BIOLOGICAL SURVEY OF SAN FRANCISCO BAY 1963-1965

J. A. Aplin. Department of Fish and Game, Menlo Park, California

San Francisco Bay stands as a geographical entity and one of California's major natural resources. The bay area is several hundred square miles and, although about 75 per cent is publicly owned, this represents eight counties and 68 municipalities. As a consequence, conservation planning is extremely complicated. This area around the bay has a present population of four million people and is rapidly growing.

Frequently in recent years, the Department of Fish and Game has been asked to give economic or biological evaluations in relation to extensive dredge and fill operations underway or planned for San Francisco Bay. The estuarine flora and fauna subjected to domestic and industrial wastes from the greater bay area must be evaluated in any long term management plan for the bay. Basic to the solution of these problems is a knowledge of the life existing in the area.

The waters of San Francisco Bay have, in past years, yielded harvests of marine products of considerable magnitude. The oyster, clam, smelt, herring, shrimp, and sportfisheries each has been, or is now of major consequence. Considered in the aggregate, these fisheries represented a harvest of millions of pounds (Table 1).

Table 1. Peak landings of selected species, San Francisco Bay.

Species	Pounds	Year
Clam, soft shell	302,000	1919
Herring, Pacific	4,733,000	1918
Oyster, eastern	2,000,000	1916
Shrimp, Bay	3,000,000	1929
Smelt	462,000	1945

The potential for this production still remains, and, with proper management, may be recovered.

Sport fishing activity in San Francisco is popular and increasing. Anglers frequent the piers at San Francisco and Berkeley, shore fishermen cast from selected sites along both east and west sides of the bay, and angling is popular from party boats and skiffs. Much effort is expended for striped bass, salmon, perch and flounder. In addition, jacksmelt, rockfish, and shark are taken in numbers sufficient to attract many fishermen.

In February, 1963, Marine Resources Operations, Menlo Park, initiated a biological study of San Francisco Bay. This survey is a continuing study to determine distribution and relative abundance of fish and shellfish under prevailing environmental conditions, define ecological zones of the bay, and determine food of the principal fish and its availability. Each month approximately five days research cruise time was used in work at several stations in the bay.

PROCEDURE

For this minimum study of San Francisco Bay, six fish sampling stations (Figure 1) have been established to give a maximum variation of the environmental conditions which range from essentially ocean water to brackish water, which, in some areas, are highly polluted from industrial and domestic sources. These stations are particularly described as follows:

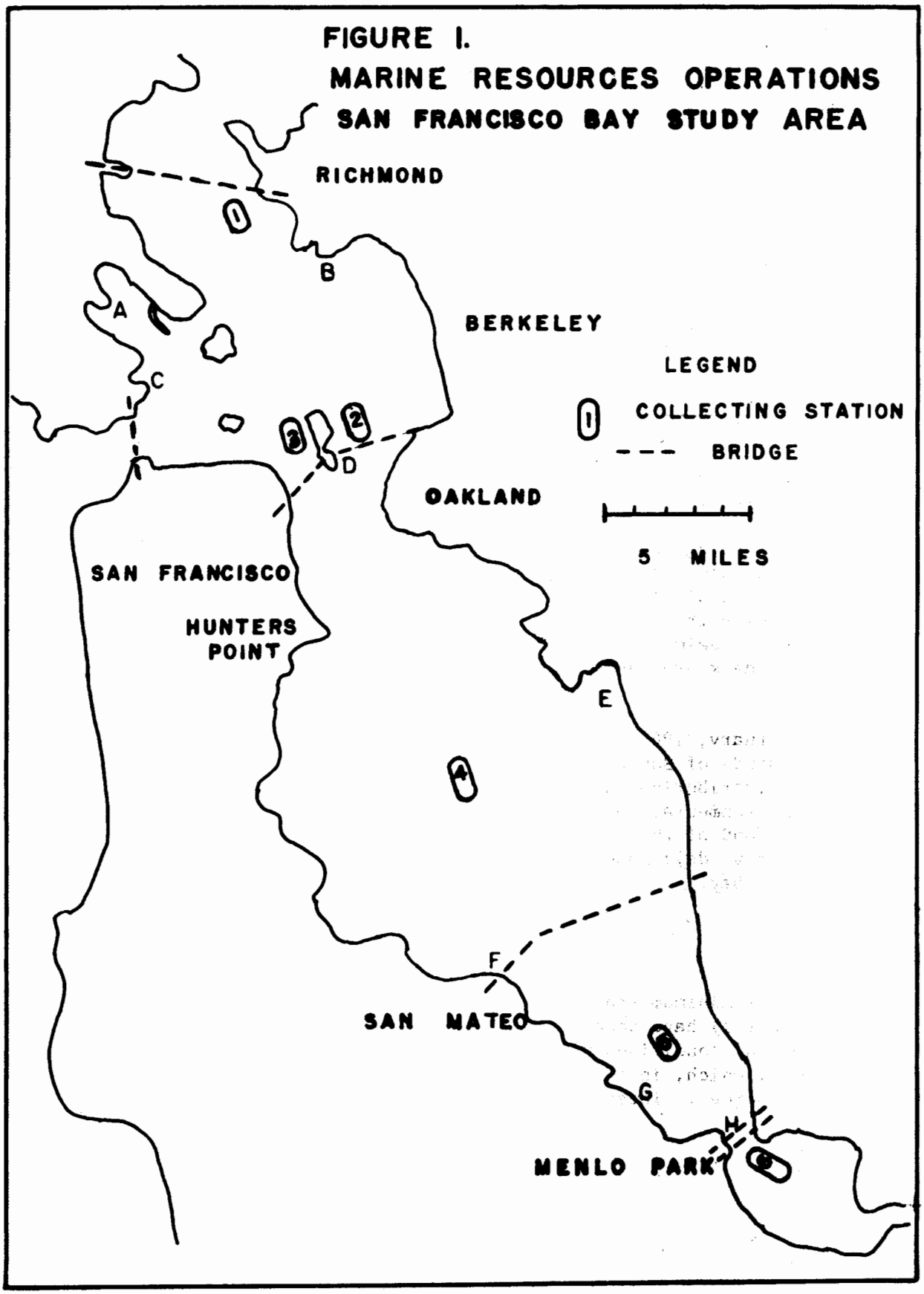
FIGURE I.
MARINE RESOURCES OPERATIONS
SAN FRANCISCO BAY STUDY AREA
RICHMOND
BERKELEY
OAKLAND
SAN FRANCISCO
HUNTERS POINT
SAN MATEO
MENLO PARK
A
B
C
D
E
F
G
H
LEGEND
COLLECTING STATION
BRIDGE
5 MILES

