2.257 Except for temporal differences, the life history and habits of the three species of bay shrimps are the same. According to Skinner, the breeding season for the Franciscan bay shrimp (Crangon[1/] franciscorum), which is the largest of the three species and forms the bulk of the commercial catch, is centered during winter through late spring but gravid females may be found year-round in certain locations (176). The mouth of Petaluma River, known as Petaluma flats, is noted for having large numbers of gravid bay female Franciscan bay shrimps year-round. The Blacktailed bay shrimp's (Crangon nigricauda) main breeding season is from spring through summer and lasts for at least six months. Both species may spawn twice per year with only a short interval between spawnings. There are no spawning data for the third species, the Spotted bay shrimp (Crangon nigromaculata).

2.258 Each species migrates toward the Golden Gate where there is higher saline water during the spawning season. Newly hatched larvae are planktonic and become an integral part of the zooplankton community. Once they metamorphose, they settle to the bottom and slowly move toward shallower, less saline water (176). Bay shrimps are found on all types of sediments but distinctly prefer the muddy substrate in depths greater than 15 feet. As they mature, they begin to move into deeper depths so that there is a gradual increase in size with increasing depth. All three species reach maturity by the end of the first year at which time they are about two inches long.

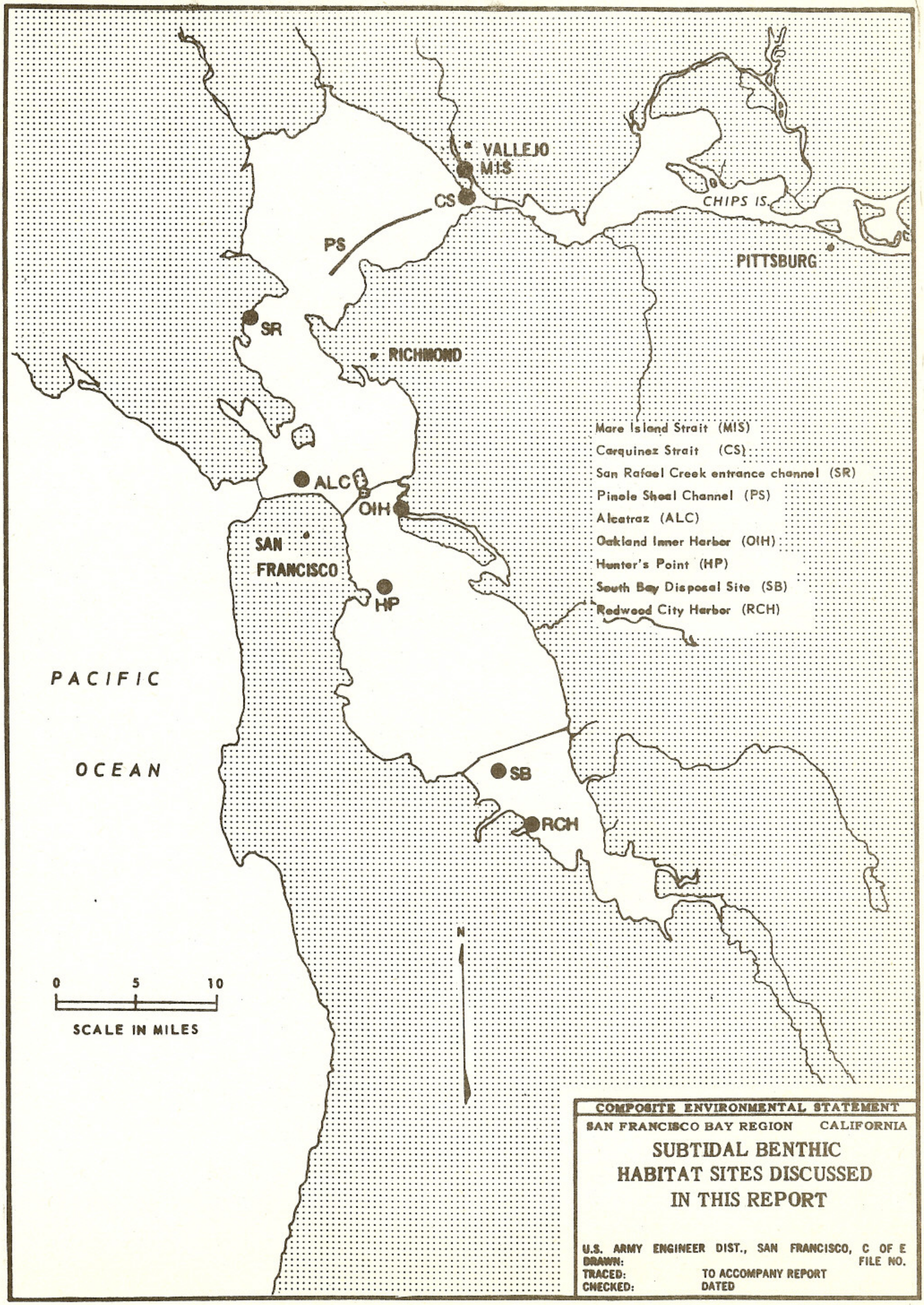
2.259 The Franciscan bay shrimp is the most tolerant to freshwater, being found far into the Delta. The other two species, the Blacktailed bay shrimp and Spotted bay shrimp, are more or less limited to San Pablo Bay southward. In Central Bay, these latter two species are more abundant than the Franciscan bay shrimp. The Franciscan bay shrimp is more abundant toward the eastern reach of San Pablo Bay and in Suisun Bay.

1/ The generic name Crago for bay shrimps has been synonymized with Crangon; Crangon being the proper generic name. For further details see Light's Manual (Smith et al., 1975).

2.260 Rather than list and compare the distribution patterns of the individual species of subtidal bottom animals for each sub-bay which is not only difficult for the general reader to assimilate but also difficult to relate to dredging/disposal effects in the Bay (since no data or studies are available with respect to impacts of dredging and disposal for most individual bottom animal species), the comparisons of the bottom fauna will be made regarding selected project areas and disposal sites in the Bay. Impacts on the bottom biota, which are discussed in detail in Section IV, can be more easily related to with this approach. For those readers desiring more detailed information concerning the multitude of subtidal benthic organisms in the Bay, their distribution in the various sub-bays and so on, the reader should refer to the SERL reports, the U.S. Fish and Wildlife Service special report (245), and publications by Aplin (4), Kelley (89) and Appendix D of the Dredge Disposal Study (224).

