NOAA Technical Report NMFS 78 August 1989

Survey of Fishes and Water Properties of South San Francisco Bay, California, 1973-82

Donald E. Pearson

U.S. Department of Commerce

NOAA TECHNICAL REPORT NMFS

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Robert Mosbacher, Secretary
National Oceanic and Atmospheric Administration
William E. Evans, Under Secretary for Oceans and Atmosphere
National Marine Fisheries Service
James Brennan, Assistant Administrator for Fisheries

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Survey of Fishes and Water Properties of South San Francisco Bay, California, 1973-82

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ABSTRACT

The objective of this study was to describe the physical and ichthyological changes occurring seasonally and annually in the south San Francisco Bay, based on the results of 2,561 otter trawl and water samples obtained between February 1973 and June 1982. Temperature varied predictably among seasons in a pattern that varied little between years. Salinity also underwent predictable seasonal changes but the pattern varied substantially between years. The most abundant species of fish were northern anchovy (*Engraulis mordax*), English sole (*Parophrys vetulus*), and shiner surfperch (*Cymatogaster aggregata*). The majority of the common fish species were most abundant during wet years and least abundant in dry years. Numeric diversity was highest during the spring and early summer, with no detectable interannual trends. Species composition changed extensively between seasons and between years, particularly years with extremely high or extremely low freshwater inflows. All the common species exhibited clustered spatial distributions. Such spatial clustering could affect the interpretation of data from estuarine sampling programs. Gobies (Family Gobiidae) were more abundant during flood tides than during ebb tides. English sole were significantly more abundant in shallower areas. Shiner surfperch showed significant differences in abundance between sample areas.

Introduction

With approximately 3.5 million people living in the area, the San Francisco Bay (also known as the San Francisco Estuary) is heavily impacted by man's activities. One of the most critical environmental issues for this estuary is the role of freshwater inflow. As increasing demands are placed on the freshwater sources to the estuary, it becomes increasingly important to understand the estuary as it is affected by freshwater inflow.

San Francisco Bay has four distinct sections: the delta, north bay, central bay, and the south bay (Fig. 1). The delta is formed by the confluence of the Sacramento and San Joaquin Rivers and is a region of freshwater. The north bay includes the null zone (tidal wedge) which varies in location depending on river outflows (Rozengurt et al. 1987). Most freshwater entering the estuary comes from the delta and passes through the north bay (Conomos 1979). The central bay connects the Pacific Ocean, the north bay, and south bay. Generally quite deep, the cental bay is probably the most diverse region of the estuary based on habitat types, hydrology, and geography. The south bay is shallow, with a mean depth of only 3 meters (McCulloch et al. 1970), and obtains most of its freshwater from the north bay (Conomos 1979). Flushing of the south bay is generally poor.

Two major ecological studies have been conducted on large portions of the San Francisco Bay. One, an ongoing study by the California Department of Fish and Game (DFG), is a long-term sampling program of the entire estuary with the specific goal of determining the effects of freshwater inflow on the estuary. As part of the study, they hope to obtain baseline data and achieve a more complete understanding of the ecology of the estuary (Perry Herrgesell, Calif. Dep. Fish Game, Wilson Way, Stockton, CA 95211, pers. commun. Sept. 1988). To accomplish these goals, DFG samples 42 stations throughout the estuary. Each station is sampled once a month using an otter trawl, a midwater trawl, and a water sampler. They have found that most fish species within the estuary show a mixed response to delta outflows (DFG 1987).

The other important ecological study of San Francisco Bay was done by Aplin (1967), in which he examined six stations in south San Francisco Bay from 1963 to 1966. Each station was sampled once a month using a midwater trawl, an otter trawl, a water sampler, and a sediment sampler. Results were tabulated with little attempt to interpret the data. One of Aplin's sampling stations was located near one of the stations used in the present study, and specific details of his results are compared with those of this study in the "Species Composition" section.

This study was undertaken to examine the spatial and temporal variation of selected elements of the fish fauna and of water characteristics of the estuarine habitat in the south San Francisco Bay. By intensively examining a small portion of the estuary from February 1973 to June 1982, it was possible to determine relative abundances by month and year of the most common fish species. Patterns of distribution were also examined. In addition, it was possible to test for the

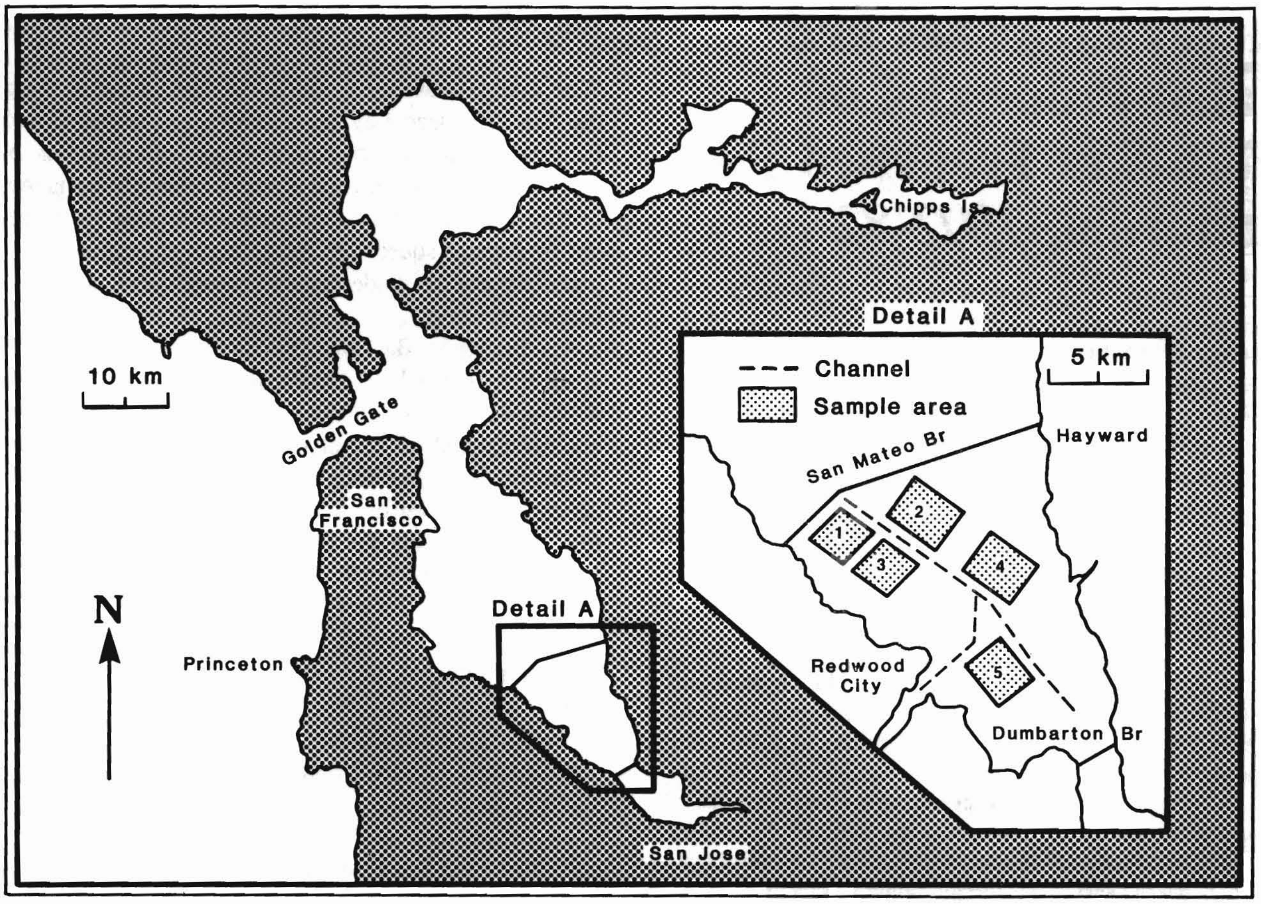

Figure 1
Locations of five sampling stations in south San Francisco Bay, California, used in this study.

effects of tide, time, depth, and location on fish catches. Sampling was done by Marine Ecological Institute (MEI), a private, nonprofit, educational organization, as part of their marine science education program.

This study differs from the Aplin and DFG studies in several respects: its more limited geographic scale, its reliance on a larger number of samples each month (Appendix A) and on longer-term sampling, and the fact that it was conducted as part of an education program. An intensive examination of a small region of the estuary is useful because it reveals some of the small-scale biological characteristics of the environment.

An additional characteristic of this study which makes it valuable is the time-period covered. Two events during the study period, a drought in 1976-77 and two extremely wet years in 1974 and 1980 (Table 1), made it possible to examine the effects of large fluctuations in freshwater inflow on the salinity and biota of the area. The intensive nature of this study allowed reasonably accurate estimates of relative abundances of major species during these events.

Materials and methods

Sampling

During the study period, Marine Ecological Institute (MEI) conducted educational cruises in south San Francisco Bay. Each cruise took four hours, and occasionally two cruises were made in a single day. On a typical cruise, two trawls, two water samples, and a sediment grab sample were made, each at one of five sampling stations (Fig. 1). The time, location, depth, and distance of each trawl were recorded.

The five sampling stations were loosely defined. Each station was bounded on one side by the deepwater channel and on the opposite side by shallows, with roughly defined endpoints. The stations were in depths of 1.5 to 14 meters. Sediment samples were collected with a Petersen grab sampler having a 2-liter capacity or occasionally using a Phleger core sampler with a 1-meter-long shaft. The sediments were qualitatively examined for texture and contents; no attempt was made at quantification. Water samples were collected with a Kemmerer bottle from 1 meter below the surface. The temperature was determined using an electronic meter or occasionally with a thermometer, both with an accuracy of $\pm 0.5°C$. Salinity was determined by hydrometer

Table 1
Mean monthly delta outflow values (mean m^3/s) at Chipps Island monitoring station, south San Francisco Bay. Source: Calif. State Water Resour. Board, Sacramento, CA (unpubl. data, Nov. 1988).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1973	2869	2891	2158	631	331	204	130	169	316	398	1696	2153
1974	3925	1688	2172	3091	723	480	250	362	594	524	679	793
1975	494	1592	1855	977	815	637	315	270	380	478	509	568
1976	265	212	222	250	115	111	123	128	101	103	103	119
1977	124	139	87	87	113	71	91	70	79	59	112	240
1978	1873	1589	2402	1715	1137	257	113	168	334	273	309	249
1979	862	1312	1069	410	380	151	152	98	143	221	345	539
1980	3345	3433	2807	812	592	421	317	118	280	209	189	353
1981	625	618	750	330	254	129	150	90	133	144	1017	2352
1982	2766	2510	2266	3967	1638	807	477	380	734	651	1108	2507
1983	2497	4904	7705	3341	2773	2031	1218	691	887	914	2098	4399
1984	2855	1175	988	417	317	226	289	233	384	337	734	879
1985	428	441	295	196	208	147	139	65	90	267	195	267
Mean	1764	1732	1913	1250	725	436	291	219	343	352	699	1186
SD	1342	1392	1971	1347	759	528	301	176	257	240	629	1287

with an accuracy of ±0.5 ppt. The otter trawl had a 4.9-meter headline, 3.8-cm mesh, with 0.64-cm mesh (stretched) in the codend. The net was secured to the ship with 23-meter warps. After the net was fully deployed, a timer was set for 10 minutes at which time the net was recovered manually. The catch was placed in holding tanks on deck where the fish were counted and identified.

Analysis

Since these data were collected as part of an education program, analysis methods had to take into account several unusual characteristics of the data set. The two most important problems were unequal sampling effort between months and the sometimes imprecise species identifications.

Initially about 3,500 trawls were made. Data were discarded from 939 trawls because of hung-up nets or illegible or misplaced data sheets. A total of 2,561 trawls remained for analysis. To correct for differences in the number of trawls per month (Appendix A), the results were reported as mean catch-per-trawl per month. Statistical techniques capable of handling unequal sample sizes were used as required. All analyses were done on this basis except the species list (Table 2). Data from months with less than five trawls were not used in this study due to the possibility of clustered distributions which might reduce the reliability of abundance estimates.