Station No.	Location	Average Depth in feet
1	1/4 mile south of Redrock	30
2	1/2 mile east of Treasure Island	30
3	1/4 mile west of Treasure Island	50
4	1/4 mile west of radar pylon at north end of San Bruno Shoal	30
5	1/2 mile north of No. 2 buoy at entrance to Redwood City Harbor, (midway between the centers of the San Mateo and Dumbarton bridges)	30
6	1/2 mile east of the Dumbarton railroad bridge	20

Each station was sampled monthly with the exceptions of July, 1963, January, 1964; July, 1964 and February 1965, when boat overhauls and crew vacations were necessary. At each visit to a station, we undertook several activities.

1. A 25-foot square-mouthed midwater trawl was towed for 20 minutes at the surface. The corners of the net were spread by four "doors", each about 18 inches square. This net normally has a 15-foot square fishing spread. The cod end is of ½-inch stretched mesh which catches fish as small as 1 inch long.

2. In 1963, a 10-foot beam trawl was fished for 20 minutes. This net, mounted on a steel frame with sled runners, fished an area 4 feet high and ten feet wide as it slid along the bottom. The net was of 1-inch stretched mesh. This net often collected oyster shells or mud from the bottom. Also the heavy beam made handling difficult. Since March, 1964, the bottom sampling has been done with a 15-foot otter trawl. Duplicate tows are frequently made to check consistency of collections.

3. During 1963, bottom samples were collected with a 103-cubic inch orange peel dredge, frozen aboard the vessel, and later examined for invertebrates by San Jose State College.

4. During 1963, plankton tows of 20 minutes were made with a net of 28 mesh per inch and a ½ meter mouth. Plankton samples were submitted to San Jose State for sorting.

5. Temperatures and salinities at the surface were taken by bucket thermometer and extended scale hydrometers.

   Bottom water temperatures and salinities were taken from water collected with a Kemmerer type sampler. At the shallow station (No. 6) only surface observations were made. Temperature was determined to 0.1°C. and salinities to 0.1%.

In addition to the regular station samples, a series of consecutive bottom tows were made from north of Station 1 to the south end of the bay. These catches indicated the sampling stations were characteristic of the respective part of the bay.

Seven daytime sets with a trammel net were also made. Trammel netting did not yield significantly different results.

Ten sampling cruises were made in 1963 and in 1964. In 1965 there were 11 cruises. Our netting operations produced the following totals: 1963 - 80,000 fish, 1964 - 81,000 fish, 1965 - 273,000 fish. The take of anchovies was both more numerous and had greater weight than the catch of all other species combined. Several times an anchovy haul was over 1,000 pounds and could not be hoisted aboard so was dumped without tabulation. On April 24, 1964, feeding schools of anchovies south of the Dumbarton bridge were estimated to contain several hundred tons of fish. More meaningful totals without anchovies would be, 1963 - 27,000 fish, 1964 - 49,000 fish, and 1965 - 34,000 fish.

