the mothball fleet in Benicia, was low in winter and early spring of 1997, ranging from 250-700 clams/m2, and increased in late spring reaching a peak in June of 2,500 clams/m2. Summer, fall, and early winter densities were variable ranging from 600 clams/m2 to 2,500 clams/m2 from July through December. A winter minimum of 56 clams/m2 was measured in January of 1998. The low numbers of clams in winter may be partly due to high freshwater outflow to the site.

The influence of high outflow from February through April 1997 may have kept P. amurensis numbers relatively low at D7 in Grizzly Bay until late summer. January through August abundances ranged from 370 to 1,650 clams/m2. Fall abundance rose to peak in October and December at 3,500 clams/m2. The rise in density during early fall may have been due to a late summer (second) spawning event. A winter minimum of 60 clams/m2 was measured in January 1998. Density trends at D7 appear to differ from the more westerly study areas, with population peaks occurring later in the year.

Site D4 at Collinsville is the most easterly station where P. amurensis is found. Historically, the abundance of clams found at this site have been low. In 1997, abundances ranged from 0 to 40 clams/m2 from January through September, with a small peak of 200 clams/m2 in February. Fall levels gradually rose in November to a peak of 1,000 clams/m2. This peak may have been caused by a late summer spawning event.

- ## Notes on the Invasion of the Chinese Mitten Crab (Eriocheir sinensis) and their Entrainment at the Tracy Fish Collection Facility

Scott Siegfried, US Bureau of Reclamation

There has been an exponential increase in the numbers of Chinese mitten crabs entrained at the Tracy Fish Collection Facility (TFCF) since they were first collected there in September 1996. These catadramous crabs have expanded their range from the San Francisco Bay into the Sacramento-San Joaquin Delta. They are drawn on their annual seaward breeding migration to Central Valley Project export flows pumped through the TFCF. The numbers entrained at the TFCF increased from dozens in 1996 to tens of thousands in 1997 to over 775,000 in 1998. Of the crabs entrained at the TFCF in 1998, over 500,000 were extrapolated from ten-minute fish counts taken every two hours (subsampling) and an additional 275,000 or more may have been removed by trapping. Over 90% were collected in September and October (Figure 1). When peaks began in 1997 and 1998, they coincided closely with the onset of cooler water temperatures (Figures 2 and 3).

As the numbers and range of mitten crabs has increased, so has the length of time over which they are collected. Now they are captured nearly year-round. The majority entrained have been males (Figure 4), travelling at night (Figure 5). Trapping efforts at TFCF indicate that they primarily move along the bottom of the channel. If the crabs continue to increase at the present rate and south delta barriers are not in place, as many as 20 million may migrate to the TFCF in September and October, 1999.

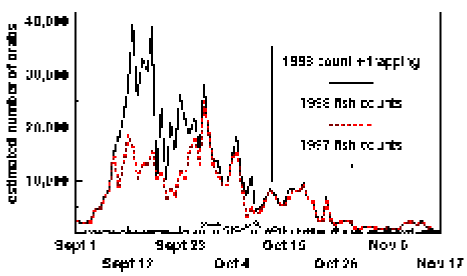

Figure 1 Comparison between estimated numbers of Chinese mitten crabs entrained daily at the TFCF expanded from ten-minute fish counts in 1998 with trapping and ten-minute fish counts in 1997 and 1998 with no trapping

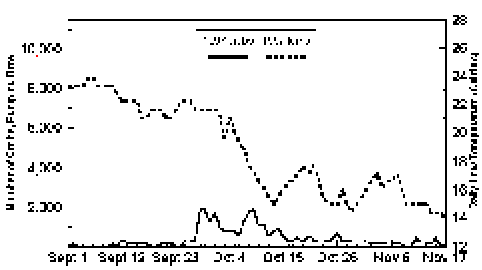

Figure 2 Comparison between estimated numbers of Chinese mitten crabs collected daily at the TFCF expanded from ten-minute fish counts and daily low water temperature in 1997

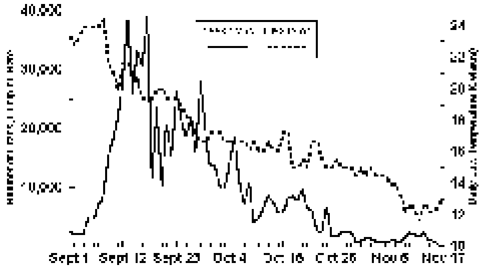

Figure 3 Comparison between estimated numbers of Chinese mitten crabs collected daily with trapping at the TFCF expanded from ten-minute fish counts and daily low water temperature

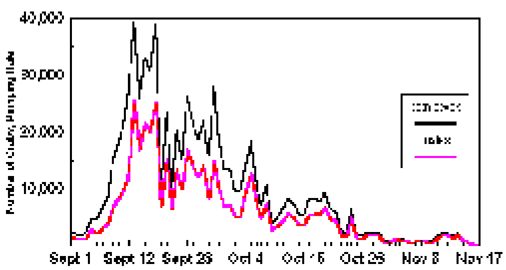

Figure 4 Sex ratio of Chinese mitten crabs collected daily at the TFCF expanded from ten-minute fish counts from 1 Sep to 18 Nov 1998. Based on sex ratio data of TFCF mitten crabs verified by Kathy Hieb, DFG.

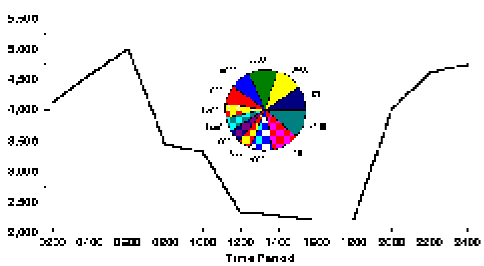

Figure 5 Diel composition of Chinese mitten crabs collected in ten-minute fish counts with trapping from 1 Sep to 18 Nov 1998

In September 1998, the mitten crabs began to migrate to the TFCF in such high numbers that they clogged many of the fish salvage features. This resulted in the deaths of thousands of fish that would have been salvaged under normal operations. To successfully salvage fish, it became imperative to separate them from crabs. Mechanical crab removal or separation efforts were completed in the secondary channel and holding tanks and included trapping, dipping, and screening. Captured crabs were buried and killed off-site. The effects of crab trapping on fish salvage were not well quantified but numerous qualitative observations were made. White catfish, yellowfin gobies, and other bottom dwelling fish species were captured in traps (direct loss) while few or none of the midwater or pelagic fish species were captured. Indirect loss due to the traps' interference with salvage "criteria" flows could not be determined from the limited testing.

Another effort involved using a travelling screen, originally designed for removing debris in the secondary channel laboratory model located at USBR's Denver Technical Services Center (TSC). This unit was tried and tested for removing mitten crabs from TFCF's secondary channels. This modular unit fit within the eight foot wide channel, but did not occupy its entire height. The screen was operated for six days and was at least 80% efficient under most conditions. TSC engineers believe that with improvements to better fit the TFCF secondaries, it could remove over 90% of the crabs. Plans are underway to have a full-sized unit built and installed to fit the TFCF's secondary channels before the mitten crab migration in 1999. This unit will be the centerpiece of a mitten crab management plan for TFCF that will also include an ambitious suite of contingencies.

- **Delta Smelt Investigations**

Dale A. Sweetnam, Department of Fish and Game

Both 1997 and 1998 hydrologies were characterized as "wet" but resulted in very different environmental conditions for delta smelt. Peak outflows in 1998 occurred in February with minor peaks in March and June (Figure 1). Flows remained unusually high through June (>50,000 cfs). In contrast, 1997 peak outflows occurred in January; however, by March, flow conditions resembled a "dry" year. Additional analyses are ongoing to determine how the changes in habitat conditions brought about by these different hydrologies affected the delta smelt population.

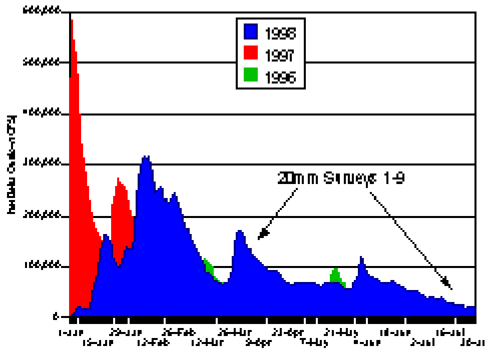

Figure 1 Net delta outflow index for January through July 1998 and 1997. Vertical bars represent the dates of the nine 20 mm surveys.

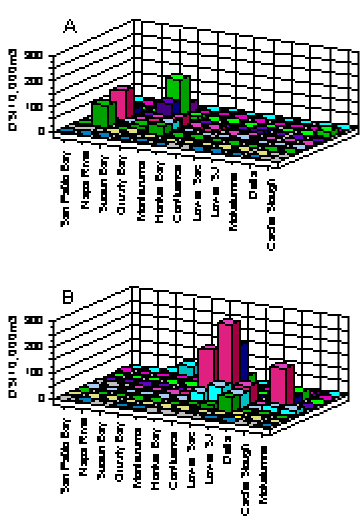

Figure 2 Delta smelt density and distribution in 20 mm surveys in (A) 1998 and (B) 1997. Bars represent the average density (delta smelt/10,000 m3) in each area sampled by survey. Survey dates for 1997 are similar to those for 1998.

Delta smelt distribution in the spring extended from the lower Sacramento and San Joaquin rivers to Montezuma Slough and Napa River (surveys 1 and 2, Figure 2A). By mid-May, the main distribution shifted to Suisun Bay and remained there throughout the summer although a portion of the population remained in Montezuma Slough and the

Napa River (see Figure 2A). Delta smelt were not observed in the Cache Slough area until survey 7. By comparison, the 1997 distribution of delta smelt was concentrated above the confluence for the majority of the spring and summer (Figure 2B). For additional information, please view the delta smelt distribution and abundance plots (in other words, 20 mm bubble plots) by survey and year that are posted on DFG's Central Valley Bay-Delta Branch web site at http://www.delta.dfg.ca.gov.

A general map identifying potential delta smelt spawning locations based on the presence of delta smelt yolk-sac larvae in 1998 and 1997 is presented in Figures 3A and 3B. Preliminary analysis of juvenile distribution suggests that delta smelt move to brackish water (about 2,000-8,000 FS/cm) at lengths between 25-40 mm depending on the year (Figure 4).

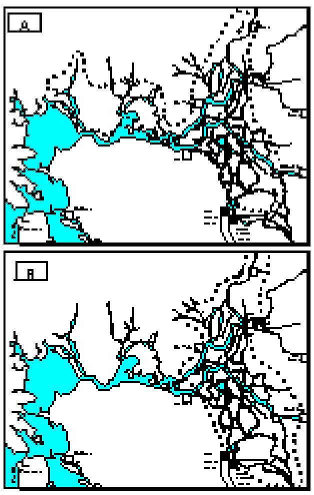

Figure 3 Delta smelt spawning locations in (A) 1998 and (B) 1997. Dashed line represents a generalized area in which delta smelt spawning potentially occurred based on the presence of larvae in the 20 mm surveys and location of prespawning adults captured in several other sampling surveys.

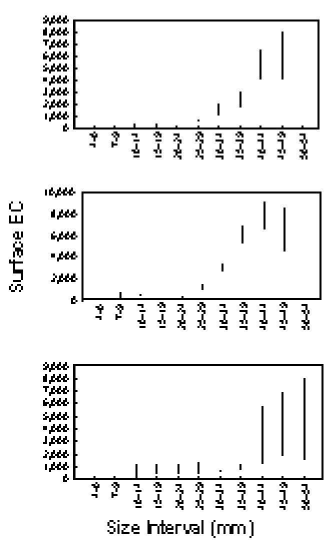

Figure 4 Delta smelt length against surface conductivity, 1995-1997. Horizontal bars represent delta smelt length intervals (5 mm groups) plotted against surface conductivity (FS/cm) from the 20 mm survey. Vertical bars represent 95% confidence intervals.

Delta smelt indices from both the summer townet survey and the fall midwater trawl survey vary dramatically from year to year and do not necessarily covary (Figures 5 and 6). The 1998 summer townet abundance index was 3.3, relatively low and similar to the 1995-1997 index. The fall midwater trawl index was 417.6, slightly higher than the 1997 index of 360.8. With the addition of the 1997 and 1998 indices, the pattern of high abundances in odd years in the 1990s has been broken (see Figure 6).

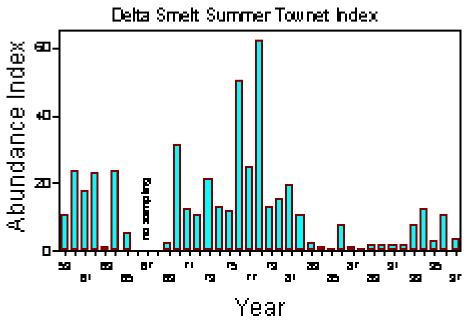

Figure 5 Summer townet abundance index for delta smelt. Values represent the sum of volume-weighted means of eight sampling areas. The average of the first two surveys is used. No sampling from 1966-1968.

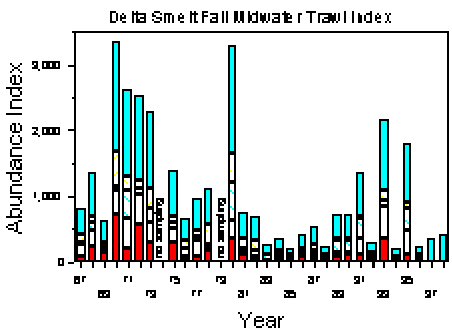

Figure 6 Fall midwater trawl abundance index for delta smelt. Values represent the sum of volume-weighted means of 17 sampling areas sampled monthly, September through December. No sampling in 1974 and 1979.

Salvage of delta smelt at the Central Valley Project and the State Water Project in 1998 was considerably less than in 1997. A total of 988 delta smelt was salvaged at both facilities in 1998 (Figure 7A) compared to 85,791 in 1997 (Figure 7B). The 1998 salvage exhibits the characteristic peaks of delta smelt salvage: small peaks in January and March through April, resulting from adult delta smelt moving upstream into fresh water to spawn and a small peak in June and July of young-of-the-year delta smelt. Salvage of young-of-the-year delta smelt in 1998 was considerably less than salvage in 1997, probably because of high outflows in spring and summer which moved delta smelt downstream in Suisun Bay. Also, salvage in 1997 did not exhibit the early peak of adults in January and February, probably due to high outflows and reduced exports during that time.

