■ Interagency Ecological Program for the San Francisco Estuary ■

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Of Interest to Managers

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Welcome to the annual Status and Trends issue of the IEP newsletter. In this issue, researchers report annual abundance indices and trends for a wide variety of taxa collected from the San Francisco Estuary. Originally conceived as simply a venue for data reports, the Status and Trends issue has evolved as authors began making linkages between environmental variables and species' trends. You'll find such information interspersed through many of this issue's articles, but a couple sections are of particular note. The first is Kate Lee and Andy Chu's 2007 water-year flow and export retrospective: river flows and delta outflow perform important functions for the estuary discussed in subsequent articles. Second is the "Physical Setting" section of the fish trends article by Maxfield Fish, Kathryn Hieb, Dave Contreras, Virginia Afentoulis and Jennifer Messenio, which also discusses 2007 river flow patterns as well as ocean temperatures and ocean currents that influence species' abundance trends in the estuary.

The "Highlights" section starts with a Delta Water Project Operations summary for the first quarter 2008 by Kate Le and Andy Chu that describes patterns of river flow and export magnitude. They observe that modest January outflows surpassed those needed for water quality and fish habitat, but exports were still constrained to meet Old and Middle River flow targets to protect delta smelt. Additional flow pulses occurred later in the quarter and exports continued to be constrained based on Judge Wanger's orders to protect delta smelt.

Next Heather Webb and Lori Wichman provide another in a series of reports documenting fish catches (actually catch per unit effort) from the trawling and beach seining components of the Delta Juvenile Fish Monitoring Program, US Fish and Wildlife Service. The trawl sampling reported (October 2007- February 2008) documents the start of juvenile Chinook salmon emigration (complemented by Beach Seining summary), the end of juvenile American shad emigration and most of the longfin smelt adult spawning migration. Other catches probably represent dispersal of fishes downstream within riverine habitats.

The Status and Trends section is started by Kate Le and Andy Chu and their water-year 2007 retrospective. River flows stimulate important biological process in the estuary ecosystem by carrying nutrients and sediment, facilitating downstream migrations, transporting planktonic organisms and creating low salinity habitat. Kate and Andy report that 2007 outflow was the lowest since 2001. They describe the regulations protecting delta habitat (flow and X2 standards in Water Rights Decision 1641) during the low flow conditions and note that additional export restrictions were imposed January through June to protect delta smelt from entrainment. Their article contains many more river flow and export details and multi-year comparisons of interest.

Copepods and mysid shrimp comprise important spring and summer foods for young fishes, and for delta smelt throughout its life. April Hennessy and Kathy Hieb describe trends in zooplankton and mysid shrimp abundance and distribution through 2007. Not much good news: abundance of brackish water copepods, *Acartia* and *Acartiella*, increased in the upper estuary as a result of low outflows, while abundance declined of the more well know fish food copepods, *Eurytemora* and *Pseudodiaptomus.* The latter declines occurred in part because their habitat was pushed farther upstream by encroaching brackish water. As young fish grow, mysid shrimp, which are substantially larger than copepods, become important food sources, particularly for longfin smelt and striped bass, and to some degree for delta smelt. Mysid shrimp abundance was very low throughout the year, even though abundance increased slightly for a couple rare species.

Bay shrimp represent another food-web link between mysids and fishes. Kathryn Hieb describes estuarine shrimp abundance trends up through **2006 only**. Increased freshwater outflow in 2006, reshuffled the relative abundances of the common estuarine shrimps. Kathy reports that abundance of the upper estuary shrimp, *Crangon franciscorum* continues to exhibit a strong positive relationship with spring outflow, and high flows in 2006 produced its highest abundance in almost a decade. The more marine of the estuary shrimps, *C. nigricauda*, *C. nigromaculata*, and *Heptacarpus*, declined somewhat as expected, but their abundance remained relatively high. Note that a large number of fishes did well in 2006 also (see article by Max Fish and others).

Kathryn Hieb reports again, this time on trends in *Cancer* crabs and the Chinese mitten crab through 2007; the latter was not detected in the estuary during 2007. The San Francisco Estuary is an important rearing area for

Cancer magister, the Dungeness crab, and Kathy reports a substantial increase in juvenile numbers in 2007. Abundance reached levels similar to the late 1990s and early 2000s, and bodes well for coastal commercial catches in another 2 years. Two of the 3 other *Cancer* crabs also exhibited large abundance increases, which might lead to enhanced future recreational crabbing.

Maxfield Fish, Kathryn Hieb, Dave Contreras, Virginia Afentoulis and Jennifer Messenio, comprise the researchers on the San Francisco Bay Study, Fall Midwater Trawl Survey and Summer Townet Survey. These researchers provide an overview of near-coastal ocean temperatures, currents and upwelling for 2007 and put these factors in context with species' life histories. Possibly of most concern is the continued low abundance of 3 of the 4 POD fish species: delta smelt, longfin smelt and age-0 striped bass. All were at or near record low abundance in 2007 and only threadfin shad exhibited a slight abundance increase. Unusual distribution shifts were observed and described for the 2 smelts. Juvenile American shad and splittail abundance declined as expected with the low spring river flows in 2007; low age-0 splittail abundance is noted as being common in the year after a big spawning year such as 2006, regardless of river flow and floodplain inundation conditions. Abundance increased in 2007 for some upper estuary bottom dwelling fishes such as age-0 starry flounder and Shokihaze goby. The starry flounder increase highlights the duel influences of ocean conditions and outflow on abundance; in this case, favorable ocean conditions rather than outflow led to increased abundance. These authors report that 2007 was unique in terms of upwelling and temperature patterns (see text); yet lower estuary pelagic and demersal species generally responded favorably, particularly those considered part of the Pacific Northwest fauna, like Pacific herring, Pacific staghorn sculpin, and English sole.

Finally, Geir Aasen and Russ Gartz report monthly and annual salvage of 7 fishes for 2007, and describe salvage trends at the state and federal fish facilities over the past 25 years. The seven fishes chosen represent a combination of those in high abundance (threadfin shad and striped bass) and those of management concern (Chinook salmon, steelhead, delta smelt, longfin smelt and splittail), which also includes the former 2. They also provide a summary of monthly and annual export levels for both pumping plants; export level is often strongly related to the numbers of fish salvaged. Low salvage in 2007 of delta smelt, longfin smelt and age-0 striped bass generally reflects their low abundance in the estuary; threadfin shad numbers increased modestly in 2007 and are reflected in increased salvage.

IEP QUARTERLY HIGHLIGHTS

DELTA WATER PROJECT OPERATIONS (January through March 2008)

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Hydrological conditions in the Delta region were very typical initially but became dry toward the end during the months of January to March 2008. San Joaquin River (SJR) average daily flow ranged between 37 and 130 cubic meters per second (1,306 cfs and 4,590 cfs). Sacramento River daily average flow ranged between 260 and 1,160 cubic meters per second (9,181 cfs to 40,960 cfs). Daily Net Delta Outflow Index (NDOI) ranged between 200 and 1,368 cubic meters per second (7,062 cfs and 48,300 cfs). As shown in Figure 1, all river flows and outflow increases appeared to be a direct response to the precipitation events.

Project operations (exports) in the delta during the January through March 2008 period were predominantly restricted by the fishery-protective flow actions prescribed in Judge Wanger's Interim Court Order to protect Delta Smelt. Modest river and Delta outflows in January exceeded minima required by the Bay-Delta Standards in D-1641 (Figure 2): the minimum monthly outflow of 127 cubic meters per second (4,500 cfs) and the 7-day average outflow of 99 cubic meters per second (3,500 cfs). Nonetheless, exports were restricted to meet the combined Old and Middle River flows objective prescribed in Judge Wanger's Interim Court Order. Starting in February, additional habitat protection outflows were required (Figure 2) at Chipps Island for the entire months of February and March. These outflow requirements can be achieved in two ways: 1) maintaining the average position of X2 at Chipps Island (river kilometer 75, measured upstream from the Golden Gate) by either the daily or 14-day average EC of 2.64 mmhos/cm; or 2) alternatively, meeting the requirement by a 3-day average outflow of 323 cubic meters per second (11,400 cfs). Other flow and water quality standards listed in Figure 2 to be noted were Export to Inflow ratio transition from 65% to 35% in February and the Vernalis base flow requirements in February and March.

Projects exports shown in Figure 3 were restricted mainly due to the delta smelt actions. No significant plant maintenance activities or power outages occurred during these months.

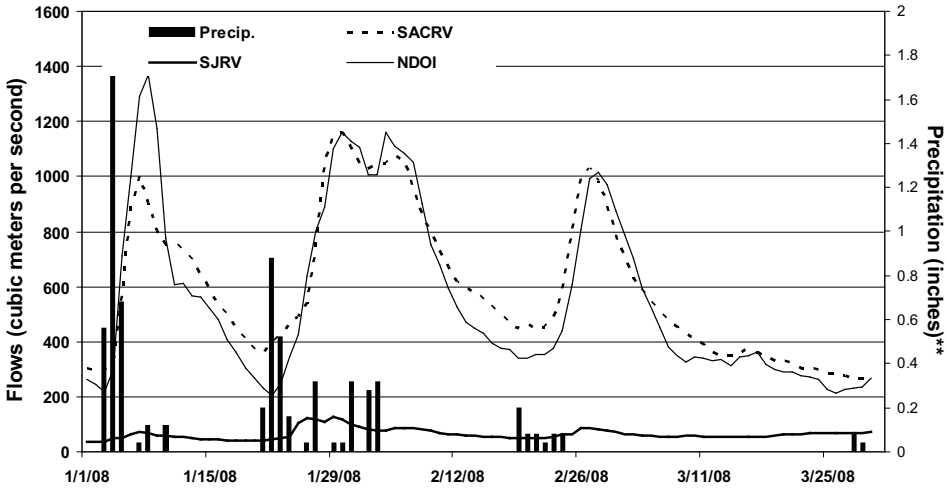

Figure 1 January through March 2008 Sacramento River, San Joaquin River, Net Delta Outflow Index, and Stockton Fire Station Precipitation

DRAFT

Bay-Delta Standards

Contained in D-1641

DRAFT

CRITERIA	Jan 08	Feb 08	Mar 08
FLOW/OPERATIONAL			
• Fish and Wildlife			
SWP/CVP Export Limits			
Export/Inflow Ratio	65%	35%	35%
Minimum Outflow - mon.	4500 cfs		
- 7 day ave	3500 cfs		
Habitat Protection Outflow, X2		7,100 - 29,200 cfs or X2 days	
		29 days at Chipps	31 days at Chipps
River Flows:			
@ Rio Vista - min. mon. avg.			
@ Vernalis: Base -min. mon. avg.		2280 cfs	2280 cfs
- 7 day average		1824 cfs	1824 cfs
Pulse objective			
Delta Cross Channel Gates	Nov.-Jan. may be closed up to a total of 45 days	Closed	
WATER QUALITY STANDARDS			
• Municipal and Industrial			
All Export Locations	250 mg/l Chlorides		
Contra Costa Canal	Cl <= 150 mg/l for 165 days		
• Agriculture			
Western/Interior Delta			
Southern Delta	30 day running avg EC <= 1.0 mS		
• Fish and Wildlife			
San Joaquin River Salinity			
Suisun Marsh Salinity	12.5	8.0 mhtEC	

Water Year Classification: (Feb 1 Forecast) -- Previous Month's Index (8RI for JAN): 1.700 MAF
SVI (40-30-30 @ 50%) = 6.3 (Dry)
SJV (60-20-20 @75%) = 2.4 (Dry)

Figure 2 January through March 2008 Bay-Delta Standards of D-1641

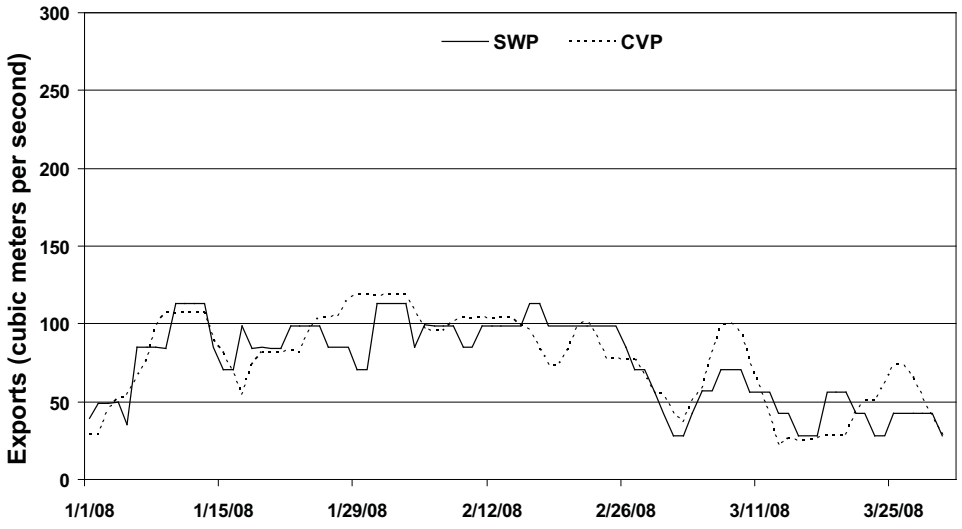

Figure 3 January through March 2008 State Water Project and Central Valley Project Exports

Delta Juvenile Fish Monitoring Program

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The Delta Juvenile Fish Monitoring Program (DJFMP) of the US Fish and Wildlife Service (USFWS), Stockton Office, has monitored the relative abundance and distribution of juvenile Chinook salmon (*Onchorynchus tshawyscha*) in the lower Sacramento and San Joaquin rivers and in the delta for the Interagency Ecological Program since the 1970s (Brandes and McLain, 2001). The program expanded in the early 1990s to monitor other juvenile fish species. This report summarizes results from trawling and the beach seine survey from October 2007 to February 2008.

Trawling

For the reporting period, ten 20-minute Kodiak trawls were conducted on a near continuous basis 3 days a week at Mossdale (San Joaquin River River Mile (RM) 54) and Sherwood Harbor (Sacramento River RM 55). Midwater trawls were conducted at Chipps Island (Suisun Bay RM 18) 3 days a week from October 1 to December 7, 2007 and January 7-9, 2008, with increased effort from December 8, 2007 to January 5, 2008 and January 17 to February 4, 2008 for capture of coded wire tagged (CWT) Chinook salmon as part of the Delta Action 8 Study. Trawling at Chipps Island was suspended January 11-16 and February 5-7, 2008 due to take concerns of the endangered delta smelt. However, midwater trawls were resumed downstream at Benicia (Suisun Bay RM 1) daily February 8-15 and 3 days a week February 18-29, 2008. This change in sampling location was a compromise in order to continue sampling for juvenile Chinook salmon, while minimizing take of delta smelt. The USFWS is currently considering a permanent change in sampling locations and will investigate its options and sampling alternatives this coming year.

Capture of unmarked Chinook salmon was greater at Sherwood Harbor (n = 1,233 fish) than at the other 2 trawling locations (Chipps and Benicia) combined during the reporting period. Of the unmarked Chinook salmon captured at Sherwood Harbor, 1,181 were fall-run sized, 1 was late fall-run sized, 31 were winter-run sized, and 20 were spring-run sized. The first winter-run sized Chinook salmon was captured in the Sherwood Harbor trawl on January 7, 2008 and the catch of unmarked salmon continued for the remainder of the reporting period. Crews trawling at Mossdale captured 2 fall-run sized unmarked Chinook salmon. Chipps Island collected 42 unmarked Chinook salmon: 1 fall-run sized, 27 late fall-run sized, and 14 winter-run sized. Trawling efforts at Benicia resulted in the capture of 3 winter-run sized unmarked Chinook salmon. A total of 251 marked (adipose fin-clipped) Chinook salmon were recovered during the sampling period: 185 at Chipps Island, 57 at Sherwood Harbor, and 9 at Benicia.

Weekly and mean of weekly catch per unit effort as fish/10,000 m^3) were calculated for the reporting period at each sampling location for all fish species and unmarked salmon races. For the reporting period, we captured a total of 19,159 fish, not including marked salmon. Catch by sampling location was: 2,446 fish representing 26 species at Sherwood Harbor; 3,352 fish of 28 species at Mossdale; 12,705 fish of 25 species at Chipps Island, and 656 fish of 17 species at Benicia. At Sherwood Harbor, fall-run sized Chinook salmon and ammocoete lamprey (*Lampetra* spp.) dominated the catch (Table 1). Mossdale catches were mostly comprised of inland silverside (*Menidia beryllina*) followed by threadfin shad (*Dorosoma petenense*) (Table 2). At Chipps Island, American shad (*Alosa sapidissima*) and threadfin shad were consistently captured throughout the sampling period (Table 3). Benicia trawls, similar to the Chipps Island trawls, were dominated by American shad, striped bass (*Morone saxatilis*), and longfin smelt (*Spirinchus thaleichthys*) (Table 4).

Table 1 Weekly catch per unit effort (fish /10,000 m^3) of the 5 most abundant fish species between October 2007 and February 2008 at Sherwood Harbor

Week starting	*Fall-run sized Chinook salmon*	*Ammocoete lamprey*	*River lamprey*	*Threadfin shad*	*Inland silverside*
10/1/2007	0	0	0	0.98	0
10/7/2007	0	0	0	0	0
10/14/2007	0	0	0	0	1.31
10/21/2007	0	0	0	0	0
10/28/2007	0	0	0	0	15.68
11/4/2007	0	0	0	1.24	1.16
11/11/2007	0	0	0	1.23	0
11/18/2007	0	0	0	1.31	1.15
11/25/2007	0	0	0	3.74	1.59
12/2/2007	0	0	0	2.86	2.59
12/9/2007	0	0	0	1.87	1.24
12/16/2007	0	0	0	1.43	2.58
12/23/2007	0	0	1.17	1.78	1.38
12/30/2007	0	0	0	2.20	3.34
1/6/2008	4.32	28.97	29.98	2.52	1.28
1/13/2008	2.70	0	0	2.44	0.88
1/20/2008	1.55	0	0	1.68	0
1/27/2008	8.97	6.31	2.01	2.57	1.92
2/3/2008	6.17	1.44	2.35	1.11	1.08
2/10/2008	3.24	0	0	1.36	0
2/17/2008	1.36	0	0	2.24	0
2/24/2008	8.84	5.75	0	1.45	0
sum of catch	1,181	423	222	174	119
% of catch	49.33	17.29	9.08	7.11	4.87
Ave CPUE (SE)	1.69 (0.62)	1.93 (1.34)	1.61 (1.36)	1.55 (0.21)	1.69 (0.70)

Table 2 Weekly catch per unit effort (fish /10,000 m^3) of the 5 most abundant fish species between October 2007 and February 2008 at Mossdale

Week starting	*Inland silverside*	*Threadfin shad*	*Pacific lamprey*	*Bluegill*	*Golden shiner*
10/1/2007	9.39	18.48	0	3.36	0
10/7/2007	11.54	20.76	0	5.46	0
10/14/2007	10.59	6.95	0	2.12	0
10/21/2007	11.96	4.04	0	1.34	0
10/28/2007	2.79	2.60	0	1.33	0
11/4/2007	6.96	2.32	0	0	0
11/11/2007	2.86	1.33	0	1.31	3.29
11/18/2007	4.18	1.50	0	1.49	0
11/25/2007	6.57	1.82	0	1.59	0
12/2/2007	4.73	1.67	0	1.28	0
12/9/2007	4.95	2.47	0	0	0
12/16/2007	24.30	1.14	0	0	0
12/23/2007	66.42	1.47	0	0	0
12/30/2007	21.85	1.68	0	0	0
1/6/2008	17.42	2.82	12.56	3.95	2.58
1/13/2008	6.03	1.50	0	4.05	3.49
1/20/2008	14.70	1.50	0	2.20	4.26
1/27/2008	1.90	1.86	4.25	2.59	1.23
2/3/2008	5.62	1.38	1.29	1.26	1.55
2/10/2008	3.69	1.20	0	1.72	0
2/17/2008	2.59	1.46	0	1.71	1.66
2/24/2008	1.94	1.32	0	3.03	1.72
sum of catch	2,344	291	209	190	88
% of catch	69.93	8.68	6.24	5.67	2.63
Ave CPUE (SE)	11.04 (2.96)	3.69 (1.13)	0.82 (0.59)	1.81 (0.31)	0.90 (0.29)

Table 3 Weekly catch per unit effort (fish /10,000 m^3) of the 5 most abundant fish species between October 2007 and February 3, 2008 at Chipps Island

Week starting	*American shad*	*Threadfin shad*	*Top smelt*	*Striped bass*	*Longfin smelt*
10/1/2007	5.55	13.60	0	1.00	0.57
10/7/2007	5.08	6.36	0	0.99	0
10/14/2007	4.28	6.44	0	0.88	0
10/21/2007	6.19	2.41	0	3.31	0
10/28/2007	8.61	5.00	0.70	3.80	0
11/4/2007	7.85	23.78	1.55	2.25	1.68
11/11/2007	6.19	3.06	2.21	1.35	0.67
11/18/2007	6.22	2.52	1.13	1.01	0.83
11/25/2007	11.62	8.29	2.35	1.57	1.70
12/2/2007	6.98	6.45	2.30	1.01	0.74
12/9/2007	3.64	6.95	1.81	1.21	1.53
12/16/2007	7.66	4.42	2.36	1.00	1.56
12/23/2007	3.07	2.32	2.92	1.20	1.74
12/30/2007	3.94	1.89	1.72	0.77	1.41
1/6/2008	1.16	1.42	0	0.60	0.54
1/13/2008	3.20	1.44	0	0.81	1.25
1/20/2008	1.68	0.80	0	0.90	1.13
1/27/2008	1.54	0.86	0	1.76	1.68
2/3/2008	1.25	1.08	0	2.14	3.21
sum of catch	6,003	4,555	667	563	555
% of catch	47.25	35.85	5.25	4.43	4.37
Ave CPUE (SE)	5.04 (0.65)	5.22 (1.27)	1.00 (0.25)	1.45 (0.20)	1.07 (0.19)

Table 4 Weekly catch per unit effort (fish /10,000 m^3) of the 5 most abundant fish species February 8-29, 2008 at Benicia

Week starting	*American shad*	*Striped bass*	*Longfin smelt*	*Pacific herring*	*Sacramento splittail*
2/3/2008	2.26	2.51	2.30	0.52	0.52
2/10/2008	1.23	1.53	1.16	0.87	0.43
2/17/2008	1.47	0.83	2.37	0.48	0.41
2/24/2008	1.89	3.01	0.81	0.38	1.73
sum of catch	232	171	150	45	21
% of catch	35.37	26.07	22.87	6.86	3.20
Ave CPUE (SE)	1.71 (0.23)	1.97 (0.49)	1.66 (0.40)	0.57 (0.11)	0.77 (0.32)

Beach Seining

For the reporting period, the DJFMP collected a total of 990 beach seine samples at 55 sites. We conducted 72 seine hauls on the lower Sacramento River (5 sites), 111 seine hauls on the San Joaquin River (9 sites), 727 seine hauls in the delta (32 sites), and 80 seine hauls in San Pablo and San Francisco bays (9 sites) (Brandes and McLain, 2001). The lower Sacramento River, delta, and San Joaquin River sites were typically sampled once per week, and bay sites were sampled every other week.

We captured 1,939 fall-run sized fish, 9 late fall-run sized, 19 winter-run sized, and 30 spring-run sized, unmarked Chinook salmon in the delta. We captured 212 fall-run sized fish, 1 late fall-run sized, 35 winter-run sized, and 9 spring-run sized unmarked Chinook salmon

on the lower Sacramento River. One winter-run sized salmon was captured on the San Joaquin River and none reported in the bay seines. In addition, 89 marked salmon were recovered in the beach seines during the reporting period.

