■ Interagency Ecological Program for the San Francisco Estuary ■

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Of Interest to Managers

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In this status and trends issue, authors continue the tradition of providing annual updates on water parameter measures and species abundance. Similar to last year, several authors broadened their scope and provide more insight into why species responded in a particular manner. In addition, three contributed articles provide diverse examples of how working groups and projects are evaluating survey methodology and information with the goal of optimizing the survey or improving management or research utility of information developed.

Although each status and trend article can stand alone, a little research and selective reading can provide a better understanding of the environmental conditions that influenced the biological responses reported. Parts of three articles present the environmental background material. The first article is in last year's status and trends issue (Vol 16, Number 2, pp. 58-59). Here Kate Le describes first quarter 2003 flows and exports, showing two modest flow pulses in January followed by declining flows through March. Another modest flow pulse occurred in April and May, after this article was written. In the current issue, Kathryn Hieb, Tom Greiner and Steven Slater ("San Francisco Bay Species: 2003 Status and Trends", p. 17) describe improved early season flow conditions for 2003 compared to 2001 and 2002, but as you will see in the species accounts, 2003 flows were not sufficient to result in consistently detectable improvement of freshwater and anadromous species abundance. The anadromous American shad was a major exception, posting record high indices (see Bryant and Souza p. 14, and Foss p. 32).

At the other end of the estuary, Hieb and others report that the marine environment remained relatively cool temperature-wise in 2003. Cool temperatures and favorable currents positively affected survival and recruitment of young marine invertebrates and fishes (e.g., Dungeness crab and English sole) to the lower estuary. Finally, Erin Chappell ("Chinook Salmon Catch and Escapement", p. 28) explains how cooler ocean temperatures and upwelling positively affect marine survival of Chinook salmon and displays adult return numbers for Central Valley stocks.

Although we've recently added relative abundance indices for steelhead (see Foss p. 32) and threadfin shad (see Bryant and Souza p. 14), this year because of staffing limitations other contributions from projects sampling shoreline habitats were absent or reduced: no contribution from the Resident Shoreline Fishes survey and an abbreviated contribution from Delta Juvenile Fishes Monitoring Project. Thus, for this year there is no tracking of ongoing dispersal through the Delta of nonnative fishes (e.g., inland silverside and red shiner) or the increase in largemouth bass and sunfishes with the expansion of the aquatic plant *Egeria densa*.

In "Why We Do a 'Post-VAMP' Shoulder for Delta Smelt" (p. 44), Victoria Poage presents an overview of several "management tools", explains their biological basis, and describes their use in protecting delta smelt from loss at the South Delta pumps. She provides preliminary evidence that the tools may be working. However, the best evidence the tools are working is that water and regulatory agency personnel continue to work together to employ and improve these tools!

As part of a larger, ongoing internal evaluation of Environmental Monitoring Program, Heather Peterson and Marc Vayssières report (p. 38) on another analytical study in series aimed at understanding the "representativeness" of individual benthic sampling locations and optimizing the sampling program (see also IEP Newsletter Vol. 16 (2) pp. 51-56). Here they compare species composition, densities and diversity indices between two nearby locations in Old River. Even though repeated benthic samples from a single location can be highly variable, these authors show that, for a sizable group of organisms, annual abundance patterns for both locations were very similar over time. Results of this and other work will be used to make decisions about adding or reducing sampling sites and will help better understand the strengths of the current program.

In another effort to improve the utility of information, DFG fisheries monitoring staff embarked on a study to develop biomass indices for commonly collected estuarine fishes. The fishes captured by long-term monitoring projects tend to be small, short-lived species (e.g., threadfin shad, yellowfin goby) or the young of larger species (e.g., striped bass, English sole). As such they can represent both primary predators in a food web or a forage base for large piscivorous species such as older striped bass, largemouth bass, or pikeminnow. Russ Gartz presents the foundation for producing fish biomass indices in his article "Length-Weight Relationships for 18 Fish Species Common to the San Francisco Estuary" (p. 49). He describes the methods and quality control for collection of length-weight data and presents current relationships for 18 fish species. These relationships along with historically collected length measurements will allow estimation of historic species and community biomass, and potentially provide new insights into species and community dynamics.

Finally, Kate Le's article "Delta Water Project Operations" (p. 58), describes first quarter flows and exports for calendar year 2004. We hope to expand upon these data and present a summary of the flows and exports for winter-spring 2004 as a lead article in the next year's "Status and Trends" issue. As stated above, flows and exports can strongly influence the abundance and distribution of organisms in the upper estuary.

Status and Trends

Phytoplankton and Chlorophyll Abundance and Distribution in the Upper San Francisco Estuary in 2003

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Introduction

The status and trends of environmental water quality, phytoplankton, zooplankton, and benthos are all monitored through the IEP's Environmental Monitoring Program (EMP). The EMP is mandated by the State Water Resources Control Board Water Right decision 1641, which permits the water management and export activities of the State Water Project and the Central Valley Project. Staff from the Department of Water Resources, the US Bureau of Reclamation, Department of Fish and Game, and the US Geological Survey complete all activities associated with the EMP. Monitoring involves the collection of discrete samples each month at established stations, as well as continuous monitoring of water quality conditions at seven shore-based stations (Figure 1). More information about the EMP can be found at http://www.iep.water.ca.gov/emp.

These articles summarize results from 2003 monitoring of phytoplankton, chlorophyll, and benthic organisms.

2003 Status and Trends—Chlorophyll and Phytoplankton

Chlorophyll *a* and phytoplankton samples were collected monthly at 11 monitoring stations (Figure 1) throughout the upper San Francisco Estuary (Figure 1). Phytoplankton are small free-floating or attached algae that can range from tiny, single-celled organisms (less than 5 µm in diameter) to larger colonial organisms (Horne 1994). They are an important source of food in the estuary for zooplankton, invertebrates, and some species of fish.

Phytoplankton biomass is an indicator of the status of primary productivity in the estuary. Chlorophyll *a* is one of the main groups of pigments contained in the algal species that make up phytoplankton (Horne 1994). Chlorophyll *a* concentration was measured for each of the 11 monitoring stations to estimate overall phytoplankton biomass in the estuary. Phytoplankton samples were collected and analyzed separately to determine which species were present in the estuary.

Percent chlorophyll *a* concentration is used as an indicator of actively increasing phytoplankton biomass. The percentage of chlorophyll *a* increases during the initial stages of a phytoplankton bloom when cell division is exponential, and decreases during the decline phase of the bloom when the pigment breakdown products (pheophytin) increase. Percent chlorophyll *a* concentration is computed as the ratio of chlorophyll *a* concentration to chlorophyll *a* plus pheophytin concentration multiplied by 100%.

To collect chlorophyll *a* samples, discrete water samples were filtered using a fiberglass filter with a 47 mm diameter and 1.0 µm pore size at a pressure of 10 in. of mercury. Chlorophyll *a* extractions were completed at Bryte Laboratory according to *Standard Methods for the Examination of Water and Wastewater, 20th ed. 1998.* Phytoplankton identification and enumeration was also performed at Bryte Laboratory using the Utermohl inverted microscopic method. Detailed field collection methodology and laboratory analysis information can be found at: http://www.iep.water.ca.gov/emp/Metadata/metadata_index.html.

Percent chlorophyll *a* concentrations during spring, summer, and early fall 2003 were well above 60% at most monitoring sites. This relatively high percentage of chlorophyll *a* indicates that phytoplankton biomass was increasing throughout the estuary during this period. Chlorophyll *a* concentration ranged from a minimum of 0.42 µg/L in the San Joaquin River at Potato Point (D26) in January to a maximum of 64.5 µg/L in the San Joaquin River at Vernalis (C10) in May. The concentration averaged 2.3 µg/L throughout most the estuary, except in the San Joaquin River at Buckley Cove (P8), Disappointment Slough near Bishop Cut (MD10), and C10. Chlorophyll *a* concentrations at P8 and MD10 ranged from a minimum of 0.93 µg/L to a maximum of 46.1 µg/L and averaged 10.6 µg/L. Station C10 tended to have the highest chlorophyll *a* concentrations throughout the year with a mean of 23.8 µg/L and a maximum of 64.5 µg/L. This peak was well below the high of 118.0 µg/L recorded there in August 2002.

Overall, chlorophyll *a* concentrations were higher in spring and summer, when maximum values were measured at most stations. and lower in late fall and winter. Chlorophyll *a* maxima for San Pablo Bay near Pinole Point (D41), Sacramento River above Point Sacramento (D4), and MD10 occurred during early and mid spring. In Suisun Bay at Bulls Head near Martinez (D6), the maximum occurred during late spring followed by a minor peak in early fall. Chlorophyll *a* maxima for Suisun Bay off Middle Point near Nichols (D8) and Grizzly Bay at Dolphin near Suisun Slough (D7) occurred in late spring followed by secondary peaks during the summer. Chlorophyll *a* maxima occurred at C10 and P8 in late spring and early fall, with minor peaks occurring in midsummer and late spring, respectively. There were two equivalent maximum values for the Sacramento River at Greens Landing (C3) during early spring and mid-summer. The maximum chlorophyll *a* concentration for Old River opposite Rancho Del Rio (D28A) occurred in mid-spring followed by secondary peaks during summer. At station D26 the maximum concentration occurred in late summer, while spring values constituted a minor peak.

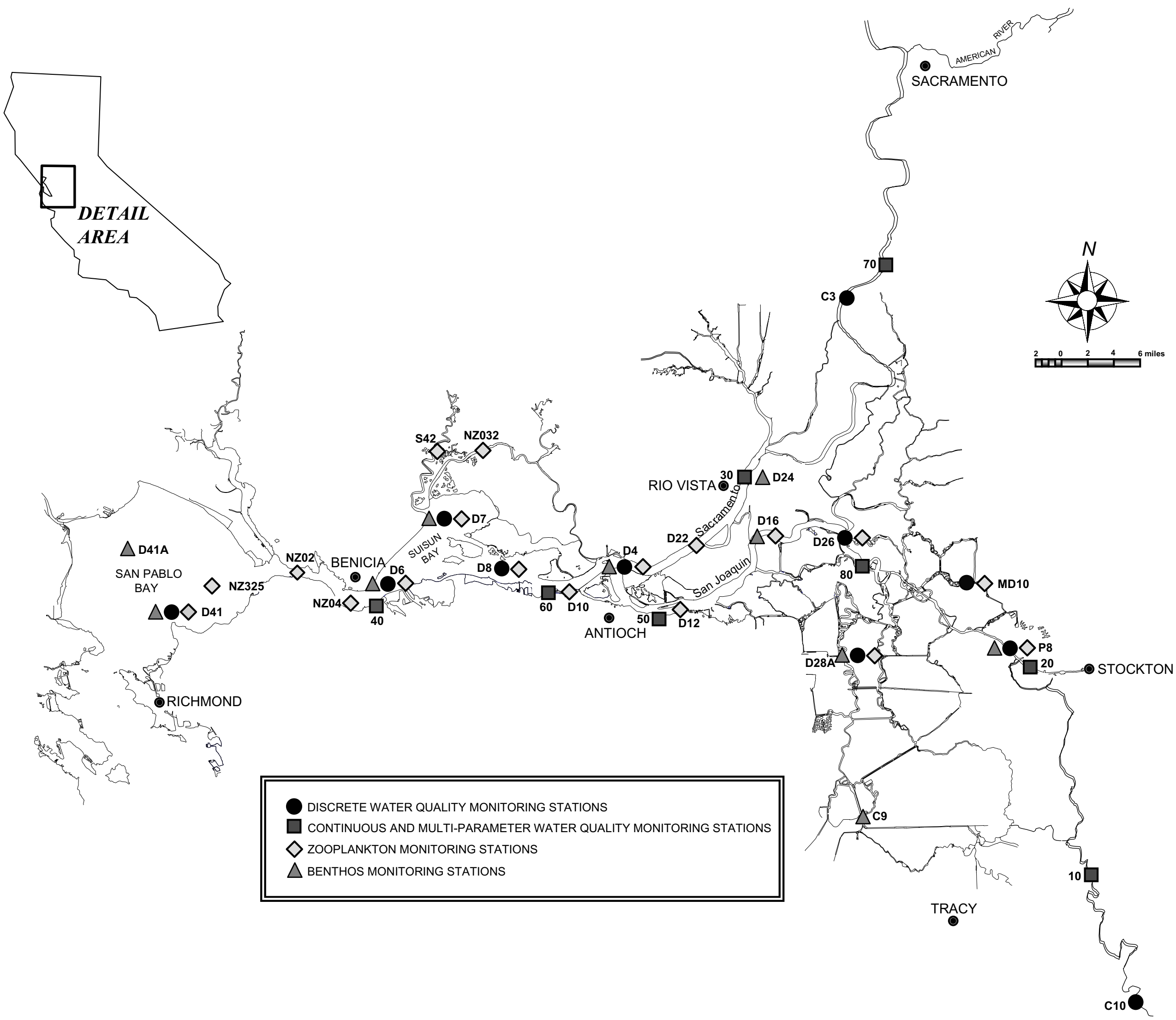

Figure 1 IEP Environmental Monitoring Program sampling sites in the San Francisco Estuary

Phytoplankton species composition changes seasonally in response to many variables, including the availability of nutrients and light, extent of inflows, salinity intrusion, and water temperature. Phytoplankton species associated with spring chlorophyll *a* peaks at stations C3, D28A, MD10, D4, and D26 included cryptomonads, primarily *Rhodomonas* sp., green algae, and diatoms. The diatoms *Achnanthes gibberula* and *Aulacoseira granulata* were dominant at C3 and MD10, respectively. Spring phytoplankton peaks at stations C10 and P8 consisted primarily of the diatoms *Cyclotella* sp., *Thalassiosira eccentrica*, and *Skeletonema potamus*; the peaks also included green algae, cryptomonads, and an euglenoid. The spring chlorophyll *a* peaks at stations D6, D7, D8, and D41 consisted primarily of cryptomonads, diatoms, and green algae, but also included unidentified flagellates and the dinoflagellate *Glenodinium* sp. at D41.

Summer and fall phytoplankton assemblages tended to differ from spring compositions throughout the estuary. An assemblage of unidentified flagellates, green algae (which consisted of predominantly *Chlorella* sp.), cryptomonads, and diatoms comprised the summer peaks at stations C3, D28A, and D26. The blue-green alga *Merismopedia* sp. was also prevalent at D26. The most common species during the summer and fall peaks at stations C10 and P8 were the diatoms *Centric diatom* sp., *Pennate diatom* sp., and *Cyclotella* sp.; the green algae *Closterium setaceum* and *Carteria cordiformis*; unidentified flagellates; the cryptomonad *Rhodomonas sp;,* and the blue-green alga *Synechocystis* sp. The summer and fall peaks at stations D6, D7, and D8 consisted of cryptomonads, unidentified flagellates, diatoms, and the blue-green alga *Aphanizomenon flos-aquae.*

References

Horne, A.J. and C.R. Goldman. 1994. Limnology. McGraw-Hill, United States of America. 576 pp.

Benthic Monitoring

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The benthic monitoring component of the Environmental Monitoring Program (EMP) documents changes in the composition, density, and distribution of the benthic biota within the upper San Francisco Estuary. Benthic biota can respond to changes in physical factors within the estuary such as freshwater inflows, salinity, and substrate composition. As a result, data collected on benthic biota can provide an indication of physical changes occurring within the estuary. Because operation of the State Water Project and the Central Valley Project can impact the flow characteristics of the estuary and subsequently influence the density and distribution of benthic biota, benthic monitoring is an important component of the EMP. Benthic monitoring is also used to detect and document the presence of species newly introduced to the estuary.

Benthic monitoring is conducted at ten sites within the estuary, with four benthic samples and one sediment sample taken at each site. Starting in October 2003 and coinciding with the beginning of the 2004 water year, the sampling regime changed from monthly to quarterly in response to a recent programmatic review by the State Water Resources Control Board.

Samples are analyzed by a private consultant and all organisms are identified to the lowest taxon possible and enumerated. Sediment composition analysis is conducted at the Department of Water Resources' Soils and Concrete Laboratory. Field collection methodology and laboratory analysis of benthic macroinvertebrates and sediment composition is described in detail at http://www.iep.ca.gov/emp/Metadata/metadata_index.html.

As a result of the geographically diverse sampling regime, 17 new organisms were added to the benthic species list in 2003. These 17 organisms are not necessarily new to the upper San Francisco Estuary; they are merely new organisms to the benthic monitoring component of the EMP. The new species and the locations where they were collected are listed in Table 1.

Of the 179 species of benthic macrofauna collected in 2003, ten species represented 90% of all organisms collected. These ten species include: (1) the amphipods *Americorophium stimpsoni*, *Americorophium spinicorne*, *Corophium alienense, Monocorophium acherusicum, Ampelisca abdita*, and *Gammarus daiberi*; (2) the aquatic oligochaete *Varichaetadrilus angustipenis*, (3) the Asian clams *Potamocorbula amurensis* and *Corbicula fluminea;* and, (4) the cumacean *Nippoleucon hinumensis*. The only change in these dominant species from 2002 was the removal of *Limnodrilus hoffmeistri*, an oligochaete, and the addition of *Nippoleucon hinumensis,* a cumacean.

Table 1 Location, date, and lowest taxonomic identification of taxa collected for the first time in 2003 by the benthic monitoring component of the Estuarine Monitoring Program.

Location	Date collected	Family	Genus	Species	Common name
D41	February	Paraonidae	*Aricidea*	*species A*	Polychaete
D41	February	Cirratulidae	*Tharyx*	*parvus*	Polychaete
D41	May	Callianassidae	*Callianassa*	*species A*	Crustacean
D41	May	Cancridea	*Cancer*	*magister*	Crustacean
D41	September	Terebellidae	*Pista*	*pacifica*	Polychaete
D41	September	Aglajidae	*Melanochlamys*	*diomedea*	Gastropod
D41	September	Tellinidae	*Macoma*	*species A*	Bivalve
D41A	May	Paguridae	*Pagurus*	*samuelis*	Crustacean
D41A	July	Ampithoidae	*Ampithoe*	*valida*	Crustacean
D41A	July	Corophiidae	*Monocorophium*	*uenoi*	Crustacean
D24	February	Pholoididae	*Pholoides*	*aspera*	Polychaete
D24	February	Hygrobatidae	*Hygrobates*	*species A*	Arachnid
D24	February	Tipulidae	*Tipula*	*species A*	Diptera
D24	March	Psychodidae	*Psychoda*	*species A*	Diptera
D24	March	Empididae	*Neoplasta*	*species A*	Diptera
D24	May	Sumuliidae	*Simulium*	*species A*	Diptera
C9	April	Naididae	*Arcteonais*	*lomondi*	Oligochaete

Of the ten dominant species listed above, *Ampelisca abdita*, *Nippoleucon hinumensis*, and *Potamocorbula amurensis* represent macrofauna that inhabit a more saline environment and were found in San Pablo Bay (D41 and D41A), Suisun Bay (D6), and Grizzly Bay (D7). *Americorophium stimpsoni* and *Americorophium spinicorne* tolerated a wider range of salinity and were collected in the more saline western sites, as well as the more brackish to freshwater eastern sites such as the San Joaquin River at Twitchell Island (D16) and the Sacramento River above Point Sacramento (D4). The remaining five species are predominantly freshwater species and were collected at sites east of Suisun Bay.

Neomysis and Zooplankton Monitoring

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The term zooplankton includes animals of varying lengths: copepods, which average 1.0-1.2 mm for adults; cladocerans, which average 0.6-2.0 mm; and rotifers, which average 0.1-0.2 mm. Mysid shrimp are considered to be macrozooplankton and range from 2 to 18 mm in length. All of the native zooplankters of the upper estuary have decreased in abundance since they were first monitored in 1968 (mysids) or 1972 (other groups). In addition, many non-indigenous copepods and several mysids have been introduced to the estuary. The general picture of greatly reduced abundance compared to baseline conditions in the early 1970s did not change in 2003, although some taxa did increase over 2002 levels.

Zooplankton and phytoplankton samples were taken monthly at sampling sites of the Environmental Monitoring Program. The fixed sites are shown on Figure 1 of the phytoplankton and chlorophyll abundance in the upper San Francisco Estuary article of this issue. In addition to the fixed sites, two “floating stations”, located where the bottom electrical conductance was 2 and 6 mS/cm respectively, were sampled each month.

Abundance indices were calculated as the mean number per cubic meter of water filtered for each season and year and were based on data from all stations sampled since 1972 plus the “floating stations”. Spring is defined as March through May, summer as June through August, and fall as September through November.

Since its introduction in 1993, the cyclopoid copepod *Limnoithona tetraspina* has been numerically the most abundant copepod, having mean seasonal abundance > 7,000/m^3 (Figure 1). It is most abundant in Suisun Marsh, Suisun Bay, and the lower Sacramento River. In the spring and summer of 2003 its abundance remained essentially the same as in 2002; its fall abundance was approximately 72% as large as in fall 2002 (23,732 for 2002 and 17,068 for 2003). The long-term trends show that spring abundance peaked in 1998 and has been declining ever since. Summer abundance was stable until 2000, and then rose and remained high from 2001 to 2003. Fall abundance was stable and high from 1999 until 2003, when it dropped to about 70% of the mean for the previous 4 years (24,266 to 17,068).

Eurytemora affinis, an introduced calanoid copepod that has been in the estuary since before the start of monitoring, has declined in all seasons since 1972, especially in summer and fall (Figure 2). The decline became particularly steep in the late 1980s, probably due to competition for food and predation by the Asian clam, *Potamocorbula amurensis*. In contrast to summer and fall, the spring downtrend has been gradual and has shown a more gradual drop since the late 1980s. Summer abundance has increased from its all-time low in 1991, although 2003 abundance was lower than 2002. Fall abundance has oscillated widely since 1991 and was lower in 2003 than in 2002.

Pseudodiaptomus forbesi, an introduced calanoid copepod, entered the estuary in 1989 at about the time *Potamocorbula* became abundant in Suisun Marsh (Figure 2). There has been a strong and variable downtrend in *P. forbesi* in spring since the peak in 1992 and it has been less abundant than *Eurytemora* was in the 1970s. For summer and fall, the highest abundance occurred in 1989. The causes of the subsequent decline are unknown. *P. forbesi* summer and fall abundance has been generally about the same as *E. affinis* abundance was in the 1970s.

Several native species of the calanoid copepod, *Acartia*, enter Suisun Bay and the Delta from the lower bays. Because they are brackish water species that occur at the seaward end of the upper estuary, the abundance indices are strongly influenced by outflow. When outflow is high, the population center is located seaward of the sampling area, thus artificially reducing the abundance index. Prior to 1995, spring abundance was stable, with the exception of two dips coincident with dips in the mean electroconductivity of the seaward sampling stations (Figure 3). Summer and fall abundance declined prior to 1995. Abundance for all seasons has been generally increasing since 1995 as has the mean electroconductivity of the seaward sampling stations.

Acartiella sinensis is an introduced brackish water calanoid copepod that is most abundant in Suisun Bay. Its spring abundance has been very variable, with a sharp rise in 2002 after three years of very low abundance, followed by a small drop in 2003 (Figure 3). It has been more abundant in summer and fall than in spring.

The calanoid copepod genus *Acanthodiaptomus* (formerly *Diaptomus*) contains several native freshwater species. Its abundance has been lowest in fall and highest in summer. Spring abundance has been slowly declining since 1972. Summer and fall abundance declined sharply in the late 1970s and early 1980s (Figure 4). In 2003, spring and fall abundance declined to less than half of the values since 1998. Summer abundance, which declined from 1998 to 2002, increased slightly in 2003.

Sinocalanus doerrii is an introduced freshwater calanoid copepod that was most abundant in summer and fall in the early 1980s (Figure 4). Long-term declines occurred in these seasons, culminating in low points in the mid-1990s. Since then abundance has been increasing, with the greatest increase occurring in summer. Spring abundance has been variable and without a visible trend. Little change occurred in 2003 in any season.

Acanthocyclops (formerly *Cyclops*) contains several native freshwater cyclopoid species. It has experienced consistent downtrends in all seasons since the 1970s (Figure 5). Between 1989 and 1994 summer abundance was well below the long-term trend line. In 2003, abundance increased in spring, but declined in summer and fall relative to 2002.

The most abundant cladoceran genera in the upper estuary are *Bosmina*, *Daphnia*, and *Diaphanosoma*. They are all native freshwater genera that have shown downtrends since the early 1970s in all seasons, especially in fall (Figure 6). Summer abundance has stabilized since the late 1980s and may even be gradually increasing. Abundance increased slightly in 2003 for all seasons.

The native brackish water rotifer, *Synchaeta bicornis*, is most abundant in summer or fall (Figure 7). Its spring abundance pattern has been erratic, but declining, and its summer and fall abundance has shown a long-term decline since the late 1970s. None were collected in spring 2002 or 2003. Small increases in abundance occurred in summer and fall 2003.

Other rotifer species have also undergone long-term declines since the early 1970s (Figure 8), with the greatest declines in summer. Since about 2000, there has been a reversal of this trend.

The introduced mysid, *Acanthomysis bowmani*, has been much more abundant since its introduction in 1991 than *Neomysis mercedis,* but has not been as abundant as *N. mercedis* was in the 1970s through the mid-1980s (Figure 9). *A. bowmani* abundance increased rapidly in all seasons soon after its introduction. This increase tapered off through the mid- to late-1990s in all seasons and abundance has since declined in fall with only a slight upturn in 2003. Abundance was down in spring and summer of 2003 compared to 2002.

Prior to 1996, *N. kadiakensis*, a native mysid, occurred downstream from the upper estuary sampling area. It began appearing regularly in the macrozooplankton catches in 1996. Since 2001 *N. kadiakensis* has been the second most abundant mysid species in the upper estuary. It is most abundant in spring when its range extends almost into freshwater. Its abundance has been slowly increasing in all seasons but changed little in 2003 (Figure 9).

Prior to 1989, the native mysid shrimp, *N. mercedis*, was the only mysid species present in high numbers in the upper estuary. It suffered a population collapse in all seasons in 1989 (Figure 9) that was probably caused by predation and competition from Potamocorbula amurensis. No *N. mercedis* were taken in spring or fall 2003 and only a few in summer 2003. It is now the third most abundant mysid in the upper estuary.

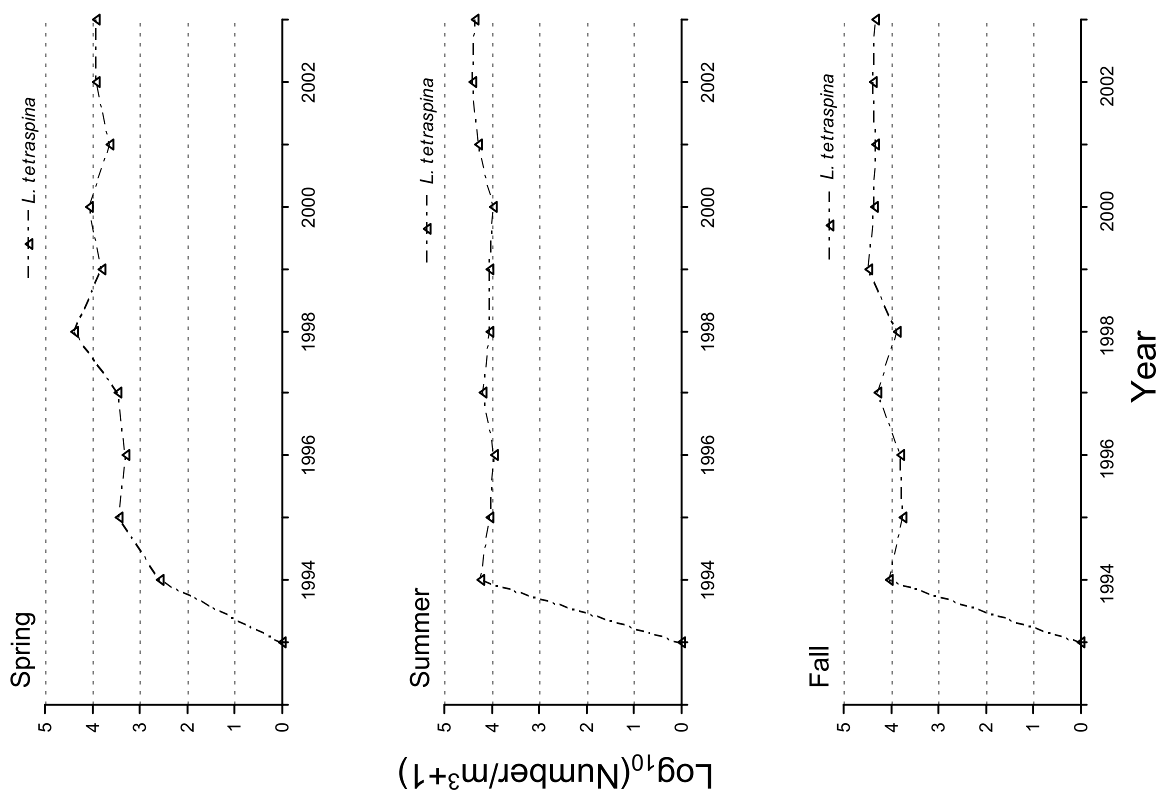

Figure 1 Log of mean abundance of *Limnoithona tetraspina* in spring, summer, and fall 1993-2003.