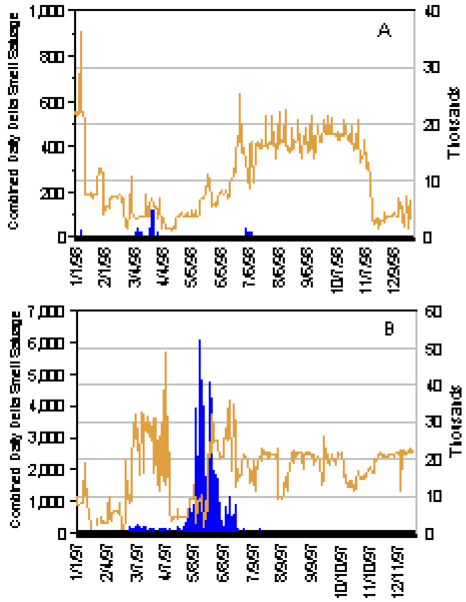

Figure 7 Delta smelt salvage at the CVP and SWP in (A) 1998 and (B) 1997. Bars represent combined daily salvage of delta smelt. Line represents combined daily exports in acre-feet.

We completed a second year of sampling to investigate the use of shallow water by larval delta smelt. Since the majority of sampling sites were downstream of delta smelt distribution (see Figure 2), additional delta sites were added in 1998. Representative habitat types were stratified into dead-end sloughs, river channels, flooded islands, and bay shoals. Sampling sites included: Cache Slough, Napa River, Decker Island, Franks Tract, Sherman Island, Montezuma Slough, and Honker Bay. Each habitat contained a shore station, a shallow shoal and slough station, and a deep, mid-channel station. Analyses of the 1998 sampling data are underway for delta smelt, Pacific herring, longfin smelt, and Sacramento splittail. Preliminary results from 1997 suggest the following:

1. Larval delta smelt are mainly surface oriented;
2. Juvenile delta smelt are exclusively surface oriented; and
3. Larval delta smelt are not found in significantly higher densities along the shore.

The third Delta Smelt Workshop was held on 1 and 2 October (see article: IEP Newsletter 12(1):40-3). Following are some conclusions from the presentations.

1. There is not a strong relationship between delta smelt abundance and outflow as there is with other species in the estuary with similar life histories.
2. Delta smelt are feeding more extensively on the exotic Pseudodiaptomus forbesi than the declining native Eurytemora affinis; however, it does appear that they have a strong "preference" for Eurytemora.
3. Delta smelt are smaller now than in the past.
4. Delta smelt were older and larger in Suisun Bay than in upstream areas of the Sacramento and San Joaquin rivers.
5. Delta smelt are poor, slow, unsteady swimmers.
6. Delta smelt temperature tolerance limits were 6 to 29 °C.
7. Delta smelt salinity tolerance limits ranged from freshwater to 19.

8. Splittail and Longfin Smelt Abundance

Randall Baxter, Department of Fish and Game

Splittail Abundance

Splittail abundance (all ages combined) reached a record high in the 1998 fall midwater trawl survey (Figure 1). Young-of-the-year (YOY) made up 85% of the total index. Though not record indices, YOY indices for the bay study midwater and otter trawls reached levels comparable to 1995, again indicating strong recruitment in 1998 (Figures 1 and 2).

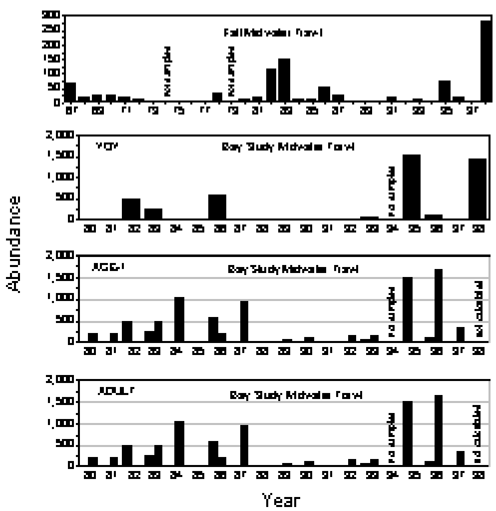

Figure 1 Splittail annual abundance indices from the fall midwater trawl survey (all ages combined) and bay study midwater trawl survey (age groups separated)

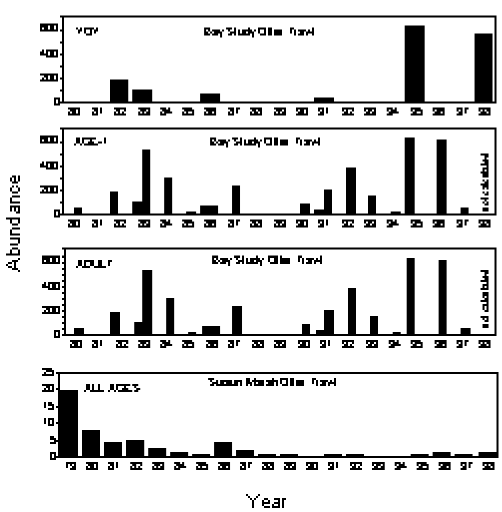

Figure 2 Splittail annual abundance indices from the bay study otter trawl survey (age groups separated) and the Suisun Marsh otter trawl survey (all ages combined)

A total splittail index was calculated for the Suisun Marsh otter trawl survey for consistency until historical indices can be recalculated using updated YOY length criteria. The 1998 index ranked slightly above that of 1995, but remained only a small fraction of indices from 1983 and earlier (see Figure 2). This suggests 1998 recruitment approximated that of 1995 and improved over the drought years (1987-1992); however, Suisun Marsh abundance has not yet recovered to pre-drought levels.

Age-1 and adult abundance indices for bay study trawl surveys have not been calculated for 1998. Previous indices indicated good recruitment of the 1995 year class to age-1 and adult in 1996 and 1997, respectively (see Figures 1 and 2). Both indices of age-1 abundance reached record high levels in 1996. Adult indices in 1997 were not as high, but adults are not easily caught by trawling.

Longfin Smelt Abundance

Longfin smelt abundance increased substantially in 1998, relative to 1996 and 1997 (Figure 3). Since most longfin smelt spawn at or just before age two, 1998 YOY resulted from 1996 year class spawners, the first even-year recruits from a post-drought "wet" year. Historically, strong year classes alternated years and were a function of outflow during the early larval period (DFG 1992). Good flows in 1996 and better flows in 1998 allowed even-year year classes to build on one another. Extreme outflow conditions in 1997 resulted in poorer-than-expected longfin smelt abundance and led partly to a shift to even-year dominance in 1998.

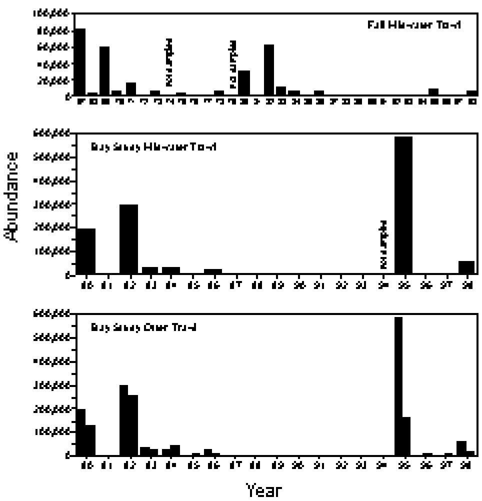

Figure 3 Longfin smelt annual abundance indices from the fall midwater trawl survey (all ages combined), and bay study midwater trawl and otter trawl surveys (age-0 only)

References

[DFG] California Department of Fish and Game. 1992. Estuary dependent species. Entered by the California Department of Fish and Game for the State Water Resources Control Board 1992 Water Quality/Water Rights Proceedings on the San Francisco Bay/Sacramento-San Joaquin Delta. WRINT-DFG Exhibit 6.

- ## San Francisco Bay Species Abundance

Kathy Hieb, Department of Fish and Game

Annual abundance trends and distributions for the shrimp Crangon franciscorum, Dungeness crab, and 14 common San Francisco Bay fish are summarized in this article. Some life history information was included in the 1997 status and trends reports for many of these species (DeLeón 1998; Hieb 1998). In 1998, above-average ocean temperatures through summer and high freshwater outflow and associated low salinities in winter and spring were important in determining abundance and distribution of species in the San Francisco Bay (hereafter referred to as the bay).

Abundance of juvenile C. franciscorum was the highest for the study period in 1998 (Figure 1), continuing the trend of increasing indices since 1995. Due to successive high outflow years since 1995, we believe that the brood stock population has increased to record levels for the study period. In 1998, this relatively large brood stock population and high freshwater outflow were important factors controlling recruitment of juvenile C. franciscorum to the bay. Distribution of juveniles was centered in San Pablo Bay in May and June 1998 and slowly shifted upstream through summer and fall. By October, our highest catches were in western Suisun Bay.

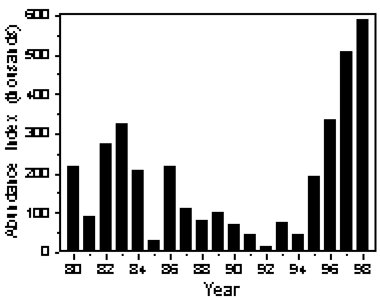

Figure 1 Annual abundance of juvenile C. franciscorum, May-October, otter trawl

Abundance of age-0 Dungeness crab was 0 in 1998 (Figure 2), reflecting unfavorable ocean conditions in winter 1997-1998. High temperatures associated with the strong El Niño event and a strong northward Davidson current are believed to result in poor survival and retention of Dungeness crab larvae in the Gulf of the Farallones.

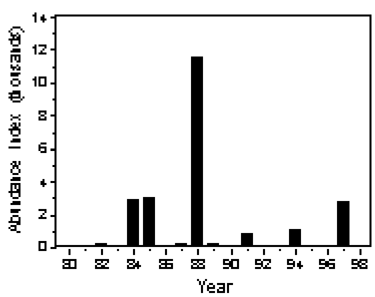

Figure 2 Annual abundance of age-0 dungeness crab, May-July, otter trawl

The 1998 abundance index of northern anchovy was similar to the 1995-1997 indices (Figure 3). The seasonal abundance pattern was very predictable, with the highest monthly indices in summer; however, we did not observe the precipitous decline in abundance in fall 1998 that was reported in fall 1997 (Hieb 1998). Northern anchovy were widely distributed from South to San Pablo bays in 1998, with the highest catches in Central Bay and lower San Pablo Bay.

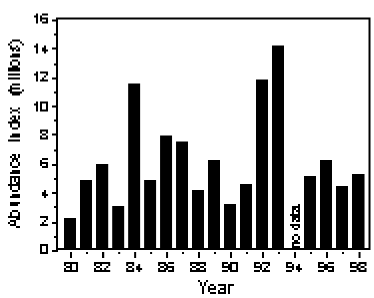

Figure 3 Annual abundance of northern anchovy (all sizes), April-October, midwater trawl

Abundance of age-0 Pacific herring was again low in 1998 (Figure 4). We believe this was a result of poor brood stock condition due to El Niño and high winter flows, which transported Pacific herring larvae from the bay. From May through July, juvenile Pacific herring were widely distributed from South to San Pablo bays. Through late summer and fall, they emigrated from the bay and those remaining were concentrated in Central Bay.

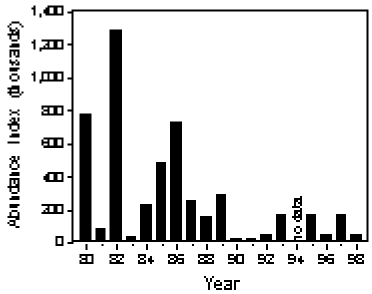

Figure 4 Annual abundance of age-0 Pacific herring, April-September, midwater trawl

Abundance of age-0 jacksmelt was also relatively low in 1998, continuing the trend of low indices for the past decade (Figure 5). In 1998, our highest catches were in South Bay, with only one age-0 jacksmelt collected in San Pablo Bay.

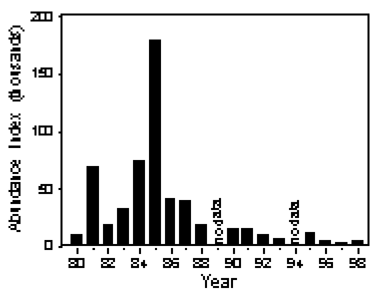

Figure 5 Annual abundance of age-0 jacksmelt, July-October, midwater trawl

White croaker abundance increased slightly in 1998, primarily due to an increase in abundance of age-0 fish (Figure 6). Age-1 abundance was the lowest since 1982, reflecting the record low age-0 abundance in 1997. In 1998, most white croaker were collected from northern South Bay to lower San Pablo Bay.

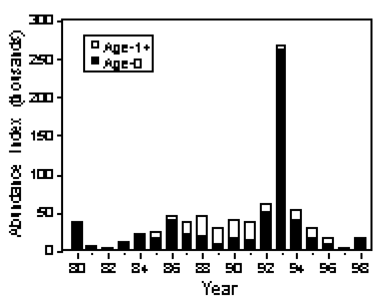

Figure 6 Annual abundance of age-0 and age-1+ white croaker, February-October, otter trawl

Bay goby abundance declined from 1997 to 1998 and the index was the fifth lowest for the study period (Figure 7). This decline in abundance was most likely due to the high outflows and associated decrease of high salinity nursery areas in the bay. In 1998, bay gobies were concentrated in Central Bay and were uncommon in San Pablo Bay.

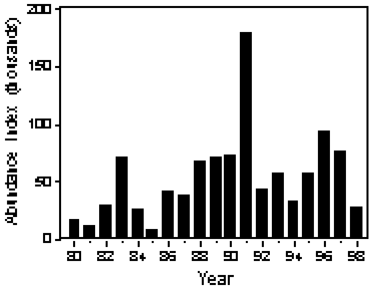

Figure 7 Annual abundance of bay goby (all sizes), February-October, otter trawl

Abundance of the introduced yellowfin goby increased slightly in 1998 from 1996 and 1997 (Figure 8), continuing a trend of highly variable abundance relative to outflow. Although the highest indices have been in years with high outflow (for example, 1986, 1993, and 1995), not all high outflow years had high abundance. In 1988, age-0 yellowfin gobies were most common in San Pablo and Suisun bays, with relatively few collected from the lower rivers.

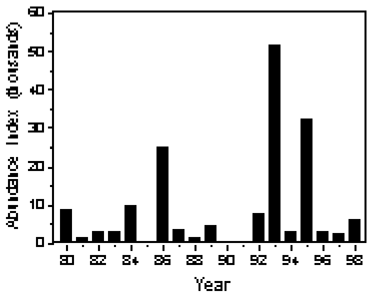

Figure 8 Annual abundance of age-0 yellowfin goby, May-October, otter trawl

The 1998 abundance index of age-0 staghorn sculpin was the second lowest for the study period and substantially lower than the 1995-1997 indices (Figure 9). Fish were widely distributed from South to Suisun bays in 1998, with the highest catches in San Pablo Bay.

