Miscellaneous Species

Randall Baxter

Brown Rockfish

Introduction

The brown rockfish, *Sebastes auriculatus*, is a demersal, marine fish, which ranges from Hipolito Bay, Baja California, to southeast Alaska (Miller and Lea 1972). It is found from the subtidal zone to 55 m, and grows to about 550 mm TL (Miller and Lea 1972). It is a minor component of sport fisheries in San Francisco Bay and offshore and of commercial fisheries along the coast (Adams 1980).

Both males and females reach maturity as early as age 3 at 260 mm TL. Half reach maturity at age 5 at 310 mm TL, and some mature as late as age 10 at 380 mm TL (Wyllie–Echeverria 1987). Brown rockfish can live to 19 years and possibly longer (Wyllie–Echeverria 1987, Stein and Hassler 1989). Fertilization is internal and larvae hatch within the ovary and are released at the 1st feeding stage during winter and early spring (Kendall and Lenarz 1986, Wang 1986). Multiple broods in 1 year are possible (Willie–Echeverria 1987). Although some gravid females are found in San Francisco Bay, most parturition is believed to occur in coastal waters (Kendall and Lenarz 1986, Wang 1986). The larvae and early juveniles are pelagic, whereas older juveniles settle out of the water column and are found in association with structure near the bottom (Turner and others 1969, Feder and others 1974). San Francisco Bay appears to be an important habitat for juvenile brown rockfish, which enter it and remain within a limited "territory" for several years before moving to deeper water and offshore (Kendall and Lenarz 1986).

Methods

A January 1 birth date was assigned to all age–0 fish, which were separated from age–1+ fish by an examination of the length frequencies. Cutoff lengths (minimum size of age–1+ fish) for the separation of age–0 and age–1+ fish were set at 30, 35, 45, 55, 65, 75, 85, 90, 98, 102, 106, and 110 mm TL for January to December, respectively. Most brown rockfish were collected in the otter trawl, so only otter trawl data were analyzed for this species. April to October and February to October index periods were used for age–0 and age–1+ life stages, respectively. No corrections were made for missing 1989 data.

Results

Catch and Length

Most brown rockfish were taken in the otter trawl: 1,165 fish ranging from 31 to 340 mm TL. Twelve brown rockfish, 34 to 72 mm TL, were caught in the beach seine, and 19 from 29 to 92 mm TL were taken in the midwater trawl. Only 3 unmeasured larvae and 1 juvenile of 36.5 mm TL were collected by the plankton net. The length data for 1981 to 1988 show that 3 age groups (age 0, age 1, and age 2), were present in the estuary (Figure 1).

Annual Abundance

Abundance of age–0 brown rockfish was highest in 1993 and much lower in all other years (Figure 2, Table 1). None were collected during the April to October index period in 1983, 1992, and 1995. No trend was apparent and no relationship with water year type existed.

Age–1+ brown rockfish showed an annual abundance pattern similar to that of age–0 fish. The abundance of age–1+ fish was highest in 1994 and 1995, much lower in all other years, and showed no trend or relationship with water year type (see Figure 2, Table 2).

Seasonal Abundance

The month when age–0 fish were first captured varied greatly, ranging from April to November (Figure 3, see Table 1). Seasonal abundance varied annually but age–0 fish were usually present from at least June to September (see Table 1). On the average, abundance was highest in August. The high December abundance (see Figure 3) was due to late and high immigration in 1983, when age–0 fish did not appear until November (see Table 1).

The monthly mean abundance of age–1+ fish peaked in March and June but there were wide variations from year to year (see Figure 3, see Table 2).

Annual Distribution

Age–0 brown rockfish ranged from South Bay to San Pablo Bay in most years and in 1984 they reached Suisun Bay (Figure 4). The CPUE was most often highest in Central Bay and in some years was highest in San Pablo Bay or South Bay. Distribution did not appear to be related to water year type.

Although age–1+ brown rockfish ranged from South to San Pablo bays, the CPUE was much higher in Central Bay than in other regions (Figure 5). Age–1+ fish were collected in San Pablo Bay only in 1981, and in South Bay only from 1980 to 1984, and again in 1994 and 1995.

Seasonal Distribution

The seasonal distribution of age–0 brown rockfish was irregular. In April, May, and June, when age–0 fish were first entering the estuary or were just large enough for capture in the otter trawl, they ranged from South Bay to San Pablo Bay (Figure 6). They were found in Suisun Bay only in July 1984, a month after high CPUE occurred in San Pablo Bay. On the average, CPUE in San Pablo Bay declined after July and was low or 0 for the rest of the year. The South Bay CPUE increased later in the year than that of San Pablo Bay and remained relatively high through October. Data from 1980, 1985, 1988, and 1991 show that the increase in Central Bay CPUE in November and December coincided with a CPUE decline in South Bay and to a lesser degree in San Pablo Bay (see Figure 6).

Most age–1+ brown rockfish remained in Central Bay all year (Figure 7). Age–1+ fish were in South Bay from midwinter through summer and San Pablo Bay only in February 1981.

Soon after they first appeared in the estuary from April to June, age–0 brown rockfish were found mainly in shoal areas, a distribution that persisted until November (Figure 8). By December, all age–0 fish had moved to channels. Age–1+ fish were found only in channels, except from February to May and again in October when a few were captured at shoal stations.

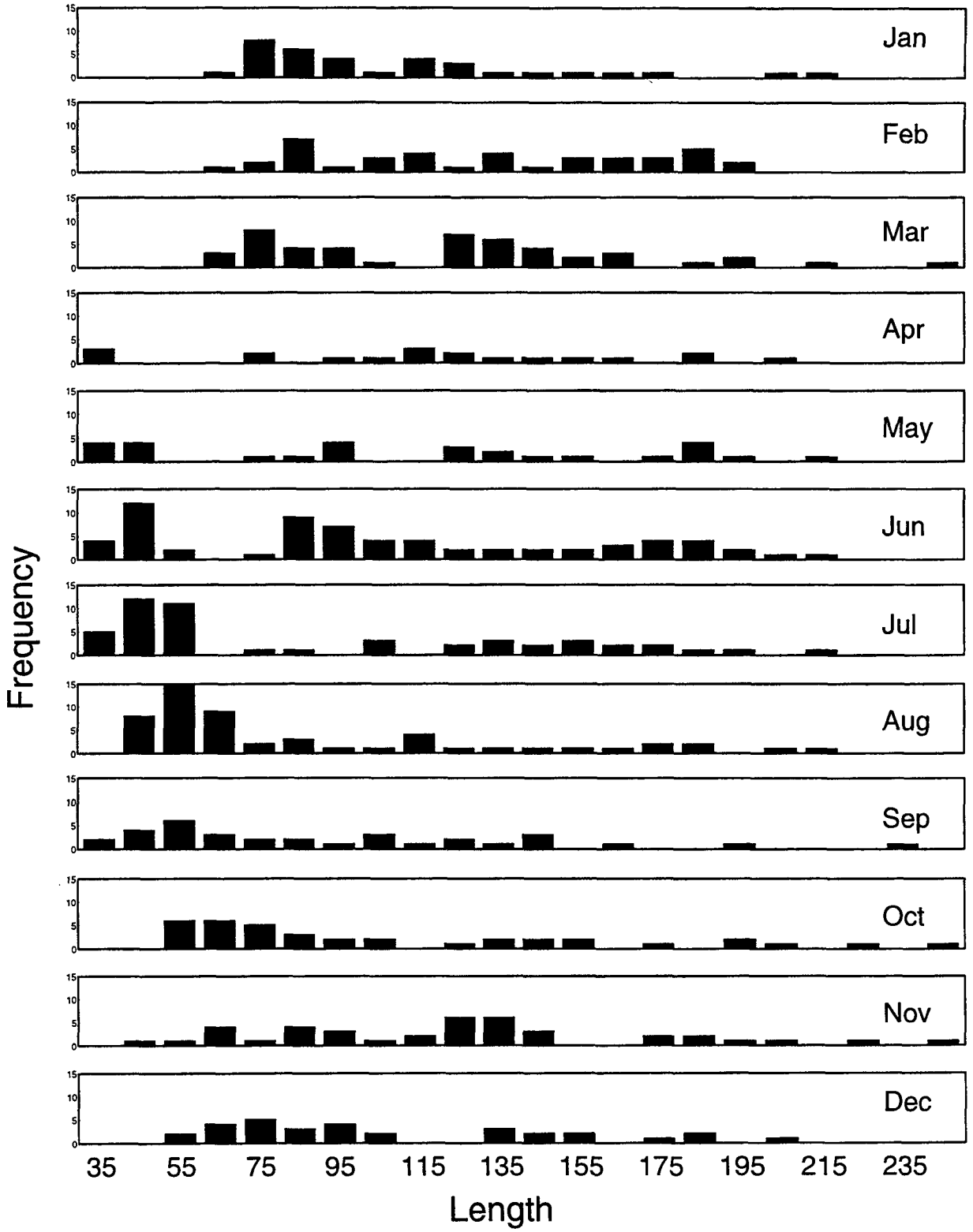

Figure 1 Length frequency (mm TL) by month of brown rockfish collected with the otter trawl from 1981 to 1988. Fish at 268 and 340 mm are not shown.

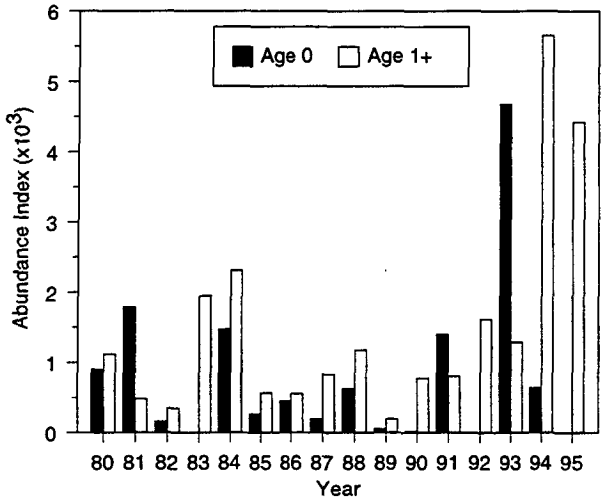

Figure 2 Annual abundance of age–0 and age–1+ brown rockfish from the otter trawl from 1980 to 1995. Data are the means of April to October and February to October monthly indices, respectively.

Table 1 Monthly abundance of age–0 brown rockfish captured in the otter trawl from 1980 to 1995. Annual abundance indices are in the far right column. Seasonal abundance indices are in the bottom row (mean 1981 to 1988 monthly abundance).

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Apr–Oct*
1980		0	0	154	0	134	3124	2150	154	572	469	216	898
1981	0	0	0	0	0	532	4299	2663	979	4078	406	156	1793
1982	0	0	0	219	497	134	0	0	262	0	625	134	159
1983	0	0	0	0	0	0	0	0	0	0	243	6639	0
1984	0	0	0	0	0	1452	975	5747	1753	408	162	703	1476
1985	0	0	0	0	0	115	324	189	269	985	460	0	269
1986	0	0	0	0	0	1205	802	750	438	0	469	189	456
1987	0	0	0	0	0	0	525	606	0	216	1514	919	192
1988	0	0	0	583	1219	622	344	487	1163	0	0	0	631
1989	0	0	0	0	281	0	0	0					56
1990		0	0	0	0	173	0	0	0	0			25
1991		0	0	189	344	622	2846	2094	2423	1271			1398
1992		0	0	0	0	0	0	0	0	0			0
1993		0	0	0	0	5526	17002	5755	1517	2932			4676
1994		0	0	0	325	297	1190	838	1866	0			645
1995	0	0	0	0	0	0	0		0	0	0	0	0
1981–1988	0	0	0	100	215	508	909	1305	608	711	485	1093	

Table 2 Monthly abundance of age–1+ brown rockfish captured in the otter trawl from 1980 to 1995. Annual abundance indices are in the far right column. Seasonal abundance indices are in the bottom row (mean 1981 to 1988 monthly abundance).