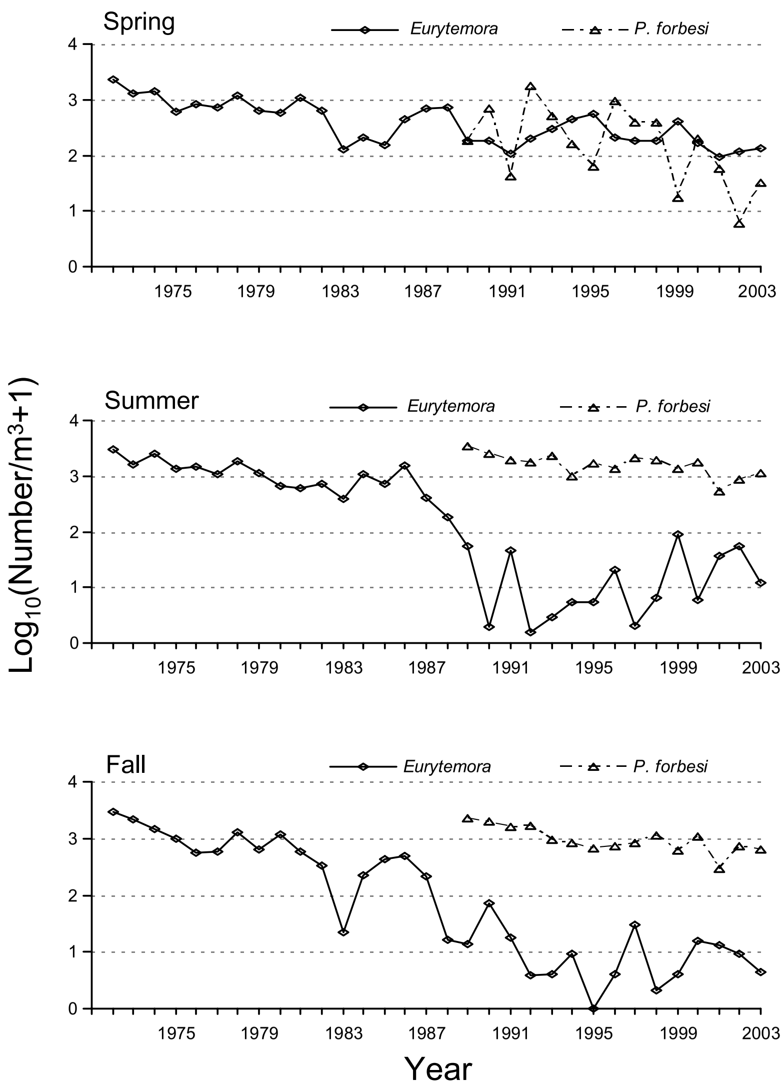

Figure 2 Log of mean abundance of ***Eurytemora affinis*** **and** ***Pseudodiaptomus forbesi*** **in spring, summer, and fall 1972-2003.**

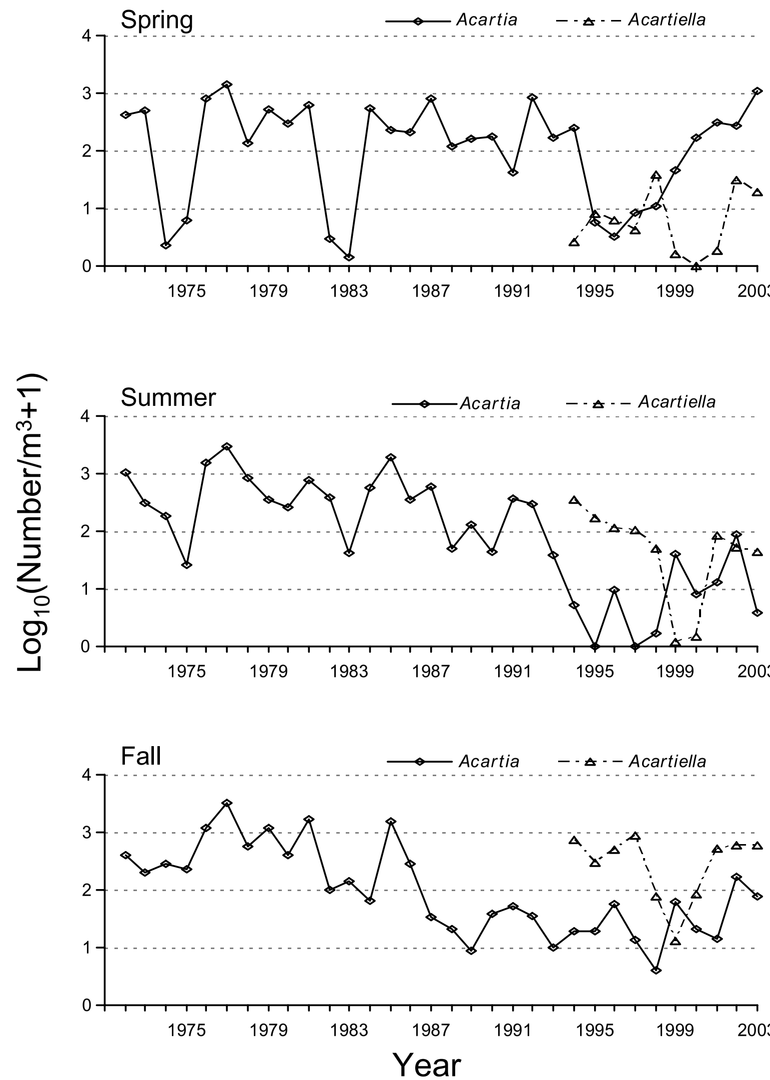

Figure 3 Log of mean abundance of ***Acartia*** **spp. and** ***Acartiella sinensis*** **in spring, summer, and fall 1972-2003.**

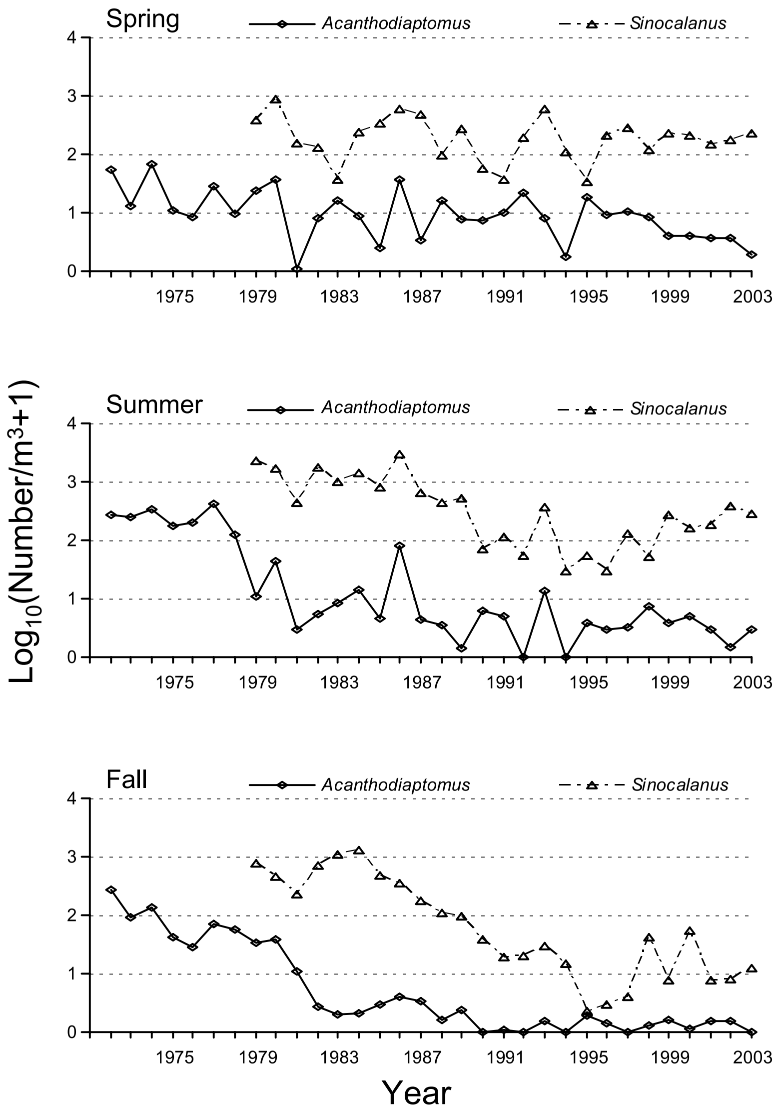

Figure 4 Log of mean abundance of *Acanthodiaptomus* (formerly *Diaptomus)* spp. and *Sinocalanus doerrii* in spring, summer, and fall 1972-2003.

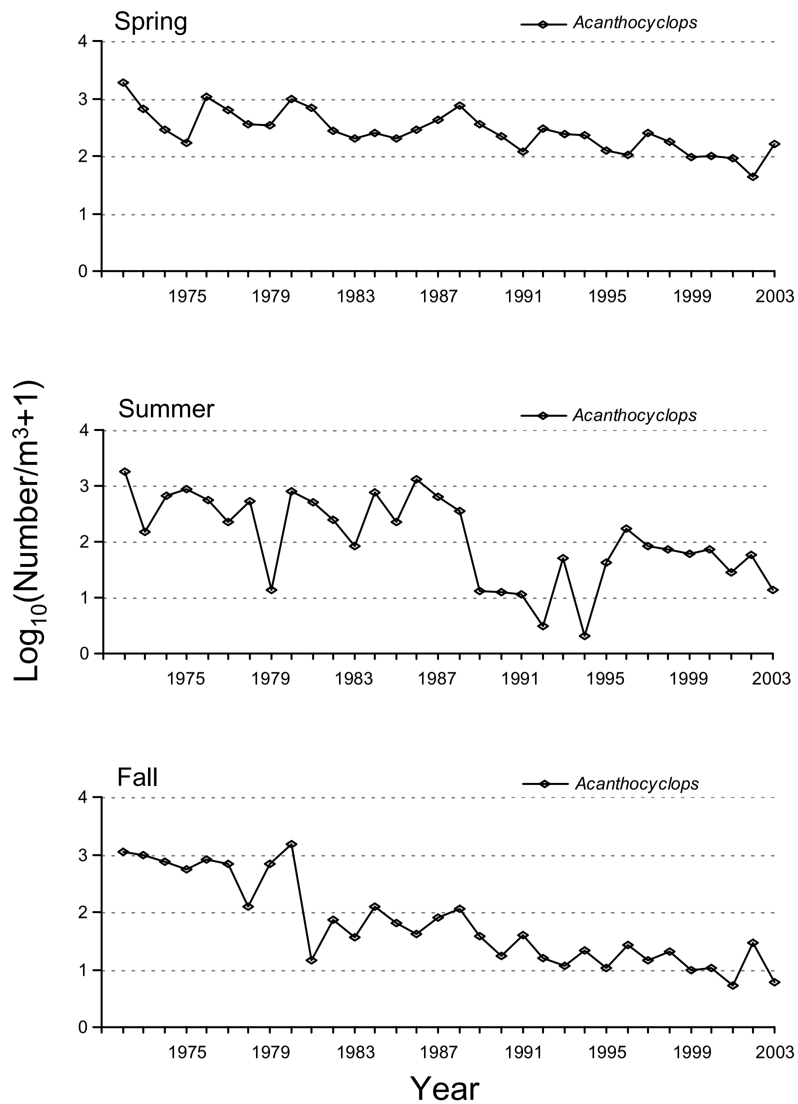

Figure 5 Log of mean abundance of *Acanthocyclops* spp. in spring, summer, and fall 1972-2003.

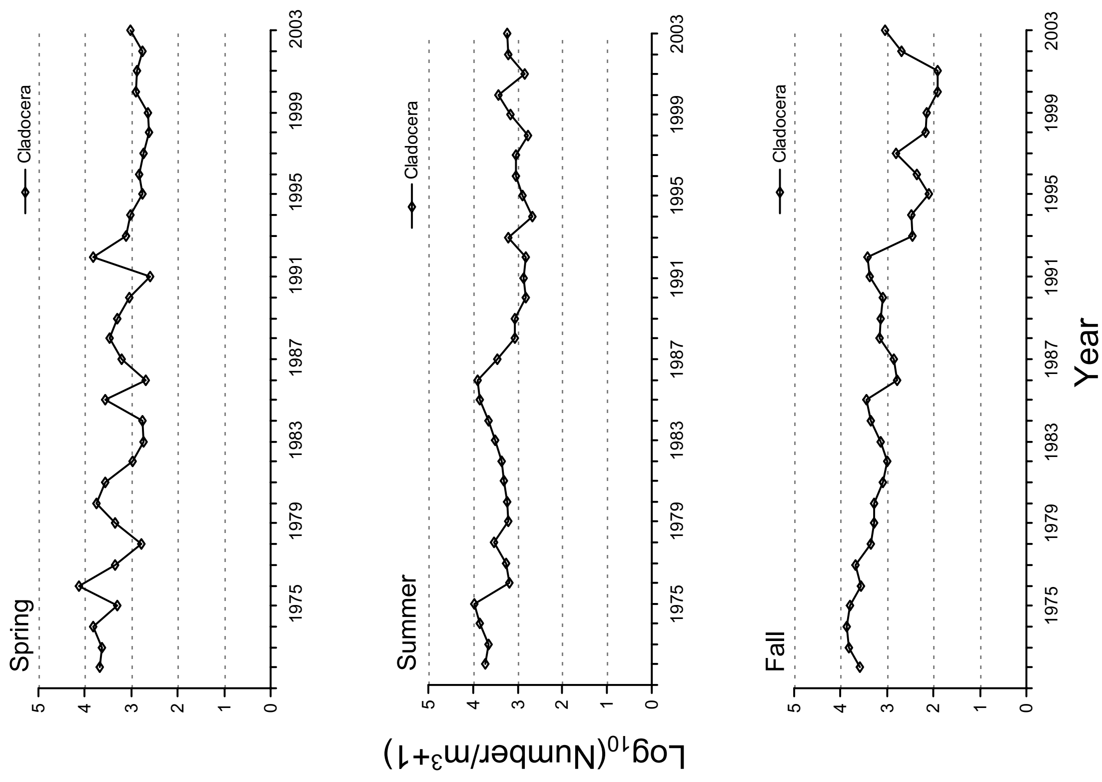

Figure 6 Log of mean abundance of Cladocera in spring, summer, and fall 1972-2003.

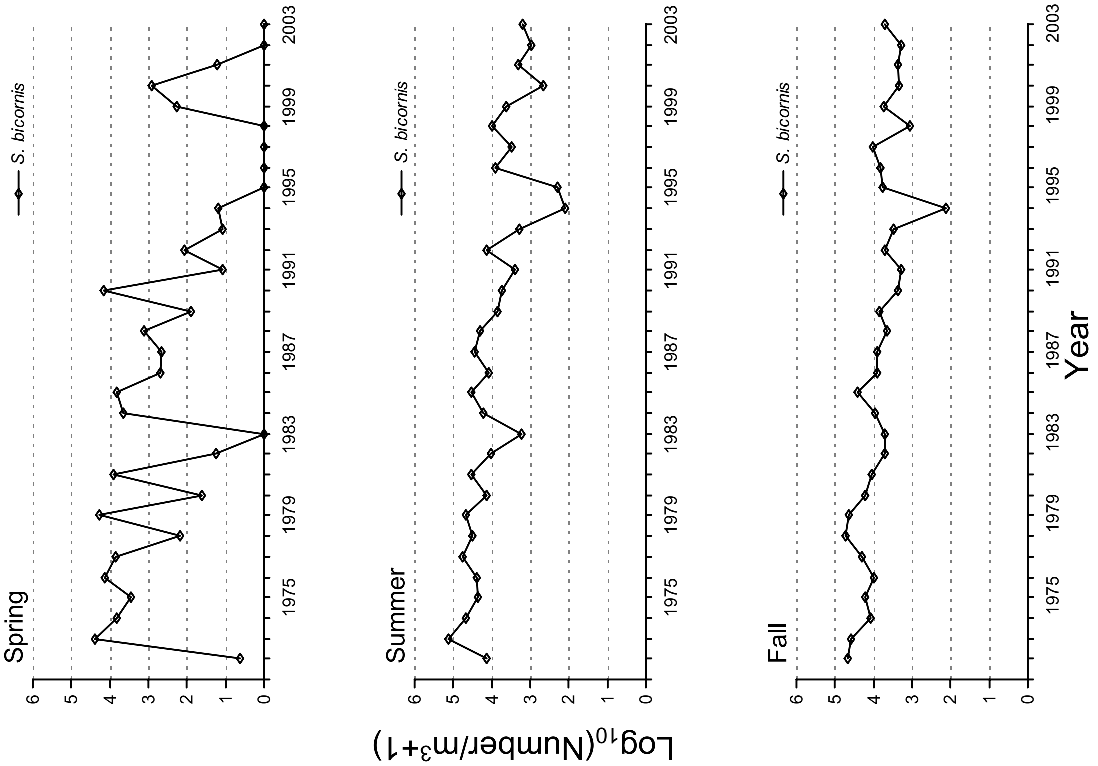

Figure 7 Log of mean abundance of *Synchaeta bicornis* in spring, summer, and fall 1972-2003.

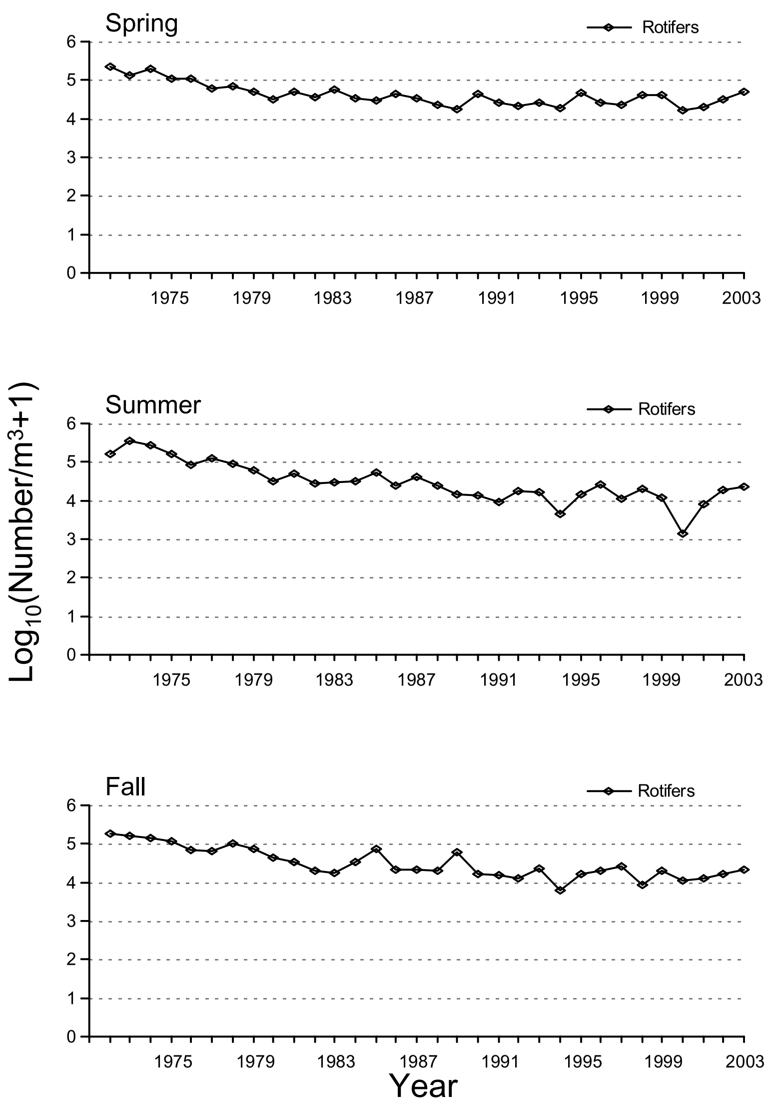

Figure 8 Log of mean abundance of rotifers other than *Synchaeta bicornis* in spring, summer, and fall 1972-2003.

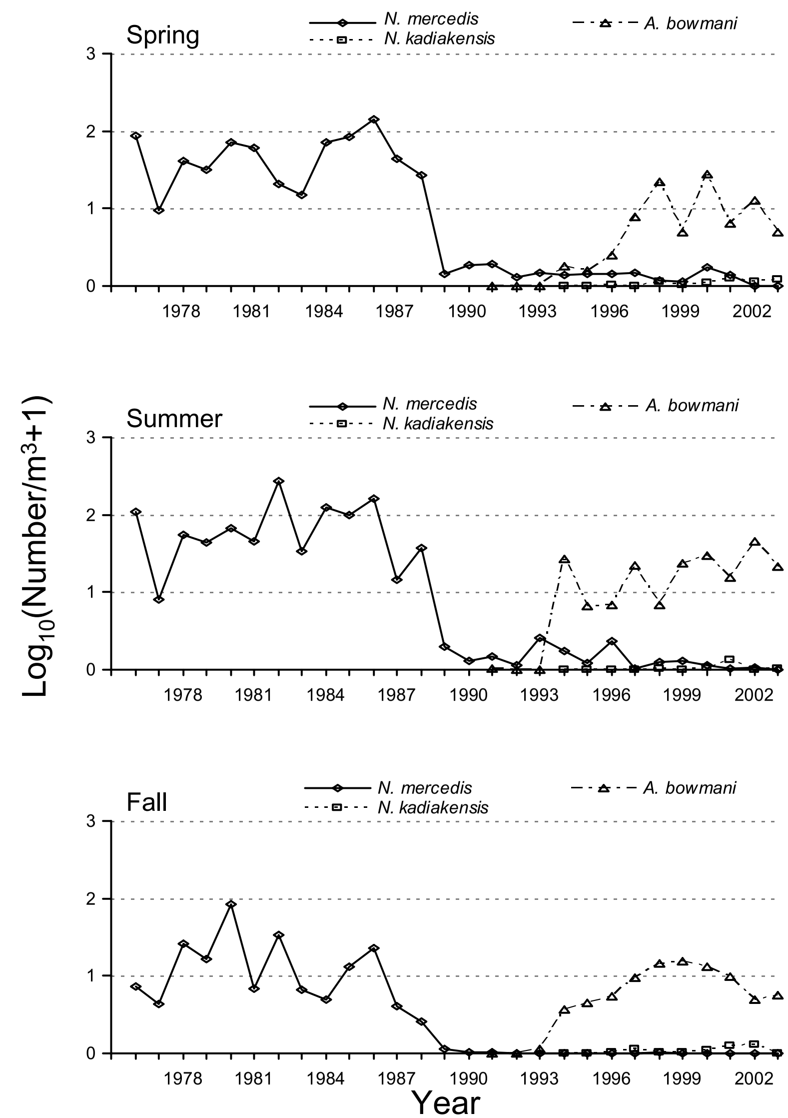

Figure 9 Log of mean abundance of *Neomysis mercedis*, *Acanthomysis bowmani*, and *Neomysis kadiakensis* in spring, summer, and fall 1968-2003.

Delta Juvenile Fish Monitoring Project

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Historically, the US Fish and Wildlife Service (USFWS), Stockton Office, has monitored the relative abundance and distribution of juvenile Chinook salmon (*Oncorhynchus tshawyscha*) in the lower Sacramento and San Joaquin rivers and Delta for the Interagency Ecological Program (IEP). In the early 1990s, the program expanded to monitor other juvenile fish species in the Delta.

All Species

For the reporting period of October 2003 through February 2004, the Delta Juvenile Fish Monitoring Project conducted sampling at more than 55 seine sites and trawled at three locations. Seine sites were distributed throughout the lower Sacramento River (upstream of river mile [RM] 60), San Joaquin River (upstream of RM 41), and Delta, with a few sites in the San Pablo and San Francisco bays. Trawling was conducted at Mossdale (San Joaquin River RM 54), Sherwood Harbor (Sacramento River RM 55), and Chipps Island (Suisun Bay RM 18). Typically, seine sites were sampled once per week and trawls were conducted three days per week. We collected 659 seine samples on the Sacramento River, 107 on the San Joaquin River, and 92 on San Pablo and San Francisco bays combined. We conducted 892 trawls at Chipps Island, 607 at Sherwood Harbor, and 560 at Mossdale. In all, we captured 141,277 fish comprised of 57 species.

During beach seining, 93,875 fish were captured: 26,327 from the Sacramento River, 47,110 from the Delta, 17,313 from the San Joaquin River, and 3,125 from San Pablo and San Francisco bays. Inland silversides (*Menidia beryllina*; n = 41,515), red shiners (*Cyprinella lutrensis*; n = 17,812), Chinook salmon (n = 13,947), and threadfin shad (*Dorosoma petenense;* n = 13,780) dominated the catch in the Sacramento and San Joaquin rivers and the Delta, while top smelt (*Atherinops affinis*; n = 3,021) dominated the catch in the bays. In addition, we captured 19 rainbow trout (*O. mykiss*), 11 Delta smelt (*Hypomesus transpacificus*), and 3 splittail (*Pogonichthys macrolepidotus*).

We captured 47,402 fish while trawling: 4,602 from the Sacramento River at Sherwood Harbor, 3,004 from the San Joaquin River at Mossdale, and 39,796 from Chipps Island. Chinook salmon (n = 3,894) and threadfin shad (n = 452) dominated the catch on the Sacramento River. On the San Joaquin River, inland silversides (n = 1,863) and threadfin shad (n = 987) were the most commonly captured species. At Chipps Island, longfin smelt (*Spirinchus thaleichthys*; n = 5,249), threadfin shad (n = 902), and Chinook salmon (n = 538) dominated the catch. In addition, we captured 74 splittail, 72 Delta smelt, and 72 unmarked rainbow trout at Chipps Island; 4 splittail at Mossdale; and 16 unmarked rainbow trout at Sherwood Harbor. Approximately 1,300 nonnative freshwater shrimp (*Exopalaemon modestus*) were also captured during trawling.

Juvenile Chinook Salmon

The majority (n = 13,832) of unmarked Chinook salmon were captured while beach seining. Most of these were captured in the Sacramento River (n = 6,909) and the Delta (n = 6,919). Three were captured in the San Joaquin River and one was captured in San Pablo Bay. We captured Chinook salmon beginning in November on the Sacramento River; the catch increased throughout December and peaked in January. Catch in February was similar to December.

Fewer (n = 3,901) Chinook salmon were captured while trawling. Nearly all of these were captured in the Sacramento River at Sherwood Harbor; only 81 were captured at other trawl sites (70 at Chipps Island and 11 in the San Joaquin River at Mossdale). We captured Chinook salmon throughout the sampling period; however, almost all Chinook salmon were captured from December through February. Catch of Chinook salmon peaked in February.

A relatively small number (n = 635) of marked (adipose fin-clipped) Chinook salmon were recovered during the sampling period; 537 were recovered trawling and 98 were recovered beach seining. Of the 537 marked Chinook salmon recovered while trawling, 469 were recovered at Chipps Island and 68 at Sherwood Harbor. Of the 98 marked Chinook salmon recovered while beach seining, 43 were recovered on the Sacramento River and 55 were recovered from the Delta.

Other Activities

In addition to our IEP sampling obligations, a number of other projects were conducted during the sampling period. In December, we released approximately 218,000 late-fall Chinook salmon (obtained from Coleman National Fish Hatchery) as part of the Delta Action 8 experiments. Also in December, we assisted the US Geological Survey with acoustic monitoring near Georgiana Slough. Throughout the sampling period, we continued to assess fish distribution and abundance at Liberty Island as part of an ongoing California Bay-Delta Authority project.

Summer Townet Survey and Fall Midwater Trawl Survey Status and Trends

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Young striped bass (*Morone saxatilis*) are indexed twice in their first year of life, first by the Summer Townet Survey (TNS) and later by the Fall Midwater Trawl Survey (FMWT). The 2 indices can be compared to each other and are used to evaluate age-0 population trends. The TNS is conducted annually to obtain an index of abundance for age-0 striped bass (the 38.1-mm Index) soon after their larval stage and to determine their distribution within the upper estuary. The FMWT, also conducted annually, evaluates abundance and distribution of age-0 striped bass several months after the 38.1-mm Index is determined. Each survey calculates an abundance index for delta smelt (*Hypomesus transpacificus*). The FMWT also calculates indices for longfin smelt (*Spirinchus thaleichthys*), American shad (*Alosa sapidissima*), and splittail (*Pogonichthys macrolepidotus*).

The TNS has been conducted since 1959, with the exception of 1966 when no boat was available for sampling. Exceptionally wet weather and a protracted spawning period resulted in no index for 1983 and an approximated index for 1995. An index was not set in 2002 due to record low catches, consistently small fish throughout the season, and boat breakdowns which left the survey incomplete. The FMWT survey has been running since 1967, with no sampling occurring in 1974 and 1979. The abundance indices have been used to follow age-0 striped bass population trends and to assess the effects of water management on striped bass recruitment.

The TNS begins in June and samples 32 sites from eastern San Pablo Bay to Rio Vista on the Sacramento River and to Stockton on the San Joaquin River. All sites are sampled during a five-day period. The survey is repeated at two-week intervals until the mean length of striped bass caught exceeds 38.1-mm. Sampling at each site consists of up to three 10-minute, stepped, oblique tows with a ski-mounted net. Each survey index is calculated by summing the catch at each station and multiplying by a weighting factor representing the amount of water (in acre-feet) at that station. The weighted catches are then summed and divided by 1,000, resulting in the survey index (Chadwick 1964). For the annual striped bass TNS index, the two surveys that bracket the period of time when striped bass reach a mean size of 38.1-mm fork length are log-transformed and the index is interpolated between the two surveys (Chadwick 1964; Turner and Chadwick 1972). The TNS delta smelt index is calculated by averaging the first two survey indices.

The FMWT survey samples 116 stations from San Pablo Bay east to Stockton on the San Joaquin River and to Hood on the Sacramento River. The index calculation (the same for all species) uses catch data from 100 of the 116 stations sampled monthly from September to December. The remaining 16 stations are used to increase the spatial coverage to track distribution of delta smelt. These stations are grouped into 14 areas. The mean monthly catch for each area is multiplied by a weighting factor representing the volume of water in that area. This value is summed for all areas to obtain a monthly index. The sum of the four monthly indices constitutes the annual FMWT abundance index.

The 2003 TNS completed six surveys from June 9 to August 22, 2003. The striped bass 38.1-mm Index was set on July 28, 2003, at 1.5 based on results from surveys 4 and 5 (Table 1). This is the second lowest index in the 45-year history of the survey (Figure 1). The lowest index was set in 1998 at 1.4 and the index has not been above 10 since 1994. These low indices show a severe decline from the historical indices, which peaked at 117 in 1965 (Figure 1). The FMWT striped bass index was 108, a slight increase (34%) from last year's index of 71; however, these indices were still the two lowest on record.

Table 1 Mean length, sample size, and survey indices for striped bass and delta smelt from townet surveys 1-6, 2003.

	Survey 1	*Survey 2*	*Survey 3*	*Survey 4*	*Survey 5*	*Survey 6*
Striped Bass						
Mean length (mm FL)	14.8	16.8	25.9	34.7	44.8	58.3
N	919	542	150	77	67	15
Survey index	16.3	14.3	3.4	1.5	1.5	0.3
Delta Smelt						
Mean length (mm FL)	29	33	41	40	47	47
N	40	47	91	53	55	52
Survey index	1.5	1.6	3.9	2.1	1.9	2.1

Few to no young striped bass were caught in the southern or eastern Delta during the TNS in 2003. The percentage of striped bass caught in Suisun Bay increased as the summer went on, while the percentages caught in Montezuma Slough and the San Joaquin River fluctuated throughout the summer (Table 2). This pattern was mimicked in the FMWT survey. Age-0 striped bass were detected in the eastern and southern Delta only in September. Suisun Bay and the Carquinez Strait area accounted for the largest percentage of the index in every month of the 2003 survey.

The 2003 delta smelt index was 1.6, the lowest since 1988 (Figure 2). This index is nearly a three-fold decrease from last year's index of 4.7. The total catch of delta smelt by survey increased after the index was set (Table 1). The overall trend in delta smelt indices from the TNS has been down over the last four years. The 2003 FMWT delta smelt index was 210, which is an increase from 2002 (139); however, the overall trend has been downward since 1999 and there are only 7 other years in which the delta smelt index was lower than 2003.