2.261 The selected areas discussed below are: Redwood City Harbor, South Bay Disposal Site (an area no longer used), Hunter's Point Disposal Site (no longer used), Oakland Inner Harbor, Alcatraz Disposal Site, San Rafael Creek entrance channel, Pinole Shoal Channel, Mare Island Strait and Carquinez Strait Disposal Site. Suisun Bay is also briefly discussed but the description is not specific to any given project site. Except for San Rafael Creek, Pinole Shoal Channel and Suisun Bay, the biological information for all sites are primarily taken from Appendix D of the Dredge Disposal Study (for specific details concerning the study, such as sampling methods, precise location of sample stations, species lists, etc, Appendix D of the DDS should be referred to). Information for the San Rafael Creek entrance channel and Pinole Shoal is based on data generated by Kelley and the U.S. Fish and Wildlife Service (a study sponsored by the Corps), and Suisun Bay data are based on Kelley. Plate II-40 shows the sites that are discussed in some detail.

2.262 (a) <u>Redwood City Harbor</u>. Two sample stations were established at this project site during the SRI study; one at the entrance to the navigation channel between buoys 2 and 3, and another further up the channel between buoys 5 and 6. The stations were selected this way in order to assess the recovery time of the bottom fauna from an experimental dredging operation in March 1973. The downstream station (between buoys 2 and 3) was dredged by hopper and the upstream station was used as a reference station. Both stations were periodically sampled for one year from March 1973 (before dredging) to June 1974. The pre-dredge sampling in March established that the two stations were quite similar in species composition and relative abundance (at least for the month of March).


VALLEJO
MIS
CS
CHIPS IS.
PS
PITTSBURG
SR
RICHMOND
Mare Island Strait (MIS)
Carquinez Strait (CS)
San Rafael Creek entrance channel (SR)
Pinole Shoal Channel (PS)
Alcatraz (ALC)
Oakland Inner Harbor (OIH)
Hunter's Point (HP)
South Bay Disposal Site (SB)
Redwood City Harbor (RCH)
ALC
OIH
SAN FRANCISCO
HP
PACIFIC
OCEAN
SB
RCH
N
0 5 10
SCALE IN MILES
COMPOSITE ENVIRONMENTAL STATEMENT
SAN FRANCISCO BAY REGION CALIFORNIA
SUBTIDAL BENTHIC HABITAT SITES DISCUSSED IN THIS REPORT
U.S. ARMY ENGINEER DIST., SAN FRANCISCO, C OF E
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2.263 The next sampling occurred in September, six months after the experimental dredging was completed. Results revealed that although there was no reduction in total numbers of species between March and September samples at the dredged station, the species composition and numbers of organisms markedly changed. For example, 10 of the polychaete species (worms) collected in September were not present in March. Only three of the 15 arthropod species in March were common to both sampling periods (nine were new in the September samples, three that were present in March were absent in September). However, the ubiquitous amphipod *Ampelisca milleri* and mud mussel, *Musculus senhousia* were abundant during both periods. These two species appear to be characteristic of the bottom fauna in the lower reach of South Bay.

2.264 Number of organisms increased about 20 times in the September sample over the March sample at the dredged station but progressively decreased into 1974. The March 1974 sample, however, was still 10 times more than that of the March 1973 sample.

2.265 Species difference between March and September 1973, at the reference station, although apparent, was not as noticeable as at the dredged station for these two sample periods. Population at the reference station also increased in September but only doubled as compared to a 20-fold increase at the dredged station. The doubling was primarily due to increased numbers of *Ampelisca* and a polychaete, *Streblospio benedicti*, whereas the 20-fold increase at the dredged station was due to many species. Subsequent sampling in 1974 revealed a progressive population increase which contrasted to the decreasing trend of the dredged station for the same period.

2.266 After one year since the dredging experiment began, the last samples were taken in June 1974. Results indicated that by this time, the species composition between the two stations was again similar even though the overall population at the dredged station was 1.5 times larger than the reference station. From the data, it appears that there is a rapid recovery rate (within a year) of the bottom fauna after dredging. Seasonal and recruitment cycles of a given species are evidently important in re-establishing the species population at this area. The species compositional change after dredging is probably due to the combination of a natural, seasonal change (as evidenced from the reference site) and the invasion of opportunistic species finding an open niche. The more abundant species, such as *Ampelisca milleri*, the polychaetes *Exogone lourei*, *Streblospio benedicti*, and the mud mussel, *Musculus senhousia* were little affected by dredging. These common species no doubt experienced a net reduction immediately after dredging but quickly recovered within the next sampling period (within six months) and continued to be abundant up to June 1974 when the field surveys terminated.

2.267 In terms of relative abundance, aside from those common species already mentioned above, oligochaetes (distant relatives to the polychaete worms) were also very numerous. As a general class of worms, there were no apparent detrimental effects on oligochaetes from dredging although there might have been negative effects on the species level. Identification of oligochaete species was not attempted by SRI because of the confused taxonomic state of these worms. Nematodes were abundant at both stations year-round but individual species were not identified. The only bivalve of any abundance in the entrance channel was the mud mussel, which is interesting, since Wooster (see Tidal Flat Habitat discussion) noted small beds of Soft-shell and Japanese littleneck clams on the shallow tidal flats of Redwood City Harbor (262).

2.268 (b) South Bay Disposal Site. This site, which was a 1500 x 3000-foot area in 30 feet of water just south of the San Mateo-Hayward Bridge, was an aquatic dredge disposal site used for a couple of years in the early 1970's in attempt to centralize dredge disposal in the lower reach of South Bay (Plate II-40). Before 1972, dredge disposal in South Bay was indiscrimminate, taking place just about anywhere at the convenience of the dredger. When the South Bay Disposal Site was established by the Corps, it served as a discharge point for dredgings from Redwood City Harbor and various marinas situated in the lower reach of South Bay, but because Redwood City Harbor has not been maintained since FY 1972 and most of the marinas require infrequent maintenance, the South Bay Disposal Site was used infrequently and received relatively small quantities. Today, this disposal site is no longer used for dredge disposal and the closest designated aquatic disposal area for dredging from South Bay harbors and marinas is the Alcatraz site (Plate I-2).

2.269 Two sample stations were established at this disposal site during the SRI study. One was at the southern end where the sediments from the experimental dredging of 5000 cubic yards from Redwood City Harbor were disposed at. The other station was at the northern end which was presumably uninfluenced by the disposal at the opposite end, 3,000 feet away.