The ten most commonly caught fish listed in order of their frequency are:

Anchovy
Shiner perch
English sole
Pacific herring
Sanddab
Jacksmelt
Staghorn sculpin
Tomcod
Midshipman
Starry flounder

In order of times they occurred in a possible 132 tows in 1965, they rank as follows:

Anchovy	91
Shiner perch	82
Pacific herring	58
Jacksmelt	55

Midshipman	53
Staghorn sculpin	53
English sole	39
White croaker	38
Tomcod	37
Sanddab	35

Nineteen fish species have occurred at all six stations. They are:

Northern anchovy	Pacific staghorn sculpin
Bay goby	American shad
White croaker	Leopard shark
Starry flounder	Brown smoothhound
Pacific herring	Topsmelt
Jacksmelt	English sole
Northern midshipman	Pacific tomcod
Pile perch	California tonguefish
Shiner perch	Spiny dogfish shark
Bat Ray	

Six additional species have wide distribution in the bay, having taken in at least five of the six stations. These species are:

Walleye perch	White seaperch
Bay pipefish	Big skate
Striped bass	Whitebait smelt

The surface dwellers often appear in catches of a bottom tow by being taken when the net is on the way down or up.

Totals by station for 1965:

Station	Total fish catch
1	28,655
2	36,562
3	148,430
4	18,500
5	13,581
6	27,488

The sampling locations nearest the Golden Gate, Stations No. 1, 2, and 3 yielded the greatest variety of fish (Table 1). This is not at all surprising because there is a mixing of bay and ocean waters, and Sacramento River waters in the area bounded by the Golden Gate, San Rafael, and Bay Bridges. At Station No. 6, nearest the south end of San Francisco Bay, fewer species were taken. In this part of the Bay, mixing of water masses is the least. However, the occurrence of fish species south of the Dumbarton Bridge reveals that, though the waters receive

Table 2. Numbers of species taken at each station by month in 1965.

Station	Jan.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Means
1	17	15	16	23	21	17	16	22	17	6	8	16
2	11	14	18	17	22	17	14	17	11	18	13	16
3	14	11	17	22	20	15	21	17	20	15	21	18
4	15	5	14	15	17	9	15	8	4	4	14	11
5	14	9	11	11	3	12	7	9	7	12	11	10
6	10	7	11	16	8	6	11	13	9	9	9	10
Means	14	10	15	17	15	13	14	14	11	11	13	

large quantities of waste from south bay communities, water quality off the City of Palo Alto is such that a rich assemblage of fauna exists. (Table 2.)

INVERTEBRATES

Of 125 bottom tows made, 101 had bay shrimp present. This indicates their widespread distribution in the bay and their availability throughout the year. On August 12, 1964, a 20-minute tow of the 15-foot otter trawl caught 400 pounds of shrimp at the station south of the Dumbarton Bridge. Occasional examinations of fish stomachs indicated that shrimp are a major food for bay fish.

Benthos

a 100-cubic-inch orange-peel bottom sampler was used at the six established stations in the bay which were determined for the study of fishes. One sample was taken each month except July during 1963 at each station. In a few cases, a second sample was taken. The volume of the samples actually varied considerably since the sampler penetrated further in soft mud than in sand and shell. Very soft samples averaged about 3 liters while the ones containing the most shell were about half this. The samples were either processed immediately or placed in deep freeze for future processing.

In processing, the material was washed through a series of sieves of graduated mesh, beginning with 7 or 10 mm. and going down to 1 mm. Animals were removed, preserved in formalin or alcohol. Most of them were carefully measured except for the very small forms that occurred in great numbers. Observations were recorded for the substrate of each sample.

In addition to the orange-peel samples, additional material was obtained from hauls of the beam trawl used for collecting fishes. This net sometimes dug into the substrate and brought up many bottom specimens. There were several advantages to this incidental sampling. We obtained crabs which escape the orange-peel sampler; we found some species that the bottom samplers did not penetrate deep enough to reach, or we found that the species was more numerous than our sample indicated.

Because of the very small size of our sample in relation to the size of the area which it represented, little can be determined about the total population or density patterns of a species. It is disappointing to be able to take only one sample when many more are needed for adequate statistical analyses. However, we did secure information of a general nature which helps in determination of distribution of animals in the bay substrates. (Table 3.) A brief discussion of the phyla represented at the several stations is presented below.

Table 3. Distribution of species and specimen numbers taken by Orange-Peel Dredge at six stations, San Francisco Bay, April-December, 1963.

