■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER

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Of Interest to Managers

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The IEP community lost a leader, mentor and scientist in August 2006 with the passing of Randy Brown. This newsletter owes its existence to Randy's vision and influence as a founder, and its status to his decade plus of persistence obtaining content and diligence as chief editor. His wide ranging interests and recognition of the connectivity of upstream and downstream environs to the Delta lead to a broad newsletter focus, which included everything from adult Chinook salmon returns to recruitment of Dungeness crabs. He also initiated the annual status and trends issue to apprise managers regularly of the "well being" of species from throughout the estuary and watersheds. The final section of this newsletter contains four perspectives on Randy Brown. Steve Ford begins by describing Randy's management accomplishments and is followed by three more, personal accounts from Wim Kimmerer, Zach Hymanson and Lauren Buffaloe of how Randy personalized the work of science and its publication (pg. 57).

Highlights

We begin with highlights from three projects investigating fish predation, incidental mortality and stress during "Collection", "Handling", "Trucking" and "Release" (CHTR) phases of fish salvage at south delta fish protective facilities (pg. 4). Understanding the sources of stress and mortality is the first step in reducing them. Though it's early to draw firm conclusions, current findings are interesting. Based on partial analyses, Geir Aasen found that striped bass predation did not appear to increase during confinement in fish transport trucks; moreover, >50% of striped bass stomachs were empty in both pre- and post-CHTR samples. Jerry Morinaka examined adult delta smelt survival through the CH and CHTR phases in experiments conducted Dec 2005-March 2006. For both treatments, Jerry found high 48-hour post treatment survival, ranging from 83-100% in CH experiments and 90-100% in CHTR experiments, suggesting adult delta smelt do successfully survive the salvage during cool-water periods. Virginia Afentoulis used cortisol levels (a stress indicator) to assess stress in adult delta smelt exposed to CH, TR and CHTR phases of the fish recovery process. She reports preliminary results are inconclusive and is waiting for lab results from 2006 tests to refine the analyses. In the last Highlight, Theresa Rettinghouse, reports on how strip-spawning delta smelt dramatically improved egg production at the Fish Conservation and Culture Lab. This process resulted in 2-4 fold increases in percent of eggs hatching, and substantially improves their ability to produce delta smelt for experimental purposes, such as those described by the preceding three CHTR researchers.

Status and Trends

This, the 10^{th} annual status and trends issue of the IEP newsletter, contains 7 articles describing trends in outflow and exports, zooplankton, estuarine juvenile fishes, *Cancer* crabs, species salvaged, juvenile Chinook salmon and adult Chinook salmon. Once again we begin with Kate Le, who summarizes delta outflow, central California rainfall and SWP and CVP water exports (see pg. 7). She begins with descriptions of the high outflows in the first half of 2006 that bode well for species like longfin smelt in 2006; however, it's the 2005 flows and exports that influenced 2005 fish and invertebrate abundance trends presented in subsequent articles. Delta outflow for 2005 proved modest with two spring peaks that might have enhanced delta smelt abundance. Modest outflow peaks in December 2004 and March 2005 were exceeded in May 2005. Export pumping was generally consistent and high except during the Vamp period (April-May).

No startling changes occurred in upper estuary zooplankton or mysid numbers in 2005. Baxter and Hieb (pg. 13) show a spring decline for the copepod *Pseudodiaptomus forbesii*, which forms substantial portions of the diets of most upper estuary fishes, followed by increased in abundance in summer, possibly reflecting the late, high spring flows. The abundances of other copepods and mysids were variable, but generally declined in 2005 or increased yet remained below recent annual levels, possibly providing a poorer feeding environment than in recent years.

Intermediate winer-spring outflows, high exports and mediocre zooplankton abundances resulted in poor recruitment for upper estuary pelagic fishes. Tom Greiner and others (pg. 16) found low abundance in 2005 for all

POD species: delta smelt, striped bass, longfin smelt and threadfin shad. For delta smelt in particular, modest spring flows and reduced spring exports were expected to provide modest benefits that did not materialize. Splittail benefited from increased March and May flows regionally in the San Joaquin and Mokelumne rivers, but this was not apparent from trawl indices. Upper estuary bottom fish abundances remained much the same or increased slightly in 2005. Lower estuary fishes displayed variable responses, but many declined with cessation of favorable cool-water coastal conditions. Many lower estuary bottom fishes, including English sole, speckled sanddab, bay goby, staghorn sculpin, declined in 2005, but remained well above long-term average levels. Lower estuary pelagic fishes, such as Pacific herring and jacksmelt, declined sharply in 2004 and 2005 respectively; the herring due to a combination of low adult stocks, low winter outflow and slightly warmer winter water temperatures. In contrast, warm coastal waters from fall 2004 through spring 2005 lead to successful local recruitment for California halibut, which in turn will improve fishing 2-3 years from now when they reach legal size.

Two important crab species declined in the estuary in 2005. Since being salvaged by the thousands in the late 1990s, Kathryn Hieb reports Chinese mitten crab has undergone a continuous decline and was hardly detected in 2005 (see pg. 32; see also Russ Gartz's article pg. 35). The Dungeness crab, an important commercial species, declined sharply in 2005 following a pattern similar to many lower estuary bottom fishes. It's another species responding negatively to warming coastal waters.

Even with exports reduced well below capacity during February through May 2005, Russ Gartz reports that total State Water Project exports reached an all time high of a little more than 4 million acre feet (pg. 35; Differences between Russ' and Kate Le's export totals result from differing reporting periods -- calendar year for Russ and water year, October 2004-September 2005, for Kate Le). Nonetheless, salvage decreased in 2005 for many species of concern including delta smelt, striped bass, longfin smelt, Chinook salmon and steelhead, owing in part to high spring flows in the San Joaquin River.

Good spring outflows and reduced spring export-pumping lead to increased juvenile Chinook salmon catch at Chipps Island (and reduced salvage). Modest, rather than high, 2005 winter flows allowed Chinook salmon fry to rear upstream (low beach seine abundance in lower rivers and delta) and emigrate later and larger as smolts during higher spring flows; emigration during relatively high spring flows is believed to result in better survival (see Brandes and others pg. 41).

Adult Chinook salmon returns to Central Valley rivers were very good overall, even though some river stocks declined from recent highs (see Erin Chappell's article, pg. 46).

Contributed Papers

Is weak phytoplankton production the basis for the pelagic fish decline? Alan Jassby reviews literature supporting a possible linkage, including his own previous work indicating a 1975-1995 decline in primary production (pg. 51). He uses Environmental Monitoring Program discrete sampling data to investigate site-specific trends in phytoplankton biomass and production through 2004. He concludes that long-term declines in fish production are very likely linked to the extremely low levels of primary production reached in the 1990s, but more recent production and biomass trends have been flat throughout the Delta and Suisun Bay, and significantly positive upstream and downstream; thus, recent trends were not consistent with POD fish declines. He proposes that possible changes in phytoplankton species composition and nutritional value could have contributed to recent fish declines, and states that these aspects are being investigated.

IEP QUARTERLY HIGHLIGHTS

Fish Predation in the Collection, Handling, Transport, and Release (CHTR) Phase during the State Water Project's Fish Salvage Operations

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The spring season of the CHTR Stomach Analysis Study was conducted from April through July 2005. Stomach samples from predators were taken from pre and post CHTR collections at Skinner Delta Fish Protective Facility. Only 18 trials were completed due limited access to a fish transport truck. Striped bass constituted >90% of the predators captured followed by white catfish and yellowfin goby. Preliminary data analysis indicated that majority of predators' stomachs were empty and the incidence rate of stomach content suggests that predation in the tanker truck was not significant. The winter trials were conducted during December 2005 through March 2006. A total of 56 trials were completed. Once again, striped bass constituted >90% of the predators captured followed by white catfish and yellowfin goby. Lab and data analysis is currently underway.

Testing for the CHTR Digestion Index Study was conducted from April through August, 2005. Predators were allowed to consume prey at will in a controlled experiment and euthanized at set time intervals post feeding to determine digestion rate over time. A total of 46 tests were conducted. Striped bass and white catfish were used as predators and delta smelt and Sacramento splittail were used as prey. Preliminary data analysis indicates that 33% of striped bass ate while only 23% of white catfish ate. The winter experiments were conducted from December 2005, through March 2006. A total of 79 tests were completed. Striped bass and white catfish were used as predators and delta was used as prey. Preliminary data analysis indicates that 10% of striped bass ate while 6% of white catfish ate. Lab and data analysis is currently underway.

Acute Mortality and Injury of Delta Smelt Associated with Collection, Handling, Transport, and Release (CHTR) at the State Water Project's Salvage Facility

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Experiments using injected groups of marked cultured delta smelt were conducted at the Skinner Fish Facility from late December 2005 through the month of March 2006. All experiments involved injecting cultured delta smelt into a holding tank which had salvaged fish for up to 10 hours. The two types of treatments used were collection and handling (CH) which simulates the loading process into the fish truck, and collection, handling, transport and release (CHTR) which simulates the fish transport and fish release in addition to the truck loading process. Preliminary results for both types of experiments have indicated a high survival of adult delta smelt 48 hours post treatment. To date, the 48-hour survival for the CH experiments have ranged from 83% to 100% whereas the 48-hour survival for the CHTR experiments ranged from 90% to 100%. A total of 21 wild adult delta smelt were collected while conducting the CH and CHTR experiments and every wild delta smelt survived for 48 hours post treatment.

Due to the late spawn of delta smelt at the UCD Delta Smelt Culture Facility in Byron, CA, the juvenile delta smelt will not reach the optimal size for conducting the CH and CHTR experiments until sometime in May 2006. Therefore, the CH and CHTR experiments using adult delta smelt will continue through the month of April. The juvenile testing period will extend from May until early July which will conclude the field portion of the study.

Stress Indicators during Collection, Handling, Transport, and Release (CHTR) Phase of the State Water Project's Fish Salvage Operations

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In December 2005, the CHTR program continued on with a second year of full implementation of the CHTR stress indicators work that measures cortisol levels from adult delta smelt exposed to the Collection, Handling, Transport and Release (CHTR) portion of fish salvage operations. However, last year's experiments did not encompass the winter months (December-February).

From December 2005 through March 2006, the following experiments were completed (in which adult cultured and wild delta smelt were sampled for blood plasma): 9 full Collection, Handling, Transport and Release (CHTR) trials, 10 Transport and Release (TR), and 13 Collection and Handling (CH) trials. Data analysis (ANOVA of means) of the December 2005 CHTR, TR, and CH trials (i.e. treatments) is in process and preliminary results show that there may be a difference in the cortisol (the primary stress indicator hormone) levels between treatments. The 2006 work will be added to this data and we will determine if the trends seen last year will be reflected in this year's data as well.

Plasma from adult delta smelt collected this year to date is already undergoing EIA (enzyme linked immunosorbent assay) for cortisol at the UC Davis Endocrinology lab. Cortisol values will be available for entry into the current database this spring (2006). This stress indicator study portion of the CHTR program will be completed in May 2006 and data analysis and final report writing will continue through January 2007.

Fish Conservation and Culture Lab (FCCL), Spring 2006

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This year the spawning of captive (wild caught) delta smelt officially began on March 6, 2006. We now use manual expression and in-vitro fertilization (strip spawning) to spawn all fish. We have strip-spawned 170 females so far and continue to strip spawn once a week.

In the past years, we have used two spawning procedures:

1. Natural Spawning egg collection: All broodfish tanks were checked each morning for the presence of eggs during the spawning season (February-May). Females broadcast their eggs along the bottom of the tank during the night and early morning hours. The adhesive eggs are found in a single layer on the tank bottom in areas associated with higher flow (near the water inlet or the airstone). An egg scraper is used to cleave the egg stalks and collect the loosened eggs. A net can then be placed at the external standpipe to collect the manually detached eggs when the tank is flushed. The eggs are thoroughly cleaned to minimize the incidence of fungal and bacterial outbreaks. Small mesh screens are used to separate the eggs from debris (silt, food, feces, plant debris, etc.). Fish may release eggs in response to one or more stressors, as we observed many of these egg batches were not fertilized.

2. In-vitro fertilization (strip spawning) procedures: Brood fish are examined weekly for ripe eggs and running milt and sorted into holding buckets. A ripe female is removed from a holding bucket, and dried gently with a paper towel. Her eggs are gently expressed into a small plastic dish, followed by the milt from two to three males. Water is added to activate the sperm. After 10 minutes, the incubation dishes are rinsed to remove excess milt, refilled, and placed into water baths and maintained at 15-16C.

Strip spawning or manual expression of eggs improved our production of eggs and egg quality:

a. Total egg harvest appeared to be higher when strip spawned, as many females tend to retain ripe eggs. Over-ripe females often died without releasing their eggs.

b. Strip-spawned eggs were cleaner. Naturally deposited eggs collected from the tank were mixed with fish food and feces, which was difficult to separate.

c. Scheduled removal of gametes streamlined egg harvest and provided control of egg production (i.e. once per week).

d. Good broodstock management resulted in the ability to produce large batches of eggs on a pre-determined day, rather than collecting small batches daily.

During the 2004 and 2005 seasons (Table 1) the percent hatch of naturally deposited eggs (15-38%) was considerably lower than that of strip spawned eggs (70.1-75.2%). Overall the quality of eggs manually expressed from the females and fertilized in-vitro appeared to be better than eggs spawned naturally in the tank.

Table 1 Percent hatch of delta smelt eggs in natural and in-vitro spawning during 2004 and 2005

	Eggs	*Larvae*	*% hatch*
2004 Season			
Naturally spawned eggs	*155,962*	*59,280*	*38*
Strip-spawned eggs	*433,820*	*326,176*	*75.2*
Total	*589,782*	*385,456*	*65.4*
2005 Season			
Naturally spawned eggs	*13,006*	*1951*	*15*
Strip-spawned eggs	*481,137*	*337,368*	*70.1*
Total	*494,143*	*339,319*	*68.7*

STATUS AND TRENDS

Delta Water Project Operations Status and Trends

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October 2005 through March 2006 Hydrologic and Exports Conditions

During October 2005 through March 2006, daily Sacramento River flows ranged between 300 and 2,500 cubic meters per second (11,000 cfs and 88,000 cfs) as shown in Figure 1, with the largest peak of 2,484 cubic meters per second (87,718 cfs) on December 29, 2005. San Joaquin River flow ranged between 50 and 600 cubic meters per second (1,765 cfs and 21,186 cfs), with the largest peak of 561 cubic meters per second (19,825 cfs) on January 10, 2006. Net Delta Outflow Index (NDOI) ranged between 70 and 10,500 cubic meters per second (2,472 cfs and 370,763 cfs), with the largest outflow index of about 10,483 cubic meters per second (370,172 cfs) on January 4, 2006. WY 2006 started off slow with low river levels and outflows, but ended the calendar year with very high river flows and outflows than the previous year as a result of many large and intense precipitation events that occurred in December 2005, January 2006, and March 2006.

During October 2005 through March 2006, daily export rates at the State Water Project (SWP) ranged between 30 and 300 cubic meters per second (1,059 cfs and 10,593 cfs) and the Central Valley Project (CVP) ranged between 100 and 150 cubic meters per second (3,531 cfs and 5,297 cfs), except in the later half of March 2006, where both SWP and CVP pumping dropped as a result of low water demands. Typically, CVP export rates were more stable than SWP as shown in Figure 2. SWP pumping rate during the October 2005 through March 2006 was primarily to meet demands and reservoirs south of the Delta. There were only two occasions when pumping was reduced for water quality concerns at Holland Tract: once in late November 2005 and again in the later half of March 2006 due to low water demands with all reservoirs being filled near to capacity due to water supply abundance resulting from the December 2005, January 2006, and March 2006 precipitation contributions.

During the October 2005 through March 2006 period, the first onset of precipitation occurred in early November 2005 with a daily total of 0.08 inches as shown in Figure 1. The largest daily precipitation event during this period occurred on December 18 with a daily total of 1.24 inches. Thereafter, large amounts of precipitation continued almost daily for the remainder of December 2005 and ended the calendar year with a monthly rainfall total of 5.7 inches. The 2006 New Year started off with a bang since the largest recorded outflow of about 10,500 cubic meters per second (370,763 cfs) resulted from the impressive December rainfall runoffs. Sporadic rain systems continued in January 2006, followed by a dry spell in February 2006. However, March broke the dry spell and was a record setting month with the most days of rainfall. Although lower than December 2005 monthly rainfall totals, the March 2006 total of 4.8 inches was the second largest compared to other months.

Percent inflow diverted limits during October 2005 through March 2006 were met as shown in Figure 3. From October 2005 through January 2006, the standard is 65% using the 3-day running average, and from February to mid-March of 2006 the standard is 35% using the 14-day running average.

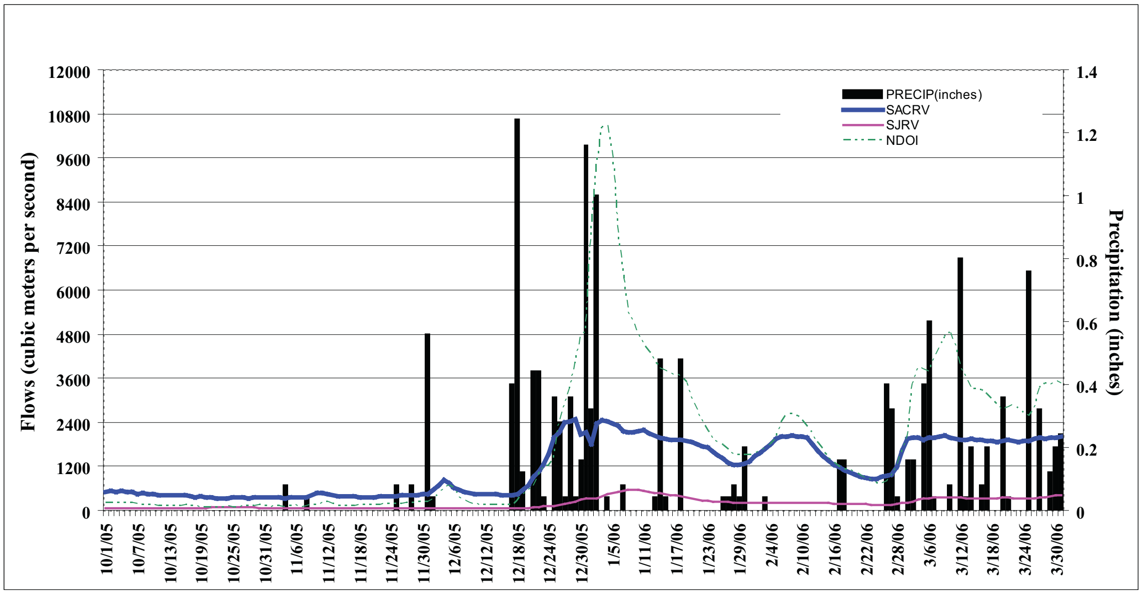

Figure 1 October 2005 through March 2006 Sacramento River, San Joaquin River, Net Delta Outflow, and Precipitation

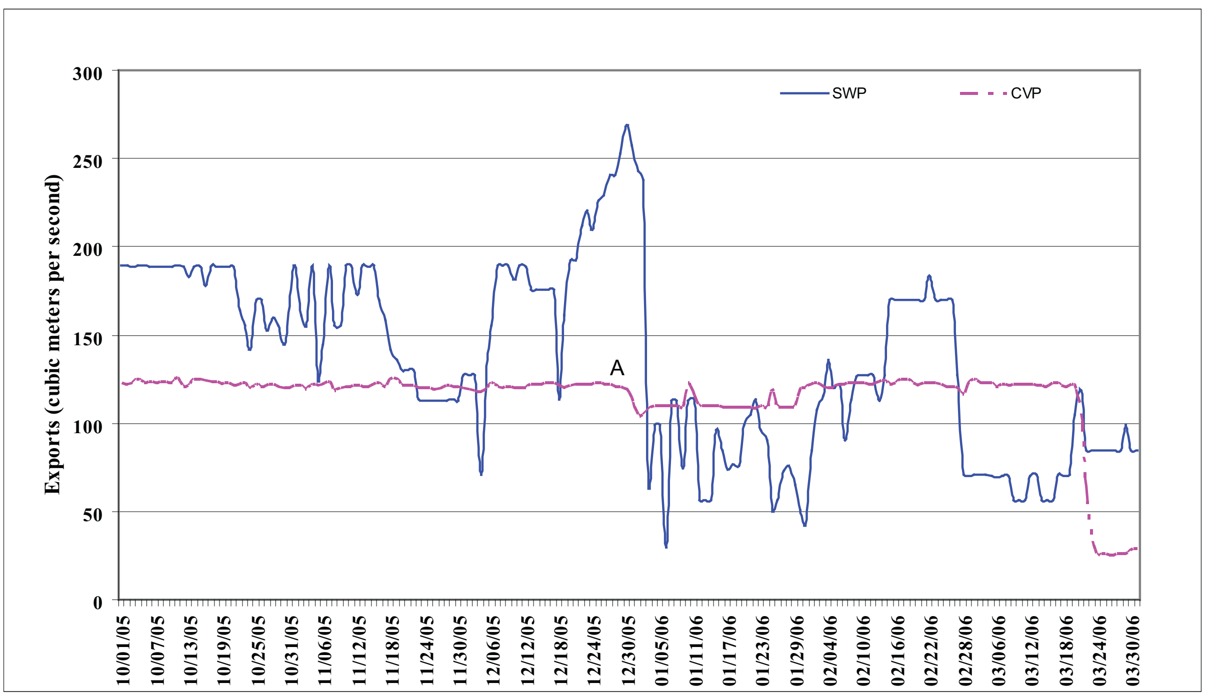

Figure 2 October 2005 through March 2006 State Water project and Central Valley Project Pumpings

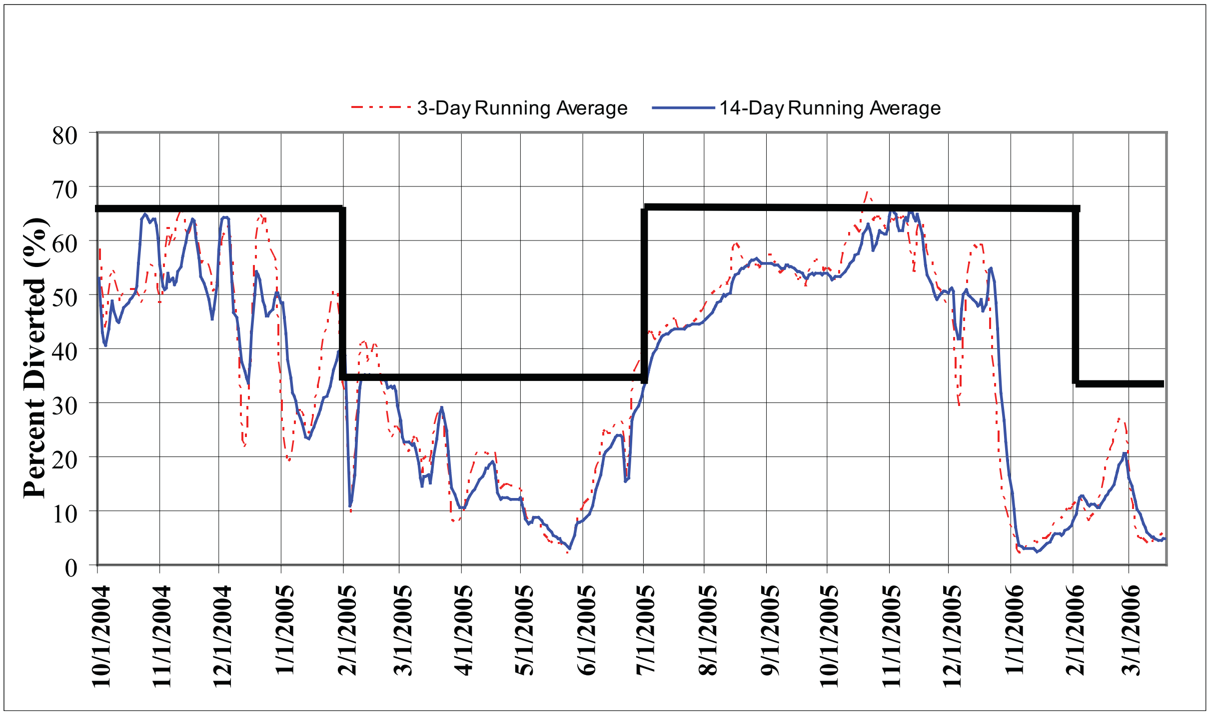

Figure 3 October 2004 through March 2006 Percent Inflow Diverted

River Flows and Net Delta Outflow Index - Water Year 2005

The hydrologic conditions for water year 2005 started off normal. During the period of October to December of 2004, Sacramento River flow, San Joaquin River flow, and NDOI were below 900 cubic meters per second as shown in Figure 4. Thereafter, the amount and frequency of precipitation increased resulting in an increase of Sacramento River and NDOI flows. These flows continue to fluctuate through May 2005 with Sacramento River and NDOI peaking at 2,200 and 2,550 cubic meters per second, respectively, as shown in Figure 4. Thereafter, no rainfall activity caused both flows to decrease below 566 cubic meters per second (20,000 cfs) and continue to decline for the remainder of the water year.

San Joaquin River flow as shown in Figure 4 was stable and below 62 cubic meters per second (2,200 cfs) through December 2004. San Joaquin flow during October through December 2004 was similar to the previous year for this time period. However, from mid-January 2005 to July 2005, San Joaquin flow was about 150 to 400 cubic meters per second higher than the previous year for the same period.

Comparison of monthly average flow levels of Sacramento River, San Joaquin River, and NDOI during October 2005 through March 2006 (05-06 year) to those of October 2004 through March 2005 (04-05 year) are as follows and are shown in Figure 5:

- **October:** Sacramento River and San Joaquin River monthly average flows were slightly higher, whereas NDOI was lower in 05-06 than 04-05 year. Sacramento flow was about 63 cubic meters per second (2,224 cfs) and San Joaquin flow was about 17 cubic meters per second (600 cfs) higher, whereas NDOI was about 78 cubic meters per second (2,754 cfs) lower.

- **November**: Similar to October flow pattern difference but to a lesser extent; the Sacramento River and San Joaquin River monthly average flows were slightly higher, whereas NDOI was lower in 05-06 than 04-05 year. Sacramento flow was about 59 cubic meters per second (2,083 cfs) and San Joaquin flow was about 12 cubic meters per second (424 cfs) higher, and NDOI was about 15 cubic meters per second (530 cfs) lower.