Based on direct observation and discussion with the ship's crew, some species identifications were considered questionable. In addition, many species had been recorded only to family level. Captured taxa were organized using a simple classification system described below:

Primary species
1 Readily identifiable to species, and
2 common (at least 1% of total catch);

Primary family
1 Readily identifiable to family, and
2 common (as a family composing at least 1% of catch);

Secondary species
1 Readily identifiable to species, and
2 uncommon (<1% of catch);

Secondary family
1 Readily identifiable to family, and
2 uncommon (<1% of total catch);

Tertiary species
1 Identification questionable and/or
2 uncommon or rare in the catch;

Tertiary family
1 Identification questionable and/or
2 uncommon or rare in the catch.

Data on the primary species/families were considered sufficiently reliable to yield valid seasonal and yearly trends and to allow statistical testing of distribution and the effects of trawl variables. The secondary species/family data were deemed inadequate for statistical analysis, and only yearly and seasonal trends were used. Data on the tertiary species/families were considered unreliable, and no analysis was performed.

Seasonal trends were determined from the unweighted mean monthly catch-per-trawl. To determine yearly trends, relative values for the month of peak abundance were compared for each of the primary species/families showing pronounced seasonal trends. Otherwise, the mean monthly catch values were compared over the entire year.

Prior to examining temporal and spatial distribution patterns of the primary species/families, it was necessary to test the effects of tide, time, depth, and location on catches. This was necessary because MEI made no attempt to sample equally at all depths, tide states, times, or sampling stations. In order to combine all of the trawls from an entire

Table 2
Species list for south San Francisco Bay from Marine Ecological Institute's trawl study, 1973-82. (M = marine, F = fresh, E = estuarine, A = anadromous).

Species	Type	*N*	Category
Northern anchovy, *Engraulis mordax*	M	199,389	Primary species
English sole, *Parophrys vetulus*	M	49,469	Primary species
Shiner surfperch, *Cymatogaster aggregata*	M	37,469	Primary species
Gobys, Family Gobiidae		7,017	Primary family
Yellowfin goby, *Acanthogobius flavimanus*	E		
Chameleon goby, *Tridentiger trigonocephalus*	M		
Bay goby, *Lepidogobius lepidus*	M		
Cheekspot goby, *Ilypnus gilberti*	M		
Pacific herring, *Clupea harengus*	M	6,534	Primary species
Sanddabs, Family Bothiidae		6,052	Primary family
Pacific sanddab, *Citharichthys sordidus*	M		
Speckled sanddab, *Citharichthys stigmaeus*	M		
Staghorn sculpin, *Leptocottus armatus*	E	3,344	Primary species
Dwarf surfperch, *Micrometrus minimus*	M	2,446	Primary species
Barred surfperch, *Amphistichus argenteus*	M	1,107	Secondary species
White surfperch, *Phanerodon furcatus*	M	919	Secondary species
Brown rockfish, *Sebastes auriculatus*	M	884	Secondary species
Pile surfperch, *Damalichthys vacca*	M	744	Secondary species
Smelt, Family Osmeridae and Atherinidae		510	Secondary family
Longfin smelt, *Spirinchus thaleichthys*	E		
Surf smelt, *Hypomesus pretiosus*	M		
Night smelt, *Spirinchus starksi*	M		
Topsmelt, *Atherinops affinis*	M		
Jacksmelt, *Atherinopsis californiensis*	M		
California tonguefish, *Symphurus atricauda*	M	507	Secondary species
Brown smoothhound, *Mustelus henlei*	M	461	Secondary species
Leopard shark, *Triakis semifasciata*	M	423	Secondary species
Walleye surfperch, *Hyperprosopon argenteum*	M	388	Secondary species
Bay pipefish, *Syngnathus leptorhynchus*	M	382	Secondary species
White croaker, *Genyonemus lineatus*	M	380	Secondary species
Shad, Family Clupeidae		357	Secondary family
Threadfin shad, *Dorosoma petenense*	F		
American shad, *Alosa sapidissima*	A		
Diamond turbot, *Hypsopsetta guttulata*	M	333	Secondary species
Bat ray, *Myliobatus californica*	M	333	Secondary species
Plainfin midshipman, *Porichthys notatus*	M	310	Secondary species
Bonyhead sculpin, *Artedius notospilotus*	M	265	Secondary species
Starry flounder, *Platichthys stellatus*	E	262	Secondary species
California halibut, *Paralichthys californicus*	M	252	Secondary species
Black surfperch, *Embiotoca jacksoni*	M	123	Tertiary species
Spiny dogfish, *Squalus acanthias*	M	96	Tertiary species
Lingcod, *Ophiodon elongatus*	M	65	Tertiary species
Pacific tomcod, *Microgadus proximus*	M	58	Tertiary species
Pacific sardine, *Sardinops sagax caeruleus*	M	40	Tertiary species
Striped bass, *Morones saxatilis*	A	30	Tertiary species
Sand sole, *Psettichthys melanostictus*	M	22	Tertiary species
Skates, Family Rajidae		14	Tertiary family
Big skate, *Raja binoculata*	M		
California skate, *Raja inornata*	M		
Sturgeon, Family Acipenseridae		9	Tertiary family
Green sturgeon, *Acipenser medirostris*	A		
White sturgeon, *Acipenser transmontanus*	A		
Rubberlip surfperch, *Rhacochilus toxotes*	M	2	Tertiary species
Rainbow surfperch, *Hypsurus caryi*	M	2	Tertiary species
Opaleye, *Girella nigricans*	M	1	Tertiary species
Cabezon, *Scorpaenichthys marmoratus*	M	1	Tertiary species
Rex sole, *Glyptocephalus zachirus*	M	1	Tertiary species
C-O sole, *Pleuronichthys coenosus*	M	1	Tertiary species
Calico rockfish, *Sebastes dallii*	M	1	Tertiary species
Longjaw mudsucker, *Gillichthys mirabilis*	M	1	Tertiary species
Spotfin croaker, *Roncador stearnsii*	M	1	Tertiary species
Saddleback gunnel, *Pholis ornata*	E	1	Tertiary species
Sevengill shark, *Notorynchus maculatus*	M	1	Tertiary species

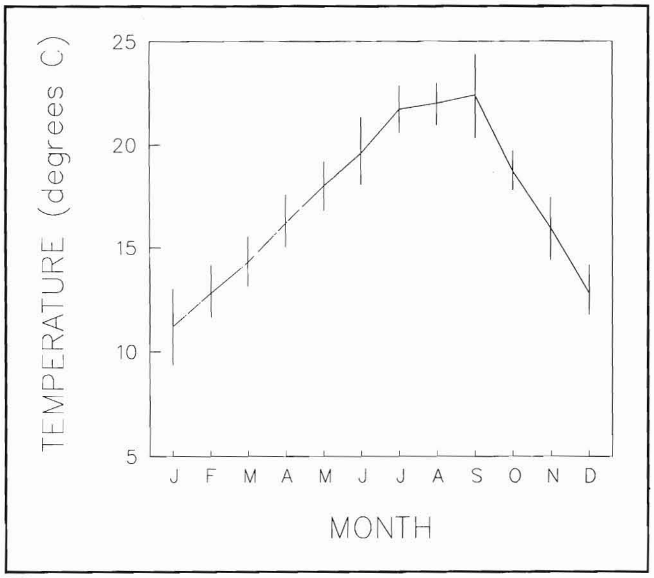

Figure 2
Seasonal temperature trends (mean and standard deviation) in the south San Francisco Bay study area, 1973-82.

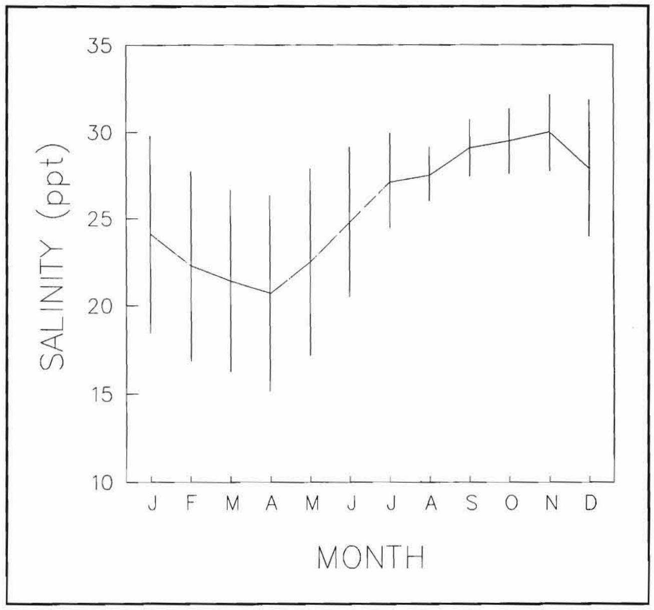

Figure 3
Seasonal salinity trends (mean and standard deviation) in the south San Francisco Bay study area, 1973-82.

month into a single abundance value, it was important to eliminate as many variables as possible. The analysis was also useful for describing the distribution of different species. The 15 months showing highest abundances of the primary species were selected from the data set. A Friedman's test (nonparametric, randomized block design) was employed, with each month used as a block. Those months were omitted in which total catch of a species was less than 5 fish.

To test for the effect of location on catch, the samples were sorted by station, then mean catch-per-trawl was calculated, and the stations were ranked within the block. To test for tidal effects on catch, the trawls from each month were divided into flood- and ebb-tide groups, and mean catch-per-trawl was calculated. To test for the effect of time of day, the samples were sorted into two groups: trawls made before 10:00 a.m., and trawls made after 12:00 p.m. To test for the effect of depth on catch, the samples from each month were divided into two groups: samples from less than 3-meter depths and those taken in depths greater than 4 meters.

To examine distribution patterns, the variance-to-mean ratios for each month were plotted on histograms for each species. The histograms were then inspected for evidence of clustering which would show as skewing of the histogram at some ratio greater than 1.0.

Results

Physical characteristics

Temperature

Water temperatures in the sample area underwent distinct seasonal changes during the study period (Fig. 2). From a mean monthly low in January of 11.0°C, the temperature climbed to a mean monthly high of 22.5°C in September. The highest monthly average was recorded in September of 1979 at 24.5°C, and the lowest mean monthly temperature was in January 1982 at 8.5°C (Appendix B). Standard deviations were less than 1.7°C, indicating little variation from year to year.

Salinity

Salinity also showed a distinct seasonal pattern (Fig. 3), but standard deviations of monthly means between years were high. The mean monthly low of 20.5 ppt (SD = 5.70 ppt) occurred in April. The mean monthly high of 30.0 ppt (SD = 1.7 ppt) occurred in November. The highest monthly salinity was 33.5 ppt in December 1977, and the lowest monthly value was 12.5 ppt in April 1982 (Appendix C). During the 1977 drought, the lowest monthly salinity was 30.5 ppt. Salinity can drop rapidly in the area, as evidenced by a decrease from 30.5 ppt in December 1979 to a mean value of 19.5 ppt in January 1980.

Substrate

Although no quantitative analysis was performed, sediment samples appeared to be similar between stations. The northwest station had a small region of exposed oystershell bed with some live oysters. Otherwise, the substrate consisted of a fine silty clay with variable amounts of crushed shell material. Color of the substrate varied from light brown to dark blackish-brown. Some samples had a strong odor of hydrogen sulfide. Living organisms typically included amphipods, polychete worms, cockles, clams, and mussels. In samples with oyster shells, several other types of invertebrates were observed. Some of the core samples revealed a layer of oyster shells buried at variable depths beneath the top layer of sediment. It was not possible to examine yearly or monthly variations of the substrate samples.

Icthyological characteristics

General

A total of 59 species were observed during the study (Table 2). The species were sorted according to the classification scheme described earlier into six primary species, two primary families, 16 secondary species, two secondary families, 18 tertiary species, and two tertiary families. Of the 59 species, one was a freshwater type, five were anadromous, seven were classified as estuarine, and the rest were marine (Table 2). All of the primary species/families were marine.

