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 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 Bay Study 2010 Crab Status and Trends report also in this issue. Of the 52 stations currently samples, 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 cm/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 4th consecutive low outflow year and the longest period of low outflow since the 1987-1992 drought (Figure 1).

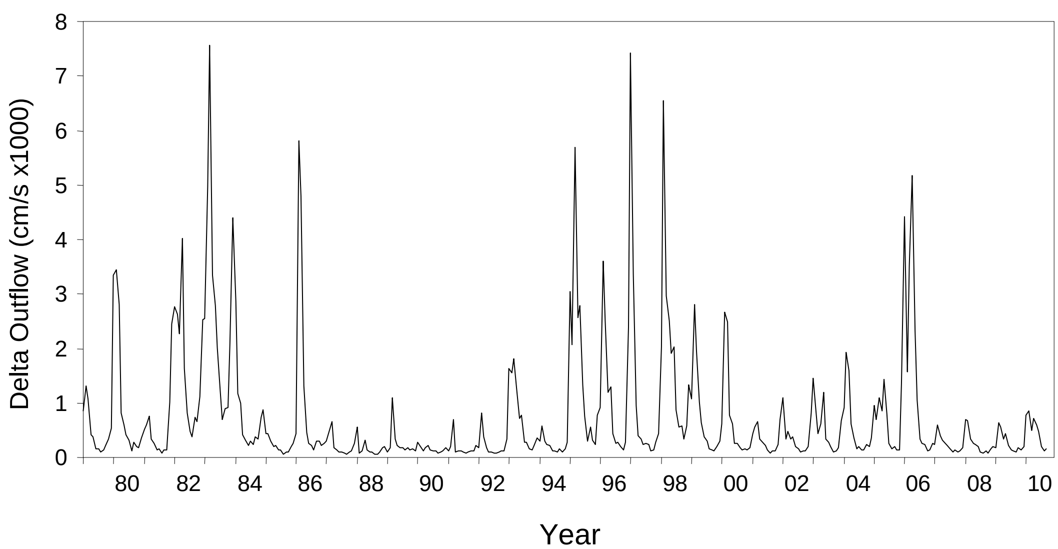

Figure 1. Mean monthly Delta outflow (cm/s) at Chipps Island, 1979-2010.

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

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).

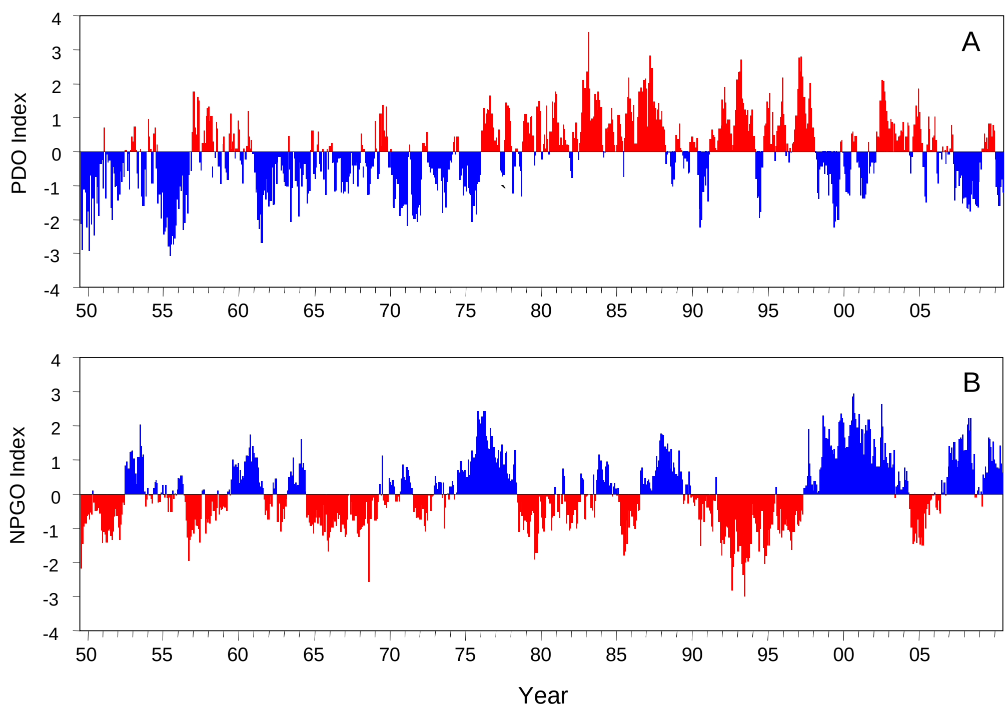

Figure 2. A) Monthly Pacific Decadal Oscillation (PDO) indices, 1950-2010 and B) Monthly North Pacific Gyre Oscillation (NPGO) indices, 1950-2010.

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).