No delta smelt were caught in the southern or eastern Delta during the TNS. The majority of delta smelt were caught in Suisun Bay and the Sacramento River (Table 2). Few were caught in Montezuma Slough. The proportion of delta smelt caught in the Sacramento River decreased with each survey until survey six, when it jumped to 50%. These smelt likely shifted their distribution from Suisun Bay (Table 1). This shift in distribution of delta smelt continued after the TNS period, as evidenced by most delta smelt caught in the September FMWT survey coming from the Sacramento River; this distribution was maintained throughout the duration of the FMWT survey. The percentage of the FMWT delta smelt index from the lower Sacramento River never fell below 81% and very few smelt were collected within the southern or eastern Delta.

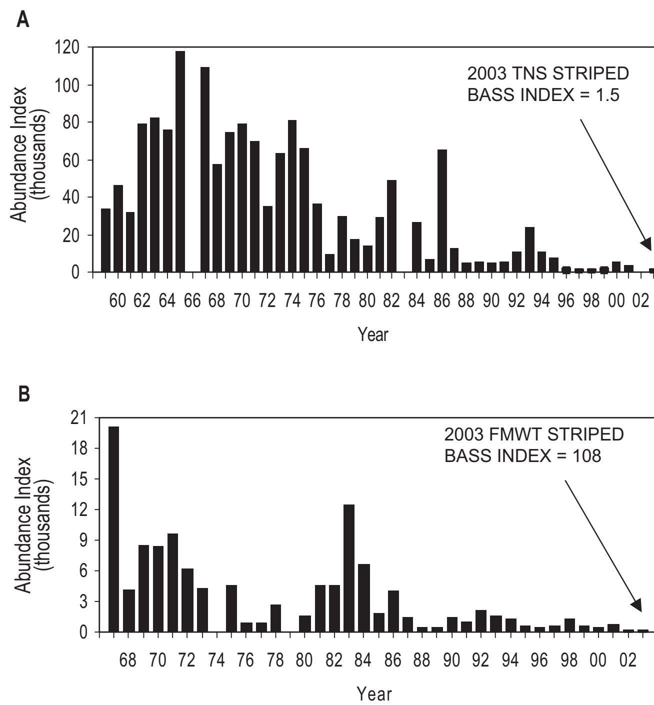

Figure 1 Age-0 striped bass abundance indices for (A) Summer Townet Survey, 1959-2003 (no sampling occurred in 1966, the index was invalid in 1983 due to high flows, and no index was calculated in 2002); and (B) Fall Midwater Trawl Survey, 1967-2003 (no sampling occurred in 1974 and 1979).

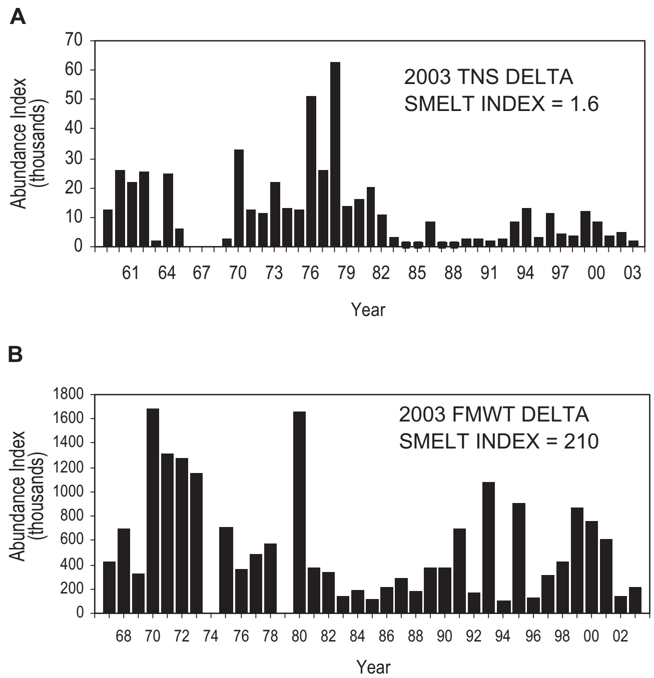

Figure 2 Delta smelt abundance indices for (A) Summer Townet Survey, 1959-2003 (no sampling occurred in 1966, and delta smelt were not enumerated in 1967-68); and (B) Fall Midwater Trawl Survey, 1967-2002 (no sampling occurred in 1974 and 1979).

The 2003 FMWT longfin smelt index was 191, a significant decrease from last year's index of 707 (Figure 3). There were only two other years in which the index was lower (1991 and 1992) and these coincided with the end of a protracted drought period. Longfin smelt distribution was centered within Suisun Bay in every month except December, when distribution shifted into the lower Sacramento River.

After a steady increase in annual abundance from the mid-1990s through 2001, threadfin shad abundance in 2003 was low for the second year in a row (Figure 4). Threadfin shad were captured entirely within the Delta.

The 2003 FMWT splittail indices were 6 (age-0), 3 (age 2+), and 9 (all ages combined.) No age-1 splittail were collected this year. Of the 12 fish that comprise the indices, 7 were collected in Montezuma Slough and the remainder in Grizzly Bay.

The majority of the annual indices of relative abundance calculated from these two long-term monitoring projects are decreasing, and many are at all-time lows (for example, TNS delta smelt, FMWT longfin smelt, and age-0 striped bass). With the exception of American shad abundance (Figure 5), which has been steadily increasing beyond historic levels, it is difficult to find any upward shift in fish abundance. The TNS and FMWT programs will continue to monitor whether or not these trends persist.

Table 2 Percentages of survey index by area for striped bass and delta smelt for townet surveys 1-6, 2003.

Species and Area	*Survey 1*	*Survey 2*	*Survey 3*	*Survey 4*	*Survey 5*	*Survey 6*
Striped Bass						
Montezuma Slough	62.0	12.0	30.0	46.0	27.0	23.0
Suisun Bay	14.9	21.0	32.0	33.0	45.0	52.0
Sacramento River	20.1	49.0	11.0	19.0	7.0	25.0
San Joaquin River	2.2	17.0	24.0	0.0	21.0	0.0
East Delta	0.5	1.0	3.0	1.0	0.0	0.0
South Delta	0.3	0.0	0.0	1.0	0.0	0.0
Delta Smelt						
Montezuma Slough	1.8	6.7	0.1	0.0	0.4	0.2
Suisun Bay	28.0	38.7	58.2	62.4	85.9	49.3
Sacramento River	58.3	44.7	38.3	37.6	13.7	50.5
San Joaquin River	11.9	9.9	3.4	0.0	0.0	0.0
East Delta	0.0	0.0	0.0	0.0	0.0	0.0
South Delta	0.0	0.0	0.0	0.0	0.0	0.0

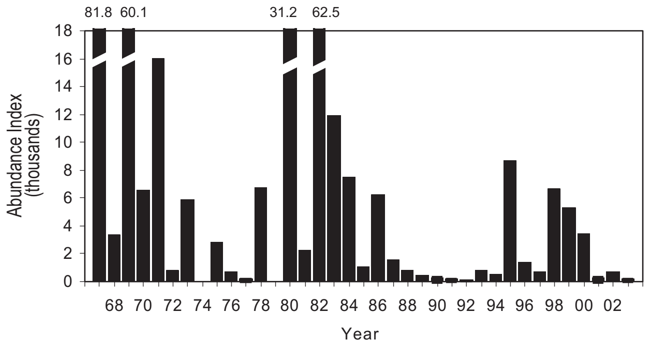

Figure 3 Longfin smelt abundance indices for Fall Midwater Trawl Survey, 1967-2003 (no sampling occurred in 1974 and 1979).

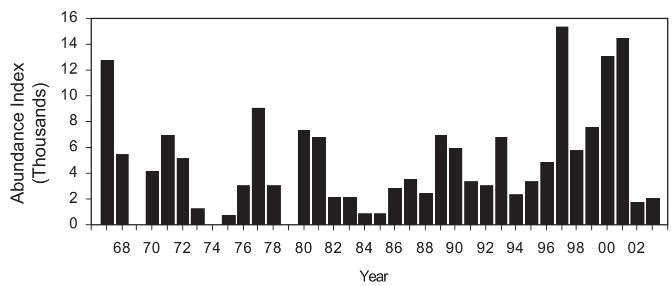

Figure 4 Threadfin shad abundance indices for Fall Midwater Trawl Survey, 1967-2003 (no sampling occurred in 1974 and 1979).

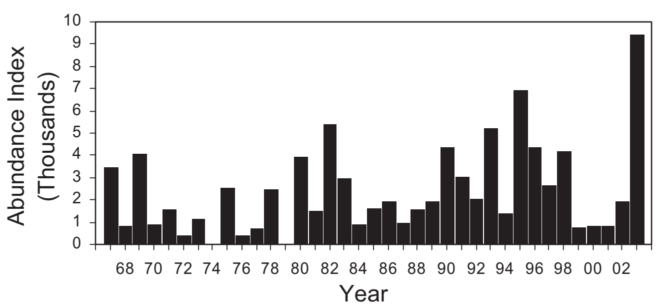

Figure 5 American shad abundance indices for Fall Midwater Trawl Survey, 1967-2003 (no sampling occurred in 1974 and 1979).

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San Francisco Bay Species: 2003 Status and Trends Report

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Annual abundance trends from 1980-2003 and distributional patterns for 2003 are summarized in this article for the most commonly collected crabs and fishes from San Francisco Estuary. Shrimp abundance trends are summarized from 1980-2002 for 6 species, as the 2003 shrimp samples were not processed by March 2004. Summary life history information for most of these species was presented in the 1997 Status and Trends reports (DeLeón 1998 and Hieb 1998); additional life history information and methods of abundance index calculation can be found in IEP Technical Report 63 (Orsi 1999).

Freshwater outflow and ocean conditions, including temperature, nearshore surface currents, and upwelling, are four of the most important physical factors controlling abundance and distribution of species in the estuary, especially downstream of the Delta. Water year 2003 was classified as “Above Normal”, after two consecutive “Dry” water years. The January-May average daily outflow was 32,146 cfs, compared to 16,024 cfs in 2001 and 18,643 cfs in 2002. However, March 2003 outflow was lower than either March 2001 or 2002, with an average daily outflow of only 15,761 cfs. In 2003, there were 2 outflow peaks, one in February and another in April.

Sea surface temperatures (SSTs) in the Gulf of the Farallones have generally been below average since 1999, when the ocean climate regime shifted from warm to cool along the west coast (Peterson and Schwing 2003). However, winter 2002-2003 SSTs were approximately 0.5 °C warmer than the long-term (1925-2002) monthly means.

Southerly winds from winter storms drive the winter nearshore surface currents, and in winters with frequent storms, such as 2002-2003, the nearshore surface flow is northward (Davidson Current) and onshore (Coriolis effect). Winter 2002-2003 upwelling indices for the coastal area near the San Francisco Bay were negative, which is also indicative of northward and onshore movement of surface water. Summer upwelling indices were well above average in 2003, continuing the trend of strong summer upwelling since 1999, when the ocean climate regime shifted.

The estuary's physical setting in 2003 was similar to 1999 and 2000, with above average outflow, strong summer upwelling, and a moderate northward surface current in winter (Davidson Current). Although winter SSTs were slightly warmer in 2002-2003 than in recent years, it was the 5th winter of the cool ocean regime. The San Francisco Estuary is situated between 2 major faunal regions, the cold-temperature fauna of the Pacific Northwest and the subtropical fauna of southern and Baja California, and as such is a transitional area with elements of both faunas (Parrish and others 1981). A cool ocean regime is hypothesized to benefit cold-temperate species, including many of the rockfishes, lingcod, cabezon, English sole, and starry flounder.

The 2002 abundance index of juvenile *Crangon franciscorum,* the California bay shrimp, was almost identical to the 2001 index (Figure 1). Spring 2002 freshwater outflow was almost identical to 2001, continuing the trend of lower indices in years with lower outflow. The relationship between juvenile *C. franciscorum* abundance and March-May outflow remains strongly positive (both variables log transformed, $R^2 = 0.547$, $n = 23$). Since *C. franciscorum* rears in shallow brackish areas of the estuary, this relationship has been hypothesized to be partially due to changes in the area of low-salinity shoal habitat, which decreases in low outflow years. Based on the total (all sizes) *C. franciscorum* index, it was again the 2nd most common shrimp species collected in the estuary in 2002 (Table 1). However, over the entire study period *C. franciscorum* has been the most common shrimp species collected.

Distribution of *C. franciscorum* in 2002 was almost identical to 2001, with shrimp collected from South Bay to the lower Sacramento River near Rio Vista and the lower San Joaquin River to Santa Clara Shoal. In spring and summer, the highest catches were from our stations near the Dumbarton and San Mateo bridges in south Bay and from upper San Pablo Bay to Honker Bay. As salinities increased over summer, the center of distribution moved upstream, and by fall, the highest catches were from Suisun Bay to the lower Sacramento River.

The abundance of *Crangon nigricauda*, the blacktail bay shrimp, increased almost 250% in 2002 from 2001 (Table 1), resulting in 3 consecutive years of increasing indices. It was also the highest individual shrimp species annual index and resulted in the highest all species shrimp annual index for the study period.

At this time, we do not understand why the *C. nigricauda* index increased to these record highs. This abundance trend is shared with several estuarine demersal fishes, including the bay goby, staghorn sculpin, plainfin midshipman, English sole, and speckled sanddab (see below). These species have varying reproductive strategies, as some spawn in the ocean and others in the estuary. All rear in polyhaline (18-30 ppt) areas of the estuary and, although common in estuaries along the Pacific coast, are not estuary-dependent. Note that *C. nigricauda* catches decreased substantially in November and December 2002 and preliminary data indicates that the 2003 index decreased. *C. nigricauda* rears in cooler, higher salinity water than *C. franciscorum* and was collected from South to Honker bays in 2002, with the highest catches at our Central Bay and lower San Pablo Bay channel stations from March to August. Catches were also high at several South Bay shoal stations in April and May.

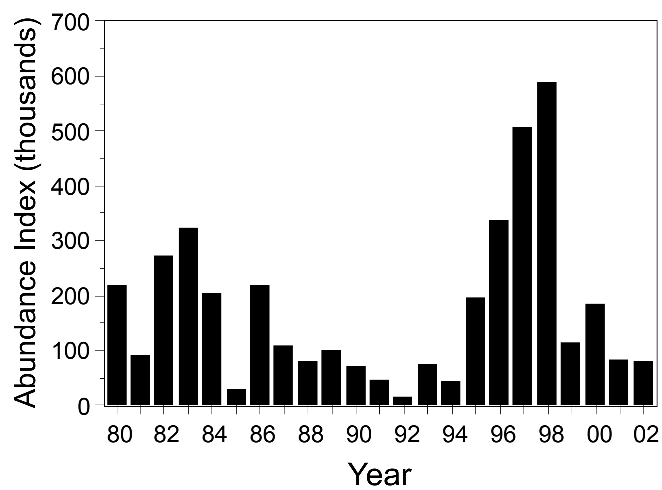

Figure 1 Annual abundance of juvenile *Crangon franciscorum*, May-October, otter trawl.

Table 1 Annual abundance indices (thousands) of the 5 most common shrimp species and all shrimp species combined, February-October, otter trawl. The indices include all sizes (juveniles and adults) for each species.

Year	*C. franciscorum*	*C. nigricauda*	*C. nigromaculata*	*Heptacarpus*	*Palaemon*	*All species*
1980	225.7	53.5	2.7	3.2	4.7	289.8
1981	119.2	22.1	0.5	0.5	5.1	147.3
1982	366.2	16.0	1.4	0.2	3.0	386.8
1983	328.3	38.8	16.0	0.6	1.3	385.0
1984	330.8	14.7	7.8	3.1	7.0	366.2
1985	57.8	19.7	3.1	3.1	3.9	88.3
1986	258.5	55.6	6.7	2.9	5.5	334.6
1987	142.9	75.5	9.6	6.8	2.4	239.0
1988	98.6	111.8	10.7	8.6	1.7	231.5
1989	100.2	118.6	22.1	27.4	4.6	273.1
1990	67.3	168.6	44.8	19.9	3.5	304.7
1991	51.4	190.3	63.0	41.1	4.7	350.7
1992	24.8	134.6	66.4	18.5	4.6	249.1
1993	70.5	128.0	78.6	25.4	4.0	308.3
1994	48.0	102.0	56.0	15.9	2.1	224.5
1995	180.6	78.8	33.1	4.3	3.7	302.3
1996	286.9	159.3	35.3	14.9	2.2	501.2
1997	444.4	163.9	43.4	9.1	4.9	668.0
1998	539.0	128.5	53.1	4.8	9.0	737.5
1999	159.5	134.6	42.0	13.2	4.1	354.2
2000	157.3	242.6	20.7	42.2	3.1	467.5
2001	92.9	259.6	12.0	56.6	5.2	427.0
2002	96.1	652.7	15.0	78.0	4.9	848.9

The abundance index of *Crangon nigromaculata*, the blackspotted bay shrimp, increased slightly in 2002, but was the 2nd lowest index since 1988 (Table 1). This species is found in cooler, higher salinity water than either *C. franciscorum* or *C. nigricauda* and is the most common species collected in the nearshore ocean area adjacent to the estuary (SFPUC 2003). In 2002, it was collected from South Bay to Carquinez Strait with the highest catches at 2 channel stations near Angel Island in Central Bay.

In 2002, abundance of *Heptacarpus stimpsoni,* the Stimpson coastal shrimp, again increased (Table 1); as for *C. nigricauda*, it has had 3 consecutive years of record high indices. *H. stimpsoni* was collected from South Bay to Carquinez Strait in 2002, with the highest catches at the Treasure Island station in Central Bay and several channel stations scattered throughout South, Central, and lower San Pablo bays.

We first collected *Exopalaemon modestus,* the introduced Siberian freshwater shrimp, in fall 2000 in the lower Sacramento River. We collected only 3 in 2000, all from lower Sacramento and San Joaquin river stations. In 2001, we collected a total of 2,164 *E. modestus*, with 2,141 from our river stations, and in 2002 we collected 9,929, of which 9,242 were from these same stations. Although we do not yet have abundance data from 2003, there is distributional information available from this and other studies indicating a continued expansion of range. Distribution expanded slightly downstream in 2003, as we observed a few *E. modestus* in San Pablo Bay. In 2003, the distribution of *E. modestus* ranged from San Pablo Bay to near Knights Landing on the Sacramento River and to Mud Slough, a tributary of the San Joaquin River in northern Merced County. Based on information from several sources, abundance continued to be highest in Suisun Marsh, the lower Sacramento River, Liberty Island, and the Yolo Bypass in 2003. As this species is widespread in the upper estuary and portions of the watershed upstream of tidal influence, IEP does not adequately sample its entire range with existing monitoring programs.

Abundance of *Palaemon macrodactylus*, the introduced oriental shrimp, decreased slightly in 2002 (Table 1) and it remained a minor component of our total shrimp catch. As this species prefers structured shallow water habitats, such as vegetation and pilings, it is more common in the estuary than our sampling indicates. In 2002, *P. macrodactylus* was most common in South Bay, near the Dumbarton Bridge, and from Carquinez Strait to the channel near Pittsburg. But it was uncommon at our lower Sacramento River stations in 2002, with only 23 collected here (0.9% of the total catch upstream of San Pablo Bay). In 2001, we collected 400 *P. macrodactylus* at these same stations (10.9% of the total catch upstream of San Pablo Bay). *Exopalaemon modestus* was the dominant shrimp species in the lower Sacramento River in 2002, with almost 8,700 collected. As both *E. modestus* and *P. macrodactylus* rear in shallow areas with vegetation or structure, *P. macrodactylus* abundance possibly decreased locally due to competitive interactions with or predation by *E. modestus.* In contrast, *C. franciscorum* catches at our lower Sacramento River stations increased in 2002 from 2001, probably because of slightly higher salinities in 2002. *C. franciscorum* reproduces far downstream of the Delta and rears over mud and silt substrates, rather than in shallow vegetated areas.

The 2003 abundance index of age-0 *Cancer magister*, the Dungeness crab, increased from 2002 and was the 3rd highest index for the study period (Table 2). It was also the 3rd consecutive year of high indices in the estuary. This relatively high index was likely due to winter 2002-2003 ocean conditions that again resulted in strong *C. magister* recruitment. Although SSTs increased slightly in winter 2002-2003, nearshore temperatures were cool compared to the strong El Niño years of the 1980s and 1990s. Also, the Davidson Current was moderate when compared to years with very frequent winter storms, such as 1982, 1983, 1995, and 1998. Relatively cool SSTs and a moderate or weak northward Davidson Current are hypothesized to result in increased survival and retention of *C. magister* larvae in the Gulf of the Farallones, which leads to increased nearshore settlement of juvenile crabs.

In 2003, age-0 *C. magister* were first collected in April, with most immigrating to the estuary in May. They moved upstream over the next several months, and by July were common in upper San Pablo Bay and Carquinez Strait. Our catches at the Alcatraz Island and other Central Bay stations were also high through summer, a pattern observed in other recent years with high abundance, particularly in 1999, 2000, and 2002. These crabs were smaller than those collected in San Pablo Bay and Carquinez Strait, and are believed to be crabs that had reared in the ocean for their first several months.

Abundance of age-0 *Cancer gracilis,* the slender crab, declined in 2003 from 2002, (Table 2) but continued the trend of higher indices since the early 1990s. Although *C. gracilis* were collected from South Bay to lower San Pablo Bay in 2003, approximately 76% of the age-0 crabs was collected at the Treasure Island, Angel Island, and Raccoon Strait stations in Central Bay.

Table 2 Annual abundance indices of age-0 *Cancer* crabs from the otter trawl. The index period is May-July for *C. magister*, May-October for all other species.

Year	*C. magister*	*C. gracilis*	*C. antennarius*	*C. productus*
1980	52	17	102	0
1981	94	152	76	9
1982	268	87	0	4
1983	0	151	28	4
1984	2884	154	50	41
1985	3072	220	20	38
1986	5	59	0	89
1987	194	93	61	79
1988	11578	223	21	138
1989	263	204	29	30
1990	31	159	112	160
1991	796	656	171	132
1992	0	371	60	62
1993	54	616	398	71
1994	1097	1016	603	166
1995	58	227	367	40
1996	66	411	1126	198
1997	907	1131	351	86
1998	0	1624	718	149
1999	2862	221	89	249
2000	2176	251	849	93
2001	10700	1906	276	142
2002	5215	796	119	238
2003	8006	495	425	139

The 2 rock crabs—*Cancer antennarius*, the brown rock crab, and *Cancer productus*, the red rock crab—are usually less common than either *C. magister* or *C. gracilis* in our trawls. Since both species prefer protected areas, such as rocky substrates and pilings, low catches in a trawl survey are expected. The 2003 age-0 *C. antennarius* index increased from 2002, while the age-0 *C. productus* index decreased (Table 2), but both indices were above the 1980-2002 averages. As observed for *C. gracilis*, both rock crabs have a trend of higher indices since the early 1990s. In 2003, age-0 *C. antennarius* were again collected from South to San Pablo bays, but were most common at shoal stations near San Leandro in South Bay north to the Berkeley Flats in Central Bay. Almost 50% was collected at the Alameda shoal station, which is not used to calculate the index reported here. Age-0 *C. productus* were also collected from South to San Pablo bays, but were most common at Central Bay channel stations. In 2003, approximately 50% was collected at the Alcatraz Island station.

The 2003 age-0 brown smoothhound (*Mustelus henlei*) abundance index declined by 86% from 2002 and was the lowest since 2000 and the 4th lowest of the study period (Figure 2). Indices tended to be higher in low outflow years, such as 2002. We collected brown smoothhound monthly, with the exception of July, at stations throughout south, central, and lower San Pablo bays.

In 2003, the age-0 Pacific herring (*Clupea pallasii*) abundance index decreased to 56% of the 2002 index, and was only slightly greater than either the 2000 or 2001 indices (Figure 3). In March, a few age-0 fish were collected in South Bay south of the Dumbarton Bridge and San Pablo Bay near Pinole Point. By April, age-0 fish were collected throughout most of South, Central, and San Pablo bays. The single largest catch in 2003, 13% of all age-0 fish collected, was at the Southampton Shoal station in Central Bay in April. After April, most age-0 fish moved from the shoals and were collected in the channels of South, Central, and San Pablo bays. From May to September, an increasingly large proportion of the fish was collected from Central Bay channel stations. By October, collection declined to a few dozen fish, as most age-0 Pacific herring emigrated from the estuary.

The 2003 northern anchovy (*Engraulis mordax*) abundance index was almost identical to the 2002 index, but was the 3rd lowest since 1990 (Figure 4). Our 2003 monthly indices for April and October were only 2% and 8%, respectively, of their historic averages. This abundance decrease of northern anchovy, a warm-subtropical species, may be due to a southward migration along the coast of the subpopulation normally found in the estuary in response to the cool ocean regime. We collected northern anchovy from South Bay to Suisun Bay, near Port Chicago. Sporadic large collections were made from May through September from stations near Hayward in South Bay to Point San Pablo in San Pablo Bay.

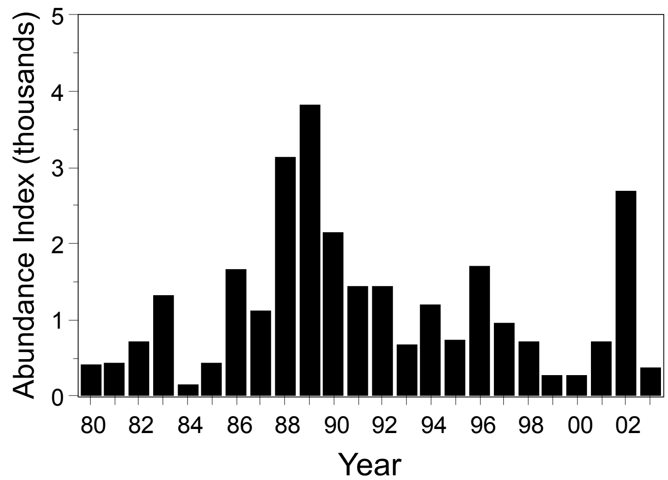

Figure 2 Annual abundance of age-0 brown smoothhound, April-October, otter trawl.

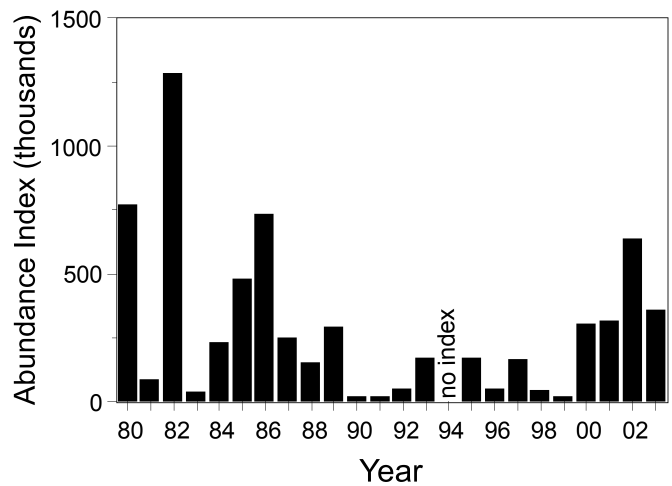

Figure 3 Annual abundance of age-0 Pacific herring, April-September, midwater trawl.

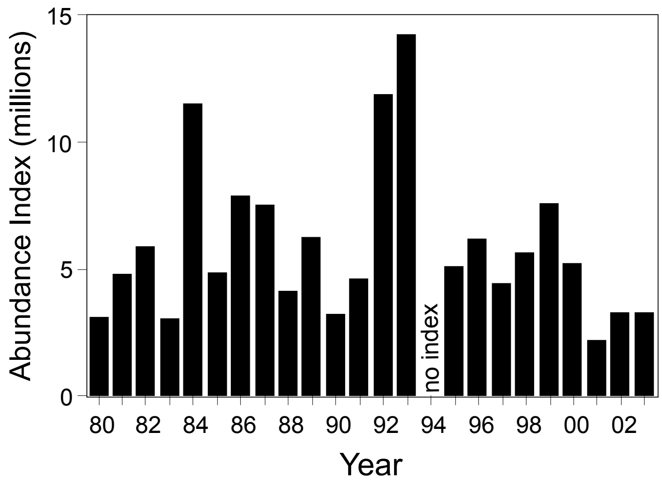

Figure 4 Annual abundance of northern anchovy (all sizes), April-October, midwater trawl.

The 2003 age-0 longfin smelt (*Spirinchus thaleichthys*) abundance indices decreased from 2002 for both the midwater trawl (Figure 5A) and the otter trawl (Figure 5B). The decrease in the midwater trawl index was the 5th consecutive year of decline and also the 2nd lowest index for the study period. The 2003 otter trawl index was 22% of the previous year and the 2nd lowest index in 9 years. Age-0 longfin smelt were so uncommon in the midwater trawl in 2003 (n = 38) that distributional trends were difficult to discern. They were sporadically collected from San Pablo Bay to the lower Sacramento River, with a slow movement upstream through fall. In contrast, the otter trawl collected age-0 fish from South Bay to the lower Sacramento River. The largest single catch occurred at our Treasure Island station in May. From May to July, age-0 longfin smelt were collected from Central to Suisun bays, but from August to October, they were collected only in Central and Suisun bays. In November and December, catches increased and distribution broadened, and age-0 fish were collected from the South Bay to the lower Sacramento River.

Although the 2003 age-0 plainfin midshipman (*Porichthys notatus*) index declined from 2002, it was the 2nd highest index for the study period and the 3rd consecutive year of high indices (Figure 6). Age-0 midshipmen were collected from South Bay to Suisun Bay in 2003, with distribution broadest in August. Overall, they were most common at Central Bay channel stations, with 77% of our total 2003 catch from these stations.

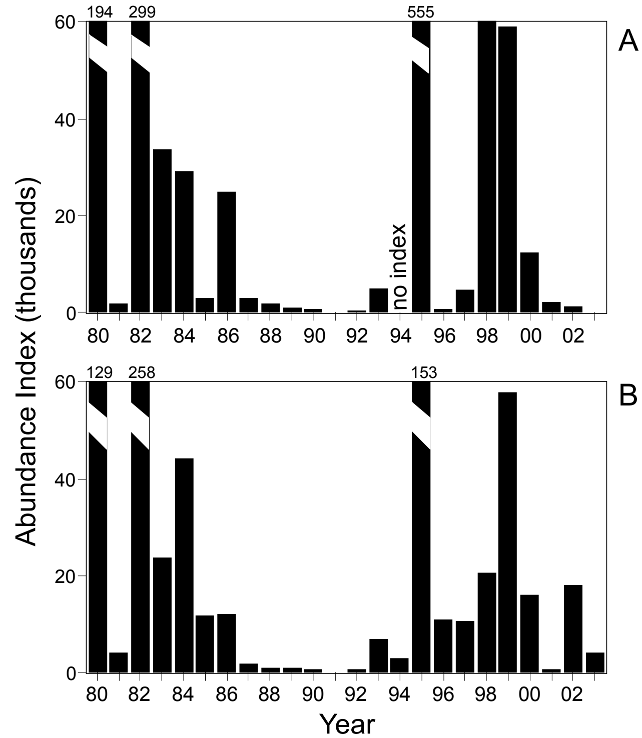

Figure 5 Annual abundance of age-0 longfin smelt, May-October: (A) midwater trawl, (B) otter trawl.