A total of 80,501 fish representing 50 species were captured in beach seines during the sampling period: 2,041 fish from the lower Sacramento River, 38,531 fish from the delta, 37,948 fish from the San Joaquin River, and 2,041 fish from the bays. The Sacramento sucker (*Catostomus occidentalis*) was the most prevalent species in the lower Sacramento River samples, followed by inland silverside, fall-run sized Chinook salmon, golden shiner (*Notemigonus* crysoleucas), and threadfin shad (Table 5). In the San Joaquin River seines, threadfin shad and red shiner (*Cyprinella lutrensis*) were the most prevalent species caught. The delta seines, which included sites from as far north as Sacramento, west to Antioch, and south to the water project facilities, were dominated by inland silverside (Table 6). Top smelt (*Atherinops affinis*) was the most abundant fish caught in the bay seines.

References

Brandes, P. L. and J. S. McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. In: Contributions to the Biology of Central Valley Salmonids, R.L. Brown, editor. California Department of Fish and Game Fish Bulletin 179, Volume 2, 39-136.

Table 5 Weekly catch per unit effort (fish /10,000 m^3) of the 5 most abundant fish species between October 2007 and February 2008 in the lower Sacramento River region beach seines

Week starting	*Sacramento sucker*	*Inland silverside*	*Fall-run sized Chinook salmon*	*Golden shiner*	*Threadfin shad*
10/1/2007	0.02	0	0	0	0
10/7/2007	0.06	0	0	0.17	0
10/14/2007	0.43	0	0	0	0
10/21/2007	0.43	0.36	0	0	0.04
10/28/2007	1.06	0.19	0	0.07	0.44
11/4/2007	0.11	0.21	0	0	0.68
11/11/2007	0.03	0.17	0	0.92	0.79
11/18/2007	0.40	0.12	0	0.30	0.72
11/25/2007	0.22	0.94	0	0.19	0.13
12/2/2007	0.19	0.20	0	0.13	0.10
12/9/2007	0.08	0.18	0	0.16	0.29
12/16/2007	0.04	0.15	0	0.45	0
12/23/2007	0.32	0.71	0	0.02	0
12/30/2007	0.17	0.26	0.04	0.33	0
1/6/2008	0.84	0.23	0.15	0.06	0.02
1/13/2008	0.27	0.98	0.83	0.06	0
1/20/2008	0.36	0.19	0.25	0.58	0
1/27/2008	0.24	0.04	0.20	0.04	0
2/3/2008	0.23	0.13	0.08		0
2/10/2008	0.68	0.28	0.70	0.05	0
2/17/2008	0.84	0.53	0.37	0.08	0
2/24/2008	0.30	0.14	0.34	0.02	0
sum of catch	603	366	212	154	138
% of catch	29.54	17.93	10.39	7.55	6.76
Ave CPUE (SE)	0.33 (0.06)	0.27 (0.06)	0.13 (0.05)	0.17 (0.05)	0.15 (0.06)

Table 6 Weekly catch per unit effort (fish /10,000 m^3) of the 5 most abundant fish species between October 2007 and February 2008 in the delta region beach seines

Week starting	*Inland silverside*	*Fall-sized Chinook salmon*	*Sacramento sucker*	*Bluegill*	*Threadfin shad*
10/1/2007	1.31	0	0.06	0.12	0.13
10/7/2007	3.92	0	0.06	0.06	0.04
10/14/2007	2.10	0	0.19	0.03	0.06
10/21/2007	5.82	0	0.25	0.83	1.31
10/28/2007	1.28	0	0.08	0.03	0.95
11/4/2007	1.17	0	0.09	0.03	0.02
11/11/2007	3.61	0	0.18	0.19	0.34
11/18/2007	0.87	0	0.14	0.60	0.04
11/25/2007	4.28	0	0.04	1.16	0.03
12/2/2007	2.21	0	0.26	0.61	0.03
12/9/2007	2.12	0	0.34	0.04	0
12/16/2007	1.60	0.03	0.08	0	0.02
12/23/2007	7.06	0.53	0.18	0.10	0
12/30/2007	2.86	0.02	0.03	0.02	0.09
1/6/2008	0.71	0.62	0.25	0.30	0.02
1/13/2008	0.86	0.50	0.23	0.02	0.01
1/20/2008	0.83	0.24	0.10	0.03	0
1/27/2008	0.79	0.47	0.04	0.02	0.06
2/3/2008	0.33	0.77	0.10	0.01	0
2/10/2008	0.80	0.64	0.23	0.03	0
2/17/2008	0.50	0.61	0.15	0	0
2/24/2008	0.22	0.34	0.14	0.03	0.02
sum of catch	33,230	1,939	700	592	532
% of catch	86.24	5.03	1.82	1.54	1.38
Ave CPUE (SE)	2.06 (0.39)	0.22 (0.06)	0.15 (0.02)	0.19 (0.07)	0.14 (0.07)

STATUS AND TRENDS

DELTA WATER PROJECT OPERATIONS

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Precipitation

After a wet year in 2006, the water year 2007 was comparatively dry. On a monthly basis, precipitation events were spotty in October 2006 and January 2007. In comparison, November and December of 2006 had more rainfall. However, the bulk of larger rainfall events came in February and then tapered off into mid-May 2007. Nonetheless, the total amount of rainfall for the year was lower than an average year and consequently led to a 'dry' water year classification.

River Flows and Net Delta Outflow Index

The hydrologic conditions for water year 2007 reflected the rainfall pattern (Figure 1). Flow patterns from Sacramento River, San Joaquin River, and net Delta outflow were low and increases corresponded directly to the precipitation events. Throughout the year, these flows remained below 1,200 cubic meters per second (cms), except during one February peak (Figure 1). Consequently, water year 2007 became the driest year since water year 2001. As usual, the Sacramento River flows were generally higher than net Delta outflow and San Joaquin River flows.

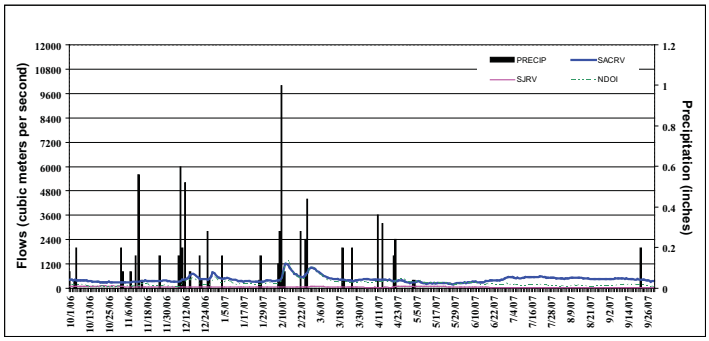

Figure 1 Average daily flows (cubic meters per second) in water year 2007 (October 2006 through September 2007) for the Sacramento River, the San Joaquin River, and Net Delta Outflow, and total daily precipitation for the same period

Exports

During water year 2007, export patterns were coordinated between the Projects (Figure 2) to first ensure the compliance with Bay-Delta Standards (Figure 3). The Minimum Delta Outflow, the Habitat Protective Outflow, and the Export and Inflow Ratio listed in the Bay-Delta Standards often restricted the export levels at the different times of year. For example, the export levels were controlled by the minimum monthly outflow between October 2006 and January 2007. Afterward, beginning in February 2007 and continuing through June 2007, the habitat protective outflows of 201 cms – 827 cms(7,100 cfs – 29,200 cfs) became controlling over the export levels. In addition, the export to inflow (E/I) ratio placed the limits of 65% between July through January, and 35% between February and June. In February 2007, the E/I ratio limits were relaxed to 45%. In general, the CVP export level appeared to be more stable than SWP.

Besides meeting the Bay-Delta Standards, regular minor maintenance activities were spread out throughout the year. Based on delta smelt concerns, restrictions on pumping were imposed on both projects at different times from mid January 2007 till June 2007.

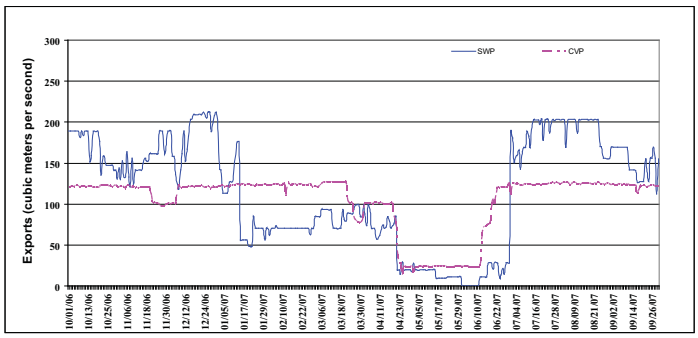

Figure 2 Average daily export rates (cubic meters per second) for water year 2007 (October 2006 through September 2007) at the State Water Project (SWP) and Central Valley Project (CVP) pumping facilities

Percent of Inflow Diverted

Both the 3-day and 14-day running averages of percent inflow diverted showed that levels remained below the D-1641 standards (Figure 4). From October 2006 through January 2007, the standard was 65%. In February, the E/I limit was relaxed to 45% due to a dry January. Then, from March through June of 2007 the standard returned to 35%. Applicable 3-day standards were in place only when the Delta was in the balanced conditions with storage withdrawal.

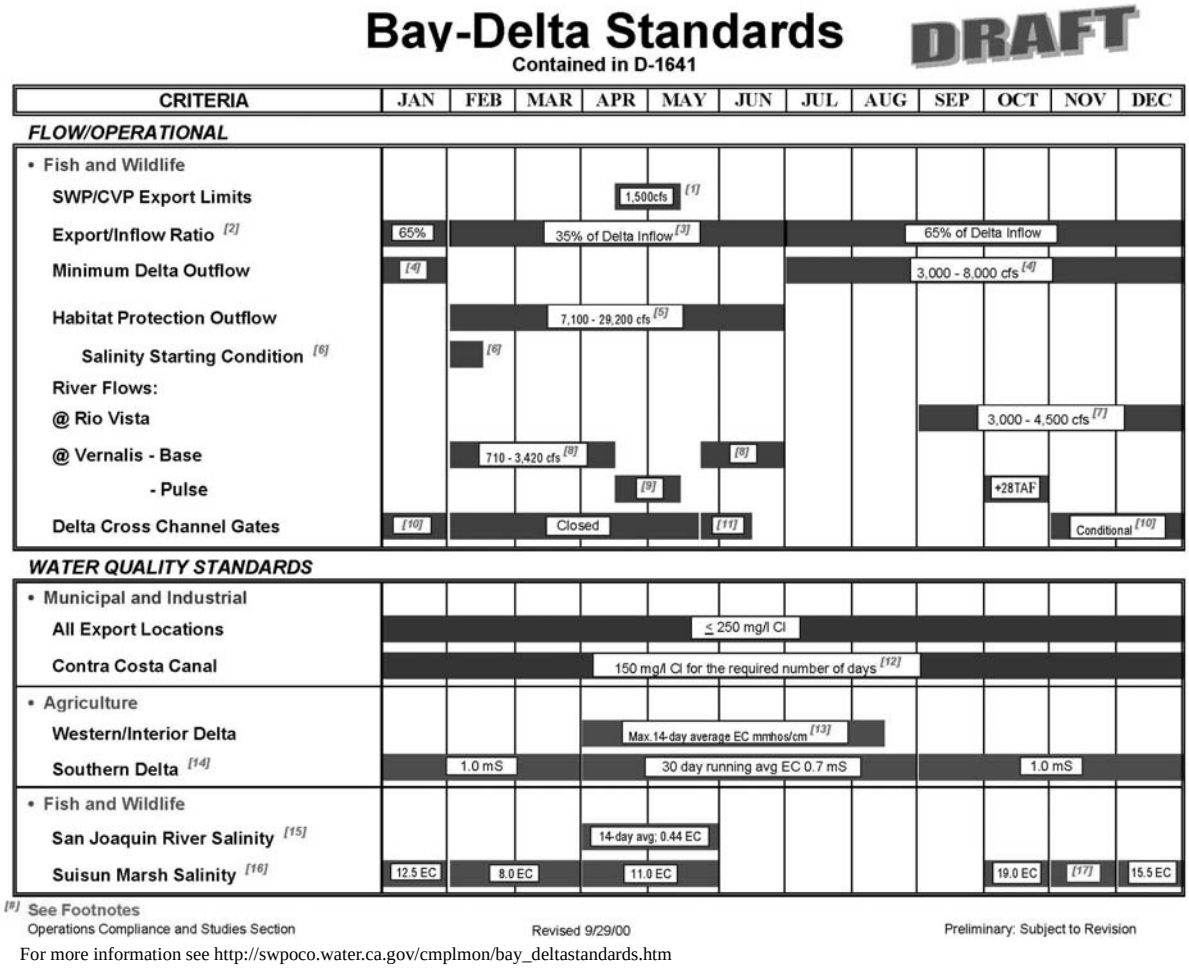

Figure 3 D-1641 Bay-Delta Standards

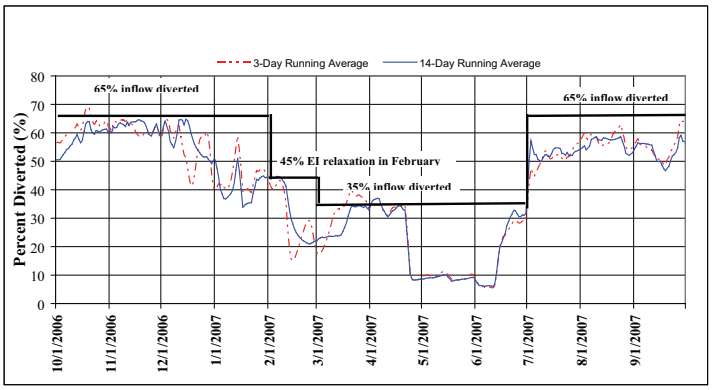

Figure 4 Average daily percent of inflow diverted into the state and federal water export facilities for water year 2007 (October 2006 through September 2007) and the D 1641 percent diverted limits for the same period

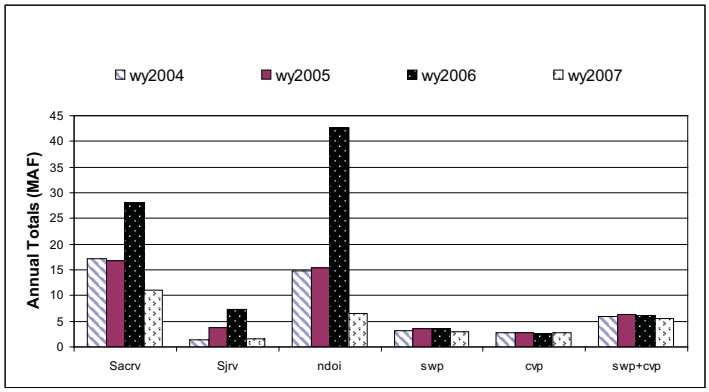

Figure 5 WY2007 (October 2006 through September 2007) Annual Total Discharges for the Sacramento River, the San Joaquin River, Net Delta Outflow and annual total exports for the SWP, CVP and both facilities combined in comparison to the three previous water years

WY 2007 Annual Totals Comparison

Water year 2007 (October 2006 through September 2007) annual totals were calculated and compared to those of the previous 3 years (Figure 5) for the following parameters:

Sacramento River Flow = 11.12 MAF
San Joaquin River Flow = 1.57 MAF
Net Delta Outflow Index = 6.51 MAF
State Water Project = 2.95 MAF
Central Valley Project = 2.67 MAF
SWP + CVP = 5.62 MAF

In comparison to WY 2004, 2005 and 2006, annual totals from Sacramento River, San Joaquin River, and NDOI during water year 2007 were much lower, except for the San Joaquin River in 2004, when the total was about equal to 2007 (Figure 5). The NDOI annual totals (MAF) exhibited the largest difference, followed by the Sacramento River, then the San Joaquin River totals. Total pumping at CVP remained very consistent across all years, whereas SWP dropped slightly in 2007, thus dropping the combined (Figure 5).

WY 2007 Monthly Average Inter- Annual Comparison

Sacramento River

Monthly average flows in October, November, and July through September for water year 2007 were similar to the previous three years (Figure 6). River flows between December and June during water year 2007 were lower than previous years' monthly average values.

San Joaquin River

Monthly average flows in all months during water year 2007 were about equal to or lower than the previous 3 years, except from October through December (Figure 6). The largest monthly flow difference was in April.

NDOI

Net Delta outflow followed a typical annual pattern with low levels in early fall and summer, and high in winter and spring, but water year 2007 average outflows were as low or lower than the 3 previous years for every month (Figure 6) due to drier water year type. The 2007 monthly outflow levels were very low, even during the winter and spring months. The largest monthly average difference occurred in April between 2006 and 2007, followed by January, March, and May. The largest difference, in April, was consistent with the largest river flow difference observed in both rivers. This pattern could also be attributed to the VAMP process. .

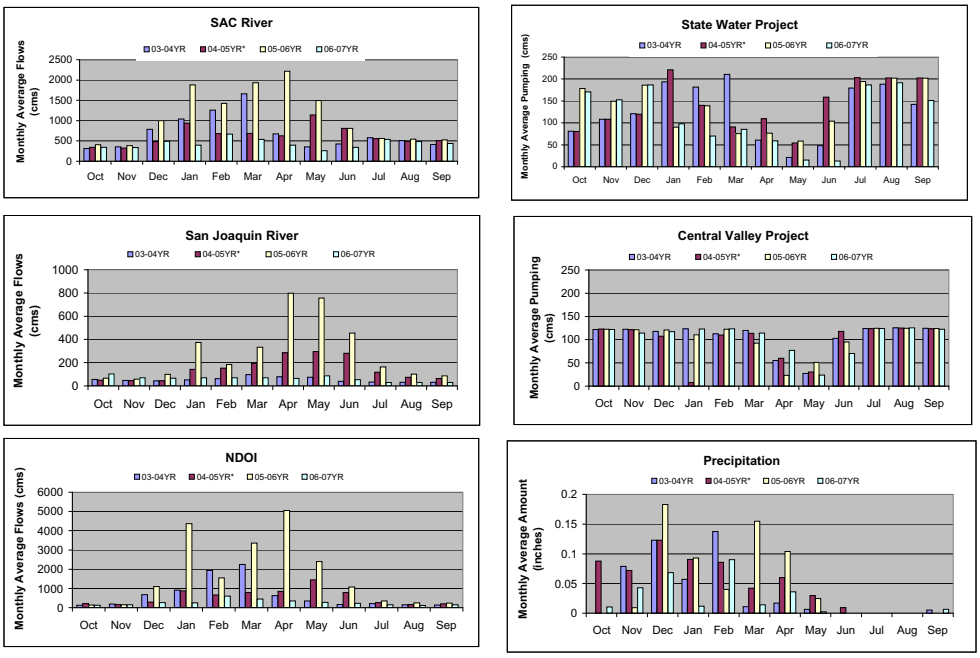

Figure 6 Monthly average flows, exports and precipitation totals for water years 2004 though 2007 for comparison

Precipitation

Rainfall events during water year 2007 mostly occurred during November through April period (Figure 6). The largest precipitation occurred in February 2007, followed by December, November, April, March, January, then October. Compared to 2 previous years, February was the only month with rainfall totals much higher than previous water year and slightly higher than water year 2005. With the exception of February, the rainfall totals between December and May months for water year 2007 were lower than the previous 2 years. November precipitation for water year 2007 was much higher than water year 2006, but lower than water years 2004 and 2005. Overall, water year 2007 precipitation pattern was normal with early fall events followed by winter and spring activities, but the amounts produced were too low during the fall and winter months and too late for February large rainfall amount to make up the dry period.

State Water Project

During October through December, monthly average exports during water year 2007 were similar to those of 2006 and substantially higher pumping than those of water years 2004 and 2005. Between January and June of 2007, SWP pumping was generally lower than 2004, 2005, and 2006, except in January and March. July and August pumping for all years were similar with a small reduction in 2007 (Figure 6). September pumping resembles that of 2004, and is lower than those of 2005 and 2006.

Central Valley Project

Water year 2007 pumping patterns were about the same level as previous years during October, November, and July through September (Figure 6). Overall, pumping was consistent and stable, except during January and April through June when there was more pumping fluctuations compared to previous years.

Zooplankton Monitoring 2007

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Introduction

The Zooplankton Study has estimated the abundance of zooplankton taxa in the upper San Francisco Estuary, from eastern San Pablo Bay through the eastern Sacramento-San Joaquin Delta and Suisun Marsh, since 1972 as a means of assessing trends in fish food resources. The study also detects and monitors zooplankton recently introduced to the estuary and determines their effects on native species. Three gear types are used: 1) a pump for sampling microzooplankton <1.0 mm long, including rotifers, copepod nauplii, and adult copepods of the genus *Limnoithona*, 2) a modified Clarke-Bumpus (CB) net for sampling mesozooplankton 0.5-3.0 mm long, including cladocerans, copepodids (immature copepods), and adult copepods, and 3) a macrozooplankton net for sampling zooplankton 1-20 mm long, including mysid shrimp. Here seasonal abundance indices are presented from 1974 through 2007 for a select group of the most common copepods, cladocerans, rotifers, and mysids.

Methods

During 2007, sampling occurred monthly from January through December at 22 stations, including 12 core stations (i.e., stations sampled consistently since study inception in 1972) and 2 floating entrapment zone (EZ) stations located at bottom electrical conductivity of 2 and 6 mS/cm (about 1 and 3 ‰). Indices presented here were calculated using 16 stations: the 12 core stations, the 2 EZ stations, and 2 additional stations sampled consistently since 1974 (Suisun Slough station NZS42 and Disappointment Slough station MD10; http://www.bay-delta.water.ca.gov/emp/Metadata/DiscreteWQ/discreteWQ_stations_map.html). Previous reports used data from the 12 core stations and 2 EZ stations starting in 1972. Since this report utilizes data from 2 additional stations, indices are presented starting in 1974 and may be slightly lower or higher than previous reports. However, overall trends remain as previously reported. Data were grouped into 3 seasons: 1) spring, March through May, 2) summer, June through August, and 3) fall, September through November. January, February, and December were not always sampled historically and therefore these were not used for long-term trend analyses. Abundance indices were calculated as the mean number of each taxon per cubic meter (reported as catch-per-unit effort, CPUE) by gear, season, and year at all 16 core and floating EZ stations. Relative calanoid copepod abundance for each season of 2007 is presented using mean CPUE from all 22 stations sampled. Similar to 2004, 2005, and 2006 Status and Trends reports, indices reported below were separated by gear type and taxon, whereas pre-2004 reports combined the CB and pump data for each taxon into a single index.

The abundance indices and distributions presented here reflect the low Delta outflow and subsequent high salinities of 2007. In low outflow years, brackish-water taxa, such as copepods of the genus *Acartia*, are found further upstream and therefore are more common in the Zooplankton Study sampling area. Conversely, freshwater and lower salinity taxa, such as the copepods *Pseudodiaptomus forbesi* and *Sinocalanus doerrii*, are less common in the sampling area due to reduced transport downstream by outflow and less low salinity habitat within the sampling area.