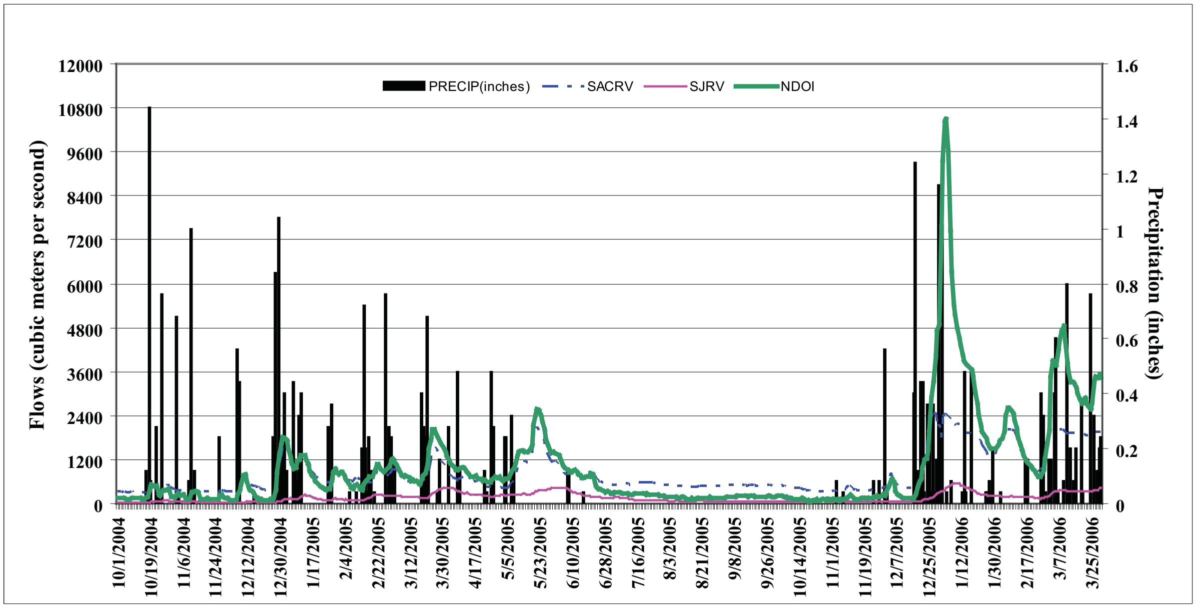

Figure 4 October 2004 through March 2006 Sacramento River, San Joaquin River, Net Delta Outflow, and Precipitation

- **December**: Both river flows and NDOI monthly average flows were higher in 05-06 year than 04-05 year. Sacramento flow was about 500 cubic meters per second (17,655 cfs) higher, San Joaquin flow was about 55 cubic meters per second (1,942 cfs) higher, and NDOI was about 800 cubic meters per second (28,248 cfs) higher.

- **January**: Both river flows and NDOI monthly average flow differences were the largest compared to other months and significantly higher in 05-06 year than 04-05 year; Sacramento flow was about 940 cubic meters per second (33,192 cfs) higher, San Joaquin flow was about 232 cubic meters per second (8,192 cfs) higher, and NDOI was about 3,495 cubic meters per second (123,411 cfs) higher.

- **February**: Both river flows and NDOI monthly average flow differences were higher in 05-06 year than 04-05 year, but to a much lesser difference than January. Sacramento flow was about 741 cubic meters per second (26,165 cfs) higher, San Joaquin flow was about 32 cubic meters per second (1,130 cfs) higher, and NDOI was about 887 cubic meters per second (31,320 cfs) higher.

- **March**: There was a close resemblance to January monthly average flow pattern differences but to a larger extent (i.e. 1,000 cm^3/s) except for San Joaquin flow; Sacramento flow was 1,248 cubic meters per second (44,000 cfs) higher, NDOI was 2,573 cubic meters per second (90,850 cfs) higher, whereas San Joaquin flow was only 140 cubic meters per second (4,943 cfs) higher.

Exports

During water year 2005, exports actions at both SWP and CVP are shown in Figure 6 and were operated for water quality concern in October 2004, for outflow standards from mid-November 2004 through mid-December 2004. For the remainder of the water year, the water projects were operated for fishery concern (February 2005) and maintenance (weed spray late June 2005).

Monthly average comparisons of export levels at SWP and CVP during October 2005 through March 2006 (05-06 year) to that of October 2004 through March 2005 (04-05 year) are as follow and are shown in Figure 6:

- **October:** Export action at CVP in 05-06 was similar to 04-05; SWP action in 05-06 was significantly higher than previous year. (i.e. 98 cubic meters per second or 3,460 cfs).

- **November:** Export action at CVP in 05-06 was similar to 04-05; SWP action in 05-06 was higher than previous year. (i.e. 41 cubic meters per second or 1,447 cfs).

- **December**: Export actions at both SWP and CVP were higher in 05-06 than 04-05 year. SWP was 66 cubic meters per second (2,330 cfs) higher and CVP was 14 cubic meters per second (500 cfs) higher.

- **January**: Exports at both SWP and CVP were lower with the largest difference at SWP. SWP pumping was 131 cubic meters per second (4,625 cfs) lower due to water quality concerns, whereas CVP was 8 cubic meters per second (280 cfs) lower.

- **February**: CVP pumping was slightly higher (i.e. 12 cubic meters per second or 420 cfs) in 05-06 than 04-05, whereas SWP was similar to previous year.

- **March**: Both SWP and CVP pumping were lower in 05-06 than 04-05 as a result of lower demands. SWP was 16 cubic meters per second (560 cfs) lower and CVP was 21 cubic meters per second (740 cfs) lower.

Precipitation

There was no precipitation in October 2005 as shown in Figure 5. For December, January, and March, precipitation in 05-06 was higher than 04-05, however, were lower than 04-05 in October, November, and February. The largest observed rainfall difference between 05-06 and 04-05 was in March, followed by December, November, and February.

Percent of Inflow Diverted

Figure 3 is a plot of the 3-day and 14-day percent inflow diverted. During water year 2005, all percent diverted were met for the year. From October 2004 through January 2005, the standard was 65% with the 3-day running average as the controller. From February to June of 2005, the standard was 35% with the 14-day running average as the controller.

WY 2005 Annual Totals Comparison

Water year 2005 (October 2004 through September 2005) annual totals are calculated and shown in Figure 7 for the following parameters:

Sacramento River Flow = 16.72 MAF
San Joaquin River Flow = 3.77 MAF
Net Delta Outflow Index = 15.38 MAF
State Water Project = 3.62 MAF
Central Valley Project = 2.67 MAF
SWP + CVP = 6.29 MAF

Compared to previous water year annual totals, San Joaquin, NDOI, SWP, and combined exports were higher as shown in Figure 7, with the largest difference seen in San Joaquin annual totals (MAF).

All data reported from October 2004 through September 2005 are from historical DAYFLOW data set, and all data thereafter are from DWR, Operations preliminary data set.

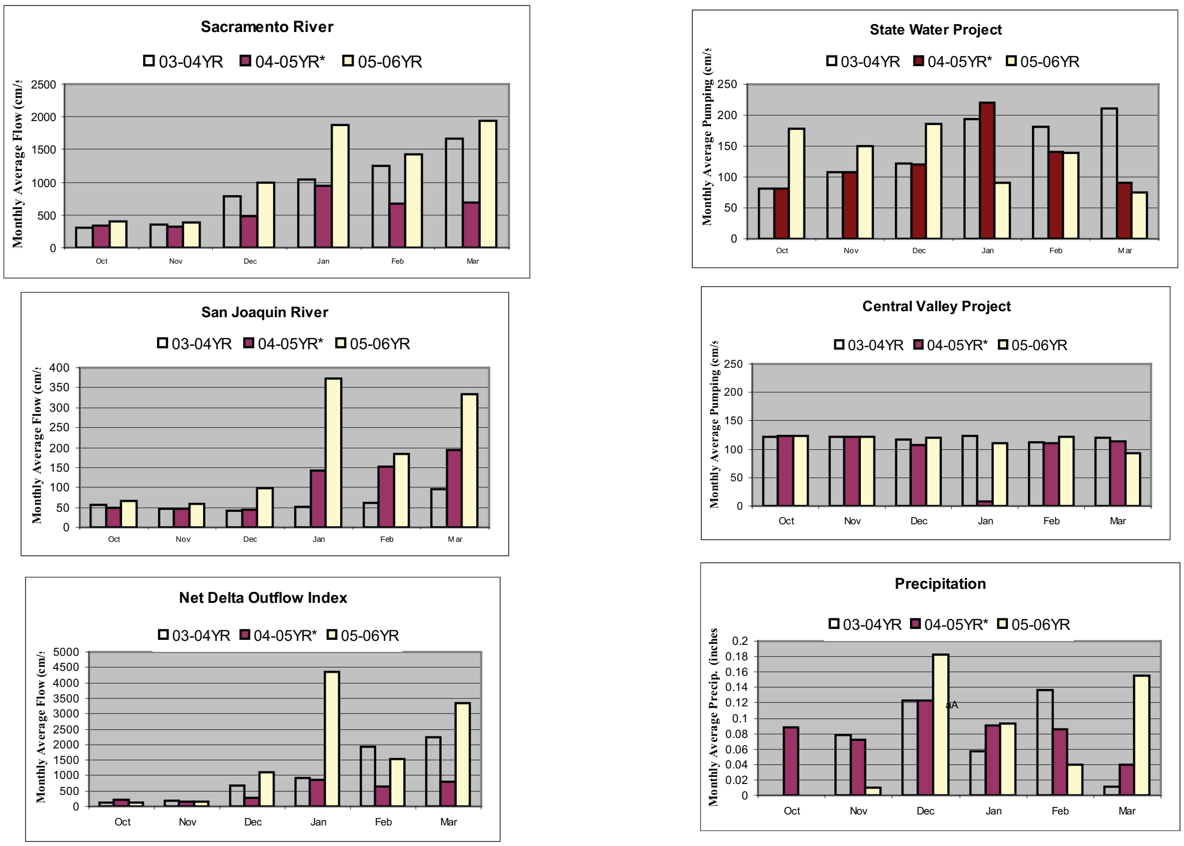

Figure 5 Monthly Average River Flows, Exports, and Precipitation for 2003-2004, 2004-2005 and 2005-2006

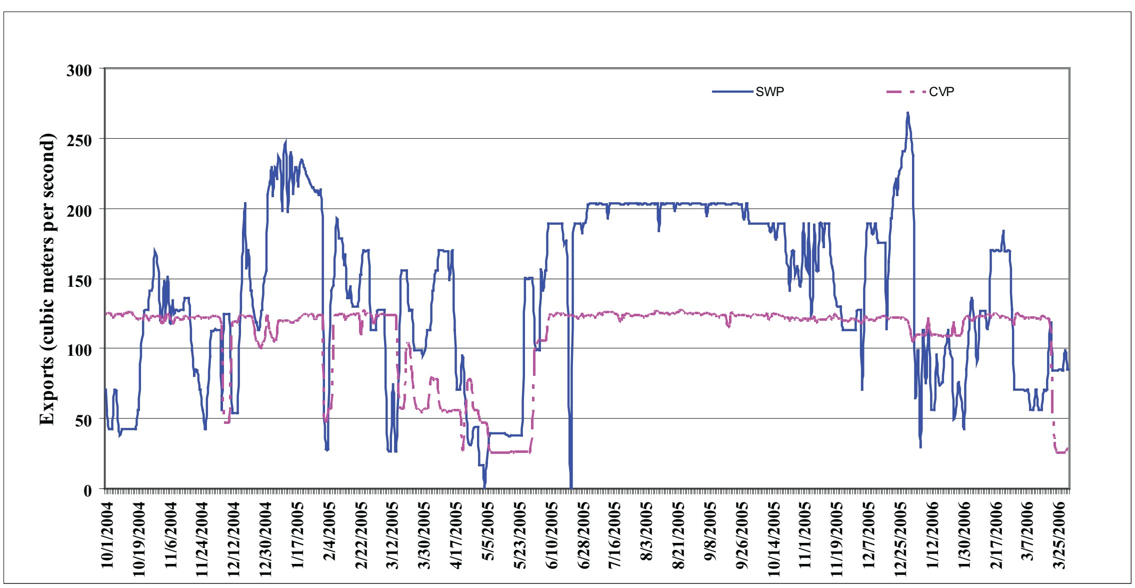

Figure 6 October 2004 through March 2006 State Water Project and Central Valley Project Pumpings

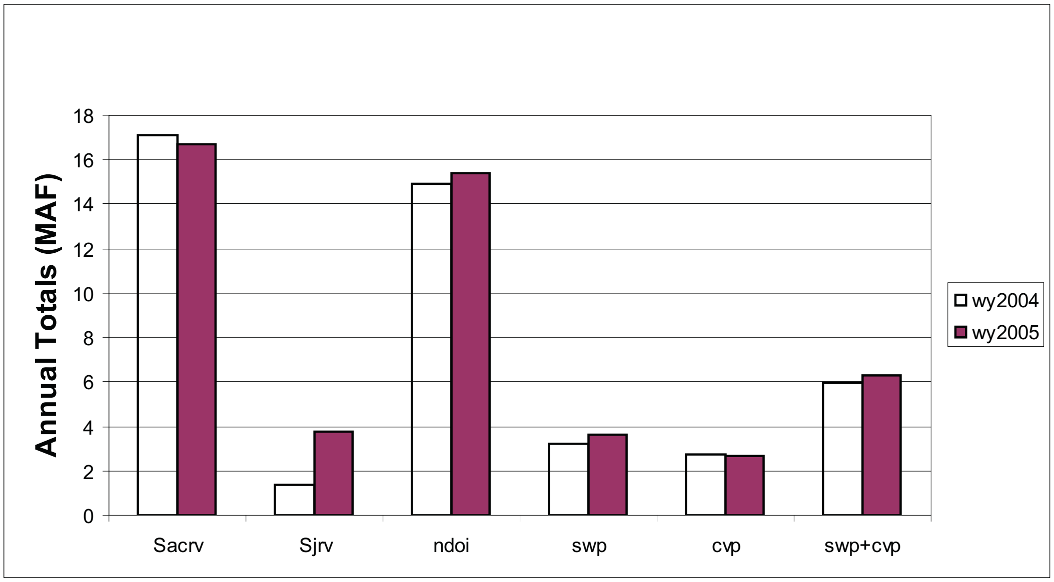

Figure 7 WY 2005 (October 2004 through September 2005) Annual Totals

Zooplankton Monitoring 2005

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Introduction

The Zooplankton Study has estimated the abundance of zooplankton taxa since 1972 as a means to assess trends in the fish food resources of the upper San Francisco Estuary. The study uses 3 gear types: a pump sampler for microzooplankton <1 mm long, a Clark-Bumpus (CB) net for mesozooplankton 0.5-3.0 mm long, and a mysid net, which captures macrozooplankton 1-20 mm long. Thus, sampling covers the size range of organisms fed upon by larval and juvenile fishes. Here we present trends in seasonal abundance through 2005 of a select group of copepods and mysids.

Methods

In 2005, sampling took place monthly from January through December at all 13 core locations with all 3 gear types. Long-term trend analyses don't include the winter months December, January, and February because they were not always sampled historically. In November 2004, we changed configuration of the CB net frame. The manufacturer quit making the historically used brass net frame, which incorporated an integrated impeller and meter, so we switched to an acrylic tube of similar dimensions with an internally mounted General Oceanics flow meter. Here we make no correction for any potential differences in capture efficiency between the gears. Abundance indices were calculated as the mean number per cubic meter of each taxon by gear, season and year across all core stations (i.e., those sampled since study inception in 1972). Data were grouped into seasons: spring – March through May; summer – June through August; and fall – September through November. Similar to the 2004 status and trends report, indices are presented separately for each gear type and taxon (historically CB and pump indices for each taxon were combined). The CB indices presented below incorporate database corrections initiated in spring 2005 that continued through May 2006. Due to corrections, the current indices will vary from those presented in the past, but overall trends remain the same.

Copepods

Two representatives of the cyclopoid copepod genus *Limnoithona* inhabit in the upper estuary, the historically common *L. sinensis* and *L. tetraspina*, which was introduced to the estuary in 1993. Since 1993, *L. tetraspina* has mostly supplanted *L. sinensis* and become the most numerically dominant copepod species in the upper estuary. Due to its small size *L. tetraspina* is not completely retained by the CB net, so indices for both the pump and CB net are presented. Except for spring pump abundance, which remained the same from 2004 to 2005, *L. tetraspina* abundance declined in 2005 in both gears and all seasons (Figure 1). *L. sinensis* continues to be collected in very low numbers, but is not recorded separately from *L. tetraspina*.

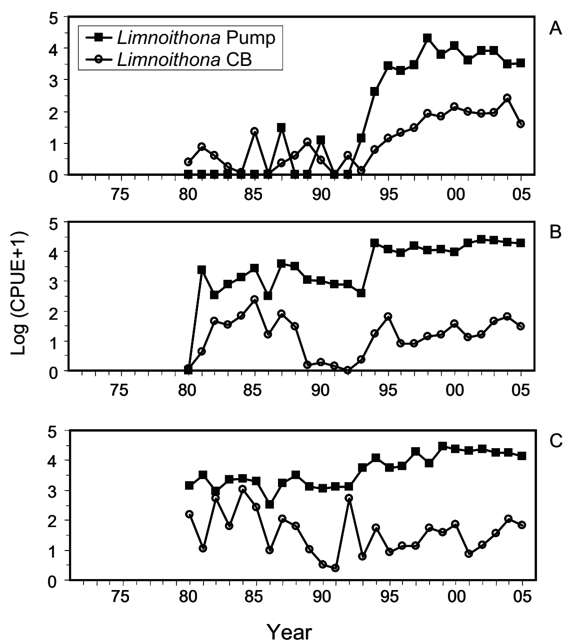

Figure 1 Abundance of *Limnoithona sinensis* and *L. tetraspina* combined (Log of mean catch*m^3 +1) from the pump and CB net in Spring (A), Summer (B), and Fall (C), 1972 – 2005

Eurytemora affinis, a calanoid copepod introduced to the estuary before monitoring began in 1972, was once a major food source for young fishes in spring, summer and fall. Since sampling began, E. affinis has suffered declines in all seasons, but the down-trends were particularly sharp for summer and fall during the late-1980s (Figure 2), subsequent to the introductions of the Asian clam, Corbula amurensis, and another copepod, Pseudodiaptomus forbesi. In spring 2005, after slight increases from 2001 through 2004, E. affinis abundance declined to the 2001 level (Figure 2A). Summer abundance, which fluctuated widely during the 1990s and early 2000s, increased slightly in 2005, but remained very low (<10/m3; Figure 2B). Although fall 2005 E. affinis abundance was higher than summer abundance, it declined slightly from 2004 and was low relative to the 1970s and mid 1980s (Figure 2C).

The introduced calanoid copepod, *Pseudodiaptomus forbesi*, was first detected in summer 1988, but by 1989 it attained summer and fall abundance levels comparable to those of *E. affinis* before its decline (Figures 2B and 2C). *P. forbesi* abundance has also declined since its introduction, yet it has remained relatively abundant during summer and fall when compared to other copepod species. In spring 2005, after a sharp increase in 2004, abundance declined sharply (Figure 2A). Summer 2005 abundance of *P. forbesi* increased substantially from 2004, whereas the fall abundance decline that began in 2003 continued (Figure 2C).

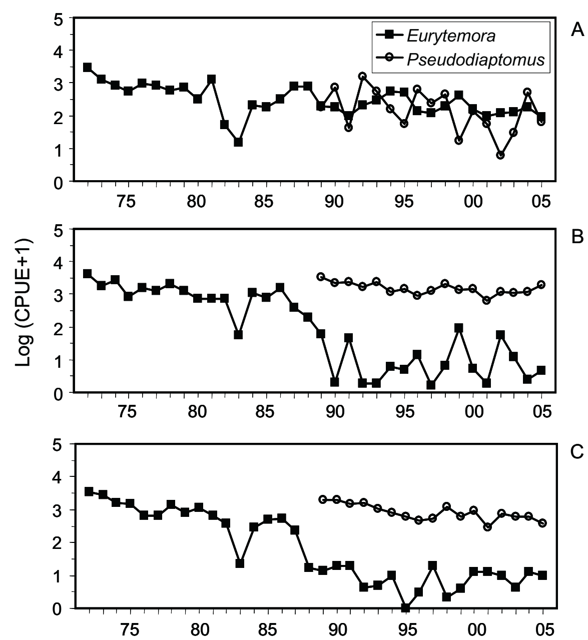

Figure 2 Abundance of *Eurytemora affinis* and *Pseudodiaptomus forbesi* (Log of mean catch*m^3 +1) from the CB net in Spring (A), Summer (B), and Fall (C), 1972 – 2005

Several species of the native calanoid copepod genus *Acartia* expand their range into the Suisun Bay and the western delta as salinity increases seasonally and annually. Conversely, their affinity for brackish water is sufficiently strong that high outflow shifts them seaward of the sampling area, resulting in low seasonal and annual abundance levels. The steadily increasing trend in spring abundance that started in 1997 was not hindered by either the high spring flows of the late 1990s or the small outflow pulse in 2003 (Figure 3A). Even though spring flows were not particularly high in 2004 and 2005, abundance declined sharply in 2004 followed by only a small increase in 2005 (Figure 3A). Summer abundance reached very low levels (< 5/m3) during the mid- to late-1990s, but has increased and remained higher since 1999 except in 2003 and 2005 (Figure 3B). Fall abundances did not decline to the same sequential low levels during the mid- to late-1990s as occurred during summer. Nonetheless, there was a general decline in fall abundance during the 1990s followed by an increase to consistently higher levels starting in 1999 (Figure 3C). There was a recent peak in fall abundance in 2002 followed by a decline through 2005.

First recorded in spring of 1979, *Sinocalanus doerrii* is a freshwater calanoid copepod, initially most abundant in summer (Figure 3). Within 5 years of its introduction, *S. doerrii* abundance began to decline in summer and fall. This trend continued through the mid-1990s. Thereafter summer and fall abundance increased modestly until recently. Spring abundance, always more variable than summer or fall, declined to a local minima in 1995 followed by a steady increase through 2004 (Figure 3A). Spring 2005 abundance declined substantially, but remained at a moderate level (> 100/m3). Summer abundance peaked in 2002, then declined sharply in 2003 and 2004, followed by a slight increase in 2005 (Figure 3B). Fall abundance dropped to very low levels (<10/ m3) in the mid-1990s before increasing somewhat through 2003. Abundance declined in 2004 and again in 2005, equaling the record low level of 1994 (Figure 3C).

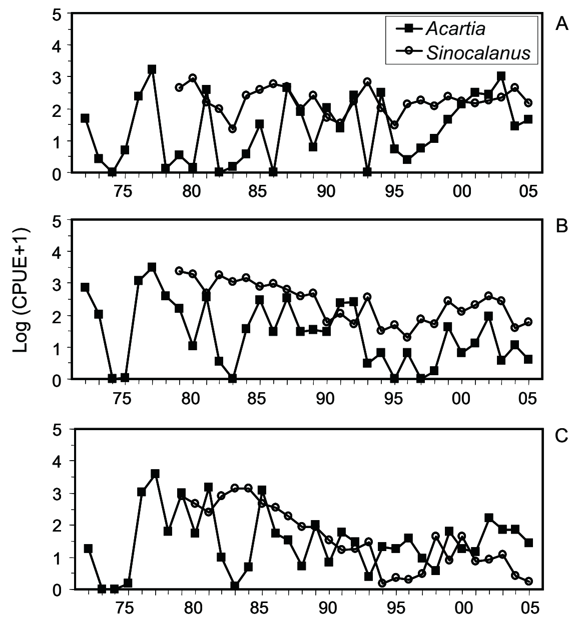

Figure 3 Abundance of *Acartia* spp. and *Sinocalanus doerrii* (Log of mean catch*m^3 +1) from the CB net in Spring (A), Summer (B), and Fall (C), 1972 – 2005

Mysids

The introduced mysid, *Acanthomysis bowmani*, has been the most abundant mysid since fall 1993 when it was first captured by the survey. Spring *A. bowmani* abundance has fluctuated annually since 2002 at a lower range than during the late 1990s and early 2000s, and reached the minima of its oscillation in 2005 (Figure 4A). Summer abundance has generally been higher than spring abundance; summer 2005 abundance increased slight from 2004, ending the slight decline since 2002 (Figure 4B). *A. bowmani* maintained moderate abundance (>10/ m3) into fall, exhibiting a sharp increase in 2005 and reinforcing the turn-around begun in 2004 (Figure 4C).

Neomysis mercedis, historically the only common mysid in the upper estuary, declined in spring 2005 to the record lows of 2002 and 2003 (Figure 4A). Low spring abundance rendered *N. mercedis* inconsequential as a food source through open water areas of the upper estuary in 2005. Abundance increased only slightly from spring to summer 2005 (Figure 4B). Summer abundance increased somewhat from 2004, but remained at an extremely low level, similar to years since 1997. For the first time since the mid-1990s no *N. mercedis* were captured during fall at the core stations (Figure 4C).

Neomysis kadiakensis began appearing regularly in mysid catches in 1996, but has never become common. Though it ranks 2nd in abundance to *A. bowmani*, its current levels are roughly similar to *N. mercedis*. In 2005, *N. kadiakensis* abundance increased slightly in spring, remained stable in summer and declined slightly in fall, while at very low levels (Figure 4A-4C). Since introduction, *N. kadiakensis* has extended its range into low salinity water at the confluence of the Sacramento and San Joaquin rivers, leading to the belief that some of these upper estuary specimens might be a second species, *N japonica*. Currently, no physical characteristics have been established to separate the 2 species.

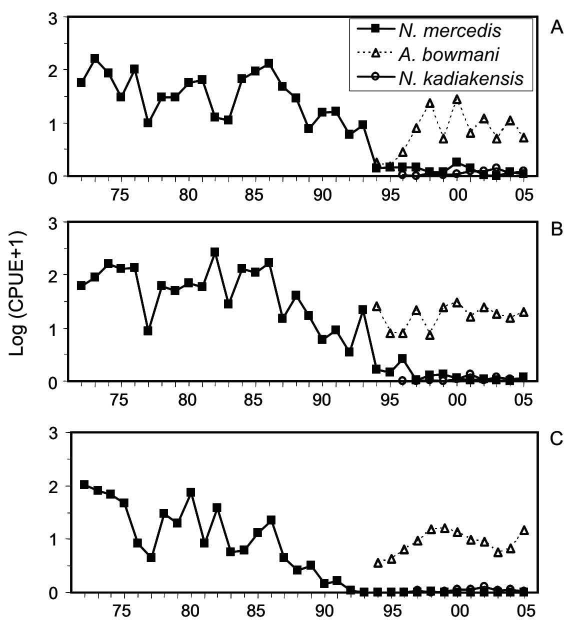

Figure 4 Abundance of *Neomysis mercedis*, *Acanthomysis bowmani*, and *Neomysis kadiakensis* (Log of mean catch*m3 +1) from the mysid net in Spring (A), Summer (B), and Fall (C), 1972 - 2005

2005 Fishes Annual Status and Trends Report for the San Francisco Estuary

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Introduction

The 2005 Status and Trends fishes report includes data from 4 of IEP's long-term 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). 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 several of the surfperches. Several pelagic species that spawn and rear in the upper estuary have undergone severe declines in recent years and are presented first. This group is followed by the upper estuary demersal fishes, the marine pelagic fishes, surfperches, and marine demersal fishes. Within each section the species are presented phylogenetically.

Methods

The TNS has been conducted annually since 1959, and indices have been calculated for all years except 1966, 1983, and 2002. It produces annual abundance indices for age-0 striped bass (the 38.1-mm index) and age-0 delta smelt. 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, it was standardized to 6 surveys per year. The striped bass index is interpolated between the 2 surveys that bracket the mean size of 38.1-mm fork length (FL) (Chadwick 1964, Turner and Chadwick 1972), which was between surveys 4 and 5 in 2005. The delta smelt index is the average of the first 2 survey indices. The 2005 TNS completed 6 surveys at 2-week intervals from June 13 to August 26, 2005.

