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STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME
FISH BULLETIN 165
The Marine Resources of Anaheim Bay

Edited by
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Long Beach, California

1975

ABSTRACT

This report describes 4 years of marine research in Anaheim Bay, Orange County. The history and oceanographic studies describe the background for biological work on marsh plants, invertebrates and fishes. This bulletin attempts to describe what species were present during the study period, their relative abundances, and in some cases a more detailed account of their life histories and population dynamics. The studies were centered on that portion of Anaheim Bay that is landward of the Pacific Coast Highway, within the U.S. Naval Weapons Station, Seal Beach; however, annotated checklists are included on invertebrates and fishes of the outer harbor, seaward of the highway. There are 51 species of marsh plants and algae reported. The invertebrates are noted in annotated checklists, with most attention being centered on the polychaetes and parasitic crustaceans. Some detailed data is given and discussed on polychaete distribution and abundances. Comparisons are given of polychaete populations in pristine Anaheim Bay and developed Huntington Harbour. Forty five species of fish are recorded from the inner portion of the bay and 42 species from the outer harbor. Information is given on the abundances, food, and capture of these species. More detailed accounts of the life histories of six of the more common fish species are described. These include the arrow goby, Clevelandia ios; shiner surfperch, Cymatogaster aggregata; California killifish, Fundulus parvipinnis; Pacific staghorn sculpin, Leptocottus armatus; California halibut, Paralichthys californicus; and diamond turbot, Hypsopsetta guttulata. Life histories include discussions on the numbers, age, growth, food and feeding, and behavior in Anaheim Bay. Where applicable comparisons are drawn with populations elsewhere, such comparisons tend to indicate that the Anaheim Bay salt marsh is an area of very high growth rates and productivity.

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ACKNOWLEDGMENTS

This study could not have been attempted without the great help and cooperation of the U. S. Navy. Especially, the authors would like to thank Rear Admiral J. W. Williams Jr., Commandant of the Eleventh Naval District; Captains E. N. Simpson, F. F. Jewett II, W. E. Betzer, and Commander H. P. Madera, U. S. N. commanding officers; Commander L. H. Nelson, executive officer; and Lt. Commanders H. R. Frauenfelder and B. H. Edelson, public works officers; all of the Naval Weapons Station, Seal Beach, California.

We are grateful to all those who helped in many various ways, particularly thanked are C. L. Hubbs who kindly read and gave valuable comments on many of the papers; D. Lindsey and C. Edwards who assisted with the field work.

Individual authors express their gratitude to those other authors who contributed to their studies through the pooling and sharing of field data.

Credit for the illustrations of the diamond turbot and California halibut goes to Cynthia Klepadlo.

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Appreciation is expressed to the California Department of Fish and Game for publication assistance.

INTRODUCTION

The research described in this bulletin was conducted in Anaheim Bay, within the U. S. Naval Weapons Station, Seal Beach, California, and is the result of 4 years of investigations by the faculty and graduate students at California State University, Long Beach. The following authors are or were faculty members: Baker, Chen, Hill, Ho, Lane, and Reish. The remaining authors with the exception of J. M. Lane are or were students. Papers by students are the culmination of studies made as master's thesis projects. All papers represent an attempt to describe biology of a pristine southern California salt marsh. All the studies are marine in nature describing elements of aquatic plants, vertebrates, and invertebrates. Terrestial and aerial organisms are not included.

Anaheim Bay is located on the north coast of Orange County near the Los Angeles County line. The area within the Naval Weapons Station has been a relatively undisturbed salt marsh since the cut off of river input in 1862. Disturbance of the marsh area due to the operation of this weapons station has been minimal. Dredging of the mouth and adjacent harbor area has in fact enhanced the marsh since it prevented formation of a beach dam and permitted uninterrupted tidal flow. There are three main areas in the marsh; that part covered with vegetation, the tidal mud flats, and that portion of the channels that is permanently under water.

All scientific work conducted on the Naval Weapons Station at Seal Beach is supervised by members of an advisory board to the U. S. Navy Wildlife Management Plan, Seal Beach Naval Weapons Station. This board includes members from the U. S. Navy, Bureau of Sport Fisheries and Wildlife, U. S. Department of the Interior, California Department of Fish and Game, and the Ecological Advisory Committee, California State University, Long Beach.

1. A HISTORY OF ANAHEIM BAY

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and
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Anaheim Bay, located at 33°44'N, 118°04'W, is just south of Seal Beach, California, and is part of a physiographic region known as the Sunset Gap. This gap is bordered by Landing Hill to the northwest and Bolsa Chica Mesa to the southeast (Figures 1, 2). Landing Hill is a part of the Seal Beach dome, and Bolsa Chica Mesa is a part of the Huntington Beach anticline. The bay overlies a Pleistocene syncline depression that has been partially backfilled by alluival deposits of riverine and tidal origin (California Department of Water Resources, 1968). This area is a part of the floodplain of the San Gabriel and Santa Ana Rivers (Houghton, 1970) although neither river flows through the bay area at present. Because of the proximity of the San Gabriel River mouth to Anaheim Bay, the river has had great effect on the sediments and salinity of the immediate area; especially since the 1867–68 flood when the San Gabriel shifted its course from the present Los Angeles River bed (Troxell, 1942).

Sunset Gap is mostly flat, typical of the coastal floodplains; however, there are some irregularities in the surface, such as Hog Island. This island is a part of a dissected scarp of the Newport-Inglewood Fault; a fault that runs parallel to the coast some 3000 to 5500 feet inland. The fault has not only affected the structure of this area, but acts as a hydraulic barrier to lateral ground water movement (California Department of Water Resources, 1968). Coastward of this fault a barrier beach shelters the tidal marsh. Tidal marshes made up the majority of Sunset Gap's area at one time, but during the flood of 1862 the Santa Ana River shifted its course to capture much of the drainage area of Anaheim Bay. Previous to this flood the marsh was much larger and was polyhaline in nature. Because of the area's rapid transition from a largely semirural complex to a metropolitan area in the last 2 decades, much of the tidal marsh has undergone change. Anaheim Bay has shrunk approximately 30% in size in 95 years (U.S. Coast and Geodetic Survey Map, 1949). Practically all that is left of Sunset Gap's salt marsh is found in Anaheim Bay, within the U.S. Naval Weapons Station, an area approximately 674.3 acres in size. The existing marsh remains relatively unchanged.

Anaheim Bay became a part of the U.S. in 1849 and detailed recorded history started from that time. Middens (refuse heaps of shells) found on Hog Island and north of the marsh itself at the present site of the military housing provide evidence of early Indian habitation.

The Anaheim Bay area was known historically as a port. In 1849 General Stockton established a trench position near Landing Hill to repulse an expected landing of munitions by a French schooner from Mazatlan. These positions were renewed in 1860 for an artillery base for Captain Shinn's Light Artillery detachment to repulse a reported Confederate threat (Grimshaw, 1937).

Anaheim Landing at the bay's ocean exit has been an important regional port for over a hundred years. It was established in 1868 when the California Legislature granted the Anaheim Lighter Company, with August Langenberger, a store-owner of Anaheim as general manager, a 20 year franchise to operate this new port (Friis, 1965). Cargo was handled not only for Anaheim but for the inland

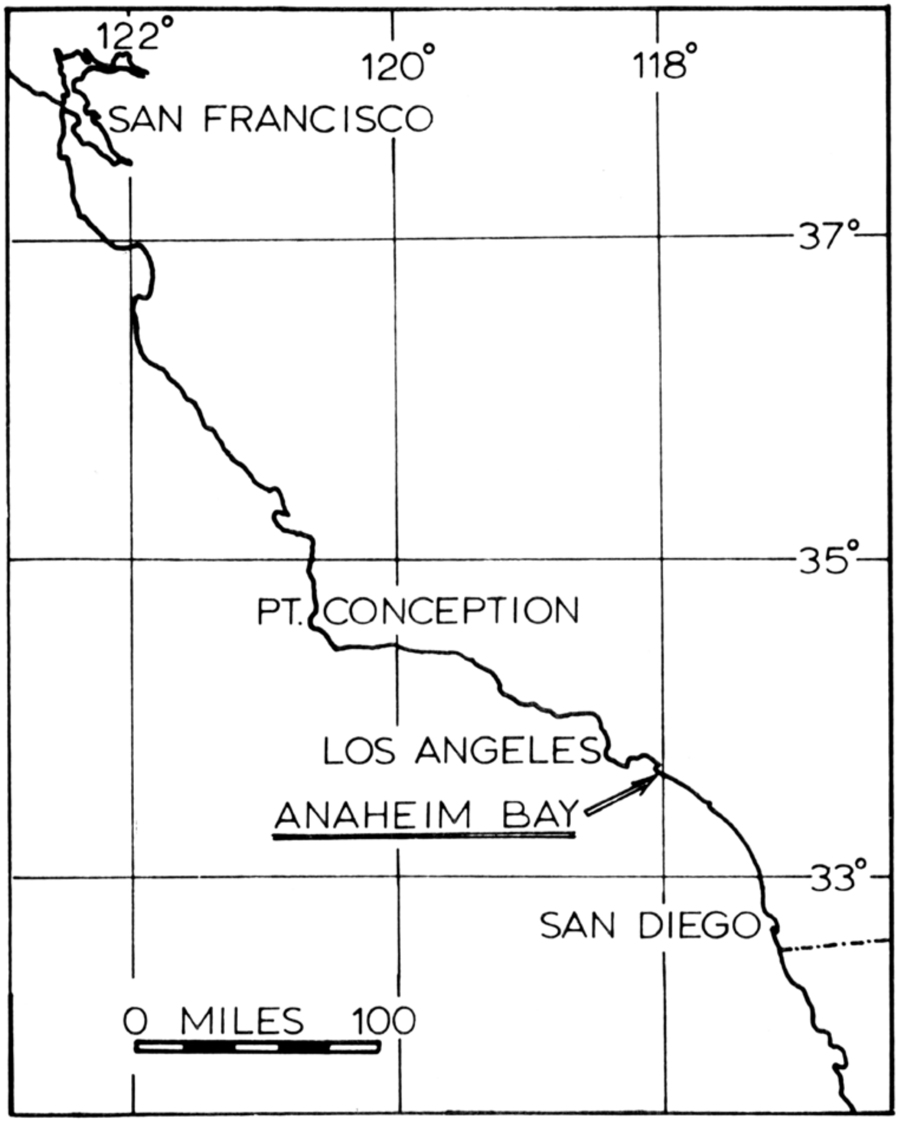

FIGURE 1—Location of Anaheim Bay on the California Coast

centers of San Bernardino, Yuma, and Salt Lake City (Anaheim Gazette, 1932). By 1875 with the advent of the Southern Pacific Railroad, business waned to such a point that the Anaheim Lighter Company was taken over by Westminster, a settlement only 4.5 miles away. This acquisition diminished Anaheim Landing's importance as a regional port.

When Orange County was established in March 1889, Anaheim Bay was included. It was around this time that the Bay became a resort of considerable fame. The bay and surrounding coastal area enjoyed a boom partially resulting from the region's increasing use by sportsmen. Twenty three gun clubs occupied the Sunset and Bolsa gaps between 1899–1900. These clubs took advantage of one of the greatest natural habitats for wildlife and game birds in the world. The Bolsa Chica Gun Club was granted permission, under the State Tideland Overflow and Reclamation Act, to reclaim tidelands surrounding its property. This permission allowed the closing of the Los Patos ocean channel, the creation of tidal gates, and the excavation of a new channel between Bolsa Chica Gap and Sunset Gap (Talbert, 1952).

On January 14, 1944, the United States Government took over Anaheim Landing as well as most of Anaheim Bay for a naval station. Although piers, railways, jetties, and ammunition magazines were added to the area, the tidal flats were not developed but kept as a buffer between the ammunition and the public for safety reasons.

The preservation of the marsh as it now exists (Figure 3) appears assured. In response to efforts by the navy and interested citizen groups, Congressman C. Hosmer introduced legislation (H.R. 13010) to create the Seal Beach Wildlife Refuge. In August 1972 the U.S. Government declared the Anaheim Bay area within the U.S. Naval Weapons Station a National Wildlife Refuge.

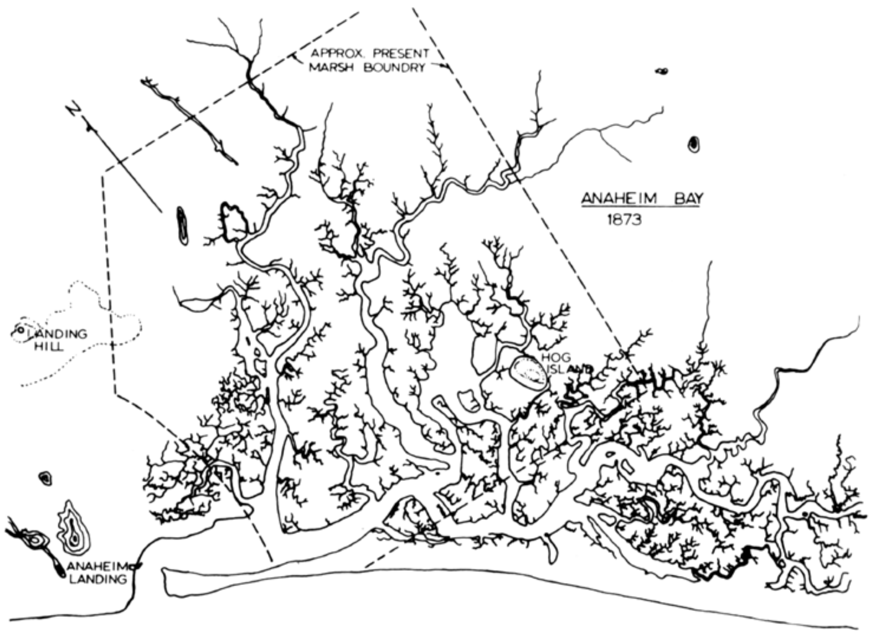

FIGURE 2—Anaheim Bay in 1873. Map is based on United States Coast Survey, Topographic Map Register No. 1345.

FIGURE 2—Anaheim Bay in 1873. Map is based on United States Coast Survey, Topographic Map Register No. 1345

The first biological collections from the bay were made in 1910 and 1911 by P. S. Barnhart. Both fish and invertebrates were collected for the Zoology Department, University of Southern California (J. Haig, pers. comm.). In 1912 Elmer Higgins of the California Fisheries Laboratory made some fish collections. The first published work on the area (Hubbs, 1916) was the result of fish collections made by Carl Hubbs in 1913. The first thesis to result from collections of invertebrates from Anaheim Landing made in 1927 and 1928 was written by Lena Higgins at the University of Southern California.

FIGURE 3—Anaheim Bay salt marsh, 1970. Stippled areas represent mud flats exposed between mean low and mean high tide. All areas except those marked islands or roads are flooded at extreme high tides.

FIGURE 3—Anaheim Bay salt marsh, 1970. Stippled areas represent mud flats exposed between mean low and mean high tide. All areas except those marked islands or roads are flooded at extreme high tides

2. EARLY COLLECTIONS OF FISHES FROM ANAHEIM BAY MADE BETWEEN 1919 AND 1928

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Carl L. Hubbs has kindly allowed me to go through his files and glean from them lists of the collections of fish taken in Anaheim Bay between 1919 and 1928. These collections were made by Hubbs and the California State Fisheries Laboratory. Personnel of the laboratory mentioned in the files include W. F. Thompson, Elmer Higgins, F. N. Clark, and W. A. Selle; there were, as indicated in Hubbs' notes, other unnamed personnel.

At present the collections reside at the Museum of Zoology, University of Michigan. An examination of the species represented in these collections reveals that several fish species that are common today were not present in the early collections (Table 1). A few species that have not been taken recently were found in collections recorded by Hubbs. Such variations are to be expected due to probable differences in collecting techniques, amount of collecting, and habitat changes.

Between March and November 1944, the jetties were built and the harbor dredged to accommodate Navy ships. These changes would have had considerable effect on the habitat; adding hard substrate, deep water, possibly removing eel grass beds, and changing the current patterns. The harbor dredging kept the mouth of the bay open and conceivably increased the tidal circulation in the upper bay. The jetties in fact created an outer harbor, which did not exist during the 1920's.

Most of the fish that were taken by Hubbs and others, which have not been collected today, are coastal open water forms found immediately offshore (i.e. Gymnura marmorata, Hyporhamphus rosae, Strongylura exilis, Chromis punctipinnis, Oxyjulis californica, and Scorpaena guttata) . Other species such as Albula vulpes and Sardinops sagax caeruleus are not common today. Ilypnus gilberti, common in early collections, is very rare now. The two species of Syngnathus found in the early collections are apparently absent at the present time.

Many species taken in our recent studies were not collected by Hubbs *et al.* These include Menticirrhus undulatus, Genyonemus lineatus, Paralabrax maculatofasciatus, Hyperprosopon argenteum, Damalichthys vacca, Phanerodon furcatus, and Heterostichus rostratus plus many less common species.

The most notable missing species from the early collections is Atherinops affinis which today is the most numerous fish throughout the whole bay system. At present A. affinis is so common that it is taken in almost every collection. The absence of this species from the early collections indicates that there must have been a much lower Atherinops population in the bay at that time. Schultz (1933), however, reported this species from Anaheim Bay, probably taken in the early 1930's. Perhaps the jetties, dredging, and increased tidal flows in the upper areas allowed a buildup of the population to present high levels.

Despite these differences, of the 34 species collected during the 1920's, 24 have been found in recent studies.

TABLE 1

Fish Collections—1919–1928

Species	Number taken	Collection date	Site	UMMZ number*
Mustelus californicus	(3)	7-Oct-1922	Anaheim Bay	61029–61031
Gymnura marmorata	(1)	6-Aug-1926	Anaheim Landing	71123
Urolophus halleri	(6)	7-Oct-1922	Anaheim Bay	61108–61113
Albula vulpes	(5)	13-Aug-1919	Anaheim Landing	60713 & 71134
Anchoa compressa	(110)	7-Oct-1922	Anaheim Bay	61028
Anchoa compressa	(29)	15-Oct-1924	Anaheim Landing	71102
Anchoa compressa	(4)	6-Aug-1926	Anaheim Landing	71113
Anchoa compressa	(116)	16-June-1927	Anaheim Bay	80849
Anchoa compressa	(3)	8, 18-June-1928	Bay View Anaheim Slough	85918
Anchoa delicatissima	(21)	7-Oct-1922	Anaheim Bay	61024
Anchoa delicatissima	(16)	15-Oct-1924	Anaheim Landing	71101
Anchoa delicatissima	(2)	6-Aug-1926	Anaheim Landing	71112
Anchoa delicatissima	(365)	16-June-1927	Anaheim Bay	80850
Anchoa delicatissima	(1)	17-Feb-1928	Bay View Anaheim Slough	86059
Engraulis mordax	(105)	7-Oct-1922	Anaheim Bay	61156
Engraulis mordax	(404)	15-Oct-1924	Anaheim Landing	71103
Engraulis mordax	(1)	6-Aug-1926	Anaheim Landing	71111
Engraulis mordax	(3)	17-Feb-1928	Bay View Anaheim Slough	86061
Sardinops sagax	(1)	15-Oct-1924	Anaheim Landing	71097
Hyporhamphus rosae	(8)	7-Oct-1922	Anaheim Bay	60927
Strongylura exilis	(1)	7-Oct-1922	Anaheim Bay	60926
Fundulus parvipinnis	(1)	25-April-1919	Anaheim Landing	71132
Fundulus parvipinnis	(3)	23-May-1919	Goose Creek Anaheim Bay	60796
Fundulus parvipinnis	(1)	13-Aug-1919	Anaheim Landing	60797
Fundulus parvipinnis	(5)	7-Oct-1922	Anaheim Bay	60928
Fundulus parvipinnis	(97)	13-May-1923	Anaheim Bay	60931
Fundulus parvipinnis	(6)	16-June-1927	Anaheim Bay	80857
Fundulus parvipinnis	(1)	17-Feb-1928	Bay View Anaheim Slough	86063
Fundulus parvipinnis	(277)	8, 18-June-1928	Bay View Anaheim Slough	85913
Fundulus parvipinnis	(5)	6, 16-Sept-1928	Anaheim Bay	85901
Paralabrax clathratus	(6)	7-Oct-1922	Anaheim Bay	60941
Paralabrax clathratus	(3)	15-Oct-1924	Anaheim Landing	71099
Paralabrax clathratus	(1)	17-March-1926	Anaheim Bay	71129
Paralabrax clathratus	(4)	17-Feb-1928	Bay View Anaheim Slough	86060
Paralabrax nebulifer	(2)	13-Aug-1919	Anaheim Landing	60800
Paralabrax nebulifer	(1)	7-Oct-1922	Anaheim Bay	60937
Paralabrax nebulifer	(9)	6-Aug-1926	Anaheim Landing	71122
Paralabrax nebulifer	(3)	16-June-1927	Anaheim Bay	80860
Mugil cephalus	(1)	6-Aug-1926	Anaheim Landing	71114
Roncador stearnsi	(3)	7-Oct-1922	Anaheim Bay	63451 & 92610
Roncador stearnsi	(1)	16-June-1927	Anaheim Bay	80852
Cymatogaster aggregatus	(39)	23-May-1919	Anaheim Bay Goose Creek	64164 & 64171
Cymatogaster aggregatus	(19)	7-Oct-1922	Anaheim Bay	63741
Cymatogaster aggregatus	(6)	6-Aug-1926	Anaheim Landing	71117
Cymatogaster aggregatus	(12)	16-June-1927	Anaheim Bay	80855
Embiotoca jacksoni	(19)	7-Oct-1922	Anaheim Bay	63313 & 92589
Hypsurus caryi	(1)	6-Aug-1926	Anaheim Landing	71121
Chromis punctipinnis	(1)	6-Aug-1926	Anaheim Landing	71115
Oxyjulis californica	(1)	6-Aug-1926	Anaheim Landing	71120
Girella nigricans	(2)	7-Oct-1922	Anaheim Bay	92626
Girella nigricans	(6)	6-Aug-1926	Anaheim Landing	71118
Girella nigricans	(1)	8, 18-June-1928	Bay View Anaheim Slough	85917
Scorpaena guttata	(2)	7-Oct-1922	Anaheim Bay	92609
Scorpaena guttata	(5)	16-June-1927	Anaheim Bay	80851

TABLE 1

Fish Collections—1919–1928

Species	Number taken	Collection date	Site	UMMZ number*
Leptocottus armatus	(1)	13-Aug-1919	Anaheim Landing	71125
Leptocottus armatus	(21)	7-Oct-1922	Anaheim Bay	66098
Leptocottus armatus	(2)	13-May-1923	Anaheim Bay	66204
Leptocottus armatus	(2)	17-March-1926	Anaheim Bay	71126
Leptocottus armatus	(4)	6-Aug-1926	Anaheim Landing	71124
Leptocottus armatus	(31)	16-June-1927	Anaheim Bay	80861
Leptocottus armatus	(1)	17-Feb-1928	Bay View Anaheim Slough	86058
Leptocottus armatus	(1)	8, 18-June-1928	Bay View Anaheim Slough	85913
Syngnathus auliscus	(1)	16-June-1927	Anaheim Bay	80856
Syngnathus californiensis	(29)	7-Oct-1922	Anaheim Bay	65488
Syngnathus californiensis	(1)	17-March-1926	Anaheim Bay	71130
Syngnathus californiensis	(16)	17-Feb-1927	Bay View Anaheim Slough	86067
Clevelandia ios	(2)	25-April-1919	Anaheim Landing	94680
Clevelandia ios	(1)	23-May-1919	Goose Creek Anaheim Bay	64144
Clevelandia ios	(4)	7-Oct-1922	Anaheim Bay	63595
Clevelandia ios	(5)	13-May-1923	Anaheim Bay	63597
Clevelandia ios	(3)	17-March-1926	Anaheim Bay	71128
Clevelandia ios	(3)	6-Aug-1926	Anaheim Landing	71137
Clevelandia ios	(4)	17-Feb-1928	Bay View Anaheim Slough	86064
Clevelandia ios	(15)	8, 18-April-1926	Bay View Anaheim Slough	85195
Ilypnus gilberti	(1)	23-May-1919	Goose Creek Anaheim Bay	64142
Ilypnus gilberti	(6)	15-Oct-1924	Anaheim Landing	71100
Ilypnus gilberti	(1)	16-June-1927	Anaheim Bay	80853
Ilypnus gilberti	(6)	8, 18-June-1928	Bay View Anaheim Slough	85916
Quietula y-cauda	(1)	17-Feb-1928	Bay View Anaheim Slough	86066
Porichthys myriaster	(2)	7-Oct-1922	Anaheim Bay	63610-Named Paratypes
Hypsoblennius gilberti	(1)	16-June-1927	Anaheim Bay	136091
Hypsoblennius gentilis	(1)	15-Oct-1924	Anaheim Landing	71098
Hypsoblennius gentilis	(11)	16-June-1927	Anaheim Bay	80859
Hypsopsetta guttulata	(1)	7-Oct-1922	Anaheim Bay	92455
Hypsopsetta guttulata	(1)	13-May-1923	Anaheim Bay	63269
Hypsopsetta guttulata	(?)	6-Aug-1926	Anaheim Landing	71119
Hypsopsetta guttulata	(2)	16-June-1927	Anaheim Bay	80858
Hypsopsetta guttulata	(1)	17-Feb-1928	Bay View Anaheim Slough	86069
Hypsopsetta guttulata	(66)	8, 18-June-1928	Bay View Anaheim Slough	85909
Paralichthys californicus	(8)	7-Oct-1922	Anaheim Bay	61175
Paralichthys californicus	(3)	13-May-1923	Anaheim Bay	61180
Paralichthys californicus	(1)	15-Oct-1924	Anaheim Landing	71104
Paralichthys californicus	(3)	6-Aug-1926	Anaheim Landing	71116
Paralichthys californicus	(2)	16-June-1927	Anaheim Bay	80862
Paralichthys californicus	(2)	17-Feb-1928	Bay View Anaheim Slough	86068
Paralichthys californicus	(23)	8, 18-June-1928	Bay View Anaheim Slough	85905-908
Pleuronichthys ritteri	(1)	13-May-1923	Anaheim Bay	61174

* UMMZ number is the collection number at the University of Michigan Museum of Zoology where the specimens are stored.

TABLE 1—Cont'd.

3. PHYSICAL AND CHEMICAL PARAMETERS OF THE ANAHEIM BAY SALT MARSH

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and
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3.1. INTRODUCTION

The physical and chemical study of the environment in Anaheim Bay was initiated in April 1969, with monthly sampling at one station, Station 8 (Figure 4). In January 1970 three more stations, Stations 2, 3, and 4, were added. The survey was extended to cover both the west and east arms in December 1970, with a total of 15 stations being sampled.