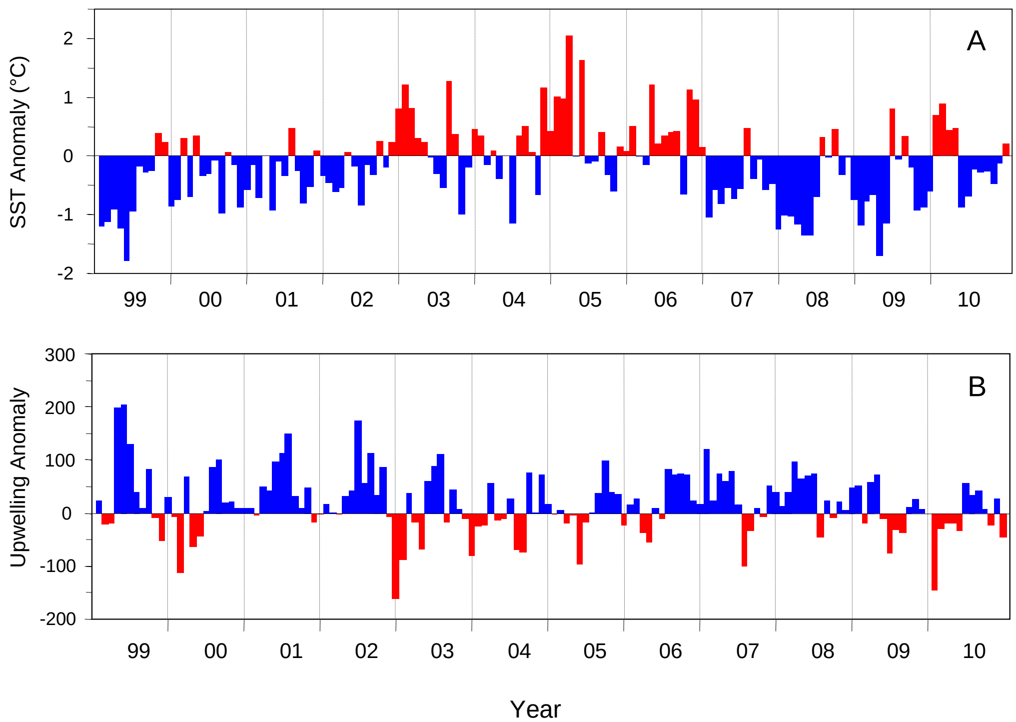

Figure 3. A) Monthly Sea Surface Temperature (SST, °C) anomalies from Southeast Farallon Island, 1999-2010 and B) Monthly upwelling index anomalies (39°N), 1999-2010.

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 over 14°C for several days in September and October (Figure 4), but were slightly below the long-term mean through November (Figure 3a).

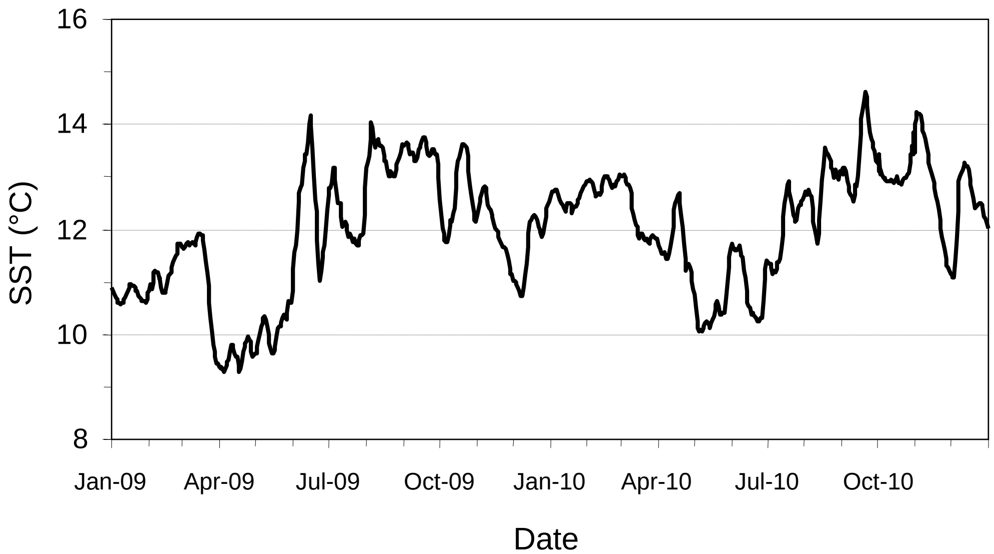

Figure 4. Daily Sea Surface Temperature (SST, °C) from Southeast Farallon Island, January 1, 2009 to December 31, 2010, 7-day running mean.

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).

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.