(Hydroids, bryozoans omitted from specimen count at all stations)

Station and substrate	Number of species	Number of specimens	Species unique to station
Station 1 - predominantly sand with some mud and fine shell	16	39*	2
Station 2 - predominantly sand and shell but with some mud. More varied than Station 1.	16	60*	3
Station 3 - mostly homogeneous sand and mud, usually with empty bamboo worm tubes.	19	123*	1
Station 4 - Predominantly mud with shell fragments.	11	98	2
Station 5 - sticky mud with some sand, little or no shell. More varied than 4 or 6.	13	549	1
Station 6 - uniformly very sticky mud with no sand or shell.	7	93	1

* Gemma gemma, amphipods, and chelifers omitted from the specimen count at three stations. These would add thousands at Stations 1 and 2, and hundreds at Station 3.

Porifera

Several small encrusting sponges were observed, but no attempt was made to identify them. One globular free sponge which is believed to be Tetilla mutabilis was taken in a grab sample at Station 4 and was seen in numbers in dredged material from Stations 4 and 5.

Coelenterata

Fraser lists 95 species of hydroids as occurring in San Francisco Bay. No attempt was made to find and identify all the hydroids that might have been present. The most abundant was Obelia dichotoma found particularly in material from Stations 3 and 4.

Stylatula elongata, the slender sea pen, was collected in 2 samples at Station 1 (3 specimens), in 3 samples at Station 2 (12 specimens), and in larger numbers in all samples from Station 3 (33 specimens). At Station 3 very small specimens were found in October. The substrate was sand with some mixed mud.

Diadumene leucolena is a small orange anemone (an introduced species) which was collected in grab samples at Station 5. It was seen to be very abundant both at Stations 4 and 5 from dredged material. It was found fastened to shells, stones, pieces of wood, and even submerged leaves all through the spring months.

Bryozoa

Here again, no attempt was made to find and identify the species of this phylum. Membranipora spp. was seen on shells and stones at all stations except 6. In the dredged material one species of arborescent bryozoa was common. Identification is being sought.

Nemertinea

Only 4 specimens were collected.

Polychaeta

Glycera americana, one specimen in each of two samples, was found at Station 1, which was notably lacking in polychaetes. It also occurred in one sample from Station 3. In all three cases, the substrate was sand with some mixture of mud.

Glycera capitata was found in three samples at Station 2. Four very tiny glycerids found in May at this station were probably G. capitata.

Pectinaria californiensis occurred in one sample from Station 1, three samples at Station 2, and in one sample at Station 3. Empty shells were found in several samples where no living worms were taken. In all cases but one, the substrate was a mixture of sand, mud, and broken shell.

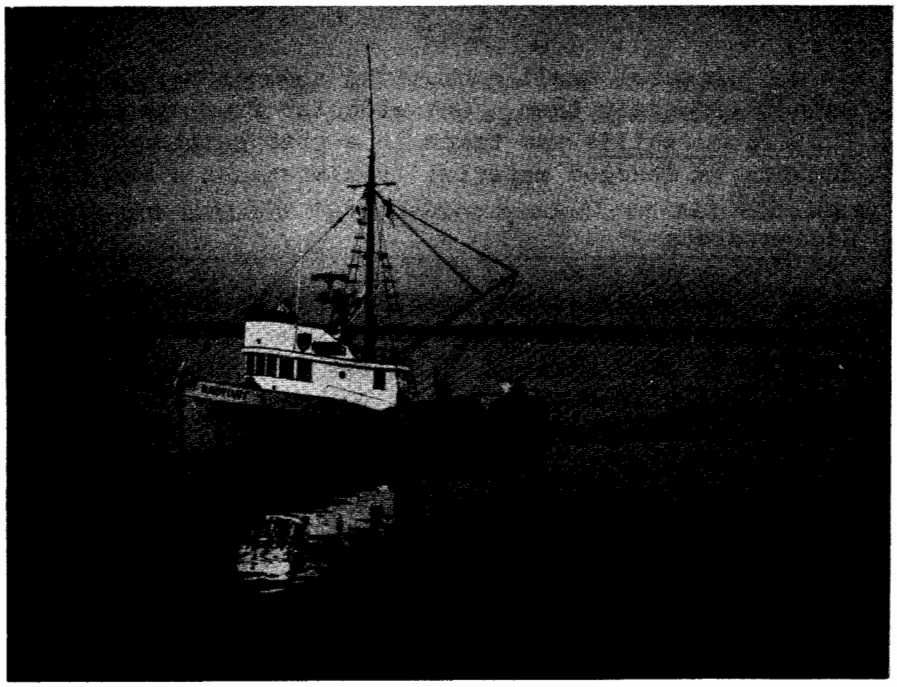

Figure 2. Setting the Midwater Trawl. September 1965

Figure 3. Sorting Fish. 20 December 1965

In the exceptional case, the substrate had very little sand but did contain broken shell.