The FMWT has sampled annually since 1967, with the exception of 1974 and 1979. It was designed to determine the relative abundance and distribution of age-0 striped bass in the estuary, but data is also used for other upper estuary pelagic species, including American 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 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 a few data gaps, most significantly limited sampling with the midwater trawl in 1994 and no winter sampling from 1989 to 1997. Abundance indices are routinely calculated for 35+ pelagic and demersal fishes and several species of crabs and caridean shrimp; only the most common species are included in this report. The Bay Study samples 52 stations, of which 35 have been consistently sampled since 1980 and are used for the 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 San Pablo Bay and the Napa River. Surveys have been conducted every other week from early March through July since 1995. Three tows are completed at each of the 48 stations with a 1,600 µm mesh net (Dege and Brown 2004). This survey gets its name from the size (20 mm) at which delta smelt are retained and readily identifiable at the CVP and SWP fish facilities.

Data from all 4 surveys was used to describe trends and distribution of upper estuary pelagic fishes when available, but only Bay Study midwater trawl data was used for the marine pelagic fishes and Bay Study otter trawl data for demersal fishes.

Physical Setting

The 2005 winter-spring delta outflow was very similar to 2003 and 2004, with a mean daily outflow of 1,007 cm/s for January-May. However, the 2005 pattern was very different, with 3 major peak outflow events: approximately 1,800 cm/s in early January, 2,000 cm/s in late March, and 2,600 cm/s in late May (see Kate Le's article in this issue).

The San Francisco Estuary is situated between 2 major faunal regions, the cold-temperature fauna of the Pacific Northwest and the subtropical fauna of southern and Baja California, and is a transitional area with elements of both faunas (Parrish et al. 1981). The northern Pacific Ocean has been in a cold-water regime since 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. However, a warm water event in fall 2004 resulted in Gulf of the Farallones' sea surface temperatures (SSTs) 1-2°C higher than the historic means. From August through November 2004, SSTs were routinely >14°C, with temperatures >15°C and occasionally 16°C for several weeks in August and September. These were the highest SSTs reported for the Gulf of the Farallones since the strong 1997-98 El Niño event, although this was not an El Niño event.

In 2005, SSTs remained above average through March, returned to near the historic mean in April, but were 0.5-2°C above average in summer 2005, concurrent with a late spring transition and weak coastal upwelling. The transition from winter to summer ocean conditions occurred in June rather than April or May due to a series of late storms. Once upwelling started in June, the anomalies were negative through August. This was a major change from recent years with very strong upwelling, especially 1999 and 2001-2003. The warmer SSTs, late spring transition, and weak summer upwelling were associated with poor juvenile rockfish recruitment, low euphausiid biomass, and high chick and adult mortality for some seabirds in the Gulf of the Farallones (Schwing personal communication, see "Notes").

Upper Estuary Pelagic Fishes

American shad

The American shad (*Alosa sapidissima*) is an introduced anadromous species that spawns in the rivers in late spring, rears in fresh water through summer, and migrates to the ocean in late summer and fall. It rears for 2-5 years in the ocean before returning to fresh water to spawn.

Most males mature at age 3 or 4 and most females at age 4 or 5; many fish only spawn once, but some fish spawn annually, reaching a maximum age of 7 years. All life stages of American shad are planktivores.

The 2005 FMWT American shad index was 1,744, nearly double the 2004 index, but well below the highest index in 2003 (Figure 1A). Peak emigration was in September and October, with catches slowly declining through December. American shad were widely distributed, collected in every FMWT area in every survey. The majority were collected in San Pablo and Suisun bays in September, the lower Sacramento River in October, and Suisun Bay in November and December.

The 2005 Bay Study age-0 American shad index was 22,186, the 2nd highest for the study period (Figure 1B). Indices have fluctuated widely in recent years, as 2003 had the 3rd highest index, and the 2001, 2002, and 2004 indices were well below the study-period average. Bay Study American shad catches peaked in August and September and rapidly declined through December. In 2005 it was collected from South Bay near the San Mateo Bridge to our most upstream stations in the lower Sacramento River near Steamboat Slough and in the lower San Joaquin River at Old River Flats. In August, most fish were collected in the lower San Joaquin River and in September they were common in both the lower Sacramento and San Joaquin rivers.

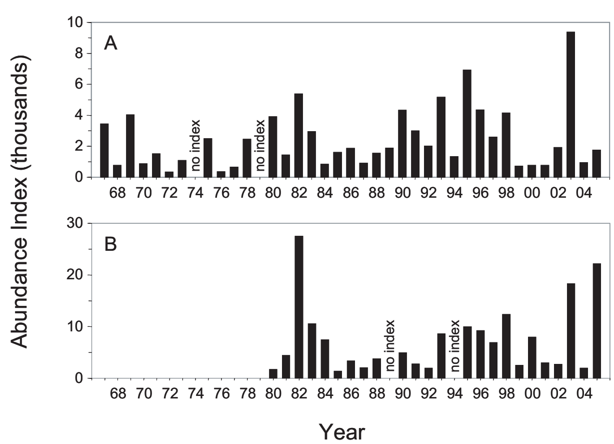

Figure 1 Annual abundance of American shad: A) FMWT, all sizes, September-December, B) Bay Study midwater trawl, all sizes, January-December

Threadfin shad

The threadfin shad (*Dorosoma petenense*) is a small, short-lived introduced planktivore. It reproduces in freshwater but can be found throughout the estuary. In river systems it is most common in slower moving waters, such as dead-end sloughs. The 2005 FMWT threadfin shad index was 2,866, more than double last year's near record low index, but continued the trend of below-average indices for the past 4 years (Figure 2). The majority (83%, n=1606) of threadfin shad were caught in the eastern delta, especially in the Stockton Deep Water Channel between the Calaveras River and Fourteenmile Slough. Distribution was broadest in December, when fish were collected in all of the FMWT areas.

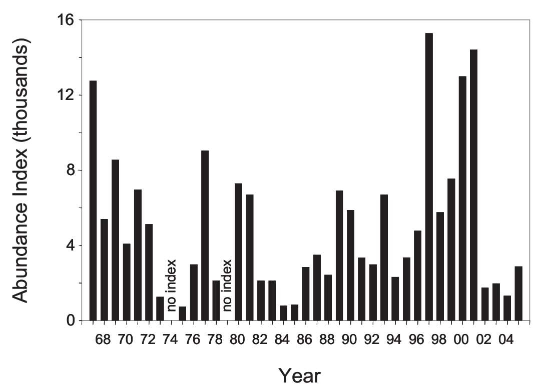

Figure 2 Annual abundance of threadfin shad, FMWT, September-December

Delta smelt

The delta smelt (*Hypomesus transpacificus*) is a small (55-70 mm FL) osmerid endemic to the upper San Francisco Estuary. It was listed as a state and federal threatened species in 1993. Historically one of the most common fish in the estuary, the population declined dramatically in the early 1980s. Delta smelt is considered environmentally sensitive because it typically lives for 1 year, has a limited diet, and resides primarily in the interface between salt and fresh water. In addition, females produce only 1,000 to 3,000 eggs and the planktonic larvae have a low survival rate. Possible reasons for the delta smelt's decline include reductions in fresh water outflow, extremely high fresh water outflows (which push them too far down the estuary), entrainment losses at water diversions, changes in food type and abundance, toxic substances, disease, competition, and predation.

The 2005 TNS delta smelt index was 0.3, the lowest on record (Figure 3A), and was the 5th consecutive year of very low indices. TNS delta smelt indices have been low since 1983, except for from a modest upturn in the late 1990s. In 2005, catch increased after survey 2 when the index was set (Table 1), which is not an uncommon occurrence. Distribution did not change substantially over the 6 surveys. Delta smelt were most common in Suisun Bay in all surveys (89%, n=106), followed by the Sacramento River (9%, n=11). No delta smelt were caught in the south or east delta and only 1 was collected in Montezuma Slough.

The 2005 FMWT delta smelt index was 26, the lowest index on record (Figure 3B). The 2004 index of 74 was the previous record low and indices have been very low since 2002. In 2005 only 12 delta smelt were collected in Suisun Bay, 10 in the lower Sacramento River, and 3 in the lower San Joaquin River. Suisun Bay was the only area where delta smelt were caught in all 4 surveys and no delta smelt were collected in San Pablo Bay, Carquinez Strait, or the eastern delta by the FMWT in 2005.

The 2005 Bay Study age-0 delta smelt index was 501, approximately 32% of the 2004 index (Figure 3C). Bay Study delta smelt indices were near record low in 2001 and 2002 rather than in 2004 and 2005. Age-0 fish were collected from Carquinez Strait to the lower Sacramento and San Joaquin rivers, with the majority from our Sacramento River channel station near Sherman Island (46%, n=27) and our Honker Bay shoal station (17%, n=12).

The 2005 20-mm Survey delta smelt index was 15.5, the highest index since 2000 (Figure 3D). Delta smelt were first collected in survey 1 (mid-March) in the lower Sacramento River and near Medford Island in the San Joaquin River. By late April delta smelt were widely distributed, ranging from the Napa River to the south delta and Cache Slough in the north delta. This distribution pattern continued until early June, when delta smelt were no longer found in the south delta. By the final survey in early July, no delta smelt were caught in the Napa River, and distribution was centered in Suisun Bay and the lower Sacramento River.

Table 1 Mean length, catch, and survey indices for delta smelt and striped bass during Townet surveys 1-6, 2005

	Survey 1	*Survey 2*	*Survey 3*	*Survey 4*	*Survey 5*	*Survey 6*
Delta Smelt						
Mean length (mm FL)	44	35	37	45	43	51
Catch	5	12	13	31	33	26
Survey index	0.17	0.41	0.30	1.08	0.98	1.24
Striped Bass						
Mean length (mm FL)	23	28	28	23	44	49
Catch	212	97	62	63	26	10
Survey index	3.0	2.2	1.0	2.2	0.6	0.2

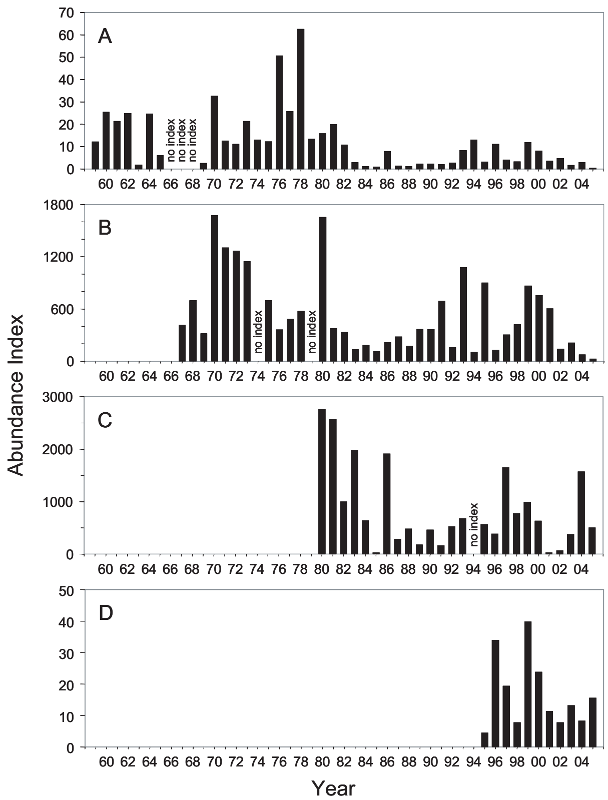

Figure 3 Annual abundance of delta smelt: A) TNS, age-0; B) FMWT, all sizes, September-December; C) Bay Study midwater trawl, age-0, June-October; D) 20-mm Survey larvae and juveniles

Longfin smelt

The longfin smelt (*Spirinchus thaleichthys*) is a short-lived anadromous species that spawns in freshwater in late winter and spring and rears in fresh to marine water. Some age-0 and age-1 fish apparently emigrate to the ocean in late-summer and fall for a short period, often returning to the estuary in late fall of the same year. A few longfin smelt mature at the end of their 1st year and the remainder at the end of the 2nd year, with a few living to spawn again at age-3. A strong positive correlation between longfin smelt abundance and outflow has been reported (Stevens and Miller 1983). However, this relationship changed in the late 1980s, with a strong correlation between abundance and outflow, but abundance at a lower level relative to outflow (Kimmerer 2002). Possible reasons for this change include a decline in phytoplankton and zooplankton abundance due to grazing by the introduced clam, *Corbula amurensis* (Kimmerer 2002), and dominance of the introduced copepod, *Limnoithona tetraspina,* which is very small and may not be consumed by larval and juvenile fish.

The 2005 FMWT longfin smelt index was 129, a decrease from the 2004 index and the 2nd lowest index for the study period (Figure 4A). Only 1992, the last year of a protracted drought, had a lower index. Catches steadily increased over the fall, with 1 fish collected in September and 50 in December. The FMWT collected longfin smelt from San Pablo Bay to the Sacramento River lower in 2005, with none from the lower San Joaquin River or the eastern delta. Overall, most were from Suisun Bay (46%, n=31), followed by San Pablo Bay (31%, n=21) and the Lower Sacramento River (19%, n=13), with only 2 from Carquinez Strait.

The 2005 Bay Study age-0 longfin smelt midwater trawl abundance index of 617 was less than half the 2004 index (Figure 4B), while the 2005 otter trawl index of 8,459 was more than double the 2004 index (Figure 4C). The 2005 midwater trawl longfin index was the 2nd lowest since 1992, continuing the trend of very low indices the past 5 years. Although the 2005 otter trawl longfin smelt index increased, it still marked the 6th consecutive year of relatively low indices. While longfin smelt had a modest recovery from 1995 to 1999, the mean 2000-2005 midwater trawl index was only 2% of the mean 1995-1999 index. The decline in the otter trawl was not as precipitous, as the mean 2000-2005 index was 17% of the 1995-1999 mean.

The Bay Study first collected age-0 longfin smelt in May and catches peaked in June and July. Distribution was centered in Central Bay from May through August and broadened from September on. By December, fish were collected from South Bay through Honker Bay. Overall, the majority of fish (67%, n=187) were collected in Central Bay, especially at our Treasure Island station. Trace element analysis of longfin smelt otoliths found fish initially rearing in brackish waters and moving either into either lower salinity or marine waters early in their first year of life, indicative of alternate life history strategies (Hobbs et al. 2005).

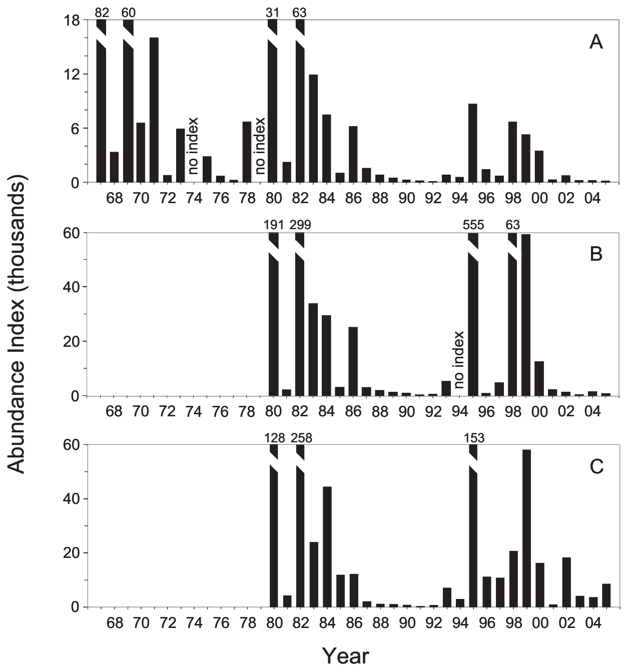

Figure 4 Annual abundance of longfin smelt: A) FMWT, all sizes, September-December; B) Bay Study midwater trawl, age-0, May-October; C) Bay Study otter trawl, age-0, May-October

Splittail

The splittail (*Pogonichthys macrolepidotus*) is endemic to the San Francisco Estuary and its watershed. During increased river flows from late fall through spring, adults migrate upstream from brackish and tidal freshwater to forage and spawn on inundated floodplains and river margins of the Sacramento, San Joaquin, Cosumnes, Napa and Petaluma rivers. Most spawning takes place March through May. Young disperse downstream as larvae when river levels drop rapidly or as juveniles in late-spring and early summer when backwater and edge-water habitats diminish with flows. Year class strength is related to the duration of floodplain inundation; moderate to large splittail year-classes result from inundation periods of 30 days or more. In 2005, several modest outflow spikes occurred from early January through late May, but none were of sufficient duration in the Sacramento River to result in much production of young; San Joaquin River flows were relatively high from late March through June and did result in successful splittail reproduction (see Real Time Monitoring for Mossdale Trawl May-June 2005 at http://www.delta.dfg.ca.gov/data/rtm2005/). Also, USFWS Beach Seine catches at Wimpy's on the Mokelumne River suggest that the Cosumnes River produced good numbers of splittail in 2005 (see Real Time Monitoring Maps at http://www.delta.dfg.ca.gov/data/rtm2005/).

Splittail produced in the San Joaquin and Cosumnes rivers in 2005 were not well reflected in trawl abundance indices. The 2005 FMWT splittail index (all ages combined) was again very low at 5 (Figure 5A). This index derived from a single age-0 fish captured in the lower Napa River and continues the trend of low FMWT indices since 2001. The 2005 Bay Study age-0 splittail midwater trawl index was 74, little changed from 2004 (Figure 5B). Similarly, the 2005 Bay Study age-1 midwater trawl index was virtually identical to that of 2004 (Figure 5C). For both age groups all but 1 of the 11 splittail caught were from channel stations in Suisun Bay or near the confluence of the Sacramento and San Joaquin rivers. No age-2 and older splittail have been collected since 2002 (Figure 5D). Although out of the ordinary, large splittail are not well captured by trawl gear.

Striped bass

The striped bass (*Morone saxatilis*) is an introduced anadromous species that supports a valuable sport fishery. Striped bass reproduces in spring in the rivers and rears in fresh and brackish water areas of the estuary. Females mature at age 4 or 5, males at age 2 or 3, with fish living to 20 years. The population of legal-size fish was probably 3 to 4.5 million in the early 1960s, 1.9 million in the early 1970s, 600,000 in 1994, and 1.5 million in 2000, the last year for which a population estimate has been calculated. Based on our understanding of factors controlling striped bass abundance in the estuary (Stevens et al. 1985), this most recent adult population increase was unexpected and remains unexplained. In contrast to the adult population, age-0 striped bass abundance has been low since the mid-1980s, with the lowest indices in the past 4 years. The age-0 striped bass decline is corroborated by all of the IEP long-term monitoring programs.

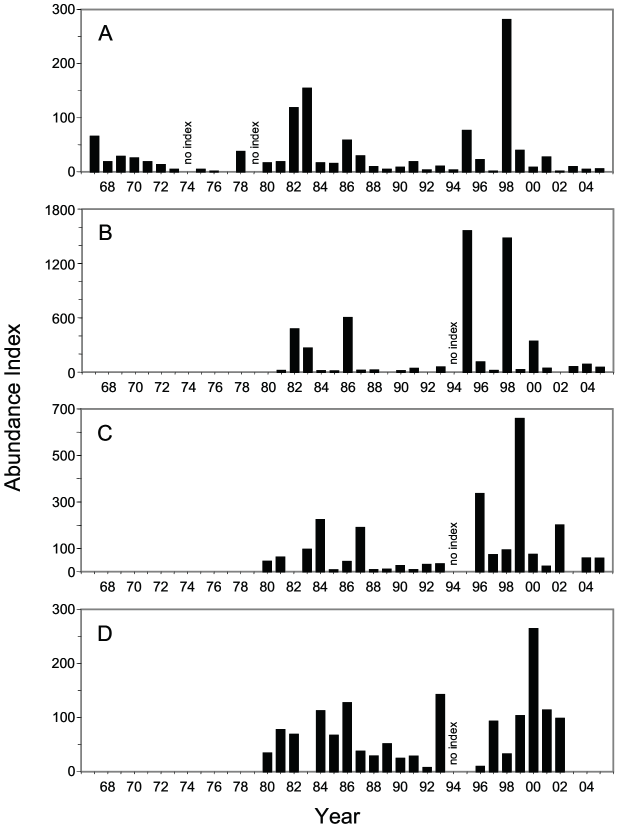

Figure 5 Annual abundance of splittail: A) FMWT, all sizes, September-December; B) Bay Study midwater trawl, age-0, May-October; C) Bay Study midwater trawl, age-1, February-October; D) Bay Study midwater trawl, age-2+, February-October

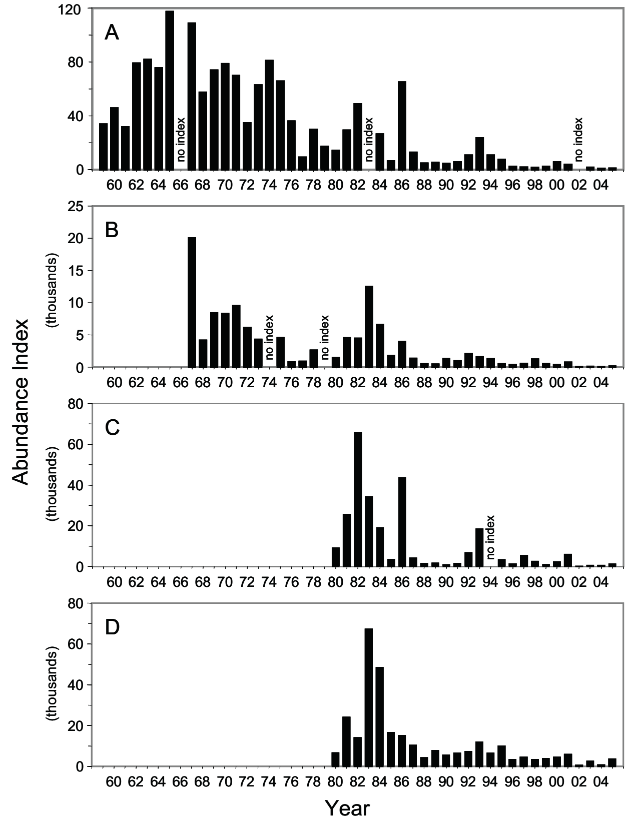

Figure 6 Annual abundance of age-0 striped bass: A) TNS 38.1-mm index; B) FMWT, September-December; C) Bay Study midwater trawl, June-October; D) Bay Study otter trawl, June-October

The 2005 TNS striped bass 38.1-mm index was 0.9, with a set date of August 6, 2005. This was only 0.1 above the record low index from 2004. The TNS index has not been above 10 since 1994 (Figure 6A). There has been a severe decline from the historical indices, which peaked in 1965. In 2005, catch was highest in survey 1 and declined each survey (Table 1). Age-0 striped bass were collected in all areas except the south delta, with the majority (71%, n=334) from Montezuma Slough. Initially, fish were collected only in Montezuma Slough and Suisun Bay, but distribution expanded to upstream areas in surveys 2 and 3, with a few fish collected in the lower Sacramento and San Joaquin rivers and the eastern delta. Distribution contracted in survey 4, and by survey 6, fish were collected only in Montezuma Slough, Suisun Bay, and the lower Sacramento River.

The 2005 FMWT striped bass index was 121, more than double 2004's record low index (Figure 6B). But the 2002 to 2005 indices were the 4 lowest for this survey, which followed another decline in the mid 1980s. Fish were collected in all of the FMWT areas in 2005, with the majority (75%, n=69) from Suisun Bay. Distribution was broadest in September, with fish collected from San Pablo Bay to the eastern delta. No fish were collected in the eastern delta after September and in San Pablo Bay after October. Distribution continued to contract through December, when fish were collected from Carquinez Strait through the lower Sacramento River.

Both the 2005 Bay Study midwater trawl and otter trawl age-0 striped bass abundance indices were more than double the 2004 indices (Figures 6C and 6D). However, this was a very modest increase, as both indices were near record lows in 2004. Overall, the otter trawl collects far more age-0 striped bass than the midwater trawl, and

2005 was not an exception. From June to December, the otter trawl collected 735 age-0 bass while the midwater trawl collected only 96. Catches from these gears peaked in July, decreased through September, and then again peaked in October.

The Bay Study collected age-0 striped bass from San Pablo Bay through the lower Sacramento and San Joaquin rivers in 2005. In early summer most fish were collected from Suisun and Honker bays, but distribution shifted slowly upstream through fall. By October and November, most were collected in the lower Sacramento and San Joaquin rivers. In December, distribution shifted downstream, with most fish from Suisun Bay and the lower Sacramento River. Age-0 striped bass were also strongly associated with the shoals, with 95% (n=696) of all fish collected at shoal stations by the otter trawl in 2005.

Upper Estuary Demersal Fishes

Shokihaze goby

The introduced shokihaze goby, *Tridentiger barbatus*, was first collected in the estuary by the Bay Study in 1997. Since it is common upstream of our original sampling area, abundance is calculated as the annual mean catch-per-unit effort (CPUE, #/10,000 m^2) for all 52 stations sampled, including the lower Sacramento and San Joaquin river stations added in 1991 and 1994. In 2005, mean CPUE for fish >19 mm total length (TL) was a record high for the study period (Figure 7). The 2005 shokihaze goby catch exceeded our combined catch of the 2 other introduced *Tridentiger* gobies, the shimofuri goby (*T. bifasciatus*) and the chameleon goby (*T. trigonocephalus*), and also the yellowfin goby total catch. In 2005, shokihaze gobies were collected in South Bay at our channel station south of the Dumbarton Bridge and from western San Pablo Bay near Point San Pablo to the lower Sacramento River at Steamboat Slough and to the lower San Joaquin River at San Andreas Shoal. Over a 5 month period in 2005, a record number of fish (n=15) were collected in South Bay south of the Dumbarton Bridge. The majority (84%, n=377) of fish were collected from the channel stations in Suisun Bay and the lower Sacramento River.

Yellowfin goby

The yellowfin goby (*Acanthogobius flavimanus*) is found throughout the estuary, but is most common in shallow brackish and fresh water habitats. The 2005 yellowfin goby age-0 index doubled from 2004 and was the largest index since 2000, yet was half of the 1980-2005 study-period average (Figure 8). In 2005 yellowfin gobies were collected throughout the estuary from South Bay south of the Dumbarton Bridge through the western delta at our most upstream stations in the lower Sacramento River near Steamboat Slough and in the lower San Joaquin River at Old River Flats. The majority of age-0 fish were collected in Suisun Bay (61%, n=118) and San Pablo Bay (23%, n=44).