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Feb–Oct*
1980		721	1103	2299	865	0	2650	1109	1325	0	721	1607	1119
1981	1758	857	1244	0	1385	0	216	278	0	406	0	0	487
1982	2298	0	0	219	714	1623	0	0	0	618	0	340	353
1983	688	185	3256	696	649	2054	8681	594	811	622	243	8545	1950
1984	216	2954	5895	1219	811	6925	1109	1758	0	162	0	0	2315
1985	1336	1028	541	0	216	703	0	622	433	1568	2596	0	568
1986	243	0	162	352	0	3705	811	0	0	0	406	0	559
1987	0	1677	1325	892	865	379	1001	325	1055	0	2245	784	835
1988	2380	4922	865	379	919	297	0	1433	1487	270	649	0	1175
1989	0	1163	0	216	0	0	0	0					197
1990		541	1947	2136	1623	216	270	0	297	0			781
1991		568	297	0	1433	2136	865	919	433	595			805
1992		2623	1866	4570	2758	1568	0	865	325	0			1619
1993		865	2136	2921	2731	622	1325	433	0	568			1289
1994		3358	9179	4558	5825	11845	4273	4874	6328	649			5654
1995	3743	3624	22426	865	1839	1055	2136		2975	460	216	1136	4423
1981–1988	1115	1453	1661	470	695	1961	1477	626	473	456	767	1209	

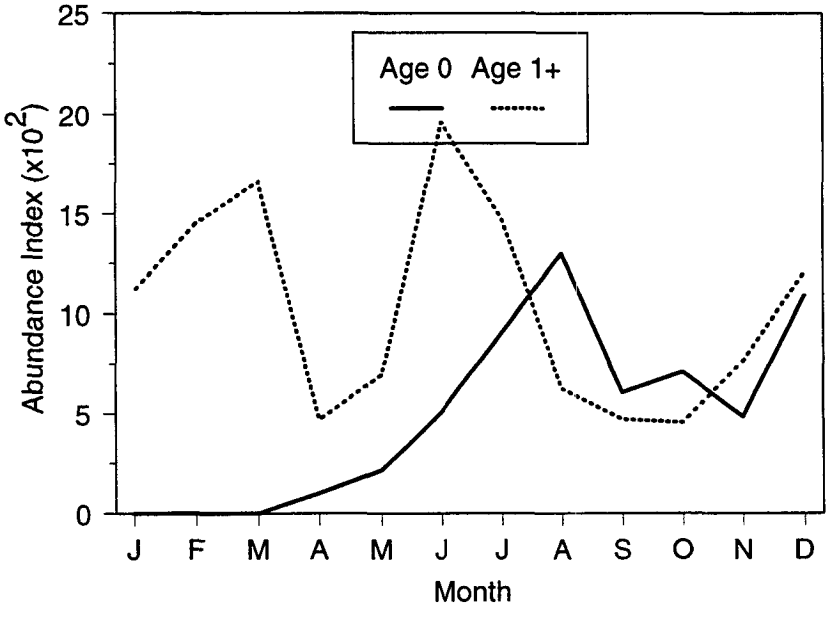

Figure 3 Seasonal abundance of age–0 and age–1+ brown rockfish collected with the otter trawl. Data are mean abundance by month from 1981 to 1988.

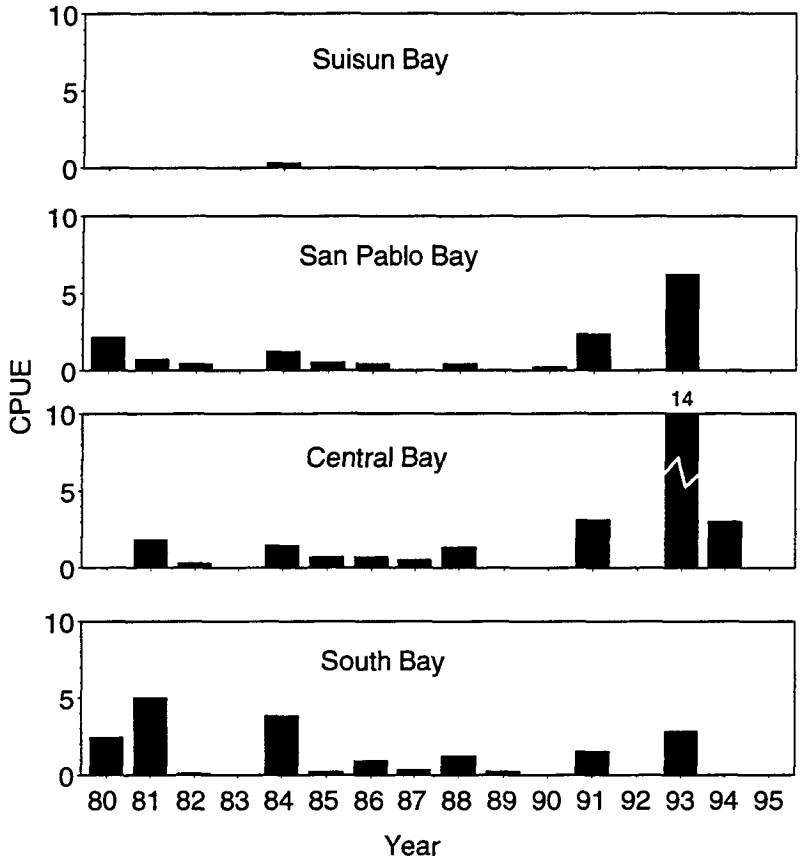

Figure 4 Annual distribution of age–0 brown rockfish collected with the otter trawl from 1980 to 1995. Data are mean CPUE by region for April to October. None were captured in the west delta.

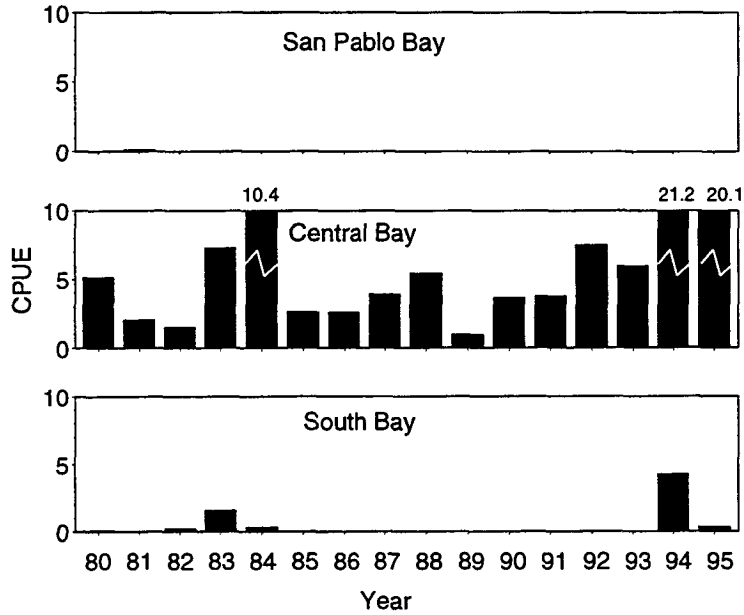

Figure 5 Annual distribution of age–1+ brown rockfish collected with the otter trawl from 1980 to 1995. Data are mean CPUE by region for February to October. None were captured in Suisun Bay or the west delta.

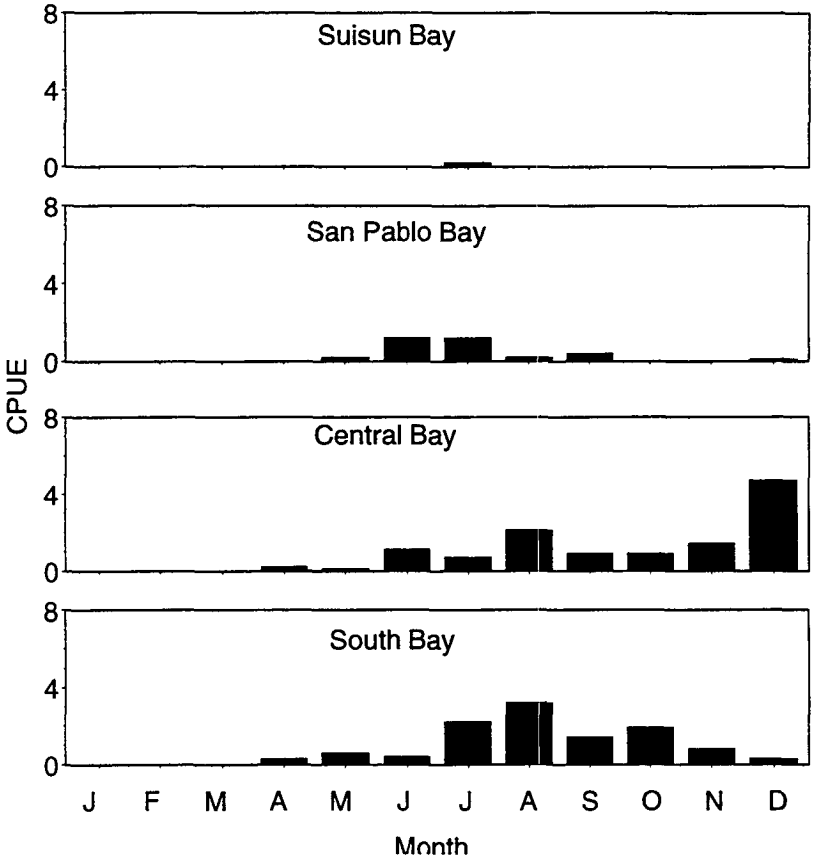

Figure 6 Seasonal distribution of age–0 brown rockfish collected with the otter trawl. Data are mean CPUE by region for 1981 to 1988. None were captured in the west delta.

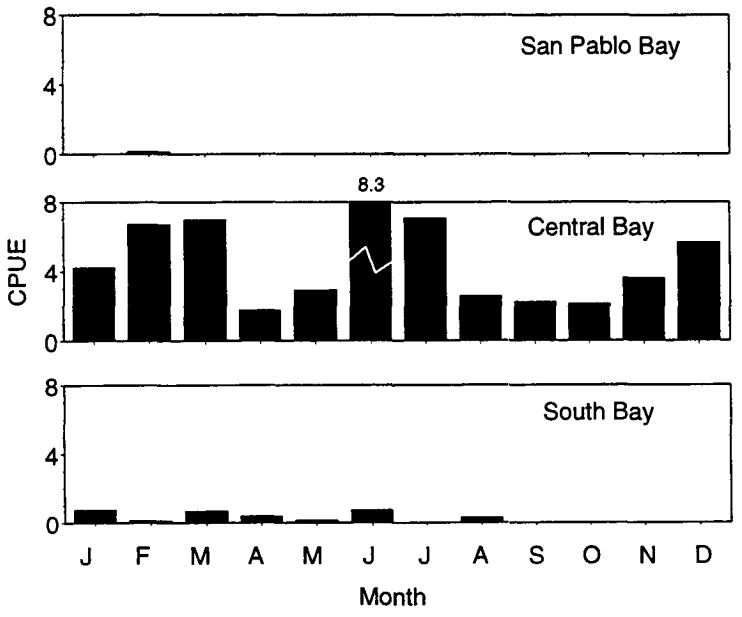

Figure 7 Seasonal distribution of age–1+ brown rockfish collected with the otter trawl. Data are mean CPUE by region for 1981 to 1988. None were captured in Suisun Bay or the west delta.

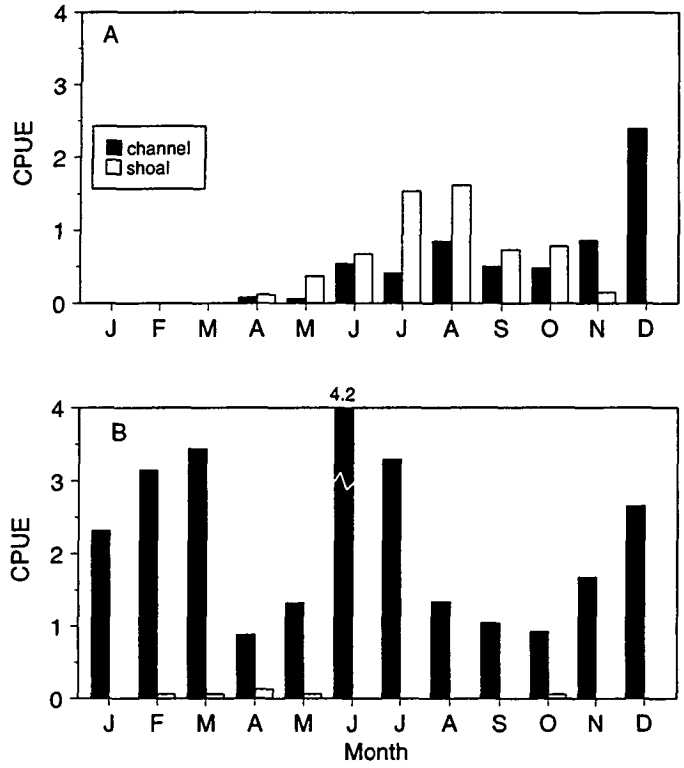

Figure 8 Depth distribution (shoal and channel) of (A) age-0 and (B) age-1+ brown rockfish collected with the otter trawl. Data are mean CPUE by month and age group for 1981 to 1988.