Axiothella rubrocincta, the bamboo or joint worm, was the most numerous and wide-spread polychaete. It occurred in one sample at Station 1, one at Station 2, in 50 per cent of the samples from Station 3, and in 50 per cent of those from Station 4. While it was not found in Station 5, there were empty tubes. Some living specimens were taken in dredged material from this station. The tubes of this worm must be very resistant and long lasting as they were in extraordinary abundance in many samples. The worm was most abundant in rather sticky pure mud. Since the substrate in Stations 6 is of this nature and the worm shows some tolerance (the substrate in Stations 1 and 2 was sandy), its distribution must be limited by some other factor. Total specimens 68.

Nereis zonata was found in one sample from Station 4, two from Station 5, and two from Station 6. Nineteen specimens were recovered, all from mud in which there was some sand.

Nenthes succinea was somewhat more widely distributed than N. zonata since it was found at Stations 3, 4, 5 and 6. Fewer specimens (15) were taken however. They seemed to require the same substrate and were taken in the same sample twice.

Nereis procera was found in dredged material at Station 5.

Marphysa sanquinea was found only at Station 6 in homogeneous sticky mud.

Lumbrinereis zonata occurred in one sample at Station 3.

Mollusca

Musculus senhousei, the mud mussel, was extremely abundant. It occurred in masses fastened together by byssal threads. One mass examined contained 75 individuals. This mussel was taken at all stations except 1 and 3. Stations 2 and 4 had only 6 specimens while station 5 had 485 and Station 6 had 36. The largest specimen was 36 mm., greatest length.

Mytilus edulis, the bay mussel, was found in small numbers, and of small size at scattered locations. Only 8 specimens were obtained at Stations 4, 5, and 6. The largest was 20 mm. in length, no indication that the areas sampled are suitable for the maturing of this species.

Macoma nasuta, the bent-nosed clam, was found at Stations 1, 2, and 3. The maximum size was 30 mm. but most were smaller. They occurred in 50% of the samples at both Stations 2, and 3, and in one-third of those at Station 1. Thirty-three specimens were taken. There was no correlation between season and size.

Macoma inconspicioua was taken only at Station 1. It occurred in two samples, in one case with M. nasuta. Both of these clams were found on sandy bottoms where there was some admixture of mud.

Tapes semidecussata, the Japanese littleneck, was abundant. It was not found at Station 1 or 2, and only four specimens in two of the samples at Station 3. At Station 4, 49 specimens were found in four samples. At Station 5, all samples but one contained this clam - 142 specimens. At Station 6, 5 specimens were found three times. All were very small. Again no specimens approached maximum size, the largest being 31 mm. According to Fitch, the maximum is about 77 mm. There are, however, areas in the channel at Station 5 which are favorable for complete development. Large specimens were taken by dredging.

The three species of oysters which have been harvested in times past from San Francisco Bay were Crassostrea virginica, the eastern oyster; Crassostrea gigas, the Pacific oyster; and Ostrea lurida, the native oyster. The eastern oyster production was from growth of young oysters brought in from the Atlantic coast by rail for several years after completion of the transcontinental railroad. About 1938, Pacific oyster seed was being brought to California from Japan, but few marketable oysters were produced in San Francisco Bay. San Francisco Bay did prove suitable for the spawning of the eastern and Pacific oysters. The most recent planting was made in 1958, but all the seed was lost in deposits of soft mud. The native oysters have never been an important product from San Francisco Bay. Beds of Ostrea lurida shells have been dredged from the deeper waters of south San Francisco Bay for many years for use in poultry feed and the making of cement. Geologists have reported that these shell beds are evidence of large populations of native oysters over 2,000 years ago.

Solen sicarius, the sickle razor clam, was found in two samples from Station 1, and in three samples from Station 3. The substrate in all cases was sand with some mud in homogeneous mixture. One specimen was 75 mm. in length while the others were small.

Clinocardium nuttallii, the basket cockle, occurred in one sample in Station 1, 2 samples at Station 2, and 1 sample at Station 3. All specimens were small, the largest 20 mm. The substrate was muddy sand with fine shell fragments in some cases.

Mya arenaria, the soft-shell clam, was found once, one small specimen at Station 3.

Gemma gemma occurred in almost unbelievable numbers in a surprising range of substrates. Care was taken to estimate the numbers carefully. This species did not occur at Stations 1, 4, 5, or 6. Only 32 specimens were found at Station 3. Station 2, however, had them present in all samples except the December one. In two cases, 2000 or more were present in a single sample.

Schizothaerus nuttallii, the gaper, was found only once in fine mud at Station 6. Specimens were 20 mm. in length.

Gastropoda

Nassarius obsoletus, the mud snail, was very common. This is an introduced species. It occurred in two samples from Station 1, one sample from Station 3, one sample from Station 5, and three samples from Station 6. It was abundant in dredge samples from both 4 and 5 so that our sampling here may have been biased. It was usually found in rather heavy mud but did occur, as at Station 1, in a sandy substrate. There seemed to be no seasonal peak of size and maximum size animals were found.