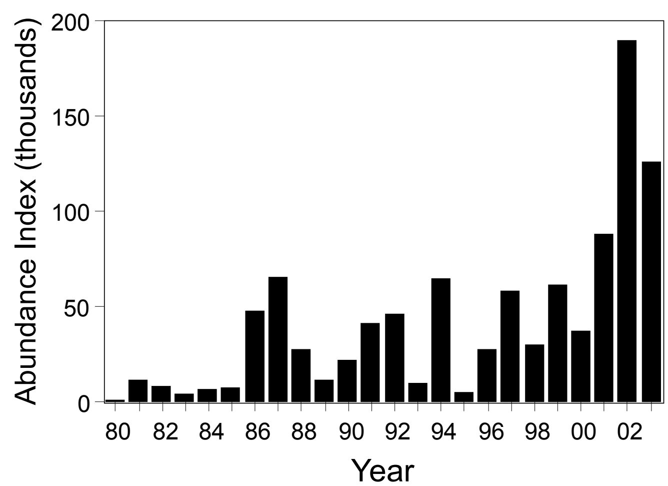

Figure 6 Annual abundance of age-0 plainfin midshipman, June-October, otter trawl.

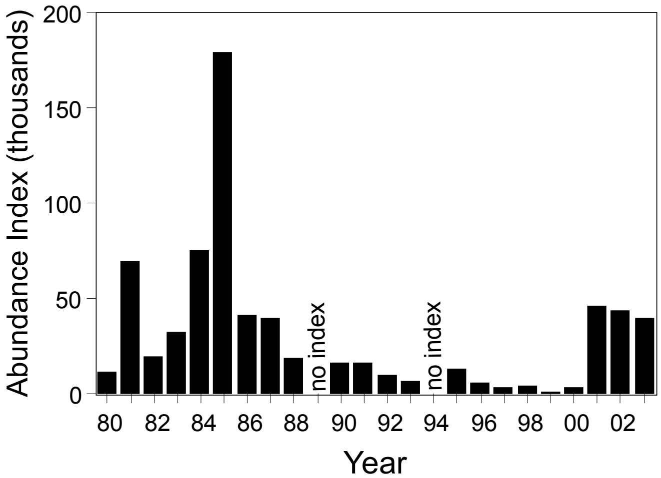

Figure 7 Annual abundance of age-0 jacksmelt, July-October, midwater trawl.

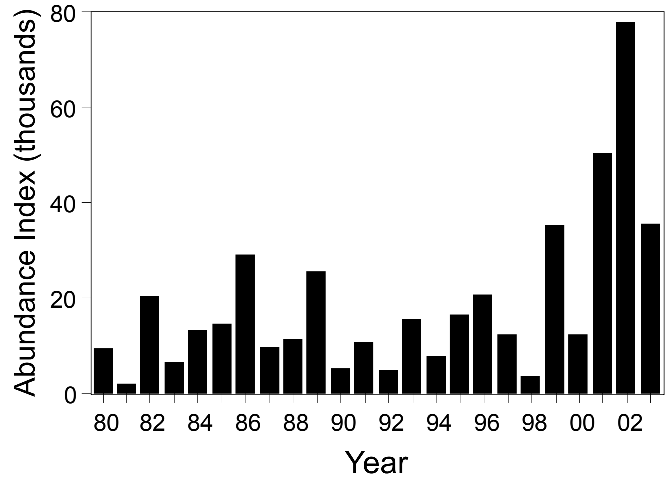

Figure 8 Annual abundance of age-0 staghorn sculpin, February-September, otter trawl.

Age-0 jacksmelt (*Atherinopsis californensis*) abundance was slightly lower in 2003 than in either 2002 or 2001, but was still the 8th highest for the period of record (Figure 7). Juvenile jacksmelt rear in shallow areas (< 2 m) of South, Central, and San Pablo bays; after growing to about 50 mm total length (TL) they begin to migrate to deeper water, where they are vulnerable to our gear. In 2003 more than 96% of age-0 jacksmelt was collected between July and October and by November, most had emigrated to the ocean. We collected age-0 jacksmelt from lower South Bay to mid San Pablo Bay.

The 2003 age-0 Pacific staghorn sculpin (*Leptocottus armatus*) abundance index decreased to 46% of the 2002 index, yet remained the 3rd highest index for the study period (Figure 8). During 2003, Pacific staghorn sculpin were collected at nearly every station from South through Suisun bays, and 1 fish was collected near Rio Vista on the lower Sacramento River. However, the majority of fish (79%) were collected from Central Bay. There was also a distinct movement from shoals to the channel with growth, as most age-0 fish were collected at shoal stations in April and May and by July most were collected from channel stations.

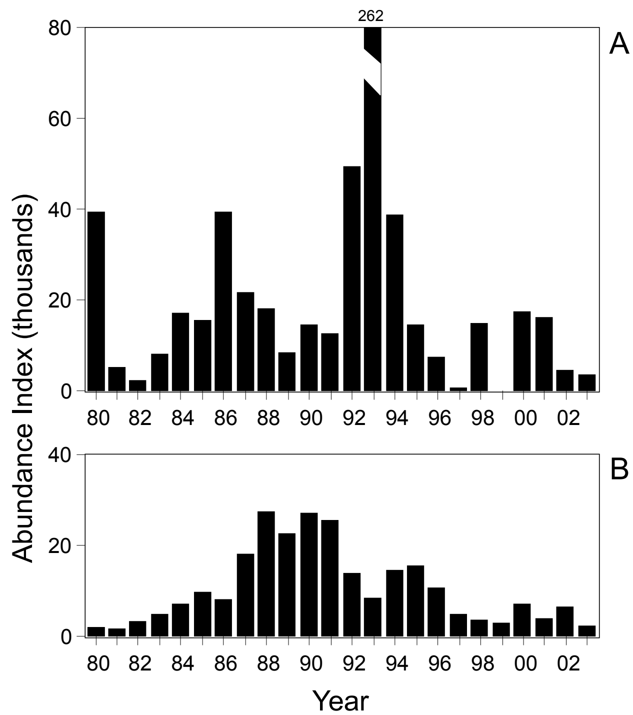

Figure 9 Annual abundance of white croaker, February-October, otter trawl: (A) age-0, (B) age-1+.

The 2003 age-0 white croaker (*Genyonemus lineatus*) abundance index decreased by about 18% from 2002 and was the 4th lowest index for the study period (Figure 9A). The age-1+ index also decreased and was the lowest since 1981 (Figure 9B). White croaker is a warm subtropical marine species. As such, age-0 abundance in San Francisco Estuary was related positively to elevated ocean temperatures, while age-1+ abundance was highest during the 1987-

1992 drought, when salinities were high and relatively stable year-round in the estuary. Age-0 and age-1+ white croaker were collected year-round throughout South, Central, and San Pablo bays upstream to Carquinez Strait and were most abundant from May to July. The majority of white croaker immigrated to Central Bay from the ocean by May and returned to the ocean by November.

We have observed 3 trends in the abundance of the 7 most common surfperch species of San Francisco Estuary: (1) five of the 6 surfperch species that declined precipitously during the late 1980s and early 1990s have increased in abundance during recent years; (2) one species, pile perch, has shown no sign of recovery; and (3) one species, black perch, did not show an abundance decline.

The 5 species that have shown some abundance increase in recent years are discussed in order of strongest to weakest recovery: walleye surfperch, shiner perch, white seaperch, barred surfperch, and dwarf perch. Age-0 walleye surfperch (*Hyperprosopon argenteum*) abundance increased by approximately 50% in 2003 from 2002, and was the 4th highest index for the period of record (Table 3). Three consecutive years of above average indices indicate a return to the population levels observed in the early 1980s. Walleye surfperch were collected primarily at shoals from Candlestick Point in South Bay north to Point San Pablo.

Table 3 Annual abundance indices for the most common surfperch species. The age-0 walleye surfperch index is from May-August; the shiner perch age-0, white seaperch (all sizes), and pile perch age-0 indices are from May-October; the barred perch (all sizes) index is from April-September; and dwarf perch (all sizes) and black perch (all sizes) indices are from February-October. The walleye surfperch index is from the midwater trawl and all other indices are from the otter trawl.

Year	*Walleye sp.* *age-0*	*Shiner perch* *age-0*	*White seaperch* *all*	*Barred sp.* *all*	*Dwarf perch* *all*	*Pile perch* *age-0*	*Back perch* *all*
1980	1825	19516	588	455	439	857	0
1981	11672	42764	1248	942	543	998	129
1982	2460	43705	349	335	259	471	54
1983	994	16148	271	1330	460	778	88
1984	5589	14386	873	673	50	110	216
1985	543	16616	138	73	0	301	66
1986	454	24617	309	0	0	254	17
1987	2180	18069	265	239	0	0	0
1988	693	7746	148	134	66	0	62
1989	2046	6953	48	101	97	153	101
1990	681	8181	95	79	26	0	48
1991	32	2724	0	84	15	0	0
1992	665	6142	0	41	0	0	100
1993	925	6341	0	43	0	0	97
1994	no index	3241	0	80	0	0	125
1995	0	6661	0	0	0	0	0
1996	906	4404	0	59	0	0	225
1997	94	23896	0	155	0	0	231
1998	467	4384	36	48	0	75	65
1999	548	6237	0	46	0	0	36
2000	1843	4640	0	43	0	31	119
2001	10813	20594	106	55	0	0	248
2002	2354	26134	260	59	0	42	95
2003	3513	15896	371	352	111	0	63

In 2003, abundance of age-0 shiner perch (*Cymatogaster aggregata*) decreased by 39% from 2002 (Table 3), but was still the 4th highest index since 1987 and continued the recovery trend from the low indices of the late 1980s and mid-1990s. Catch was spread throughout the year and was highest in November, a month not used for the index. We collected shiner perch at both channels and shoals throughout South, Central, and San Pablo bays, upstream to Carquinez Strait. Central Bay accounted for almost 75% of the total catch.

The 2003 white seaperch (*Phanerodon furcatus*) abundance index increased for the 3rd consecutive year and was the highest since 1984 (Table 3). We collected a total of 42 white surfperch in 2003, 11 of which were from stations and months used for index calculation. We collected white seaperch from our South Bay channel station near Point San Bruno to our Central Bay shoal station near Corte Madera.

The 2003 barred surfperch (*Amphistichus argenteus*) abundance index was the highest since 1984 (Table 3). Ten barred surfperch were collected in South Bay and 7 from our shoal station west of Hayward.

In 2003, we collected our 1st dwarf perch (*Micrometrus minimus*) at an index station since 1991 and the index was the highest since 1983 (Table 3). But only 3 of the 12 collected in 2003 were from index stations. Eight of the 12 were from the Corte Madera shoal station and the remaining 4 were from the shoals near San Leandro and Hayward and the channel east of Redwood Creek in South Bay.

The 2003 pile perch (*Rhacochilus vacca*) abundance index was 0, showing no sign of recovery in the estuary and continued the trend of very low or 0 indices since 1987 (Table 3). No pile perch were caught with our otter trawl, the net used for index calculation. Only 1 pile perch was collected with our midwater trawl in June, at our shoal station near Candlestick Point.

Black perch (*Embiotoca jacksoni*) was the only surfperch species common in the estuary that did not show a distinct decline in Bay Study catch during the late 1980s or early 1990s (Table 3). Black perch catch has never been high, but remained relatively constant throughout the study period. The black perch index for 2003 was the lowest since 1999, at about 70% of the historical average. We collected 10 black perch in 2003, only 2 of which were from stations and months used for index calculation. These fish were collected from Central Bay to our station near Mare Island in San Pablo Bay.

In 2003, the bay goby (*Lepidogobius lepidus*) abundance index decreased slightly from the 2002, yet was the 2nd highest index for the study period (Figure 10). Since 2001, 3 of the 4 highest bay goby indices for the study period have occurred. Bay gobies were collected from South Bay to Suisun Bay in 2003, but the majority (85%) were from Central Bay. As for several other species, there was a seasonal movement from shoals to channels with growth; from April to June, most were collected at shoal stations, but moved to the channel stations in July and August.

The shokihaze goby (*Tridentiger barbatus*) has been common upstream of our historic sampling area; therefore, abundance was determined as annual mean catch-per-unit effort (CPUE) for all stations sampled, including the stations on the lower Sacramento and San Joaquin rivers added in 1994. In 2003, mean CPUE for fish > 19 mm TL increased slightly from the previous year, and was the 2nd largest index since their discovery in 1997 (Figure 11). The rapid increase in shokihaze gobies observed in the estuary from 1998 to 2001 leveled off somewhat in 2002 and 2003. Shokihaze gobies were collected from San Pablo Bay through the western Delta in 2003, with 87% of all fish coming from channel stations in Suisun Bay and the lower Sacramento River. They were common in Suisun Bay throughout the year and in the lower Sacramento River from July through December. Only a single fish was collected from the San Joaquin River. In 2003 the shokihaze goby catch exceeded our combined catch of the 2 other introduced *Tridentiger* gobies, the shimofuri goby (*T. bifasciatus*) and the chameleon goby (*T. trigonocephalus*), for the 3rd consecutive year.

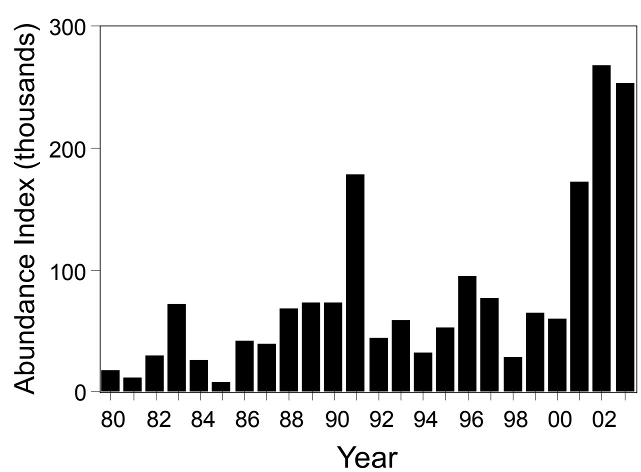

Figure 10 Annual abundance of bay goby, February-October, otter trawl.

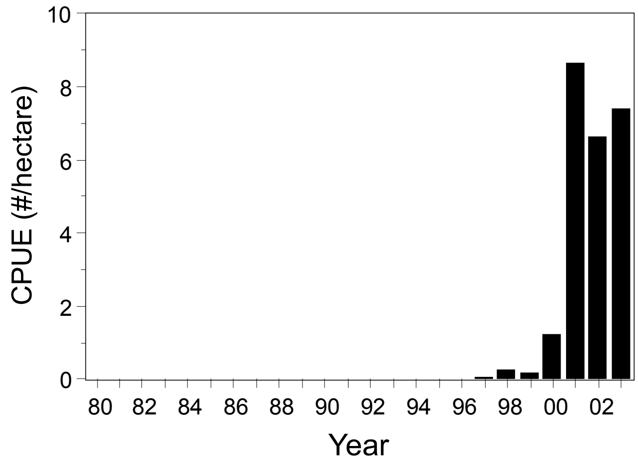

Figure 11 Annual CPUE (#/hectare) of shokihaze goby (all sizes), January-December, otter trawl.

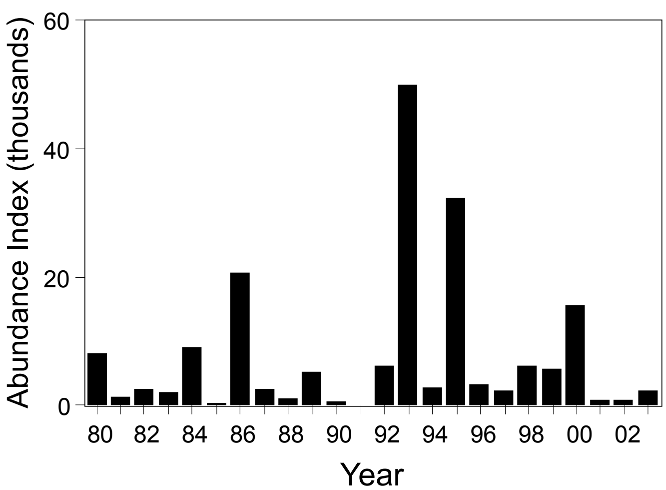

Figure 12 Annual abundance of age-0 yellowfin goby, May-October, otter trawl.

The 2003 yellowfin goby (*Acanthogobius flavimanus*) age-0 index increased from 2002 and was the largest index since 2000 (Figure 12); however, it was only 32% of the 1980-2002 average index. Yellowfin gobies were distributed widely from South Bay to the western Delta. The majority (72%) of age-0 yellowfin gobies was collected from Suisun Bay through the lower Sacramento and San Joaquin rivers from May through September.

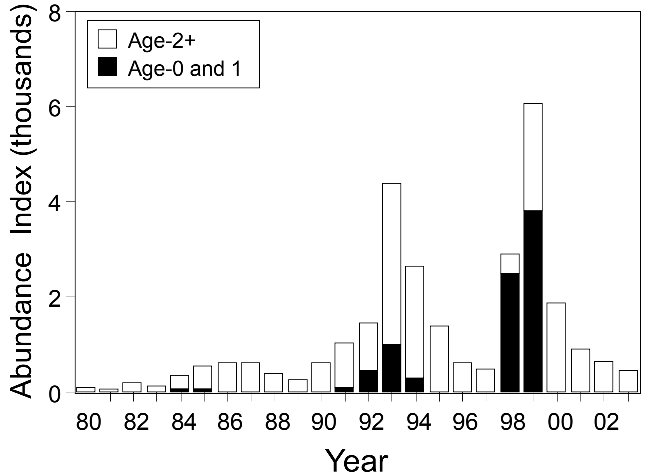

Figure 13 Annual abundance of juvenile (age-0 and age-1) and age-2+ California halibut, February-October, otter trawl.

No age-0 or age-1 California halibut (*Paralichthys californicus)* were collected during 2003, the 4th consecutive year with no young fish collected in the estuary (Figure 13). The lack of age-0 and age-1 fish was expected as SSTs in the Gulf of the Farallones have remained below 14 °C, the temperature reported to be necessary for successful reproduction. SSTs exceeded 14 °C in August and September 2003, but we had no recruitment of age-0 fish to our gear through December 2003. In 2003, the age-2+ California halibut index decreased from 2002, continuing the trend of declining indices since 1999 (Figure 13). Age-2+ fish were collected in South and Central bays throughout the year, with only 1 fish collected in San Pablo Bay. These fish ranged from 235 to 816 mm TL; most were age-5 and age-6, as 12 of the 17 fish collected were > 573 mm TL.

The 2003 age-0 English sole (*Parophrys vetulus*) abundance index increased slightly from 2002 (Figure 14), continuing the trend of high indices since the 1999. This increase in abundance corresponds with a shift to cooler ocean temperatures; we believe that English sole, a cold-temperate species, has benefited from these ocean conditions. During spring 2003, age-0 English sole migrated from the ocean to shoals from South Bay to Carquinez Strait to rear. By late summer, as temperatures in the shallows increased, most English sole migrated back to the channels of Central Bay. Overall, our age-0 catches were greatest at the channel stations by Angel Island and our shoal station at Treasure Island, which accounted for 57% of the age-0 catch in 2003.

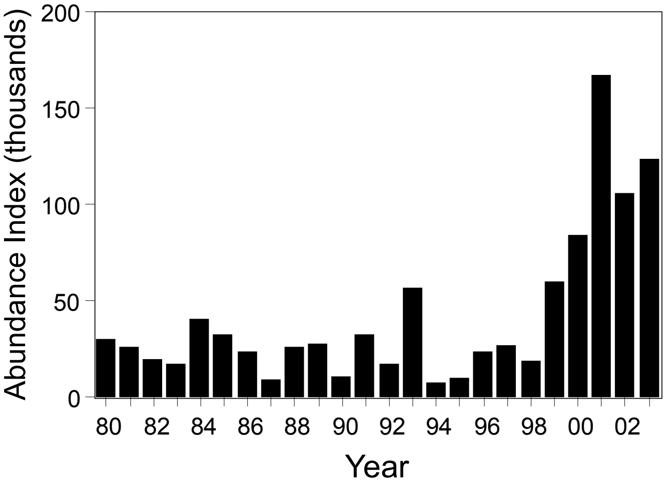

Figure 14 Annual abundance of age-0 English sole, February-October, otter trawl.

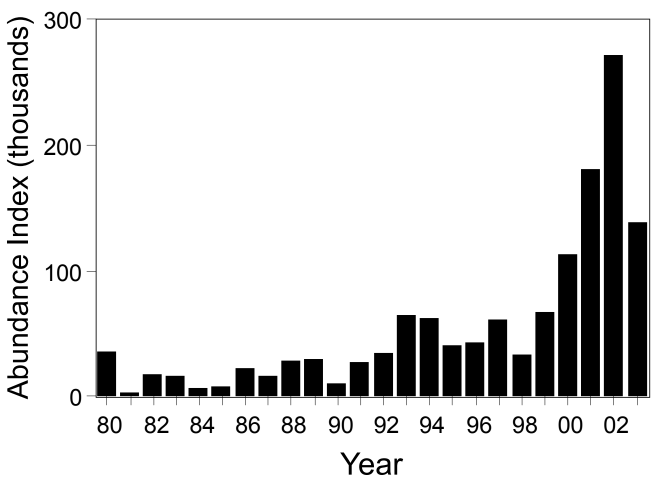

Figure 15 Annual abundance of speckled sanddab (all sizes), February-October, otter trawl.

The 2003 speckled sanddab (*Citharichthys stigmaeus*) abundance index decreased to nearly half the 2002 index, yet was the 3rd highest index of the study period (Figure 15). Record speckled sanddab abundance indices have occurred since 2000, corresponding with cooler ocean temperatures and strong summer upwelling. Such conditions could benefit speckled sanddabs as they have a very long pelagic period and do not settle until after the upwelling season ends. Speckled sanddabs were distributed from South through San Pablo bays in 2003, with a single fish collected from Suisun Bay near the Benicia Bridge. Fish in South and San Pablo bays were most common at the shoals, but only from January to May. By June, the majority of speckled sanddabs moved from South and San Pablo bays to Central Bay and remained common there through December.

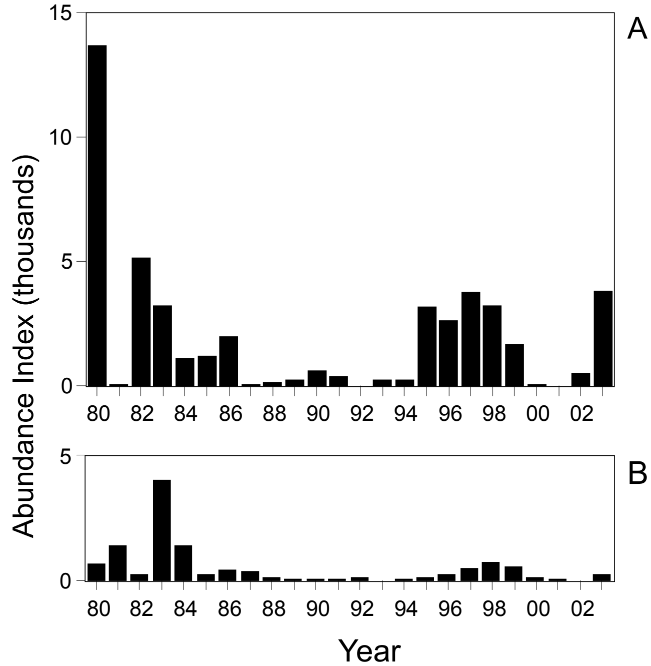

Figure 16 Annual abundance of starry flounder, otter trawl: (A) age-0, May-October; (B) age-1, February-October.

Age-0 starry flounder (*Platichthys stellatus*) abundance increased in 2003 to the highest level since 1982 (Figure 16A). The abundance of age-0 starry flounder, which are estuarine dependant, is positively correlated to spring freshwater outflow. March through May 2003 average outflow was about 10,000 cfs greater than in either 2001 or 2002. Although this index increase was expected, the magnitude may have been fueled by an increase in broodstock size. A moderately high number of starry flounder were produced during the high outflow years of the late 1990s and these fish matured by 2003. Also, starry flounder is a cold-temperate species and therefore, is predicted to benefit from the cool ocean regime. We collected age-0 starry flounder from May to December from South Bay, south of the Dumbarton Bridge, to our furthest upstream stations both on the Sacramento River, just upstream of Rio Vista, and the San Joaquin River, at Old River Flats. Catch was highest at San Pablo and Suisun Bay shoal stations. The 2003 age-1 starry flounder abundance index was well below average, but did increase considerably from 2002, which was the 2nd lowest for the study period (Figure 16B). Age-1 starry flounder were collected throughout the estuary, but were most abundant in San Pablo and Suisun bays.

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Chinook Salmon Catch and Escapement

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In 2003 the ocean catch of Central Valley Chinook salmon south of Point Arena decreased in both the commercial and recreational fisheries from 2002. However the catch per unit effort (CPUE) increased between 2002 and 2003. Compared to the 1970-2003 period of record, the ocean catch was below average while the CPUE remained above average, as it has since 1994.

The total escapement of fall, spring, and winter run Chinook salmon also decreased from 2002 to 2003, but remained above the average escapement for the 1970-2003 period. In 2003 the fall run Chinook escapement to the Sacramento River system was the third highest for the 1970-2003 period and was the greatest contributor to the Central Valley fall run escapement. Spring run escapement to both Butte and Deer creeks decreased from 2002 to 2003. However, the escapements were still higher than the average escapement from the 1977-1994 period. Spring run escapement to Mill Creek increased in 2003 to the highest level since 1975. Winter run escapement decreased from 2002 to 2003, but was the second highest escapement since 1981. The three-year cohort replacement rate also indicates that population is continuing the upward trend started in 1995.

The numbers for the ocean fisheries' CPUE and the Central Valley escapement indicate that the Chinook populations continue to improve as they have since 1995. Favorable ocean conditions and harvest restrictions are contributors to this trend.

Ocean Harvest Index and Ocean Catch for the Central Valley Chinook Fall Run

The Pacific Fisheries Management Council (PFMC) sets escapement goals for fall run Chinook annually. They also develop harvest levels to protect listed Central Valley winter and spring run Chinook, as well as Klamath River fall run Chinook. These include setting minimum size limits, gear restrictions, and season restrictions south of Point Arena. These restrictions reduce harvest of all Chinook runs.

The PFMC's Central Valley Chinook ocean harvest index (OHI) is an approximate harvest rate. The OHI is calculated by dividing the total ocean catch south of Point Arena by the catch plus escapement. The OHI does not include inland harvest, which may account for up to 25% of the returning adults. In 2003 the OHI remained 34%, the same as the 2002 OHI, due to continued high escapement and moderate ocean harvest (Figure 1). The Central Valley fall run escapement was the third highest for the 1970-2003 period, with 595,000 spawners (Figure 1).

Statewide the ocean catch increased between 2002 and 2003. For the commercial fishery, the number of days fished decreased from 17,300 in 2002 to 15,600 in 2003, but the CPUE increased from 22,600 fish/day to 31,300 fish/day (Figure 2). The CPUE (fish/day) decreased in Washington and Oregon but remained well above average for the 1970-2003 period (Figure 2).

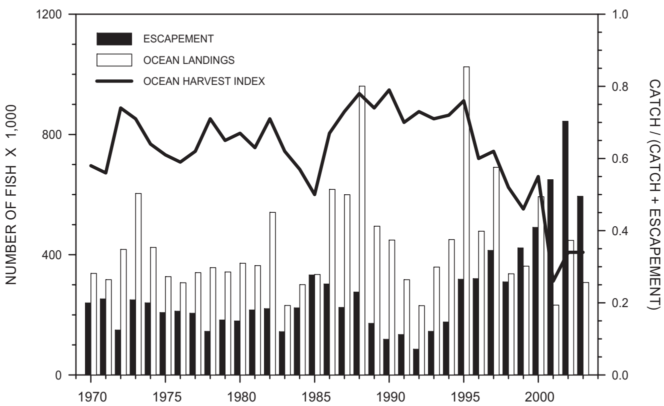

Figure 1 Pacific Fisheries Management Council (PFMC) Chinook salmon ocean catch, the Central Valley fall run Chinook adult spawner escapement, and ocean harvest index, 1970-2003.

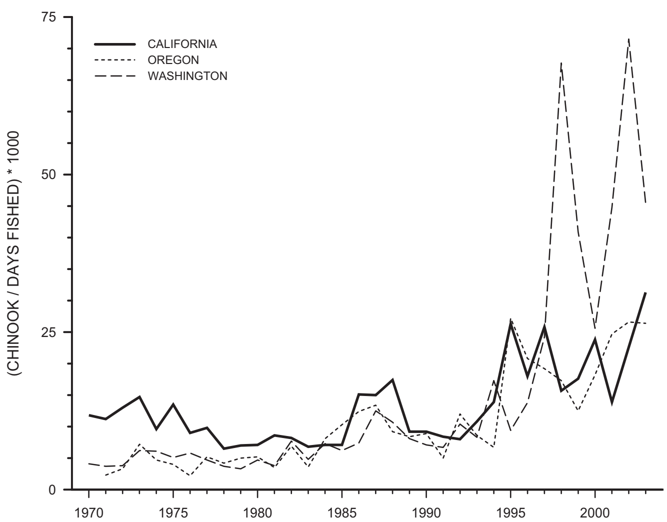

Figure 2 Chinook salmon catch per unit effort in the California, Oregon, and Washington commercial trolls, 1970-2003.

Recent oceanic conditions indicate a continuation of the La Niña conditions that developed in 1998 and 1999, as well as a shift to the negative phase of the Pacific Decadal Oscillation (PDO) (Schwing and others 2002). This pattern is represented by stronger upwelling and cooler waters in much of the California Current System (CCS). Biological productivity within the CCS increases under these conditions. For example, copepod biomass has doubled since the onset of the current La Niña-like conditions, with a 200% increase within the last two years alone (Schwing and others 2002).

This increased productivity promotes the growth and survival of juvenile salmon during their first summer at sea and may largely determine subsequent year-class strength (Schwing and others 2002). The adult Chinook returning this year entered the ocean as juveniles during this period of increased productivity. Higher-than-average CPUE and escapement in 2003 indicate that the current ocean conditions are indeed contributing to increased Chinook survival off the California coast.

Central Valley Fall Chinook Escapement

In 2003 the PFMC set the escapement goal range of 122,000 to 180,000 natural and hatchery adults for the Sacramento River system. The estimated number of natural spawners was 431,000, far exceeding the PFMC management goals (Figure 3). The cohort escapement was at the third highest level in the last three decades at about 447,000 (Figure 4). I calculated the cohort escapement by adding three-year olds from the current year and two-year olds from the previous year. Natural spawner escapement to the mainstem Sacramento River decreased from 2002 levels, but remained above the average escapement for the 1970-2003 period (Figure 5). Escapement increased slightly from the escapement in 2000 (Figure 5). The hatchery escapement was the highest in the 1970-2003 period, with approximately 88,300 spawners.