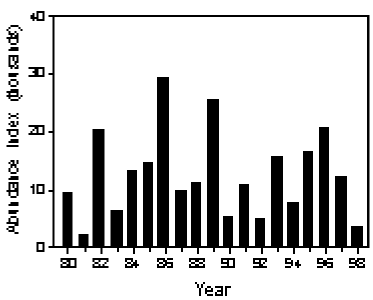

Figure 9 Annual abundance of age-0 staghorn sculpin, February-September, otter trawl

After a moderate increase in 1997, abundance of age-0 shiner perch declined in 1998 to an index similar in magnitude to the 1988-1996 indices (Figure 10). Abundance of age-0 pile perch was again 0 in 1998 (Figure 11), while abundance of
age-0 walleye surfperch was again very low (Figure 12). A large portion of the age-0 shiner perch and walleye surfperch were collected at the Berkeley Pier station in 1998.

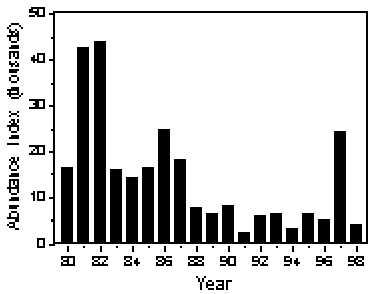

Figure 10 Annual abundance of age-0 shiner perch, May-October, otter trawl

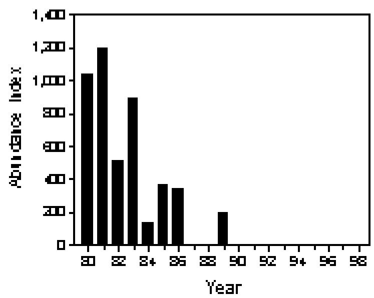

Figure 11 Annual abundance of age-0 pile perch, June-October, otter trawl

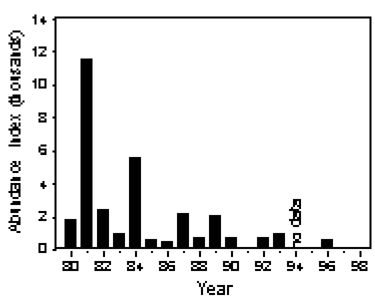

Figure 12 Annual abundance of age-0 walleye surfperch, May-August, midwater trawl

Abundance of California halibut increased substantially in 1998 (Figure 13), primarily due to strong recruitment of age-0 fish. There was one cohort of age-0 fish in winter 1998 (spawned in 1997) and another larger cohort in fall 1998 (spawned in winter 1998). The presence of a relatively large number of age-0 California halibut in the bay is indicative of local spawning rather than a northward movement of older fish to the bay. The majority of age-0 California halibut were collected at South Bay shoal stations in 1998.

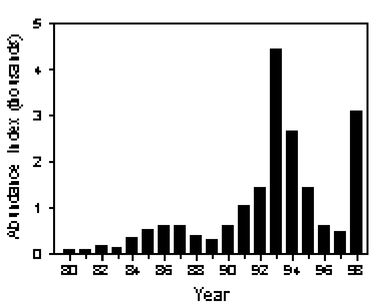

Figure 13 Annual abundance of California halibut (all sizes), February-October, otter trawl

The abundance of age-0 English sole decreased slightly in 1998 from 1997 (Figure 14), but the index was higher than the 1994-1996 indices. Factors controlling recruitment of English sole to the bay continue to be poorly understood. In 1998, most age-0 fish were collected in Central Bay, with a very small portion of the total catch from either South or San Pablo bays. In 1983, another strong El Niño year with very high outflow, English sole catches were low in San Pablo Bay, but not in the South Bay.

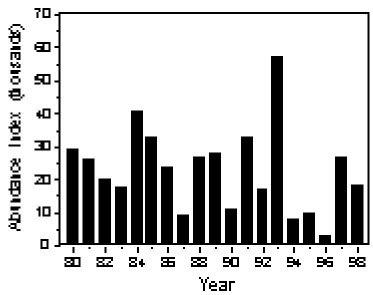

Figure 14 Annual abundance of age-0 English sole, February-October, otter trawl

Although abundance of speckled sanddab declined in 1998 (Figure 15), it remained the most abundant species of flatfish in the bay. In 1998, most were collected from Central Bay.

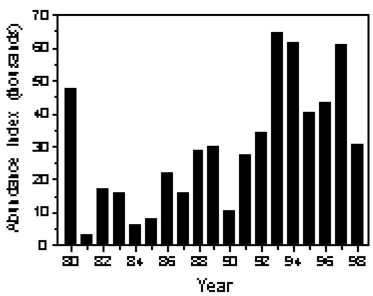

Figure 15 Annual abundance of speckled sanddab (all sizes), February-October, otter trawl

The 1998 abundance index of age-0 starry flounder was very similar to the 1995-1997 indices (Figure 16A) and the 1998 index of age-1 starry flounder (the 1997 year class) increased slightly (Figure 16B). In 1998, age-0 fish were distributed from San Pablo Bay to fresh water in the lower Sacramento and San Joaquin rivers while, age-1 fish were concentrated in San Pablo and Suisun bays, with a few collected in South Bay and the lower rivers.

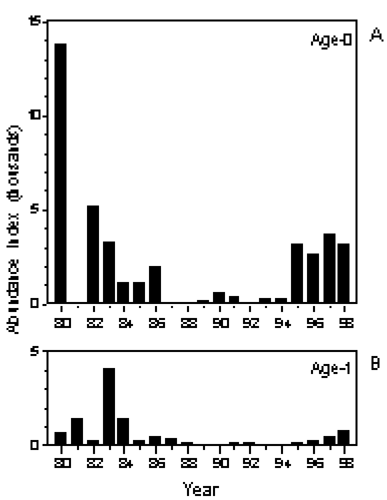

Figure 16 Annual abundance of starry flounder, otter trawl: (A) age-0, May-October and (B) age-1, February-October

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DeLeón S. 1998. Surfperch abundance trends in San Francisco Bay. IEP Newsletter 11(2):40-3.

Hieb K. 1998. Bay species. IEP Newsletter 11(2):46-9.

- ## White Sturgeon Abundance

David W. Kohlhorst, Department of Fish and Game

Measures of adult white sturgeon abundance in the Sacramento-San Joaquin Estuary are available intermittently from 1967 to 1998. Three measures are used to assess trends in population size: (1) mark-recapture abundance estimate based on tagging in the fall in San Pablo and Suisun bays and recapture of tagged fish in the same and subsequent tagging periods; (2) catch per net-hour in trammel nets used to catch sturgeon for tagging; and (3) total catch of white sturgeon during tagging.

Abundance of adult white sturgeon seems to vary in a cyclical manner, with high abundance in 1967 and 1968, the mid-1980s, and the late 1990s (Figure 1). All three measures of abundance are consistent in showing this pattern, but differ in depicting the magnitude of variations. Between 1994 and 1997, estimated abundance of white sturgeon greater than 102 cm total length increased from 26,000 to 142,000; a population estimate is not available for 1998 because of insufficient recaptures of tagged fish. From 1994 to 1998, catch per net-hour of fish over 101 cm increased from 3.8 to 11.2 and catch during tagging increased from 593 to 1,469 fish. Both the abundance estimate and catch rate suggest a substantial increase in sturgeon abundance in the estuary since 1994. The apparent increase in abundance may be due to a combination of recruitment of the strong 1982 and 1983 year classes since 1994 and return of fish to the estuary from the ocean after the end of the persistent drought of the late 1980s and early 1990s.

Evidence for the contribution of a few, strong year classes to the present high abundance of white sturgeon can be seen in length-frequency distributions from tagging during the 1990s (Figure 2). A mode consisting of several year classes from the early 1980s, when high flows produced good year classes, progresses from about 95 cm in 1991 to 135 cm in 1998, an increase of about 5 to 6 cm per year. The paucity of fish from the 1985-1992 drought, when reproduction was largely unsuccessful, becomes evident in 1997 and 1998 and suggests that the adult population will decline in the near future due to a lack of recruitment.

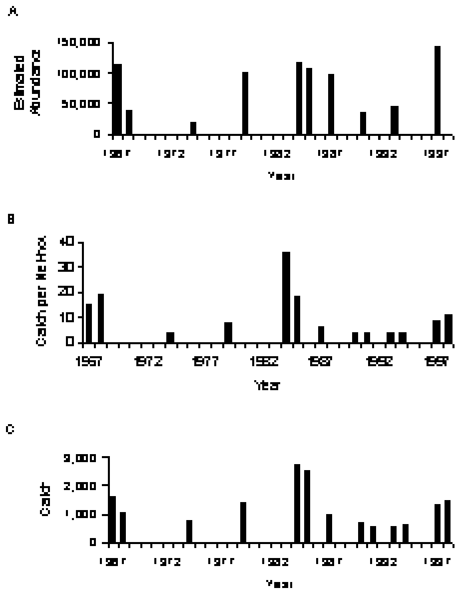

Figure 1 Abundance measures for white sturgeon $102 cm total length from 1967 to 1998 in the Sacramento-San Joaquin Estuary: (A) abundance based on mark-recapture population estimates; (B) catch per net-hour during tagging; (C) catch during tagging. Mark-recapture values in 1990, 1993, and 1998 are missing because tag recoveries were insufficient to calculate in an estimate.

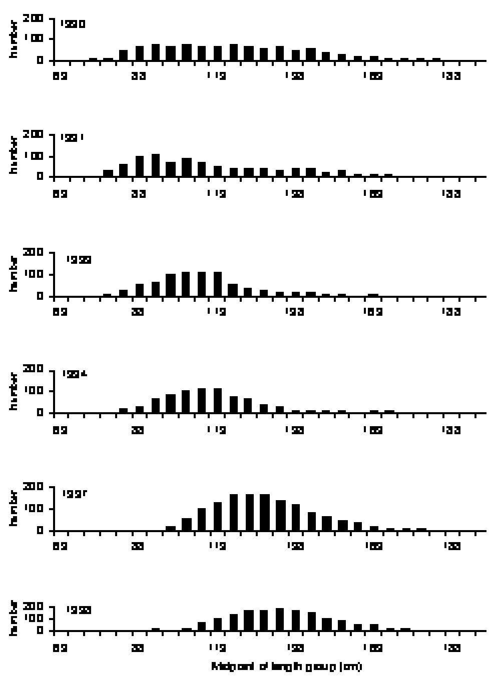

Figure 2 Length frequency distributions of white sturgeon caught in trammel nets during fall tagging in San Pablo Bay, 1990-1998

- ## Juvenile Fall-run and Winter-run Chinook Salmon Abundance

Jeff McLain and Rick Burmester, US Fish and Wildlife Service

Juvenile chinook salmon abundance and distribution is monitored by beach seine in the lower Sacramento and San Joaquin rivers, the Sacramento-San Joaquin Delta, and San Francisco Bay. In addition, trawling at Sacramento and Mossdale is conducted to document the movement of juveniles into the delta. Trawling at Chipps Island is conducted to document the relative density of juveniles leaving the delta.

Juvenile Fall-run Chinook Salmon Abundance

Densities in the north delta beach seine between January and March 1998 were the second highest observed since 1986. Catches during these months are composed mostly of fall-run and spring-run fry, as the beach seine is most efficient at capturing the smaller juveniles rearing near shore. The high catches in the delta during this time in 1998 were likely a result of the high outflow conditions. There is a significant relationship between flow at Freeport during February and mean density of fry in the north delta beach seine between January and March (Figure 1).

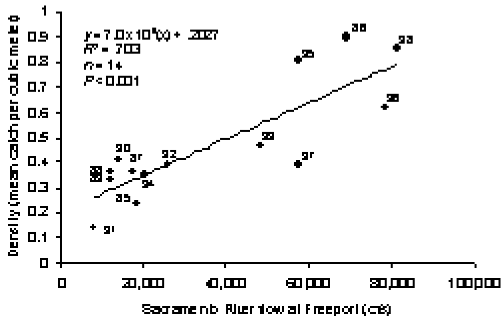

Figure 1 Juvenile chinook salmon fry density in the north delta beach siene (between Sherman Island and Discovery Park on or adjacent to the Sacramento River) in January and March against mean February flow on the Sacramento River at Freeport, 1985-1998

The relative densities of juvenile salmon in the Sacramento midwater trawl between April and June 1998 were low compared to average catches between 1988 and 1998 (Figure 2). Catches were also generally low in 1995, 1996, and 1997 relative to the average in the past (all high flow years). Catches between April and June consisted mostly of smolt-sized fall-run salmon and mainstem spring-run salmon and can be heavily influenced by salmon from Coleman hatchery. The low density observed in 1998 may likely reflect that as flows increased, the proportion of the population entering the delta as larger juveniles was reduced. This hypothesis is supported by the relationship between density and flow (Figure 3). The 1998 data appeared to fit within the established relationship.

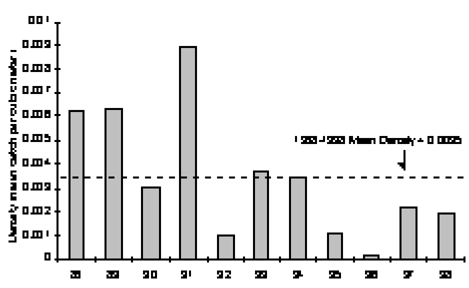

Figure 2 Juvenile chinook salmon density in the Sacramento midwater trawl between 1 Apr and 30 Jun 1988-1998. There was no sampling in April 1992. In 1990, trawling was at Courtland, about 20 mi downstream of the Sacramento site. Dotted line is mean density for 1988-1998.

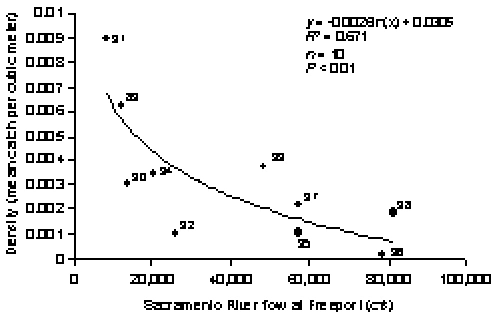

Figure 3 Unmarked chinook salmon smolt density in the midwater trawl at Sacramento between April and June 1989-1997 against mean daily flow on the Sacramento River at Freeport during February

Smolt density at Chipps Island between April and June in the 1998 midwater trawl were higher than the 1978 to 1998 mean. These catches consisted mostly of fall-run and spring-run smolts and were often heavily influenced by hatchery salmon. Density between April and June 1998 appears to support the established significant relationship between mean flow at Rio Vista and mean catch per cubic meter at Chipps Island (Figure 4).