Nassarius fossata was found in two samples from Station 1, and in three samples from Station 2. It was always on a substrate of sand with some mud.

Nassarius cooperi was found in two samples from Station 2, and from one sample from Station 3. It was found in one sample with N. fossata.

Nassarius mendicus was found only once at Station 5.

Several other gastropods were found only once: Crepidula nivea at Station 4 in November, Epitonium sp. at Station 4 in November, Ocenebra sp. from Station 5 in October, Olivella biplicata from Station 1, Bittium sp. from Station 2 in June. Urosalpinx cinereus was found at Station 6. In a dredged sample, nine large specimens of the introduced conch, Buscycon canaliculatus, were taken at Station 4.

Crustacea

Aside from the gammarids and chelifers which were extremely numerous in spring samples from Station 1 and 2, few crustaceans were taken in grab samples. This is undoubtedly due to the fact that surface dwelling crabs can escape the sampler. Most of our specimens were recovered from material brought up by beam trawl.

Cancer magister was taken only once. This was a very small (carapace width 12 mm.) specimen obtained at Station 2.

Cancer antennarius was taken once in a grab sample and two specimens of large size were taken by dredge at Station 4.

Cancer productus was taken at Station 4 by dredge.

Cancer gracilis was taken at Station 4 by dredge.

Pachygrapsis crassipes was found once, in a most unlikely situation in mud brought up at Station 6.

Pugettia Richii was taken at Station 5.

Inachoides tuberculatus. A spider crab was taken in several hauls at Stations 4 and 5. This presented problems of identification, but we think this is correct. This crab has a distribution given by Schmitt and by Rathbun as extending north into Monterey Bay. We have more than a dozen specimens.

PLANKTON

This plankton study was made to determine relative abundance and seasonal variations of zooplankton. An exact quantitative analysis was not possible, but the data gives us a general picture. The animals collected were at, or very near, the surface and of 1 mm. or more in size. (Table 4.) This limitation excluded protozoans, planulae, trochophores, immature copepods, and possibly some of the smallest mature copepods. In this study of the zooplankton, the volume of the sample was reduced to 50 cc. by straining away the excess liquid. The larger organisms picked out included amphipods, mysids, postlarval crabs and a few isopods and chaetognaths. These were counted for the whole sample. The remainder of the sample was carefully stirred and a 1 cc. aliquot removed. The sample was stirred again and another aliquot removed. This was repeated. The three aliquots were combined, put into a Petri dish and the animals identified and counted. Where a great many copepods were found the sample was estimated by counting random squares.

Table 4. Relative abundance of principal plankton forms in Aliquot Parts of plankton samples collected from April, 1963, through February, 1964.

Animals	Stations						
	1	2	3	4	5	6	(Totals)
Copepods	92	57	329	196	203	138	1015
Calanus	830	881	1355	856	788	996	5706
Paralabidocera	26	122	285	222	215	215	1085
Acartia	848	1060	1969	1269	1206	1296	7648

The species of copepods could be distinguished with practice except in the case of Acartia clausii and A. tonsa which required an examination of minute structures at high magnification. It was decided impractical to separate these so they are lumped in the tables. In treating the larval crustaceans, no attempt was made at specific identification.

Brachyuran larvae are identified simply as Brachyuran zoea and postlarval stages (mysis and megalops). The zoeal and postlarval stages of the anomuran crabs were separated from those of the brachyurans. Larval stages of the Cragonidae, readily distinguishable because of the long fifth leg, were listed separately.

San Francisco Bay plankton tends to have a shifting distribution. This is shown in the data for monthly hauls. Phyto-plankton is concentrated below the surface except in the darkest winter months and the members of the food chains dependent directly on phytoplankton or on the primary consumers follow this pattern. In the case of the mysids, found in the winter months, we were obtaining samples of 'strays' since these are primarily bottom animals that may swim up at night and be found in small numbers in the upper zone. Amphipods also tend to be subsurface but not as definitely bottom dwellers as mysids.

Crab zoea and postlarval stages were important elements of the plankton. These first appeared in large number in April (though they might have been there in March - we had no March samples.) They continued through June and dropped off sharply by August. A few were present in September. They are a more important element than their mere numbers indicate since they are big enough to contribute considerable biomass. Most of the larvae were brachyuran crabs. A few Porcellanidae larvae were found. Cragonidae larval forms were very rare in the plankton, particularly considering the great numbers of gravid female shrimp found in the areas sampled. They must spend their larval life in deeper waters or in some other portion of the bay.

Amphipods occurred throughout the year in moderate numbers. The only sample containing a large number was a sample in May at Station 1.