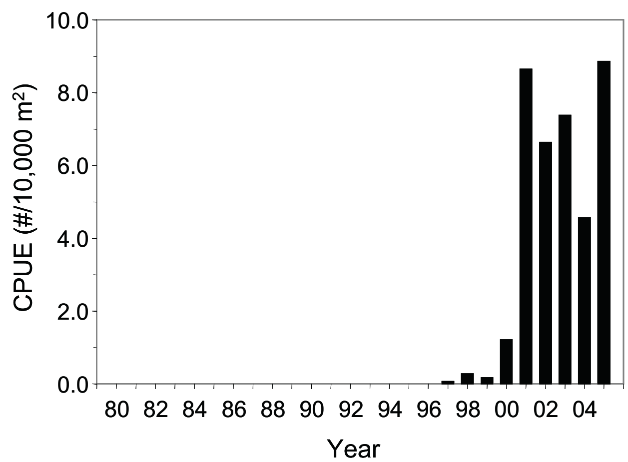

Figure 7 Annual CPUE (#/10,000 m2) of shokihaze goby (all sizes), Bay Study otter trawl, January-December

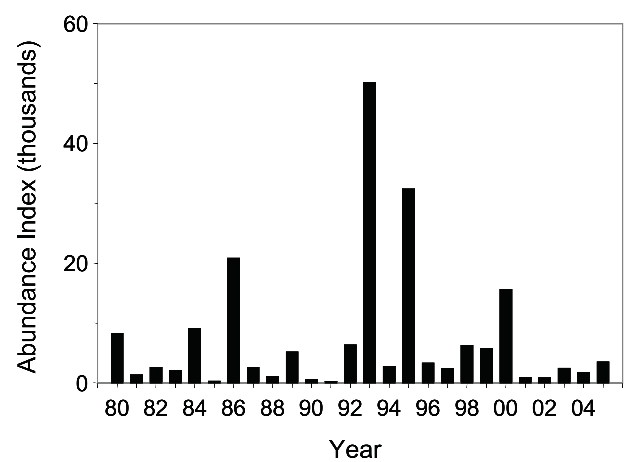

Figure 8 Annual abundance of age-0 yellowfin goby, Bay Study otter trawl, May-October

Starry flounder

The starry flounder (*Platichthys stellatus*) is an estuary-dependent species that spawns in the ocean, but rears in brackish to fresh water areas of estuaries. The 2005 age-0 starry flounder index was near the study-period average (Figure 9), and was well above the very low indices from 1987-1994 and 2000-2002, possibly due to higher spring outflow in 2005. We collected age-0 starry flounder from June to December with highest catches in June and declining throughout the year. They ranged from our San Pablo Bay shoal stations to the Sacramento River just upstream of the Rio Vista Bridge and to our furthest upstream station on the San Joaquin River, at Old River Flats. Catches were highest at shoal stations in San Pablo Bay (31%, n=36) and Suisun Bay (43%, n=49), with 85% (n=98) of all age-0 fish collected from shoal stations.

The 2005 age-1 starry flounder abundance index was 62% of the study-period average, and was nearly identical to the 2003 and 2004 indices (Figure 9). Age-1 starry flounder were collected from South, Central, and San Pablo bays upstream to the Rio Vista Bridge on the Sacramento River and Santa Clara Shoal on the San Joaquin River. Most fish were collected during February and April from shoal stations in Honker Bay and the Sacramento River near Decker Island. Also, 98% (n=45) of all age-1 starry flounder was collected at shoal stations.

The trend of declining age-2+ starry flounder abundance continued in 2005, as the index was only 41% of the average (Figure 9). Indices averaged 1,917 from 1980 through 1987 and only 426 from 1988 to 2005. We caught age-2+ starry flounder every survey and January (n=6), February (n=10), and December (n=5) accounted for 52% of the catch. We collected age-2+ starry flounder from San Pablo Bay to just upstream of the Rio Vista Bridge on the Sacramento River and to our furthest upstream station on the San Joaquin River, with 88% (n=35) from shoal stations.

Marine Pelagic Fishes

Pacific herring

Pacific herring (*Clupea pallasii*) is an estuary-dependent species that spawns and rears in higher salinity areas (>20‰) of the estuary. The 2005 age-0 Pacific herring abundance index decreased to 52% of the 2004 index, the 3rd consecutive year of decline, and the lowest index in 6 years (Figure 10). After very low age-0 indices through the 1990s, there was a modest increase from 2000-2002, yet the 2005 index was a return to the levels of 1998-1999. CDFG has recorded landings for the Pacific herring fishery in San Francisco Bay since 1972, and landings were a record low 145 tons for the 2004-2005 season (Moore 2005). The Pacific herring fishery runs December through March, targeting adult fish entering the estuary to spawn, and landings of adult fish have declined each year since 2002 (Moore 2005).

In January and March of 2005, a few age-0 Pacific herring were collected in the estuary, but catches increased substantially in April and peaked in May. In April, fish were collected throughout most of South, Central, and San Pablo bays and in Carquinez Strait. In May, fish were also collected in Suisun and Grizzly bays. In June and July, the majority of age-0 Pacific herring were found in the channels of San Pablo and Central bays. Between August and October, age-0 fish moved back to Central Bay and by December, most age-0 Pacific herring had emigrated from the estuary.

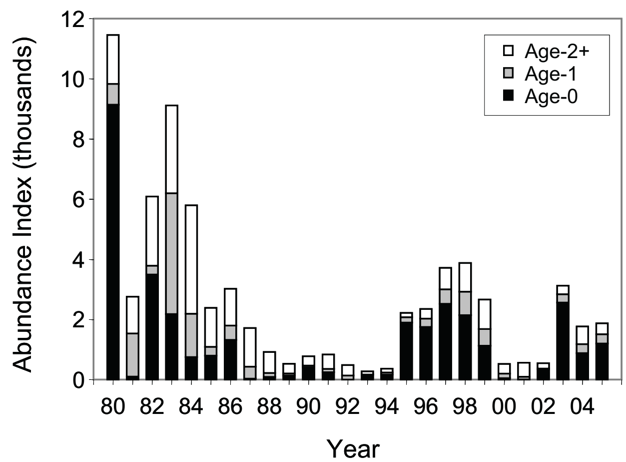

Figure 9 Annual abundance of age-0, age-1, and age-2+ starry flounder, Bay Study otter trawl, February-October

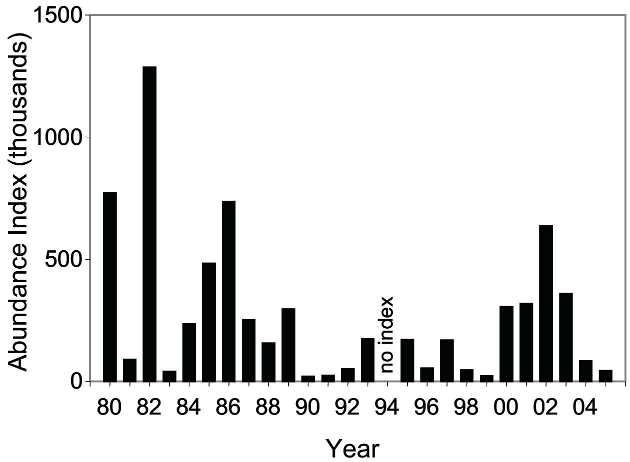

Figure 10 Annual abundance of age-0 Pacific herring, Bay Study midwater trawl, April-September

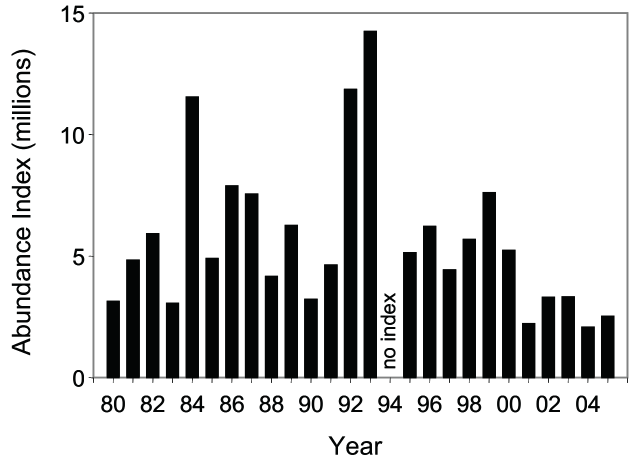

Figure 11 Annual abundance of northern anchovy (all sizes), Bay Study midwater trawl, April-October

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. The 2005 northern anchovy abundance index was slightly higher than 2004's record low index, but continued a 5-year trend of below average indices (Figure 11). The 3 lowest indices for the study occurred during this 5-year period. The San Francisco Estuary is situated between the northern and central anchovy subpopulations and our catches reflect the size and coastal movements of these subpopulations. The most recent abundance decrease in the estuary may be due to a southward migration of the central subpopulation in response to the cool ocean regime. 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 and size. We collected northern anchovy throughout South, Central, and San Pablo bays and in Suisun Bay near the Mothball Fleet. Occasional large collections (>1,000 fish) were made from lower San Pablo Bay to just south of the San Mateo Bridge from April through October. Central Bay accounted for about half (n=27,658) of our total 2005 catch (n=56,350).

Jacksmelt

The jacksmelt (*Atherinopsis californensis*) seasonally migrates from the coast to bays and estuaries to spawn and rear. Age-0 jacksmelt abundance was much lower in 2005 than from 2001-2004, and was only 15% of the study-period average (Figure 12). 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 our gear. In 2005, catches peaked in May-June and again in October. We collected age-0 jacksmelt from South Bay to lower San Pablo Bay, with most from mid and northern South Bay. Catch was evenly spread between shoal (n=92) and channel (n=86) stations.

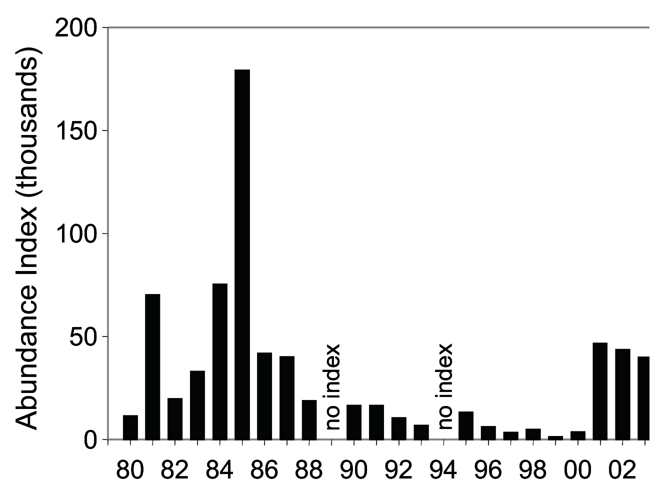

Figure 12 Annual abundance of age-0 jacksmelt, Bay Study midwater trawl, July-October

Surfperches

Most of the surfperches are transient species, immigrating to bays and estuaries to give birth to live, fully formed young in late spring and summer. All of the surfperches common to San Francisco Estuary underwent abundance declines in the 1980s per Bay Study trawl and sportfish survey data (DeLeón 1998). Consequently, CDFG changed the sportfish regulations in 2002, adopting a closed season for all surfperches except for shiner perch from April 1 to July 31 in San Francisco Bay. A 5-fish combination bag limit for all species except for shiner perch and a 20-fish bag limit for shiner perch were also implemented for all areas of California.

We have observed 3 abundance trends for the 7 most common surfperch species of San Francisco Estuary: 1) Four of the 6 surfperch species that declined precipitously during the late 1980s and early 1990s have increased in abundance in recent years, 2) Two species, barred surfperch and pile perch, have shown little sign of recovery, and 3) One species, black perch, did not show an abundance decline.

In 2005, only walleye surfperch increased in abundance index from 2004. The 4 species that have shown some abundance increase in recent years are discussed in order of strongest to weakest recovery: walleye surfperch, white seaperch, shiner perch, and dwarf perch.

The 2005 age-0 walleye surfperch (*Hyperprosopon argenteum*) abundance index increased from 2004 and was 139% of the study period average (Table 2). Four of the 5 past years had above average indices, indicating a return to the population levels observed in the early 1980s. Thirty-four age-0 walleye surfperch were collected in 2005 from May-November. One was collected in South Bay, by Candlestick Point, and the rest were caught at Central Bay shoal stations. The highest catches were from our station near the Berkeley Fishing Pier (n=30), which accounted for 88% of the total age-0 catch (n=34).

The 2005 white seaperch (*Phanerodon furcatus*) abundance index was only about 10% of the 2004 index and was the lowest since 2000 (Table 2). We collected a total of 8 white surfperch in 2005, only 1 of which was from stations and months used for index calculation. We collected white seaperch from our South Bay shoal station near the Oakland Airport to our Central Bay channel station northeast on Angel Island.

In 2005, abundance of age-0 shiner perch (*Cymatogaster aggregata*) decreased to 25% of the 2004 index, returning to the low levels observed from the late 1980s to the mid 1990s (Table 2). Age-0 fish were collected from April through December, with the highest catches in July (n=104). Central Bay shoal stations accounted for 79% (n=195) of the total catch. As fall progressed, age-0 shiner perch migrated to deeper Central Bay stations and most had emigrated from the Bay by November.

In 2005 we caught a total of 12 dwarf perch (*Micrometrus minimus*), but only 1 was from an index station and month. The index was approximately 34% of the 2004 index (Table 2). All 12 dwarf perch were from shoal stations from near Corte Madera in Central Bay to just south of the San Mateo Bridge in South Bay.

The 2005 barred surfperch (*Amphistichus argenteus*) abundance index was based on 1 fish and was 44% of the 2004 index and 24% of study-period mean (Table 2). Only 2 barred surfperch were collected in 2005, both at our shoal station south of the San Mateo Bridge in South Bay.

The 2005 pile perch (*Rhacochilus vacca*) abundance index was 0, showing no sign of recovery in the estuary and continued the trend of very low or 0 indices since 1987 (Table 2). One age-1+ pile perch was collected in January from our shoal station near Alameda Island, which is neither an index month nor station.

Black perch (*Embiotoca jacksoni*) was the only surfperch common in the estuary that did not show a distinct decline in Bay Study catch during the late 1980s or early 1990s (Table 2). Black perch catch has never been high, but has remained relatively constant throughout the study period. The black perch index for 2005 was slightly below the historical average and was 37% of the 2004 index. We collected 5 black perch, all from Central Bay, between August and December 2005, 3 of which were from stations and months used for index calculation.

Table 2 Annual abundance indices for selected surfperch species from the Bay Study otter trawl. The age-0 walleye surfperch, white seaperch (all sizes), and age-0 shiner perch indices are from May-October. The dwarf perch (all sizes) and black perch (all sizes) are from February-October while the barred perch (all sizes) index is from April-September and age-0 pile perch is from June-October.

	walleye sp	white seaperch	shiner perch	dwarf perch	barred sp	pile perch	black perch
Year	age-0	all	age-0	all	all	age-0	all
1980	1,277	588	19,516	439	455	857	0
1981	8,089	1,248	42,764	543	942	998	129
1982	1,640	349	43,705	259	335	471	54
1983	663	271	16,148	460	1,330	778	88
1984	3,846	873	14,386	50	673	110	216
1985	362	138	16,616	0	73	301	66
1986	322	309	24,617	0	0	254	17
1987	1,453	265	18,069	0	239	0	0
1988	486	148	7,746	66	134	0	62
1989	2,046	48	6,953	97	101	153	101
1990	516	95	8,181	26	79	0	48
1991	22	0	2,724	15	84	0	0
1992	443	0	6,142	0	41	0	100
1993	617	0	6,341	0	43	0	97
1994	no index	0	3,241	0	80	0	125
1995	405	0	6,661	0	0	0	0
1996	684	0	4,404	0	59	0	225
1997	231	0	23,896	0	155	0	231
1998	537	0	4,384	0	48	75	65
1999	848	0	6,237	0	46	0	36
2000	1,229	0	4,640	0	43	31	119
2001	8,121	106	20,594	0	55	0	248
2002	12,277	260	26,134	0	59	42	95
2003	2,439	371	15,896	111	352	0	63
2004	896	487	24,849	94	115	0	253
2005	2,916	47	6,225	32	51	0	93

Marine Demersal Fishes

Brown smoothhound

The brown smoothhound (*Mustelus henlei*) is the most common shark collected by the Bay Study in the estuary. It immigrates to bays and estuaries to pup in late spring and summer and young fish emigrate to the ocean in fall. The 2005 age-0 brown smoothhound abundance index was 72% of the 2004 index and only 52% of the study-period average (Figure 13). We collected 14 age-0 brown smoothhound from April through December. Most fish (86%, n=12) were collected at channel stations throughout South, Central, and lower San Pablo bays.

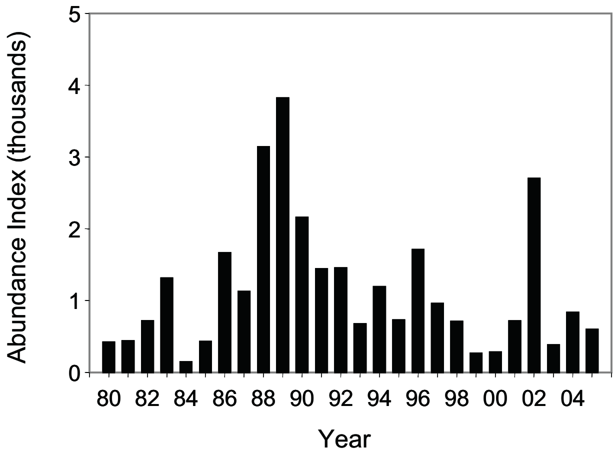

Figure 13 Annual abundance of age-0 brown smooth-hound, Bay Study otter trawl, April-October

Leopard shark

The leopard shark (*Triakis semifasciata*) is a popular sportfish that immigrates to very shallow areas of the estuary, especially in South Bay, to pup in summer. The Bay Study does not effectively sample age-0 leopard sharks because they are born and rear in areas too shallow to navigate with our boat. Because catches are often very low, we report catch from February-October at our original stations rather than abundance indices. Our 2005 otter trawl age-0 February-October catch remained at 4, while our age-1+ catch increased to 17 and our combined catch was the highest since 1989 (Figure 14). However, there has been a downward trend in catch since 1984, with an apparent step change in 1999. Catch averaged 38 fish per year from 1980 to 1983, declined to 14 fish per year from 1984 to 1998, and declined again to only 7 fish per year from 1999 to 2004. Because of potential over harvest of leopard sharks, a 36-inch size limit and a 3-fish bag limit was implemented in 1991 for the sport fishery. We collected a total of 32 leopard sharks during 2005, from South Bay to San Pablo Bay, just north of Point San Pablo, with 88% (n=28) from South Bay.

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 though December; occasionally, some fish remain until spring. After 4 consecutive years of record high indices, the 2005 age-0 index decreased to just 19% of the 2004 index (Figure 15). Age-0 plainfin midshipmen were first collected in June and were most common in October. Distribution was broadest in September and October, with fish collected from South Bay south of the Dumbarton Bridge to Suisun Bay near Port Chicago. The majority of age-0 plainfin midshipman (53%, n=491) were collected from the Central Bay channel stations in 2005.

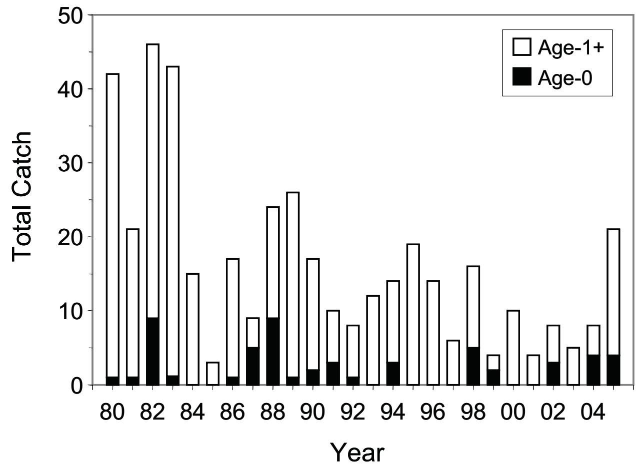

Figure 14 Annual catch of leopard shark (all sizes), Bay Study otter trawl, January-December

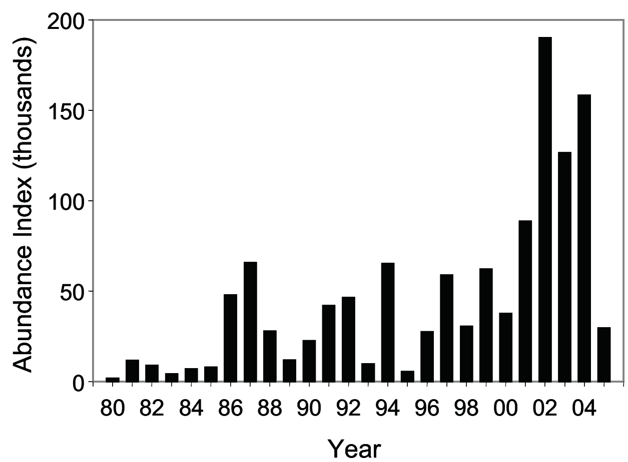

Figure 15 Annual abundance of age-0 plainfin midshipman, Bay Study otter trawl, June-October

Pacific staghorn sculpin

The Pacific staghorn sculpin (*Leptocottus armatus*) is a common species that usually rears in higher salinity areas, but is also found in brackish water and occasionally in fresh water. Throughout the estuary it rears in intertidal and shallow subtidal areas from late winter through early summer. The 2005 Pacific staghorn sculpin age-0 abundance index was 41% of the 2004 index, and was the lowest since 1998 (Figure 16). Indices have steadily declined since record high abundance in 2002. Age-0 fish were first collected in March in South and San Pablo bays. In April and May, distribution broadened and fish were collected from South to Suisun bays, with a single fish collected upstream in the lower Sacramento River, north of Sherman Lake. Migration of age-0 fish to Central Bay began in June and continued through September. The majority (62%, n=226) of age-0 Pacific staghorn sculpin were collected at shoal stations in 2005, although by September 90% (n=37) were from channel stations.

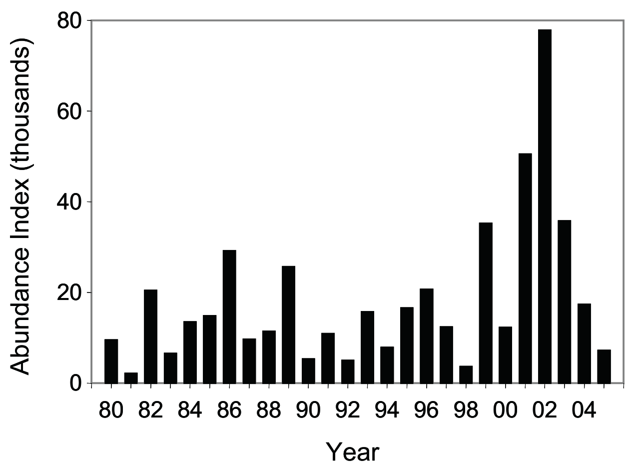

Figure 16 Annual abundance of age-0 Pacific staghorn sculpin, Bay Study otter trawl, February-September

White croaker

The white croaker (*Genyonemus lineatus*) is a common coastal species that frequents bays and estuaries. The 2005 age-0 white croaker abundance index decreased from 2004 to the 4th lowest for the study period, about 10% of the study-period average (Figure 17). Age-0 catch has been below average for the past 10 years and exceptionally low the past 4 years. White croaker is a warm-subtropical marine species and as such, age-0 abundance in San Francisco Estuary is related positively to elevated ocean temperatures; therefore, a higher index was anticipated than observed. Perhaps a longer duration of elevated SSTs is required before a response is detectable. The age-1+ index also decreased in 2005 and was only about 21% of study-period average (Figure 17). It was the 2nd lowest index for the study period and the 9th consecutive year of below average indices. Age-1+ abundance was highest during the 1987-1992 drought, when salinities were high and relatively stable year-round in the estuary.

In 2005, age-0 white croaker were collected from South Bay to Carquinez Strait and had the widest distribution in May; by late summer the majority had migrated to Central Bay and by October most had emigrated to the ocean. Overall, 60% (n=61) of the 2005 age-0 catch was from our channel stations near Angel Island; most of these fish were collected in September, just prior to emigration. Age-1 white croaker were collected throughout most of South Bay to San Pablo Bay, with 64% (n=57) from Central Bay. Catch was sporadic, with no age-1 white croaker collected in South Bay from July-November and in Central Bay in January, November, or December. The seasonality of catch was almost the opposite in San Pablo Bay, where no age-1 white croaker were caught from April-August.

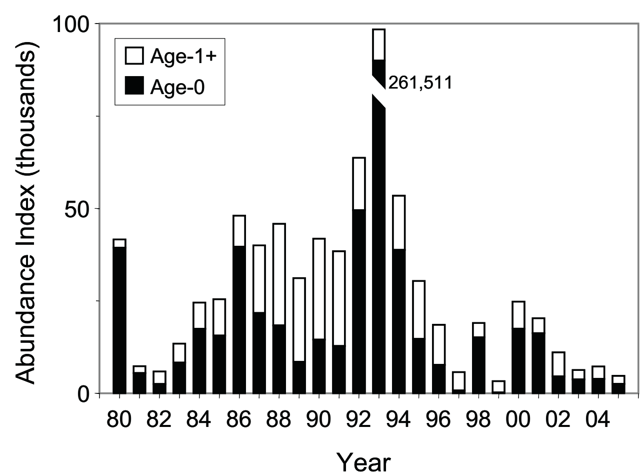

Figure 17 Annual abundance of age-0 and age-1+ white croaker, Bay Study otter trawl, February-October

Bay goby

The bay goby (*Lepidogobius lepidus*) is one of the most common native gobies in the estuary. It is a resident species that rears in the higher salinity areas and has a 2-3 year life span. In 2005, the bay goby abundance index decreased to 33% of the 2004 index and was the lowest index since 1986 (Figure 18). Three of the 4 highest indices occurred from 2001 to 2003, but the 2005 index was well below the study-period average. In 2005, bay gobies were collected from South Bay through San Pablo Bay, except for the extreme downstream and upstream stations. From June to August, as water temperatures increased, fish moved from South and San Pablo bays to Central Bay. In November and December, with cooler water temperatures, bay goby distribution again extended from South to San Pablo bays. Overall, the majority (72%, n=885) were from Central Bay; also, 67 % of the total catch (n=32) was from shoal stations.