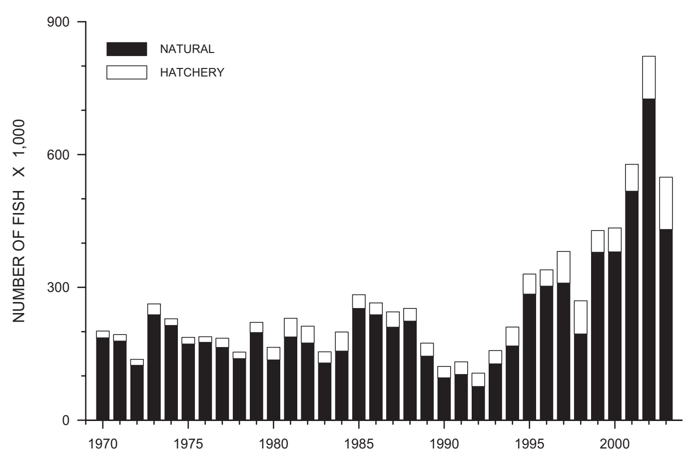

Figure 3 Annual fall run escapement to the Sacramento River and major tributaries, natural and hatchery contribution, 1970-2003.

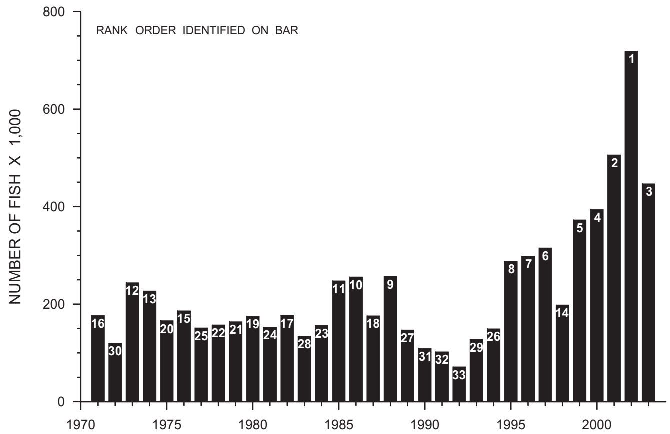

Figure 4 Annual natural fall run cohort escapement to the Sacramento River and major tributaries, 1970-2003.

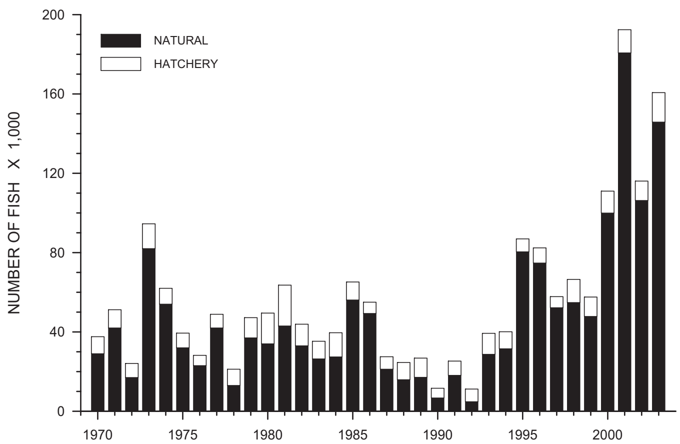

Figure 5 Annual fall run escapement to the mainstem Sacramento River, natural and hatchery contribution, 1970-2003.

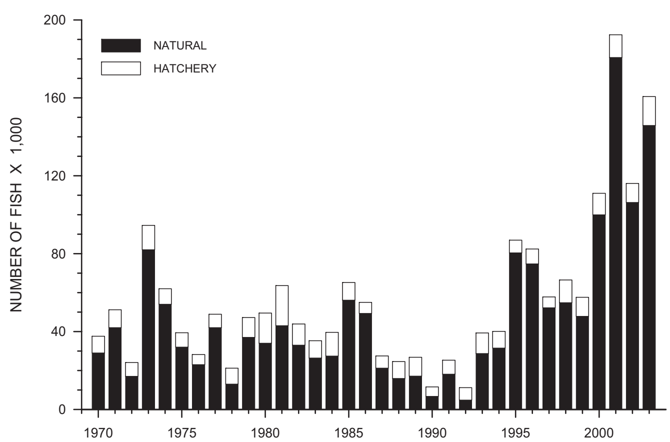

Figure 6 Annual fall run escapement to the American River, natural and hatchery contribution, 1970-2003.

Natural spawner escapement in the American River increased from about 106,000 in 2002 to 146,000 in 2003 and was the second highest escapement in the 1970-2003 period (Figure 6). The hatchery spawner escapement also increased from about 9,800 in 2002 to 14,900 in 2003. In the Feather River the estimated escapement decreased to 89,000 in 2003 and also decreased from the escapement three-years earlier (Figure 7). Hatchery escapement to the Feather River also decreased to about 15,000 in 2003. The estimated Yuba River fall run escapement increased from 23,000 in 2002 to 29,000 in 2003 (Figure 8). In 2003 the escapement almost doubled from the escapement three years earlier (Figure 8).

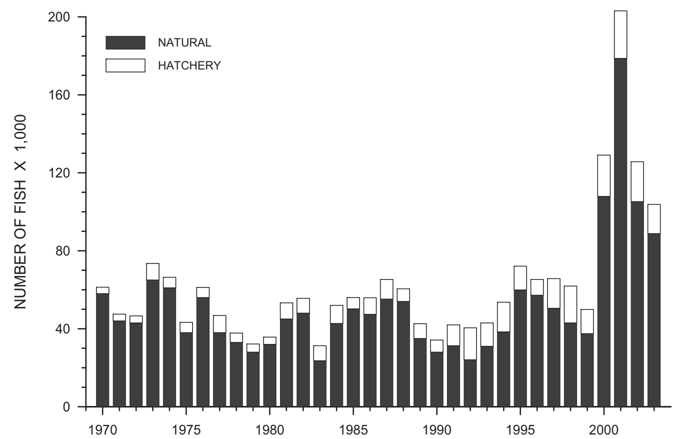

Figure 7 Annual fall run escapement to the Feather River, natural and hatchery contribution, 1970-2003.

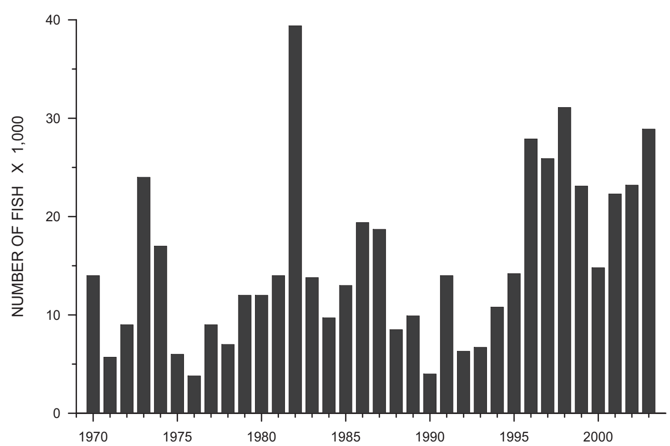

Figure 8 Annual natural, fall run escapement to the Yuba River, 1970-2003.

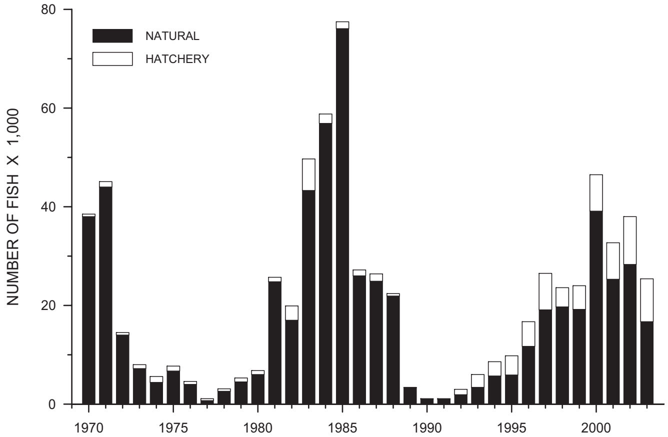

Figure 9 Annual fall run escapement to the San Joaquin River system, natural and hatchery contribution, 1970-2003.

On the San Joaquin River system, the estimated natural spawner escapement decreased to about 17,000 in 2003, which is the lowest level since 1996 (Figure 9). The escapement was less than half the escapement of three years earlier. The hatchery spawners also decreased from about 9,700 in 2002 to 8,700 in 2003, but increased compared to the escapement from three years earlier (Figure 9). The hatchery spawners accounted for approximately 34% of the total escapement, which is more than double the average number of hatchery spawners for the 1970-2003 period (Figure 9). In 2003 the PFMC closed recreational salmon fishing in the San Joaquin system because of concerns over the low escapement in recent years. The San Joaquin River system includes spawners from the Mokelumne, Stanislaus, Tuolumne, and Merced rivers and has constituted less than 10% of the total Central Valley spawner escapement since 1986.

Sacramento River System Spring Run Escapement

The escapement in Deer Creek increased to the highest level since 1975, with approximately 2,760 natural spawners (Figure 10). The number of spawners was substantially higher than the estimated 640 spawners in 2000 (Figure 10). The number of natural spawners decreased slightly on Mill Creek with an estimated escapement of 1,430, but more than doubled from escapement three years earlier (Figure 10).

The Butte Creek escapement decreased from about 8,770 in 2002 to 4,400 in 2003 based upon a snorkel methodology (Figure 10). The Department of Fish and Game (DFG) has also been using carcass surveys to estimate escapement on Butte Creek since 2001. Based on results from the carcass survey, the estimated escapement of natural spawners was 6,100. Pre-spawn mortalities were not included in the spawner escapement surveys; however, a separate carcass survey was conducted to evaluate pre-spawning mortality, which was estimated to be 11,231 salmon. High summer temperatures and Chinook densities resulted in a significant level of pre-spawn mortality due to outbreaks of both *Ichthyophthirius multiphilis* (Ich) and *Flavobacterium columnare* (Columnaris) (DFG 2003). Total escapement to Butte Creek was approximately 17,000 salmon. Even with the high pre-spawn mortality the estimated escapement to Butte Creek continues to surpass the escapement to the other spring run tributaries and the mainstem Sacramento River (Figure 10).

Winter Run Escapement to the Sacramento River below Keswick Dam

The PFMC estimated the winter run escapement at 9,800 based on the extrapolated counts at Red Bluff Diversion Dam in 2002 (Figure 11); this was the highest escapement since 1981. The three-year cohort replacement rate was 2.5, exceeding the PFMC target rate of 1.77 (Figure 11). I calculated the cohort replacement rate by dividing the sum of the current year's three-year-olds and the previous year's two-year-olds by the same value from three years earlier. The gates at Red Bluff Diversion Dam were raised during much of the upstream migration to allow the passage of winter run and spring run Chinook.

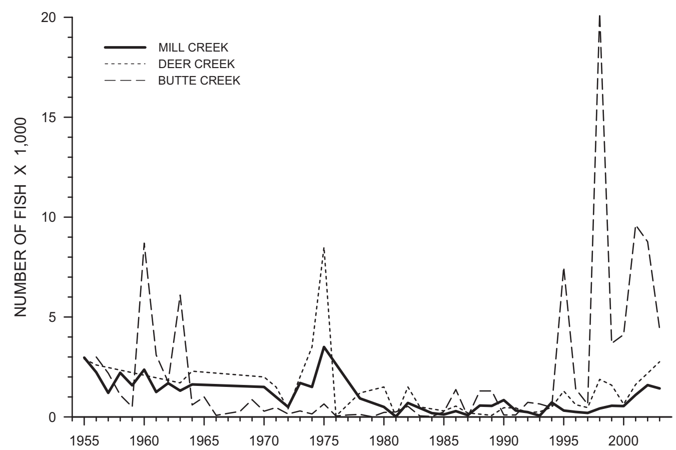

Figure 10 Annual spring run escapement to Mill, Deer, and Butte creeks, 1956-2003.

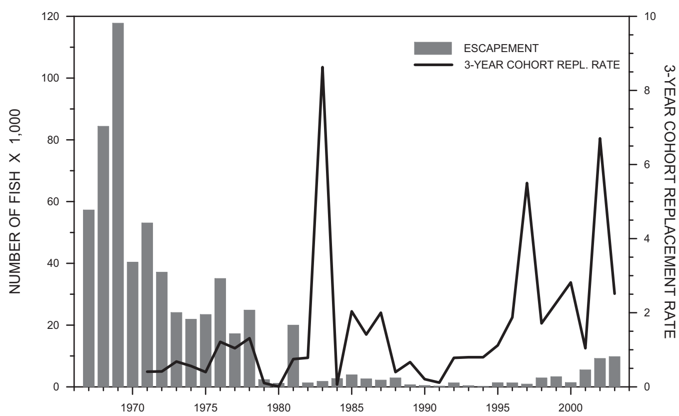

Figure 11 Annual winter run escapement and the three-year cohort replacement rate to the upper Sacramento River, 1967-2003.

NMFS and DFG have used carcass surveys as an alternative method of estimating escapement since 1996. In 2003, NMFS and DFG estimated the winter run escapement at about 9,500 using the carcass survey, which is a 42% increase from the escapement in 2000. Currently the two methodologies are under review by NMFS, DFG, and PFMC.

Acknowledgements

Most of the data presented in this article is published in the PFMC's *Review of the 2003 Ocean Salmon Fisheries* report. A copy of the report is available by calling (503) 820-2280 or online at http://www.pcouncil.org. I thank Colleen Harvey Arrison (DFG) for providing the spring run Chinook escapement data for Mill and Deer creeks and Tracy McReynolds (DFG) for providing the spring run Chinook escapement data for Butte Creek.

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Fish Salvage at the State Water Project and Central Valley Project Fish Facilities

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Introduction

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

Exports

State Water Project (SWP) water exports totaled about 4.37 billion m^3 (3,546,000 acre-feet) in 2003, compared to about 3.44 billion m^3 (2,792,000 acre-feet) in 2002. During 2003, monthly water exports at the SWP ranged from a low of about 66.5 million m^3 (53,956 af) in May to a high of about 527 million m^3 (427,610 af) in August (Figure 1), similar to the 2002 range of about 47.4 million m^3 (38,455 af) to 510.3 million m^3 (414,034 af).

Central Valley Project (CVP) water exports totaled about 3.42 billion m^3 (2,776,000 af), compared to about 3.08 billion m^3 (2,501,000 af) in 2002. Monthly water exports at the CVP in 2003 ranged from a low of about 110.8 million m^3 (90,000 af) in May to about 329.4 million m^3 (about 267,000 af) in March (Figure 1), compared to the 2002 range of about 65.2 million m^3 (53,000 af) to about 329.0 million m^3 (about 267,000 af).

Fish Salvage

About 4.25 million fish were salvaged at the SWP in 2003, and almost 7.49 million fish were salvaged at the CVP. At the SWP facility, American shad was the predominant species salvaged, whereas threadfin shad was by far the most abundant at the CVP. American shad accounted for almost 48% of the annual salvage at the SWP (Figure 2) and threadfin shad accounted for about 84% of the annual salvage at the CVP (Figure 3). There has been an increase in the annual proportion of threadfin shad in the total salvage at both facilities in recent years (Figure 4), which is particularly evident at the CVP facility since 1995.

Density of fish (individuals salvaged per 10,000 m^3) at the SWP was highest in July (34) and at the CVP in November (97) (Figure 5). American and threadfin shad together accounted for much of the salvage in July at the SWP (82%) and threadfin shad made up most of the CVP salvage during November (91%).

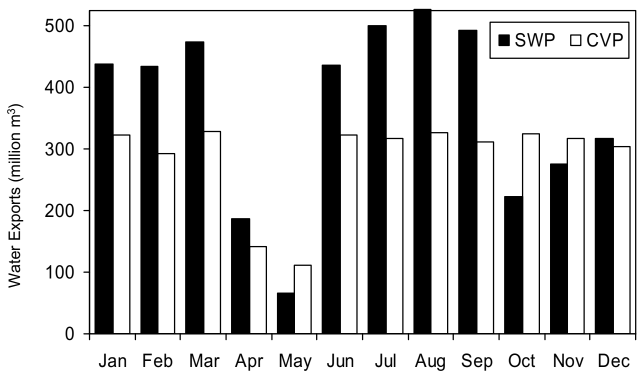

Figure 1 Monthly water exports in 2003 by SWP and CVP.

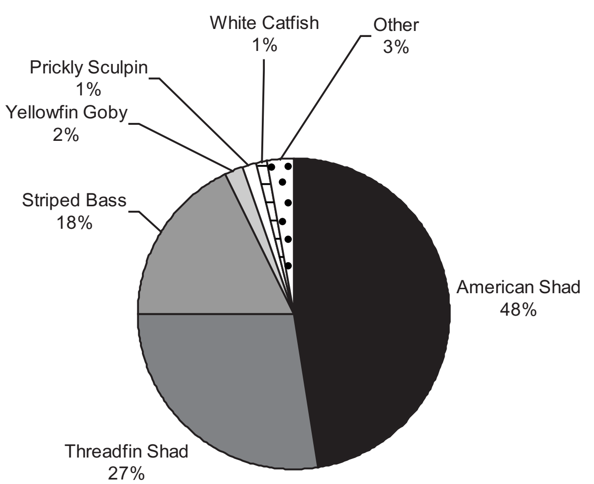

Figure 2 Relative species contribution to 2003 annual salvage at SWP.

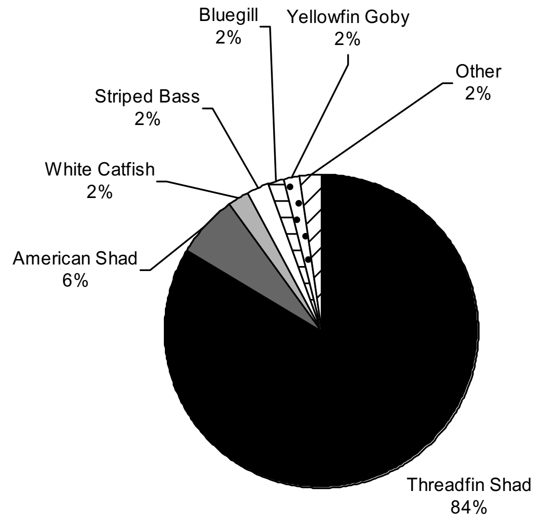

Figure 3 Relative species contribution to 2003 annual salvage at CVP.

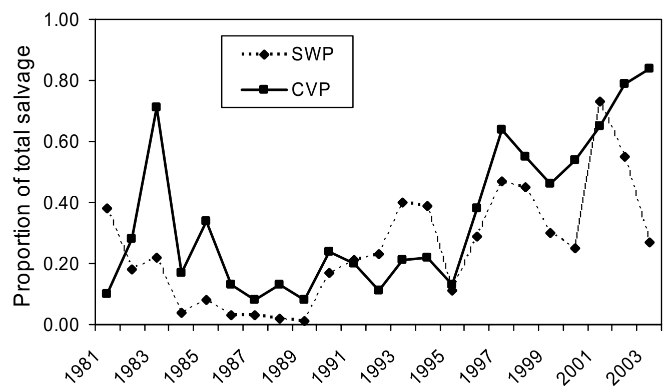

Figure 4 Proportion of threadfin shad in total salvage at SWP and CVP.

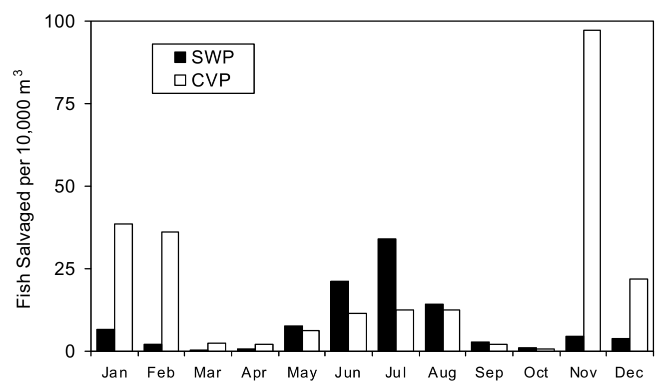

Figure 5 Monthly fish salvage density in 2003 at SWP and CVP.

Delta Smelt

Estimated salvage of delta smelt at the SWP in 2003 was 21,248, fewer than the 49,823 salvaged in 2002, and much fewer than in 1999 and 2000 (Figure 6). An unusually high percentage of the delta smelt were adults (39%), mostly salvaged during January (Figure 7).

In 2003, 16,662 delta smelt were salvaged at the CVP, only slightly fewer than the 18,396 salvaged in 2002. Although only 23% of the delta smelt salvage was adults, the 3,756 adults salvaged in January were the most in that month since 1988. This is the second consecutive year that peak adult salvage has occurred in January. Previous to 2002, there had been a 3-year period of high delta smelt salvage in February.

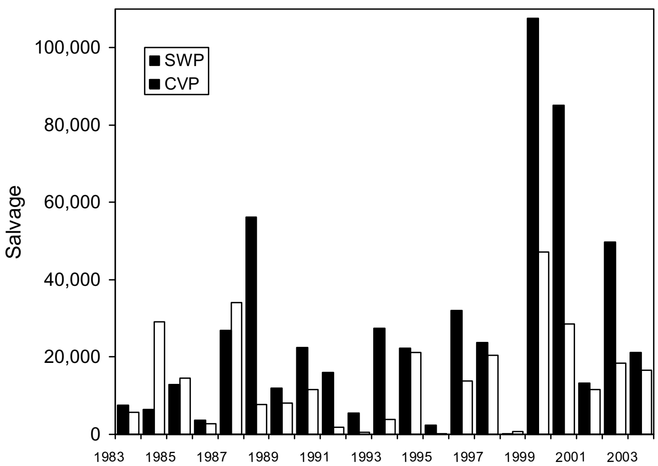

Figure 6 Annual delta smelt salvage at SWP and CVP.

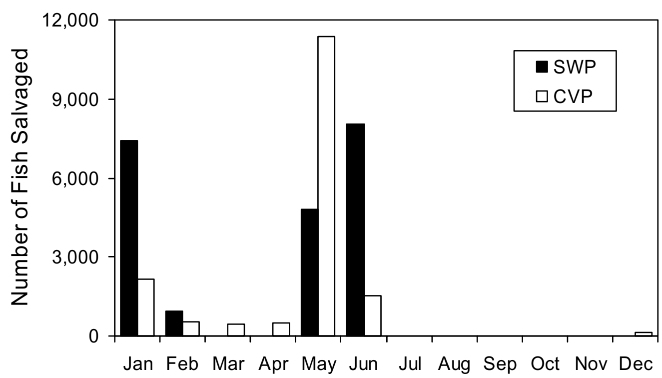

Figure 7 Monthly delta smelt salvage at SWP and CVP in 2003.

Chinook Salmon

The combined (SWP+CVP) salvage of Chinook salmon was 33,989, more than the 21,909 salvaged in 2002, but less than the 1993-2002 annual average (80,753), and far less than the 1983-1992 annual average (289,553) (Figure 8). About 28% of the salmon salvaged last year were adipose fin clipped, indicating hatchery origin. Of the naturally-produced salmon, almost two-thirds (65.4%) were spring-run, 26% were fall-run, and the remainder (8%) were winter-run (as determined by fork length only) (Figure 9).

The SWP facility salvaged slightly more Chinook salmon (clipped and unclipped combined) than the CVP facility during 2003, reversing a long term trend of higher salvage at the CVP. Salmon salvage at both facilities peaked in May, but an unusually high proportion of the total salmon salvage came in January (Figure 10).

Salmon loss, an estimate of the mortality resulting from entrainment at the export facilities, is based on estimates of pre-screen loss (predation), louver efficiency, and handling and trucking mortality. Total salmon loss (SWP+CVP) in 2003 was 84,766, more than twice the total salmon salvage. Approximately 32% of the salmon lost were adipose fin clipped, compared to 42% in 2002. SWP loss was much higher than CVP loss (Table 1), reflecting the high predation mortality rate (75%) in Clifton Court Forebay.

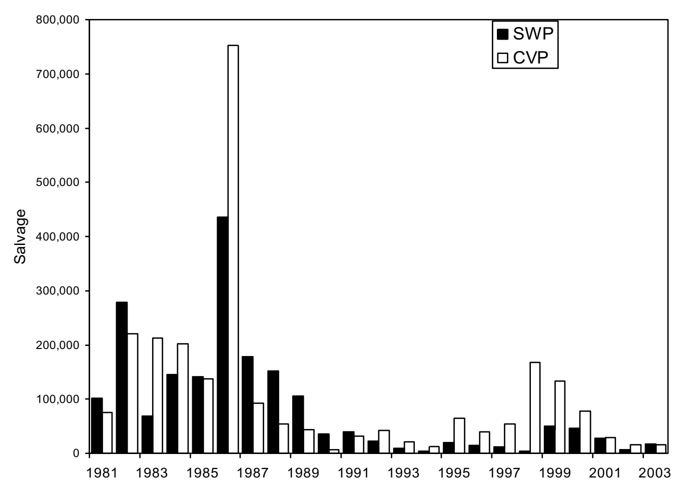

Figure 8 Annual Chinook salmon salvage at SWP and CVP.

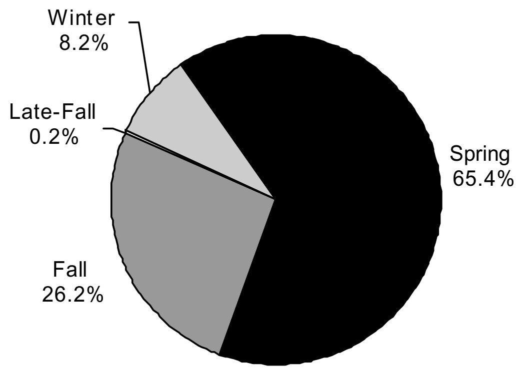

Figure 9 Percent of Chinook salmon runs in 2003 salvage at SWP and CVP. Race determined solely by length.

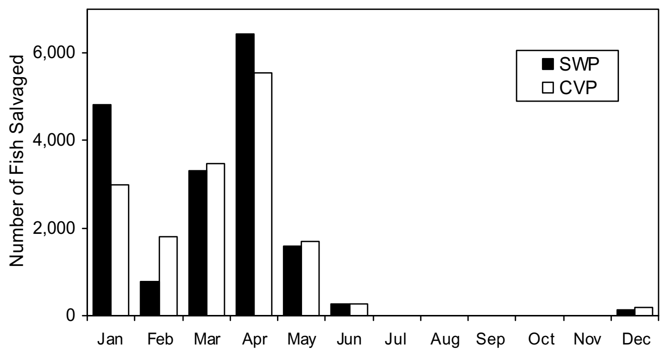

Figure 10 Monthly salvage of Chinook salmon at SWP and CVP in 2003.

Table 1 Wild Chinook salmon loss at CVP and SWP in 2003.

Race	*SWP*	*CVP*	*Total*
Fall	8,482	2,948	11,430
Late-fall	133	8	141
Winter	5,164	528	5,692
Spring	35,565	4,818	40,383
Total	49,345	8,301	57,646

Steelhead Trout

Steelhead salvage at both facilities in 2003 was higher than in 2002 (Figure 11). The SWP salvaged 5,766 steelhead, more than double the 2002 total and higher than the 1993-2002 mean of 3,407 per year. The CVP salvaged 6,871, the most in any year since 1993 and far above the 1993-2002 mean of 2,449 per year. Steelhead salvage was highest during January at both facilities (Figure 12).

About 86% of the steelhead salvaged at the SWP were adipose fin-clipped, indicating hatchery origin, and about 78% of CVP salvaged steelhead were clipped. This proportion of hatchery steelhead was the highest of any year since 1997, when fin clipping of all hatchery fish began.

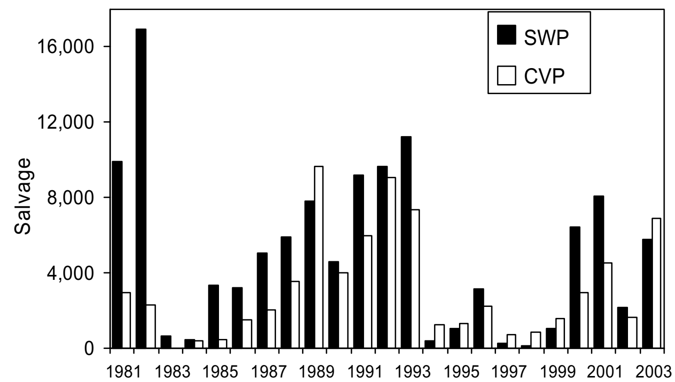

Figure 11 Annual steelhead salvage at SWP and CVP.

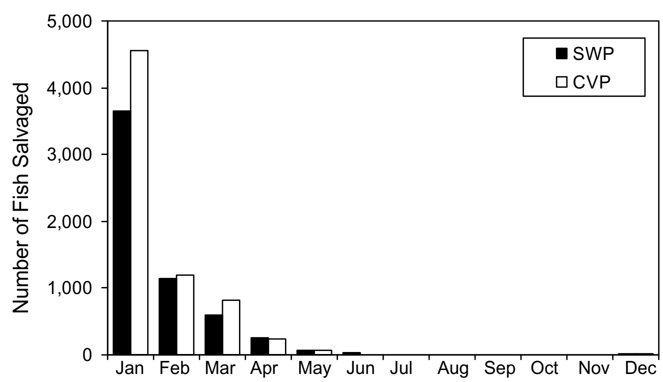

Figure 12 Monthly salvage of steelhead at SWP and CVP in 2003.

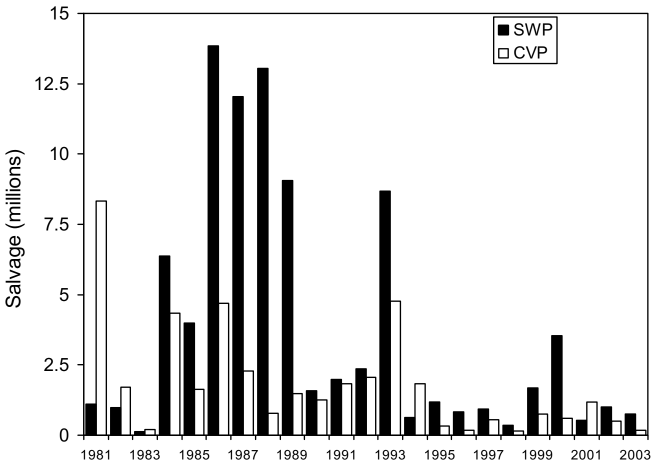

Figure 13 Annual striped bass salvage at SWP and CVP.

