■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER

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Of Interest to Managers

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The annual Status and Trends issue of the IEP newsletter (Spring Issue) provides venue for IEP and other researchers to report monitoring results from projects sampling in the San Francisco Estuary and its watershed. Originally conceived as a forum for data reports, over the years editors and authors have tried to expand the taxa covered and describe linkages between environmental variables and species' abundance trends and distribution patterns. This issue continues that evolution. Moreover, the large number of articles submitted this year begin in this issue and carry over into the Summer Issue.

In the "Highlights" section, Kate Le and Andy Chu provide a summary of first-quarter-2009 Delta outflow and Delta Water Project Operations. They describe another dry winter punctuated by a modest outflow increase lasting from mid-February through mid-March. They report that low outflow conditions in January and early February constrained exports, whereas after outflows increased, exports were restrained by water quality and fisheries protections.

River flows stimulate important biological processes, so the Status and Trends section starts with a water-year 2008 retrospective by Kate Le and Andy Chu, to establish some of the environmental context for subsequent articles describing species abundance responses. They report that 2008 was the driest year since 1994, exhibiting three modest flow pulses in early January, late-January/early February and late February. Low water-year outflows through January lead to relaxation of the February export to inflow ratio, potentially allowing a larger proportion of inflow to be exported, nonetheless annual exports for both state and federal facilities were the lowest observed in recent years.

Copepods and mysid shrimp comprise important foods for young upper-estuary fishes, and for delta smelt throughout its life. April Hennessy describes the copepod and mysid abundance responses in 2008, and observes that responses were generally good. Abundance increased and densities were relatively high for important spring copepods Eurytemora and Sinocalanus. Pseudodiaptomus, a summer dominant copepod, exhibited slight increases in spring and summer abundance, and maintained near-summer levels into fall. The brackish water copepods, Acartia and Acartiella, were again found in good abundance in the upper estuary as a result of low outflows. As young fish grow, mysid shrimp become an important food source, particularly for longfin smelt and striped bass, and to some degree for delta smelt. The mysid shrimp, *Hyperacanthomysis longirostris*, rebounded strongly in spring and summer 2008, but fall abundance remained low. The other upper estuary mysid species remained very uncommon. Increased copepod and mysid numbers in spring and summer suggest an improved feeding environment in 2008 compared to 2007.

Upper and lower estuary fishes continue to exhibit very different abundance responses. Maxfield Fish, Dave Contreras, Virginia Afentoulis, Jennifer Messineo and Kathryn Hieb provide 2008 abundance trend information derived from 4 trawl surveys. Possibly of most concern was the continued low 2008 abundance of the 4 POD fish species: delta smelt, longfin smelt, age-0 striped bass and threadfin shad. Three of the 4 POD fishes (delta smelt, longfin smelt and striped bass) increased slightly and threadfin shad declined to a record low. Juvenile American shad declined to record lows and splittail abundance was zero for trawl indices, though there was evidence of 2008 splittail recruitment from other surveys. Upper estuary bottom dwelling fishes declined, and only 1 of 3 remained relatively abundant. Once again lower estuary pelagic and demersal species generally responded favorably (except northern anchovy), particularly those considered part of the Pacific northwest fauna, like Pacific herring, Pacific staghorn sculpin, and English sole.

During the water export process, some entrained fishes are diverted from the export flow and "salvaged" to be returned to the Delta. Trends in salvaged fishes provide additional insight into Delta fish abundance, particularly for fishes that reproduce in, rear in, or migrate through the south Delta, such as threadfin shad and splittail. Geir Aasen updates annual salvage trends through 2008 for 7 fishes of management concern: juvenile Chinook salmon, juvenile steelhead, juvenile striped bass, delta smelt, longfin smelt, splittail, and threadfin shad. Interestingly, state salvage of threadfin shad declined in 2008 and recently exhibited a pattern similar to the Fall Midwater Trawl, whereas federal salvage increased in 2008 to among the 5 highest salvage totals since 1982. Low salvage in 2008 of delta smelt, longfin smelt and age-0 striped bass generally reflected their low abundance in the estuary. Relatively low numbers of splittail continue to show in salvage even though they were not detected by the trawl surveys.

IEP QUARTERLY HIGHLIGHTS

DELTA WATER PROJECT OPERATIONS (January through March 2009)

Kate Le and Andy Chu (DWR), kle@water.ca.gov

Hydrological conditions in the Delta region were very dry between January and mid February 2009 as shown in Figure 1. During this period, the flows in Sacramento, San Joaquin, and Net Delta Outflow Index (NDOI) were below 310 cubic meters per second (cms; 11,000 cfs) with a brief and small increase in outflow and Sacramento River flow at the end of January. However, the remaining period after mid-February was a complete turn around of hydrologic conditions in the Delta with large flows coming down from Sacramento and subsequently resulting in very high outflow. However, San Joaquin flows remained the same without much changes through the entire period of January to March, as shown in Figure 1, which indicates that most of the storm events were concentrated from the northern reach of the Delta. The largest peak flows for both Sacramento and NDOI occurred in early March, surpassing 1133 cms (40,000 cfs). San Joaquin River (SJR) average daily flow ranged between 29 and 70 cubic meters per second (1,024 cfs and 2,472 cfs). Sacramento River daily average flow ranged between 189 and 1,327 cubic meters per second (6,673 cfs to 46,857 cfs). Daily NDOI ranged between 105 and 1,470 cubic meters per second (3,708 cfs and 51,907 cfs).

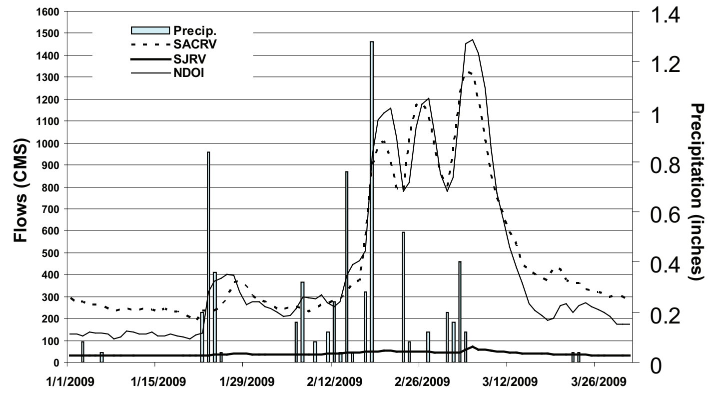


Figure 1 January through March 2009 Sacramento River, San Joaquin River, Net Delta Outflow Index, and Stockton Fire Station Precipitation

Project operations in the Delta during the January through March 2009 period were restricted by the drier hydrological conditions earlier and the fishery protections later. The fishery actions were governed by the latest US Fish and Wildlife Service's Biological Opinion dated December 15, 2008 for the protection of Delta Smelts and CA Department Fish and Game's (DFG) Incidental Take Permit pursuant to DFG Code Sections 2081(b) and 2081(c). As to the Bay-Delta Standards in D-1641 (see Figure 2), the minimum monthly outflow of 127 cms (4,500 cfs) and the 7-day average outflow of 99 cms (3,500 cfs) were required for January. Starting in February, the habitat protection outflows were required to be met for 24 days in February and the entire month of March at Chipps Island. Alternatively, the habitat protection outflows requirements at Chipps Island could also be met with a three-day average outflow of 323 cms (11,400 cfs). Other noteable flow and water quality standards listed in Figure 2 were Export to Inflow ratio transition from 65% to 35% in February and the Vernalis base flow requirements in February and March.

Project exports shown in Figure 3 were restricted by the drier hydrological conditions earlier and the fishery protections later. Exports at both projects reduced to about 30 cms (~1,000 cfs) in early February for a short period due to drier hydrological conditions. No significant plant maintenance activities or power outages occurred during these months.

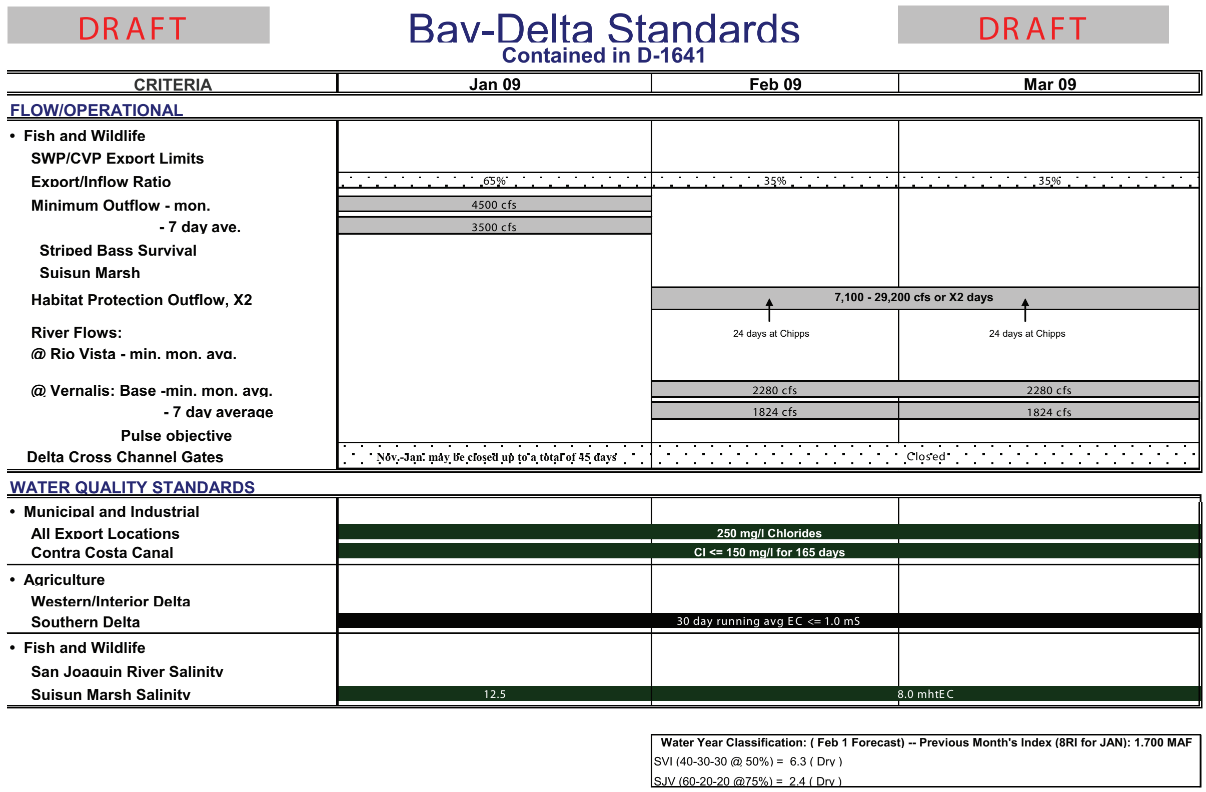


Figure 2 January through March 2009 Bay-Delta Standards of D-1641

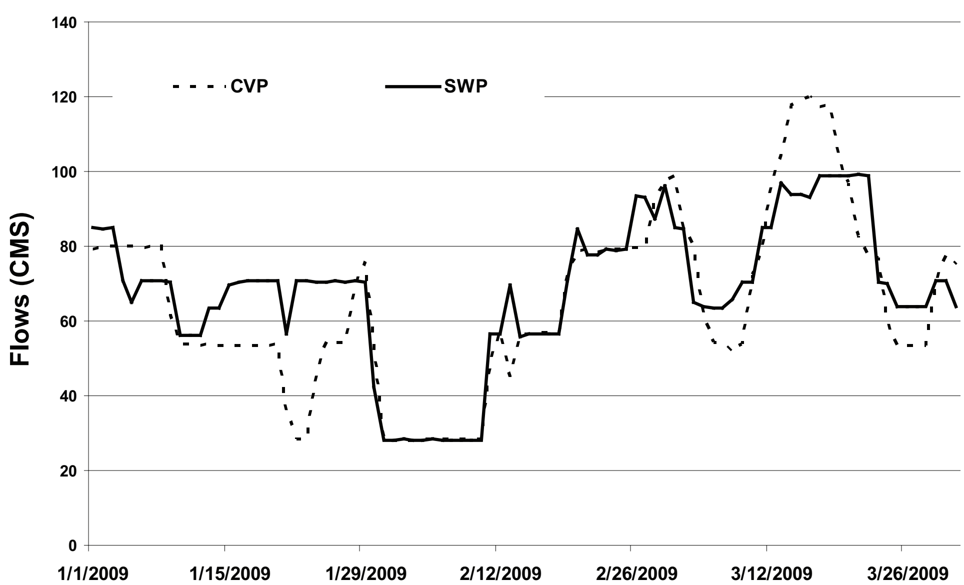


Figure 3 January through March 2009 State Water Project and Central Valley Project Exports

STATUS AND TRENDS

DELTA WATER PROJECT OPERATIONS WATER YEAR 2008 ANNUAL SUMMARY

Kate Le, Andy Chu (DWR), kle@water.ca.gov

Precipitation

Water year (WY) 2008 (October 2007 through September 2008) was drier than WY 2007. Precipitation occurred primarily between October 2007 and February 2008; the majority of rainfall occurred in January 2008, peaking nearly 1.7 inches (Figure 1).

River Flows and Net Delta Outflow Index

Hydrologically, most of the high flows occurred during the precipitation events in January and February (Figure 1). Otherwise, the river flows for the rest of year were in the range of 1,200 cubic meters per second (cms). As a result, WY 2008 is the second driest year since WY 1994. As usual, the Sacramento River flows were generally higher than net Delta outflow and San Joaquin River flows. The flow patterns after April were similar to the pattern during WY 2007, and remained below 425 cms through the end of the water year. Lower precipitation resulted in less runoff, and a water year classification as a 'critical' year for 2008.

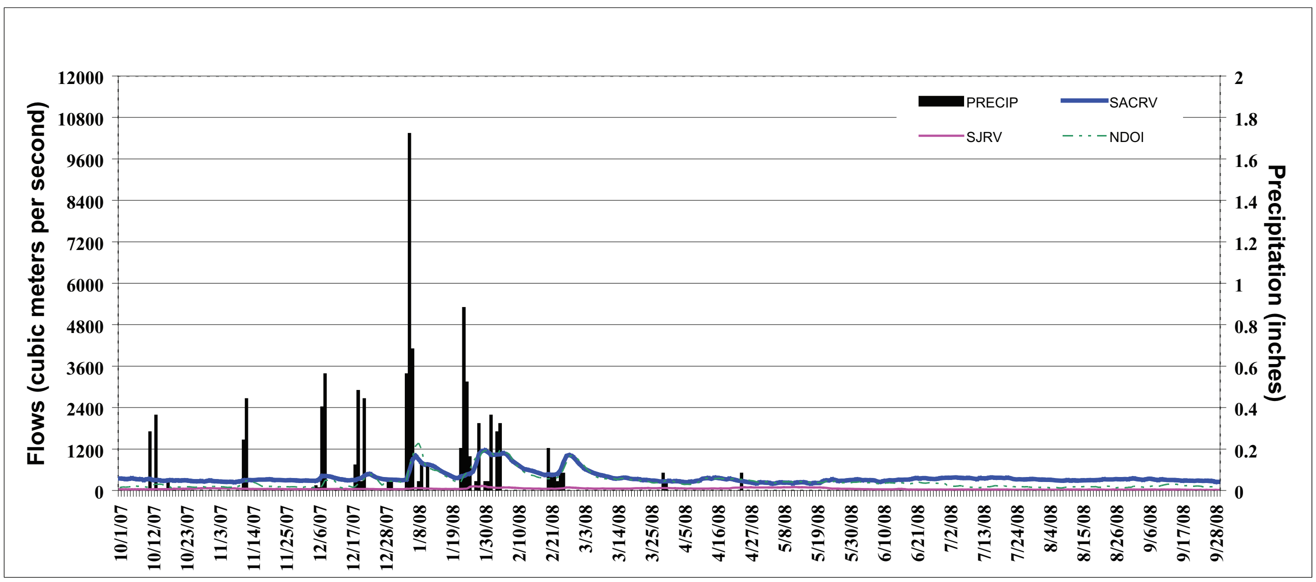


Figure 1 WY 2008 average daily flow in the Sacramento River, San Joaquin River and Net Delta Outflow in cubic meters per second, and total daily precipitation in inches

Exports

During WY 2008, exports (Figure 2) were coordinated between the State Water Project (SWP) and Central Valley Project (CVP) Operation Offices to primarily ensure the compliances with the Bay Delta Standards (see Figure 3). The required minimum monthly outflow in October 2007 was 113 cms (4,000 cfs) and between November 2007 and January 2008 was 127 cms (4,500 cfs), whereas the 7-day average outflow was 85 cms (3,000 cfs) in October 2007 and 99 cms (3,500 cfs) between November 2007 and January 2008. From February 2008 through June 2008, the habitat protection outflows, also know as X2 requirements, were met either by maintaining salinity or 3-day outflows ranging between 201 cms to 827 cms (7,100 cfs to 29,200 cfs; see Figure 3 footnotes 5 and 6). Export to inflow (E/I) ratio requirements were set at 65% from July through January and 35% from March through June with the exception of February 2008 when the E/I ratio was relaxed from 35% to 45%. Other flow requirements were necessary in WY 2008, such as the base flow for San Joaquin River at Vernalis during the months of February to June and Sacramento River flow at Rio Vista in the months of September to December (Figure 3). In addition, various water quality standards are highlighted in Figure 3.

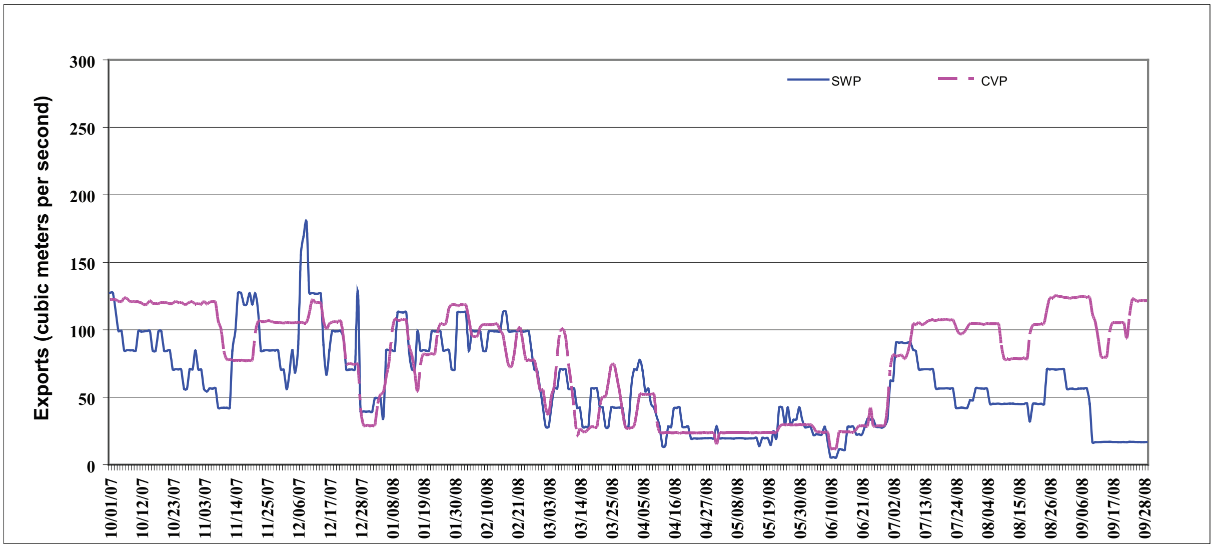


Figure 2 State Water Project and Central Valley Project daily average exports during WY 2008

Overall, the export patterns were very similar between CVP and SWP, except during scheduled maintenance activities and/or when the Coordinated Operation Agreement sharing imbalance increased (Figure 2). The primary restrictions on exports were imposed from late December 2007 until June 2008 due to delta smelt concerns, but VAMP controlled exports during parts of April and May (Figure 3, footnote 1). During the summer months, both SWP and CVP pumping increased to deliver their water supply allocations and accommodate other water transfers (Figure 2).