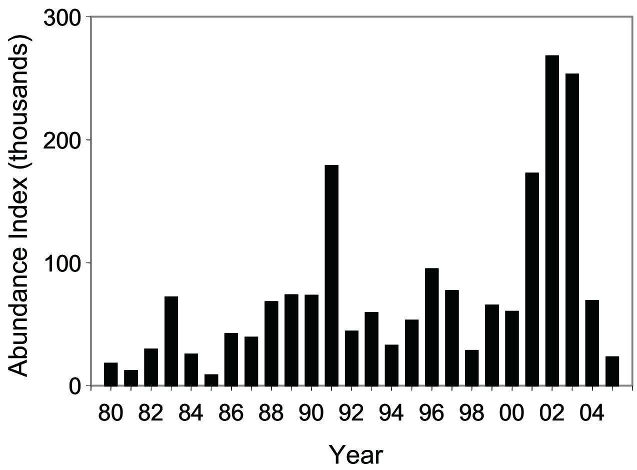

Figure 18 Annual abundance of bay goby (all sizes), Bay Study otter trawl, February-October

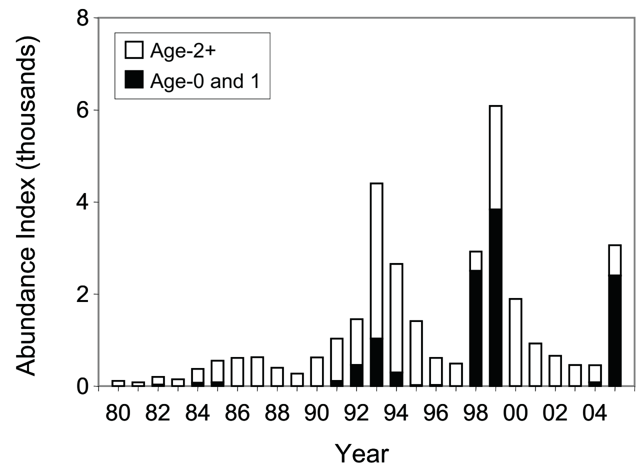

Figure 19 Annual abundance of juvenile (age-0 and age-1) and age-2+ California halibut, Bay Study otter trawl, February-October

California halibut

The California halibut (*Paralichthys californicus)* is a subtropical species that became common in San Francisco Estuary in the 1980s and 1990s, concurrent with the recent warm-water regime. The 2005 combined age-0 and age-1 California halibut index increased from 2004 and was the 3rd largest for the study period (Figure 19). The age-2+ California halibut index also increased from 2004 and was the largest index since 2002 (Figure 19). The majority (81%, n=91) of age-0 and age-1 fish were collected from September through December. Fish were collected from South Bay to the Carquinez Strait, with 62% (n=69) from South Bay. The appearance of age-0 fish is believed to be in response to Gulf of the Farallones SSTs exceeding 14°C in August, September, and November 2004. Laboratory experiments have shown high larval mortality at 12°C and increased survivorship and growth with higher temperatures (Gadomski and Caddell 1991). The majority (73%) of age-2+ California halibut were also collected from September through December in South through San Pablo bays. Age-2+ fish ranged from 200 mm to 1,010 mm FL (mean=357 mm FL), indicating several year classes were present in the estuary.

English sole

English sole (*Pleuronectes vetulus*) is a common flatfish species that spawns along the coast in winter and rears in both the ocean and estuaries. The 2005 age-0 English sole abundance index decreased to just 20% of the 2004 index (Figure 20), reversing the trend of high indices since 1999. Poor recruitment of age-0 English sole, a cold-temperate species, may have been due to the warm SSTs in the fall and winter of 2004-2005, which may have resulted limited maturation of gonads or poor survival of eggs and larvae. We collected the first age-0 fish in February, but peak catch was in July. Distribution of age-0 English sole in 2005 was atypical, as they were most common in Central Bay all months, with some movement to San Pablo Bay in June and July. There was a strong seasonal movement from the shoals to channels in September associated with emigration back to the ocean, and by December, all fish remaining were collected from the Central Bay channel. However, 80% (n=666) of all age-0 English sole were collected at shoal stations in 2005.

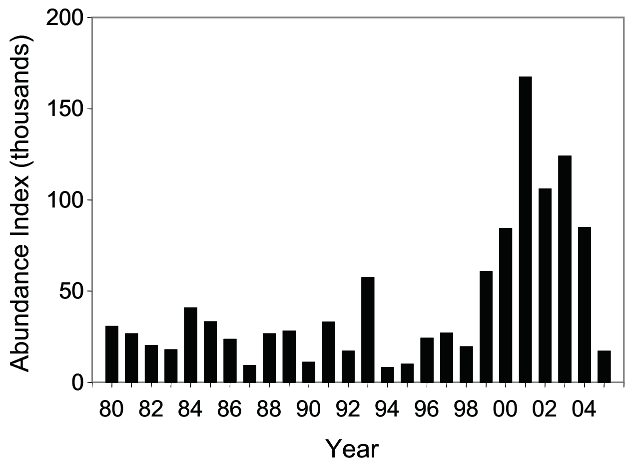

Figure 20 Annual abundance of age-0 English sole, Bay Study otter trawl, February-October

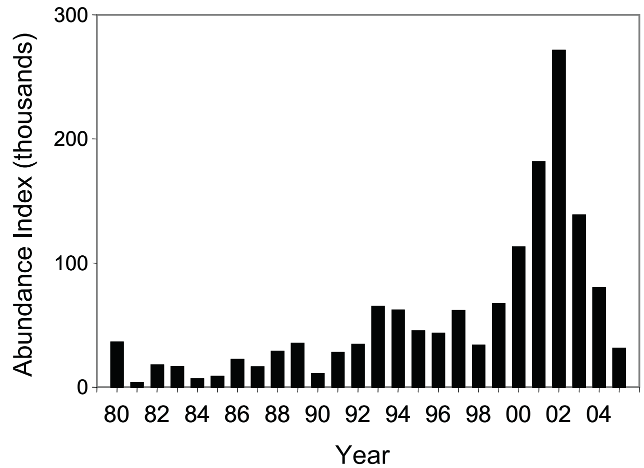

Figure 21 Annual abundance of speckled sanddabs (all sizes), Bay Study otter trawl, February-October

Speckled sanddab

The speckled sanddab (*Citharichthys stigmaeus*) is one of the most abundant flatfishes in the estuary. It spawns along the coast and juveniles migrate into the estuary to rear for up to a year. The 2005 speckled sanddab abundance index decreased to 39% of the 2004 index and was the lowest index since 1992 (Figure 21). Record speckled sanddab abundance indices occurred from 2000 to 2004, corresponding with cooler ocean temperatures and strong summer upwelling. Speckled sanddab has a very long pelagic period and do not settle until after the upwelling season ends. In 2005, weak upwelling was not as beneficial for distribution of speckled sanddabs as previous years. Speckled sanddabs were collected from South through San Pablo bays in 2005, but the majority of fish (95%, n=1,323) were collected in Central Bay. Fish in South and San Pablo bays were most common at the shoals, but only from January to May. By June, most speckled sanddabs moved into Central Bay and remained common there through December. In November and December after temperatures decreased, fish were again collected in South and San Pablo bays.

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Notes

Franklin Schwing, NOAA Fisheries Service, email, April 11, 2006.

2005 Annual Status and Trends Report – Common Crabs of the San Francisco Estuary

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This report summarizes the abundance trends and distributional patterns of the most common *Cancer* crabs and *Eriocheir sinensis,* the Chinese mitten crab, in the San Francisco Estuary. Most of the data is from the San Francisco Bay Study (Bay Study) otter trawl, with additional mitten crab data from Suisun Marsh otter trawls and CVP and SWP salvage.

***Cancer* crabs**

Cancer magister, the Dungeness crab, is a valuable sport and commercial species that reproduces in the ocean in winter and rears in nearshore coastal areas and estuaries. Small juvenile *C. magister*, 5-10 mm carapace width (CW), immigrate to San Francisco Estuary in spring, rear for 8-10 months, and emigrate to the ocean in fall and winter when approximately 100 mm CW. Estuary-reared crabs reach legal size at the end of their 3rd year, 1-2 years before ocean-reared crabs.

The abundance index of age-0 *Cancer magister* was very low in 2005 (Figure 1), comparable to the previous lowest indices, most of which were in years with an El Niño event. Although not an El Niño event, the above average sea surface temperatures in fall-winter 2004 (see the Fishes Status and Trends report for the physical settings summary) likely resulted in poor embryo and larval survival and subsequently a weak year class. This followed 4 years of very high age-0 *C. magister* indices in the estuary, which were concurrent with cooler ocean temperatures and favorable nearshore currents in fall and winter.

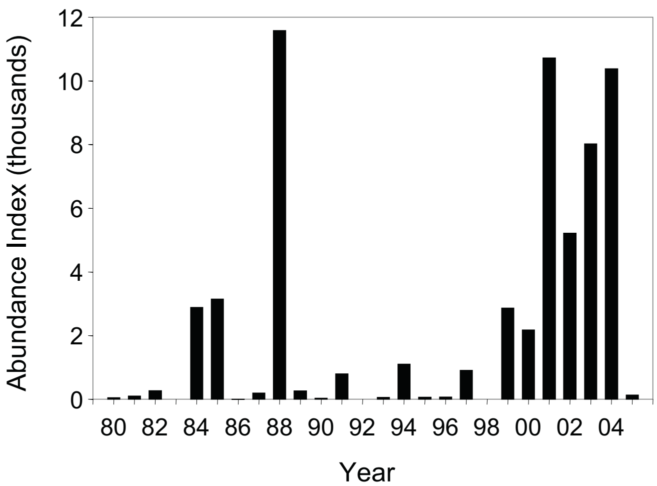

Figure 1 Annual abundance of age-0 Cancer magister, Bay Study otter trawl, May-July, 1980-2005

These recent strong year classes were reflected in the Central California *C. magister* crab landings. Landings have surpassed 4 millions pounds the past 4 fishing seasons, with 4.5 million pounds landed in the 2005-06 season through early April 2006 (Kalvass, personal communication, see "Notes"); Central California landings last exceeded 4 million pounds in the late 1950s. The 2001 year class of estuary-reared crabs was legal size and available to the fishery in the 2003-04 season, the 2002 year class in the 2004-05 season, the 2003 year class in the 2005-06 season, and the 2004 year class will be legal size for the 2006-07 fishing season.

In 2005, the first age-0 *C. magister* were collected in May in Central Bay. Catches were sporadic in Central Bay throughout summer and fall, with a few age-0 crabs collected in Carquinez Strait in November and December. As in recent years with high abundance, we collected *C. magister* at our Alcatraz Island station that were likely very small age-1 crabs that had reared in the ocean their first year; 15 of the 22 age-0 *C. magister* collected in 2005 were from this station. Although these smaller crabs did not rear in the estuary for their entire first year, they were categorized as age-0 crabs based on size and contributed to the annual abundance index.

Cancer antennarius, the brown rock crab, is common to rocky areas and other areas with structure. It and *C. productus*, the red rock crab, are targeted by sport anglers fishing from piers and jetties in the higher salinity areas of the estuary. The abundance of age-0 *C. antennarius* decreased in 2005 to a level typical of the 1980s and early 1990s (Table 1). This followed a period of above average indices the since the mid-1990s. In 2005, age-0 *C. antennarius* were again collected from South Bay through San Pablo Bay, but were most common at the shoal station near Alameda and the channel station near Hunter's Point in South Bay. Shoal catches were highest in late summer and fall (younger age-0 crabs) and channel catches were highest in winter (older age-0 crabs).

Cancer gracilis, the slender crab, is smaller than the other 3 species of *Cancer* crabs, rarely exceeding 85 mm CW. It is common in open sandy or sand-mud habitats rather than rocky areas; researchers have hypothesized that because of its small size it cannot compete with the rock crabs for the more "preferred" protected habitats. In contrast to *C. magister* and *C. antennarius*, the abundance of age-0 *C. gracilis* increased slightly in 2005 (Table 1). However, the 2004 and 2005 indices were well below the study-period mean and followed a decade plus of relatively high indices. Of the 58 age-0 *C. gracilis* collected in 2005, 56 were from Central Bay in 2005 and the remaining 2 from South Bay. The highest catches were at our Treasure Island and Angel Island stations.

Cancer productus is the least common of the 4 *Cancer* crabs we collect in the estuary with the otter trawl, reflecting a strong preference for rocky intertidal and subtidal marine habitats rather than its actual abundance in the estuary. The 2005 abundance index of age-0 *C. productus* decreased from 2004 (Table 1) and was less than the study-period mean. In 2005, 63% (n=25) of the age-0 *C. productus* were collected at our Alcatraz Island station, which has a substrate of gravel and small rocks.

Eriocheir sinensis

Eriocheir sinensis, the Chinese mitten crab, was first collected in the estuary in the early 1990s, but likely introduced to South Bay in the late 1980s. After several years of rapid population growth and expanding distribution, the population of *E. sinensis* peaked in 1998-99 (Table 2).

Table 1 Annual abundance indices of age-0 Cancer crabs from the Bay Study otter trawl, 1980-2005. The index period is May-October for all species

Year	*C. gracilis*	*C. antennarius*	*C. productus*
	age-0	*age-0*	*age-0*
1980	17	102	0
1981	152	76	6
1982	87	0	4
1983	151	28	4
1984	154	50	41
1985	216	20	38
1986	59	0	89
1987	93	71	79
1988	223	21	138
1989	203	29	30
1990	159	113	160
1991	656	171	128
1992	371	60	62
1993	616	398	71
1994	1,017	603	166
1995	227	367	40
1996	411	1,126	198
1997	1,131	351	86
1998	1,621	718	149
1999	222	90	249
2000	251	849	93
2001	1,921	276	142
2002	796	119	238
2003	522	424	140
2004	112	1,765	139
2005	132	144	57

All data sources indicate that the population has been declining over the past 4 years. In 2005, the Bay Study adult *E. sinensis* mean catch-per-unit-effort (CPUE) was the lowest since 1996, when we first collected it north of the Bay Bridge. We collected only 2 adult males from San Pablo Bay and 1 ovigerous female from South Bay in 2005. Suisun Marsh adult CPUE was again 0 in 2005. The combined CVP and SWP estimated total salvage was 18 adults in fall 2005, the lowest since *E. sinensis* was first detected at the CVP fish salvage facility in fall 1996.

USFWS monitoring for juvenile *E. sinensis* in Delta tributaries again detected no crabs in 2005. There were also no public reports of *E. sinensis* sightings made to the toll-free reporting line, the web page reporting form, or from the postage-paid mailer in 2005 (Bergendorf, personal communication, see “Notes”). When numbers are low, the only detectable impact of *E. sinensis* is stealing bait from sport anglers at some locations in the Delta and Suisun and San Pablo bays.

We do not understand what controls the estuary’s *E. sinensis* population, although winter temperatures and outflow are hypothesized to effect larval survival and settlement time. A “boom-and-bust” cycle has been reported for some introduced species, although this may not be universally true for all introductions.

Acknowledgements

I thank Robert Schroeter of UC Davis for the unpublished *E. sinensis* size and catch data from Suisun Marsh and Russ Gartz of DFG for the CVP and SWP salvage data.

Notes

Pete Kalvass, CDFG, email, April 12, 2006

David Bergendorf, USFWS, e-mail, February 9, 2006.

Table 2 Annual adult *Eriocheir sinensis* CPUE and estimated total salvage, 1996-2005. Bay Study CPUE is from October (year)-March (year+1), Suisun Marsh CPUE is from July-December, and CVP and SWP salvage is from September-November

Year	*Bay Study CPUE* (#/tow)	*Suisun Marsh CPUE* (#/tow)	*CVP salvage* est. total	*SWP salvage* est. total
1996	0.02	0.00	50	
1997	0.34	0.07	20,000	
1998	2.51	0.89	750,000	
1999	0.96	1.08	90,000	34,000
2000	0.93	0.02	2,500	4,700
2001	3.25	0.17	27,500	7,300
2002	1.07	0.04	2,400	1,200
2003	0.15	0.00	650	90
2004	0.12	0.00	750	370
2005	0.01	0.00	0	18

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

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Introduction

The Tracy Fish Collection Facility (TFCF, Federal Facility) and the Skinner Delta Fish Protective Facility (SDFPF, State Facility) divert (salvage) fish from water exported from the San Francisco Estuary. The TFCF began operation in 1957 and the SDFPF began operation in 1968. Both the TFCF and the SDFPF use a louver-bypass system to salvage fish from the exported water. The salvaged fish are returned to the San Francisco Estuary by loading the salvaged fish into tanker trucks and trucking them to predetermined release sites.

Exports

The State Water Project (SWP) exported roughly 4.97 billion m^3 (4,028,860 acre-feet); a record high for all years of record since 1981. The next highest annual exports occurred in 1989 (4.67 billion m^3) and 2000 (4.61 billion m^3). Monthly exports ranged from a high of 590 million m^3 (478,574 af) in January to a low of 150 million m^3 (121,442 af) in May (Figure 1). Exports from June through December were more stable and ranged from 403 – 539 million m^3 (326,840 – 436,628 af) (Figure 1).

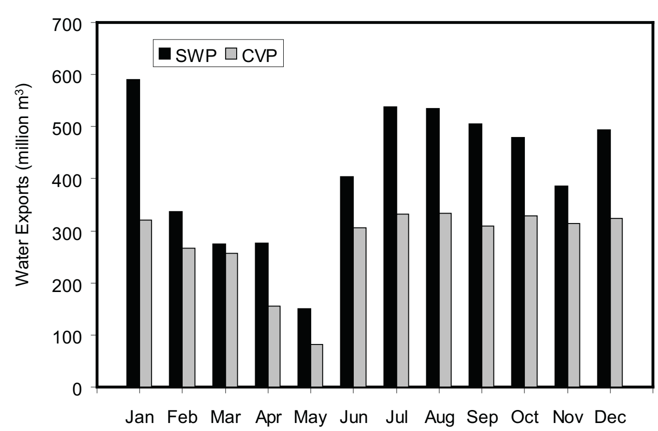

Figure 1 Monthly water exports for the SWP and CVP, 2005

The Central Valley Project (CVP) exported 3.33 billion m^3 (2,697,077 af) of water in 2005, almost the identical amount exported in 2004 (3.32 billion m^3). Monthly exports followed the same trend as the SWP. Exports decreased from a high of 320 million m^3 (259,248 af) in January to a low of 81 million m^3 (65,857 af) in May (Figure 1). Monthly exports from June through December were stable, ranging from 306 – 334 million m^3 (247,959 – 271,049 af) (Figure 1).

Fish Salvage

Threadfin shad was a large component of annual salvage of fish at both facilities. The SWP salvaged roughly 3.02 million fish while the CVP salvaged roughly 2.43 million fish. Density (individuals salvaged per 10,000 m^3) was highest at SWP in July and at CVP in November (Figure 2). Threadfin shad were the predominate species at CVP, making up 46% of the annual salvage (Figure 3). Threadfin shad were the second most predominant5 species at SWP, making up 39% of annual salvage while American shad made up 41% (Figure 4). The percentage of annual salvage of threadfin shad decreased from 2004 for both facilities (Figure 5).

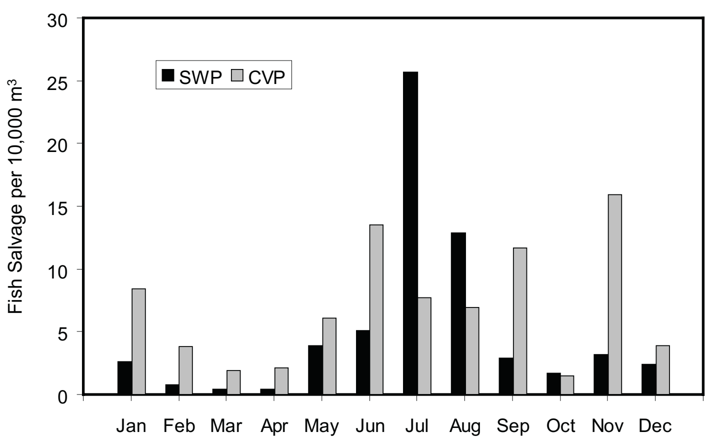

Figure 2 Fish salvage density at the SWP and SVP, 2005

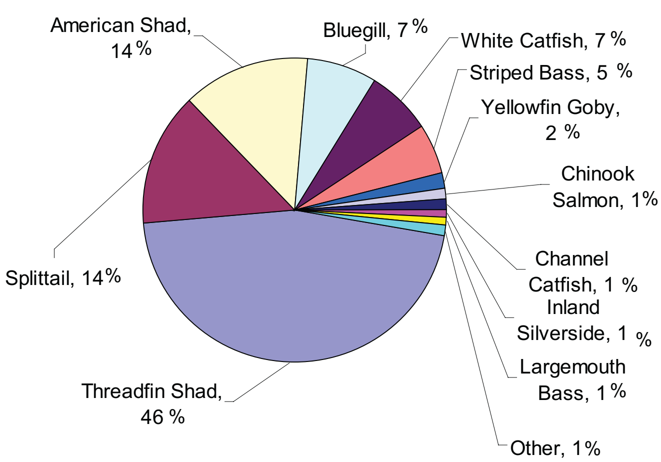

Figure 3 Relative species composition at the CVP, 2005

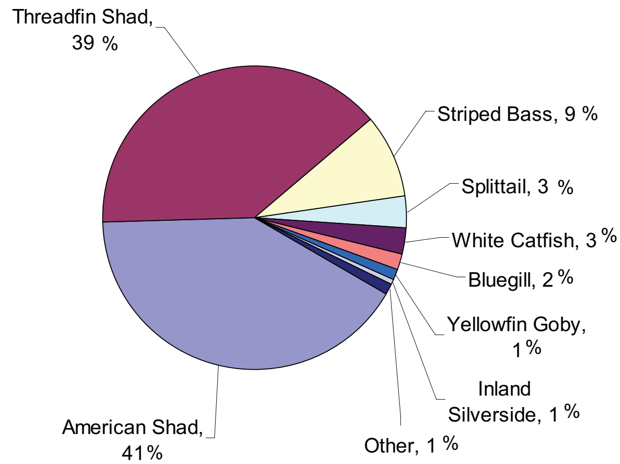

Figure 4 Relative species composition at the SWP, 2005

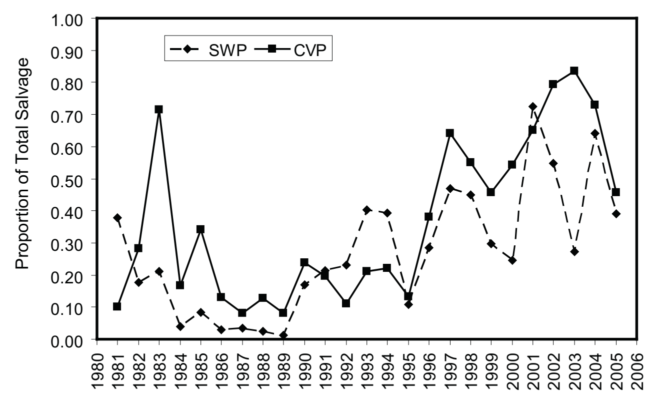

Figure 5 Relative proportion of threadfin shad in salvage at the SWP and CVP, 1981-2005

Delta smelt

The salvage of delta smelt at both facilities was very low in 2005, but not record lows. The salvage of delta smelt at SWP was 2,922 and at CVP it was 830. The low of record (since 1981) was 276 for SWP in 1998 and 180 for CVP in 1995. However, salvage at both facilities has been in constant decline since 2002, when it had increased from 2001 (Figure 6). Salvage of delta smelt in 2005 occurred in 2 discrete pulses for both facilities. Salvage occurred mainly in January-February (adults, previous year class) and May-June (juveniles, current year class) (Figure 7).

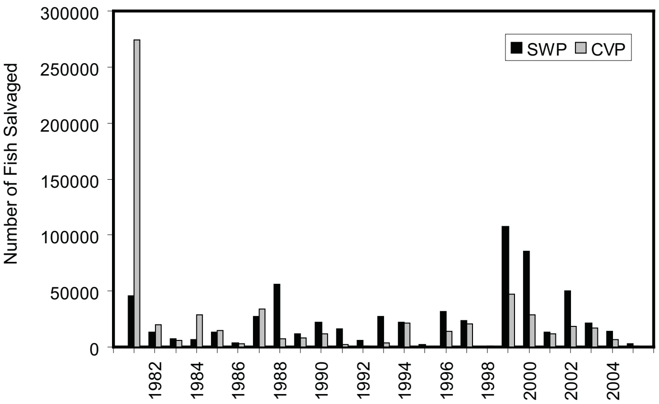

Figure 6 Annual salvage of delta smelt at the SWP and CVP, 1981-2005

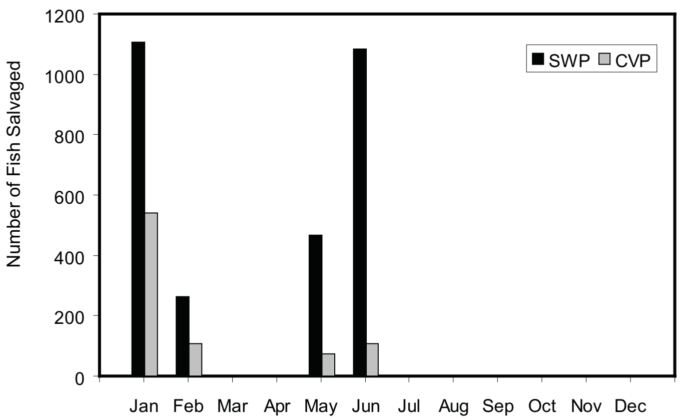

Figure 7 Monthly salvage of delta smelt at the SWP and CVP, 2005

Chinook Salmon

Low numbers of Chinook salmon were salvaged at both facilities, a continuation of a trend since 2002 (Figure 8). The annual salvage of wild and hatchery salmon (combined salvage) was 13,065 at SWP and 25,637 at CVP. The combined salvage of salmon consisted primarily of wild (unclipped) fish: 78% wild and 22% hatchery (adipose clipped). Combined salvage of wild salmon consisted primarily of fall and spring run sized fish (determined by fork length, Figure 9, Table 1). The CVP salvaged roughly twice the wild salmon, 19,963, as the SWP, 10,345 (Table 1). The monthly salvage of wild salmon was highest from March through June for the CVP and April through June for the SWP (Figure 10).

Loss, an estimate of mortality resulting from entrainment at the facilities, was higher for wild fish and at the SWP. Loss was almost 4 times greater for wild as opposed to hatchery fish (both facilities combined): wild - 60,856, hatchery – 16,408. Loss was 3 times greater at the SWP, 46,192, than the CVP, 14,664 (wild fish, Table 1).