2.270 Although the disposal quantity and numbers of bottom samples taken were limited, SRI concluded that there was no evidence of adverse effects on the bottom fauna as a result of depositing 5000 cubic yards of Redwood City Harbor channel sediments at the preselected disposal area (224). Post-disposal samples revealed little change in numbers of organisms and the dominant organisms sampled before disposal continued to dominate the population numbers subsequent to disposal. These dominants included, among others, the polychaete Exogone lourei, the amphipod Ampelisca milleri, and various oligochaetes. Species composition changed little between pre and post-disposal except for additional species of polychaetes and arthropods noted during the post-disposal sampling period. The increased species number was probably due to introduced species from the dredged site as well as natural seasonal fluctuations of species in that area.

2.271 The undisturbed sample station located at the northern end of the site contained the same general dominant species as did the disturbed southern station, but the species composition was quite different between the two stations. For example, 12 taxa or types belonging to the three dominant groups of organisms in the Bay (Polychaeta, Arthropoda and Mollusca) were found exclusively at the disturbed station whereas 22 taxa were found only at the undisturbed station of numbers, however, these 34 mutually exclusive types constituted a very minor sum, amounting to only 0.27 percent of the total number of noncolonial specimens collected from both stations. Later samples at the undisturbed station also revealed an overall increase in species numbers over the earlier samples, similar to that observed at the disturbed station. This phenomenon is attributed to seasonal fluctuations and not to sampling error because during each sample period, five replicate samples were taken per station which are felt to be an adequate number to obtain a representative overview of the bottom fauna at that station and at that particular time.

2.272 Although overall species composition differed between stations, the South Bay Disposal Site is considered rather rich in variety of species. Over 90 types were enumerated from this site and were well represented by polychaetes, arthropods, molluscs, bryozoans (moss-like animals), and coelenterates (sea pens, anemonies, etc).

2.273 (c) Hunter's Point Disposal Site. This particular site is located just offshore of Hunter's Point, San Francisco, in 50 feet of water. The 2000-foot diameter circular site was also established in 1972 to regulate aquatic dredge disposal from harbors in the general vicinity but like the South Bay Disposal Site, this site was seldomly used. The Hunter's Point site is no longer used for dredge disposal and if aquatic disposal is necessary from harbors in this area, the dredged material must either go to the Alcatraz site or to the 100-fathom site outside the Golden Gate.

2.274 Only one sample station was used during the study and no disposal took place at this site during the study. The variety of species collected here was even greater than at the South Bay Disposal Site, numbering 138 species or types which was the largest number of species collected from any station in San Francisco Bay. More than just the usual groups of nematodes (roundworms), polychaetes, oligochaetes, arthropods and molluscs were represented at this site; such as coelenterates, nemerteans (worm-like animals), bryozoans, protozoans (single-celled organisms), echinoderms (sea cucumbers, etc.), sipunculids (commonly called peanut worms), phoronids (worm-like animals living in chitinous tubes) and tunicates. Most of the latter types were derived from the continental shelf outside the Golden Gate and are strictly marine species.

2.275 Again, the most numerous bottom animals were Ampelisca milleri and Exogone lourei plus a few arthropods (Corophium acherusicum, for example) and annelids (segmented worms). Ampelisca accounted for 84.6 percent of the total number of arthropods and about 55 percent of the total noncolonial specimens. Molluscs, however, were not abundant, although 20 species were represented at this site.

2.276 (d) Oakland Inner Harbor. The SRI sample station was located just inside the entrance channel of Oakland Inner Harbor between the Oakland Naval Supply Center and the Alameda Naval Air Station. This station, of all the sample areas in San Francisco Bay, was the most densely populated and contained a rich variety of animal types. This station hosted 137 identified taxa, being only one less than at Hunter's Point. This station also contained 22 year-round species; more than at any other station in San Francisco Bay. Considering the annual frequency of maintenance dredging in this area, the diversity and number of year-round species are astounding.

2.277 Only six of the 137 taxa were considered abundant which made up 94.6 percent of the total number of specimens collected at this station for one year, as compared to eight taxa at Hunter's Point (which comprised 91.4 percent of the total specimen count). From only one station at this project site, it is impossible to determine whether more or less species or taxa would be considered abundant if no dredging occurred but observations made at the two sampled stations at Redwood City Harbor where the downstream station was dredged and the upstream station was not, there was no difference in numbers of abundant taxa (11 for each station constituting over 90 percent of the total count) and taxa between these two stations were very similar.

2.278 As observed at most other areas around the Bay, large numbers of nematodes and oligochaetes inhabited the Oakland Inner Harbor station. Unlike the South Bay sample stations (South Bay Disposal Site, Redwood City Harbor and Hunter's Point), the polychaete Streblospio benedicti was the most abundant animal collected as opposed to the amphopod, Ampelisca milleri. Ampelisca was not considered abundant even though it was collected year-round. Arthropods were not well represented numerically although relatively large numbers of species were encountered. The second most abundant polychaete was Exogone lourei which was also relatively common in South Bay.

2.279 Of the molluscs, the Gem clam, Gemma gemma was the most common, accounting for 93.2 percent of all molluscs collected. The Gem clam was one of the six taxa and the only mollusc considered common from this station. Other molluscs of some abundance were Macoma nasuta (Bent-nose clam), Macoma inquinata, Mysella sp. and Musculus senhousia (mud mussel).

2.280 (e) Alcatraz Disposal Site. This 2000-foot diameter circular site, which is located about 1/3 mile south of Alcatraz Island and in about 130 feet of water, is one of three Corps-designated aquatic dredge disposal sites in San Francisco Bay west of Carquinez Strait (Plate I-2). The other two are in San Pablo Bay. Approximately 2.1 million cubic yards of Corps dredged material are disposed here every year plus another 1.2 million cubic yards by other interests.

2.281 The Alcatraz site was unique in species diversity. A total of 133 taxa was collected which was only five less than the most diverse station at Hunter's Point. Unlike other areas, nearly all were considered transients except for three types which were found year-round. The three, year-round types were unidentified species of nematodes, oligochates and the bivalve Adula diegensis. It is possible that the unidentified individual species of nematodes and oligochaetes could have been transients. Transient species occur only at certain times of the year and in case of SRI's sampling period (March 1973-June 1974), greatest numbers and kinds occurred in December.

2.282 In terms of numerical abundance, the most abundant taxa were Nemertea, Nematoda, Oligochaeta, three polychaete species and one amphipod (Photis brevipes). None of the common species such as Ampelisa, Exogone, Streblospio, and Gemma found so abundant at Redwood City Harbor, Hunter's Point, Oakland Inner Harbor and other sites were at all numerous at the Alcatraz site. No species of mollusc were abundant. Like the bottom fauna of Hunter's Point, the great majority of the 133 taxa collected can be considered typically marine, originating from outside the Golden Gate.