Surface and bottom temperature, salinity, dissolved oxygen, and Secchi disc transparency were measured at monthly intervals. Water samples were collected with a Van Dorn sampler at 1 m intervals. A number of parameters was measured using various methods (Table 2).

TABLE 2

Type and Accuracy of Equipment and Methods Used in This Study

Item	Instrument/Method	Accuracy
Temperature	Mercury thermometer	0.1° C
	YSI telethermometer	0.5° C
Salinity (69-71)	Refractometer	0.1 ‰
(70-71)	Inductive Salinometer ("Beckman" model)	0.01 ‰
Dissolved oxygen	Winkler's method	0.1 ppm
	Oxygen sensor (Polarographic type IBC model 145)	0.1 ppm
Transparency	Secchi disc	5 cm
Current velocity	Current meter (Hydro product)	0.1 knot
Sediment	Wentworth scale, wet sieving and weighing	0.1%
Phosphate	Spectrophotometric method as described by Strickland and Parsons (1968)	0.1 µg at P/1
Nitrite		0.1 µg at N/1
Nitrate		0.1 µg at N/1
Silicate		0.1 µg at Si/1
Organic Carbon content	Leco Gasometric carbon analyzer Model 523	0.01%

TABLE 2

Type and Accuracy of Equipment and Methods Used in This Study

3.2. SEDIMENT

The marshland occupies an area of about 3 km^2 (741.3 acres) inside the outer harbor of Anaheim Bay. Due to tidal cycles the water is in direct exchange with the Pacific Ocean. This marine marshland forms a transition zone between the coastal land and bay water. The total area of the tidal channels and mud flats is about 0.5 km^2 (130 acres) (Figures 2 and 3).

Sediment samples were collected from the channels and grassy marsh (Figure 4). Part of each sample was treated with hydrogen peroxide and then subjected to grain size analysis. A separate portion was used for organic carbon analysis. The Wentworth scale was used to describe substrate grain sizes found in and around the middle arm (Figure 5). Since the percentage of gravel was rarely over 5%, particles greater than 2 mm (0.08 inch) in diameter have been grouped with sand as one of the three major components.

FIGURE 4—Stations from which physical and chemical data were taken. Stations marked "X" were used for water analysis, while stations marked "O" were used for sediment analysis.

FIGURE 4—Stations from which physical and chemical data were taken. Stations marked "X" were used for water analysis, while stations marked "O" were used for sediment analysis

Many of the samples collected from the middle arm channel were silty sand or sand (Figure 5). On the marsh surface, sandy clayey silt becomes predominant. The median diameter of all samples collected ranged from .2 to .02 mm (0.01 to 0.001 inch). Within the middle arm channel there is a gradual change from clayey silt in the back bay area to silty sand at the channel mouth. This change is almost completely masked on the vegetated marsh surface by the nature of the deposition environment at each location; e.g. the degree of exposure to tidal currents, the abundance of vegetation in the vicinity, and the supply of fragments due to surface erosion and/or erosion by rainfall.

All these factors are important in affecting the manner of deposition of bottom materials found on the marsh surface and in the channels. As expected, the sorting coefficient of most of the samples collected was greater than the average value of 1.4 to 1.8 (Figure 6).

Organic carbon content was determined by using an organic carbon analyzer with a Leco induction furnace (Figure 7). A 1 g sample was combusted and the evolved carbon dioxide absorbed. Percentages of carbon are directly proportional

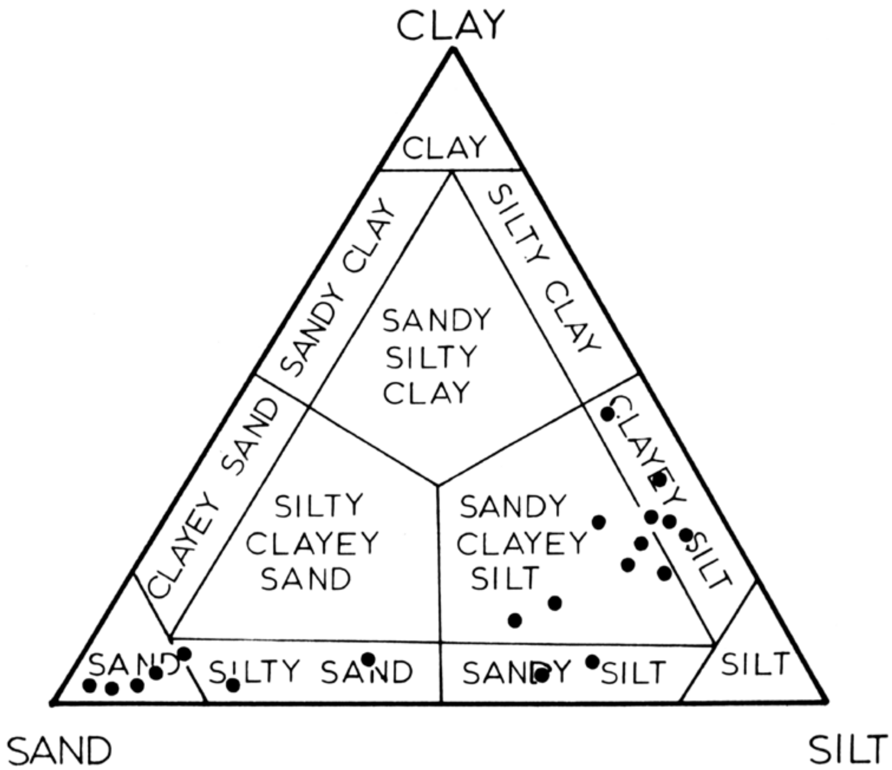

FIGURE 5—Substrate grain size, Wentworth analysis. Sand = 1.000 — 0.062 mm (usually less than 0.250 mm). Silt = 0.062 — 0.004 mm. Clay = less than 0.004 mm.

FIGURE 5—Substrate grain size, Wentworth analysis. Sand = 1.000 - 0.062 mm (usually less than 0.250 mm). Silt = 0.062 - 0.004 mm. Clay = less than 0.004 mm

to the amount of carbon dioxide and can be estimated directly from a conversion scale. Samples indicated the highest percentage of organic carbon occurs near Stations 1 and 2 with a value of 8.2%. The lowest value, 0.5%, occurred near Stations 5 and 14. There is no systematic distribution pattern. The amount of organic carbon depends primarily on the degree of decomposition of floating algae. The blackish, silty, clayey mud samples in the tidal channel areas have a higher percentage of organic matter than those from the adjacent flats.

3.3. TEMPERATURE

The average depth of the water in the channels was approximately 2 to 3 m (6.5 to 9.8 feet) at high tide; therefore, considerable diurnal and seasonal fluctuations in water temperature exist.

The major source of heat is from direct solar radiation. Typically the weather in southern California is warm and dry with intense sunlight, resulting in water temperatures slightly higher than air temperatures (Figure 8).

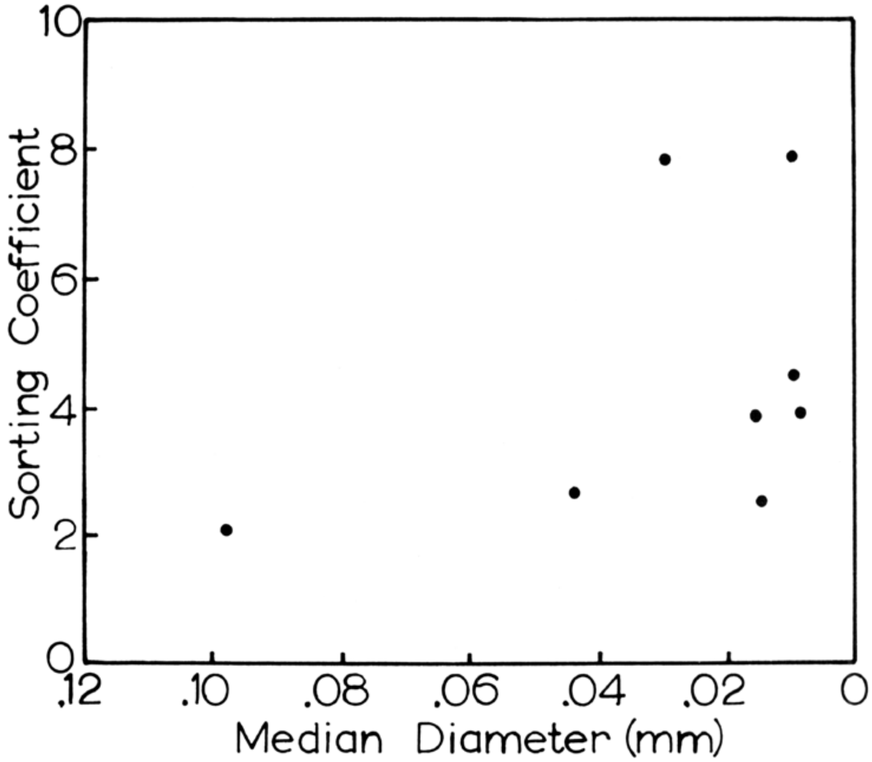

FIGURE 6—Sorting coefficient and median diameter of particles in sediment samples that were analyzed.

FIGURE 6—Sorting coefficient and median diameter of particles in sediment samples that were analyzed

In the channels the maximum and minimum monthly mean water temperature was 23.7 and 12.4 C (74.6 and 54.3 F). The highest temperature was 26 C (78.8 F) recorded on August 30, 1969, and the lowest was 11 C (51.8 F) recorded on January 10, 1971 (Figure 9).

The diel temperature fluctuations depends on both atmospheric conditions and tidal stages. In daytime the inflow of tidal water brings in cooler oceanic water and lowers water temperature at high tide. As well as this exchange of heat, a small amount of heat is conducted through the sediment-water interface. In summer the surface of the exposed marshland is very warm and the heat conducted warms incoming oceanic water. In winter, however, exposed marshland may be cooler than the air temperature, and the temperature of the incoming oceanic water subsequently will be lowered. Based on hourly observations of surface water temperature at Station 4 (Figure 10), the predominant factor is the exchange of heat due to temperature differences between water in the outer harbor and that in the marshlands. A fluctuation of 1 to 3 C (1.8 to 5.4 F) due to tidal influx was often observed.

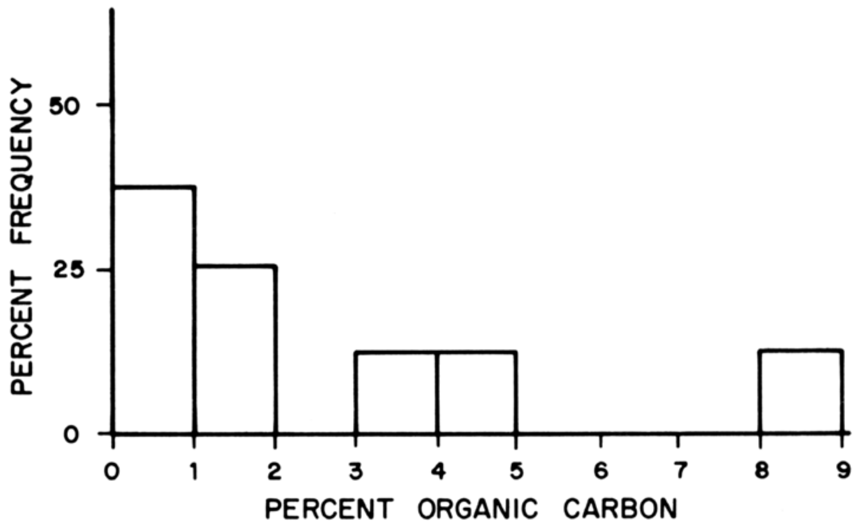

FIGURE 7—Amounts of organic carbon found in 16 sediment samples, expressed as percent frequency.

FIGURE 7—Amounts of organic carbon found in 16 sediment samples, expressed as percent frequency

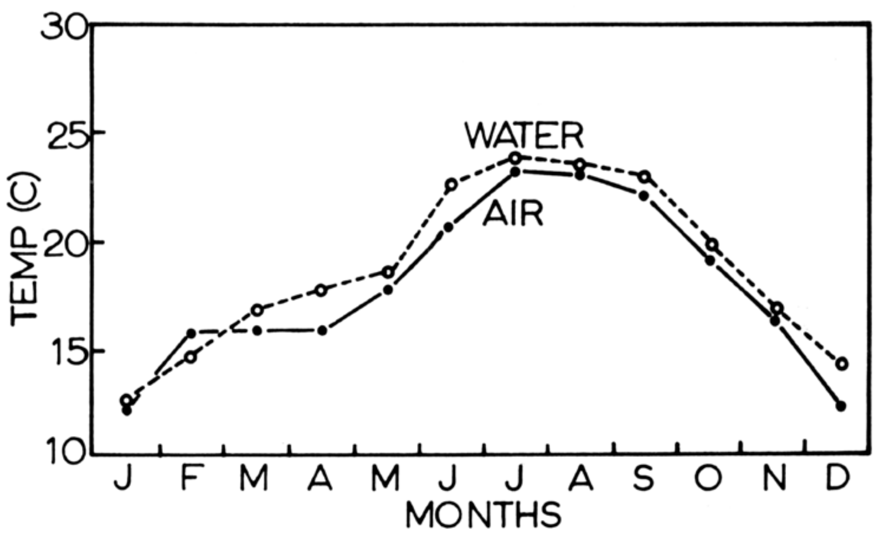

FIGURE 8—Comparison of monthly mean air (solid line) and water (broken line) temperatures in Anaheim Bay, 1970. All stations are included.

FIGURE 8—Comparison of monthly mean air (solid line) and water (broken line) temperatures in Anaheim Bay, 1970. All stations are included

The water is shallow; therefore, the tide causes strong mixing action and keeps the water column homothermal. During summer the surface water temperature

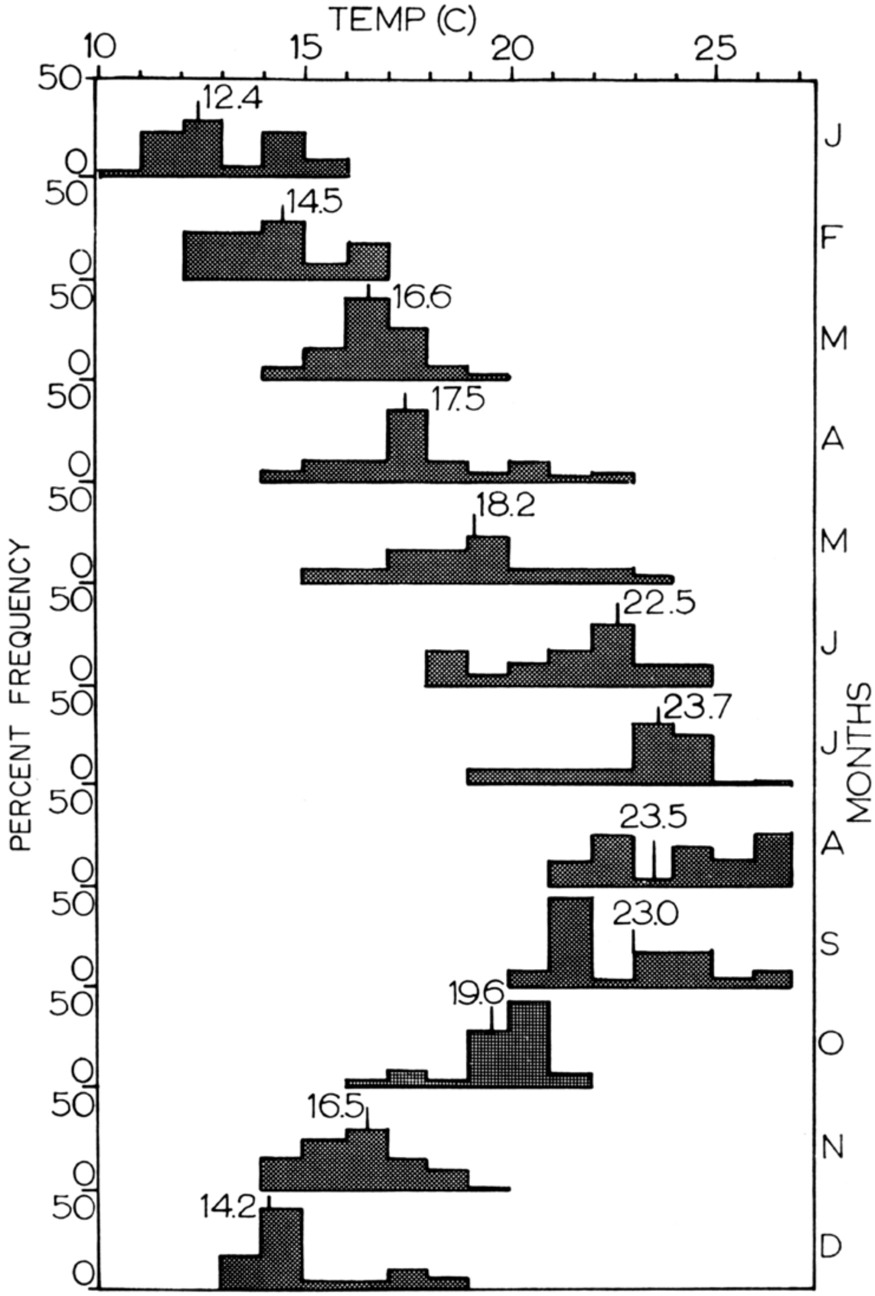

FIGURE 9—Monthly frequency histograms and means of the surface water temperature. Data are from 1969, 1970, and 1971. All stations are included.

FIGURE 9—Monthly frequency histograms and means of the surface water temperature. Data are from 1969, 1970, and 1971. All stations are included

was about 0.5 C (0.9 F) warmer than the bottom water (Figure 11). This difference was diminished during winter. Occasionally there was a temperature inversion (Figure 12). Most frequently such inversions occur on winter nights and after a heavy rainfall when the freshwater from surface runoff forms a low salinity stable layer. The strong density gradient prevents mixing even though the surface water is cooler than deeper bottom water. Such a phenomenon was only of short duration since tidal action causes internal downward mixing and the water returns to homothermal and homohaline conditions again.

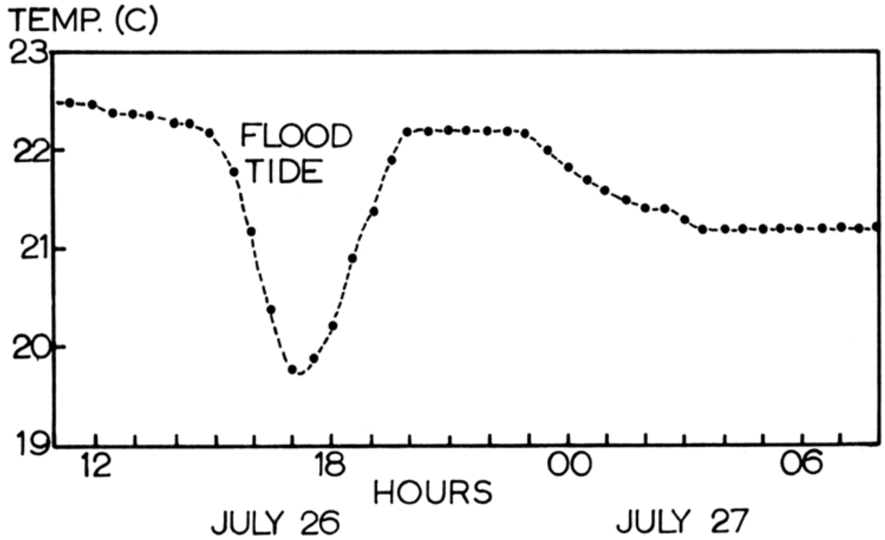

FIGURE 10—Surface temperatures recorded over a 21 hour period at Station 4. Note cooling effect of incoming tidal water.

FIGURE 10—Surface temperatures recorded over a 21 hour period at Station 4. Note cooling effect of incoming tidal water

Longitudinally the temperature distribution pattern varied seasonally (Figure 13). In general water in the upper marsh area was cooler in winter and warmer in summer than that in the lower marsh area. Comparing the summer records of Station 2 near the mouth of the middle arm, and Station 4, about 1 km (0.6 miles) up the channel, the average surface water temperature increased from about 21 C (69.8 F) at Station 2 to 25 C (77.0 F) at Station 4. From December to February the water temperature decreased by about 1 to 2 C (1.8 to 3.6 F) between Stations 4 and 2. For the remainder of the year, because of tidal turbulence and the shallowness of the water, there was no noticeable difference in temperature between these two stations.

3.4. SALINITY

The annual salinity distribution pattern can be divided into two major periods. From May to October, the amount of influx of freshwater was insignificant, and the exchange of water in the marsh channels was through tidal action. Each tidal cycle brings in sea water from the mouth of Anaheim Bay. This water after residing in the marsh flats, become gradually modified. The mean salinity values during this period ranged from 34.2[o/oo] to 34.5[o/oo], slightly higher than the water in the outer harbor, which ranged from 33.5[o/oo] to 34.0[o/oo] (Chan and Renshaw, 1971). The higher salinity is a common phenomenon in marine marshlands and is due to the combined effects of evaporation and the excretion of salt by marsh plants (Phleger, 1970). Due to solar radiation, the salinity in the channels was observed to be over 35[o/oo] in several cases. Some tidal pools in the upper marshland become hypersaline, 40[o/oo].

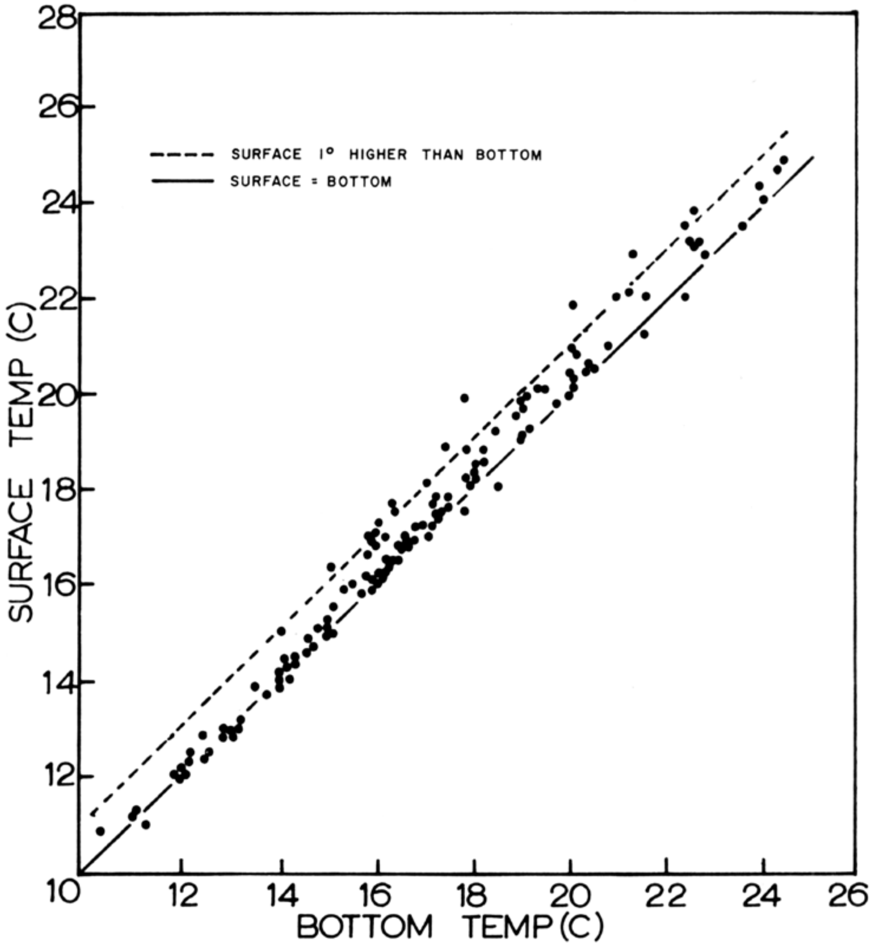

FIGURE 11—Comparison of surface and bottom water temperatures. Data were taken during 1970–71 at Stations 2, 3, and 4.

FIGURE 11—Comparison of surface and bottom water temperatures. Data were taken during 1970–71 at Stations 2, 3, and 4

Mean monthly salinity values became significantly reduced in December as soon as the rainy season began. Surface salinity values were often recorded to be less than 30[o/oo] (Figure 14). The resulting surface runoff of freshwater was insufficient to maintain a permanent gradient of increasing salinity towards the lower marshland (Figure 15). During high tide, the sea water moved towards the upper marshland as a bottom layer. Complete mixing and returning to vertical homohaline conditions through internal turbulence and mixing was achieved after several tidal cycles.

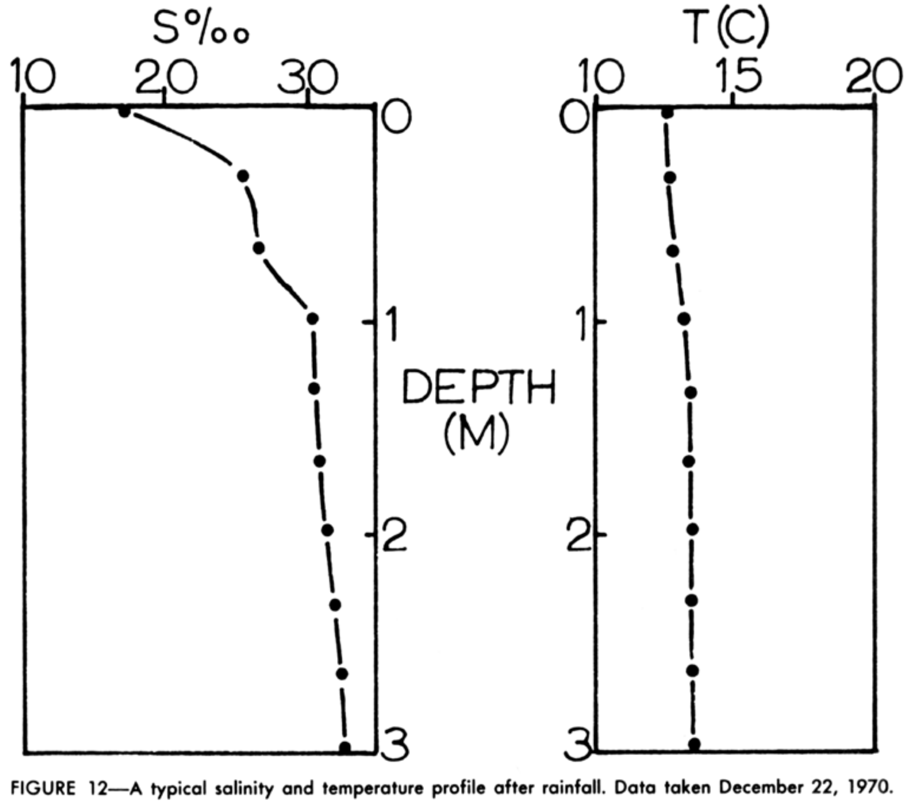

FIGURE 12—A typical salinity and temperature profile after rainfall. Data taken December 22, 1970

3.5. DISSOLVED OXYGEN

The observed pattern of dissolved oxygen concentration was the result of tidal effect and photosynthetic activity. Flooding not only brings in well oxygenated sea water from the outer harbor but causes mixing of surface water with bottom water. Thus water in the channels exhibited a uniform vertical oxygen distribution and was usually within 10% of air saturation levels. The seasonal variation was small; the general pattern seems to be that the dissolved oxygen level was about 6 to 8 ppm in summer months and 7 to 11 ppm in winter months. Higher oxygen concentration in winter months was the result of its increasing solubility at lower water temperatures and salinities. Diel variation of 1 to 2 ppm probably reflects photosynthetic activity (Figure 16). Phleger and Bradshaw (1966) showed that variations of dissolved oxygen are similar to the pattern of pH variations. The increase in dissolved oxygen in daytime, related to the photosynthesis by marsh flora, also increases the pH value 1 unit above incoming sea water.