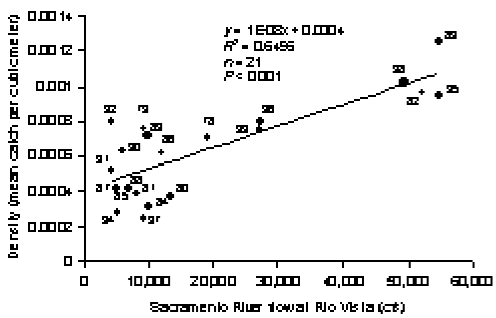

Figure 4 Unmarked chinook salmon smolt density in the midwater trawl at Chipps Island between April and June 1978-1998 against mean daily Sacramento River flow at Rio Vista between April and June

Densities of fall-run salmon between February and June 1998 on the lower San Joaquin River were much higher than in previous years (Figure 5). It is difficult to interpret abundance patterns relative to flow based on data from the last four years, as they were all classified as wet years. Observed densities may be a result of high flows or the number of spawners using the San Joaquin basin during fall 1997. More years of sampling are needed to analyze the reasons for the variation in densities at seine sites on the lower San Joaquin River.

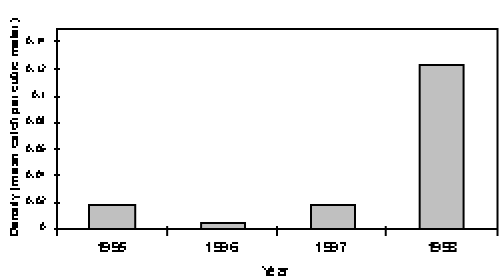

Figure 5 Juvenile chinook salmon density in the beach seine on the lower San Joaquin River between 1 Feb and 30 Jun, 1995-1998

Densities of juvenile salmon between January and March 1998 in the San Francisco Bay beach seine were nearly double the mean, also a result of the high flows present in 1998. A significant relationship exists between the mean flow at Freeport and mean catch between January and March in the San Francisco Bay seine (Figure 6). This suggests that many fry rear in the San Francisco Bay in wet years.

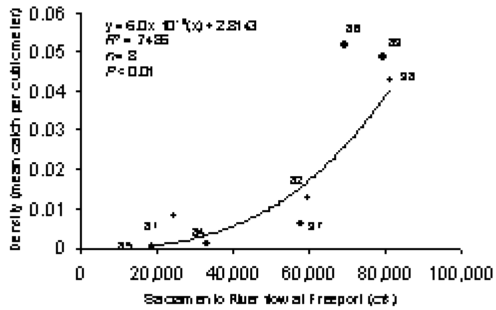

Figure 6 Chinook salmon fry density in the San Francisco Bay beach seine against mean February flow at Freeport between 1 Jan and 31 Mar, 1981-1986, 1997, and 1998. No sampling was conducted from 1987 to 1996.

Juvenile Winter-run Chinook Salmon Abundance

The classification of salmon as winter-run is based on a daily size criterion model developed by Fisher (1992). Density of winter-run salmon during 1998 in the lower Sacramento River beach seine was above the five-year average (Figure 7). Relative density of winter-run salmon during 1998 was below normal in the delta seine, in the Kodiak trawl at Sacramento, and in the midwater trawl at Chipps Island (Figures 8, 9, and 10). It is unclear why the relative abundance was high in the lower Sacramento River but low in the delta.

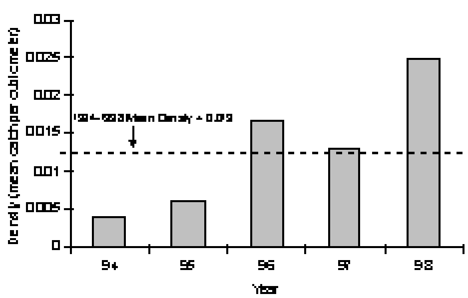

Figure 7 Juvenile winter-run chinook salmon density in the lower Sacramento River beach seine against mean February flow at Freeport between 1 Dec and 28 Feb, 1994-1998

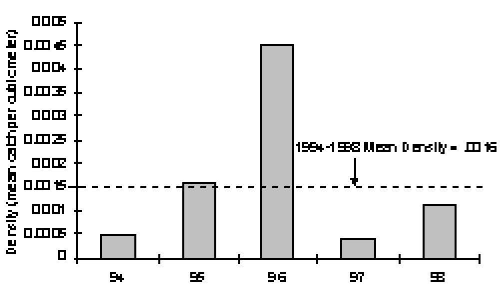

Figure 8 Juvenile winter-run chinook salmon density in the delta beach seine between 1 Jan and 31 Mar, 1994-1998

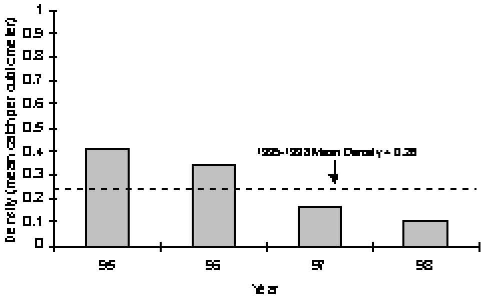

Figure 9 Juvenile winter-run chinook salmon density in the Sacramento Kodiak trawl between 1 Jan and 31 Mar, 1995-1998. The 1997 mean density does not include January because high flows prevented sampling.

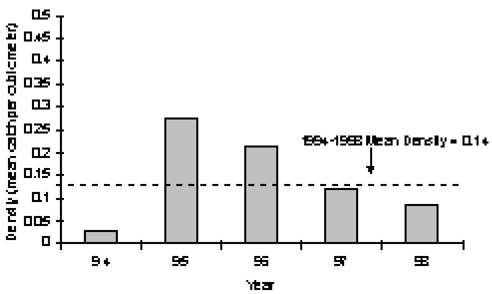

Figure 10 Winter-run chinook salmon smolt density in the Chipps Island midwater trawl between 1 Jan and 30 Apr, 1994-1998

- ## Chinook Salmon Catch and Escapement

Randall Brown and Erin Chapell
Department of Water Resources

The following information was taken from the February 1999 report "Review of the 1998 Ocean Salmon Fisheries" by the Pacific Coast Fishery Management Council (PFMC). Copies of the report can be obtained by calling (503) 326-6352. In the report, note that the spawning escapement estimate for the Feather River as shown in Appendix Table B-1 is incorrect. The correct estimate is 43,000.

As in the past few years, in 1998 the PFMC took actions to reduce the ocean harvest of winter-run chinook salmon and Klamath River fall-run chinook salmon. These actions had the ancillary effect of reducing landings of non-target runs.

Figure 1--Central Valley Chinook Salmon Annual Abundance Index

The index consists of estimated ocean harvest plus total Central Valley escapement. The index does not include inland harvest, which may be up to 25% of the salmon leaving the ocean. The 1998 abundance index of 565.3 was below the 1970-1998 average of 665.3.

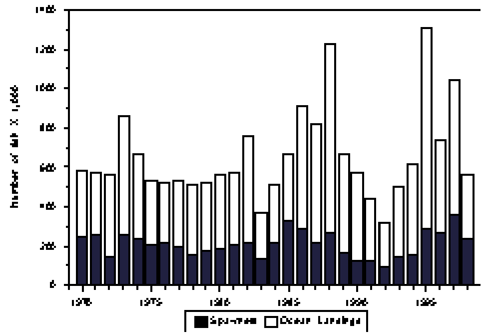

Figure 1 Central Valley chinook salmon annual abundance index, 1970-1998

The low index may be in part due to less-than-average ocean fishing effort. The ocean recreational effort was estimated to be about 150,000 angler trips compared to a 1982-1997 average of 205,000 trips. Commercial fishermen fished an estimated 12,000 days in 1998 compared to an average of 41,000 days from 1982 through 1997.

Figure 2--Ocean Commercial and Recreational Catch

In 1998, commercial fishermen landed about 65% of the total number of chinook caught in the ocean, which is slightly below the 1970-1997 average of 71%.

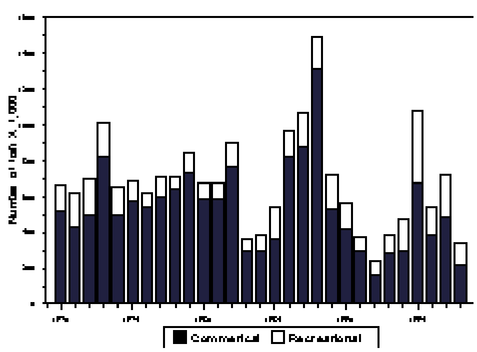

Figure 2 Annual California commercial and recreational chinook salmon ocean catch

Figure 3--Ocean Harvest Index

The ocean harvest was significantly less than preseason predictions. The ocean harvest index consists of the estimated ocean harvest divided by the sum of the ocean harvest and total Central Valley escapement. It does not include inland harvest.

The 1998 ocean harvest index of 57% is the third lowest during the period of record and is significantly lower than the indices in from about 74% to 79% seen from about 1985 through 1995.

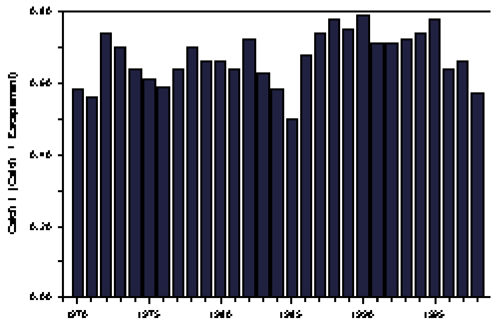

Figure 3 Central Valley chinook salmon ocean harvest index, 1970-1998

As mentioned earlier, the lower ocean harvest is likely due to harvest regulations to protect winter-run chinook and Klamath fall-run chinook. Some economic factors may be coming into play as pen-reared Atlantic salmon make up a larger portion of the fresh salmon market.

Figure 4--Sacramento Valley Escapement

In contrast to ocean harvest and total Central Valley escapement in 1998, the natural and hatchery chinook runs to Sacramento River mainstem and tributary streams and hatcheries was among the strongest seen since 1970.

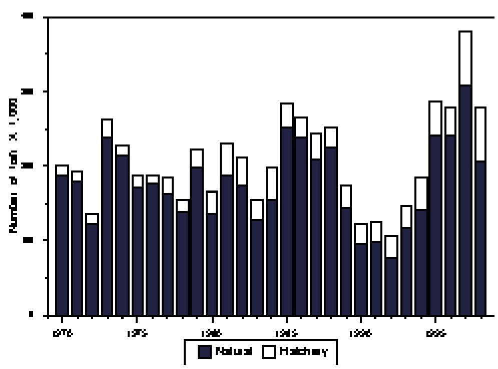

Figure 4 Annual fall-run chinook salmon escapement to the Sacramento River and major tributaries, natural and hatchery contribution

The strong escapement was at least in part due to the reduction in ocean catch. Most of the escapement was to the Feather and American rivers and Battle Creek--streams that have major fall-run hatcheries. The total escapement met the PFMC's spawning escapement goal of between 122,000 and 180,000 adults. This estimate includes hatchery and naturally spawning fish. Note that all production from the Nimbus Hatchery is trucked to near Carquinez Strait for release as smolts.

Figure 5--American River Escapement

The 1998 escapement to the American River was the fourth strong year in a row and the fourth highest year in the 1970-1998 period of record.

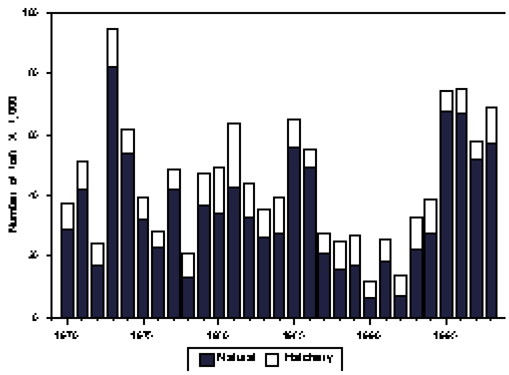

Figure 5 Annual fall-run chinook salmon escapement to the American River, natural and hatchery contribution

Figure 6--Feather River Escapement

As on the American River, the 1998 escapement to the Feather River was strong. Similarly, the entire production from the Feather River Hatchery is trucked to near Carquinez Strait for release.

DWR continues to tag more than a million Feather River Hatchery juveniles each year to help determine the hatchery's contribution to catch, spawning, and straying. This fall, DWR will contract with a university scientist to begin analyzing the tag returns from these releases.

Feather River escapement to the Feather River Hatchery includes what are now called spring-run chinook. Through the use of microsatellites, UC Davis geneticists will soon be able to determine if there is an actual spring run to the hatchery.

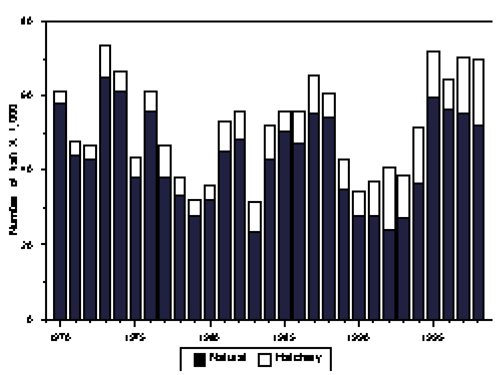

Figure 6 Annual fall-run chinook salmon escapement to the Feather River, natural and hatchery contribution

Figure 7--Fall-run Chinook Salmon Escapement to the Yuba River

Earlier data have indicated that Yuba River fall-run chinook are a naturally spawning run with little input from the Feather River Hatchery. The tagging program now underway on the Feather River and the recovery of tagged salmon on the spawning grounds will be used to determine the source of fall-run chinook spawning in the Yuba River. Whatever the source of the fish, the 1998 escapement was the second best for the period of record.

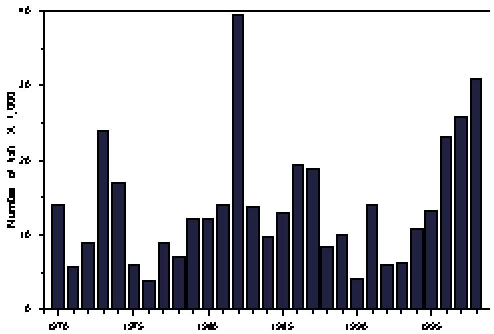

Figure 7 Annual natural fall-run chinook salmon escapement to the Yuba River

Although 1998 was the third consecutive year with reasonably good escapement to San Joaquin tributaries, it was not as good as might be expected from past records (Figure 8). The relatively low numbers are in spite of the lower ocean harvest.