Time of day showed no significant effect on the catch of any of the primary species/families (Table 3). Gobies (Family Gobiidae) were significantly more abundant during flood tides than during ebb tides, indicating a movement into the sample areas. English sole (*Parophrys vetulus*) were significantly more abundant in shallower areas. Shiner surfperch (*Cymatogaster aggregata*) abundances were significantly different between stations, with station 4 (Fig. 1) having the smallest catches. These findings made it necessary to assure that each of the significant variables were equally represented in each month. For months when this was not the case, catches of the affected species were sorted, mean catch-per-trawl was calculated for each sort group of the variable, and an unweighted mean catch-per-trawl was computed. These values were then used in subsequent examinations.

The distribution analysis revealed that all of the primary species/families exhibited clustered distributions. Figure 4 shows the histograms of the variance-to-mean ratios for all months in the study. Since all of the histograms show the variance-to-mean ratio is usually much greater than 1.0, there is clear evidence of clustering. Since most species showed no significant differences between stations, the aggregations were considered to be smaller than catches at sampling stations, with the possible exception of shiner surfperch. Of the primary species/families, northern anchovy (*Engraulis mordax*) and English sole exhibited the strongest degree of clustering, and Pacific herring (*Clupea harengus*) and staghorn sculpin (*Leptocottus armatus*) showed the lowest degree. The clustering is probably spatial in nature since there was no difference in catch based on time or tide. The only exception to this was the goby family which are probably both spatially and temporally clustered, with groups of fish moving into the study areas during flood tides.

Seasonal changes

All of the primary species/families except dwarf surfperch show clear seasonal trends (Fig. 5). Although the data are less reliable, the majority of secondary species/families also appear to show pronounced seasonal trends. In nearly all species, peak abundance occurs from March through July with progressively lower abundance through October and November (Appendix D). Some species such as northern anchovy and shiner surfperch were abundant year-round. Others were nearly absent during many months, including English sole which were virtually absent from August through December.

Numeric diversity exhibited a seasonal change, with peak diversity of 5.3 species per trawl occurring in April (Fig. 6). Lowest diversity typically occurred in October, with 2.2 species per trawl. Timing of maximum and minimum diversities varied substantially between years (Appendix E).

Species composition varied substantially among seasons (Fig. 7). While at least six of the eight primary species/families were always among the ten most abundant species, their relative abundances varied substantially through the year. In January the total number of fish was low but relative abundance of the species was fairly uniform. In October the total number of fish was high but relative abundance of the species was decidedly skewed, with two species (northern anchovy and shiner surfperch) making up 95% of the catch.

Table 3
Results of nonparametric randomized block analyses (Friedman's Test) on trawling variables in south San Francisco Bay, 1973-82, from Marine Ecological Institute study. Critical value for depth, tide, and time (α=0.05, 1 df) = 3.841. Critical value for location (α=0.05, 3 df) = 7.815. Asterisks indicate significant effects.

Species	Depth	Tide	Time	Location
Northern anchovy	0.042	0.657	0.566	1.325
English sole	6.194*	1.887	1.633	3.402
Shiner surfperch	1.887	0.657	0.033	14.960*
Pacific herring	0.657	1.887	3.232	2.805
Goby family	0.657	6.194*	1.633	1.667
Sanddab family	1.887	3.733	1.633	1.111
Staghorn sculpin	3.733	0.042	1.633	0.902
Dwarf surfperch	0.042	0.657	0.566	4.541

Annual changes

Many species exhibited large changes in abundance from year to year (Table 4). Northern anchovy was four times as abundant in 1973 as in any other year. English sole was very abundant in 1974 and nearly absent in 1977. White croaker (*Genyonemus lineatus*) and California tonguefish (*Symphurus atricauda*) were nearly absent in all years except 1977. For those species with identifiable yearly differences, 49% were most abundant in 1974 and 50% were least abundant in 1977. Based on delta outflows (Table 1), 1974 was the wettest year and 1977 was the driest.

Although diversity varied between years, there were no detectable trends in the variation. In a comparison of wet and dry years, both magnitude and timing of high/low diversity appeared to vary randomly (Appendix E). Comparison of the warmest year (1979) with the coldest year (1982) also failed to show any trends.

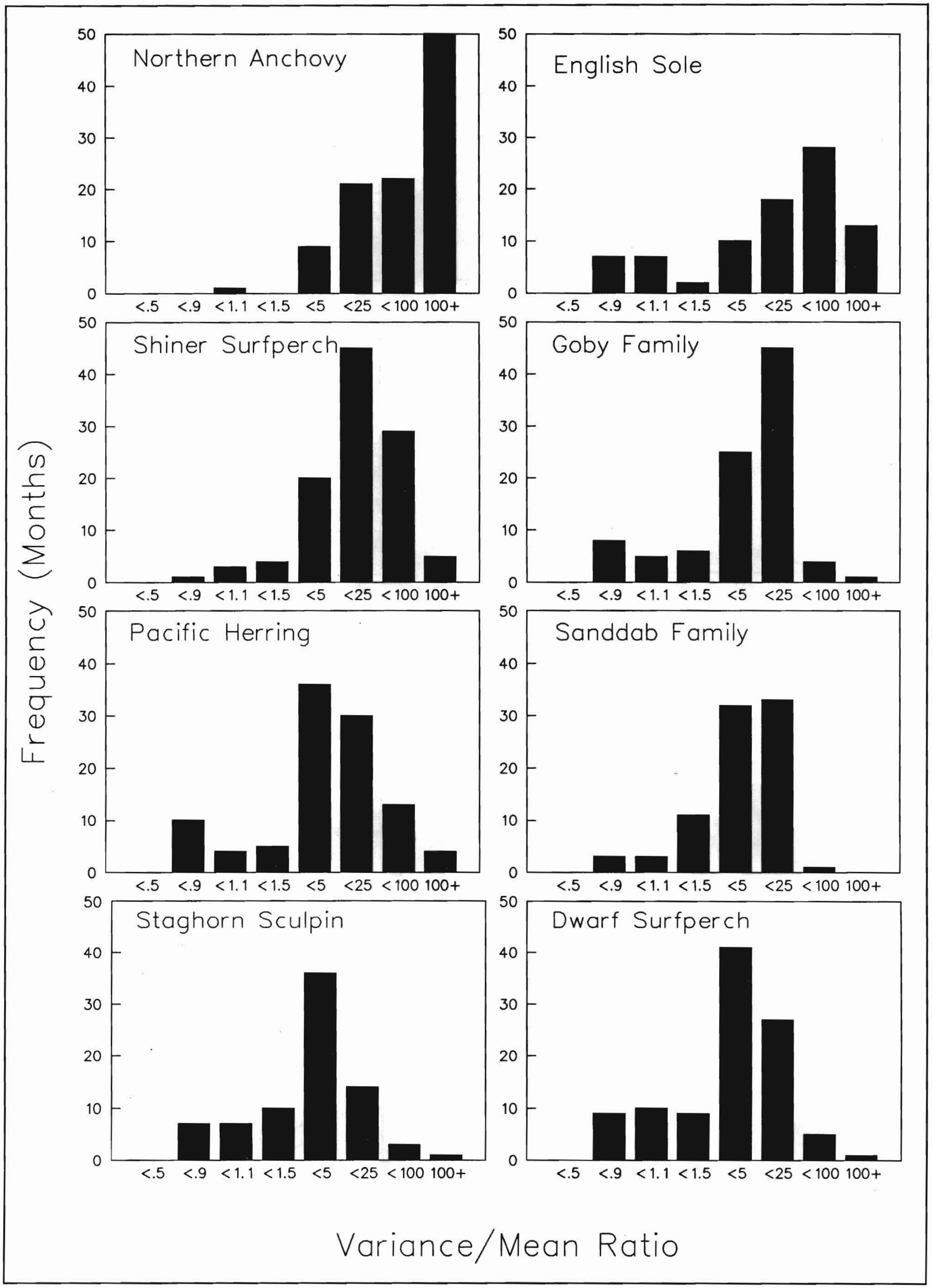

Figure 4

Variance-to-mean ratios of monthly catches of the most abundant fish species collected in otter trawls, south San Francisco Bay, 1973-82. Note the clustered distribution of species in the study area.

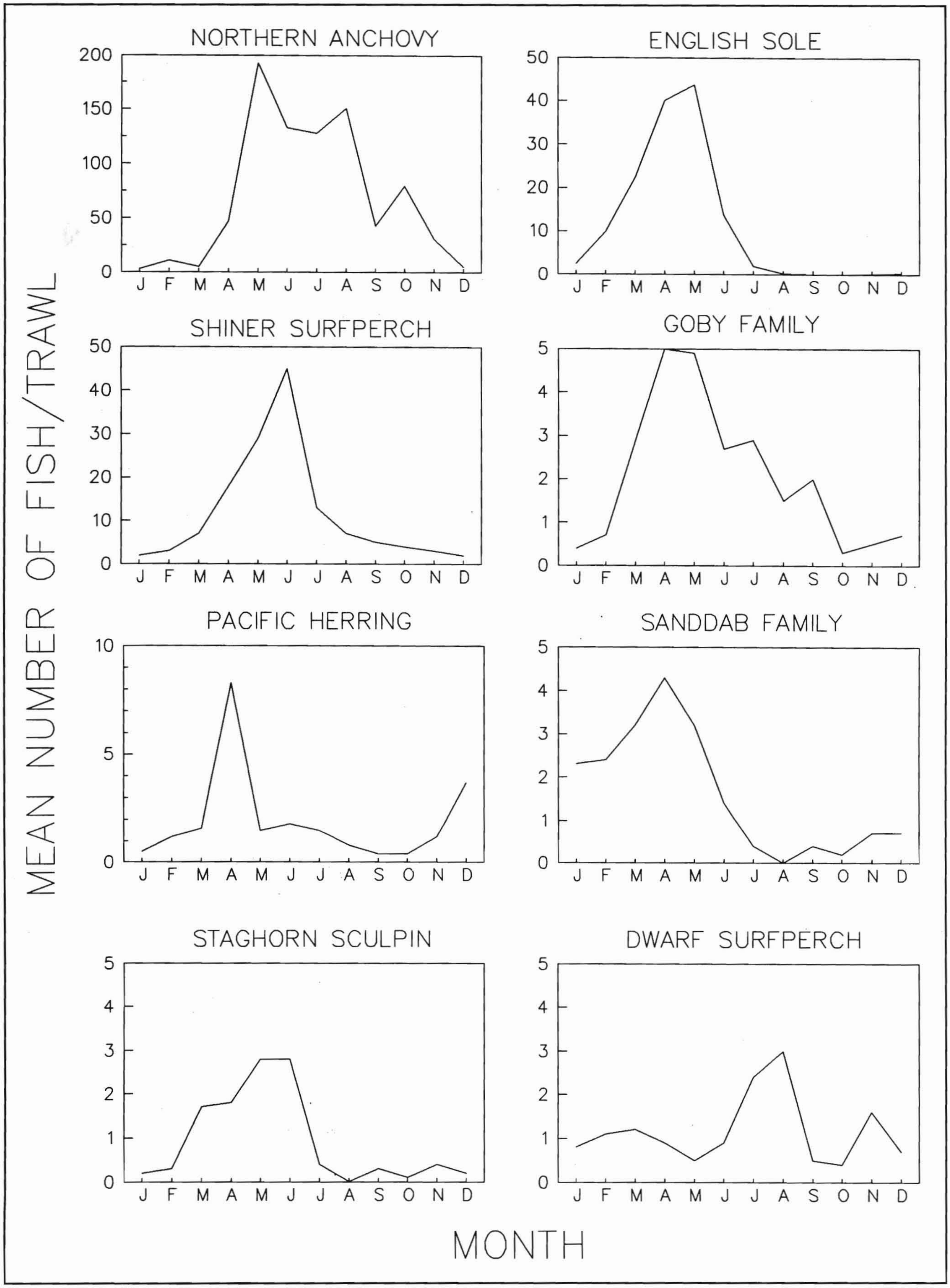

Figure 5
Seasonal abundance trends of the most common fish species caught in otter trawls, south San Francisco Bay, 1973-82.