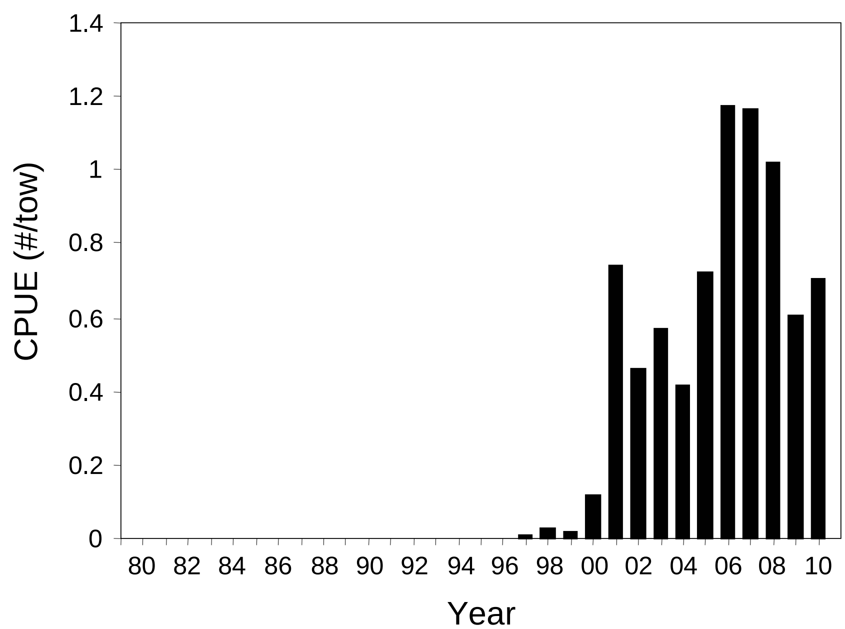

Figure 5. Annual catch-per-unit-effort (CPUE) of Shokihaze goby (all sizes), Bay Study otter trawl, January-December.

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).

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.

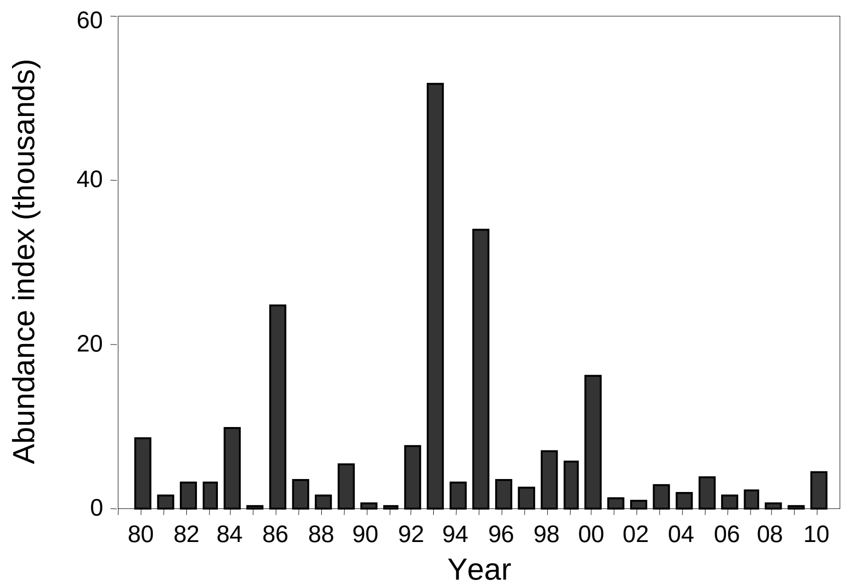

Figure 6. Annual abundance of age-0 yellowfin goby, Bay Study otter trawl, May-October.

Starry flounder

The starry flounder (*Platichthys stellatus*) is an estuary-dependent species that spawns in the ocean 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 over 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.

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 over 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).