Preliminary genetic information indicates that San Joaquin fall-run chinook can not be distinguished from other Central Valley fall runs. DFG received a CALFED grant to further investigate the genetics of San Joaquin stocks spawning in the main tributaries.

Figure 8--Escapement to the San Joaquin System

In 1998, the California Fish and Game Commission listed spring-run chinook as threatened. NMFS will announce their decision whether to list spring-run chinook (as well as fall-run and late fall-run) sometime this summer.

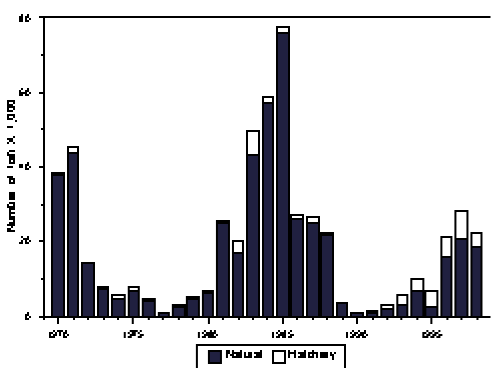

Figure 8 Annual fall-run chinook salmon escapement to the San Joaquin River system, natural and hatchery contribution

Figure 9--Spring-run Chinook Salmon Escapement

Most of the spring-run chinook spawn in Deer, Mill, and Butte creeks. The 1998 escapement was the second highest on record.

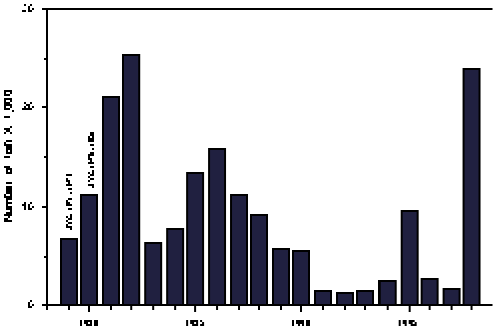

Figure 9 Annual spring-run chinook salmon escapement to the upper Sacramento River

As shown in Figure 10, in 1998 most of the spring-run chinook spawned on Butte Creek.

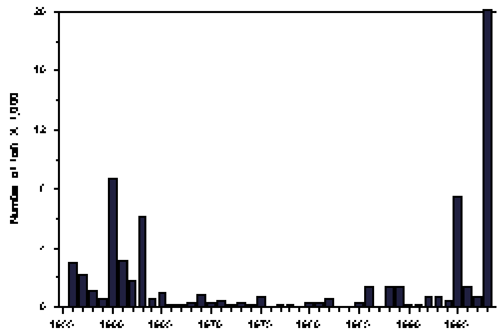

Figure 10 Annual spring-run chinook salmon escapement to Butte Creek

Genetic analysis has shown that the Butte Creek spring-run chinook are "true" spring-run but are different from those in Mill and Deer creeks. (There have been concerns that spring-run chinook on Butte Creek originated from Feather River Hatchery plants.)

Figure 11--Winter-run Chinook Salmon Escapement

The 1998 spawning estimate was more than 2,600 fish, the highest escapement in the past decade.

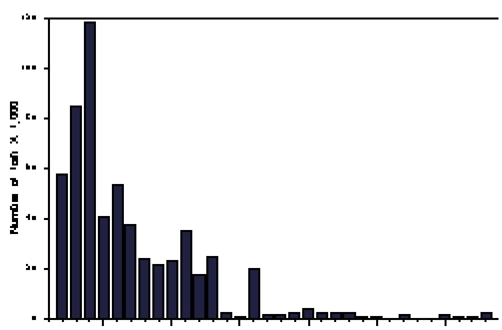

Figure 11 Annual winter-run chinook salmon escapement to the upper Sacramento River

- **Striped Bass and American Shad Abundance**

Russ Gartz, Stephen Foss, and Lee Miller
Department of Fish and Game

Striped Bass Abundance

Indices of abundance of young-of-the-year striped bass (Morone saxatilis) are calculated by two Department of Fish and Game surveys: the summer townet survey (TNS) and fall midwater trawl survey (FMWT). The TNS has been ongoing since 1959 (except in 1966) and the FMWT has been ongoing since 1967 (except in 1974 and 1979). Usually the indices from the two surveys are highly correlated, but 1998 was an exception.

The TNS measures an index of striped bass abundance when the catch mean length is 38 mm. Five surveys were required to determine the index, which was set on 30 August, the latest of record. In 1998, the 38 mm index was 1.4, the lowest of the survey's 39-year history (Figure 1). Results from 1998 were similar to those of 1997 when we reported the previous record low young striped bass index of 1.6. However, the 1998 index was much lower than expected for the spring and early summer flow conditions, which continued the trend of the previous 3 years.

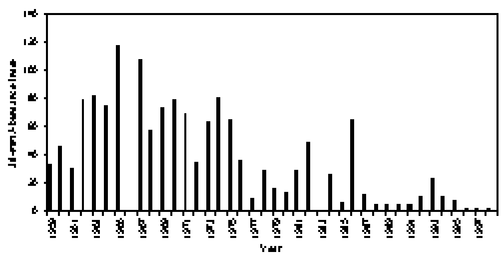

Figure 1 Annual 38 mm striped bass abundance indices. No survey was done in 1966.

Monthly abundance indices for September through December and a fall index, which is the sum of the four monthly indices, are calculated for the FMWT. Although the 1998 fall index was greater than the 1997 fall index, the long-term trend is downward (Figure 2). The 1998 fall index for striped bass was 1,217 (more than double the 1997 fall index of 568) and was above 1,000 for the first time since 1994 (1,259). However, it was close to the average fall index of the last ten years (Table 1).

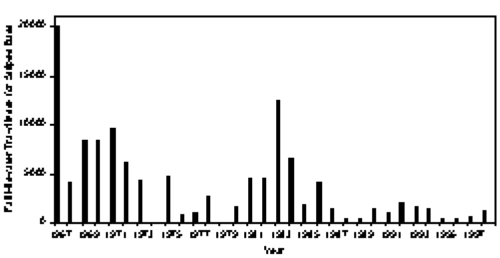

Figure 2 Fall midwater trawl indices for young-of-the-year striped bass, 1967-1998. No surveys were done in 1974 or 1979.

The 1998 distribution of striped bass was further downstream than the 1997 distribution and reflects the high fall outflow. In 1997, striped bass were concentrated in the delta from September through December with some westward expansion from October through December (Foss and Miller 1998a). In 1998, striped bass were consistently found in Suisun Bay (which includes Montezuma Slough and the shipping channel up to Chipps Island) from September through December (Table 2). The average September outflow was about 4,000 cfs in 1997 and about 20,000 cfs in 1998.

The 1998 FMWT was hampered by boat breakdowns and bad weather, especially in November and December. The November survey took almost the entire month to complete (instead of the usual two weeks) and during the December survey seven stations from the lower San Joaquin River and four stations from the eastern delta could not be sampled. These eleven stations, comprising 11% of the stations used in calculating the monthly index, could result in underestimating the December index and, ultimately, the fall index. However, from September through November, the majority of striped bass were downstream of the confluence of the Sacramento and San Joaquin rivers (see Table 2) and the December and fall indices are only slightly underestimated.

Table 1 Means, standard deviations, and standard errors of fall midwater trawl indices over ten-year periods of record for young-of-the-year striped bass and American shad and the results of a Kruskal-Wallis test for differences between periods of recorda

Statistic	*Time Period*		
	1967-1977	*1978-1988*	*1989-1998*
Young-of-the-year Striped bass			
Mean fall index	6,699	3,964	1,023
Standard deviation	5,554	3,524	552
Standard error	1,756	1,114	174
Kruskal-Wallis test results: chi square = 11.677, P > chi square = 0.00029 on two degrees of freedom.			
American shad			
Mean fall index	1,552	2,287	3,568
Standard deviation	1,318	1,436	1,723
Standard error	416	454	545
Kruskal-Wallis test results: chi square = 8.800, P > chi square = 0.0118 on two degrees of freedom.			

aNo surveys were done in 1974 and 1979.

The 1998 fall index (1,217) was much higher than expected based on the townet 38 mm index of 1.4. We investigated this by calculating a survival index between the summer and fall indices after converting them to their original index units:

$$\text{survival index} = \frac{\text{mean monthly fall midwater trawl index} \times 10^{[illegible]}}{\text{townet 38 mm index} \times 10^{[illegible]}}$$

The mean annual survival index (excluding 1983, when the townet index was biased) is 0.41 with a standard deviation of 0.39. The 1998 survival index was 2.18, 4.5 standard deviations from the mean and a definite outlier. Excluding 1983, the next highest survival index was 0.88 in 1997. For the 1998 survival index to equal the annual mean, the townet index would have to be roughly five times its present value (7.4) or the fall index would have to be one-fifth its present value (230).

There are three possible hypotheses to explain these results. None of these hypotheses exclude each other, so it is possible that each played a role.

Table 2 Percentage, by area, of monthly midwater trawl indices for young-of-the-year striped bass and American shad from September through December 1998a

Area	*Month*			
	Sep	*Oct*	*Nov*	*Dec*
Striped bass				
San Pablo Bay	0.0	0.8	8.7	3.9
Carquinez Straitb	4.0	4.8	19.2	9.6

Suisun Bayc	90.7	69.2	66.1	86.3
Lower Sacramento River	1.5	14.2	5.0	0.2
Lower San Joaquin River	0.5	10.5	1.0	0.0
Eastern delta	3.3	0.5	0.0	0.0
American shad				
San Pablo Bay	9.6	6.5	30.0	32.5
Carquinez Straitb	2.8	3.2	10.2	33.7
Suisun Bayc	17.0	5.4	44.2	23.1
Lower Sacramento River	22.2	13.6	5.1	2.8
Lower San Joaquin River	21.4	39.8	4.8	2.7
Eastern delta	27.0	31.5	5.7	5.2

aSeven stations in the lower San Joaquin River and four stations in the eastern delta were not sampled in December.

bThe "Carquinez Strait" includes the lower Napa River.

cThe "Suisun Bay" includes Montezuma Slough.

One hypothesis is that young striped bass are "washed-out" from the townet sampling area by high flows. Mean April-through-July outflow was very high (64,000 cfs) and could be expected to contribute to the 38 mm index being underestimated; however, the data are inconsistent with regard to this hypothesis. Only three other years have had mean April-through-July outflow exceeding 60,000 cfs: 1982 (62,000 cfs); 1983 (82,000 cfs); and 1995 (65,000 cfs). In 1982 and 1995, the survival indices were 0.22 and 0.17, respectively, both relatively low and within one standard deviation of the mean survival for all years (see above). Evidence supporting washout comes from the 1983 surveys. In 1983, the survival index would have been 2.03, similar to the 1998 index. The 1983 townet 38 mm index was known to be biased and has not been used because the fall index was high (12,476) and 47% of that index came from San Pablo Bay, a clear indication that fish were there during the summer TNS. However, in 1998, neither the TNS nor the FMWT caught large numbers of striped bass in San Pablo Bay as would be expected with a "washout." Despite the extra sampling effort of four added stations in San Pablo Bay, the TNS caught only one striped bass there (Foss 1998). San Pablo Bay only contributed a small percentage to each monthly midwater trawl index (see Table 2).

A second hypothesis is that cool temperatures produced a protracted spawning in 1998 with many small cohorts over a lengthened spawning season. This could have produced a wide distribution in fish lengths and a low density of striped bass, resulting in few fish being vulnerable to the townet at any one time, whereas the full range of lengths produced in such a year would be vulnerable to the midwater trawl.

A third hypothesis is that low water clarity enhanced the fishing efficiency of the midwater trawl, thus increasing the catch and perhaps decreasing predation and enhancing survival. Mean water clarity for September and October 1998 (November and December data were not available) was the third lowest of record.

American Shad Abundance

American shad indices (Alosa sapidissima) are calculated by the midwater trawl survey using the same protocol for striped bass. The 1998 fall index for American shad was 4,141, greater than the 1997 fall index of 2,594. The overall trend in the fall index is upward, despite wide fluctuations (Figure 3) (see Table 1).

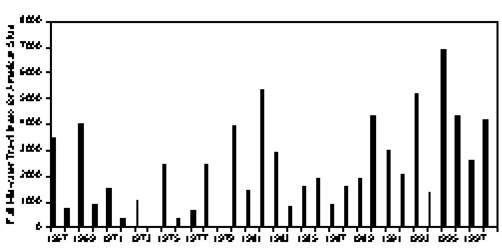

Figure 3 Fall midwater trawl indices for American shad, 1967-1998. No surveys were done in 1974 or

1979.

Whereas young-of-the-year striped bass have declined due to the impacts of water diversions in the delta, American shad are increasing. This may be due in part to their use of nursery areas upstream of the delta where they are not affected by export pumping at early life stages. Although the decline in adult striped bass is removing a potential predator, Stevens (1966) did not identify American shad as a major food source of striped bass. Two hypothesis are worth investigating: (1) increases in the adult stock have lead to greater egg production and (2) the survival of the young has increased due to changes in the environment or the zooplankton community.

In 1998, American shad were found from the delta to San Pablo Bay but the highest concentrations shifted with time as the population migrated downstream (see Table 2). In September and October, the main concentrations of American shad were in the lower Sacramento and San Joaquin rivers and the delta. However, in November and December, the distribution shifted into Suisun Bay, the Carquinez Strait, and San Pablo Bay. The pattern of distribution and movement was roughly the same as in 1997 (Foss and Miller 1998b).

It is likely that the December American shad index was underestimated, but with a small effect on the fall index (see above). In November, 84% of the index had shifted west and out of the delta (see Table 2). Also, most American shad (85%) were caught in September and October with the monthly index dropping rapidly from 2,093 in October to 515 in November and finally to 214 in December.

More information about young-of-the-year striped bass and American shad may be viewed on the Internet at http://www.delta.dfg.ca.gov/data/mwt98/.

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Fish Salvage at the SWP and CVP Facilities

Jane Arnold, Department of Fish and Game

In 1998, monthly water exports at the State Water Project (SWP) ranged from a low of 1,839 acre-feet (af) in April to a high of 295,816 af in October (Figure 1), less than the 1997 range of 43,000 af to 410,000 af. A portion of the California Aqueduct was under repair last spring, hence the low pumping rates from February through May. Monthly exports of water at the Central Valley Project (CVP) ranged from 579 af in December to 268,748 af in August.

