Interagency Ecological Program for the San Francisco Estuary

IEP NEWSLETTER

VOLUME 25, NUMBER 1, Fall/Winter 2012

Of Interest to Managers

Gonzalo Castillo (USFWS), gonzalo_castillo@fws.gov

Geir Aasen reports the fish salvage at the CVP's Tracy Fish Collection Facility (TFCF) and the SWP's Skinner Delta Fish Protective Facility (SDFPF) during the 2011 Water Year. Special consideration is given for Chinook salmon, for which in addition to salvage, loss is reported (the estimated number of fish entrained by the facility minus the number of fish that survive salvage operations). Salvage is also reported for all species combined and for selected species (steelhead, striped bass, delta smelt, longfin smelt, splittail, and threadfin shad). The SWP reported record high water exports (4.90 billion m^3) in WY 2011 which was the highest export rate recorded since 1981. The CVP exported 3.13 billion m^3 of water which was an increase from exports in 2008-2010 but was comparable to exports from 2002 to 2007. Annual fish salvage (all fish species combined) at the TFCF was high (8,724,498), but well below the record high salvage of 37,659,835 in 2006. Annual salvage at the SDFPF was 3,092,553, an increase from 2007-2010 which ranged from 646,290 to 2,484,282. Splittail were the most-salvaged species at both facilities. Threadfin shad and American shad were the 2nd and 3rd most salvaged fish at TFCF. American shad and striped bass were the 2nd and 3rd most-salvaged fish at SDFPF.

Kathleen Fisch reports the delta smelt refugial population maintained in an effort to preserve the genetic and demographic integrity of the species. The captive refugial population is located at the Fish Conservation and Culture Laboratory and it is managed in collaboration with the UCD Genomic Variation Laboratory. The refugial population progressed to the 4th generation in 2011. Delta smelt were spawned in genetically recommended single pair crosses, with 516 fish successfully paired, including 68 wild fish incorporated into the captive population this generation. The genetic diversity of the parental generation was assessed to genetically monitor the captive population. The refugial population continues to maintain the genetic diversity of the delta smelt population and is demographically stable. Future generations in captivity will be similarly managed.

Kathryn Hieb reports the abundance trends and distributional patterns of the 4 most common *Cancer* crabs and the Chinese mitten crab through 2010 in the San Francisco Estuary. The 2010 age-0 Dungeness crab (*Cancer magister*) abundance index was the 4th highest for the 31-year study period. Favorable ocean conditions in winter 2009-2010, when larval *C. magister* hatched and reared in the Gulf of the Farallones, are thought to have resulted in this good year class. The introduced Chinese mitten crab (*Eriocheir sinensis*) population steadily declined since 2001, with often none collected since 2005. The only mitten crab reported in 2010 from several surveys was 1 adult crab collected at the CVP Fish Facility, which was expanded to 3 crabs salvaged.

Julio Adib-Samii reports the Smelt Larval Survey (SLS) conducted from January to March, 2011. The bi-weekly catch SLS reports enable the Smelt Working Group (SWG) to assess their entrainment risk. The SLS reports are the basis for Old and Middle River (OMR) flow recommendations made to the Water Operations Management Team (WOMT). A total of 62,455 fish representing 18 species were collected, with Pacific herring, prickly sculpin, and longfin smelt comprising 97.9% of the total catch. Although distributional criteria for longfin smelt were met in 2 of the 5 surveys conducted in 2011 (i.e., detection of larvae in 8 of 12 south Delta stations), high flows on the Sacramento River relieved the mandated OMR flow advice to WOMT. High flows throughout the 2011 SLS field season presumably flushed longfin larvae downstream, reducing the overall risk of entrainment at the water export facilities, resulting in no management actions based on SLS results.

Finally, **Maxfield Fish, Jennifer Messineo, and Kathryn Hieb** report the 2010 Bay Study Fishes Annual Status and Trends. The IEP-CDFG Bay Study data has been used to describe abundance trends and distribution of fishes from South San Francisco Bay to the western Delta since 1980. Sampling is conducted monthly with an otter trawl for demersal fishes and a midwater trawl for pelagic fishes. The upper estuary demersal species and marine pelagic species showed no consistent trends as a group. However, several marine demersal species, including brown rockfish, speckled sanddab, and bay goby had record or near record abundance indices for the 31-year study period. It is thought that ocean conditions in 2010, with cooler temperatures and stronger upwelling, were favorable to recruitment of these and several other cold-temperate species. In contrast, annual abundance of California halibut, a warm sub-tropical species, showed consecutive declines the past 4 years, particularly for ages 0 and 1. Among the surfperches, only walleye surfperch abundance increased in 2010 and shiner perch, the most common surfperch, had the lowest abundance index for the study period.

IEP QUARTERLY HIGHLIGHTS

Fish Salvage at the State Water Project's and Central Valley Project's Fish Facilities During the 2011 Water Year

Geir Aasen (CDFG) gaasen@dfg.ca.gov

Introduction

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

This report summarizes the 2011 water year (10/1/2010-9/30/2011) salvage information from the TFCF and the SDFPF, and discusses data from 1981 to 2011 water years for its relevance to salvage trends in recent years. 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[1] (*Spirinchus thaleichthys*), splittail (*Pogonichthys macrolepidotus*), and threadfin shad[1] (*Dorosoma petenense*).

Systematic sampling was used to estimate the numbers and species of fish salvaged at both facilities. Bypass flows into the fish-collection buildings were sub-sampled once every 1 to 2 hours for 1 to 30 minutes at the SDFPF and once every 2 hours for 10 to 120 minutes at the TFCF. Fish 20 mm FL (fork length) or larger were identified and numerated. These fish counts were expanded to estimate the total number of fish salvaged in each 1- to 2-hour period of water export. For example, a sub-sample duration of 10 minutes over a 120-minute salvage period equals an expansion factor of 12. These incremental salvage estimates were then summed across time to develop monthly and annual species-salvage totals for each facility.

Chinook salmon loss estimates are presented because the loss model has been widely accepted and has undergone extensive field validation. Loss is the estimated number of fish entrained by the facility minus the number of fish that survive salvage operations (California Dept. of Fish and Game 2006). Salmon salvage and loss were summarized by origin (i.e., hatchery fish defined as adipose fin clipped or wild fish defined as non-adipose fin clipped) and race (fall, late-fall, winter, spring). Race of Chinook salmon is determined solely by criteria based on length and salvage date.

Larval fish (< 20 mm FL) were also collected and examined to determinethe presence of sub-20 mm delta smelt. Larval sampling at TFCF ran from March 17 through June 17 and from March 17 through June 23 at SDFPF. Larval samples were collected once for every 6 hours of water export. To retain these smaller fish, the fish screen used in the routine counts was lined with a 0.5 mm Nitex net. Larval fish from TFCF were identified to species by TFCF personnel and larval fish from SDFPF were identified to species by California Dept. of Fish and Game personnel.

Water Exports

The SWP exported 4.90 billion m^3 of water which was the highest export rate recorded for 1981-2011 and a marked increase from exports in 2010 (3.04 billion m^3) and 2009 (1.99 billion m^3) (Figure 1). The CVP exported 3.13 billion m^3 of water which was an increase from exports in 2008-2010 (ranging from 2.30 to 2.60 billion m^3), but was comparable to exports in recent years from 2002 to 2007.

The exports of the two water projects generally followed a similar seasonal pattern. Exports at the CVP reached a maximum in October through December 2010, January, and July -September 2011 (Figure 2). During these periods, 2.16 billion m^3 was exported by the CVP, representing about 69.0% of annual export. Exports at the

1 Pelagic Organism Decline (POD) species

SWP reached a maximum in December 2010 and January and July through September 2011 (Figure 2). During these periods, 2.62 billion m^3 was exported by the SWP, representing about 53.5% of annual export. CVP monthly exports ranged from 125.85 to 316.66 million m^3. SWP monthly exports ranged from 123.57 to 537.55 million m^3.

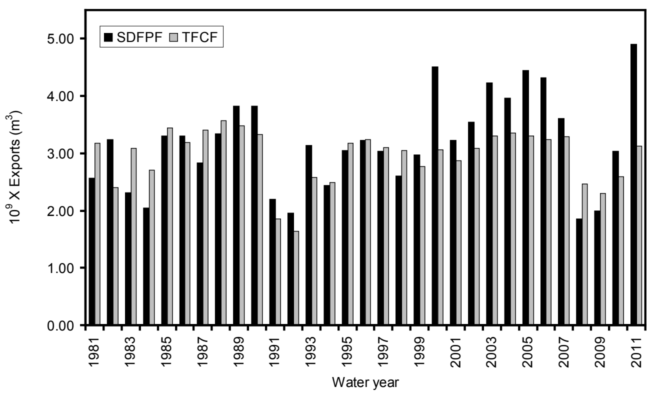

Figure 1 Annual water exports in billions of cubic meters for the SWP and the CVP, 1981 to 2011

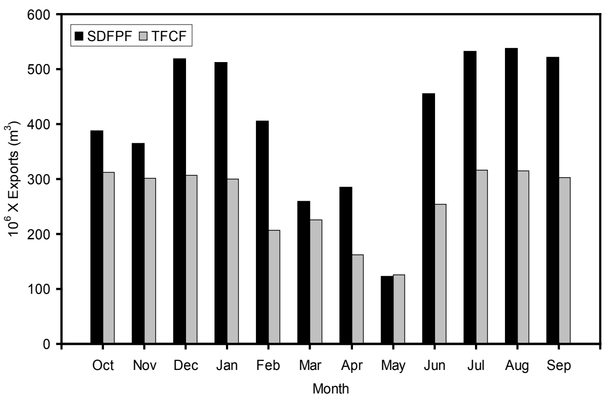

Figure 2 Monthly water exports in millions of cubic meters for the SWP and the CVP, 2011

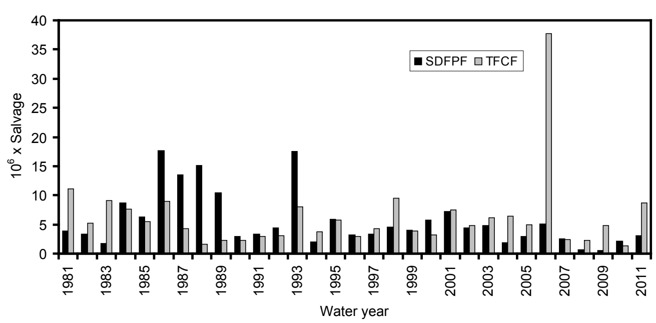

Figure 3 Annual salvage of all fish taxa combined at the SDFPF and the TFCF, 1981 to 2011

Total Salvage and Prevalent Species

Annual fish salvage (all fish species combined) at the TFCF was high at 8,724,498 (Figure 3). TFCF salvage was an increase from the record-low in 2010 (1,318,613), but well below the record high salvage of 37,659,835 in 2006 (Figure 3). Annual salvage at the SDFPF was 3,092,553. SDFPF salvage was an increase from 2007-2010 which ranged from 646,290 to 2,484,282.

Splittail were the most-salvaged species at both facilities (Figure 4 and Table 1). Threadfin shad and American shad were the 2nd and 3rd most-salvaged fish at TFCF. American shad and striped bass were the 2nd and 3rd most-salvaged fish at SDFPF. Relatively few Chinook salmon, steelhead, delta smelt, and longfin smelt were salvaged at the SDFPF (< 0.7% of total annual salvage combined) and the TFCF (< 0.3% of total annual salvage).

Chinook Salmon

SDFPF salvage (18,830) was an increase from 2010 (1,882) and 2009 levels (2,463), but continued a declining trend which started in 2001 (Figure 5). Mean 2001-2011 SDFPF salvage was about 10-fold lower than salvage in the 1980's and the late 1990's. Salvage of Chinook salmon at the TFCF (18,135) was higher than in 2010 (7,463) and 2009 (4,668). Mean 2001-2011 TFCF salvage was about 7-fold lower than salvage in the 1980's and the late 1990's.

Salvaged Chinook salmon at TFCF were primarily wild spring-run and fall-run fish which comprised 94% of wild fish (Table 2). Salvaged Chinook salmon at SDFPF were also primarily wild spring-run and fall-run fish which comprised 95% of wild fish. The majority of wild fall-run fish at the SDFPF and TFCF were salvaged in June (Figure 6).

Loss of Chinook salmon (all origins and races) was higher at the SDFPF (87,132) than at the TFCF (13,546; Table 2). Greater entrainment loss at the SDFPF than at the TFCF was attributable to greater pre-screen loss.

Table 1 Annual (by water year) fish salvage and percentage of annual fish salvage (%) collected from the SDFPF and TFCF in 2011

SDFPF			***TFCF***		
Species	Salvage	%	Species	Salvage	%
Splittail	1,326,065	42.9	Splittail	7,660,024	87.8
American shad	558,731	18.1	Threadfin shad	591,111	6.8
Striped bass	507,619	16.4	American shad	100,233	1.1
Threadfin shad	463,622	15.0	Bluegill	86,932	1.0
Bluegill	88,112	2.8	White catfish	74,913	0.9
White catfish	34,767	1.1	Channel catfish	40,288	0.5
Largemouth bass	32,420	1.0	Striped bass	39,583	0.5
Chinook salmon	18,830	0.6	Largemouth bass	29,096	0.3
Inland silverside	17,278	0.6	Sacramento sucker	27,362	0.3
Yellowfin goby	15,398	0.5	Yellowfin goby	22,081	0.3
Prickly sculpin	9,587	0.3	Chinook salmon	18,135	0.2
Channel catfish	5,888	0.2	Common carp	8,841	0.1
Unknown species	5,100	0.2	Inland silverside	8,359	<0.1
Shimofuri goby	2,035	<0.1	Golden shiner	3,200	<0.1
Rainwater killifish	1,446	<0.1	Unknown lamprey	2,651	<0.1
Unknown lamprey	1,346	<0.1	Shimofuri goby	2,080	<0.1
Steelhead	1,213	<0.1	Rainwater killifish	1,921	<0.1
Western mosquitofish	1,007	<0.1	Black crappie	1,909	<0.1
Bigscale logperch	689	<0.1	Prickly sculpin	1,680	<0.1
Common carp	499	<0.1	Redear sunfish	1,454	<0.1
Golden shiner	350	<0.1	Warmouth	796	<0.1
Black crappie	222	<0.1	Steelhead	445	<0.1
Starry flounder	85	<0.1	Western mosquitofish	408	<0.1
Pacific staghorn sculpin	72	<0.1	White sturgeon	133	<0.1
Brown bullhead	55	<0.1	Brown bullhead	132	<0.1
Riffle sculpin	20	<0.1	Threespine stickleback	123	<0.1
Tule perch	14	<0.1	Fathead minnow	108	<0.1
Sacramento pikeminnow	12	<0.1	Bigscale logperch	104	<0.1
Threespine stickleback	12	<0.1	Tule perch	102	<0.1
White sturgeon	10	<0.1	Black bullhead	57	<0.1
Black bullhead	8	<0.1	Delta smelt	51	<0.1
Redear sunfish	8	<0.1	Goldfish	40	<0.1
Goldfish	5	<0.1	Pacific brook lamprey	28	<0.1
Hardhead	4	<0.1	White crappie	24	<0.1
Hitch	4	<0.1	Sacramento pikeminnow	12	<0.1
Warmouth	4	<0.1	Sacramento blackfish	12	<0.1
Smallmouth bass	4	<0.1	Green sturgeon	12	<0.1
Fathead minnow	4	<0.1	Pacific staghorn sculpin	12	<0.1
Pumpkinseed	4	<0.1	Red shiner	12	<0.1
Blue catfish	4	<0.1	Starry flounder	11	<0.1
Green sturgeon	2	<0.1	Green sunfish	9	<0.1
White crappie	1	<0.1	Blue catfish	8	<0.1
			Hitch	4	<0.1
			Longfin smelt	4	<0.1

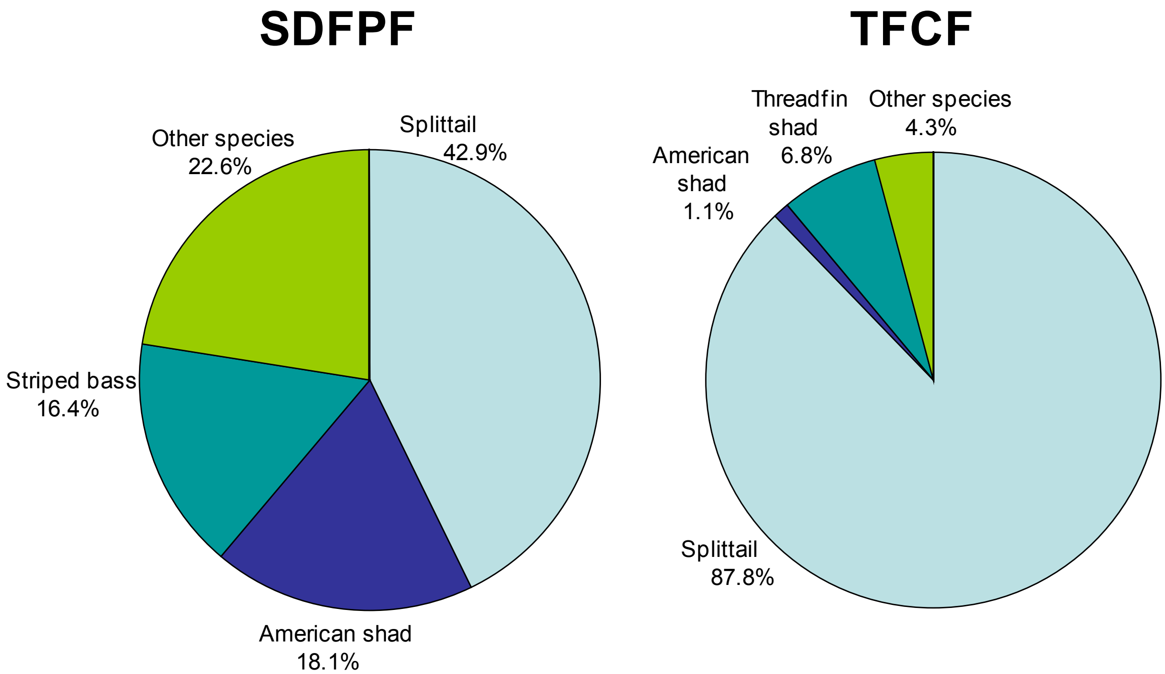

Figure 4 Percentages of annual salvage for the 3 most prevalent fish species and other fish species combined at the SDFPF and TFCF, 2011

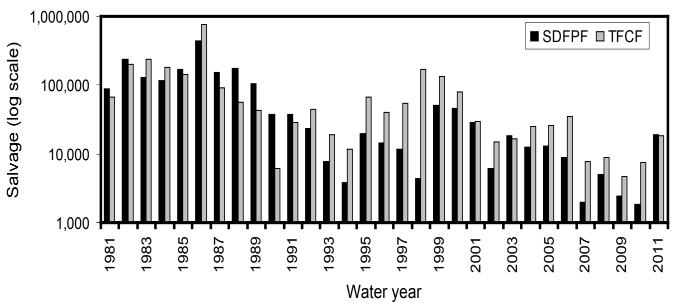

Figure 5 Annual salvage of Chinook salmon (all races and wild and hatchery origins combined) at the SDFPF and the TFCF, 1981 to 2011. The logarithmic scale is log_{10}.