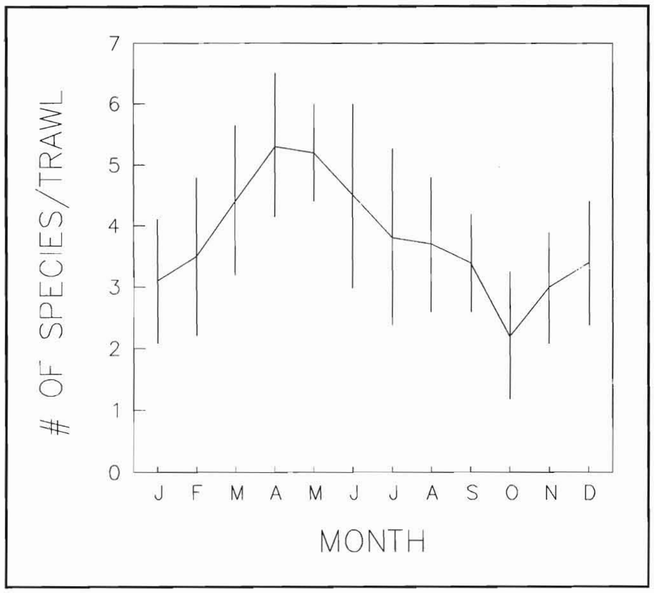

Figure 6
Seasonal trends in numeric diversity of fish species caught in otter trawls, south San Francisco Bay, 1973-82, showing standard deviation range.

Table 4
Highest and lowest abundances of common fish species captured in otter trawls, south San Francisco Bay, 1973-82. Abundances given as mean number of fish per trawl during the month of highest/lowest abundance.

	Highest		Lowest	
Common name	Year	Abundance	Year	Abundance
Northern anchovy	1973	936.8	1980	62.1
English sole	1974	101.2	1977	1.5
Shiner surfperch	1974	85.0	1977	18.2
Goby family	1976	10.2	1978	3.5
Pacific herring	1974	13.9	1977	0.6
Sanddab family	1974	14.0	1976	1.1
Staghorn sculpin	1974	7.4	1977	1.1
Dwarf surfperch	1974	10.8	1977	1.0
Barred surfperch	1979	3.1	1975	0.2
White surfperch	1974	4.5	1977	0.2
Brown rockfish	1974	5.1	1976	0.1
Pile surfperch	1974	4.0	1977	0.1
Smelt family	1977	4.0	?	0.0
California tonguefish	1977	4.7	?	0.0
Brown smoothhound shark	1973	2.8	1979	0.2
Leopard shark	1980	2.3	1977	0.2
Bay pipefish	1979	1.8	1977	0.2
White croaker	1977	7.5	?	0.0
Diamond turbot	1978	1.3	1982	0.1
Bat ray	1976	1.3	1978	0.2
Starry flounder	1974	0.5	1982	0.0

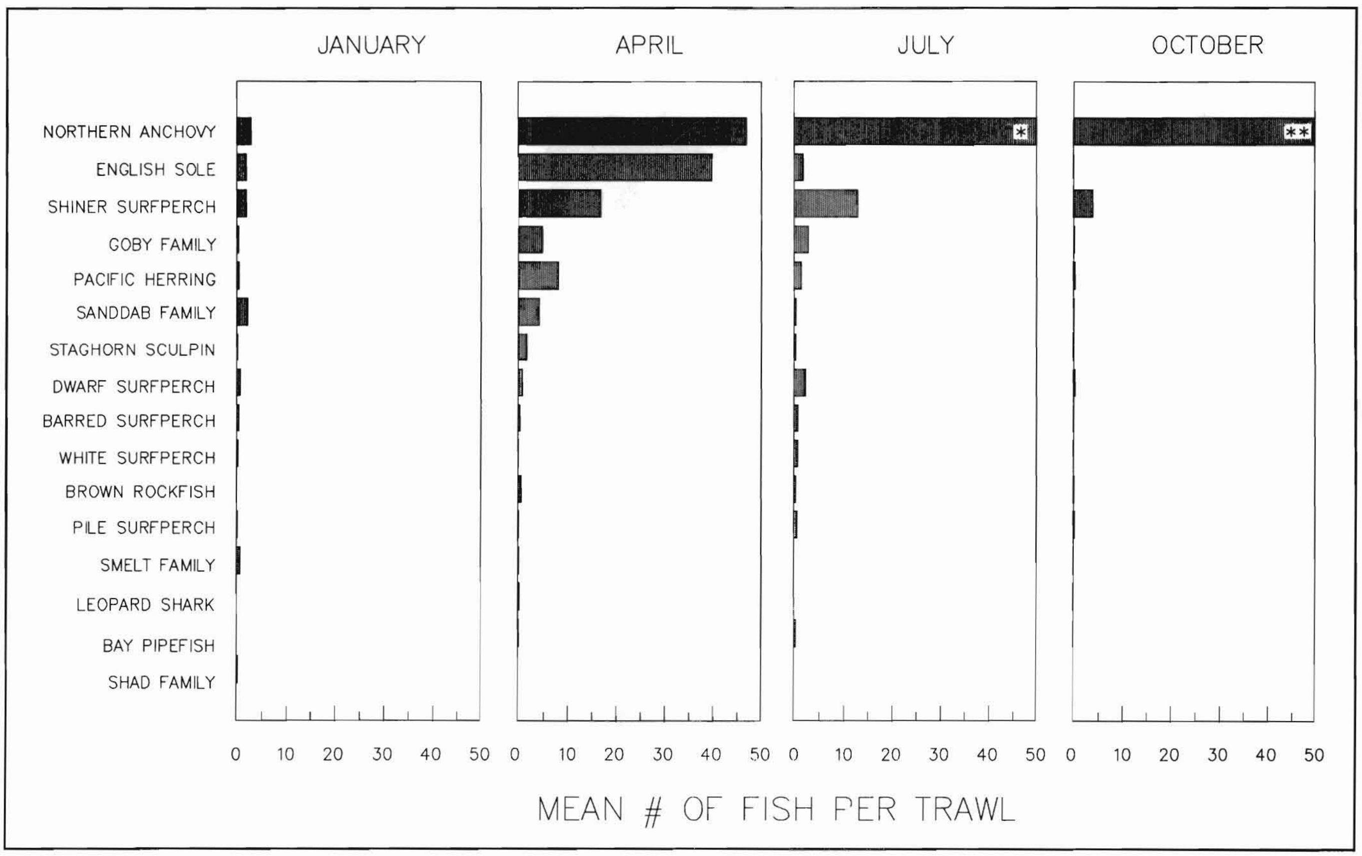

Figure 7
Seasonal comparison of the most abundant species caught in otter trawls, south San Francisco Bay, 1973-82. Abundance values are unweighted. Actual values for northern anchovy exceed the vertical axis (*80 fish per trawl, **129 fish per trawl).

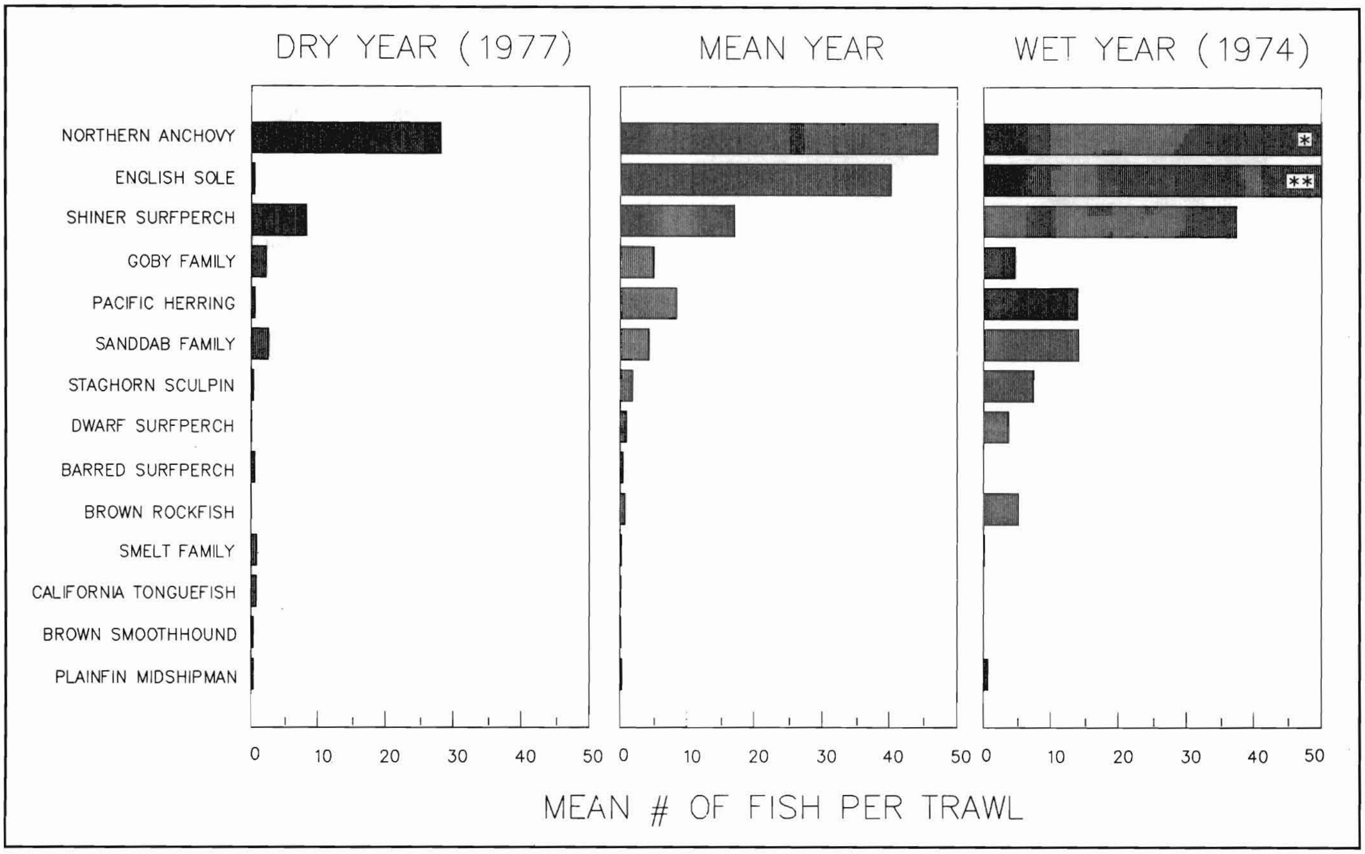

Figure 8

Comparison of species composition in otter trawls, south San Francisco Bay, in April during a wet year (1974), a dry year (1977), and the unweighted mean value for 1973-82. Actual values for northern anchovy and english sole exceed the vertical axis (*61 northern anchovy per trawl, **191 English sole per trawl).

Annual change in species composition was also large (Fig. 8). During the drought year 1977, English sole were effectively absent, many species were present in reduced numbers, and some species were more common. The wettest year, 1974, saw increased abundances of most species but little change in relative abundances of the most common species. This may indicate that excess flows over a certain level may alter only total abundance of species but not species composition, although this is only conjecture.

Discussion

Life history

All of the primary species/families use the estuary as a nursery area, although the estuary may not be the exclusive nursery area for many species (Table 5). Northern anchovy spawn both in the ocean and the estuary and all of its life-cycle stages are found within the estuary. Anchovy were highly abundant throughout their months of spawning (April and September). Although English sole do not spawn in the estuary, juveniles use the estuary for the first year of their life. It is not known how important the estuary is to the survival of juvenile English sole, but one study in Oregon indicates that it may be quite important (Olson and Pratt 1973). Peak abundances of juvenile sole occurred approximately 2-3 months after their peak spawning time in January, which is consistent with the 7-10 week larval stage reported for this species. Shiner surfperch are common both in the estuary and in nearshore coastal waters. In this study shiners were present year-round, although they were most abundant during the spring, when spawning occurs. The gobies (Family Gobiidae) were most abundant during the spring when most species spawn. Pacific herring (*Clupea harrengus*) use the estuary as a spawning ground, laying their eggs on eelgrass beds and hard substrates. Herring support a lucrative fishery within the estuary, although commercial fishing is rare in the sample area. Peak abundance of herring in March coincides with hatching of the eggs in early spring. Sanddabs spawn in the ocean but, like English sole, are found as juveniles within the estuary. Peak abundance of sanddabs in spring does not appear to coincide with any stage in their life cycle. Staghorn sculpin spawn both in the ocean and the estuary during the spring and winter. This may coincide with their late-spring/early-summer peak abundances. Dwarf surfperch spawn both in the estuary and the ocean during late spring and early summer. No clear seasonal trends were

Table 5
Life history stages of selected species collected in south San Francisco Bay as part of Marine Ecological Institute trawl study, 1973-82. Spawning locations: O = ocean, E = estuary, D = delta (or freshwater). Estuarine stages: A = adult, J = juvenile, L = larvae. Lower-case letters imply lesser importance. Source: Wang 1981.