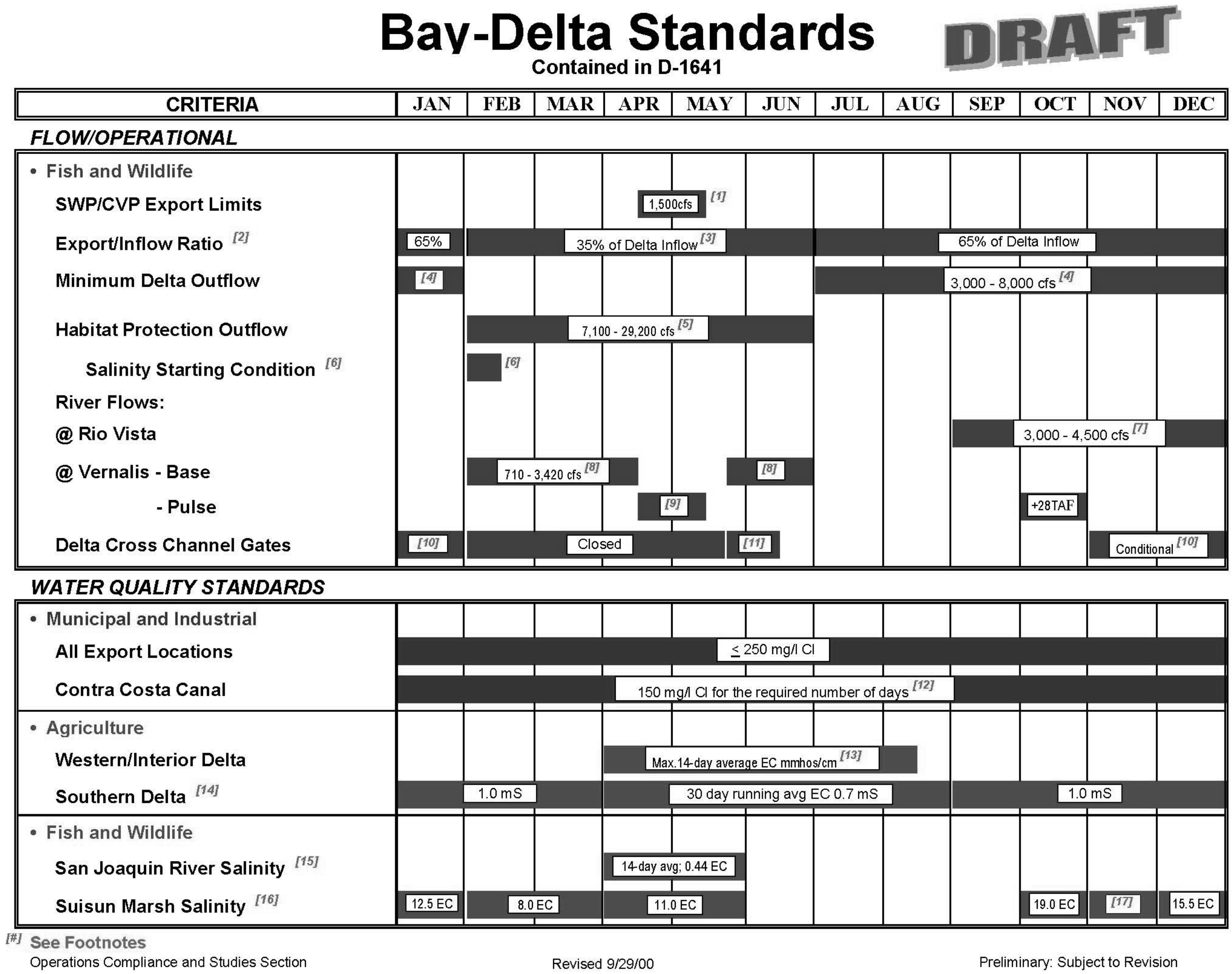
Percent of Inflow Diverted

Percent inflow diverted generally remained within compliance based on both the 3-day and 14-day averages of the E/I ratio (Figure 4). E/I ratio limits were discussed in the Exports section above.

WY 2008 (October 2007 through September 2008) annual flow and export totals were calculated (see below) and compared to those from WYs 2004-2007 (Figure 5).

- Sacramento River Flow = 9.59 MAF
- San Joaquin River Flow = 1.22 MAF
- Net Delta Outflow Index = 6.88 MAF
- State Water Project = 1.52 MAF
- Central Valley Project = 1.98 MAF
- Total SWP and CVP = 3.51 MAF

In comparison to WY 2004 through WY 2007, annual flows from Sacramento River, NDOI, and San Joaquin River during WY 2008 were the lowest, except for WY 2008 NDOI which is a bit higher than for WY 2007 only (Figure 5). Total pumping at both CVP and SWP dropped compared to past years with more reduction at SWP than CVP (Figure 5).



For footnote information see http://swpoco.water.ca.gov/cmplmon/bay_deltastandards.htm

Figure 3 Summary of D-1641 Bay-Delta Standards

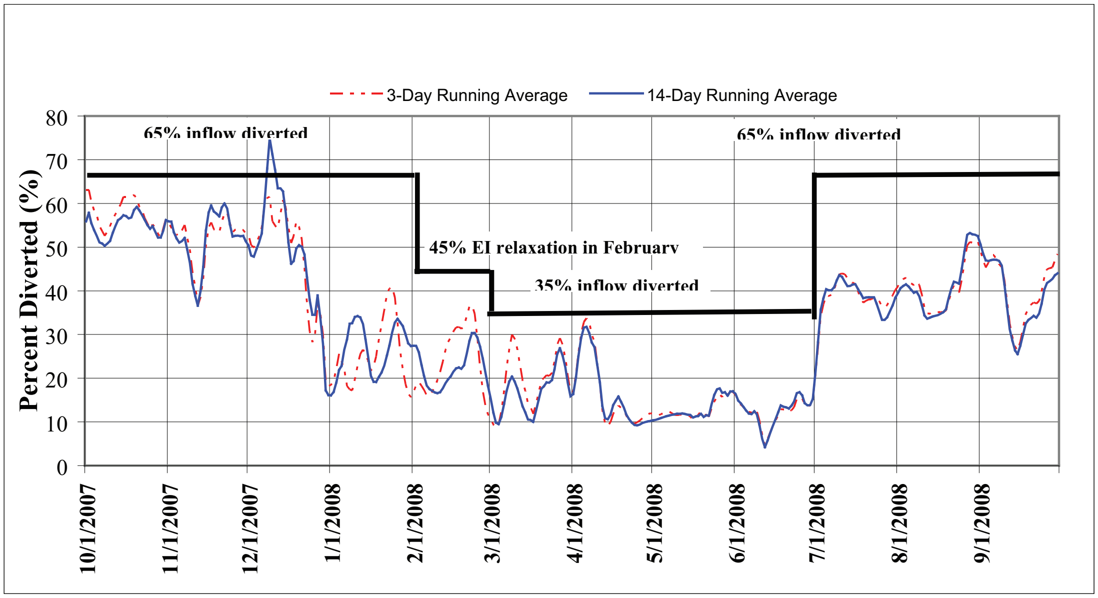


Figure 4 WY 2008 percent of daily average inflow diverted and D1641 (see Figure 3) monthly upper limits (black lines) to percent inflow diverted

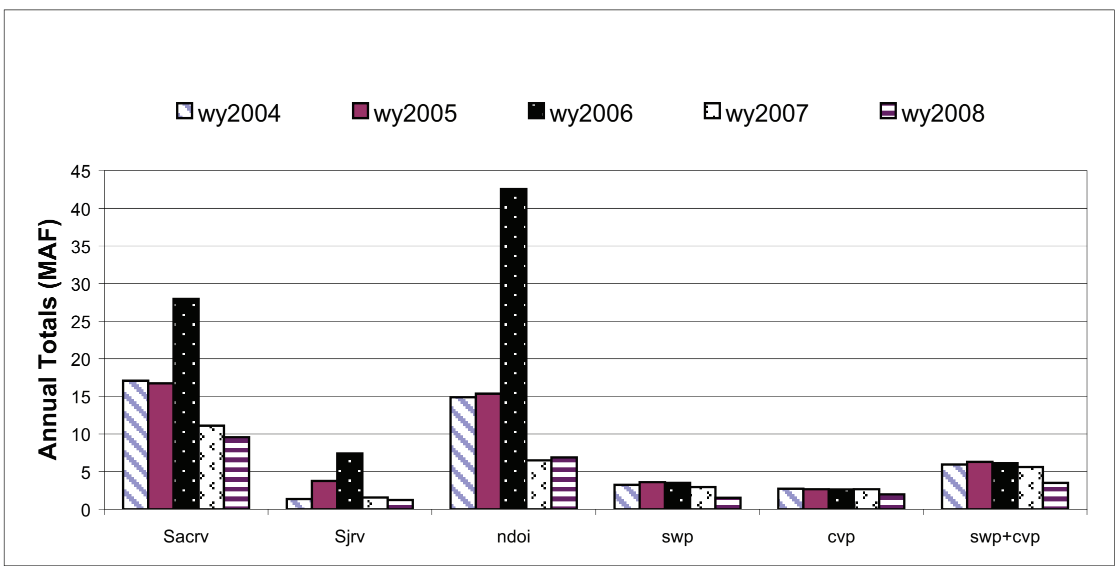


Figure 5 Annual discharge and export totals (in millions of acre feet) for water years 2004-2008

Monthly Average Inter-Annual Comparisons

Sacramento River

Monthly average flows in all months, except January and February, were lower in 2008 than the previous four years (Figure 6). In January and February 2008, Sacramento River flows where higher than WY 2007, but overall still lower than the previous three water years.

San Joaquin River

Monthly average flows in all months of WY 2008 were as low as or lower than those of the same months in all previous years (Figure 6).

NDOI

Monthly outflow followed a typical pattern with low levels in summer and early fall and high in winter and spring. The largest monthly average difference was in April, followed by January, March, and May. The largest difference in April is consistent with the largest river flow difference observed in both rivers. The overall outflow pattern for water year 2008 was very low, even during the winter and spring months as shown in Figure 6. In comparison to WY 2007, the WY2008 outflow index was similar except in January and February due to precipitations.

Precipitation

Rainfall mostly occurred during the fall and winter months of WY 2008. The largest monthly precipitation total for 2008 occurred in January followed by December, February, November, and October (Figure 6). Comparing with the previous four water years, the monthly total for January 2008 was the second highest monthly total for the period of comparison (Figure 6).

State Water Project

Monthly average export rates during WY 2008 were lower or about the same as those for the previous four water years, except for the months of February, May, and June when exports were higher than WY 2007 during these months (Figure 6). SWP pumping dropped off substantially in 2008 during the July through September period compared to previous four years.

Central Valley Project

Monthly average pumping rates were usually the lowest in WY 2008 compared to the same months during the past four water years (Figure 6). CVP monthly average pumping rates were very consistent across months of July through December and years 2004-2007, but somewhat lower in 2008. From January through June, monthly average exports varied widely between month and years, and averages for 2008 were not always the lowest for the month (Figure 6).

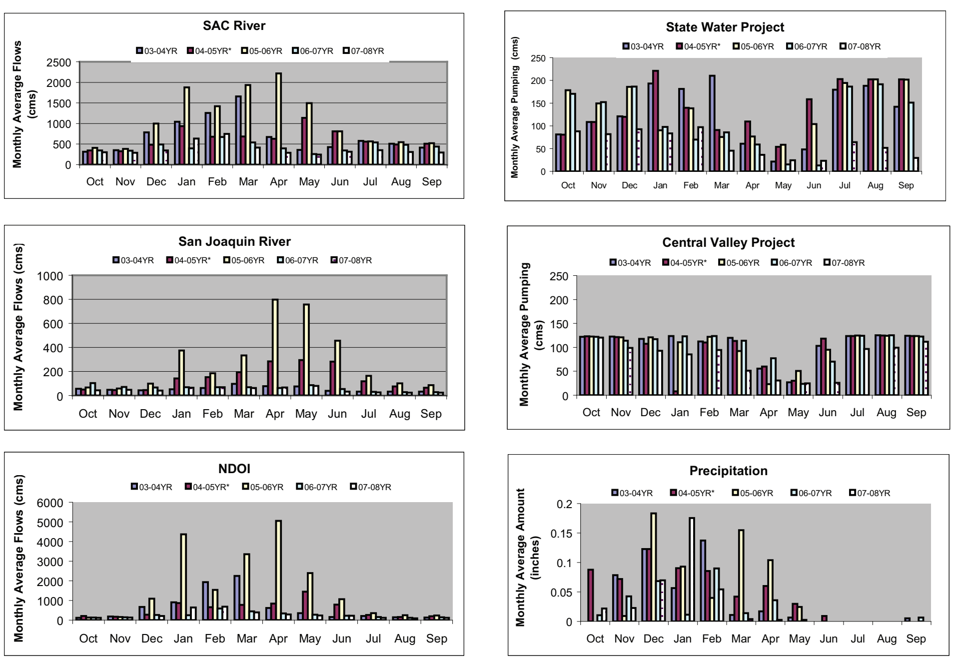


Figure 6 Monthly average flows and exports, and precipitation totals for water years 2004-2008

Zooplankton Monitoring 2008

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Introduction

The Zooplankton Study has estimated the abundance of zooplankton taxa in the upper San Francisco Estuary, from eastern San Pablo Bay through the eastern Sacramento-San Joaquin Delta and Suisun Marsh, since 1972 as a means of assessing trends in fish food resources. The study also detects and monitors zooplankton recently introduced to the estuary and determines their effects on native species. Three gear types are used: 1) a pump for sampling microzooplankton <1.0 mm long, including rotifers, copepod nauplii, and adult copepods of the genus *Limnoithona*, 2) a modified Clarke-Bumpus (CB) net for sampling mesozooplankton 0.5-3.0 mm long, including cladocerans, copepodids (immature copepods), and adult copepods, and 3) a macrozooplankton net for sampling zooplankton 1-20 mm long, including mysid shrimp. Here seasonal abundance indices are presented from 1974 through 2008 for a select group of the most common copepods, cladocerans, rotifers, and mysids.

Methods

During 2008, sampling occurred monthly from January through December at 22 stations, including 12 core stations (i.e., stations sampled consistently since study inception in 1972) and 2 floating entrapment zone (EZ) stations located at bottom electrical conductivity of 2 and 6 mS/cm (about 1 and 3 ‰). Indices presented here were calculated using 16 stations: the 12 core stations, the 2 EZ stations, and 2 additional stations sampled consistently since 1974 (Suisun Slough station NZS42 and Disappointment Slough station MD10; www.bay-delta.water.ca.gov/emp/Metadata/DiscreteWQ/discreteWQ_stations_map.html). Reports published prior to 2007 used data from 1972 forward that included only the 12 core stations and 2 EZ stations. Since this report utilizes data from 2 additional stations, indices start in 1974 and may be slightly different than those reported prior to 2007. However, overall trends remain the same.

Data were grouped into 3 seasons: 1) spring, March through May, 2) summer, June through August, and 3) fall, September through November. January, February, and December were not always sampled historically and therefore were not used for these long-term trend analyses. Abundance indices were calculated as the mean number of each taxon per cubic meter of water (reported as catch-per-unit effort, CPUE) by gear, season, and year for the 16 core and floating EZ stations. Relative calanoid copepod abundance for each season of 2008 used data from all 22 stations sampled. Similar to the 2004 through 2007 Status and Trends reports, indices reported below were separated by gear type and taxon, whereas pre-2004 reports combined the CB and pump data for each taxon into a single index. Mysid indices presented here include corrections made in 2009. Most corrections were minor and resulted in index changes of less than 1 mysid per cubic meter, but the fall 2005 *Hyperacanthomysis longirostris* index previously reported as 11.6 m^{-3} has been corrected to 3.3 m^{-3} due to an incorrect sub-sample recorded at 1 station. However, overall mysid trends remain the same.

Copepods

Both congeners of the cyclopoid copepod genus Limnoithona inhabit the upper estuary: L. sinensis, introduced in 1979, and L. tetraspina, introduced in 1993. In 1993, L. tetraspina mostly supplanted the historically common, and slightly larger, L. sinensis and numerically became the dominant copepod species in the upper estuary. L. tetraspina is common in both brackish and freshwater. As an ambush predator that feeds on motile prey (Bouley and Kimmerer 2006), L. tetraspina may have benefited from the upper estuary phytoplankton species composition changing from non-motile diatoms to motile flagellates. Despite the high densities of L. tetraspina in the estuary, it may not be a readily available food source for visual predators, like delta smelt, due to its small size and relatively motionless behavior in the water column (Bouley and Kimmerer 2006). Both pump and CB net indices are presented here because L. tetraspina is not completely retained by the CB net, especially in summer and fall when adults are smaller than in winter and spring. Pump L. tetraspina abundance increased in 2008 from 2007 in all seasons (Figure 1), whereas CB abundance increased in spring, but decreased in summer and fall. Spring 2008 CB abundance was the highest since monitoring began (300 m^{-3}), but only a fraction of the spring 2008 pump abundance (5,897 m^{-3}). Summer and fall CB abundance continued the decline that started in 2007. L. tetraspina was most abundant during late summer and early fall 2008 in the lower Sacramento River, Suisun Marsh, and Suisun Bay. L. sinensis continued to be collected in low numbers in 2008.

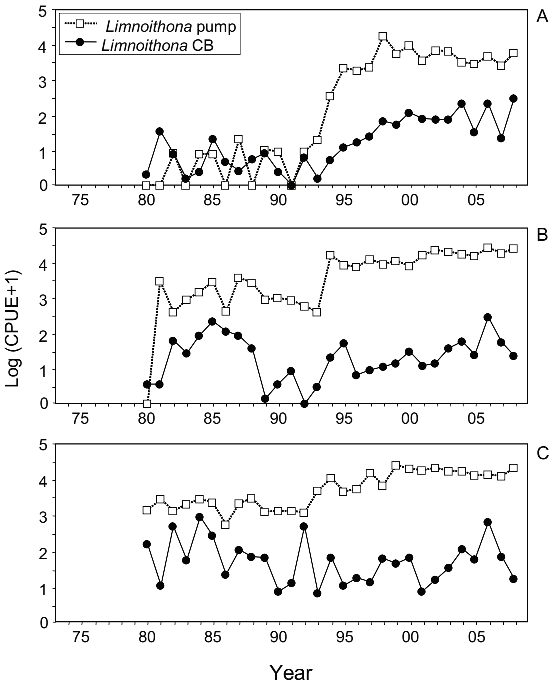

Figure 1 Abundance of *Limnoithona tetraspina* and *L. sinensis* combined (Log of mean catch*m^{-3}+1) from the pump and CB net in Spring (A), Summer (B), and Fall (C), 1974 - 2008

Eurytemora affinis, a calanoid copepod introduced to the estuary before monitoring began, was once a major food for larval and juvenile fishes of many species and adults of planktivores, such as delta smelt and threadfin shad. It is found throughout the upper estuary in every season and is most abundant in salinities less than 6 ‰. *E. affinis* abundance declined in all seasons since monitoring began, with the sharpest downturns during summer and fall of the late-1980s (Figure 2), subsequent to the introductions of the overbite clam, *Corbula amurensis*, and the calanoid copepod *Pseudodiaptomus forbesi*. Prior to these introductions, *E. affinis* abundance was usually highest during summer; however, since 1987 abundance has been highest in spring and has dropped abruptly in summer, when both *P. forbesi* abundance and *C. amurensis* grazing rates increase. In 2008, *E. affinis* was the fifth most abundant calanoid copepod in the study area across all months. Its relative abundance was highest in spring, when it accounted for 29% of the total calanoid copepod CPUE (Figure 3A). After a sharp decline in spring 2007, spring 2008 *E. affinis* abundance rebounded and was the highest since 1994 (Figure 2A), although similarly high levels occurred in spring 1995, 1999, and 2006. Summer and fall *E. affinis* abundance decreased in 2008, and were amongst the lowest on record (Figure 2B and 2C). In 2008, *E. affinis* abundance peaked in March in Suisun Marsh (3,340 m^{-3}). As outflow decreased during April and May, the abundance peak shifted upstream to the lower Sacramento River (1,144 m^{-3}). After May, *E. affinis* abundance was extremely low throughout the study area.

Pseudodiaptomus forbesi is an introduced freshwater calanoid copepod first detected in the upper estuary in 1988. By 1989, *P. forbesi* summer and fall abundance was comparable to *E. affinis* before its decline (Figure 2). Although *P. forbesi* abundance has declined slightly since its introduction, it has remained relatively abundant in summer and fall compared to other copepods. In 2008, *P. forbesi* was the most abundant calanoid copepod in the study area across all months. Its relative abundance peaked in summer, when it accounted for 78% of the total calanoid copepod CPUE (Figure 3B). Spring abundance has always been highly variable and increased slightly in 2008 (Figure 2A). Summer and fall abundance have been less variable than spring. Summer abundance also increased slightly from 2007 to 2008 (Figure 2B), while fall abundance increased moderately and was the highest since 2002 (Figure 2C). During summer and fall 2008, *P. forbesi* was common in all regions upstream of Suisun Bay, but was most abundant in June and July in the south Delta in Frank's Tract and Old River, where the mean CPUE was 6,006 m^{-3}.