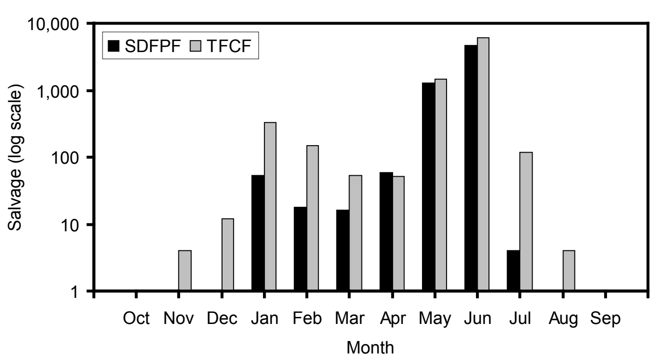

Figure 6 Monthly salvage of wild, fall-run Chinook salmon at the SDFPF and the TFCF, 2011. The logarithmic scale is log_{10}.

Steelhead

Salvage of steelhead (wild and hatchery origins combined) continued the pattern of mostly low salvage observed since 2005 (Figure 7). Salvage at the SDFPF (1,213) was lower than in 2010 (1,543). Similarly, TFCF salvage (445) was lower than in 2010 (3,088).

The TFCF salvaged 274 hatchery steelhead and 171 wild steelhead. The SDFPF salvaged 609 hatchery steelhead, 577 wild steelhead, and 27 steelhead of unknown origin.

Salvage of wild steelhead at both facilities occurred predominantly in the first half of the calendar year (Figure 8). Wild steelhead at the SDFPF were salvaged most frequently in April and June and in March at the TFCF.

Striped Bass

Salvage at the TFCF (39,583) was a record-low. Salvage at the TFCF and SDFPF (507,619) continued the generally-low trend observed since the mid-1990's (Figure 9). Prior to 1995, annual striped bass salvage was generally above 1,000,000 fish.

Table 2 **Chinook salmon annual (by water year) salvage, percentage of annual salvage, race and origin (wild or hatchery), and loss at the SDFPF and the TFCF, 2011**

Facility	Origin	Race	Salvage	Percentage	Loss
SDFPF					
	Wild				
		Fall	6,044	36	28,397
		Late-fall	36	<1	152
		Spring	10,018	59	46,453
		Winter	861	4	3,783
	Total Wild		**16,959**		**78,785**
	Unknown Race		**4**		**17**
	Hatchery				
		Fall	912	50	4,293
		Late-fall	469	25	2,009
		Spring	140	8	681
		Winter	312	17	1,347
	Total Hatchery		**1,833**		**8,330**
	Unknown Race and origin		**34**		**148-158***
	Grand Total		**18,830**		**87,132**
TFCF					
	Wild	Fall	8,238	49	5,906
		Late-fall	160	1	105
		Spring	7,636	45	6,051
		Winter	842	5	577
	Total Wild		**16,876**		**12,639**
	Hatchery				
		Fall	736	59	532
		Late-fall	224	18	154
		Spring	136	11	111
		Winter	151	12	102
	Total Hatchery		**1,247**		**899**
	Unknown Race		**12**		**8**
	Grand Total		**18,135**		**13,546**

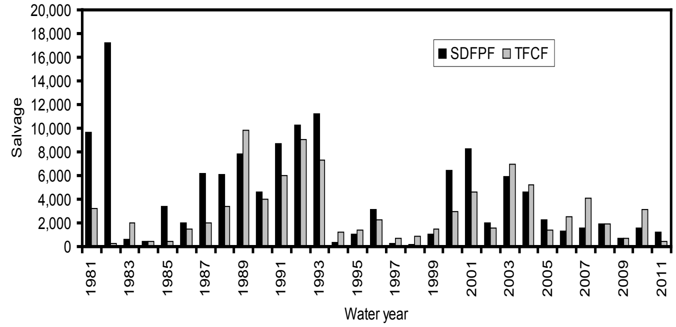

Figure 7 Annual salvage of steelhead (wild and hatchery origins combined) at the SDFPF and the TFCF, 1981 to 2011

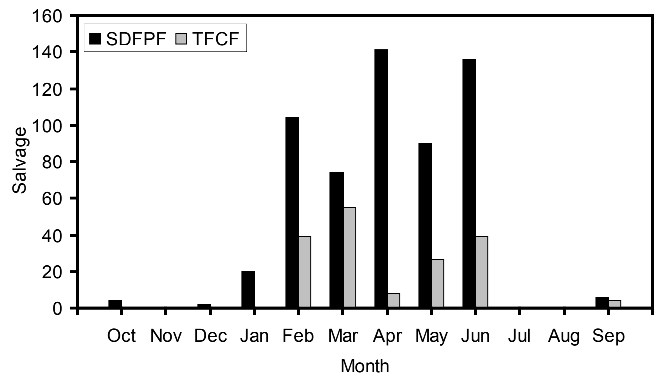

Figure 8 Monthly salvage of wild steelhead at the SDFPF and the TFCF, 2011

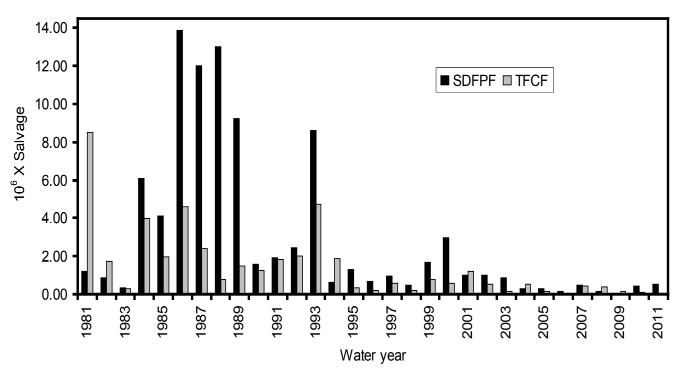

Figure 9 Annual salvage of striped bass at the SDFPF and the TFCF, 1981 to 2011

Most striped bass salvage at the SDFPF and the TFCF occurred in July and August (Figure 10). At the SDFPF, July salvage (331,167) and August salvage (63,006) accounted for 77.7% of annual salvage. At the TFCF, salvage during July (14,575) and August (8,236) accounted for 57.6% of annual salvage. Striped bass were salvaged every month at both facilities, with the lowest monthly salvage occurring in May at both the SDFPF (501) and the TFCF (37).

Delta Smelt

Record-low numbers of delta smelt were salvaged at TFCF (51) (Figure 11). Salvage at the TFCF was also low in 2010 (99). No delta smelt were salvaged at SDFPF for the first time recorded for 1981-2011 and salvage was low in 2010 (22).

Adult delta smelt were only salvaged in January (8), February (4), March (36), and April (3) at the TFCF. No juvenile delta smelt were salvaged at the TFCF.

Delta smelt less than 20 mm were first detected on June 9 at the SDFPF and were observed for 3 days there. No delta smelt less than 20 mm were detected at the TFCF.

Longfin Smelt

Longfin smelt at both facilities continued to be salvaged at very low levels or not at all compared to the early 2000s and the late 1980s (Figure 12). Only 4 adult longfin smelt were salvaged in January at TFCF and none were salvaged at SDFPF. No longfin smelt less than 20 mm were detected at either facility.

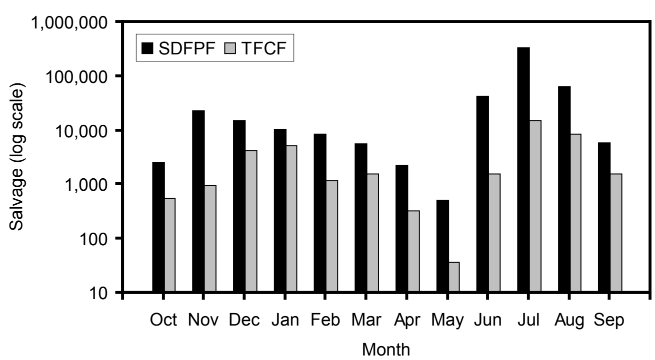

Figure 10 Monthly salvage of striped bass at the SDFPF and the TFCF, 2011. The logarithmic scale is log_{10}.

Splittail

Salvage of splittail at both facilities was higher than in 2010 (Figure 13). Salvage at the SDFPF (1,326,077) was much higher than in 2010 (28,062). Salvage was a record high at the TFCF (7,660,024) which was substantially higher than in 2010 (160,929). Splittail salvage has followed a boom-or-bust pattern, often varying year to year by several orders of magnitude.

Threadfin Shad

Annual salvage at the SDFPF (463,610) was lower than at the TFCF (591,111) (Figure 14). Salvage at the SDFPF was lower than in 2010 (725,433). Similarly, TFCF salvage was lower than in 2010 (763,105). Similar to splittail, annual salvage of threadfin shad has varied greatly through time.

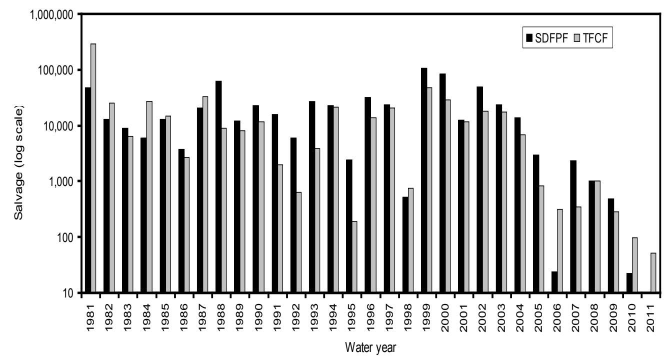

Figure 11 Annual salvage of delta smelt at the SDFPF and the TFCF, 1981 to 2011. The logarithmic scale is log_{10}.

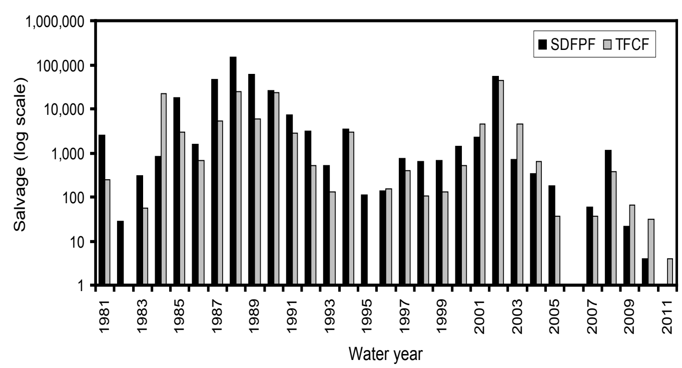

Figure 12 Annual salvage of longfin smelt at the SDFPF and the TFCF, 1981 to 2011. The logarithmic scale is log_{10}.

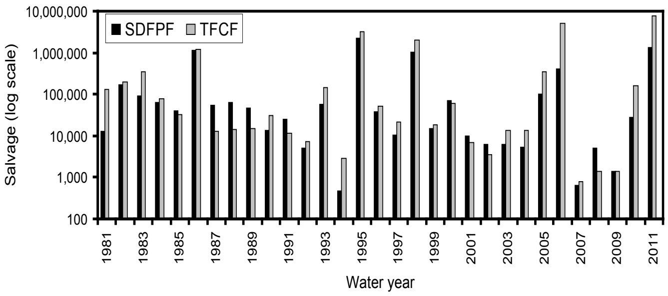

Figure 13 Annual salvage of splittail at the SDFPF and the TFCF, 1981 to 2011. The logarithmic scale is $\log_{10}$.

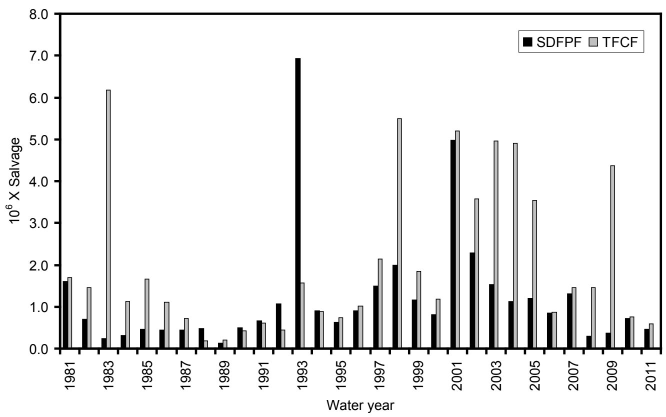

Figure 14 Annual salvage of threadfin shad at the SDFPF and the TFCF, 1981 to 2011

References

California Dept. of Fish and Game. 2006. Chinook salmon loss estimation for Skinner Delta Fish Protective Facility and Tracy Fish Collection Facility. Protocol. Stockton: California Dept. of Fish and Game; p. 4. Available from the California Dept. of Fish and Game, Bay-Delta Region East, 4001 N. Wilson Way, Stockton, California 95205.

Delta Smelt Captive Refugial Population--2011 Season Summary

Kathleen Fisch (UCD and San Diego Zoo Global Institute for Conservation Research kfisch@sandiegozoo.org), Brian Mahardja (UCD), Theresa Rettinghouse, Luke Ellison, Galen Tigan, Joan Lindberg (FCCL-UCD), Bernie May (UCD)

The captive delta smelt refugial population is located at the Fish Conservation and Culture Laboratory (FCCL) of University of California, Davis (UCD), and is managed in collaboration with the UCD Genomic Variation Laboratory. The captive refugial population was initiated in 2008, and has progressed to the F_4 generation in 2011 (Fisch et al. 2009; 2010).

Spawning season 2011 for the delta smelt refugial population started in late January 2011 and concluded on June 1, 2011. A total of 1,753 fish were uniquely tagged and genetically analyzed according to the methods in Fisch et al. (2009, 2010). The pedigree was reconstructed and the pairwise kinship of all individuals was calculated using 12 microsatellite markers. Fish were spawned in genetically recommended single pair crosses, and 516 fish were successfully paired, based on a modified method of minimal kinship selection, representing 187 of the 233 families made in 2010 (Fisch et al. 2010). A total of 68 wild fish were incorporated into the captive population this generation.

The genetic diversity of the parental F_3 generation was assessed to genetically monitor the captive population. A total of 259 alleles were identified and allelic richness (AR) ranged from 6.27 to 29.56 alleles at each locus (Tables 1 and 2). The mean expected heterozygosity (HE), including wild fish incorporated into the captive population, was 0.84 (ranging from 0.46-0.96) (Table 1). These values were not significantly lower than the founding generation F_0. When compared across all loci, the difference between generations was not significant ($P<0.05$).

In conclusion, the captive refugial population continues to maintain the genetic diversity of the delta smelt population and is demographically stable. Future generations in captivity will be similarly managed in an effort to preserve the genetic and demographic integrity of the delta smelt population.