Salinity and Temperature

Both age–0 and age–1+ brown rockfish were primarily found in salinities >20‰, yet changes in monthly mean salinity still reflected seasonal changes in the estuary (Figures 9 and 10). For age–0 fish, salinity means increased from a minimum of 26.4‰ in April to a maximum of 32.9‰ in October, before declining to 29.0‰ in December (see Figure 9). Age–1+ fish, though found in salinity ranges similar to age–0, were caught earlier in the year and their salinity means (24.1‰, 27.6‰, 23.6‰, and 24.3‰ from January to April) reflected reduced Central Bay salinity in winters of 1983 and 1984 (see Figure 10). As estuarine salinity increased from May to July, mean salinity for age–1+ fish increased to about 31‰ then remained at that level through the rest of the year.

Except for July, monthly temperature means for age–0 and age–1+ brown rockfish closely approximated one another for months when both groups were present and varied with the seasonal patterns in the estuary (see Figures 9 and 10). The temperature means for age–0 fish increased from 14.2 °C in April to a maximum of 19.5 °C in July before declining to a minimum of 13.0 °C in December (see Figure 9). In January, the temperature mean of age–1+ fish was at a minimum of 9.4 °C (see Figure 10). They were found in increasingly warm water through August when the mean reached a maximum of 18.7 °C before declining to 13.3 °C in December.

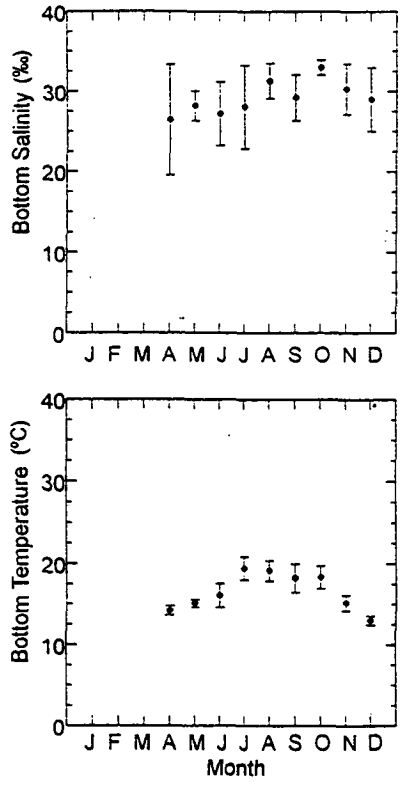

Figure 9 Salinity (‰) and temperature (°C) distributions of age–0 brown rockfish collected with the otter trawl. Data are mean ±1 standard deviation CPUE-weighted bottom salinity and temperature by month for 1981 to 1988.

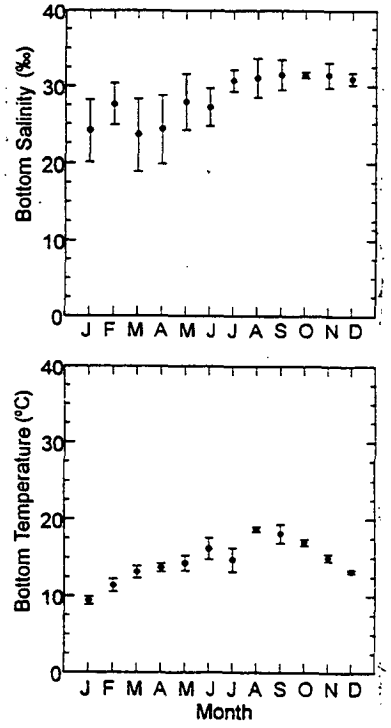

Figure 10 Salinity (‰) and temperature (°C) distributions of age–1+ brown rockfish collected with the otter trawl. Data are mean ±1 standard deviation CPUE-weighted bottom salinity and temperature by month from 1981 to 1988.

Discussion

Brown rockfish reproduce primarily on the open coast—fish <34 mm were rarely caught in the estuary—and age–0 fish immigrate to the estuary and use it as a nursery area (Kendall and Lenarz 1986, this study). They remain in the estuary for 1 to 2 years before migrating to the open coast to complete their life cycle (Kendall and Lenarz 1986, this study). The sporadic abundance and distribution of both age classes probably did not reflect their true abundance and distribution, but was caused by the difficulty in sampling with an otter trawl around their preferred habitat: rocks, pilings, and other bottom structures. The seasonal changes in age–1+ abundance (see Figure 3) may be caused by a change habitat in response to environmental conditions. Declining salinity during winter and early spring may cause fish to move from shallow water habitat, where they are protected by structure, to deeper, open water habitats where salinity is higher but they are more vulnerable to the otter trawl. Likewise, the summer abundance peak may result from increased vulnerability either as fish move to deeper, cooler water as temperature rises or as fish emigrate from the estuary.

The age–0 index is probably also biased because some age–0 fish may have been caught either before settlement, when entering the estuary post-settlement, or when moving between areas. Regardless of the potential biases, the data substantiate the claims of Kendall and Lenarz (1986) that brown rockfish use the estuary as a nursery area.

The differences in the salinity and temperature distributions of the age groups reflects the presence of age–1+ fish in the estuary during winter, whereas age–0 fish were generally not caught until late spring or summer when both salinity and temperature had increased. As was the case for other "marine" species such as speckled sanddab, age–0 fish had a broader geographic range than age–1+ fish.

References

Adams, P.B. 1980. Life history patterns in marine fishes and their consequences for fisheries management. Fishery Bulletin 78:1–12.

Feder, H.M., C.H. Turner, and C. Limbaugh. 1974. Observations on fishes associated with kelp beds in southern California. California Department of Fish and Game, Fish Bulletin 160.

Kendall Jr., A.W. and W.H. Lenarz. 1986. Status of early life history studies of northeast Pacific rockfishes. Proceedings of the International Rockfish Symposium, October 1986, Anchorage, Alaska.

Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. California Department Fish and Game, Fish Bulletin 157: 1–249.

Stein, D. and T.J. Hassler. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (pacific southwest)—brown rockfish, copper rockfish, and black rockfish. U.S. Fish and Wildlife Service Biological Report 82 (11.113).

Turner, C.H., E.E. Ebert, and R.R. Given. 1969. Man-made reef ecology. California Department of Fish and Game, Fish Bulletin 146.

Wang, J.C.S. 1986. Fishes of the Sacramento–San Joaquin Estuary and adjacent waters, California: A Guide to the early life histories. Interagency Ecological Study Program for the Sacramento–San Joaquin Estuary, Technical Report 9.

Wyllie–Echeverria, T. 1987. Thirty-four species of California rockfishes: Maturity and seasonality of reproduction. Fishery Bulletin 85:229–250.

Pacific Pompano

Introduction

The Pacific pompano, also called the Pacific butterfish, *Peprilus simillius*, is a schooling, pelagic, marine fish, which is found from Magdalena Bay, Baja California, northward to the mouth of the Fraser River, British Columbia (Miller and Lea 1972). It reaches a maximum size of about 280 mm TL and generally inhabits depths between 9 and 90 m (Miller and Lea 1972). It is not taken very often by anglers and because of its small size is not commercially important.

Age at maturity is not known. Spawning probably takes place from spring through midsummer in coastal marine waters (Fitch and Lavenberg 1971, Goldberg 1980, Walker and others 1987). Eggs and larvae are pelagic and are found in both inshore and offshore coastal waters (Gruber and others 1982). Juveniles and adults form small, dense schools and inhabit inshore coastal areas (Fitch and Lavenberg 1971).

Methods

Age classes were not clearly distinguishable in length frequency distributions, so all fish were treated as a single group. Annual abundance indices were calculated as the average of February through October monthly midwater trawl indices without correction for months when no sampling occurred (for example, February, March, and August 1995). No index was calculated for 1994 due to insufficient sampling. Distribution analyses were based on midwater trawl CPUE averaged for February to October for annual distribution and for 1981 to 1988 for seasonal distribution. Salinity and temperature statistics were calculated from CPUE-weighted mean profile measurements, also for the period 1981 to 1988.

Results

Catch and Length

Most Pacific pompano (1,461 fish) were collected in the midwater trawl. They ranged from 62 to 201 mm FL (Figure 1). Only 19 fish from 87 to 177 mm FL were caught with the otter trawl, and none were caught in the beach seine or the plankton net. The length frequency data indicates that at least 2 year classes were present. One year class had abundance modes between 90 and 110 mm FL and was present between April and August. The other year class had modes >130 mm FL and was present in all months except December.

Annual Abundance

Pacific pompano were collected in all years except 1985. The annual abundance indices had 3 modes: a small one in 1981, the highest mode in 1992, and an intermediate one in 1995 (Figure 2, Table 1). Abundance was usually higher in years after 1986.

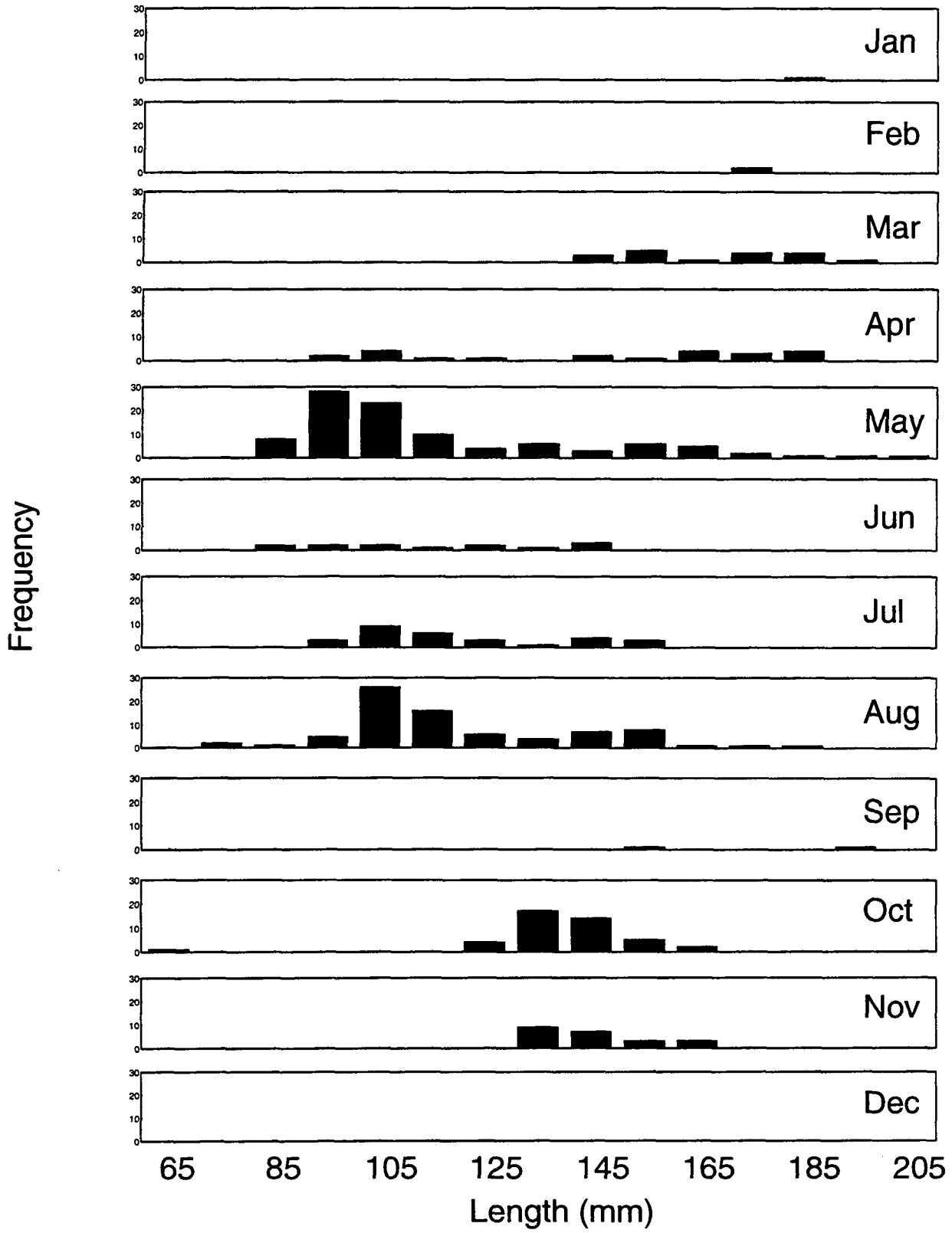

Figure 1 Length frequency (mm FL) of Pacific pompano captured with the midwater trawl from 1981 to 1988

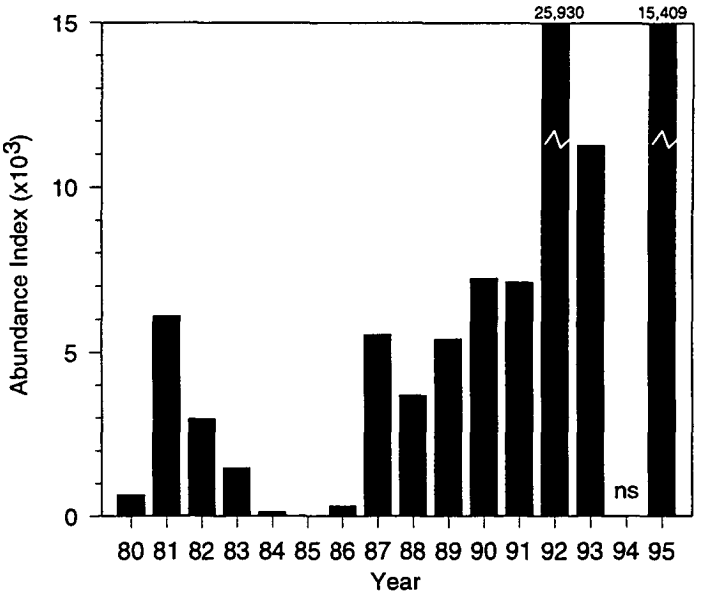

Figure 2 Annual abundance of Pacific pompano (all ages) captured with the midwater trawl from 1980 to 1995. Sampling in 1994 was not sufficient (ns) to calculate an index.