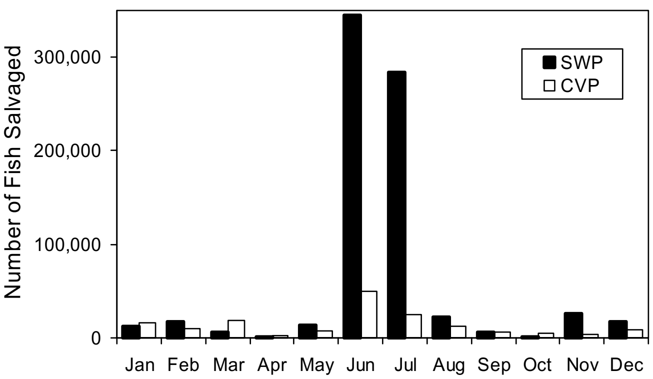

Figure 14 Monthly salvage of striped bass at SWP and CVP in 2003.

Striped Bass

In 2003, the SWP salvaged only 753,555 striped bass, about 40% of the 1993-2002 average of 1.94 million per year (Figure 13). At the CVP, about 165,000 striped bass were salvaged, only a small percentage of the 10-year average of 1.09 million per year. Striped bass salvage peaked in June at the both facilities (Figure 14).

American Shad

More than 2 million American shad were salvaged in 2003 at the SWP and about 486,000 were salvaged at the CVP. The SWP total was much higher than the 1993-2002 average of 768,000 (Figure 15) and was the highest of any year since at least 1981. Monthly salvage of American shad at the SWP peaked at just over 1.1 million in July. In contrast, the bulk of American shad at the CVP were salvaged in November (about 203,000). Since 1981, there has been a general trend of higher American shad salvage at both facilities (Figure 15).

Splittail

The 2003 combined (SWP+CVP) splittail salvage was almost 20,000, which was slightly more than double the 2002 combined total (Figure 16). Splittail salvage totals in 1986, 1995, and 1998 dwarfed the salvage totals for 2003 and all other years since 1980. Splittail salvage in 2003 was dominated by young-of-the-year (YOY) salvage during June (Figure 17).

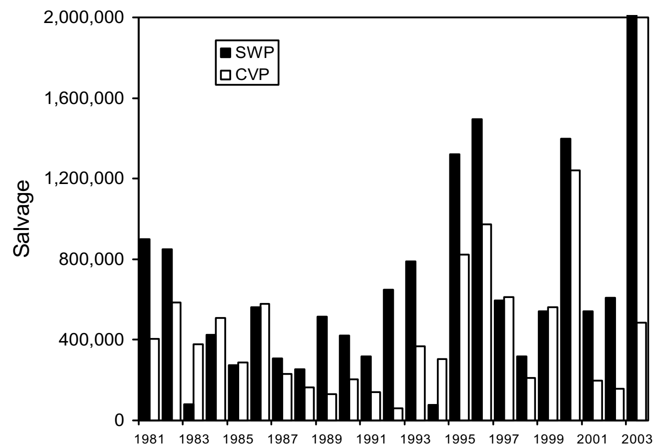

Figure 15 Annual American shad salvage at SWP and CVP.

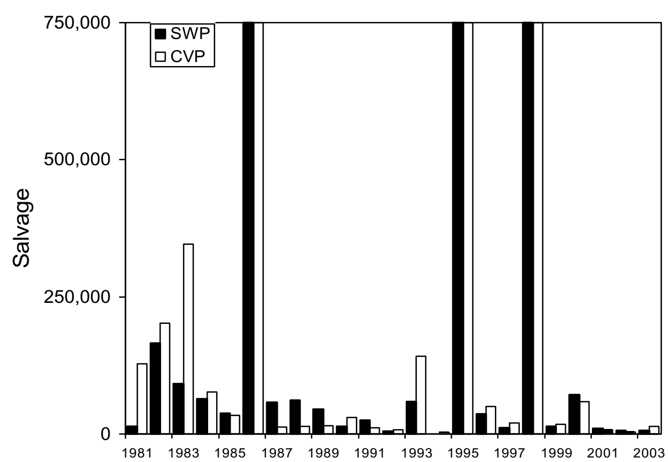

Figure 16 Annual splittail salvage at SWP and CVP. Columns for 1986, 1995, and 1998 were truncated for scale considerations.

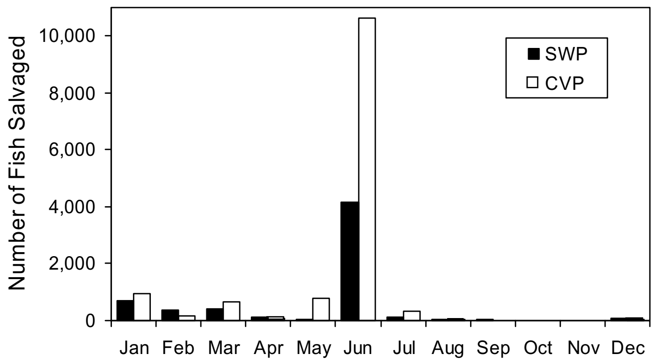

Figure 17 Monthly splittail salvage at SWP and CVP in 2003.

Longfin Smelt

Longfin smelt salvage was slight compared to the near record 2002 salvage total of 98,000. In 2003, most of the longfin were found at the CVP (about 87% of the 5,268 total). Almost all of the salvage occurred in April and May and was made up of YOY fish.

Chinese Mitten Crab

The highest numbers of adult mitten crabs at the fish facilities occur during September through December, during their downstream migration for reproduction. Mitten crabs are considered a nuisance at the fish facilities because they interfere with the effective salvage of fish.

At the CVP, the first adult mitten crab of the fall migration appeared on October 4, about 1 month later than usual. The delay in migration may have been due to higher than normal autumn water temperatures. CVP daily crab numbers peaked on November 2, when an estimated 72 crabs entered the facility (Figure 18). In 2003, an estimated 672 crabs entered the holding tanks. The 2003 seasonal total of crabs was much lower than any of the last 6 years. In contrast to other years since 1999, the traveling screen control device was not deployed due to low numbers of crabs. About 60% of the crabs were male.

Although mitten crabs appeared at the SWP 9 days earlier than at the CVP, only 90 entered the holding tanks during the 2003 fall season. No crab control device was installed at the SWP in 2003.

Water Temperatures

The mean annual water temperature in 2003 at the CVP facility was 17 °C, equal to the mean temperature in 2002. The temperature recorder at the SWP facility was faulty for part of the year, so data are not presented. Water temperatures peaked approximately July 27, at about 27.3 °C. The coolest temperatures occurred near January 1, when they fell to about 8 °C (Figure 19). The most notable feature of the 2003 temperatures was the warm autumn; temperatures in late October, for example, were up to 4 °C warmer than the same time in 2002.

Salvage data can be obtained from DFG's Central Valley Bay-Delta Branch website (http://www.delta.dfg.ca.gov/data/salvage).

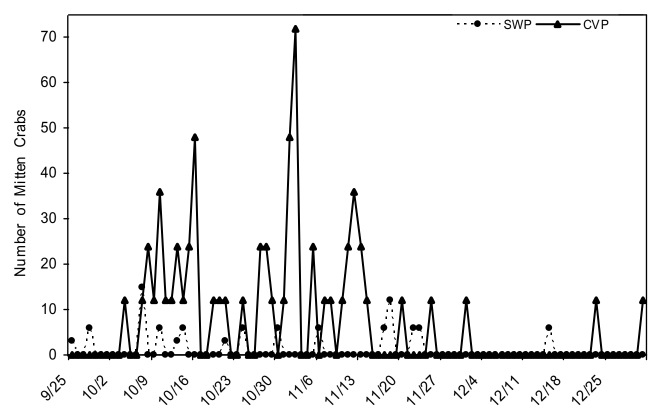

Figure 18 Daily mitten crabs counted at SWP and CVP in 2003.

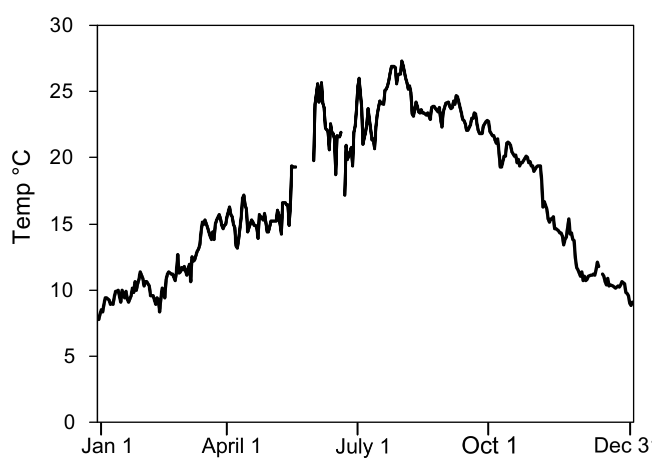

Figure 19 Daily water temperatures at SWP and CVP fish facilities.

CONTRIBUTED PAPERS

Cross-Channel Variability in Benthic Habitat: Old River

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Introduction

Benthic invertebrates are a vital link between the physical habitat at the bottom of water bodies and the pelagic realm above. Due to their sedentary nature, they integrate local environmental conditions over time. The composition of the benthic community provides an indication of the environmental conditions of their habitat. Benthic invertebrates are prey to many species of fish, birds, and mammals in the estuary, transferring not only energy and nutrients, but also contaminants, up the food chain as they are consumed.

The Interagency Ecological Program's Environmental Monitoring Program (EMP) has monitored benthic invertebrates in the upper San Francisco Estuary since the mid-1970s. This article is part of an ongoing retrospective analysis of EMP's historic benthos data that focuses on cross channel variability at site "D28A" located in Old River. This effort is one of many small steps taken to achieve the broader goal of optimizing the benthic monitoring program to address the contemporary informational needs of the San Francisco Estuary's management and scientific communities. The specific questions that we seek to answer here are: (1) Do benthic habitats and community assemblages vary between positions across a river channel? (2) Are benthic samples taken at a single channel position sufficiently representative of benthos assemblages across the channel to characterize long-term changes in the benthos community of a particular section of the river?

Materials and Methods

The EMP has sampled benthic macrofauna (organisms larger than 0.5 mm) at two cross-channel positions in Old River near its confluence with Rock Slough (Figure 1) biannually from 1977 to 1979 and monthly from 1980 to 1995, at a depth of about 12 feet at both positions. Three replicate samples were taken at each position on each sampling date. Benthic invertebrates were identified to lowest taxonomic level (generally to species) and counted. We used these counts to calculate species abundance per square meter, species richness, and Shannon diversity index. We also computed species constancy—the probability of finding a species in any one grab over the sampling period—by channel position, which allows us to determine if species favor one position over the other. This probability was computed for a given period at a given position as the number of grabs where the species was found divided by the total number of grabs.

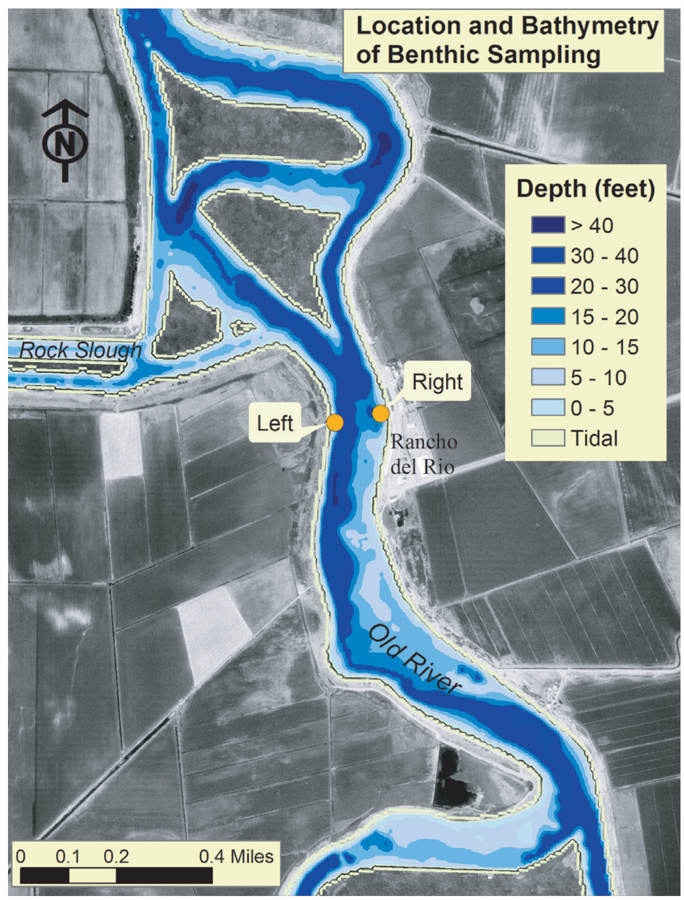

Figure 1 Location and bathymetry of the benthic sampling positions across the Old River channel.

The EMP also collected sediment samples at each channel position on each of the benthos sampling dates. We summarized sediment analysis results as percentage of organic matter (combustible at 440 °C), fines (particles < = 0.08 mm), and sand (0.08 to 2.5 mm). No gravel was found at this location.

We used box plots computed with the S-Plus statistical software to compare the distribution of species abundance, richness, diversity, and sediment composition values at the two channel positions over the period. Box plots show not only the central tendency and spread of data but indicate skewness, as well. On our box plots, the diamond indicates the median and the box extends from the first to the third quartile, showing the interquartile range that contains 50% of the values. The box's whiskers extend either to the extreme value of the data or a distance 1.5 times the interquartile range from the median whichever is less, and dash symbols represent values falling outside. The shaded area shows the median's 95% confidence interval; two medians with 95% confidence intervals that do not overlap are different at a 5% significance level.

Results

The abundance of benthic invertebrates over the sampling period were generally much higher at the right channel position than the left; median values were 14,500 and 3,500 individuals per m^2 respectively (Figure 2A). The variability in abundance among sampling dates was also greater on the right with an interquartile range of 15,400 versus 4,700 on the left. Species richness was also significantly higher at the right position, with median values of 21 and 16 species per sample respectively (Figure 2B). Species diversity as measured by the Shannon index was similar at the two positions with median index values of 1.57 on both sides, though the variability of the Shannon index was somewhat greater at the left position (Figure 2C).

A scatter plot of species constancy at the right channel position versus constancy at the left position (Table 1 and Figure 3) shows which species were most often part of the D28A benthic community and also indicates whether a particular species tended to favor one of the two positions. Species that fall along the diagonal of the plot were represented equally on both sides of the channel. No species of importance—including the dominant bivalve *Corbicula fluminea,* known to be an important consumer of phytoplankton and the amphipod species *Americorophium spinicorne*, *A. stimpsoni*, and *Gammarus daiberi,* known to be important components of the diets of resident fishes (Feyrer and others 2003)—were found on only one of the sides. However, many species were found more consistently on the right side than on the left, and only a few organisms were more likely to be found on the left side. This concurs with the greater species richness found at the right position (Figure 2B).

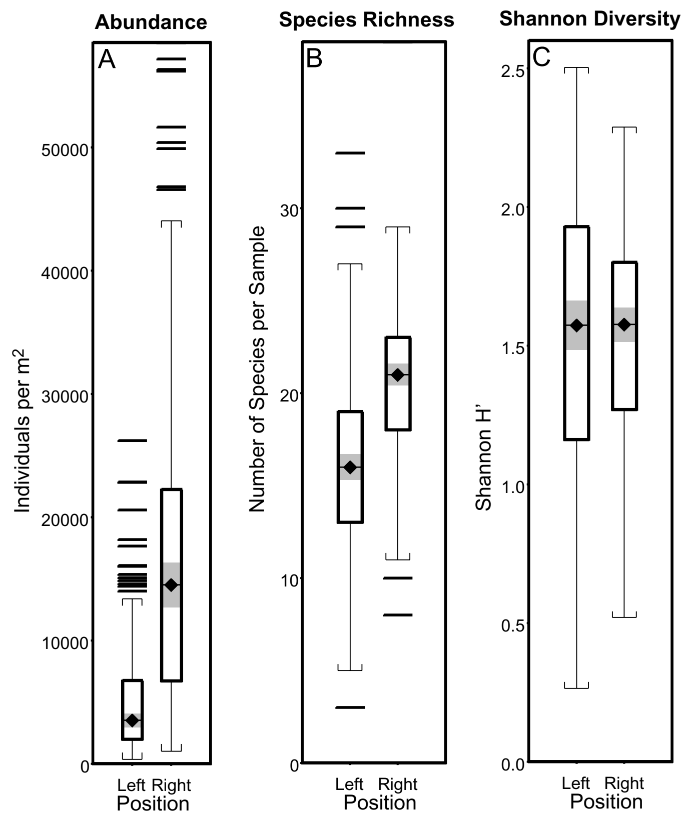

Figure 2 (A) Abundance, (B) species richness, and (C) species diversity. For details about box plots, see "Materials and Methods" section.

Table 1 Characteristics of species found in at least 10% of the samples at either of the channel positions.

Symbol on Plot	*Genus-Species, (date if introduced)*	*Life form*	*Feeding habit*	*Situation in sediment*
B1	*Pisidium compressum*	Bivalve	Sub-surface deposit feeding [2]	Sub-surface [2]
B2	*Pisidium casertanum*	Bivalve	Sub-surface deposit feeding [2]	Sub-surface [2]
B3	*Corbicula fluminea,* (1945) [3]	Bivalve	Suspension or deposit pedal feeding [8]	Sub-surface [A]
S	*Melanoides tuberculata, (*1988) [3]	Aquatic snail	Deposit [2]	Free living [2]
I	*Procladius* sp. *A*	Midge	Predatory or deposit [7]	Free living [7]
C1	*Hyalella azteca*	Gammarid amphipod	Mixed surface deposit and suspension [4]	Free living [4]
C2	*Gammarus daiberi,* (1983) [3]	Gammarid amphipod	Surface deposit [B]	Possibly burrows [4]
C3	*Americorophium stimpsoni*	Gammarid amphipod	Mixed surface deposit and suspension [B]	In tube, above surface [6]
C4	*Americorophium spinicorne*	Gammarid amphipod	Mixed surface deposit and suspension [B]	In tube, above surface [6]
C5	*Candona* sp. *A*	Ostracod	Suspension [5]	
C6	*Isocypris* sp. *A*	Ostracod		
P1	*Laonome* sp. *A,* (1989) [3]	Polychaete worm	Suspension [11]	In tube, protrude from sediment [11]
P2	*Manayunkia speciosa,* (1963) [3]	Polychaete worm	Surface deposit [11]	In tube, protrude from sediment [11]
P3	*Neanthes limnicola*	Polychaete worm	Predatory or deposit [11]	In tube or free living [11]
O1	*Sparganophilus eiseni*	Tubificid worm	Head-down deposit [1]	In tube, protrude from sediment [1]
O2	*Varichaetadrilus angustipenis,* (1982) [3]	Tubificid worm	Head-down deposit [1]	In tube, protrude from sediment [1]
O3	*Teneridrilus mastix*	Tubificid worm	Head-down deposit [1]	In tube, protrude from sediment [1]
O4	*Spirosperma nikolskyi*	Tubificid worm	Head-down deposit [1]	In tube, protrude from sediment [1]
O5	*Quistadrilus multisetosus*	Tubificid worm	Head-down deposit [1]	In tube, protrude from sediment [1]
O6	*Limnodrilus hoffmeisteri*	Tubificid worm	Head-down deposit [1]	In tube, protrude from sediment [1]
O7	*Ilyodrilus templetoni*	Tubificid worm	Head-down deposit [1]	In tube, protrude from sediment [1]
O8	*Ilyodrilus frantzi capillatus*	Tubificid worm	Head-down deposit [1]	In tube, protrude from sediment [1]
O9	*Branchiura sowerbyi,* (1952) [3]	Tubificid worm	Head-down deposit [1]	In tube, protrude from sediment [1]
O10	*Bothrioneurum vejdovskyana*	Tubificid worm	Head-down deposit [1]	In tube, protrude from sediment [1]
O11	*Aulodrilus pluriseta*	Tubificid worm	Head-down deposit [1]	In tube, protrude from sediment [1]
O12	*Aulodrilus limnobius*	Tubificid worm	Head-down deposit [1]	In tube, protrude from sediment [1]
N1	*Mermithid* sp. *A*	Nematode worm	Parasitic [10]	Free living [10]
N2	*Dorylaimus* sp. *A*	Nematode worm	Predatory [10]	Free living [10]
N3	*Teratocephalus* sp. *A*	Nematode worm	Predatory or deposit [10]	Free living [10]
R	*Prostoma graecense*	Nemertean, ribbon worm	Predatory [8]	Free living [8]

Notes: [A] Personal observation; [B] *Americorophium* are assigned to the "mixed strategy" feeders by inference from Dixon and Moore (1997) who reported that *Corophium* of several different feeding habits occasionally acquired deposited matter. They were also assigned based on a personal communication with J.W. Chapman (Oregon State University), who indicated that consumption of both suspended and epibenthic phytoplankton and particle-bound bacteria is not unexpected because, for many particles in this pool, suspension versus deposition of particles is influenced by tidal current activity.

References: [1] Brinkhurst and Gelder (2001). [2] Brown (2001). [3] Cohen, A.N. and J.T. Carlton (1995).[4] Covich and Thorp (2001); [5] Delorme (2001); [6] Dixon and Moore (1997). [7] Hershey and Lamberti (2001). [8] Kolasa (2001). [9] McMahon (1999). [10] Poinar (2001). [11] Rouse and Pleijel (2001).

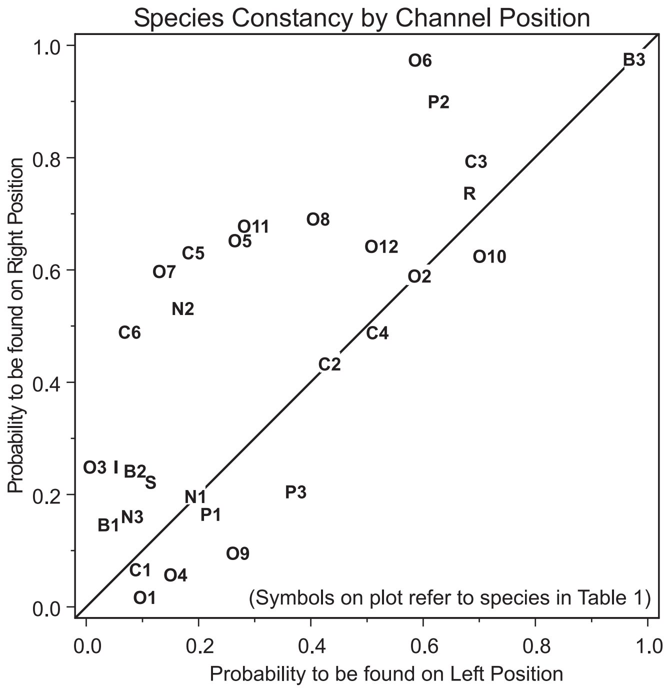

Figure 3 Scatter plot of species constancy—the probability to find a species in any one grab over the period—at the right channel position versus constancy at the left position. Species that fall along the diagonal of the plot were represented equally on both sides of the channel. Although the most numerous and most constant species can be found at both positions, the right position has a richer tubificid worm community. Tubificid worms generally feed on organic matter deposited below the sediment surface and tend to favor substrates with higher percentage of fine sediments. The most important species in terms of biomass, *Corbicula fluminea* (B3), is found in almost all samples and in equal number on the right and left positions.

Plots of abundance of individual benthic species at each channel position revealed how the benthic community composition and species abundance varied over time at the two sampling positions. Three basic patterns were noted:

1. Species whose pattern of change in abundance over time was the same at both positions. They included the bivalve, *Corbicula fluminea* (introduced in 1945); amphipods, *Americorophium spinicorne*, *A. stimpsoni*, and *Gammarus daiberi* (introduced in 1983); the polychaete worm *Neanthes limnicola*; and the oligochaete worm *Varachaetadrilus angustipenis* (introduced in 1982) (for example, Figure 4).

2. Species with similar temporal dynamics on both sides, but with dissimilar magnitude of abundance, notably, several species which were very biased toward the right side position. These included the oligochaetes *Ilyodrilus frantzi capillatus*, *Ilyodrilus templetoni*, *Limnodrilus hoffmeisteri*, and *Teneridrilus mastix*; *Candona* spp. A. and the ostracod *Isocypris* spp. A; and the nematode *Dorylaimus* spp. A. (for example, Figure 5).

3. Species with a different pattern of abundance over time on each side, including *Manayunkia speciosa*, *Quistadrilus multisetosis*, *Aulodrilus pluriseta*, and the ostracod *Candona* sp. *A*. (for example, Figure 6).

There were significant differences in the composition of the bottom substrate of the two positions (Figure 7). The sediment composition at the left position was much more variable than on the right, as indicated by the relative size of the interquartile ranges. The median percent fines at the right channel position was 92% fines with three-fourths of the samples having over 83% fines and little, if any, sand. The median percent fines at the left channel position was 74% with three-fourths of the samples having less than 87% fines and often a large proportion of sand. Organic matter comprised about 10% of the sediment at both positions.

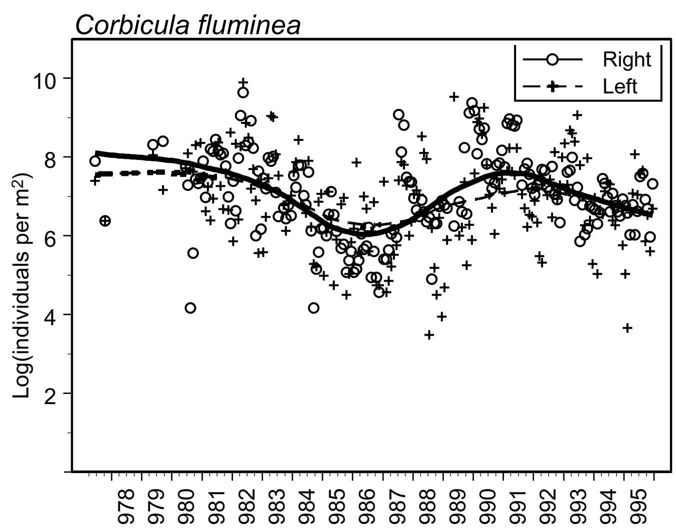

Figure 4 Patterns of abundance of *Corbicula fluminea* were similar at both channel position over time. Note: abundance in each sample was plotted on a log scale with zero abundance samples added at zero. Curve is loess fit of abundance values including zeros.

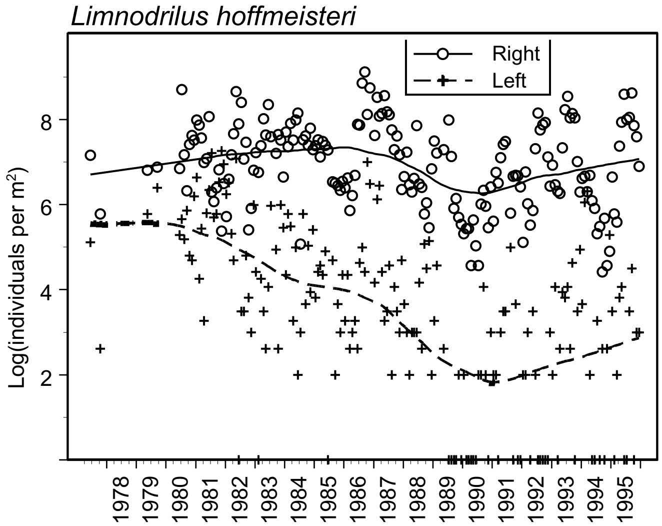

Figure 5 Abundance of *Limnodrilus hoffmeisteri* at each channel position shows similar trends on both sides but with dissimilar magnitudes of abundance. See "Note" in Figure 4 caption.

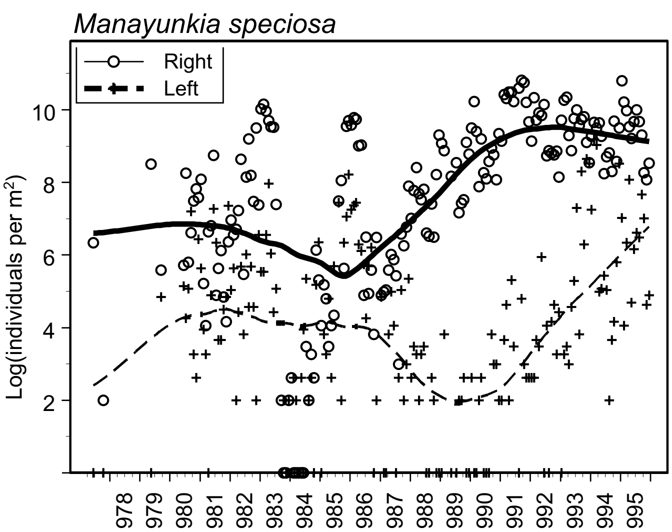

Figure 6 Abundance of *Manayunkia speciosa* shows different (sometimes divergent) patterns of abundance over time at each channel position. See "Note" in Figure 4 caption.

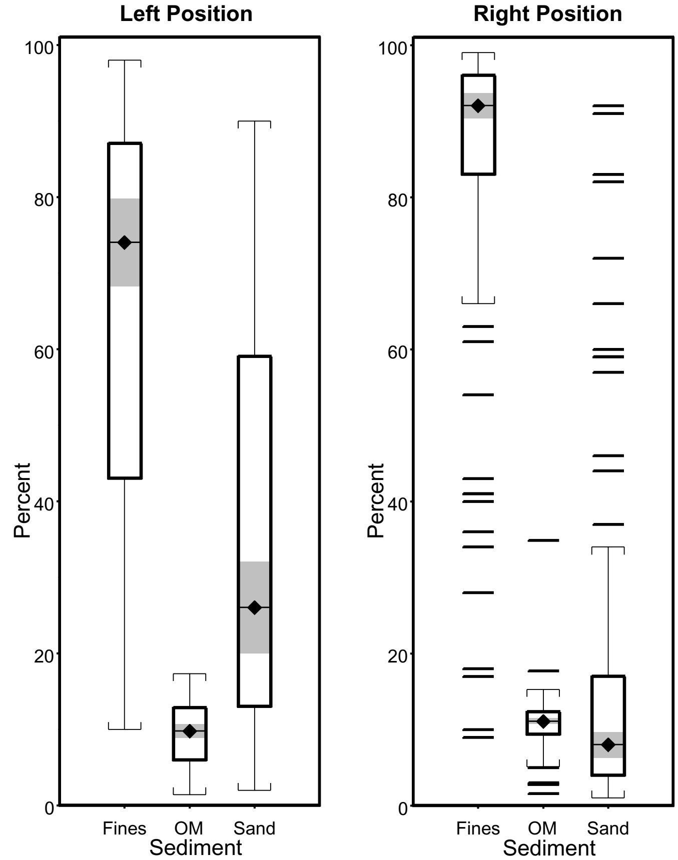

Figure 7 Sediment composition. For details about box plots, see "Materials and Methods" section.