Table 1 Allelic diversity and heterozygosity of the F_3 generation of captive delta smelt at 12 microsatellite loci, including locus name, number of individuals genotyped (N), number of alleles (A), observed heterozygosity (H_o), expected heterozygosity (H_E), p-value from tests of deviations from Hardy-Weinberg Equilibrium and the inbreeding coefficient for each locus (F_{IS})

F3 Generation						
Locus	N	A	H_O	H_E	P	F_{IS}
HtrG103	413	18	0.901	0.892	0.001*	-0.010
HtrG104	329	07	0.477	0.460	0.7400	-0.038
HtrG109	405	15	0.879	0.869	0.7000	-0.011
HtrG114	414	29	0.915	0.942	0.6000	0.029
HtrG115	410	26	0.915	0.931	0.5500	0.018
HtrG116	365	07	0.501	0.522	0.6500	0.040
HtrG117	366	20	0.902	0.911	0.3700	0.011
HtrG119	170	29	0.929	0.947	0.4500	0.019
HtrG120	456	16	0.807	0.814	0.3100	0.009
HtrG126	398	32	0.915	0.946	0.7800	0.033
HtrG127	461	32	0.905	0.956	0.2700	0.054
HtrG131	355	28	0.924	0.947	0.2300	0.025
Average	---	21.58	0.830	0.840	---	0.010

*Statistically significant at P<0.05 after Bonferroni correction

Table 2 Allelic richness[1] of each generation of captive delta smelt at 12 microsatellite loci.

Captive Population				
Locus	F_0	F_1	F_2	F_3
HtrG103	20.2	18.1	17.5	17.9
HtrG104	06.5	06.8	06.2	06.3
HtrG109	18.5	16.8	17.2	14.2
HtrG114	27.3	26.7	26.7	26.9
HtrG115	24.4	22.7	23.4	23.9
HtrG116	08.3	07.7	06.6	06.8
HtrG117	23.2	19.2	18.5	18.8
HtrG119	30.8	31.0	30.2	29.0
HtrG120	17.3	17.1	16.3	15.1
HtrG126	30.6	29.8	28.6	29.5
HtrG127	31.6	33.0	30.0	29.6
HtrG131	28.1	27.5	27.3	26.7
Average	22.2	21.4	20.7	20.4

[1] Allelic richness (AR) based on a minimum sample size of 170 diploid individuals

Literature Cited

Fisch, K., Rettinghouse, T., Ellison, L., Tigan, G., Lindberg, J. and B. May. 2009. Delta smelt refugial population development and genetic management—2009 season summary. Interagency Ecological Program Newsletter 22(3): 3-9.

Fisch, K., Mahardja, B., Rettinghouse, T., Ellison, L., Tigan, G., Lindberg, J. and B. May. 2010. Captive Breeding Plan for the Endangered Delta Smelt Refugial Population: Genetic Management and Fish Rearing Modifications for 2010. Interagency Ecological Program Newsletter 23(3): 13-20.

2010 Status and Trends Report Common Crabs of the San Francisco Estuary

Kathryn Hieb (CDFG), khieb@delta.dfg.ca.gov

Introduction

This report summarizes abundance trends and distributional patterns of the 4 most common *Cancer* crabs and *Eriocheir sinensis* (the Chinese mitten crab) through 2010 in the San Francisco Estuary. Most of the data are from the San Francisco Bay Study (Bay Study) otter trawl, with additional *E. sinensis* data from the UC Davis Suisun Marsh otter trawls and the Central Valley Project (CVP) and State Water Project (SWP) fish salvage facilities. Indices of relative abundance were used for Bay Study annual and seasonal abundance, while catch-per-unit-effort (CPUE) as crabs per 5-minute tow was used for Bay Study regional and channel-shoal distribution. More detail about the Bay Study sampling methods and the referred to ocean temperature and upwelling figures can be found in the companion 2010 Bay Study Fishes Status and Trends Report, page 20, this issue. UC Davis otter trawl mitten crab CPUE was also number per tow, while the fish facilities data was the estimated number of adult crabs salvaged in fall. Daily upwelling indices from the NMFS Pacific Fisheries Environmental Laboratory were plotted for 2010 39ºN.

Cancer crabs

Cancer magister

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 the 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).

Cancer magister recruitment is episodic and cyclic, with several extremely strong year classes often followed by poor year classes or no recruitment. The 2010 age-0 *C. magister* abundance index was the fourth highest for the 31-year period of record (Figure 1) and the second consecutive year of strong recruitment. Favorable ocean conditions in winter 2009-2010, when larval *C. magister* hatched and reared in the Gulf of the Farallones (GOF), likely resulted in this strong year class. GOF sea surface temperatures (SSTs) were about 1°C cooler than the long-term mean in late 2009 (Figure 3A, Bay Study Fishes Status and Trends Report, page 22), which would have increased larval survival. Infrequent storms in winter and spring should have resulted in a weak northward-flowing surface current and retention of *C. magister* larvae and megalopae (the last larval stage, which is planktonic for weeks) in the GOF. We expected good recruitment of age-0 *C. magister* in the estuary in 2010 from this combination of cooler SSTs and weaker surface currents. Most small juvenile *C. magister*, <10 mm CW, entered the estuary in May 2010, which is the usual period of peak settlement. This is additional evidence that larvae and megalopae were not transported some distance offshore by unfavorable ocean currents in winter or early spring.

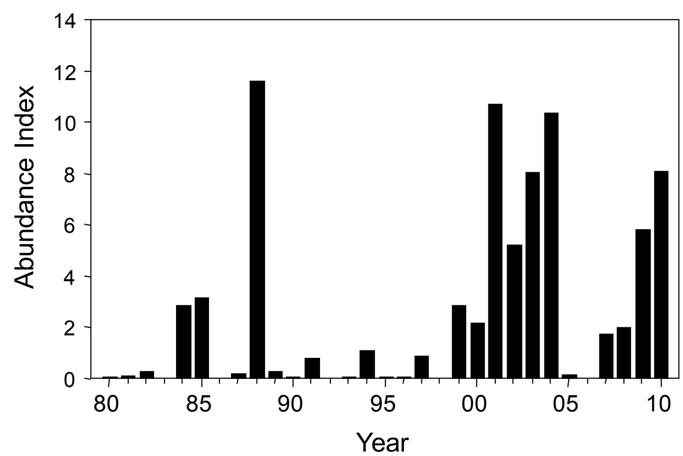

Figure 1 Annual abundance indices of age-0 Cancer magister, Bay Study otter trawl, May to July, 1980-2010

Cancer magister commercial fishing landings are also cyclic, and often reflect the strong and weak year classes in the estuary. Central California commercial landings surpassed 5 million pounds annually from the 2002-03 to 2006-07 fishing seasons, dropped to about 1 million pounds in 2008-09, but then increased to a record 19 million pounds in the 2010-11 fishing season (Figure 2). 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 weaker 2005, 2006, and 2007 year classes contributed to the fishery from the 2007-08 to 2009-10 seasons. However, the record landings in 2010-2011 were unexpected based on the relatively week 2008 year class of estuary-reared crabs. The larger 2009 year class did not contribute to the fishery until the 2011-12 season, which was in progress when this report was written.

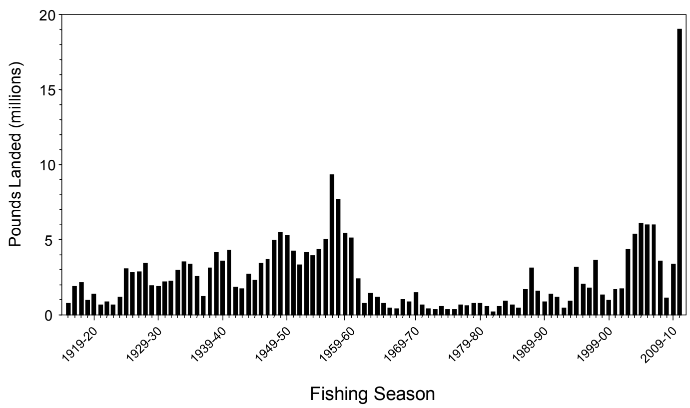

Figure 2 Annual landings of Cancer magister in the Central California Management Area (south of the Mendocino-Sonoma County line), 1915-16 to 2010-11 fishing seasons. Data from DFG's Marine Region.

In 2010, the first age-0 *C. magister* were collected in April, with peak immigration of the smallest juveniles in May and peak age-0 abundance in July and August. Age-0 abundance decreased substantially in September but increased again in November and December. The fall increase was primarily due to upstream age-0 crabs that moved from shallow subtidal areas to depths sampled by the otter trawls, as they staged for emigration. The 2009 year class, as age-1 crabs, was collected through November 2010. Age-1 abundance peaked in March and April and dropped off rapidly after May.

Age-0 *C. magister* were collected from south of the Dumbarton Bridge in South Bay, to just upstream of Ryer Island in Suisun Bay in 2010. A distinct group of age-0 crabs entered the estuary in May and June and migrated upstream to rear, ultimately from eastern San Pablo Bay through western Suisun Bay. From special studies in past years, we assumed that this group was also common in the lower Napa River and Napa-Sonoma Marsh. Another group either remained in Central Bay after immigration or was composed of crabs that moved between the ocean and Central Bay. As expected based on water temperature, the upstream group grew faster than the Central Bay group, although the Central Bay group may have had constant recruitment of slower growing crabs from the ocean. By December, the upstream group had a mean size of 72 mm CW, while the Central Bay group had a mean size of 50 mm CW. A size difference of approximately 20 mm has been common for these 2 regions in recent years.

Since 1999, there has been a trend of proportionally more age-0 *C. magister* collected in Central Bay in summer and fall, especially at the Alcatraz Island station. In 2010, 85% of the age-0 catch from June to October was from Central Bay, but only 4% from the Alcatraz Island station. The largest Central Bay catches in 2010 were from the 3 channel stations between Angel Island and the San Rafael-Richmond Bridge. We have hypothesized that the proportionally larger percentage of the *C. magister* catch from Central Bay much of the past decade was somehow related to colder than normal ocean temperatures and strong upwelling in summer (Figures 3A and 3B, Bay Study Fishes Status and Trends Report, page 22, this issue). We have reported similar trends for English sole, speckled sanddab, plainfin midshipman, and several other demersal marine fishes (see the 2010 Bay Study Fishes Status and Trends Report, this issue).

Age-0 *C. magister* were, overall, more common at channel stations in 2010, with an average of 13.2 crabs/tow for the channels and 3.6 crabs/tow for the shoals (May to December, South Bay through Suisun Bay). However, there were seasonal shifts to and from the shoals. Age-0 crabs were more common in the channels from May through August, largely due to immigration and upstream migration, but shifted to the shoals from September through November for rearing and back to the channels in December, as they staged for emigration. Some of the high channel catches in summer were the group that may have moved between the bay and ocean. These catches confounded the channel-shoal shifts, but the group that migrated upstream in spring and early summer to rear over the shoals in San Pablo and Suisun bays was distinct.

Age-1 *C. magister* were, overall, most common in Central Bay in 2010, with some consistently collected in San Pablo Bay and Carquinez Strait through August. There was a large downstream migration of age-1 crabs to Central Bay early in the year, associated with an outflow peak in late January and early February. Age-1 crabs were, as in past years, more common in the channels, with an average of 3.1 crabs/tow for the channels and 1.0 crabs/tow for the shoals (January through November, South Bay through Suisun Bay).

Cancer antennarius

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. *C. antennarius*, *C. productus* and *C. gracilis* (the graceful rock crab) reproduce in the nearshore ocean and higher salinity areas of the San Francisco Estuary, primarily in winter. Therefore, estuary and ocean conditions may control larval survival and year-class strength of these 3 species.

The 2010 age-0 *C. antennarius* abundance index was slightly higher than the 2009 index, and the fourth consecutive above average index (Table 1). *C. antennarius* abundance in the estuary is probably related to ocean temperatures, with the highest abundance often, but not always, in years with the coldest winter-spring SSTs. SSTs in early winter 2009-2010 were about 1°C cooler than the long-term mean, but not as cool as the previous 3 winters (see Figure 3A, Fishes Status and Trends report, page 22). In 2010, age-0 *C. antennarius* abundance peaked November, with smaller peaks in January, July, and September. Small, newly settled juveniles, <10 mm CW, were collected all months except for March and May, with most in November, followed by July and September.

Cancer antennarius was collected from South Bay, near Coyote Point, through lower San Pablo Bay in 2010. The highest age-0 catches were from the shoal stations off Oakland and Alameda, near Berkeley Marina, and just downstream of Point Pinole and the 2 channel stations near Hunter's Point in South Bay. Except for January, age-0 crabs were more common at shoal stations in 2010, with an annual CPUE of 1.8 crabs/tow for the shoals vs. 0.6 cabs/tow for the channels (January to December, South Bay through San Pablo Bay). Age-1+ *C. antennarius* were collected primarily from channel stations south of the Bay Bridge and at Alcatraz Island, with a few from nearby shoal stations.

Table 1 Annual abundance indices of age-0 *Cancer* **crabs from the Bay Study otter trawl, 1980-2010. 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	1017	166
1995	367	227	40
1996	1126	411	198
1997	351	1131	86
1998	718	1621	149
1999	90	222	249
2000	849	251	93
2001	276	1921	142
2002	119	796	238
2003	424	522	140
2004	1765	112	139
2005	144	132	57
2006	46	81	71
2007	987	418	58
2008	1703	543	50
2009	556	471	68
2010	630	321	193
1980-2010 Average	384	431	96

Cancer gracilis

Cancer gracilis, the graceful rock crab, is the smallest of the four *Cancer* crab species reported here, rarely exceeding 85 mm CW. It is common in open sandy or sand-mud habitats rather than rocky areas; researchers have hypothesized that because of its small size it cannot compete with the rock crabs for the more "preferred" protected habitats with structure. The 2010 abundance index of age-0 *C. gracilis* again declined from the previous year (Table 1) and was below the long-term study mean. Age-0 abundance peaked in August, but this peak was comprised of larger crabs, 30-39 mm CW. Recently settled juvenile *C. gracilis*, <10 mm CW, were collected from March through July, with most in March, followed by May.

In 2010, *C. gracilis* was collected from the shoal station near Coyote Point in South Bay to the channel station near Point Pinole in San Pablo, with 78% (n=226) of all crabs collected from the Central Bay. The highest catches were from the shoal stations near Candlestick Point in South Bay and Treasure Island, Southampton Shoal, and Paradise Cay in Central Bay. There was a seasonal channel-shoal pattern, with crabs more common in the channels in winter and the shoals from May through October. However, *C. gracilis* annual CPUE was the same at channels and shoals, with an average of 0.8 crabs/tow (January to December, South Bay through San Pablo Bay).

Cancer productus

Cancer productus, the red rock crab, is overall the least common of the four *Cancer* crabs most often collected by the otter trawl in the estuary, reflecting its strong preference for rocky intertidal and subtidal marine habitats not sampled by the trawl. In a survey conducted by CDFG from 1982 to 1994 with baited ringnets at piers, it was the second most common *Cancer* crab collected. The 2010 age-0 *C. productus* abundance index was the highest since 2002 and approximately twice the study-period mean (Table 1). In spite of this increase, we collected only 25 age-0 *C. productus* in 2010, with even fewer contributing to the annual index. Age-0 abundance peaked in September, with a slightly smaller peak in July. Most small, recently settled *C. productus* (<10 mm CW) were collected in September, but a few of these smallest crabs were also collected in March, June, and October.

Cancer productus was collected from near San Leandro in South Bay to Point Pinole in San Pablo Bay in 2010, with 76% (n=56) from Central Bay. Channel habitat was favored all months, with mean channel CPUE 4 times shoal CPUE (0.4 vs. 0.1 crabs/tow, January to December, South Bay through San Pablo Bay). Juvenile *C. productus* reportedly settle on spatially complex substrates and move to areas with more open space as they grow (Orensanz and Gallucci 1988). Because we tow over soft substrates rather than rocky areas, we are likely not able to detect this type of distributional pattern. We did collect larger *C. productus*, > 50 mm CW, only in channels in 2010.

Ocean Conditions and Recruitment of Cancer Species

Ocean conditions in winter 2009-2010, with relatively cool winter temperatures in the first half and a weak northward flowing surface current, should have favored *C. antennarius*, *C. gracilis*, and *C. productus* recruitment. *C. antennarius* and *C. productus* age-0 abundance indices increased from 2009 and were above the study-period mean, but *C. gracilis* abundance decreased from 2009 and was below the study-period mean (Table 1). Peak larval hatching of all 3 species is reportedly in winter, but multiple broods may occur and megalopae have been collected in San Francisco Estuary in other seasons (Hieb 1999). Since timing of juvenile settlement was not identical for these 3 species in 2010, they likely responded differently to upwelling and ocean currents. For example, based on the collection of the smallest juvenile *C. gracilis*, most settled before early May 2010, which was before the strongest upwelling (Figure 3). In contrast, the largest number of small, recently settled *C. antennarius* were collected in November 2010 and *C. productus* in September 2010, when upwelling weakened (Figure 3). These fall cohorts of *C. antennarius* and *C. productus* were likely from larvae hatched after winter 2009-2010, as larval development is usually 2 to 3 months and any crabs hatched in winter would be larger than 10 mm CW by the next fall. We also collected small juveniles of all 3 species sporadically through spring and summer, evidence of multiple cohorts or prolonged settlement from winter reproduction.