Table 1 Annual and seasonal abundance of all ages of Pacific pompano collected with the midwater trawl from 1980 to 1995

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Feb–Oct*
1980		1239	0	0	0	570	4057	0	0	0	0	0	652
1981	0	0	4357	5796	7561	2871	2698	31520	0	0	267	0	6089
1982	0	493	2362	0	6192	1265	0	12183	1186	3020	0	0	2967
1983	602	0	0	6010	0	257	6919	0	0	0	0	0	1465
1984	0	0	0	0	1159	0	0	0	0	0	0	0	129
1985	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	504	0	2147	0	0	0	0	0	295
1987	0	0	0	610	34861	4238	7716	0	0	1823	0	0	5472
1988	0	0	0	1266	11708	0	1127	0	0	19629	13722	0	3748
1989	0	0	705	12253	21383	1866	1920	0					5447
1990		1641	1436	7293	14230	24900	11670	4017	493	0			7298
1991		0	0	14507	3169	7487	10436	23014	2277	26204			9677
1992		0	0	60877	59797	1661	0	42355	8261	60890			25982
1993		0	0	1662	42499	14191	39821	642	0	2174			11221
1994		0	3634	10708									4781
1995				588	56870	20723	5787		6900	1315	0	548	15364
1981–1988	75	62	840	1710	7748	1079	2576	5463	148	3059	1749	0	

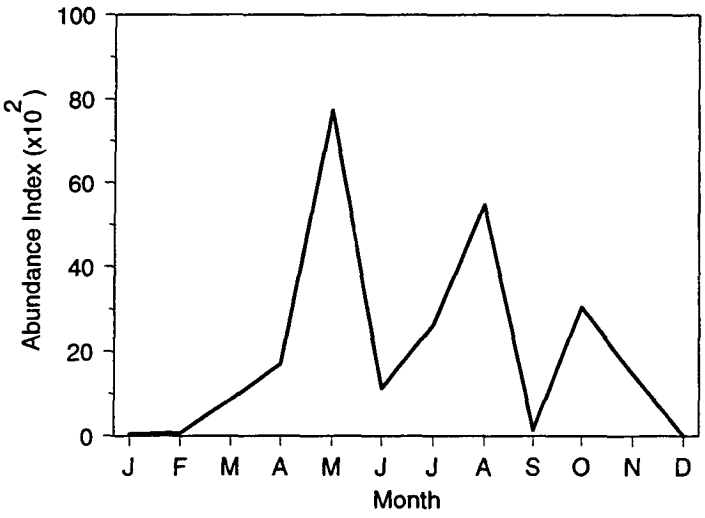

Figure 3 Seasonal abundance of Pacific pompano captured in the midwater trawl from 1981 to 1988

Seasonal Abundance

Pacific pompano collections were highly variable from month to month in most years (see Table 1). Yet, they have been collected in every month of the year in different years. They were generally most abundant from April or May to August (Figure 3); however, abundance remained high in the falls of 1988, 1991, and 1992 (see Table 1). In several years (1981, 1982, 1988, 1991, and 1992) there were spring and late summer or fall abundance modes. Few fish were collected from November to March.

Distribution

Although Pacific pompano were collected from South Bay to Suisun Bay, very few were collected outside of Central Bay (Figure 4). The use of South and San Pablo bays occurred in spring, mostly from 1981 to 1992 (Figure 5), years when CPUE was high in Central Bay.

Pacific pompano were collected from mesohaline salinities, but were mostly in polyhaline and euhaline salinities that averaged 29.6‰ (Figure 6). The collection temperature averaged 15.2 °C (see Figure 6).

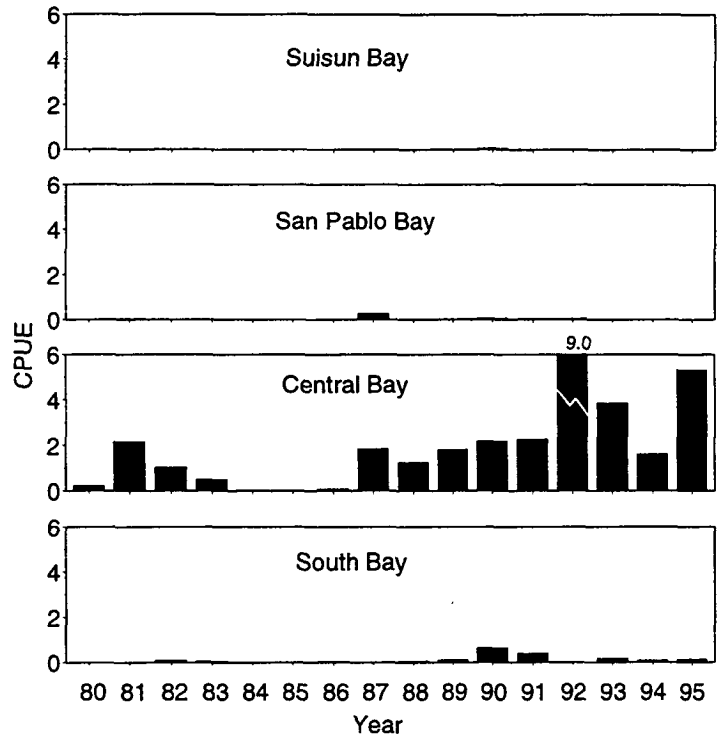

Figure 4 Annual distribution of Pacific pompano captured in the midwater trawl. Data are the average CPUE for February to October.

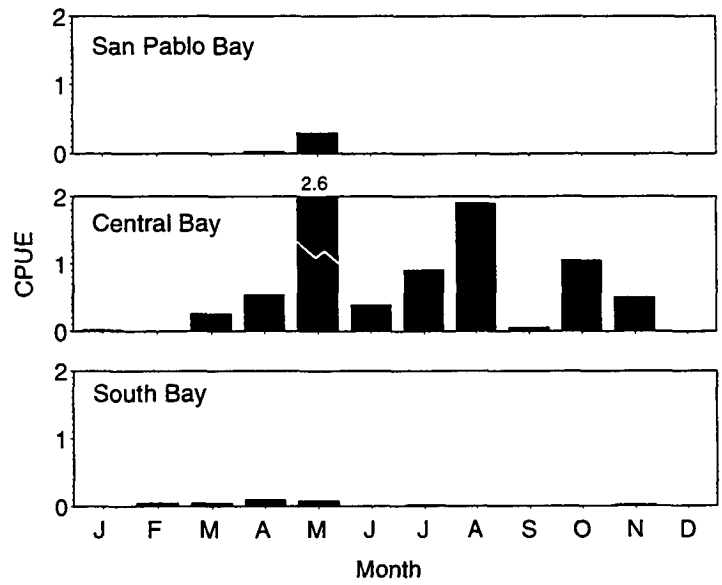

Figure 5 Seasonal distribution of Pacific pompano captured in the midwater trawl. Data are the average CPUE for 1981 to 1988.

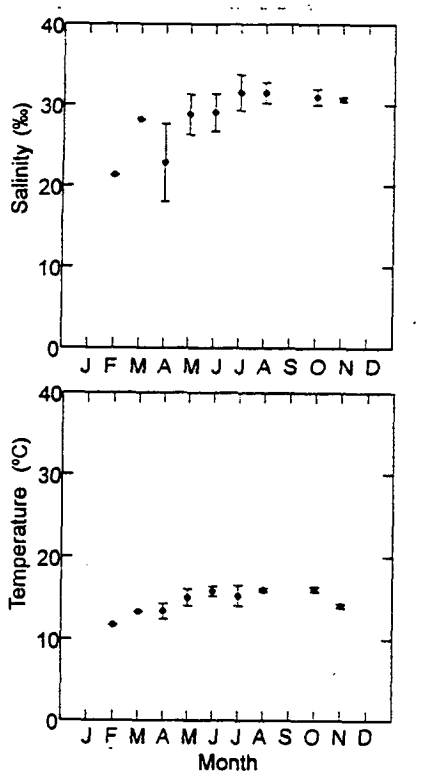

Figure 6 Salinity (‰) and temperature (°C) distributions (mean ±1 standard deviation) of Pacific pompano captured in the midwater trawl

Discussion

The Pacific pompano appears to use San Francisco Bay as an extension of its coastal marine habitat. Its salinity and temperature distributions and seasonal abundance suggest that it might be seeking relatively warmer euhaline water in the estuary once cold oceanic upwelling starts in the spring and it leaves the estuary in fall when upwelling ceases and estuary temperatures peak (see Salinity and Temperature chapter, Figure 12).

References

Fitch, J.E. and R.J. Lavenberg. 1971. Marine food and game fishes of California. University of California Press, Berkeley, California. California Natural History Guides 28.

Goldberg, S.R. 1980. Seasonal spawning cycle of the Pacific butterfish, *Peprilus simillimus* (Stromatedae). Fishery Bulletin 78:977–978.

Gruber, D., E.H. Ahlstrom, and M.M. Mullin. 1982. Distribution of ichthyoplankton in the Southern California Bight. CalCOFI Report Number 23.

Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. California Department Fish and Game, Fish Bulletin 157.

Walker Jr., H.J., W. Watson, and A.M. Barnett. 1987. Seasonal occurrence of larval fishes in the near-shore southern California Bight off San Onofre, California. Estuarine, Coastal and Shelf Science 25:91–109.

Pacific Tomcod

Introduction

The Pacific tomcod, *Microgadus proximus*, is a demersal, marine fish found from Point Sal, California, to Unalaska Island, Alaska (Miller and Lea 1972). It is found from near surface to about 220 m and reaches a maximum size of 305 mm TL (Miller and Lea 1972). Because of its small size it has little sport or commercial value but shows up occasionally in coastal fisheries for other types of fish.

Maturity is probably reached at age 2 and >200 mm TL (Emmett and others 1991). Spawning occurs in marine coastal waters during winter and spring (Richardson and Pearcy 1977, Matarese and others 1981), but can extend into the summer off San Francisco Bay (Wang 1986). Eggs have not been identified from plankton samples and consequently are believed to be demersal and adhesive (Dunn and Matarese 1987). Larvae and small juveniles (<50 mm) are pelagic and most common in nearshore coastal waters (Richardson and Pearcy 1977, Matarese and others 1981), but they can occasionally be found in estuaries (Misitano 1977, Wang 1986). Juveniles become demersal at about 50 mm TL and remain associated with the bottom for the rest of their lives (Richardson and Pearcy 1977, Matarese and others 1981). They inhabit bays and estuaries from San Francisco Bay northward and their abundance increases with latitude (Emmett and others 1991).

Methods

A January 1 birth date was assigned to all age–0 Pacific tomcod. These were separated from age–1+ fish by visual inspection of length frequency data. Cutoff lengths (minimum size of age–1+ fish) for the separation of ages 0 and 1+ were set at 70, 80, 90, 100, 110, 120, 130, 140, 150, 155, 160, and 165 mm TL for January through December, respectively. Since virtually all Pacific tomcod were collected with the otter trawl, only otter trawl data was analyzed for this species. A July to October index period was used for age–0 fish and a February to August period for age–1+ fish. No correction was made for missing 1989 data. Seasonal distributions of both age groups included data only from years in which all 12 months were sampled and in which fish in these age classes were collected.