There was no area of stagnation or anaerobic condition, nor were there significant decreases in dissolved oxygen content during the period of high surface runoff of freshwater. The only instance of lowering of dissolved oxygen concentrations was observed in bottom water of the west arm. This water was characterized by the unusual low dissolved oxygen content and higher than normal salinity (Figure 17). Since such conditions have never been observed in the other arms, it would suggest that the oil island brine effluent caused such a change in hydrography.

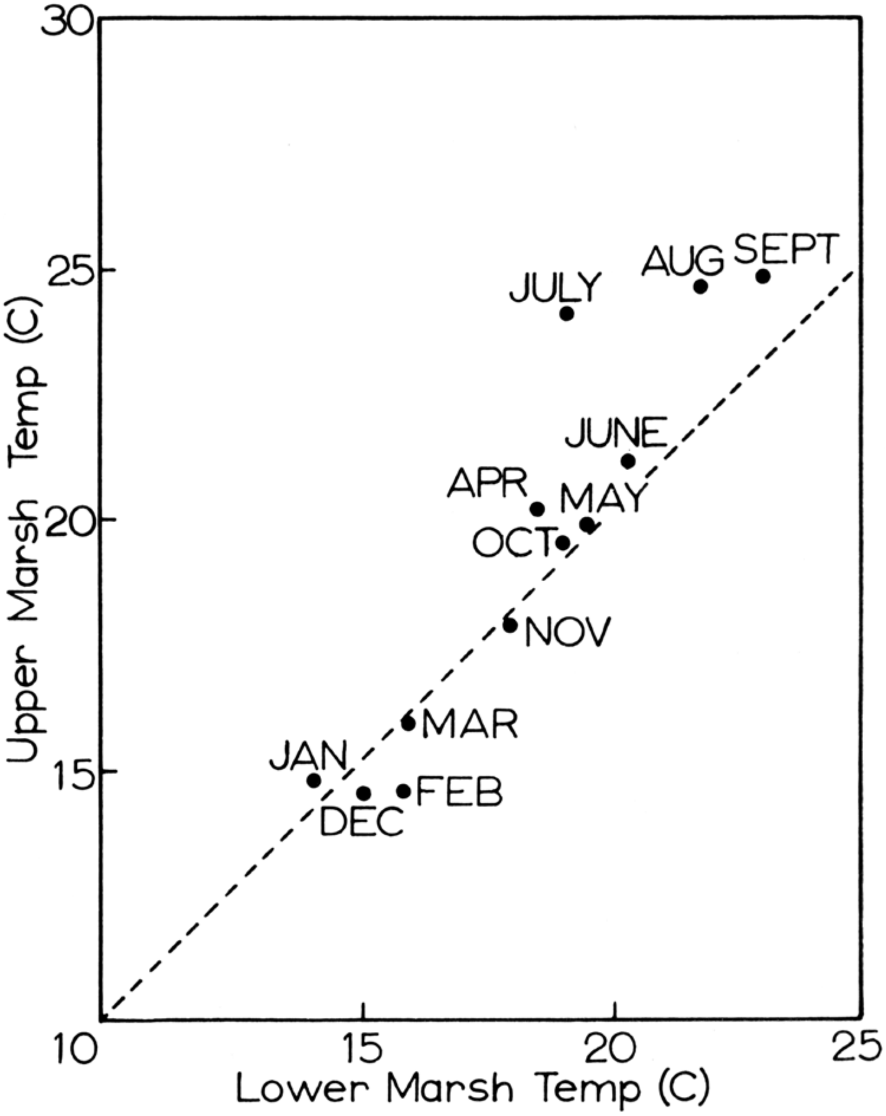

FIGURE 13—Comparison of monthly mean water temperature in the upper marsh at Station 4 and in the lower marsh at Station 2.

FIGURE 13—Comparison of monthly mean water temperature in the upper marsh at Station 4 and in the lower marsh at Station 2

Such alteration of water characteristics was of short duration and the water returned to the normal homohaline and uniform oxygen concentration after several tidal cycles. Nevertheless, it did present a more hostile environment to benthic organisms with a case of animal die-off being reported during the summer of 1971.

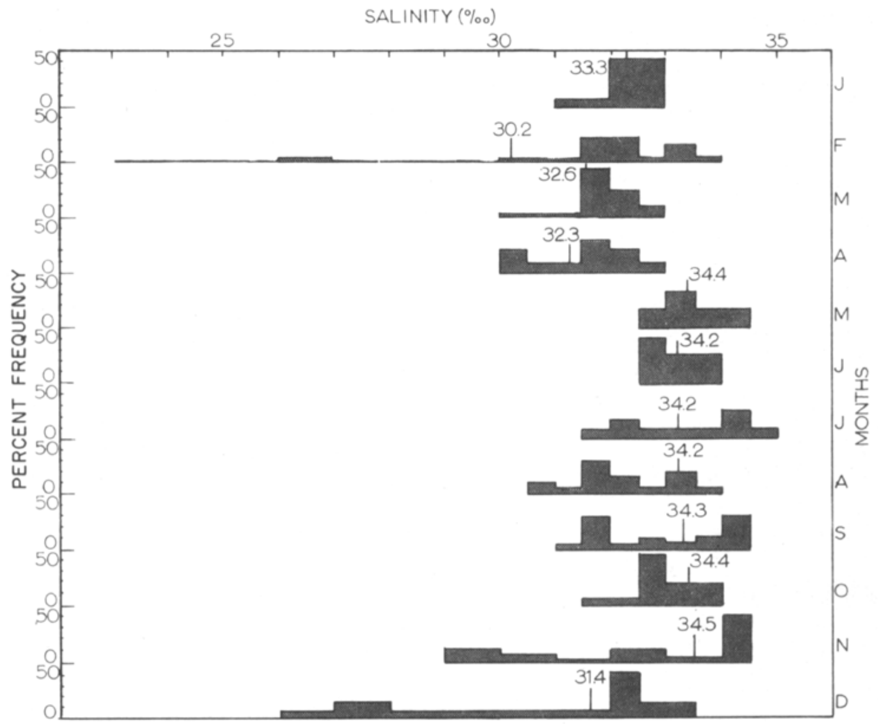

FIGURE 14—Monthly frequency histograms and means of the surface salinity. Data are from 1970–71, all stations are included.

FIGURE 14—Monthly frequency histograms and means of the surface salinity. Data are from 1970–71, all stations are included

3.6. NUTRIENTS

Phosphorus, nitrogen, and silicon are the most important nutrients for plant growth. They are taken from water by the organisms and replenished through resolution or decomposition. Since water in the marshland is in direct exchange with the outer harbor, nutrient cycles are interfered with by conditions in the outer harbor. The marshlands also may serve as a nutrient trap or semienclosed system when the supply from local sources exceeds the degree of dilution from tidal fusing action.

In general, the ranges of concentration closely follow nutrient concentration patterns off the Anaheim harbor area as reported by the State Water Quality Control Board in 1965 and Crippen and Reish in 1969 (Table 3).

The annual distribution pattern (Figure 18) shows high levels of nutrients occurred in spring. The major source is apparently from local surface runoff. After a heavy rainfall considerable quantities of phosphorus, nitrogen, and silicon are added to surface runoff through erosion, leaching of fertilized lawns, and urban drainage. For other months concentrations of nitrogen and silicon are rather uniform and low, which is typical of surface sea water in the coastal area.

TABLE 3

Comparison of the Range of Nutrient Concentrations

Nutrient	Present study Anaheim marshland	Allan Hancock Foundation Continental shelf off Anaheim Bay	Crippen and Reish L.A. Harbor	
			L.A. 7*	L.A. 50*
	μg at/l**	mg/l**	μg at/l**	μg at/l**
Phosphate P	0.6– 3.6	0.012–0.165	0.52– 2.14	0.12–5.89
Nitrate N	0.5– 6.4	0.01 –0.15	4.80–18.20	0.0 –0.51
Nitrite N	0.2– 0.7	no data	2.82–28.20	0.0 –0.84
Silicate Si	4.4–28.3	0.05 –0.94	no data	no data

* L.A. 7 is situated in Watchhorn Basin which was described as healthy. L.A. 50 is in the inner harbor and was described as polluted by Crippen and Reish (1969).
** 1 μg at P/liter = 0.028 mg P/liter
1 μg at N/liter = 0.014 mg N/liter
1 μg at Si/liter = 0.028 mg Si/liter

TABLE 3

Comparison of the Range of Nutrient Concentrations

Higher levels of phosphorus in July and August probably indicate the rapid turnover time for this element (Rigler, 1964). If such is the case, phosphorus is not only in high demand in the marshland, but is easier to maintain at high concentration levels throughout the year.

The average nitrogen/phosphorus ratio varies from 1:1 to 5:1 which is low in comparison with the normal 15:1 for open ocean water. However, this does not necessarily signify a limited nitrogen supply in the marshland. Algae are able to fix gaseous nitrogen, and significant amounts of nitrogen may exist in the form of ammonia and organic nitrogen compounds.

It is concluded that general nutrient levels are being maintained at relatively stable low levels. During periods of observation there was no bloom growth of primitive autotrophic organisms or upsets in the marshland community ecosystem which normally result from high nutrient concentrations. If any influx of nutrients occurred, either through natural or artificial sources, tidal flushing action was capable of restoring the marsh to its original conditions and effectively prevented any eutrophication in the entire area.

3.7. TRANSPARENCY

Measurement of water transparency provides information on optical purity and permits an estimate of the depth of the euphotic zone. This zone is usually defined by primary productivity workers as the area where 99% of the surface ambient radiant energy is absorbed.

Comparing Anaheim Bay water with coastal water off southern California, there is a decrease in transparency and an increase in total extinction coefficient in the marshland. This is caused by a large increase in the number and size of suspended particles. Tibby and Terry (1958) indicate average Secchi disc depths for southern California coastal water range from 620 to 1240 cm (20.34 to 40.68 feet); while in the tidal marshland values ranged from 20 to 220 cm (0.66 to 6.56 feet) with significant seasonal variations (Figure 19). During December to May

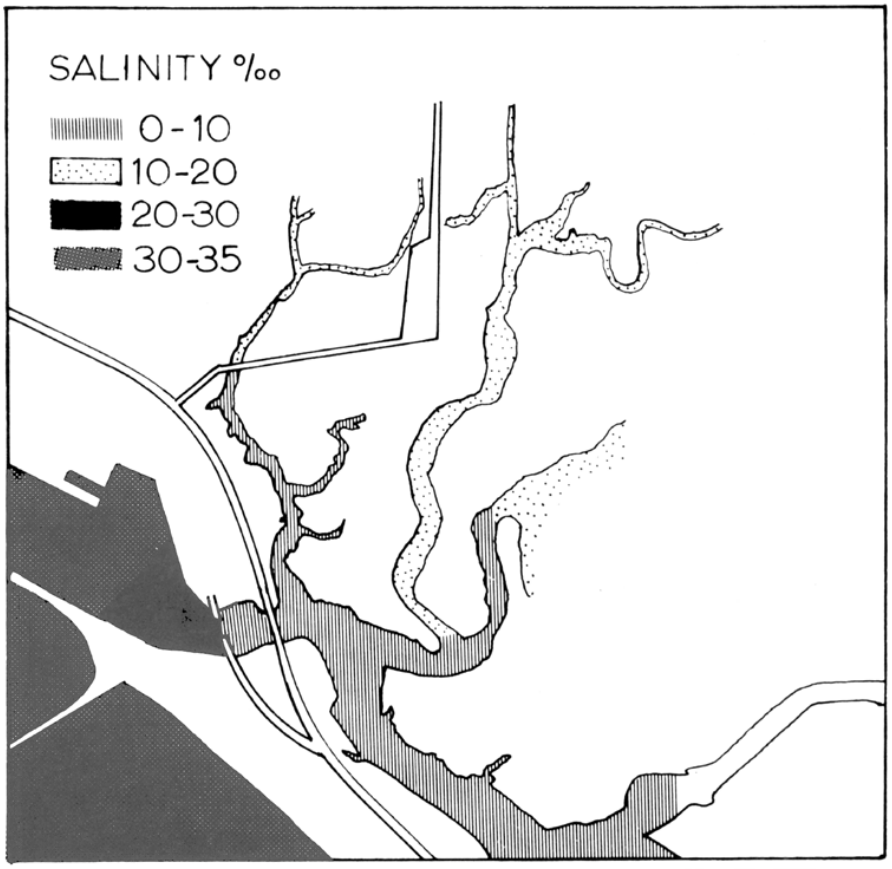

FIGURE 15—Pattern of surface salinities in Anaheim Bay after rainfall on December 22, 1970.

FIGURE 15—Pattern of surface salinities in Anaheim Bay after rainfall on December 22, 1970

the depth dropped abruptly to a 30 to 50 cm (0.98 to 1.64 feet) level as a result of erosion by surface runoff of fresh-water from rainfall. Heavy rainfall in the October to December period also causes a corresponding change in water transparency.

Comparing the mean value of water transparency for Station 4 and Station 2, there was a definite gradual decrease in depth in the upper marsh channel. The longitudinal difference in water transparency was much greater during the summer months as the precipitation was minimal during this period and there was an increased influx of clear ocean water. Such seasonal variations of water transparency were most significant at Station 2 situated at the outer edge of the middle arm.

Holmes (1970) discussed use of Secchi disc to estimate the depth of the euphotic zone. He suggested that a factor of "Secchi disc transparency" times 3.5 was most appropriate for water with a "Secchi disc transparency" of less than 5 m (16.41 feet). Using this factor during the summer, the euphotic zone in the middle arm was estimated to extend the depth of the whole water column. In winter, however, the "Secchi disc transparency" was less than 50 cm (1.6 feet)

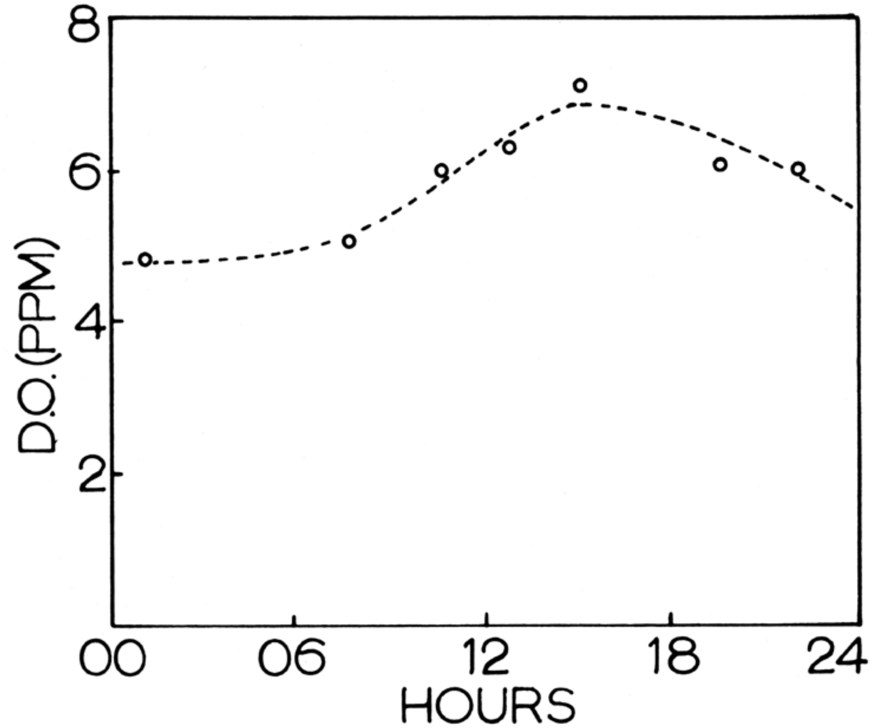

FIGURE 16—Diel variation in dissolved oxygen content.

FIGURE 16—Diel variation in dissolved oxygen content

and the depth of the euphotic zone was about 1.7 m (5.5 feet). During this period primary production in water was limited to the surface layer of the water. Another variation in transparency was caused by tidal flow; this was especially noticeable at Stations 2 and 3, and less noticeable at Station 4. Water was clearest near the end of the flood tide and at high slack water, and was generally more turbid near the end of the ebb. This, no doubt, was caused by clearer outer harbor water entering with the flood tide, and by an increase in turbidity caused by current erosion of banks and mud flats, and turbulence in the channels.

3.8. CIRCULATION OF WATER IN THE MARSH CHANNELS

Water movement in marsh channels is fairly simple. Corresponding to the change of tide, net water motion in the middle arm is approximately N.E. and S.W. The amplitude of tidal current is a function of tidal range which can be taken as about ± 1.5 m (4.9 feet). At low tide the water mean depth in the middle arm is about 1 m (3.2 feet), with only about 70% of the area covered by water. The difference in water volume between high and low tide (the tidal prism volume) gives an approximate estimate for the flushing action of tidal movement. A conservative estimate of tidal prism volume of the marsh channels is about 50% to 60% of the total high tide volume.

Current measurements were taken at Station 4. Maximum current velocity was observed to be greater than 3 knots, and the time average value was about 0.5 knots. From these preceding considerations it is apparent that the channel water is in frequent exchange with the outer harbor water.

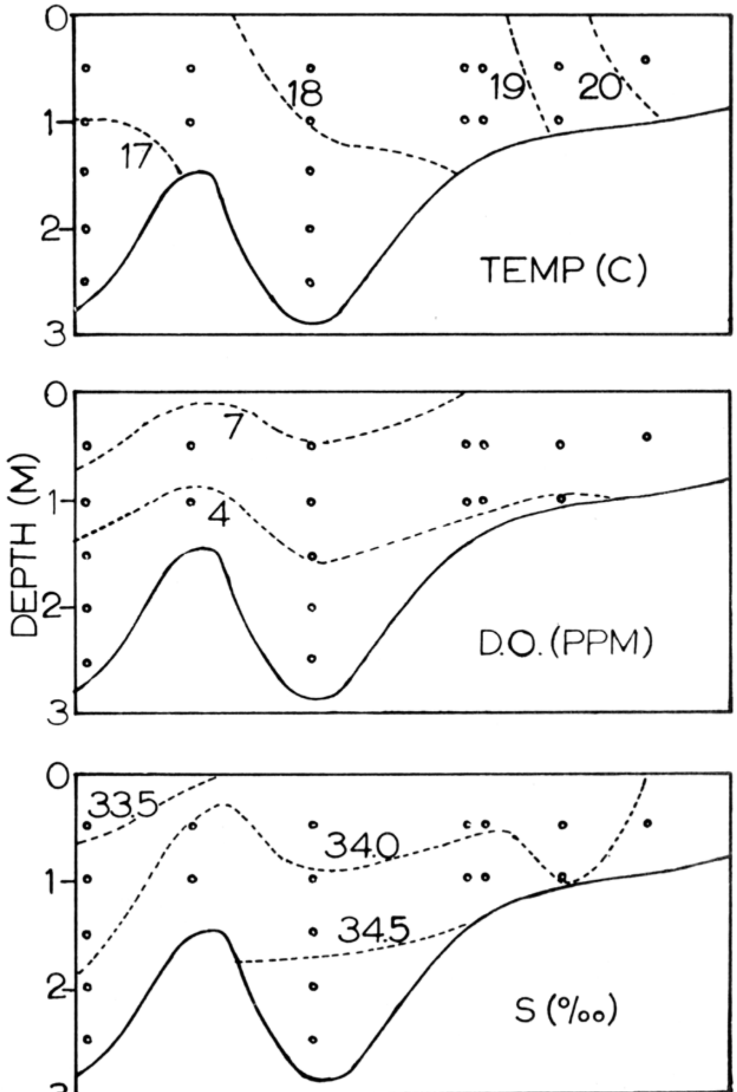

FIGURE 17—Temperature, dissolved oxygen and salinity profiles observed below Station 15 in the west arm on May 29, 1971. Note the decrease in dissolved oxygen and higher salinity encountered in this area.

FIGURE 17—Temperature, dissolved oxygen and salinity profiles observed below Station 15 in the west arm on May 29, 1971. Note the decrease in dissolved oxygen and higher salinity encountered in this area

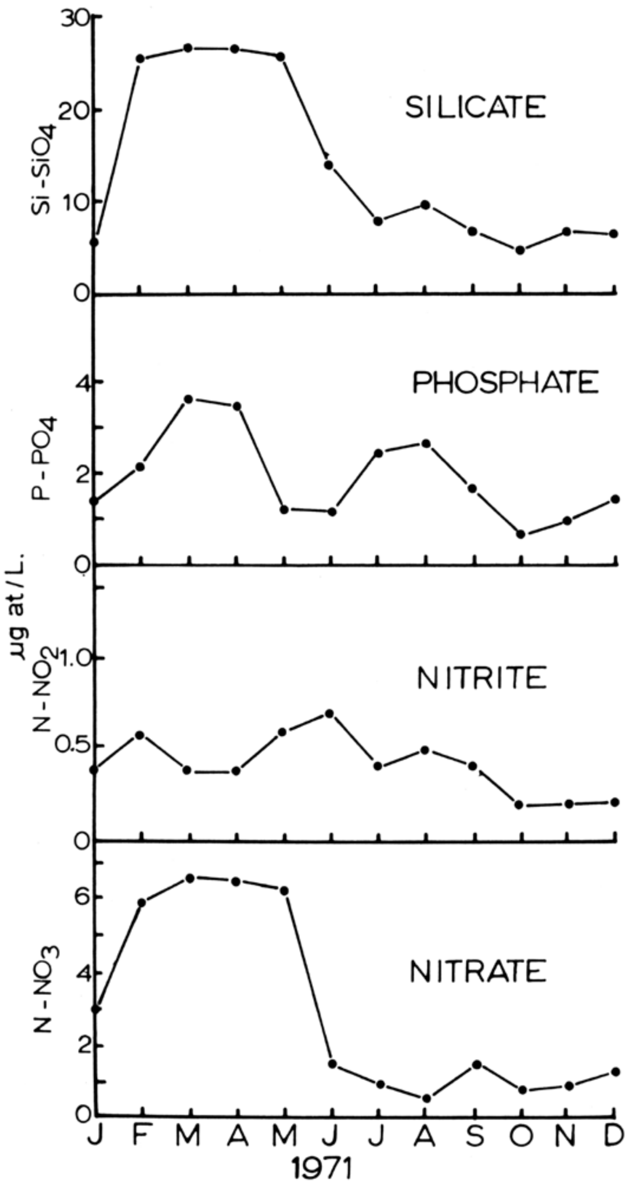

FIGURE 18—Monthly nutrient content, measured from water samples taken at Station 4 in the middle arm.

FIGURE 18—Monthly nutrient content, measured from water samples taken at Station 4 in the middle arm

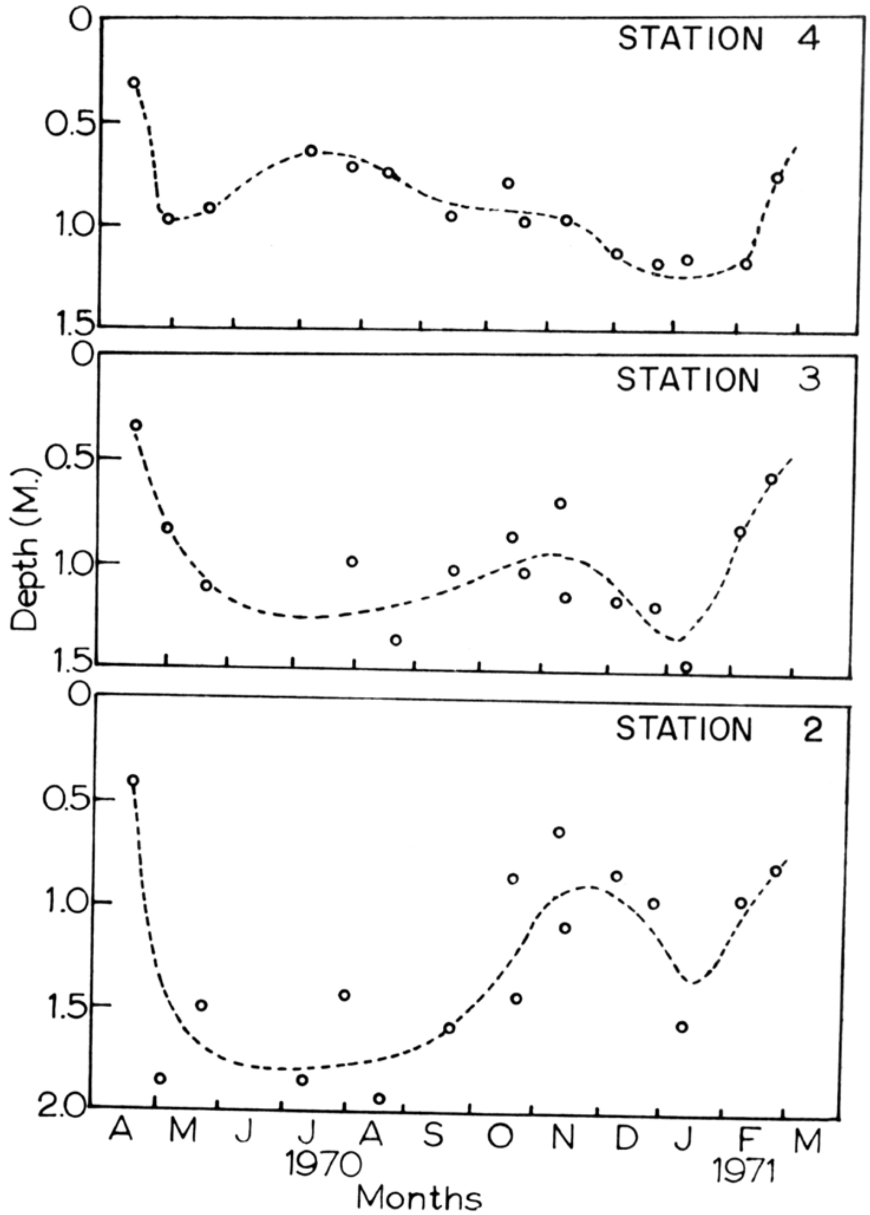

FIGURE 19—Variations in Secchi disc depths taken at Stations 2, 3, and 4 in the middle arm.