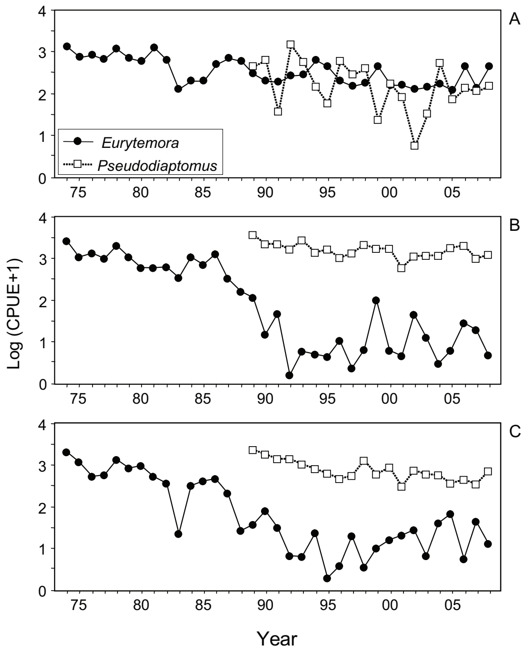

Figure 2 Abundance of *Eurytemora affinis* and *Pseudodiaptomus forbesi* (Log of mean catch*m^{-3}+1) from the CB net in Spring (A), Summer (B), and Fall (C), 1974 - 2008

Several species of the native calanoid copepod genus *Acartia* are abundant in San Pablo Bay and expand their range into Suisun Bay and the western delta as salinity increases seasonally and annually. Conversely, their affinity for higher salinities is sufficiently strong that their distribution shifts seaward of the sampling area during high-outflow events, resulting in low seasonal and annual abundance. In 2008, *Acartia* was the second most abundant calanoid copepod in the study area across all months, which was predictable given the relatively low delta outflow (see Le and Chu page 5 this issue). Relative abundance peaked in spring, when *Acartia* accounted for 27% of the total calanoid copepod CPUE (Figure 3A). *Acartia* abundance declined in all seasons of 2008 from 2007 (Figure 4). Due to low-outflows in 2007 and 2008, spring abundance was higher than it had been from 2004 through 2006 (Figure 4A). The highest summer abundances corresponded with the lowest outflow years, and 2008 summer abundance was similar to other low outflow years (Figure 4B). Fall 2008 abundance was similar to the drought years 1987-1992 (Figure 4C). Due to low flows in 2008, *Acartia* densities were high throughout the year in San Pablo Bay with peaks in March (4,838 m^{-3}) and September (4,509 m^{-3}).

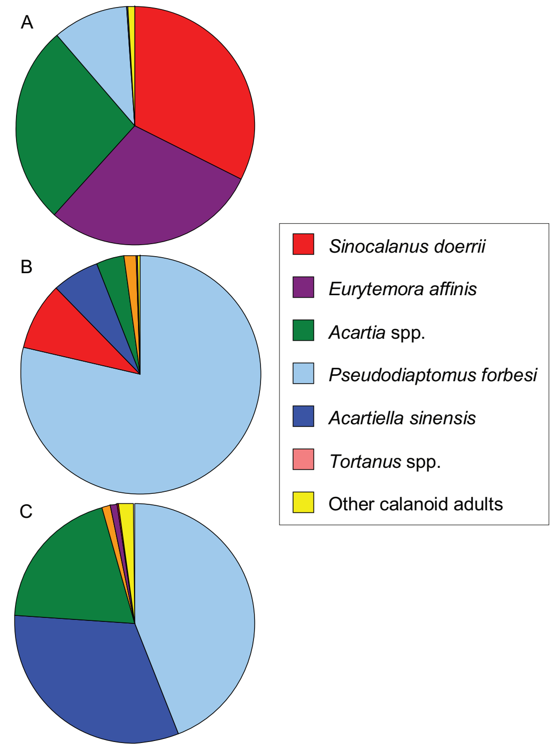

Figure 3 Relative abundance of the most common calanoid copepods (mean catch*m^{-3}) from the CB net from all stations in Spring (A), Summer (B), and Fall (C), 2008

Acartiella sinensis is an introduced calanoid copepod first recorded in spring 1994 that is most abundant in the entrapment zone during summer and fall. In 2008, *A. sinensis* was the third most abundant calanoid copepod in the study area across all months. Its relative abundance was highest in fall, when it accounted for 32% of the total calanoid copepod CPUE (Figure 3C). Spring abundance has always been highly variable, but declined steadily from 2004 through 2007, followed by a slight increase in 2008 (Figure 4A). Summer abundance decreased from 1994 through 1998, then sharply declined in 1999 and remained very low in 2000 (Figure 4B). Since 2001, summer abundance rebounded from the record lows of 1999 and 2000, and in 2007, reached its second highest summer abundance since its introduction, before declining again in 2008. Fall abundance has been relatively stable since 2001, and fall 2008 abundance was the second highest since its introduction (Figure 4C). In 2008, *A. sinensis* abundance peaked in fall in the lower Sacramento River in the entrapment zone (1,519 m^{-3}).

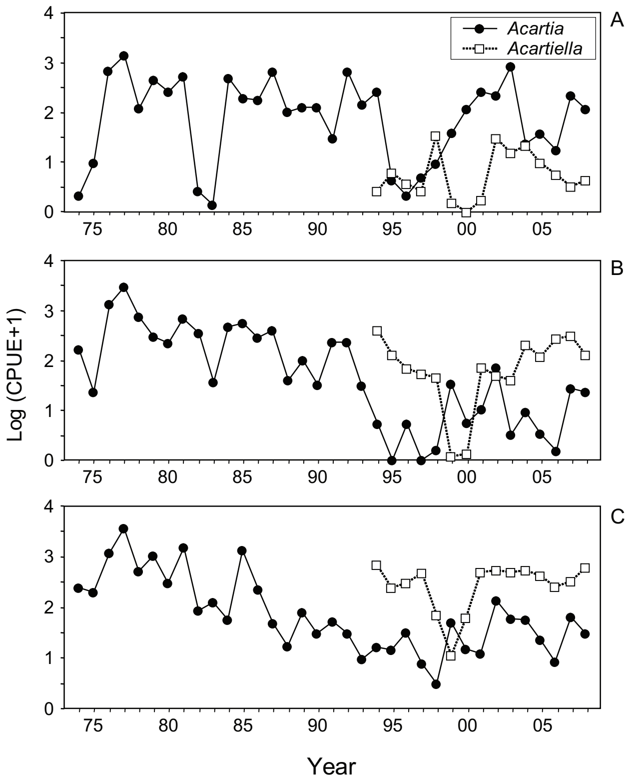

Figure 4 Abundance of *Acartia* spp. and *Acartiella sinensis* (Log of mean catch*m^{-3}+1) from the CB net in Spring (A), Summer (B), and Fall (C), 1974 - 2008

The introduced freshwater calanoid copepod *Sinocalanus doerrii* was first recorded in spring 1979. Initially most abundant in summer, *S. doerrii* abundance began to decline during summer and fall in the mid-1980s (Figure 5B and 5C). This downward trend continued through the mid-1990s, followed by a modest increase until recently. In 2008, *S. doerrii* was the fourth most abundant calanoid copepod in the study area across all months. Its relative abundance peaked in spring, when it accounted for 33% of the total calanoid copepod CPUE (Figure 3A). *S. doerrii* abundance increased in 2008 from 2007 in all seasons (Figure 5). Spring abundance, which has always been more variable than summer or fall abundance, was lowest in 1995 and steadily increased through 2004 before declining again in 2005 and 2006 (Figure 5A). Subsequently, abundance increased slightly in 2007 and in 2008 spring abundance was the highest since 1993. Summer and fall abundance declined sharply in 2004 and remained low through 2007, before increasing in 2008 to the highest abundance since 2003 (Figure 5B and 5C). In 2008, *S. doerrii* was most abundant May and June in the lower Sacramento and San Joaquin rivers, and the southern delta (1,800 m^{-3}). After June, densities were low throughout the estuary.

Tortanus dextrilobatus is an introduced brackish-water calanoid copepod first recorded in spring 1994. *T. dextrilobatus* is a large carnivorous copepod whose abundance increases in the sampling area as flows decrease during summer and fall. In 2008, *T. dextrilobatus* was one of the least abundant calanoid copepods in the study area; relative abundance peaked in summer when it accounted for only 2% of the total calanoid copepod CPUE (Figure 3B). *T. dextrilobatus* abundance increased in all seasons of 2008 from 2007 (Figure 5). Spring and fall abundance rose steadily in 2007 and 2008 (Figure 5A and 5C). In 2008, summer abundance was the highest it has been since monitoring began (Figure 5B). In June 2008 *T. dextrilobatus* was most abundant in Carquinez Strait (142 m^{-3}), but July through September abundance peaked further upstream in eastern Suisun Bay (222m^{-3}).

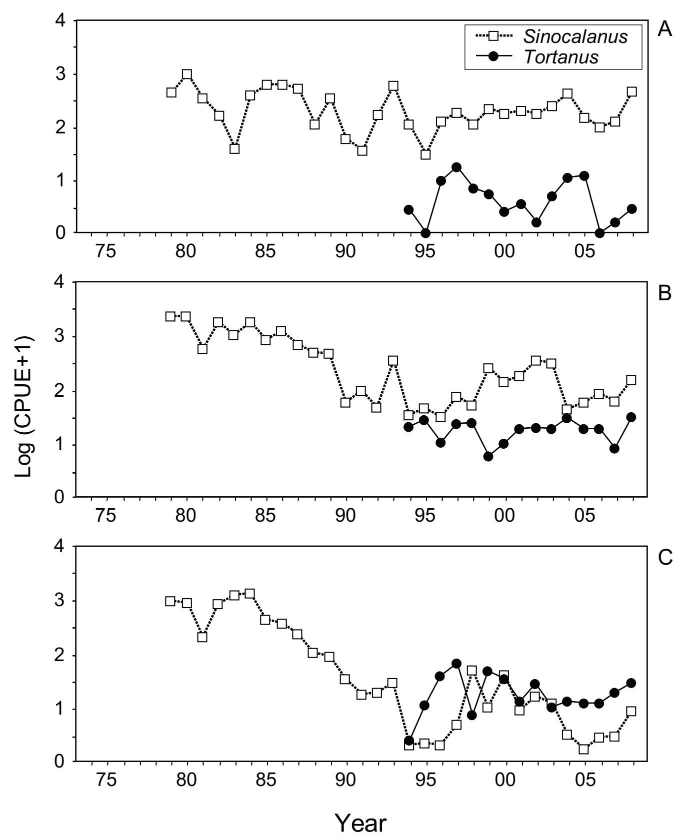

Figure 5 Abundance of *Sinocalanus doerrii* and *Tortanus dextrilobatus* (Log of mean catch*m^{-3}+1) from the CB net in Spring (A), Summer (B), and Fall (C), 1974 - 2008

Cladocerans

Bosmina, *Daphnia*, and *Diaphanosoma* are the most abundant cladoceran genera in the upper estuary. Combined, these native freshwater cladocerans had an overall downward trend since the early 1970s, especially in fall (Figure 6). From 2007 to 2008, abundance decreased in spring and summer, but increased in fall (Figure 6). Low outflow in 2008 reduced dispersal, which allowed for high densities of cladocerans in the eastern delta in summer and fall. Cladocerans were common throughout the upper estuary upstream of the entrapment zone in 2008, and were most abundant in the eastern delta from April through December. Peak densities occurred in the lower San Joaquin River near Stockton in April and May (24,461 m^{-3}), and again in December (21,678 m^{-3}). Another peak occurred in September in Disappointment Slough (19,481 m^{-3}), also in the eastern delta.

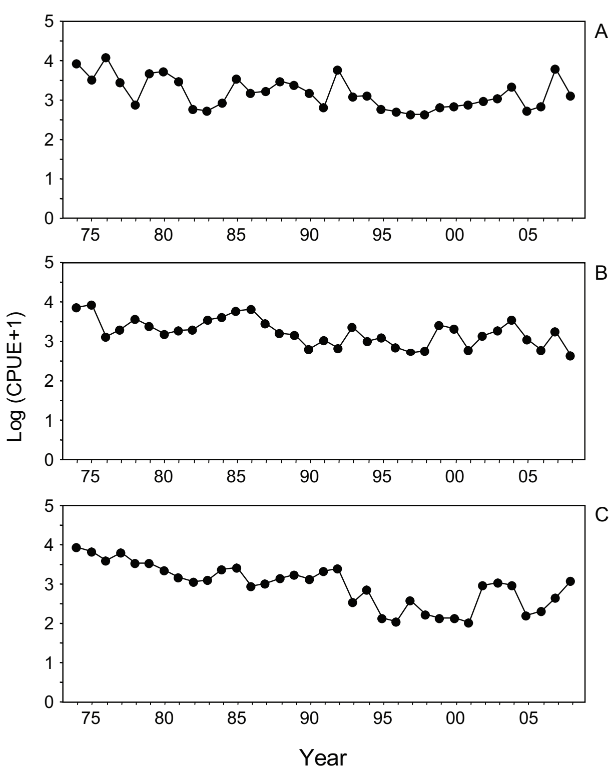

Figure 6 Abundance of Cladocera (Log of mean catch $*m^{-3}+1$) from the CB net in Spring (A), Summer (B), and Fall (C), 1974 - 2008

Rotifers

Synchaeta bicornis is a native brackish-water rotifer that is usually most abundant in the upper estuary in summer and fall, when salinity increases. However, summer and fall abundances have experienced long-term declines since the 1970s (Figure 7). Spring abundance, although erratic, has also shown an overall downward trend (Figure 7A). After a peak in spring 2000, abundance declined sharply in 2001, and from 2002 through 2007 there was no catch during spring at any core stations. In spring 2008, catches at several stations in Suisun Marsh, Suisun Bay, and the lower Sacramento River raised spring abundance to the highest level since 2000. In 2008, summer abundance increased to the highest level in 10 years after recovering from a low in 2006 (Figure 7B). Fall 2008 abundance increased slightly from the low in 2007, but was the third lowest since monitoring began (Figure 7C). In 2008, *S. bicornis* was most abundant from June through September in Suisun Marsh, Suisun Bay, and the lower Sacramento River. Peak densities occurred in Montezuma Slough (a large slough in Suisun Marsh) and Suisun Bay in July (45,286 m^{-3}), and further upstream, near the confluence of the Sacramento and San Joaquin rivers and the lower Sacramento River in August (43,862 m^{-3}).

Abundance of all other rotifers, without *S. bicornis*, declined in all seasons from the early 1970s through the 1980s, but stabilized since the early 1990s (Figure 7). In 2008, spring abundance continued the steady increase that began in 2006 and reached the highest level since 1995 (Figure 7A). However, both summer and fall abundance declined in 2008 from 2007 to amongst the lowest on record (Figure 7B and 7C). Rotifers were common throughout the study area in 2008, with peak abundance in the lower San Joaquin River near Stockton, where mean CPUE for the year was 113,729 m^{-3}. Suisun Marsh had extremely high densities of rotifers during April 2008 when CPUE was 745,522 m^{-3}, after which densities were low.

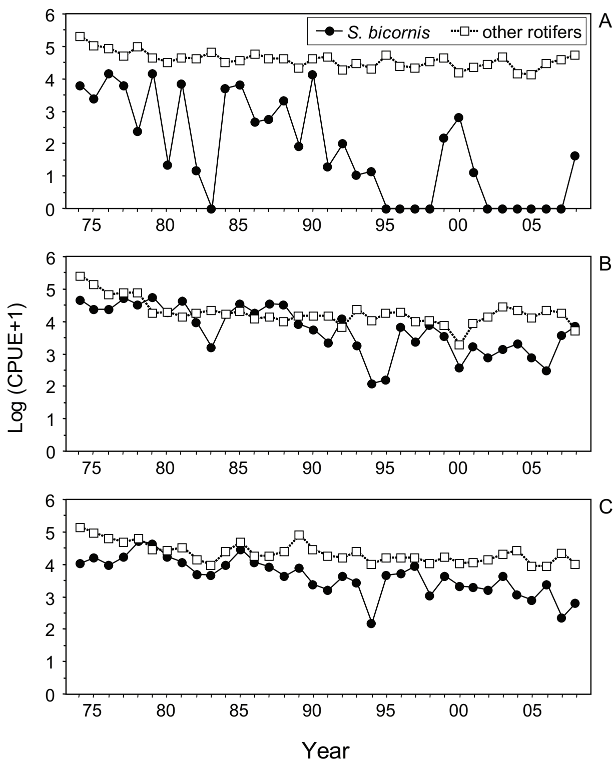

Figure 7 Abundance of *Synchaeta bicornis* and rotifers excluding *S. bicornis* (Log of mean catch*m^{-3}+1) from the pump in Spring (A), Summer (B), and Fall (C), 1974 - 2008

Mysids

Hyperacanthomysis longirostris (formerly *Acanthomysis bowmani*) is an introduced mysid first collected by the study in summer 1993, and has been the most abundant mysid in the upper estuary every season since summer 1995 (Table 1). *H. longirostris* is commonly found in densities of more than 10 m^{-3}, and occasionally in densities of more than 100 m^{-3}. Spring *H. longirostris* abundance increased between 1995 and 1998, and fluctuated annually thereafter. In 2008, spring abundance increased and was the third highest abundance since its introduction. *H. longirostris* was most abundant in summer with an average abundance (across years) of 18 m^{-3}. Since 2001, summer abundance has had a downward trend; however, abundance remained at a moderate level in summer 2008 and was only slightly below the summer average. After a local peak in 2004, *H. longirostris* fall abundance declined, resulting in 2007 and 2008 fall abundances at and near record lows of less than 1 m^{-3}. In 2008, *H. longirostris* was most abundant May through July in eastern Suisun Bay, near the confluence of the Sacramento and San Joaquin rivers, where the mean density was 134 m^{-3}. After August, densities were low throughout the estuary.

Neomysis mercedis, historically the only common mysid in the upper estuary, suffered a severe population crash in the early 1990s. In 2008, it was the fourth most abundant mysid in the sampling area across all months for the second year in a row. *N. mercedis* was most abundant in spring and summer, and prior to the population crash spring and summer densities averaged more than 50 m^{-3} (Table 1). Since 1994, mean spring abundance has been less than 1 m^{-3}, rendering *N. mercedis* inconsequential as a food source in most open-water areas of the upper estuary. Although spring 2008 abundance increased slightly from the record low of 2007, it was the third lowest abundance since monitoring began. Summer abundance also increased slightly in 2008 from 2007, but continued to remain at the extremely low levels observed since 1997. Since 2005, no *N. mercedis* were caught during fall at any of the stations sampled. *N. mercedis* was very rare throughout the study area with densities less than 1 m^{-3} at every station since June 2006, except 1 station in the San Joaquin River near Potato Slough in June 2008 (2.861 m^{-3}).

Neomysis kadiakensis is a native brackish-water mysid that regularly appeared in mysid samples beginning in 1996, but was not common until recently (Table 1). Since 2001, *N. kadiakensis* has been the second most abundant mysid in the study area, but at much lower densities than *H. longirostris*. In 2008, *N. kadiakensis* abundance increased from 2007 in all seasons. Although spring and summer 2008 abundances were still low relative to *H. longirostris*, both were higher than any previous spring or summer abundances. For the first time since being introduced, seasonal abundance was greater than 1 m^{-3} in spring 2008. *N. kadiakensis* was most abundant in Suisun Marsh in 2008 from April through July, where mean density exceeded 5 m^{-3}. As flows decreased throughout summer and fall, distribution shifted to eastern Suisun Bay near the confluence of the Sacramento and San Joaquin rivers. Since the late 1990s, *N. kadiakensis* has extended its range into lower salinity water at the confluence of the Sacramento and San Joaquin rivers, leading to the hypothesis that some of the upper-estuary specimens may be a second species, *N. japonica*. To date no physical characteristics have been published to separate these 2 species

Table 1 Seasonal abundance of the most common mysid species (mean catch*m^{-3}) from the macrozooplankton net

Year	*Hyperacanthomysis longirostris*			*Neomysis mercedis*			*Neomysis kadiakensis*			*Alienacanthomysis macropsis*		
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
1974-1989				54.506	87.293	18.154						
1990				23.458	7.612	0.436						
1991				32.058	18.331	0.489						
1992				4.223	1.989	0.076						
1993			2.470	7.850	22.503	0.008						
1994	0.932	21.604	2.063	0.449	0.733	0.004						
1995	0.437	7.180	4.407	0.590	0.370	0.000				0.000	0.000	0.004
1996	1.636	11.693	4.432	0.541	1.432	0.001	0.032	0.001	0.017	< 0.001	0.000	0.003
1997	6.939	27.630	7.714	0.565	0.063	0.000	0.011	0.011	0.385	0.006	0.000	0.004
1998	18.136	6.015	18.691	0.181	0.238	0.025	0.108	0.041	0.006	0.005	0.000	0.008
1999	3.888	34.697	14.329	0.264	0.288	0.001	0.037	0.007	0.075	0.014	0.000	0.001
2000	23.580	38.453	9.958	0.880	0.136	0.001	0.074	0.165	0.465	0.003	0.000	0.001
2001	4.767	13.441	8.956	0.422	0.052	0.001	0.285	0.351	0.143	0.013	0.001	0.001
2002	10.121	21.224	7.516	0.022	0.069	0.001	0.209	0.254	0.753	0.005	0.000	0.002
2003	4.342	21.307	4.555	0.022	0.046	< 0.001	0.314	0.209	0.166	0.038	0.000	0.003
2004	9.915	13.725	5.044	0.150	0.016	0.002	0.129	0.106	0.170	0.001	0.000	0.001
2005	4.010	16.281	3.265	0.092	0.141	0.000	0.173	0.104	0.077	0.003	0.000	0.004
2006	7.186	14.143	1.967	0.321	0.137	0.000	0.071	0.727	0.051	0.001	0.000	0.001
2007	0.969	8.997	0.575	0.005	0.023	0.000	0.176	0.306	0.122	0.004	< 0.001	0.025
2008	17.696	14.574	0.715	0.063	0.108	0.000	1.359	0.820	0.154	0.027	< 0.001	0.155
Average:	7.637	18.064	6.041	26.978	41.456	8.329	0.229	0.239	0.199	0.009	< 0.001	0.015

Alienacanthomysis macropsis is a native brackish-water mysid found most often in San Pablo Bay and Carquinez Strait that was first consistently enumerated by the study in 1995. *A. macropsis* has never been common in the sampling area and therefore indices were not reported until 2007. *A. macropsis* was slightly more abundant than *N. mercedis* in 2008, and was the third most abundant mysid in the upper estuary across all stations and surveys for the second year in a row, although it remained a minor component of the mysid community. Spring 2008 abundance increased from 2007 and was the second highest abundance since being recorded (Table 1). Summer abundance increased slightly from 2007 to 2008, but remained extremely low. Fall 2008 abundance was the highest since enumeration of *A. macropsis* began, and was approximately 35 times the mean 1995-2007 fall abundance. In 2008, *A. macropsis* was most abundant in December in Suisun Bay, but abundance peaks also occurred earlier in February and March in Carquinez Strait and San Pablo Bay.