Results

Catch and Length

Six larvae and no age–0 Pacific tomcod were collected with the plankton net and none with the beach seine. We captured 24 fish with the midwater trawl, ranging from 104 to 225 mm TL. The otter trawl was by far the most effective gear, capturing 931 fish, ranging from 13 to 271 mm TL.

Only 2 of the age–0 Pacific tomcod caught with the otter trawl were <50 mm TL. They measured 13 and 29 mm. Most age–0 fish were >90 mm and were easily distinguished from older age classes by length (Figure 1).

Annual Abundance

No age–0 Pacific tomcod were collected from 1984 to 1987 or in 1989 and 1992 (Figure 2, Table 1). Annual abundance was very low in most years compared to the peak in 1995 (see Figure 2). There was no trend in abundance.

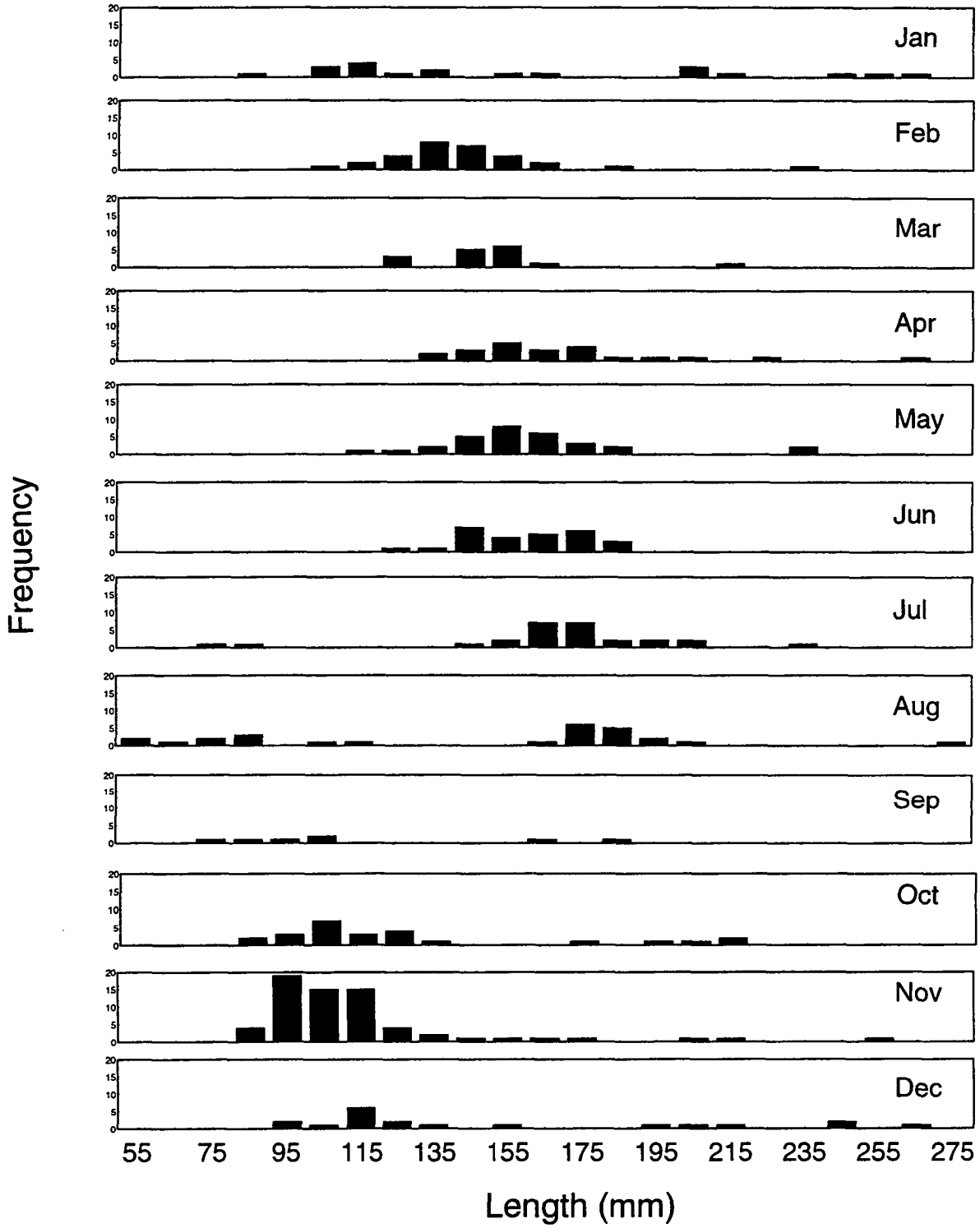

Figure 1 Length frequency (mm TL) by month of Pacific tomcod captured in the otter trawl from 1981 to 1988. Two fish, 13 and 29 mm TL, are not shown.

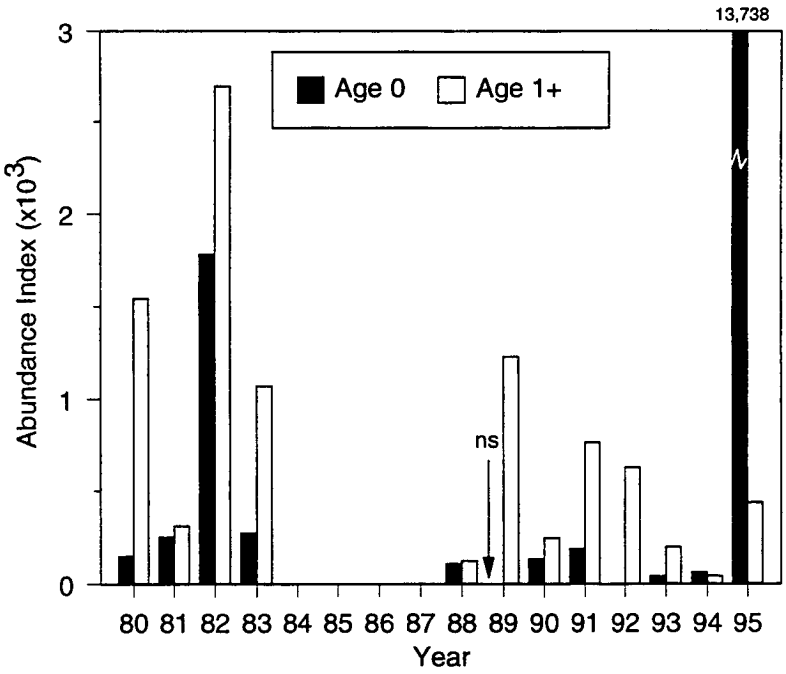

Figure 2 Annual abundance of Pacific tomcod captured in the otter trawl from 1980 to 1995

Table 1 Monthly abundance of age-0 Pacific tomcod captured with the otter trawl from 1980 to 1995. Annual abundance indices are in the far right column. Seasonal abundance indices are in the bottom row (mean 1981 to 1988 monthly abundance).

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Jul–Oct*
1980		0	409	0	0	0	194	0	186	0	970	404	95
1981	0	0	0	0	0	0	0	0	0	1004	11141	870	251
1982	0	0	0	0	0	0	576	1461	978	4026	2245	719	1760
1983	0	0	0	0	0	0	0	1060	0	0	0	0	265
1984	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	142	284	1147	2146	107
1989	0	0	0	0	0	0	0	0					0
1990		0	0	0	0	0	0	0	225	328			138
1991		0	0	0	0	0	0	427	328	0			189
1992		0	0	0	0	0	0	0	0	0			0
1993		0	0	0	0	0	0	0	0	171			43
1994		0	0	0	0	0	0	0	0	237			59
1995	0	0	0	0	0	0	0		29636	11596	31196	21217	13744
1981–1988	0	0	0	0	0	0	72	315	140	664	1817	467	

Table 2 Monthly abundance of age–1+ Pacific tomcod captured with the otter trawl from 1980 to 1995. Annual abundance indices are in the far right column. Seasonal abundance indices are in the bottom row (mean 1981 to 1988 monthly abundance).

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Feb–Aug Index*
1980		3466	1098	2034	1907	1340	1138	1067	1229	759	979	0	1721
1981	1104	400	549	665	341	0	212	557	0	0	0	569	389
1982	2248	3906	1784	740	3919	4923	4716	2246	439	1540	1074	792	3176
1983	1270	2132	874	2608	1925	768	358	966	0	0	0	0	1376
1984	0	0	0	0	0	0	0	0	0	0	0	305	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	305	0	0	0	0	0	0	0	0	0	0	0	0
1988	186	213	247	655	0	0	0	0	0	0	0	0	159
1989	1314	2225	764	1084	1949	900	1647	0					1224
1990		1440	237	376	0	0	0	0	0	194			293
1991		1266	0	1618	178	1355	290	2133	0	0			977
1992		1645	1717	2294	0	0	0	0	0	0			808
1993		0	693	838	237	0	0	0	0	0			253
1994		0	388	0	0	0	0	0	0	0			55
1995	194	189	717	0	1067	1262	284		0	0	261	978	586
1981–1988	639	831	432	583	773	711	661	471	55	193	134	208	

No age–1+ Pacific tomcod were collected from 1984 to 1987 during the February to August index period (see Figure 2, Table 2). However, some age–1+ fish were collected in December 1984 and January 1987 (see Table 2). Abundance of age–1+ fish peaked in 1982 but no trends in abundance were apparent.

Seasonal Abundance

Two age–0 Pacific tomcod were collected in March 1980, otherwise the month of 1st collection ranged from July to October (see Table 1). No age–0 fish were collected in 1989 and 1992, but sampling ended early in those years. Abundance was highest from October to December (Figure 3, see Table 1).

Age–1+ Pacific tomcod were collected throughout the year, although they were least abundant from September to December (see Figure 3, see Table 2). On the average, abundance was highest in February and May.

Annual Distribution

The distribution of age–0 Pacific tomcod was restricted to Central Bay in all years except 1982, when they entered San Pablo Bay (Figure 4). Age–1+ fish were more widely distributed and were generally found from South to San Pablo bays, but the age–1+ CPUE was always highest in Central Bay (Figure 5). In 1980, a few age 1+ fish were collected in Suisun Bay.

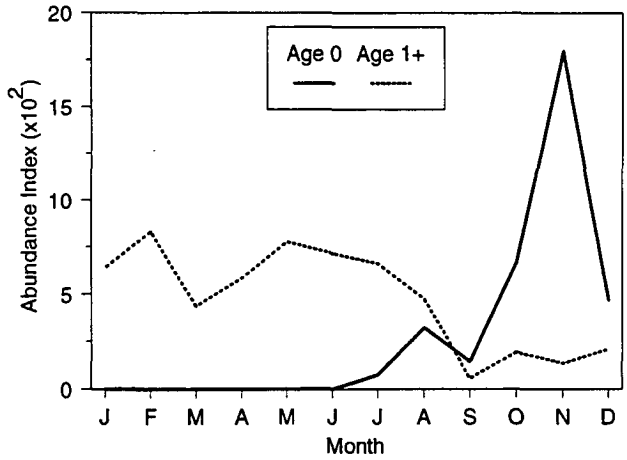

Figure 3 Seasonal abundance of Pacific tomcod captured in the otter trawl from 1981 to 1988

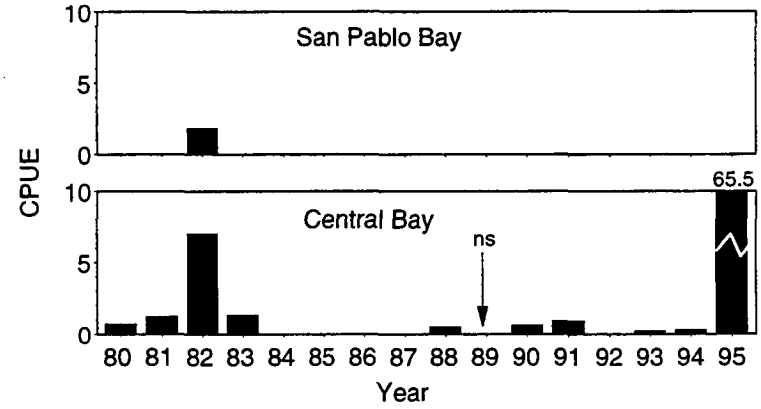

Figure 4 Annual distribution of age–0 Pacific tomcod by region. Data are the mean CPUE for July to October.

