

Methods

Sampling Surveys, Frequency, and Station Location

Three types of sampling surveys were conducted: open water, beach seine, and ringnet (Table 1). The open water survey began in February 1980. We collected samples monthly from 35 stations from South Bay to the Sacramento River at Sherman Island and the San Joaquin River at Antioch (Figure 1). Seven stations were added in 1988, 4 in 1990, and 6 in 1994. Data from the additional stations were only used for some channel-shoal comparisons.

The beach seine survey started in August 1980 at 27 shore stations located primarily in San Francisco and San Pablo bays but also with stations in the delta at Antioch and Sherman Island (Figure 2). To reduce expenditures, the beach seine survey ended in January 1987.

Table 1 Months sampled by year and gear type from 1980 to 1996

<i>Year</i>	<i>Midwater and Otter Trawls</i>	<i>Plankton Net</i>	<i>Beach Seine</i>	<i>Ringnet</i>
1980	February-December	February-December	August-December	
1981	January-December	January-December	January-December	
1982	January-December	January-December	January-December	May-December
1983	January-December	January-December	January-December	January-December
1984	January-December	January-December	January-December	January-December
1985	January-December	January-December	January-December	January-December
1986	January-December	January-December	January-December	January-December
1987	January-December	January-December	January	January-December
1988	January-December	January-December		January-December
1989	January-August	January-July		January-December
1990	February-October			July-December
1991	February-October			July-December
1992	February-October			July-December
1993	February-October			July-December
1994	February-October ^a			
1995	January-December ^b			
1996	January-December ^c			

^a Midwater trawl sampled only February to April.

^b Midwater trawl sampled April to December, except August; otter trawl did not sample in August.

^c Midwater trawl sampled April to December.