2.283 (f) San Rafael Creek Channel. The Corps entrance channel to the mouth of San Rafael Creek is close to two miles long crossing an extensive shallow flat (Plate I-5). In the shallower portions of the flat, toward the mouth of the Creek (the intertidal area), Wooster found relatively large beds of Soft-shell clams and to a lesser extent of Japanese little-necks (approximately 400,000 specimens of both species) which are known to extend below the intertidal (262). The U.S. Fish and Wildlife Service (USFWS) noted that these two species were quite common below the intertidal near the West and East Marin Islands in three to four feet (MLLW), the islands being one to 1½ miles offshore of San Rafael Creek adjacent to the entrance channel (245). Other molluscs frequently found by USFWS in this area were the mud mussel, Bent-nose clam, Inconspicuous clam (Macoma inconspicua) and the Mud snail (Nassarius obsoletus).

2.284 In addition to the molluscs, USFWS collected numerous unidentified polychaetes, the amphipods Photis californica and Corophium sp., and other arthropods. As far as the Corps knows, no other sampling has been conducted in this area.

2.285 (g) Pinole Shoal Channel. Sampling at the mouth of San Rafael Creek was a small part of a two-year study that was conducted by USFWS under contract from the Corps to determine the short-term effects of dredging and disposal in San Pablo Bay. The concentrated sampling effort was made in the Pinole Shoal Channel. Their report did not contain numerical or relative abundance data but frequencies of occurrence of species were noted. They found the amphipod Photis californica to be the most common bottom animal in Pinole Shoal Channel which was in agreement with SERL's findings in San Pablo Bay. Unlike SERL, however, USFWS did not collect any Gem clams which SERL found to be the second most common benthic animal in San Pablo Bay. The apparent difference in Gem clam results between USFWS and SERL need not be considered inconsistent with each other because Painter noted that the Gem clam was the most abundant clam collected in shallow water in San Pablo Bay (129). Painter found very few, if any, Gem clams in deep water. The Soft-shell clams, mud mussels and Japanese littlenecks were commonly collected in Pinole Shoal Channel by all three of the above investigators. Painter found the Japanese littlenecks to be the most numerous clam in deep water.

2.286 All three investigators also commonly collected oligochaetes, polychaetes, (such as Streblospio benedicti and Glycinde armigera), other amphipods (Corophium spp.) and molluscs (such as the Mud snail, Nassarius obsoletus) in the navigation channel. A note of interest is the Dungeness crab which is purported to be abundant in San Pablo Bay but is not caught with conventional benthic grab samplers. USFWS used an otter trawl sampler to collect bottom fish in San Pablo Bay and frequently caught Dungeness crabs in the channel and in shallower areas such as on the flats offshore of San Rafael Creek. Their importance has been alluded to earlier and the Dungeness crab is discussed in greater detail under Open Bay Habitat.

2.287 (h) Mare Island Strait. Two sample stations were regularly sampled by SRI in Mare Island Strait. One station was in the navigation channel and the other was toward the east bank of the Strait outside the channel. The predominant bottom invertebrates from both stations were unidentified oligochaetes constituting 87.3 percent of the total collection from the channel station and 95.7 percent from outside the channel. Although occuring in much less abundance, the next most frequently sampled animals in the channel station were nematodes (4.9%) and copepods

(5.7%), most of which were also unidentified to the species level. Together, the oligochaetes, nematodes and copepods comprised 98 percent of all specimens sampled in Mare Island Strait channel. Seasonal fluctuations were noted for these animals with oligochaetes occuring in greatest abundance in September and least in March. This was also true for the nematodes but copepods were most abundant in December and least in March.

2.288 Molluscs found in great abundance in the SERL study in San Pablo Bay were not evident in the Mare Island Strait Channel. The dominant mollusc was Macoma balthica. A total of 33 taxa of subtidal bottom invertebrates was identified from the channel station.

2.289 The station outside the channel (an undredged area) was almost completely inhabited by oligochaetes, comprising greater than 95 percent of the total sample during each survey period. Although fewer species or types were encountered from this station (26 species or types), the population was about six times larger than the channel station. Also, a seasonal fluctuation in numbers per species was not as evident in this undredged sample station as it was in the channel. Populations were relatively stable throughout the sample year.

2.290 Nematodes (1.1%) were the next most abundant animals at the undredged station. Streblospio benedicti was the most common polychate worm in both the channel and outside channel stations. Macoma balthica and the Soft-shell clam (Mya arenaria) were the most numerous molluscs sampled.

2.291 (i) Carquinez Strait Disposal Site. Dredge material from Mare Island Strait is biannually disposed of at the Carquinez Strait Disposal Site (see Plate I-2). Sampling over a one year period by SRI revealed that there was a greater diversity of bottom invertebrates here than, but not as populous as, Mare Island Strait. There was little difference between the two SRI stations at the Carquinez disposal site (one station in the center and the other at the northern boundary of the site) in terms of species numbers (47 and 48 species respectively) and the more common types.

2.292 As in Mare Island Strait, oligochaetes were the most numerous types collected; being most numerous in the center of the disposal area in June and most numerous at the northern boundary station in September. Nematodes at both stations were the second most numerous kinds of animals. Of the polychaetes, which were not nearly as numerous as oligochaetes, the most common was Streblospio benedicti being most abundant at the northern boundary station. Benthic copepods were sparsely collected here. Molluscs were not abundant but the prevalent species were Macoma balthica and the Soft-shell clam.

2.293 (j) Suisun Bay. In contrast to the rest of the Bay system, Suisun Bay is brackish to freshwater. A "faunal break" separating the "brackish and freshwater biota" from the "salt water biota" was first observed by Filice in the eastern end of Carquinez Strait with a salinity average of 9.5 ppt (53). This observation has more or less been supported by subsequent studies (59,129). The "faunal break" is a transition zone where most organisms of marine origin cannot cross and successfully survive on the "other side" and vice versa with organisisms of freshwater origin. For an estuarine system where freshwater grades into salt water, the transition zone is primarily dictated by salinity. This zone can move upstream or downstream to some extent depending on freshwater flow but when averaged over a year or several years, the zone can be considered in eastern Carquinez Strait.

2.294 In general, the fauna west of this zone (San Pablo Bay southward) is quite homogeneous, with the great majority of organisms of marine origin. The fauna east of this zone (Suisun Bay and upstream) is derived mainly from the freshwater aquatic habitats of central California (exceptions are introduced "exotic" species that have successfully survived).