Copepods

Both congeners of the cyclopoid copepod genus *Limnoithona* inhabit the upper estuary: *L. sinensis*, introduced in 1979, and *L. tetraspina*, introduced in 1993. In 1993, *L. tetraspina* mostly supplanted the historically common *L. sinensis* and numerically became the dominant copepod species in the upper estuary. *L. tetraspina* is common in both brackish and freshwater. Due to its small size, *L. tetraspina* is not completely retained by the CB net, so indices for both the pump and the CB net are presented. *L. tetraspina* abundance decreased in 2007 from 2006 for both gears in all seasons (Figure 1), although densities were still much higher than any other copepod in 2007. *L. sinensis* continued to be collected in low numbers in 2007. In 2007, *L. tetraspina* was most abundant in spring at the floating entrapment zone stations, which were located in the vicinity of the lower Sacramento River and the confluence of the Sacramento and San Joaquin rivers. As flows decreased during summer and fall, *L. tetraspina* was abundant throughout the study area, with peak densities occurring in Suisun Marsh and Suisun Bay.

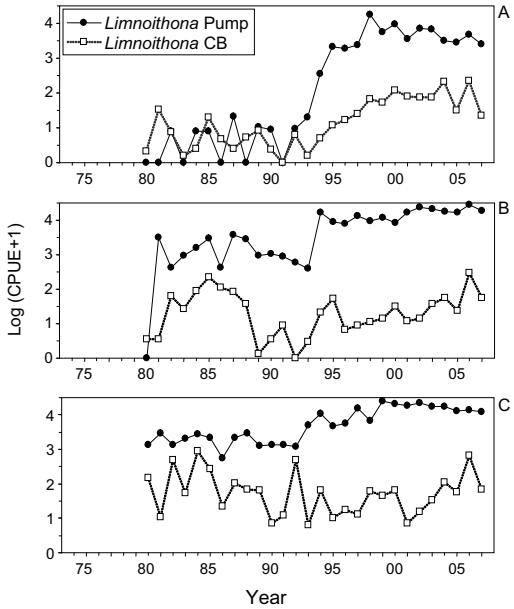

Figure 1 Abundance of *Limnoithona tetraspina* and *L. sinensis* combined (Log of mean catch*m^3+1) from the pump and CB net in Spring (A), Summer (B), and Fall (C), 1974 - 2007

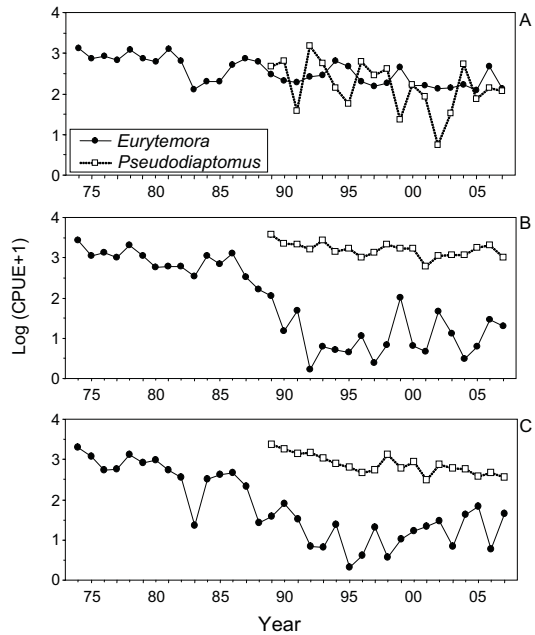

Figure 2 Abundance of *Eurytemora affinis* and *Pseudodiaptomus forbesi* (Log of mean catch*m^3+1) from the CB net in Spring (A), Summer (B), and Fall (C), 1974 - 2007

Eurytemora affinis, a calanoid copepod introduced to the estuary before monitoring began in 1972, was once a major food source for larval and juvenile fishes of many species and adults of planktivores, such as delta smelt and threadfin shad. It is found throughout the upper estuary in every season and is most abundant in salinities less than 6 ‰. *E. affinis* abundance declined in all seasons since monitoring began, with the sharpest down turns during summer and fall of the late-1980s (Figure 2), subsequent to the introductions of the Asian overbite clam, *Corbula amurensis*, and the calanoid copepod, *Pseudodiaptomus forbesi*. In 2007, *E. affinis* was the fourth most abundant calanoid copepod in the study area across all surveys. Its relative abundance was highest in spring, when it accounted for 10% of the total calanoid copepod CPUE (Figure 3A). After reaching a local maximum in 2006, spring abundance of *E. affinis* declined in 2007 to the fourth lowest spring abundance on record (Figure 2A). Summer abundance also decreased in 2007, but was not amongst the lowest on record (Figure 2B). After declining sharply in 2006 to the fourth lowest fall abundance since monitoring began, *E. affinis* abundance increased in fall 2007 (Figure 2C). In 2007, *E. affinis* abundance peaked during spring in the eastern Delta (286 m^{-3}); similarly high abundances occurred in spring and fall in Suisun Marsh (277 m^{-3} and 267 m^{-3} respectively).

Pseudodiaptomus forbesi is an introduced freshwater calanoid copepod first detected in the upper estuary in 1988. By 1989, *P. forbesi* summer and fall abundance was comparable to *E. affinis* before its decline (Figure 2). Although *P. forbesi* abundance has declined slightly since its introduction, it has remained relatively abundant in summer and fall compared to other copepods. In 2007, *P. forbesi* was the second most abundant calanoid copepod in the study area across all surveys. Its relative abundance peaked in summer, when it accounted for 58% of the total calanoid copepod CPUE (Figure 3B). Spring abundance has always been highly variable, but had an overall downward trend (Figure 2A). *P. forbesi* abundance decreased in both summer and fall 2007 from 2006, and was the second lowest on record for each season (Figures 2B and 2C). During summer and fall 2007, *P. forbesi* was common in all regions upstream of Suisun Bay, but was most abundant in June and July in the lower San Joaquin River near Stockton, where the mean CPUE was more than 6,800 m^{-3}.

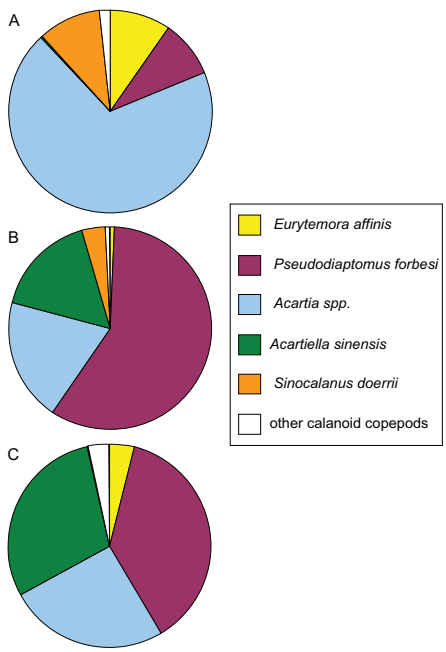

Figure 3 Relative abundance of the most common calanoid copepods (mean catch*m^3) from the CB net from all stations in Spring (A), Summer (B), and Fall (C), 2007

Several species of the native calanoid copepod genus *Acartia* are abundant in San Pablo Bay and expand their range into Suisun Bay and the western Delta as salinity increases seasonally and annually. Conversely, their affinity for higher salinities is sufficiently strong that their distribution shifts seaward of the sampling area during high-outflow events, resulting in low seasonal and annual abundance. In 2007, *Acartia* was the most abundant calanoid copepod in the study area across all surveys. Its relative abundance peaked in spring, when it accounted for 69% of the total calanoid copepod CPUE (Figure 3B). *Acartia* abundance increased in 2007 from 2006 in every season (Figure 4). The steadily increasing trend in spring abundance that started in 1997 was not hindered by the high spring outflows of the late-1990s. After reaching the second highest spring abundance in 2003, abundance declined sharply in 2004 and remained relatively stable in spring 2005 and 2006 before increasing again in 2007 (Figure 4A). The highest summer abundances corresponded with the lowest outflow years, and 2007 summer abundance was similar to other low outflow years (Figure 4B). Fall 2007 abundance was similar to the drought years 1987-1992 (Figure 4C). Due to the low flows in 2007, *Acartia* densities were high throughout the year in San Pablo Bay and Carquinez Strait (2560 m^{-3}).

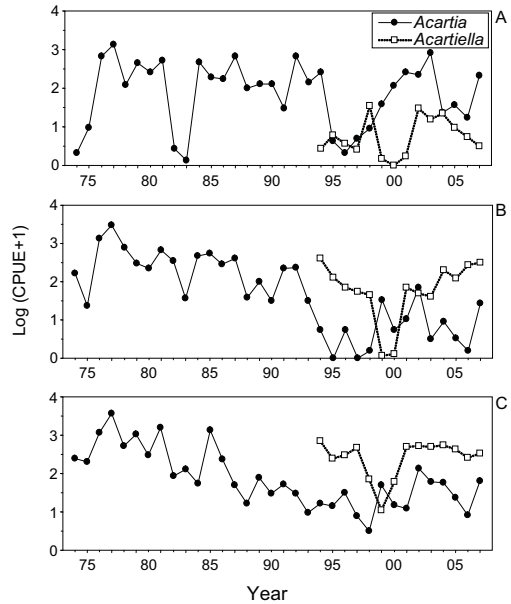

Figure 4 Abundance of *Acartia* spp. and *Acartiella sinensis* (Log of mean catch*m^3+1) from the CB net in Spring (A), Summer (B), and Fall (C), 1974 - 2007

Acartiella sinensis is an introduced calanoid copepod first recorded in spring 1994 that is most abundant in the entrapment zone during summer and fall. In 2007, *A. sinensis* was the third most abundant calanoid copepod in the study area across all surveys. Its relative abundance was highest in fall, when it accounted for 29% of the total calanoid copepod CPUE (Figure 3C). Spring abundance has always been highly variable, but has decreased steadily since 2004 (Figure 4A). Summer abundance decreased from 1994 through 1998, then sharply declined in 1999 and remained very low in 2000 (Figure 4B). Since 2001, summer abundance has rebounded from the record lows of 1999 and 2000, and in 2007 reached its second highest summer abundance since its introduction. Fall abundance has been relatively stable since 2001 (Figure 4C). In 2007, *A. sinensis* abundance peaked in the lower Sacramento River and Suisun Bay, with a mean CPUE of 668 m^{-3} from July through November.

The introduced freshwater calanoid copepod *Sinocalanus doerrii* was first recorded in spring 1979. Initially most abundant in summer, *S. doerrii* abundance began to decline during summer and fall in the mid-1980s (Figure 5B and 5C). This downward trend continued through the mid-1990s, followed by a modest increase until recently. In 2007, *S. doerrii* was the fifth most abundant calanoid copepod in the study area across all surveys. Its relative abundance peaked in spring, when it accounted for 10% of the total calanoid copepod CPUE (Figure 3A).

Spring abundance, which has always been more variable than summer or fall abundance, was lowest in 1995 and steadily increased through 2004 (Figure 5A). Subsequently, abundance decreased in spring 2005 and 2006, but increased slightly in 2007. Summer abundance declined sharply in 2004, and then increased slightly in 2005 and 2006, before decreasing again in 2007 (Figure 5B). In the mid-1990s, fall abundance dropped to very low levels and then increased and remained higher through 2003. Fall abundance declined in 2004 and 2005, and although increased slightly in 2006 and 2007, levels were similar to the record lows of the mid-1990s (Figure 5C). In 2007, *S. doerrii* was most abundant from April through June in the lower Sacramento River, Frank's Tract, and the southern Delta where mean CPUE exceeded 400 m^{-3} in each area; after which densities were low throughout the estuary.

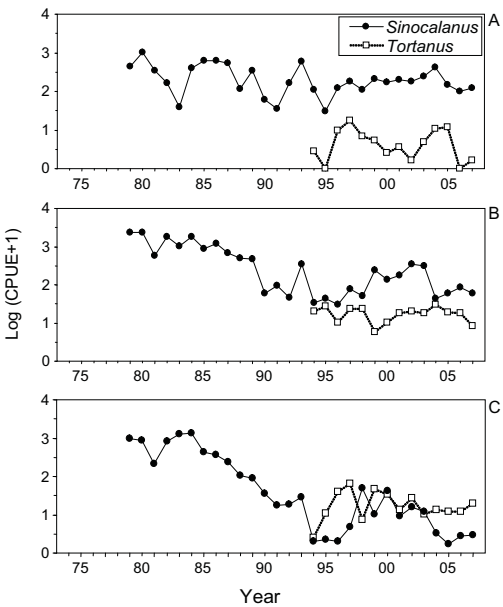

Figure 5 Abundance of *Sinocalanus doerrii* and *Tortanus dextrilobatus* (Log of mean catch*m^3+1) from the CB net in Spring (A), Summer (B), and Fall (C), 1974 - 2007

Tortanus dextrilobatus is an introduced brackish-water calanoid copepod first recorded in spring 1994 that is most abundant at the highest salinities sampled, suggesting that it may be more abundant downstream of the sampling area. *T. dextrilobatus* becomes more abundant in the sampling area as flows decrease during summer and fall. In 2007, *T. dextrilobatus* was one of the least abundant calanoid copepods; relative abundance peaked in fall when it accounted for only 2% of the total calanoid copepod CPUE. *T. dextrilobatus* abundance increased in spring and fall in 2007 from 2006, but decreased in summer (Figure 5). In 2007, *T. dextrilobatus* was most abundant during summer and fall in Carquinez Strait, Suisun Bay, and Suisun Marsh with a mean CPUE of 32 m^{-3}.

Cladocerans

Bosmina, *Daphnia*, and *Diaphanosoma* are the most abundant cladoceran genera in the upper estuary. Combined, these native freshwater cladocerans had an overall downward trend since the early 1970s, especially in fall (Figure 6). Abundance increased in all seasons from 2006 to 2007 (Figure 6), probably as a result of reduced dispersal due to low outflow allowing for very high densities, particularly in the eastern Delta. These cladoceran genera were common throughout the upper estuary upstream of the entrapment zone in 2007, and were most abundant in the eastern Delta from March through November where CPUE was 23,530 m^{-3}. During April in the lower San Joaquin River near Stockton, density exceeded 200,000 m^{-3}.

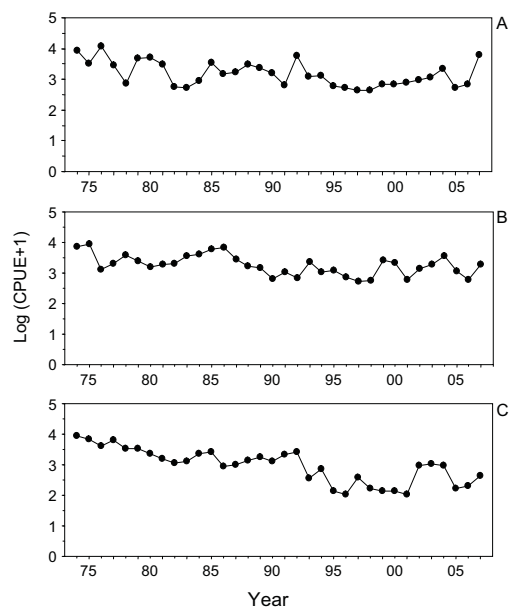

Figure 6 Abundance of Cladocera (Log of mean catch*m^3+1) from the CB net in Spring (A), Summer (B), and Fall (C), 1974 - 2007

Rotifers

Synchaeta bicornis is a native brackish-water rotifer that is usually most abundant in the upper estuary in sum-

mer and fall, when salinity increases. However, summer and fall abundances have experienced long-term declines since the 1970s (Figure 7). Spring abundance, although erratic, has also shown an overall downward trend (Figure 7A). After a peak in spring 2000, abundance declined sharply in 2001, and since 2002 there has been no catch during spring at any core stations. Summer abundance increased from one of the lowest since sampling began in 2006 to the highest level since the late 1990s in 2007 (Figure 7B). Fall 2007 abundance decreased from 2006 dropping to the second lowest index on record (Figure 7C). In 2007, *S. bicornis* was most abundant from July through September in Carquinez Strait and Suisun Bay when mean CPUE exceeded 12,000 m^{-3}.

All other rotifers, without *S. bicornis*, experienced abundance declines in all seasons from the early 1970s through the 1980s, but have stabilized since the early 1990s (Figure 7). Spring and fall abundances increased from 2006 to 2007 (Figure 7A and 7C), whereas summer abundance declined slightly (Figure 7B). Rotifers were common throughout the study area in 2007, with peak abundance in the eastern Delta, where mean CPUE for the year exceeded 160,000 m^{-3}.

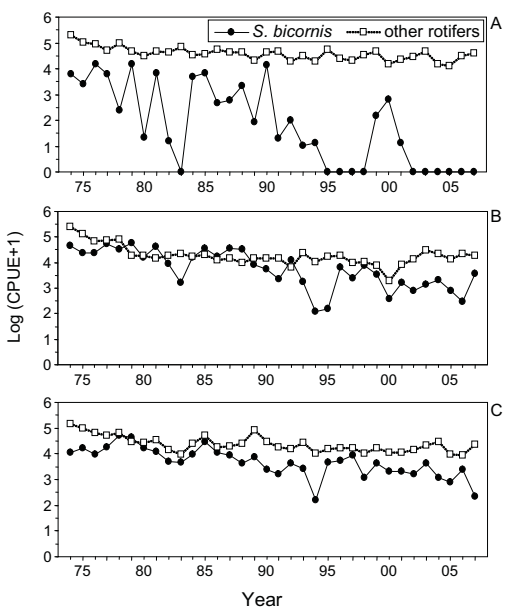

Figure 7 Abundance of *Synchaeta bicornis* and rotifers excluding *S. bicornis* (Log of mean catch*m^{3}+1) from the pump in Spring (A), Summer (B), and Fall (C), 1974 - 2007

Mysids

Hyperacanthomysis longirostris (formerly *Acanthomysis bowmani*) is an introduced mysid first collected by the study in summer 1993, and has been the most abundant mysid in the upper estuary every season since summer 1995 (Table 1). *H. longirostris* is commonly found in densities of more than 10 m^{-3}. Spring *H. longirostris* abundance increased between 1995 and 1998, and fluctuated annually thereafter. In 2007, spring abundance declined to the third lowest since being introduced. *H. longirostris* is most abundant in summer with an average annual abundance of 18 m^{-3}. Since 2001, summer abundance has had a downward trend; however, abundance remained at a moderate level in summer 2007. After a peak in 2005, *H. longirostris* fall abundance decreased sharply in 2006 and again in 2007 to the lowest fall abundance since being introduced. In 2007, *H. longirostris* was most abundant April through June in Suisun Marsh, where mean density was 27 m^{-3}. As flows decreased throughout summer, the center of distribution shifted upstream to eastern Suisun Bay and the lower Sacramento River.

Neomysis mercedis, historically the only common mysid in the upper estuary, suffered a severe population crash in the early 1990s and in 2007 was the fourth most abundant mysid in the sampling area across all surveys. *N. mercedis* is most abundant in spring and summer, and prior to the population crash of the early 1990s spring and summer densities averaged more than 50 m^{-3} (Table 1). Since 1994, mean spring abundance has been less than 1 m^{-3}, rendering *N. mercedis* inconsequential as a food source in most open-water areas of the upper estuary. Although spring abundance increased slightly from 2005 to 2006, it remained at very low levels, and in 2007 dropped to the lowest spring abundance since monitoring began. Summer abundance declined slightly in 2007 from 2006 and continued to remain at the extremely low levels observed since 1997. In fall 2005, 2006, and 2007, no *N. mercedis* were collected at any of the stations sampled. In 2007, *N. mercedis* was very rare throughout the study area, with densities less than 1 m^{-3} at every station, including the Suisun Marsh stations that in recent years had substantially higher densities than other regions.

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

Year	*Hyperacanthomysis longirostris*			*Neomysis mercedis*			*Neomysis kadiakensis*			*Alienacanthomysis macropsis*		
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
1974-1989				54.284	85.238	18.108						
1990				23.466	7.521	0.436						
1991				31.530	18.331	0.488						
1992				4.223	1.964	0.076						
1993			2.470	7.077	20.345	0.008						
1994	0.935	21.604	2.064	0.449	0.733	0.004						
1995	0.438	7.180	4.407	0.589	0.370	0.000				0.000	0.000	0.000
1996	1.636	11.777	4.432	0.550	1.432	0.001	0.033	0.001	0.017	<.001	0.000	0.003
1997	7.041	27.630	7.714	0.552	0.063	0.000	0.006	0.011	0.399	<.001	0.000	0.000
1998	18.136	5.792	18.692	0.181	0.238	0.024	0.103	0.041	0.006	0.005	0.000	0.008
1999	3.888	34.697	14.329	0.285	0.296	0.001	0.037	0.007	0.075	0.004	0.000	0.001
2000	23.067	38.453	11.196	0.850	0.136	0.001	0.073	0.165	0.465	0.003	0.000	0.001
2001	5.305	13.441	8.937	0.388	0.048	0.001	0.243	0.351	0.143	0.011	0.001	0.001
2002	10.099	21.155	7.516	0.022	0.069	0.001	0.209	0.254	0.753	0.005	0.000	0.002
2003	4.341	21.307	4.555	0.022	0.046	<.001	0.314	0.209	0.166	0.038	0.000	0.003
2004	9.915	13.725	5.044	0.150	0.016	0.002	0.129	0.106	0.170	0.001	0.000	0.001
2005	4.010	16.281	11.613	0.092	0.141	0.000	0.173	0.104	0.077	0.003	0.000	0.004
2006	7.186	14.143	1.967	0.321	0.137	0.000	0.071	0.727	0.051	0.001	0.000	0.001
2007	0.969	8.997	0.575	0.005	0.023	0.000	0.176	0.306	0.122	0.004	<.001	0.025

Neomysis kadiakensis is a native brackish-water mysid that regularly appeared in mysid samples beginning in 1996, but has never become common (Table 1). Since 2001, *N. kadiakensis* has been the second most abundant mysid in the study area, but at much lower levels than *H. longirostris*. Spring and fall abundance increased slightly from 2006 to 2007, although remained very low. After reaching the highest summer abundance in 2006, summer abundance decreased in 2007. In 2007, *N. kadiakensis* was most abundant in Suisun Marsh from April through September, where mean density exceeded 1 m^{-3}; as flows decreased throughout summer and fall, distribution shifted to Suisun Bay. Since the late 1990s, *N. kadiakensis* has extended its range to low salinity water at the confluence of the Sacramento and San Joaquin rivers, leading to the hypothesis that some of the upper-estuary specimens may be a second species, *N. japonica*. To date no physical characteristics have been published to separate these 2 species.

Alienacanthomysis macropsis is a native brackish-water mysid found most often in San Pablo Bay and Carquinez Strait that was first consistently enumerated by the study in 1995. *A. macropsis* has never been common in the sampling area and therefore indices have not previously been reported. However, in 2007 *A. macropsis* became slightly more abundant than *N. mercedis*, and for the first time was the third most abundant mysid in the upper estuary across all stations and surveys. Although spring and summer 2007 abundance increased slightly from 2006, *A. macropsis* remained a minor component of the mysid community (Table 1). Fall 2007 abundance was the highest since *A. macropsis* has been enumerated, and was approximately 10 times the mean fall 1995-2006 abundance. *A. macropsis* was found in San Pablo Bay and Carquinez Strait during every survey of 2007, except July and August when none were collected. In 2007, *A. macropsis* was most abundant in December in Suisun Bay, Carquinez Strait, and San Pablo Bay, where the average density was slightly greater than 1 m^{-3}.

2007 Shrimp Annual Status and Trends Report for the San Francisco Estuary

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This report summarizes annual abundance trends from 1980 through 2006 and distribution during 2006 for the most commonly collected caridean shrimp from San Francisco Estuary. The shrimp data is from the San Francisco Bay Study (Bay Study) otter trawls, with additional *Exopalaemon modestus* data from the UC Davis Suisun Marsh otter trawl survey and the USFWS beach seine survey. The 2007 Bay Study shrimp samples should be processed and the data available by late 2008.