FIGURE 19—Variations in Secchi disc depths taken at Stations 2, 3, and 4 in the middle arm

3.9. DISCUSSION

Water in the marsh channels presents a natural coastal oceanic environment to the marine life. Tidal action is probably the most important factor in keeping water well oxygenated and euhaline. Although water conditions are modified continuously by climatic and atmospheric condition, tidal exchange with coastal oceanic water acts as a buffer so that a stable coastal oceanic environment is maintained. Nevertheless, as reported by Macdonald *et al* (1970), any modifications in tidal influence by dikes or fills, either partial or complete, would alter the physical environment as well as the biotic distribution pattern.

4. PLANTS OF ANAHEIM BAY

Plants associated with the marsh and channels of Anaheim Bay, and in particular the Seal Beach Naval Weapons Station, are typical of the southern California coastal salt marsh environment. The majority of plants involved are part of a distinct association referred to as the Salt-Marsh Community. This community is adapted to both the fluctuation of tides and soil salinity.

4.1. THE ALGAE

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Thirteen stations were defined along the middle arm of the bay. Eight of these were shore transects subject to tidal flooding and drying; on these transects naturally occurring algae were studied. The remaining five were half submerged plastic bottles, on which colonizing algae were studied. Both types were spread throughout the middle arm from a small tidal waterfall at the head of the arm to its mouth. Collections and observations were made every 2 weeks for a year in 1971 and 1972.

Several types of substrates were available to the algae; hard rocky surfaces, exposed to a tidal current twice a day; floating hard surfaces; sediments; and other vegetation.

The most common algae are discussed in order of decreasing abundance. Sources used in identification were: Setchell and Gardner (1903), Smith (1969), and Scagel (1966).

4.1.1. Enteromorpha

This was by far the most abundant genus with E. crinita (Roth) J. Agardh being the most common species found. It occurred on most substrates, in varying amounts, all year round. During winter it was scarce, found only in small amounts entwined around the bases of marsh plants. Sexual reproduction occurred in spring, with rapid growth in early summer. Dense mats of this algae occurred on all substrates during its midsummer abundance peak.

Enteromorpha spp. was common on moist areas around the base of marsh plants, and on the upper edges of channel banks. It floated in dense masses when the tide was in. Algal mats also were found on mud banks, where strands or masses had become embedded. Mats may grow to cover areas as large as 7 m^2 (8.4 $yards^2$) with a thickness of 5 cm (2 inches). Enteromorpha also grew on the floating bottles where it attached by holdfasts. These plants reached a length of 2 m (6.5 feet).

Vegetative propagation is very important to Enteromorpha. It is dispersed from established mats by masses or strands that break off and become free floating. Such strands may become entwined or embedded in other areas and begin to grow. As many as 110 new branches may arise from a 0.5 cm^2 (0.8 $inches^2$) section of an embedded thallus.

4.1.2. Gracilaria verrucosa (Hudson) Papenfuss

This was the second most abundant alga observed; however, there is some question in identification as no reproductive structures were found. In their absence, the possibility exists that the alga is Gracilariopsis sjoestedtii (Kylin) Dawson. Gracilaria was brought in by tides and was usually found on the upper edges of banks from the mouth of the middle arm to opposite the north end of the oil island. It was never found attached by a holdfast but grew from embedded or entwined sections of thalli. Abundance was constant throughout the year.

4.1.3. Bryopsis hypnoides Lamouroux, and Polysiphonia sp

These algae occurred only in areas of strong tidal currents and attached to hard substrates (rocks, plastic bottles, etc.). The strong current appeared necessary to keep their fronds silt-free. Colonization of these plants occurred on all plastic bottles, but they soon died on those bottles without sufficient current. The only area with abundant populations of these algae was the tidal waterfall at the head of the middle arm. Abundance was constant all year except for a slight decrease during summer.

4.1.4. Ulva lactuca Linnaeus

This was the least abundant of the algae discussed. It grew on the plastic bottles and on rocks in sheltered, moderately silt-free water.

4.2. THE VASCULAR PLANTS OF THE SALT MARSH

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Long Beach, California

Vascular plants of Anaheim Bay and the associated marsh exist in zones. This zonation is caused largely by the tidal action and soil salinity. Each zone can be determined by the plants which exist within it and is named accordingly. Commencing with the aquatics and progressing to the higher sandy margins of land fills, these zones are (i) the Zostera, (ii) the Spartina, (iii) the Batis/Salicornia, (iv) the Distichlis, and (v) the Carpobrotus/Gasoul.

The influence of man on Anaheim marsh is evident when examining the list of taxa. Within the Weapons Station there are the plants typical of an undisturbed salt marsh, and there are a number of plants which are present only because of man-made fill roadways around the area's perimeter. Along these roadways one can find many invading weedy plants which are restricted to these "man-made habitats". Therefore, this list of vascular plants includes those taxa represented in the marsh proper and along margins of fill areas. Plants which are found on surrounding higher elevations are technically out of the marsh and not included.

The list is arranged alphabetically by family and genus with the dicots preceding the monocots. Brief notations are made as to the abundance of each of the taxa: r = rare, o = occasional, c = common, a = abundant, and va = very abundant. Additional notations indicate general areas of the marsh where representative specimens may be found.

4.2.1. DICOTS

Family Aizoaceae

Carpobrotus aequilaterus (Haworth) N. E. Brown, Sea-Fig, r, sandy margins of road fills.
Carpobrotus edulis (Linneaeus) Bolus, Hottentot-Fig, c, sandy margins of road fills.
Gasoul crystallinum (Linnaeus) Rotm., Ice Plant, c to o, sandy margins of road fills.
Gasoul nodiflorum (Linnaeus) Rotm., Ice Plant, o, lower margins of road fills.

Family Apiaceae

Apium graveolens Linnaeus, Wild Celery, o, weed, margins of road fills.
Conium maculatum Linnaeus, Poison Hemlock, o, weed, margins of islands and road fills.

Family Asteraceae

Ambylopappus pusillus Hooker & Arnott, r, margins of fill areas.
Ambrosia psilostachya de Candolle, r, higher sandy margins along road fills.
Baccharis emoryi Gray, o, weed, margins of road fills.
Baccharis viminea de Candolle, Mule Fat, o, weed, margins of road fills.
Cotula coronopifolia Linnaeus, Brass-Buttons, o, margins of road fills.
Grindelia robusta Nuttall, Gum Plant, r, sandy margins of road fills.
Jaumea carnosa (Lessing) Gray, o, upper part of Salicornia zone.
Pluchea purpurascens (Swartz) de Candolle, Marsh Fleabane, r, in Distichlis zone.

Family Bataceae
Batis maritima Linnaeus, Saltwort, a to c, intertidal zone.
Family Brassicaceae
Brassica campestris Linnaeus, Wild Mustard, o, weed invading upper margins of road fills.
Lepidium sp., Pepper-Grass, o, upper margins of road fills.
Raphanus sativus Linnaeus, Wild Radish, o, weed invading upper margins of road fills.
Family Boraginaceae
Heliotropium curassavicum Linnaeus var. oculatum (Heller) Johnston, Heliotrope, o, margins of road fills.
Family Caryophyllaceae
Spergularia marina (Linnaeus) Grisebach, Sand-Spurrey, r, low sandy areas.
Family Chenopodiaceae
Atriplex californica Moquin-Tandon in de Candolle, Saltbush, r, sandy margins of fill areas.
Atriplex watsonii A. Nelson, Saltbush, o, sandy margins of fill areas.
Chenopodium ambrosioides Linnaeus, Pigweed, r, fill areas.
Salicornia bigelovii Torrey, Pickleweed, c to o, high tide margins, often in Batis zone.
Salicornia subterminalis Parish, Pickleweed, a, high tide margins.
Salicornia virginica Linnaeus, Pickleweed, va, high tide margins, above Batis zone.
Suaeda californica Watson, Sea-Blite, c to o, sandy margins of fill areas.
Family Convolvulaceae
Cressa truxillensis Humboldt, Bonpland, & Kunth, Alkali Weed, o, sandy margins of road fills.
Family Cuscutaceae
Cucusta salina var. *major* Yuncker, Dodder, r, hemiparasite, on Salicornia.
Family Fabaceae
Melilotus indica (Linnaeus) Allioni, Sweet-Clover, o, weed, invader of higher sandy margins of fill areas.
Family Frankeniaceae
Frankenia grandifolia Chamisso & Schlechtendal, a, above Salicornia margins.
Family Plumbaginaceae
Limonium californicum (Boissier) Heller, Sea-Lavender, o, sandy margins of fill areas.
Family Polygonaceae
Polygonum lapathifolium Linnaeus, Willow-Weed, o, wet upper margins of marsh.
Rumex crispus Linnaeus, Dock, c, weed, invader of upper margins of fill area.

Family Saururaceae

Anemopsis californica (Nuttall) Hooker & Arnott, Yerba Mansa, o, sometimes in Salicornia zone.

4.2.2. MONOCOTS

Family Cyperaceae

Scirpus cernuus Vahl var. californicus (Torrey) Beetle, Bulrush, r, tidal flats.

Scirpus robustus Pursh, Bulrush, o, high tide zone.

Family Juncaceae

Juncus acutus Linnaeus var. sphaerocarpus Engelmann, Rush, o, large clumps in Salicornia zone.

Family Juncaginaceae

Triglochin concinnum Burtt-Davy, Arrow-Grass, o, edge of Batis/Salicornia zone.

Family Poaceae

Distichlis spicata (Linnaeus) Greene ssp. stricta (Torrey) Beetle, Salt Grass, va, from Salicornia zone up to higher margins of fills.

Monanthochloe littoralis Englemann, Shore Grass, o, in flats along road fills.

Parapholis incurva (Linnaeus) C. E. Hubbard, Sickle Grass, o, margins of road fills.

Spartina foliosa Trinius, Cord Grass, va, emergent, most common plant in marsh.

Family Typhaceae

Typha sp., Cat-Tail, r, along drainage ditches.

Family Zosteraceae

Zostera marina Linnaeus, Eel-Grass, r, in water of deeper channels.

5. ANNOTATED CHECKLIST OF THE MARINE INVERTEBRATES OF ANAHEIM BAY

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and
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5.1. INTRODUCTION

The first published major study including invertebrates from Anaheim Bay was by Hartman (1939–1957) who recorded 19 species of polychaetes in connection with her monographic studies. Nearby upper Newport Bay, accessible to the public, has been more extensively studied (Bane, 1968; Barnard and Reish, 1959; MacGinitie, 1939; Frey, Hein, and Sprull, 1970).

The purpose of this report is to record the invertebrate species known from the salt marsh area of Anaheim Bay so that this information may be utilized as background data in understanding biological characteristics of a more or less pristine region of southern California. Furthermore, such an inventory is essential as a prerequisite to further ecological studies in Anaheim Bay.

5.2. MATERIALS AND METHODS

Intertidal collections were made sporadically from each of the arms of the bay during the 1970–1972 period. Areas were reached either on foot or by boat. Larger species were identified in the field. Samples of mud were taken at different intertidal levels, preserved in formalin, and washed through an 0.246 mm (0.01 inches) mesh screen in the laboratory. Subtidal samples were made with a size one Hayward orange-peel bucket, preserved, and washed through a 0.7 mm (0.03 inches) mesh screen in the laboratory. Fouling organisms were collected from an old dock in the middle arm and from buoys at the entrance to the bay near Station 1 (Figure 20).

5.3. RESULTS

A total of at least 116 species of invertebrates has been collected from the salt marsh area of Anaheim Bay. The total of nematodes and copepods is minimal since no attempt was made to identify such organisms except for those parasitic on fish (see chapter on parasitic crustacea). of the species identified, polychaetes comprised 76 species, or about 65%; crustaceans 17, or about 15%; and molluscs 15, or 13%.

A cephalocarid crustacean, as yet undescribed, is the only species encountered which is unknown from southern California; nevertheless, it may occur elsewhere and has been overlooked because of its small size. A large population of the echuiroid Urechis caupo was found intertidally in the middle arm. This species was previously known from Newport Bay, but apparently is rare or no longer present there (Michael J. Smith, Kerckhoff Marine Laboratory, pers. comm., January 20, 1972).

At least eight species of polychaetes are presently unknown from any other bay or harbor of southern California, including Glycera convoluta, Glycera robusta, Lumbrinereis zonata, Protodorvillea gracilis, Rhynocospio arenicola, Dasybranchus lumbricoides, Notamastus magnus, and Nichomache personata. However, in all cases, these species are known from shallow offshore waters (Hartman, 1968, 1969).

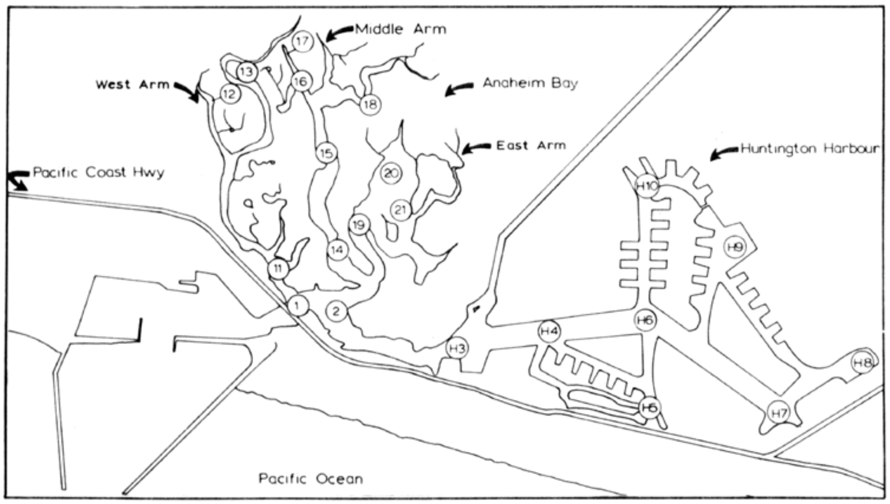

FIGURE 20—Stations visited for invertebrate studies.

FIGURE 20—Stations visited for invertebrate studies

PHYLUM COELENTERATA

Class Anthozoa

Anthopleura elegantissima (Brandt); Hand, 1955a, p. 55.

Occurrence: Many specimens were seen attached to the rocks at Station 19.

Diadumene leucolena Verrill; Hand, 1955b, p. 223.

Occurrence: Many specimens were present on the rocks at Station 19.

PHYLUM PLATYHELMINTHES

Class Turbellaria

Occurrence: Several unidentified flatworms were collected from mussel beds attached to the buoy at Station 1 and at several benthic stations. No attempt was made to identify these organisms.

Class Trematoda

Occurrence: The California horn snail, Cerithidea californica, is host for many larval stages of parasitic trematodes. No attempt was made to identify these larvae but many different types have been observed (Martin, 1955).

PHYLUM NEMATODA

Occurrence: Countless numbers of unidentified nematodes were retained on a 0.246 mm (0.01 inches) mesh screen. They were present in all intertidal collections.

PHYLUM NEMERTEA

Occurrence: Specimens were observed in mussel beds attached to the buoy at Station 1 and the old dock at Station 15, as well as some of the benthic stations. No attempt was made to identify them.

PHYLUM ANNELIDA

Class Oligochaeta

Occurrence: Unidentified oligochaetes were very abundant, especially intertidally at the inner reaches of all three arms of the bay. Many also were collected from the benthos. No attempt was made to identify them.

PHYLUM ANNELIDA

Class Polychaeta

Family Polynoidae

Halosydna brevisetosa Kinberg; Hillger and Reish, 1970, p. 87.

Halosydna johnsoni (Darboux); Hartman, 1939, p. 34.

Occurrence: Specimens were collected at Station 1 from clumps of Mytilus edulis attached to buoys and from the benthos. Hartman (1939) reported it from Anaheim Bay from Crepidula clumps.

Family Chrysopetalidae

Paleonotus bellis (Johnson); Hartman, 1968, p. 187.

Occurrence: Specimens were collected at Station 1 from clumps of Mytilus edulis attached to buoys and from the benthos.

Family Phyllodocidae

Anaitides williamsi Hartman; Hartman, 1968, p. 239.

Occurrence: Stations 1 and 21, benthos.

Eteone pacifica Hartman; Hartman, 1968, p. 255.

Occurrence: Station 1, benthos.

Eteone sp.

Occurrence: Immature specimens were collected intertidally at the upper reaches of the west arm of the bay.

Eumida sanguinea (Oersted); Hartman, 1968, p. 275.

Occurrence: It was taken subtidally at the entrance of the inner bay from the outer reaches of the middle arm and at the buoy at Station 1.

Phyllodocids, unidentified.

Many small phyllodocids were not identified; they were taken from the benthos at several stations (Table 4).

Family Hesionidae

Ophiodromus pugettensis (Johnson); Hartman, 1968, p. 369.

Occurrence: This species was collected subtidally at Station 1 and at the outer reaches of the middle arm; specimens were taken intertidally from the mud flats near Hog Island.

Family Syllidae

Exogone lourei Berkeley and Berkeley; Hartman, 1968, p. 425.

Occurrence: Collected subtidally from the outer stations of the bay and the middle arm to Station 20.

Sphaerosyllis pirifera Claparede; Hartman, 1968, p. 457.

Occurrence: Station 1, benthos.

Syllis gracilis Grube; Hartman, 1968, p. 463.

Occurrence: Station 1, benthos.

Typosyllis fasciata (Malmgren); Hartman, 1968, p. 485.

Occurrence: Station 1, benthos.

Family Nereidae

Neanthes arenaceodentata (Moore); Reish, 1968a, p. 217.

Occurrence: It was collected from the benthos in the inner reaches of the middle and east arms of the bay except at Station 19.

Neanthes succinea (Frey and Leuckart); Hartman, 1968, p. 529.

Occurrence: Station 23, benthos.

Nereis procera (Ehlers); Hartman, 1968, p. 549.

Occurrence: Station 11, benthos.

Platynereis bicanaliculata (Baird); Hartman, 1968, p. 559.

Occurrence: Station 1, benthos.

Family Nephtyidae

Nephtys caecoides Hartman; Hartman, 1940, p. 240; 1950, p. 102, 1968, p. 102.

Occurrence: Stations 11, 16, and 22, benthos. Hartman (1940, 1950) reported it from Anaheim Bay.

Nephtys cornuta franciscana Clark and Jones; Hartman, 1968, p. 581.

Occurrence: Present in the benthos at six stations from the mouth of the upper bay into the middle and east arms.

Family Glyceridae

Glycera americana Leidy; Hartman, 1940, p. 246; 1968, p. 613.

Occurrence: Station 18, intertidal. Hartman (1940), intertidal.

Glycera convoluta Keferstein; Hartman, 1940, p. 247; Hartman, 1968, p. 619.

Occurrence: Hartman (1940) reported it from collections made in December 1938; not in present collections.

Glycera robusta Ehlers; G. longissima. Hartman, 1940, p. 245 (not G. longissima Arwidsson, 1899). Hartman, 1950, p. 69; 1968, p. 627.

Occurrence: Data same as for G. convoluta.

Family Goniadidae

Glycinde armigera Moore; Hartman, 1950, p. 49; 1968, p. 643.

Occurrence: Data as Glycera convoluta.

Glycinde sp.

Occurrence: Two juvenile specimens were collected at Station 11.

Goniada littorea Hartman; Hartman, 1950, p. 23; 1968, p. 655.

Goniada uncinigera Hartman, 1940, p. 252 (not G. uncinigera Ehlers, 1901).

Occurrence: This species was collected at Station 1 and the middle arm especially subtidally at Station 16. Hartman (1950) reported it from Anaheim Bay.

Marphysa sanguinea (Montagu); Hartman, 1968, p. 733.

Occurrence: One specimen was collected from the high intertidal muddy sand flat at Station 1 and one was taken subtidally at Station 18.

Family Lumbrineridae

Lumbrineris erecta (Moore); Hartman, 1944a, p. 149; 1968, p. 753.

Occurrence: Station 1, subtidal. Hartman (1944a), intertidal.

Lumbrineris minima Hartman; Hartman, 1944a, p. 155; 1968, p. 769.

Occurrence: It was collected subtidally from Station 1 into most of the middle arm and Station 21. Hartman (1944a) reported it from the intertidal mud flats.

Remarks: Anaheim Bay is the type locality of this species (Hartman, 1944a).

Lumbrineris zonata (Johnson); Hartman, 1944a, p. 146; 1968, p. 777.

Occurrence: Hartman (1944a) reported it from the bay.

Family Dorvilleidae

Protodorvillea gracilis (Hartman); Hartman, 1968, p. 825.

Stauronereis gracilis Hartman, 1938, p. 100. Dorvillea gracilis (Hartman), 1944a, p. 189.

Occurrence: Hartman (1944a) reported three specimens from the intertidal reaches of Anaheim Bay.

Family Orbiniidae

Haploscoloplos elongatus (Johnson); Hartman, 1957, p. 273; 1969, p. 19.

Occurrence: This species was taken from many subtidal localities from Station 1 and extending up to include most of the middle arm and outer reaches of the east arm of the bay. Hartman (1957), intertidal.

Naineris dendritica (Kinberg); Hartman, 1969, p. 25.

Occurrence: Stations 1 and 13, subtidal.

Family Spionidae

Boccardia proboscidea Hartman; Hartman, 1969, p. 95.

Occurrence: Station 17, intertidal.

Boccardia uncata (Berkeley); Hartman, 1969, p. 103.

Occurrence: Station 13, intertidal and subtidal; Station 18, intertidal.

Nerinides acuta (Treadwell); Hartman, 1969, p. 119.

Occurrence: Very abundant species which was taken subtidally at all stations in each of the three arms of the bay except Station 19.

Nerinides maculata Hartman; Hartman, 1969, p. 121.

Occurrence: Station 13, subtidal.

Nerinides pigmentata (Reish); Hartman, 1969, p. 123.

Occurrence: Station 11, subtidal.

Polydora brachycephala (Hartman); Hartman, 1969, p. 129.

Occurrence: Station 16, subtidal.

Polydora ligni Webster; Hartman, 1969, p. 137.

Occurrence: Station 1, subtidal.

Polydora limicola Aunenkova; Hartman, 1969, p. 139.

Occurrence: Station 1, subtidal.

Polydora websteri Hartman; Hartman, 1969, p. 151.

Occurrence: This species was very abundant in intertidal mud flats throughout the west and middle arms of the bay, except Station 19, and near Hog Island. It was taken from mussel beds attached to the buoys at Station 1 and the old dock at Station 15.

Prionospio cirrifera Wiren; Hartman, 1969, p. 155.

Occurrence: This species was widely distributed subtidally throughout the bay. A few species were taken intertidally at Station 14 and near Hog Island.

Prionospio heterobranchia newportensis Reish; Hartman, 1969, p. 157.

Occurrence: A few specimens were taken subtidally at Stations 1 and 16.

Prionospio pinnata Ehlers; Hartman, 1969, p. 161.

Occurrence: Stations 11 and 16, subtidal.

Prionospio pygmaeus Hartman; Hartman, 1969, p. 163.

Occurrence: It was taken subtidally from Station 2 and into the middle and east arms of the bay.

Pseudopolydora kempi (Southern); Hartman, 1969, p. 167.

Occurrence: Stations 13 and 23, subtidal.

Rhynchospio arenincola Hartman; Hartman, 1969, p. 171.

Occurrence: This species was found subtidally at nearly every station in each of the three arms of the bay and at Station 2.

Spiophanes missionensis Hartman; Hartman, 1969, p. 185.

Occurrence: This species was taken subtidally from several stations throughout the bay, but especially from the middle arm.

Streblospio benedicti Webster; Hartman, 1969, p. 189.

Occurrence: This was one of the more frequently encountered species in the bay, both intertidally and subtidally. It is present in intertidal mud flats in all three arms of the bay, and subtidally at every station but one.

Family Magelonidae

Magelona californica Hartman; Hartman, 1944b, p. 320.

Occurrence: Hartman (1944b) reported one specimen from the bay.

Family Chaetopteridae

Telepsavus costarum Claparede; Hartman, 1969, p. 219.

Occurrence: Station 16, subtidal.

Family Cirratulidae

Chaetozone corona Berkeley and Berkeley; Hartman, 1969, p. 235.

Occurrence: Station 21, subtidal.

Chaetozone multioculata Hartman; Hartman, 1969, p. 239.

Occurrence: Station 1, subtidal.

Cirriformia luxuriosa (Moore); Hartman, 1969, p. 251.

Occurrence: This species was very abundant on the bottom at Stations 18 and 19. The current is especially strong at these stations since this channel drains much of the water from the tidal area on the other side of the road at Station 19. Additional subtidal collections were made of C. luxuriosa at Stations 1 and 13.

Cirriformia spirabrancha (Moore); Hartman, 1969, p. 253.

Occurrence: Station 19, intertidal between the rocks.

Tharyx parvus Berkeley; Hartman, 1969, p. 265.

Occurrence: Collected subtidally from the mouth and outer portions of each of the three arms of the bay.

Family Cossuridae

Cossura candida; Hartman, 1969, p. 271.

Occurrence: This was one of the more frequently collected polychaetes from the benthos; it was taken at Stations 1 and 14, and at all stations in the middle and east arms.

Armandia bioculata Hartman; Hartman, 1969, p. 323.

Occurrence: This species was found abundantly subtidally at the mouth of the upper bay and at all stations in the middle and east arms of the bay. Some specimens were taken from mussel beds attached to the buoy at Station 1.

Polyophthalmus pictus (Dujardin); Hartman, 1969, p. 339.