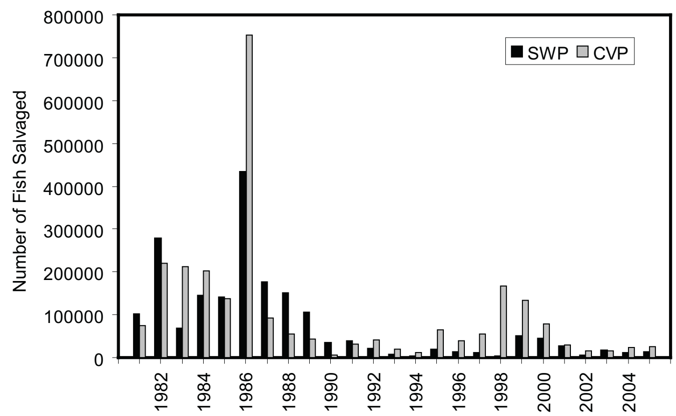

Figure 8 Annual salvage of wild and hatchery Chinook salmon (combined) at the SWP and CVP, 1981-2005

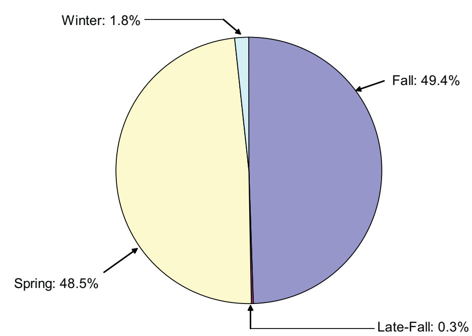

Figure 9 Relative contribution of wild Chinook salmon by race at the SWP and CVP (combined), 2005

Table 1 Wild Chinook salmon salvage and loss, 2005

Race	*SWP - Annual Salvage*	*CVP Annual Salvage*	*Total Salvage*	*SWP - Annual Loss*	*CVP - Annual Loss*	*Total Annual Loss*
Fall	5,571	9,409	14,980	25,170	6,718	31,888
Late-fall	15	84	99	66	54	120
Spring	4,443	10,245	14,688	19,552	7,742	27,294
Winter	316	225	541	1,404	150	1,554
Total	10,345	19,963	30,308	46,192	14,664	60,856

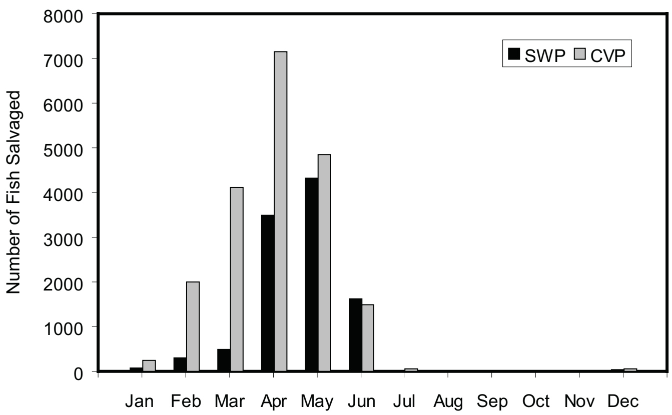

Figure 10 Monthly salvage of wild Chinook salmon at the SWP and CVP, 2005

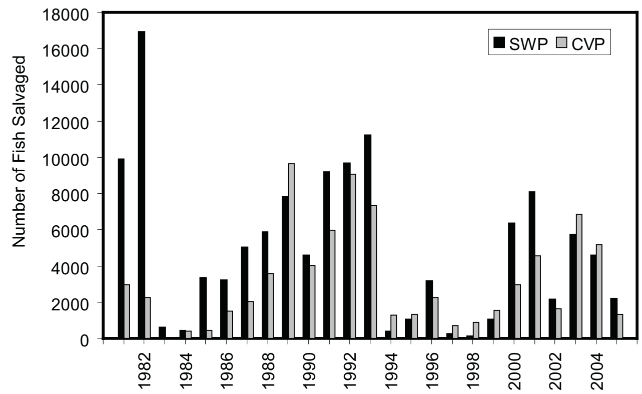

Figure 11 Annual salvage of wild and hatchery steelhead (combined) at the SWP and CVP, 1981-2005

Steelhead

The salvage of steelhead was low for both facilities in 2005 and continued a decline in salvage that started in 2003 (Figure 11). The salvage of hatchery steelhead was almost twice that of wild steelhead: 2,207 hatchery as opposed to 1,297 wild. The SWP salvaged 1,414 hatchery origin, 779 wild and 3 of unknown origin for a total of 2,196 salvaged. The CVP salvaged 793 hatchery origin, 518 wild, and 36 of unknown origin for a total salvage of 1,347 steelhead. The pattern of monthly salvage of steelhead was the same for both facilities with monthly salvage peaking in March for the CVP and April for the SWP (Figure 12).

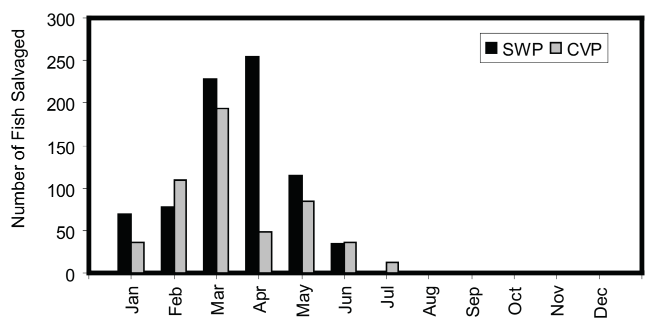

Figure 12 Monthly salvage of wild steelhead at the SWP and CVP, 2005

Striped Bass

The annual salvage of striped bass at both facilities in 2005 was very low. The SWP salvaged 269,825. The CVP salvaged 124,537, a new low for the period since 1981. The low values of salvage at both facilities in 2005 are a continuation of low values since 2001 (Figure 13). The monthly salvage of striped bass at both facilities predominately occurred in 2 pulses: January – March and June – December (Figure 14). Salvage at the SWP was driven by salvage in July, which accounted for 51% of the annual salvage (Figure 14).

American Shad

The trend of annual American shad salvage was different depending upon facility. Salvage of American shad at SWP in 2005 was 5 times that in 2004: 1,228,387 as opposed to 242,780. However, large inter-annual variation in salvage at SWP was not unique to 2004-2005, especially after 1993 (Figure 15). The salvage of American shad at the CVP was 329,047 and continued a decline that began after 2003 (Figure 15). The bulk of salvage at SWP occurred during July and August while at CVP the bulk of salvage was from October – December (Figure 16).

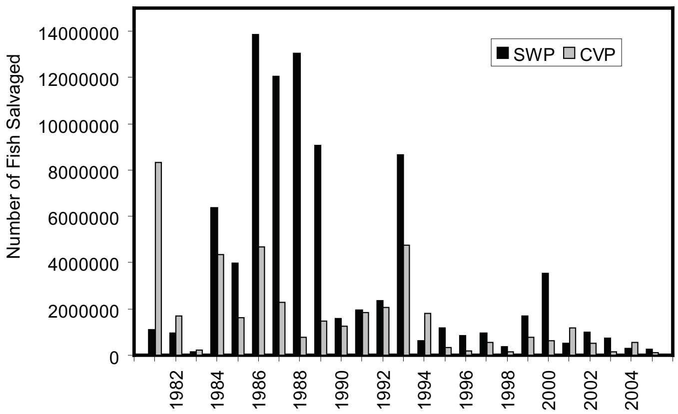

Figure 13 Annual salvage of striped bass at the SWP and CVP, 1981-2005

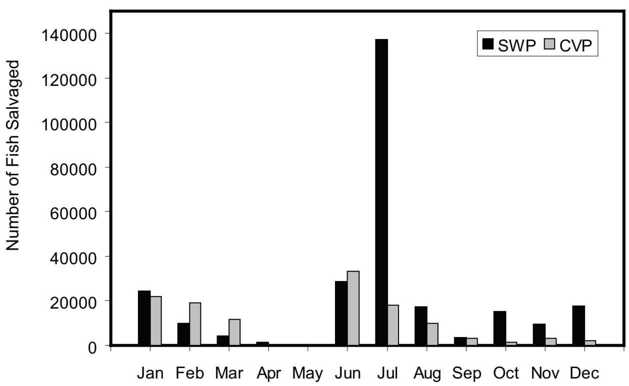

Figure 14 Monthly salvage of striped bass at the SWP and CVP, 2005

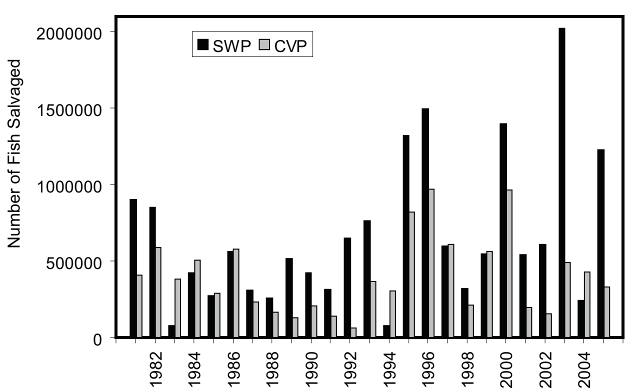

Figure 15 Annual salvage of American shad at the SWP and CVP, 1981-2005

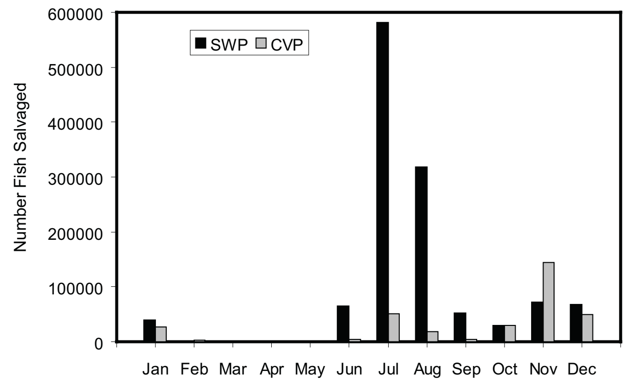

Figure 16 Monthly salvage of American shad at the SWP and CVP, 2005

Splittail

The salvage of splittail at both facilities was high in 2005, but not near record high values. The SWP salvaged 102,308 splittail in 2005; annual salvage totals over 67,000 were uncommon (Figure 17). The CVP salvaged 342,655 splittail in 2005; the facility rarely salvaged more than 135,000 splittail annually (Figure 17). However, the salvages in 2005 are dwarfed by all time record salvages in 1986, 1995, and 1998 (Figure 17).

The splittail salvage was confined to a narrow time frame, May – July (Figure 18), and was comprised primarily of age-0 fish. Length ranges were: SWP, 21 – 431 mm FL and CVP, 20 – 395 mm FL. However, 95th percentiles occurred at 81 mm FL for the SWP and 82 mm FL for the CVP.

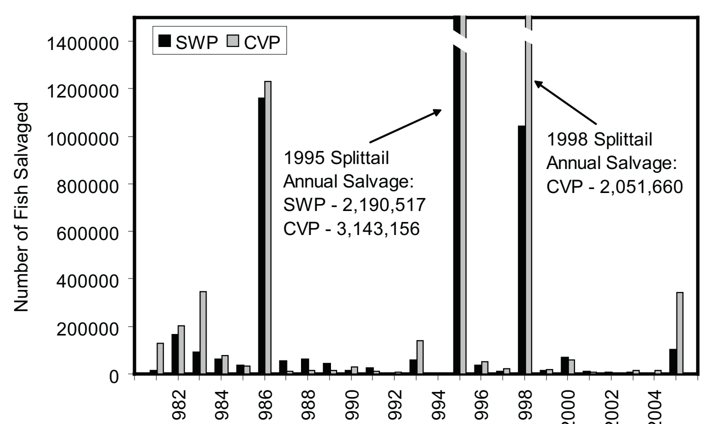

Figure 17 Annual salvage of Sacramento splittail at the SWP and CVP, 1981-2005. Columns for 1995 and 1998 have been truncated for scale considerations.

Longfin Smelt

The salvage of longfin smelt in 2005 was low: the SWP salvaged 183 and the CVP salvaged 36. Low salvage has been typical at both facilities since 1981 except in low outflow years 1984-85, 1987-1990 and 2002 (Figure 19).

Chinese Mitten Crabs

Mitten crab salvage was the lowest recorded for both facilities since 1999. The salvage for CVP was:

- 1999 – 25,104
- 2000 – 2,124
- 2001 – 18,144
- 2002 – 1,383
- 2003 – 804
- 2004 – 745
- 2005 – 48

The salvage for SWP was:

- 1999 – 33,902.5
- 2000 – 5,110.3
- 2001 – 7,452
- 2002 – 1,271
- 2003 – 160
- 2004 – 366
- 2005 – 39

Chinese mitten crabs have been less than 1% of the annual salvage for each facility in any given year since 1999.

In 2005, mitten crabs were salvaged on 4 days at the SWP and 5 days at CVP. The CVP salvaged a total of 48 mitten crabs on January 6, 19, 21 and 31. The SWP salvaged a total 39 mitten crabs on January 2 and 21, April 8, September 18 and October 15.

Temperature

The mean daily water temperature displayed the same basic pattern for both facilities, with the range of temperatures being larger for SWP. Mean daily temperature generally increased and peaked in July and then decreased until December (Figure 20). Mean daily temperature at the CVP ranged from $8.0^0 - 26.4^0$ C while mean daily temperature at the SWP ranged from $1.7^0 - 27.6^0$ C. However, the low temperatures observed at SWP in the first part of the year (January – May), are abnormally low. A possible explanation is a malfunction in the temperature sensor that was corrected later in the year. This is suggested by the close tracking of SWP and CVP mean daily temperatures sometime after the middle of June (Figure 20).

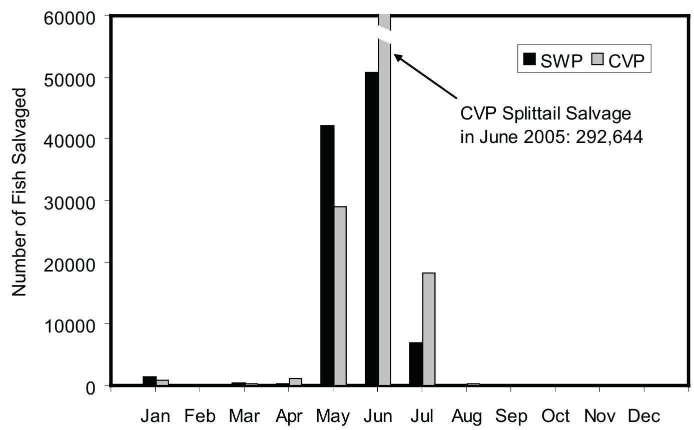

Figure 18 Monthly salvage of splittail at the SWP and CVP, 2005. The column for CVP, June, has been truncated for scale considerations.

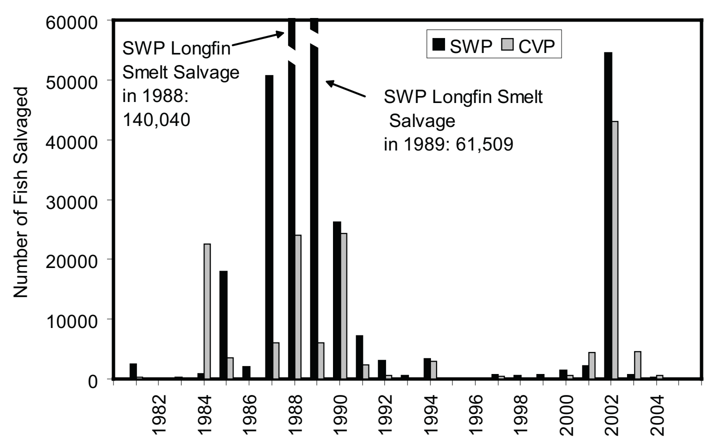

Figure 19 Annual salvage of longfin smelt at the SWP and CVP, 1981-2005. Columns for SWP 1988 and SWP 1989 have been truncated for scale considerations.

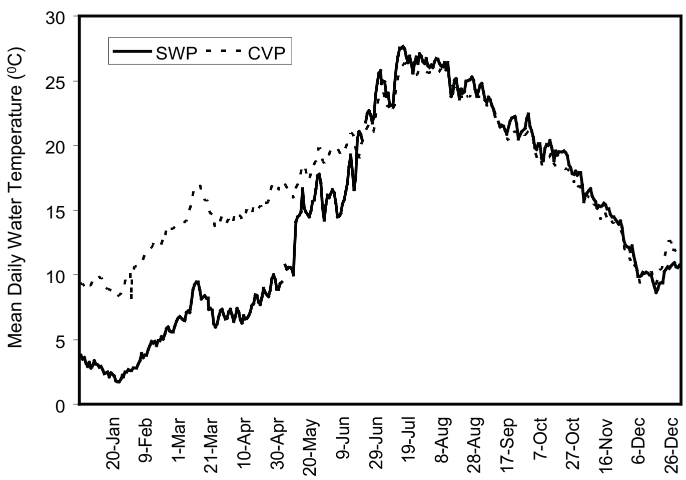

Figure 20 Mean daily water temperatures at the SWP and CVP, 2005

Estimating Relative Abundance and Survival of Juvenile Chinook Salmon in the Sacramento - San Joaquin Estuary

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Introduction

Relative juvenile Chinook salmon (*Oncorhynchus tshawytscha*) abundance and survival has been estimated in the Sacramento-San Joaquin Estuary for several years to evaluate population trends over time. Abundance and survival estimates prior to 1997 were summarized and discussed in a previous document (Brandes and McLain, 2001). The purpose of this article as well as one presented previously (IEP Newsletter, 2003) is to update trend analyses with recent abundance and survival estimates and to determine if trends observed in previous data have continued.

Previous analyses indicated that the abundance of juvenile salmon in the beach seine, between January and March in the North Delta and Bay areas, was positively related to Sacramento River flow at Freeport in February (r^2=0.69, p<0.01 and r^2=0.98, p<0.01, respectively)(Brandes and McLain, 2001). It was also shown that catch in the Sacramento trawl between April and June was inversely related to flow at Freeport in February (r^2 = 0.88, p<0.01)(Brandes and McLain, 2001). We have hypothesized that in years with high winter flows (February used as a surrogate month), less juvenile Chinook stay upstream to migrate into the Delta later as smolts (Brandes and McLain, 2001). Furthermore, abundance at Chipps Island between April and June was correlated to flows at Rio Vista between April and June (r^2=0.78, p<0.01)(Brandes and McLain, 2001), indicating that overall the number of juvenile Chinook salmon leaving the Delta increases as flows increase.

Previous analyses on juvenile salmon survival in the Delta and upstream indicates that survival for groups released near Red Bluff Diversion Dam survive at a higher rate in wet years than those released in the Delta near Clarksburg (Brandes and McLain, 2001). In addition, fry released in the north Delta (Isleton) appeared to survive better than those released in the interior Delta (mouth, North or South Fork of the Mokelumne River) in the drier years (Brandes and McLain, 2001).

Methods

Relative juvenile salmon abundance

The USFWS Stockton office has employed two sampling methods to monitor the relative abundance of juvenile Chinook salmon in the Sacramento-San Joaquin Rivers and Estuary: beach seining, and midwater trawling, Beach seining occurs in six geographical regions and includes the lower Sacramento River between Elkhorn and Colusa (Region 1), the north Delta (Region 2), the central Delta (Region 3), the south Delta (Region 4), the San Joaquin River from Mossdale upstream to the mouth of the Tuolumne River (Region 5), and the San Francisco and San Pablo Bays (Region 6)(Figure 1). Midwater trawling has been conducted on the Sacramento River just downstream from Sacramento (in 1990 sampling was further downstream near Courtland) and at Chipps Island below the confluence of the Sacramento and San Joaquin Rivers (Figure 1).

Each gear targets different life-stages of juvenile Chinook salmon. The beach seine is considered more efficient for smaller juvenile salmon (fry) rearing near the shore, whereas the trawls sample in the middle of the channel where the larger juvenile salmon (smolts) migrate. Also the peak of fry catch is between January and March whereas the peak of smolt catch is between April and June. Juvenile salmon catches are made up of primarily fall run, but sampling at stations in the Sacramento River, the Delta and the Estuary below the confluence could also capture winter, spring and late-fall run.

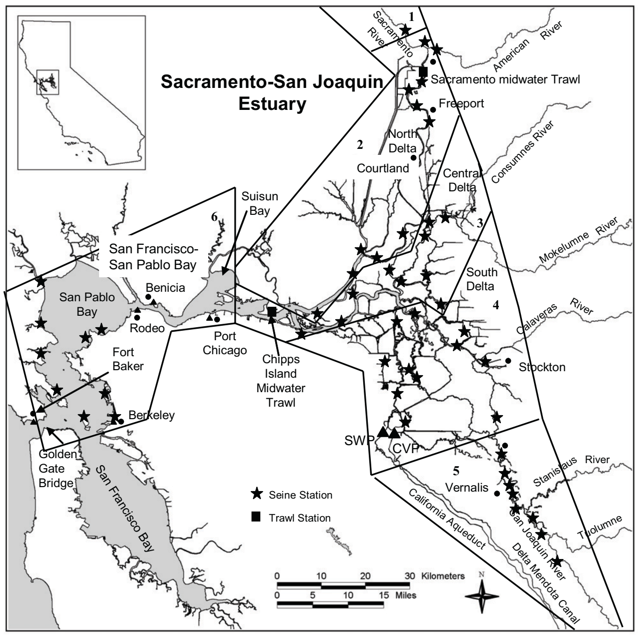

Figure 1 Trawl and beach seine sites in relation to sampling regions. Region 1 is on the lower Sacramento River and includes beach seine sites at Knights Landing, Reels Beach, South Meridian, Wards Landing and Colusa State Park (not shown), Region 2 is in the North Delta, Region 3 is the Central Delta, Region 4 is the South Delta, Region 5 is the lower San Joaquin River and Region 6 is San Francisco/San Pablo Bay.

The estimates of abundance of juvenile salmon caught in the beach seine and in the trawls include unmarked hatchery fish and progeny from natural fish spawning in the rivers. Marked fish caught in the sampling have been excluded from these estimates of abundance. In recent years, no unmarked fry have been released from the hatcheries to limit competition with wild stocks.

Relative abundance of juvenile Chinook salmon in each region or trawl was estimated by averaging three monthly catch per cubic meter (CPM^3) estimates (January – March for fry and April – June for smolts). Each monthly average CPM^3 was estimated by averaging the four weekly CPM^3 values, and the weekly values were obtained by averaging the daily CPM^3 values within each week. Daily CPM^3 was obtained by averaging tows or sites within each region by day. CPM^3 by site or tow was obtained by dividing the catch at each site or tow by the volume of water sampled.

The volume of water sampled in the beach seine was estimated using the following formula:

$$V = L*W*1/2\ D$$

where: V= the volume of water sampled for the beach seine

L = the length of the area sampled perpendicular to shore

W = the width of the area sampled parallel to shore, and

D = the average depth of the two points furthest from shore.

The volume of water sampled in each tow of the trawl was calculated using the formula:

$$V = A*D$$

where: V= the volume of water sampled by the trawl,

A = the fishing area of the mouth of the net and

D = the distance in linear meters traveled during the tow based on a flow meter

The mouth area used was based on previous measurements of horizontal and vertical distances between doors that hold the net open (USFWS 1994). The distance in linear meters traveled was estimated by multiplying the meter rotations (General Oceanics flowmeter) by the Standard Speed Rotor Constant (26874) and dividing the result by a conversion factor (999999).

Relative juvenile salmon survival

To estimate relative survival of juvenile salmon upstream and at differing locations in the Delta from mark and recapture techniques, paired groups of marked fall run hatchery fry (< than 60 mm) were released in several years and recovered one to four years later in the ocean fishery. Survival in two "paired" regional areas was estimated in several years and compared with each year to assess relative survival between regions. The paired group design allows relative survival between regions to be estimated by factoring out parameters common to both groups, such as fish size, hydrology, water temperature etc. Recovery rates in the ocean fishery vary between years, thus only comparisons between paired groups released in the same year is valid. This method assumes recovery rates within a pair are similar over the entire 3 year ocean recovery period. An index of survival was obtained for each release group by dividing the number of expanded ocean recoveries by the number released. The group released on the Sacramento River just downstream of Red Bluff Diversion Dam was paired with a group in the Delta released at Clarksburg to compare upper Sacramento River fry survival to that observed in the Delta. Groups released at Isleton were paired with groups released on the Lower Mokelumne River to compare survival in the North Delta to that in the Central Delta (Figure 2). For each pair, roughly 50,000 hatchery fry were released at each location in February or March with a second set released approximately 2 weeks later. In recent years, we have incorporated two tag codes for each release to obtain some measure of variation around each release. The groups were released at the two locations usually within a day or so of each other, but in some years they were released as many as five to eight days apart. Fish were of similar size within pairs. To examine patterns of survival, average recovery rates (plus and minus 1 standard deviation) were calculated from both groups released per location by year. In some years, only one group of pairs with only one tag code per release group was released; thus, for those years only the point estimate could be reported. Ocean recovery rates were only reported for fry releases made prior to 2004, because of insufficient recovery periods.

Results

Relative juvenile salmon abundance

The total combined monthly average CPM^3 for all beach seine regions, between January and March, was relatively low in 2005 (Figure 3) when compared to the same 3-month averages for years since 1995, but higher than most years previous to 1995. In most years, the lower Sacramento River or North Delta region has the highest regional CPM^3, followed by the Central Delta region, with relatively low CPM^3 values in the San Joaquin River and Bay regions.

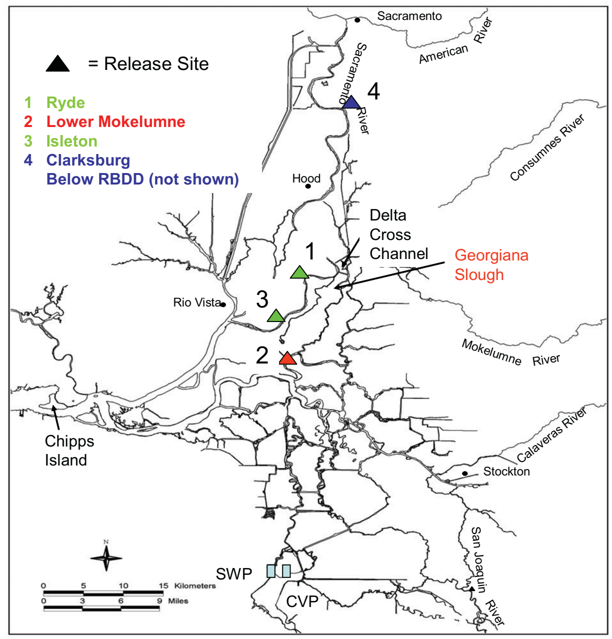

Figure 2 Release sites for marked Chinook salmon fry released on Sacramento River and interior Delta

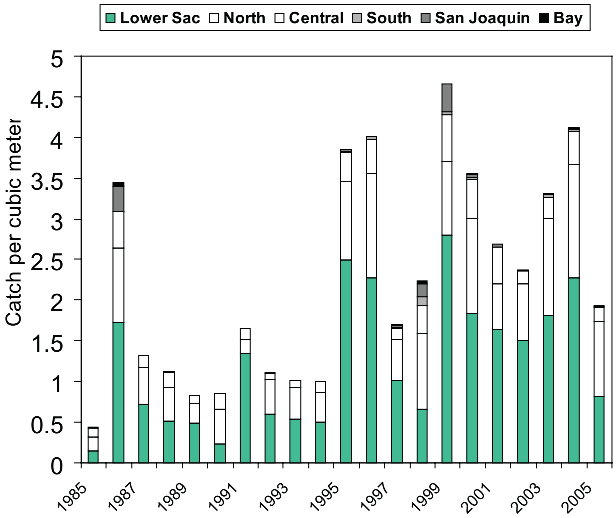

Figure 3 Summed mean catch per cubic meter for January through March of all unmarked juvenile Chinook in the lower Sacramento, North Delta, Central Delta, South Delta, San Joaquin, and Bay region beach seines between 1985 and 2005. Bay region beach seining was not conducted between 1987 and 1996 and the San Joaquin beach seine started 1994.

With recent data added, we found that the abundance of juvenile salmon per unit flow in the north Delta in 2002-2005 appeared greater than in previous years (Figure 4). In the Bay, abundance per unit flow was generally similar to historical values, with possibly 2003 being an exception (Figure 5).

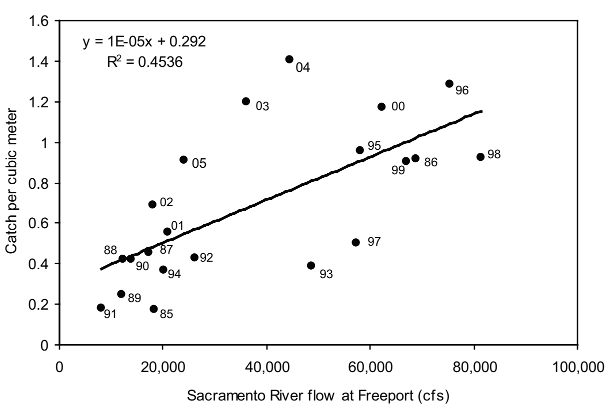

Figure 4 Mean catch of Chinook salmon fry between January 1 and March 31,1985 through 2005, in the North Delta beach seine region regressed with mean February flow at Freeport.