Crangon franciscorum, the California bay shrimp, is the largest of the common shrimp in the estuary and usually the most abundant. It is targeted by the Bay Shrimp commercial trawl fishery because of its size and abundance. Planktonic larvae hatch in late winter and spring in higher salinity (>25 ‰) areas of the estuary and, in high outflow years, the nearshore coastal area. Juveniles migrate upstream and rear in shallow brackish water for several months and maturing shrimp migrate back to cooler, higher salinity areas for reproduction. *C. franciscorum* reaches maturity within 1 year and some females live 1.5 to 2 years.

The 2006 juvenile *C. franciscorum* abundance index was over 3 times higher than the 2005 index and was the highest index since 1998 (Figure 1). Based on a total index (i.e., all sizes), *C. franciscorum* was the most abundant shrimp species in the estuary in 2006 (Table 1). Adult shrimp from the 2005 cohorts were most common from January through May 2006, with a few collected through August, while juvenile abundance peaked from May through November, an unusually long period. The largest juvenile cohort was first collected in April, a second smaller cohort in July, and a third very small cohort in February. By December, male *C. franciscorum* from the 2006 cohorts had a modal size of approximately 46 mm total length (TL), while females were approximately 55 mm TL.

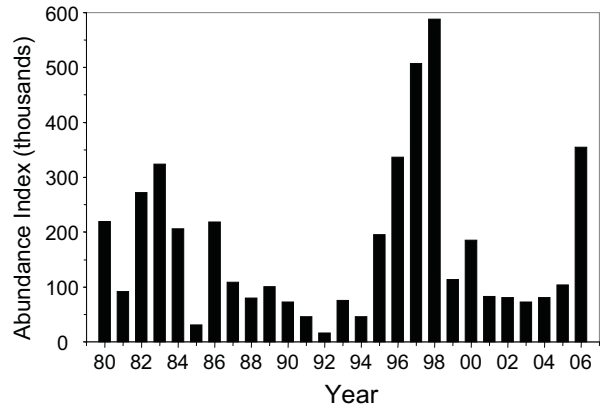

Figure 1 Annual abundance indices of juvenile *Crangon franciscorum*, May to October, otter trawl

Due to the high freshwater outflow in 2006, *C. franciscorum* distribution was not as broad as in 2005 for most of the year. Through April, most adult shrimp were collected in Central Bay, although distribution did extend into the channels of South and San Pablo bays,. In spring and summer, the highest juvenile catches were in San Pablo Bay. By June, juveniles were also common in Carquinez Strait and the southern most South Bay stations and by July they were collected in Suisun and Honker bays. *C. franciscorum* was not collected in the lower Sacramento River until August and in the lower San Joaquin River until November. Maturing *C. franciscorum* started to migrate downstream in fall, and by December the highest catches were again in Central Bay.

The increased *C. franciscorum* abundance in 2006 was predicted based on the increased freshwater outflow in spring 2006. March to May outflow continued to have a strong positive relationship with juvenile *C. franciscorum* abundance (both variables log transformed, r^2 = 0.553, n=27; Figure 2). Since *C. franciscorum* is estuary-dependent and rears in shallow brackish areas, this relationship is believed to be partially due the quantity of low-salinity shoal habitat increasing or decreasing with outflow. San Pablo Bay is an important nursery area in higher outflow years, and has a larger shoal area than upstream embayments. *C. franciscorum* juvenile CPUE at San Pablo Bay shoal stations averaged nearly 1,400 shrimp/tow from May to August 2006, compared to only 400 shrimp/tow in 2005 and 230 shrimp/tow in 2004, when outflow was much lower.

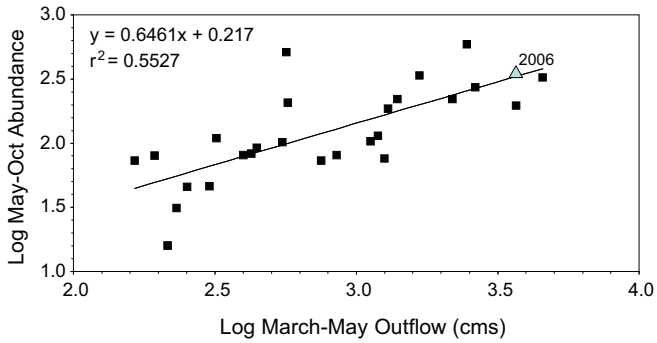

Figure 2 Annual abundance indices of juvenile *Crangon franciscorum*, May to October, vs. March to May outflow. Both axes are log transformed.

Crangon nigricauda, the blacktail bay shrimp, is usually the second most common caridean shrimp in the estuary. Similar to juvenile *C. franciscorum*, juvenile *C. nigricauda* migrate to warmer, lower salinity areas to rear and adults migrate back to cooler, higher salinity areas for reproduction. However, all life stages of *C. nigricauda* are found in cooler, higher salinity areas than *C. franciscorum* and therefore *C. nigricauda* is not considered to be an estuary-dependent species. Peak reproduction is usually in spring, and multiple cohorts are common. *C. nigricauda* abundance decreased in 2006 (Table 1), likely in response to the very high spring outflow and reduced salinities throughout much of its normal range within the estuary. Although the trend of above average *C. nigricauda* indices continued in 2006, it was no longer the most abundant shrimp species in the estuary but ranked second behind *C. franciscorum*. In 2006, *C. nigricauda* abundance peaked in January and February (the 2005 cohorts) and from June to August (the 2006 cohorts). Abundance dropped sharply in March and April 2006 with the record high spring outflow. Typical for this species, several cohorts of juvenile shrimp were collected in 2006: the first in January, the second and largest appeared in April and May, a third in August, and a fourth very small cohort in December. By December, the majority of the 2006 cohorts were mature, with a modal size of 38 mm TL for males and 50 mm TL for females.

C. nigricauda was collected from South Bay through San Pablo Bay in 2006. Overall, the highest catches were from the channel stations near Alcatraz and Angel islands and Southampton Shoal in Central Bay. Juvenile *C. nigricauda* were most common at channel stations from near Hunter's Point in South Bay throughout Central Bay through May, and expanded to the Central and San Pablo Bay shoals in June and July. From August to October, distribution continued to shift upstream, with the highest catches from San Pablo Bay in October. Adult *C. nigricauda* were most common at Central Bay channel stations during all months, although distribution expanded into San Pablo Bay to near Point Pinole in late summer and fall and to South Bay near the Dumbarton Bridge in November.

Crangon nigromaculata, the blackspotted bay shrimp, is found in cooler, higher salinity water than either *C. franciscorum* or *C. nigricauda* and is the most common shrimp collected in the nearshore ocean area adjacent to the estuary (SFWQB 2003). *C. nigromaculata* abundance decreased in 2006, but remained above the study-period average (Table 1). This abundance decrease was expected with the high spring outflows and was similar in magnitude to the *C. nigricauda* abundance decrease reported above. Abundance peaked in January and February, before the highest outflow events, and from June through September. *C. nigromaculata* ranged from South Bay to mid San Pablo Bay in 2006, with most collected in the channels just south of the Bay Bridge and near Angel Island, and from Southampton Shoal in Central Bay. Distribution was relatively broad in January and February, contracted to primarily Central Bay with the high outflows in spring, and expanded again in June. Most of the San Pablo Bay catches were from the channel stations from July to December.

Heptacarpus stimpsoni, the Stimpson coastal shrimp, is a small shrimp common over soft bottoms and eelgrass beds in the higher salinity regions of the estuary. In 2006, *H. stimpsoni* abundance decreased, continuing the decline that began after the record high abundance in 2002 (Table 1). As for *C. nigricauda* and *C. nigromaculata*, the *H. stimpsoni* abundance decrease was attributed to the very high outflows in spring 2006. *H. stimpsoni* was collected from South Bay, near the San Bruno Shoal, through Central Bay in 2006. None were collected in San Pablo Bay for the first time since 1983, another very high outflow year. The highest catches occurred at the channel stations south of Yerba Buena Island and near Angel Island.

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

Year	*C. franciscorum*	*C. nigricauda*	*C. nigromaculata*	*Heptacarpus*	*Palaemon*	All species
1980	225.7	46.4	1.7	1.0	4.7	279.5
1981	119.2	22.1	0.5	0.5	5.1	147.4
1982	366.4	16.0	1.5	0.2	3.0	387.1
1983	328.5	38.8	16.0	0.6	1.3	385.2
1984	330.9	14.7	7.8	3.1	7.0	366.4
1985	57.8	19.7	3.1	3.1	3.9	88.3
1986	258.6	55.6	6.7	2.9	5.5	334.7
1987	142.9	75.5	9.6	6.8	2.4	238.9
1988	98.6	111.8	10.7	8.6	1.7	231.5
1989	100.2	118.6	22.1	27.4	4.6	273.1
1990	67.3	168.6	44.8	19.9	3.5	304.7
1991	51.4	190.3	63.0	41.1	4.7	350.8
1992	24.8	134.7	66.4	18.5	4.5	249.0
1993	70.5	128.1	78.6	25.4	4.0	308.3
1994	48.0	102.0	56.0	15.9	2.1	224.5
1995	180.6	78.8	33.1	4.3	3.7	302.3
1996	287.0	159.4	35.3	14.9	2.2	501.3
1997	444.5	163.9	43.4	9.1	4.9	667.9
1998	540.6	128.5	53.1	4.8	9.0	739.0
1999	159.5	134.6	42.0	13.2	4.1	354.3
2000	157.5	242.7	20.7	42.2	3.1	467.5
2001	92.9	259.6	12.0	56.6	5.2	427.0
2002	96.1	652.9	15.0	78.0	4.9	848.7
2003	77.3	379.5	15.7	67.5	1.5	544.2
2004	91.7	333.7	20.5	29.0	1.9	477.5
2005	106.0	365.5	46.8	17.9	4.1	541.1
2006	395.2	267.7	34.0	10.1	7.6	715.0
% change 2005-2006	372.8%	73.2%	72.6%	56.4%	185.4%	
% total 2006	55.3%	37.4%	4.8%	1.4%	1.1%	

Palaemon macrodactylus, the oriental shrimp, was introduced from Asia in the 1950s (Newman 1963). It is found in tidal brackish and freshwater areas, preferring shallow habitats with structure, such as vegetation and pilings. Since these habitats are not sampled well by trawls, *P. macrodactylus* is likely more common in the estuary than our sampling indicates. Although abundance increased in 2006 (Table 1) and was the second highest for the study period, *P. macrodactylus* remained a minor component of our total shrimp catch. Abundance also increased in other high outflow years (1983 and 1998), probably because shrimp moved into the sampling area in response to flow or salinity. In 2006, *P. macrodactylus* was most common in South Bay, near the Dumbarton Bridge, San Pablo Bay, and Carquinez Strait.

P. macrodactylus has been uncommon at our lower Sacramento River stations since 2002, when the recently introduced *Exopalaemon modestus* became common. This trend continued in 2006, when only 6 *P. macrodactylus* were collected at the 7 Sacramento River stations. *E.*

modestus was the dominant shrimp species in the lower Sacramento River from 2002 through 2006 (see next section). Since both *E. modestus* and *P. macrodactylus* rear in shallow areas with vegetation or other structure, the reduced catch of *P. macrodactylus* in the upstream portion of its distribution may have resulted from competitive interactions with or predation by *E. modestus*. But high outflow likely contributed to the low Sacramento River *P. macrodactylus* catch in 2006, as very few were collected there in 1998, a high outflow year which predates the introduction of *E. modestus*.

Exopalaemon modestus, the Siberian prawn, is another introduced shrimp from Asia. It is common in tidal brackish and freshwater areas of the estuary as well as in rivers and sloughs upstream of the delta. *E. modestus* is the only shrimp species in the estuary that can complete its life cycle in freshwater. Because it is most common at the upstream stations added in the 1990s that are not included in the Bay Study abundance indices, mean number per tow (catch per unit effort or CPUE) for all stations upstream of Carquinez Strait is used to describe trends instead of annual abundance indices. Suisun Marsh annual CPUE is mean number per 5 minute tow for all stations, while USFWS beach seine CPUE is catch per volume (seine volume*0.25) for selected stations.

E. modestus was first collected in the lower Sacramento River in 2000 and its abundance and distribution rapidly expanded within 1 to 2 years. In 2006, Bay Study catch and CPUE decreased slightly while Suisun Marsh catch and CPUE increased over twofold (Table 2). USFWS beach seine *E. modestus* CPUE decreased at most locations upstream of the confluence in 2006 (Table 2), with the highest CPUE at the stations near Stockton, Knights Landing, and Rio Vista.

E. modestus was again the most common caridean shrimp in the lower Sacramento and San Joaquin rivers in 2006, where it has outnumbered both the native *C. franciscorum* and the introduced *P. macrodactylus* since 2002. However, high freshwater outflow probably contributed to low *C. franciscorum* and *P. macrodactylus* abundance in the lower rivers in 2006 due to their salinity preferences. *E. modestus* was also the most common caridean shrimp collected from 2002 to 2006 in Suisun Marsh (Schroeter, et al. 2006; UC Davis unpublished data).

E. modestus catch peaked from September to December in the Bay Study and Suisun Marsh trawls. *E. modestus* reproduces in summer, so this seasonal pattern probably resulted from either juvenile shrimp moving into the sampling area or reaching a size effectively retained by the otter trawl. We have collected relatively few ovigerous *E. modestus* since 2000, a trend that continued in 2006, when only 3% (n=39) of all females were ovigerous. By comparison, 31% of all *P. macrodactylus* females collected in 2006 were ovigerous. Data from the Bay Study and other sources indicates that the primary *E. modestus* reproductive areas are in freshwater, upstream of our study area, and in Suisun Marsh.

In 2006, *E. modestus* was most common in the lower Sacramento River channel near Sherman and Decker islands and Rio Vista in the Bay Study trawls. It was also widespread throughout Suisun, Grizzly, and Honker bays to Carquinez Strait, and occasionally collected in San Pablo Bay. *E. modestus* was collected at all Suisun Marsh stations in 2006, but was most common in Denverton, Peytonia, Boynton, and Nurse sloughs. *E. modestus* did not expand its upstream distribution in 2006 according to the available data. As of late 2006, *E. modestus* had been collected from Ward's Landing (Colusa County) on the Sacramento River in the north, to Mud Slough (Merced County), a tributary of the San Joaquin River, in the south.

Table 2 Annual catch and CPUE of *Exopalaemon modestus* from several studies and gears. Bay Study and Suisun Marsh otter trawl CPUE is mean catch per tow and USFWS beach seine CPUE is catch per volume (seine volume*0.25). Bay Study data is from January 2000 to December 2006, Suisun Marsh data is from March 2002 to December 2006, and USFWS beach seine data is from July 2002 to December 2006.

	CDFG OT		UC Davis OT		USFWS seine		
	Carquinez Strait to lower Sacramento and SJ rivers		Suisun Marsh		Knights Landing	San Joaquin River, Stockton to Mossdale	San Joaquin River, near Tuolumne River
Year	Catch	CPUE	Catch	CPUE	CPUE	CPUE	CPUE
2000	3	0.01					
2001	2163	8.94					
2002	9929	41.37	7636	25.6	0.11	0.00	0.00
2003	8022	30.39	13838	51.2	0.56	0.02	0.00
2004	3696	14.10	3441	12.6	1.26	0.03	0.01
2005	3318	12.57	5490	19.7	0.57	0.08	0.16
2006	3087	11.84	12410	47.0	0.13	0.10	0.02

Acknowledgements

I thank John Durand and Robert Schroeter of UC Davis for the unpublished Suisun Marsh data and Jonathan Speegle of USFWS for the unpublished beach seine data.

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2007 Crabs Annual Status and Trends Report for the San Francisco Estuary

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This report summarizes abundance trends and distributional patterns of the most common *Cancer* crabs and *Eriocheir sinensis*, the Chinese mitten crab, through 2007 in the San Francisco Estuary. Most of the data is from the San Francisco Bay Study (Bay Study) otter trawl, with additional *E. sinensis* data from the UC Davis Suisun Marsh otter trawl survey and the CVP and SWP fish salvage facilities.

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 then emigrate from the estuary when approximately 100 mm CW. Estuary-reared crabs reach legal size at the end of their third year, 1 to 2 years before ocean-reared crabs. This faster growth is hypothesized to

be due to warmer temperatures and more abundant prey resources in the estuary (Tasto 1983).

The abundance index of age-0 *Cancer magister* increased in 2007, after 2 very poor years (Figure 1). Abundance in 2007 was comparable to 1999 and 2000, but not nearly as high as from 2001 to 2004. Ocean temperatures were slightly above average in late 2006 and below average in early 2007 (see the Physical Settings section of the Fishes Status and Trends report, page 29), when *C. magister* were hatching and rearing in the Gulf of the Farallones a combination that may not have affected larval survival. Infrequent winter storms should have resulted in a weak northward-flowing Davidson Current and retention of *C. magister* larvae in the Gulf of the Farallones. However, *C. magister* juveniles entered the estuary very late in 2007, with a few in May and the majority in June. This late entry was probably due to strong upwelling through May 2007 that transported larvae offshore. Relatively strong upwelling in early spring may also have affected estuary abundance, because a portion of the year class likely settled too far offshore to locate the estuary.

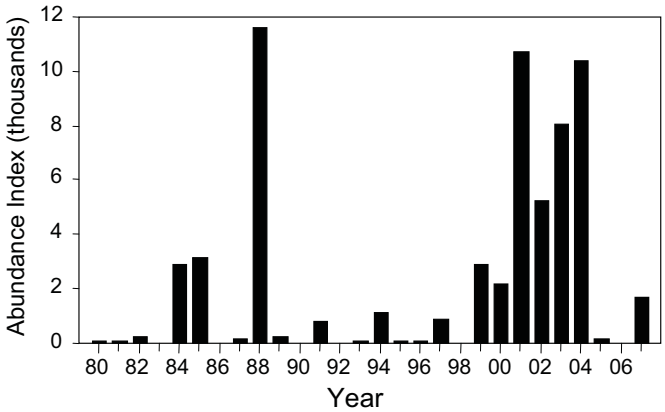

Figure 1 Annual abundance indices of age-0 *Cancer magister*, Bay Study otter trawl, May to July, 1980-2007.

The strong *C. magister* year classes earlier this decade were reflected in commercial landings. Central California landings surpassed 4 million pounds annually for the 2002-03 to 2006-07 fishing seasons, but only 2.5 million pounds were landed in the 2007-08 season through late April 2008 (B. McVeigh, personal communication, see "Notes"). The strong year classes of estuary-reared crabs from 2001 to 2004 reached legal size and entered the fishery consecutively from the 2003-04 to 2006-07 fishing seasons, while the weak 2005 year class first contributed to the fishery in 2007-08.

In 2007, we collected age-0 *C. magister* from South Bay to Carquinez Strait, with most from Central Bay in all months. There was a group of age-0 crabs that migrated upstream to rear, with the typical movement up the channel and over the San Pablo and western Suisun Bay shoals. Another group of crabs, possibly a later settlement, appeared to remain in Central Bay. The group that reared upstream reached a mean size of approximately 100 mm CW by December, while the group that remained in Central Bay had a mean size of only 35 mm CW.

The following 3 *Cancer* species reproduce in both the nearshore ocean and higher salinity areas of the estuary in winter. Therefore, estuary and ocean conditions may control larval survival and year-class strength.

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. In 2007, the age-0 *C. antennarius* abundance index increased from the very low 2006 index, and was the third highest index of the study period (Table 1). Peak abundance occurred in July and August, when a large number of small juveniles <20 mm CW were collected. More favorable ocean conditions and increased salinities within the estuary likely contributed to increased *C. antennarius* abundance in 2007.

In 2007, *C. antennarius* was collected from South Bay, near San Bruno Shoal, to San Pablo Bay, near Point Pinole. The highest age-0 catches were from the channel station near Hunter's Point in South Bay, the nearby shoal station off Alameda, and the shoal station just downstream of Point Pinole. Age-1+ *C. antennarius* were collected only at the Hunter's Point and Alcatraz Island stations in 2007. Smaller age-0 crabs again favored the shoals, with 64% of the crabs <35 mm CW collected from shoal stations. All *C. antennarius* ≥35 mm CW were collected at channel stations.

Cancer gracilis, the slender crab, is the smallest of the 4 *Cancer* crab species reported, 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 smaller size it cannot compete with the rock crabs for the more "preferred" protected habitats with structure. The 2007 abundance index of age-0 *C. gracilis* increased after 3 of the lowest annual indices in 20 years (Table 1). Age-0 abundance peaked from June to September; this peak included a number of recently settled juveniles.

C. gracilis was collected from near Candlestick Park in South Bay to near Point Pinole in San Pablo Bay 2007, with 99% (n=364) of all crabs collected from Central Bay. The highest catches were from the 3 Central Bay channel stations near Alcatraz and Angel Islands and the Southampton Shoal station.

Cancer productus is overall the least common of the 4 *Cancer* crabs collected by the otter trawl in the estuary, reflecting its strong preference for rocky intertidal and subtidal marine habitats not sampled by the trawl rather than its actual abundance. The 2007 age-0 *C. productus* abundance index decreased slightly from the 2006 index, resulting in 3 consecutive years of relatively low abundance (Table 1). Abundance peaked in April and May, and almost no age-0 crabs collected after June.

C. productus was collected from near Candlestick Park in South Bay to near Point Pinole in San Pablo Bay in 2007, with the majority from Central Bay. Eighty percent (n=56) of all *C. productus* were collected at the Alcatraz Island station, which has a gravel and small rock substrate, and all but 3 were collected from channel stations.

More favorable ocean conditions, combined with reduced freshwater outflow and increased salinities in 2007 likely resulted in the increased abundance of *C. antennarius* and *C. gracilis* in 2007. Although *C. productus* abundance was again low in our trawls, it was by far the most common crab collected by baited ringnets and traps in Central Bay for post-Cosco Busan oil spill special collections in November 2007. All of the *Cancer* crabs had a broader distribution in 2007, which was due to increased salinities and higher abundance.

Table 1 Annual abundance indices of age-0 *Cancer crabs* from the Bay Study otter trawl, 1980-2007. The index period is from May to October for *C. antennarius* and *C. gracilis* and from April to October for C. productus.

Year	*C. antennarius*	*C. gracilis*	*C. productus*
	age-0	age-0	age-0
1980	102	17	0
1981	76	152	6
1982	0	87	4
1983	28	151	4
1984	50	154	41
1985	20	216	38
1986	0	59	89
1987	71	93	79
1988	21	223	138
1989	29	203	30
1990	113	159	160
1991	171	656	128
1992	60	371	62
1993	398	616	71
1994	603	1,017	166
1995	367	227	40
1996	1,126	411	198
1997	351	1,131	86
1998	718	1,621	149
1999	90	222	249
2000	849	251	93
2001	276	1,921	142
2002	119	796	238
2003	424	522	140
2004	1,765	112	139
2005	144	132	57
2006	46	81	71
2007	987	418	58

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 *E. sinensis* population peaked in 1998 (Table 2). All data sources indicate that the population has steadily declined since 2001. In fall and winter 2007-08, no adult *E. sinensis* were collected at either fish facility or by the Bay Study or UC Davis Suisun Marsh trawl surveys in the northern estuary. There were also no reports of adult *E. sinensis* in South Bay (M. Seiff, personal communication, see “Notes”), the first year since 1994 that none were collected there.