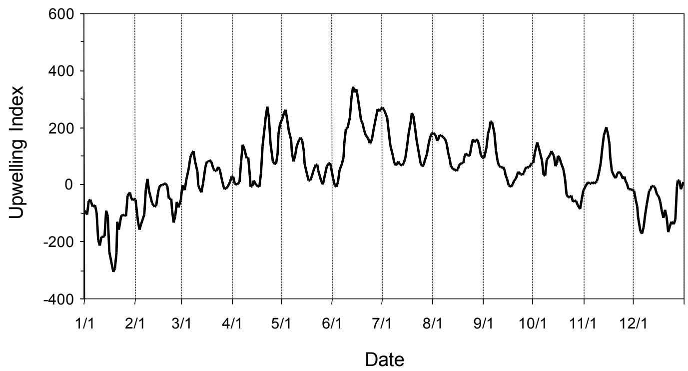

Figure 3 2010 daily upwelling indices (m3/sec along each 100 meters of coastline) from 39ºN, 5-day running mean. Data from NOAA's Pacific Fisheries Environmental Laboratory.

Eriocheir sinensis

Eriocheir sinensis, the Chinese mitten crab, was first collected in the estuary in the early 1990s, but likely introduced to South San Francisco 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 steadily declined after 2001, with few or no crabs collected from 2005 through early 2011. In fall and winter 2010-2011, 3 adult *E. sinensis* were estimated salvaged at USBR's Central Valley Project facility, but no crabs were collected by either the San Francisco Bay Study or UC Davis Suisun Marsh trawl surveys (O'Rear, personal communication, see "Notes") in the northern estuary. There were also no reports of adult *E. sinensis* in South Bay trawls conducted by the Marine Science Institute (Seiff, personal communication, see "Notes"), the fifth consecutive year that none were collected there.

There were no public reports of *E. sinensis* made to the toll-free reporting line, the web page reporting form, or from the postage-paid mailer in 2010 (Thompson, personal communication, see "Notes"). One common impact of *E. sinensis* is bait stealing from sport anglers in the Delta, and Suisun and San Pablo bays, which is often reported. From such public reports, we may learn of an increase in the *E. sinensis* population before it is detected by our surveys.

Table 2 Annual adult Eriocheir sinensis CPUE and estimated total salvage, 1996-2010. 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	not counted
1997	0.34	0.07	20,000	not counted
1998	2.51	0.89	750,000	not counted
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
2008	0.00	0.00	0	0
2009	0.00	0.00	0	0
2010	0.00	0.00	3	0

I previously hypothesized that ocean conditions may control *E. sinensis* recruitment to the San Francisco Estuary (Hieb 2009). The planktonic larvae, which have minimal or no estuary-retention mechanisms (Hanson and Sytsma 2008), would be transported to the coast in years with high freshwater outflow. In addition, successful development of E. sinensis larvae in the laboratory occurred only at temperatures >12°C, with the highest survival at 18°C (Anger 1991). Winter ocean SSTs were often >12°C during the El Niño events of the 1990s. Several of these years also had very high outflow, which would have transported larvae to the coastal ocean. Here, larvae could have survived and developed at the warmer temperatures, in contrast to the much cooler estuary. In winter 2009-2010, nearshore SSTs were between 11 and 13°C (Figure 4, Bay Study Fishes Status and Trends report, page 22, this issue) and freshwater outflow was low, a combination that would have resulted in no or poor *E. sinensis* recruitment. This was supported by no reports or collections of juvenile *E. sinensis* in 2010 or 2011.

Acknowledgements

I thank Pete Kalvass of California Department of Fish and Game for the unpublished Cancer magister 2010-11 commercial landing data.

Notes

Pete Kalvass, CDFG, email, February 1, 2012.
Teejay O'Rear, UC Davis, email, January 31, 2012.
Marylou Seiff, Marine Science Institute, email, February 7, 2012
Jon Thompson, USFWS, email, February 10, 2012
Daily upwelling indices from www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling/NA/data_download.html

References

Anger, K. 1991. Effects of temperature and salinity on the larval development of the Chinese mitten crab *Eriocheir sinensis* (Decapoda: Grapsidae). Marine Ecology Progress Series 72:103-110.
Hanson, E. and M. Sytsma. 2008. The potential for mitten crab *Eriocheir sinensis* H. Milne Edwards, 1853 (Crustacea: Brachyura) invasion of Pacific Northwest and Alaskan Estuaries. Biological Invasions 10(5):603-614.
Hieb, K. *Cancer* crabs. In: J. Orsi, editor. Report on the 1980-1995 fish, shrimp, and crab sampling in the San Francisco Estuary, California. IEP Technical Report 63, 503 pp.
Hieb, K. 2009. 2008 Status and Trends Report: Common Crabs of the San Francisco Estuary. IEP Newsletter, 22(3):12-16.
Orensanz, J.M. and V.F. Gallucci. 1988. Comparative study of postlarval life-history schedules in four sympatric species of *Cancer* (Decapoda: Brachyura: Cancridae). Journal of Crustacean Biology 8(2):187-220.
Tasto, R.N. 1983. Juvenile Dungeness crab, *Cancer magister* studies in the San Francisco Bay area. Pages 135-154 in: P.W. Wild and R.N. Tasto, editors. Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. California Department of Fish and Game, Fish Bulletin 172.

2011 Smelt Larva Survey

Julio Adib-Samii, California Department of Fish and Game (jadibsamii@dfg.ca.gov)

The Department of Fish and Game (DFG) successfully completed the 2011 field season of the Smelt Larva Survey (SLS) in late March. Initiated in 2009, the SLS monitors the distribution and relative abundance of larval longfin smelt (*Spirinchus thaleichthys*) in near real-time. These data are used to assess the vulnerability of larva to entrainment at Delta water diversions. Longfin smelt are the focus of this program following their 2009 listing as threatened under the California Endangered Species Act.

From January 18 to March 23, 2011, DFG conducted 5 bi-weekly Delta-wide surveys consisting of a single sample (one 10-minute stepped oblique tow) taken at 35 locations (Figure 1). The towed net (length = 3.35 m, mouth area = 0.37 m^2, mesh size = 505 µm) was mounted to a rigid steel frame. Skis were attached to the frame to prevent the frame and net from digging into the substrate during deployment. Once a tow is complete, all larval fish were preserved in 10% buffered formalin and returned to our Stockton laboratory for identification to the lowest possible taxon. A full description of methods and protocol are available through this author.

A total of 62,455 fish representing 18 species (Table 1) were collected during the 2011 field season. Pacific herring (*Clupea pallasi*), prickly sculpin (*Cottus asper*), and longfin smelt - which comprised 97.9% of total catch - were the most-abundant and most-widely distributed species encountered. Yellowfin gobies (*Acanthogobius flavimanus*) were the fourth most-abundant and the remaining 14 species comprised less than 1% of total catch (Table 1).

Longfin smelt showed broad distributions throughout each survey and were collected in 82.9% (n = 145) of all the samples taken (Figure 2). The highest densities of longfin smelt occurred at or downstream of the Sacramento-San Joaquin confluence in every survey. Average longfin lengths (Figure 3) suggest that older (i.e., larger) larvae occurred at or downstream of the confluence more than they occurred upstream of the confluence– an indication of downstream transport.

The SLS is a useful tool for resource management. The bi-weekly catch reports allow the Smelt Working Group (SWG) to determine the distribution and abundance of longfin smelt larvae and assess their entrainment risk. These catch reports provided the SWG basis for Old and Middle River (OMR) flow recommendations made to the Water Operations Management Team (WOMT) and DFG's Director, as required by Condition 5.2 of the California Endangered Species Act Incidental Take Permit No. 2081-2009-001-03 (SWP – ITP), which states: "To protect larval and juvenile longfin smelt during the January through June period, the SWG or DFG SWG personnel shall provide OMR flow advice to the WOMT and to the Director weekly." Further, "When a single Smelt Larva Survey (SLS) or 20 mm Survey (20 mm) sampling period results in : 1) longfin smelt larvae or juveniles found in 8 or more of the 12 SLS or 20 mm stations in the south Delta (Stations 809, 812, 815, 901, 902, 906, 910, 912, 914, 915, 918, 919) or, 2) catch per tow exceeds 15 longfin smelt larvae or juveniles in 4 or more of the 12 survey stations listed above, OMR flow advice shall be warranted." However, the SWP - ITP was written to allow favorable flow conditions in the Sacramento or San Joaquin rivers to act in place of restrictive OMR flow advice: "When river flows are: 1) greater than 55,000 cfs in the Sacramento River at Rio Vista; or 2) greater than 8,000 cfs in the San

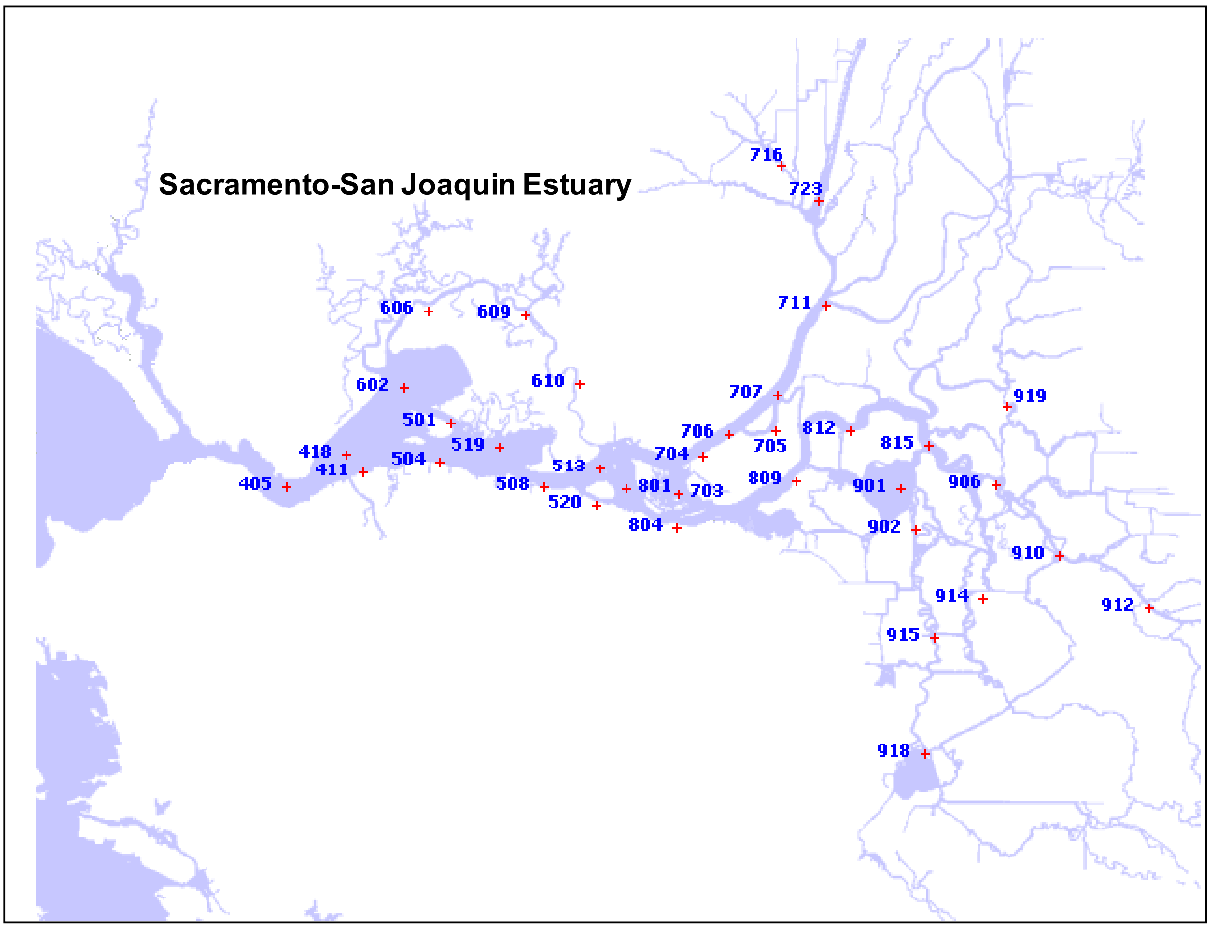

Figure 1 Station locations sampled by the Department of Fish and Game's Smelt Larva Survey, 2011, in the upper Sacramento-San Joaquin Estuary

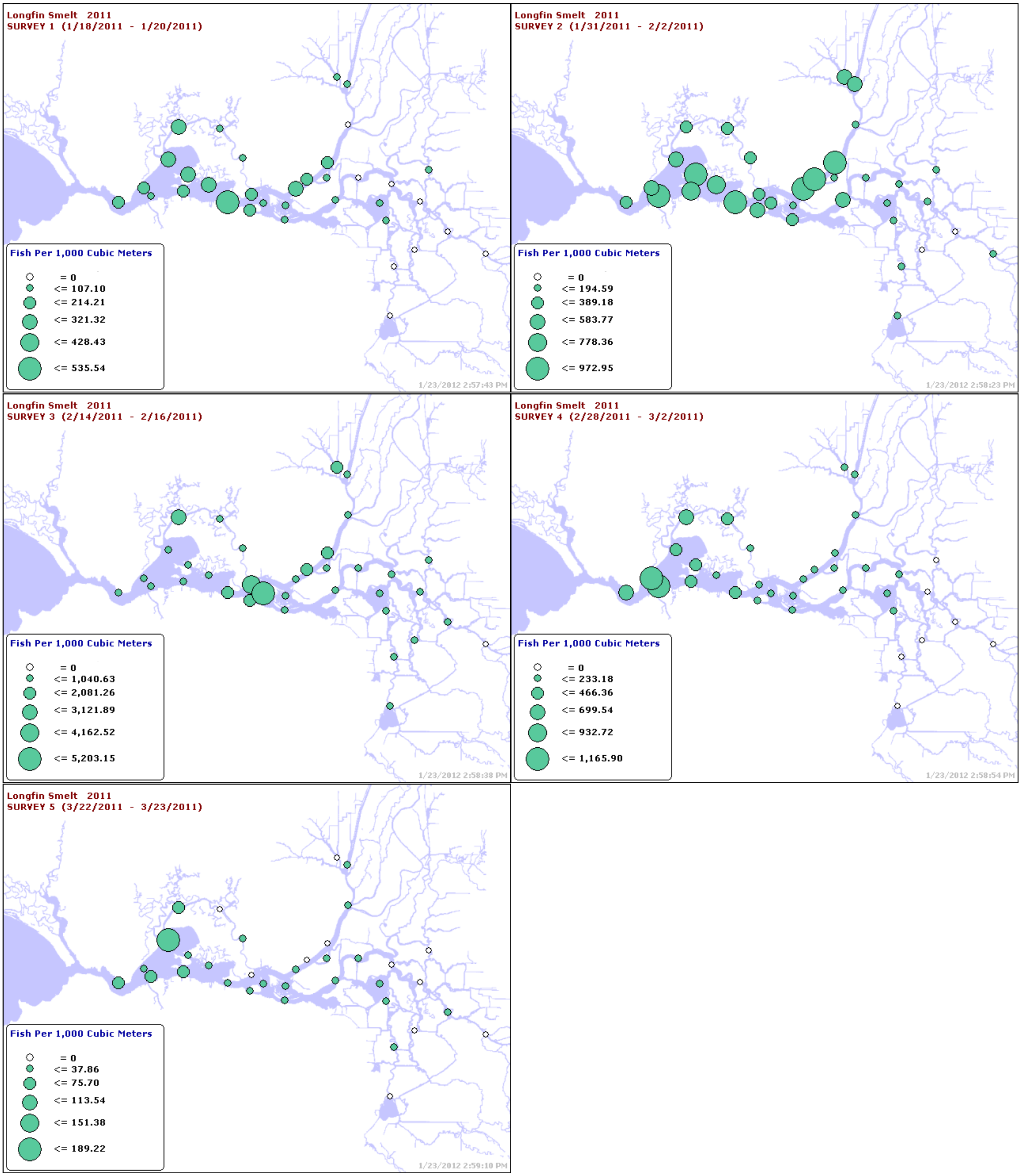

Figure 2 Distribution and catch per unit effort of longfin smelt collected by the Department of Fish and Game's Smelt Larva Survey, 2011, in the upper Sacramento-San Joaquin Estuary. Bubble plots are taken from the Smelt Larva Survey web-page (http://www.dfg.ca.gov/delta/projects.asp?ProjectID=SLS).

Joaquin River at Vernalis, the Condition [5.2] would not trigger or would be relaxed if triggered previously" (available at http://www.dfg.ca.gov/delta/data/longfinsmelt/documents/ITP-Longfin-1a.pdf).