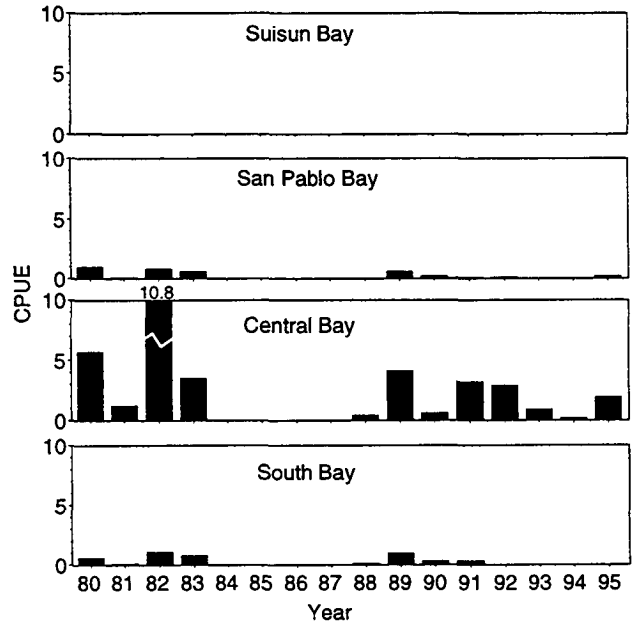

Figure 5 Annual distribution of age–1+ Pacific tomcod by region. Data are the mean CPUE for February to October.

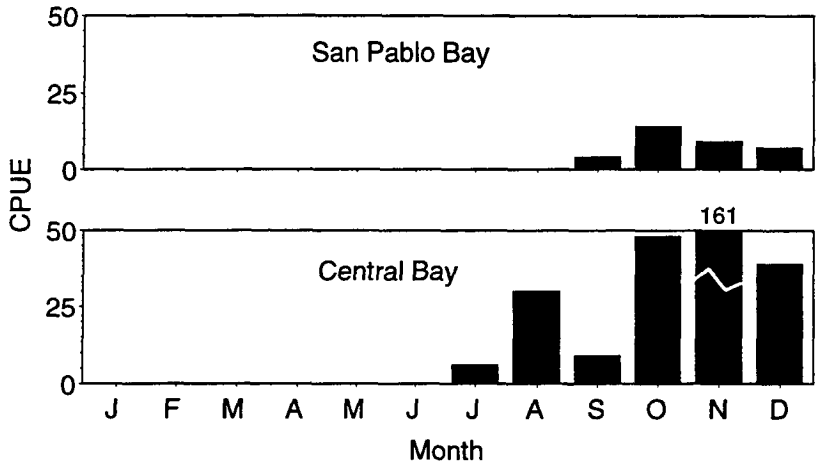

Figure 6 Seasonal distribution of age–0 Pacific tomcod by region. Data are the mean CPUE x 10 for 1980 to 1983 and 1988.

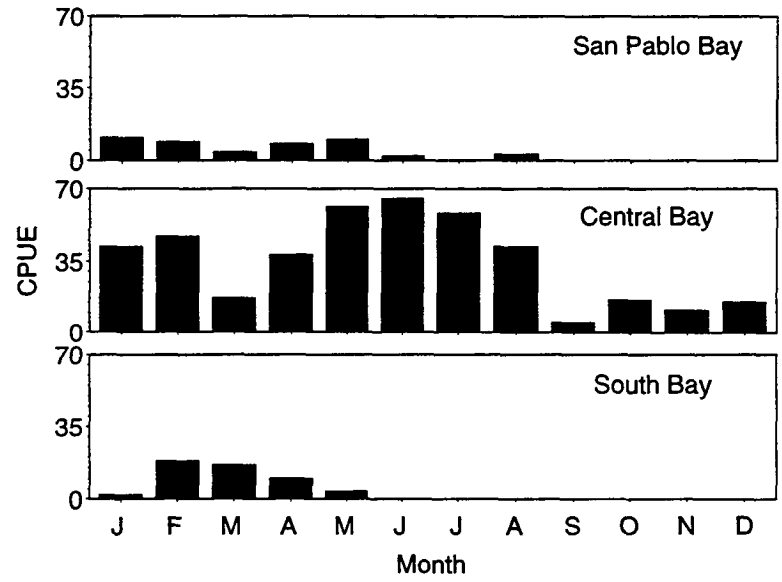

Figure 7 Seasonal distribution of age–1+ Pacific tomcod by region. Data are the mean CPUE x 10 for 1981 to 1983 and 1988.

Seasonal Distribution

Age–0 Pacific tomcod were concentrated in Central Bay in all months (Figure 6). The highest CPUE was in November. They were found in San Pablo Bay only from September to December 1982.

Age–1+ Pacific tomcod were caught in South and San Pablo bays primarily from January to May when Central Bay catches were usually high (Figure 7). By June or July age–1+ fish had left both South and San Pablo bays and CPUE in Central Bay peaked.

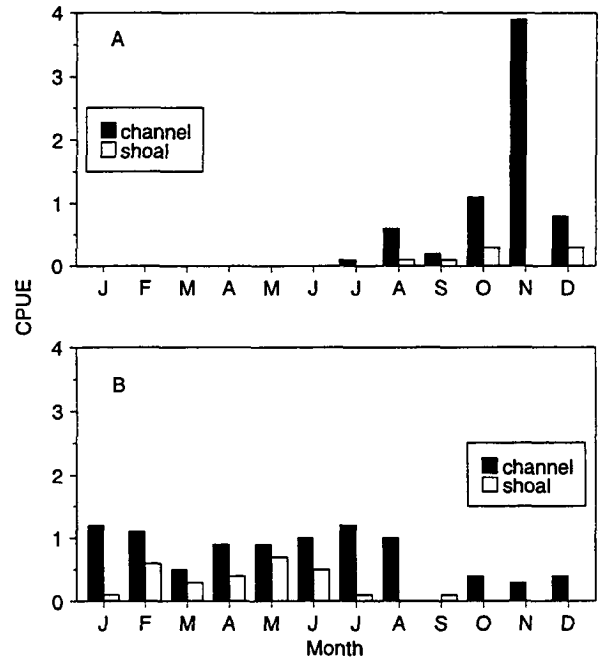

Figure 8 Seasonal depth distribution of (A) age–0 and (B) age–1+ Pacific tomcod captured in the otter trawl from 1981 to 1988

Pacific tomcod were strongly channel oriented throughout their residence in the estuary (Figure 8). This orientation was most distinct as age–0 fish entered the estuary in fall and winter. The use of shoal areas increased for age–1+ fish in late winter and spring before declining in summer (see Figure 8). Few age–1+ fish were caught on shoals in late summer and fall when most of them were leaving the estuary for the coast as shown by the declining catches in all bays (see Figure 7).

Salinity and Temperature

The Pacific tomcod is one of the few species for which the salinity distribution of age–0 fish was narrower and higher than that of the age–1+ fish (Figures 9 and 10). Age–0 Pacific tomcod were found only in polyhaline and euhaline salinities, but age–1+ fish also extended into mesohaline salinities.

Age–1+ Pacific tomcod were found at temperatures as low as 7 °C, but age–0 fish were not found below 11 °C (see Figures 9 and 10). Nevertheless, the mean temperatures for both age groups were similar: 13.8 °C for age 0 and 13.3 °C for age 1+. Neither age group was found above 18 °C.

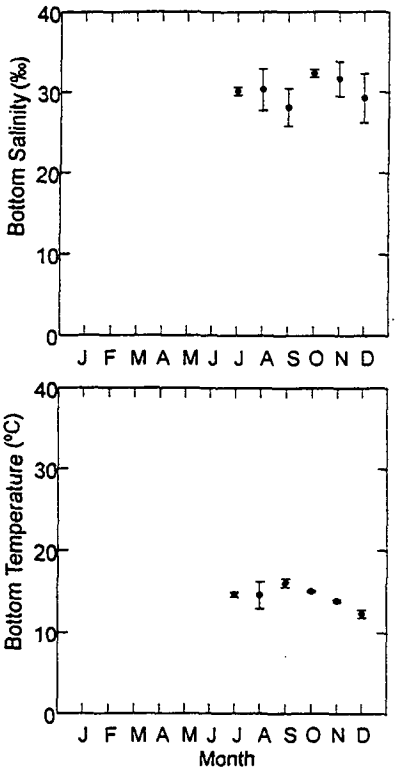

Figure 9 Seasonal temperature (°C) and salinity (‰) distributions (mean ±1 standard deviation) of age–0 Pacific tomcod

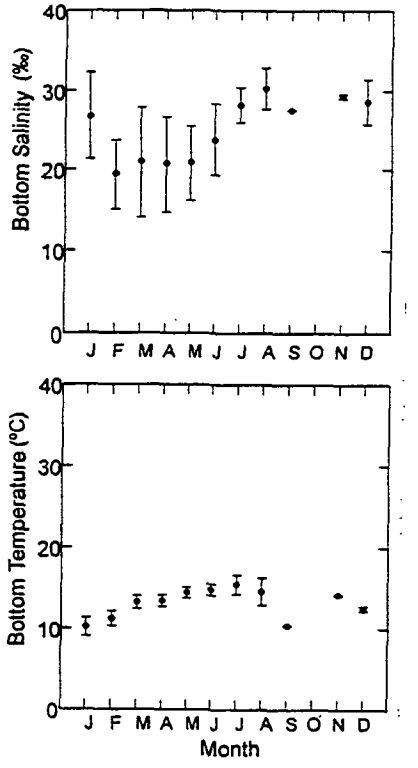

Figure 10 Seasonal temperature (°C) and salinity (‰) distribution (mean ±1 standard deviation) of age–1+ Pacific tomcod

Discussion

Pacific tomcod appear to use the estuary starting late in their 1st year of life; they remain for another year or more, then return to the open coast. However, not all year classes were represented in estuary sampling (see Figure 2). The distribution and abundance patterns of Pacific tomcod suggest that the estuary represents a range expansion of a marine population, rather than a nursery habitat.

Many factors could have contributed to the absence of both age groups from the estuary between 1984 and 1987 including temperature, food supply in the estuary, and overall abundance in the ocean. We lack information to assign a cause, however, the estuary is at the southern limit of the Pacific tomcod's range. If ocean conditions did not bring the fish far enough south they would not have appeared in the estuary. Within the estuary, distribution of both age groups appears more limited by high temperatures than by low salinities. Neither age group was collected from temperatures >18 °C, though such temperatures were common during the summer and fall in regions other than Central Bay (see Salinity and Temperature chapter, Figures 6 through 10). High temperature could be expected to limit the distribution of a species at the southern edge of its range.

The higher salinity distribution of age–0 fish appears to be a result of fall collection and a January 1 birth date rather than a change in salinity tolerance with age. There was considerable size overlap (and probably age overlap also) between age–0 fish in late fall and age–1+ fish in winter. Age–1 fish dispersed farther into the estuary than age–0 fish and remained through winter as salinity decreased to the low to middle 20‰ range. This suggests that size or development stage were not responsible for the difference. High temperatures in the fall may have limited estuarine dispersal of age–0 fish.

The possibility of bias in calculating the annual abundance of age–0 fish and to a lesser degree age–1+ fish was increased by the reduction in sampling effort in the late 1980s and early 1990s (see Methods chapter, Table 1). Age–0 fish were most abundant in the estuary from late fall to December. Hence, not including November and December (and September and October in 1989) in index calculations made some indices lower than they might have been otherwise.

References

Dunn, J.R. and A.C. Matarese. 1987. A review of the early life history of northeastern Pacific gadoid fishes. Fisheries Research 5:163–184.

Emmett, R.L., S.A. Hinton, S.L. Stone, and M.E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries. Volume II. ELMR Report 8. Species life history summaries. NOAA/NOS Strategic Environmental Assessments Division, Rockville, Maryland.

Matarese, A.C., S.L. Richardson, and J.R. Dunn. 1981. Larval development of Pacific tomcod, *Microgadus proximus*, in the northeast Pacific Ocean with comparative notes on larvae of walleye pollock, *Theragra chalcogramma*, and Pacific cod, *Gadus macrocephalus* (Gadidae). Fishery Bulletin 78:923–940.

Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. California Department Fish and Game, Fish Bulletin 157.

Misitano, D.A. 1977. Species composition and relative abundance of larval and post-larval fishes in the Columbia River estuary. Fishery Bulletin 75:218–222.

Richardson, S.L. and W.G. Pearcy. 1977. Coastal and oceanic fish larvae in an area of upwelling off Yaquina Bay, Oregon. Fishery Bulletin 75:125–145.

Wang, J.C.S. 1986. Fishes of the Sacramento–San Joaquin Estuary and adjacent waters, California: A Guide to the early life histories. Interagency Ecological Study Program for the Sacramento–San Joaquin Estuary, Technical Report 9.

Plainfin Midshipman

Introduction

The plainfin midshipman, *Porichthys notatus*, is a demersal marine fish found in the Gulf of California and from Gorda Bank, Baja California, northward to Sitka, Alaska (Miller and Lea 1972). It reaches a maximum size of 380 mm TL and inhabits depths from the intertidal to 328 m (Miller and Lea 1972). It is trapped commercially in San Francisco Bay for striped bass bait.