USFWS monitoring for juvenile *E. sinensis* in the delta and its tributaries again detected no crabs in 2007. 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 2007 (D. Walther, personal communication, see “Notes”). One impact of *E. sinensis* commonly reported is bait stealing from sport anglers in the delta and Suisun and San Pablo bays,. From such public reports, we may learn of an

increase in the *E. sinensis* population before it is detected by our surveys.

What controls the *E. sinensis* population in the estuary is not understood, although winter temperatures and outflow are hypothesized to control survival and growth of larvae and timing of juvenile settlement. Larvae hatch in winter in the lower estuary and have no retention mechanisms, so high winter outflows can transport them from the estuary. Under these circumstances, ocean conditions may control larval survival in addition to estuary conditions. A "boom-and-bust" cycle has been reported for some introduced species, although this may not be universally true for all introductions.

Table 2 Annual adult *Eriocheir sinensis* CPUE and estimated total salvage, 1996-2007. Bay Study CPUE is from October (year) to March (year+1), Suisun Marsh CPUE is from July to December, and Central Valley Project (CVP) and State Water Project (SWP) fish facilities salvage is from September to November.

Year	Bay Study CPUE	Suisun Marsh CPUE	CVP salvage	SWP salvage
	(#/tow)	(#/tow)	est. total	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
2006	0.00	0.00	12	0
2007	0.00	0.00	0	0

Acknowledgements

I thank Robert Schroeter of UC Davis for the unpublished *E. sinensis* data from Suisun Marsh and Geir Aasen of DFG for the CVP and SWP fish facilities salvage data.

Notes

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Marilou Seiff, Marine Science Institute, email, May 8, 2008.

Denise Walther, USFWS, April 15, 2008.

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2007 Fishes Annual Status and Trends Report for the San Francisco Estuary

Maxfield Fish, Kathryn Hieb, Dave Contreras, Virginia Afentoulis, and Jennifer Messineo (CDFG)[1]

Introduction

The 2007 Status and Trends fishes report includes data from 5 of IEP's long-term fish monitoring surveys in the San Francisco Estuary: 1) the Summer Townet Survey (TNS), 2) the Fall Midwater Trawl Survey (FMWT), 3) the San Francisco Bay Study (Bay Study), 4) the Delta Smelt 20-mm Survey (20-mm Survey) and 5) the USFWS Beach Seine Survey. In addition, fish facilities salvage data is used in the splittail section. The most recent abundance indices, long-term abundance trends, and distributional information are presented for the most common species in the estuary and some less-common species of interest, such as splittail and the surfperches. Several pelagic species that spawn and rear in the upper estuary,

1. Authorship: Introduction, Methods, and Physical Setting, K. Hieb; American and threadfin shad, longfin smelt, splittail, plainfin midshipman, and white croaker, D. Contreras; delta smelt, striped bass, and the surfperches, V. Afentoulis; the gobies, flatfishes, and Pacific staghorn sculpin, M. Fish; Pacific herring, northern anchovy, and jacksmelt, J. Messineo.

and have undergone severe declines in recent years, are presented first. The upper estuary demersal fishes, marine pelagic fishes, surfperches, and marine demersal fishes follow this group. Within each section, species are presented phylogenetically.

Methods

The TNS has been conducted annually since 1959, and juvenile striped bass 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 currently begins in June and samples 32 sites from eastern San Pablo Bay to Rio Vista on the Sacramento River and to Stockton on the San Joaquin River. Historically the number of surveys ranged from 2 to 5 each year; as of 2003, sampling was standardized to 6 surveys per year. The striped bass index is interpolated between the 2 surveys that bracket when the year class reaches 38.1-mm fork length (FL) mean size (Chadwick 1964, Turner and Chadwick 1972); this occurred between surveys 3 and 4 in 2007. The delta smelt index is the average of the first 2 survey indices. In 2007, the TNS completed 6 surveys at 2-week intervals from June 11 to August 24.

The FMWT has sampled annually since 1967, except 1974 and 1979, when no surveys were conducted, and 1976, when sampling was limited and indices were not calculated. The FMWT was designed to determine the relative abundance and distribution of age-0 striped bass in the estuary, but 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 to Hood on the Sacramento River. The index calculation (Stevens 1977) uses catch data from 100 of the 116 stations; the remaining 16 stations were added to increase spatial coverage for delta smelt.

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

The 20-mm Survey monitors larval and juvenile delta smelt distribution and relative abundance throughout their historical spring range, which includes the entire delta downstream to eastern San Pablo Bay and the Napa River. Surveys have been conducted every other week from early March to July since 1995, with 9 surveys completed in 2007. Three tows are completed at each of the 48 stations with a 1,600-µm mesh net (Dege and Brown 2004). The survey name is derived from the size (20 mm) at which delta smelt are retained and readily identifiable at the CVP and SWP fish facilities.

USFWS has conducted beach seine sampling weekly since 1992 at approximately 40 stations in the delta and the Sacramento and San Joaquin rivers upstream of the delta (Brandes and McLain 2001). Data from the months May and June -- when age-0 splittail are effectively collected by USFWS beach seining -- and from 30 stations ranging from Sherman Lake at the confluence of the Sacramento and San Joaquin rivers upstream to Ord Bend on the Sacramento River, and almost to the Tuolumne River confluence on the San Joaquin River were used to calculate the annual splittail abundance index. Fish facilities salvage calculation methods are summarized in Geir Aasen's article, page 11 of this issue.

Data from the TNS, FMWT, and Bay Study was used to describe trends and distribution of upper estuary pelagic fishes when available, while only Bay Study midwater trawl data was used for the marine pelagic fishes and Bay Study otter trawl data for demersal fishes. The 20-mm Survey data was used for delta smelt and the USFWS beach seine and fish facilities salvage data for splittail. Catch-per-unit-effort (CPUE), specifically catch per tow, was consistently used to analyze and report distribution.

Physical Setting

Delta outflow in 2007 was the lowest since 1994, with a mean January-June daily outflow at Chipps Island of 340 cm/s. The 2007 outflow was about 10% of the 2006 outflow for the same periods in winter and spring. There were 2 relatively short outflow peaks in 2007, one in mid February that averaged approximately 1,000 cm/s over a week and one in early March that averaged approximately

800 cm/s over a week plus (see Kate Le's article, page18 of this issue). These 2 outflow events reduced salinities in much of Suisun Bay and Carquinez Strait to less than 2 ‰ in early March, and produced the lowest salinities of the year in the upper estuary.

The San Francisco Estuary is situated between 2 major marine faunal regions, the cold-temperature fauna of the Pacific Northwest and the subtropical fauna of southern and Baja California, and is a transitional area with elements of both faunas (Parrish et al. 1981). The northern Pacific Ocean reportedly entered a cold-water regime in 1999 (Peterson and Schwing 2003), which is hypothesized to benefit many cold-temperate species, including Dungeness crab, English sole, and many of the rockfishes. Gulf of the Farallones sea surface temperatures (SSTs) were slightly above the long-term mean in late 2006, associated with weak El Niño (warm ocean) conditions in the eastern equatorial Pacific. This was followed by below average SSTs (-0.5 to -1.3°C) in the Gulf of the Farallones in 2007, associated with a moderate La Niña (cool ocean) event that appeared in late summer 2007. For most of October and November 2006, daily SSTs were >14°C and occasionally >15°C at the Farallon Islands, whereas SSTs rarely exceeded >14°C in September and October 2007 (Warzybok and Bradley 2007). The most recent warm-water event of note was in fall 2004, when the Gulf of the Farallones SSTs were the highest since the very strong 1997-98 El Niño event.

The coastal ocean along central California is marked by 3 seasons: the upwelling season, from spring to late summer; the oceanic season, from late summer to late fall; and the Davidson Current season, from late fall to spring. During the upwelling season, prevailing northwesterly winds result in a southward surface flow, known as the California Current. Due to the Earth's rotation (Coriolis Effect), there is a net movement of surface waters offshore. These waters are replaced by nutrient-rich, cold water that is transported or upwelled from deeper areas. Upwelling is responsible for the high productivity of the California Current System. When the winds weaken in fall, upwelling stops, surface coastal waters warm, and productivity declines. In winter, southwesterly winds result in a northward surface flow, or the Davidson Current. This current, in conjunction with the Coriolis Effect, produces an onshore and downward transport of surface water, or downwelling. Many coastal fish and invertebrate species in the California Current Region reproduce in winter during the Davidson Current season, when pelagic eggs and larvae are likely to be transported to or retained in nearshore areas. Juveniles settle to the bottom nearshore and enter estuaries to rear before the onset of upwelling, as pelagic life stages present during the upwelling season will be transported offshore, often far from their preferred nearshore nursery areas.

The spring transition to the upwelling season was not later than usual in 2007, as in 2005 and 2006. Due to persistent strong coastal winds, upwelling indices for the West Coast were well above the mean for January through May 2007 (Goericke et al. 2007) and resulted in cooler SSTs that should have been favorable for primary and secondary production. Yet, juvenile rockfish recruitment and reproductive success for some seabirds, especially the planktivores, was poor in the Gulf of the Farallones (NMFS 2007, Warzybok and Bradley 2007). Upwelling indices in Central California decreased in June and July 2007, but upwelling for the season was near the long-term mean. This pattern of strong upwelling in spring followed by somewhat weaker upwelling in summer is unique for recent years. It fits neither the pattern of weak upwelling, warmer SSTs, and poor ocean productivity reported for 2004-2006 nor the pattern of strong summer upwelling, colder SSTs, and high ocean productivity reported for 1999-2003.

Upper Estuary Pelagic Fishes

American shad

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

The 2007 FMWT American shad (all ages) index was only 24% of the 2006 index, the second lowest index on record (Figure 1A). With the exception of the record high index in 2003, indices have been below or near the study-period average since 1998. American shad were collected from west Suisun Bay to the lower Sacramento River and

South Delta in 2007. They were most common in the lower Sacramento River all months of the survey.

The 2007 Bay Study midwater trawl age-0 American shad index was 7% of the 2006 index (Figure 1B) and the lowest index for the entire study period. The Bay Study collected age-0 American shad from August through December, and abundance peaked in November. They were collected from San Pablo Bay to the upstream limit of the study area, but were most common in the lower Sacramento River. Fish were collected further downstream from October to December, which reflected emigration from the estuary.

American shad indices decreased for both surveys in 2007, which may have resulted from low delta outflow. In the past, American shad abundance has shown a positive correlation with delta outflow during the rearing period (Stevens and Miller 1983). This response has been suppressed since the introduction of *C. amurensis* in the late 1980s (Kimmerer 2002).

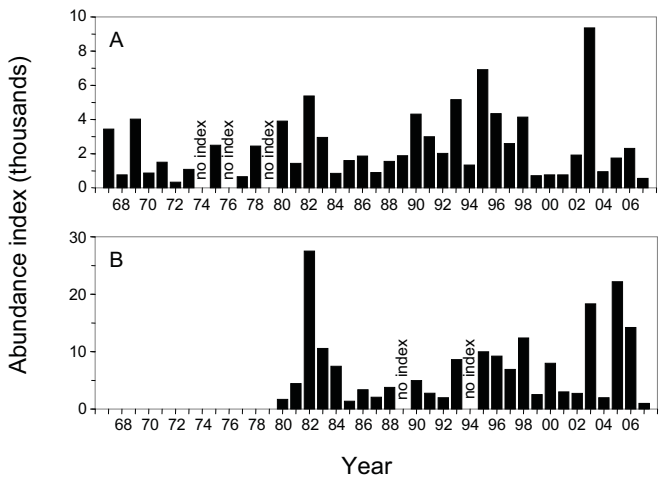

Figure 1 Annual abundance of American shad: A) FMWT, all sizes, September-December, B) Bay Study midwater trawl, age-0, July-October

Threadfin shad

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

The 2007 FMWT threadfin shad (all ages) index was 1.4 times the 2006 index (Figure 2). Since 2001, threadfin shad abundance has been below average, with a slight increasing trend. In 2007, FMWT catch was low from September through November, but substantially increased in December due to one large catch (n = 1747). Threadfin shad were collected from San Pablo Bay to the lower Sacramento River and South Delta. The majority of threadfin shad were collected in the South Delta in 2007, with a mean CPUE of 68 fish/tow. This was not unusual, as high catches from stations near Stockton have been observed in the past.

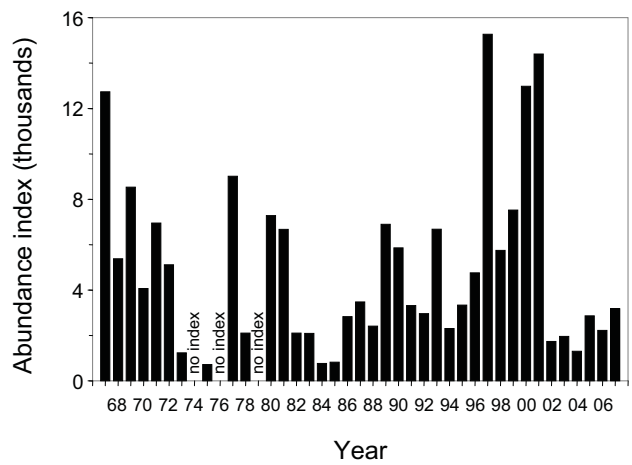

Figure 2 Annual abundance of threadfin shad (all sizes), FMWT, September-December

Delta smelt

The delta smelt (*Hypomesus transpacificus*) is a small (55-70 mm FL) osmerid, endemic to the upper San Francisco Estuary. The delta smelt population declined dramatically in the 1980s and it was listed as a state and federal threatened species in 1993. This species is considered environmentally sensitive because it typically lives for one year, has a limited diet, and resides primarily in the interface between salt and fresh water. In addition, females produce only 1,200 to 2,600 eggs (Moyle et al. 1992). Since the introduction of *Corbula amurensis* and its subsequent negative effects on phytoplankton and zooplankton production, several other important aspects of habitat suitability have changed, further affecting delta smelt abundance. One current hypothesis regarding the continued population decline is that fall carrying capacity has been reduced by human-induced changes and climate

variability. Increased water clarity and specific conductance, as described in Feyrer et al. (2007), are indicative of this reduced carrying capacity. Additional reasons for the delta smelt's decline include entrainment losses of larvae and juveniles in spring and adults in fall at water diversions, contaminants, including the toxic alga *Microcystis*, continued changes in prey availability, and predation.

The 2007 TNS delta smelt index was 0.4, the same as the 2006 index (Figure 3A) and comparable to the low indices observed since 2001. Delta smelt abundance peaked in survey 3, and decreased thereafter (Table 1). In 2007, the TNS collected delta smelt in western and eastern Suisun Bay and the lower Sacramento River, but none were collected in the lower San Joaquin River or South Delta. Although the range was similar to 2006, the center of distribution differed, likely due to changes in outflow. In June and July 2007, most delta smelt were caught in eastern Suisun Bay, near the confluence, and in Montezuma Slough, whereas, in 2006, most were caught in western Suisun Bay and the lower Napa River. In August 2007, delta smelt moved upstream to the lower Sacramento River near Decker Island. For the same period in 2006, most delta smelt were collected in eastern Suisun Bay, including Montezuma Slough and the confluence.

The 2007 FMWT delta smelt index was 68% of the 2006 index and the second lowest on record (Figure 3B). In September 2007, sampling detected a highly unusual distribution pattern, with 7 delta smelt captured at 6 western Suisun Marsh and Bay locations, all at salinities over 8 ppt. Based on September 2007 catch and salinity data, and a historical FMWT catch probability by salinity analysis by Feyrer et al. (2007), the probability was exceedingly small ($p = 0.001$) that such a distribution occurred by chance, given the historical delta smelt salinity distribution (K. Newman, personal communication, see "notes"). Although the cause of this distribution shift was not determined, it may have resulted from further deteriorating habitat conditions due to a very large bloom of the toxic alga *Microcystis aeruginosa* in the vicinity of Antioch in early August. In subsequent months, the FMWT delta smelt distribution was more typical, with the center of distribution ranging from Montezuma Slough to near Decker Island in the lower Sacramento River.

Although the 2007 Bay Study age-0 delta smelt index increased from the 2006 index of 0 (Figure 3C), it was still the fifth lowest index on record and only 18% of the study-period mean. With the exception of 2004, Bay Study indices have been below average since 2001. Age-0 delta smelt were first collected in July 2007 and abundance peaked in September. They were initially collected in Suisun Bay, Honker Bay, and near western Sherman Island, but from September through December catches were concentrated in the lower Sacramento River, near Decker Island.

The 2007 20-mm survey delta smelt index was 10% of the 2006 index (Figure 3D). It was the lowest index since the inception of the survey in 1995 and reaffirmed the abundance decline observed by the other long-term monitoring surveys. In mid-March, delta smelt distribution was centered in the lower portions of the Sacramento and San Joaquin rivers. By the third week of May, distribution expanded to eastern Suisun Bay, in the confluence area, and Montezuma Slough. In June and July, most delta smelt were collected near the confluence or in the lower Sacramento River, between Sherman and Decker islands.

Table 1 Mean length, catch, and indices by survey for delta smelt and striped bass for the Townet Survey, 2007

	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Survey 6
Delta Smelt						
Mean length (mm FL)	44	28	46	38	42	-
N	10	10	22	1	7	0
Survey Index	0.2	0.5	0.9	<0.1	0.2	0
Striped Bass						
Mean length (mm FL)	18	22	30	52	56	-
N	64	45	20	2	5	0
Survey Index	1.1	0.9	0.7	0.1	0.3	0

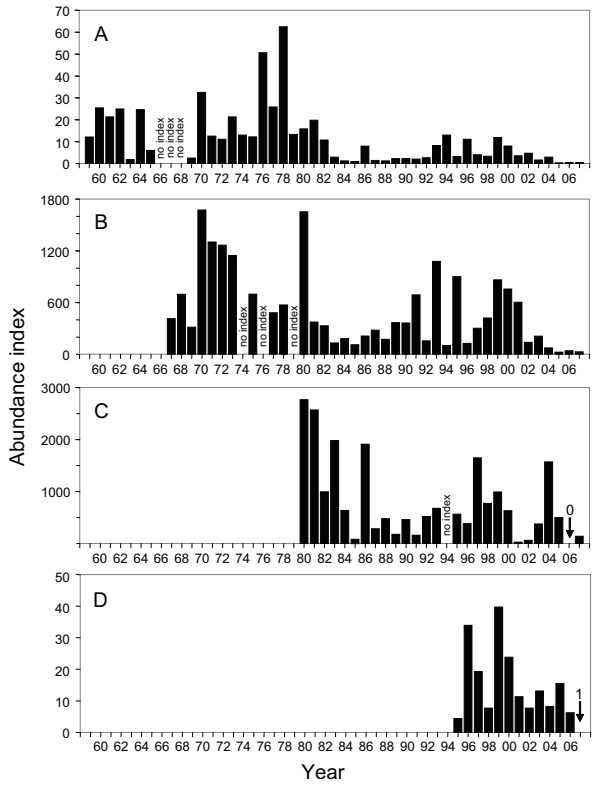

Figure 3 Annual abundance of delta smelt: A) TNS, age-0; B) FMWT, all sizes, September-December; C) Bay Study midwater trawl, age-0, June-October; D) 20-mm Survey larvae and juveniles

Longfin smelt

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

The 2007 FMWT longfin smelt (all ages) index was 1% of the 2006 index and the lowest on record (Figure 4A). No age-0 longfin smelt were captured by FMWT in 2007. A few adult longfin smelt (all maturing) were collected from San Pablo Bay and west Suisun Bay from September to November. They immigrated to western and eastern Suisun bays and the lower Sacramento River in December.

The 2007 Bay Study midwater trawl (BSMWT) age-0 longfin smelt index was 16% of the 2006 index, and the fourth lowest for the study period (Figure 4B). The BSMWT collected fish from May through November and abundance peaked in June. Age-0 longfin smelt were collected from South Bay through the lower Sacramento River, with most from San Pablo Bay.

The 2007 Bay Study otter trawl (BSOT) age-0 longfin smelt index was 17% of the 2006 index (Figure 4C), similar to the BSMWT. Age-0 fish were first collected in May by the otter trawl and abundance peaked in July and August. In 2007, age-0 longfin smelt from BSOT were most common in Central Bay until November, when they migrated to Suisun Bay.

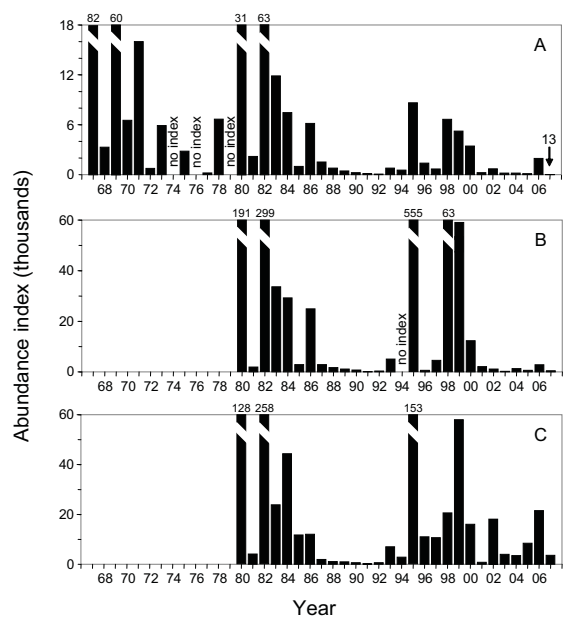

Figure 4 Annual abundance of longfin smelt: A) FMWT, all sizes, September-December; B) Bay Study midwater trawl, age-0, May-October; C) Bay Study otter trawl, age-0, May-October

Low outflow in winter and spring 2007 likely resulted in decreased longfin smelt abundance indices for both surveys. The FMWT longfin smelt abundance-outflow rela-

tionship decreased after the introduction of *C. amurensis* (Figure 5). The 2003 to 2005 indices were below the fitted line for the post-*C. amurensis* abundance-outflow relationship, but not as low as 2007.

The low 2007 FMWT longfin smelt index also could have been because the survey samples only a portion of the longfin smelt's habitat. The Bay Study collected most age-0 fish in Central Bay in 2007, well downstream of the FMWT sampling range. This distribution has been observed in past years, especially when outflow was high. However, longfin smelt were typically distributed farther upstream, from Suisun Bay to the lower Sacramento River, during previous low outflow years. We do not know why longfin smelt were distributed farther downstream than expected for the low outflow conditions of 2007.

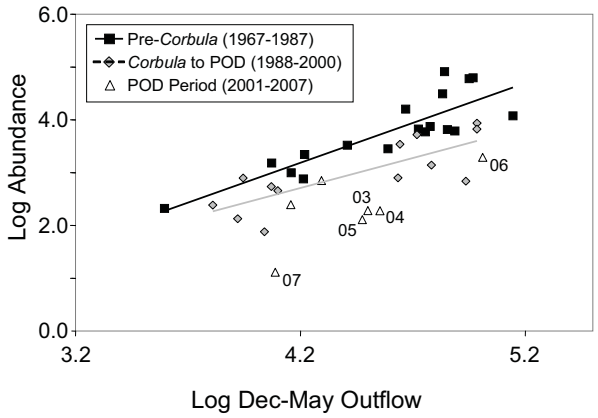

Figure 5 FMWT longfin smelt age-0 abundance index vs. outflow relationships pre- (1967-1987; solid line) and post (1988-2007; dashed line) *Corbula amurensis* introduction

Splittail

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

The 2007 FMWT splittail (all ages) index was 25% of the 2006 index (Figure 6A) and consisted of 1 age-1+ splittail collected in Grizzly Bay during September. No other splittail was captured by the FMWT for the remainder of the survey.