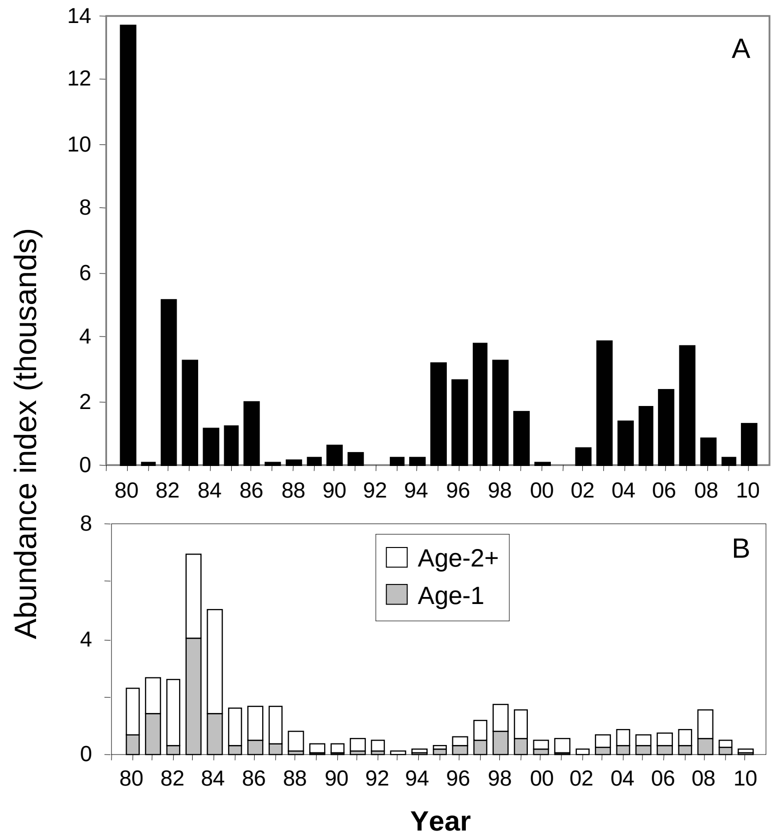

Figure 7. Annual abundance of starry flounder: A) age-0, Bay Study otter trawl, May-October, and B) age-1 and age-2+, Bay Study otter trawl, February-October.

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 over 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. Over 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.

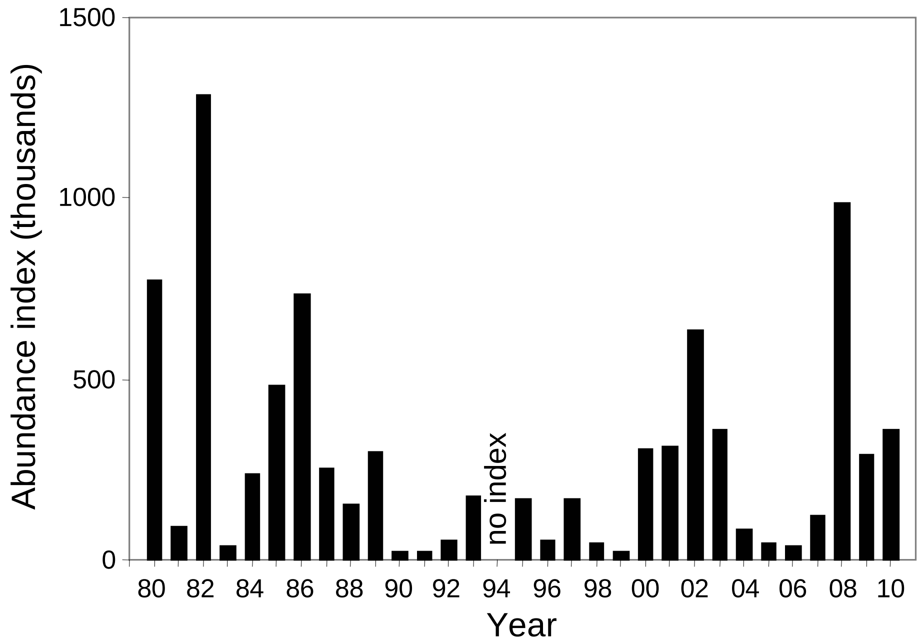

Figure 8. Annual abundance of age-0 Pacific herring, Bay Study midwater trawl, April-September.

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).

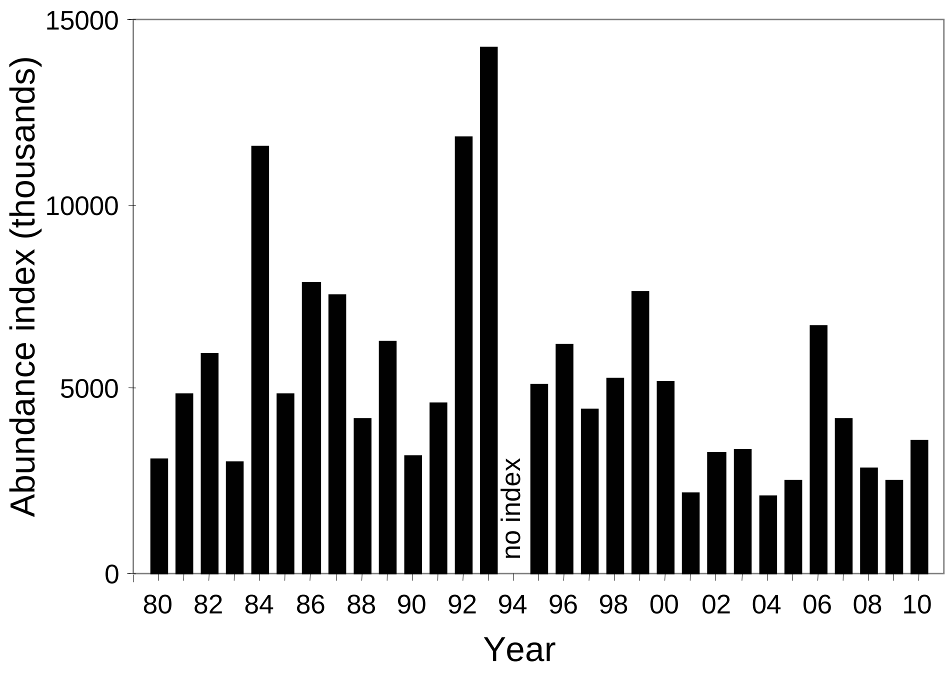

Figure 9. Annual abundance of northern anchovy (all sizes), Bay Study midwater trawl, April-October.