The age at maturity is not known, but Wang (1986) collected mature individuals from 165 to 181 mm TL. In San Francisco Bay, spawning takes place from April through August (Wang 1986). Males excavate nests under solid structures in the intertidal zone. Females enter the nests to deposit demersal, adhesive eggs, which the male fertilizes and guards until the larvae are free-swimming (Hart 1973). Larvae develop rapidly into juveniles and settle to the bottom. Both sexes are believed to die after spawning (Fitch and Lavenberg 1971).

Juveniles and adults bury themselves in soft sediments during the day and move into the water column at night to feed (Fitch and Lavenberg 1971). Juveniles tolerate lower salinities than adults and have occasionally been found in freshwater in the lower Sacramento–San Joaquin Delta (Wang 1986).

Methods

A January 1 birth date was assigned to all age–0 fish. Cutoff lengths for the separation of age–0 and age–1+ fish were determined by examination of length frequency data. Cutoff lengths were set at 25, 30, 35, 40, 45, 55, 65, 75, 80, 85, 90, and 95 mm TL for January to December, respectively. This resulted in some fall-hatching fish being designated as age–1+ at 4 to 5 months of age and <70 mm TL. Such fish were designated as small age–1+ fish to distinguish them from older individuals. Only otter trawl data were used in the analyses.

Abundance indices for age–0 fish were calculated for the June to October period, and for age–1+ fish, from February to September.

Results

Length Analysis

Four larval and 205 age–0 plainfin midshipman were captured in the plankton net. Eighteen plainfin midshipman ranging from 21 to 36 mm TL were caught in the beach seine, and 5,645, ranging from 22 to 340 mm, were caught in the midwater trawl. The otter trawl was by far the most effective gear, capturing 10,766 fish from 17 to 348 mm (Figure 1).

Age–0 plainfin midshipman (25 to 65 mm) were caught from June to December. They showed little indication of growth during the months they were present.

Small, 35 to 65 mm, age–1+ plainfin midshipman were present in January and grew until July or August when they disappeared from the catch (see Figure 1). Larger, ≥125 mm, age–1+ fish appeared in April and became more abundant during summer but disappeared by October. The largest fish were present in May and June.

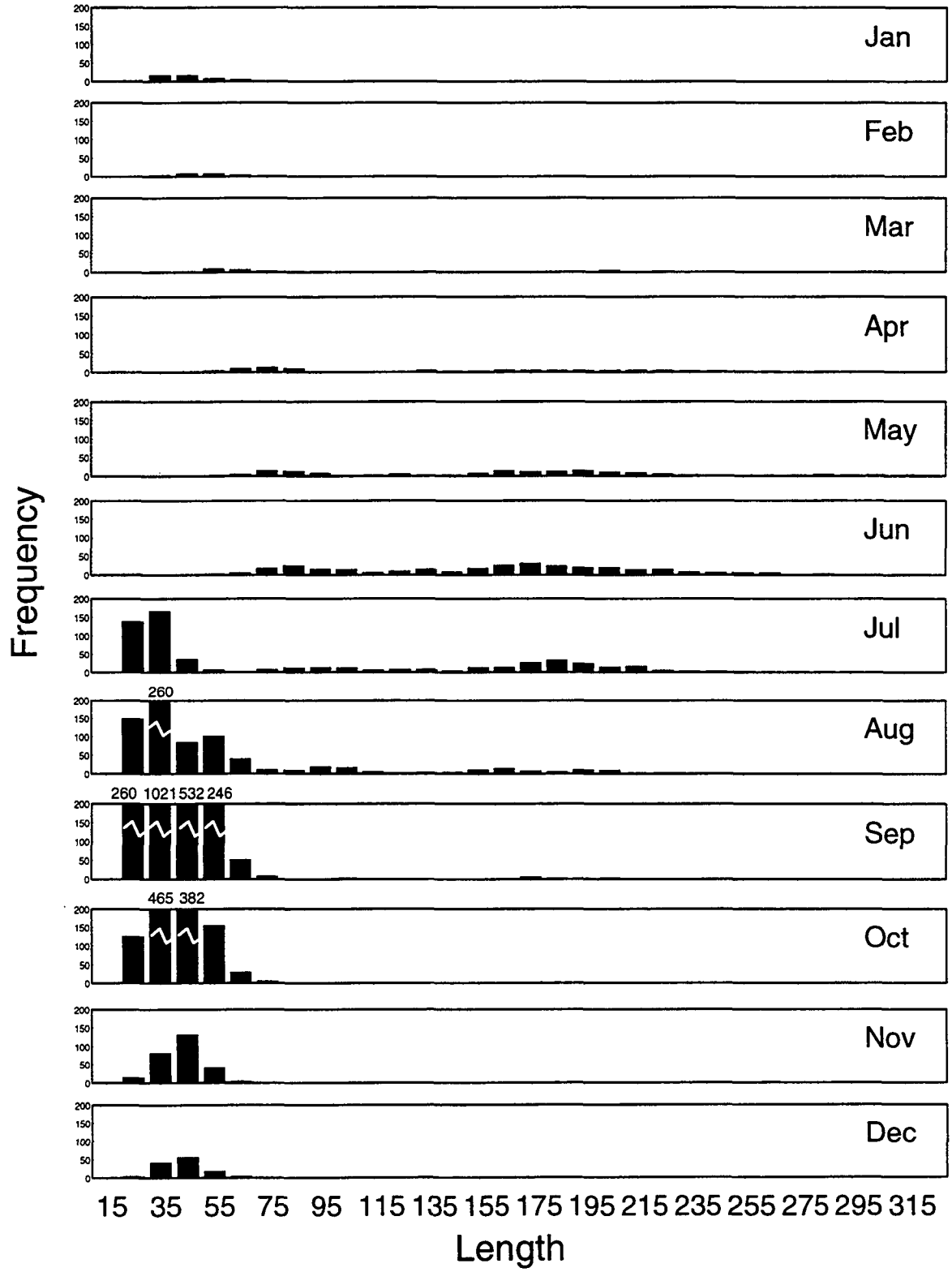

Figure 1 Length frequency (mm TL) by month of plainfin midshipman captured in the otter trawl from 1981 to 1988

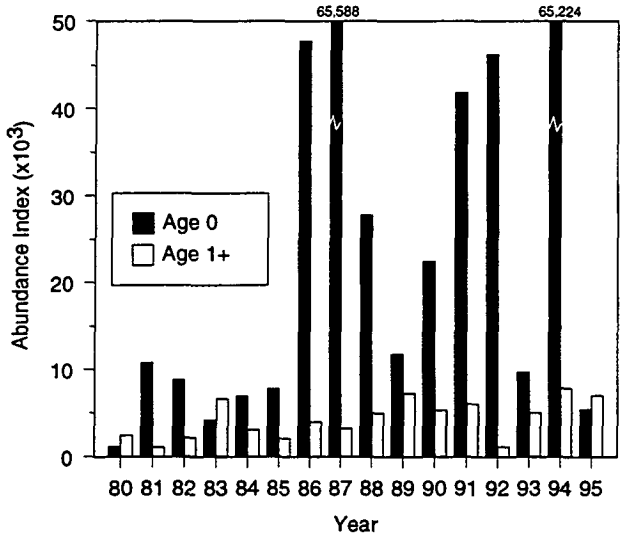

Figure 2 Annual abundance of plainfin midshipman captured in the otter trawl from 1980 to 1995

Table 1 Monthly abundance of age–0 plainfin midshipman collected with the otter trawl from 1980 to 1995. Annual abundance indices are in the far right column. Seasonal abundance indices are in the bottom row (mean 1981 to 1988 monthly abundance).

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*June–Oct*
1980		0	0	0	0	0	0	154	4511	1396	3114	649	1212
1981	0	0	0	0	0	0	11288	3871	5898	32903	0	188	10792
1982	0	0	0	0	0	0	0	12416	12440	19404	1799	1730	8852
1983	0	0	0	0	0	0	1016	1393	3376	15099	14779	10876	4177
1984	0	0	0	0	0	0	4380	10412	17052	2943	2494	4376	6957
1985	0	0	0	0	0	0	9703	4082	10507	14808	1471	667	7820
1986	0	0	0	0	0	0	117	20429	192760	25603	9260	4276	47782
1987	0	0	0	0	0	0	10582	37418	134580	145361	31156	2073	65588
1988	0	0	0	0	0	622	34323	50201	42730	11093	2956	933	27794
1989	0	0	0	0	216	500	6270	28464					11745
1990		0	0	0	0	3150	46477	20148	28824	13777			22475
1991		0	0	0	0	216	2540	15424	139236	51760			41835
1992		0	0	0	0	1313	2552	37463	117471	72678			46295
1993		0	0	0	0	0	2119	8425	9403	28557			9701
1994		0	0	0	0	6316	12385	56663	175813	74945			65224
1995	0	0	0	0	0	0	0		15367	6489	5304	14277	5464
1981–1988	0	0	0	0	0	78	8926	17528	52418	33402	7989	3140	

Annual Abundance

The abundance of age–0 plainfin midshipman was bimodal with peaks in 1987, the highest year, and 1994 (Figure 2, Table 1). Abundance showed no relationship with water year type and had no trend, although it was consistently low from 1980 to 1985. Age–1+ fish were much less abundant than age–0 fish and their abundance showed less variability (see Figure 2, Table 2). Abundance of age–1+ fish was highest in 1994 and almost as high in 1983, 1989, and 1995. With the exception of 1992, abundance was consistently high from 1988 to 1995. As for age–0 fish, no relationship existed between abundance and water year type.

Table 2 Monthly abundance of age–1+ plainfin midshipman collected with the otter trawl from 1980 to 1995. Annual abundance indices are in the far right column. Seasonal abundance indices are in the bottom row (mean 1981 to 1988 monthly abundance).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Feb–Sep
1980		0	373	1823	1641	4922	8107	1906	974	0	48	0	2468
1981	250	0	404	1998	1269	694	3245	1298	0	0	0	0	1114
1982	770	0	1201	3223	4822	6781	1420	0	0	0	0	0	2181
1983	703	402	288	1952	5601	12112	17694	15277	0	0	270	0	6666
1984	3867	0	243	992	4340	14108	4732	281	0	0	0	0	3087
1985	156	2246	648	622	649	3939	3651	4976	0	0	0	0	2091
1986	344	379	644	919	2706	13297	11917	1812	162	0	0	0	3980
1987	2217	313	1839	922	4801	5341	6303	4036	2272	0	0	0	3228
1988	597	1117	1379	8177	6629	16536	4206	2031	0	0	0	219	5009
1989	0	216	1487	10368	4907	22271	10128	1682					7294
1990		1320	4070	8729	9234	10868	6636	1731	0	0			5324
1991		0	865	1704	8654	9710	18724	8951	0	0			6076
1992		0	947	2697	1768	1757	1557	622	0	703			1169
1993		682	777	4563	9044	6106	13989	4752	243	0			5020
1994		1859	1885	3056	5144	10706	19984	18873	1601	0			7889
1995	5146	930	3666	2736	13194	12316	13969		2362	0	0	0	7025
1981–1988	1113	557	831	2351	3852	9101	6646	3714	304	0	34	27	

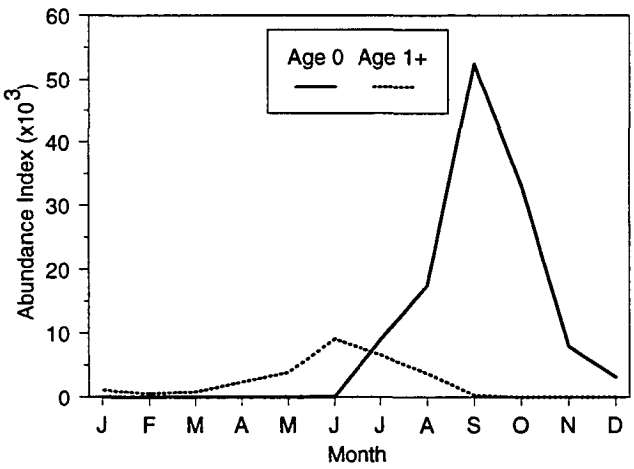

Figure 3 Seasonal abundance of plainfin midshipman captured in the otter trawl from 1980 to 1995

Seasonal Abundance

Age–0 plainfin midshipman were 1st collected in May, but only in 1989. They were more often first taken in June or July, although in 1980 and 1982 none were caught until August (see Table 1). On the average, abundance of age–0 fish peaked in September and declined sharply thereafter (Figure 3).