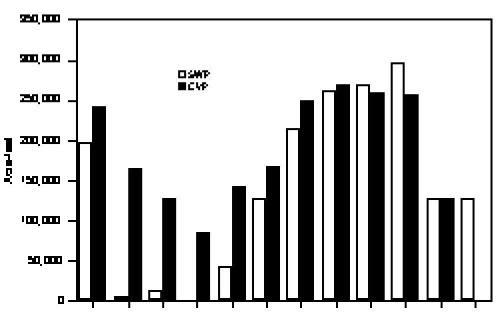

Figure 1 Monthly mean acre-feet of water exported in 1998 by facility

The number of fish salvaged per acre-foot was highest at the SWP in July (5.3) and the CVP in September (8.0) (Figure 2). Chinook salmon salvage was relatively low at the SWP in 1998; the peak salvage was 1,713 fish. At the CVP, salmon salvage was high in January, February, and May: a range of 37,000 to almost 50,000 fish were salvaged in those months (Figure 3). The majority of salmon salvaged in January were fall-run-sized fish, but in May and June, the majority was a mix of fall-run- and spring-run-sized fish. Striped bass salvage peaked in July and August with more than 70,000 striped bass at the SWP and more than 154,000 at the CVP (Figure 4). Young-of-the-year striped bass accounted for the high numbers salvaged at the facilities in July and August. Salvage of American shad peaked twice at the SWP, once in August with more than 101,000 salvaged and again in October (Figure 5). At the CVP, salvage of American shad ranged from zero in April, May, and June to more than 73,000 fish in November. Nearly all American shad salvaged were age-0 fish. Splittail salvage was highest earlier in the year than American shad salvage with almost 1,100,000 salvaged in June and 681,222 in July at the CVP (Figure 6). Splittail salvage at the SWP was less than at the CVP. The highest recorded salvage was 582,518 in July. Few longfin smelt and delta smelt were salvaged at either facility (Figures 7 and 8). Longfin smelt were salvaged in the greatest numbers at the SWP in April (616), while delta smelt salvage was greatest at the CVP in March (584).

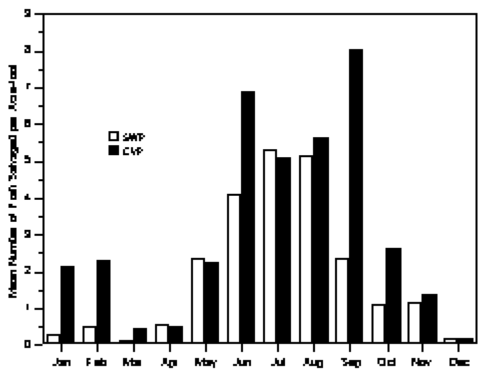

Figure 2 Number of fish salvaged per acre-foot of water exported in 1998

In 1998, splittail salvage at the SWP and CVP was the third highest since 1980, accounting for 25% of total fish salvaged at both facilities (Figures 9 and 10). Chinook salmon, steelhead rainbow trout, delta smelt, and longfin smelt salvage were low compared to previous years. In 1998, salvage of striped bass was the lowest at both facilities since 1983 (Figures 11 and 12). Since 1993, striped bass have been salvaged in low numbers relative to the period 1984 to 1989. Conversely, since 1994, American shad salvage peaked from1995 to 1997 with a high of 1.5 million salvaged at the SWP and 972,000 salvaged at the CVP in 1996.

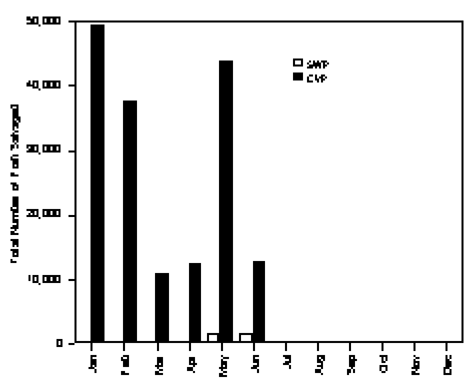

Figure 3 Number of chinook salmon salvaged in 1998 by month and facility

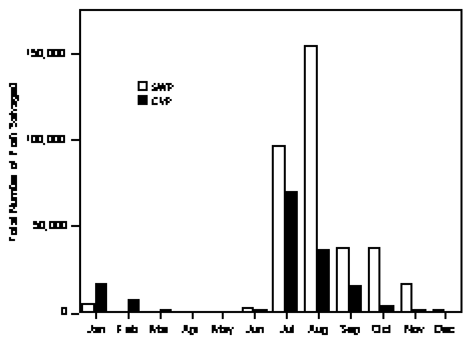

Figure 4 Number of striped bass salvaged in 1998 by month and facility

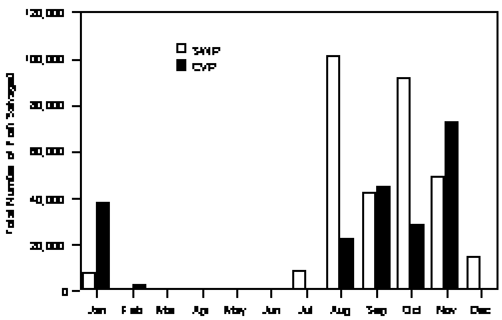

Figure 5 Number of American shad salvaged in 1998 by month and facility

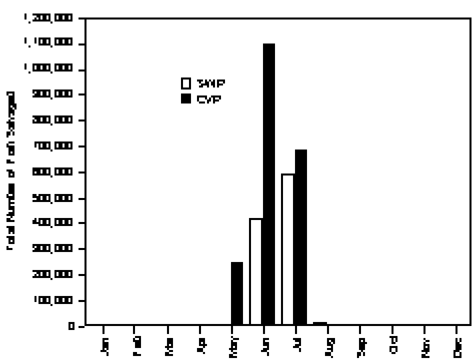

Figure 6 Number of splittail salvaged in 1998 by month and facility

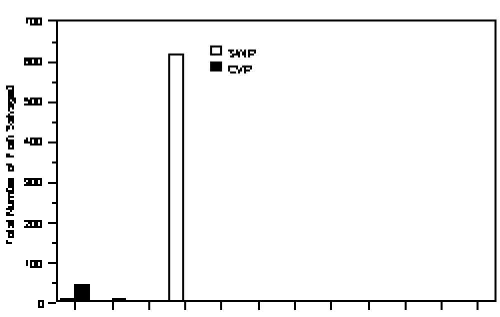

Figure 7 Number of longfin smelt salvaged in 1998 by month and facility

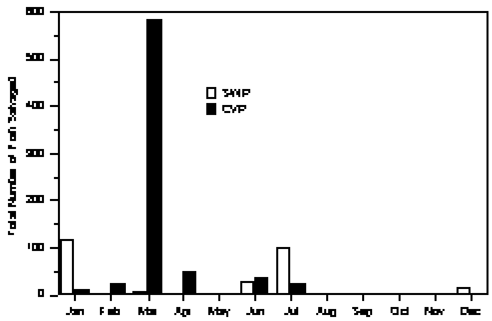

Figure 8 Number of delta smelt salvaged in 1998 by month and facility

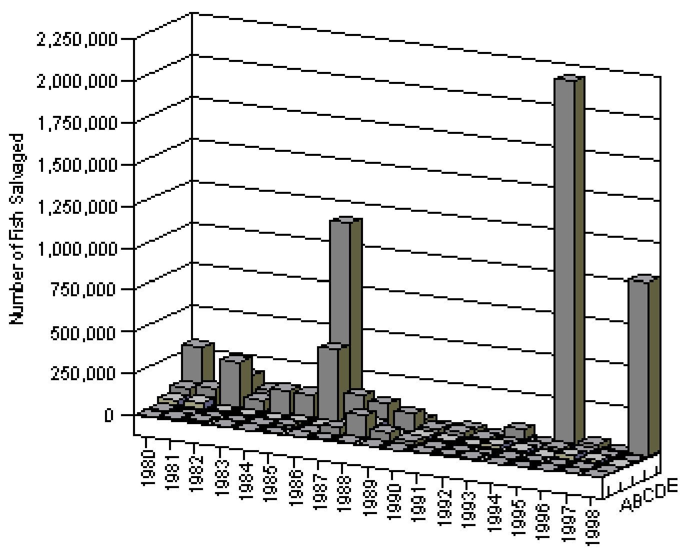

Figure 9 Number of fish of special concern salvaged at the SWP: (A) steelhead; (B) longfin smelt; (C) delta smelt; (D) chinook salmon; and (E) splittail.

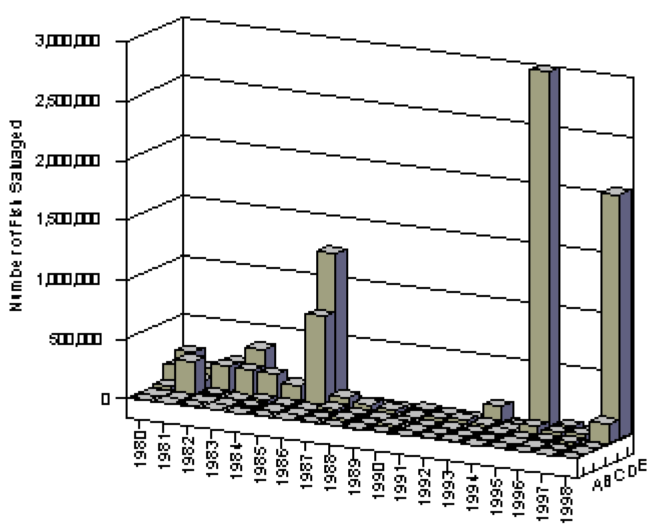

Figure 10 Number of fish of special concern salvaged at the CVP: (A) steelhead; (B) longfin smelt; (C)

delta smelt; (D) chinook salmon; and (E) splittail.

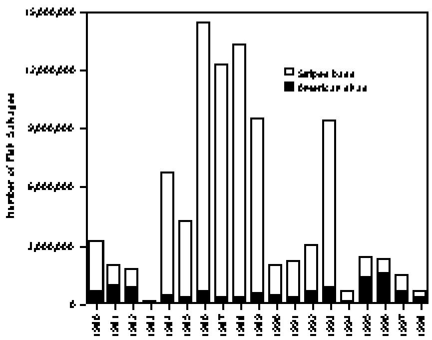

Figure 11 Salvage of American shad and striped bass at the SWP

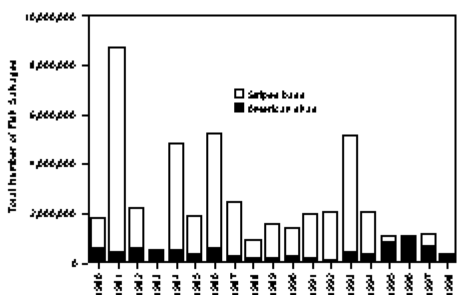

Figure 12 Salvage of American shad and striped bass at the CVP

- **Estuarine Species Abundance, X2, and Sacramento-San Joaquin Delta Exports**

Dr. B.J. Miller1, Dr. Tom Mongan1, and Alison Britton2
1Consulting Engineer
2Consultant, data analysis

We updated the relationships between estuarine species abundance and springtime values of X2. X2 is the distance in kilometers from the Golden Gate Bridge to the location where salinity is 2 psu (practical salinity units) one meter above the bottom. We obtained data up to and including 1997 where possible.

The Asian clam (Potamocorbula amurensis), first reported in 1986, changed the Suisun Bay, Honker Bay, and western delta ecosystems.

> Its populations became so large in some areas, notably Suisun Bay, that standing crops of phytoplankton were decimated and primary production plummeted to about 20 percent of its previous value. In addition to competing directly with zooplankton for what appeared to be limited phytoplankton food resources, the clam impacted zooplankton populations directly by capturing juvenile stages of some species. Because these zooplankton were key food items for the larvae of some fish species, this posed the prospect of a cascading series of indirect negative impacts on the already beleaguered fish populations of the bay. (from Hollibaugh 1996)

This fundamental change means that data from the pre-clam period cannot be combined with data from the post-clam period for the purposes of statistical analysis because there is no a priori reason for assuming that both types of systems respond in an identical fashion to changes in delta outflow.

Therefore, we segregated the data into two sets: pre-Asian clam and post-Asian clam (before 1988 and after 1987, respectively). We reanalyzed the statistical significance of those relationships for both of those periods.

We used the method described by Kimmerer (Kimmerer 1998), namely, linear regressions of the logarithm of abundance against X2.

Figures 1 through 10 show data from these two periods for various species. Table 1 summarizes the results of statistical analyses of these data.

We added an analysis for total caridean shrimp to accompany the analysis for Crangon franciscorum. C. franciscorum is one of several species of caridean shrimp that seem to play the same ecological role as forage species in the bay and delta (Kathy Hieb, personal communication, see Notes section). For this reason we suspected that the relationship between C. franciscorum and X2 was, in fact, just a measure of the distribution of one species of caridean shrimp and not a measure of the availability of total caridean shrimp for forage.