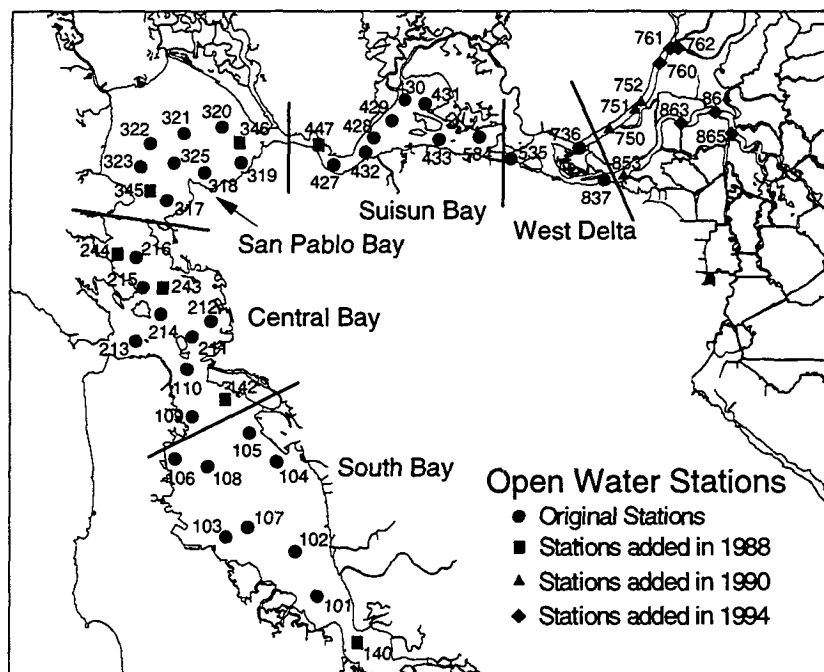


Figure 1 Map of open water stations

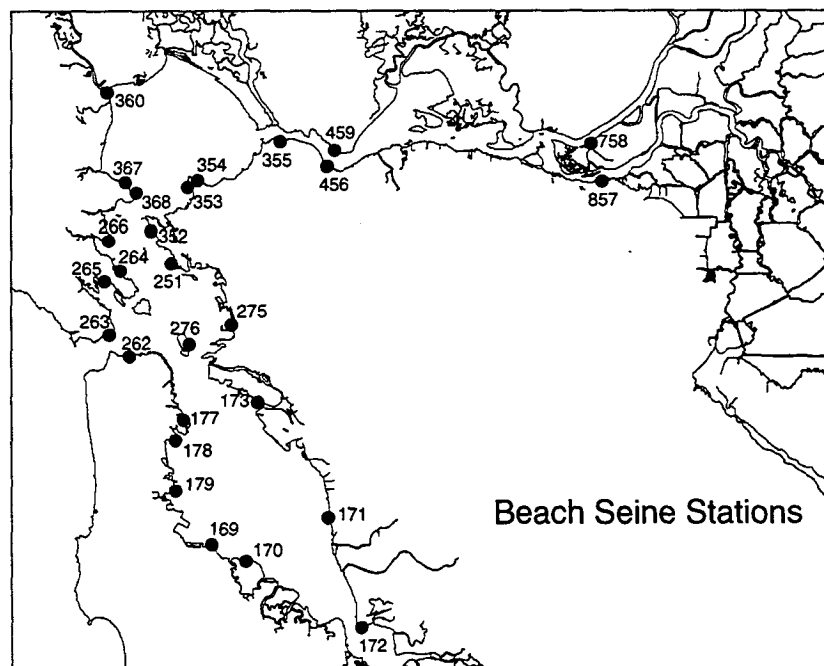


Figure 2 Map of beach seine stations

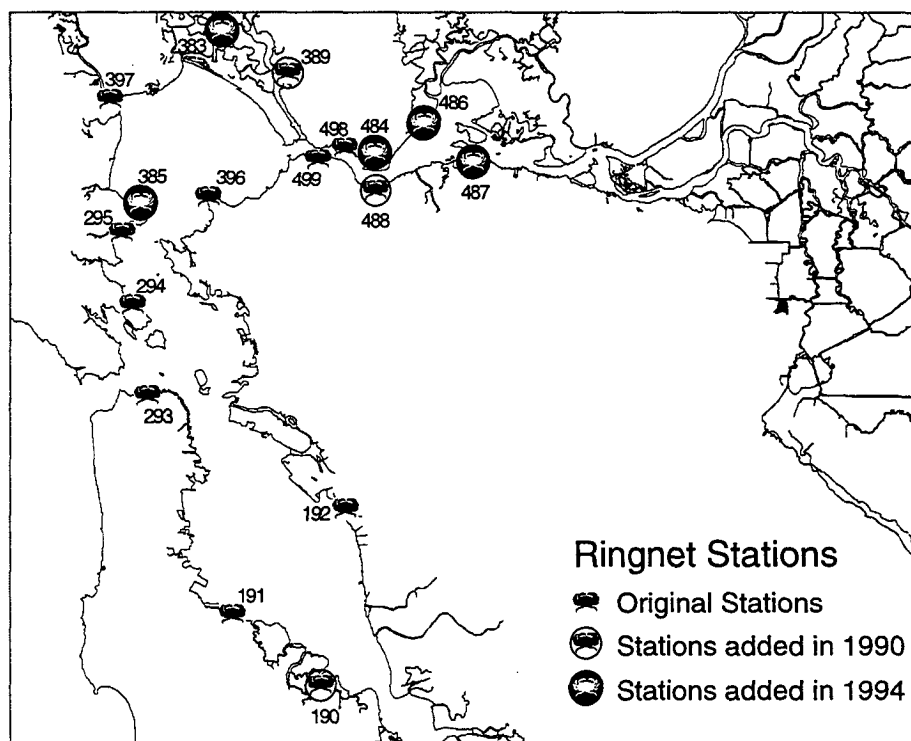


Figure 3 Map of ringnet stations

In May 1982, a monthly ringnet survey for crabs began at 9 stations in San Francisco and San Pablo bays and in Carquinez Strait (Figure 3). In 1990, sampling frequency was restricted to July to December and 3 new stations were added. In 1994, 5 stations were added and stations 190, 191, 192, and 293 were dropped.

Sampling Gear and Techniques

Open water stations were sampled with midwater and otter trawls and a plankton net. The otter trawl had a 4.9-m headrope, a 2.5-cm stretch mesh body, and a 1.3-cm stretch mesh codend. A 5:1 scope (ratio of cable out to water depth) was used to keep the otter trawl on the bottom. It was towed on the bottom and against the current for 5 minutes, and then retrieved. The distance towed was measured in nautical miles using Loran-C, starting from when the net reached the bottom and ending when retrieval began. Prior to May 1981, when the Loran was first used, and later for any tow on which the Loran malfunctioned, distance towed was estimated as the mean distance towed at that station. The area swept by the trawl was calculated as the product of the door spread and the distance towed (converted to meters from nautical miles), assuming a 70% door spread of 3.4 m.

The midwater trawl mouth measured 3.7 m^2 . The mesh graduated in 9 sections from 20.3 cm stretch mesh at the mouth to 1.3 cm at the codend. A 5:1 scope was used when setting the midwater trawl. It was towed with the current for 12 min and retrieved obliquely. The volume filtered was calculated as the product of the net mouth area (10.7 m^2) and the distance traveled, as measured by a flowmeter suspended off the side of the boat.