	Spawning		
Species	Location	Months	Stages
Northern anchovy	O/E	IV,IX	A,J,L
English sole	O	XI-II	J,l
Shiner surfperch	E	III-VIII	A,J
Yellowfin goby	O/E	IV-VIII	A,J,L
Bay goby	O/E	XI-VI	A,J,L
Cheekspot goby	O/E	?	A,J,L
Chameleon goby	E	V-VIII	A,J,L
Pacific herring	E	XI-IV	A,J,L
Speckled sanddab	O	III-IX	J,l
Staghorn sculpin	O/E	IX-IV	A,J,L
Dwarf surfperch	O/E	IV-VIII	A,J
Barred surfperch	O/E	?	A
White surfperch	O/E	?	A
Brown rockfish	O	XI-III	J,l
Pile surfperch	O/E	?	A,J
California tonguefish	E	VI-IX	A?,J
Brown smoothhound	O/E		A,J
Leopard shark	O/E	IV-VI	A,J
Walleye surfperch	O/E	III-VIII	A,J
Bay pipefish	E	V-VIII	A,J
White croaker	O/E	XI-V	A,J
Threadfin shad	D	IV-VIII	A
American shad	D	IV-VII	A,J
Diamond turbot	O	III-VII	A,J,l
Bat ray	O/E		A,J
Plainfin midshipman	O/E	V-VIII	A,J,L
Bonyhead sculpin	O/E	?	A,J
Starry flounder	O/E	XI-II	A,J,L
California halibut	O	II-VII	A,J,L

observed for this species, and therefore it is not possible to determine whether a peak exists which would coincide with a stage in their life cycle. Many of the secondary species/families share similar life histories.

Distribution pattern

The majority of species in the study area exhibit spatial clustering on a small scale. Clustering in fish is caused by both behavioral and environmental factors. In the study area there are few distinct habitats: no rocky areas, eelgrass beds, or wharf pilings. The substrate is believed to be relatively uniform. While schooling behavior accounts for the spatial clustering in anchovy, herring, and perch, the explanation for clustering in the flatfish is less clear. It is possible that the benthic environment is less uniform than previously thought. This is supported by the strong contagious distribution of English sole and sanddabs (Fig. 4). Such a distribution could be explained by a variable habitat. Jones (1961) found that benthic invertebrates in the estuary exhibited a clustered distribution. Recent studies by the U.S. Geological Survey (USGS) have found a series of north-south furrows in the south San Francisco Bay (John Chin, USGS, Menlo Park, CA 94025, pers. commun. Oct. 1988). The furrows are hundreds of meters in length, several meters wide, and up to a meter deep. The substrate in the bottom of the furrows may be somewhat coarser than on the sides. The furrows are thought to be hydrological in origin and may account for some of the clustering of benthic fish species. For example, if the bottom of the furrows are found to have substrates more favorable for food, this could cause fish to congregate. This is only speculation, however, and requires further investigation.

Table 6
Comparison of the ten most abundant species in the south San Francisco Bay, February-July, combined for all years, as reported in this study and in the Aplin study (1967). Species organized according to form used by Marine Ecological Institute.

MEI		Aplin	
Species	%	Species	%
Northern anchovy	61.60	Northern anchovy	95.08
English sole	15.70	Smelt family	2.26
Shiner surfperch	13.70	Shiner surfperch	1.25
Goby family	2.30	Pacific herring	0.77
Pacific herring	1.90	English sole	0.22
Sanddab family	1.80	Shad family	0.19
Staghorn sculpin	1.20	Staghorn sculpin	0.09
Dwarf surfperch	0.90	Goby family	0.07
Barred surfperch	0.40	Striped Bass	0.04
White surfperch	0.30	Leopard shark	0.04

Species composition

The most abundant species were found to be northern anchovy, English sole, and shiner surfperch. Aplin (1967) listed northern anchovy, smelts, and shiner surfperch as the most abundant species in the MEI study area. Direct comparison between Aplin's study and ours is not possible, due to Aplin's manner of presentation. However, by computing percent composition for all years during the interval of February-July for each study, it is possible to arrive at a rough comparison of species composition between the two studies (Table 6).

Aplin found large concentrations of northern anchovy, which made up 95% of his catch compared with only 62% of the catch in this study. Smelt (all species combined) made up 2.3% of Aplin's catch but less than 1% of ours. English sole comprised less than 1% of Aplin's catch compared with 16% of ours. Dwarf surfperch were never taken by Aplin, but they were the eighth most abundant species in this study. Aplin collected large numbers of striped bass (*Morone saxatilis*), which were fairly rare in this study. Aplin caught 8 showy snailfish (*Liparis pulchellus*), 2 king salmon (*Oncorhynchus tshawytscha*), and 2 steelhead (*Salmo gairdnerii*), all of which were never caught in our study. During Aplin's 4-year study he recorded 29 species compared with 59 in our 9.5-year study. Explaining these differences provides important insights into the design of a sampling program for the estuary.

The near absence of smelt from this study was in distinct contrast to the high levels in Aplin's study. The DFG study (1987) also indicates large numbers of smelt in the area. The explanation for this difference lies in the fact that the majority of smelt were caught by midwater trawl. The otter trawl is unable to sample the upper water column, and consequently the smelt present in the sample area were not caught in our study. Aplin collected 8 showy snailfish, and the DFG study indicates this species is caught by otter trawl only in the deep channel (Pat Coulston, Calif. Dep. Fish Game, Stockton, CA 95211, pers. commun. Sept. 1988). Since few of the trawls in this study were made in the deep channel, Showy snailfish were missed by MEI. The differences in relative abundance of northern anchovy between the Aplin study and ours can be explained by two factors: use of the midwater trawl, and the patchy distribution of this species. Because Aplin combined the midwater trawls with otter-trawl data, because both otter and midwater trawls can catch large numbers of anchovy, and because there is an overlap in the portion of the water column swept by the two types of net, it is concluded that their abundance in Aplin's study is higher relative to the benthic species than in actuality. The higher abundance of striped bass and the presence of steelhead and salmon are due either to historical changes in abundance or gear effectiveness. In this study, 59 species were collected compared with 29 in the Aplin study. In a study of otter trawls in Santa Monica bay, Fay et al. (1978) concluded that it took more than 100 trawls to catch 95% of the catchable species. Therefore, the difference in number of species may be attributed in part to the small number of trawls used in the Aplin study.

This study examined the effect of location on catch of the primary species/families. Although a significant difference in catch of shiner surfperch was observed between the five stations, the overall effect on the abundance estimates was small; therefore, it can be concluded that a single station can be used to represent a fairly large geographic area. This is an important consideration when designing a sampling program.

Given the clustered distributions found in this study, and the finding by Fay et al. (1978) that multiple tows were required to assess species composition in Santa Monica Bay, it seems apparent that multiple trawls are important for assessing species abundance in a given area. Equally apparent is the necessity for midwater trawls and perhaps other methods (beach seines, gillnets, traps) in analyzing species composition of the estuary.

Wet vs. dry years

Although the primary objective of this study was to examine the ecological nature of the study area, it was also possible to examine the differences between wet and dry years. Although 1982 actually showed higher freshwater inflows than 1980, 1982 was excluded from this comparison because the trawl data were incomplete. Results of this study indicate that the majority of common species were most abundant during wet years and least abundant during dry years (Table 4). The specific objective of the ongoing DFG study is to determine the effect of delta outflows on species abundance within the estuary. A direct comparison between the DFG study and this one is not possible, but an indirect comparison can be made.

DFG has ranked species on a five-step scale based on response to outflow: positive, slightly positive, mixed, slightly negative, and negative. To do this they classified each of the 6 years in their study as either wet or dry and then classified the response of the species. Their study, conducted from 1980 to 1985, included both midwater and otter trawls and was estuary-wide. In order to compare our results with theirs, a similar ranking system was established.

Based on delta outflows (Table 1) 1974 and 1980 were defined as wet years, and 1976 and 1977 as dry years. A species which was most abundant in a wet year and least abundant in a dry year was classified as a positive-response species. If a species was either most abundant in a wet year or least abundant in a dry year, it was classified as a slightly positive-response species. A species with neither highest nor lowest abundance in a wet or dry year, or with both in the same type year, was classified as a mixed-response species. A species with highest abundance in a dry year or lowest abundance in a wet year was classified as a slightly negative-response species. A species most abundant in a dry year and least abundant in a wet year was classified as a negative-response species.

Table 7 compares the observed responses to outflow between our study and the DFG study (1987). Of the species observed in my study, 48% showed a positive response and 10% showed no response compared with 24% and 52%, respectively, in the DFG study. California tonguefish were nearly absent from our study in all years except 1977, when they were very common; thus they were classified as a negative-response species. On the other hand, the DFG study classified them as a positive-response species. English sole, the second most abundant species in this study, were nearly absent during the 1977 drought and were classified as a positive-response species, whereas DFG classified them as a mixed-response species. Pearson (1985) found a significant correlation between delta outflows and English sole abundance in the south San Francisco Bay. The present study indicates that 62% of the species show at least a slightly positive response to wet years. The DFG study indicates 33% of the species showed a slightly positive response or better to wet years.

Table 7
Species abundance responses to increased delta outflows into south San Francisco Bay, as determined by this study and the California Department of Fish and Game study (DFG 1987).

Species	MEI	DFG
Northern anchovy	Slightly negative	Mixed response
English sole	Positive	Mixed response
Shiner surfperch	Positive	Mixed response
Goby family	Slightly negative	Positive
Pacific herring	Positive	Slightly positive
Sanddab family	Positive	Positive
Staghorn sculpin	Positive	Slightly positive
Dwarf perch	Positive	Negative
Barred surfperch	Mixed response	Mixed response
White surfperch	Positive	Mixed response
Brown rockfish	Positive	Mixed response
Pile perch	Positive	Mixed response
California tonguefish	Negative	Positive
Brown smoothhound	Mixed response	Mixed response
Leopard shark	Positive	Positive
Walleye surfperch	Positive	Negative
Bay pipefish	Slightly positive	Negative
White croaker	Negative	Mixed response
Diamond turbot	Slightly negative	Mixed response
Bat ray	Slightly negative	Mixed response
Starry flounder	Slightly positive	Positive

Some of the differences in interpretation between ours and the DFG study may be due to the effect of the different time-periods sampled. In DFG's study, 1981 was classified as dry, but delta outlfows that year were more than twice as great as either year classified as dry (1976 and 1977) (Table 1) in this study. On the other hand, the wettest year in the MEI sampling program (1974) had only about half the volume of delta outflows as the wettest year in the DFG study (1983). Although both studies had extreme ranges of outflows, the effect of the differences between the two studies could be relevant in the interpretation of wet-versus-dry response. In addition, 5 years of the MEI study were not classified as either wet or dry. This conservative approach allows for the possibility of average flows and avoids the forced explanation of species abundance as the effect of either high or low flows. Consequently, it was surprising to find more species showing a strong response (either positive or negative) to outflow in the MEI study than in the DFG study. This is particularly true given that all of the years in the DFG study were classified as either wet or dry.