Both the 2007 BSMWT and BSOT age-0 splittail abundance indices were 0 (Figure 6B and 6C). This has occurred several times in the survey's history.

The 2007 USFWS beach seine age-0 splittail index was 10% of the 2006 record high index (Figure 6D). Distribution data suggests that splittail spawned in the upper Sacramento River near Colusa, the south fork of the Mokelume River, and the South Delta near Dad's Point in May. Most age-0 splittail were collected in the mid and upper Sacramento River near Reel's Beach and Colusa in June. These locations are miles upstream of the nearest trawl location for any of the long-term monitoring surveys.

Splittail salvage from the Tracy Fish Collection Facility in 2007 decreased considerably from the 2006 record high salvage (see Geir Aasen's article, Figure 15 page 17). Similar salvage was reported in 1994, 2002, and 2003, other low flow years.

The poor 2007 splittail year class likely resulted from low winter-spring outflow. Also, recruitment often diminished the year after a strong year class (Moyle et al. 2004). The FMWT and Bay Study sampling areas are probably downstream of the age-0 splittail's primary rearing areas, which are the rivers for the early portion of the year, as evidenced by the USFWS beach seine distribution data. This is in contrast to 2006, a high outflow year, when splittail reared from the South Delta to the lower Sacramento River. During low outflow years, splittail may need to travel farther upstream to find their critical spawning habitat of inundated floodplains or flooded river terraces.

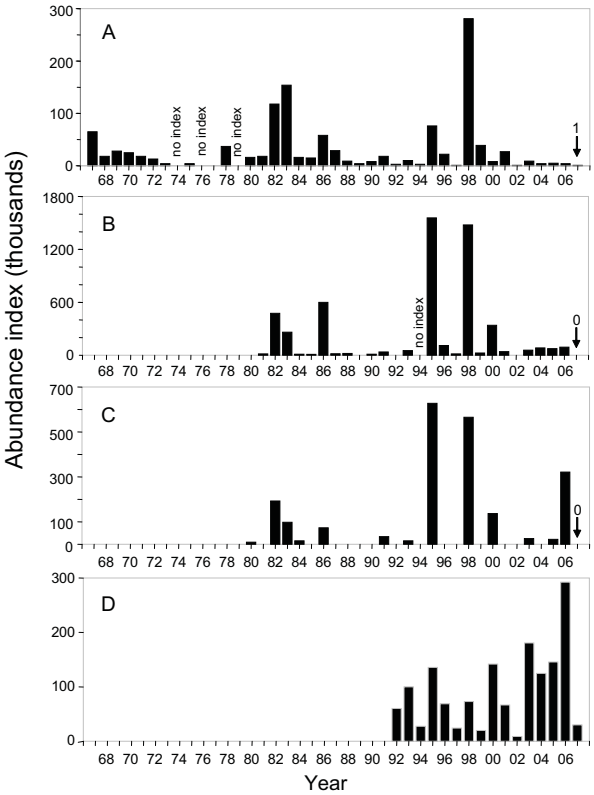

Figure 6 Annual abundance of splittail: A) FMWT, all sizes, September-December; B) Bay Study midwater trawl, age-0, May-October; C) Bay Study otter trawl, age-0, May-October; D) USFWS beach seine, May - June

Striped bass

Striped bass (*Morone saxatilis*) is an anadromous fish that was first introduced to the San Francisco Estuary over 125 years ago. Striped bass spawn in the rivers in spring and juveniles rear in fresh and brackish waters of the estuary. The population of legal-size fish in the San Francisco Estuary declined from nearly 4.5 million in the early 1960s, to only 600,000 in 1994. The population increased to about 1.6 million in 2000 and the most recent estimate, for 2005, was 1.0 million (CDFG, unpublished data). Age-0 striped bass abundance has steadily declined since the mid-1980s and some of the lowest TNS and FMWT indices on record occurred in the past 6 years, a period when the adult population showed a modest recovery. Based on our understanding of factors controlling striped bass abundance in the estuary, the most recent adult population increase was unexpected and remains unexplained. Stevens et al. (1985) hypothesized that low striped bass recruitment was related to: 1) the declining adult population, 2) reduced planktonic food supply, 3) loss of large numbers of young striped bass to diversions, and 4) population-level effects of contaminants.

The 2007 TNS striped bass 38.1-mm index was set at 0.3 on July 17, based on results from surveys 3 and 4 (Table 1). This was the lowest index in the 48-year history of the survey and continued the downward trend observed since the mid 1980s (Figure 7A). Striped bass abundance peaked in survey 1 and declined thereafter, with a slight increase from survey 4 to 5 and no fish collected in survey 6. They were widely distributed during the first 3 surveys, with fish collected in all areas each survey, except in the lower Sacramento River during survey 3. Distribution contracted in surveys 4 and 5, when fish were collected only in western Suisun Bay, Montezuma Slough, and the lower Sacramento and San Joaquin rivers, near the confluence.

The 2007 FMWT age-0 striped bass abundance index was 23% of the 2006 index (Figure 7B) and the third lowest on record. Indices since 2001 have been extremely low in comparison to historical FMWT indices. Abundance peaked in September and decreased thereafter; in December, only 2 striped bass were caught, resulting in the lowest monthly index in the history of the survey. In 2007, all age-0 striped bass collected by the FMWT were from western and eastern Suisun Bay, including stations near the confluence.

The 2007 BSMWT and BSOT age-0 striped bass indices were lower than the 2006 indices (Figures 7C and 7D). The 2007 BSMWT index was 31% of the 2006 index, but comparable to other recent years. The 2007 BSOT index was 14% of the 2006 index and was the third lowest index on record. Typically, the BSOT catches more age-0 striped bass than the BSMWT and this trend continued in 2007, with 711 collected in the otter trawl and 77 collected in the midwater trawl from June to December. The BSMWT first collected age-0 fish in August and abundance peaked in September. The BSOT first collected age-0 fish in June and abundance peaked from September to November.

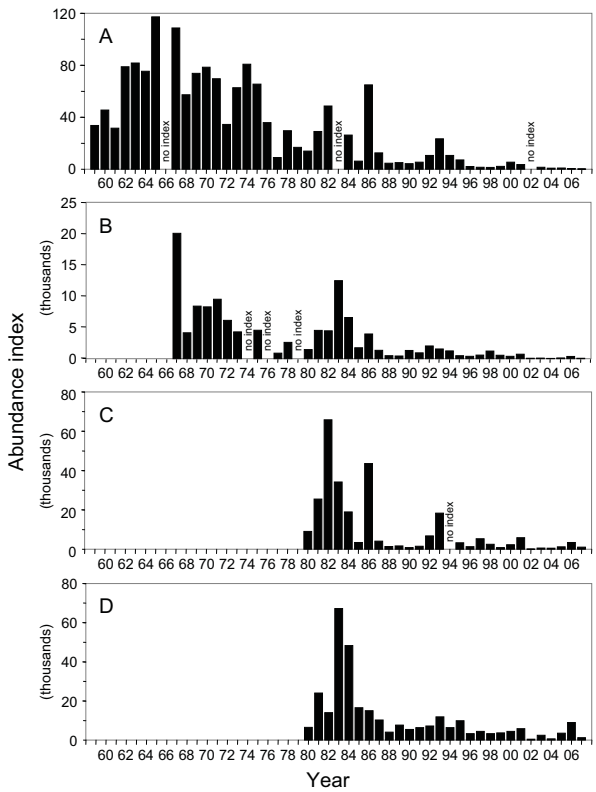

Figure 7 Annual abundance of age-0 striped bass: A) TNS 38.1-mm index; B) FMWT, September-December; C) Bay Study midwater trawl, June-October; D) Bay Study otter trawl, June-October

In 2007, the Bay Study collected age-0 striped bass from San Pablo Bay eastward to the lower Sacramento River near Rio Vista and to San Joaquin River at Old River Flats, the upstream limits of the study area. Fish were most common in the lower San Joaquin River all surveys, with a mean CPUE of 20 fish/tow from July through December in the otter trawl. Otter trawl collected fish were also strongly associated with the shoals (<7m deep), with a mean shoal CPUE of 4 fish/tow, 8 times the channel CPUE of 0.5 fish/tow. Catches from the midwater trawl also exhibited slightly higher shoal catches, with shoal CPUE 1.8 times higher than the channel CPUE.

In 2007, age-0 striped bass abundance decreased in all the long-term monitoring surveys, most likely a result of low outflow in spring. By contrast, age-0 striped bass abundance increased in 2006 for all the long-term surveys except the TNS in response to increased outflow. Striped bass survival and abundance have typically responded favorably to increased outflow, although these responses have been dampened since the invasion of the clam *C. amurensis* in the late 1980s (Kimmerer 2002; Sommer et al. 2007). Although age-0 striped bass abundance has been declining or very low for almost 2 decades, juvenile striped bass are still common in benthic shoal habitats and throughout much of Suisun Marsh. From the Bay Study otter trawl data, it appears that age-0 striped bass abundance in channels has declined at a higher rate than over the shoals. Mean channel post-*Corbula* (1987-2007) CPUE was only 9% of the mean pre-*Corbula* (1980-1986) CPUE. Although the mean post-*Corbula* shoal CPUE also declined, it was 25% of the mean pre-*Corbula* CPUE. One hypothesis is that juvenile striped bass are exploiting benthic shoal habitats for food resources such as amphipods, rather than the more pelagic mysids that were historically abundant and a large part of their diet (Bryant and Arnold 2007). As a result, age-0 striped bass are now less effectively captured by the TNS and FMWT, the traditional young striped bass surveys that primarily sample the water column, not the bottom or near-bottom habitats. These 2 surveys also sample almost exclusively at channel locations in the delta, whereas both channel and shoal locations are sampled downstream of the delta.

Upper Estuary Demersal Fishes

Shokihaze goby

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

In 2007 the mean Shokihaze goby CPUE was virtually identical to 2006, which was the highest CPUE for the study period (Figure 8). For the first time, the Shokihaze goby was collected in all regions in 2007. Record Shokihaze goby catches (n=94) were collected in San Pablo Bay from January through June, surpassing the 2006 record (n=64). Age-0 fish recruited to the otter trawl in July, with large catches occurring in the lower Sacramento River from August to November. As in 2006, the Shokihaze goby showed a strong association with deep waters of the estuary with 2.11 fish/tow from the channel stations and 0.30 fish/tow from the shoal stations in 2007.

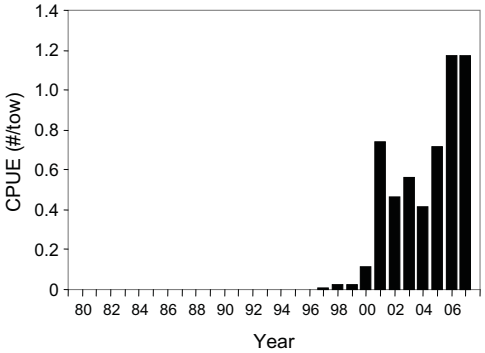

Figure 8 Annual catch-per-unit-effort (CPUE; #/tow) of Shokihaze goby (all sizes), Bay Study otter trawl, January-December

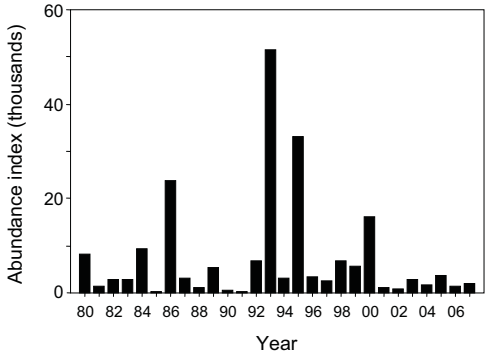

Figure 9 Annual abundance of age-0 yellowfin goby, Bay Study otter trawl, May-October

Yellowfin goby

The yellowfin goby (*Acanthogobius flavimanus*) is an introduced fish from Asia. It is partially catadromous: adults migrate to brackish water to spawn from December through July and most die after spawning. Juvenile fish migrate upstream to lower salinity and fresh water habitats to rear through summer and fall (Moyle 2002). The 2007 yellowfin goby age-0 abundance index was slightly higher than the 2006 index, but only 27% of the study-period average (Figure 9). The 2007 year class recruited to the otter trawl in July, which was atypical of low outflow years, in which May historically provided the first age-0 catches of the year. Abundance peaked in July and again in September.

In 2007, yellowfin gobies were collected from South Bay, south of the Dumbarton Bridge to the most upstream stations in the lower Sacramento River near Rio Vista and in the lower San Joaquin River at Old River Flats. Age-0 distribution was somewhat erratic, but the general pattern was one of highest CPUE in the lower rivers in July and August and in Suisun Bay from September through November. Age-0 yellowfin gobies showed an association with shallow water, with 0.7 fish/tow at shoal stations and 0.4 fish/tow at channel stations in 2007. The highest age-1+ yellowfin goby abundance occurred from January through April, during the spawning season. After the spawning season ended, age-1+ abundance was very low for the remainder of the year, which was likely due to the majority dying after spawning (i.e., partial semelparity). Age-1+ yellowfin goby distribution was centered in Suisun and San Pablo bays. This was a slight upstream distribution shift from 2006, likely a result of low delta outflow in 2007.

Starry flounder

The starry flounder (*Platichthys stellatus*) is an estuary-dependent species that spawns in the ocean, but rears in brackish and fresh water areas of estuaries. Since 2003 there has been a trend of increasing overall abundance, which continued in 2007 (Figure 10). The 2007 age-0 starry flounder index was 57% higher than the 2006 index and nearly double the study period average (Figure 10A). The 2007 starry flounder year class recruited to the otter trawl in May and catch peaked in July. In 2007, age-0 fish were collected in every embayment of the estuary. Age-0 CPUE peaked in May in the Sacramento River, June in Suisun Bay, and July in San Pablo Bay, indicating a downstream migration. As in previous years, age-0 fish were strongly associated with shallow water, with 1.1 fish/tow at shoal stations and only 0.4 fish/tow at channel stations in 2007.

The 2007 age-1 starry flounder abundance index was 67% of the study period average, similar to the 2003 through 2006 indices (Figure 10B). Age-1 starry flounder were collected in all months except June, and in all embayments. Age-1 CPUE peaked in February and March in Suisun Bay and the lower Sacramento River. Age-1 starry flounder CPUE was 4.5 times higher at shoal stations (0.18/tow) than at channel stations (0.04/tow).

The 2007 age-2+ starry flounder index was 33% higher than 2006, but was only 64% of the study period average (Figure 10B). Since the late 1980s, adult (age-2+) stock declined dramatically and has yet to recover to historical levels. Age-2+ starry flounder were collected in every survey except August, and every region except the San Joaquin River, with the highest CPUE in San Pablo Bay. Similar to the younger age groups, age-2+ CPUE was 5 times higher at shoal stations (0.15/tow) than at channel stations (0.03/tow).

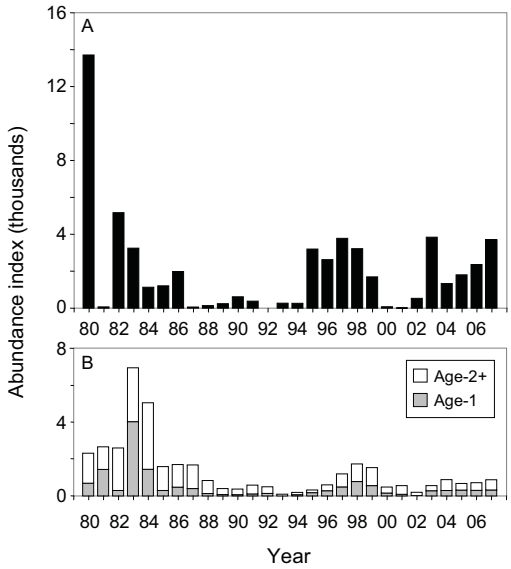

Figure 10 Annual abundance of starry flounder: A) age-0, Bay Study otter trawl, May-October, and B) age-1 and age-2+, Bay Study otter trawl, February-October

Marine Pelagic Fishes

Pacific herring

The Pacific herring (*Clupea pallasii*) is an estuary-dependent species that spawns and rears in higher salinity areas (>20‰) of the estuary. Spawning occurs in late winter and early spring and takes place on substrates such as aquatic vegetation, rocks, pier pilings and other man-made structures. After hatching, young Pacific herring remain in near shore waters and begin to school. Juveniles can be found in shallow bays and inlets until summer and early fall, when they migrate to deeper waters. In fall, Pacific herring emigrate from the estuary to spend 2-3 years rearing in the ocean before reaching maturity and returning to spawn. The 2007 Pacific herring age-0 index was more than 3 times the 2006 index, and was the first increase since 2002 (Figure 11). It was still below the study-period mean and the levels reported in the early 2000s. Age-0 fish were first collected in March and catches peaked in May. By November, most age-0 Pacific herring had emigrated from the estuary. In 2007, they were collected from South Bay to eastern Suisun Bay, near Pittsburg, a much wider distribution than in 2006. Distribution was broadest in May, and fish started to move to Central Bay in June, when temperatures increased in San Pablo and South bays. Overall, CPUE was highest in San Pablo Bay, followed by Central and South bays.

The CDFG Herring Project has recorded landings for the Pacific herring fishery in San Francisco Bay since 1972. The commercial Pacific herring fishery runs from December through March, targeting adult fish entering the estuary to spawn. The 2006-2007 landings were the second lowest on record at 310 tons. Commercial landings decreased 58% from the previous year and were only 7% of the 2006-2007 quota of 4502 tons. These severe declines in San Francisco Bay herring landings over the past few years were not necessarily indicative of a declining adult Pacific herring population. Increasing fuel prices and decreasing market value of herring products have decreased the profitability of the Pacific herring fishery, and resulted in decreased fishing effort, which partially explains the low landings.

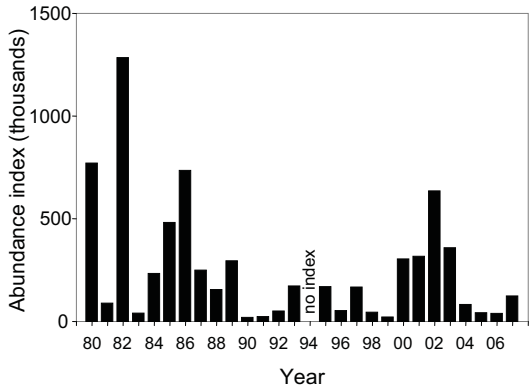

Figure 11 Annual abundance of age-0 Pacific herring, Bay Study midwater trawl, April-September

Northern anchovy

The northern anchovy (*Engraulis mordax*) is the most abundant fish in the lower estuary and an important prey species for many fishes and seabirds. The 2007 abundance index for northern anchovy was 38% of the 2006 index (Figure 12). Even though the index was the second highest since 2001, it remained below the study-period average. The northern anchovy population is separated into 3 subpopulations, the northern, central, and the southern (Vrooman et al. 1981). San Francisco Estuary is situated between the northern and central subpopulations and our catches reflect the size and coastal movements of these subpopulations. Although the central subpopulation is the largest and historically the most heavily fished, there are currently no stock assessments, so we cannot

confirm subpopulation movements or size, or how these might influence local abundance.

In 2007, northern anchovy catches peaked in May and August, and were lowest in winter. Fish were collected from South Bay to western Suisun Bay, with CPUE highest in Central Bay, followed by South and San Pablo Bays. Overall, the highest catches were from the shoal station near Treasure Island, which was dominated by a very large catch of over 18,000 fish in May, and from the channel station near Angel Island. Few anchovies were collected in San Pablo Bay until May and none were collected in western Suisun Bay until June. CPUE was slightly higher at shoal stations than channel stations, although there was a strong seasonal component to this distributional pattern. Anchovies were more common at shoal stations only in May and June, and shifted distribution to the channels in July.

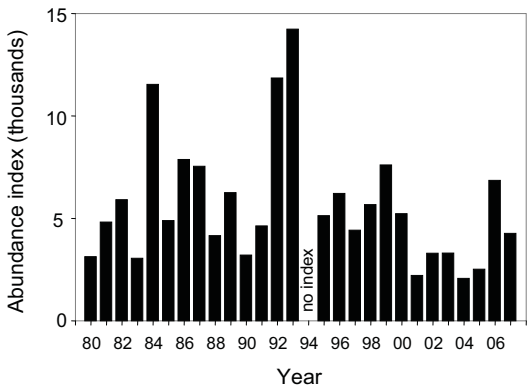

Figure 12 Annual abundance of northern anchovy (all sizes), Bay Study midwater trawl, April-October

Jacksmelt

The jacksmelt (*Atherinopsis californiensis*) seasonally migrates from the nearshore coast to bays and estuaries to spawn and rear. Most reproduction occurs in South Bay and 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. The 2007 age-0 jacksmelt abundance index was nearly 6 times the 2006 index (Figure 13) and also the highest index since 1985 and the second highest index on record. Age-0 jacksmelt were first collected in June of 2007 and abundance peaked in September and October. We collected age-0 fish from South Bay to mid San Pablo Bay, with the majority from Central Bay. Jacksmelt were most common in South Bay through June, but as age-0 fish migrated from their primary rearing areas in South Bay, distribution broadened to the other regions. By September, CPUE was consistently highest in Central Bay. Age-0 fish were generally most common at channel stations from winter to early spring and at shoal stations from late spring through fall.

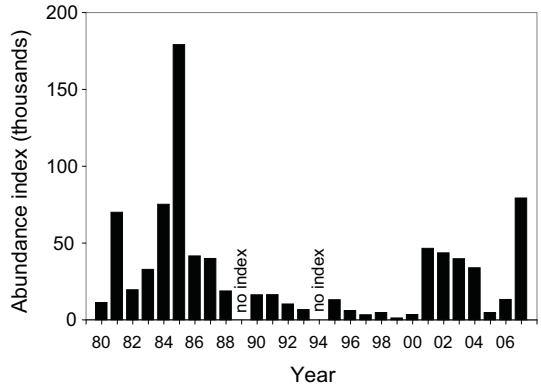

Figure 13 Annual abundance of age-0 jacksmelt, Bay Study midwater trawl, July-October

Surfperches

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

Shiner perch

In 2007, the abundance of age-0 shiner perch (*Cymatogaster aggregata*) increased slightly from the 2006 index, but was still only 37% of the study period average (Table 2). This small increase followed 3 years of decreasing abundance. Age-0 fish were collected from May to December, with abundance peaks in July and December. Age-0 shiner perch were collected from South through San Pablo bays in 2007, but were by far most common in Central Bay, with a mean CPUE of 4.1 fish/tow. There was some seasonal movement in 2007, as a few shiner perch were collected in San Pablo and South

bays in summer, but by fall they were only found in Central Bay. Average CPUE at shoal stations was 2 times higher than at channel stations. No seasonal migration pattern to the channel was observed, as fish continued to inhabit predominately shoal stations in the Central Bay through December.

Walleye surfperch

The 2007 age-0 walleye surfperch (*Hyperprosopon argenteum*) abundance index decreased to just 15% of the 2006 index and was the lowest since 1997 (Table 2). Nine age-0 walleye surfperch were collected in 2007, from June through November, but only 3 were from both an index station and the index period. All 9 were collected at 3 shoal stations: near the Berkeley Fishing Pier, Alameda, and the Oakland Airport. The 2007 age-1+ index was 46 times the 2006 record low index, with 23 fish collected. These fish were collected from South Bay, near Coyote Point, to San Pablo Bay, near Point Pinole, but most came from Central Bay. All but 1 were collected from shoal stations.