2.295 There are three dredging projects in Suisun Bay that are discussed in the Composite Statement but since there are no specific biological data for these three project areas, the Suisun Bay subtidal benthos will be generally described.

2.296 Compared to the other three sub-bays, the Suisun Bay subtidal bottom supports relatively few bottom animal species (Plate II-36). Of the three major groups (Annelida, Arthropoda and Mollusca), the annelids and arthropods are the most numerous. Particularly abundant are the polychaetes, Neanthes succinea and Polydora uncata (Neanthes being an important food item for young-of-the-year Striped bass), and the amphipod Corophium spinicorne (which is also heavily preyed upon by young Striped bass). Storrs et al found numbers of the freshwater Asian clam, Corbicula fluminea in Suisun Bay (188), whereas Painter did not (129).

2.297 The more freshwater-tolerant marine species (euryhaline species) can be found in Suisun Bay but in reduced numbers and usually confined to the western or downstrean end. Some of the species include the polychaete Streblospio benedicti, barnacle species, the amphipod Corophium insidiosum, the Soft-shell clam and the Petricola pholadiformis clam. The marine-tolerant freshwater species can be found in San Pablo Bay during high flows in winter and spring but are not normally successful in breaching the "faunal break" at any other time.

2.298 (3) Bottom Fish. There are certain species of fish that spend the majority of their time on the bottom, either feeding and/or actually living on the bottom. These are termed bottom fish in contrast to the pelagic fish species which may feed on the bottom but spend most of their time swimming or foraging in the water column. The latter group of fishes (which includes the anadromous fishes) are discussed under Open Bay Habitat.

2.299 Of the 20 most common fish species listed by Aplin in his survey of Central and South Bays, at least 13 can be considered bottom fishes (4). These generally included gobies, sculpins, flounders (flat-fishes), sharks and rays which are important predators of the three major groups of subtidal invertebrates in the Bay. Worms, clams and amphipods form an important diet of these bottom fishes. Flounders, particularly Starry flounders, are abundant in the Bay and are a popular sportfish. Several species of sharks, such as the Leopard shark, Brown smoothhound and the Spiny dogfish, are also caught by anglers but are not prized as sportfishes.

2.300 The U.S. Fish and Wildlife Service found the same bottom fishes in their survey of San Pablo Bay (245). The more numerous bottom fishes of Suisun Bay are the White catfish, Sacramento sucker, carp and the Staghorn sculpin (western end of Suisun Bay). The White catfish preys on the amphipod Corophium, annelid worms and clams, and the Staghorn sculpin in Suisun Bay feeds on worms and shrimps (59).

2.301 The White catfish (Ictalurus catus), which is the most abundant catfish species in California, is a very popular sportfish especially in the Delta. Approxmately one-third of the catfish caught in California are from the Delta, of which most are the White catfish species (28). It can weigh as much as 12 pounds but rarely exceed eight.

2.302 Table II-18 list some of the common bottom fishes inhabiting the San Francisco Bay system.

TABLE II-18

SOME OF THE MORE COMMON BOTTOM FISHES OF SAN FRANCISCO BAY 1/

Common Name 2/ (Species Name)	Remarks
Sevengill shark (Notorynchus maculatus)	Permanent resident; Central & South Bays
Leopard shark (Triakis semifasciata)	Permanent resident; Central & South Bays
Brown smoothhound (Mustelus henlei)	Permanent resident; San Pablo Bay & southward
Spiny dogfish (Squalus acanthias)	Permanent resident; San Pablo Bay & southward
Big skate (Raja binoculata)	Permanent resident; San Pablo Bay & southward
Bat ray (Myliobatis californica)	Permanent resident; San Pablo Bay & southward
Sacramento sucker (Catostomus occidentalis)	Permanent resident; Suisun Bay & upstream
Carp (Cyprinus carpio)	Permanent resident; Suisun Bay & upstream
Splittail (Pogonichthys macrolepidotus)	Permanent resident; Suisun Bay & upstream
White catfish (Ictalurus catus)	Permanent resident; Suisun Bay & upstream
Black bullhead (Ictalurus melas)	Permanent resident; Suisun Bay & upstream
Brown bullhead (Ictalurus nebulosus)	Permanent resident; Suisun Bay & upstream
Pacific tomcod (Microgadus proximus)	Permanent resident; All sub-bays
Pacific sanddab (Citharichthys sordidus)	Permanent resident; San Pablo Bay & southward
Speckled sanddab (Citharichthys stigmaeus)	Permanent resident; San Pablo Bay & southward
Sand sole (Psettichthys melanostictus)	------------- San Pablo Bay & southward
English sole (Parophrys vetulus)	Permanent resident; San Pablo Bay & southward
Starry flounder (Platichthys stellatus)	Permanent resident; All sub-bays
California tonguefish (Symphurus atricauda)	-------------
White croaker (Genyonemus lineatus)	-------------

TABLE II-18 (Cont'd)

Common Name 2/ (Species Name)	Remarks
Lingcod (*Ophiodon elongatus*)	Permanent resident; San Pablo Bay & southward
Cabezon (*Scorpaenichthys marmoratus*)	------------- San Pablo Bay & southward
Bonyhead sculpin (*Artedius notospilotus*)	Permanent resident.
Buffalo sculpin (*Enophrys bison*)	Permanent resident.
Pacific Staghorn sculpin (*Leptocottus armatus*)	Permanent resident; All sub-bays
Prickly sculpin (*Cottus asper*)	Permanent resident; Suisun Bay & upstream
Bay goby (*Lepidogobius lepidus*)	Permanent resident.
Longjaw mudsucker (*Gillichthys mirabilis*)	Permanent resident.
Arrow goby (*Clevelandia ios*)	Permanent resident.
Yellowfin goby (*Acanthogobius flavimanus*)	Permanent resident; All Sub-bays
Plainfin midshipman (*Porichthys notatus*)	Permanent resident.
Bay pipefish (*Syngnathus griscolineatus*)	Permanent resident.
Penpoint gunnel (*Apodichthys flavidus*)	-------------
Rockweed gunnel (*Xererpes fucorum*)	-------------
Brown rockfish (*Sebastes auriculatus*)	Permanent resident; San Pablo Bay & southward
Threespine stickleback (*Gasterosteus aculeatus*)	Permanent resident; Suisun Bay & upstream

1/ Other than anadromous fishes.
2/ Common names after American Fisheries Society, 1970.
Principal Sources: Ruth, 1969; Aplin, 1967; Ganssle, 1966; and U.S. Fish and Wildlife Service, 1970.

f. Open Bay Habitat.