Age–1+ plainfin midshipman were either not collected or were not abundant from September to December (see Figure 3, see Table 2). Ninety-five percent of age–1+ fish collected in January and February and about 62% of those collected in March were small and newly recruited. On the average, age–1+ abundance peaked in June and declined sharply in fall (see Figure 3, see Table 2).

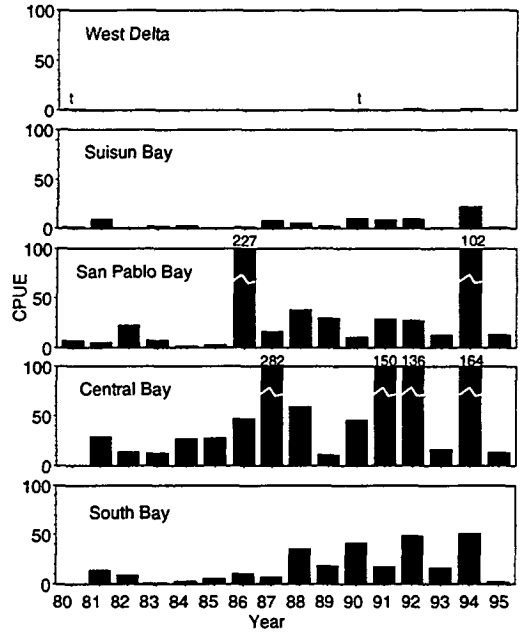

Figure 4 Annual distribution of age–0 plainfin midshipman captured in the otter trawl from 1980 to 1995. Data are mean CPUE for July to October by region. Numbers too small to show at this scale are indicated with a "t" (*trace*).

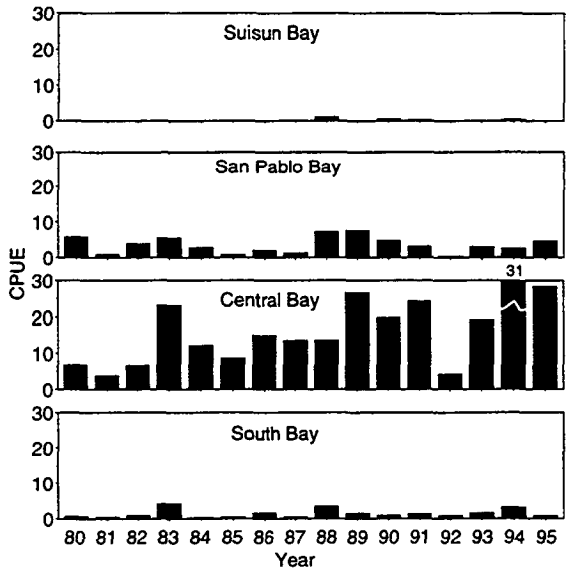

Figure 5 Annual distribution of age–1+ plainfin midshipman captured in the otter trawl from 1980 to 1995. Data are the mean CPUE for February to September by region.

Annual Distribution

Age–0 plainfin midshipman usually ranged from South to Suisun bays but the annual CPUE was generally highest in Central Bay and next highest in San Pablo Bay (Figure 4). In 1980, 1992, and 1994, a few age–0 fish were present in the west delta (too few to show in Figure 4). Age–1+ fish had a similar distribution but with an even stronger concentration in Central Bay (Figure 5). None were caught in the west delta.

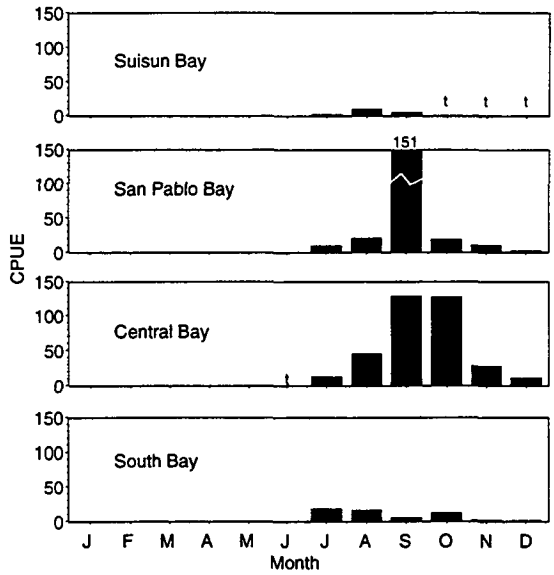

Figure 6 Seasonal distribution of age–0 plainfin midshipman captured in the otter trawl. Data are the mean CPUE by region for 1981 to 1988. Numbers too small to show at this scale are indicated with a "t" (trace).

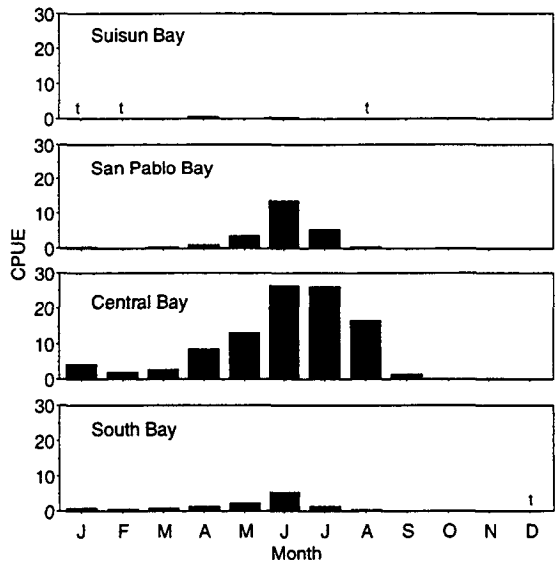

Figure 7 Seasonal distribution of age–1+ plainfin midshipman captured in the otter trawl. Data are the mean CPUE by region for 1981 to 1988. Numbers too small to show at this scale are indicated with a "t" (trace).

Seasonal Distribution

The average 1981–1988 seasonal distribution of age–0 plainfin midshipman showed that CPUE was highest in South Bay in July, in Central Bay in August, in San Pablo Bay in September, and again in Central Bay from October to December (Figure 6).

The CPUE of age–1+ plainfin midshipman was always higher in Central Bay than in other regions throughout the year (Figure 7). From January to March, the age–1+ fish were primarily new recruits and their distribution was proportionally similar to that of age–0 fish in December.

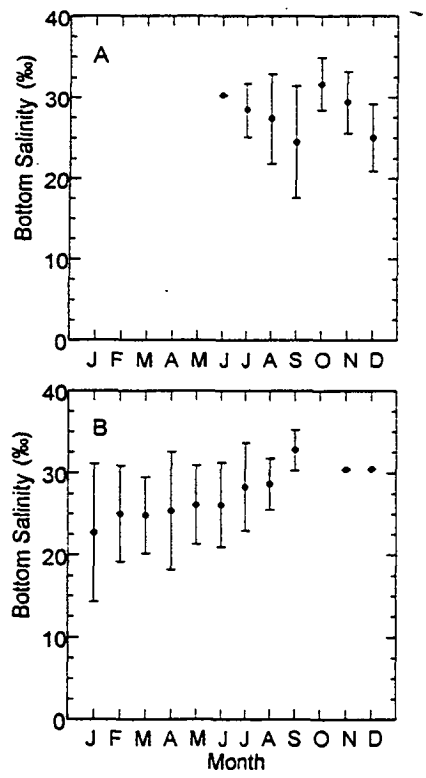

Figure 8 Seasonal salinity (‰) distribution (mean ±1 standard deviation) of (A) age–0 and (B) age–1+ plainfin midshipman captured in the otter trawl from 1981 to 1988

Salinity and Temperature

Although age–0 plainfin midshipman were found as far upstream as the west delta, both age groups occupied primarily salinities >15‰ (Figure 8). Age–0 fish were initially captured in the net in Central Bay at a salinity of about 30‰. As CPUE increased in other regions, mean salinity declined to about 24.5‰ in September. Rapid emigration from Suisun and San Pablo bays between September and October resulted in an abrupt increase in mean salinity to about 31‰. Fish congregated in Central and South bays in October before leaving the estuary. Mean salinity declined from October to December as fish emigrated from Central and South bays more rapidly than those that remained in San Pablo Bay, and as estuarine salinity declined.

In January, the few age–1+ plainfin midshipman collected were found in a wide range of salinities with a mean of about 23‰ (see Figure 8). Through March their salinity distribution narrowed and the mean increased slightly to about 25‰ as their geographic distribution shifted toward Central and South bays (see Figure 7). In April, as mature fish began entering the estuary in search of nest sites, their salinity distribution broadened slightly, but as the process continued through its peak in June the distribution stabilized around a mean salinity of about 26‰. After June, mean salinity climbed to almost 33‰ in September as fish immigrated to the coast.

Age–0 plainfin midshipman were found at the highest temperatures ($\bar{\chi}$ = 18 to 20 °C) and over the broadest temperature range in July and August as they first recruited to the net (Figure 9). From September through December mean temperature declined to just above 12 °C.

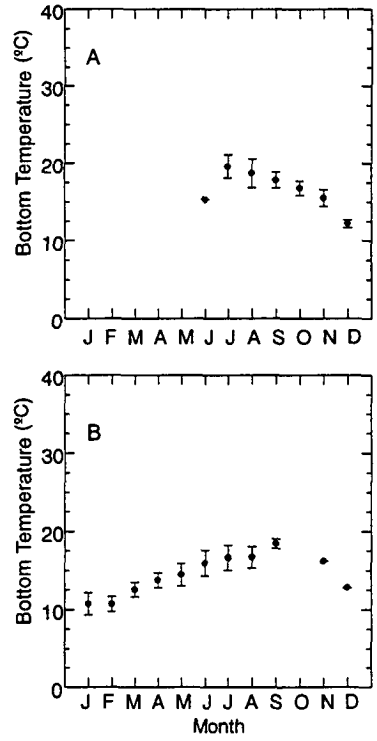

Figure 9 Seasonal temperature (°C) distribution (mean ±1 standard deviation) of (A) age–0 and (B) age–1+ plainfin midshipman captured in the otter trawl from 1981 to 1988

Age–1+ plainfin midshipman were collected from cool temperatures in January and February (mean temperature about 11 °C, see Figure 9). As abundance increased to a peak in June, mean temperature increased to about 16 °C. After June, age–1+ fish began to emigrate as estuarine temperatures continued to increase (see Salinity and Temperature chapter, Figure 12). The two processes counteracted each other and mean temperature rose only slightly through August. After August, temperature statistics were based upon few fish.

Discussion

The dates and locations of capture of age–1+ plainfin midshipman indicate that they used the estuary as a spawning ground. Age–1+ fish were collected from April through August, their reported spawning period (Wang 1986), and their distribution was similar to the subsequent distribution of age–0 fish. Furthermore, age–1+ fish were rare or absent from collections in the estuary during fall, and those collected before April were mostly newly recruited (that is, age 1). Thus, most older age–1+ fish were only in the estuary during their spawning season.

The seasonal pattern of abundance and the length-frequency distribution suggests that age–0 plainfin midshipman used the estuary as a nursery area, as did some younger age–1+ fish. Other age–0 fish appeared to emigrate out of the estuary in fall to return as young age–1+ the next spring. These young age–1+ fish remained in the estuary until August when a large decline in their abundance indicated they had emigrated to the ocean. The timing of this decline coincided with the decline and presumed emigration of older, possibly mature, fish.

Another indication that both age groups emigrated to the ocean was their seasonal shift in distribution. In fall, the abundance of age–0 fish in South and San Pablo bays declined as abundance increased in Central Bay, indicating a movement toward the Golden Gate. In November and December abundance dropped in Central Bay, suggesting that age–0 fish emigrated from the estuary. Age–1+ fish showed a similar pattern of movement but apparently emigrated in August and September.

The plainfin midshipman may mature and spawn in 1 year. However, the presence of age classes older than age 1, and the fact that most spawners are believed to die after spawning (Fitch and Lavenberg 1971), suggests that some age–1 fish do not spawn or that some spawners survive to spawn a 2nd time.

Although age–0 fish can tolerate freshwater (Wang 1986), few were collected in salinities <17‰. However, their salinity range would have been lower if the fish in their 1st winter of life that were found in low salinity water had been classified as age–0 instead of age–1+. Instead, inclusion of these young fish in the age–1+ group lowered the salinity range of the age–1+ fish.

References

Fitch, J.E. and R.J. Lavenberg. 1971. Marine food and game fishes of California. University of California Press, Berkeley, California. California Natural History Guides Volume 28.

Hart, J.L., editor. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada, Bulletin 180.

Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. California Department Fish and Game, Fish Bulletin 157.

Wang, J.C.S. 1986. Fishes of the Sacramento–San Joaquin Estuary and adjacent waters, California: A Guide to the early life histories. Interagency Ecological Study Program for the Sacramento–San Joaquin Estuary, Technical Report 9.