Discussion

Our results indicate that sampling at a single cross-channel position at this location (as implemented by the EMP in 1996) provides reasonable data on trends in abundance of many dominant, ubiquitous species such as *Corbicula fluminea*, *Americorophium spinicorne*, *A. stimpsoni*, and *Gammarus daiberi* and *Varachaetadrilus angustipenis*, but may not capture the population dynamics of other species that thrive in specialized benthic sub-habitats. Differences in benthic community between the two sampling sites can, in this case, be related to differences in the local physical environment at each site. The physical forces that influence sediment composition undoubtedly also influence the benthic biota. The greater variability of substrate composition at the left channel position indicates a more energetic situation, with more frequent physical disturbance. The relative stability at the right position seems to allow seasonal population growth of the several species that exhibit higher constancy there. The divergent population dynamics that several species exhibit at the two channel positions indicate that important changes in habitat for those species do not occur synchronously at D28A left and right channel positions. This means that one sampling position is not sufficient to characterize long-term changes in the entire benthos community of a particular section of the river.

Why are we looking at this now?

The EMP is part of a comprehensive environmental monitoring effort for the upper San Francisco estuary required by the State Water Resources Control Board's (SWRCB) Water Right Decision 1641 (D-1641) and its predecessors. According to D-1641, the EMP is legally obliged (1) to ensure compliance with Bay-Delta water quality objectives; (2) to identify meaningful changes in any significant water quality parameters potentially related to operation of the State Water Project (SWP) or the Central Valley Project (CVP); and (3) to reveal trends in ecological changes potentially related to SWP or CVP operations. Along with water quality, phytoplankton, and zooplankton monitoring, the EMP also includes a benthic monitoring element.

D-1641 requires reviews of its monitoring programs every three years to ensure that the monitoring goals are met. The most recent review, completed in 2003, indicated that the time has come to consider changes in the benthic monitoring program to bring the program up to date with contemporary understanding of the physical, chemical, and biological processes of the estuary. In particular, since the start of this program, we have learned that (1) the benthic community is a recipient of a high number of exotic species (Cohen and Carlton, 1995; Peterson, 2002; Gehrts, this issue); (2) some benthic species consume large amounts of phytoplankton, which can significantly reduce the food availability for pelagic consumers (Cloern and others, 1985; Nichols, 1985; Alpine and Cloern, 1992); and (3) benthic species can be bioaccumulators of certain contaminants and thus influence the flow of contaminants in the food web (Stewart, 2001). It has been suggested that the benthic monitoring program consider the interdependence of other components of the ecosystem with the benthic community and adapt the EMP program to monitor critical, environmentally induced changes in the benthic community that could negatively affect the ecosystem. Optimizing the sampling program requires finding a balance between detecting local community changes, documenting the status and trends of benthic organisms throughout the estuary, and maintaining the valuable integrity of the long-term data sets that have already been collected. Discussions with local experts are taking place now regarding how the sampling program might be altered to improve the informational value of this monitoring effort.

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Why We Do a "Post-VAMP Shoulder" for Delta Smelt

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Introduction

The delta smelt (*Hypomesus transpacificus*) is endemic to the San Francisco Estuary and the Sacramento-San Joaquin Delta, which has undergone a profound transformation over the past 150 years. This small euryhaline planktivore is generally found near the surface in open waters in or just landward of the region of fresh and saltwater mixing (Moyle, 2002). Delta smelt are listed as threatened under the federal Endangered Species Act (ESA) of 1973. Although highly variable, delta smelt fall abundance indices have exhibited a marked decline over the past 30 years.

Several monitoring methods are used to obtain information on the various life stages of delta smelt and its abundance and distribution in the Delta, including fall and spring midwater trawls (the latter evolved into the Kodiak Trawl survey), beach seining, the Chipps Island trawl, and 20-mm surveys. Non-survey indicators related to delta smelt abundance or distribution include year-type hydrology (wet vs. dry), location of the salt/freshwater mixing zone (X2), water quality, water temperature, rate of export pumping, and incidental take at the Central Valley Project (CVP) and State Water Project (SWP) export facilities. Delta smelt are vulnerable to entrainment at the CVP and SWP export facilities as larvae, juveniles, and adults.

In this article I describe some of the management tools developed to protect delta smelt and other fishes, the biological basis for their development and use, and present some preliminary indications of their success in protecting delta smelt.

What is the Environmental Water Account?

The Environmental Water Account (EWA) is a key component of CALFED's water management strategy. Created to address the problems of declining fish populations and water supply reliability, the EWA aims to protect both fish and water users by providing for more flexible water project operations in the Bay-Delta. The EWA buys water from willing sellers or diverts surplus water when safe for fish, then banks, stores, transfers, and releases it as needed to protect fish and compensate water users for deferred diversions.

To benefit delta smelt, water from the EWA allows curtailment of water project export pumping, which directly reduces incidental take at the CVP and SWP pumps in the south Delta. Pumping curtailments from January through March minimize take of pre-spawning and spawning adult delta smelt, which are considered the most critical life stage. In an annual species these adults represent the individuals who have successfully avoided death occurring at earlier life stages to achieve reproductive maturity. Actions taken in April through June minimize take of late-spawning adults or larvae and juveniles. After June, delta smelt emigrate from the south delta and are no longer vulnerable to entrainment by the pumps.

What is the Vernalis Adaptive Management Program?

Pursuant to the San Joaquin River Agreement (SJRA), the Vernalis Adaptive Management Program (VAMP) is designed to protect fall-run Chinook salmon in the San Joaquin River by improving smolt survival through the Delta. Through the VAMP, information is gathered on the relative effects of flows in the lower San Joaquin River, water project export pumping rates, and the operation of a fish barrier at the head of Old River on Chinook salmon survival. The VAMP provides fisheries benefits during a 31-day April-May pulse flow period by reducing export pumping and increasing flows on the San Joaquin River and its tributaries.

In addition to the SJRA, flows on the lower San Joaquin River are regulated by biological opinions issued by US Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration (NOAA) Fisheries and by the State Water Resources Control Board's Decision 1641. Springtime pulse flows are required, with a coincident reduction of exports, to support habitat quality, protect larval delta smelt, and assist the out-migration of juvenile Chinook salmon. Water to support these pulse flows is provided by acquisitions from the San Joaquin River tributaries under CVPIA §3406(b)(3) and by CVP water pursuant to CVPIA §3406(b)(2).

What is the "Post-VAMP shoulder" and Why Do We Do It?

Simply stated, extending export curtailments beyond the VAMP spring pulse flow period (usually ending May 15) is referred to as the post-VAMP shoulder. The post-VAMP shoulder is intended to improve habitat and afford delta smelt larvae the opportunity to move north and west toward rearing areas in Suisun Bay, Suisun Marsh, and the lower Sacramento River. Water that is not exported during the post-VAMP shoulder curtailment must either be accounted for under CVPIA §3406(b)(2) or reimbursed by the EWA.

As hydrologic models improved over time, our understanding of Delta processes has evolved from the belief that the Delta is a riverine flow dominated system to one that is tidally dominated except during brief periods of high river flow. Nonetheless, analysis has shown that positive central Delta flows may benefit delta smelt larvae hatched in the central Delta by reducing entrainment at the export pumps (Nobriga and others, 2001). The hypothesis behind the post-VAMP shoulder is that, should the CVP and SWP resume full export capability immediately following the VAMP, planktonic delta smelt larvae in the south Delta would in many years suffer very high entrainment losses. While quantitative relationships between Delta flows and fish migration are still under investigation, it is thought that the post-VAMP shoulder provides habitat conditions that promote western migration of young delta smelt and improve their overall survival.

A recommendation to implement a post-VAMP shoulder is made following interagency discussion at the staff level, both by the b(2) Interagency Team (b(2)IT)[1] and the Data Assessment Team (DAT)[2], and with the advice of the Delta Smelt Work Group[3]. These teams consider factors including incidental take at the pumps, Delta conditions, and the distribution and abundance of delta smelt as indicated by various monitoring measures. The DAT formulates a recommendation, which is submitted to the Water Operations Management Team (WOMT)[4] for discussion and decision making. When the post-VAMP shoulder is implemented, the temporary fish barrier at the head of Old River is removed and tidal operation of the south Delta temporary barriers is suspended to maximize migration opportunities for young delta smelt. Export reductions are maintained until incidental take of delta smelt declines, 20-mm surveys indicate that delta smelt distribution is primarily north and west of Franks Tract, or south Delta water temperatures warm to a point at which delta smelt survival is negatively affected.

1. The b(2)IT was established to implement and account for expenditures of environmental water made available by section 3406(b)(2) of the Central Valley Project Improvement Act. It consists of staff-level representatives of the CVPIA implementing agencies.

2. The DAT consists of staff from the five EWA implementing agencies, plus representatives from the academic and stakeholder communities.

3. The Delta Smelt Work Group was established in the 1995 USFWS Biological Opinion on the Operations Criteria and Plan for the Central Valley Project and the State Water Project. It is an interdisciplinary team of experts from state and federal agencies, academia, and the stakeholder community.

4. The WOMT consists of management-level decision makers from the five EWA implementing agencies.

Decision Criteria

The decision criteria for implementation of the post-VAMP shoulder are found in the delta smelt decision tree, as presented by Nobriga and others (2001). Factors to consider include (1) the previous year's fall midwater trawl index, (2) abundance of juvenile delta smelt in the south Delta, (3) incidental take levels, (4) below-normal or dry hydrology, and (5) the length of the spawning season, as indicated by water temperatures in the south Delta (Table 1). The extent and duration of the post-VAMP shoulder would depend upon the level of concern, as well as upon available EWA water resources, the degree to which juveniles appear to be migrating north and west based on 20-mm survey data, and temperatures in the south Delta.

In the case of the 2003 post-VAMP shoulder, concern was high as the 2002 FMWT was the fifth lowest since 1967. USFWS convened the Delta Smelt Work Group (Work Group) on May 12 to discuss the potential to institute a post-VAMP shoulder. Although the fourth survey of the 20-mm survey indicated an improvement in distribution of larval fish over previous surveys (Figure 1), overall numbers sampled were very low, resulting in a heightened level of concern. Noting that the expected benefits from export curtailments would fall off sharply after May 31 as the south Delta continued to warm, the Work Group recommended that most of the remaining EWA assets be applied to a VAMP shoulder, saving very little for potential fish actions in June. The Work Group recommended (1) breaching the Head-of-Old-River Barrier immediately following the conclusion of the VAMP and tying open the flap gates on the agricultural barriers, (2) restricting CVP and SWP exports to a combined 1,500 cfs through May 18, and (3) ramping up exports beginning May 19 to a rate at which combined exports did not exceed the San Joaquin River flow at Vernalis (approximately 2,000 cfs). The fifth period of 20-mm sampling completed on May 24 indicated that a substantial fraction of juveniles were still migrating toward rearing habitat in Suisun Bay, and most were north and west of Franks Tract, where they were generally regarded as being beyond the influence of the export facilities (Figure 1). As south Delta water temperatures climbed and EWA debt began to accumulate, the Management Agency biologists recommended that export pumping begin ramping up to full capacity beginning on May 28.

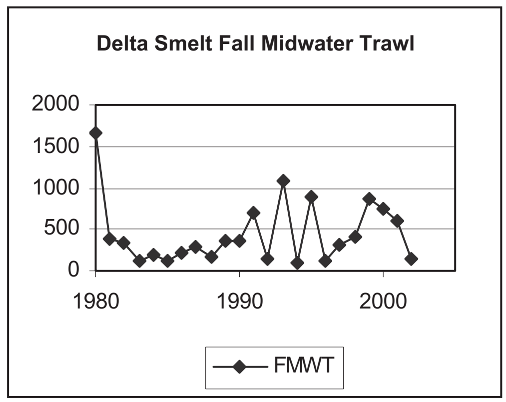

Figure 1 Trends in abundance of delta smelt, as indicated by the Fall Midwater Trawl, calendar years 1980-2002.

Table 1 Factors leading to the recommendation of a post-VAMP shoulder since the inception of the Environmental Water Account.

Decision Criterion[a]	*2001*	*2002*	*2003*
FMWT-1[b]	Low concern	Low concern	High concern
Distribution (20mm) and Abundance	Central and South Delta, lower Sacramento River	Central and South Delta, lower Sacramento River	Central Delta, lower Sacramento River, Suisun
Incidental Take[c]	Low concern	Concern	Concern
Hydrology	Dry	Dry	Dry early, Wet late
South Delta Temperature[d]	Warming → Warm	Warming → Warm	Warming → Warm

[a] See Nobriga and others 2001 (delta smelt decision tree) for explanations of decision criteria

[b] Indicates the value of the fall midwater trawl index for the previous year; for the purposes of this paper only, concern was assessed as "high" if the value was below the median value of 394, moderate if the value fell between the median and the mean, and "low" if the value exceeded the mean of 565

[c] From the 1995 USFWS biological opinion; for the purposes of this paper only, concern was assessed as "high" if take approached or exceeded the reconsultation level and "low" if take did not exceed the heightened-concern level

[d] South Delta water temperatures for May 1-3: 10-15 °C = Cool, 16-20 °C = Warming; > 20 °C = Warm

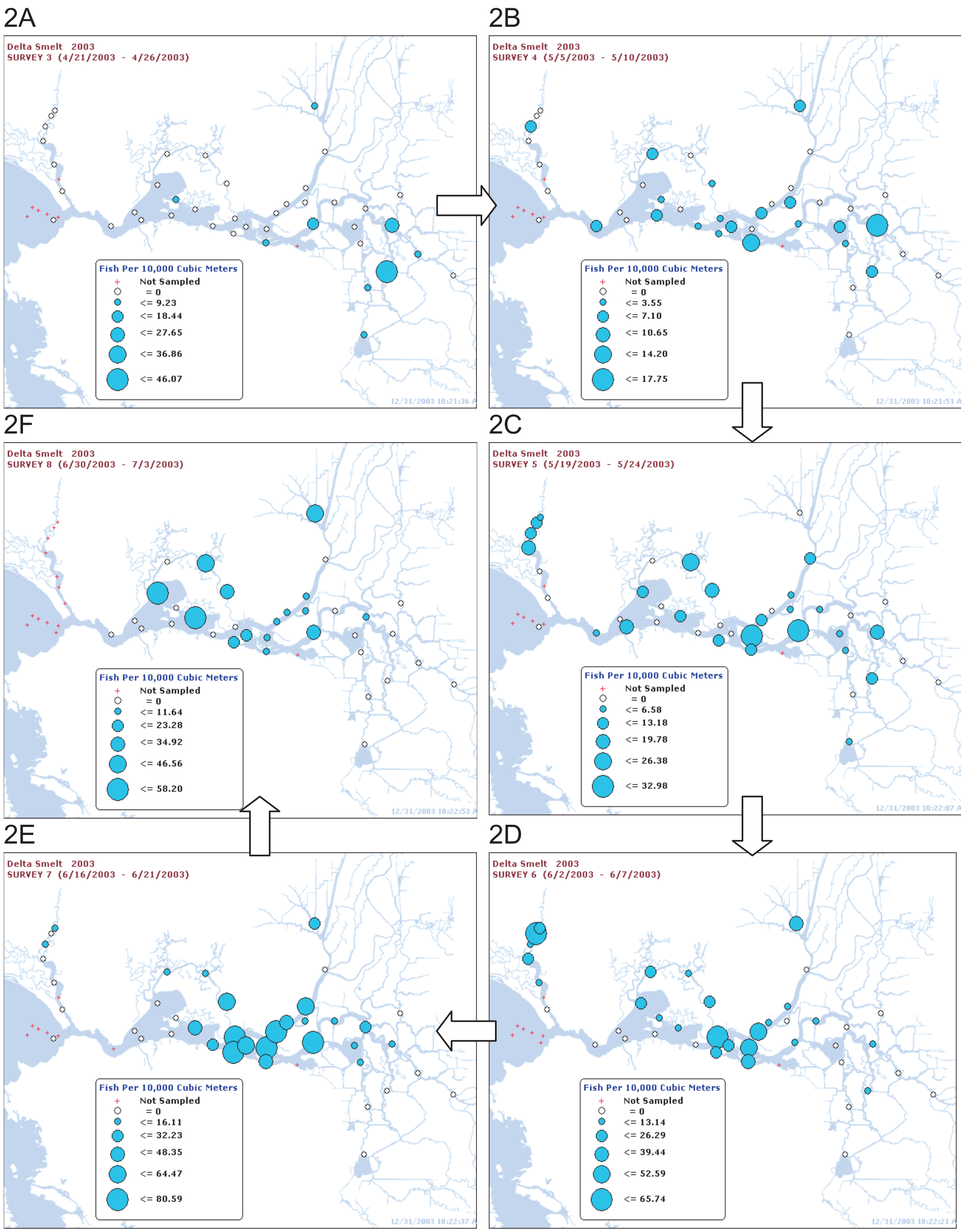

Figure 2 Results of surveys 3 through 8, covering the post-VAMP period, 2003 (clockwise from upper left).

Is the Post-VAMP Shoulder Effective?

The purpose of the post-VAMP shoulder is to afford delta smelt larvae the opportunity to migrate from their hatching areas in the south Delta to rearing habitat in Suisun Bay, Suisun Marsh, and the lower Sacramento River. Currently, quantitative relationships between Delta flows and fish migration are still under investigation. Nonetheless information obtained from the Department of Fish and Game's 20-mm survey has provided qualitative indicators of success. Figure 2 illustrates the north- and westward movement of delta smelt during the post-VAMP shoulder in 2003; 20-mm plots from 2001 and 2002 exhibit a similar pattern. However, because directed investigations have not been conducted, it would be premature to conclude that this apparent movement occurs as a result of the post-VAMP shoulder.

Factors that influence incidental take (i.e., loss that results from, but is not the primary purpose of, operation of the state and federal export facilities, presently estimated from daily salvage) of delta smelt at the pumps have not been definitively described. However, delta smelt take appears to increase with their relative abundance the previous fall, as indicated by the FMWT (compare Figures 1 and 3, and Table 2). All that can be said with certainty is that, in the three years in which the EWA has provided a post-VAMP shoulder (2001-2003), incidental take of delta smelt has not reached the reconsultation level (Table 3).

Incidental take of delta smelt exceeded the reconsultation level in the post-VAMP period (May) in 1996, 1999, and 2000, years of above-normal hydrology (Table 3). Had the appropriate tools existed in 1996, 1999, and 2000, a post-VAMP shoulder may have been appropriate, after due consideration of the decision criteria.

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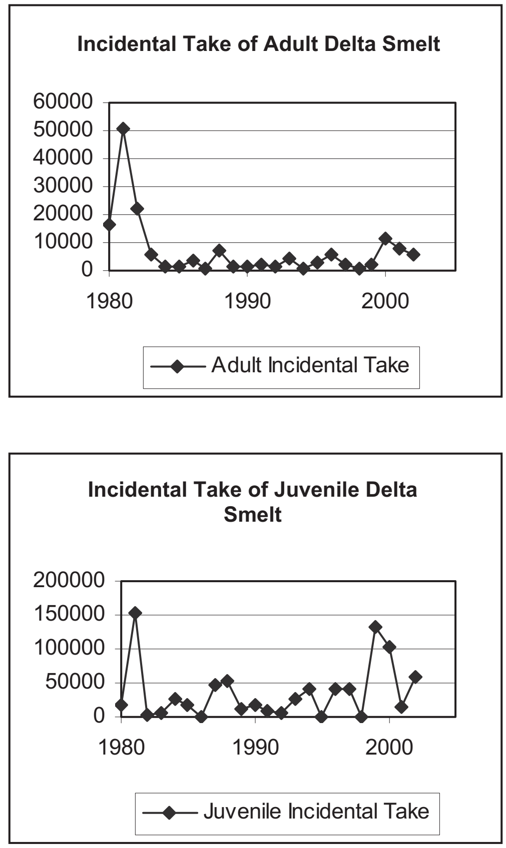

Figure 3 Trends in incidental take of delta smelt, calendar years 1980-2002.

Table 2 Coefficients of correlation for calendar years 1980-2002.

	Adult take[a]	*Juvenile take*[b]	*FMWT*	*FMWT-1*
Adult take	1			
Juvenile take	0.532954	1		
FMWT	0.141327	0.069574	1	
FMWT-1	0.673357	0.60474	-0.11846	1

[a] Estimated as the total incidental take for January, February, and March for a given year
[b] Estimated as the total incidental take for April, May, and June

Table 3 Combined salvage of delta smelt at the South Delta Export Facilities since the 1995 USFWS Biological Opinion.

Year and Water Year Type	*1995 (AN[a])*	*1996 (AN)*	*1997 (AN)*	*1998 (AN)*	*1999 (AN)*	*2000 (AN)*	*2001 (BN[b])*	*2002 (BN)*	*2003 (BN)*	*Reconsultation Level*	
FMWT (year-1)	899	127	303	420	864	756	603	139	210	Below Normal	Above Normal
December	54	0	18	281	16	126	192	1,129	2,800	8,052	733
January	2,057	4,189	0	130	28	802	181	5,231	9,561	13,354	5,379
February	481	1,290	1,730	24	1,466	7,831	3,870	280	1,494	10,910	7,188
March	16	155	1,159	592	564	2,746	3,772	225	483	5,386	6,979
April	24	111	32,828	48	410	1,746	520	372	504	12,354	2,378
May	0	30,399	7,876	4	58,929	49,500	13,170	47,361	16,324	55,277	9,769
June	0	9,441	228	66	73,368	50,490	2,418	11,926	10,156	47,245	10,709
WY Total	2,632	45,733	43,931	1,269	154,651	70,216	24,466	66,548	41,334		

[a] Above-normal year as defined by the USFWS 1995 Biological Opinion on the effects of long-term operation of the Central Valley Project and State Water Project (USFWS 1995)

[b] Below-normal year (USFWS 1995)

Length-Weight Relationships for 18 Fish Species Common to the San Francisco Estuary

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Introduction

Historically, the Department of Fish and Game (DFG) has used abundance indices (a relative index that reflects the numbers of fish) from the Summer Townet Survey (TNS), Fall Midwater Trawl Survey (FMWT), and the San Francisco Bay Study (SFBS) to track the trends in abundance of various species in the San Francisco Estuary. Abundance indices are easy to calculate and can provide insight into the relationship between young fish abundance and important environmental variables, such as outflow (see Turner and Chadwick 1972 for an example with striped bass [*Morone saxatilis*], Stevens and Miller 1983 for examples with Chinook salmon [*Onchorhynchus tshawytscha*], American shad [*Alosa sapidissima*], longfin smelt [*Spirinchus thaleichthys*], and delta smelt [*Hypomesus transpacificus*]).

Despite their long usage, abundance indices have one drawback: each fish caught is treated as 1 unit regardless of size (length) or condition (the "well being" of a fish, Anderson and Neumann 1996). The relationship between fish length (routinely collected) and mass (traditionally referred to as weight in fisheries science) is nonlinear (Anderson and Neumann 1996). Abundance indices do not take this nonlinear aspect into account. Therefore, there may be biological relationships that abundance indices are incapable of revealing or explaining. The weight of a fish can be used to calculate two different indices: biomass and condition.

Biomass indices are another relative index reflecting the mass of a collection of fish (such as a year class) rather than numbers (as with abundance indices). Biomass indices can take into account the nonlinear nature of mass and, when used for trend analysis, could reveal relationships with important environmental variables (such as outflow, see above) that may not be detected using abundance indices.

Condition indices give an indication of the overall condition or "fatness" (or as Anderson and Neumann 1996 put it, "well being") of an individual fish, rather than a group of fishes. Condition indices are determined by dividing the actual weight of a fish by some reference weight (Anderson and Neumann 1996) for a given length. Therefore it is possible to determine the average condition index for a given year class or a subset of a year class, based on region for example. The mean condition index could then be related to environmental variables, such as prey density, to help determine what prevailing circumstances might enhance or detract from survival of a given species.

The first step in calculating either a biomass or condition index is to determine the length-weight relationships (LWR) for the species in question. In the absence of weighing all fish caught or extrapolating from a subsample, the LWRs for selected species are necessary to transform the length data that is routinely collected by the TNS, FMWT, and SFBS into weight for the calculation of a biomass index. To calculate a condition index, one or more LWRs are needed to determine a "reference weight" to compare with the actual weight of a fish to determine a condition index (Anderson and Neumann 1996). Depending upon the technique used to develop the reference weight, a single LWR is needed (Le Cren 1951) or multiple LWRs from the same species are needed (Murphy, Brown, and Springer 1990).

The goal of long-term monitoring activities by DFG's Central Valley Bay-Delta Branch is to determine biomass and condition indices for routinely encountered species and life stages in the TNS, FMWT, and SFBS. To accomplish this, a Length-Weight Study (LWS) was started in 2003. The first part of this study is the determination of LWRs for species routinely caught by the TNS, FMWT, and SFBS. This report details the LWRs determined as of December 2003. The calculation and evaluation of biomass and condition indices is scheduled for the later part of 2004 and into 2005. Due to budget constraints, the evaluation of condition indices has been curtailed to one species (striped bass) instead of the original four (longfin smelt, delta smelt, and threadfin shad [*Dorosoma pentenese*]).

Methods

The intention of the LWS was to determine the weight of fish just after capture, therefore giving the most accurate representation. Ideally, this would have been accomplished by weighing the fish immediately after capture on the boat. However, the balance (Mettler-Toledo AG-204) needed for the LWS would not function properly due to the motion of the boat. Therefore, the LWS preserved specimens in isotonic salt solution (roughly 12 ppt) and on ice. Isotonic salt solution was chosen to minimize water gain or loss through osmosis. Specimens were returned to DFG in Stockton and refrigerated on beds of ice to extend the time before they began to rot. They were not frozen because the effects of freezing could not be accounted for. Other data collected were: the date, time, and location of capture; the survey; and the gear used.

Processing consisted of weighing and measuring specimens. All fish were weighed to the nearest 0.1 mg if possible. For specimens that exceeded the limits of the balance (200 g) another balance was used and fish were weighed to the nearest gram. Fish that had ruptured (that is, the guts had burst or extruded through the abdominal wall) were excluded from processing. Fish that were bleeding slightly (mainly from the gills or eyes) were included. All fish were measured (standard length, total length, and, where applicable, fork length) to the nearest millimeter using a measuring board similar to those used in the field. For specimens that exceeded the limits of the measuring board (180 mm), a tape measure was used. This occurred for 14 specimens or 0.4% of all specimens collected between April and December 2003. The LWS definition of standard length is "from the most anterior part of the fish to the most posterior point where the body ends and the caudal fin rays begin". This definition was necessary as finding the hypural plate (Anderson and Neumann 1996) on small fish was difficult.

The goal for the time between capture and processing (holding time) was set at ≤ 2 days. This relatively quick "turnaround time" was determined necessary to process specimens before they rotted. The time between capture and processing (processing time) was determined by subtracting the Julian date when a fish was captured from the Julian date that a fish was processed. The minimum, maximum, and mean processing times were determined. Some processing times were omitted from the analysis due to recording errors. This resulted in 42 observations or 1.2% of all observations omitted from this analysis.

Species specific length-weight relationships were determined using the following formula (Anderson and Neumann 1996):

$$WEIGHT = a*LENGTH^{b}$$

This approach was chosen because it displays LWRs in their actual (non-transformed) form vice the log transformation (Anderson and Neumann 1996). Analysis was conducted using PROC NLIN (nonlinear regression) in SAS (SAS Institute, Inc. 1989). Species-specific LWRs were determined for all length measurements taken. Weight variability in relation to length was evaluated, by inspection, using either fork length or total length, as appropriate.

Table 1 Species collected for the Length-Weight Study (LWS) and minimum, mean, and maximum holding times (April-December 2003).

Species	Scientific name	Minimum	Holding time (days) mean (n)	Maximum
Speckled sanddab	(*Citharichthys stigmaeus*)	1	2.2 (220)	4
English sole	(*Pleuronectes vetulus*)	1	2.1 (178)	4
Plainfin midshipman	(*Porichthys notatus*)	1	1.7 (165)	4
Shiner surfperch	(*Cymatogaster aggregata*)	1	2.3 (162)	7
Northern anchovy	(*Engraulis mordax*)	1	1.8 (326)	4
Pacific herring	(*Clupea pallasi*)	1	1.4 (259)	6
Pacific sardine	(*Sardinops sagax*)	1	1.0 (39)	1
American shad	(*Alosa sapadissima*)	1	3.3 (429)	7
Bay goby	(*Lepidogobius lepidus*)	1	1.7 (202)	5
Yellowfin goby	(*Acanthogobius flavimanus*)	1	1.4 (171)	6
Staghorn sculpin	(*Leptocottus armatus*)	0	2.2 (132)	7
Topsmelt	(*Atherinops affinis*)	1	1.8 (248)	5
Jacksmelt	(*Atherinop californiensis*)	1	2.2 (75)	5
Striped bass	(*Morone saxatilis*)	0	1.4 (288)	4
Threadfin shad	(*Dorosoma petenense*)	1	2.2 (210)	8
Longfin smelt	(*Spirinchus thaleichthys*)	0	2.3 (295)	7
Delta smelt	(*Hypomesus transpacificus*)	1	2.3 (179)	7
Cheekspot goby	(*Ilypnus gilberti*)	2	2.0 (24)	2
Species with only 1 specimen collected—excluded from analysis				
Starry flounder	(*Platichthys stellatus*)	Processed 6 days after capture		
California grunion	(*Leuresthes tenuis*)	Processed 4 days after capture		
Brown smoothhound	(*Mustelus henlei*)	Processed 3 days after capture		

Results

Specimen collection began in April 2003 and ended in December 2003. Fishes were collected during the TNS, FMWT, SFBS, and the USFWS Beach Seine surveys (it was necessary to collect some topsmelt [*Atherinops affinis*] from inshore areas), with a total of 21 species being represented (Table 1). A large range of sizes, depending upon species, was also represented (Table 2). In all, 3,647 specimens were collected. There were 3 species where only 1 specimen was collected (Tables 1 and 2). These species were excluded from further analysis, resulting in 18 species with LWRs.

The goal of processing fish within ≤ 2 days of capture was not strictly met. Mean holding times ranged from 1 to 3.3 days (Table 1). Fish were held from 0 to 8 days after capture (Table 1). However, the majority of mean holding times were roughly 2 days (Table 1). After about one week, a noticeable odor of rotting fish was detected in the refrigerator.

Although all LWRs were significant (F test, $p < 0.0001$, Figures 1-18), the majority of relationships (14 out of 18) are considered to be incomplete[1] as the full size range for these species had not been adequately covered. For some fall or winter species, this was due to the late start (April 2003) of the LWS. The areas where more data are necessary are primarily at the lower and upper limits (ends) of the length range for the species requiring more observations (Table 3). Plainfin midshipman (*Porichthys notalus*) was the only species with a gap in the "middle" of the length-weight data where more data were deemed necessary (between 89 and

1. Gartz (2003) stated that the collection of specimens was complete for bay goby. Further analysis by the LWS, after the article was submitted, has indicated that more specimens are needed.