In 2011, distributional criteria (i.e., detection of larvae in 8 of 12 south Delta stations) for longfin smelt were met in 2 of the 5 surveys conducted. In both of these cases, flow on the Sacramento River far exceeded the threshold that relieves the mandate of OMR flow advice to WOMT (Table 2). These favorable flows that persisted throughout the 2011 SLS field season presumably flushed longfin larvae downstream, reduced the overall risk of entrainment at the state and federal water export facilities, and ultimately resulted in no resource management actions based on SLS results.

The 2012 SLS is scheduled to begin in early January and conclude in March or April (depending on water year type). Existing SLS data are available through our FTP site (ftp://ftp.delta.dfg.ca.gov/Delta%20 Smelt/), and fish distribution maps are available on our project web page (http://www.dfg.ca.gov/delta/projects.asp?ProjectID=SLS).

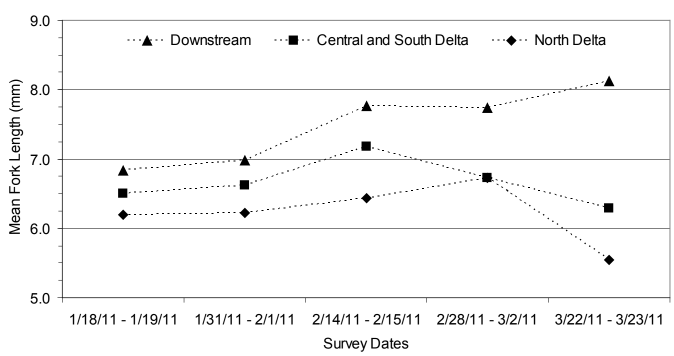

Figure 3 Mean fork lengths of longfin smelt collected in the Department of Fish and Game's Smelt Larva Survey, 2011. Fork lengths are grouped by survey number for three distinct geographic regions. Downstream refers to stations west of Decker Island on the Sacramento River and west of Jersey Point on the San Joaquin River. Central and South Delta refers to stations within the Central and South Delta. North Delta refers to stations upstream of Decker Island on the Sacramento River.

Table 1 Total species caught from the Department of Fish and Game's Smelt Larva Survey, 2011

Common Name	*n*	*% of Catch*
Pacific herring	40,594	65.00%
prickly sculpin	11,439	18.32%
longfin smelt	9,099	14.57%
yellowfin goby	1,267	2.03%
threespine stickleback	10	<0.02%
bigscale logperch	9	<0.01%
bay goby	8	<0.01%
delta smelt	5	<0.01%
wakasagi	5	<0.01%
Pacific staghorn sculpin	4	<0.01%
white croaker	4	<0.01%
Sacramento sucker	3	<0.01%
shimofuri goby	2	<0.01%
white catfish	2	<0.01%
splittail	1	<0.01%
threadfin shad	1	<0.01%
inland silverside	1	<0.01%
centrarchids (unid)	1	<0.01%

Table 2 State Water Project's Incidental Take Permit for longfin smelt (SWP – ITP) management actions based on the Department of Fish and Game's Smelt Larva Survey, 2011

Survey	*Distribution / Abundance Criteria*	*Action / Advice*	*Basis*
1	Not Met	None	N/A
2	Distribution Critieria Met	None	Sacramento River flow >55,000 cfs
3	Distribution Critieria Met	None	Sacramento River flow >55,000 cfs
4	Not Met	None	N/A
5	Not Met	None	N/A

2010 Bay Study Fishes Annual Status and Trends Report for the San Francisco Estuary

Maxfield Fish, Jennifer Messineo, and Kathryn Hieb (CDFG)[1]

Introduction

This 2010 Status and Trends fishes report includes data from the San Francisco Bay Study (Bay Study), one of the Interagency Ecological Program's (IEP's) long-term fish monitoring surveys. Results for the upper estuary pelagic species collected by the Townet Survey, the Fall Midwater Trawl, and the Delta Smelt 20-mm Survey were reported in the Spring 2011 IEP Newsletter (Contreras et al. 2011). The most recent abundance indices, long-term abundance trends, and distributional information are presented here for other common species in the estuary and some less-common species of interest, such as the surfperches. Presented first are the upper estuary demersal fishes, followed by the marine pelagic fishes, surfperches, and marine demersal fishes. Within each section, species are presented phylogenetically.

Methods

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 some data gaps, most significantly: limited midwater trawl sampling in 1994, no winter sampling from 1989 to 1997, and limited sampling at stations in and near the confluence of the Sacramento and San Joaquin rivers in 2007 and 2008 to reduce delta smelt take. Abundance indices are routinely calculated for 35+ fishes and several species of crabs and caridean shrimp. Only the fishes are included in this report; the crabs and shrimp are subjects of separate annual reports, with the 2010 Crab Status and Trends report also in this issue (see page 11). Of the 52 stations currently sampled, 35 have been consistently sampled since 1980 ("core" stations) and are used to calculate the annual abundance indices. Stations are fairly evenly distributed between channels and shoals in most regions, although depths <3 meters are not sampled. Most stations have a soft substrate, such as mud, sand, or a mix of shells – we purposely do not tow in rocky areas or eelgrass beds. Additional information about study methods, including index calculation, can be found in IEP Technical Report 63 (Baxter et al. 1999).

Bay Study midwater trawl data was used to describe abundance trends and distribution of the pelagic fishes and otter trawl data for demersal fishes. Catch-per-unit-effort (CPUE), as catch per tow, was consistently used to analyze and report distribution.

Several physical data sets were used to describe the oceanic and estuarine environmental conditions that were in turn related to abundance trends and distributional patterns. Daily outflow at Chipps Island was from Dayflow (DWR); the 1979-2010 daily values were averaged to monthly values and plotted. Monthly Pacific Decadal Oscillation (PDO) indices, from Nathan Mantua (University of Washington), and North Pacific Gyre Oscillation (NPGO) indices, from Emanuele Di Lorenzo (Georgia Institute of Technology), were plotted for 1950-2010. Monthly ocean upwelling anomalies (base period 1946-2010, 39°N), from the NMFS Pacific Fisheries Environmental Laboratory, were plotted from 1999 to 2010. Daily sea surface temperatures (SSTs), from Southeast Farallon Island (Scripps Institute of Oceanography), were used to calculate monthly values and anomalies, with 1925-2010 as the base period for the anomalies. Monthly SST anomalies from 1999 to 2010 and daily SSTs from January 2009 through December 2010 (7-day running mean) were plotted. See "Notes" for the data download URLs.

Physical Setting

Delta outflow was relatively low in 2010, with a mean January to June daily outflow at Chipps Island of 651 m^3/s. Although this was 65% higher than the 2009 outflow for the same period and the highest January to June outflow since 2006, it was the fourth consecutive low outflow year and the longest period of low outflow since the 1987-1992 drought (Figure 1).

The San Francisco Estuary is situated between 2 major marine faunal regions, the cold-temperate fauna of

1 Authorship: Introduction, Methods, and Physical Setting, K. Hieb (khieb@dfg.ca.gov); the gobies, flatfishes, plainfin midshipman, and Pacific staghorn sculpin, M. Fish (mfish@dfg.ca.gov); Pacific herring, northern anchovy, jacksmelt, the surfperches, brown rockfish, and white croaker, J. Messineo (jmessineo@dfg.ca.gov).

the Pacific Northwest and the warm-temperate fauna of southern and Baja California, and is a transitional area with elements of both faunal groups (Parrish et al. 1981). The northern Pacific Ocean reportedly entered a cold-water regime in 1999 (Peterson and Schwing 2003), which is hypothesized to be beneficial to many cold-temperate species, including Dungeness crab, English sole, and many of the rockfishes. This most recent cold-water regime was preceded by a warm-water regime from 1977 to 1998, which resulted in increased abundance of warm-temperate species in San Francisco Estuary, including California halibut, white croaker, Pacific sardine, and California tonguefish.

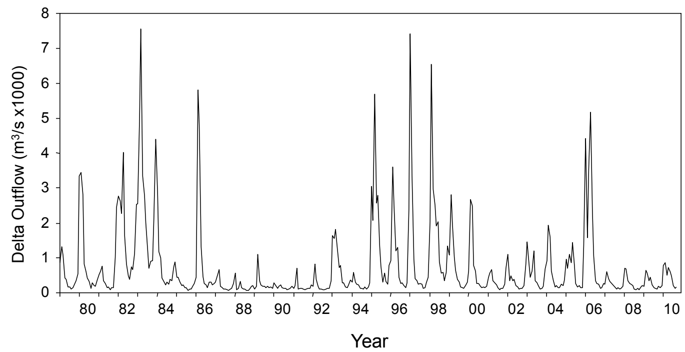

Figure 1 Mean monthly Delta outflow (m^3/s) at Chipps Island, 1979-2010

The PDO and NPGO are 2 basin-scale ocean climate indices. A positive PDO index is most strongly associated with warmer ocean temperatures, a stronger Alaska Current, and a weaker California Current, while a positive NPGO index is associated with increased salinity, upwelling, nutrients, and primary production and a stronger California Current (Di Lorenzo et al. 2008, Di Lorenzo et al. 2009). The PDO has the strongest effect north of 38°N while the NPGO has the strongest effect south of 38°N, with San Francisco Estuary situated at approximately 37°N. Major ecosystem regime shifts have occurred in the North Pacific when the PDO and NPGO show strong, simultaneous, and opposite sign reversals, such as in 1999 (Di Lorenzo et al. 2008). During cold-water regimes, the PDO indices are generally negative and the NPGO indices positive (Figure 2), with frequent La Niña events. Warm-water regimes generally have positive PDO indices and negative NPGO indices (Figure 2), with frequent and strong El Niño events. However, because the PDO and NPGO indices have fluctuated between cooler and warmer states the past decade, there is some question if a sustained cold-water regime is in place (Bjorkstedt et al. 2010).

From summer 2009 through early 2010, there was an El Niño event in the tropics, resulting in positive PDO indices and slightly negative NPGO indices (Figure 2). Spring 2010 was neutral in the tropics, but a La Niña event developed rapidly in summer 2010 and continued through early 2011. This La Niña event resulted in negative PDO and positive NPGO indices in mid- to late-2010 (Figure 2). There is often a time delay between the appearance of La Niña and El Niño events in the tropics and their effects along the Central California coast, and not all tropical events manifest similarly at this latitude. Although the central California coast has been in a cold-water regime for the past decade, there were 4 El Niño events ranging from 6 to 11 months in the tropics in this period. Consequently, we observed a number of months during the last decade above average SSTs and reduced upwelling, most from late 2002 through 2006 and in early 2010 (Figure 3).

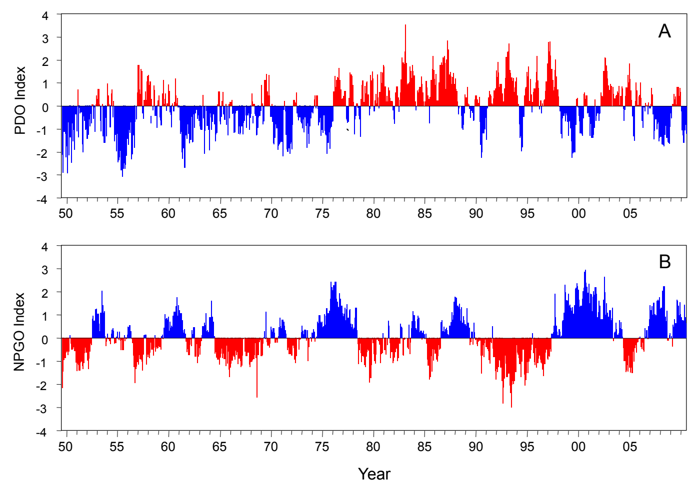

Figure 2 A) Monthly Pacific Decadal Oscillation (PDO) indices, 1950-2010 and B) Monthly North Pacific Gyre Oscillation (NPGO) indices, 1950-2010

Gulf of the Farallones (GOF) SSTs were about 1°C cooler than the long-term mean in late 2009 and slightly warmer than the long-term mean in early 2010 (Figure 3a), when many marine fishes that rear in San Francisco Estuary spawn in coastal waters. SSTs decreased rapidly in early May 2010 with the onset of upwelling (Figure 4) and were near 10°C, almost 1°C cooler than the long-term mean (Figure 3a). SSTs increased through summer and fall 2010 to a peak of just more than 14°C for several days in September and October (Figure 4), but were slightly below the long-term mean through November (Figure 3a).

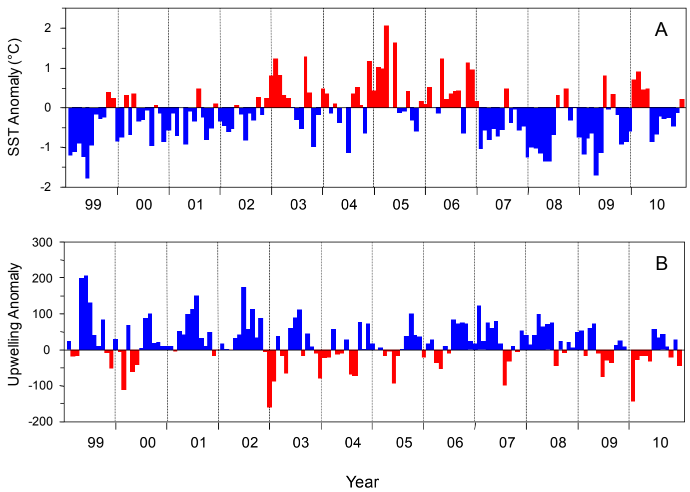

Figure 3 A) Monthly Sea Surface Temperature (SST, °C) anomalies from Southeast Farallon Island, 1999-2010 and B) Monthly upwelling index anomalies (39°N), 1999-2010

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 and the 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 winds weaken in fall, upwelling stops, surface ocean waters warm, and productivity declines. In winter, southwesterly winds result in a northward surface flow, or the Davidson Current. This current, in conjunction with the Coriolis Effect, produces an onshore and downward transport of surface water, or downwelling. Many coastal fish and invertebrate species in the California Current Region reproduce in winter during the Davidson Current season, when pelagic eggs and larvae are likely to be transported to or retained in nearshore areas. Juveniles of most species settle to the bottom nearshore and enter estuaries to rear before the onset of upwelling, because pelagic life stages present during the upwelling season will be transported offshore, often far from their preferred nearshore nursery areas.

Coastal upwelling, as indicated by the monthly anomalies from near San Francisco Estuary, was weak through March 2010, concurrent with the El Niño event, then stronger than average from May through November, concurrent with the La Niña event (Figure 3b). These conditions were highly favorable for primary and secondary production in the GOF in spring 2010, as reflected by high reproductive performance for most seabirds at the Farallon Islands in 2010 (Warzybok and Bradley 2010). Euphausiids and smaller forage fishes, especially juvenile rockfishes, were very abundant in the GOF and contributed directly to the increased breeding success and chick survival of the Cassin's and Rhinoceros auklets, Common Murre, Pigeon Guillemot, and Pelagic Cormorant (Warzybok and Bradley 2010). However, Brandt's Cormorant and Western Gull had poor reproductive success in 2010, in part due to the lack of northern anchovy and larger forage fishes (Warzybok and Bradley 2010).

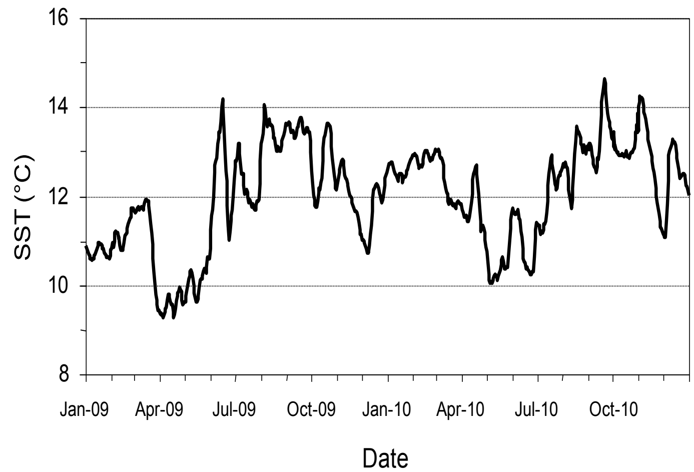

Figure 4 Daily Sea Surface Temperature (SST, °C) from Southeast Farallon Island, January 1, 2009 to December 31, 2010, 7-day running mean

Upper Estuary Demersal Fishes

Shokihaze goby

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

In 2010, the Shokihaze goby mean CPUE (all sizes) was slightly higher than the 2009 CPUE and the sixth highest since the species' first collection (Figure 5). Since a large spike in abundance in 2001, population levels have been fairly consistent relative to other species in the estuary. Shokihaze gobies were collected in all embayments except for the San Joaquin River in 2010. They exhibited a strong association with deep-water habitat, with 91% collected from channel stations.