Occurrence: Station 1, subtidal.

Family Capitellidae

Capitella capitata (Fabricius); Hartman, 1969, p. 361.

Occurrence: The majority of specimens was collected subtidally from the inner reaches of the three arms of the bay; additional specimens were collected from

the benthos at Station 1 and intertidally near Hog Island.
Capitita ambiseta Hartman; Hartman, 1969, p. 369.
Occurrence: One of the more commonly encountered polychaetes in the bay; it was taken both intertidally and subtidally from throughout the bay.
Dasybranchus lumbricoides Grube; Hartman, 1947, p. 431; 1969, p. 373.
Occurrence: Intertidal (Hartman, 1947).
Notomastus magnus Hartman; Hartman, 1947, p. 412; 1969, p. 401.
Occurrence: Intertidal (Hartman, 1947).
Notomastus (Clistomastus) tenuis Moore; Hartman, 1947, p. 420; 1969, p. 397.
Occurrence: Station 18 and Hartman (1947), intertidal.
Notomastus sp.
Occurrence: Four small specimens of this genus were collected at Station 11.
Family Maldanidae
Axiothella rubrocincta (Johnson); Hartman, 1969, p. 431.
Occurrence: Station 1, subtidal.
Nicomache personata Johnson; Hartman, 1969, p. 467.
Occurrence: Station 1, subtidal.
Family Oweniidae
Owenia collaris Hartman; Hartman, 1969, p. 493.
Occurrence: Station 17, subtidal.
Family Sabellariidae
Sabellaria gracilis Hartman; Hartman, 1969, p. 507.
Occurrence: Station 1, subtidal.
Family Pectinariidae
Pectinaria californiensis Hartman; Hartman, 1941, p. 333; 1969, p. 515.
Occurrence: Intertidal (Hartman, 1941).
Family Ampharetidae
Amphicteis glabra Moore; Hartman, 1969, p. 545.
Occurrence: Station 11, subtidal.
Family Terebellidae
Amaeana occidentalis (Hartman); Hartman, 1969, p. 581.
Occurrence: Station 16, subtidal.
Pista alata Moore; Hartman, 1969, p. 611.
Occurrence: Station 1 and 16, subtidal.
Thelepus setosus (Quatrefages); Hartman, 1969, p. 649.
Occurrence: Station 1, subtidal.
Family Sabellidae
Chone sp.
Occurrence: Two small specimens were taken subtidally at Station 1.
Euchone limnicola Reish; Hartman, 1969, p. 683.
Occurrence: Many specimens were collected subtidally from the junction of the three arms and from the middle and east arms.
Megalomma pigmentum Reish; Hartman, 1969, p. 709.
Occurrence: Several specimens were collected subtidally from the mouth, middle and east arms of the bays.

PHYLUM MOLLUSCA
Class Gastropoda
Order Mesogastropoda
Family Potamididae
Cerithidea californica (Haldman); McLean, 1969, p. 32.

Occurrence: The California horn snail is the most conspicuous invertebrate present in Anaheim bay. It is distributed throughout the area in countless numbers from the marsh grass zone into the high tidal mud flat zone. This snail harbors larval stages of many species of trematodes.

Family Calyptraeidae
Crepidula onyx Sowerby; McLean, 1969, p. 36.

Occurrence: The onyx slipper shell was taken from the buoy at Station 1.

Family Naticidae
Polinices reclusianus (Deshayes); McLean, 1969, p. 37.

Occurrence: A few specimens of the southern moon snail were collected from the intertidal muddy sand beach at Station 1.

Order Neogastropoda
Family Nassariidae
Nassarius tegula (Reeve); McLean, 1969, p. 48.

Occurrence: The mud nassa was collected intertidally near Stations 1 and 18 and subtidally at Station 18.

Subclass Opisthobranchiata
Order Tectibranchiata
Family Atyidae
Haminoea sp.

Occurrence: Several specimens were collected intertidally at Station 18.

Class Pelecypoda
Order Filibranchia
Family Mytilidae
Mytilus edulis Linnaeus; McLean, 1969, p. 66.

Occurrence: The bay mussel is found in Anaheim Bay wherever solid substrate exists. They were attached to the floating buoys at Station 1, to the rocks at Stations 19 and near 23, and to the old dock at Station 15.

Geukensia demissa (Dellwyn); McLean, 1969, p. 68.

Occurrence: Many specimens are present at the end of the bay's east arm near Station 23.

Remarks: This species was introduced accidentally into San Francisco Bay from the east coast (Reish, 1968b); it is now known from Alamitos Bay and Newport Bay in southern California.

Order Eulamellibranchiata
Family Veneridae
Chione fluctifraga (Sowerby); McLean, 1969, p. 78.

Occurrence: It was collected intertidally and subtidally from the middle arm at Stations 18 and 19 respectively.

Chione undatella (Sowerby); McLean, 1969, p. 78.

Occurrence: The wavy chione was collected intertidally through most of the middle arm of the bay and subtidally at Station 1.

Protothaca staminea (Conrad); McLean, 1969, p. 7.

Occurrence: Specimens were collected subtidally at Stations 1 and 19.

Family Tellinidae

Macoma nasuta (Conrad); McLean, 1969, p. 83.

Occurrence: Intertidal specimens were collected near Hog Island, and subtidal ones were taken from the upper reaches of the mud channels.

Macoma secta (Conrad); McLean, 1969, p. 84.

Occurrence: Station 18, subtidally.

Family Psammobiidae

Tagelus californianus (Conrad); McLean, 1969, p. 87.

Occurrence: The California jackknife clam is distributed throughout much of Anaheim Bay both intertidally and subtidally. Shorebirds have been observed feeding on intertidal populations of this clam, and siphons have been found in fish stomachs.

Family Myidae

Cryptomya californica (Conrad); McLean, 1969, p. 88.

Occurrence: Intertidal specimens were collected at the entrance of the mud channels and subtidal ones came from Station 18.

Family Hiatellidae

Hiatella arctica (Linnaeus); McLean, 1969, p. 89.

Occurrence: Many specimens were seen nestling within mussels atttached to buoys near Station 1.

PHYLUM ARTHROPODA

Class Crustacea

Subclass Cephalocarida

Cephalocarid, unidentified.

Occurrence: One specimen was collected from the intertidal mud flats near Hog Island. Repeated attempts to find this small crustacean at this locality and other localities have been unsuccessful. But specimens have been found in the stomachs of arrow gobies, Clevelandia ios, taken in the middle arm of Anaheim bay. This is the second report of a cephalocarid from the eastern Pacific Ocean; Jones (1961) reported Lightiella serendipita from San Francisco Bay.

Subclass Ostracoda

Ostracods, unidentified.

Occurrence: Several species of ostracods have been encountered both intertidally and subtidally throughout the bay; no attempt was made to identify these crustaceans.

Subclass Copepoda

Copepods, unidentified.

Occurrence: Calanoid copepods have been collected in plankton hauls and harpacticoid copepods are present in intertidal muds and in subtidal collections; no attempt was made to identify them.

Subclass Cirripedia

Family Balanidae

Balanus amphitrite Darwin; Reish, 1968b, p. 45.

Occurrence: Specimens were observed attached to buoys at Station 1, the old dock at Station 15, and on the rocks at Station 19.

Balanus crenatus Bruguiere; Cornwall, 1951, p. 329.

Occurrence: Present at the same stations as B. amphitrite.

Family Chthamalidae

Chthamalus fissus Darwin; Reish, 1968b, p. 46.

Occurrence: Present at the same stations as B. amphitrite.

Subclass Malacostraca

Order Cumacea

Oxyurostylis pacifica Zimmer; Zimmer, 1936, p. 437.

Occurrence: Station 18, intertidal; Station 1, subtidal.

Order Tanaidacea

Tanaids, unidentified.

Occurrence: Unidentified tanaids were present in intertidal samples taken at Station 18.

Order Isopoda

Family Sphaeromatidae

Paracerceis gilliana (Richardson); Schultz, 1969, p. 121.

Occurrence: Many specimens were observed within mussels attached to buoys at Station 1 and the old dock at Station 15.

Family Limnoriidae

Limnoria tripunctata Menzies; Menzies, 1951, p. 88.

Occurrence: Some specimens were seen within the wood of the old dock at Station 15. This is the only locality within the bay where permanent wood structures are present. Undoubtedly, driftwood containing gribbles floats into the bay from time to time.

Order Amphipoda

Family Ampithoidae

Ampithoe plumulosa Shoemaker; Barnard, 1969, p. 84.

Occurrence: Specimens were taken from mussel beds attached to buoys at Station 1.

Family Corophiidae

Corophium acherusicum Costa; Barnard, 1954, p. 36.

Occurrence: Widely distributed throughout the bay both intertidally and subtidally. It was particularly abundant from the inner reaches of each of the three channels and from the buoys at Station 1.

Family Caprellidae

Caprella equilibra Say; McCain, 1968, p. 25.

Occurrence: Most of the specimens were collected from buoys at Station 1; others were collected subtidally from Stations 1 and 19.

Order Decapoda

Family Callianassidae

Callianassa californiensis Dana; Schmitt, 1921, p. 116.

Occurrence: The bay ghost shrimp is one of the more conspicuous invertebrates present in Anaheim Bay. It is widely distributed throughout the bay both intertidally and subtidally.

Upogebia pugettensis (Dana); Schmitt, 1921, p. 114.

Occurrence: A few specimens were dug from intertidal mud flats near Station 1.

Family Grapsidae

Hemigrapsus oregonensis (Dana); Schmitt, 1921, p. 272.

Occurrence: The yellow shore crab is widely distributed and common throughout the bay. It burrows into the banks of the channels in the high tide horizon.

Family Pinnotheridae

Pinnixa franciscana Rathbun; Schmitt, 1921, p. 263.

Occurrence: While this species of sea crab was taken only in a subtidal collection at Station 16, undoubtedly it is more widely distributed since it lives in the burrows of the bay ghost shrimp, Calliansassa californiensis, and is often found in the stomachs of some fish.

PHYLUM ECTOPROCTA

Bugula neritina (Linnaeus); Osburn, 1950, p. 154.

Occurrence: Station 1, attached to buoy.

PHYLUM PHORONIDIA

Phoronis sp.

Occurrence: An unidentified species of Phoronis was taken intertidally at Station 17.

PHYLUM CHORDATA

Subphylum Urochordata

Styela plicata (Lesueur); Van Name, 1945, p. 295.

Occurrence: Specimens were attached to rocks at Station 19 where there is a strong tidal current.

6. ADDITIONAL INVERTEBRATES TAKEN FROM FISH STOMACHS IN ANAHEIM BAY

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The following invertebrates were not collected by Reish *et al* in their study, but were found in the stomachs of fish taken in the inner portion of Anaheim Bay. While the possibility exists that some of these invertebrates may have been carried into the bay in the stomachs of fish, this is unlikely since most of these food items were from non-migrating fishes. Food from migrating fish would digest quickly and thus anything in the stomachs of fish in the bay was probably eaten there.

Most of the invertebrates eaten by the fish are already listed in the preceding paper, Reish *et al;* the following includes only additional species. As many of these organisms were partially digested, it was often possible to identify them only to larger taxonomic groups. This list takes them as far as identification was possible and, where possible, follows Reish (1972).

PHYLUM PROTOZOA
Class Rhizopoda
Order Foraminifera
PHYLUM PORIFERA
Probably Haliclona and Leucosolenia.
PHYLUM COELENTERATA
Class Hydrozoa
PHYLUM ANNELIDA
Class Polychaeta
Family Onuphidae
Diopatra sp.
PHYLUM MOLLUSCA
Class Gastropoda
Order Archaeogastropoda
Family Trochidae
Tegula sp.
Family Littorinidae
Littorina sp.
Family Olividae
Olivella sp.
Order Tectibranchiata
Family Bullidae
Bulla sp.
Order Nudibranchiata
Class Pelecypoda

Order Teleodesmacea
Family Cardiidae
Laevicardium sp.
Family Mactridae
Schizothaerus nuttalli
Class Cephalopoda
Order Decapoda
Family Loliginidae
Loligo opalescens
Order Octopoda
Family Octopodidae
Octopus sp.
PHYLUM ARTHROPODA
Class Crustacea
Subclass Copepoda
Order Calanoida
Family Calanidae
Calanus sp.
Family Acartiidae
Acartia tonsa
Order Cyclopoda
Clausidium vancouverense
Subclass Malacostraca
Order Mysidacea
Order Isopoda
Suborder Oniscoidea
Family Ligiidae
Ligia sp.
Order Amphipoda
Suborder Gammaridea
Family Gammaridae
Elasmopus raparx
Family Hyalidae
Allorchestes sp.
Hyale plumulosa
Hyale rubra
Hyale sp.
Family Oedicerotidae
Monoculodes sp.
Family Liljeborgiidae
Listrella sp.

Family Aoridae
Amphidentopis sp.
Suborder Caprellidae
Family Caprellidae
Caprella californica
Order Decapoda
Suborder Natantia
Family Crangonidae
Crangon californiensis
Family Alphidae
Alpheus sp.
Suborder Reptantia
Section Anomura
Family Paguridae
Holopagurus pilosus
Section Brachyura
Family Cancridae
Cancer gracilis
Cancer antennarius
Family Grapsidae
Pachygrapsus crassipes
Class Pycnogonidae
PHYLUM ECTOPROCTA
PHYLUM CHORDATA
Subphylum Urochordata
Class Ascidiacea
Order Aplousobranchea
Amaroucium californica
Order Stolidobranchia
Styela plicata
Eugyra arenosa

As well as the preceding "marine invertebrates" a moderate number of insects live in the marsh and are eaten by fish. The insect fauna of the Anaheim Bay salt marsh is presently being studied in E. Sleeper's laboratory at California State University, Long Beach.

7. A QUANTITATIVE STUDY OF THE BENTHIC POLYCHAETOUS ANNELIDS OF ANAHEIM BAY AND HUNTINGTON HARBOUR, CALIFORNIA

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7.1. INTRODUCTION

The initial quantitative benthic invertebrate surveys on the Pacific Coast were made in San Francisco Bay (Packard, 1918). Subsequent studies of the Pacific Coast have been summarized by Reish (1963b) and Reish and Barnard (1967). Most of the bays and harbors of southern California that have been altered by man were surveyed for benthic invertebrates during the 1952–1963 period. These included Los Angeles-Long Beach Harbors (California Dept. Water Resources, 1952a; Reish, 1959, 1971), Alamitos Bay (Reish, 1963a), the mouth of the San Gabriel River (Turner and Strachan, 1969), Newport Bay (Barnard and Reish, 1959) and San Diego Bay (California Dept. Water Resources, 1952b). However, many protected waters of southern California have yet to be studied for benthic invertebrates.

The present study involves two areas, one of which is primarily unaltered (Anaheim Bay). The other has undergone extensive changes during construction of a private home-marina complex (Huntington Harbour*). The two main objectives of this study were to catalogue quantitatively the subtidal polychaetous annelids in these areas and to determine what, if any, changes in the polychaete fauna resulted from the dredging and construction of Huntington Harbour. Only the benthic polychaetes were identified in this study since they comprise well over half of the microscopic animals in and on the bottom (Reish, 1961a) and thus give a good indication of benthic conditions (Day, 1963). Polychaetes also have been used as indicators of environmental conditions, especially pollution (Reish, 1955; Wass, 1967).

7.2. MATERIALS AND METHODS

In the early 1960's the southern reaches of Anaheim Bay underwent extensive dredge-and-fill operations in order to construct a residential-recreational marina complex which became known as Huntington Harbour. Channels were dredged to a depth of 3.1 to 3.9 m (10.2 to 12.8 feet) and were lined with vertical concrete walls. Virtually all natural intertidal mudflats and vegetation were eliminated. In sharp contrast to Huntington Harbour, Anaheim Bay remains essentially a natural salt marsh.

7.2.1. Station Locations

Stations were selected in advance to represent major portions of the area (Figure 20). Stations 1 and 2 lie within Anaheim Bay, but were dredged during the construction of Huntington Harbour. Stations 3 to 10 lie within the dredged

* The developers of Huntington Harbour chose to use the British spelling of "harbour" for this marina. Elsewhere, the American spelling "harbor" is used.

TABLE 4

Number of Species and Specimens of Polychaetes Collected from Anaheim Bay

Species	Stations 1		2		11		12		13	
	7-70	1-71	7-70	1-71	7-70	1-71	7-70	1-71	7-70	1-71
Halosydna brevisetosa	2	4								
Harmothoe sp.	3									
polynoid fragment				1						
Paleonotus bellis		4								
Anaitides williamsi	5	5								
Eteone pacifica	2									
Eteone sp.										
Eumida sanguinea	3			1		2				
phyllodocids, unidentified		13								
Ophiodromus pugettensis	9	12								
Exogone lourei	17	42	5	1	4	2				
Sphaerosyllis pirifera	3									
Syllis gracilis	1									
Typosyllis fasciata	3									
Neanthes arenaceodentata										
Neanthes succinea										
Nereis procera					4					
Platynereis bicanaliculata		1								
Nephtys caecoides						4				
Nephtys c. franciscana			2			8				
Glycinde sp.						2				
Goniada littorea			3							
Lumbrineris erecta	5	1								
Lumbrineris minima	1		5	3	16	8				
Stauronereis rudolphi	2	4	5	3	12	2				
Haploscoloplos elongatus		1	18	6	4	30				
Nainereis dendritica		1						4		
Boccardia uncata							2			
Nerinides acuta					8	6			8	
Nerinides maculata							1			
Nerinides pigmentata						2				
Polydora brachycephala										
Polydora ligni		3								
Polydora limicola		1	30							
Prionospio cirrifera	6	16		2	44	60	3		42	87
Prionospio h. newportensis	3		4		4					
Prionospio pinnata					4					
Prionospio pygmaeus			4		4	6				
Pseudopolydora kempi							3			
Rhynchospio arenincola			10		40		1			
Spiophanes missionensis					4	6			2	
Streblospio benedicti		1			56	92	68	16	170	44
Telepsavus costarum										
Chaetozone corona										
Chaetozone multioculata		2								
Cirriformia luxuriosa	19	3						4		
Tharyx parvus	2		1			2				
Cossura candida			6	2		68			2	
Armandia bioculata	8	183	11	96		90				
Polyophthalmus pictus	1									
Capitella capitata		1					96	12		
Capitita ambiseta	2	1	180	60	376	572			28	14
capitellid fragment		1								
Notomastus sp.					4					
Axiothella rubrocincta	1	4								
Nichomache personata	1									
maldanid fragment	1									
Owenia collaris										
Sabellaria gracilis	1									
sabellariid fragment	1									
Amphicteis glabra						2				
Amaeana occidentalis										
Pista alata	1									
Thelepus setosus	6									
Chone sp.		2	1							
Euchone limnicola										
Megalomma pigmentum	1									
Number of species	28	23	15	10	15	19	7	4	6	3
Number of specimens	110	306	285	175	584	964	174	36	252	145

TABLE 4

Number of Species and Specimens of Polychaetes Collected from Anaheim Bay

TABLE 4

Number of Species and Specimens of Polychaetes Collected from Anaheim Bay

Stations																
14		15		16		17		18		19		20		21		
7-70	1-71	7-70	1-71	7-70	1-71	7-70	1-71	7-70	1-71	7-70	1-71	7-70	1-71	7-70	1-71	Totals
																6
																3
										1						2
																4
											4					14
																2
								2								2
	1		1													8
																13
2											4					27
	2	4						4								81
																3
																1
																3
		20		4				2		1		1		6		34
															4	4
																4
																1
	2												8			14
1	10		3								8		28			60
																2
25	13							2		4		1				48
																6
4	3		8					2			4					54
																28
4	15		6					2	3	5	8	2	4			108
																5
																2
2	2	24	1	12				10			8	1		9		91
																1
																2
	2															2
																3
																31
6	31	40	22		72			40	18	24	40		24	32	4	613
	1															12
1																5
4	2		1					2	3		4		8			38
														8		11
11	1	132		8				90		30	8	26	12	1		370
	7		2		16						12					49
21	64	72	9	112	96		30	164	9	6	180	26	128	147	100	1611
1																1
											4					4
																2
				28	128	72	850									1104
6	11	12	27					14	9		4					88
114	91	260	101	12		12	10	424	663	12	404	111	198	556	240	3286
4	53		2		24		30		12		20		48	1	4	586
																1
		4		4	16	40	20	14	3				4	6	12	232
46	149	72	65		120			18	15	1	184	68	96	194	216	2477
																1
																4
																5
																1
																1
		4														4
																1
																1
																2
	2															2
	1															2
																6
																3
	3		2						3				4			12
	2							14				2				19
16	23	11	14	7	7	3	5	16	10	9	16	9	12	10	7	-------
252	468	644	250	180	472	124	940	804	738	84	896	238	562	960	580	11223

TABLE 4

Number of Species and Specimens of Polychaetes Collected from Anaheim Bay

TABLE 5

Number of Species and Specimens of Polychaetes Collected from Huntington Harbour

Species	Stations 3		4		5		6		7		8		9		10		Totals
	7-70	1-71	7-70	1-71	7-70	1-71	7-70	1-71	7-70	1-71	7-70	1-71	7-70	1-71	7-70	1-71	
Halosydna brevisetosa				1													1
Harmothoe lunulata			3														3
Eteone dilatae				1				1									2
Eteone sp.															1		1
Eumida sanguinea		1		1		2											4
Ophiodromus pugettensis			3	6		1		1					1			1	13
Exogone lourei									2								2
Neanthes arenaceodentata									2		1						3
Neanthes succinea													1	4			5
Nephtys caecoides														1		1	2
Nephtys c. franciscana		7	7	10	1												25
Goniada littorea		1															1
eunicid fragment									2								2
Lumbrineris erecta							5		6		4	8	1	5			29
Lumbrineris minima	7	3	11	16	8	7	35	20	7	20	3		5	3	38	10	193
Stauronereis rudolphi	2	1	4	33	1	1		2	8	56	1	2	5	1	2		119
Haploscoloplos elongatus	1	26	38	28	10	9	13	12	49	40	12	5	48	12	16	4	323
Nerinides acuta	2		3	3				1	4	2	6	3	4	8		1	37
Nerinides pigmentata			1														1
Polydora ligni									10	4	2		30	20		5	71
Prionospio cirrifera	5	12	10	8		1		17	55	196	3	4		8		2	321
Prionospio h. newportensis	1		3					3									7
Prionospio pygmaeus											1						1
Prionospio malmgreni		1		4					1								6
Pseudopolydora kempi	2					1		1	2		2		14				22
Rhynchospio arenincola	2		1											2		1	6
Spiophanes missionensis			2					1									3
Streblospio benedicti		1	2	19				1	130	12	42	6	117	17			347
Tharyx parvus	1		26	77	1			3			1		3	6			118
Cossura candida	1	18	27	28	3	3		14	7	20				3		1	125
Armandia bioculata		95		27				10		10		2		12			156
Capitella capitata									4	2	1						7
Capitita ambiseta	2	94	120	168	5	12		39	3			2	2	11		2	460

TABLE 5

Number of Species and Specimens of Polychaetes Collected from Huntington Harbour

capitellid fragment	1	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	1
maldanid fragment	......	......	......	1	......	......	......	......	......	......	......	......	......	......	......	......	1
Amphicteis glabra	......	......	2	9	......	......	......	......	......	......	......	......	......	......	......	......	11
Amaeana occidentalis	1	......	......	2	......	......	......	1	......	......	......	......	......	......	......	......	4
Pista alata	1	......	......	7	......	2	......	3	5	......	......	......	2	2	8	5	35
Pista brevibranchiata	......	......	2	......	......	......	......	......	......	......	......	......	......	......	......	......	2
Euchone limnicola	5	1	8	19	4	8	62	11	3	2	......	......	10	2	8	9	152
Megalomma pigmentum	......	......	3	3	......	1	6	1	2	......	......	......	2	......	......	......	18
sabellid fragment	4	......	1	......	......	......	......	......	......	......	......	......	......	......	1	......	6
Number of species	16	13	21	22	8	12	5	19	19	11	13	8	15	17	7	12	......
Number of specimens	38	261	277	471	33	48	121	142	302	364	79	32	245	117	74	42	2646

TABLE 5—Cont'd.

channels of Huntington Habour while Stations 11 to 21 were located within the natural tidal channels of Anaheim Bay.

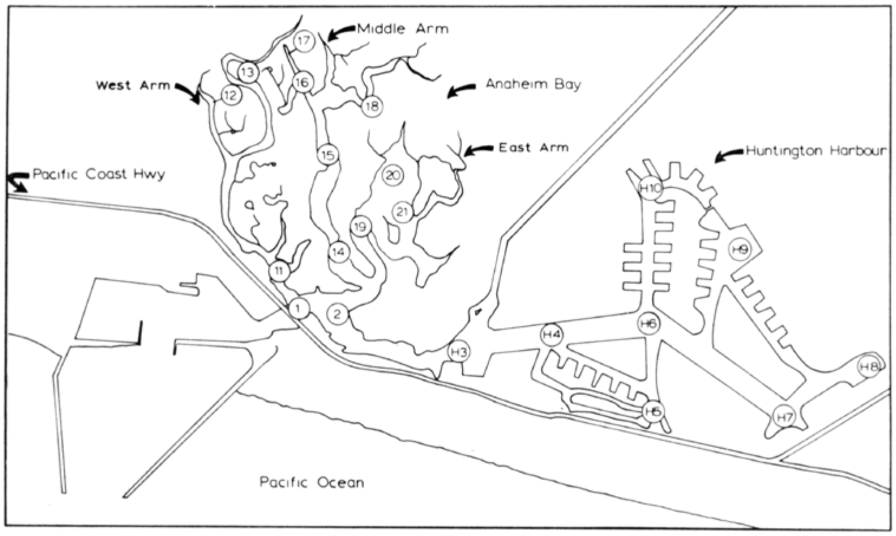

TABLE 5—Cont'd.

7.2.2. Sampling Procedures

Collections were made at each of the 21 stations on July 30 and 31, 1970, and January 28 and 29, 1971. All samples were taken in midchannel from a skiff with a size one Hayward orange-peel bucket provided with a skirt. Samples were placed in 1 gallon jars and preserved with formalin. In the laboratory the volume of each sample was noted, and the samples were washed through a Tyler screen with 0.7 mm (0.03 inches) openings. The material retained on the screen was saved for later sorting, identification, and counting. Systematic treatment of polychaetes followed Hartman (1968, 1969) except as noted.