References:

Bouley, P. and W.J. Kimmerer. 2006. Ecology of a highly abundant, introduced cyclopoid copepod in a temperate estuary. Marine Ecology Progress Series. 324: 219-228.

2008 Fishes Annual Status and Trends Report for the San Francisco Estuary

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Introduction

The 2008 Status and Trends fishes report includes data from 4 of the Interagency Ecological Program's long-term fish monitoring surveys in the San Francisco Estuary: 1) the Summer Townet Survey (TNS), 2) the Fall Midwater Trawl Survey (FMWT), 3) the San Francisco Bay Study (Bay Study), and 4) the Delta Smelt 20-mm Survey (20-mm Survey) (see Honey et al. 2004 for additional fish surveys). The most recent abundance indices, long-term abundance trends, and distributional information are presented for the most common species in the estuary and some less-common species of interest, such as splittail and the surfperches. Four pelagic species that spawn and rear in the upper estuary have undergone severe declines in recent years (Sommer et al. 2007) and are presented first. The upper estuary demersal fishes, marine pelagic fishes, surfperches, and marine demersal fishes follow this group. Within each section, species are presented phylogenetically.

Methods

The TNS has been conducted annually since 1959, and its data has been used to calculate age-0 striped bass indices for all years except 1966, 1983, and 2002. In addition, age-0 delta smelt indices have been calculated for the period of record, except for 1966-1968. The TNS begins in June and samples 32 sites from eastern San Pablo Bay to Rio Vista on the Sacramento River and Stockton on the San Joaquin River. Historically the number of surveys ranged from 2 to 5 each year; as of 2003, sampling was standardized to 6 surveys per year, starting in early June and running every other week through August. The striped bass index is interpolated using data from the 2 surveys that bracket when age-0 striped bass reach or surpass 38.1-mm fork length (FL) mean size (Chadwick 1964, Turner and Chadwick 1972). The delta smelt index is the average of the first 2 survey indices.

The FMWT has sampled annually since 1967, except 1974 and 1979, when no surveys were conducted, and 1976, when sampling was limited and indices were not calculated. The FMWT was designed to determine the relative abundance and distribution of age-0 striped bass in the estuary, but its data is also used for other upper estuary pelagic species, including American shad, threadfin shad, delta smelt, and longfin smelt. The FMWT survey samples 116 stations monthly from September to December in an area ranging from San Pablo Bay to Stockton on the San Joaquin River and Hood on the Sacramento River. The index calculation (Stevens 1977) uses catch data from 100 of the 116 stations; the remaining 16 stations were added to increase spatial coverage for delta smelt.

The Bay Study has sampled from South San Francisco Bay to the western delta monthly with an otter trawl and midwater trawl since 1980. There are data gaps, most significantly limited midwater trawl sampling in 1994, no winter sampling from 1989 to 1997, and limited sampling at stations in and near the confluence of the Sacramento and San Joaquin rivers in 2007 and 2008 to reduce delta smelt take. This most recent data gap resulted in no Bay Study delta smelt indices for 2007 and 2008. Abundance indices are routinely calculated for 35+ fishes and several species of crabs and caridean shrimp; only the most common fish species are included in this report, while the crabs and shrimp are subjects of separate annual reports. Of the 52 stations the Bay Study currently samples, 35 have been consistently sampled since 1980 ("core" stations) and are used to calculate the annual abundance indices. Additional information about study methods, including index calculation, can be found in IEP Technical Report 63 (Baxter et al. 1999).

The 20-mm Survey monitors larval and juvenile delta smelt distribution and relative abundance throughout their historical spring range, which includes the entire delta downstream to eastern San Pablo Bay and the Napa River. Surveys have been conducted every other week from early March to July since 1995, with 9 surveys completed in 2008. Three tows are completed at each of the 48 stations using a 1,600-μm mesh net (Dege and Brown 2004). The survey name is derived from the size (20 mm) at which delta smelt are retained and readily identifiable at the Central Valley Project and State Water Project fish facilities.

Data sets from the TNS, FMWT, and Bay Study were used to describe abundance trends and distribution of upper estuary pelagic fishes when available, while only Bay Study midwater trawl data was used for the marine pelagic fishes, Bay Study otter trawl data for demersal fishes, and the 20-mm Survey data for delta smelt larvae and small juveniles. Catch-per-unit-effort (CPUE), reported as catch per tow, was consistently used to analyze and report distribution.

Physical Setting

Delta outflow in 2008 was the second lowest since 1994, with a mean January to June daily outflow at Chipps Island of 405 cm/s. In 2008, outflow marginally increased over 2007 for the same January to June period. There were 3 relatively short outflow peaks in 2008, one in early January that averaged approximately 1,000 cm/s for a week, one from late January to early February that averaged approximately 1,000 cm/s for 2 weeks, and one from late February to early March that averaged approximately 900 cm/s over a week (Dayflow 2008). These three outflow events maintained X2 in the vicinity of Middle Ground (river kilometer 70) from late January through mid-March and resulted in the lowest salinities of the year in the upper estuary. From mid- to late-March, X2 moved up to Chipps Island (river kilometer 75), where it remained through mid-May (end of Vernalis Adaptive Management Plan), after which X2 began a slow steady shift upstream through the remainder of the water year.

The San Francisco Estuary is situated between 2 major marine faunal regions, the cold-temperature fauna of the Pacific Northwest and the subtropical fauna of southern and Baja California, and is a transitional area with elements of both faunas (Parrish et al. 1981). The northern Pacific Ocean reportedly entered a cold-water regime in 1999 (Peterson and Schwing 2003), which is hypothesized to be beneficial to many cold-temperate species, including Dungeness crab, English sole, and many of the rockfishes. Gulf of the Farallones (GOF) sea surface temperatures (SSTs) were slightly below the long-term mean in late 2008 (PRBO Conservation Science unpublished data), associated with the onset of a La Niña event in the eastern equatorial Pacific. As the La Niña developed, ocean temperatures continued to decrease in the GOF through spring 2008. In April and May 2008, monthly average GOF SSTs were 1.4°C cooler than the long-term average, with several periods of daily SSTs <9.5°C, the coolest reported in 2008. The La Niña event ended in summer 2008, but was the strongest cold-water event in the GOF since 1999-2000. GOF SSTs were near average from July through September 2008. In fall, SSTs were at their annual maximum, with daily SSTs >15°C in early October. For the remainder of year, the daily SST rarely exceeded 13°C, with slightly below average monthly SSTs.

The coastal ocean along central California is marked by three seasons: the upwelling season, from spring to late summer; the oceanic season, from late summer to late fall; and the Davidson Current season, from late fall to spring. During the upwelling season, prevailing northwesterly winds result in a southward surface flow, known as the California Current. Due to the Earth's rotation (Coriolis Effect), there is a net movement of surface waters offshore. These waters are replaced by nutrient-rich, cold water that is transported or upwelled from deeper areas. Upwelling is responsible for the high productivity of the California Current System. When the winds weaken in fall, upwelling stops, surface coastal waters warm, and productivity declines. In winter, southwesterly winds result in a northward surface flow, or the Davidson Current. This current, in conjunction with the Coriolis Effect, produces an onshore and downward transport of surface water, or downwelling. Many coastal fish and invertebrate species in the California Current Region reproduce in winter during the Davidson Current season, when pelagic eggs and larvae are likely to be transported to or retained in nearshore areas. Juveniles of most species settle to the bottom nearshore and enter estuaries to rear before the onset of upwelling, because pelagic life stages present during the upwelling season will be transported offshore, often far from their preferred nearshore nursery areas.

In 2008, coastal upwelling near San Francisco Estuary was strong in March and April, with one of the earliest spring transition dates in recent years, moderate in May and June, then relatively weak in from July to September. The strong upwelling in March and April was associated with the almost complete lack of storms after early March 2008 and the coolest SSTs of the year. These conditions should have been favorable for primary and secondary production in the GOF in spring. Juvenile rockfish recruitment improved from 2007 to 2008 and reproductive success for some seabirds, significantly improved from 2005-2007 to 2008 in the Gulf of the Farallones (NMFS 2009, Warzybok and Bradley 2008). Summer productivity may have been hindered by weak upwelling after June. This pattern of early strong upwelling was also observed in 2007, although peak upwelling was in January, March, and April 2007 vs. March and April 2008.

Upper Estuary Pelagic Fishes

American shad

The American shad (*Alosa sapidissima)* was introduced into the Sacramento River in 1871 and is now found throughout the estuary. This anadromous species spawns in rivers in late spring, rears in fresh water through summer, and migrates to the ocean in late summer and fall. It spends approximately 3 to 5 years maturing in the ocean before returning to freshwater to spawn. Most males reach maturity within 3 to 4 years of age, while most females reach maturity within 4 to 5 years of age. Spawning occurs in the Sacramento, Feather, and American rivers from April through June, after which a large percentage of adults die (Stevens 1966). All life stages of American shad are planktivores.

The 2008 FMWT American shad (all ages) index was only 49% of the 2007 index and the lowest index on record (Figure 1A). With the exception of the record high index in 2003, indices have been below the study-period average since 1998. Seventy-seven percent of the total American shad catch occurred in December. American shad were collected in all areas of the estuary in 2008 but were most abundant from western Suisun Bay to the lower Sacramento River. They were most common in the lower Sacramento River from September through November and moved downstream into western Suisun Bay in December.

The 2008 Bay Study midwater trawl age-0 American shad index was higher than the 2007 index (Figure 1B), but the third lowest for the study period. The Bay Study collected age-0 American shad from July through December, and abundance peaked in August. They were collected from San Pablo Bay to the lower Sacramento and San Joaquin rivers and most common in the lower Sacramento River just upstream of Rio Vista. Contrary to what was observed in the FMWT survey, few fish were captured by the Bay Study during December.

The FMWT American shad index decreased while the Bay Study index increased in 2008. American shad were most abundant in Bay Study sampling in August, before the FMWT survey samples. However, both surveys produced relatively low abundance indices, which were attributed to low freshwater outflow in 2008. American shad abundance has shown a positive correlation with delta outflow during the rearing period (Stevens and Miller 1983). This response changed since the introduction of *C. amurensis* in the late 1980s, but unlike other fish species, American shad abundance per unit of outflow increased after 1987 (Kimmerer 2002).

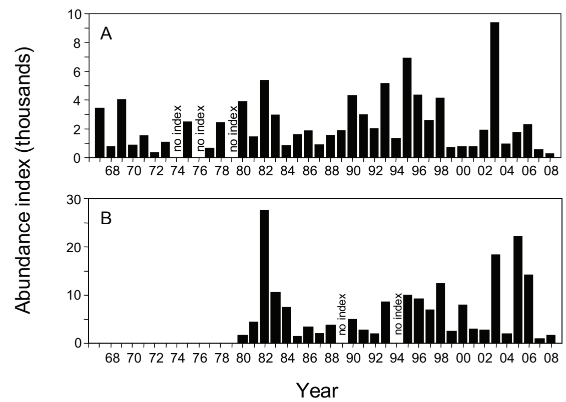

Figure 1 Annual abundance of American shad: A) FMWT, all sizes, September-December, B) Bay Study midwater trawl, age-0, July-October

Threadfin Shad

The threadfin shad (*Dorosoma petenense*) was introduced into reservoirs in the Sacramento-San Joaquin watershed in the late 1950s and quickly became established in the delta. Although it is found throughout the estuary, it is commonly associated with oligohaline to freshwater dead-end sloughs and other low-velocity areas (Wang 1986). It is planktivorous its entire life, feeding on zooplankton and algae (Holanov and Tash 1978). Threadfin shad may reach maturity at the end of their first year and live up to 4 years. Spawning occurs in late spring and summer and peaks from May to July (Wang 1986).

The 2008 FMWT threadfin shad (all ages) index was 14% of the 2007 index (Figure 2) and the lowest index on record. Since 2001, threadfin shad abundance has been below average but showed a slight increasing trend until this year. Threadfin shad were collected from San Pablo Bay to the lower Sacramento River and southern delta. They were most common in the southern delta in the Stockton Deep Water Channel. No threadfin shad were collected in the northern delta.

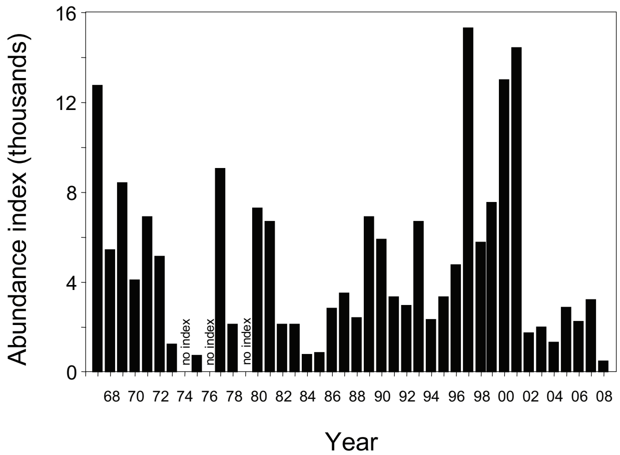

Figure 2 abundance of threadfin shad (all sizes), FMWT, September-DecemberDelta smelt

The delta smelt (*Hypomesus transpacificus*) is a small (55-70 mm FL) osmerid endemic to the upper San Francisco Estuary. The delta smelt population declined dramatically in the 1980s and it was listed as a state and federal threatened species in 1993. This species is considered environmentally sensitive because it typically lives for one year, has a limited diet, and resides primarily in the interface between salt and fresh water. In addition, females have low fecundity and produce on average 1,200 to 2,600 eggs (Moyle et al. 1992).

One current hypothesis regarding the continued population decline is that habitat size has been reduced during summer and fall by human-induced changes and climate variability. Using data collected by the TNS, Nobriga et al. (2008) found that at regional scales, delta smelt capture was well-predicted using water clarity, specific conductance, and water temperature. Three distinct geographic regions emerged showing similar long-term declining trends in delta smelt occurrence: 1) the confluence of the Sacramento and San Joaquin rivers, 2) Suisun Bay, and 3) the southern Sacramento-San Joaquin Delta, including the San Joaquin River upstream of False River. The confluence area typically produced the highest delta smelt relative abundance whereas abundance varied inversely with specific conductance in Suisun Bay and inversely with increasing water clarity and water temperatures in the San Joaquin River and southern delta, indicating these latter regions represent marginal habitat. Similarly, for fall, Feyrer et al. (2007) determined that water clarity and specific conductance predicted delta smelt occurrence. When habitat suitability was modeled based on these factors, it declined long-term in Suisun Bay and the southeast Delta.

The 2008 TNS age-0 delta smelt index was 1.5 times the 2007 index (Figure 3A) but comparable to the low indices observed since 2004. Delta smelt TNS catch totals in 2008 were bimodal, peaking in early June and then again in mid-July. In summer 2008, delta smelt were dispersed from western Suisun Bay to the lower Sacramento and lower San Joaquin rivers. This is in contrast to 2007, when no delta smelt were collected in the lower San Joaquin River. At the beginning of June 2008, delta smelt catch was centered at the confluence of the Sacramento and San Joaquin rivers. By July, delta smelt catch extended westward into Montezuma Slough and Grizzly Bay, but was still concentrated in the lower Sacramento River near the confluence. By August, the majority of delta smelt were collected in Grizzly Bay.

The 2008 FMWT delta smelt index declined by 18% from the 2007 index and was the lowest on record (Figure 3B). In September 2008, delta smelt were found in the lower Sacramento River and Cache Slough. Their distribution expanded downstream in October and November to include western Suisun Bay. By December, delta smelt were caught only in the lower Sacramento River.

In 2008 and 2007, the Bay Study did not report an age-0 delta smelt index because they did not sample with the midwater trawl at stations where delta smelt catch might have been high. The index in 2006, the last year reported, was 0 (Figure 3C). With the exception of 2004, Bay Study indices were below the survey average from 2001 to 2006.

Although the 2008 20-mm Survey delta smelt index was 2.9 times the 2007 index (Figure 3D), it was the second lowest index since 1995, the inception of this survey. Delta smelt larvae were first collected in April in the Lindsey Slough area and the San Joaquin River from the Old River confluence upstream to about Turner Cut. By the end of May, juveniles were widely distributed from Cache Slough and the Sacramento Deep Water Channel through the lower Sacramento and San Joaquin rivers and into the south delta. Their distribution remained essentially unchanged through mid-June, but in early July, when the 20mm Survey concluded, juvenile delta smelt were concentrated in the Cache Slough complex, the Sacramento Deep Water Channel approximately 4 miles upstream of its downstream terminus, and in the lower Sacramento River near the confluence with the San Joaquin River.

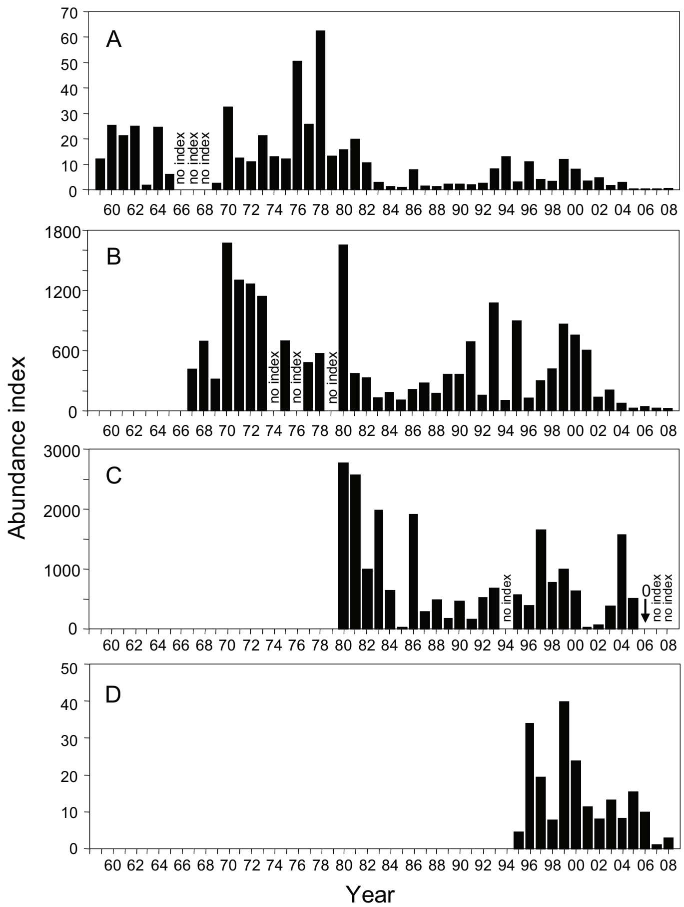

Figure 3 Annual abundance of delta smelt: A) TNS, age-0; B) FMWT, all sizes, September-December; C) Bay Study midwater trawl, age-0, June-October; D) 20-mm Survey larvae and juveniles

Longfin smelt

The longfin smelt (*Spirinchus thaleichthys*) is a short-lived anadromous species that spawns in freshwater in winter and spring and rears primarily in brackish water (Moyle 2002). Some age-0 and age-1 fish immigrate to the ocean in summer and fall, often returning to the estuary in late fall of the same year. A few longfin smelt mature at the end of their first year and most at the end of their second year, with a few living to spawn again at age-3 (Wang 1986, Moyle 2002). A strong positive relationship between longfin smelt abundance and winter-spring outflow has long been observed (Stevens and Miller 1983). However, this relationship changed during the late 1980s, after the introduction of the overbite clam, *Corbula amurensis*. Although the slope of the outflow-abundance relationship did not change appreciably, longfin smelt abundance post-*Corbula* declined to a fraction of the pre-*Corbula* abundance (Kimmerer 2002). This decline corresponded with a decline in phytoplankton and zooplankton abundance due to grazing by *C. amurensis* (Kimmerer 2002).

Although the 2008 FMWT longfin smelt (all ages) index was approximately 10 times higher than the 2007 index, it was the third lowest on record (Figure 4A). Longfin smelt were collected from October through December, with most in November and December. They were found from San Pablo Bay to the confluence of the Sacramento and San Joaquin rivers, but most common in eastern Suisun Bay. This year's abundance index was comprised mostly of 2008 year class fish: abundance likely increased due to the large number of 2006 year-class fish that spawned in early 2008. Alternating strong and weak year classes of longfin smelt are not unusual due to the relationship between broodstock abundance and recruitment.