The plankton net was made of 505 μm mesh, had a mouth area of 0.38 m^2 , and was mounted on a steel sled with the net bottom 12 cm above the skids. A flowmeter positioned in the mouth of the net measured the flow of water through the net. The net was set to a 5:1 scope, towed for 5 min on bottom, and retrieved obliquely.

Shore sampling was conducted with a beach seine (15.2 m x 1.2 m) with 3-mm mesh. A bag (1.2 m x 1.2 m x 1.2 m) was sewn into the middle of the net. The headrope was marked at 0.5 m intervals so it could be used to measure the distance from shore at the start of a haul. The maximum depth of the set was measured using a scale marked at 0.1 m intervals on the net poles. The area sampled was calculated as the product of the distance from the shore (tow length) and the distance along the shore (tow width). Volume swept was calculated as half of the product of tow area and maximum depth. One, and when possible, 2 tows were made per station at flood tide.

Ringnets were 0.86 m in diameter and had 2.5-cm stretch mesh webbing. Four ringnets baited with fish heads were fished for 30 min at low slack tide.

In both otter and midwater trawl samples, fish and *Cancer* crabs were identified to species and all shrimp were separated from detritus and other invertebrates. Up to 50 randomly selected fish of each species were measured to the nearest millimeter fork length (FL) or total length (TL) for fish without forked tails and the rest were counted. For several fish species, individuals less than a specified length (minimum cutoff length) were not counted or measured because they were too small to be collected efficiently by the mesh size used. This procedure was first followed in 1984, but previous years' data were corrected before analyses were done. In 1989, in addition to total length, wing width was measured for bat rays. A wing width-total length relationship converted previous length measurements to wing widths. For all *Cancer* crabs, up to 30 randomly selected individuals of each species were sexed and carapace width (CW) was measured with calipers to the nearest millimeter. The rest were counted. *Cancer magister* were measured inside the 10th anterolateral teeth and all other species at the widest point of the carapace. *Cancer magister* >29 mm CW were sexed as were crabs >19 mm CW of other species.

Up to 0.94 L of sorted shrimp from each otter trawl sample were fixed in 10% formalin and processed in the laboratory. Any unidentified fish or crabs were fixed or frozen for later identification.

Larger fish and crabs collected in the beach seine were identified, counted and measured in the field as for otter and midwater trawl samples, but no minimum lengths were used. Fish and crabs not identified in the field and up to 0.94 L of shrimp were fixed in 10% formalin and returned to the laboratory for identification or processing. If necessary, subsamples of fish were taken.

If more than 0.94 L of small fish or shrimp was collected, the total volume was measured for each species of fish or all shrimp before further processing. For fish, a subsample of 0.24 L to 0.94 L, depending on the size of the fish, was randomly taken from the total volume. From the subsample, 50 fish were selected at random and measured as before and the rest were counted to determine the number per unit volume. Total catch was calculated as the product of number per unit volume and total volume.

For shrimp, a 0.94 L subsample was fixed as before, total and subsample volumes were recorded, and the sample was returned to the laboratory for further processing. In the laboratory, up to 100 randomly selected non-ovigerous shrimp of each species were sexed and measured (total length, including rostrum), and a maximum of 50 randomly selected ovigerous shrimp of each species were categorized by egg developmental stage and measured.

Specific conductance and temperature were measured at each station on all surveys. For open water stations during 1980 and for all beach seine stations, only surface measurements were made. A surface water sample was taken with a bucket, temperature was immediately measured to the nearest 0.1 °C, and the sample returned to the laboratory for conductance measurements with a conductance meter. From 1981 through February 1990, conductance and temperature were measured at 1 m depth intervals for stations where depth was <7 m and at 2 m intervals for deeper stations, using a Hydrolab Digital 4021 or Martex 10 Water Quality Monitor. After February 1990, a Seabird Electronics 19 Seacat Profiler was used to record specific conductance, temperature, and depth every 0.5 s during deployment to the bottom and retrieval. The data were averaged to derive a value for every meter of depth in 1990 and every half meter from 1991 to 1996. All conductance data were converted to salinity at 25 °C using the equation:

$$S^{0}_{\infty} = -100 \ln \left(\frac{1 - C_{25}}{178.5} \right), \text{ where } C_{25} \text{ is specific conductance in milliSiemens/cm at } 25 \text{ }^{\circ}\text{C}.$$

For ringnet stations, a Van Dorn sampler was used to collect a bottom water sample. Temperature was immediately measured to the nearest 0.1 °C and the sample returned to the laboratory to measure conductance with a conductance meter.