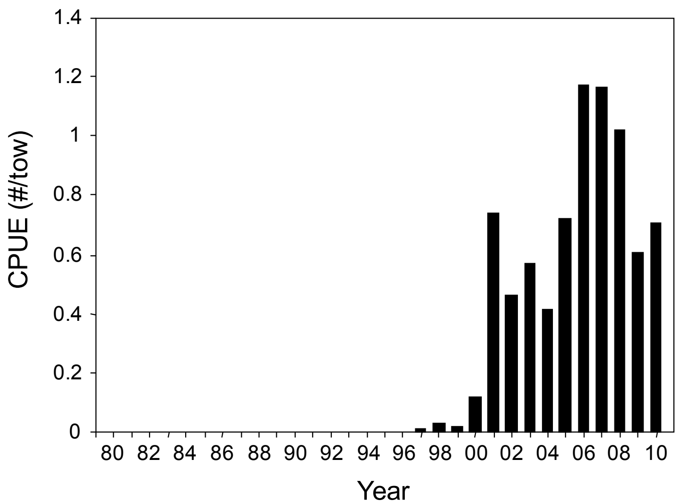

Figure 5 Annual catch-per-unit-effort (CPUE) of Shokihaze goby (all sizes), Bay Study otter trawl, January-December

Age-0 fish first recruited to the gear in August near the confluence of the Sacramento and San Joaquin rivers. In subsequent months, distribution ranged from the Carquinez Strait to Rio Vista. As in years past, the Sacramento River channel station near lower Sherman Island was the most productive age-0 Shokihaze goby station, averaging 15 fish/tow (August to December) and reaching a maximum of 28 fish/tow in December.

Age-1+ Shokihaze goby CPUE was highest in Suisun Bay all year (0.5 fish/tow). Distribution was widest in winter and by April fish were primarily restricted to Suisun Bay and the confluence of the Sacramento and San Joaquin rivers, as adult fish prepared to spawn. By late summer, age-1+ abundance was very low, as most adult fish had spawned and died.

Yellowfin goby

The yellowfin goby (*Acanthogobius flavimanus*) is an introduced fish from Asia with a partially catadromous life history. 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 2010 age-0 yellowfin goby abundance index increased to almost 13 times the 2009 index and was the highest since 2000 (Figure 6). In spite of this increase, abundance has been relatively low since 2001. Age-0 yellowfin gobies first recruited to the gear in May in Suisun Bay and the lower Sacramento River. Age-0 fish were collected in every embayment in 2010, with highest CPUE in Suisun Bay (2.1 fish/tow, May to December). However, there was some seasonal movement, with the highest CPUE in either Central or San Pablo bays after September, when fish likely made a downstream pre-spawn migration. As expected, age-0 yellowfin gobies were associated with shallow water; mean CPUE for shoal stations (1.2 fish/tow, May to December) was 3 times that for channel stations (0.4 fish/tow).

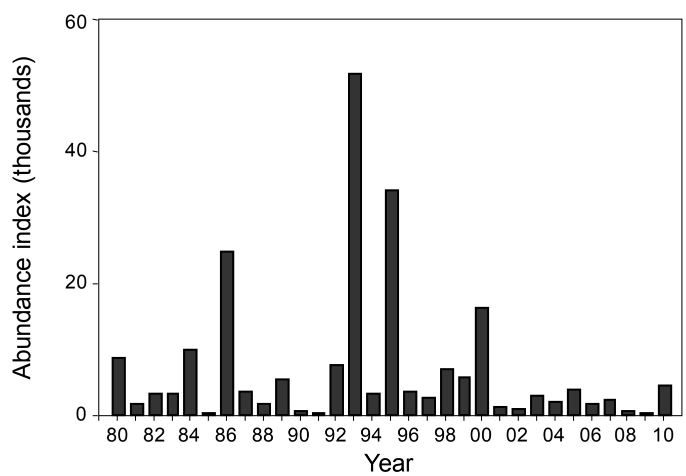

Figure 6 Annual abundance of age-0 yellowfin goby, Bay Study otter trawl, May-October

Age-1+ yellowfin gobies were collected from all embayments in 2010, but were most common in San Pablo Bay (0.8 fish/tow, January to June). Age-1+ distribution was broadest in January, after which distribution shifted towards the spawning grounds in San Pablo Bay. By June, almost all age-1+ fish had spawned and died.

Starry flounder

The starry flounder (*Platichthys stellatus*) is an estuary-dependent species that spawns in the ocean in winter and rears in shallow brackish and fresh water areas of estuaries. Starry flounder rear in San Francisco Estuary for up to 4 years before immigrating to the ocean. In 2010, the age-0 starry flounder abundance index was more than 5 times the 2009 index but still just 67% of the study-period mean (Figure 7a). This increase in age-0 abundance was likely a result of higher Delta outflow in 2010 (Figure 1), as a positive relationship between abundance and outflow has been reported (Kimmerer 2002). The 2010 year class first recruited to the gear in May and was collected through the end of the year, with abundance highest in June and July.

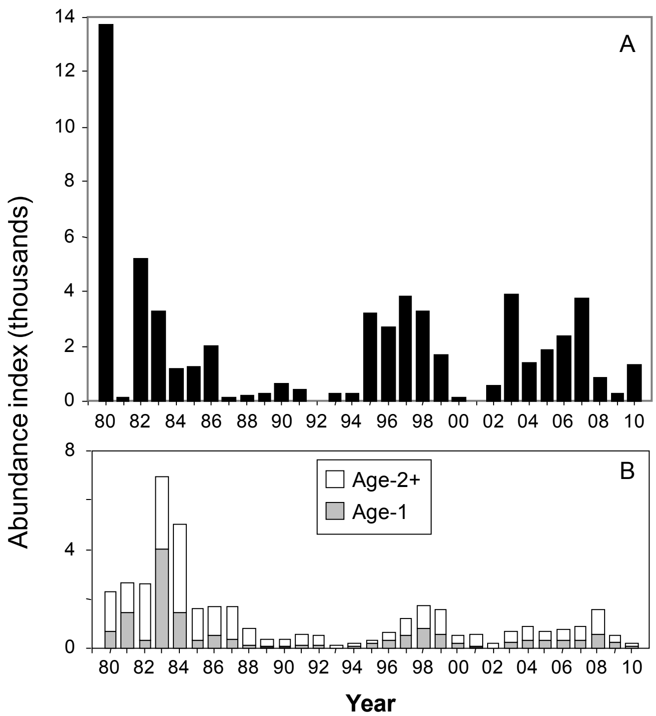

Figure 7 Annual abundance of starry flounder: A) age-0, Bay Study otter trawl, May-October, and B) age-1 and age-2+, Bay Study otter trawl, February-October

Age-0 starry flounder were concentrated upstream of Carquinez Straight, although several fish were collected at shoal stations in San Pablo Bay in June and July. They were most common in Suisun Bay (1.6 fish/tow, May to December), followed by the lower Sacramento River and the confluence. Age-0 starry flounder were consistently associated with shallow water; CPUE at shoal stations (0.60 fish/tow) was more than 4 times higher than at channel stations (0.14 fish/tow).

In 2010, the age-1 starry flounder index declined for the second consecutive year; this was expected because of the very low 2009 age-0 index (Figure 7b). Age-1 starry flounder were collected from the Carquinez Straight upstream in 2010. Annual CPUE was 7 times higher at shoal stations (0.07 fish/tow, January to December) than channel stations (0.01 fish/tow).

The age-2+ starry flounder index also declined for the second consecutive year and was the lowest since 1995 (Figure 7b). This was also expected, as the 2008 age-0 and 2009 age-1 indices declined from previous years. The few age-2+ starry flounder collected were widely distributed throughout the estuary, from South San Francisco Bay to the Sacramento and San Joaquin rivers. Annual CPUE was 5 times higher at shoal stations (0.05 fish/tow, January to December) than at channel stations (0.01 fish/tow).

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 when adhesive eggs are deposited on substrates such as aquatic vegetation, rocks, pier pilings, and other man-made structures. After hatching and larval development, young Pacific herring remain in shallow waters and begin to school. Juveniles can be found in shallow subtidal areas and sloughs until late spring, when they migrate to deeper waters within the estuary. By fall, age-0 Pacific herring emigrate from the estuary to spend 2 to 3 years rearing in the ocean before reaching maturity and returning to spawn.

The 2010 age-0 index increased 26% from the 2009 index, but was about a third of the relatively high 2008 index (Figure 8). After 4 years of very low indices from 2005 to 2007, indices were above the study-period mean from 2008 to 2010. Age-0 fish began recruiting to the gear in March and abundance peaked in May, with more than 63% of the year's fish caught then. By August, most had likely emigrated from the estuary. However, a relatively large catch of 204 fish occurred in October near Hunter's Point. In 2010, distribution was widest in April, when age-0 Pacific herring were caught from South Bay, near the San Mateo Bridge, through Honker Bay. Through spring and summer, fish migrated to Central Bay before they emigrated from the estuary. During all months, CPUE was highest in Central Bay (36 fish/tow, March to December), followed by San Pablo Bay (31 fish/tow). The high Central Bay CPUE can be in part attributed to a large catch of 1,510 fish near Treasure Island in May. Some seasonal channel-shoal movement was also evident, as fish were more common on the shoals in late spring, but moved to the channels in summer.

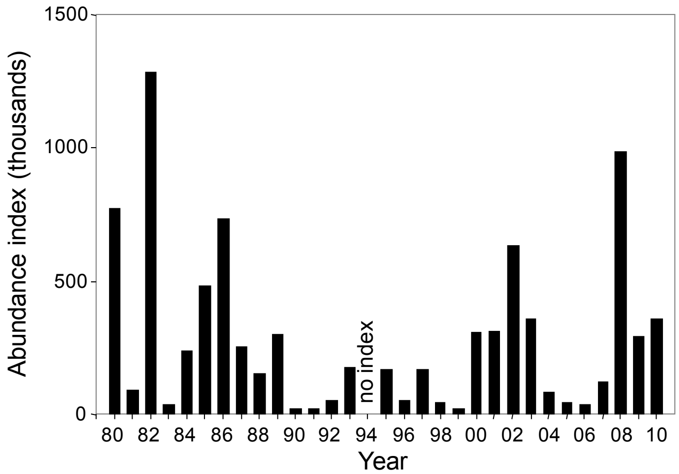

Figure 8 Annual abundance of age-0 Pacific herring, Bay Study midwater trawl, April-September

The CDFG Herring Project has recorded landings for the commercial Pacific herring fishery in San Francisco Bay since 1972. The fishery runs from December through March, targeting adult fish entering the estuary to spawn. The spawning biomass estimate of 4,844 tons for winter 2008-2009 was the lowest ever reported and consequently there was no herring fishery in San Francisco Bay in winter 2009-2010. The recent declines in San Francisco Bay herring landings and biomass were attributed to poor environmental and biological conditions in San Francisco Bay and the ocean. Multiple years of drought have increased salinity within the bay, which in turn reduced the number of spawning events. In addition, ocean conditions were poor in 2005 and 2006, when juveniles that comprised a large number of the 2008 and 2009 returning adult populations entered the ocean. Warmer sea surface temperatures and low ocean productivity in those years reduced fish survival, as evident by low numbers of adult fish returning to spawn during the 2008-2009 season.

Northern anchovy

The northern anchovy (*Engraulis mordax*) is the most common fish in the lower estuary and an important prey species for many fishes and seabirds (Bergen and Jacobson 2001). Anchovies typically move from the ocean to the estuary in spring and summer, coincident with high coastal upwelling, where they feed and reproduce. Most move out of the estuary in fall, as upwelling ceases. Often juveniles remain in the estuary until winter, when they return to the ocean. This winter movement may be delayed if freshwater outflow is low and in years with low freshwater flow, anchovies are found in the estuary year round. The 2010 northern anchovy abundance index (all sizes) increased nearly 43% from the 2009 index (Figure 9). Although 2010 marked the first increase in 4 years, the index was still below the study-period mean and continued the general trend of low abundance since 2001. Poor reproductive performance in 2010 for several seabird species whose diet primarily consists of anchovies, including cormorants and gulls, was again attributed to low anchovy abundance (Warzybok and Bradley 2010).

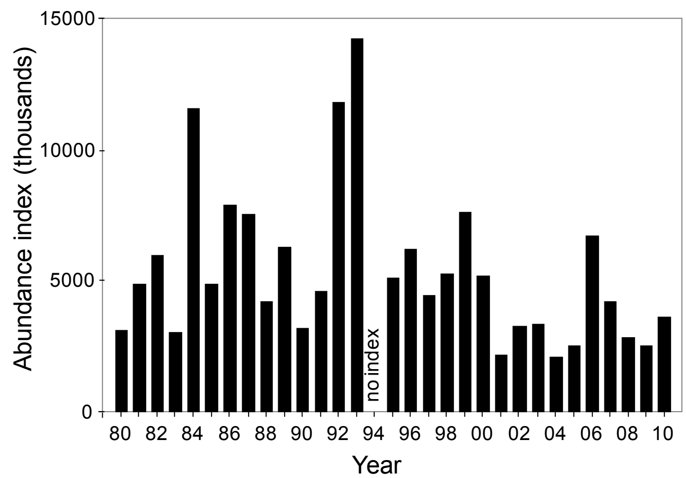

Figure 9 Annual abundance of northern anchovy (all sizes), Bay Study midwater trawl, April-October

Vrooman et al. (1981) separated the northern anchovy population into northern, central, and southern subpopulations. The San Francisco Estuary is situated between the northern and central subpopulations, and our catches may reflect changes in the size and coastal movements of these subpopulations. Although the central subpopulation is the largest and historically the most heavily fished, there are currently no stock assessments, so we cannot confirm subpopulation movements or size from fisheries data. However, there were unpublished reports from CDFG and NMFS that northern anchovy were more common in the Southern California Bight in 2008 and 2009, leading to the conclusion that the central subpopulation shifted south with colder ocean temperatures. Although anchovy stock distribution information was not available for 2010, low northern anchovy catches in a NMFS GOF fishes survey in spring 2010 were attributed to lower anchovy abundance, a more offshore or southerly distribution, or both (Bjorkstedt et al. 2010).

Northern anchovies were collected every month in 2010, but catches remained low until April, peaked in October, and declined thereafter. Once coastal upwelling increased in early summer, abundance in the estuary increased dramatically. Conversely, when upwelling decreased, abundance in the estuary decreased. Few anchovies were collected in San Pablo and South bays until June, and upstream range was widest during summer. Fish were collected from South Bay near the Dumbarton Bridge to Grizzly Bay, with CPUE highest in Central Bay (448 fish/tow, April to December), followed by South (181 fish/tow) and San Pablo (144 fish/tow) bays. The highest regional CPUE was in Central Bay in October, with 1,873 fish/tow. This high CPUE was in part attributed to 2 separate catches of more than 4,000 fish. There was no obvious depth preference for anchovies in South Bay. However, fish in San Pablo and Central bays were more abundant in the channels than the shoals most months of 2010.

Jacksmelt

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

The 2010 age-0 jacksmelt abundance index was only a third of the 2009 index, following 3 years of strong indices (Figure 10). It was also less than the study-period mean and marked the third lowest index during the last 10 years. In 2010, all but 3 age-0 jacksmelt were collected between June and November, with peak abundance in July. Age-0 fish were collected from South Bay near the Dumbarton Bridge to upper San Pablo Bay near the Carquinez Bridge, but more than 57% of the total catch was from Central Bay. Overall, CPUE was highest in Central Bay (4.2 fish/tow, June to November), followed by South Bay (3.0 fish/tow). It appears that most age-0 fish moved from South and San Pablo bays to Central Bay after August. Concurrent with this shift, a seasonal channel-shoal movement was also evident; fish were more common on the shoals in summer and then moved to the channels in late summer and early fall before emigrating from the estuary in late fall.

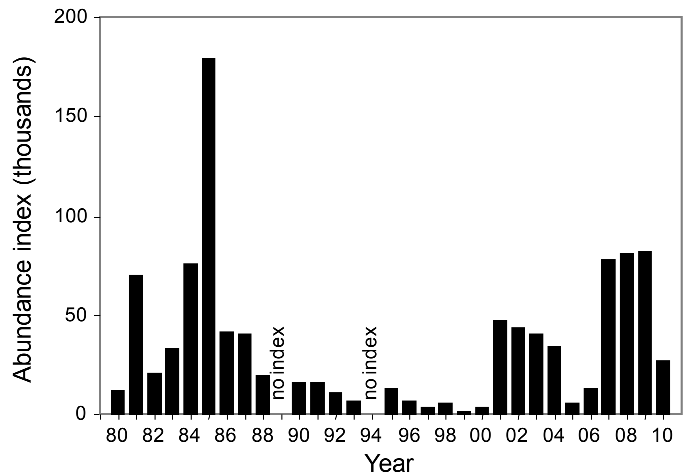

Figure 10 Annual abundance of age-0 jacksmelt, Bay Study midwater trawl, July-October

Surfperches

Most surfperches are transient species, migrating into bays and estuaries to give birth to live, fully formed young in late spring and summer, and returning to the coastal ocean in fall and winter. All of the surfperches common to San Francisco Estuary underwent abundance declines in the 1980s per Bay Study trawl and sport fish survey data (DeLeón 1998). Consequently, in 2002, CDFG changed the sport fish regulations for San Francisco and San Pablo bays, adopting a closed season for all surfperches, except shiner perch (*Cymatogaster aggregata*), from April 1 to July 31, and a 5-fish combination bag limit for all species except shiner perch, which was given a 20-fish bag limit throughout the year.