2.303 (1) Introduction. This habitat encompasses all the open water areas of the San Francisco Bay system and constitutes a volume of 235 billion cubic feet at mean tide level (168). Its surface area covers 420 square miles at mean tide and 441 square miles at mean high tide.

2.304 The myriad of species inhabiting the water column is astounding, ranging from single-celled microscopic plants to highly intelligent marine mammals. The diversity of plants and animals utilizing the open waters of the Bay is too great to allow a complete discussion here and thus aquatic life is discussed in general terms with emphasis on the more common or more important species to man, with the full realization that any habitat (and therefore the entire ecosystem) involves thousands of species, each important to the integrity of the habitat.

2.305 The open bay habitat is divided into two broad communities, the plankton and neckton communities. The communities are based on the inhabitants' locomotive abilities, with the plankton community characterized by floating or weak swimming plants and animals and the neckton community characterized by free-swimming fish (not spending much time on the bottom if at all) and marine mammals. Additionally, there are many waterbirds that utilize the open bay even though they are not restricted to this one habitat.

(2) Plankton.

2.306 (a) Suspended Microscopic Plants and Animals. These creatures constitute inumerable kinds of plants and animals - usually quite small - that either live their entire lives in the water column or live a brief portion of their lives (usually the young stages) in the water column and spend the remainder of their time on the bottom. The plant components of the plankton, or phytoplankton, form the first link of the food chain which eventually incorporates all other life forms in the Bay. Phytoplankton plays the same role as saltmarsh plants and benthic diatoms of the tidal flats; that of converting inorganic material into nutrient-rich organic foods that can be assimilated by its predators. As a by-product of synthesizing organic material, the phytoplankton also produces large amounts of oxygen and thus helps keep the water well oxygenated. The phytoplankton community is dominated by diatoms, similar to those species found on the tidal flats. There are over 25 genera of diatoms found in the Bay (256) and they can be extremely abundant throughout the Bay system at certain times of the year. Other types of phytoplankton occur less frequently and include the green algae and dinoflagellates (single-celled plants that have two whip-like appendages).

2.307 Seasonality of phytoplankton abundance is quite pronounced in the Bay. In San Pablo Bay south, the population peaks in spring and is at a minimum in fall whereas in Suisun Bay, the population (essentially all freshwater species) climaxes in late summer and is lowest in the winter. Suisun Bay contains fewer species of phytoplankton than the other sub-bays but is ten times more numerically abundant than the other three sub-bays (188). Maximum concentrations in Suisun Bay were estimated in SERL's study to be about two million cells per liter of water (a liter is slightly larger than a quart; 1 liter = 1.06 qt). The minimum concentration in Suisun Bay was about equal to the maximum concentration in the lower reach of South Bay. Not all species of phytoplankton in the same area climax at the same time, however. For example, in Central Bay, the overall maximum abundance occurs in spring but green algae and certain species of diatoms are more frequent during the summer and dinoflagellates in the winter.

2.308 In addition to seasonal changes, phytoplankton abundance fluctuates daily with the tidal cycle. SERL's studies noted that some diatom species are more abundant at higher-high slack tide than others, and some at lower-low slack tide. Dinoflagellates are prevalent at higher-high slack whereas green algae at lower-lower slack water.

2.309 The second component of the plankton community is the small animals that drift and feed among the phytoplankton. These creatures are called zooplankton. Unlike, phytoplankton, the zooplankton cannot synthesize food from inorganic material and thus must prey on those that do the synthesizing or upon other zooplankters to obtain the necessary nutrients.

2.310 Seasonal abundance of zooplankters is not as easily discernable as the phytoplankton, but in general, zooplankters are most abundant in the summer and least in the winter and early spring in Suisun, San Pablo and South Bays (188). In Central Bay seasonal changes are much more complex. Studies by SERL indicate that in north Central Bay, the zooplankton peaks in summer with an apparent secondary peak in the winter. For the rest of Central Bay, there are also two peaks during the year: one in summer and the other during spring. The complex seasonal pattern of zooplankton in Central Bay is due to the greater diversity of species in this sub-bay than in the other sub-bays, and each species or group of species has its own cyclic pattern.

2.311 By far, the most common zooplankter is the copepod. Both the adult and nauplii (larvae) stages are abundant and occur throughout the Bay system but being most common in Central Bay. Other important types of animals that make up the zooplankton community are: cirripedes (young, free-swimmining stage of barnacles), polychaete larvae, gastropod veligers (swimming stage of snails) and numerous fish eggs. Table II-19 list the more common kinds of animals that compose the zooplankton in the Bay.

2.312 There are two kinds of zooplankters that are commercially important as adults, but make up only a small proportion of the zooplankton community. These are the young stages of Dungeness crab and several species of shrimps which are described in greater detail later on.

2.313 Zooplankton abundance, like phytoplankton, fluctuates daily depending on the species and tidal cycle. Most species are more common on higher-high slack water than at other times and include copepods; and young stages of cirripedes, decapods (crabs), mysids (shrimps), tunicates, cumaceans (shrimp-like animals that inhabit the bottom as adults), echinoderms (sea stars, sea urchins, etc.) and molluscs. Other types, such as fish eggs and larvae, ostracods (seed shrimps, which are crustaceans), certain species of young snails, rotifers ("wheel animalcules") and chaetognaths (arrowworms), are more frequent at lower-low tide. There are exceptions to the above general observations depending on locale. Fish eggs and larvae in western Suisun Bay are more common at the higher-high tidal stage in contrast to lower-low tide in the other sub-bays which indicate their primary source is to the west (marine origin). In South San Francisco Bay, tidal difference in species occurrence is not as readily apparent as in Central or San Pablo Bays.

2.314 Frequency of occurrence (see Table II-19 for definition) of zooplankton species is also dependent on the sub-bays which reflects environmental gradients in the Bay system such as salinity. Most of the types listed in Table II-19 are, however, found in all four sub-bays to one degree of abundance or another. Tunicate larvae, for example, are twice as frequent in Central Bay as in South Bay; fish eggs and larvae are two to three times more common in South Bay than northward; and echinoderm larvae are mostly found in Central Bay (188). At the extreme ends of the Bay system, the lower reach of South Bay and Suisun Bay, the frequency of occurrence of most zooplankters is less than in the central portions of the Bay.