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 over 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 below 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 over 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.

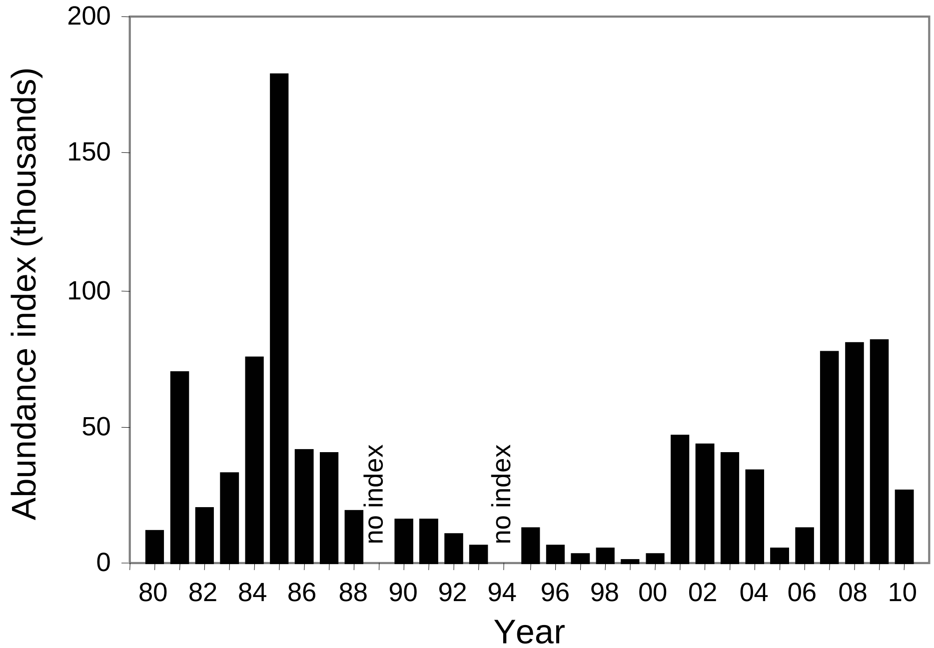

Figure 10. Annual abundance of age-0 jacksmelt, Bay Study midwater trawl, July-October.

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.

	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

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.

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 (Figure11). 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.

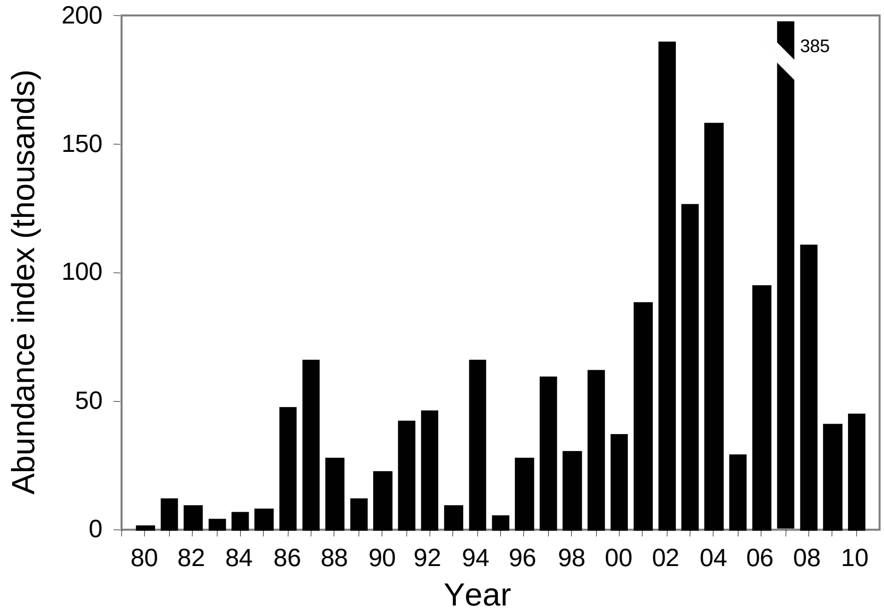

Figure 11. Annual abundance of age-0 plainfin midshipman, Bay Study otter trawl, February-October.

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 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 over 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).