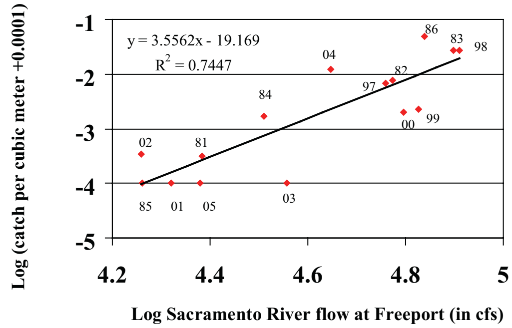

Figure 5 Mean log of catch per cubic meter + 0.0001 of juvenile Chinook salmon between January and March at beach seine sties within San Francisco Bay region versus log of mean flow at Freeport during February between 1981 and 1986 and between 1997 and 2005

Average CPM[3] of juvenile salmon caught in the Sacramento midwater trawl between April and June in 2005 was roughly similar to that observed since 1996 (Figure 6). In recent years, (2001-2003 and 2005) fewer juvenile Chinook migrated downstream past Sacramento between April and June when mean February flows were less than 40,000 cfs (Figure 7).

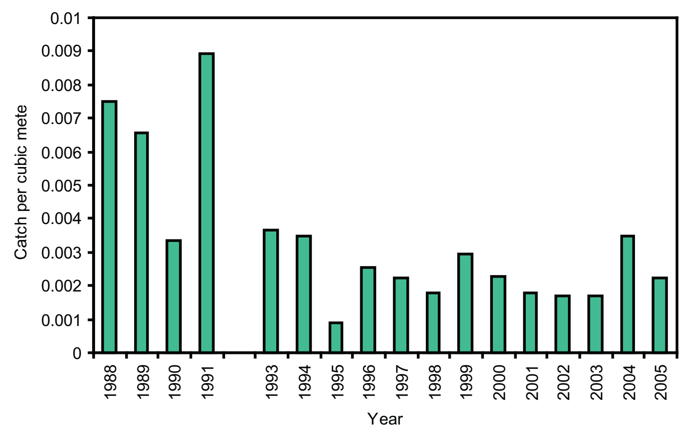

Figure 6 Mean catch of Chinook salmon smolts between April 1 and June 30, 1985 through 2005, in the midwater trawl at Sacramento. There was no sampling during April 1992, so that year was not included.

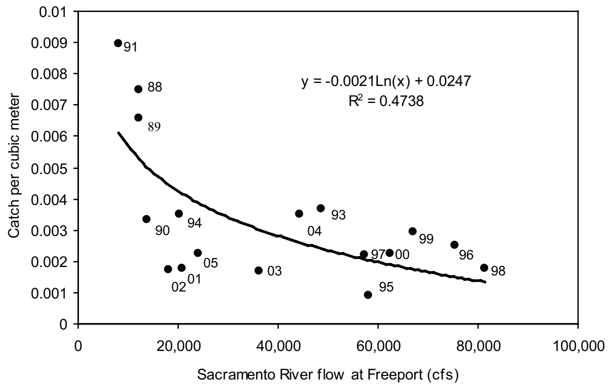

Figure 7 Mean catch of Chinook salmon smolts between April 1 and June 30, 1985 through 2005, in the midwater trawl at Sacramento regressed with mean February flow at Freeport. There was no sampling during April 1992, so that year was not included.

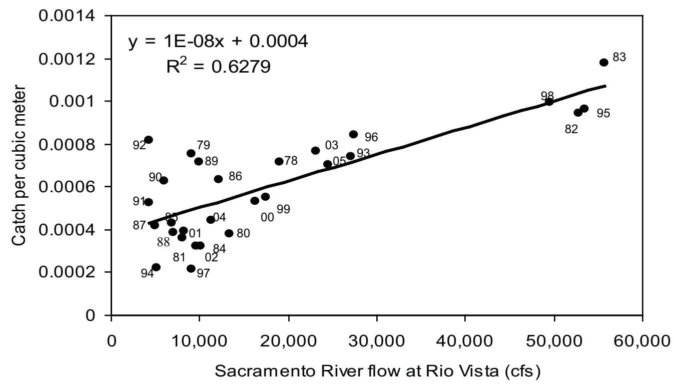

Figure 9 Mean catch of unmarked Chinook salmon smolts per cubic meter in the midwater trawl at Chipps Island between April and June of 1978 to 2005 versus mean daily Sacramento River flow at Rio Vista between April and June in cfs

Average CPM[3] of juvenile Chinook salmon caught between April and June at Chipps Island, indicate that indices in 2005 were higher than in 2004 and higher than indices observed since 1999, except for 2003 (Figure 8). Average Sacramento River flow at Rio Vista between April and June appears to account for the differences in abundance observed between years at Chipps Island (Figure 9), especially when flows are greater than about 20,000 cfs, such as was the case in 2003.

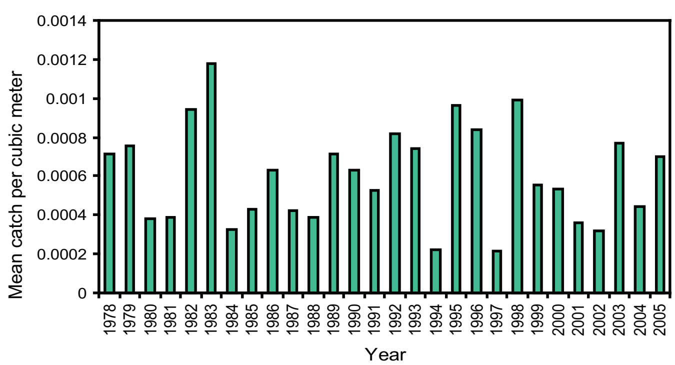

Figure 8 Mean catch of unmarked Chinook salmon smolts per cubic meter in the midwater trawl at Chipps Island between April and June of 1978 to 2005

Relative juvenile salmon survival

Relative survival, for hatchery fry released in the upper Sacramento River near Red Bluff, appears generally higher than for fry released in the Delta at Clarksburg (Figure 10). The differences in ocean recovery rates were greatest when mean February river flow at Freeport was greater than about 35,000 cfs (1980, 1986, 2000 and 2003). In contrast, fry released at Isleton appeared to survive better than those released in the lower Mokelumne River in 2002 and 2003, two of the drier years (mean February river flows at Freeport of less than 40,000 cfs (Figure 11).

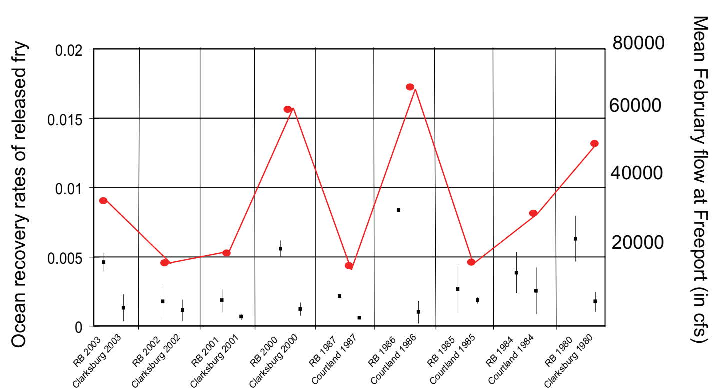

Figure 10 Mean recovery rates (+/- 1 standard deviation) in the ocean fishery (black squares and line) of fall run Chinook salmon fry (<60 mm) released below Red Bluff Diversion Dam (RB) and in the Delta (Clarksburg) between 1980 and 2003 and mean February flow (in cfs) at Freeport (large red circles)

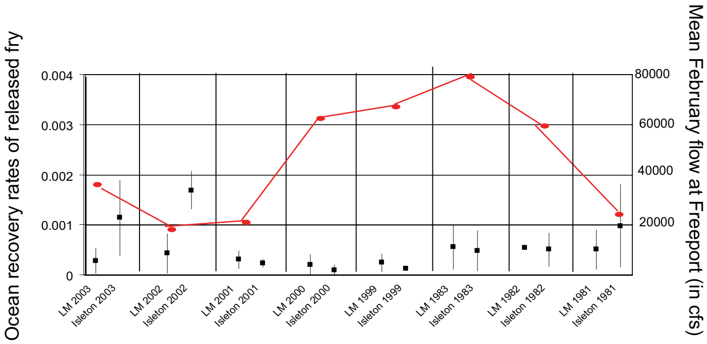

Figure 11 Mean recovery rates (+/- 1 standard deviation) in the ocean fishery (squares) of fall run Chinook salmon fry (<60 mm) released in the Delta at the Lower Mokelumne River just upstream of the San Joaquin River and on the Sacramento River at Isleton between 1981 and 1983 and 1999-2003 and mean February flow (in cfs) at Freeport (line)

Summary

Hydrology appears to account for some of the differences we see in relative juvenile salmon abundance and survival; however, the hydrology does not appear to account for the potential changes in the proportion of juvenile salmon entering the Delta as fry or smolts. The abundance of juvenile salmon per unit flow in the North Delta beach seines between January and March may have increased, while abundance may have decreased in the Sacramento trawl between April and June in many of the last five years. It is uncertain why these potential changes have occurred but may be related to limiting rearing habitat in near-by hatchery supported streams (American and Feather Rivers). Overall production at Chipps Island did not appear to change. Relative fry survival upstream and within the Delta also appears to be affected by hydrology with the greatest survival observed upstream in wet years. Potentially fry released upstream in wet years benefit from floodplain habitat not available in dry years or in the Delta. The lowest survival was observed in the Central Delta in the last two years when data is available (2002 and 2003). Both of these years were relatively dry during the month of February. Mortality may be higher on fry released in the central Delta in drier years from higher water temperatures and predation, and an increased potential for entrainment at the south Delta agricultural diversions and export facilities.

Measuring juvenile salmon abundance and survival indices over a long period of time allows us to monitor the relative differences in the juvenile salmon population between years and to put yearly observations into perspective. Once we take into account the variation in abundance and survival due to changes in hydrology, anomalies due to other factors can be better identified in the future.

References

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IEP Newsletter, 2003. IEP Newsletter for the Interagency Ecological Program for the San Francisco Estuary., Vol 16, Number 2, Spring 2003 pages 27-31

USFWS. 1994. 1993 Annual Progress Report: Abundance and Survival of Juvenile Chinook salmon in the Sacramento- San Joaquin Estuary. Stockton (CA): US Fish and Wildlife Service.

Central Valley Chinook Salmon Catch and Escapement

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In 2005, the ocean catch of Central Valley Chinook salmon south of Point Arena decreased in both the commercial and recreational fisheries from 2004. The catch per unit effort (CPUE) statewide also decreased between 2004 and 2005. Compared to the 1970-2005 period of record both the ocean catch and catch per unit effort were below average.

The total escapement of Central Valley Chinook salmon was higher in 2005 than in 2004 and remains above the average escapement for the 1970-2005 period of record. In 2005, the fall-run Chinook escapement to the Sacramento River system increased from 2004 and was the greatest contributor to the Central Valley fall-run escapement. Spring-run escapement to Mill, Deer, and Butte creeks increased from 2004 to 2005. Winter-run escapement increased substantially between 2004 and 2005 based on the mark-recapture carcass survey estimate.

Central Valley Chinook Ocean Harvest Index and Ocean Catch

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

The PFMC's Central Valley Chinook ocean harvest index (OHI) is an approximate harvest rate. The OHI is calculated by dividing the total ocean catch south of Point Arena by the catch plus escapement. The ocean harvest index does not include inland harvest, which may be up to 25% of the returning adults. In 2005, the OHI decreased to 46% due to decreased ocean harvest (Figure 1). The estimated Central Valley Chinook escapement increased to 451,600 spawners (Figure 1).

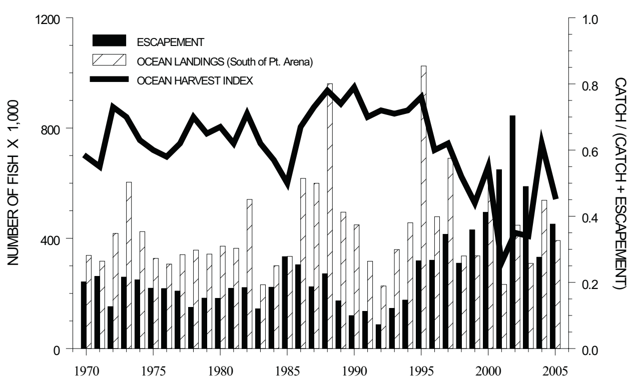

Figure 1 PFMC Chinook salmon ocean catch, the Central Valley Chinook total adult spawner escapement, and the ocean harvest index, 1970-2005

Statewide the ocean catch decreased between 2004 and 2005. For the commercial fishery, the number of days fished decreased from 21,700 in 2004 to 16,700 in 2005 and the CPUE decreased from about 23,100 fish/day to 16,700 fish/day (Figure 2). The CPUE (fish/day) increased in Oregon and decreased in Washington but the CPUE for all three states remained well above average for the 1970-2005 period (Figure 2).

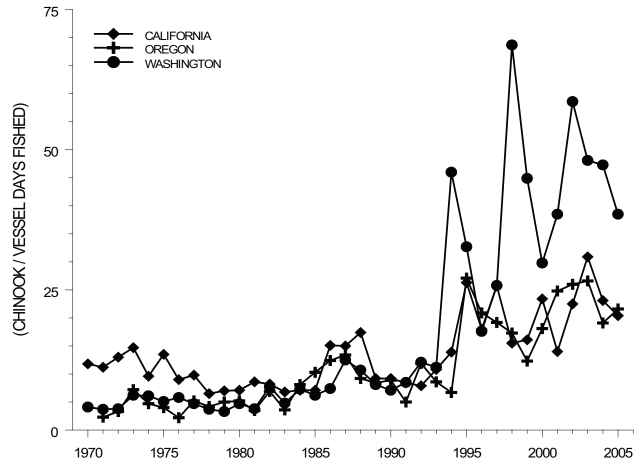

Figure 2 Chinook salmon catch per unit effort (estimated total number of fish caught / total number of boat days fished) in California, Oregon, and Washington, 1970-2005

Central Valley Fall run Chinook Escapement

Escapement data reported to the PFMC are partitioned into "natural" and "hatchery" categories. Natural escapement includes all fish returning to spawn in natural areas; these fish are of both natural and hatchery origin. Available data indicate that hatchery-produced fish constitute a majority of the natural fall run Chinook spawners in the Central Valley. Hatchery escapement includes all fish returning to the hatcheries; these fish are also of both natural and hatchery origin. These terms, as defined here, are used throughout this paper and in each of the figures.

In 2004, a spawner escapement goal of 122,000 to 180,000 Sacramento River system fall run Chinook (hatchery and natural adults combined) guided PFMC management for this stock. The estimated number of natural spawners was approximately 200,400 exceeding the PFMC management goals (Figure 3).

The fall-run Chinook escapement to the mainstem Sacramento and Yuba rivers increased from 2004 levels but escapement to the Feather and American rivers decreased (Figures 4-7). In the San Joaquin River system the fall-run Chinook escapement increased from 2004 levels but remained slightly below the average escapement for the 1970-2004 period (Figure 8).

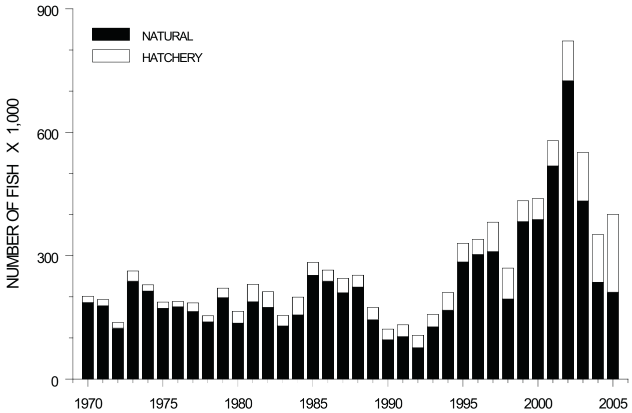

Figure 3 Annual natural and hatchery fall run Chinook escapement to the Sacramento River and major tributaries, 1970-2005

Natural spawner escapement to the mainstem Sacramento River increased from about 77,800 in 2004 to 100,000 in 2005 but remained below the average escapement for the 1970-2005 period (Figure 4). Natural spawner escapement in the American River decreased from about 88,900 in 2004 to 53,000 in 2005 but remained above the average escapement for the 1970-2005 period (Figure 5). In the Feather River, the estimated escapement decreased from 54,200 in 2004 to 43,100 in 2005 and dropped below the average escapement for the 1970-2005 period (Figure 6). The estimated Yuba River fall-run escapement increased slightly from 14,500 in 2004 to 15,100 in 2005 and remains just below the average escapement for the 1970-2005 period (Figure 7).

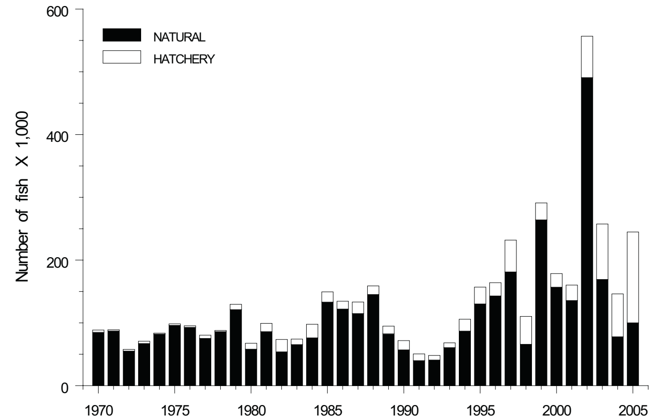

Figure 4 Annual natural and hatchery fall run Chinook escapement to the mainstem Sacramento River, 1970-2005

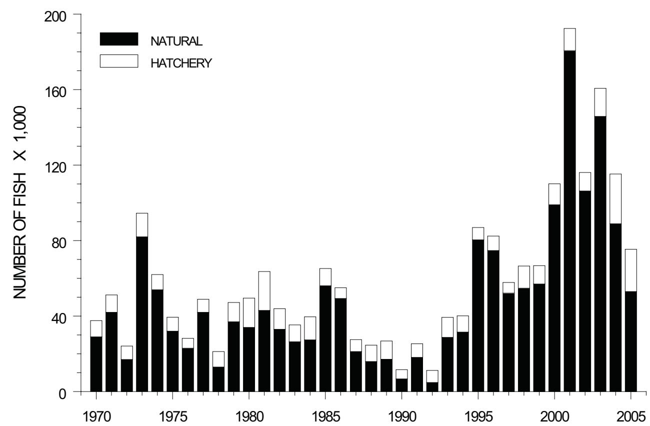

Figure 5 Annual natural and hatchery fall run Chinook escapement to the American River, 1970-2005

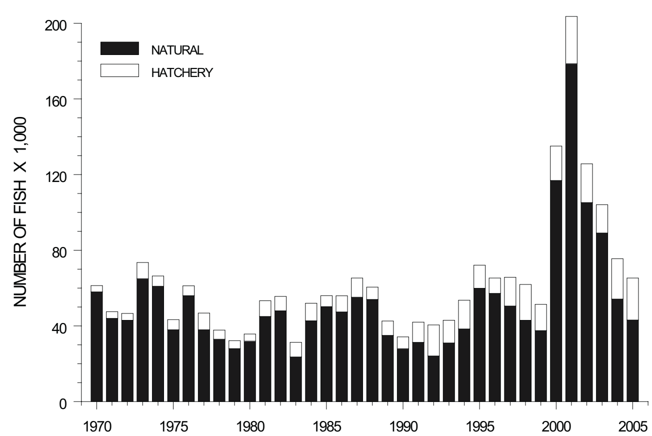

Figure 6 Annual natural and hatchery fall run Chinook escapement to the Feather River 1970-2005

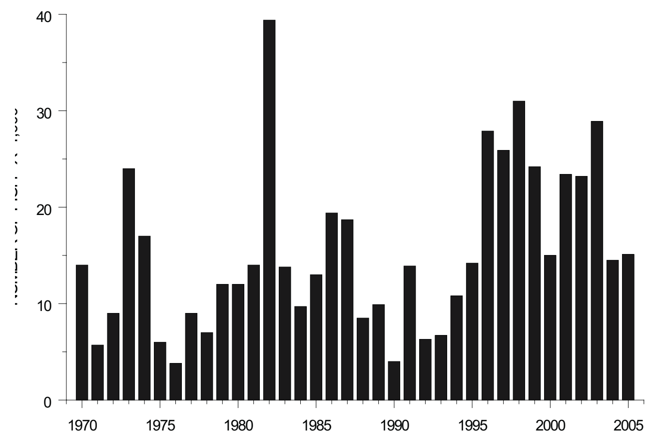

Figure 7 Annual natural fall-run Chinook escapement to the Yuba River, 1970-2005

On the San Joaquin River system, the estimated natural spawner escapement increased from about 10,500 in 2004 to 17,000 in 2005 (Figure 8). However, the escapement decreased from the escapement from three-years earlier and remains below the average escapement for the 1970-2004 period. In 2005, the hatchery spawners accounted for approximately 26% of the total escapement which remains above average number of hatchery spawners for the 1970-2005 period (Figure 8). The San Joaquin River system includes spawners from the Mokelumne, Stanislaus, Tuolumne, and Merced rivers and has constituted less than 10% of the total Central Valley spawner escapement since 1986.

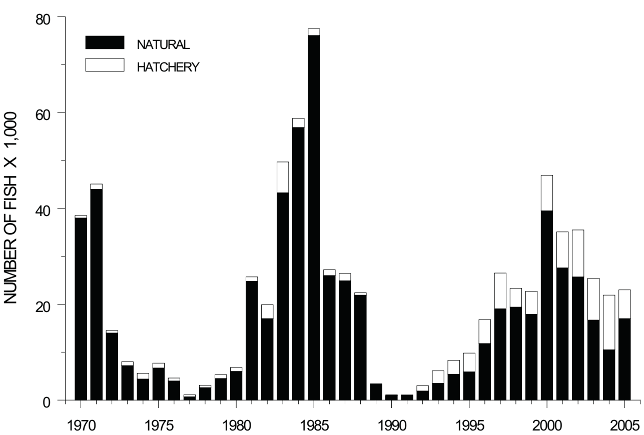

Figure 8 Annual natural and hatchery fall-run Chinook escapement to the San Joaquin River system, 1970-2005

Sacramento River System Spring-run Chinook Escapement

In 2005, the escapement to Deer Creek increased to approximately 2,240 natural spawners (Figure 9). The number of spawners was similar to the estimated 2,190 spawners from three years earlier (Figure 9). The number of natural spawners also increased on Mill Creek with an estimated escapement of 1,150 which was lower than escapement three years earlier (Figure 9).

The Butte Creek escapement increased from about 7,400 in 2004 to 10,600 in 2005 based on a snorkel survey methodology (Figure 9). The estimated escapement increased from the estimated 8,800 spawners three years earlier. The estimated escapement to Butte Creek continues to surpass the other spring-run tributaries and the mainstem Sacramento River (Figure 9).

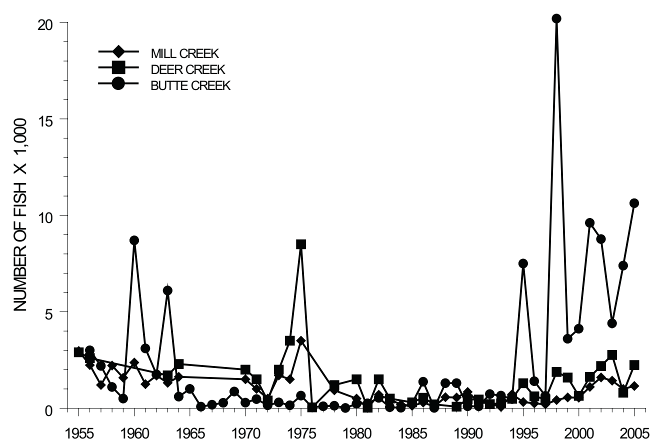

Figure 9 Annual spring-run Chinook escapement to Mill, Deer, and Butte creeks, 1956-2005

Winter-run Escapement to the Sacramento River below Keswick Dam

DFG has been using the mark-recapture carcass survey data to estimate escapement since 2001. The estimated in-river escapement of winter-run Chinook nearly doubled from about 7,701 in 2004 to 15,730 in 2005. This was the highest total escapement estimated since 1981. The number of adult females returning to spawn in 2005 was higher than in the three previous years.

Escapement estimates based on extrapolated counts at Red Bluff Diversion Dam from 1967 through 2005 were examined for long-term population trends (Figure 10). The estimated escapement decreased from approximately 7,200 in 2004 to 5,300 in 2005. This may have been due to unusually high Sacramento River flows early in the winter-run migration season, prior to gate closure at Red Bluff Diversion Dam. A cohort replacement rate was calculated by dividing the sum of the current year's three-year olds and the previous year's two-year olds by the same value from three years earlier. This cohort replacement rate was 0.7 in 2005 based on Red Bluff Diversion Dam data (Figure 10).

Most of the data presented in this article is published in the PFMC's *Review of the 2005 Ocean Salmon Fisheries* and the PFMC's 2006 Preseason report. A copy of the report is available by calling (503) 820-2280 or on-line at www.pcouncil.org. I thank Colleen Harvey Arrison (DFG) for providing the spring run Chinook escapement data for Mill and Deer creeks and Tracy McReynolds (DFG) for providing the spring run Chinook escapement data for Butte Creek.

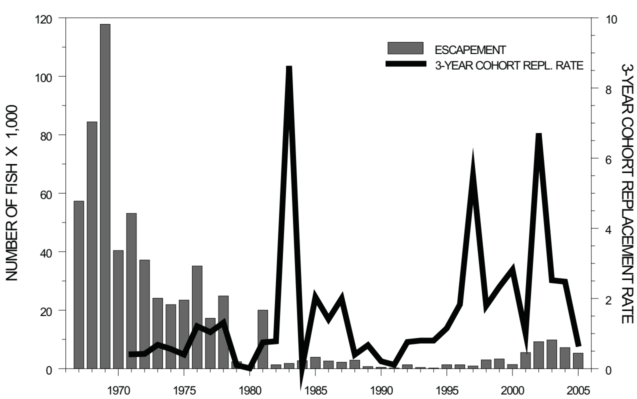

Figure 10 Annual winter-run Chinook escapement to the upper Sacramento River and the three-year cohort replacement rate, based on extrapolated counts at Red Bluff Diversion Dam, 1967-2005

CONTRIBUTED PAPERS

Phytoplankton Biomass and Production in the Delta and Suisun Bay: Current Conditions and Trends[1]

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Introduction

Phytoplankton biomass is the main source of energy and organic matter for higher trophic levels in the Sacramento-San Joaquin Delta and Suisun Bay (Jassby et al. 1993, Jassby and Cloern 2000, Sobczak et al. 2005). Phytoplankton biomass and production has been low compared to other estuaries since the beginning of routine monitoring in the 1970s. During the period 1975-1995, Delta-wide primary production declined even further (Jassby et al. 2002).