The 2008 Bay Study midwater trawl (BSMWT) age-0 longfin smelt index was 2.7 times the 2007 index, but far below the study-period average (Figure 4B). The BSMWT collected age-0 fish from June through December and monthly abundance peaked in June. Age-0 longfin smelt were collected from Central Bay to the lower Sacramento River, with the highest catches occurring in Central Bay in summer and at the confluence of the Sacramento and San Joaquin rivers or just upstream of the confluence in the lower Sacramento River in late fall.

The 2008 Bay Study otter trawl (BSOT) age-0 longfin smelt index was 1.7 times the 2007 index (Figure 4C), an abundance increase similar to the BSMWT. Age-0 fish were collected from June through December and abundance peaked in September. They were collected from South Bay through eastern Suisun Bay, but were most common in Central Bay most months.

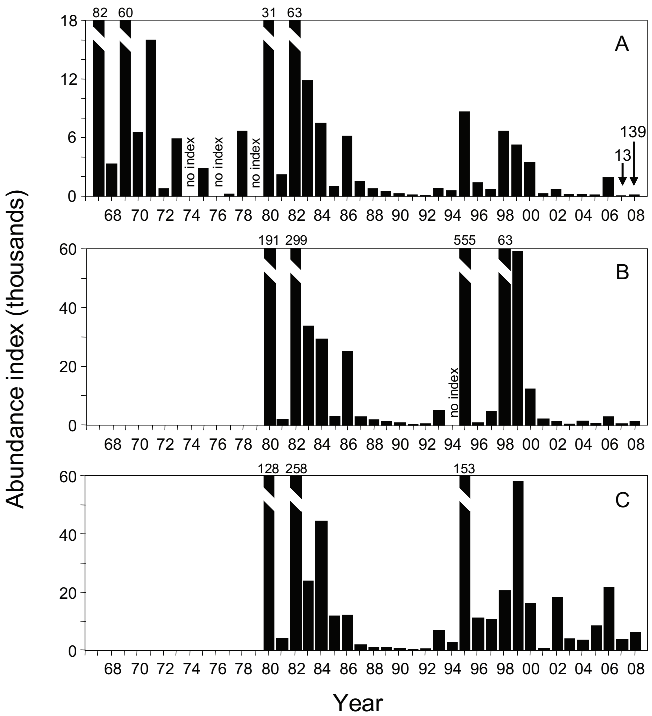

Figure 4 Annual abundance of longfin smelt: A) FMWT, all sizes, September-December; B) Bay Study midwater trawl, age-0, May-October; C) Bay Study otter trawl, age-0, May-October

Longfin smelt abundance increased in all 3 gears in 2008, despite the low winter-spring outflow. This increase may be attributed to recruitment from the strong 2006 year class. In spite of this increase, the 2008 FMWT index remained below the fitted line for the post-*C. amurensis* abundance-outflow relationship (Figure 5).

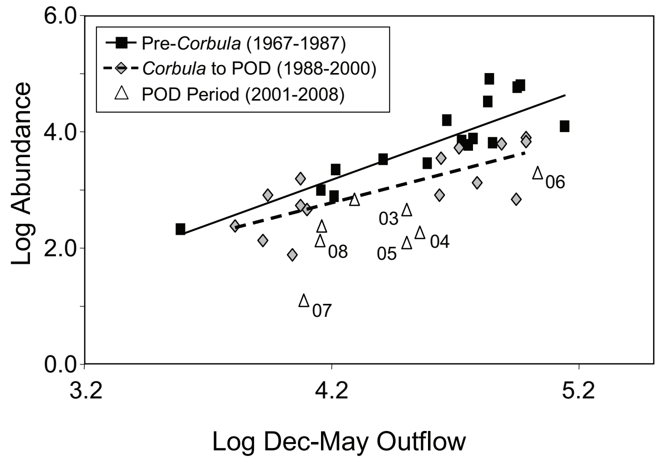

Figure 5 FMWT age-0 longfin smelt abundance index vs. outflow relationships pre- (1967-1987; solid line) and post (1988-2008; dashed line) Corbula amurensis introduction

Changes in the food web due to *C. amurensis* appeared to have affected longfin smelt distribution, similar to what was reported for northern anchovy by Kimmerer (2006). Longfin smelt FMWT distribution shifted towards higher salinity waters soon after *C. amurensis* was introduced (Figure 6) and the Bay Study has collected most age-0 longfin smelt in Central Bay and western San Pablo Bay in recent years, irrespective of outflow. Longfin smelt diet historically contained a high proportion of the mysid, *Neomysis mercedis* (Feyrer et al. 2003). The decline of *Neomysis mercedis* has been attributed to competition with *C. amurensis* for food (Orsi and Mecum 1996). Longfin smelt may have moved to higher salinity areas to find prey items, especially mysids, which were not impacted by *C. amurensis*.

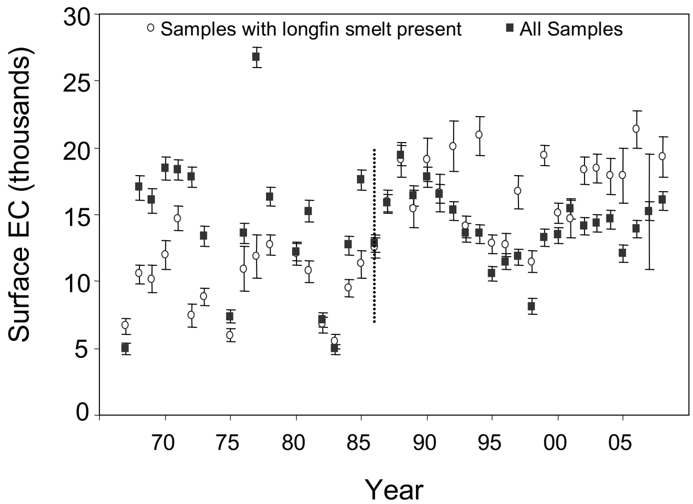

Figure 6 Average (± 1 SD) surface water electrical conductivity (EC) for FMWT samples with longfin smelt present and all samples. Dotted line represents the year C. amurensis was discovered

Splittail

The splittail (*Pogonichthys macrolepidotus*) is endemic to the San Francisco Estuary and its watershed. Adults migrate upstream from tidal brackish and freshwater habitats during increased river flows from late fall through spring to forage and spawn on inundated floodplains and river margins (Sommer et al. 1997, Moyle et al. 2004). Such migrations are known to occur in the Sacramento, San Joaquin, Cosumnes, Napa and Petaluma rivers, as well as Butte Creek and other smaller tributaries. Most spawning takes place from March through May. Young disperse downstream as larvae, when river levels drop, or as juveniles in late spring and early summer, when backwater and edge-water habitats diminish with reduced flows. Year-class strength is related to the timing and duration of floodplain inundation, as moderate to large splittail year classes resulted from inundation periods of 30 days or more in the spring months (Sommer et al. 1997, Moyle et al. 2004).

Age-0 splittail may not be effectively sampled by a majority of the long term monitoring surveys since their affinity is for shallow water and their year class strength is dependent on flood events in the spring. The U.S. Fish and Wildlife Service Delta Juvenile Fish Monitoring Program beach seine survey calculates an abundance index for age-0 splittail; however, the index was not updated for 2008. Splittail were collected in the beach seine from February 24 through May 31, 2008 (Behen 2008).

The 2008 FMWT splittail (all ages) index was 0 (Figure 7A), following 6 years of very low indices.

The BSMWT collected no age-0 splittail in 2008, resulting in 8 consecutive years with very low or 0 indices (Figure 7B). The BSMWT did collect 12 older splittail, most from the 2006 year class. Only 1 age-0 splittail was collected in 2008 by the BSOT, but at a non-index station (Old River Flats in the San Joaquin River), resulting in a zero index for the 2nd consecutive year (Figure 7C).

Age-0 splittail were virtually not detected by trawl surveys in 2008, but there was some evidence of splittail recruitment from other studies. Reece and Sommer (2008) reported that juvenile splittail dominated native fish catches in their Yolo Bypass rotary screw trap during May and June 2008 (n=388). Weekly beach seining late February through May 2008 produced modest juvenile splittail catches (n=150) in the lower Sacramento River (Behen 2008). Aasen (page 36, this issue) reported splittail salvage for 2008 was in the low thousands for both fish salvage facilities; typically, salvage is dominated by age-0 fish (Moyle et al. 2004).

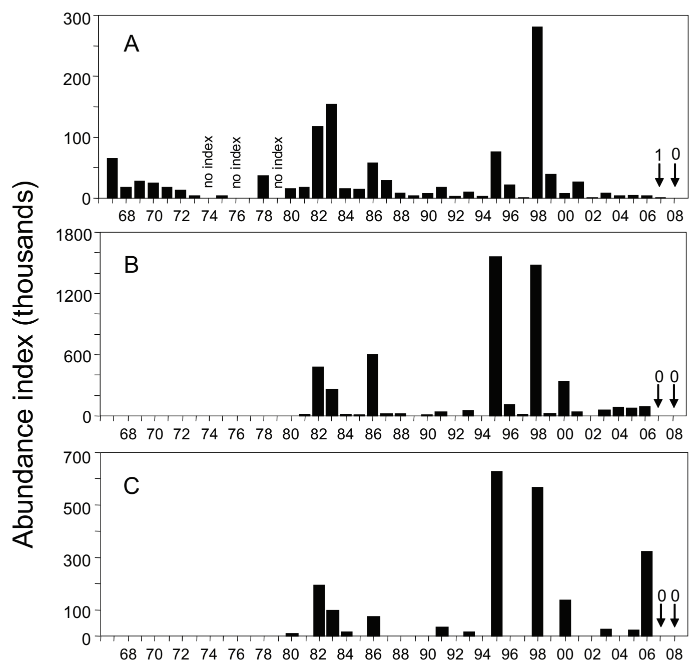

Figure 7 Annual abundance of splittail: A) FMWT, all sizes, September-December; B) Bay Study midwater trawl, age-0, May-October; C) Bay Study otter trawl, age-0, May-October

Striped bass

Striped bass (*Morone saxatilis*) is an anadromous fish first introduced to the San Francisco Estuary over 125 years ago. Adult striped bass forage in the nearshore ocean and coastal bays and migrate up rivers to spawn in spring. Juveniles rear in fresh and brackish waters of the estuary. The population of legal-size fish in the San Francisco Estuary declined from nearly 4.5 million in the early 1960s, to only 600,000 in 1994, and then increased to about 1.6 million in 2000. More recent population estimates of legal-size age-3 and older fish were about 946,000 in 2002, 829,000 in 2003, 1.3 million in 2004, 1 million in 2005, and 588,000 in 2007 (the 2004-2007 estimates are preliminary, Marty Gingras, personal communication). Age-0 striped bass abundance steadily declined since the mid-1980s, and TNS and FMWT indices where generally low in the late 1990s and early 2000s when the adult population had a modest recovery. Stevens et al. (1985) hypothesized that low striped bass recruitment was related to: 1) the declining adult population, 2) reduced plankton food supply, 3) loss of large numbers of young striped bass to water diversions, and 4) population-level effects of contaminants. Based on our understanding of factors controlling striped bass abundance in the estuary, the adult population increases in 2000 and 2004 were unexpected and remain unexplained.

The 2008 TNS striped bass 38.1-mm index was 1.1, which was 3.7 times the record low index of 0.3 in 2007 (Figure 8A). Even though this was the highest index since 2003, it still fell among the lowest 10% of indices on record. Age-0 striped bass abundance peaked in mid-June and stayed relatively high through early July. After mid-July, abundance decreased through the end of the survey in mid-August. In June, striped bass were found from the confluence of the Sacramento and San Joaquin rivers and eastern Montezuma Slough throughout all of the San Joaquin River and south delta sampling stations, and in the lower Sacramento River. By mid-July, they were concentrated in the lower Sacramento River and eastern Montezuma Slough, but caught in all other regions. In August only a few striped bass were captured, all in either Carquinez Strait or Montezuma Slough

The 2008 FMWT age-0 striped bass index was 2.7 times greater than the 2007 index. However, it was the sixth lowest index on record and consistent with the low indices seen since 2001 (Figure 8B). In September 2008, age-0 striped bass were distributed from San Pablo Bay to lower Sacramento and San Joaquin rivers, but absent in the northern delta. Catch was centered in Grizzly Bay in September. In October, they were most common in the lower San Joaquin River, but also found in Suisun Bay. In November and December, striped bass were found throughout Suisun Bay, in Montezuma Slough, and the lower Sacramento River.

The 2008 BSMWT age-0 striped bass index increased slightly from 2007 (Figure 8C), continuing the trend of very low indices since 2002. Although the 2008 BSOT index was 5.4 times the 2007 index (Figure 8D), it was consistent with low indices since the establishment of *C. amurensis* in 1987. The BSOT has been more effective at catching age-0 striped bass than the BSMWT, as was observed in 2008, when the BSOT collected 1,484 age-0 striped bass in 2008, while the BSMWT collected only 118 fish. This difference was in part because the BSMWT sampled 16 fewer times in an effort to reduce delta smelt take: from the confluence to the upstream limit of the study area, there were 75 midwater trawl tows and 91 otter trawl tows from June through December 2008. The BSMWT first collected age-0 striped bass in July and abundance peaked in September. The BSOT first collected age-0 striped bass in June and abundance peaked in July.

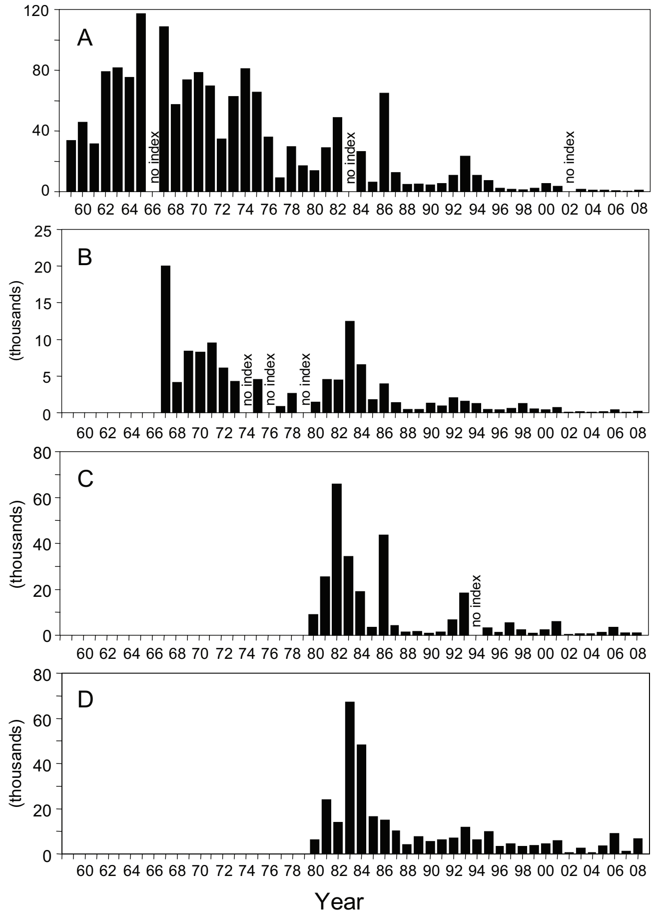

Figure 8 Annual abundance of age-0 striped bass: A) TNS 38.1-mm index; B) FMWT, September-December; C) Bay Study midwater trawl, June-October; D) Bay Study otter trawl, June-October

The Bay Study collected age-0 striped bass from San Pablo Bay to the uppermost stations in the study area in the Sacramento and San Joaquin rivers in 2008. The BSOT age-0 striped bass catch was highest at the San Joaquin River shoals (Santa Clara shoal, Old River Flats, and the shoal station near Antioch), followed by Suisun Bay. The BSOT again collected greater numbers of age-0 striped bass at shoal stations (91% of total June through December catch) versus channel stations. The BSMWT showed age-0 striped bass were most abundant in Suisun and Honker bays, with scattered collections through the lower Sacramento and San Joaquin rivers. In contrast to the BSOT, only 26% of the total BSMWT age-0 catch occurred at shoal stations.

Although the 2008 water year was considered critically dry, with total freshwater outflow similar to 2007, age-0 striped bass abundance rebounded slightly for all long-term monitoring surveys. This was perhaps due to the different timing of peak outflows and more plentiful food resources for larvae in 2008 (April Hennessy, figures 2 and 5, pages 13 and14 this issue). Striped bass survival and abundance has historically showed a positive correlation to outflow, although these responses have been dampened since the invasion of the clam *C. amurensis* in the late 1980s (Kimmerer 2002, Sommer et al. 2007). Although age-0 striped bass abundance has been very low for almost 2 decades, juvenile striped bass were still relatively abundant in benthic shoal habitats. Age-0 striped bass CPUE declined more at channel stations then shoal stations per the Bay Study otter trawl data. The average CPUE from channel stations post-*Corbula* (1987-2008) was 9% of the mean pre-*Corbula* (1980-1986) CPUE. In comparison, the mean shoal stations post-*Corbula* CPUE was 25% of the mean pre-*Corbula* CPUE. One hypothesis is that juvenile striped bass are successfully exploiting benthic shoal habitats for food resources such as amphipods, switching from the more pelagic mysids that were historically abundant and a large part of their diet (Bryant and Arnold 2007, Feyrer et al. 2003).

The current explanation for the overall decline of abundance of age-0 striped bass is an ecosystem-wide decline in suitable habitat for rearing (Feyrer et al. 2007), resulting in a reduction in carrying capacity (e.g., Kimmerer et al. 2000). Habitat suitability based on water clarity and specific conductance was correlated with age-0 striped bass presence, and changes in these habitat parameters were associated with anthropogenic modifications to the ecosystem (Feyrer et al. 2007).

Upper Estuary Demersal Fishes

Shokihaze goby

The Shokihaze goby (*Tridentiger barbatus*), is native to China, Japan, Korea, and Taiwan, and was first collected in the San Francisco Estuary by the Bay Study in 1997 (Greiner 2002). It is a short-lived species; age-1 fish spawn in brackish water during spring and early summer, and die in late summer and fall (Slater 2005). Since the Shokihaze goby is most common upstream of the Bay Study original sampling area, abundance is calculated as the annual mean catch-per-unit effort (CPUE, #/tow) for all 52 stations sampled by the otter trawl, including the lower Sacramento and San Joaquin river stations added in 1991 and 1994.

In 2008, the Shokihaze goby mean CPUE (all sizes) declined slightly from 2007 yet was the third highest CPUE on record and nearly twice the average since the species' first collection (Figure 9). Shokihaze gobies were collected in all embayments except for Central Bay. They exhibited a strong association with deep-water habitat, with densities 13 times higher at channel stations (1.96 fish/tow) than at shoal stations (0.15 fish/tow).

Shokihaze goby densities were highest in Suisun Bay most months, but CPUE increased substantially in the lower Sacramento River from August through December. One of the Suisun Bay channel stations adjacent to the "Mothball Fleet" was the most productive Shokihaze goby station, averaging 9.6 fish/tow for the year and reaching a maximum of 57 fish/tow in October.

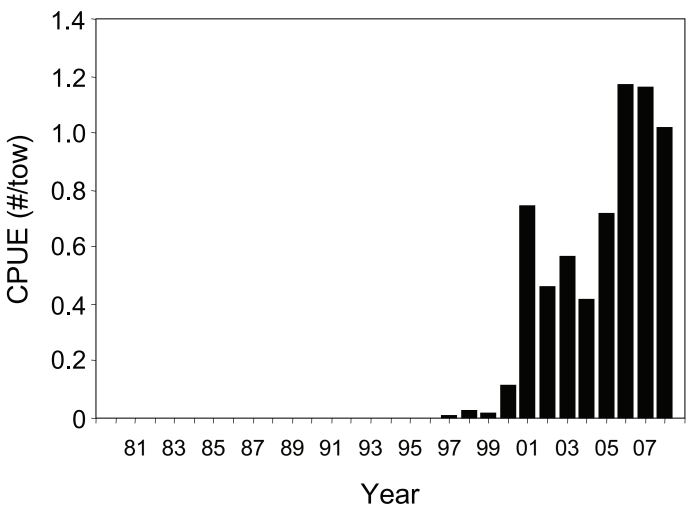

Figure 9 Annual catch-per-unit-effort (CPUE; #/tow) of Shokihaze goby (all sizes), Bay Study otter trawl, January-December

Yellowfin goby

The yellowfin goby (*Acanthogobius flavimanus*) is an introduced fish from Asia. It is partially catadromous: adults migrate to brackish water to spawn from December through July and most die after spawning. Juvenile fish migrate upstream to lower salinity and fresh water habitats to rear through summer and fall (Moyle 2002).

The 2008, age-0 yellowfin goby abundance index declined from 2007 and was third lowest index on record (Figure 10), continuing the trend of very low indices since 2000. Age-0 yellowfin gobies first recruited to the gear in June in Suisun Bay and abundance peaked in July. Age-0 fish were collected from all embayments except Central Bay, with highest densities in Suisun Bay (0.43 fish/tow, June-December). Age-0 yellowfin gobies were again associated with shallow water in 2008, with shoal station CPUE (0.19 fish/tow) more than double that for channel stations (0.09 fish/tow).