7.3. RESULTS

The 42 samples analyzed yielded 13,853 individual polychaetes, representing 24 families and 69 species (Tables 4 and 5). However, in the following comparisons between Anaheim Bay and Huntington Harbour, all data from Stations 1 and 2 were excluded since it was felt these stations were not representative of either. When data from Stations 1 and 2 were excluded, the total number of individuals considered is reduced to 12,922, representing 21 families and 52 species. of these 52 species, 32 were found at least once in both areas; 8 additional species were found only in Huntington Harbour for a total of 40, and 12 were found only in Anaheim Bay for a total of 44. of the 52 species identified, 19 (or 37%) were relatively rare: five or fewer specimens were found at just one station and on only one occasion.

Collections from the eight stations located in the dredged channels of Huntington Harbour contained more species per station (13 in July; 14 in January) than did the 11 stations in the natural channels of Anaheim Bay (10 in July; 11 in January). Nevertheless, there were almost three times as many individuals per station in Anaheim Bay (391 in July; 550 in January) as in Huntington Harbour (146 in July; 184 in January). When these figures are combined to give a figure of number of individuals per species per station, the differences in numbers of animals present become even more striking; 45 in Anaheim Bay and 12 in Huntington Harbour.

7.3.1. Polychaete Assemblages

In order to compare the benthos of Anaheim Bay with that of Huntington Harbour, a major polychaete assemblage was described for each area. When a given species comprised 10% or more of the specimens of polychaetes in a sample, it was considered a "major species" at that station. Theoretically there could be 10 major species at each station, but there were seldom more than three.

Before a species was considered a major species over an entire area, three additional aspects were considered:

1) At what percent of the stations in an area was that species a major species?
2) What percent of all polychaetes in the area did the species comprise?
3) Was the species' abundance about the same in both July and January collections?

On the basis of these factors, species were ranked separately for each area in order of decreasing importance (Table 6).

TABLE 6

Major Polychaete Assemblages Described in Anaheim Bay and Huntington Harbour

	No. Stations Present	No. Stations Major	No. of Specimens
Anaheim Bay			
Primary major species*			
Cossura candida	17 of 22	13	3278
Streblospio benedicti	22	16	1645
Capitita ambiseta	17	14	1431
Secondary major species**			
Prionospio cirrifera	17	4	589
Armandia bioculata	10	2	288
Rhynchospio arenincola	12	2	360
Capitella capitata	12	4	231
Cirriformia luxuriosa	5	4	1082
Huntington Harbour			
Primary major species*			
Capitita ambiseta	12 of 16	5	460
Haploscoloplos elongatus	16	13	323
Secondary major species**			
Lumbrineris minima	15	8	196
Prionospio cirrifera	12	4	321
Streblospio benedicti	10	8	317
Euchone limicola	14	6	152
Cossura candida	11	4	125
Armandia bioculata	6	1	156

* Primary major species were those which comprised a major portion of the collection (at least 13%) and appeared in at least 75% of the samples.
** Secondary major species were those which were moderately abundant (at least 5%) and appeared in a substantial portion of the samples.

TABLE 6

Major Polychaete Assemblages Described in Anaheim Bay and Huntington Harbour

7.3.1.1. Anaheim Bay

The benthos of the natural channels in Anaheim Bay had three major species of polychaetes (Table 6): Cossura candida, Streblospio benedicti, and Capitita ambiseta; 7,109 specimens of these species were taken, some 70% of all worms from the marsh. Each of the three was found in at least 17 of the 22 samples examined, and each comprised 10% or more of the individuals in at least 13 samples. They were considered a primary major species.

On the basis of total numbers, Cossura candida was the most common species in the marsh; 3,278 individuals were taken, 1,503 in July and 1,775 in January, which accounted for almost one-third of all polychaetes from the area. Streblospio benedicti was present in 21 of the 22 samples and was a major species in 16 of them; in all 1,645 specimens (803 in July, 842 in January) or 16% were collected. Capitita ambiseta was found in 17 of the 22 samples and made up more than 10% in 14 of them. In July 808 specimens were counted and 1,431 in January, accounting for 22% of all polychaetes collected in Anaheim Bay.

Five additional species appeared in moderate numbers. These species were: Prionospio cirrifera, Capitella capitata, Cirriformia luxuriosa, Rhynchospio arenicola, and Armandia bioculata (Table 6).

7.3.1.2. Huntington Harbour

In the dredged channels of Huntington Harbour two polychaete species Capitita ambiseta and Haploscoloplos elongatus, were considered primary major species (Table 6). Six additional species were called secondary major species, but in contrast to the situation in Anaheim Bay, the line between primary and secondary major species was difficult to draw. Altogether 460 specimens were collected (132 at five of the eight stations in July and 328 at seven stations in January), and these represented 18% of all polychaetes from the area. However, Capitita comprised more than 10% of the sample at only two stations in July and three in January. Only 187 specimens of Haploscoloplos elongatus were collected in July and 136 in January, or 13% of the total. These specimens were evenly dispersed. Haploscoloplos was found in all stations in both collections; it was a major species at seven stations in July and six in January.

The six secondary major species all displayed a balance among the factors used to define major species; percent of all polychaetes collected, number of stations at which a species predominated, and similarity of summer and winter distribution. These species included: Lumbrineris minima, Prionospio cirrifera, Streblospio benedicti, Euchone limnicola, Cossura candida, and Armandia bioculata (Table 6).

7.3.2. Relative Abundances of Prevalent Polychaetes

Another means was employed to elicit differences between polychaete faunas of Anaheim Bay and Huntington Harbour. In this method, the 14 species which comprised 1% or more of the total collection were considered. The abundance of each was computed by dividing the number of individuals of each of those species in an area by the number of stations in that same area. This procedure accounts for the fact that there were more stations in the bay than in the harbour, but it also assumes an even distribution. The method was applied separately to the summer and winter collections, but since the results were very similar, they were combined (Table 7). Absolute abundances were eliminated and the column labelled "factor" indicates how many times as abundant a species was in one area than in the other.

Eleven of the 14 species considered showed at least a twofold difference in abundance between the two areas. of the three which did not, Armandia bioculata was seasonal. The other two, Tharyx parvus and Nerinides acuta, were the least abundant of the 14 species. It is interesting, then, that virtually all of the prevalent species were distinctly more abundant in either Anaheim Bay or Huntington Harbour. This fact probably reflects actual differences in the bottom environments and the worms' various tolerances to environmental differences.

7.3.3. Individual Species

Several species had unusual abundance or distribution patterns which may reflect differences in biological or environmental conditions.

Seventeen species were found only at Station 1. Presumably their occurrence at Station 1 is related to its greater depth, or some other parameter such as substrate, water movement, or temperature, which are determined, in part, by depth.

Several species were restricted more or less to the dredged channels of Huntington Harbour. Neither Polydora ligni nor Lumbrineris erecta was abundant, but both were found exclusively in Huntington Harbour. Euchone limnicola was found in both study areas but was 10 times as abundant in Huntington Harbour as in Anaheim Bay. Interestingly, this sabellid was found by Reish (1963a) only after dredging operations in nearby Alamitos Bay. Stauronereis rudolphi, Ophiodromus pugettensis, Pista alata, and Prionospio heterobranchia newportensis occurred in moderate numbers, but only at stations that were at least 2.7 m (8.8 feet) deep. They were therefore more abundant in Huntington Harbour and were never found at the inner stations of Anaheim Bay.

Five species of the family Spionidae were more abundant in Anaheim Bay than in Huntington Harbour. Among the more prevalent species (Table 7), Streblospio benedicti and Prionospio cirrifera were four times and two times more abundant, respectively, in the shallow, natural channels. Relatively few specimens of Prionospio pygmaeus, Spiophanes missionensis, and Rhynchospio arenincola were collected; however, over 90% of the individuals of each species were from stations in Anaheim Bay. Unlike the other spionids, Rhynchospio arenincola has not been reported from any of southern California's modified bays. If it is restricted to very natural conditions, it may well be saved from extinction by the presence of Wildlife Refuges in this and possibly other areas. Rhynchospio arenincola was also seasonal; in July a total of 340 specimens was collected at 10 of the 11 stations in the marsh, and it was a major species at four of these stations. In January Rhynchospio appeared at only three stations; 21 specimens were counted, and it was never a major species.

Armandia bioculata was slightly more abundant in the marsh and assumed more importance in winter than in summer. In July a total of 24 individuals was

TABLE 7

Relative Abundances * of the Fourteen Most Common Polychaetes of Anaheim Bay and Huntington Harbour

Species which were more abundant in Anaheim Bay than in Huntington Harbour	Factor**
Cirriformia luxuriosa	infinite
Rhynchospio arenincola	40.0 ×
Cossura candida	20.0 ×
Capitella capitata	5.0 ×
Streblospio benedicti	4.0 ×
Capitita ambiseta	3.0 ×
Prionospio cirrifera	2.0 ×
Armandia bioculata	1.5 ×
Nerinides acuta	1.5 ×
Species which were more abundant in Huntington Harbour than in Anaheim Bay	
Euchone limnicola	10.0 ×
Haploscoloplos elongatus	4.0 ×
Lumbrineris minima	2.0 ×
Stauronereis rudolphi	2.0 ×
Tharyx parvus	1.5 ×

* Abundance = Number of individuals of a species in an area divided by the number of stations in the area.
** Factor = Number of times a species is more abundant in one area than in the other. Areas are Anaheim Bay and Huntington Harbour.

TABLE 7

Relative Abundances of the Fourteen Most Common Polychaetes of Anaheim Bay and Huntington Harbour

found at all stations sampled. In January, 718 specimens were found in 17 of the 21 samples.

Most of the specimens of Cirriformia luxuriosa were found at Stations 16 and 17. The substrate was unique at these stations, consisting of fine sand and mud interspersed with cobble.

7.4. DISCUSSION

One of the primary purposes of this study was to document any changes in the polychaete fauna following dredging activity in comparison to a nearby undisturbed area. Since changes were observed, some speculations as to their causes will be discussed.

It should be noted that the study was conducted at least 5 years after the major dredging of Huntington Harbour was completed. Furthermore, all the prevalent species reproduce either throughout the year or have extended reproductive periods (Reish, 1961b). Presumably there has been sufficient time for species to become established in Huntington Harbour. It is therefore assumed that the assemblage described herein is relatively stable. This assumption is substantiated by work in nearby Alamitos Bay by Reish (1961a) who found that community stability there was reached 2 to 3 years after dredging. It is reasonable to suppose that the changes observed in the present study resulted from an actual change of habitat, not merely the disruption of one.

One effect of the dredging operation was the elimination of intertidal mudflats and natural marsh vegetation. It is possible that these environments play some role in establishing and/or maintaining the natural subtidal polychaete assemblage. It is also possible that the changes observed were effected by the deepening of the channels which changed the physical and chemical parameters.

Conditions of dissolved oxygen, salinity, and temperature in dredged channels more closely resemble those in the parent water mass than they do in undredged channels. The above parameters were measured at the time of the January collection and differences between Anaheim Bay and Huntington Harbour were detected. However, the measurements were not comprehensive and may not represent persistent conditions. At the time of measurement, salinity in Anaheim Bay was somewhat higher (mean = 33.8[o/oo]) than in Huntington Harbour (mean = 33.2[o/oo]). One might expect this as a result of evaporation effects in the shallow channels; however, temperatures in the marsh were somewhat lower (mean = 12.2 C, 53.9 F) than in the harbour (mean = 13.9 C, 57.0 F). In any event, it is generally true that both salinity and temperature fluctuate more widely in shallow water than in deep water.

It can be hypothesized that the combination of fluctuating environmental conditions may serve to exclude certain species from specific areas in Anaheim Bay. Stations in the marsh averaged fewer species per sample than those in the harbor, although a higher total number of species was found in the marsh. Conversely, Huntington Harbour with more stable conditions would be tolerable to more species per area so that inter and intraspecific competition might reduce the numbers of each. Huntington Harbour stations had about one-third the number of individuals per species as those in Anaheim Bay.

The nature of the substrate is of major importance in determining which animals settle and thrive on a particular bottom (Sanders, 1958; Nichols, 1970). Sediments in Huntington Harbour were less variable in particle size than those in Anaheim Bay. In screening the samples it was observed that those from

TABLE 8

Common Subtidal Polychaetes of Southern California's Embayments With Their Relative Abundances *

Species	L.A.-L.B. Harbors	San Gabriel River	Lower Newport Harbor	Upper Newport Harbor	Alamitos Bay (1954)	Alamitos Bay (1956)	Alamitos Bay (1959–62)	Catalina Harbor	Anaheim Bay	Huntington Harbour
Capitita ambiseta	P	I	M	P	M	M	M	P	M	M
Lumbrineris minima	P	--	M	I	I	M	I	M	P	I
Haploscoloplos elongatus	P	--	M	I	P	I	I	I	P	M
Capitella capitata	M	M	M	P	M	P	--	--	P	P
Cossura candida	M	--	M	P	I	P	P	--	M	I
Stauronereis rudolphi	I	--	M	P	P	M	I	P	P	I
Tharyx spp.	M	--	I	P	M	P	P	I	P	I
Prionospio cirrifera	P	P	I	P	--	P	I	P	M	M
Prionospio h. newportensis	P	--	I	I	I	P	P	M	P	P
Armandia bioculata	P	--	I	I	P	P	P	--	I	I
Streblospio benedicti	--	--	P	P	M	P	--	--	M	M
Polydora spp.	P	I	P	P	I	--	P	P	--	P
Cirriformia luxuriosa	I	--	--	--	P	P	--	--	I	--
Euchone limnicola	--	--	--	--	--	--	M	--	P	I
Nerinides acuta	--	--	P	P	P	P	--	--	P	P
Neanthes succinea	--	P	--	--	I	--	--	--	P	P

* Data are from various papers by Reish. Species are arranged in approximate order of decreasing importance; M = major, I = important, and P = present.

TABLE 8

Common Subtidal Polychaetes of Southern California's Embayments With Their Relative Abundances

dredged channels had several times as much particulate organic debris as those from natural channels. The large pieces (up to 2 cm, 0.79 inches long) appeared to be vascular, possibly Spartina sp. and Salicornia sp. from the salt marsh. This material might wash out of the marsh and become trapped in the deeper, dredged channels of Huntington Harbour.

Thus on the basis of observed substrate differences we can suppose that the nature of the sediments played some role in producing the faunal differences occurring between Anaheim Bay and Huntington Harbour.

7.4.1. Comparison With Other Studies

The biological results of the present study were compared with the results of surveys of several other local embayments (Barnard and Reish, 1959; Reish, 1956, 1959, 1961a, 1963a, 1964; Reish and Winter, 1954). The most remarkable feature of the comparison was the repeated appearance of a limited number of species in positions of importance. Thirteen commonly encountered species (and two genera) were so prevalent that one could probably describe the benthos of any southern California area embayment as being characterized by several or all of them (Table 8). One species, Capitita ambiseta, was found in all studies and usually in substantial numbers. It is probably the single most common polychaete in southern California's subtidal, inshore waters.

The total numbers of species reported as present in each of the four major areas are: Los Angeles-Long Beach Harbor, 69; Newport Harbor, 61; Alamitos Bay, 70; Anaheim Bay-Huntington Harbour, 69. These figures suggest that polychaete diversity is about equal in the four areas. However, the number of species found in a study area depends to a large extent on the number of stations and the number of visits to each station. These factors were not constant in the four study areas. It is apparent, though, that none of the areas is greatly different in terms of the number of polychaete species present.

7.5. SUMMARY

A total of 13,853 individual polychaetes, representing 69 species and 24 families, was analyzed. Thirty-two species were found commonly in both study areas; eight additional species were found only in Huntington Harbour and 12 more only in Anaheim Bay. A total of 17 species was limited to the dredged channel within Anaheim Bay.

Samples from the dredged channels averaged more species (13.5) per sample than those from natural channels (10.5). Conversely, Anaheim Bay had almost three times as many individuals per station as Huntington Harbour—470 versus 165.

A major polychaete assemblage was described in each of the study areas. Anaheim Bay was characterized strongly by Cossura candida, Streblospio benedicti, Capitita ambiseta, and five secondary major species. Huntington Harbour was weakly characterized by Capitita ambiseta, Haploscoloplos elongatus, and six secondary major species.

A comparison of the relative abundances of the prevalent species was made. Virtually all the prevalent species were distinctly more abundant in one area or the other.

8. PARASITIC CRUSTACEA

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This is a preliminary report on some crustaceans parasitic on the fishes in Anaheim Bay. The parasites were brought to my attention by E. David Lane, Peter L. Haaker, Robert Tasto, and Richard Sandell in their course of life history studies of the host fishes. No further systematic survey of parasitic crustaceans in the bay was attempted.

Five copepod species and two isopod species were recovered from four host species. Considering the number of host species occurring in the bay, this record of seven species represents only a small fraction of the vast assemblage of parasitic Crustacea yet to be found. These seven parasitic species constitute new records of both host and locality, and two of the crustaceans are new to science.

This report deals with a general account of both copepods and isopods. A taxonomical treatment of some copepods has been given elsewhere (Ho, 1972), and that of the isopods is in preparation.

8.1. COPEPODA

Order Cyclopoida

Family Chondracanthidae

Acanthochondria soleae? (Krøyer)

Host: California halibut, Paralichthys californicus (Ayres)

Only one female was found attached to the urohyoid. The parasite was recovered in very bad condition, being pressed and preserved between the hyoid and the wall of the mouth. Although positive identification of the specimen is impossible due to the scarcity and the injury of the specimen, it seems closer to A. soleae than to any other species of the genus. The combination of the elongated caudal process and the long modified leg 2 in this specimen is very reminiscent of A. soleae.

A. soleae is only known to occur on the European flat fishes. However, its occurrence on eastern Pacific flat fishes seems not improbable, for a closely related European species, A. cornuta (Müller), has been reported from flat fishes occurring on both the east and west coasts of North America (Ho, 1970).

A. soleae is a rather large and greatly transformed copepod about 6 mm (0.24 inches) in length. The female attaches to the host by means of the modified, hook-like second antennae. The male is typically dwarf (usually less than a millimeter) and attached to the specialized "vermiform process" on the genital segment of the female. Both female and male are so modified that they completely lose the ability of locomotion. Although the life history of this parasite is unknown, it appears that during their early larval stages they infect the host fish. After securing a particular site in the gill cavity, they undergo a gradual but intensive transformation. The male attaches to the female as early as the first copepodid stage. The mature female produces two long egg sacs containing hundreds of eggs. The hatched nauplii are carried away in the respiratory current of the host.

Family Bomolochidae

Holobomolochus prolixus (Cressey)

Hosts: California halibut, Paralichthys californicus (Ayres) Pacific staghorn sculpin, Leptocottus armatus Girard

This is a small copepod about 1.5 mm (0.06 inches). Although it is less transformed than Acanthochondria soleae and capable of moving around on the host, it never has been found outside the gill cavity.

Only the female is parasitic. The male is rare and found on the fish only at the time it is in amplexus with the female. To date this is the most abundant parasitic crustacean found in the bay.

The entire cephalothorax of the female is modified into a cup-like structure. The appendages on the cephalothorax also are modified to reinforce this suctorial device for fastening to the host. However, there is no such adaptive modification seen in the male. The male, about 0.7 mm (0.03 inches) in length, holds the female by means of paired claw-like maxillipeds.

This parasite was first reported by Cressey (1969) from a C-O turbot, Pleuronichthys coenosus Girard, collected at La Jolla, California. The present record is the second reporting and is the first report of a male.

Family Taeniacanthidae

Taeniacanthodes haakeri Ho

Host: California halibut, Paralichthys californicus (Ayres)

The size of this species is about the same as that of Holobomolochus prolixus. The same adaptive modification of the cephalothorax for attaching to the host is displayed by the female. While H. prolixus was found exclusively in the gill cavity, this species was recovered only from the dorsal or anal fins, but never from the pectoral, pelvic, or caudal. From 11 California halibut, 24 ovigerous females and 21 copepodid larvae were recovered from the membrane between the fin rays.

Only two species are known in this genus (Ho, 1969, 1972). The other species, Taeniacanthodes gracilis Wilson, is parasitic on the broad flounder, Paralichthys squamilentus Jordan and Gilbert, and, the bay whiff, Citharichthys spilopterus Günther, in the Gulf of Mexico.

Order Caligoida

Family Caligidae

Lepeophtheirus bifidus Fraser

Hosts: Diamond turbot, Hypsopsetta guttulata (Girard) California halibut, Paralichthys californicus (Ayres)

This is one of the most active species of parasitic copepods present on fish. When a fish directly out of the water is examined for parasites, one can see them scuttling on the host's body surface. Although they can move freely on the body surfaces, they rarely wander into the gill cavity or the oral cavity. Both sexes are parasitic and the female (4 mm, 0.16 inches long) is always larger than the male (2.5 mm, 0.10 inches).

The cephalothorax of both male and female is modified to act as a suction cup in attaching to the host, but at mating the male holds the female with claw-like maxilliped.

This species is known from only one record reported by Fraser (1920) on rock sole, Lepidopsetta bilineata (Ayres), from Vancouver Island, British Columbia.

Family Pandaridae

Achtheinus oblongus Wilson

Hosts: Shovelnose guitarfish, Rhinobatos productus (Ayres) Gray smoothhound, Mustelus californicus Gill

Fourteen females (6.79 mm, 0.27 inches) and two males (4.34 mm, 0.17 inches) were found attached to the host by paired hook-like second antennae driven into the host flesh. This parasite has been recorded from seven species of sharks occurring on the west coast of North America ranging from San Francisco Bay to Baja California. However, this is the first record from a shovelnose guitarfish.

Cressey (1967) has grouped all ten species described in the genus Achtheinus as one species and called it "Perissopus oblongatus (Wilson)". While synonymization of species is highly desirable, it seems to me that the generic status ought to be retained. The justifications for resurrecting the genus Achtheinus are (i) the dorsal plates of the second pedigerous segment are much smaller than the succeeding two pairs and concealed underneath the cephalothorax (exposed and larger than the immediately following plates in Perissopus) , (ii) the third pair of legs have two-segmented rami (one-segmented in Perissopus) , and (iii) the caudal rami are large and well developed (rudimentary in Perissopus) .

8.2. ISOPODA

Suborder Flabellifera

Family Cymothidae

Braga sp.

Host: Diamond turbot, H. guttulata (Girard)

Only one female was recovered from the gill cavity. It is a new species. I am aware of only one species of the genus Braga which is known to occur on the west coast of North America, i.e. B. occidentalis (Boone). It was reported from the coast of California as a free living form (Boone, 1918). The present species differs from B. occidentalis chiefly by its longer body, a larger and round cephalon, an acuminate telson, and a pair of uropods extending beyond the tip of the telson. Lironeca vulgaris (Stimpson)

Host: California halibut, Paralichthys californicus (Ayres)

This is a fairly common species of isopod found in the gill cavity of several species of rockfish, surfperch, and flounder on the west coast of North America ranging from Washington to Baja California. This species can be readily distinguished from another common species of the west coast, Lironeca californica (Schioedte and Meinert), by its ovate body and broad telson (nearly two times as broad as long).

It is worthy of mention here that several specimens of the parasitic copepod, Clausidium vancouverense (Hadden), were found free in the stomach of a Pacific staghorn sculpin, Leptocottus armatus Girard. The copepod parasite is known to be parasitic in the branchial cavity of the bay ghost shrimp, Callianassa californiensis Dana, from Newport Beach, California (Wilson, 1935). A subsequent collection of bay ghost shrimp made by Peter L. Haaker at Anaheim Bay was found to be heavily parasitized by C. vancouverense. In one instance, as many as 38 copepods were obtained from a single host. Therefore, it is conceivable that the copepod parasites were ingested by fish together with their host shrimp.

9. INVERTEBRATES, ESPECIALLY BENTHIC ANNELIDS IN OUTER ANAHEIM BAY

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During 1972 a survey of benthic polychaetes was conducted in the outer reaches of Anaheim Bay (Figure 21) in connection with a graduate course in polychaete systematics. Each student was required to sort, count, and identify the polychaetes present in one shipek grab taken in May 1973. All specimens were examined, verified, or corrected by the author. The students were John Dorsey, Kevin Herbinson, James Martin, Fred Piltz, Glenn Reilly, Mark Rossi, Stephen Rossi, Richard Rowe, John Shisko, Sue Williams, and Jack Word.

Additional species of invertebrates previously unknown from Anaheim Bay are noted below in the systematic list. The known 152 invertebrate species in the bay consist of 107 polychaetes, or 71%; crustaceans 18, or 12%; and molluscs 17, or 11%. This number will perhaps double if and when such environments as the rocky jetty are studied.

The subtidal benthos is dominated at all stations in the outer bay by Capitita ambiseta and secondarily by Prionospio cirrifera and Echone limnicola. The benthic fauna may be considered more or less uniform throughout the outer bay with a large number of species found only at a few stations.

The following list includes only species which were hitherto unreported from Anaheim Bay. During the collection of invertebrates from the outer area of Anaheim Bay, special attention was focused on the polychaetes and they are reported in more detail (Table 9).

PHYLUM COELENTERATA

Class Anthozoa

Stylatula elongata (Gabb); Ricketts and Calvin, 1968, p. 463.

Specimens were taken from the benthos at several stations in the outer bay.

Cerianthus aestuari Torrey and Kleeburger; Ricketts and Calvin, 1968, p. 464.

Collected at Station L.

PHYLUM ANNELIDA

Class Polychaeta

Family Polynoidae

Harmothoe imbricata (Linnaeus); Hartman, 1968, p. 79.

Harmothoe sp.

Juvenile specimens, probably Harmothoe imbricata.

Family Sigalionidae

Sthenelais verruculosa Johnson; Hartman, 1968, p. 169.

Family Phyllodocidae

Eteone californica Hartman; Hartman, 1968, p. 249.

Eteone dilatae Hartman; Hartman, 1968, p. 251.

Family Hesionidae

Glyptis arenicola glabra Hartman; Hartman, 1968, p. 363.

Family Pilargidae
Ancistrosyllis hamata (Hartman); Hartman, 1968, p. 377.
Sigambra tentaculata (Treadwell); Hartman, 1968, p. 391.
Family Nephtyidae
Nephtys californiensis Hartman; Hartman, 1968, p. 579.