TABLE II-19

MEAN FREQUENCY OF OCCURRENCE OF ZOOPLANKTERS IN SAN FRANCISCO BAY

Organism	Mean Frequency of Occurrence 1/ %
Copepods, adult	97
Copepod nauplii	71
Cirripede nauplii and cyprid larvae	57
Ploychaete larvae	52
Gastropod veligers	37
Fish eggs	28
Amphipoda	21
Lamellibranch veligers	21
Tunicate larvae	21
Cladocera	20
Decapod zoea	20
Cyphonaute larvae	19
Mysidacea	17
Rotifera	17
Isopoda	16
Cnidaria	12
Ostracoda	12
Echinoderm larvae	9
Chaetognatha	3
Cteriophora	2
Cumacea	1

1/ Frequency of occurrence is the percent of total samples in which a particular kind of animal was found irrespective of its abundance in any given sample.

SOURCE: Storrs, Pearson, and Selleck, 1966.

2.315 Although all species of zooplankton are important to the overall ecosystem of the Bay, certain species have been studied more than others, either because of their commercial importance or their importance as food to commercially valuable fish (such as the Striped bass). Two species are discussed in further detail and are: the Opossum shrimp and the larval stage of the Dungeness crab. The discussion of these two species will give one a better idea as to the role and importance of the zooplankton community in the overall estuarine ecosystem.

2.316 (b) Opossum shrimp. Unlike the bay shrimps, the Opossum shrimp (Neomysis mercedis)1/ is a brackish water to freshwater crustacean and is confined to Suisun Bay and upstream. This zooplankter is much smaller than bay shrimps (3/4th-inch as adult) but can be very abundant in Suisun Bay during certain times of the year. The Opossum shrimp has been intensively studied by California Fish and Game for a number of years because of its importance to the diet of young-of-the-year Striped bass and because of political considerations that could alter the environment of the Delta; thus affecting the Opossum shrimp.

2.317 Opossum shrimps in Suisun Bay are generally abundant during the summer which coincides with their spawning period, and decline in population in fall until they reach a minimum in winter. Greatest abundance seems to be concentrated in Montezuma Slough at the north end of Suisun Bay, which is adjacent to Suisun Slough where periodic dredging is required (see Plate I-18).

2.318 Abundance and distribution are primarily affected by salinity and temperature. During the summer, a period of minimal freshwater flow, the population is centered at the eastern end of Suisun Bay and even further upstream during a dry year. Optimun salinity appears to be between 0.5 and 4.0 ppt (76), and although high salinity (say, greater than 10 ppt) may not harm adult Neomysis, it appears to inhibit production (28). The late spring increase in Opossum shrimp coincides with increasing water temperature and the population reaches a maximum between 68°-72°F. According to Heubach, temperatures greater than 72°F are detrimental to Neomysis, which could be the reason for the late summer and fall decrease in population (76).

1/ The scientific name of the Opossum shrimp has been recently corrected from Neomysis awatschensis to Neomysis mercedis. For details, see Simmons et al., 1974, and Smith et al., 1975.

2.319 Light and tides also affect its abundance and distribution. During the day, Neomysis is found near the bottom and at night is randomly distributed throughout the water column. At ebb tide it is closer to the bottom than at flood tide, and farthest off the bottom at slack tide.

2.320 Neomysis is an omnivorous filter feeder, ingesting detrital matter and phytoplankton (principally diatoms). It may also be a particulate feeder as well since it does eat zooplankton (rotifers and small crustaceans).

2.321 (c) Dungeness crab. It has been becoming more apparent in recent years that San Pablo Bay is an important nursery area for young Dungeness crabs (Cancer magister). Little is known of the life history of Dungeness crabs in San Francisco Bay but the California Fish and Game is currently studying this dependence.

2.322 Based on limited data gathered by California Fish and Game, it appears that gravid female Dungeness occur strictly outside the Golden Gate (they do not enter the Bay). Mating takes place in the ocean in late spring or early summer but the eggs are not laid until fall. The eggs are not extruded into the water colunm but are carried under the abdomen of the female until they hatch in late winter or early spring. A single female crab may lay over 2.5 million eggs - all attached to her abdomen.

2.323 Once the eggs hatch, they become free-swimming and are now part of the expansive zooplankton community of the ocean. Those outside the Golden Gate are swept into the Bay during flood tide and are distributed through the northern reach of the Bay. The planktonic larval crabs feed among the Bay plankton and rapidly grow. At the same time, they are being eaten in tremendous numbers by salmon, Striped bass and by a myriad of other predators.

2.324 The larval crabs are part of the plankton community for about five months (December through May or June) after which they transform into minature adults and descent to the bottom to assume a benthic existence. They prefer a sandy bottom which they enjoy burrowing into but occasionally are found on a mud substrate. They rarely are found on rocky shores. As they mature, they slowly migrate along the bottom toward the Golden Gate and eventually out to the sandy bottom ocean. Dungeness crabs are reported to range from Alaska to Baja California. The distribution of immature Dungeness in San Francisco Bay is shown in Plate II-38.

2.325 (3) Fish. Ruth lists 131 species of fish that can be found in the San Francisco Bay system, ranging from strictly marine to strictly freshwater species (149), which reflect the diversity of the Bay estuarine environment. Ruth's list included all species of fish (bottom and pelagic fishes) but under this habitat description (aquatic habitat), the pelagic or free-swimming fishes not directly dependent on the bottom are the only ones discussed. Bottom fishes are briefly described under subtidal Benthic Habitat. Table II-20 lists some of the common pelagic fish species in the Bay system.

2.326 (a) Marine species. Probably the most abundant marine pelagic fish species in terms of numbers and biomass in the Bay is the Northern anchovy, Engraulis mordax. This species is an ocean fish that moves into bays to spawn in late spring and early summer; thus San Francisco Bay is an important nursery area for the Northern anchovy as well as for other fish as will be realized later. Large schools of adult anchovies enter the Bay during the spawning period and leave by late summer. Their eggs are pelagic, meaning that they are free-floating and are part of the zooplankton community. Along with the rest of the zooplankton, enormous quantities are preyed upon. Immature anchovies are found from South Bay to San Pablo Bay year-round (to a lesser extent in Suisun Bay) and since they are plankton feeders, they prodigiously feed on the abundant Bay plankton. Adult anchovies are an important commercial harvest of the ocean and are used primarily for bait.