Other Surfperches

The 2007 barred surfperch (*Amphistichus argenteus*) abundance index was based on 3 fish and increased from the 2006 index (Table 2), which was based on 1 fish. One age-0 and 1 age-1+ fish were collected in South Bay and 1 age-1+ fish was collected in Central Bay, all at shoal stations. Historically, the majority of barred surfperch have been collected from South Bay shoal stations, especially stations along the eastern shore. Barred surfperch is commonly associated with eelgrass beds in the Bay (Merkel & Associates 2005), a habitat not sampled by our trawl.

The 2007 pile perch (*Rhacochilus vacca*) abundance index was 0, showing no sign of recovery in the estuary and continuing the trend of very low or 0 indices since 1987 (Table 2).

The 2007 white seaperch (*Phanerodon furcatus*) abundance index was also 0, which was the same as 2006 index (Table 2). The species also had 10 consecutive years of zero indices from 1991 to 2000. White seaperch abundance increased from 2001 through 2004, but declined from 2005 to 2007. Four white seaperch were collected in 2007, but all were from January and November, non-index months. These 4 fish were collected from Central Bay, near Treasure Island and Angel Island, and in San Pablo Bay near Point Pinole.

Black perch (*Embiotoca jacksoni*) was the only surfperch common in the estuary that did not show a distinct decline during the late 1980s or early 1990s (Table 2). However, black perch catch has remained relatively low throughout the study period. The 2007 black perch index was 58% of the 2006 index, marking the third consecutive year of declining abundance. Only 1 fish, collected in Central Bay near Angel Island, contributed to the 2007 index.

The 2007 dwarf perch (*Micrometrus minimus*) index was very similar to the 2005 and 2006 indices (Table 2), all below the study-period mean. Three dwarf perch were collected in 2007, but only 1 was from an index station and the index period. Two fish were from shoal stations, 1 in South Bay and 1 in Central Bay, and 1 was from a Central Bay channel station. Historically, dwarf perch were commonly collected from the shoal stations off Coyote Point and northeast of the San Mateo Bridge in South Bay and south of Point San Quentin in Central Bay. This is another species that is strongly associated with eelgrass beds in the estuary and is under sampled by our trawls.

Table 2 Annual abundance indices for selected surfperch species from the Bay Study. The age-0 shiner perch, age-0 and age-1+ walleye surfperch, age-0 pile perch, and white seaperch (all sizes) indices are from May-October. The barred perch (all sizes), black perch (all sizes), and dwarf perch (all sizes) indices are from February-October.

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

Marine Demersal Fishes

Plainfin midshipman

The plainfin midshipman (*Porichthys notatus*) migrates from coastal areas to bays and estuaries in late spring and summer to spawn. Most juveniles rear in the estuary through December, with some fish remaining until spring. The 2007 age-0 index was 4.1 times the 2006 index and the highest on record (Figure 14). However, this high index was largely due to the collection of over 4,000 fish at one Central Bay station in October. Age-0 plainfin midshipman were first collected in June and abundance was highest from September to November. They were distributed from South Bay to Suisun Bay in 2007, but most common in Central Bay all months. Over all months, channel CPUE was about 18 times higher than shoal CPUE, with little indication of a seasonal movement from shallow to deeper water.

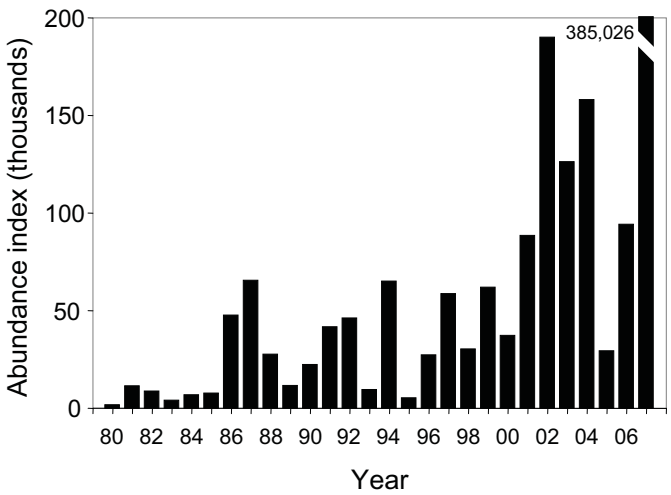

Figure 14 Annual abundance of age-0 plainfin midshipman, Bay Study otter trawl, June-October

Pacific staghorn sculpin

The Pacific staghorn sculpin (*Leptocottus armatus*) is a common native species that usually rears in higher salinity areas, but is also found in brackish and occasionally fresh water. Throughout the estuary it rears in intertidal and shallow subtidal areas from late winter to early spring. The 2007 Pacific staghorn sculpin age-0 abundance index was almost 4 times higher than the 2006 index, and was the first year the index increased since 2002 (Figure 15). Age-0 fish were collected from April through December, with peak abundance in July. They were collected primarily from South through Suisun bays, but one fish was collected in the lower Sacramento River in May. Catch was highest in Central Bay in all months, initially at the shoal stations from April through June and then at the channel stations from July through December. This distributional pattern was dominated by one catch of 201 fish at the channel station near Angel Island in July.

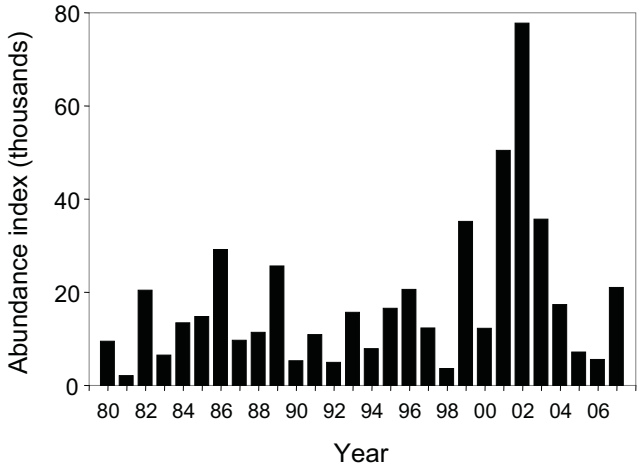

Figure 15 Annual abundance of age-0 Pacific staghorn sculpin, Bay Study otter trawl, February-September

White croaker

The white croaker (*Genyonemus lineatus*) is a common coastal species that frequents bays and estuaries. It is a member of the subtropical fish fauna and is usually more common south of Point Conception. It spawns from November through April in near-shore shallow waters and juveniles progressively move into deeper water as they mature. Although the 2007 age-0 white croaker abundance index increased from the 2006 record low index, it was the third lowest index for the study period (Figure 16). Since 1995, age-0 white croaker indices have been below the survey average. Catch was sporadic in 2007, with peaks in May and September, but no fish were collected in several months. Age-0 white croaker were collected from South Bay to San Pablo Bay in 2007, but were most common in Central Bay. From April to June, age-0 white croaker were only found at shoal stations, but shifted to channel stations in subsequent months.

Although the 2007 age-1+ index was approximately 2.5 times the 2006 index, it was the third lowest on record and the eleventh consecutive year of below-average indi-

ces (Figure 16). Age-1+ abundance was highest during the 1987 to 1992 drought, when salinity was high and relatively stable year-round in the estuary and sea surface temperatures were high due to several El Niño events. Abundance peaked in September 2007, with smaller peaks in May and July. Age-1+ white croaker were collected from South Bay to San Pablo Bay, with the center of distribution in Central Bay most months of 2007.

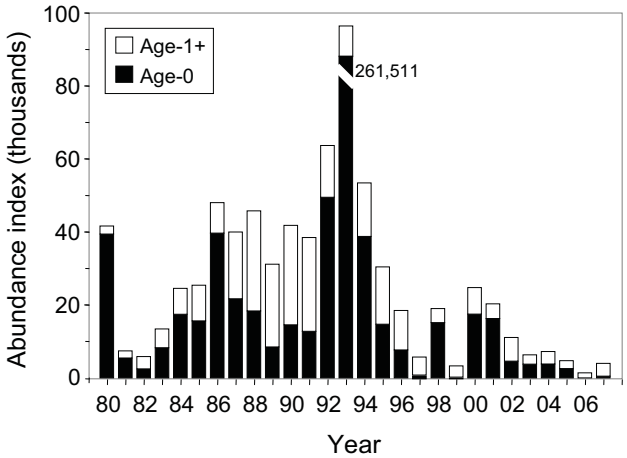

Figure 16 Annual abundance of age-0 and age-1+ white croaker, Bay Study otter trawl, February-October

Bay goby

The bay goby (*Lepidogobius lepidus*) is one of the most common gobies in the estuary. It is a native resident species that rears in the higher salinity areas and has a 2 to 3 year life span. The 2007 bay goby abundance index decreased slightly from 2006 and was 91% of the study period average (Figure 17). Abundance was lowest in January, before the 2007 year class recruited to the otter trawl, and peaked in June. Bay gobies were collected at every station in South and Central bays and at all but one station in San Pablo Bay in 2007. Fish began migrating from South and San Pablo bays to Central Bay in May and CPUE remained highest there through November. The highest catches occurred off Bluff Point at the northern end of Raccoon Strait near Angel Island, where CPUE averaged 78 fish/tow for the year (n=934) and reached a maximum of 324 fish/ tow in June.

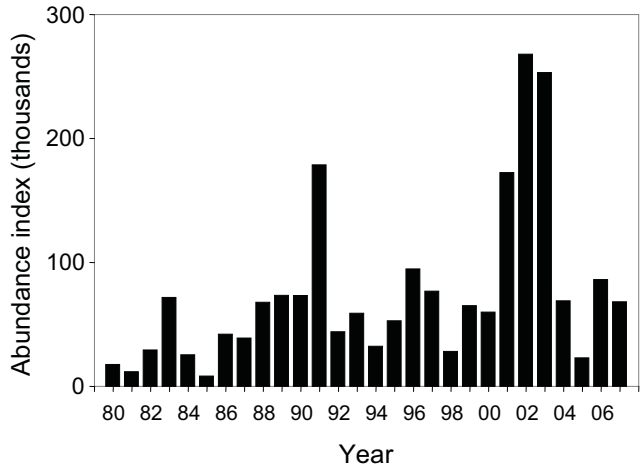

Figure 17 Annual abundance of bay goby (all sizes), Bay Study otter trawl, February-October

Chameleon goby

The chameleon goby (*Tridentiger trigonocephalus*) was introduced, presumably by way of ship ballast water, in the early 1960s. It is confined to the marine regions of the estuary and is strongly associated with structure, such as pilings and riprap. The chameleon goby reaches sexual maturity in 1 year and in San Francisco Bay, peak spawning occurs from May to September.

The 2007 age-0 chameleon goby index was 44 times the 2006 index and 10 times the previous record high (Figure 18A). The 2007 year class recruited to the otter trawl in September, primarily in South Bay. Shortly thereafter, its range expanded to include Central and San Pablo bays, although its distribution was still centered in South Bay. In 2007, 57% (n=848) of all chameleon gobies caught were age-0 fish from the shoal station near Coyote Point in November. CPUE was higher at shoal stations (6.0 fish/tow) than channel stations (1.1 fish/tow) for all months.

The 2007 age-1+ chameleon goby abundance index declined slightly from the 2006 index and was 83% of the study period average (Figure 18B). No age-1+ fish were collected in August, and subsequently the age-0 year class recruited to the otter trawl in September. This absence of adult fish preceding first collection of age-0 fish is likely indicative of structure-oriented spawning, in which mature fish were inaccessible to the otter trawl. Like the age-0 fish, age-1+ chameleon gobies ranged from South to San Pablo bays, but were most concentrated in South Bay all months.

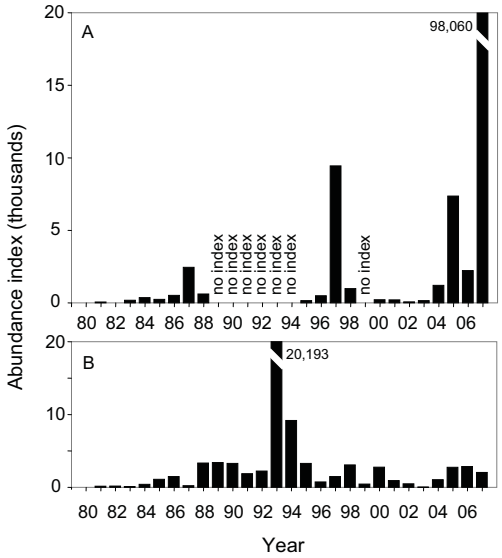

Figure 18 Annual abundance of chameleon goby: A) age-0, Bay Study otter trawl, September-December, and B) age-1+, Bay Study otter trawl, February-July

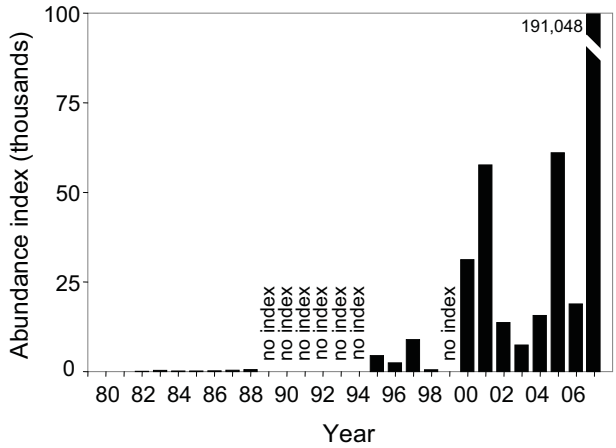

Figure 19 Annual abundance of cheekspot goby (all sizes), Bay Study otter trawl, June-December

Cheekspot goby

The cheekspot goby (*Ilypnus gilberti*) is native to the San Francisco Estuary and ranges from Tomales Bay to the southern Baja peninsula, including the Gulf of California. The cheekspot goby matures at 1 year and some fish may live to 2 years. Peak spawning takes place in spring, when males guard brood chambers where adhesive eggs are fixed to walls. The cheekspot goby is a common prey item of a wide variety of fishes and shorebirds.

The 2007 cheekspot goby index was the highest on record and was more than 3 times the previous high in 2005 (Figure 19). For the second time in the study, cheekspot goby total catch surpassed bay goby total catch; in 2007, the cheekspot goby was the second most abundant fish collected by the otter trawl (n=4,793), behind plainfin midshipmen (n=8,249). Abundance was lowest in March and peaked in September, when catch was composed almost entirely of the 2007 year-class. Distribution was centered in South Bay all year and CPUE peaked in September at 188 fish per tow. Shoal station mean CPUE (14 fish/tow) was over 2 times channel stations mean CPUE (6 fish/tow).

California halibut

The California halibut (*Paralichthys californicus)* is a member of the subtropical faunal group that became common in the San Francisco Estuary in the 1980s and 1990s, concurrent with the most recent warm-water regime. It spawns in shallow coastal waters and juveniles rear in very shallow subtidal and intertidal areas of bays and estuaries. The 2007 combined age-0 and age-1 (juvenile) California halibut index was only 2% of the 2006 index (Figure 20). Only 2 juvenile California halibut were collected in 2007; 1 in January and 1 in February, both in South Bay. The near absence of juvenile California halibut in 2007 was likely a result of cooler ocean temperatures in the Gulf of the Farallones in winter 2006-07. Laboratory experiments have shown high California halibut larval mortality at 12°C and increased survivorship and growth with higher temperatures (Gadomski and Caddell 1991).

The 2007 age-2+ California halibut index was 55% of the 2006 index, but was 2 times the study period average (Figure 20). Fish were collected from South Bay, just north of the Dumbarton Bridge to the Mothball Fleet in Suisun Bay, with the highest CPUE in Central Bay. Catch at shoal stations averaged 0.28 fish per tow and catch at channel stations averaged 0.16 fish per tow in 2007. Age-2+ fish ranged from 200 mm to 1030 mm FL, indicating several year classes were present in the estuary. The majority of age-2+ fish appear to be from the large cohort that hatched in late 2004 and early 2005, during the strongest of the recent warm-water events.

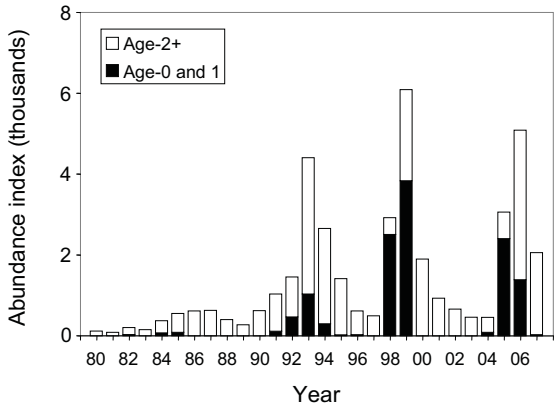

Figure 20 Annual abundance of juvenile (age-0 and age-1) and age-2+ California halibut, Bay Study otter trawl, February-October

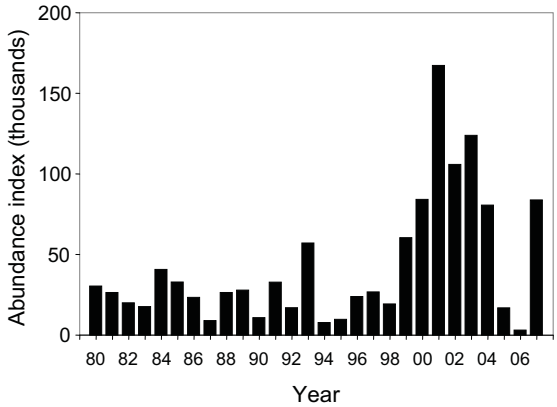

Figure 21 Annual abundance of age-0 English sole, Bay Study otter trawl, February-October.

English sole

The English sole (*Pleuronectes vetulus*) is a common flatfish that spawns along the coast in winter and rears in both the ocean and estuaries. The 2007 age-0 English sole abundance index was 27 times higher than 2006 and was the fifth highest index on record (Figure 21), an apparent return to the high indices observed from 1999 to 2004. This higher index was likely due to cooler ocean temperatures in winter 2006-07. English sole have reduced survival of eggs and larvae at temperatures above 11ºC (Alderdice and Forrester 1968). Age-0 fish were collected from March to December, with peak abundance in July and lowest abundance in November and December, as fish emigrated from the estuary. Although fish were collected from South through San Pablo bays in 2007, distribution was centered in Central Bay all months, with a mean CPUE of 22 fish/tow. Distribution of age-0 English sole in 2007 was typical of low outflow years, with a strong seasonal movement from South and San Pablo bays to Central Bay and from shoal to channel stations in late summer and fall. English sole generally rear in shallow water at salinities from 12-24‰ (Baxter et al., 1999).

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 2007 index was nearly twice the 2006 index, and was the highest since 2004 (Figure 22). Record speckled sanddab abundance indices occurred from 2000 to 2004, concurrent with strong summer upwelling and cooler ocean temperatures. The speckled sanddab has a very long pelagic period and does not settle until after the upwelling season ends. Stronger summer upwelling and associated cooler ocean temperatures in winter 2006-07 were likely factors in the increase in speckled sanddab abundance in 2007. In late winter and early spring abundance was high, but by June many fish began migrating toward the ocean. Average monthly indices from January through June were 7 times the July through December average indices. Fish were collected in South, Central, and San Pablo bays in 2007, but distribution was centered in Central Bay all months, with a mean CPUE of 16 fish/tow. In June, fish in San Pablo and South bays began to migrate to Central Bay and from August through October fish were collected only in Central Bay.

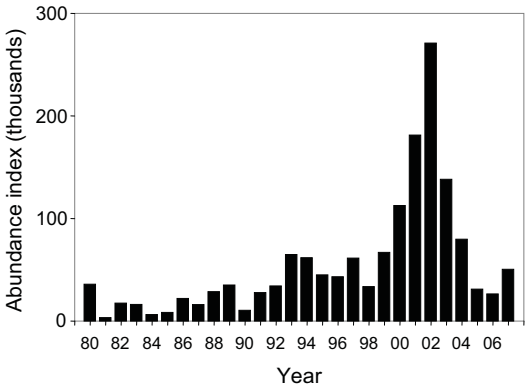

Figure 22 Annual abundance of speckled sanddab (all sizes), Bay Study otter trawl, February-October

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Notes

K. Newman, USFWS, e-mail to Randy Baxter (California Department of Fish and Game), October 5, 2007.

Fish Salvage for 2007 at the State Water Project and Central Valley Project Fish Facilities.

Geir Aasen (DFG), gaasen@dfg.ca.gov, Russell Gartz

Introduction

The Tracy Fish Collection Facility (TFCF) and the Skinner Delta Fish Protective Facility (SDFPF) divert (salvage) fish from water exported from the Sacramento-San Joaquin Delta. The TFCF began operation in 1957 and the SDFPF began operation in 1967 with both facilities using a louver-bypass system to salvage fish from the exported water. The salvaged fish are transported to predetermined release sites after being loaded into tanker trucks and returned to the western Delta. Total fish salvage was estimated by means of several steps. First, bypass flows were sampled once every 2 hours of operation for 10 to 30 minutes. All fish collected in these sampling periods were identified and numerated. These counts were expanded proportionally based on sample time to estimate the total number of fish salvaged in each 2 hour period of operation, then these expanded counts were summed across time to derive monthly and annual totals.

This report summarizes salvage information from the TFCF and the SDFPF in 2007. The following species are given individual consideration: Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), striped bass[1] (*Morone saxatilis*), delta smelt[1] (*Hypomesus transpacificus*), longfin smelt (*Spirinchus thaleichthys*), threadfin shad[1] (*Dorosoma petenense*), and splittail (*Pogonichthys macrolepidotus*).

Water Exports

The State Water Project (SWP) exported roughly 3.0 billion m^3 of water in 2007. The 2007 SWP export total was slightly lower compared to recent years (2003 to 2006) that ranged from 4.0 to 5.0 billion m^3 (Figure 1). The Central Valley Project (CVP) exported roughly 3.2 billion m^3 of water in 2007. The annual export in 2007 was comparable to recent exports that ranged from 3.2 to 3.4 billion m^3.

The majority of water exported in 2007 occurred from July through December. SWP monthly exports ranged from 26.8 to 511.0 million m^3 of water (Figure 2). From July through December, 2.1 billion m^3 of water was exported, accounting for 71% of the 2007 annual SWP export. CVP monthly exports ranged from 63.8 to 335.2 million m^3 of water. From July through December, 1.8 billion m^3 of water was exported, accounting for 57% of the 2007 annual CVP export.