Mysids were taken in small numbers during the winter months. There are apparently three closely related species all belonging to the genus Neomysis. They exist in large numbers in the winter near the bottom.

During no month was the plankton really depleted. It was surprisingly evenly distributed when one looks at the picture for the whole year though a single month might show a good deal of difference from station to station. There was a definite spring peak with a tapering off through August and September and a new build up beginning in December. There did not seem to be two peaks as the usual picture is given. This may have been a special characteristic of the year and shoud be so assumed until further data are available.

INTERTIDAL SAMPLING

A series of sampling locations (A-I, Fig. 1) were chosen for intertidal observations. Sites were selected to include a wide range of water quality, substrate material, and geographical distribution.

These few collections were not intended to be representative of the many miles of bay shoreline but were made to reveal what forms of invertebrates are generally common about the bay margin. An examination of each location was made during a minus tide on one or more dates and a list of macrofauna made. (Table 5.) Identification of species was not made for all groups of invertebrates encountered. Over two dozen species of worms are known to occur in San Francisco Bay so one heading was used for worms. Japanese littleneck clams and native littleneck clams have been combined. Similarly, the basket cockle and the spiny cockle are included under one heading and white sand clam, bent nosed clam, and the inconspicuous macoma are lumped under the generic name Macoma. The acorn barnacle is the most common invertebrate in the bay but there are several barnacle species that are difficult to distinguish which are probably present. A similar situation exists for other groups such as the sponges, sea slugs, and anemones.

Station A, Strawberry Pt. in Richardson Bay, is an area of coarse gravel eroded from the bluff above the shore. This substrate is ideal for littleneck clams. Many small Japanese littleneck clams are harvested by sport fishermen for bait. Sea lettuce (Ulva) is plentiful. Hundreds of northern midshipmen spawn under the flat rocks. The road, built in 1964 along the south shore, provides access to a favorite fishing area.

On January 23, and July 9, 1963, the following animals were found at this location:

Northern midshipman
Mud crab
Shore crab
Rock crab
Barnacles
Bay mussel
Littleneck clams
Gaper clam
Macoma clams
Lemon nudibranch
Worms

The shore from the southern limits of Sausalito south to the sewer plant was chosen as Station B. This area has some sand beach at the south end and is composed of large rocks at the north end. Numerous gaper clams were found living about 200 feet from the sewer plant. The outfall is several hundred feet offshore and does not appear to influence marine life along the beach. Deposits of hundreds of thousands of oyster drill egg cases were found on the rocks and pilings at the edge of town. This shore is much used by fishermen.

The invertebrates found July 13, 1964 include the following:

Kelp crab
Rock crab
Porcelain crab
Ghost shrimp
Barnacles
Isopods
Sea mussel
Bay mussel
Gaper clam
Cockles
Littleneck clams
Jingles
Oyster drill
Lemon nudibranch
Ochre starfish
Leather starfish
Chitons
Worms

Table 5. Occurrence of the more common invertebrates at selected shore stationsin San Francisco Bay. 1963 and 1964.

	SHORE STATIONS								
ANIMALS	A	B	C	D	E	F	G	H	I
*Barnacles	X	X	X	X	X	X	X	X	X
Bay mussel	X	X	X	X		X	X	X	
*Worms	X	X	X	X	X	X			
Littleneck clams	X	X	X	X	X				
Gaper clam	X	X			X		X		
Mud crab	X		X	X			X		
Shore crab	X	X		X				X	
Native oyster			X			X	X	X	
Ribbed horsemussel					X		X	X	X
Sea mussel		X	X	X					
*Macoma clams	X		X	X					
Rock crab	X	X		X					
Market crab			X	X					

* Species combined (see text).

Brooks Island and the Richmond jetty (Station C) ranges from rough rocky shore along the south side of the island to very soft mud on the north side. The stone jetty running west from the island does not support as much marine life as exists on the rocky southeast point of land. There are numerous patches of eel grass shoreward of the island but not bayward.

On August 24, 1964, we observed the following invertebrates in the intertidal zone:

Mud crab	Softshell clam
Market crab	Littleneck clams
Barnacles	Piddock
Bay mussel	Basket cockle
Sea mussel	Limpets
Bent nosed clam	Mud snail
Native oyster	Worms

Station D on the east shore of Yerba Buena Island from the Bay Bridge pier to the north end of the Coast Guard Base has several kinds of bottom material. The bridge pier fauna is much like that of a steep rocky shore. High on the beach is coarse gravel and rocks. However, at about the -2.0 elevation, there is an almost level sand bottom of over an acre in extent that supports a good growth of eel grass.