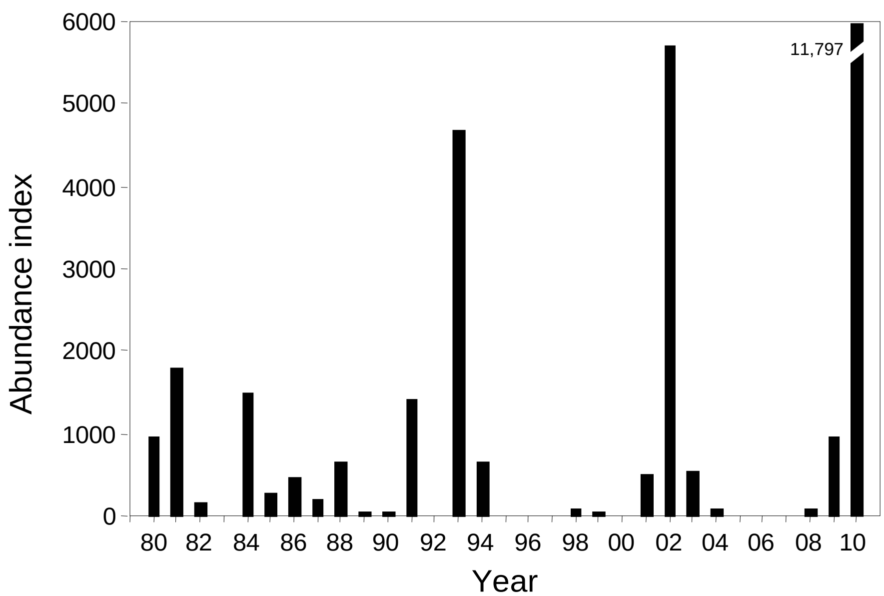

Figure 12. Annual abundance of age-0 brown rockfish, Bay Study otter trawl, April-October.

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).

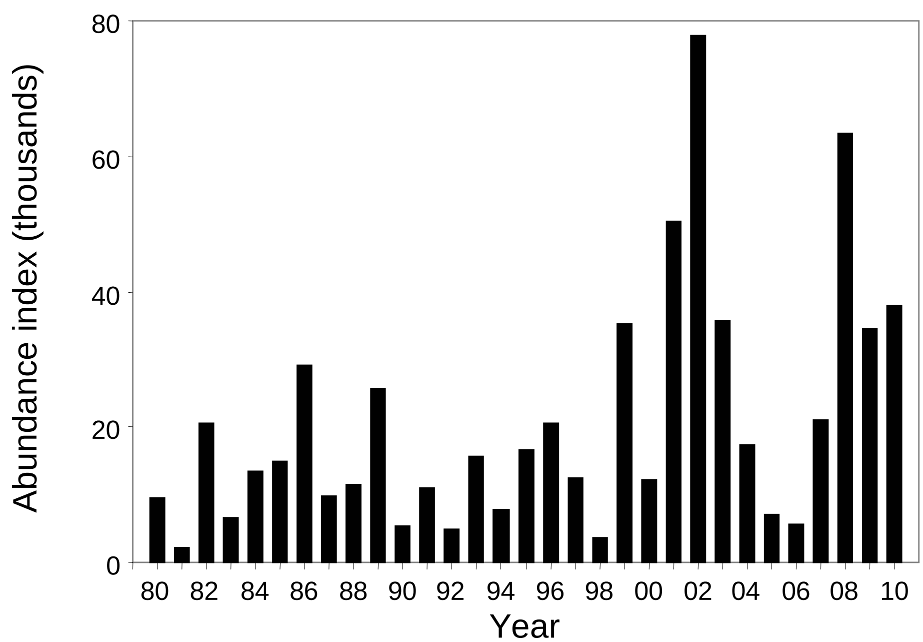

Figure 13. Annual abundance of age-0 Pacific staghorn sculpin, Bay Study otter trawl, February-September.

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.