Shiner perch

The 2010 age-0 shiner perch abundance index decreased 22% from 2009, and was only 20% of the study-period mean (Table 1). It was the lowest index on record and followed 5 relatively low indices. No age-0 fish were caught until June and abundance peaked in November. Age-0 shiner perch were collected from South Bay through San Pablo Bay in 2010, but overall were most common in Central Bay, where CPUE averaged 0.8 fish/tow (June to December). Age-0 shiner perch seemed to favor shoals over channels throughout the year, which is inconsistent with their typical migration from shoals to channels in late fall. Seasonal movement was only apparent in South Bay in December, when fish appeared to move from the shoals (0.4 fish/tow) to the channels (0.8 fish/tow).

Walleye surfperch

The 2010 age-0 walleye surfperch (*Hyperprosopon argenteum*) abundance index was nearly 5 times the 2009 index, but only 63% of the study-period mean (Table 1). Since 2002, indices have been erratic and generally low. Of the 37 age-0 walleye surfperch collected in the midwater trawl in 2010, only 12 contributed to the index; the remainder was collected at the non-index station near Alameda. All age-0 fish were collected at shoal stations near Berkeley or Alameda. The 2010 age-1+ index was more than 3 times the 2009 index and nearly 13% higher than the study-period mean (Table 1). Thirty-two age-1+ walleye surfperch were collected in the midwater trawl during 2010, distributed from South to San Pablo bays, with almost half from the shoal station near Berkeley.

Other Surfperches

The 2010 barred surfperch (*Amphistichus argenteus*) abundance index for all sizes was only 40% of the 2009 index (Table 1), and was the first annual decrease in 5 years. In 2010, the Bay Study collected 5 barred surfperch in the otter trawl, all from shoal stations in South Bay. Historically, the majority of barred surfperch have been collected from South Bay shoal stations, especially stations along the eastern shore. Barred surfperch is commonly associated with eelgrass beds in San Francisco Bay (Merkel & Associates 2005), a habitat not sampled by our trawls.

The 2010 age-0 pile perch (*Rhacochilus vacca*) abundance index was 0, showing no sign of recovery in the estuary and continuing the trend of very low or 0 indices since 1987 (Table 1). This was the fourth consecutive year that no fish were collected at either index or non-index stations. We have collected only 11 pile perch since 1990, so the decline from the 1980s (and probably prior) is long-term and has persisted through warm and cold ocean regimes.

The 2010 white seaperch (*Phanerodon furcatus*) index was 0 for the second year in a row (Table 1); no fish were collected at either index or non-index stations. After few or no age-0 fish were collected in the estuary from 1990 to 2001, abundance increased between 2002 and 2004, but returned to very low levels thereafter.

The black perch (*Embiotoca jacksoni*) was the only surfperch common in the estuary that did not show a distinct decline during the late 1980s or early 1990s (Table 1). However, black perch catches have remained low relative to the other common surfperches throughout the study period. For the first time in 15 years, the 2010 black perch index (all ages) was 0. However, 1 fish was collected during a non-index month.

For the third year in a row, the 2010 dwarf perch (*Micrometrus minimus*) index was 0 (Table 1) and no dwarf perch were collected at any stations or during any months. Historically, dwarf perch were commonly collected from shoal stations in Central and South bays. Dwarf perch is another species strongly associated with eelgrass beds in the San Francisco Bay, a habitat that is not sampled by our trawls.

Marine Demersal Fishes

Plainfin midshipman

The plainfin midshipman (*Porichthys notatus*) migrates from coastal areas to bays and estuaries in late spring and summer to spawn. Most juveniles rear in the estuary through December, with some fish remaining until spring. The 2010 age-0 abundance index was slightly higher than the 2009 index, but still below the study-period mean (Figure 11). However, the 7 highest abundance indices for the study period occurred in the past decade. Although we are not certain of the mechanism, these strong year classes were possibly a result of adult plainfin midshipman distribution shifting southward along the coast during the current cool water regime (Figure 2), increasing the relative abundance of spawning stock entering the San Francisco Estuary (Cloern et al. 2010). Slightly warmer ocean conditions may explain the 2 recent indices below the study-period mean.

Table 1 Annual abundance surfperch indices 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 surfperch*	*walleye surfperch*	*barred surfperch*	*pile perch*	*white seaperch*	*black perch*	*dwarf perch*
Year	***age-0***	***age-0***	***age-1+***	***all sizes***	***age-0***	***all sizes***	***all sizes***	***all sizes***
1980	19515	1277	642	415	857	588	0	439
1981	42760	8089	1757	691	998	1248	129	543
1982	43703	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	23897	231	643	104	0	0	231	0
1998	4383	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	1568	26	46	0	0	62	34
2007	5193	241	1205	123	0	0	36	42
2008	5935	4128	529	105	0	61	69	0
2009	3408	257	289	318	0	0	26	0
2010	2652	1252	949	126	0	0	0	0

Age-0 plainfin midshipmen were collected from June to December, with peak abundance in October. Distribution was broadest in the fall, when fish were collected from South Bay to Suisun Bay. CPUE was highest in South Bay in June and July (1.1 fish/tow), then highest in Central Bay for the remainder of the year (13.6 fish/tow, August to December). In South and Central bays, plainfin midshipman strongly favored the channels, with channel station CPUEs of 2.6 and 12.3 fish/tow, respectively (June to December) compared to shoal station CPUEs of 0.6 and 6.7 fish/tow. In contrast, CPUE of age-0 fish in San Pablo Bay was slightly higher at shoal stations than channel stations (4.5 vs. 3.4 fish/tow, September to December).

Since the late 1990s, summer plainfin midshipmen Central Bay CPUEs were markedly higher than South and San Pablo bays CPUEs. This trend persisted through various water year types and continued in 2010. The mechanism behind this apparent distributional shift is currently unexplained, but a similar increase in Central Bay CPUE during this period was also observed for other marine demersal species such as speckled sanddab, bay goby, and English sole.

Brown Rockfish

The brown rockfish (*Sebastes auriculatus*) is the most common rockfish in San Francisco Estuary and uses it as a nursery area. It is viviparous, with internal fertilization; the pelagic larvae are born in coastal waters in winter and early spring. Recently settled juveniles immigrate to the estuary in spring, where they remain for several years before moving to deeper waters, and eventually to coastal

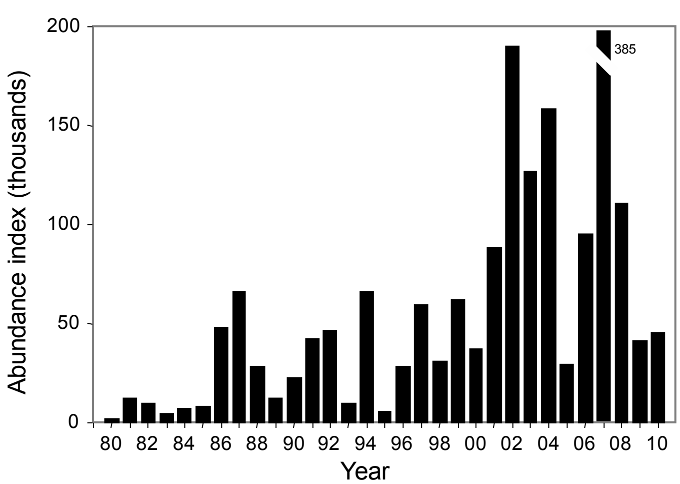

Figure 11 Annual abundance of age-0 plainfin midshipman, Bay Study otter trawl, February-October

habitats. Brown rockfish have a limited home range in the estuary and are often associated with structures such as pilings and rocks, and are thus under sampled by trawl gear such as our otter trawl.

The 2010 age-0 brown rockfish index was the highest on record, and more than 11 times the study-period mean (Figure 12). It was also nearly 13 times the 2009 index and the first strong recruitment since 2002. Although brown rockfish indices were 0 for several years in the mid-2000s, there also were 2 strong year classes in 2002 and 2010, likely due to the recent cool water regime. Other rockfish species also had strong recruitment in the GOF in 2010, with increased reproductive success and feeding rates of several seabirds at the Farallon Islands were linked increased juvenile rockfish abundance (Warzybok and Bradley 2010).

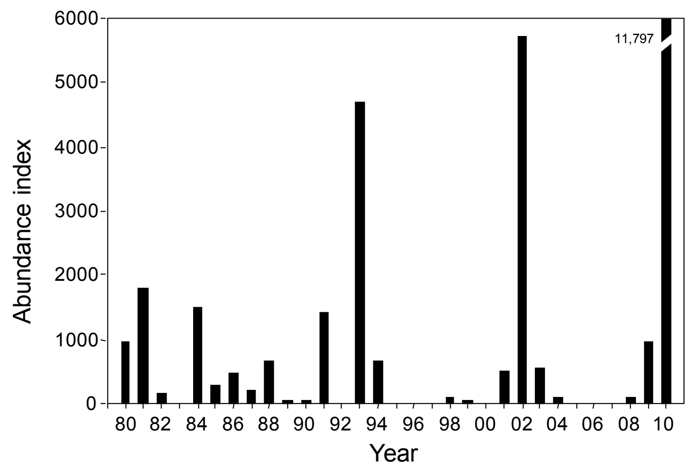

Figure 12 Annual abundance of age-0 brown rockfish, Bay Study otter trawl, April-October

Age-0 brown rockfish began recruiting to the gear in April and were collected through the remainder of the year, with abundance peaking in August. The distribution in 2010 ranged from South Bay near Coyote Point to upper San Pablo Bay, but overall CPUE was highest in Central Bay (3.0 fish/tow, April to December). Brown rockfish were most common at the channel station near Hunter's Point in northern South Bay, which is included in Central Bay for analysis, and the 2 channel stations near Angel Island. The Hunter's Point station often has the highest brown rockfish catch every year; there is surely some underwater structure nearby, including rocks and cobble, based on the debris in our trawl. The San Francisco Naval Shipyard operated at Hunter's Point from 1870 until it closed in 1994; leftover or dumped materials may be providing valuable habitat for juvenile rockfish. Age-0 brown rockfish appeared to move from South Bay to Central Bay after July. This was concurrent with a seasonal channel-shoal migration, as age-0 fish were more common on the shoals in spring and early summer (0.8 fish/tow, April to July) and then moved to the channels (1.2 fish/tow, August to December).

Pacific staghorn sculpin

The Pacific staghorn sculpin (*Leptocottus armatus*) is a native species common in higher salinity areas, but also found in brackish and occasionally fresh water. It rears in intertidal and shallow subtidal areas from late winter to early spring and migrates to deeper water through summer. The 2010 staghorn sculpin age-0 abundance index was slightly higher than the 2009 index and the fourth highest of the study period (Figure 13). The 7 highest indices on record have all occurred in the past 11 years, in association with cool ocean temperatures (Figure 3a). As with other cold-temperate species, it is likely that the adult distribution expanded southward with the recent shift in climate regime, resulting in increased spawning stock abundance inside and surrounding the San Francisco Estuary (Cloern et al. 2010).

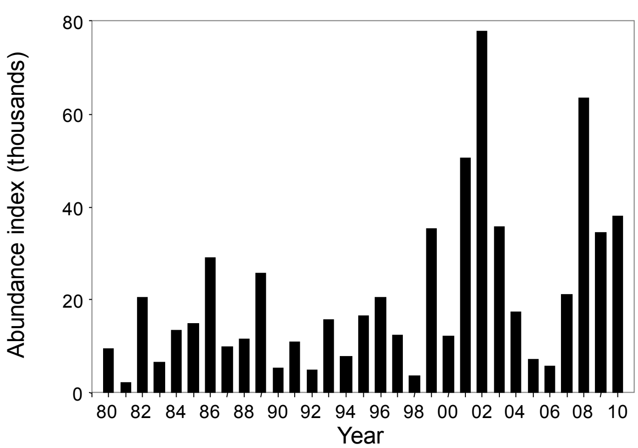

Figure 13 Annual abundance of age-0 Pacific staghorn sculpin, Bay Study otter trawl, February-September

In 2010, age-0 staghorn sculpin first recruited to the gear in March and were collected through the end of the year, with peak abundance in June and July. Age-0 fish were collected from South Bay through the lower Sacramento River near Decker Island. Distribution was broadest from March through May, and contracted as summer progressed to Central Bay (21.7 fish/tow, June to September), followed by Suisun Bay (3.8 fish/tow).

In Central Bay, Pacific staghorn sculpin (all sizes) CPUE was consistently higher at channel stations than shoal stations throughout the year (11.8 vs. 5.8 fish/tow, respectively). In contrast, fish in San Pablo and Suisun bays were more abundant at shoal stations (2.1 and 4.8 fish/tow, respectively) than channel stations (0.5 and 2.9 fish/tow) during summer.

Most Central Bay Pacific staghorn sculpin were collected between May and August and showed little evidence of growth, averaging 125mm (FL). Conversely, fish were collected in Suisun Bay consistently throughout the year with a traceable growth pattern, averaging 95mm from May to August. This combined with the channel-shoal data indicates that a distinct group of age-0 fish may have reared on the shoals of Suisun and San Pablo bays, while a separate group of adult fish, likely ocean migrants, utilized Central Bay. The use of Central Bay during summer may indicate a movement from the colder ocean during the most intense upwelling period.

White croaker

The white croaker (*Genyonemus lineatus*) is a common coastal species that frequents bays and estuaries. It is a member of the subtropical fish fauna more commonly found south of Point Conception. It spawns from November through April in shallow, nearshore waters, and juveniles progressively move into deeper water as they grow. The 2010 age-0 white croaker index increased 57% from the 2009 index (Figure 14). It was the highest index since 2002, but still only a third of the study-period mean. We have not had strong white croaker recruitment in San Francisco Bay since the mid 1990s; these previous recruitment events were at least partially associated with El Niño events. Conversely, Miller et al. (2011) documented a dramatic decrease in white croaker abundance in Southern California beginning in 1976, linking it to increasing SSTs and decreasing plankton biomass.

Age-0 white croaker were first collected in April, with abundance peaking in June and again in November. In 2010, age-0 white croaker were collected from South through San Pablo bays between May and August, but by September had migrated out of San Pablo Bay. By December, all fish had also emigrated from South Bay, with catches only occurring in Central Bay. Age-0 white croaker were most common in Central Bay all months except for May and June, when CPUE was highest in

San Pablo Bay. Annual Central Bay CPUE (April to December) was 3.7 fish/tow, followed by San Pablo Bay at 0.7 fish/tow and South Bay at 0.4 fish/tow. Age-0 white croaker were more common in channels all months except for June, with annual channel CPUE (April to December) at 1.4 fish/tow, compared to 0.6 fish/tow for shoals.

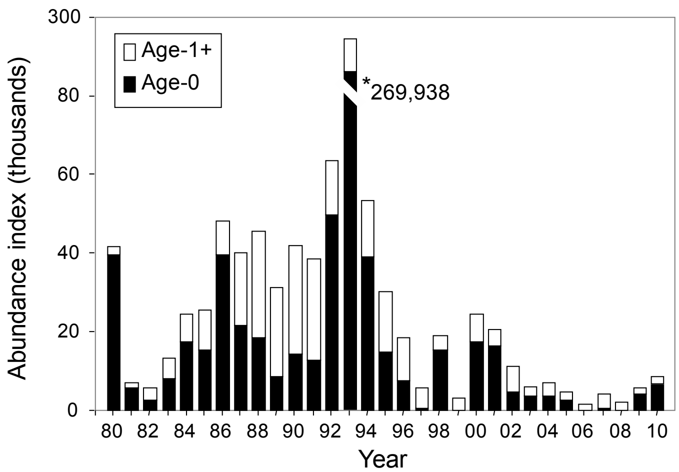

Figure 14 Annual abundance of age-0 and age-1+ white croaker, Bay Study otter trawl, February-October

The 2010 white croaker age-1+ index was 1.5 times the 2009 index (Figure 14). Although this was the first increase in 3 years, the index was still only 23% of the study-period mean and continued the trend of low indices since 1997. In 2010, age-1+ fish were collected throughout the year in Central and South bays; a few age-1+ fish were also collected in San Pablo Bay, but only in January, June, and November. Annual CPUE was highest in Central Bay (0.7 fish/tow), followed by South Bay (0.2 fish/tow). Age-1+ white croaker were more commonly caught in the channels than the shoals, with average annual channel CPUE 3 times the shoal CPUE (0.3 vs. 0.1 fish/tow).

Bay goby

The bay goby (*Lepidogobius lepidus*) is one of the most common gobies in the estuary. Often commensal with burrowing invertebrates on mudflats, it is under sampled by trawls and other towed gear. This native species rears in higher salinity areas and has a 2 to 3 year life span. Typically no more than 100 mm TL, it is an important prey item for many piscivorous species in the estuary, including California halibut, Brandt's Cormorant, and the Pacific harbor seal.