In January, age-1+ yellowfin gobies began migrating to San Pablo Bay; by February, age-1+ CPUE peaked at 5.8 fish/tow in San Pablo Bay. By April, most age-1+ yellowfin gobies had spawned and died. In contrast to age-0 fish, age-1+ fish were collected more frequently at channel stations (1.2 fish/tow) than at shoal stations (0.4 fish/tow). This trend was driven by the adults' channel-oriented spawning migration from January through March.

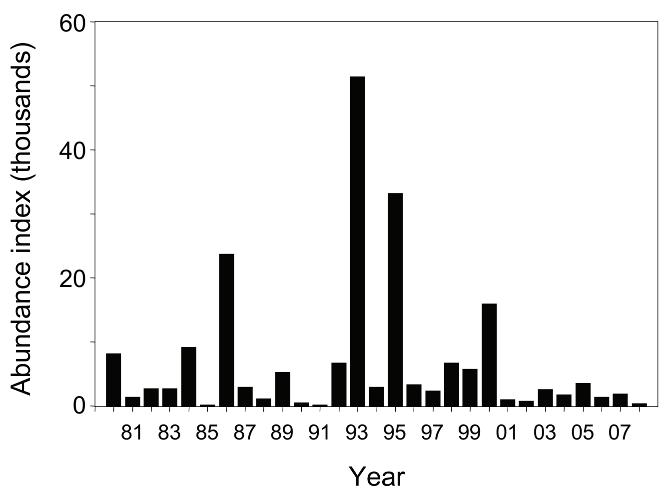

Figure 10 Annual abundance of age-0 yellowfin goby, Bay Study otter trawl, May-October

Starry flounder

The starry flounder (*Platichthys stellatus*) is an estuary-dependent species that spawns in the ocean, but rears in brackish and fresh water areas of estuaries. In 2008, the age-0 starry flounder abundance index dropped to 22% of the 2007 index and less than half of the study- period average (Figure 11A). This was the first decline in age-0 indices since 2004. In contrast, age-1 and age-2+ indices increased in 2008 (Figure 11B), following good age-0 production from 2003 to 2007. In 2008, there was a 66% increase in the age-1 index and a 78% increase in the age-2+ index, which brought both above the study-period average. Starry flounder of all 3 age classes were collected in all embayments except Central Bay, where only age-2+ fish were collected. The 2008 year class recruited to the gear in June and was collected through the end of the year. Age-0 starry flounder were most common in

Suisun Bay (1.4 fish/tow, June to December). They were associated with shallow water across all regions, from the time they were first collected through the end of the year; CPUE at shoal stations (0.53 fish/tow) was over 3 times higher than at channel stations (0.15 fish/tow).

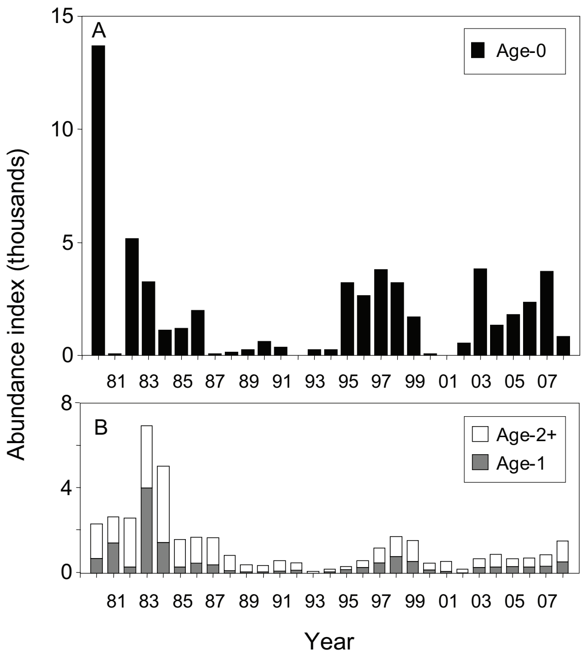

Figure 11 Annual abundance of starry flounder: A) age-0, Bay Study otter trawl, May-October, and B) age-1 and age-2+, Bay Study otter trawl, February-October

Marine Pelagic Fishes

Pacific Herring

The Pacific herring (*Clupea pallasii*) is an estuary-dependent species that spawns and rears in higher salinity areas (>20‰) of the estuary. Spawning occurs in late winter and early spring; the adhesive eggs are deposited on substrates such as aquatic vegetation, rocks, pier pilings, and other man-made structures. After hatching and larval development, young Pacific herring move to shallow waters and begin to school. Juveniles can be found in shallow subtidal areas and sloughs until late spring, when they migrate to deeper waters within the estuary. In fall, Pacific herring emigrate from the estuary to spend 2 to 3 years rearing in the ocean before reaching maturity and returning to spawn.

The 2008 age-0 index was nearly 8 times the 2007 index, and more than 3.5 times the study-period average (Figure 12). It was also the second highest index on record. Age-0 fish were first collected in March and abundance peaked in June. In 2008, fish were collected from South Bay to Chipps Island near the confluence of Sacramento and San Joaquin rivers, which was a much wider distribution than in recent years. Distribution was broadest in June; from July through early fall, fish migrated from South Bay and upstream regions to Central Bay. This was coincident with increased temperatures in San Pablo and South bays. CPUE was consistently highest in Central Bay (average 66 fish/tow for April to December), followed by San Pablo (23 fish/tow) and South (9 fish/tow) bays.

The CDFG Herring Project has recorded landings for the Pacific herring fishery in San Francisco Bay since 1972. The commercial Pacific herring fishery runs from December through March, targeting adult fish entering the estuary to spawn. The 2007-2008 landings totaled 702 tons, nearly 2.4 times higher than the previous year's landings, but well below the mean annual landings of 5,325 tons from 1972 to 2004. Approximately 64% of the 2007-2008 quota was reached. The recent declines in San Francisco Bay herring landings were not necessarily indicative of a declining adult Pacific herring population. Increasing fuel prices and decreasing market value of herring products have decreased the profitability of the Pacific herring fishery, resulting in decreased fishing effort. The Cosco Busan oil spill in November 2007 also may have deterred commercial fishermen from participating in the 2007-2008 fishery.

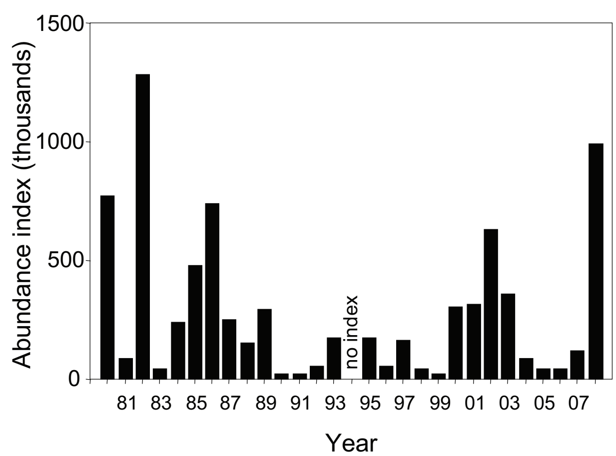

Figure 12 Annual abundance of age-0 Pacific herring, Bay Study midwater trawl, April-September

Northern anchovy

The northern anchovy (*Engraulis mordax*) is the most common fish in the lower estuary and an important prey species for many fishes and seabirds (Bergen and Jacobson 2001). The 2008 northern anchovy abundance index (all sizes) was 67% of the 2007 index (Figure 13). It was the fourth lowest index on record, and only half of the study-period average.

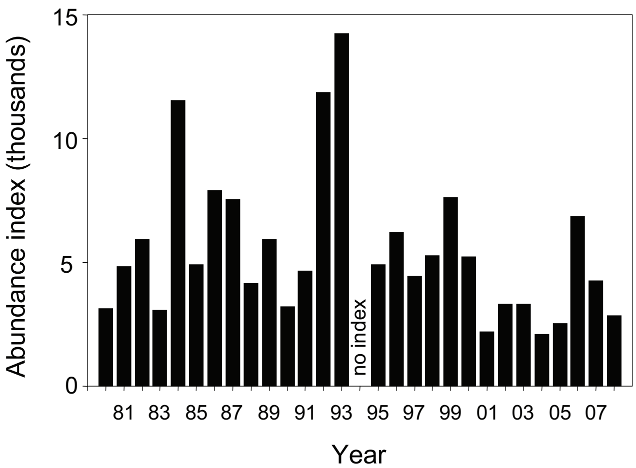

Figure 13 Annual abundance of northern anchovy (all sizes), Bay Study midwater trawl, April-October

Vrooman et al. (1981) separated the northern anchovy population into northern, central, and southern subpopulations. The San Francisco Estuary is situated between the northern and central subpopulations, and our catches reflect changes in the size and coastal movements of these subpopulations. Although the central subpopulation is the largest and historically the most heavily fished, there are currently no stock assessments, so we cannot confirm subpopulation movements or size from fisheries data.

Northern anchovies were collected every month in 2008, but abundance peaked in July, and was very low in January, February, November, and December. Fish were collected from South Bay to the lower Sacramento River near the confluence, with annual CPUE highest in Central Bay (217 fish/tow), followed by San Pablo (181 fish/tow) and South (98 fish/tow) bays. Distribution shifted seasonally, with few anchovies collected in San Pablo and Suisun bays until June. In July, the highest regional CPUE was in San Pablo Bay, where catches averaged 662 fish/tow. Anchovies used deeper waters of the estuary between January and April, with CPUE at channel stations (38 fish/tow) higher than shoal stations (1 fish/tow). There was no obvious depth preference the rest of the year.

Kimmerer (2006) suggested the overbite clam (*Corbula amurensis*), introduced prior to 1987, caused a shift in northern anchovy distribution within the estuary. As a result of food competition, anchovies have not utilized the lower salinity regions of the estuary, with a few exceptions, as they had prior to1987. Following Kimmerer (2006), northern anchovy annual CPUE was averaged for each of three salinity (S) zones: high (S>20 psu), medium (20=S>10 psu) and low (10=S>0.5 psu). Through the study period, mean CPUE exhibited downward trends in all zones, but most notably the low salinity zone (Figure 14).

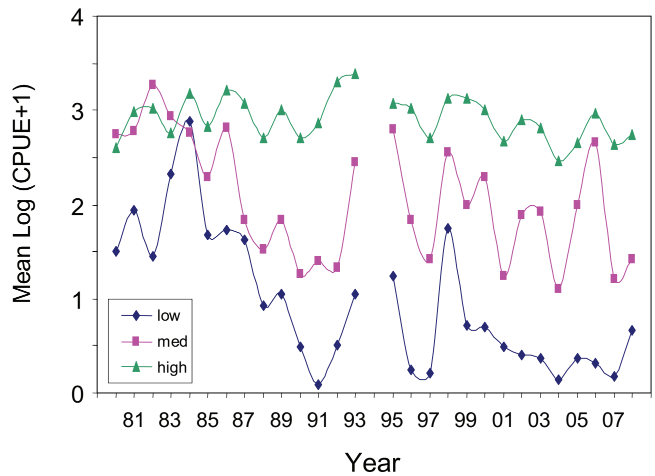

Figure 14 Northern anchovy mean CPUE by salinity zone Bay Study midwater trawl, June-October. Salinity (S) zones used: high (S>20 psu), medium (20≥10 psu) and low (10≥0.5 psu)

Jacksmelt

The jacksmelt (*Atherinopsis californiensis*) seasonally migrates from nearshore coastal waters to bays and estuaries to spawn and rear. Most reproduction within the San Francisco Estuary occurs from September to April based on the presence of ripening and ripe females in San Pablo Bay (Ganssle 1966). Juvenile jacksmelt rear in shallow (<2 m) areas of South, Central, and San Pablo bays in late spring and summer. After growing to about 50 mm FL, they begin to migrate to deeper water, where they become vulnerable to the midwater trawl.

The 2008 age-0 jacksmelt abundance index increased slightly from the 2007 index (Figure 15), making it the highest index since 1985 and the second highest index on record. In 2008, age-0 jacksmelt were collected between July and November with peak abundance in August. Age-0 fish were collected from South Bay near the Dumbarton Bridge to Suisun Bay, but over 70% of the total catch came from South Bay, where CPUE averaged 16.7 fish/tow (July to December). The next highest CPUE was in Central Bay, with 5.1 fish/tow. However, there was a strong seasonal movement, with age-0 jacksmelt most common in South Bay through August and in Central Bay in October and November, as the emigrated from the estuary. Far more age-0 jacksmelt were collected at channel stations than shoal stations, with a mean channel CPUE of 7.0 fish/tow and a mean shoal CPUE of 1.9 fish/tow.

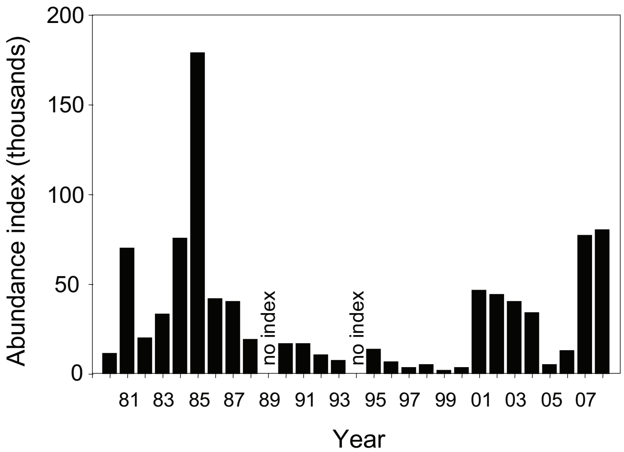

Figure 15 Annual abundance of age-0 jacksmelt, Bay Study midwater trawl, July-October

Surfperches

Most surfperches are transient species, migrating into bays and estuaries to give birth to live, fully-formed young in late spring and summer, and returning to the coastal ocean in fall and winter. All of the surfperches common to San Francisco Estuary underwent abundance declines in the 1980s per Bay Study trawl and sport fish survey data (DeLeón 1998). Consequently, in 2002 CDFG changed the sport fish regulations for San Francisco Bay, adopting a closed season for all surfperches, except shiner perch, from April 1 to July 31 and a 10-fish combination bag limit for all species except shiner perch, which was given a 20-fish bag limit.

Shiner perch

In 2008, the abundance of age-0 shiner perch (*Cymatogaster aggregata*) increased slightly from 2007, but was still only 43% of the study period average (Table 1). Age-0 fish were not collected until June, and abundance peaked in October. Age-0 shiner perch were collected from South Bay through western Suisun Bay near Benicia in 2008, but were most common in Central Bay, where CPUE averaged 2.6 fish/tow. Shiner perch were most widely distributed in late summer and early fall, and by November they were only found in Central and South bays. Average CPUE at shoal stations (1.0 fish/tow) was over 3 times higher than channel stations (0.3 fish/tow) for June through December. Some apparent seasonal channel-shoal movement was observed in October and November, when CPUE at channel stations surpassed that of shoal stations.

Walleye surfperch

The 2008 age-0 walleye surfperch (*Hyperprosopon argenteum*) abundance index was nearly 17 times the 2007 index and 2 times the study period average (Table 1). It also marked the highest index since 2002. Seventy age-0 walleye surfperch were collected in 2008, all of from Central and San Pablo bays. Fish were collected from July through November and abundance peaked in August. This peak and the annual index were dominated by a large catch of 46 fish near Point San Pablo in western San Pablo Bay. All age-0 walleye surfperch were collected at shoal stations near Alameda, the Berkeley fishing pier, and in western San Pablo Bay. The 2008 age-1+ index was 43% of the 2007 index and was less than the study-period average (Table 1). Fifteen age-1+ walleye surfperch were collected during 2008 at locations ranging from South Bay, near Candlestick Point, to San Pablo Bay, near Point Pinole; most came from Central Bay near the Berkeley fishing pier. All were collected from shoal stations.

Other Surfperches

The 2008 barred surfperch (*Amphistichus argenteus*) abundance index for all sizes decreased slightly from 2007 (Table 1). In 2008, the Bay Study collected 5 barred surfperch, but only 3 were from core stations and contributed to the 2008 index. All fish were collected at shoal stations in South Bay. Historically, the majority of barred surfperch have been collected from South Bay shoal stations, especially stations along the eastern shore. Barred surfperch is commonly associated with eelgrass beds in San Francisco Bay (Merkel & Associates 2005), a habitat not sampled by our trawls.

The 2008 age-0 pile perch (*Rhacochilus vacca*) abundance index was 0, showing no sign of recovery in the estuary and continuing the trend of very low or 0 indices since 1987 (Table 1).

The 2008 white seaperch (*Phanerodon furcatus*) index increased after 2 years of 0 indices (Table 1), but was still a fraction of the high indices seen in the early 2000s. The index was based on 1 fish collected in October at a channel station west of Alcatraz Island in Central Bay. One other white seaperch was collected by the otter trawl in Central Bay, but during a non-index month.

Black perch (*Embiotoca jacksoni*) was the only surfperch common in the estuary that did not show a distinct decline during the late 1980s or early 1990s (Table 1). However, black perch catch has remained low relative to the most common surfperches throughout the study period. The 2008 black perch index (all ages) increased from the 2007, but was based on only 2 fish collected from channel stations near Angel Island in Central Bay.

For the first time in 6 years, the 2008 dwarf perch (*Micrometrus minimus*) index was 0 (Table 1). Although 2 dwarf perch were collected in 2008, both came from non-index shoal stations in Central Bay. Historically, dwarf perch were commonly collected from shoal stations in Central and South bays. Dwarf perch is another species strongly associated with eelgrass beds in the San Francisco Bay that is under-sampled by our trawls.

Marine Demersal Fishes

Plainfin midshipman

The plainfin midshipman (*Porichthys notatus*) migrates from coastal areas to bays and estuaries in late spring and summer to spawn. Most juveniles rear in the estuary through December, with some fish remaining until spring. Following the highest index on record in 2007, the 2008 age-0 index declined 71%, but was still well above the study-period average (Figure 16). Age-0 plainfin midshipmen were collected from June to December, with peak abundance in October. Age-0 midshipmen were most abundant in South Bay in June (0.9 fish/tow), but CPUE was highest in Central Bay for the rest of the year (30.8 fish/tow). Geographic range was widest in September, when fish were collected from South Bay to the confluence of the Sacramento and San Joaquin rivers. Age-0 fish were more abundant at channel stations (11.9 fish/tow) than shoal stations (0.8 fish/tow) in 2008, consistent across all regions collected.

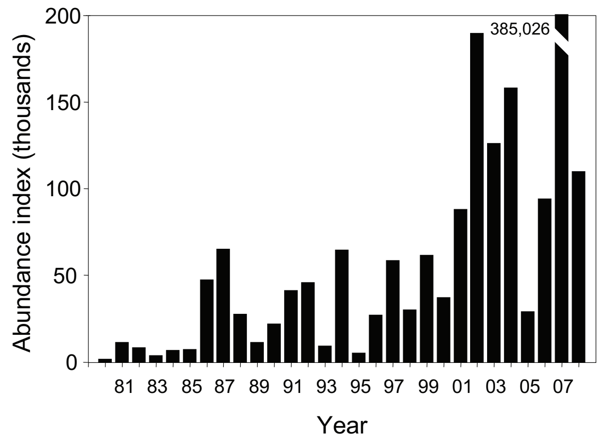

Figure 16 Annual abundance of age-0 plainfin midshipman. Bay Study otter trawl, February through October

Since the late 1990s, plainfin midshipmen were collected in higher densities in Central Bay relative to South and San Pablo bays. This trend persisted through various water year types and continued in 2008. The mechanism behind this apparent distributional shift is currently unexplained, but a similar increase in Central Bay CPUE was observed for other marine demersal species such as speckled sanddab, bay goby, and English sole.

Pacific staghorn sculpin

The Pacific staghorn sculpin (*Leptocottus armatus*) is a common native species that usually rears in higher salinity areas, but is also found in brackish and occasionally fresh water. Throughout the estuary, it rears in intertidal and shallow subtidal areas from late winter to early spring and migrates to deeper water through summer. The 2008 staghorn sculpin age-0 abundance index was 3 times the 2007 index and the second highest index on record (Figure 17). The 2 highest catches of 2008 (484 and 310 fish) occurred at non-core stations and thus did not contribute to the index, possibly biasing this index low. Age-0 Pacific staghorn sculpin were collected in all embayments in 2008, with highest densities in Central Bay, where catches averaged 14.4 fish per tow February through September. Catches were overall higher at channel stations (9.2 fish/tow) than at shoal stations (6.2 fish/tow), but shoal CPUE was nearly equal or greater than channel CPUE from June through August.