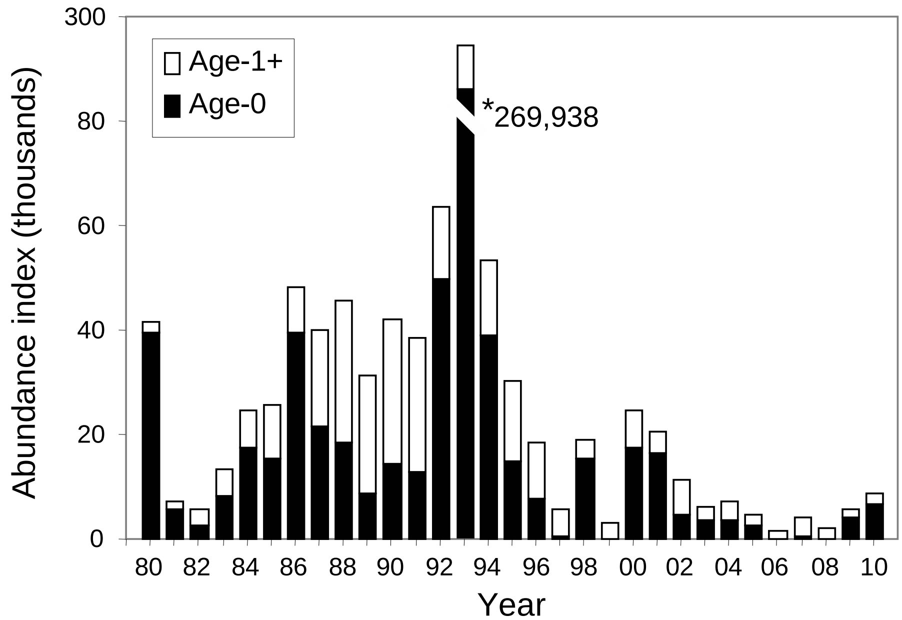

Figure 14. Annual abundance of age-0 and age-1+ white croaker, Bay Study otter trawl, February-October.

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.

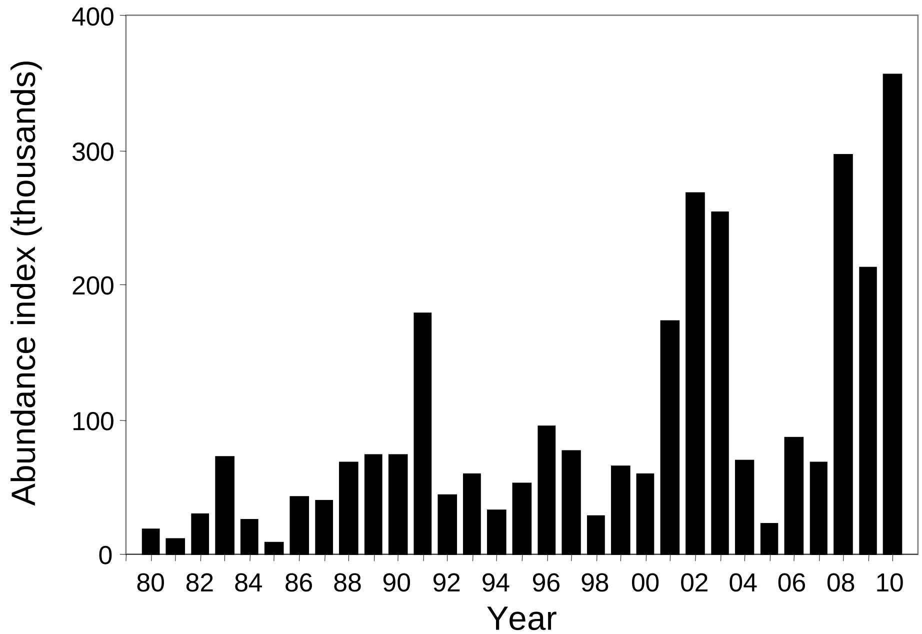

Figure 15. Annual abundance of bay goby (all sizes), Bay Study otter trawl, February-October.

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.

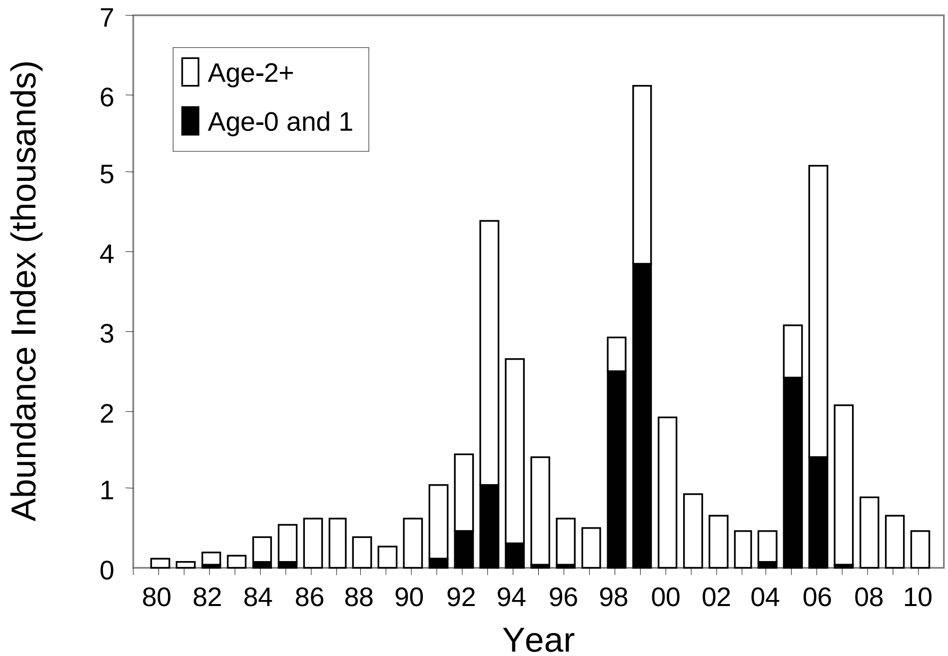

Figure 16. Annual abundance of juvenile (age-0 and age-1) and age-2+ California halibut, Bay Study otter trawl, February-October.