The 2010 bay goby index (all sizes) was the highest on record (Figure 15), and followed 2 very high indices in 2008 and 2009. It was common all months in 2010, with peak abundance from May through October. Bay gobies were collected from South through Suisun bays, but were most abundant in Central Bay all months except February, March, and April, when fish were more dispersed. Central Bay CPUE averaged 95 fish/tow (January to December) and peaked at 315 fish/tow in August. Bay gobies in Central Bay were more common at shoal stations from April through July and at channel stations all other months.

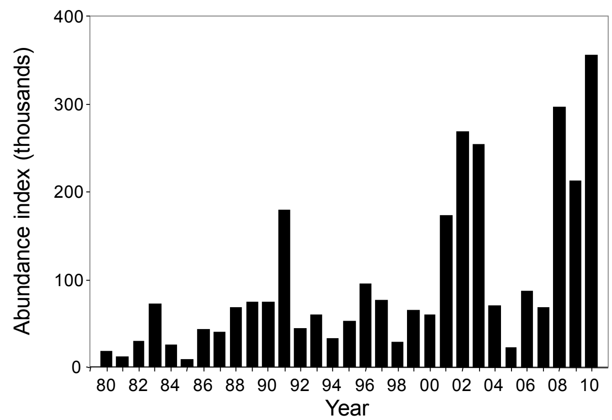

Figure 15 Annual abundance of bay goby (all sizes), Bay Study otter trawl, February-October

Age-0 bay gobies recruited to the gear throughout the year, except for September. Strongest recruitment occurred during spring, with most age-0 fish collected at San Pablo Bay shoal stations. Large numbers of adult bay gobies began to appear in May and continued to increase in abundance through August. Since proportional numbers of this larger size group were not collected in earlier months, these fish were either likely migrants from near shore coastal areas or in-bay habitats inaccessible to the trawl. The 2010 bay goby distribution was consistent with the trend of increased summer Central Bay CPUE observed for plainfin midshipman, Pacific staghorn sculpin, and several other marine demersal species in recent years.

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 (Figure 2). It spawns in shallow coastal waters and juveniles rear in very shallow subtidal and intertidal areas of bays and estuaries, and to a much lesser extent on the open coast.

The 2010 juvenile (age-0 & 1) California halibut index was 0 for the third consecutive year (Figure 16). Two juvenile halibut were collected in 2010, 1 from a non-index station in Carquinez Straight and 1 from South Bay during the non-index month of January, so neither contributed to the index. Typically we do not see evidence of reproduction unless SSTs are >13°C for at least 4 consecutive months. Continued cool ocean temperatures (Figures 3a and 4) likely limited local recruitment, exemplified by Bay Study's collection of only 7 juvenile halibut since early 2006.

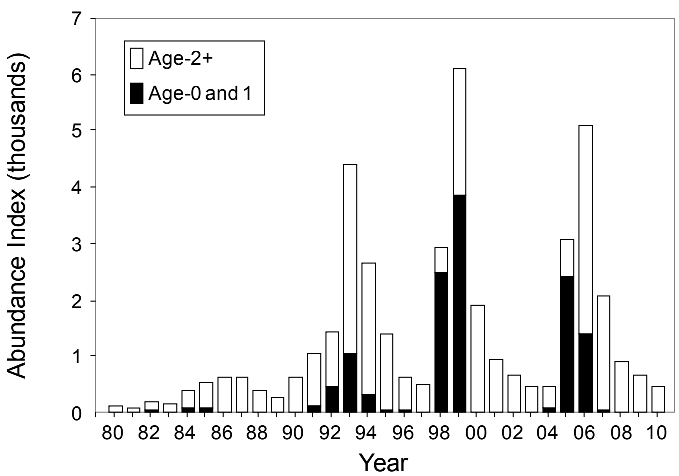

Figure 16 Annual abundance of juvenile (age-0 and age-1) and age-2+ California halibut, Bay Study otter trawl, February-October

The 2010 adult (age-2+) California halibut index declined for the fourth consecutive year to the lowest level since 2004 (Figure 16). Adult halibut were collected from South Bay through Carquinez Straight, but were most abundant in Central Bay, where CPUE averaged 0.1 fish/tow, January to December. The largest age-2+ fish was 717 mm, though most were less than the recreational fishery's minimum size limit of 559 mm. In contrast to recent years, sublegal adult halibut collected in 2010 did not appear to be from the large 2004-05 cohort, produced concurrent with the strongest of the recent warm-water events. Most of the fish collected in 2010 were smaller than the 2004-05 cohort, which indicated recruitment that is more recent. As we did not document substantial in-bay recruitment since 2004-05, these fish likely migrated from near shore coastal rearing areas, possibly from the south. During the past several years, the publicity of the high rate of angler success and lack of other fisheries to pursue has placed considerable pressure on the San Francisco Bay halibut fishery. This fishing pressure and associated harvest mortality was likely a key contributor to the 2010 adult halibut index decline.

English sole

The English sole (*Pleuronectes vetulus*) is a common flatfish that spawns along the coast in winter and rears in both the coastal ocean and estuaries. The 2010 age-0 English sole abundance index was only 61% of the 2009 index and the second year of declining indices (Figure 17). However, it was the sixth highest index on record and continued the general trend of high indices since 1999. Except for 2005 and 2006, abundance was very high this decade, with the 10 highest indices for the study period occurring in the last 12 years. During the current cool-water regime (Figure 2), adult English sole distribution likely shifted southward, increasing the abundance of spawning stock adjacent to the San Francisco Estuary (Cloern et al. 2010). In addition, cooler SSTs (Figure 3a) and strong upwelling (Figure 3b) likely enhanced egg and larval survival and growth.

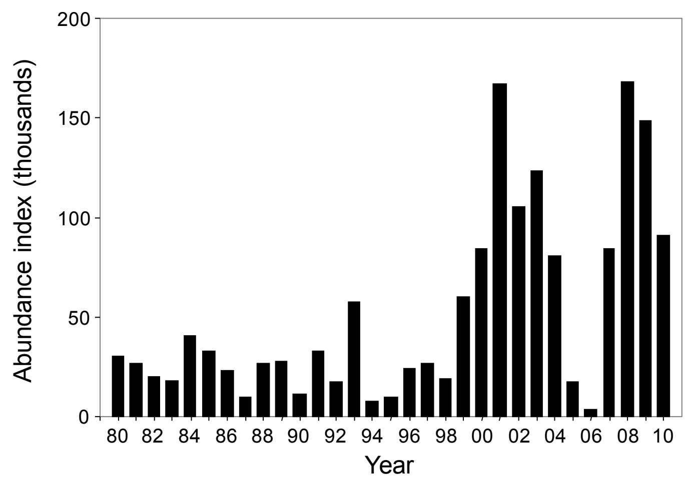

Figure 17 Annual abundance of age-0 English sole, Bay Study otter trawl, February-October

In 2010, age-0 English sole abundance was very low through March, increased sharply in April when the bulk of the cohort first appeared, and peaked in June. Abundance decreased from July through the end of the year as mortality and emigration depleted the age-0 stock inside the estuary. Age-0 English sole were collected from South through Suisun bays in 2010, with the broadest distribution from April through July. CPUEs were highest at shoal stations through June, but highest at channel stations thereafter. This was due to fish moving from the shoals to the channels with growth and an influx of larger age-0 English sole in Central Bay in summer. Age-0 CPUE was consistently highest in Central Bay, where catches averaged 25 fish/tow (January to December) and peaked at 65 fish/tow in July. Summer Central Bay catch was comprised of bay-reared fish and recent ocean immigrants, a common pattern in the recent cold-water years.

Following a typical pattern, age-1+ English sole abundance was highest in January and decreased through August, as age-1+ fish emigrated from the estuary. Age-1+ CPUE was consistently highest at Central Bay channel stations (4 fish/tow, January to August).

Speckled sanddab

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

The 2010 speckled sanddab abundance index (all sizes) was more than 4 times higher than the 2009 index and was the second highest for the study period (Figure 18). 2010 saw the largest year-to-year increase on record, in contrast to the highest abundance year of 2002, which followed 4 years of steadily increasing indices. High abundance during the past decade was likely the result of cooler ocean temperatures and stronger summer upwelling, associated with the recent climate regime shift (Figures 2 and 3).

Speckled sanddab abundance was bimodal in 2010, with peaks in winter (December 2009-January 2010) and summer. This is a common pattern in the estuary, with the winter peak usually consisting of smaller, newly settled fish and the summer peak often including larger fish. In 2010, the winter peak was composed primarily of fish 35-65mm, whereas the summer peak was composed of larger fish, most 60-80 mm, which could have been recently

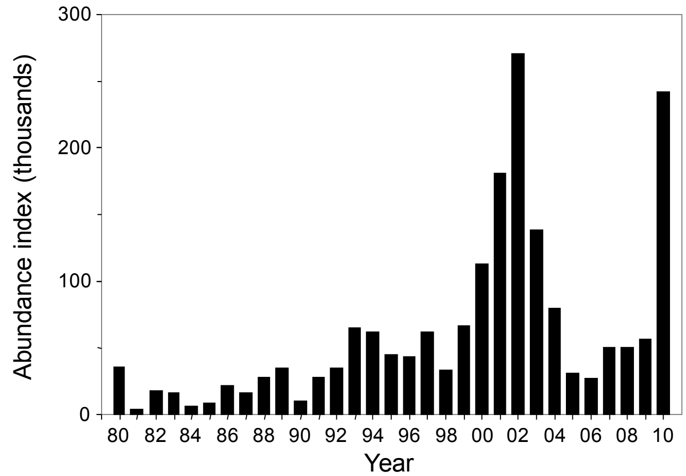

Figure 18 Annual abundance of speckled sanddab (all sizes), Bay Study otter trawl, February-October

settled after a long pelagic period. Speckled sanddab were collected from South through lower Suisun bays in 2010, with highest CPUEs in Central Bay all months (75 fish/tow, January-December) and a peak in Central Bay CPUE in June (173 fish/tow). In 2010, 95% of speckled sanddabs were collected south of the Richmond Bridge. Channel-shoal distribution was fairly even throughout the year, except in San Pablo Bay, where fish were more common at shoal stations (6 fish/tow January to December) than channel stations (2 fish/tow, January to December).

Notes

Dayflow data from water.ca.gov/dayflow/
PDO indices from jisao.washington.edu/pdo/PDO.latest
NPGO indices from www.o3d.org/npgo/data/NPGO.txt
Upwelling indices and anomalies from www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling/NA/data_download.html
Sea Surface Temperatures from shorestation.ucsd.edu/

References

Baxter, R., K. Hieb, S. DeLeón, K. Fleming, and J. Orsi. 1999. Report on the 1980-1995 fish, shrimp, and crab sampling in the San Francisco Estuary, California. J. Orsi, editor. IEP Technical Report 63, 503 pp.

Bergen, D. R. and L. D. Jacobson. 2001. Northern anchovy. Pages 303-305. In: California's Living Marine Resources: A Status Report, W. Leet, C. Dewees, R. Klingbeil, and E. Larson, editors. California Department of Fish and Game, Sacramento, California. 592 pp.

Bjorkstedt, E. P., R. Goericke, S. McClatchie, E. Weber, W. Watson, N. Lo, B. Peterson, B. Emmett, J. Peterson, R. Durazo, G. Gaxiola-Castro, F. Chavez, J.T. Pennington, C.A. Collins, J. Field, S. Ralston, K. Sakuma, S. J. Bograd, F. B. Schwing, Y. Xue, W. J. Sydeman, S. A. Thompson, J. A. Santora, J. Largier, C. Halle, S. Morgan, S. Y. Kim, K. P.B. Merkens, J. A. Hildebrand, and L. M. Munger. 2010. State of the California Current 2009-2010: Regional variation persists through transition from La Nina to El Nino (and back?). CalCOFI Reports 51:39-69.

Cloern, J. E., K. A. Hieb, T. Jacobson, B. Sansó, E. Di Lorenzo, M. T. Stacey, J. L. Largier, W. Meiring, W. T. Peterson, T. M. Powell, M. Winder, and A. D. Jassby. 2010. Biological communities in San Francisco Bay track large-scale climate forcing over the North Pacific. Geophysical Research Letters 37(21): L21602.)

Contreras, D., V. Afentoulis, K. Hieb, R. Baxter, and S. Slater. 2011. 2010 status and trends report for pelagic fishes the upper San Francisco Estuary. Interagency Ecological Program Newsletter. 24(1):27-38.

DeLeón, S. 1998. Surfperch abundance trends in San Francisco Bay. IEP Newsletter 11(2):40-43.

Di Lorenzo, E., N. Schneider, K. M. Cobb, P. J. S. Franks, K. Chhak, A. J. Miller, J. C. McWilliams, S. J. Bograd, H. Arango, E. Curchitser, T. M. Powell, and P. Rivière. 2008. North Pacific Gyre Oscillation links ocean climate and ecosystem change. Geophysical Research Letters 35(8):L08607.

Di Lorenzo, E., J. Fiechter, N. Schneider, A. Bracco, A. J. Miller, P. J. S. Franks, S. J. Bograd, A. M. Moore, A. C. Thomas, W. Crawford, A. Peña, and A. J. Hermann. 2009. Nutrient and salinity decadal variations in the central and eastern North Pacific. Geophysical Research Letters 36(14):L14601.

Ford, R. R. 1965. Distribution, population dynamics and behavior of a bothid flatfish, Citharichthys stigmaeus. Ph.D. dissertation, University of California, San Diego, 243 pp.

Ganssle, D. 1966. Fishes and decapods of San Pablo and Suisun Bays. Pages 64-94. In: Ecological studies of the Sacramento-San Joaquin Estuary. Part 1: Zooplankton, zoobenthos, and fishes of San Pablo and Suisun Bays, zooplankton and zoobenthos of the Delta, D.W. Kelley, editor. California Department of Fish and Game Fish Bulletin 133.

Greiner, T. A. 2002. Records of the Shokihaze goby, Tridentiger barbatus (Günther), newly introduced into the San Francisco Estuary. California Fish and Game 88(2):68-74.

Kimmerer, W. J. 2002. Effects of freshwater flow on abundance of estuarine organisms: Physical effects or trophic linkages? Marine Ecological Progress Series 243:39-55.

Kramer, S.H. 1990. Habitat specificity and ontogenetic movements of juvenile California halibut, Paralichthys californicus, and other flatfishes in shallow waters of southern California. Ph.D. Dissertation University of California San Diego, 266 pp.

Merkel & Associates. 2005. Eelgrass community pilot study for San Francisco Bay: Techniques for examining invertebrate and fish assemblages within multiple eelgrass beds. Report for the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project, 37 pp.

Miller, E. F., D. J. Pondella, D. S. Beck, and K. T. Herbinson. 2011. Decadal-scale changes in southern California sciaenids under different levels of harvesting pressure. ICES Journal of Marine Science: Journal du Conseil 68(10):2123-2133.

Moyle, P. B. 2002. Inland Fishes of California, revised and expanded. University of California Press, Berkeley, California, 365 pp.

Parrish, R. H., C. S. Nelson, and A. Bakun. 1981. Transport mechanisms and reproductive success of fishes in the California Current. Biological Oceanography 1(2):175-203.

Peterson, W. T. and F. B. Schwing. 2003. A new climate regime in northeast Pacific ecosystems. Geophysical Research Letters. 30(17):1896, DOI: 10.1029/2003GL017528.

Rackowski, J. P. and E. K. Pikitch. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)-Pacific and speckled sanddabs. U. S. Fish and Wildlife Service and U.S. Army Corps of Engineers. Biological Report Technical Report 82(11.107) and TR EL-82-4.

Slater, S. B. 2005. Life history and diet of the Shokihaze goby Tridentiger barbatus in the San Francisco Estuary. M.S. Thesis, California State University, Sacramento, 77 pp.

Vrooman, A. M., P. A. Paloma, and J. R. Zweiffel. 1981. Electrophoretic, morphometric, and meristic studies of subpopulations of northern anchovy, Engraulis mordax. California Fish and Game 67(1):39-51.

Warzybok, P.M. and R.W. Bradley. 2010. Status of seabirds on Southeast Farallon Island during the 2010 breeding season. Unpublished report to the US Fish and Wildlife Service. PRBO Conservation Science, Petaluma, California. PRBO Contribution Number 1769.

■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER
3251 S Street
Sacramento, CA 95816-7017

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

■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER

Gonzalo Castillo, U.S. Fish and Wildlife Service, Lead Editor
Louise Conrad, California Department of Water Resources, Contributing Editor
Randall D. Baxter, California Department of Fish and Game, Contributing Editor
Joseph Kirsch, U.S. Fish and Wildlife Service, Contributing Editor
Karen Gehrts, California Department of Water Resources, Managing Editor
Frank Keeley, California Department of Water Resources, Editor

The Interagency Ecological Program for the San Francisco Estuary
is a cooperative effort of the following agencies:

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

California Department of Fish and Game
U.S. Fish and Wildlife Service
U.S. Geological Survey
U.S. Environmental Protection Agency
National Marine Fisheries Service

BEFORE CITING INFORMATION HEREIN,
CONSIDER THAT ARTICLES HAVE NOT RECEIVED PEER REVIEW.