Table 1. Annual abundance indices for selected surfperch species from the Bay Study. The age-0 shiner perch, age-0 and age-1+ walleye surfperch, age-0 pile perch, and white seaperch (all sizes) indices are from May-October. The barred perch (all sizes), black perch (all sizes), and dwarf perch (all sizes) indices are from February-October

Year	shiner perch	walleye sp	walleye sp	barred sp	pile perch	white seaperch	black perch	dwarf perch
	age-0	age-0	age-1+	all	age-0	all	all	all
1980	19516	1277	642	415	857	588	0	439
1981	42760	8089	1757	691	998	1248	129	543
1982	43704	1640	992	223	471	349	54	259
1983	16147	663	135	1030	778	271	88	460
1984	14386	3846	922	502	110	873	216	50
1985	16616	362	1031	81	301	138	66	0
1986	24617	322	880	0	254	309	17	0
1987	18069	1453	2624	159	0	265	0	0
1988	7746	486	502	90	0	148	62	66
1989	6953	2046	493	109	153	48	101	97
1990	8181	516	341	105	0	95	48	26
1991	2724	22	505	75	0	0	0	15
1992	6142	443	297	27	0	0	100	0
1993	6341	617	112	29	0	0	97	0
1994	3241	no index	no index	53	0	0	125	0
1995	6661	405	269	36	0	0	0	0
1996	4404	684	380	39	0	0	225	0
1997	23896	231	643	104	0	0	231	0
1998	4384	537	911	32	75	0	65	0
1999	6237	848	2985	30	0	0	36	0
2000	4640	1229	114	29	31	0	119	0
2001	20594	8121	1003	41	0	106	248	0
2002	26131	12277	2079	76	42	260	95	0
2003	15898	2439	567	302	0	371	63	111
2004	24849	896	1438	76	0	487	253	94
2005	6225	2916	655	34	0	47	93	32
2006	4911	1610	27	46	0	0	62	34
2007	5193	248	1237	123	0	0	36	42
2008	5935	4128	529	105	0	61	69	0

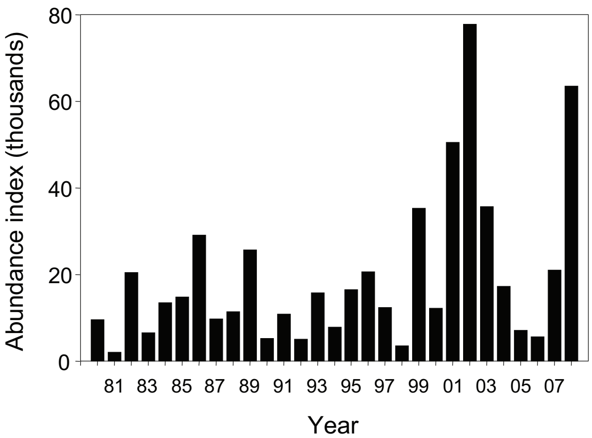

Figure 17 Annual abundance of age-0 Pacific staghorn sculpin, Bay Study otter trawl, February-September

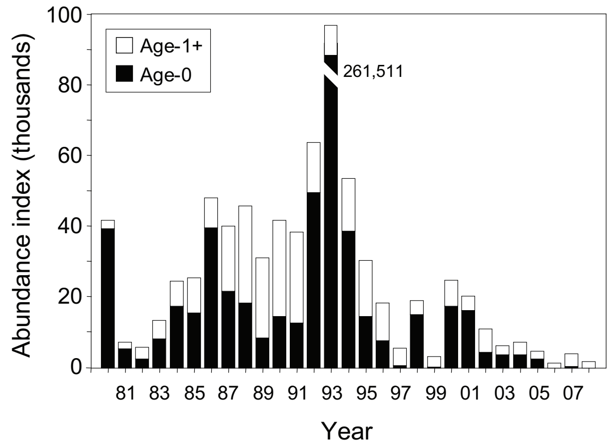

Figure 18 Annual abundance of age-0 and age-1+ white croaker, Bay Study otter trawl, February-October

White croaker

The white croaker (*Genyonemus lineatus*) is a common coastal species that frequents bays and estuaries. It is a member of the subtropical fish fauna more commonly found south of Point Conception. It spawns from November through April in shallow, nearshore waters, and juveniles progressively move into deeper water as they grow. The 2008 age-0 white croaker index was only 7% of the 2007 index and was the second lowest on record (Figure 18). Since 1995, age-0 white croaker indices have been below the study-period average. The 2008 age-0 index was based on 1 fish collected in July at a channel station near Angel Island in Central Bay. One other age-0 fish was collected in 2008; however, it was from a non-index station near Alameda.

The 2008 white croaker age-1+ index was approximately half the 2007 index (Figure 18). Both the age-0 and age1+ indices have been relatively low since the early 1990s, when salinity remained high and relatively stable year-round in the estuary and sea surface temperatures were high due to several El Niño events. In 2008, age-1+ fish were collected throughout the year, but abundance was highest in late summer and early fall. Age-1+ white croaker were collected from South Bay near the Dumbarton Bridge through western Suisun Bay near Benicia, with the center of distribution in South Bay most months of 2008. Age-1+ white croaker were more commonly caught in the channels than the shoals, with average annual channel CPUE 8 times the shoal CPUE (0.24 vs. 0.03 fish/tow).

Bay goby

The bay goby (*Lepidogobius lepidus*) is one of the most common gobies in the estuary. It is a native resident species that rears in the higher salinity areas and has a 2 to 3 year life span. The 2008 bay goby index (all sizes) was over 4 times the 2007 index and the highest index on record (Figure 19). Bay gobies were collected from South through Suisun bays but were most abundant in Central Bay all months except March and April, when densities were highest in San Pablo Bay. Central Bay CPUE averaged 70 fish/tow for the year and peaked in September at 230 fish/tow. The 2008 bay goby distribution was consistent with the long-term trend of increased Central Bay CPUE observed for plainfin midshipman and several other marine demersal species. CPUE was highest at shoal stations through June, at which point distribution shifted to channel stations; for all months, average channel and shoal CPUE was almost identical at 19 fish/tow.

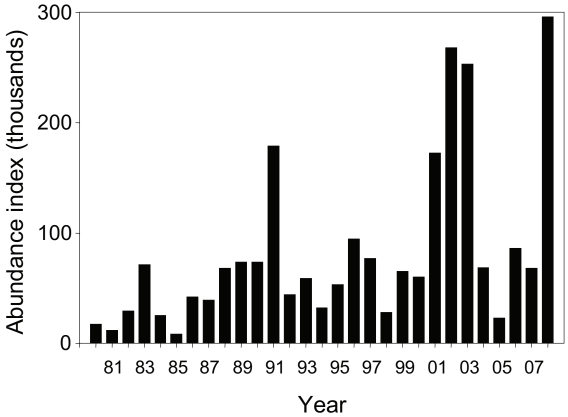

Figure 19 Annual abundance of bay goby (all sizes), Bay Study otter trawl, February-October

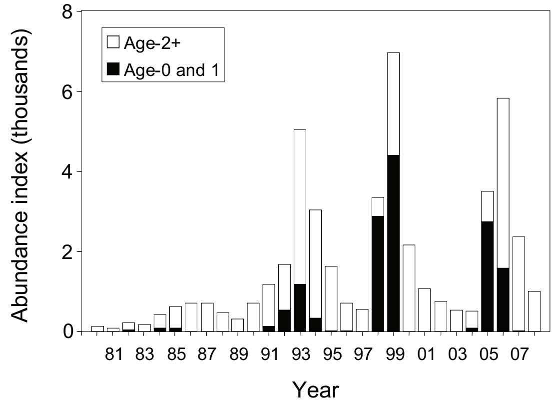

Figure 20 Annual abundance of juvenile (age-0 and age-1) age-2+ California halibut, Bay Study otter trawl, Feb-Oct

California halibut

The California halibut (*Paralichthys californicus)* is a member of the subtropical faunal group that became common in the San Francisco Estuary in the 1980s and 1990s, concurrent with the most recent warm-water regime. It spawns in shallow coastal waters and juveniles rear in very shallow subtidal and intertidal areas of bays and estuaries, and to a much lesser extent on the open coast. The 2008 juvenile (age-0 & 1) California halibut index was 0 (Figure 20). The smallest fish collected was 245 mm and it was the only fish less than 325 mm collected during 2008. Continued cold ocean conditions likely limited local recruitment, exemplified by Bay Study collection of only 1 juvenile halibut since early 2006.

The 2008 adult (age-2+) California halibut index was less than half of the 2007 index and slightly less than the study period average (Figure 20). Adult halibut were collected from South through Suisun bays, but were most common in Central Bay all months except January and November, averaging 0.22 fish/tow. Fish ranged in length from 245 mm to 745 mm and most appeared to be from the large 2004-05 cohort, produced concurrent with the strongest of the recent warm-water events. The extreme fishing pressure and associated mortality placed on California halibut over the past year due to publicity of the high rate of angler success and lack of other fisheries to pursue likely contributed to the decline in the 2008 adult halibut index.

English sole

The English sole (*Pleuronectes vetulus*) is a common flatfish that spawns along the coast in winter and rears in both the coastal ocean and estuaries. The 2008 age-0 English sole abundance index was more than twice the 2007 index and was the highest index on record (Figure 21). Fish were collected all months, with peak abundance in July. Age-0 English sole were collected from South through Suisun bays in 2008 and were most common in Central Bay all months except February, when highest densities occurred in San Pablo Bay. Central Bay CPUE averaged 30 fish per tow for the year (Feb-Oct) and 162 fish per tow in July. The 2008 English sole distribution was consistent with the long-term trend of increased Central Bay CPUE observed for plainfin midshipman, bay goby, and several other marine demersal species. Age-0 English sole were most common at shoal stations through June and at channel stations from July through December. This apparent movement from the shoals to the channel coincided with the immigration of older age-0 fish to Central Bay from the ocean in summer (see below).

There appeared to be English sole from 4 distinct origins within San Francisco Estuary in 2008. From January through April, at least 3 year classes were apparent: one spawned in fall 2007 (age-0 fish), one spawned in early 2007 (age-1 fish), and several larger individuals that were likely age-2+ fish migrating from nearshore costal areas. The age-0 fish primarily ranged from 20-100 mm in length, but were collected in relatively small numbers. From June through August very large numbers of age-0 fish ranging from 70-130 mm appeared in Central Bay. The fact that a proportional number of smaller English sole were not collected in earlier surveys indicates that larger juveniles entered the estuary opportunistically from the nearshore coast to rear.

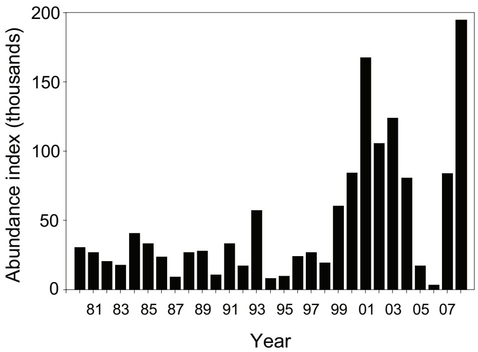

Figure 21 Annual abundance of age-0 English sole, Bay Study otter trawl, February-October

Speckled sanddab

The speckled sanddab (*Citharichthys stigmaeus*) is one of the most abundant flatfishes in the estuary. It is a short-lived species with an estimated maximum age between 36 and 42 months. Spawning occurs along the coast and peaks in summer. In southern California, spawning is coincident with a sudden drop in bottom temperature due to upwelling (Ford 1965). Larvae may be pelagic for many months, riding ocean currents first offshore then onshore, before settling to the bottom in or near coastal and estuary rearing areas, generally in less than 40 m of water (Rackowski and Pikitch 1989, Kramer 1990). Juveniles rear for up to a year in the estuary before immigrating to the ocean.

The 2008 speckled sanddab abundance index (all sizes) was nearly identical to the 2007 index and slightly below the study period average (Figure 22). The 2008 index was composed of fish from 2 year-classes: the 2007 year class that hatched in summer 2007 and the smaller 2008 year class that hatched in late spring 2008. Abundance peaked from February through April; these were fish that hatched and settled in 2007, not 2008. Distribution ranged from South Bay to San Pablo Bay from January through April, but from June to December only 6 fish were collected outside Central Bay. In 2008, 95% (n=1,731) of the 2008 speckled sanddab catch came from Central Bay stations. The 2008 speckled sanddab distribution was consistent with the long-term trend of increased Central Bay CPUE also observed for plainfin midshipman, bay goby, English sole, and several other marine demersal species. Catch was distributed fairly evenly by depth during the first half of the year, but from June to December CPUE was consistently higher at channel stations, dominated by catches in the Central Bay channels.

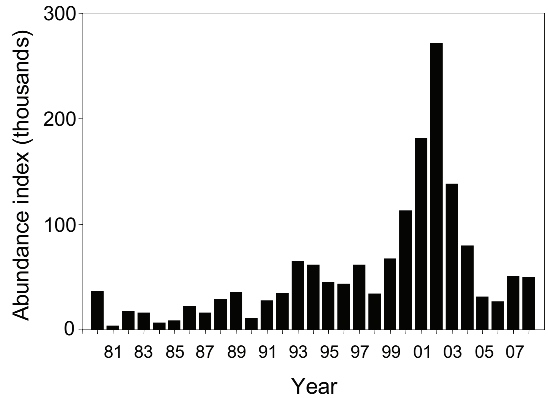

Figure 22 Annual abundance of speckled sanddab (all sizes), Bay Study otter trawl, February-October

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Notes

2008 Dayflow data from: iep.water.ca.gov/dayflow/index.html
Marty Gingras, California Department of Fish and Game, email June 29, 2009.
Jaime Janhcke, PRBO Conservation Science, email June 6, 2009.

Fish Salvage at the State Water Project's and Central Valley Project's Fish Facilities during 2008

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Introduction

Two facilities reduce the fish entrainment associated with water export by the federal Central Valley Project (CVP) and California's State Water Project (SWP). The CVP's Tracy Fish Collection Facility (TFCF) and the SWP's Skinner Delta Fish Protective Facility (SDFPF) divert (salvage) fish from water exported from the southern end of the Sacramento-San Joaquin Delta. Both facilities use louver-bypass systems to salvage fish from the exported water. The salvaged fish are periodically loaded into tanker trucks, transported to fixed release sites, and returned to the western Delta. The TFCF began operations in 1957. Operations at the SDFPF began in 1967.

Data from 1982 to 2008 were examined and discussed for analytical convenience and for their relevance to recent conditions. Systematic sampling was used to estimate the numbers and species of fish salvaged at both facilities. Bypass flows into the fish collection buildings were sampled once every 2 hours for 10 to 30 minutes. Fish, 20 mm (fork length: FL) or larger, from the sampled bypass flows were identified and numerated. These fish counts were expanded proportionally based on sample time to estimate the total number of fish salvaged in each 2 hour period of water export. These incremental salvage estimates were then summed across time to derive monthly and annual species-salvage totals for each facility.

Chinook salmon loss estimates are presented because its loss model has been widely accepted and has undergone extensive field validation compared to other species. Loss is the estimated number of fish encountered by the facility minus the number of fish that survive salvage operations. Loss was subcategorized by origin and race.

Larval and post-larval fish (< 20 mm FL) were also collected and examined to determine the presence of young delta smelt in 2008. Larval sampling began on February 19 at both facilities and ended on June 18 at the SDFPF and on June 15 at TFCF. Larval samples were collected every 6 hours during export operations. The fish screen used in the routine counts was lined with a 0.5 mm nitex net to retain larval fish. Larval fish were identified to species by TFCF personnel for both facilities.

This report summarizes the 2008 salvage information from the TFCF and the SDFPF. The following species are given individual consideration: Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), striped bass[1] (*Morone saxatilis*), delta smelt[1] (*Hypomesus transpacificus*), longfin smelt (*Spirinchus thaleichthys*), threadfin shad[1] (*Dorosoma petenense*)[1], and splittail (*Pogonichthys macrolepidotus*).

Water Exports

Water exports were substantially reduced from recent years due to reduced water inflow and legal measures to protect delta smelt. The State Water Project exported roughly 1.5 billion m^3 of water in 2008. Annual SWP exports ranged from 3.0 to 5.0 billion m^3 during 2003 through 2007 (Figure 1). The Central Valley Project exported roughly 2.2 billion m^3 of water in 2008. The annual CVP export in 2008 was also reduced compared to recent years, which ranged from 3.2 to 3.4 billion m^3 annually during 2003 though 2007.

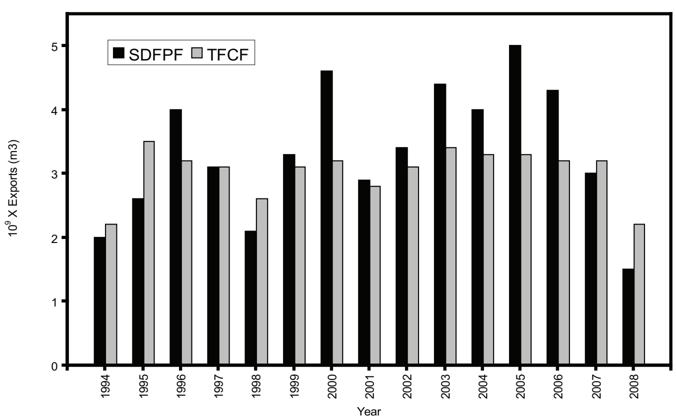

Figure 1 Annual exports in billions of cubic meters for the SWP and the CVP, 1994 to 2008

The monthly water export patterns of the two water projects showed seasonal differences. Water exports peaked during July through November at the CVP and January through February at the SWP (Figure 2). From July through November, 1.3 billion m^3 of water was exported by the CVP representing about 59% of the 2008 annual export. From January through February, 465.0 million m^3 of water were exported by the SWP and represented about 32% of the annual export. The SWP exports during August through October were also reduced compared to recent years. The SWP monthly exports ranged from 39.6 to 242.0 million m^3 of water. The CVP monthly exports ranged from 67.4 to 289.0 million m^3 of water.

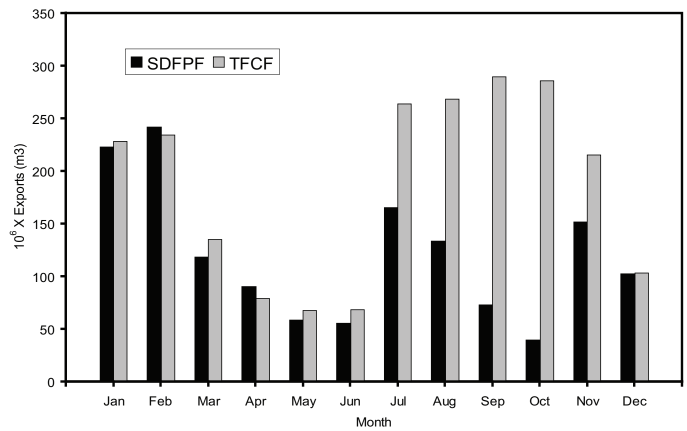

Figure 2 Monthly exports in millions of cubic meters for the SWP and the CVP in 2008

Total Salvage and Prevalent Species

Annual combined salvage (annual salvage) at the SDFPF in 2008 was 648,797 which was the lowest on record (Figure 3). The SDFPF salvage in 2008 decreased substantially in contrast to 2007 and 2006 when 2,239,066 and 5,138,457 fish were salvaged, respectively. Annual salvage at the TFCF in 2008 was 5,365,057. The TFCF annual salvage was slightly greater than that of the previous year (3,164,530) and comparable to annual salvages since 1994 (excluding 2006).

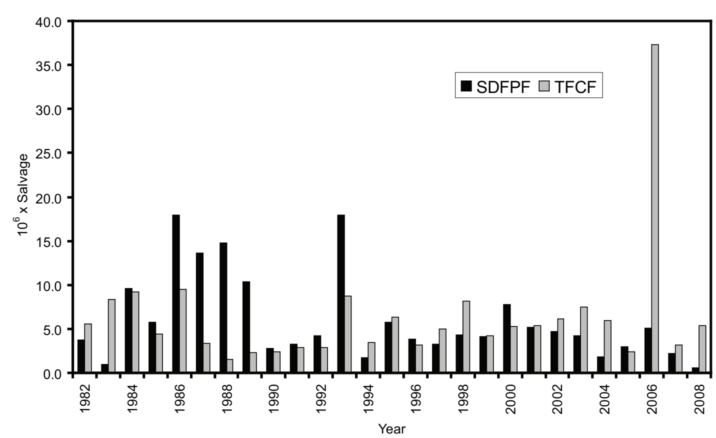

Figure 3 Annual salvage of all taxa combined at the SDFPF and the TFCF, 1982 to 2008

1. Pelagic Organism Decline (POD) species

Threadfin shad were the most salvaged fish species at both facilities. Threadfin shad dominated the annual salvage at the TFCF and accounted for 86.1% of the number of fish salvaged (Figure 4). Striped bass were the only other species to be salvaged in substantial numbers at the TFCF. Threadfin shad accounted for 43.2% of the annual salvage at the SDFPF. Striped bass and American shad also contributed to the annual salvage at the SDFPF. Threadfin shad have generally made up the bulk of salvage at both facilities in recent years. In 2008, relatively few (< 0.4% of total annual salvage) Chinook salmon, steelhead, delta smelt, longfin smelt, and splittail were salvaged at the SDFPF and TFCF.