151 mm [TL]). The LWS will collect these additional specimens as resources allow. The LWRs that are the least complete are for Pacific sardine (Figure 1) and cheekspot goby (Figure 2).

Variability increased with length for almost all relationships with few outliers (Figures 1-18). Only one gross outlier was identified for northern anchovy (111 mm [FL], 19.9342 g, Figure 3). However, given the large number of observations and the position of the outlier (in relation to length) the LWS staff considered it of little consequence on the LWR for northern anchovy.

Table 2 Minimum and maximum weight (reported to the nearest milligram) and length (measured to the nearest millimeter) measurements of species collected for the Department of Fish and Game's Length-Weight Study (April-December 2003).

	Weight (gm)		*Standard*		*Fork length (mm)*		*Total*	
Species	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*
American shad	0.547	61.943	34	162	37	172	41	202
Bay goby	0.070	6.420	22	78	N/A		26	93
Cheek goby	0.209	1.023	26	43	N/A		31	52
Delta smelt	0.065	7.230	21	86	23	94	24	102
English sole	0.205	39.478	24	138	N/A		28	165
Jacksmelt	0.908	359.700	43	298	48	326	51	350
Longfin smelt	0.055	18.412	20	114	22	122	23	132
Northern anchovy	1.010	32.620	47	141	53	148	57	163
Pacific herring	0.185	9.526	28	90	31	97	32	107
Pacific sardine	3.304	5.618	67	78	72	85	78	94
Pacific staghorn sculpin	1.956	114.785	47	178	N/A		56	209
Plainfin midshipman	0.126	105.670	18	206	N/A		20	227
Shiner surfperch	0.742	36.543	32	112	37	123	39	133
Speckled sanddab	0.410	24.945	30	115	N/A		36	137
Striped bass	0.040	41.973	14	131	15	148	16	158
Threadfin shad	0.201	41.666	25	128	28	135	30	157
Topsmelt	0.032	54.050	21	177	24	188	25	204
Yellowfin goby	0.051	49.249	16	154	N/A		19	187
Species where only 1 specimen was collected:								
Brown smoothhound[1]	96.015		293		N/A		N/A	
California grunion	5.397		80		88		95	
Starry flounder	6.510		66		N/A		77	

[1] The brown smoothhound was collected for an out-of-state organization that requested only standard length

Table 3 Species needing additional data at the lower and upper limits of the length range and the sizes needed for the LWS as of December 2003.

Species	*Less than*	*Greater than*
Topsmelt	76	154
Speckled sanddab	36	
Shiner surfperch	36	109
Staghorn sculpin	74	154
Pacific sardine	74	84
Pacific herring	39	84
Northern anchovy	56	124
Jacksmelt	56	154
English sole	36	
Cheekspot goby	36	
Bay goby	31	89
American shad		109
Delta smelt		64

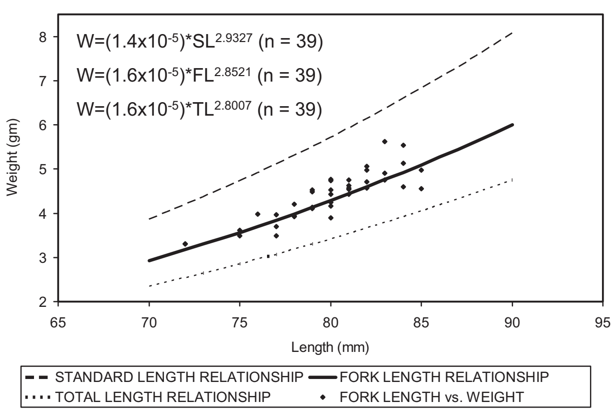

Figure 1 Length (mm)-weight (g) relationships for Pacific sardine with equations for standard length (SL), fork length (FL), and total length (TL). Relationships are from 70-90 mm.

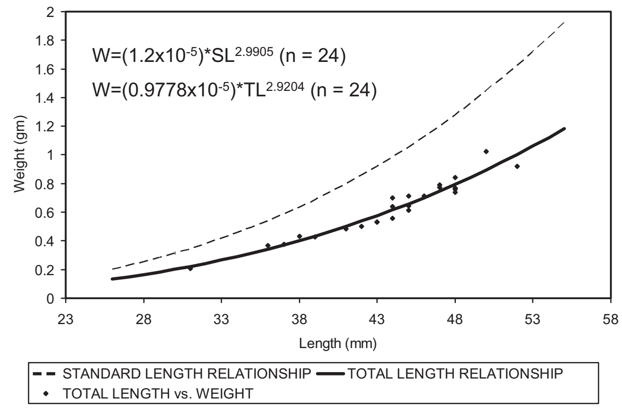

Figure 2 Length (mm)-weight (g) relationships for cheek-spot goby with equations for standard length (SL) and total length (TL). Relationships are from 25-55 mm.

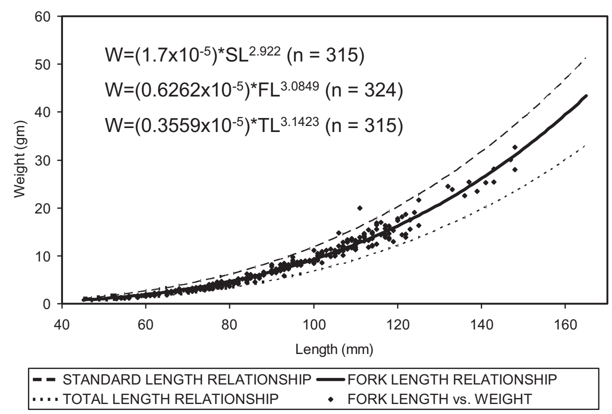

Figure 3 Length (mm)-weight (g) relationships for northern anchovy with equations for standard length (SL), fork length (FL), and total length (TL). Relationships are from 45-165 mm.

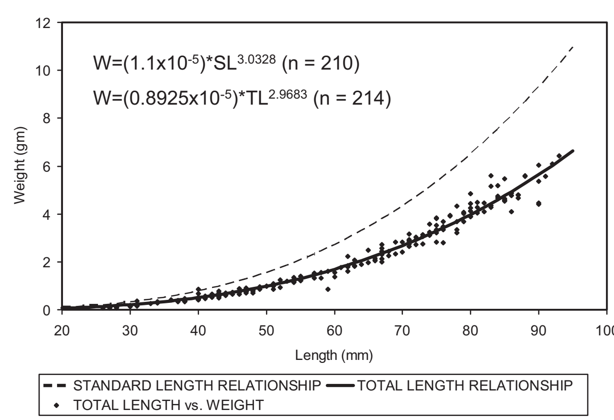

Figure 4 Length (mm)-weight (g) relationships for bay goby with equations for standard length (SL) and total length (TL). Relationships are from 20-95 mm.

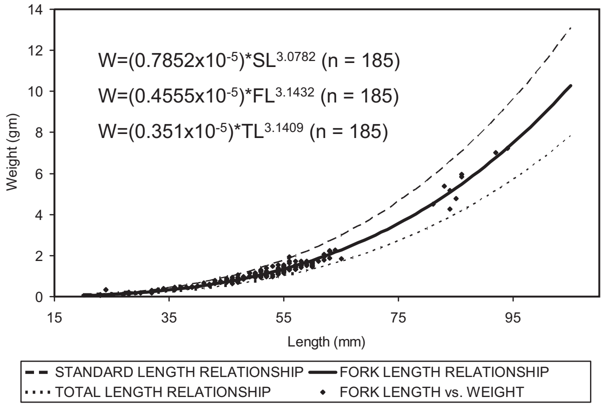

Figure 5 Length (mm)-weight (g) relationships for delta smelt with equations for standard length (SL), fork length (FL), and total length (TL). Relationships are from 20-105 mm.

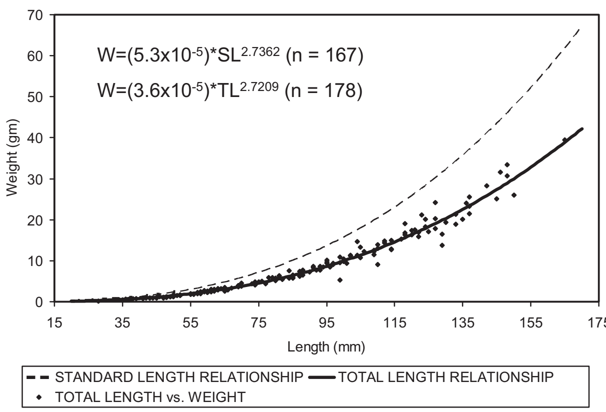

Figure 6 Length (mm)-weight (g) relationships for English sole with equations for standard length (SL) and total length (TL). Relationships are from 20-170 mm.

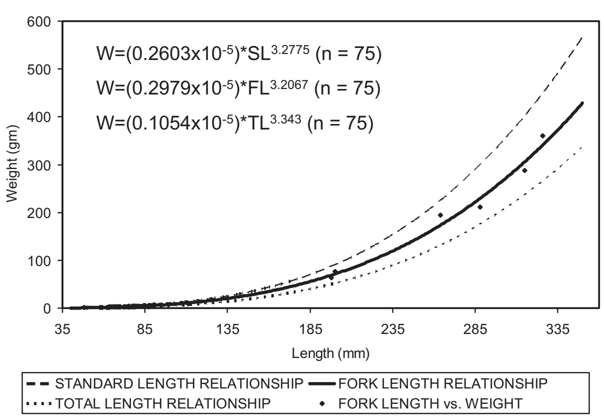

Figure 7 Length (mm)-weight (g) relationships for jacksmelt with equations for standard length (SL), fork length (FL), and total length (TL). Relationships are from 40-350 mm.

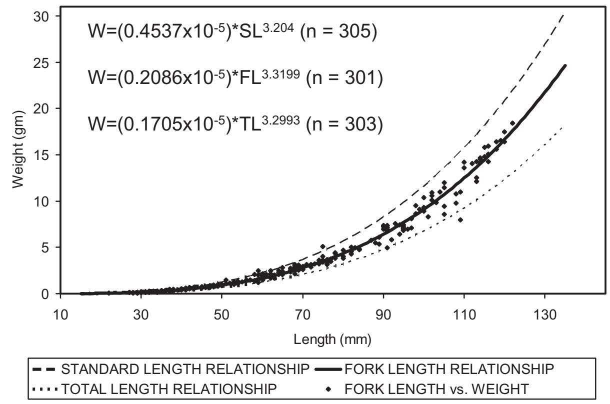

Figure 8 Length (mm)-weight (g) relationships for longfin smelt with equations for standard length (SL), fork length (FL), and total length (TL). Relationships are from 15-135 mm.

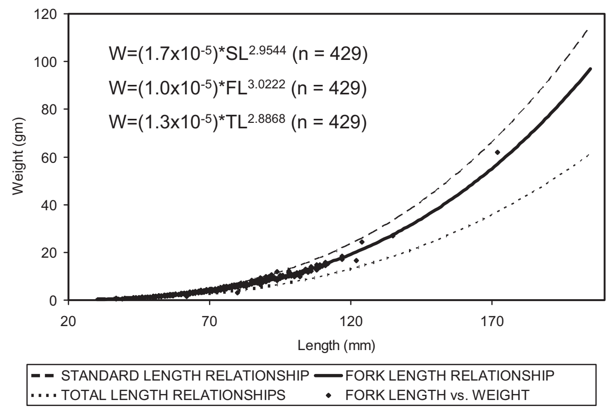

Figure 9 Length (mm)-weight (g) relationships for American shad with equations for standard length (SL), fork length (FL), and total length (TL). Relationships are from 30-205 mm.

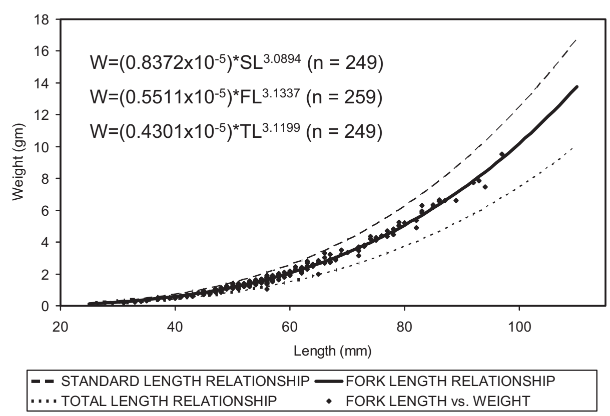

Figure 10 Length (mm)-weight (g) relationships for Pacific herring with equations for standard length (SL), fork length (FL), and total length (TL). Relationships are from 25-110 mm.

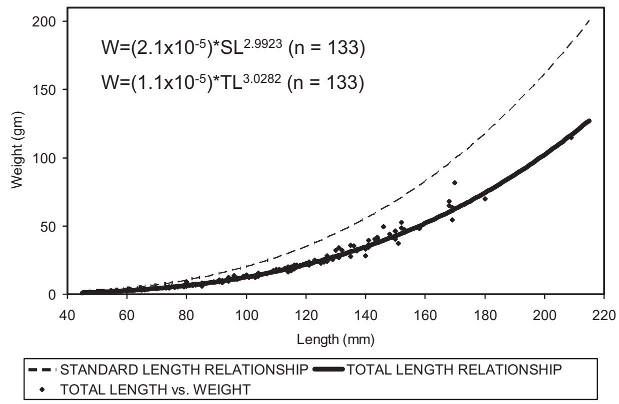

Figure 11 Length (mm)-weight (g) relationships for Pacific staghorn sculpin with equations for standard length (SL) and total length (TL). Relationships are from 45-215 mm.

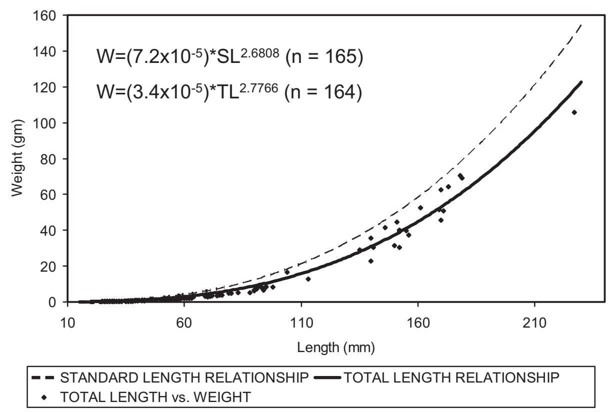

Figure 12 Length (mm)-weight (g) relationships for plainfin midshipman with equations for standard length (SL), fork length (FL), and total length (TL). Relationships are from 15-230 mm.

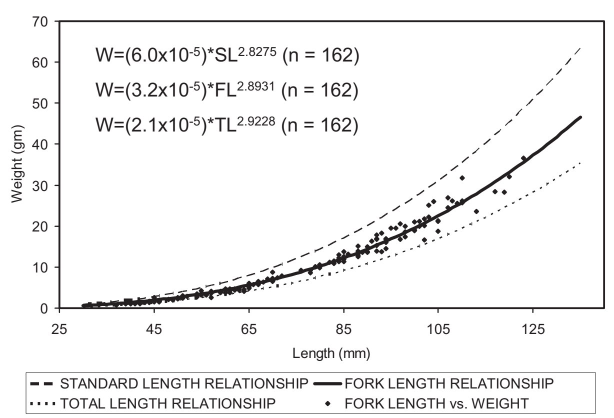

Figure 13 Length (mm)-weight (g) relationships for shiner surfperch with equations for standard length (SL), fork length (FL), and total length (TL). Relationships are from 30-135 mm.

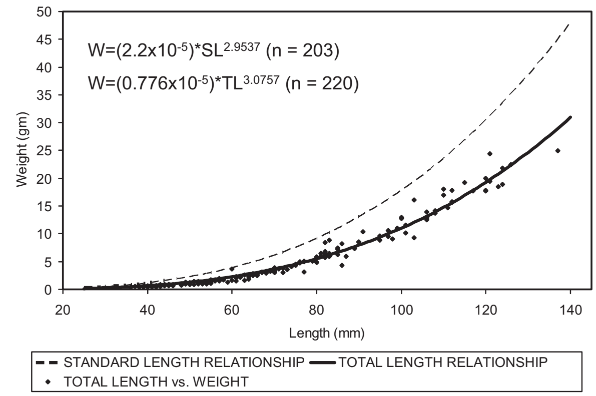

Figure 14 Length (mm)-weight (g) relationships for speckled sanddab with equations for standard length (SL), and total length (TL). Relationships are from 25-140 mm.

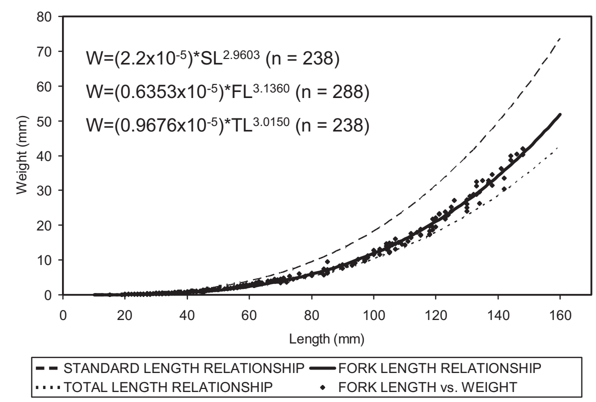

Figure 15 Length (mm)-weight (g) relationships for striped bass with equations for standard length (SL), fork length (FL), and total length (TL). Relationships are from 10-160 mm.

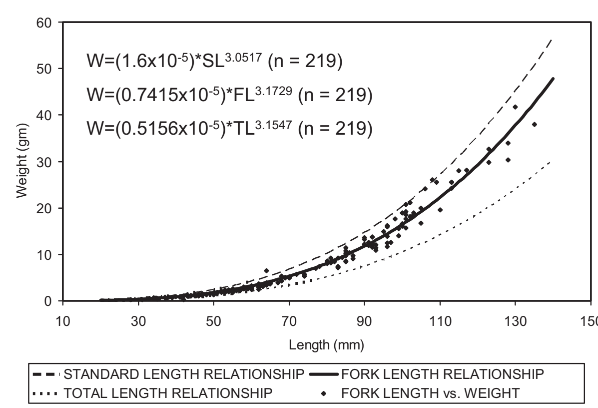

Figure 16 Length (mm)-weight (g) relationships for threadfin shad with equations for standard length (SL), fork length (FL), and total length (TL). Relationships are from 20-140 mm.

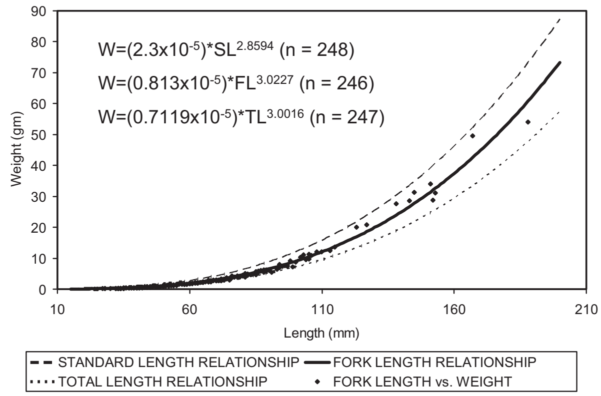

Figure 17 Length (mm)-weight (g) relationships for topsmelt with equations for standard length (SL), fork length (FL), and total length (TL). Relationships are from 15-210 mm.

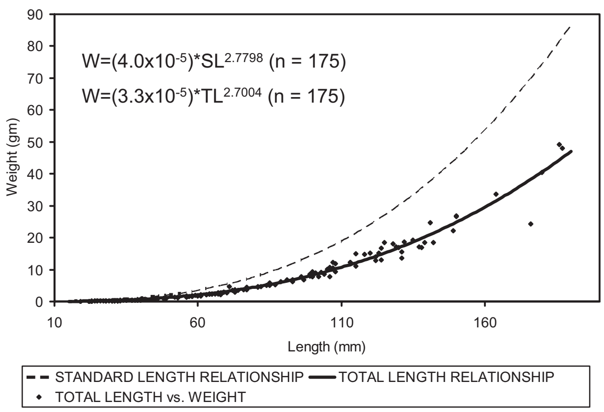

Figure 18 Length (mm)-weight (g) relationships for yellowfin goby with equations for standard length (SL), fork length (FL), and total length (TL). Relationships are from 10-190 mm.

Discussion

Despite the number of specimens already collected, the LWS has not collected length-weight data from the full range of sizes routinely encountered in a year, with the exception of 4 species (striped bass, threadfin shad, yellowfin goby, and longfin smelt). Therefore, the LWS data set is insufficient for determining the majority of LWRs and biomass indices. The LWS is collecting additional specimens of selected species in selected lengths to complete these data ranges (Table 3).

The LWS has yet to do an evaluation to determine if sufficient data have been collected to calculate useful condition indices. The LWR provides the reference weight for condition indices in a manner similar to Le Cren (1951). The LWS envisions that the condition index will take the form of weight of an individual fish divided by the LWR for a given species and length. Condition indices are used as response variables to help explain growth, mortality, and other processes. To accomplish this, sampling for the LWRs for condition indices must include fish that fully represent the length-weight variation within any given year class. Ideally, condition indices would be calculated for multiple year classes to help explain interannual trends. The LWS had originally planned to do this for 4 species: striped bass, threadfin shad, longfin smelt, and delta smelt. However, budget constraints in summer 2003 prompted the LWS to focus all sampling efforts on completing LWRs for biomass indices. Data collection for condition indices is planned for one species, striped bass, and will involve assessing the best method for collecting and processing specimens and to determining the appropriate analysis for comparing condition indices.

Conclusion

The LWS has collected more than 3,000 specimens representing 21 species. Out of the 21 species, 18 have LWRs. Only 4 species have LWRs sufficient for calculating biomass indices. It is not known if existing LWRs and the sampling schemes are adequate to calculate condition indices. Work is under way to complete the remaining LWRs for biomass indices and to determine if meaningful condition indices can be calculated.

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IEP Newsletter Distribution Delays

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The winter and spring 2004 editions of the *IEP Newsletter* have been delayed because of multiple problems with the mailing list and mailroom procedures. A new procedure has been worked out to get delivery back on track for the summer edition and for future newsletters. Expect to see the summer edition of the IEP Newsletter in mid-October.

Electronic versions of the delayed newsletters, as well as past editions, are available online at http://iep.water.ca.gov/report/newsletter/

Please contact me by e-mail or by phone (916-651-9610) if you have any questions or concerns about your subscription.

Delta Water Project Operations

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During the January through March 2004 period, San Joaquin River flow ranged between 1,476 cfs and 4,372 cfs (42 m^3/s and 124 m^3/s), Sacramento River flow ranged between 20,387 cfs to 74,662 cfs (577 m^3/s and 2,114 m^3/s), and the Net Delta Outflow Index (NDOI) ranged between 12,239 cfs and 159,637 cfs (347 m^3/s and 4,521 m^3/s) as shown in Figure 1. Precipitation during this period ranged from 0.04 in. (January 16, 2004) to 0.96 in. (January 1, 2004). In early January 2004, Sacramento River and NDOI flows started off high (above 64,000 cfs) as a result of the January 1, 2004, precipitation (0.96 in.). Thereafter, both flows began to decline and continued to decline until February 2, 2004. A February 2 precipitation event resulted in Sacramento River and NDOI flows rising above 35,000 cfs on February 7, 2004, for a brief day; then flows began a downward trend until mid-February.

The frequent precipitation events that occurred from February 19 through early March resulted in Sacramento River and NDOI flows peaking during this period, despite the largest amount of precipitation being recorded on January 1, 2004. Most of the significant precipitation events occurred in the second half of February and resulted in high Sacramento River flows and NDOI as shown in Figure 1. Sacramento River flows peaked at about 74,600 cfs (2,100 m^3/s) on February 27, 2004, and NDOI peaked at about 160,000 cfs (4,500 m^3/s) on February 29, 2004.

From January through March 2004, export actions at the State Water Project (SWP) ranged between 6,000 cfs and 8,000 cfs (170 m^3/s and 226 m^3/s). Central Valley Project (CVP) pumping was stable and ranged between 3,500 cfs and 4,500 cfs (99 m^3/s and 127 m^3/s). As a result of significant precipitation from January through March 2004, runoff and outflows were high enough that the SWP was able to pump above 6,000 cfs (170 m^3/s) for most of this period (Figure 2). There were only two reductions in SWP pumping: one in early February and one in mid-March. The SWP reduced pumping in February and March for the following reasons:

- February 2004: export-to-inflow ratio (E/I) standard at the beginning.
- March 2004: March 15 was the last day to pump above 6,680 cfs (that is, 6,680 cfs + 1/3 Vernalis flows per USACE permit)

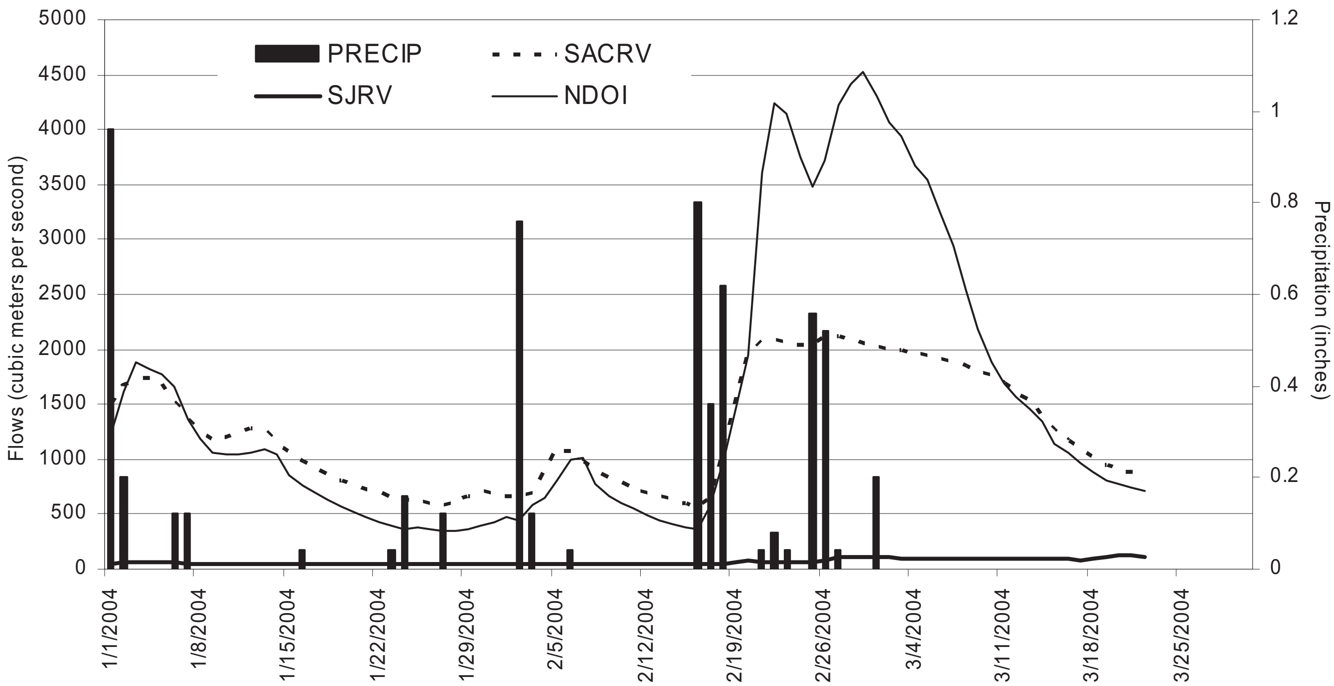

Figure 1 Precipitation, Net Delta Outflow Index, and Sacramento River and San Joaquin River flows, January through March 2004

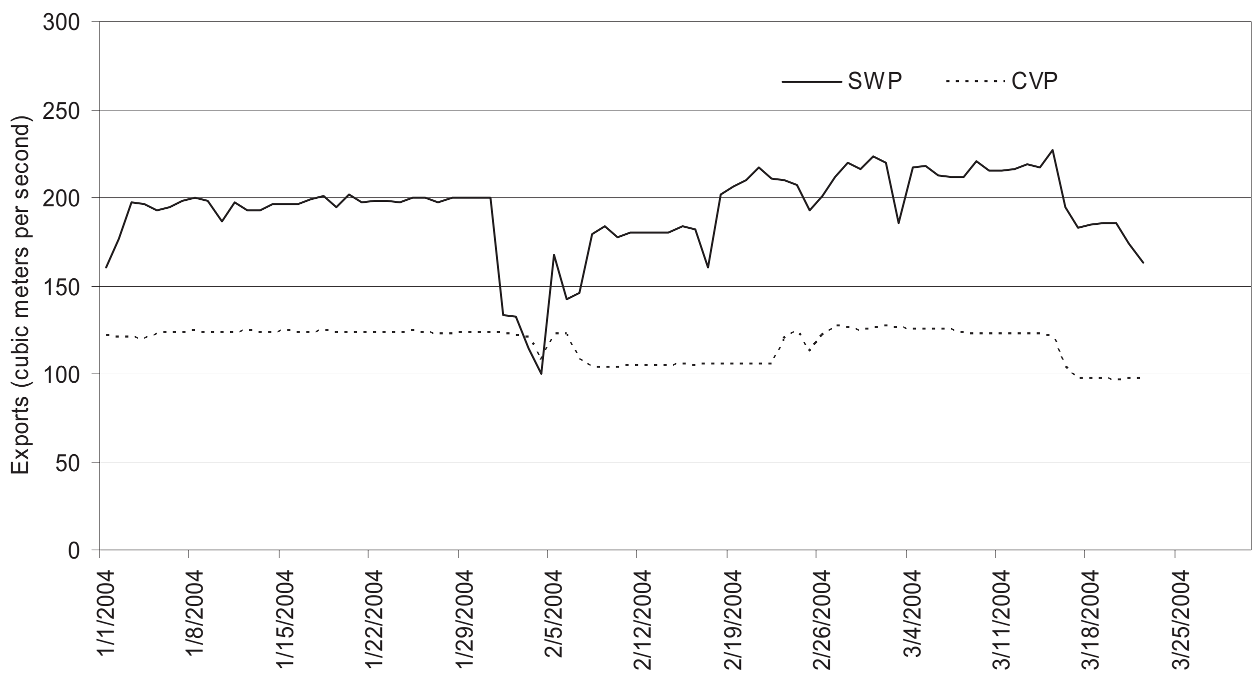

Figure 2 State Water Project and Central Valley Project Pumping, January through March 2004

■ Interagency Ecological Program for the San Francisco Estuary ■

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For information about the Interagency Ecological Program, log on to our website at http://www.iep.water.ca.gov. Readers are encouraged to submit brief articles or ideas for articles. Correspondence—including submissions for publication, requests for copies, and mailing list changes—should be addressed to Nikki Blomquist, California Department of Water Resources, P.O. Box 942836, Sacramento, CA, 94236-0001. Questions and submissions can also be sent by e-mail to: nikkib@water.ca.gov.

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California Department of Fish and Game
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