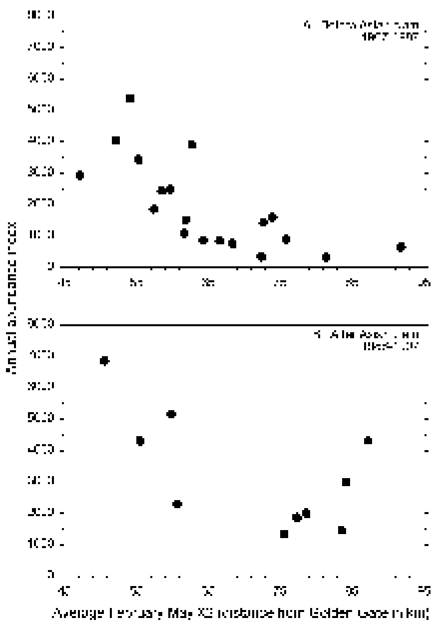

Figure 1 American shad

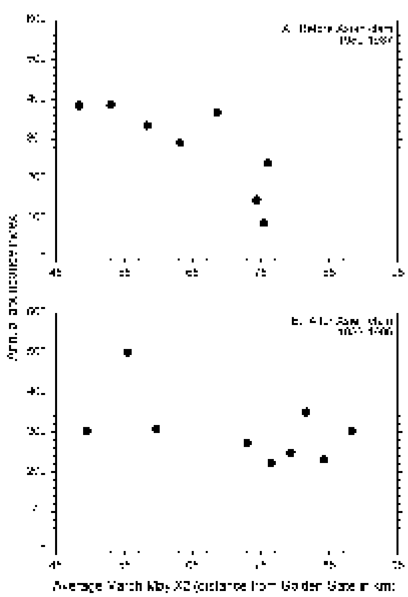

Figure 2 Total caridean shrimp

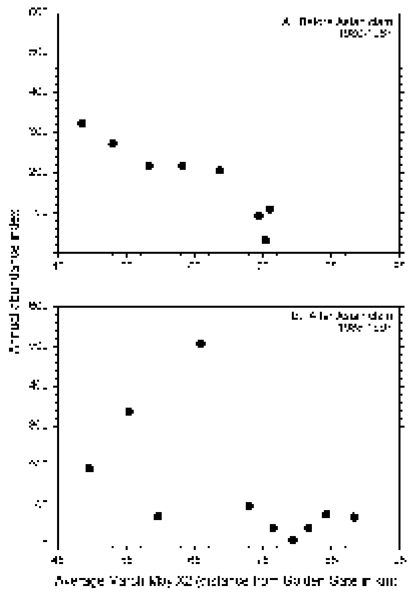

Figure 3 Crangon franciscorum

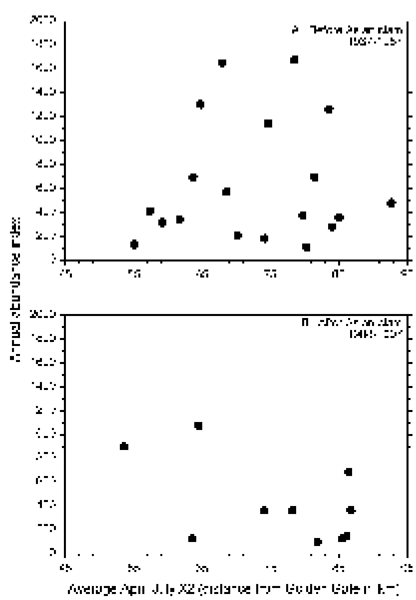

Figure 4 Delta smelt

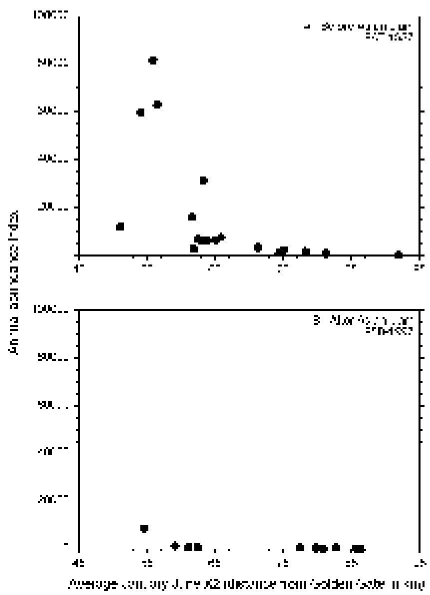

Figure 5 Longfin smelt

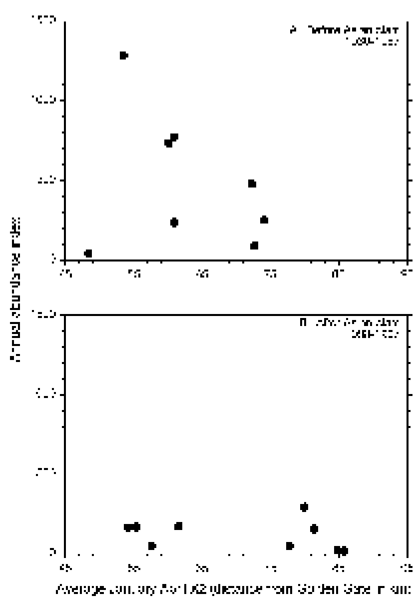

Figure 6 Pacific herring

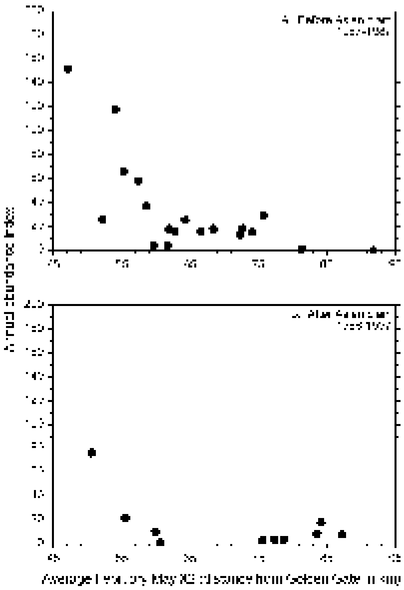

Figure 7 Splittail

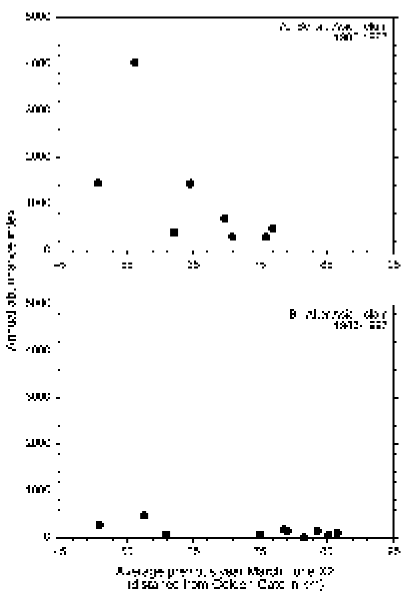

Figure 8 Starry flounder

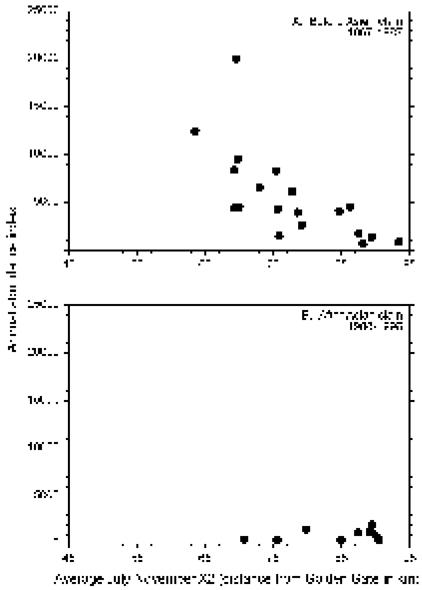

Figure 9 Striped bass (midwater trawl)

Table 1 Log abundance against X2

Species and Averaging Period	*Post-clam Years*	*Pre-clam Years*	*All Years*
American shad (midwater trawl), February through May			
n	10	19	29
P	0.08	0.0002	0.006
r2	0.33	0.58a	0.25
Caridean shrimp, March through May			
n	9	8	17
P	0.18	0.04	0.06
r2	0.24	0.55	0.22
Crangon franciscorum, March through May			
n	10	8	18
P	0.06	0.02	0.001
r2	0.38	0.65	0.49
Delta smelt (midwater trawl), April through July			
n	10	19	29
P	0.22	0.66	0.54
r2	0.18	0.01	0.01
Longfin smelt (midwater trawl), January through June			
n	10	19	29
P	0.007	3.20E-07	8.60E-08
r2	0.62	0.79	0.66
Pacific herring (midwater), January through April			
n	9	8	17
P	0.22	0.95	0.14
r2	0.21	0.0008	0.14

Splittail (midwater trawl), February through May			
n	10	19	29
P	0.36	0.0003	0.0004
r2	0.11	0.55	0.38
Starry flounder, March through June			
n	10	8	18
P	0.26	0.04	0.02
r2	0.15	0.53	0.32
Striped bass (midwater trawl), July through November			
n	9	19	28
P	0.25	0.00005	0.0005
r2	0.18	0.63	0.38
Striped bass (survival), April through June			
n	7	18	25
P	0.13	0.001	0.0002
r2	0.40	0.50	0.47

aBold text indicates significant r2 at P < 0.05.

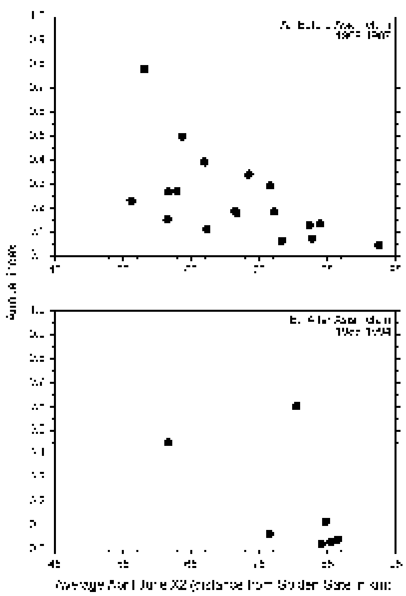

Figure 10 Striped bass (survival)

The following conclusions can be drawn from these data.

1. All of the measures of estuarine abundance, except those for delta smelt and Pacific herring, showed statistically significant relationships (P < 0.05) with X2 in the pre-clam period.

2. No species other than longfin smelt showed a statistically significant relationship in the post-clam period.

3. For any value of X2, the abundance of longfin smelt was markedly lower (about ten times) in the post-clam period as compared to the pre-clam period.

4. The abundance of longfin smelt changes very little with X2 in the post-clam period, especially at X2 values above 71 km.

5. American shad and C. franciscorum relationships with X2 were almost statistically significant (P values of 0.08 and

0.06, respectively), whereas the relation with total caridean shrimp was not significant (P = 0.18).

The abundance-X2 relationships are the basis for the X2 requirement incorporated in the 1994 Delta Accord. Extension of this requirement was part of the proposed federal actions under the Central Valley Project Improvement Act.

Although the X2 requirement has been considered important for protection of estuarine species, this reanalysis calls the fundamental reasons for the X2 requirement into question.

Incidentally, just looking at the data, the abundance graphs after the introduction of the Asian clam do not show any indication of an upward trend in abundance for X2 values greater than about 70 km. So, since the arrival of the Asian clam, there has been no indication of increased abundance for any species until X2 is less than about 70 km (steady-state outflow greater than about 20,000 cfs).

The sole exception is for striped bass survival, the ratio of summer young-of-the-year abundance to egg abundance estimate. However, the abundance of older striped bass does not seem to increase unless outflow is above about 20,000 cfs. So, it seems that changes in X2, when X2 is above about 70 km and delta outflow is below about 20,000 cfs, are now unlikely to affect abundance of estuarine species.

In drier years, when the delta is "in balance" (that is, delta inflow is just balanced by required delta outflow and exports), X2 requirements can control delta exports. For example, during the 1987-1992 drought, delta outflow was typically much less than 20,000 cfs from February through June. In critically dry years, X2 requirements can result in export curtailments in the range of 150,000 to 1,000,000 acre-feet per year (relative to exports allowed without the X2 requirement) (George Barnes and Sushil Arora, personal communication, see Notes). Post-Asian clam data indicate the curtailments would not increase the abundance of estuarine species.

Other considerations, besides estuarine abundance, affect considerations about delta outflow. In particular, delta outflow controls the salinity of the water supply for delta agriculture and the Contra Costa Water District.

We are not arguing against delta outflow requirements. However, we do suggest that rigid adherence to the X2 requirement may be not be an efficient way to produce environmental benefits. At high values of X2 (above about 70 km) and low values of delta outflow (below about 20,000 cfs), consideration should be given to relaxing the X2 requirement.

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Notes

Kathy Hieb (California Department of Fish and Game). 1988. Remarks at the spring 1988 X2 Workshop at the Contra Costa Water District.

George Barnes and Sushil Arora (California Department of Water Resources). April 1999. Memo and conversations.

- ## Climate Change and the Decline of Striped Bass

Bill Bennett1 and Liz Howard2
1UC Davis and Bodega Marine Laboratory
2US Bureau of Reclamation

Changing atmospheric-oceanic climate may have influenced the decline of the striped bass population since 1976-1977 in the San Francisco Estuary. Recently, we (Bennett and Howard 1997) presented correlations between striped bass abundance and mortality estimates (Peterson mark-recapture statistics) (Stevens and others 1985) and increasing ocean temperature due to the combined effects of a decadal climate shift and frequent El Niños (Mantua and others 1997; McGowan and others 1998). Our results suggest that the warmer Pacific Ocean stimulated frequent migrations by older adult fish to the ocean, a behavior characteristic of native populations in Atlantic estuaries. Oceanic migration is correlated with a dramatic decline of older adult fish and increasing adult mortality in the estuary as well as the higher occurrence of striped bass in the near-shore ocean since 1976-1977. In addition, we showed that loss of older fish dramatically affected the population's egg supply, which in turn affected recruitment of three-year-old individuals to the population (Bennett and Howard 1997).

In this analysis, we use time series modeling of striped bass catch per unit effort (CPUE) from commercial passenger fishing vessel (charter boat) records (Stevens and others 1985; Karpov and others 1995) to further investigate his hypothesis. Specifically, we evaluated whether (1) CPUE data adequately reflect the long-term trend in the striped bass population, (2) CPUE in the ocean increases relative to San Francisco Bay in a step-like fashion after 1976-1977, and (3) the degree to which these trends are associated with oceanic conditions.

Climate change occurs on several spatiotemporal scales. El Niños typically occur every five to seven years, last for one to three years, and since 1977, have co-occurred with a positive shift in the Pacific decadal oscillation (PDO) (Mantua and others 1977), a multi-decadal pattern of prolonged deepening of the Aleutian low pressure system and oceanographic change across the northern Pacific Ocean. While distinguishable, these two climate patterns are related, producing similar and potentially additive effects on ocean temperatures, sea level, and upwelling (Mantua and others 1997; McGowan and others 1998).

Data and Analyses

From the CPUE records (1960-1994) we calculated quarterly (four month averages) ocean catch per angler effort (CPUE) from five, ten-minute, two latitude-longitude blocks extending from the Marin coastline to Half Moon Bay (DFG numbers 446, 447, 448, 455, and 464), and from two blocks each representing San Francisco Bay (numbers 488 and 489) and San Pablo Bay (numbers 301 and 308). This provided time series of sufficient length for modeling (n = 140, Figure 1). Annual CPUE indices are correlated with annual Peterson abundance estimates (n = 26) from San Francisco Bay (r = 0.632, P < 0.001) and San Pablo Bay (r = 0.800, P < 0.001), indicating that despite numerous biases (Karpov and others 1995), the CPUE data accurately reflect long-term trend in the striped bass population, and thus constitute the best long-term record of the striped bass population (Stevens and others 1985).

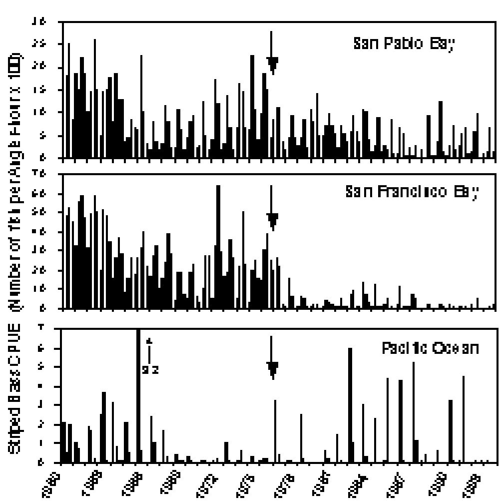

Figure 1 Seasonal (quarterly trends in striped bass CPUE from the charter boat fishery. Arrows indicate 1976-1977.