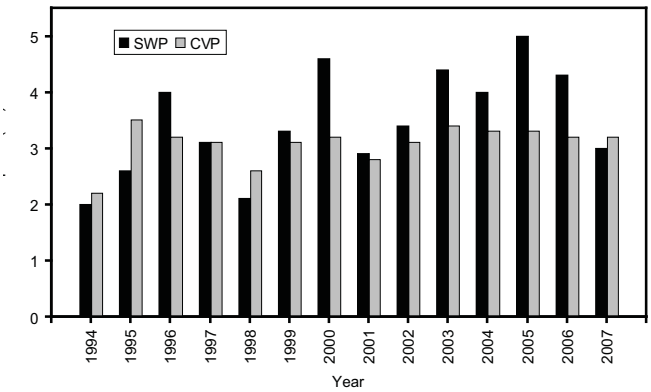

Figure 1 Annual exports in billions of cubic meters for the SWP and the CVP, 1994 to 2007

1. Pelagic Organism Decline (POD) species

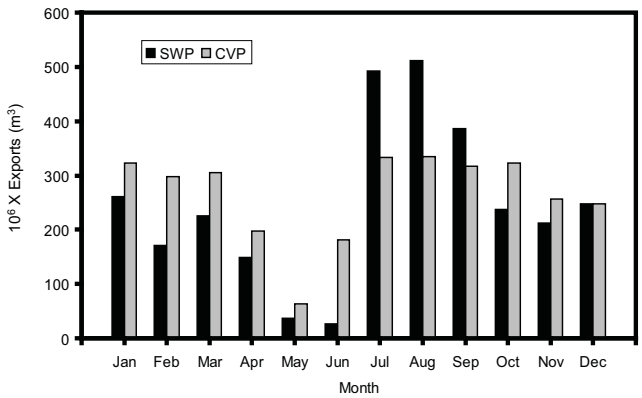

Figure 2 Monthly exports in millions of cubic meters for the SWP and the CVP in 2007

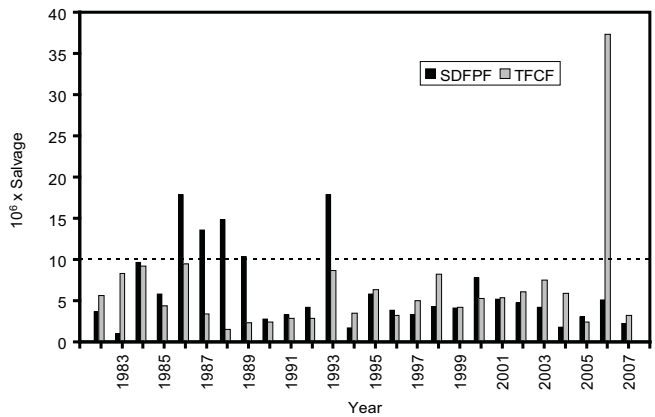

Figure 3 Annual salvage of all taxa combined at the SDFPF and the TFCF, 1982 to 2007

Total Salvage and Prevalent Species

Annual combined salvage (annual salvage) in 2007 at the TFCF (3,164,530) was one of the lowest on record. Generally, annual salvage values were below 10 million/year (Figure 3). In contrast, the 2006 annual salvage at TFCF (37,266,449) dwarfs any previous value and represents an order of magnitude increase from the TFCF annual salvage in 2007 and 2005 (2,430,642). Annual salvage at the SDFPF in 2007 was also one of the lowest on record and decreased substantially in contrast to 2006, from 5,138,457 to 2,239,066.

The annual salvage at both facilities was dominated by threadfin shad. At the TFCF, threadfin shad accounted for 70.9% of the annual salvage (Figure 4). The only other species to be salvaged in substantial numbers at the TFCF was striped bass. The situation was less lopsided at SDFPF where threadfin shad accounted for 56.2% of the annual salvage. The other species that occurred in comparable numbers at SDFPF was striped bass. Generally, threadfin shad has made up the bulk of salvage at both facilities, especially in recent years. Relatively few (< 0.3%) Chinook salmon, steelhead, delta smelt, longfin smelt, and splittail were salvaged at the SDFPF and TFCF.

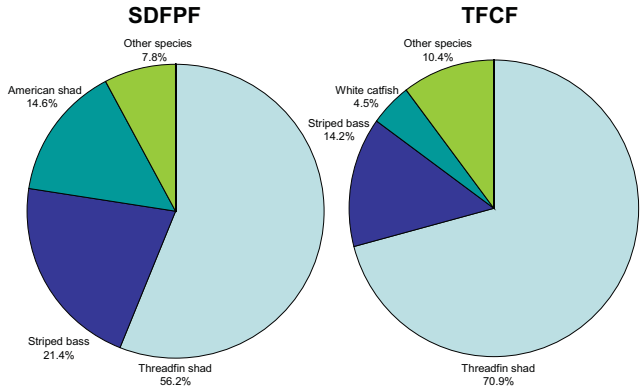

Figure 4 Percentages of annual salvage for the 3 most prevalent species and species of special interest at the SDFPF and TFCF, 2007

Chinook salmon

Annual salvage (all races and origins combined) of Chinook salmon continued to be low at both facilities with salvage at the TFCF higher than at the SDFPF. The annual salvage of 1,941 at the SDFPF in 2007 was a decrease from the annual salvage of 8,629 observed in 2006, continuing the declining trend that started in 2004 (Figure 5). The annual salvage of 7,622 salmon at the TFCF in 2007 was a substantial decrease from the annual salvage of 35,319 observed in 2006 and ended the increasing trend that started in 2002. The annual salvages from 2002 to 2007 are dwarfed by annual salvages observed in the 1980's and the late 1990's.

Salvaged Chinook salmon at both facilities were primarily wild, spring-run fish and a lesser number of wild, winter-run fish (Table 1). Wild spring-run fish comprised 52% of the annual salvage at the SDFPF and 39% of the annual salvage at the TFCF. In contrast, wild fall-run fish comprised only 24% of the annual salvage at the SDFPF and 25% of the annual salvage at the TFCF, which was a substantial relative decrease from annual salvage in 2006 when wild fall-run fish comprised 63% at the SDFPF and 82% at the TFCF. The majority of wild fall-run fish at the SDFPF and TFCF were salvaged in April (Figure 6).

Loss of salmon in 2007 was higher at the SDFPF than at the TFCF. At the SDFPF the loss of salmon was estimated at 8,321 while at the TFCF the estimated loss was 5,111.

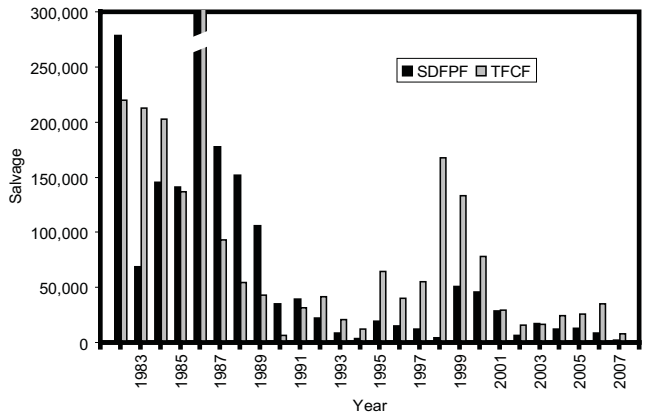

Figure 5 Annual salvage of Chinook salmon (all races and origins combined) at the SDFPF and the TFCF, 1982 to 2007. The SDFPF 1986 salvage of 435,233 and the TFCF 1986 salvage of 752,039 have been truncated for scale considerations.

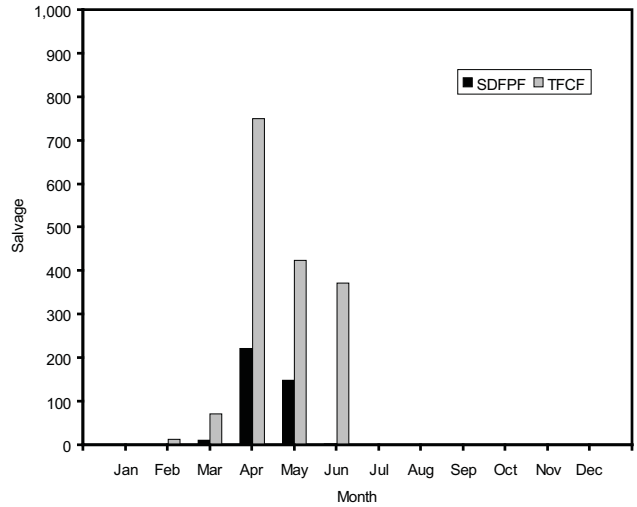

Figure 6 Monthly salvage of wild, fall run Chinook salmon at the SDFPF and the TFCF, 2007

Table 1 Chinook salmon annual salvage, percentage of annual salvage, race and origin (wild or hatchery), and loss at the SDFPF and the TFCF, 2007

Facility	Origin	Race	Salvage	Percentage	Loss
SDFPF					
	Wild				
		Fall	383	24	1,645
		Late-fall	0	0	0
		Spring	846	52	3,563
		Winter	396	24	1,729
	Total Wild		1,625		6,937
	Hatchery				
		Fall	4	1	19
		Late-fall	0	0	0
		Spring	7	2	30
		Winter	303	97	1326
	Total Hatchery		314		1,375
	Total Adult		2	<1	9
	Grand Total		1,941		8,321
TFCF					
	Wild	Fall	1,629	25	1,187
		Late-fall	12	<1	9
		Spring	2,532	39	1,649
		Winter	2,305	35	1,516
	Total Wild		6,478		4,361
	Hatchery				
		Fall	24	2	17
		Late-fall	36	3	25
		Spring	24	2	15
		Winter	1060	93	693
	Total Hatchery		1,144		750
	Grand Total		7,622		5,111

Steelhead

The annual salvage of steelhead (all origins combined) at both facilities continued to be low in 2007 (Figure 7). Annual salvage at the SDFPF in 2007 was slightly higher than in 2006; 1,561 as opposed to 1,287. This trend was also observed at the TFCF as the annual salvage in 2007 was greater than in 2006; 4,068 as opposed to 2,516.

The majority of steelhead salvaged at the SDFPF were considered wild fish while at the TFCF the majority of steelhead salvaged were of hatchery origin. At the SDFPF the salvage composition was 941 wild, 612 hatchery fish, and 8 of unknown origin. At the TFCF the salvage composition was 1,827 wild and 2,241 hatchery fish.

The salvage of wild steelhead occurred in the first half of the year for both facilities. Wild steelhead were salvaged from January through May at the SDFPF and from January through June at the TFCFF (Figure 8). At the SDFPF steelhead were salvaged most frequently in: February (144), March (450), and April (315). For the TFCF, steelhead was salvaged most frequently in: February (276), March (792), and April (720).

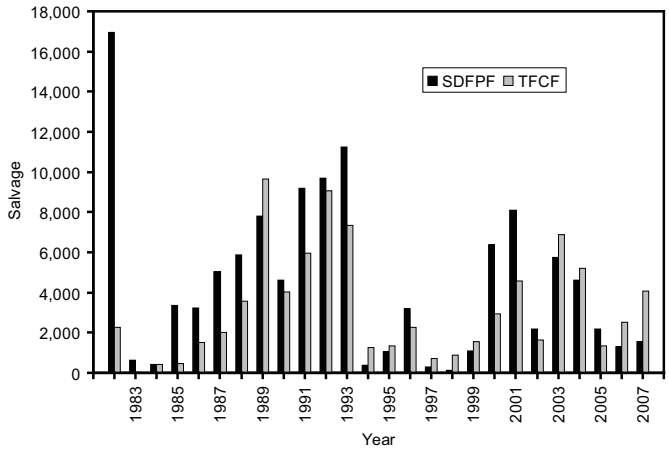

Figure 7 Annual salvage of steelhead (all origins combined) at the SDFPF and the TFCF, 1982 to 2007

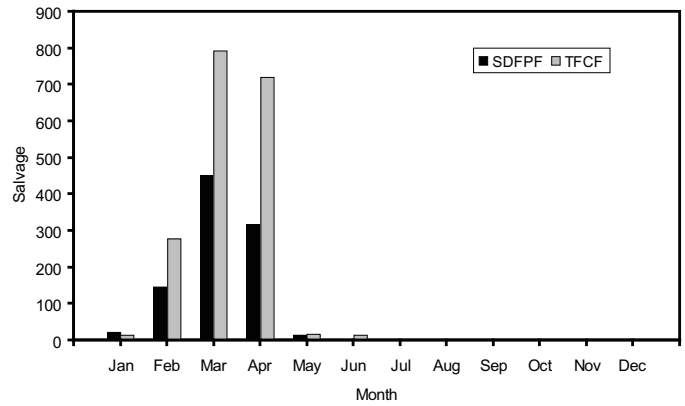

Figure 8 Monthly salvage of wild steelhead at the SDFPF and the TFCF, 2007

Striped bass

In 2007, the facilities reported low annual striped bass salvages continuing the trend in low annual salvage numbers observed since 2001 (Figure 9). At the SDFPF, the 2007 annual salvage was 479,561, an increase from the 2006 annual salvage of 140,795. The 2006 annual salvage was just slightly more than the minimum for the period of record, 131,039 in 1983. At the TFCF, the 2007 annual salvage of 447,971 was also an increase from the record low annual salvage of 37,359 in 2006. The next lowest TFCF annual salvage of 124,645 was observed in 2005.

The months of July and August accounted for the majority of striped bass salvage at SDFPF and June and July at the TFCF (Figure 10). At the SDFPF the July salvage of 362,104 and the August salvage of 89,747 accounted for 94% of the 2007 annual salvage. At the TFCF the June salvage of 231,912 and the July salvage of 180,183 accounted for 92% of the annual salvage. Striped bass were salvaged every month at both facilities with the lowest monthly salvage in November (367) for SDFPF and in October (428) at the TFCF.

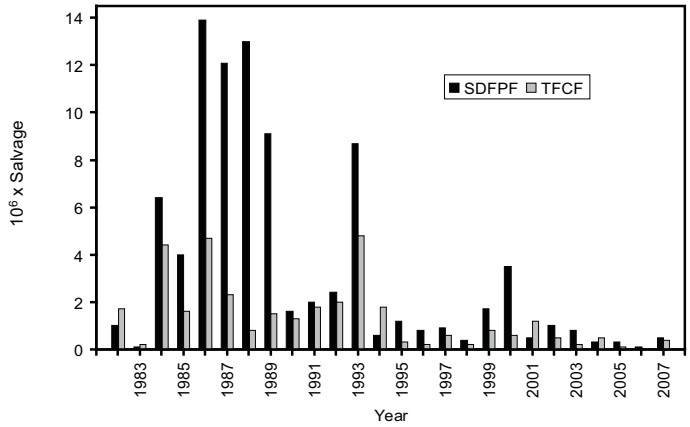

Figure 9 Annual salvage of striped bass at the SDFPF and the TFCF, 1982 to 2007

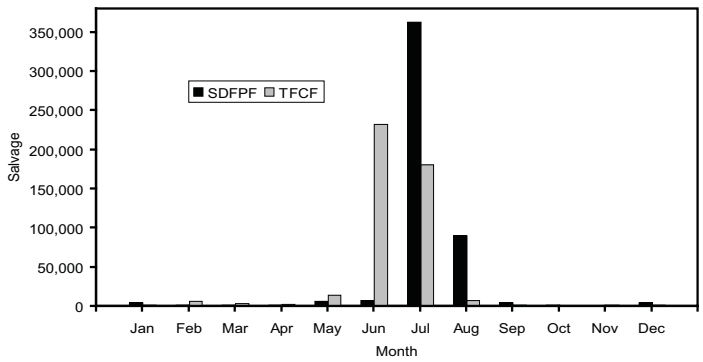

Figure 10 Monthly salvage of striped bass at the SDFPF and the TFCF, 2007

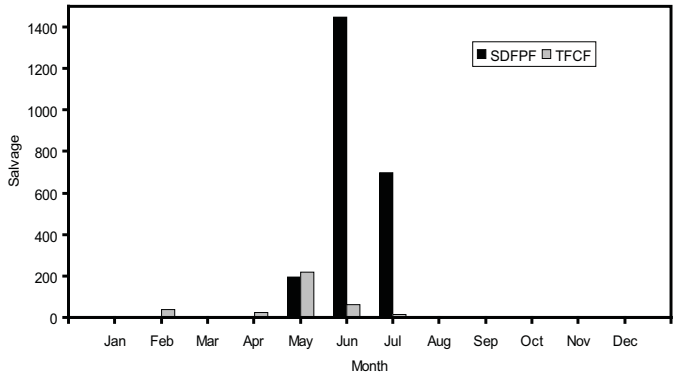

Figure 12 Monthly salvage of delta smelt at the SDFPF and the TFCF, 2007

Delta smelt

Compared to the historical levels, low numbers of delta smelt were salvaged by either facility in 2007, continuing the decline in salvage that started in 2002 (Figure 11). At the SDFPF the annual salvage in 2007 was 2,343 which was markedly higher than the 2006 annual salvage of 24. At the TFCF the annual salvage in 2007 was 348, approximately equal to the near record low annual salvage in 2006 of 312.

Delta smelt were salvaged in only a few months during the spring and summer of 2007 (Figure 12). At the SDFPF delta smelt were most frequently salvaged in June (1,449) and July (699). At the TFCF delta smelt were most frequently salvaged in May (216).

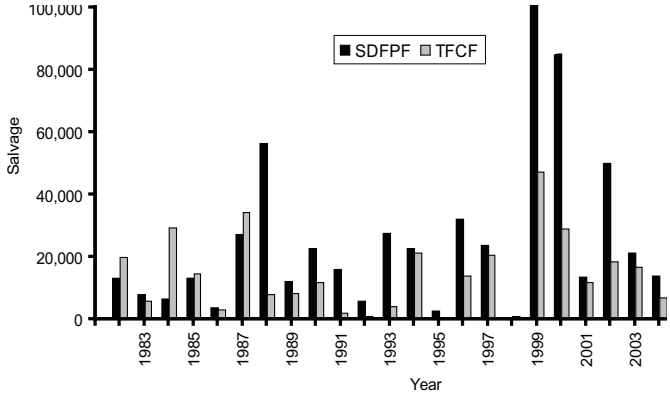

Figure 11 Annual salvage of delta smelt at the SDFPF and the TFCF, 1982 to 2007

Longfin smelt

Longfin smelt continued the decline in salvage that started in 2003 (Figure 13). The annual salvage in 2007 was 59 at the SDFPF and 48 at the TFCF. Low or zero annual salvages of longfin smelt were not uncommon. The annual salvage of 0 in 2006 at the SDFPF was a new record low for recent years (the previous low was 52 in 1982). No longfin smelt were salvaged in 1982 and 1995 at the TFCF. Large (greater than 10,000) annual salvages of longfin smelt have also been observed in: 1984, 1985, 1987-1990, and 2002.

Longfin smelt were salvaged in spring and summer at the SDFPF and in the winter and spring at the TFCF (Figure 14). At the SDFPF longfin smelt were most frequently salvaged in May (47). Twelve longfin smelt were salvaged at the TFCF in January, February, May, and December.

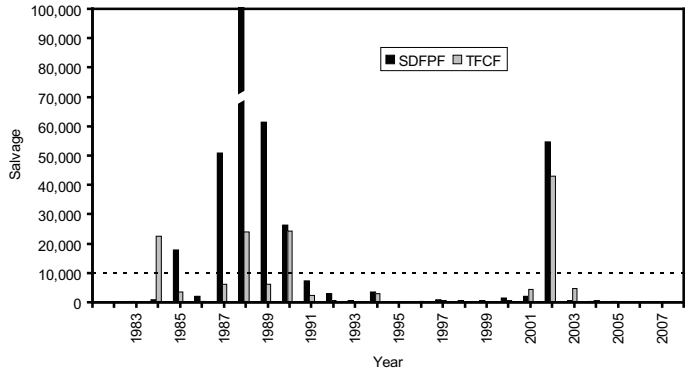

Figure 13 Annual salvage of longfin smelt at the SDFPF and the TFCF, 1982 to 2007. The annual salvage at the SDFPF for 1988 has been truncated for scale considerations (140,040).

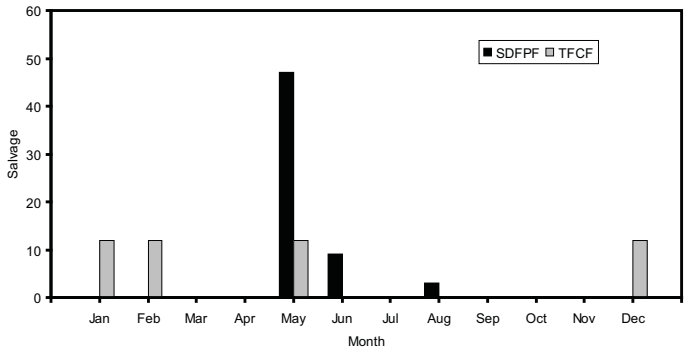

Figure 14 Monthly salvage of longfin smelt at the SDFPF and the TFCF, 2007

Splittail

The annual salvage of splittail was substantially lower for both facilities in 2007 than in 2006. The 2007 annual salvage was 538 at the SDFPF as opposed to 417,859 in 2006 (Figure 15). The 2007 annual salvage was 780 at the TFCF; a dramatic decrease from the record high value of 5,002,611 in 2006. However, large salvages (greater than 150,000) were not uncommon and have been seen in 1982, 1983, 1986, 1995, 1998, and 2005.

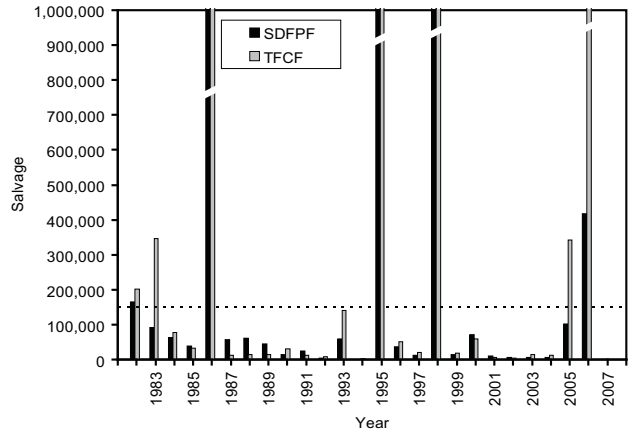

Figure 15 Annual salvage of Splittail at the SDFPF and the TFCF, 1982 to 2007. The annual salvages at the SDFPF for the following years have been truncated for scale considerations: 1986 (1,160,305), 1995 (2,190,517), and 1998 (1,042,239) . The annual salvages at the TFCF for the following years have been truncated for scale considerations: 1986 (1,231,283), 1995 (3,143,156), 1998 (2,051,660), and 2006 (5,002,611).

Threadfin shad

Annual salvage of threadfin shad at both facilities was higher in 2007 than in 2005 and 2006. At the SDFPF the 2007 annual salvage was 1,258,807 whereas the 2006 annual salvage was 857,140 and preceded by 1,183,267 in 2005 (Figure 16). At the TFCF, the 2007 annual salvage was 2,242,577, whereas the 2006 annual salvage was 717,112 and preceded by 1,111,569 in 2005.

Annual threadfin shad salvage values over 2 million were historically the exception and not the rule. At the TFCF, 8 years out of 26 had annual salvages over 2 million. At the SDFPF only 3 years out of 26 had annual salvages over 2 million. The majority of annual salvages over 2 million occurred in years since 2000 and at the TFCF.

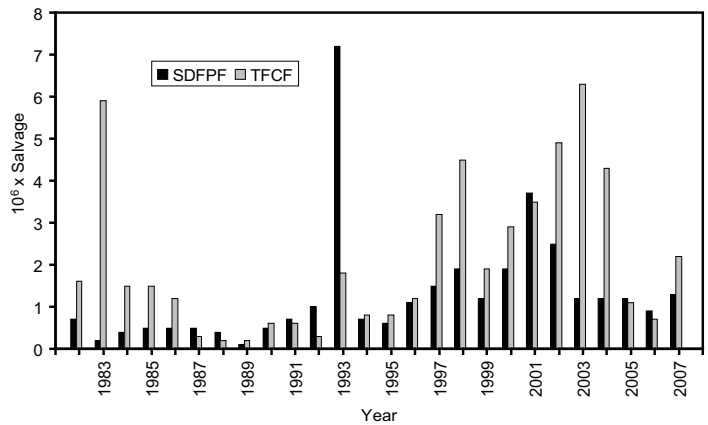

Figure 16 Annual salvage of threadfin shad at the SDFPF and the TFCF, 1982 to 2007

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U.S. Bureau of Reclamation
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