Geographical variations may also have been responsible for the observed differences. The abundance estimates in the DFG study are based on single monthly trawls in several areas throughout the estuary, while this study used multiple trawls in a small region. The south bay is a distinct and separate part of the estuary. It is possible that when a given species is examined on an estuary-wide basis, as in the DFG study, it will show a different response than when examined on an area-by-area basis. If both the DFG and MEI abundance estimates are accurate, then clearly one possible interpretation is that many species show different responses in different areas of the estuary. In designing a sampling regime for the estuary, two factors are in competition: scope of the study, and sample size. If the scope is limited, the range of questions which can be answered are limited. Typically sample size increases (and therefore reliability) as scope decreases. This study emphasized sample size but was limited in scope. Because of the large sample size used in this study, the estimates of abundance for most species should be reasonably accurate. It would be useful to look for regional differences within species in response to outflows within the estuary when the data become available. It is important, however, to note that this study cannot be applied to the estuary as a whole, but rather only to the southern portion.

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Appendix A

Trawl-effort distribution of Marine Ecological Institute study, south San Francisco Bay, 1973-82.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1973	—	31	22	46	46	22	21	10	1*	35	14	20
1974	20	35	55	36	50	—	—	—	—	12	8	11
1975	3*	—	14	29	41	5	6	—	—	25	23	17
1976	42	56	40	22	55	34	18	—	7	19	29	—
1977	34	14	55	47	58	27	12	—	2*	24	24	7
1978	16	6	22	60	44	36	8	11	—	24	32	—
1979	3*	5	29	37	55	27	19	9	9	22	6	8
1980	8	13	35	31	41	34	13	11	6	4	17	25
1981	20	31	44	60	52	19	12	8	10	19	20	6
1982	6	33	56	58	66	29	—	—	—	—	—	—

Dashes indicate no trawls; asterisks indicate less than 5 trawls (not used in study).

Appendix B

Mean monthly water temperatures (°C) for south San Francisco Bay, 1973-82.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1973	—	13.5	13.0	16.0	19.0	20.0	20.5	21.0	—	18.0	15.0	11.5
1974	10.0	11.5	13.5	16.0	16.5	—	—	—	—	18.0	—	12.5
1975	—	—	13.5	14.0	17.0	21.0	—	—	—	18.5	14.0	11.5
1976	10.5	12.0	15.5	14.5	18.0	17.0	—	—	21.0	19.5	18.5	—
1977	11.0	14.0	13.0	16.5	16.0	18.5	21.0	—	—	18.5	16.0	12.5
1978	13.0	14.0	16.0	17.0	19.0	19.5	21.0	21.0	—	18.5	16.0	—
1979	—	11.0	14.0	16.0	20.0	22.0	23.5	23.0	24.5	20.0	15.5	14.5
1980	13.5	14.0	15.5	18.0	17.5	18.0	22.5	23.0	23.5	19.5	16.5	13.5
1981	12.0	12.5	15.0	17.0	18.5	21.0	21.5	22.0	20.5	17.0	15.5	13.5
1982	8.5	12.5	13.5	16.5	18.0	19.0	—	—	—	—	—	—
Mean	11.2	12.8	14.3	16.2	18.0	19.6	21.7	22.0	22.4	18.7	15.9	12.8
SD	1.8	1.2	1.1	1.2	1.2	1.6	1.1	1.0	1.9	0.9	1.5	1.1

Appendix C

Mean monthly salinities (ppt) for south San Francisco Bay, 1973-82.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1973	—	17.0	18.5	19.0	21.5	23.0	26.0	28.0	—	29.0	26.0	21.0
1974	19.5	16.5	19.5	15.5	18.5	—	—	—	—	28.0	—	27.0
1975	—	—	20.0	18.5	18.0	21.5	23.0	—	—	27.5	28.0	29.0
1976	28.5	28.0	27.5	28.0	29.0	30.0	30.0	—	30.5	30.5	32.0	—
1977	31.0	30.5	30.5	30.5	31.0	32.0	32.0	—	—	33.0	33.0	33.5
1978	24.5	21.0	20.5	18.5	20.0	21.5	25.0	26.5	—	28.0	30.5	—
1979	—	26.0	22.0	22.0	25.0	25.0	27.5	28.5	28.5	30.0	30.5	30.5
1980	19.5	18.0	13.5	18.0	22.5	24.5	25.5	25.5	27.0	28.0	30.0	28.5
1981	29.5	26.5	25.5	24.5	26.0	27.0	28.5	29.0	30.5	31.5	30.0	26.0
1982	16.5	17.5	16.5	12.5	13.5	18.5	—	—	—	—	—	—
Mean	24.1	22.3	21.4	20.7	22.5	24.8	27.1	27.5	29.1	29.5	30.0	27.9
SD	5.7	5.4	5.2	5.6	5.4	4.3	2.8	1.5	1.7	1.9	2.2	3.9

Appendix D

Mean catch-per-trawl of fish species in south San Francisco Bay, 1973-82.
(tr indicates < 1, dash indicates no samples taken)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northern anchovy												
1973	—	1	1	64	982	357	267	327	—	331	91	5
1974	3	17	27	61	228	—	—	—	—	62	15	10
1975	—	—	tr	40	58	77	145	—	—	61	83	tr
1976	2	tr	3	10	35	155	112	—	24	13	17	—
1977	2	tr	3	28	50	124	72	—	—	26	3	tr
1978	2	2	3	205	200	185	73	226	—	44	37	—
1979	—	71	4	45	89	136	191	159	35	30	9	2
1980	1	7	2	10	62	39	26	31	12	56	5	1
1981	2	8	tr	63	230	88	139	14	100	95	20	14
1982	11	1	3	4	46	34	—	—	—	—	—	—
Mean	3	11	5	47	193	133	128	151	43	80	31	5
SD	3	23	8	59	271	98	76	132	39	98	33	5
English sole												
1973	—	tr	1	11	42	9	3	1	—	0	0	tr
1974	4	17	42	191	108	—	—	—	—	tr	0	tr
1975	—	—	14	48	101	24	9	—	—	tr	tr	1
1976	2	12	9	15	29	17	0	—	0	0	0	—
1977	tr	tr	tr	tr	1	3	0	—	—	0	0	0
1978	8	28	64	29	5	5	tr	tr	—	tr	1	—
1979	—	6	23	30	45	8	0	0	0	tr	tr	tr
1980	tr	5	20	27	63	12	3	0	0	0	0	tr
1981	4	24	47	22	11	4	0	0	0	0	0	1
1982	0	tr	4	22	32	45	—	—	—	—	—	—
Mean	2.4	9.9	22.4	40.1	43.7	13.8	1.9	0.2	0	tr	0.1	0.3
SD	2.8	10.4	21.8	54.6	37.3	13.6	3.2	0.3	0	0.1	0.1	0.4
Shiner surfperch												
1973	—	4	6	20	40	81	37	13	—	7	5	2
1974	2	6	8	37	43	—	—	—	—	2	7	tr
1975	—	—	5	25	44	34	11	—	—	1	tr	tr
1976	tr	2	4	9	34	14	11	—	3	1	tr	—
1977	1	0	5	8	12	20	12	—	—	2	3	2
1978	tr	1	4	15	42	29	2	6	—	4	2	—
1979	—	0	10	7	26	74	6	14	8	2	2	9
1980	tr	tr	12	8	17	50	11	1	3	6	3	4
1981	2	2	4	18	22	29	15	3	7	10	9	0
1982	6	7	14	33	28	36	—	—	—	—	—	—
Mean	2	3	7	18	29	45	13	7	5	4	3	2
SD	2	4	4	11	15	28	10	6	3	3	3	3
Gobies (all species)												
1973	—	0.6	0.5	0.4	1.5	5.8	7.5	2.5	—	0.1	0	0.5
1974	0.3	0.7	1.6	4.6	5.6	—	—	—	—	0.3	1.0	0.5
1975	—	—	2.4	7.8	7.9	0.4	3.3	—	—	0.3	0.2	0.1
1976	0.1	0.1	8.7	10.2	6.4	1.7	3.8	—	6.4	0.1	0.2	—
1977	0.1	0.5	1.1	2.2	4.4	4.2	3.0	—	—	0.3	1.0	0.3
1978	0.3	1.0	1.7	2.1	3.1	3.5	1.8	1.0	—	0.5	0.6	—
1979	—	0.4	1.1	3.2	5.2	1.2	0.5	0.7	0.6	0.1	0	1.0
1980	0	0.2	4.3	5.9	6.0	3.2	2.3	0.5	0.3	0.4	0.1	0.5
1981	1.0	1.5	1.9	4.6	2.6	3.1	1.3	3.0	0.8	0.4	1.2	0.2
1982	0.8	0.7	5.8	9.1	5.9	1.5	—	—	—	—	—	—
Mean	0.4	0.7	2.9	5.0	4.9	2.7	2.9	1.5	2.0	0.3	0.5	0.7
SD	0.4	0.4	2.6	3.2	1.9	1.7	2.1	1.2	2.9	0.2	0.5	0.7

Appendix D (continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pacific herring												
1973	—	1.5	1.1	2.4	1.4	0.2	0.7	0	—	0.3	2.6	15.6
1974	1.3	2.5	8.1	13.9	3.5	—	—	—	—	0	1.9	2.4
1975	—	—	0	0.9	tr	0.1	0.3	—	—	tr	0.7	3.1
1976	1.1	1.3	1.6	9.6	1.5	0.2	0	—	0	0.2	0.1	—
1977	0.1	0.1	0.5	0.6	0.4	0.1	0	—	—	0.2	0.3	1.4
1978	0.1	0.3	0.8	4.5	5.3	0.9	10.3	0.6	—	0.2	0.8	—
1979	—	0.2	0.7	7.1	1.2	3.7	0.1	3.2	0.1	0.1	1.3	1.4
1980	0.6	3.5	1.8	9.7	0.5	0.1	0.9	0.2	1.0	1.4	2.2	1.7
1981	0.2	1.2	0.2	0.5	0.1	0.2	0	0.1	0.4	1.2	0.6	0.2
1982	0.3	0.1	1.0	34.1	1.0	0.1	—	—	—	—	—	—
Mean	0.5	1.2	1.6	8.3	1.5	1.8	1.5	0.8	0.4	0.4	1.2	3.7
SD	0.5	1.2	2.4	10.2	1.7	3.6	3.6	1.4	0.5	0.5	0.9	5.3
Sanddabs (all species)												
1973	—	2.5	4.4	4.4	4.2	0.3	0.4	0.1	—	0	0.1	0.2
1974	1.8	4.2	4.2	14.0	12.1	—	—	—	—	0.1	0	0.2
1975	—	—	0.6	tr	1.4	0.8	0	—	—	0	tr	0.4
1976	0.4	0.5	0.4	0.8	0.4	1.1	0.1	—	0.6	0.1	tr	—
1977	0.8	0.7	2.3	2.6	3.2	6.6	1.6	—	—	0.5	1.4	1.1
1978	6.6	2.5	6.8	6.4	1.6	0.1	0	0	—	0.7	1.0	—
1979	—	2.6	5.5	5.4	4.5	0.2	0	0	0	0	0.7	1.9
1980	2.7	1.8	1.5	3.0	1.7	2.1	0.8	0	0	0	0.3	1.2
1981	1.9	3.6	1.8	1.8	1.4	0.6	0.1	0	0.9	0.5	2.5	0
1982	1.7	3.7	4.9	4.4	1.1	1.2	—	—	—	—	—	—
Mean	2.3	2.4	3.2	4.3	3.2	1.4	0.4	tr	0.4	0.2	0.7	0.7
SD	2.1	1.3	2.2	3.9	3.4	2.0	0.5	tr	0.5	0.3	0.9	0.7
Staghorn sculpin												
1973	—	0.5	4.4	2.1	3.6	15.9	0.9	0.1	—	0	0.1	0.2
1974	0.1	0.8	1.7	7.4	6.8	—	—	—	—	0.1	0	0.1
1975	—	—	0.7	2.2	3.2	1.8	0.3	—	—	0.1	0.1	0.4
1976	0.2	tr	0.3	0.7	4.0	1.6	0.7	—	1.0	0.1	0.1	—
1977	0.2	0	0.4	0.4	0.4	1.1	1.0	—	—	0.3	2.3	0.3
1978	0.3	0.8	1.8	0.8	0.6	0.4	0	0	—	0	tr	—
1979	—	0	3.6	1.6	3.1	1.9	0.1	0	0	0	0	0
1980	0.1	0.1	1.1	1.7	3.5	1.0	0.3	0	0	0	0.4	0.4
1981	0.2	0.4	2.9	0.8	1.1	1.2	0	0	0.2	0.2	0.2	0
1982	0.3	0.5	0.4	0.8	1.4	0.6	—	—	—	—	—	—
Mean	0.2	0.3	1.7	1.8	2.8	2.8	0.4	tr	0.3	0.1	0.4	0.2
SD	0.1	0.3	1.4	2.0	2.0	4.9	0.3	tr	0.5	0.4	0.6	0.2
Dwarf surfperch												
1973	—	1.5	0.8	1.8	2.3	1.4	10.8	10.0	—	0.4	0.4	0.6
1974	4.4	2.2	4.5	3.7	0.9	—	—	—	—	0.9	5.1	0.1
1975	—	—	0.9	0.1	0.2	0	1.3	—	—	0.1	0.1	0.2
1976	0	0.1	0.2	0.3	0.1	0.1	0.3	—	0.1	0	tr	—
1977	0.7	0.1	0.3	0.1	0.1	0.3	1.0	—	—	0.2	1.0	0.4
1978	0.1	0.2	1.4	0.3	0.2	0.3	0.4	1.0	—	0.9	0.3	—
1979	—	0	1.0	0.7	0.1	0.9	3.0	3.1	0.7	0.1	4.8	3.1
1980	0	0	0.5	0.1	0.2	tr	0.7	0.5	0.3	0.6	0.5	tr
1981	0.7	1.3	0.8	0.9	0.2	4.4	1.8	0.4	0.8	0.2	2.4	0.5
1982	0	4.6	1.6	0.5	0.1	0.3	—	—	—	—	—	—
Mean	0.8	1.1	1.2	0.9	0.5	0.9	2.4	3.0	0.5	0.4	1.6	0.7
SD	1.6	1.5	1.3	1.1	0.7	1.4	3.5	4.1	0.3	0.3	2.0	1.1