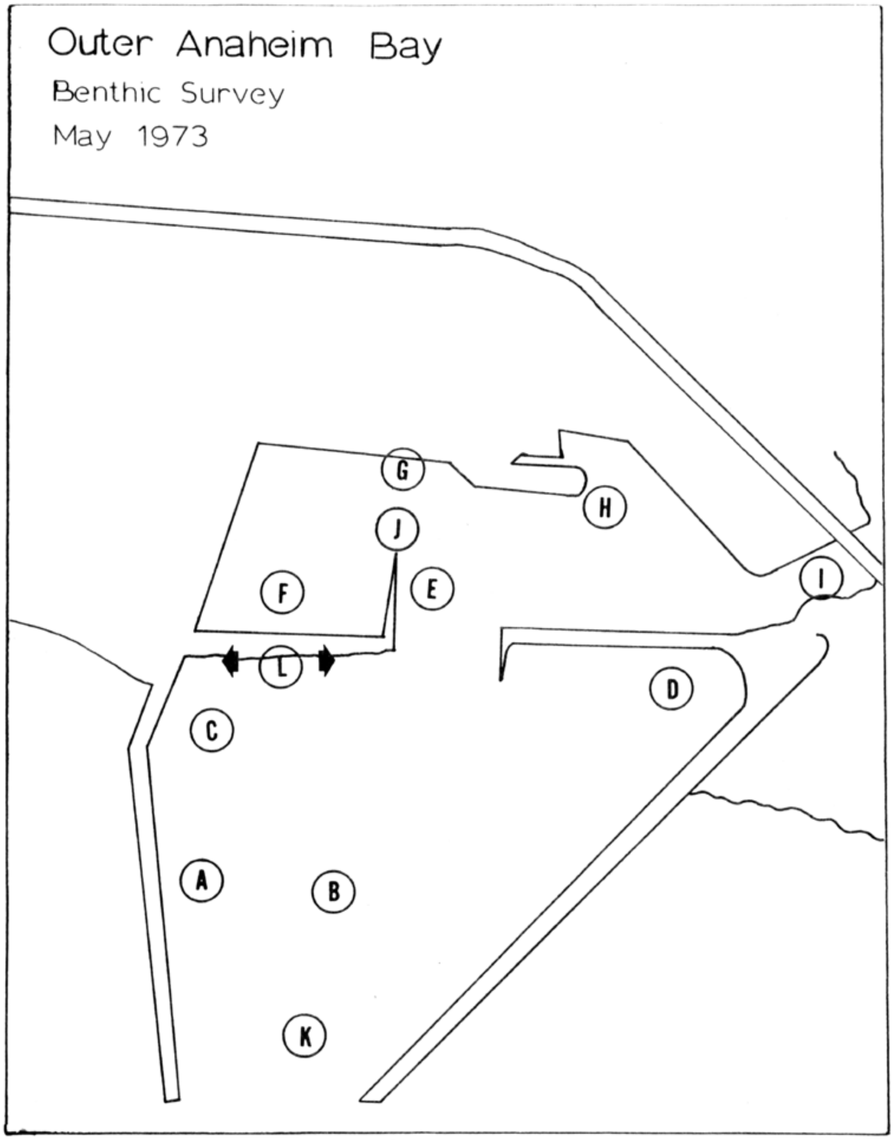

FIGURE 21—Station locations of the benthic survey conducted in May 1973. Arrows indicate regions where beach seining was conducted in 1973.

FIGURE 21—Station locations of the benthic survey conducted in May 1973. Arrows indicate regions where beach seining was conducted in 1973

Family Glyceridae

Glycera tesselata Grube; Hartman, 1968, p. 633.

Glycera sp.

Many juvenile specimens were taken in outer Anaheim Bay.

Family Goniadidae

Gonida acicula Hartman; Hartman, 1968, p. 649.

Goniadids, unidentified.

Two small specimens were collected from the benthos and could not be specifically identified.

Family Onuphidae

Diopatra splendidissima Kinberg; Hartman, 1968, p. 661.

This species is widespread throughout the sandy intertidal beaches of the outer bay; five specimens were taken intertidally.

Nothria elegans (Johnson); Hartman, 1968, p. 675.

Family Eunicidae

Marphysa disjuncta Hartman; Hartman, 1968, p. 729.

Family Lumbrineridae

Lumbrineris tetraura (Schmarda); Hartman, 1968, p. 775.

Lumbrineris sp.

Many juvenile specimens were collected from the different stations in outer Anaheim Bay. They probably belong to one of the four known species present.

Family Dorvilleidae

Stauroneris rudolphi (delle Chaije); Pettibone, 1963, p. 321.

This species was commonly encountered throughout the outer bay, but it has never been taken from the upper, undisturbed bay. It was common in Huntington Harbour.

Family Spionidae

Boccardia polybranchia (Haswell); Hartman, 1969, p. 93.

Laonice cirrata (Sars); Hartman, 1969, p. 107.

Prionospio malmgreni Claparède; Hartman, 1969, p. 159.

Pseudopolydora paucibranchiata (Okuda); Polydora (C.) paucibranchiata Okuda; Reish, 1959, p. 88.

Spiophanes fimbriata Moore; Hartman, 1969, p. 183.

Family Flabelligeridae

Pherusa papillata (Johnson); Hartman, 1969, p. 303.

Family Scalibregmidae

Scalibregma inflatum Rathke; Hartman, 1969, p. 313.

Family Maldanidae

Asychis sp.

Three juvenile specimens were taken from the benthos.

Praxillella affinis pacifica Berkeley; Hartman, 1969, p. 475.

TABLE 9

Species and Number of Specimens of Polychaetous Annelids from the Benthos of Outer Anaheim Bay, May 1973

Species	Stations										
	A	B	C	D	E	F	G	H	I	J	K
Harmothoe imbricata	7	2	6								
Harmothoe sp., juvenile										1	3
Sthenelais verruculosa	1										
Anaitides williamsi	3								1		
Eteone californica	2		1								
Eteone dilatae						1			1		3
Eteone pacifica				1							
Eumida sanguinea	1									1	
Glyptis a. glabra	1		2		1					3	2
Ophiodromus pugettensis	2					1			3		
Ancistrosyllis hamata						1	1				
Sigambra tentaculata	1	8	2	5	19	13	4	20	1	15	42
Exogone lourei	40		1					30			
Sphaerosyllis pirifera	4			3					2		
Typosyllis fasciata											1
Nereis procera	3	1	2	5	4		3	1		1	7
Nephtys californiensis								1			
Nephtys c. franciscana	26	11	13	4	10	8	12	15	2	30	24
Glycera americana											1
Glycera tesselata							2				
Glycera sp., juvenile			1	1					2	1	
Goniada acicula									1		
Goniada littorea	4										
goniadids, juveniles	2										
Marphysa disjuncta				1							
Diopatra splendidissima	2	1					1				1
Nothria elegans	1										
Lumbrineris minima	1	1	5	13	10	1	2	9	42	12	1
Lumbrineris tetraura	7								6		1
Lumbrineris zonata					3		1				
Lumbrineris sp., juvenile	27										
Stauronereis rudolphi	23		1		4	1	2	14	6	2	1
Haploscoloplos elongatus	18	11	2	14	29		15	23	10	17	16
Boccardia polybranchiata			1								
Laonice cirrata					1				2		1
Nerinides acuta	1										

TABLE 9

Species and Number of Specimens of Polychaetous Annelids from the Benthos of Outer Anaheim Bay, May 1973

Nerinides pigmentata								1			
Prionospio cirrifera	9	21	6	10	38	17	5	43	15	1	66
Prionospio malmgreni	1								1		
Prionospio pinnata	4	2	1		2		3		1	1	2
Prionospio pygmaceus	12			5					4		
Pseudopolydora paucibranchiata									1		
Spiophanes fimbriata											1
Spiophanes missionensis	1	1					1		11		
Streblospio benedicti										1	
Telepsavus costarum	1					1		1			2
Chaetozone corona	23		24	6	6	1	21	2	1	3	14
Tharyx parvus	14	6	54	15	28	14	22	8	1	21	14
Cossura candida		14	1	3	20	40	101	36		54	12
Pherusa papillata	1								1		
Scalibregma inflatum									1		
Armandia bioculata	61	55	3		25		8	10	19	80	137
Capitella capitata									56		
Capitita ambiseta	764	126	190	42	157	55	242	456	70	183	209
Notomastus (C.) tenuis						1				1	
Asychis sp.	1									1	1
Axiothella rubrocincta			1	10	11		13	1		8	
Praxillella a. pacifica			8							1	
Pectinaria californiensis	2	3	2				1	7			31
Ampharete labrops				1					5		
Amphicteis scaphobranchiata	13			6	1						6
Melinna oculata				2							
Amaeana occidentalis	18			2				1	12		
Pista alata	17		3		1				1	2	
Pista cristata							1	3		1	3
Pista disjuncta				2	2						
Streblosoma crassibranchiata			4	5			2	1		3	
Thelepus setosus				1							
Euchone limnicola	46	2	44	5	1		2	39	15	32	2
sabellid, juvenile	1										
Number of Species	40	16	25	24	22	13	23	21	31	26	28
Number of Specimens	1221	265	378	162	374	154	365	692	332	326	604

TABLE 9—Cont'd.

Family Ampharetidae

Ampharete labrops Hartman; Hartman, 1969, p. 543.

Amphicteis scaphobranchiata Moore; Hartman, 1969, p. 549.

Melinna oculata Hartman; Hartman, 1969, p. 567.

Family Terebellidae

Pista disjuncta (Muller); Hartman, 1969, p. 617.

Streblosoma crassibranchia Treadwell; Hartman, 1969, p. 641.

PHYLUM MOLLUSCA

Class Pelecypoda

Trachycardium quadragenarium (Conrad); McLean, 1969, p. 76.

Specimens were collected from subtidal waters in the outer bay area by E. D. Lane in spring 1973.

Tivela stultorum (Mawe); McLean, 1969, p. 77.

Specimens have been observed on several occasions in intertidal sandy beaches in the outer bay area.

PHYLUM ARTHROPODA

Class Crustacea

Order Decapoda

Panulirus interruptus (Randall); Ricketts and Calvin, 1968, p. 494.

Large specimens have been observed by E. D. Lane among rocks on the inside of the jetty at Anaheim Bay entrance.

10. AN ANNOTATED CHECKLIST OF THE ELASMOBRANCHS AND TELEOSTS OF ANAHEIM BAY

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10.1. INTRODUCTION

No extensive records of fish fauna for Anaheim Bay are available before April 1969. Since that time data have been gathered on those fishes captured at various stations (Figure 22) in the bay.

Three types of gear were employed for collecting fish: seine, trawl, and gill net. Two bag seines, a 15.24 x 1.83 m (50 x 6 feet) and a 9.14 x 1.22 m (30 x 4 feet) of 10 mm (# inch) and 3 mm (# inch) bar mesh respectively, were used as well as a 3.05 x 1.22 m (10 x 4 feet) 6 mm (¼ inch) mesh common sense minnow seine. Trawling was done with a shrimp otter trawl measuring 4.88 m (16 feet) in mouth width and 11.89 m (39 feet) from the cork line to the cod end, including a 1.22 m (4 feet) bag. The trawl was constructed of 38 mm (1½ inch) stretched mesh nylon netting at the cod end. A 6 mm (¼ inch) woven nylon liner was added to the cod end in May 1970. The gill net used was a 45.72 m (150 feet) monofilament nylon experimental gill net with six equal sections of 25 mm (1 inch), 51 mm (2 inch), 76 mm (3 inch), 102 mm (4 inch), 153 mm (6 inch), and 204 mm (8 inch) stretched mesh.

Seining was the only method used in 1969, while trawling and seining were primarily employed in 1970, with occasional gill net sets. The gill net was used for most of the 1971 work, with periodic seines and trawls. All gears were used at all hours of both day and night. Lengths given are indicated as total length (TL) or standard length (SL).

10.1.1. Family Carcharinidae

10.1.1.1. Mustelus californicus Gill

A common elasmobranch in the bay, the gray smoothhound was taken by all gears at all stations (except Station 8), but most commonly by gill net and trawl in the middle arm (Stations 2, 3, 4, and 5). No diel pattern of abundance was apparent; however, a seasonal trend was observed with spring and summer months having peak numbers.

of 313 captures, 189 were made in the middle arm at Station 4. This general area appears to be a congregating place, possibly for mating, since several ripe males were taken there. Males outnumbered females in captures during spring and summer months (February through July), while females outnumbered males in September through November. Several pregnant females were taken, and one gill net haul in early July 1973 captured young smoothhounds between 300 and 500 mm (11.81 and 19.68 inches). The pregnant females probably enter the bay to feed; however, they may give birth in deeper waters outside the bay since the young captured were not newborn.

FIGURE 22—Stations visited for fish studies.

FIGURE 22—Stations visited for fish studies

No specimens were captured in August 1971, and this was attributed to a serious red tide situation which may have lowered the dissolved oxygen to a critical level. The sharks may have moved out as a direct result or in response to depleted food supplies. A lack of captures again in December 1971 and January 1972 probably was due to low water temperatures of 10 to 11 C (50.0 to 51.8 F).

Food and feeding studies (Sandell, 1973) indicate a diet of invertebrates, primarily of benthic crustaceans, with a marked predominance of Callianassa sp. and Hemigrapsus oregonensis. While Callianassa is the most commonly eaten organism, H. oregonensis is the most important single food item in terms of proportion of weight in the diet. Polychaetes and echiuroid worms are taken in small numbers by all sizes while larger individuals occasionally eat clams and fish.

10.1.1.2. Mustelus henlei (Gill)

Only two brown smoothhounds were captured in the bay, both during daylight hours in 1971 at Station 4. One was taken in a January trawl, and the other, a 750 mm (29.53 inches) TL male, was taken in a July gill net set. The stomach of the latter contained crustacean remains, primarily of H. oregonensis, and smaller amounts of clam remains.

10.1.1.3. Triakis semifasciata Girard

Two leopard sharks, one 616 mm (24.25 inches) TL male and one 625 mm (24.61 inches) TL female were captured in a single gill net set in March 1971 at Station 4. One additional specimen, a 501 mm (19.72 inches) male, was captured in March 1972 in an afternoon trawl at Station 2. According to Roedel (1953), this shark is common in shallow water along the southern California coast and in bays farther north. Bane (1968) stated that they occur periodically in Upper Newport Bay, especially in the spring and summer, and Herald (1953) reported them to move in and out of bays at irregular intervals. Stomach contents of leopard sharks taken in Anaheim Bay consisted mainly of Callianassa sp. and unidentifiable crab remains, with small quantities of clam and polychaete remains present.

10.1.2. Family Squatinidae

10.1.2.1. Squatina californica Ayres

One Pacific angel shark was taken by gill net near the mouth of the bay during February 1972. This species generally is found at depths of 15 to 22 m (8 to 12 fathoms) over sandy or muddy bottoms (Fitch, 1968).

10.1.3. Family Rhinobatidae

10.1.3.1. Platyrhinoidis triseriata (Jordan and Gilbert)

Only one adult thornback was captured by trawl at Station 3 in September 1970. Due to the abundance of this species outside the bay, a somewhat higher catch was expected.

10.1.3.2. Rhinobatos productus (Ayres)

The shovelnose guitarfish was caught throughout the bay at all times of the year although it was taken less frequently in winter months. It was captured with all three types of gear but never in any great numbers. Herald (1953) stated that guitarfish, like leopard sharks, exhibit irregular movements in and out of bays. The sex of 14 of the 54 total specimens was recorded, and only one was a female (1220 mm, 48.03 inches TL). This female contained 12 well developed eggs not yet released from the ovaries, and the uterus contained five developing young.

Shovelnose guitarfish over 914 mm (35.98 inches) TL are believed to be uncommon (Baxter, 1966). of the 14 guitarfish captured by gill net from April 1971 through March 1972, 10 exceeded 960 mm (37.79 inches) TL and one exceeded 1500 mm (59.06 inches) TL; however, it should be mentioned that quite small individuals also were taken. Food studies indicate a diet of bottom invertebrates (Sandell, 1973), Callianassa being the most common item. The shovelnose guitarfish appears to utilize clams to a greater extent than any of the other elasmobranchs found in the bay.

10.1.4. Family Myliobatidae

10.1.4.1. Myliobatis californica Gill

One bat ray was reportedly taken by an angler (E. D. Lane, Environment Canada, pers. comm.). Two specimens were taken by seine in the outer harbor.

10.1.4.2. Urolophus halleri (Cooper)

The round stingray was the most commonly captured elasmobranch in the bay. This is noteworthy since, as Babel (1967) pointed out, these animals need loose sand or mud in which to burrow for food and for concealment, while protected bay waters are attractive for mating and as nursery grounds.

A total of 761 specimens was taken with greatest numbers being captured at Stations 2 and 3 in the middle arm. Although captured with all three gears, the round stingray was usually taken with trawl and seine. Lowest catches were encountered in November and December while the greatest numbers were taken in January, February, and March with no discernible diel pattern of capture. While captures were made in all months of the year, no specimens were taken at Stations 7 or 8.

Two females captured by gill net in an October 1971 night set between Stations 2 and 3 gave birth shortly after removal from the net. One (390 mm, 15.35 inches TL) had five young, and the other (414 mm, 16.30 inches TL) had six. Babel (1967) stated that round stingray young are typically born in September after mating occurs in June; nevertheless, males in mating condition were taken from the bay in January through March along with ovulating females.

The round stingray, like other elasmobranchs, relies heavily on crustaceans as food, particularly Callianassa sp. (Sandell, 1973). The remainder of its diet consists of small food items such as clams (usually siphons), small polychaetes, amphipods, and pea crabs. Clams are second to Callianassa in contribution by weight to the diet. Babel (1967) stated that young rays eat more crustaceans while larger rays utilize relatively more pelecypods. Most rays examined from Anaheim Bay were large (dish width greater than 140 mm, 5.51 inches) but still showed a heavy dependence on Callianassa, and this may be related to this crustacean's availability in the bay.

10.1.5. Family Clupeidae

10.1.5.1. Dorosoma petenense (Gunther)

Threadfin shad were taken from the bay on two separate occasions. Two juveniles, 52 and 58 mm (2.05, 2.28 inches) SL, were taken at Station 8 by seine in November 1969. An additional six adult specimens, 115, 120, 122, 125, and 132 mm (4.53, 4.72, 4.80, 4.92 and 5.20 inches) SL, were taken by gill net in April 1971 at Station 4. Water temperature at the time of both captures was 15 to 16 C (59.0 to 60.8 F). Salinity at the time of the November capture was 32.2[o/oo], while salinity for the April capture was 31.2[o/oo].

This species was originally introduced into several freshwater lakes of California in 1953. Since this species is euryhaline (Briggs, 1958), its survival in ocean waters might be expected. It has been recorded from the ocean waters of California several times (Isaacson and Poole, 1965; Bryan and Sopher, 1969); once from Belmont Shore, Long Beach (Thomas, 1962) and several times from Upper Newport Bay (Bane, 1968).

10.1.6. Family Engraulidae

10.1.6.1. Anchoa compressa (Girard)

Deepbody anchovy seasonally was one of the most abundant fish in the bay. of 1,355 specimens caught by trawl, gill net, and seine in 1970 and 1971 throughout the bay, 1,287 were taken in May through November. The most effective gears were trawl and seine, with only a few larger adults being taken by gill net.

The species appears to spawn in Anaheim Bay. Ripe adults were frequently taken in late spring and summer while juveniles have been captured in moderate numbers by seine in late summer and early fall. Larval specimens of this species were only recorded once, when large numbers were collected in one seining operation during July 1971; however, sampling plankton was not part of the study.

The gut contents of 44 adults (91 mm, 3.58 inches SL to 122 mm, 4.80 inches SL) caught by gill net in March through November 1971, indicate a fairly consistent diet of small crustaceans (Klingbeil, 1972). Major items of food by frequency of occurrence were ostracods, copepods, cumaceans, amphipods, and Callianassa sp. larva. The diet also included small polychaetes and gastropods, mysids, tanaidaceans, isopods, crab zoea, dipterans, and small gobiids (probably the arrow goby, Clevelandia ios) . The deepbody anchovy appears to utilize the entire water column in search for food since some planktonic and benthic organisms as well as dipterans appear in the diet.

It should be noted that trawl records for June 1971 indicate the capture of one slough anchovy, Anchoa delicatissima (Girard); however, this specimen was not available for laboratory identification. It is probable that some of the specimens recorded as A. compressa were in fact A. delicatissima.

10.1.6.2. Engraulis mordax Girard

of eight northern anchovy recorded from the bay, seven were caught by trawl in December 1970, and one by gill net in September 1971. Six of the specimens were night captures at Stations 2 and 7 in the lower reaches of the bay.

10.1.7. Family Batrachoididae

10.1.7.1. Porichthys myriaster Hubbs and Schultz

The specklefin midshipman was taken throughout the bay primarily between March and November. Adults were taken with gill net and trawl, while juveniles were only taken by trawl. of approximately 450 captures in the bay, juveniles far outnumber adults.

It is generally thought that Porichthys requires a hard substrate for spawning (E. D. Lane, Environment Canada, pers. comm.), and there are several such sites in the upper reaches of the bay. Males have been found nesting on the rock-protected areas of the outer bay (Carl L. Hubbs, Scripps Institute, pers. comm.). In a study of the Atlantic midshipman Porichthys porosissimus (Valenciennes), in the vicinity of Port Aransas, Texas, Lane (1967) found that adults migrate into bays and spawn in early spring and summer, while offspring leave the bays in late spring to early fall and return the next year as adults. This migration also is reflected by catch records for the specklefin midshipman in Anaheim Bay. Adults were only taken in February through September with peak catches in May and June. Those examined were found to be either in the spawning or spent condition. Juveniles appeared in catches between June and December and were most abundant in September and October.

Seventeen digestive tracts, from adults caught during the period March through August 1971, were found to be empty (Klingbeil, 1972). Decrease in feeding activity has been noted for other Porichthys in spawning condition (Hubbs, 1920; Arora, 1948; Lane, 1967).

10.1.8. Family Cyprinodontidae

10.1.8.1. Fundulus parvipinnis Girard

The California killifish was commonly seined from upper reaches and shallow tide pools of the bay especially Stations 8 and 6.

10.1.9. Family Atherinidae

10.1.9.1. Atherinops affinis (Ayres)

Topsmelt was the most frequently captured fish in Anaheim Bay, being taken in all stations. Over 5,000 specimens were taken by all three types of gear during the years 1970 and 1971. No seasonal trends of abundance are apparent, and the topsmelt appears to complete its life cycle in the bay. Juveniles and smaller adults were captured most readily by trawl and seine, while the larger faster swimming adults were taken by gill net. These captures were made throughout the bay with no distributional trends apparent.

Topsmelt exhibit an extended spawning period in Anaheim Bay with peaks in April and May. The occurrence of ripe females in January and September confirms a long spawning season (Klingbeil, 1972).

A total of 247 digestive tracts of A. affinis caught during the period February 1971 to February 1972 was analyzed for food content (Klingbeil, 1972). of these tracts, 177 were from larger topsmelt (those caught by gill net) varying from 94 to 174 mm (3.70 to 6.85 inches) SL. The remainder were caught by seine and varied in length from 16 to 81 mm (.63 to 3.19 inches).

When considering the gut content of larger A. affinis, it seems the common name, topsmelt, is a misnomer if it implies anything about this fish's diet in Anaheim Bay. The major category of gut content by weight, volume, and frequency of occurrence was detritus and sediment. Ostracods were the most frequent organisms seen in gut contents, occurring in more than 80% of the digestive tracts analyzed. Although no other food item occurred more than 35% of the time, organisms such as cumaceans, tanaidaceans, and amphipods were often abundant in guts, especially during summer months. In general, the topsmelt diet became more varied in summer. Other items of food of minor importance include foraminiferans, small gastropods, polychaetes, harpacticoid copepods, isopods, Callianassa sp. larva, dipterans, A. affinis eggs, and algae.

The smaller topsmelt caught by seine exhibited a much different diet. Detritus and sediment, although occurring 31% of the time, was seldom a major portion of the gut content. Planktonic crustaceans such as copepods, cladocerans, cirripedian larva, Callianassa sp. larva, and crab zoea form the major part of the diet of these fish. Other items of food include foraminiferans, unidentified protozoans, ostracods, amphipods, dipteran adults and larva, and algal fragments.

10.1.10. Family Syngnathidae

10.1.10.1. Syngnathus leptorhynchus (Ayres)

Bay pipefish were caught in November 1969, while seining a partially submerged eelgrass bed near the mouth of the west arm. Barnhart (1936) points out that the bay pipefish abounds in eelgrass beds and is almost wholly confined to bays. Because of gear selectivity, and since eelgrass beds have not been adequately sampled in Anaheim Bay, it is probable that the population is much larger than indicated by catch records. This species was reported in the first publication on fish from Anaheim Bay (Hubbs, 1916).

10.1.11. Family Percichthyidae

10.1.11.1. Roccus =Morone saxatilis (Walbaum)

One adult striped bass was captured by trawl at Station 2 in December 1970. This species is rarely found south of Monterey Bay (Radovich, 1963) but was recorded 40.23 km (25 miles) below the Mexican border in 1959 (Radovich, 1961). In September 1973 a second 7.26 kg (16 pounds) specimen was captured in the mouth of the bay by a sports fisherman.

10.1.12. Family Serranidae

10.1.12.1. Paralabrax maculatofasciatus (Steindachner)

Spotted sand bass were taken sporadically throughout the year with all three gears. of the 18 specimens recorded, 13 were captured at Station 2. Roedel (1953) considered the spotted sand bass to be most common in bays and lagoons, and the barred sand bass, Paralabrax nebulifer (Girard), to be found over sandy and rocky bottoms. Hence, a larger population of spotted sand bass might be expected in Anaheim Bay.

10.1.12.2. Paralabrax nebulifer (Girard)

A total of 60 juvenile barred sand bass was captured by trawl gear, primarily during the day. of these, 59 were taken in May through December 1970 and all at Stations 2, 3, and 4. Food habits of the barred sand bass, reviewed by Smith (1970), included some specimens from Anaheim Bay.

10.1.13. Family Sciaenidae

10.1.13.1. Cynoscion nobilis (Ayres)

One juvenile white seabass (81 mm, 3.19 inches TL) was captured by trawl in November 1970 at Station 4. Juveniles have been recorded from Newport Bay and Long Beach-Los Angeles harbors (Thomas, 1968).

10.1.13.2. Genyonemus lineatus (Ayres)

White croakers were taken infrequently by trawl and gill net, primarily from November to May. Twenty-five adult specimens were taken, 21 being caught at Stations 2 and 7 in the lower reaches of the bay. Sixteen of the total were night captures.

Analysis of 20 digestive tracts for food content indicates this fish is an indiscriminate bottom feeder. A total of 22 different food items was recorded, most of which were benthic organisms. Eight of these food items, amphipods, polychaetes, small molluscs, clam siphons, Callianassa sp. adults, pinnotherid crabs, ostracods, and gobies, occurred in more than 20% of the guts analyzed. Analysis of food content by weight showed that Callianassa sp. adults and polychaetes were the major items of food. The size of fish whose gut contents were analyzed varied from 182 to 369 mm (7.16 to 14.53 inches) SL (Klingbeil, 1972).