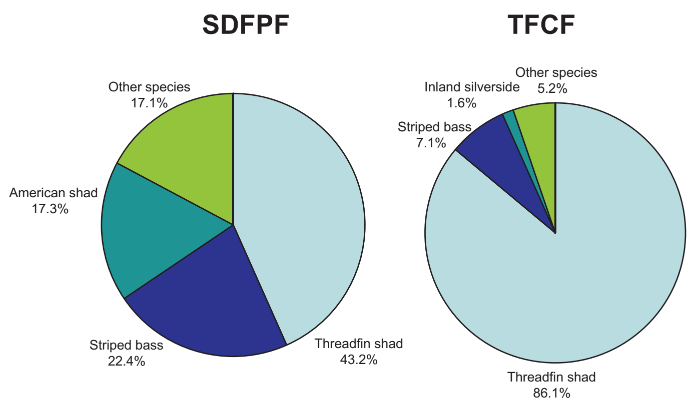

Figure 4 Percentages of annual salvage for the 3 most prevalent species and other species combined at the SDFPF and TFCF, 2008

Chinook Salmon

Annual salvage (all races and origins combined) of Chinook salmon continued to be low at both facilities. The annual salvage of 4,928 at the SDFPF in 2008 continued the declining trend which started in 2001 (Figure 5). The annual salvage of Chinook salmon in 2008 was larger than the annual salvage of 1,941 observed in 2007, but was a decrease from the annual salvage of 8,629 observed in 2006. Mean annual SDFPF salvage from 2001 to 2008 was about 8-fold lower than salvage in the 1980's. The annual salvage of Chinook salmon at the TFCF was 8,786 in 2008. The annual salvage of Chinook salmon in 2008 was similar to the annual salvage of 7,622 observed in 2007, but was a decrease from the annual salvage of 35,319 observed in 2006. Mean annual TFCF salvage from 2001 to 2008 was about 6-fold lower than salvage in the 1980's and the late 1990's.

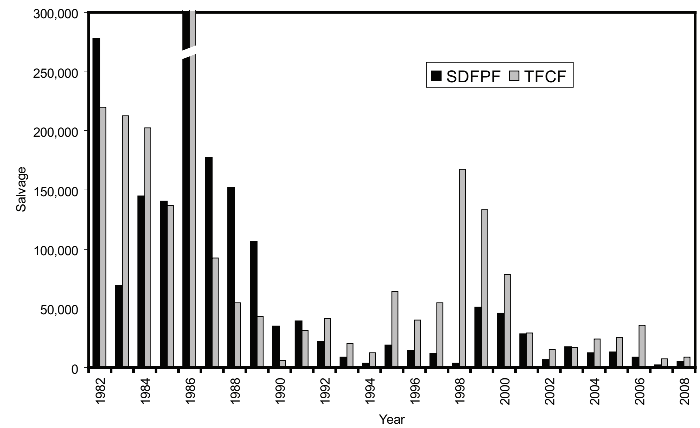

Figure 5 Annual salvage of Chinook salmon (all races and origins combined) at the SDFPF and the TFCF, 1982 to 2008. The SDFPF 1986 salvage of 435,233 and the TFCF 1986 salvage of 752,039 have been truncated for scale considerations

Salvaged Chinook salmon at both facilities were primarily wild spring-run fish and wild fall-run fish (Table 1). Spring-run fish comprised 54% and 44% of the annual salvage of wild Chinook salmon at the SDFPF and the TFCF, respectively. Wild fall-run fish comprised 40% of the annual salvage of wild salmon at the SDFPF and about 49% of the wild salmon salvaged at the TFCF. The majority of wild fall-run fish at the SDFPF and TFCF were salvaged in May (Figure 6).

Loss of Chinook salmon in 2008 was higher at the SDFPF than at the TFCF (Table 1). At the SDFPF the annual loss of salmon was estimated at 21,697 while at the TFCF the estimated annual loss was 7,010. Higher losses within Clifton Court Forebay were the major cause for the greater entrainment losses for the SWP compared to the CVP.

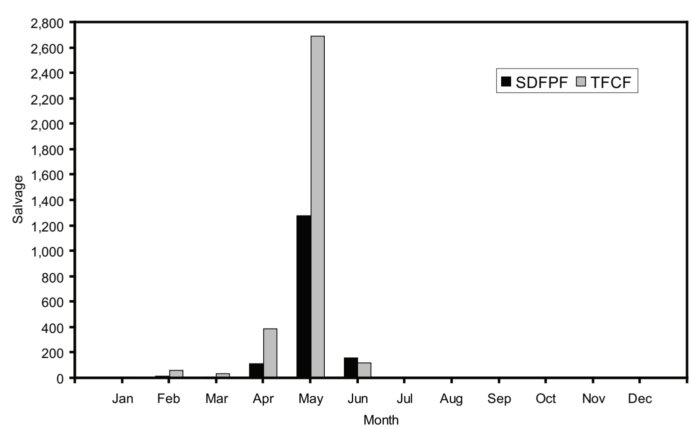

Figure 6 Monthly salvage of wild, fall-run Chinook salmon at the SDFPF and the TFCF, 2008

Table 1 Chinook salmon annual salvage, percentage of annual salvage, race and origin (wild or hatchery), and loss at the SDFPF and the TFCF, 2008

Facility	Origin	Race	Salvage	Percentage	Loss
SDFPF					
	Wild				
		Fall	1560	40	6921
		Late-fall	10	<1	45
		Spring	2142	54	9268
		Winter	207	5	917
	Total Wild		**3919**		**17151**
	Hatchery				
		Fall	0	0	0
		Late-fall	24	3	109
		Spring	48	5	206
		Winter	937	93	4231
	Total Hatchery		**1009**		**4546**
	Grand Total		**4928**		**21697**
TFCF					
	Wild	Fall	3,285	49	2,675
		Late-fall	4	<1	4
		Spring	2,954	44	2,486
		Winter	462	6	383
	Total Wild		**6,705**		**5,548**
	Hatchery				
		Fall	4	<1	3
		Late-fall	56	2	41
		Spring	59	3	45
		Winter	1,954	94	1,368
	Total Hatchery		**2,073**		**1,457**
	Unknown Race		8		5
	Grand Total		**8,786**		**7,010**

Steelhead

The annual salvage of steelhead (all origins combined) at both facilities continued to be low in 2008 and has remained low since 2005 (Figure 7). Annual salvage at the SDFPF in 2008 was higher than in 2007: 1,944 as opposed to 1,561. This pattern was opposite at the TFCF as the annual salvage in 2008 was lower than in 2007: 1,887 as opposed to 4,068.

Hatchery steelhead made up the majority of the fish salvaged at both facilities. At the TFCF, the salvage composition was 1,578 hatchery and 309 wild steelhead. The salvage composition was 1,267 hatchery and 677 wild steelhead at the SDFPF.

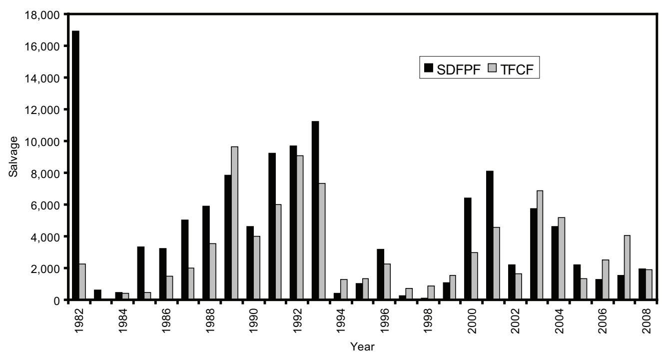

Figure 7 Annual salvage of steelhead (all origins combined) at the SDFPF and the TFCF, 1982 to 2008

The salvage of wild steelhead occurred in the first half of the year at both facilities. Wild steelhead were salvaged from January through July at the SDFPF and from January through May at the TFCF (Figure 8). Wild steelhead were salvaged most frequently during February through May at the SDFPF. At the TFCF, wild steelhead were salvaged most frequently during January through April.

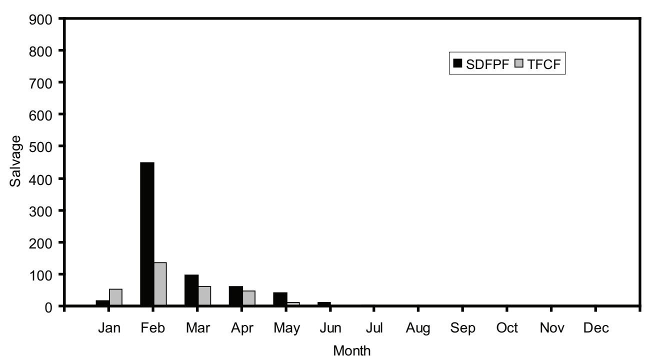

Figure 8 Monthly salvage of wild steelhead at the SDFPF and the TFCF, 2008

Striped Bass

In 2008, both facilities reported relatively low annual salvage of striped bass. At the SDFPF, the 2008 annual salvage was 145,580. The 2008 annual salvage was just slightly more than the minimum for the period of record: 131,039 in 1983. The low 2008 salvage at the SDFPF continued the generally low annual salvage observed since the mid 1990's (Figure 9). The low annual TFCF salvage of 378,916 striped bass in 2008 also continued the trend of low annual salvage since 1995. Prior to 1995, annual striped bass salvage was generally above 1,000,000 except for 1983 and 1988 at the TFCF and 1983 and 1994 at the SDFPF.

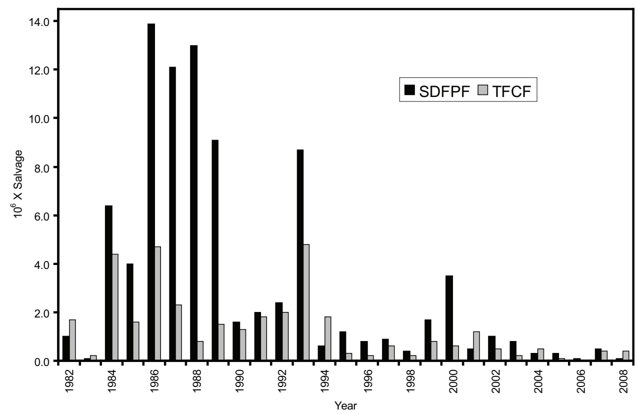

Figure 9 Annual salvage of striped bass at the SDFPF and the TFCF, 1982 to 2008

The months of January and July accounted for the majority of salvaged striped bass at the SDFPF and June and July at the TFCF (Figure 10). At the SDFPF, the January salvage of 50,111 and the July salvage of 49,386 accounted for 68% of the 2008 annual salvage. At the TFCF, the June salvage of 111,035 and the July salvage of 189,497 accounted for 79% of the annual salvage. Striped bass were salvaged every month at both facilities with the lowest monthly salvage occurring in April at both the SDFPF (131) and the TFCF (228).

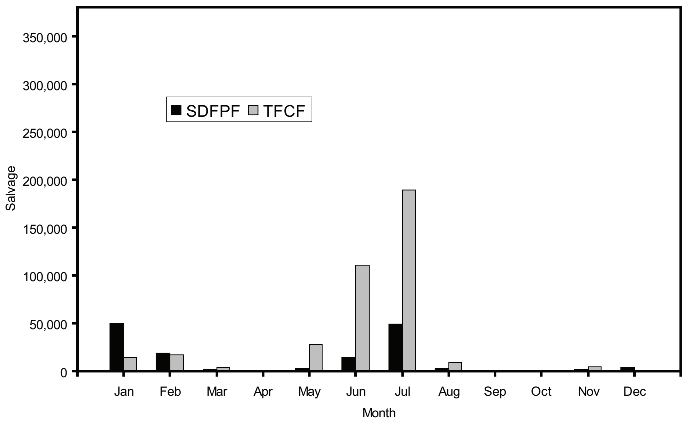

Figure 10 Monthly salvage of striped bass at the SDFPF and the TFCF, 2008

Delta Smelt

Compared to the historical levels, few delta smelt were salvaged in 2008 (Figure 11). The annual salvage at the SDFPF decreased in 2008 to 1,029 compared to 2,360 delta smelt salvaged in 2007. The annual salvage at the TFCF was higher in 2008 (1,009) compared to the near record low of 348 in 2007. The recent annual salvages of delta smelt were the lowest 4-year period of salvage on record for both facilities.

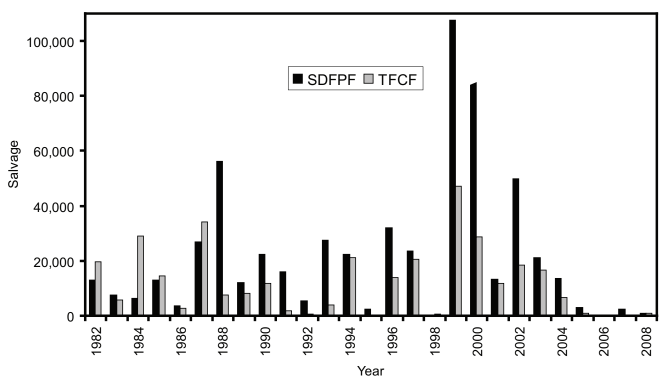

Figure 11 Annual salvage of delta smelt at the SDFPF and the TFCF, 1982 to 2008

Most delta smelt were salvaged in a few months during the first half of 2008 (Figure 12). Juvenile delta smelt were most frequently salvaged in May (416) and June (499) at the SDFPF, which accounted for 89% of the annual salvage. The salvage of delta smelt (primarily juveniles) also peaked in May and June at the TFCF.

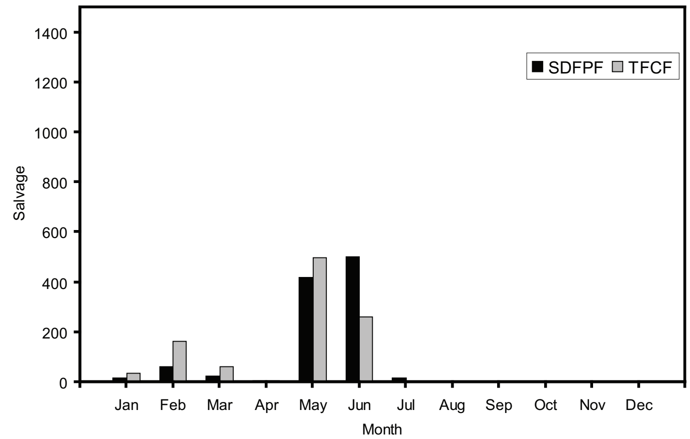

Figure 12 Monthly salvage of delta smelt at the SDFPF and the TFCF, 2008

Delta smelt less than 20 mm were first detected in larval fish samples from the TFCF on April 10 (Table 2). Delta smelt larvae or post-larvae were observed on 10 days of monitoring at the TFCF. The longest period of consecutive daily detections was a 3-day period during May 2-4. Larval delta smelt were most frequently detected in May (5 days). Delta smelt larvae were not observed from the larval fish samples from the SDFPF.

Table 2 Occurrence of delta smelt and longfin smelt larvae among larval fish collected from the TFCF in 2008. A "Y' indicates that larval delta or longfin smelt < 20 mm FL were found while an "N" indicates no detection. Number of counts per day with young smelt were recorded in parenthesis.

	Delta smelt larvae	Longfin smelt larvae
DATE	Y or N	Y or N
3/6/2008	N	Y
4/1/2008	N	Y
4/3/2008	N	Y
4/5/2008	N	Y
4/10/2008	Y	N
4/11/2008	N	Y
4/12/2008	N	Y
4/13/2008	N	Y
4/14/2008	N	Y (2)
4/15/2008	N	Y
4/16/2008	N	Y
4/17/2008	N	Y
4/19/2008	N	Y (2)
4/20/2008	N	Y
4/23/2008	Y	Y
4/24/2008	N	Y
4/28/2008	N	Y
4/30/2008	Y (2)	N
5/2/2008	Y	Y
5/3/2008	Y	N
5/4/2008	Y	N
5/25/2008	Y	N
5/29/2008	Y	N
6/1/2008	Y	N
6/4/2008	Y	N

Longfin Smelt

Longfin smelt continued to be salvaged at a low level compared to the early 2000s and the late 1980s (Figure 13). The annual salvage in 2008 was 1,112 at the SDFPF and 357 at the TFCF. Longfin smelt were salvaged in winter and spring at both facilities (Figure 14). Juvenile longfin smelt were most frequently salvaged in April (146) and May (924) at the SDFPF, which accounted for 96% of the annual salvage. The salvage of longfin smelt also peaked in April and May at the TFCF, and was composed primarily of juvenile fish.

Similar to the delta smelt findings, longfin smelt larvae or post-larvae were more frequently found in the larval fish samples from the TFCF. Young longfin smelt were detected on 17 occasions at the TFCF, mostly in April (Table 2). Only 2 longfin smelt larvae detections were made at the SDFPF on February 24 and 26. Longfin smelt were first detected in the larval fish samples from the TFCF on March 6. The longest period of consecutive daily detections was a 7-day period during April 11-17.

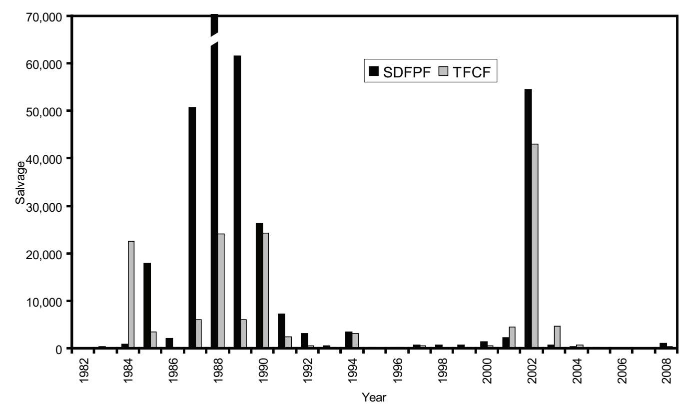

Figure 13 Annual salvage of longfin smelt at the SDFPFand the TFCF, 1982 to 2008. The annual salvage at the SDFPF for 1988 has been truncated for scale considerations (140,040).

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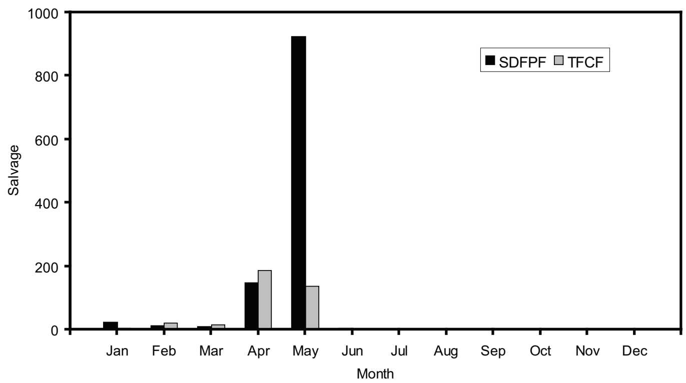

Figure 14 Monthly salvage of longfin smelt at the SDFPF and the TFCF, 2008

Splittail

The annual salvages of splittail were higher for both facilities in 2008 than in 2007, but remained low compared to recent years. The 2008 annual salvage was 4,979 at the SDFPF as opposed to 538 in 2007. The TFCF salvaged 1,439 splittail in 2008 compared to 780 in 2007. The 2007 TFCF salvage was the lowest on record since 1982 and a marked decrease from the record-high salvage of 5.0 million in 2006. Splittail salvages have followed a boom or bust pattern where annual totals often varied several orders of magnitude from year to year (Figure 15).

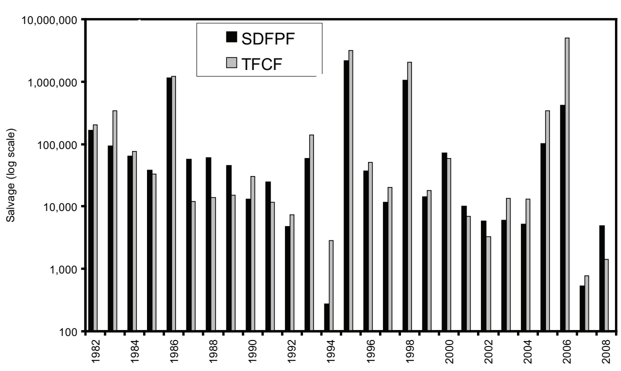

Figure 15 Annual salvage of splittail at the SDFPF and the TFCF, 1982 to 2008

Threadfin Shad

The annual salvages of threadfin shad differed greatly between facilities in 2008. Over 4 million (4,617,313) threadfin shad were salvaged at the TFCF compared to 280,084 salvaged at the SDFPF. The TFCF annual salvage was the fourth largest total and the SDFPF annual salvage was the third lowest total for their respective facilities since 1982.

The 2008 annual salvages also differed markedly from the annual salvages from the previous year (Figure 16). Similar to splittail, annual salvages of threadfin shad have varied greatly through time.

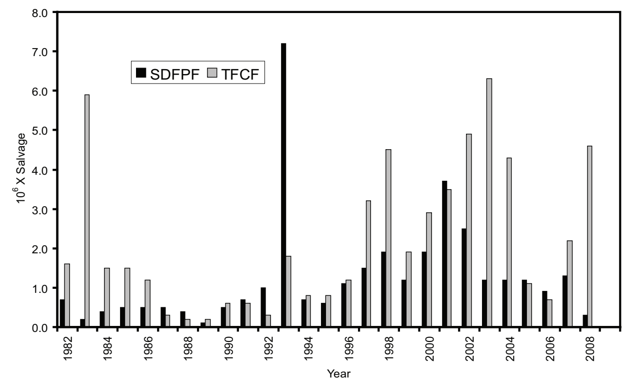

Figure 16 Annual salvage of threadfin shad at the SDFPF and the TFCF, 1982 to 2008

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