TABLE II-20

SOME OF THE MORE COMMON PELAGIC
FISHES OF SAN FRANCISCO BAY 1/

Common Name 2/ (Species Name)	Remarks
Threadfin shad (*Dorosoma petenense*)	Permanent resident; primarily freshwater.
Pacific herring (*Clupea harengus*)	Permanent resident; all sub-bays.
Northern anchovy (*Engraulis mordax*)	Permanent resident; San Pablo Bay & southward.
Sacramento smelt (*Spirinchus thaleichthys*)	Permanent resident; all sub-bays.
Surf smelt (*Hypomesus pretiosus*)	Permanent resident; San Pablo Bay & southward.
Whitebait smelt (*Allosmerus elongatus*)	------------------; San Pablo Bay & southward.
Pond smelt (*Hypomesus transpacificus*)	Permanent resident; all sub-bays.
Black crappie (*Pomoxis nigromaculatus*)	Permanent resident; Suisun Bay & upstream
Bluegill (*Lepomis macrochirus*)	Permanent resident; Suisun Bay & upstream
Largemouth bass (*Micropterus salmoides*)	Permanent resident; Suisun Bay & upstream
Smallmouth bass (*Micropterus dolomieui*)	Permanent resident; Suisun Bay & upstream
Jacksmelt (*Atherinopsis californiensis*)	------------------; San Pablo Bay & southward
Topsmelt (*Atherinops affinis*)	------------------; San Pablo Bay & southward
Black surfperch (*Embiotoca jacksoni*)	Permanent resident; San Pablo Bay & southward
Pile surfperch (*Damalichthys vacca*)	Permanent resident; San Pablo Bay & southward
Shiner surfperch (*Cymatogaster aggregata*)	Permanent resident; San Pablo Bay & southward
Dwarf surfperch (*Micrometrus minimus*)	Permanent resident; San Pablo Bay & southward
Tule surfperch (*Hysterocarpus traskii*)	Permanent resident; Suisun Bay & upstream
Walleye surfperch (*Hyperprosopon argenteum*)	Permanent resident; San Pablo Bay & southward
White seaperch (*Phanerodon furcatus*)	Permanent resident; San Pablo Bay & southward

1/ Other than anadromous fishes.
2/ Common names after American Fisheries Society, 1970.

Principal Sources: Ruth, 1969; Aplin, 1967; Ganssle, 1966; and U.S. Fish and Wildlife Service, 1970.

2.327 A species similar in feeding habit and commercial importance is the Pacific herring, Clupea harengus. The herring migrates in large schools through the Golden Gate during winter and early spring and spawns in the shallows of Angel, Alcatraz and Treasure Islands, tidal flats of Marin coast from the Golden Gate into Richardson Bay, and along the shorefront of Richmond from Point San Pablo to Point Richmond (and sometimes into Carquinez Strait). There is periodic dredging at the Sausalito Operations Base Yard and Richmond Outer Harbor which are in the vicinity where herrings spawn. Plate II-41 shows the distribution of herring in the Bay and its spawning areas. Unlike the anchovy, herring eggs are not pelagic but are very sticky and thus adhere to any solid object such as to seaweeds, rocks and beer cans. Herring eggs are an important diet of the sturgeon as well as to many birds that feed on the exposed egg masses during low tide. Young herrings can be found year-round in all four sub-bays feeding on the plankton and in turn, they are fed upon by Striped bass and other large fish. Adult herrings leave the Bay by late summer.

2.328 Other marine pelagic fishes similar in shape and feeding habit (plankton feeders) to the anchovy and herring that are of some importance to the commercial or sport fishery are the smelts (Surfsmelt and Whitebait smelt), and sliversides (Jacksmelt and Topsmelt). Smelts are of minor importance to the sportfishery whereas the silversides are popular sport fishes in the Bay. Both silverside species spawn in the Bay and their species range extends from Baja California to north of Oregon. The Jacksmelt is found in deeper waters of the Bay, in contrast to the Topsmelt which is frequently found over tidal flats.

2.329 Another important group of marine fishes are the surfperches (embiotocids) which are unique in that those fishes bear their youngs live (most families of marine fish extrude the fertilized eggs into the open water and the eggs develop externally to the parent fish). Surfperches are also unique in that they are only found in the eastern Pacific; most species of which are common to the California coast. In bays and sheltered areas along the California coast, this family of surfperches is probably the most important resident sportfish group, and is abundant enough at times to support a commercial fishery for bait. Some of the more common species in San Francisco Bay are the Shiner surfperch (most unbiquitous of the group), Walleye surfperch, Redtail surfperch, Black surfperch, Pile surfperch and White surfperch. There is also one species of freshwater embioticid which inhabits Suisun Bay and upstream. In addition to being important sportfishes, which support approximately 290,000 angler-days per year in the Bay (28), they are also very important forage fishes eaten by Striped bass and other large fish.

2.330 There are many other important marine pelagic fishes that could be discussed as well but the reader is best referred to the technical papers published concerning specific species. Other fishes belonging to this group, some of which are popular sportfishes, are listed in Table II-18.

2.331 (b) Anadromous species. Of all the fishes of the Bay this group is the most important commercially and recreationally. Anadromous fish spawn in freshwater and live the rest of their lives in the ocean and/or the estuary. The group includes 12 species, listed in Table II-21, of which the Green and White sturgeons, American shad, Steelhead rainbow trout, Chinook salmon and Striped bass will be discussed.

TABLE II-21

ANADROMOUS FISHES OF SAN FRANCISCO BAY

Common Name	Scientific Name
Pacific lamprey	*Lampetra tridentata*
Western river lamprey	*Lampetra ayresii*
Green sturgeon	*Acipenser medirostris*
White sturgeon	*Acipenser transmontanus*
American shad	*Alosa sapidissima*
Steelhead rainbow trout	*Salmo gairdnerii*
Coho (Sliver) salmon	*Oncorhynchus kisutch* (rare)
Chinook (King) Salmon	*Oncorhynchus tshawyscha*
Pink salmon	*Oncorhynchus gorbuscha* (rare)
Chum salmon	*Oncorhynchus keta* (rare)
Sockeye (Red) salmon	*Oncorhynchus nerka* (rare)
Striped bass	*Morone saxatilis*

2.332 Sturgeon. Sturgeons are considered a primitive group of fishes that are quite peculiar looking, essentially unchanged in appearence since fossil times. They have an elongated snout with four barbels on the underside of it and five rows of bony plates imbedded along the length of their bodies. Their bellies or ventral sides are quite flat and their mouths are situated on the underside of the snout behind the barbels, which indicate that they are adapted to a bottom mode of existence feeding primarily on benthic animals. The two species of sturgeons, the Green and White sturgeons, are indigenous to the Bay estuary and are the largest of the anadromous fishes, ranging upwards to seven feet and 350 pounds for the Green sturgeon and to 20 feet for the White sturgeon.