Data Analysis

Data for 32 fish species, 6 shrimp species, and 4 crab species are included in the report. Depending on species, data from 1 or more gear types are presented. For each species, size frequency data were summed by month into 2 to 50 mm intervals, depending on maximum size, and examined to determine if age-0 individuals could be reliably separated from older year classes (age 1+) by size. For species with distinguishable age-0 individuals, monthly cutoff lengths were established between the size of the largest age 0 and the smallest age 1+. These cutoff sizes were then applied to all size data to determine the age-0 fraction of the catch. In cases where no visual separation of age-0 fish or crabs was possible, either no separation was made or other criteria were used, such as length at maturity or length at age 1 from the literature, and applied to all months. Shrimp were separated into juveniles and adults based on average size at sexual maturity from the literature and unpublished CDFG data. All analyses (abundance, distribution, salinity, and temperature) were done for each age category when a distinction could be made and when there was a sufficient number of organisms collected in the age class.

Catch per unit effort (CPUE) calculations varied by gear type (Table 2). Monthly abundance indices for each species of fish, shrimp, or crab were calculated as the mean CPUE of all stations in a geographical region (for example, Suisun Bay) multiplied by the region's volume weighting factor (Table 3) (calculated by mean depth × area) and summed for all 5 regions in the case of the midwater trawl and plankton net, or by the region's areal weighting factor in the case of the otter trawl:

$$\text{Monthly Abundance Index} = \sum_{\text{REGION} = 1}^5 (\bar{X}_{\text{CPUE}} \times \text{Region Weighting Factor})$$

Annual abundance indices for species caught with the otter and midwater trawls were calculated as the average of monthly indices over the period for which the life stage was most abundant. For beach seine and ringnet surveys, no area or volume factors were calculated for the regions, so annual abundance indices were the average CPUE over a specified period of months.

Table 2 Catch per unit effort (CPUE) calculations for the otter trawl, midwater trawl, plankton net, beach seine, and ringnet

Otter Trawl

For fishes: $CPUE = (\text{number caught}/\text{tow area}) \times 10,000$
 where tow area = distance towed in meters \times 3.42 m (door spread)

For shrimps and crabs: $CPUE = \text{number caught}/5 \text{ min tow}$

Midwater Trawl

$CPUE = (\text{number caught}/\text{tow volume}) \times 10,000$
 where tow volume = number of flowmeter revolutions \times 0.0269 m/revolution \times 10.7 m² (net mouth area)

Plankton Net

$CPUE = (\text{number caught}/\text{tow volume}) \times 1,000$
 where tow volume = number of flowmeter revolutions \times 0.0269 m/revolution \times 0.38 m² (net mouth area)

Beach Seine

For demersal species: $CPUE = (\text{number caught}/\text{tow area}) \times 10,000$
 where tow volume = tow width (m) \times tow length (m)

For pelagic species: $CPUE = (\text{number caught}/\text{tow volume}) \times 10,000$
 where tow volume = tow width (m) \times tow length (m) \times 0.5 maximum depth (m)
 If more than 1 tow was made per station, CPUE was the average CPUE for both tows

Ringnet

$CPUE = \text{total number of crabs}/\text{set}$
 where a set = 4 baited ringnets fished for 30 minutes at 1 station

Table 3 Weighting factors by region and gear type

Location	Region Number	Weighting Factors	
		Midwater Trawl, Plankton Net (Volume 10 ⁸ m ³)	Otter Trawl (Area 10 ⁸ m ²)
South Bay	1	1505.38	250.15
Central Bay	2	2865.13	216.34
San Pablo Bay	3	861.40	153.54
Suisun Bay	4	471.64	55.29
West Delta	5	253.68	28.01

Seasonal abundance was calculated as an average monthly abundance index for the years 1981 to 1988 (years when all 12 months were sampled) or as the monthly abundance from a single year that was considered a representative of all years. Annual distribution was calculated as the average CPUE for each region over the specified index period. Seasonal distribution was calculated as the average CPUE for each area by month (January to December) for the years in which samples were collected in all months: 1981 to 1988 for otter and midwater trawls; 1981 to 1986 for the beach seine; and 1983 to 1989 for the ringnet. Alternatively, a single year or group of representative years was used for calculation of seasonal distribution. The methods sections of each chapter describe when this was done.

The Venice salinity classification was used to characterize salinity. This system defines salinities of 0.0‰ to 0.5‰ as limnetic, 0.5‰ to 5.0 ‰ as oligohaline, 5‰ to 18‰ as mesohaline, 18‰ to 30‰ as polyhaline, and >30‰ as euhaline.