Because current phytoplankton levels limit the growth rate of primary consumers such as zooplankton (Müller-Solger et al. 2002), the negative trends in phytoplankton biomass and production are a potential factor behind widespread Delta fish species declines during the past few decades. Several fish species have continued their declines to dramatically low levels in recent years (Hieb et al. 2005). There is at present no consensus as to whether or not these declines are a recent step decrease in response to changes in estuarine management or a continuation of the longer-term trends. In any case, one prominent hypothesis is that these recent declines represent a further restriction of the food supply.

The last analysis of Delta-wide production covered years only through 1995 (Jassby et al. 2002). It is therefore time to ask what has happened to phytoplankton biomass and production in the intervening years. Beginning in 1996, data were no longer collected at a number of key stations needed for estimating overall Delta production. Monitoring has since been restored in some cases, however, enabling us to examine phytoplankton and related data at a variety of Delta and Suisun Bay sites, even if not on an average Delta-wide basis.

This article examines recent changes in both phytoplankton biomass, as indexed by chlorophyll *a*, and phytoplankton gross primary production (GPP), as estimated from incident solar radiation, water clarity and phytoplankton biomass. It is a brief report that is part of a larger effort to understand mechanisms and develop forecasting models. The emphasis here is on a basic description of recent levels and trends of biomass and production and how they compare to the longer-term historical conditions. There is no attempt here to correct concentrations for flow, because it is the levels and trends of these measured concentrations that are of interest to higher organisms. An investigation of flow-corrected trends, however, is underway as part of the larger effort.

Methods

Environmental Monitoring Program (EMP) discrete sampling sites range from San Pablo Bay east to the upstream boundaries of the Delta on the Sacramento, Mokelumne, and San Joaquin rivers. Stations are sampled approximately monthly. Seventeen sites were chosen that had a long record without large gaps and included data for recent years. (Figure1) Data were obtained either directly from Marc Vayssières of the California Department of Water Resources or downloaded from the Bay Delta and Tributaries Project (www.bdat.ca.gov). These data were combined with earlier data collected by the U.S. Bureau of Reclamation. Variables used here include chlorophyll *a,* water depth at which photosynthetically active radiation (PAR) reaches 1% of surface PAR ("photic depth"), and turbidity. Daily irradiance was also obtained for Davis, California, the nearest location for which a long enough record is available (www.cimis.water.ca.gov).

1. This research is supported by CALFED grant ERP-02-P33.

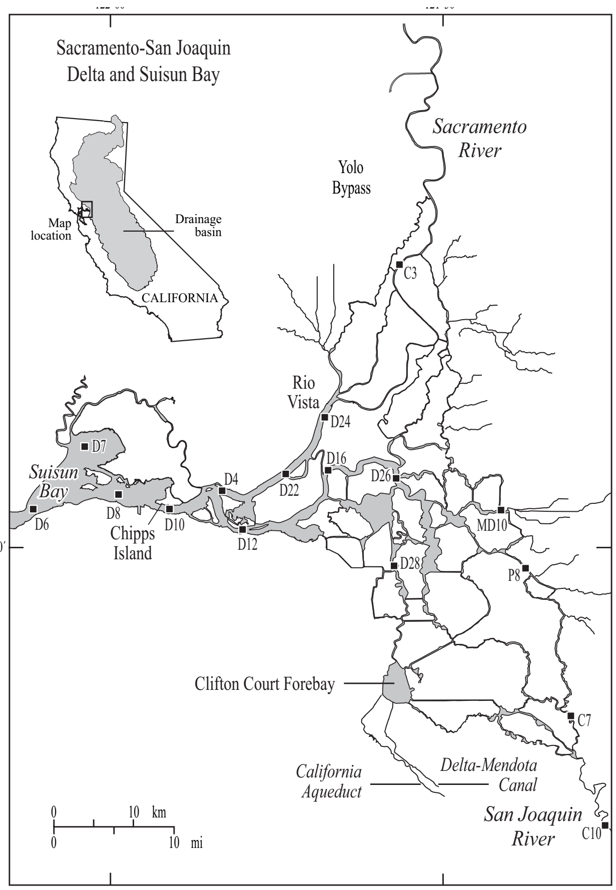

Figure 1 The Sacramento-San Joaquin Delta and Suisun Bay, showing the locations of monitoring stations used in this study, except for D41 in San Pablo Bay downstream of D6 (modified from a map by Jeanne DiLeo, U.S. Geological Survey, Menlo Park, Calif.).

Gross primary production was estimated as described by Jassby et al. (2002; see their Equation 1), using data for chlorophyll *a,* surface PAR, and estimated vertical attenuation coefficient. The attenuation coefficient could be calculated directly from the photic depth, when available. When turbidity but not photic depth was available, the attenuation coefficient was estimated from a linear model relating attenuation coefficient to turbidity. The model parameters were determined by generalized least squares with weights set to a power of the fitted values.

Monthly time series for chlorophyll *a* and GPP at each station were created from their monthly medians. Annual GPP was determined for the period March-October only, as the remaining months were often not sampled. The great majority of annual GPP takes place during this period in temperate estuaries of the northern hemisphere. Data gaps of three months or less during March-October were filled by linear interpolation. If a data gap exceeded three months, annual production was not estimated for that particular station and year.

Trends in the monthly time series were determined using the U.S. Geological Survey software package ESTREND (Slack et al. 2003). In this approach, trends are estimated by the Theil slope (median slope of all lines joining the same month in different years), and their significance is determined by the Seasonal Kendall test with a serial correlation correction.

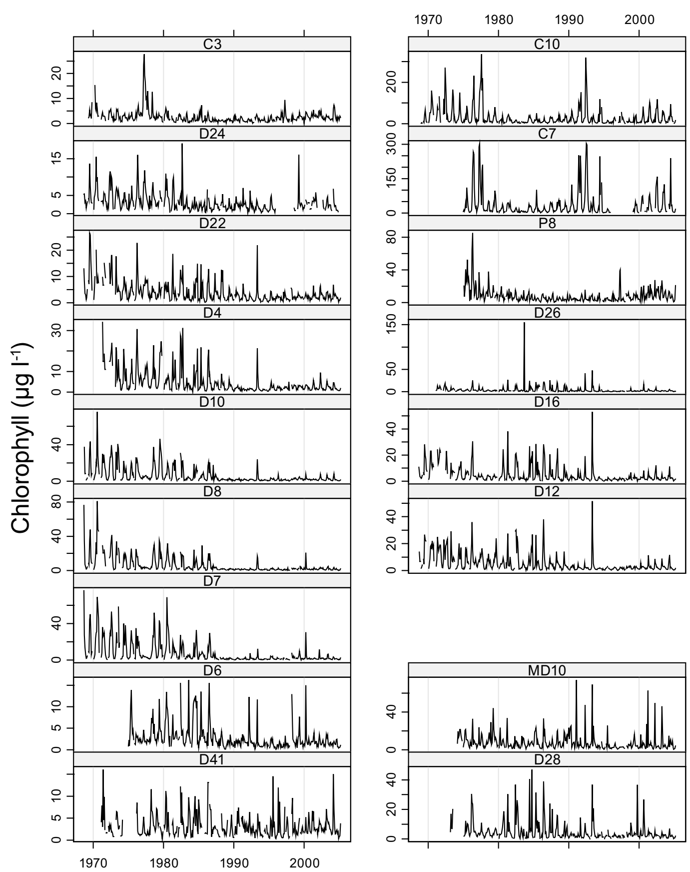

Figure 2 Monthly time series of chlorophyll *a* at stations throughout the Delta and Suisun Bay. Note that y-axes differ from plot to plot. Plots in the left column are arranged in a sequence from the Sacramento River's upstream Delta boundary through Suisun Bay to San Pablo Bay. Plots in the upper block of the right column are arranged in a sequence from the San Joaquin River's upstream Delta boundary to just before Suisun Bay.

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Table 1 Trends in chlorophyll *a* at stations throughout the Delta and Suisun Bay over the indicated time periods

Station	*Begin*	*End*	*Median chlorophyll a*	*Trend*[a]	*Trend*[b]	*Direction*[c]
			(μg l-1)	*(μg l-1 yr-1)*	*(% yr-1)*	
C3	3/1/1969	3/1/2005	2.1	-0.02	-0.8	
D24	9/1/1968	3/1/2005	2.4	-0.07	-2.7	down
D22	9/1/1968	3/1/2005	2.5	-0.09	-3.6	down
D4	3/1/1971	3/1/2005	2.5	-0.12	-4.7	down
D10	10/1/1968	3/1/2005	2.4	-0.14	-5.8	down
D8	9/1/1968	3/1/2005	2.1	-0.13	-6.2	down
D7	9/1/1968	3/1/2005	2.4	-0.19	-7.7	down
D6	1/1/1975	3/1/2005	1.9	-0.06	-3.2	down
D41	3/1/1971	3/1/2005	2.4	0.00	-0.1	
C10	1/1/1969	3/1/2005	13.0	-0.14	-1.1	
C7	1/1/1975	3/1/2005	14.6	0.00	0.0	
P8	2/1/1975	3/1/2005	5.6	-0.06	-1.0	
D26	3/1/1971	3/1/2005	2.0	-0.06	-2.7	down
D16	9/1/1968	3/1/2005	2.5	-0.08	-3.1	down
D12	10/1/1968	3/1/2005	2.6	-0.14	-5.2	down
MD10	3/1/1974	3/1/2005	5.1	-0.13	-2.5	down
D28	3/1/1973	3/1/2005	2.6	-0.07	-2.8	down

[a] Thiel trend

[b] Thiel trend divided by median. Note that this nonparametric estimate of trend is not the slope of a linear model: the long-term decline cannot be estimated simply by multiplying by the time span in years.

[c] Sign of trends significant at the $p < 0.05$ level.

Results

The monthly chlorophyll time series for each station is plotted in Figure 2. Although it is difficult to discern much detail at this plotting scale, certain general features of the data set can be seen easily. Prominent among these is the collapse of the phytoplankton community in Suisun Bay (stations D7, D8, D10) after *Corbula amurensis* invaded in 1986 (Alpine and Cloern 1992). This clear suppression of phytoplankton extends upstream on both rivers, although with a delay. A second major feature is the huge bloom size at times on the San Joaquin River upstream of the Stockton Ship Channel (stations C7 and C10), controlled largely by flow rates (Jassby 2005). A final, somewhat more subtle characteristic is the gradual decline of baseline (winter) values from the beginning of the record, especially on the Sacramento River (Jassby et al. 2002).

The overall impression of a long-term decline is confirmed by the trend tests (Table 1). The long-term trends are not significant at the most upstream stations (C3, C10, C7, P8) nor at the most downstream (D41), but they are significant at all intervening stations. All significant trends are negative and their size is large. Note that the largest percentage declines are in and around Suisun Bay.

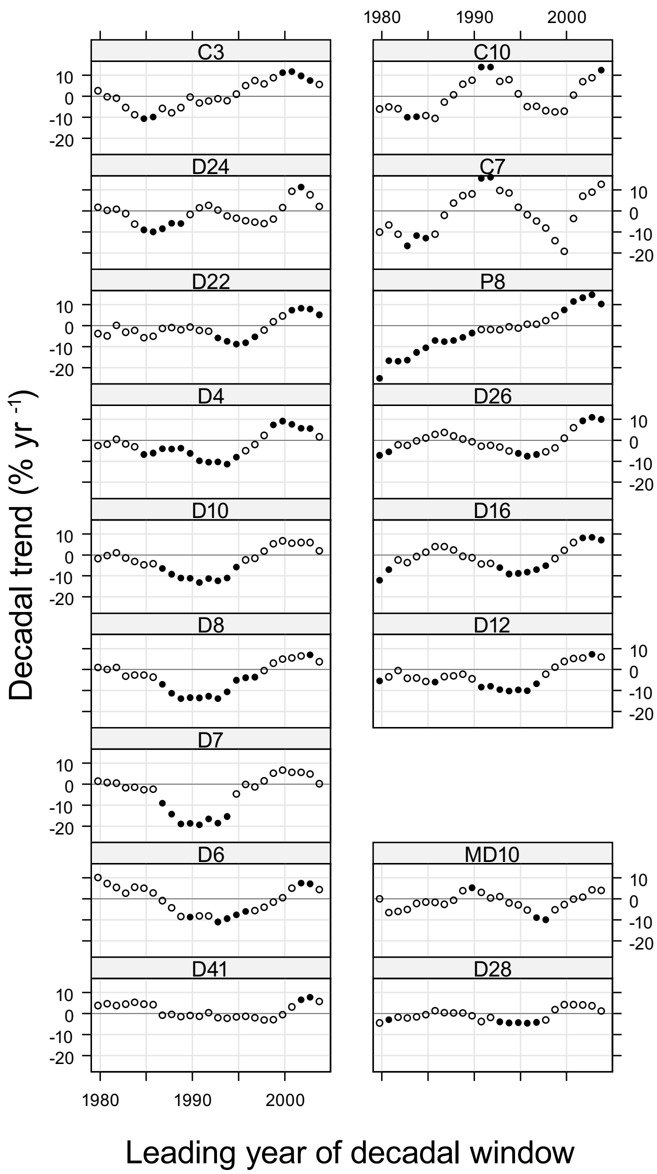

Figure 3 Decadal trends of chlorophyll a at same stations as in Figure 2. Each data point represents the Seasonal Kendall trend for the decade ending in that year. Trends that are statistically significant ($p < 0.05$) are indicated by solid circles.

If we examine the chlorophyll trends at finer time scales, however, the results change. A trend value depends on the window of time chosen for analysis, as well as the method, and so the trend itself can form a time series. We calculated the trends for a moving window 10 years wide and plotted each decadal trend value at the leading edge of the window (Figure 3). The most negative trends over the previous 10 years in Suisun Bay occurred during the early 1990s. Just upstream of Suisun Bay on the Sacramento and San Joaquin rivers, decadal trends were most negative in the mid 1990s. In recent years, however, the decadal trends have been positive over most of the Delta. Although not always statistically significant, especially within Suisun Bay, the more recent trends are therefore opposite in direction to the long-term changes. They have not, however, compensated very much for the earlier chlorophyll declines. There is some visual indication that the recent uptrends are transitory, having peaked in the last few years and now tending back to zero

GPP is a more direct measure of the food supply to consumers and higher organisms. The decline in annual GPP (i.e., March-October) by the 1990s was widespread and strong (Figure 4), and values remain at these lower levels. Because of data gaps, decadal trends in GPP are not as informative as for chlorophyll and are not carried out here. We can, however, get a sense of changes over time by examining median values of all daily estimates for successive five-year periods (Table 2). Median daily GPP in the Delta and Suisun Bay dropped from 277 mg C m^{-2} d^{-1} during the first period (1970-74) to 101 mg C m^{-2} d^{-1} during the last (2000-04), a drop of 64%. In comparison, the corresponding drop in chlorophyll was a slightly larger 68%. Both therefore have declined by about two-thirds since the start of the record. Values were even lower during the 1990s, in accordance with the evidence for recent positive trends in chlorophyll *a*.

Table 2 Median values of measured chlorophyll a and estimated gross primary production (GPP) in the Delta and Suisun Bay during successive 5-year periods

Period	*Chlorophyll*	*GPP*
	($\mu g\ l^{-1}$)	*(mg C m^{-2} d^{-1})*
1970-74	*7.1*	*277*
1975-79	*5.1*	*219*
1980-84	*4.5*	*183*
1985-89	*3.1*	*156*
1990-94	*2.0*	*97*
1995-99	*2.0*	*80*
2000-04	*2.3*	*101*

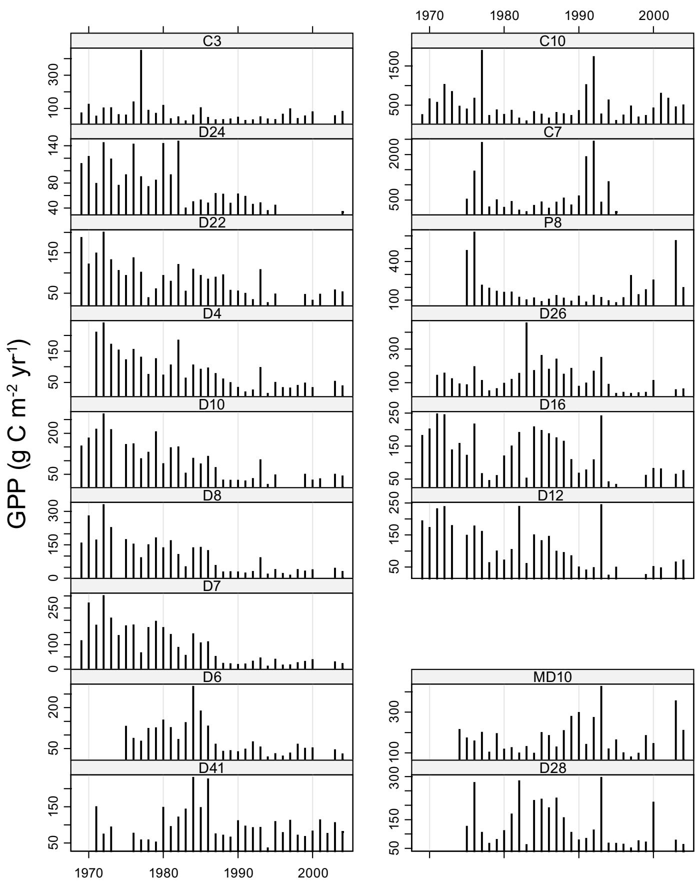

Figure 4 Annual gross primary production at same stations as in Figure 2 for the period March-October

Discussion

Even at the beginning of the historical record for this estuary, values of gross primary production were low compared to other temperate estuaries (Day et al. 1989). A subsequent decline of two-thirds places the Delta and Suisun Bay among the least productive estuaries. The relation between fisheries yield and primary production based on a cross-section of estuaries implies that the most likely response of overall fish production has been a similar decline, despite the noisiness of the relationship (Nixon 1988). The implications for individual fish species are of course less certain, but food limitation must be considered a possible major factor in the long-term decline of any fish species in the Delta. The chlorophyll data of Table 2 also have nutritional implications. Growth rate and egg production of at least some zooplankton species in the estuary respond strongly to values less than about 10 µg l^{-1} (e.g., Müller-Solger et al. 2002, Kimmerer et al. 2005). The decline in median values from 7.1 to 2.3 µg l^{-1} therefore takes place in a critical range that could have had a dramatic impact on zooplankton growth and the productivity of higher organisms dependent on it over the long term.

More recent declines of fish abundance cannot be attributed, however, simply to corresponding decreases in phytoplankton biomass and production. As we have seen, trends in biomass have been neutral, at least, over the last decade throughout the Delta and Suisun Bay. Most trends are significantly positive at stations just upstream and downstream of Suisun Bay on both rivers.

Even though trends of total phytoplankton biomass and production are not consistent with recent fish declines, it is possible that changes in species composition of the phytoplankton community play a role. Phytoplankton differ widely in their nutritional value to primary consumers, based in part on their highly unsaturated fatty acid content. In general, fatty acid content and nutritional value varies much more between than within taxa. Diatoms and cryptophytes, for example, tend to be more nutritious than cyanobacteria for many zooplankton species (Brett and Müller-Navarra 1997). Our ongoing analysis is showing that the total number of “nutritious” cells (diatoms, cryptophytes, chrysophytes, dinoflagellates and unidentified flagellates) is down in Suisun Bay even over the last decade. The first recorded toxic cyanobacteria blooms in the Delta have also occurred in recent years (Lehman 2005). The organism in question, *Microcystis aeruginosa,* is not efficiently collected by the routine phytoplankton sampling program, nor does it occur throughout the Delta so it is unlikely to be behind the recent widespread biomass increases. Nonetheless, it may be having a separate impact on the food web.

In conclusion, phytoplankton declines may underly long-term declines in higher organisms over the past 35 years. But phytoplankton biomass trends for the last decade are either neutral or positive and cannot account for more recent declines. If phytoplankton is playing a role, it is through changes in taxonomic composition of the community rather than through total biomass and production.

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In Memory Randall Brown

Steve Ford

As many of you know, Randy Brown passed away this last August. Randy had a major influence on what and how science was done in the San Francisco estuary during the last 25 years, during the latter part of his career with the California Department of Water Resources and then as an advisor to the CALFED Science Program. Among his many accomplishments, Randy was a principle founder of this newsletter and was its chief editor until his retirement from DWR in 2000. This newsletter therefore seems an appropriate place to briefly recognize a few of the ways Randy influenced the Interagency Ecological Program and those who have been associated with it.

Randy represented DWR as its IEP Coordinator. Many people also look on him as IEP's lead scientist because most people recognized Randy's strong commitment to the science of the San Francisco estuary, knew he had a good understanding of all aspects of IEP, and generally agreed on his vision of where the program should go. Of course, it helped that Randy controlled a substantial part of the IEP budget; used it to attract and retain talented scientists into studying Bay-Delta environmental issues; fostered interagency, interdisciplinary, and interregional collaboration; and could usually get agency managers' and stakeholders' trust and support for the program.

Randy also had strong, personal influence on many of IEP's agency staff and academic collaborators. He expected us to work hard, work together, and focus on getting information needed to better manage the Bay-Delta's environmental resources. Randy encouraged us to find out about what was being learned about other estuaries, apply that to our work, and to publish our findings to improve the quality of our work through the peer review process and make it more broadly available for others to build upon.

Randy Brown was chief editor of the IEP Newsletter until his retirement from DWR in 2000.

We responded to Randy's leadership, perhaps not so much because his values were unique or because he converted anyone to them, but maybe because he usually advocated values we already held. Randy tenaciously reminded us of those values and encouraged and supported us in our efforts to reflect them in our IEP activities.

Following are three personal memories of Randy. They serve as specific examples of a few of the many ways Randy influenced us. They show why Randy will be missed, and why his influence is still with us.

Randy Brown - Cohort and Friend

Wim Kimmerer

I first met Randy Brown when, new to the Bay Area, I attended one of the State Water Board's interminable hearings in about 1987. A lawyer for DWR introduced him to the Board by describing him as the scientist who never wears a tie, and I thought "I have to get to know this guy." Not only for a compatible choice of attire, but because he clearly had other ideas about what was important.

When Randy started the Food Chain Group, I joined out of interest but also to see if I could get some research funded. Eventually I was able to get funding for a series of projects on estuarine ecology. Every year my colleagues (Tim Hollibaugh and Bill Bennett) and I would submit a proposal to IEP, which would go through a review, but IEP didn't have an established process. So sooner or later Randy would say we had to go out for a beer to talk about it. Now that may seem peculiar, but we didn't have to buy the beer – and there is no quantity of beer that could have persuaded Randy to do anything he hadn't decided on his own to do. No, the main purpose of these meetings was so Randy could squeeze us for reports or whatever else he needed before agreeing to give us the money!

When Randy retired and Sam asked us to be advisors to the Science Program, our roles relative to each other changed radically. Where once he had been the person I was trying to get research money from, now he was my partner in crime. But our personal relationship did not change, which I attribute to his steadfastness. He remained quietly determined, persistent, and rigorous. He rarely said much in meetings. I don't understand how I could have "won" the coin tosses to get to give so many talks, and I never did get to see that coin, but I was always the spokesman for our team. When it came to organizing workshops, analysis, keeping track of all that was going on, and writing, though, Randy carried the heavy end of the load.

Randy occasionally wondered out loud if he had really been very effective in his roles at DWR and CALFED. Some scientists work in the lab, some in the field, some do modeling, some organize laboratories or field teams, and some organize entire communities of other scientists. I think Randy had more impact on how science is used in management in central California than any other scientist.

I still have trouble believing that he will not be calling me to talk about ten different things, from the status of some report, plans for the next workshop, his next trip, or the state of his renovations.

A Personal View

Zach Hymanson

I first met Randy Brown in 1987, but it wasn't until the early 1990's that I really started to work with him as the "chairperson" of the IEP Food Chain Group. As chairperson, I had to organize and lead the meetings, prepare the meeting notes, and at least once a month go in and talk to Randy Brown about what the science was telling us. It was during this time that we discovered our mutual interest in introduced species, particularly in understanding the ecological consequences of new introductions.

In 1990, Randy made it very clear to my boss and me that I needed to get involved with the other researchers working to document the invasion of the Asian Clam, *Corbula amurensis*. Acting under Randy's marching orders, I was able to dedicate substantial time and resources to work collaboratively with Fred Nichols, Jan Thompson, and Wim Kimmerer. Randy's clout and clear understanding of the importance of the unique situation were able to cut through the usual government red tape to get new information sooner, rather than later.

Numerous other introduced species became established in the San Francisco Estuary during the 1990's, and Randy and I continued to share information on this important stressor and its effects on the ecology of the estuary. However, it wasn't until 1998 that Randy had another talk with my boss and me about getting me involved in understanding the consequences of another introduced species. We were receiving information of a dramatic increase in the abundance of the Chinese mitten crab . First detected in 1996, the mitten crab has a catadromous life cycle, with adults immigrating down central California streams and through the Sacramento-San Joaquin Delta in the late summer and fall to reproduce in San Francisco Bay. More than a few of these crabs found there way into the fish salvage facilities of the Central Valley Water Project and the State Water Project South Delta water export facilities. Being employees of DWR we knew how important stable operation of the water projects was to California's economy. The crabs were so numerous that modification of the project operations were required to deal with the biomass. In addition, the crabs dramatically reduced the survival of fishes captured in salvage operations.

Ever faithful to the IEP, Randy encouraged me to form a new project work team to allow for the sharing and rapid dissemination of information about the status and effects of the mitten crab. I attended briefings with Randy and then director of DWR, David Kennedy to share what information we had to provide about this new invader. When it came time to brief a legislative committee about the "mitten crab invasion", Randy said "you go, you know more than me about this animal." However, the pinnacle event of this assignment came in 2000, when Randy secured approval for me to personally travel to China on a fact-finding mission. There was never much discussion about what I was supposed to do, other than learn all I could by exploring the native habitat of this critter. And it was always clear but never stated that I would write an article describing what I had learned.

I am definitely in the camp of those who directly benefited from working under and with Randy Brown. His approach to science and the integration of science practices and information into agency processes and decision-making is something that I continue to practice and try to perfect.

Thoughts on Dr. Randall Brown

Lauren Buffaloe

Describing a person who significantly enhanced my life is difficult to put into words. In short, Randy Brown appreciated me. He recognized and supported my talent and effort on the job. He respected me and brought me interesting projects. He paid attention and trusted my judgment. He gave me guidance, encouragement, and most of all, allowed me the freedom to develop professionally. He was a friend and mentor without proclaiming either. We loved to publish good science together and we did it well.

Randy Brown was DWR's IEP Coordinator and an advisor to the CALFED Science Program.

■ Interagency Ecological Program for the San Francisco Estuary ■

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■ Interagency Ecological Program for the San Francisco Estuary ■

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is a cooperative effort of the following agencies:

California Department of Water Resources
State Water Resources Control Board
U.S. Bureau of Reclamation
U.S. Army Corps of Engineers

California Department of Fish and Game
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