Appendix D (continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Barred surfperch												
1973	—	0.1	0.3	0.2	0.2	1.5	2.0	0.3	—	0.1	0.1	0.2
1974	0.1	0.2	1.7	1.3	0.1	—	—	—	—	0	0.3	0.2
1975	—	—	0	0.1	0	0.2	0	—	—	0.9	1.0	1.2
1976	0.8	0.6	tr	0	0.1	0	1.0	—	0	0	0	—
1977	0	0.3	tr	0.6	1.3	0.1	2.3	—	—	0	0.1	0.1
1978	0.8	0.8	2.1	0.3	0.3	0.5	0.3	0	—	tr	0.2	—
1979	—	0.3	0.2	0.1	1.0	3.1	0.2	0	0	0	0	0.5
1980	0.7	1.2	0.1	0.1	0.1	tr	0.4	0	0.7	0.6	0.2	0.2
1981	0	0.8	0.3	0.6	0.2	0.3	0.1	0.8	0.3	0.6	0.1	2.7
1982	1.2	0.5	0.3	0.3	0.5	0.6	—	—	—	—	—	—
Mean	0.5	0.5	0.5	0.4	0.4	0.7	0.8	0.2	0.2	0.2	0.2	0.7
SD	0.5	0.4	0.7	0.4	0.5	1.0	1.0	0.3	0.3	0.3	0.3	0.9
White surfperch												
1973	—	0	0	tr	0.1	4.0	4.6	0	—	0.3	0.1	0.1
1974	1.0	0.3	4.5	0.1	0.3	—	—	—	—	0	0	0
1975	—	—	0.1	0.7	0	0.4	0	—	—	0	0	0
1976	0.6	0	0	0	0	0	1.0	—	0	0	0	—
1977	0.2	0	0	0	0	0.2	0.1	—	—	0.1	0.4	0
1978	0	0	0.1	0.1	2.8	1.0	0	0	—	0.1	0	—
1979	—	0	0.1	0	0.1	0	0	0.1	0	0	1.0	0
1980	0	0	0.1	0	0	0.3	0	0	0	0	0	4.3
1981	0	0.1	0.1	0	0.1	0.1	0	0	0.1	0.1	0	0.2
1982	0	0.1	0	0	0	0	—	—	—	—	—	—
Mean	0.3	0.1	0.5	0.1	0.3	0.6	0.8	tr	tr	0.1	0.2	0.7
SD	0.4	0.1	1.4	0.2	0.9	1.2	1.7	tr	tr	0.1	0.3	1.6
Brown rockfish												
1973	—	0	0	0.1	0.2	0.8	1.1	0.2	—	tr	0	0.1
1974	0.5	0.7	1.4	5.1	1.2	—	—	—	—	0	0.1	0
1975	—	—	0	0.2	0.1	0	0	—	—	0	0	0.1
1976	tr	0	0	0.1	tr	0	0.1	—	0.1	0	0	—
1977	0	0	0	0	0	0.8	1.2	—	—	0.1	0.1	0
1978	0	0	0.3	tr	0.1	0.6	0	0.2	—	0.7	0.2	—
1979	—	0	1.4	0.3	0.3	0.1	0.1	0.2	0	0	0	0.8
1980	0	0	tr	0.3	tr	tr	0.2	0	1.3	0.2	0.1	0.8
1981	0.1	0.2	0.4	0.3	0.2	1.5	0.8	0.4	0.8	0.3	1.2	0.3
1982	0.3	0.2	0.7	0.4	0.4	0.3	—	—	—	—	—	—
Mean	0.1	0.1	0.4	0.7	0.3	0.5	0.4	0.2	0.6	0.2	0.2	0.3
SD	0.2	0.2	0.6	1.6	0.4	0.5	0.5	0.1	0.6	0.2	0.4	0.4
Pile surfperch												
1973	—	0.7	0.1	0.3	0.5	0.4	2.4	4.0	—	1.5	0.6	1.1
1974	1.4	0.8	0.9	0.7	0.1	—	—	—	—	1.5	1.4	0.6
1975	—	—	0.1	0	0.3	3.6	0	—	—	0	0.4	0
1976	0	0	0	0	0.1	0.4	0.2	—	0.3	0	0	—
1977	0.1	0.1	0.1	0	0	0.1	0	—	—	0	0.5	0.1
1978	0.1	0	0.1	0.1	0.3	1.6	0	0.3	—	0	0.2	—
1979	—	0.2	0.3	0.6	0.1	0.3	0.3	0.4	0.1	0	0.3	0.6
1980	0	0	0	0.1	0	0.1	1.5	0	0.2	0	0	0
1981	0.1	0.1	0.1	0.1	0	1.2	1.5	0	0	0.1	0.1	0.2
1982	0	0.2	0.1	0	0	0.4	—	—	—	—	—	—
Mean	0.2	0.2	0.2	0.2	0.1	0.9	0.7	0.9	0.2	0.3	0.8	0.4
SD	0.5	0.3	0.3	0.3	0.2	1.1	1.1	1.7	0.1	0.7	0.9	0.4

Appendix D (continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Smelts (all species)												
1973	—	0.3	0.1	0.2	0	0	0.1	0	—	0.1	0.3	0.2
1974	0.4	0.1	0.2	0.1	0.2	—	—	—	—	0	0	0
1975	—	—	0	0.3	0.6	0	0	—	—	0	0	0
1976	0.2	0.3	0	0.3	0	0	0.1	—	0	0.2	0	—
1977	4.0	3.0	0.7	0.9	0.1	0	0	—	—	0	0.1	0.4
1978	0.4	0	0.1	0.1	0	0	0	0	—	0	0	—
1979	—	0.8	0.2	0.1	0	0	0.1	0	0.1	0.1	0	0.1
1980	0.1	0.2	0.3	0.1	0	0	0.1	0	0	0	0	0.1
1981	0.2	0.1	0	0.1	0	0	0	0	0	0	0.2	0
1982	0	0.1	0.2	0.1	0.2	0	—	—	—	—	—	—
Mean	0.8	0.5	0.2	0.2	0.1	0	0.1	0	tr	tr	0.1	0.1
SD	1.4	1.0	0.2	0.2	0.2	0	0.1	0	tr	0.1	0.1	0.1
California tonguefish												
1973	—	0	0	0	0	0	0.1	0	—	0	0	0
1974	0	0	0	0	0	—	—	—	—	0	0	0
1975	—	—	0	0	0	0	0	—	—	0	0	0
1976	0	0	0	0	0	0	0	—	0	0	0	—
1977	0	0	0.2	0.8	3.4	4.7	2.8	—	—	0	0	0
1978	0	0	0	0	0.2	0.3	0	0.1	—	0	0	—
1979	—	0	0	0	0	0.1	0.1	0	0	0	0	0
1980	0	0	0	0.1	0.3	0.3	0.3	0.2	0.2	0	0	0
1981	0	0	0	0	0	0	0.1	0	0	0	0	0
1982	0	0	0	0	0.1	0.1	—	—	—	—	—	—
Mean	0	0	tr	0.1	0.4	0.6	0.4	0.1	0.1	0	0	0
SD	0	0	tr	0.3	1.1	1.5	1.0	0.1	0.1	0	0	0
Brown smoothhound sharks												
1973	—	tr	0	tr	0.6	2.8	0.3	0	—	0.1	0.1	0.1
1974	0	tr	tr	0	0.3	—	—	—	—	0.1	tr	0.1
1975	—	—	0	0.1	0.6	0.2	0	—	—	0.1	tr	0.1
1976	0	0.1	0	0	0.4	0.7	0.1	—	0.1	0	tr	—
1977	0	0.1	0.1	0.4	0.7	0.9	0.2	—	—	0.3	0.4	0.6
1978	0.1	0	0	tr	0.2	0.2	0.1	0	—	tr	0.2	—
1979	—	0	0.1	0.1	0.2	tr	0	0.1	0.1	0.1	0	0.3
1980	0	0.1	0	0.1	0.4	0.9	0	0	0	0	0.3	0.1
1981	0.1	0	0	0.2	0.2	0.1	0.1	0.1	0.2	0.3	0	0
1982	0	0	0	tr	0	0	—	—	—	—	—	—
Mean	tr	tr	tr	0.1	0.4	0.6	0.1	0.1	0.1	0.1	0.1	0.1
SD	tr	tr	tr	0.1	0.2	0.9	0.1	0.1	0.1	0.1	0.2	0.2
Leopard sharks												
1973	—	tr	0	0.3	0.8	2.3	0	0	—	tr	0	0
1974	0.1	0.2	0.1	0.2	0.2	—	—	—	—	0.2	0.5	0.1
1975	—	—	0	0.3	0.1	0	0	—	—	0	tr	0.2
1976	0.1	0.1	0.2	0.2	0.2	tr	0	—	0	0	0	—
1977	0	0.1	0.1	0.4	0.7	0.9	0	—	—	tr	0.1	0.1
1978	0.1	0.2	0.2	0.2	0.5	0.1	0	0.1	—	0	tr	—
1979	—	0	1.0	0.1	tr	0	0.1	0	0.2	0	0	0.5
1980	0.3	0	0	0.8	0.2	0.4	0	0.2	0	0	0.2	tr
1981	0.2	0.1	tr	0.5	tr	0	0	0	0	0	tr	0
1982	0	0.1	0.3	0.1	0.[illegible]	0	—	—	—	—	—	—
Mean	0.1	0.1	0.2	0.3	0.2	1.2	tr	0.1	0.1	tr	0.1	0.1
SD	0.1	0.1	0.3	0.2	0.2	2.7	tr	0.1	0.1	1.0	0.2	0.2