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 under 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. Over 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.

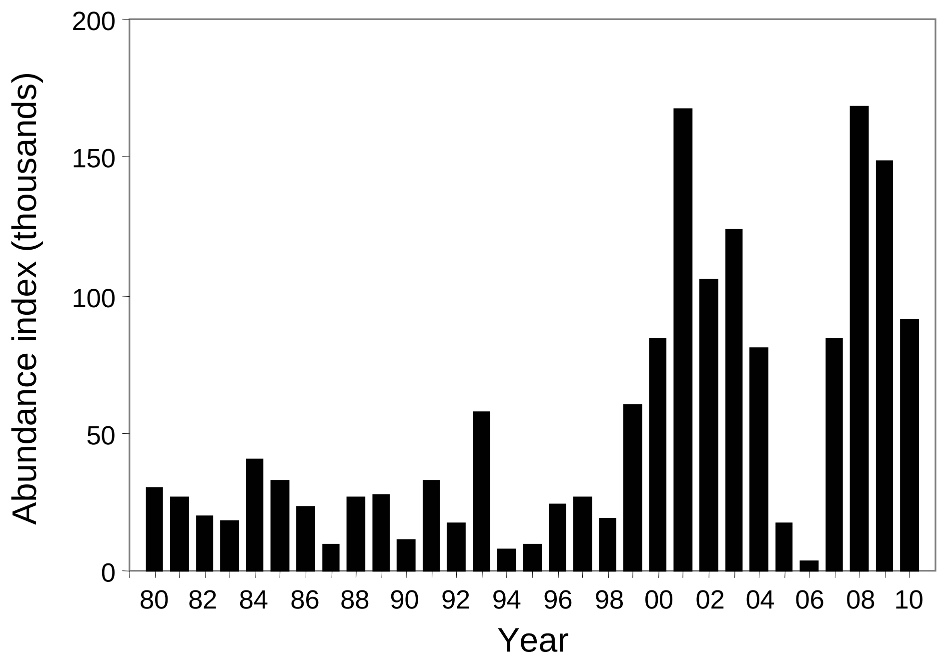

Figure 17. Annual abundance of age-0 English sole, Bay Study otter trawl, February-October.

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 over 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 over 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).

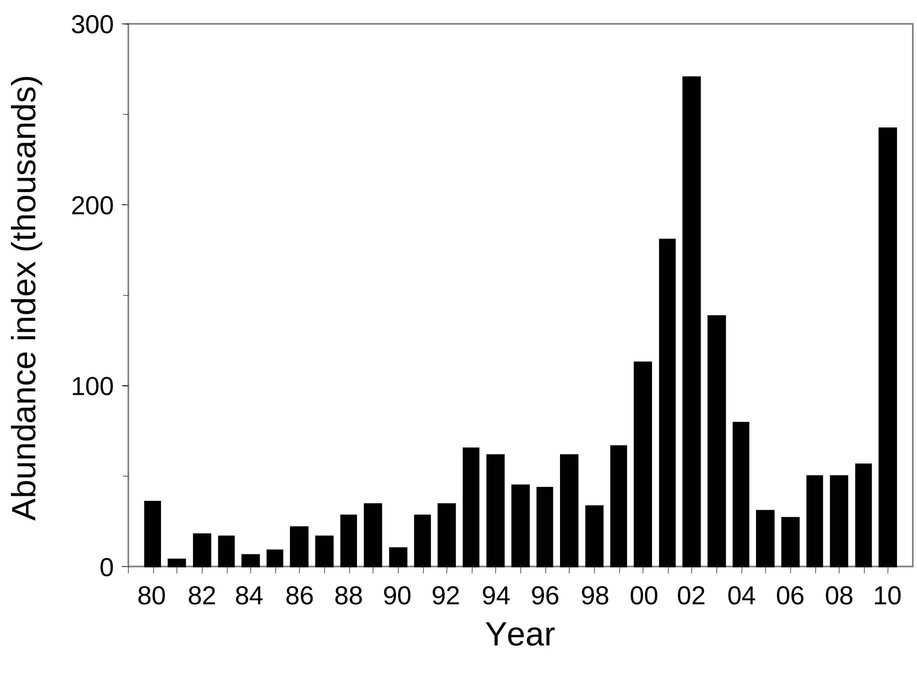

Figure 18. Annual abundance of speckled sanddab (all sizes), Bay Study otter trawl, February-October.

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 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).

Footnotes

[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).

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.