We also compiled quarterly averages of sea surface temperature from a shoreline station at Fort Point (seaward of the Golden Gate Bridge), the PDO index, and Bakun's upwelling index (Figure 2) which estimates the degree of offshore Ekman transport at lat 39°N, long 125°W (near Point Arena).

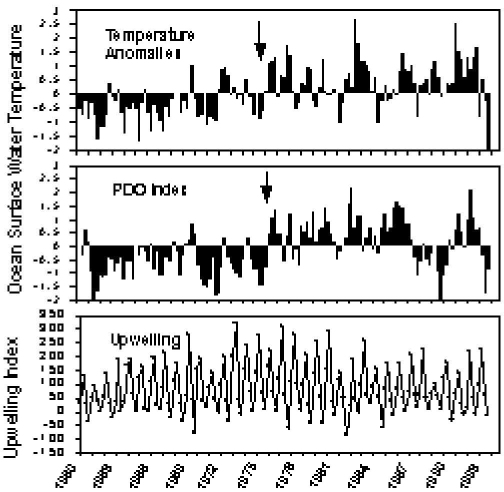

Figure 2 Seasonal (quarterly) trends in ocean environmental variables. Arrows indicate 1976-1977.

Seasonal time series of striped bass CPUE and ocean environmental variables were analyzed using Autoregressive Integrated Moving Average models (ARIMA) (Chatfield 1984), testing for non-random, step-like changes in each time series using intervention analysis (Box and Tiao 1975). The general strategy behind ARIMA modeling is to develop a time series of random processes that best fits the original data series. Residuals from the fit of the original series and the random model can be correlated with residuals from similar modeling of potential causative series (for example, ocean temperature). ARIMA models contain terms for autoregression (AR), differencing (or integration, I), and moving averages (MA). Seasonal models are more complex in that they contain one set of these terms to estimate the seasonal trend in addition to a set for the annual trend.

Seasonal model notation is (AR, I, MA)(AR, I, MA), such that the model (1,0,0)(0,1,1) incorporates one moving average and a seasonal differencing term to remove seasonal autocorrelation, as well as one autoregressive term to remove interannual autocorrelation. Interventions are added as independent variables.

We developed seasonal ARIMA models for the time series of the log-ratio of ocean CPUE to San Francisco Bay CPUE (Figure 3) and compared these with similar models containing a step-change (intervention) beginning in 1977 (Table 1). Model comparison statistics include the Akaike's Information Criterion (AIC), Schwarz's Bayesian Criterion (SBC) and the coefficient of determination (R2).

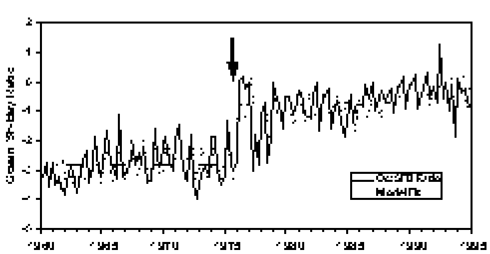

Figure 3 Seasonal log ratio of ocean to San Francisco Bay CPUE [ln(ocean + 1) - ln(SF Bay + 1)] with series fitted using an ARIMA model and intervention beginning in 1976. Horizontal lines indicate mean model fits with and without intervention. Arrow indicates 1976-1977.

Table 1 Seasonal ARIMA and intervention model results for log ratio of ocean to San

Francisco Bay striped bass CPUE, including significance of model coefficients (P), Akaike's Information Index (AIC), Schwarz's Bayesian Criterion (SBC), and coefficient of determination (R2) model evaluation criteria

Model Notation	*P*	*AIC*	*SBC*	*R2*
(1,0,0)(0,1,1)	0.000	302.9	308.7	0.677
(1,0,0)(0,1,1) + Int'76a	0.000	273.9	282.7	0.742
Int'76 = 1.811				

aInt'76 = intervention at year 1976

The model, incorporating a step-like intervention in 1976, was significant in providing the best fit to the original series (see Figure 3), as indicated by lower AIC and SBC values and a higher R2 (see Table 1). The intervention coefficient (1.811) (see Table 1) indicates the CPUE ratio increased by a factor of six after 1976. Therefore, the trend in the striped bass population changed in a step-like fashion that is not due to random processes, as did the ocean environment (Mantua and others 1997).

Cross-correlation functions to examine relationships between the CPUE and ocean environmental series were then calculated between residual values from ARIMA models that best fit the ocean environmental series (simple prewhitening) (Chatfield 1984). Correlograms (Figure 4) show the CPUE ratio is negatively correlated with sea surface temperature at lag 2 and upwelling at lag 0, whereas the PDO index is correlated at lag 0. These results indicate increases in the CPUE log ratio are associated with the positive phase of the PDO index and periods of relaxed upwelling. Therefore, trends in striped bass CPUE are clearly associated with changes in the ocean environment.

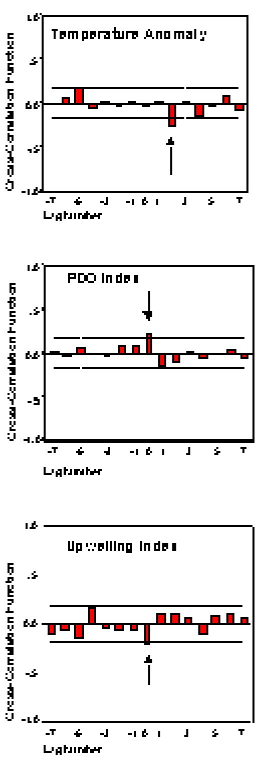

Figure 4 Correlograms showing cross-correlation functions between the log ratio of striped bass CPUE and ocean environmental series. Horizontal lines indicate the 95% confidence limits and arrows indicate significant correlations.

Why climate change?

These analyses provide further support for the hypothesis proposed by Bennett and Howard (1997) that atmospheric-oceanic climate change played a role in the decline of the estuary's striped bass population. First, the CPUE data from San Pablo Bay and San Francisco Bay provide adequate depictions of the long-term trend in the population. Second, CPUE from the ocean increased significantly relative to San Francisco Bay since 1976. While striped bass were regularly caught in the ocean during the 1960s (see Figure 2), our results indicate that since 1976 a higher proportion of the population frequented the ocean. Finally, these non-random changes in the CPUE data are significantly correlated with decadal and basin scale changes in sea surface temperature (PDO index), as well as with associated reductions in upwelling intensity. Interpretation of the negative correlation with sea surface temperature (Figure 4) requires further study, although initial examination of the correlation plot suggests the relationship may be spurious.

Future Directions

Why Do Striped Bass Migrate More Frequently to the Ocean?

Our results imply that California's striped bass are responding to environmental conditions much in the same way as native striped bass. In Atlantic estuaries, as ocean temperatures rise in late spring, older and predominantly female adults regularly migrate to the ocean dispersing along the Atlantic coastline during summer and fall to forage on schooling bait fishes. Along the central California coastline, climate change increases ocean temperatures and reduces upwelling, or offshore advective transport, such that schooling bait fish are transported on-shore (Hobson and Howard 1989). Therefore, we suggest that oceanic environmental conditions since 1976-1977 provide striped bass with two important cues for oceanic migration: warmer sea temperatures and the potential for enhanced foraging success.

What Happens to Striped Bass in the Ocean?

Very little is known about striped bass in the ocean. They are readily harvested by anglers; however, data records are sparse particularly from the shoreline fishery, which is successful during El Niño years. Conversations with anglers and bait shop owners suggest that, unlike the charter-boat fishery, the shoreline fishery occurs throughout most of the year, including spring, when striped bass are thought to be spawning in the freshwater portions of the estuary (Bennett, personal observations). Striped bass are also known to wander along the western Pacific shoreline, such that most long distance records have been documented during El Niño years (Radovich 1963). While many ocean-going striped bass return to the estuary during winter and spring, a significant portion overwinter in other estuaries and lagoons along the coast (Bennett, personal observations). Many of these fish may return to the San Francisco Estuary intermittently (in other words, biannually) to spawn. Such behavior may be sufficient to produce the apparent decline in the estuary.

Clearly, these issues require further study. Our analyses (Bennett and Howard 1997, this article) suggest that an important key to understanding the population decline of striped bass may lie in the Pacific Ocean.

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Delta Inflow, Outflow, and Pumping

Dawn Friend, Department of Water Resources

Figures 1 and 2 contain plots of some important flow and pumping measurements for calendar year 1998 and the first quarter of 1999. I have included the following notes:

- Sacramento and San Joaquin river flows and delta pumping are measured. Delta outflow is calculated.
- Delta outflows shown for 1 January through 30 September 1998 are from the DAYFLOW program. From 1 October 1998 through the end of the record, outflows are from DWR's Operations and Maintenance.
- Export and inflow ratios are calculated from a 14-day running average for the entire period shown.

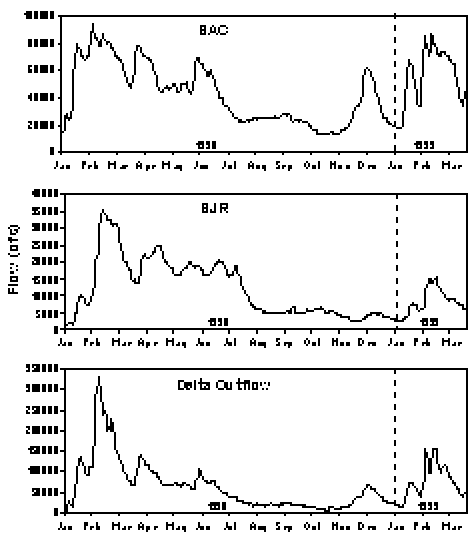

Figure 1 Sacramento and San Joaquin rivers and delta outflow for 1 Jan 1998 through 30 Mar 1999

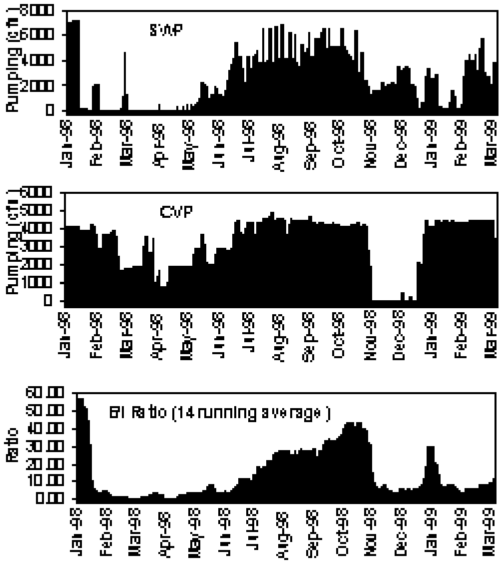

Figure 2 SWP, CVP, and 14-day E/I Ratio for 1 Jan 1998 through 30 Mar 1999

- **Errata**

Lauren Buffaloe, Department of Water Resources

In the last issue of the IEP Newsletter (volume 12, number 1), Figure 1 in the article on page 31, "Sediment inflow to the Sacramento-San Joaquin Delta and the San Francisco Bay" by Rick Oltmann and others, was missing data from 1996 and 1997. Below is a reprint of the corrected version of the figure that includes the data (open and filled circles). I thank Larry Smith (USGS) for bringing the error to my attention and George Yamamoto (USGS) for providing a corrected version of the figure.

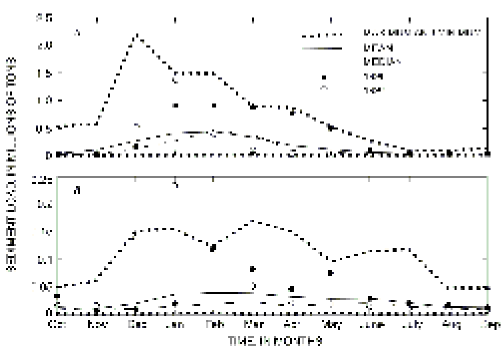

Figure 1 Monthly suspended sediment load statistics for 1960-1995 compared with 1996 and 1997 monthly suspended sediment loads for the (A) Sacramento River and (B) San Joaquin River

Setting It Straight

Accuracy is fundamental in scientific writing. It is the policy of the editors of the IEP Newsletter to promptly acknowledge errors in the Errata section. Errors should be reported to Lauren Buffaloe by phone (916) 227-1375 or e-mail (buffaloe@water.ca.gov).

1998 IEP Workshop at Asilomar a Big Success

Chuck Armor, Department of Fish and Game

The IEP Annual Workshop was held at the Asilomar Conference Center in Pacific Grove, California, on February 24-26, 1999. Approximately 300 people attended, similar to last year's attendance. The program followed the same format as last year's, with the three-day IEP Annual Workshop following the Bay-Delta Modeling Forum's meeting and conference on Tuesday, February 23. A joint session with the Bay-Delta Modeling Forum was held on Wednesday afternoon. Based on comments received from attendees, people felt this workshop was informative and useful and they gave it an above-average rating. Talks on the Yolo Bypass, breached levee work, and mitten crab work received the most positive comments. We added a new, expanded poster session, where over forty posters were displayed in a separate hall apart from the regular meeting hall. Based on the success of the expanded poster session and the overwhelming positive comments received, it will become an integral part of next year's workshop.

Suisun Ecological Workgroup Update

Eliza Sater, Department of Water Resources

Look for the Suisun Ecological Workgroup's (SEW) draft report, available for review in early May. SEW invites comments on the draft report from all interested parties. The report will be posted on SEW's web site: http://iep.water.ca.gov/suisun_eco_workgroup/. In addition, you may contact Eliza Sater at esater@water.ca.gov or (916) 227-0179 for hard copies of the report.

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1. Water year 1998 began on 1 Oct 1997 and ended on 30 Sep 1998.

2. The high San Joaquin River flow throughout 1998 was due to an exceptionally wet winter and cool spring, which provided a substantial winter snowpack and delayed spring runoff to the drainage basin of the San Joaquin River. These conditions contributed to reduced irrigation demand within the drainage basin and the maintenance of high river flow and reservoir levels throughout summer and fall 1998.

3. The Department of Water Resources' Division of Operations and Maintenance funded these special studies.

4. Summarized in: American Public Health Association and others. 1998. Standard Methods for the Examination of Water and Wastewater. 20th ed. Washington, DC: American Public Health Association Publication Office.

5. The designation C or L with a site number indicates whether the grab was from the center or the left side of the channel.