Appendix D (continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Walleye surfperch												
1973	—	0	0	0	0.2	0.3	0.1	0	—	tr	0	0
1974	0	0.3	tr	0	tr	—	—	—	—	0	0	0
1975	—	—	0	0.1	0.1	0	0	—	—	0	0	0
1976	0	0	0	0	0	tr	0.2	—	0	0	0	—
1977	0	0	0	0	0.1	0.2	0.3	—	—	0	0	0
1978	0	0	0	0	0.1	2.8	0	1.1	—	0	0	—
1979	—	0	0.1	0	tr	0.4	0.2	0.9	0	0	0.3	0.8
1980	0	0	0.1	0	0.1	1.4	0	0	0	0	0	0.1
1981	0.3	tr	0.1	0.1	tr	0.7	0	0.1	0.1	0.1	0.2	0
1982	0.3	0	tr	0.1	0.3	2.3	—	—	—	—	—	—
Mean	0.1	tr	tr	tr	0.1	0.8	0.1	0.4	tr	tr	0.1	0.1
SD	0.1	0.1	0.1	tr	0.1	0.9	0.1	0.5	0.1	tr	0.1	0.3
Bay pipefish												
1973	—	0.1	0	tr	0.1	0.1	2.6	0.3	—	tr	0.1	0
1974	0	0.1	0.2	0.5	0.6	—	—	—	—	0.1	0.1	0
1975	—	—	0.1	0	0.1	0	0	—	—	0.2	tr	0
1976	0	0	0.2	0.9	tr	tr	0.1	—	0.4	0	0.1	—
1977	0	0.1	0	tr	0	0	0.2	—	—	0	tr	0
1978	0	0	0.1	0.1	0.7	0.1	0.1	0.2	—	0.2	0.1	—
1979	—	0	tr	0.1	0.2	0.2	0.4	0.7	1.8	0.4	0	0
1980	0	0.2	0.1	0.3	0.4	0.4	0	0.2	0.7	0.1	0.2	0.1
1981	0.1	0.1	0.1	tr	tr	0.1	0.2	1.1	0	0.1	0	0
1982	0.2	0	tr	0	0	0	—	—	—	—	—	—
Mean	tr	0.1	0.1	0.2	0.2	0.1	0.4	0.5	1.5	0.1	0.1	tr
SD	0.1	0.1	0.1	0.3	0.3	0.1	1.0	0.4	1.2	0.1	0.1	tr
White croaker												
1973	—	0	0	0	0	0	0	0	—	0	0	0
1974	0.1	0	0	0	0	—	—	—	—	0	0	0
1975	—	—	0	0	0.1	0	0	—	—	0	0	0
1976	0	0	0	0	0.1	0	0	—	0	0	0	—
1977	0	0	0.1	0.3	1.5	7.5	0	—	—	0	0	0
1978	0	0	0.1	0	0	0	0	0	—	0	0	—
1979	—	0	0.1	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0.3	0	0	0	0	0	0
1981	0	0	0.1	0.2	0	0	0	0	0	0	0	0
1982	0.2	0	0.1	0.1	0.2	0	—	—	—	—	—	—
Mean	tr	0	0.1	0.1	0.2	0.9	0	0	0	0	0	0
SD	0.1	0	0.1	0.1	0.5	2.5	0	0	0	0	0	0
Shad (all species)												
1973	—	0.2	0	0.1	0	2.7	0.1	0	—	0	1.2	1.5
1974	1.2	0.5	0	0	0	—	—	—	—	0	0.4	1.1
1975	—	—	0.2	0.1	0	0	0	—	—	0	0.4	0.8
1976	0.6	0.9	0.3	0.1	0	0	0.2	—	0	0	0	—
1977	0	0	0	0	0	0	0	—	—	0	0.8	0.6
1978	0.4	0.2	0.1	0	0	0	0	0	—	0	0.1	—
1979	—	0.6	0.2	0.1	0	0	0	0	0	0	0	0
1980	0	0.5	0	0	0	0	0	0	0	0	0	0.4
1981	0.1	0	0	0	0	0	0	0	0	0	0.1	0.3
1982	0	0	0	0	0	0	—	—	—	—	—	—
Mean	0.3	0.3	0.1	tr	0	0.3	tr	0	0	0	0.3	0.7
SD	0.4	0.3	0.1	tr	0	0.9	tr	0.1	0	0	0.4	0.5

Appendix D (continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Diamond turbot												
1973	—	0.1	0.4	0.1	0.1	1.3	0.2	0	—	0	0	0.2
1974	0	0.2	0.2	0.2	0.1	—	—	—	—	0.1	0	0.2
1975	—	—	0	0.2	0.2	0	0	—	—	0	0	0.1
1976	0.2	tr	0.1	0.2	tr	0	0	—	0.1	0	0	—
1977	0.1	0	0.1	0.2	0.1	0.2	2.5	—	—	tr	0.8	0.9
1978	0.5	1.3	0.3	0.2	0.2	0	0	0	—	0	0	—
1979	—	0	0.1	0.2	tr	0	0	0	0	0	0	0.1
1980	0	0	0.7	0.2	0.1	0.1	0	0.1	0	0	0	0
1981	0.1	0.1	0.1	0.1	tr	0	0	0	0.5	0	0.1	0
1982	0	tr	0.1	0.1	0.1	0	—	—	—	—	—	—
Mean	0.1	0.2	0.2	0.2	0.1	0.2	0.3	tr	0.2	tr	0.1	0.2
SD	0.2	0.4	0.2	0.1	0.1	0.4	0.8	tr	0.2	tr	0.3	0.3
Bat rays												
1973	—	0	0	tr	0.4	1.3	0.2	0.1	—	tr	0.1	0
1974	0	0	0.1	0.3	0.3	—	—	—	—	0.1	0.3	0
1975	—	—	0.1	0.1	0.2	0	0	—	—	0	tr	0
1976	0	tr	0.2	0.6	0.2	0.3	0.1	—	0	0	tr	—
1977	0	0.1	0.1	0.3	0.3	0.3	0.3	—	—	0.2	0.1	0
1978	0	0	0.1	tr	0.2	0.1	0	0	—	0	0.1	0
1979	—	0.2	tr	0.2	0.4	0	0.1	0.2	0.4	0	0	0
1980	0	0.1	tr	tr	0.3	0.4	0	0	0	0	0.2	0
1981	0	tr	0.2	0.6	tr	0	0	0.1	0.3	0.3	0.2	0
1982	0	0	0	0	tr	tr	0.3	—	—	—	—	—
Mean	0	0.1	0.1	0.2	0.2	0.3	0.1	0.1	0.2	0.1	0.1	0
SD	0	0.1	0.1	0.2	0.1	0.4	0.1	0.1	0.2	0.1	0.1	0
Plainfin midshipmen												
1973	—	0	0	0.2	0	0.1	0.2	0.2	—	0	0	0
1974	0	0	0.1	0.6	0	—	—	—	—	0	0	0
1975	—	—	0	1.1	0.4	0.2	0	—	—	0	0	0
1976	0	0	0	0	0.1	0	0.4	—	0.7	0	0	—
1977	0	0	0	0.4	0.3	0.2	0	—	—	0	0	0
1978	0	0	0	0.1	0.1	0	0	0	—	0.1	0.3	—
1979	—	0	0.2	0.2	0	0	0.3	0.4	0	0	0	0
1980	0	0	0.1	0.2	0	0.2	0.2	0.2	0.2	0.2	0.1	0.2
1981	0	0	0	0.1	0	0	0	0	0	0	0.2	0
1982	0	0	0.1	0.5	0.3	0	—	—	—	—	—	—
Mean	0	0	0.2	0.3	0.1	0.1	0.1	0.2	0.2	0	0.1	0
SD	0	0	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Bonyhead sculpin												
1973	—	0	0	0	0	0	0	0	—	0	0	0
1974	0	0.1	0.2	1.0	0.1	—	—	—	—	0.1	0	0.3
1975	—	—	0.1	tr	0.1	0.2	0	—	—	0	0	0
1976	0	tr	0	0	tr	0	0	—	0	0	0	—
1977	0	0.2	0.2	0.2	0.2	tr	0	—	—	0	0.2	0
1978	0.1	1.3	0.1	0.1	0.2	0.2	0	0	—	0	tr	—
1979	—	0.2	tr	0.1	0	tr	0.1	0	0	0	0	0.3
1980	0	0.2	0.4	0.2	0.1	0.2	0.2	0	0	0	0.1	0
1981	0.4	0.2	0.5	0.1	0.1	0.1	0.3	0	0	0	0	0.2
1982	0.2	0.2	0.3	tr	0.1	0.1	—	—	—	—	—	—
Mean	0.1	0.3	0.2	0.2	0.1	0.1	0.1	0	0	tr	tr	0.1
SD	0.1	0.4	0.2	0.3	0.1	0.1	0.1	0	0	tr	0.1	0.1

Appendix D (continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Starry flounder												
1973	—	0.5	0.5	0.2	0.2	0.1	0.1	0	—	0	0	0.2
1974	0.4	0.2	0.1	0.1	0.1	—	—	—	—	0.1	0.3	0.2
1975	—	—	3.7	0.6	0.1	0	0.3	—	—	0	0.1	0.2
1976	0.1	0.1	tr	0.1	tr	tr	0	—	0	0	tr	—
1977	0	0	tr	0.1	tr	tr	0	—	—	0	0.3	0.1
1978	0.3	0.2	0	tr	0.2	0	0	0	—	tr	0.1	—
1979	—	0	tr	0.1	0	0	0	0	0.1	0	0	0
1980	0	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.5	0.2	0.1	0.1
1981	0.3	0.1	0.3	tr	tr	0	0.1	0	0	0	0	0
1982	0	0	tr	0	tr	0	—	—	—	—	—	—
Mean	0.1	0.1	0.5	0.1	0.1	tr	0.2	tr	0.2	tr	0.1	0.1
SD	0.2	0.1	1.1	0.2	0.1	tr	0.2	tr	0.2	0.1	0.1	0.1
California halibut												
1973	—	0	0.3	0.1	tr	0	0	0.2	—	tr	0	0
1974	0	tr	0.1	0.1	0	—	—	—	—	0	0	0.9
1975	—	—	0.1	0.1	0	0	0.3	—	—	0	0	0.1
1976	0.1	0.5	0	0	0	0	0	—	0	0	0	—
1977	tr	0.2	tr	tr	tr	0	0.1	—	—	0	0.4	1.1
1978	0.9	1.8	0.6	0.1	0.1	0	0	0.2	—	0.7	0.5	—
1979	—	0.2	0.5	0.8	0.4	0.1	0	0	0	0	0	0
1980	0	0.2	tr	0	0	tr	0	0	0	0	0.1	tr
1981	0	0.1	0.1	tr	tr	0	0	0.1	0.1	0.1	0.2	0
1982	0	0.2	0.1	0.1	0.1	tr	—	—	—	—	—	—
Mean	0.1	0.4	0.1	0.1	0.1	tr	0.1	0.1	tr	0.1	0.1	0.3
SD	0.3	0.6	0.2	0.2	0.1	tr	0.1	0.1	0.1	0.2	0.2	0.5

Appendix E

Mean number of species per otter trawl in south San Francisco Bay, 1973-82. Dash indicates no trawls.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1973	—	2.8	4.4	5.8	6.6	5.0	6.2	5.3	—	2.6	3.1	3.1
1974	4.4	4.8	5.8	8.3	6.2	—	—	—	—	3.1	3.5	3.1
1975	—	—	3.0	4.6	5.5	4.8	2.2	—	—	1.8	1.7	3.1
1976	2.4	1.8	2.8	4.7	4.5	4.0	2.9	—	3.7	1.5	1.3	—
1977	1.9	1.4	3.2	4.2	4.9	5.8	5.3	—	2.0	2.8	4.1	3.9
1978	3.8	5.3	5.3	4.1	5.2	4.9	2.5	3.5	—	3.2	2.8	—
1979	—	3.8	6.2	6.0	5.2	3.7	3.0	4.4	3.2	1.8	3.8	5.4
1980	2.4	3.8	3.9	4.7	4.8	5.4	4.3	2.5	3.7	2.4	3.2	2.6
1981	2.7	3.9	4.0	4.8	3.6	5.1	3.6	3.0	4.2	3.4	4.0	2.3
1982	4.0	4.0	5.2	5.3	5.3	5.0	—	—	—	—	—	—
Mean	3.1	3.5	4.4	5.3	5.2	4.5	3.8	3.7	3.4	2.2	3.0	3.4
SD	1.0	1.3	1.2	1.2	0.8	1.5	1.4	1.1	0.8	1.0	0.9	1.0