Animals found August 10, 1964:

Northern midshipman	Littleneck clams
Shore crab	Cockles
Mud crab	Macoma clams
Hermit crab	Jingle
Market crab	Oyster drills
Rock crab	Sea slugs
Ghost shrimps	Ochre starfish
Barnacles	Shortspine starfish
Isopods	Sponges
Bay mussel	Anemones
Rock mussel	Worms

Station E is several miles off shore from Alameda south to the mouth of San Lorenzo Creek. A drawbridge leads from Bay Farm Island to Alameda and a gravel bar follows the south side of the channel westward for about a quarter of a mile. The littleneck clam population along here is the most dense found in the Bay study. Some sandy areas along this spit are dug for worms for fishbait. A mile southeast along the channel by the old airport are many gaper clams. Intensive digging has resulted in harvest of the larger clams. Included in this station is the area around the San Leandro Marina. Soft-shell clams are the most plentiful form here. About 2 miles southeast at the mouth of San Lorenzo Creek there is a sandspit about half a mile long. The only common marine life found here are ghost shrimp.

Animals found April 5, 1963, and February 5, 1963:

Ghost shrimps	Soft-shell clams
Barnacles	Gaper clam
Ribbed horsemussel	Worms
Littleneck clams	

Station F is confined to the pilings of the San Mateo Bridge. Dredging in the area has removed most of the bottom life. Experience at other locations has shown that the marine populations should soon be re-established after shore stabilization from the mechanical change in the bottom.

Animals found March 26, 1964:

Barnacles	Native oyster
Isopods	Sponges
Bay mussel	Worms

Station G includes Port of Redwood City and the adjacent shore. The substrate is soft mud in the deeper water and along the shore except for the filled location behind the dock. Near the dock there is enough broken shell material on the surface to make walking possible. There are soft-shelled and gaper clams in the gravelly areas. This dock has had trays of living oysters hanging from it since February, 1962. At no time since then has the water quality been so bad as to kill the oysters.

Animals found December 6, 1963, March 10, 1964, and May 6, 1964:

Mud crab	Ribbed horsemussel
Skeleton shrimp	Soft-shell clams
Barnacles	Gaper clam
Isopod	Native oyster
Gribble	Sponges
Hydroids	Ascidians
Bay mussel	

Station H includes the Dumbarton Bridge and nearby shoreline. The bridge piers support Pacific oysters. These were the only ones found in the bay. They were all old individuals and probably originated from spawning of earlier plantings in the south end of the bay.

Animals found January 31, 1962, May 17, 1963, September 20, 1963, and April 18, 1964:

Shore crab	Ribbed horsemussel
Skeleton shrimp	Native oyster
Barnacles	Cockles
Gribble	Pacific oyster
Hydroids	Sponges
Bay mussel	Sea anemones

Station I is at the railroad bridge over Coyote Creek near the town of Alviso. The natural flow of fresh water from the creek as well as the considerable flow of sewage coming into the bay here limits the number of organisms that can survive. As a result, there are only three animals living here. They are acorn barnacles, ribbed horsemussels, and mud snails. However, the number of individual snails is in the hundreds per square yard. Observations were made January 16, 1963, and April 19, 1964.

The ribbed horsemussel, Arcuatula demissa, deserves special mention as it is one of the most plentiful shellfish in the bay. This bivalve was introduced from the Atlantic coast with transplants of Eastern oysters which began in 1879. The mussel lives in the high intertidal zone and prefers areas of cord grass, Spartina leiantha. This filter feeder removes all sorts of suspended matter from water. A dozen animals in a five-gallon aquarium of murky water will remove most of the floating material in a few hours. It is common in Napa Slough as well as around the south end of the bay. A single square foot of substrate in the Palo Alto Harbor vicinity contained 387 individuals with a total weight of 7.45 pounds. When projected for the acres where they have been seen growing, estimates of hundreds of tons are feasible. This shellfish is known to be high in vitamin D content and has been harvested commercially on the Atlantic coast. A venture in 1962 to harvest this mussel from San Francisco Bay beds was unsuccessful.

Large flows of freshwater run off from the Sacramento and San Joaquin rivers and at times bring the surface salinity in the north end of the bay to very low levels. Records of November, 1964, show a 14.1 parts per thousand at Southhampton Shoal. The bottom water is more saline, but the reversing tidal action causes the whole body to become almost of equal density by the time it reaches the Golden Gate. The addition of sewer effluent and irrigation waste waters also reduced the salinity. At times of maximum river flow, there are severe dieoffs of certain shellfish. Japanese littleneck clams are killed but softshell clams are unaffected. With one exception (November, 1964) salinities were normal with a range of 16.5 parts per thousand in February, 1963, to 31.9 parts per thousand in August, 1964.

Temperature means between a low of 8.6°C. in December, 1963, to a high of 21.1°C. in August, 1963, follow the long term averages. A series of cold days with strong winds from the central valley will reduce the bay water temperature below that of the open ocean. On windless days in summer or fall, exceptional highs occur in the shallow south bay waters.