10.1.13.3. Menticirrhus undulatus (Girard)

California corbina were taken sporadically throughout the year, but in greatest numbers during spring and fall. Baxter (1966) stated that corbina apparently move offshore into deeper water during winter months and when spawning during summer months. Our data reflects this pattern since only one corbina was captured in Anaheim Bay during the periods May through August and January through February. However, it should be noted that September captures were near spawning condition.

Seventy-two corbina were captured throughout the bay, almost exclusively by gill net in the lower reaches. Only five specimens were captured by seine and trawl. Available length data on fish captured from March to December 1971 include: one less than 300 mm (11.81 inches), 21 between 300 and 400 mm (11.81 and 15.75 inches), 11 between 400 and 500 mm (15.75 and 19.68 inches), and three greater than 500 mm (19.68 inches) SL (one measuring 545 mm, 21.46 inches). No juveniles were taken.

Examination of the digestive tracts of 36 specimens showed Callianassa sp. adults to occur more than 90% of the time. By weight, this represents 69% of the total food content analyzed. Other food items, occurring less often and none of which represented more than 7% of the diet by weight, included polychaetes, molluscs, clam siphons, shrimp, pinnotherid crabs, Hemigrapsus sp., and gobies. Joseph (1962) showed a primary diet of sand crabs for corbina over 200 mm (7.87 inches) SL taken from the surf zone.

10.1.13.4. Seriphus politus (Ayres)

The queenfish appears to be a year-round occasional visitor since catches were recorded for all months except March, April, and July. Twenty-five specimens were captured by all three gears, 21 of these by trawl. The majority were juveniles captured between August and February. Queenfish usually occur in shallow water over sandy bottoms (Turner and Sexsmith, 1964). Since the lower reaches of the bay are in closer proximity to these conditions, the capture of 23 specimens at Station 2 might be explained. No day-night differences in catch were observed.

10.1.13.5. Roncador stearnsi (Steindachner)

Moderate numbers of spotfin croaker were in the middle arm at Stations 2 and 3 during trawl and gill net studies in 1973 by William Maxwell and Doyle Hanan. These fish appeared to be absent or in low numbers in the inner bay during 1970 to 1972, however, there was a moderate population in 1973.

10.1.13.6. Umbrina roncador Jordan and Gilbert

A few yellowfin croakers were taken with trawl and gill net in 1973 by Maxwell and Hanan at Stations 2 and 3. No specimens of this fish were captured during the 1970 to 1972 studies. In 1973 the species was not taken as numerously as the spotfin croaker, but they were not scarce.

10.1.14. Family Embiotocidae

10.1.14.1. Cymatogaster aggregata Gibbons

The shiner surfperch was the most abundant of the surfperches in the bay. It is commonly caught in seines and trawls (see chapter on the shiner surfperch in Anaheim Bay).

10.1.14.2. Embiotoca jacksoni Agassiz

Two black surfperch were caught in the lower reaches of the bay, one by trawl at Station 2 in April 1970, and the other by gill net at Station 7 in March 1971. The gut of the latter was examined and found to be empty. The black surfperch is one of the most abundant species found along the jetty in the outer harbor.

10.1.14.3. Hyperprosopon argenteum Gibbons

A total of 16 adult walleye surfperch was captured by gill net and trawl at Stations 2, 4, and 7. All were caught during the period November through April, and 12 were caught at night. The size of these fish varied from 79 to 177 mm (3.11 to 6.97 inches) SL.

The specimens captured in November and December were considered to be mating individuals since fertilized eggs were found in some females, and Baxter (1966) stated that schools break up for mating in October through December. The females caught in January through April were in the latter stages of pregnancy.

The digestive tracts of all 16 fish were examined, and only seven categories of food were recorded: polychaetes, molluscs, copepods, gammaridean amphipods, adult Callianassa sp., gobiids, and the California killifish, Fundulus parvipinnis. By weight, the gobiids represented 58% and Callianassa sp. 30% of the total food content (Klingbeil, 1972).

10.1.14.4. Hypsurus caryi (Agassiz)

A single rainbow surfperch was caught by trawl during the day in May 1970 at Station 4. This species is found infrequently south of Los Angeles County, although its range extends as far south as Todos Santos Island (Tarp, 1952).

10.1.14.5. Phanerodon furcatus Girard

Thirty-six white surfperch were captured from November through May using all three types of gear. There were no summer captures, a common phenomenon with embiotocids in the bay. No periods of great abundance were apparent during those months where captures occurred. Captures were made throughout the bay, but they occurred most frequently in the lower reaches at Station 2.

Fifteen digestive tracts from fish varying from 134 to 184 mm (5.27 to 7.24 inches) SL were analyzed for food content. The most frequent food items were polychaetes, molluscs, gammaridean amphipods, pinnotherid crabs, and adult Callianassa sp. When the diet was analyzed by weight (Klingbeil, 1972), only three food items amounted to more than 10% of the total weight of all gut contents; polychaetes (25.7%), pinnotherid crabs (13.7%), and adult Callianassa sp. (14.5%).

10.1.14.6. Damalichthys = Rhacochilus vacca (Girard)

Pile surfperch were caught throughout the bay by all three types of gear, but most frequently by trawl and gill net. They were rarely taken in summer or fall.

of the 104 specimens recorded from the bay, 42 were analyzed for food content. The analyzed fish varied from 113 to 252 mm (4.45 to 9.92 inches) SL with 95% falling between 135 and 220 mm (5.31 and 8.66 inches). The primary food of these fish was various small molluscs (Crepidula, Cerithidia, Bulla, Pollinices, Macoma, Chione, Laevicardium, and Tagelus) which represented 44% of the diet by weight. Decapods, including Callianassa sp., Hemigrapsus sp., and pinnotherids, amounted to 39% of the diet weight (Klingbeil, 1972). Quast (1968) found this species feeds principally on demersal shelled invertebrates, and that pelecypods and hermit crabs comprised a large portion of the diet.

Female specimens caught in April and May 1971 were ready to bear young, and those caught in January and February 1972 were in earlier stages of pregnancy.

10.1.15. Family Mugilidae

10.1.15.1. Mugil cephalus Linnaeus

Although a schooling fish of bays and lagoons (Roedel, 1953), only four isolated captures were recorded during our study in Anaheim Bay. One adult striped mullet was taken by gill net in March and one in November 1971 at Station 2. A third adult specimen was taken during April 1972 by gill net near the mouth of the bay. A single juvenile was captured by seining at Station 8 in March 1971. The gut of each adult was found to contain detritus and sediment.

10.1.16. Family Blennidae

10.1.16.1. Hypsoblennius gentilis (Girard)

One bay blenny was taken by trawl during August 1971, in the main channel between the west and middle arms. This fish may be more prevalent in the lower reaches of the bay since no collecting operations were conducted in areas where the species may more commonly occur.

10.1.17. Family Gobiidae (See chapter on the gobies of Anaheim Bay)

10.1.17.1. Clevelandia ios (Jordan and Gilbert)

The arrow goby was caught in seines throughout the bay.

10.1.17.2. Gillichthys mirabilis Cooper

The longjaw mudsucker was found in the muddy substrates and burrows in the bay.

10.1.17.3. Ilypnus gilberti (Eigenmann and Eigenmann)

Cheekspot goby appears to be rare in Anaheim Bay with the only specimens taken in the outer harbor.

10.1.17.4. Quietula y-cauda (Jenkins and Evermann)

The shadow goby was caught in seines throughout the bay.

10.1.18. Family Scombridae

10.1.18.1. Sarda chiliensis (Cuvier)

This is a common pelagic offshore schooling species which occasionally wanders into Anaheim Bay. Three Pacific bonito were caught during the day in May 1971 by gill net set at Station 2. An additional specimen was captured in a December 1971 night set at Station 7. The three May captures contained no food, while the December individual contained one small atherinid.

10.1.19. Family Stromateidae

10.1.19.1. Peprilus simillimus (Ayres)

Pacific butterfish were seined on two occasions during daylight in the lower reaches of the bay. Four specimens were taken at Station 7 in September 1970, and 13 specimens were taken at Station 9 in October of the same year.

10.1.20. Family Cottidae

10.1.20.1. Leptocottus armatus Girard

Pacific staghorn sculpin were found throughout the bay. It was commonly caught in seines and trawls (see chapter on the Pacific staghorn sculpin in Anaheim Bay).

10.1.21. Family Bothidae

10.1.21.1. Citharichthys stigmaeus Jordan and Gilbert

A total of 10 specimens of Citharichthys sp. was caught by trawl in March, April, and May 1970. Seven of these were caught at Station 2, the remainder at Stations 3 or 4. The only preserved specimen was later identified as a speckled sanddab, Citharichthys stigmaeus. This species was the only representative of the genus taken in 1971 summer trawls outside the bay.

10.1.21.2. Paralichthys californicus (Ayres)

This valuable sport and commercial species, the California halibut, was caught year-round throughout the bay with trawl and seine (see chapter on the California halibut in Anaheim Bay).

10.1.22. Family Pleuronectidae

10.1.22.1. Pleuronichthys verticalis Jordan and Gilbert

Two hornyhead turbots were taken in Anaheim Bay. The first, a juvenile, was caught presumably near the mouth of the bay; however, other data were not taken. The second, an adult, was captured near the mouth of the bay by trawl during February 1972.

10.1.22.2. Parophrys vetulus Girard

A single English sole was captured in a trawl near the mouth of the middle arm at Station 2 during January 1973.

10.1.22.3. Hypsopsetta guttulata (Girard)

Diamond turbots were found throughout the bay and were caught year-round by trawl and seine (see chapter on life history of the diamond turbot in Anaheim Bay).

10.1.23. Family Cynoglossidae

10.1.23.1. Symphurus atricauda (Jordan and Gilbert)

A total of 16 California tonguefish was captured by trawl from July 1970 to January 1971. Thirteen were caught in the lower reaches of the bay at Station 2.

10.2. CONCLUSION

The fish fauna of Anaheim Bay is comparable to the fauna which Bane (1968) reported for Upper Newport Bay. Although there have been incidentals recorded from each bay which have not been recorded from the other, the more abundant species are generally common to both. Notable exceptions are: Rhinobatos productus, shovelnose guitarfish, which is infrequently taken in Upper Newport Bay but common in Anaheim Bay, and Paralabrax maculatofasciatus, spotted sand bass; Seriphus politus, queenfish; and Embiotoca jacksoni, black surfperch, which reportedly occur frequently in Upper Newport Bay but are captured rarely in Anaheim Bay. Pleuronichthys ritteri, spotted turbot, which has only been taken twice from the outer harbor of Anaheim Bay and once from Huntington Harbour is reportedly common in Upper Newport Bay (Bane, 1968).

Total numbers of fish in Anaheim Bay, as shown by catches with all gears, are relatively higher in spring and summer months. Species diversity is greatest in winter and spring, and in all seasons increases from the head of the bay to the mouth.

Studies on the fish of Anaheim Bay are continuing in an effort to further elucidate the ecological relationships in this relatively pristine environment.

11. THE LIFE HISTORY OF THE CALIFORNIA KILLIFISH FUNDULUS PARVIPINNIS GIRARD, IN ANAHEIM BAY, CALIFORNIA

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11.1. INTRODUCTION

Twenty species of the genus Fundulus occur in North America. of these only Fundulus parvipinnis Girard, the California killifish, is found along the coast of California (Girard, 1854). This species is a common inhabitant of shallow bays and salt marshes from Point Conception, California to Magdalena Bay, Mexico.

Most California killifish investigations have been physiological. Keys (1931) studied effects of decreased salinity on oxygen requirements. Effects of temperature upon respiratory metabolism were examined by Wells (1935a and 1935b). Doudoroff (1945) and Valentine and Miller (1969) studied osmoregulation.

With the exception of a study of the temperature tolerances of developing embryos by Hubbs (1965) and the field observations made by Keys (1931) and others, little consideration has been given to the life history of F. parvipinnis.

For logistic reasons, the investigation was confined to the killifish population in the upper reaches of the west arm of Anaheim Bay, California (Station 8). However, the conclusions from this study are considered to be applicable to populations in other areas.

11.2. STUDY AREA

The study channel was the east branch of the west arm. An initial study of the arm indicated F. parvipinnis is concentrated between a wooden bridge just south of the fork of the arm, and the upper reaches of the channel. Due to the distribution of fish in the channel and the ease of monitoring fish movements through the channel and a number of permanent tide pools, an area midway between the limits of the channel (Station 8) was selected for the study (Figure 22).

From middle to moderately high tide, water within the study area is confined to the main channel, seven small lateral channels, and seven permanent pools (Figure 23). From middle to low tide, water is confined only within the study channel and pools (Figure 23). Low tide-water depth ranges from 15 to 30 cm (5.90 to 11.81 inches). During high spring tides, water innundates the study area to depths ranging from 4 m (13 feet) in the study channel to 1 m (3 feet) on the grass flats. Water temperatures in Anaheim Bay varied from 11 to 26 C (51.8 to 78.8 F) while salinities ranged from 30[o/oo] to 35[o/oo] in the channels.

11.3. DESCRIPTION

Positive identification of F. parvipinnis was made by comparisons with descriptions of Girard (1854), Jordan and Evermann (1896), and Hubbs and Miller (1954). Girard (1854) and Jordan and Evermann (1896) stated that female F. parvipinnis possess a dusky lateral band, while males possess dark olive green cross-bars along the midlateral surface. Males, females, and juveniles of the Anaheim Bay population possess dark olive green cross-bars. Cross-bars; however, become obscure during spawning season.

A description of sexual dimorphic characteristics in F. parvipinnis was given by Girard (1854). These characteristics appear to be related to sexual maturity, since no dimorphic characteristics are discernable among immature fish.

Although F. parvipinnis is commonly considered a marine fish, Miller (1939) and Miller (1943) reported the presence of this species in freshwater streams attributing these occurrences to gradual acclimitization.

TABLE

11.4. MATERIALS AND METHODS

All fish were collected in fortnightly seining from April 1969 to January 1970. From June to October, collecting was done over 24 hour periods and from November to January, collecting was done over 12 hour periods, including both day and night. During each collecting period a minimum of four samples were taken. Sampling periods were established to insure that specimens were taken monthly at each phase of the tide. Minimum sample size was 25 fish; however, samples usually ranged from 110 to 250 fish.

All specimens were fixed in the field with 10% formalin in seawater solution. The specimens were washed in running freshwater 24 hours after preservation. Fish were then weighed, measured, and stored in 40% isopropyl alcohol. All lengths were standard lengths (SL), all weights were to the nearest 0.1 g.

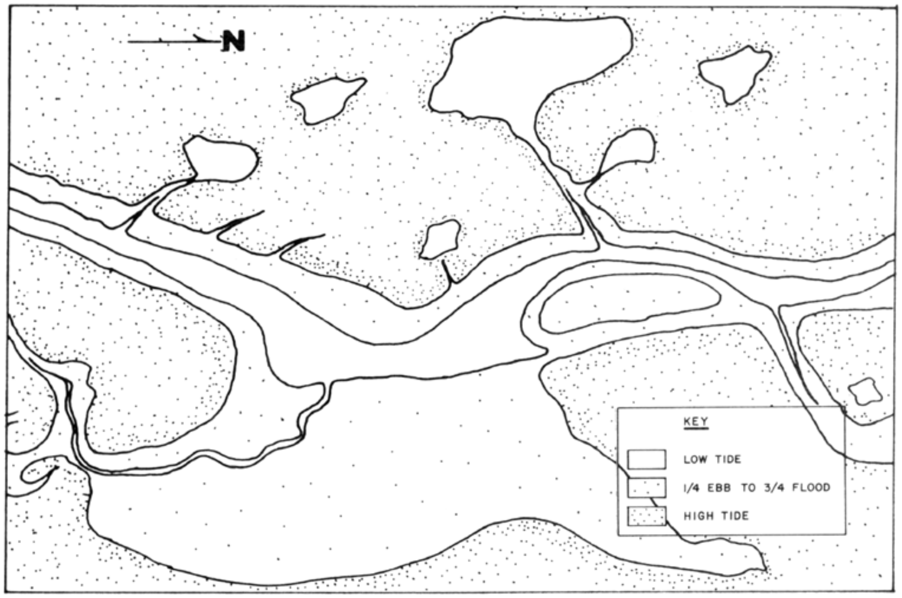

FIGURE 23—Study area (Station 8) showing outlines of areas covered by water during various phases of the tide.

FIGURE 23—Study area (Station 8) showing outlines of areas covered by water during various phases of the tide

Preserved fish were used for age and growth studies, length-weight relationships, gut analysis, and fecundity and maturation estimates. Fish used in laboratory experiments were selected from the last seine haul of a collecting period.

Localized movements of California killifish were determined by observing movements of fish tagged with a 2 m (6.56 feet) length of monofilament provided with a small styrofoam float. Generalized movements were determined by capture and recapture of fin clipped fish. A minimum of 180 fish were captured, fin clipped, and released during each sampling period. Recapture was attempted weekly. A control group of fin clipped fish was maintained in aquaria with no observable increase in mortality.

11.5. MOVEMENT AND POPULATION

11.5.1. Movement

Most movements of F. parvipinnis are tidally induced. Between mid-ebbing and low slack tide the fish move from the shallows to the deeper channels (Figure 24). On the flooding tide the direction of movement is reversed. Beginning at midflood, killifish were observed entering side channels and following the rising water line. Once water inundates the marsh grass flats, fish were noted to wander throughout the bay.

Fish move across the grass flats and into the channel on the ebbing tide by maintaining positions just ahead of the receding water line and by following the paths of least resistance (Figure 24). Similar behavior was observed in F. heteroclitus by Buttner and Brattstrom (1960) and Moore (1922), and in F. majalis by Bigelow and Schroeder (1953).

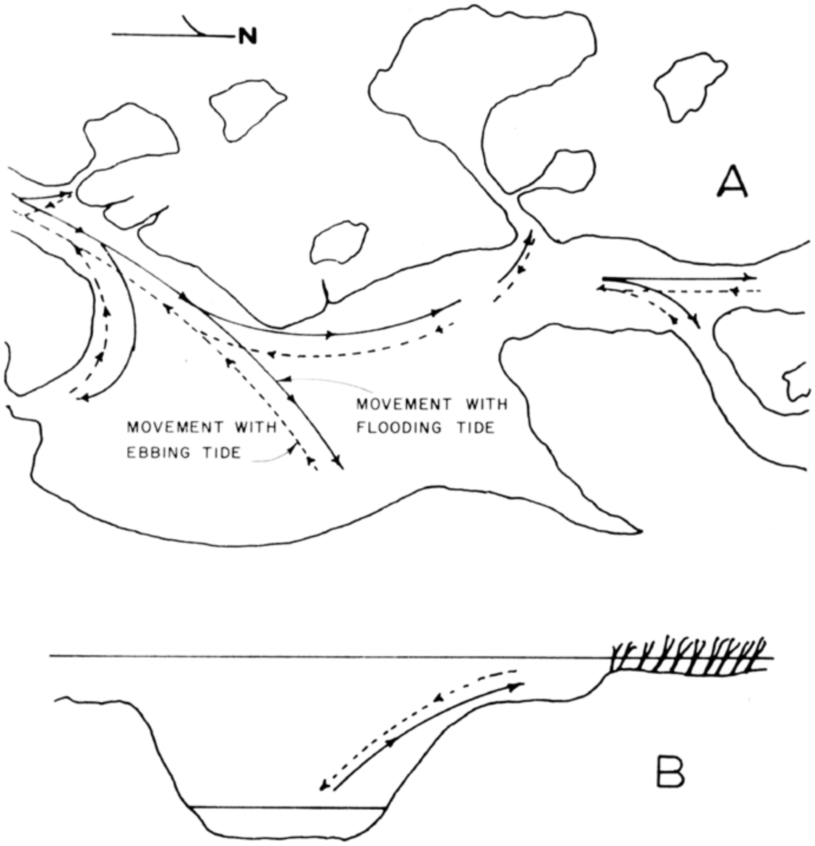

FIGURE 24—Daily movement of California killifish based on recaptures of fin clipped fish and direct observations. A, horizontal movement in response to tide; B, movement to and from channels with tide.

FIGURE 24—Daily movement of California killifish based on recaptures of fin clipped fish and direct observations. A, horizontal movement in response to tide; B, movement to and from channels with tide

11.5.2. Population

Population estimates, calculated by using the methods of Krumholtz (1944), showed that during the spawning period a relatively stable population of 24,055 ± 1,900 adult and subadult killifish was found in the study area. Recapture percentage during the period was 6.8%. Nevertheless, following the peak spawning periods, the recapture percentage dropped to 2.3% through the study channel, thus making population estimates unreliable. The high percentage of recaptures during the spawning season indicated possible homing behavior. However, the float experiment did not bear this out (Figure 25).

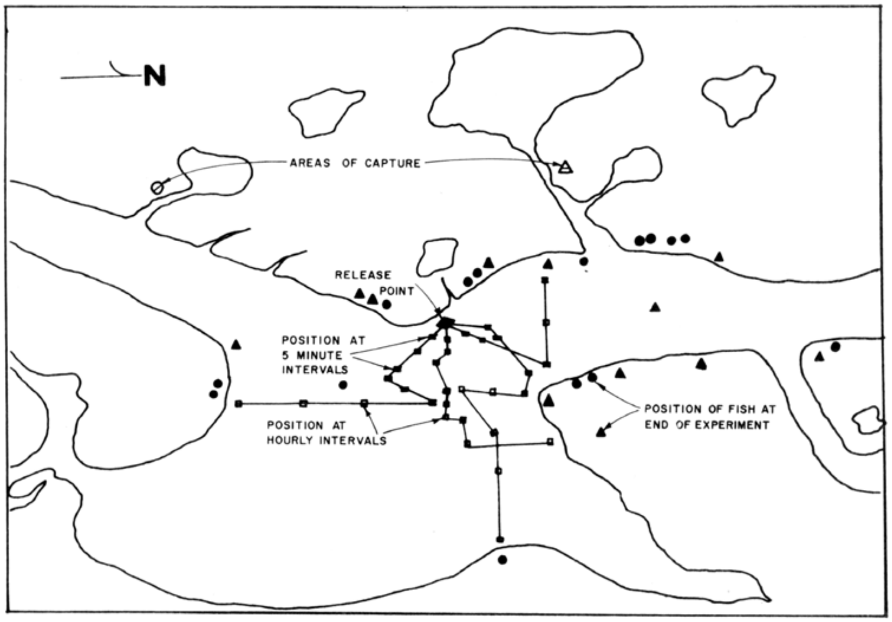

FIGURE 25—Movement of California killifish throughout a tidal cycle determined by styrofoam float marking.

FIGURE 25—Movement of California killifish throughout a tidal cycle determined by styrofoam float marking

11.6. AGE AND GROWTH

Age determination, done by means of scale reading and length frequency (Figure 26), indicated the life span of F. parvipinnis is approximately 18 months with 3% of the adults living for approximately 30 months. One annulus is found in fish 44 to 79 mm (1.73 to 3.11 inches) SL, a second is found in fish 79 to 92 mm (3.11 to 3.62 inches) SL. Young of the year first appeared in June collections. Yet the size range of the June collection and selectiveness of collecting gear suggested that first hatching took place at least as early as May.

Constant appearance of young fish between June and November, tended to mask the growth rate of the population. Two groups of fish; however, did become sufficiently distinguishable to allow analysis. That group of fish ranging in size from 24 to 30 mm (.94 to 1.18 inches) and first distinguishable in June was designated "early-hatched." Killifish ranging in size from 20 to 26 mm (.79 to 1.02 inches) in July were designated "late-hatched" (Figure 26). Due to overlap the data were weighted.

Mean lengths of both groups increased from June to January, and growth appeared linear (Figure 27). When slopes of both groups were compared they were not significantly different ($p = 0.05$). The population growth rate, based on lumping both groups and including the mean size of spawning adults, is linear and described by the equation: $SL = 21.26 + 3.344T$ where: SL = standard length in mm T = time in months

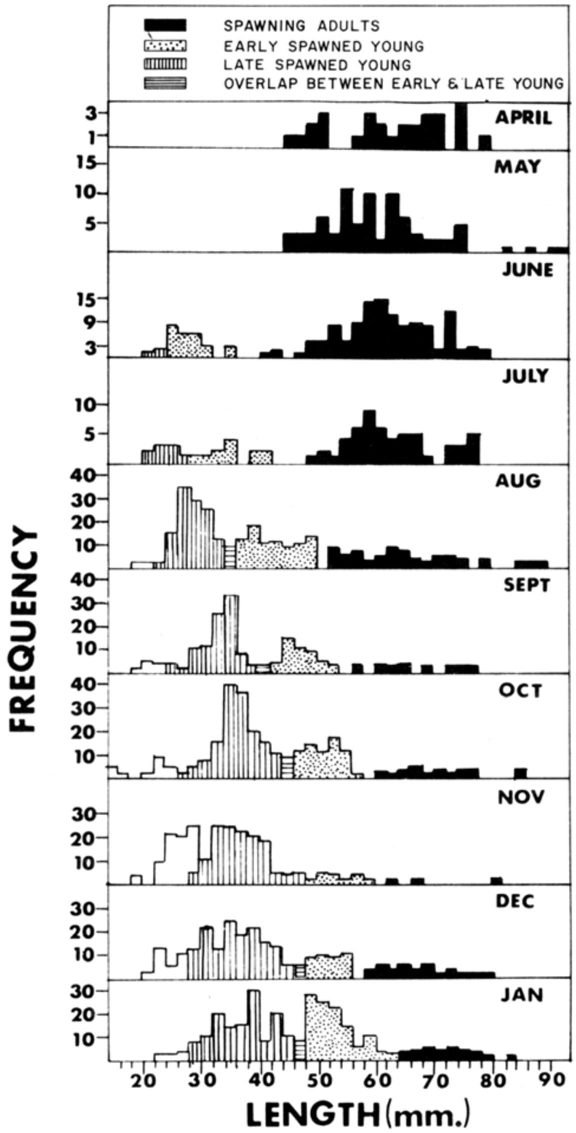

FIGURE 26—Monthly length-frequency histogram of California killifish caught by seine in Anaheim Bay. Note change in frequency scale. Data were weighted for analysis by giving the overlap areas a weight of 1 and the defined areas (both early and late) a weighted value of 2.

FIGURE 26—Monthly length-frequency histogram of California killifish caught by seine in Anaheim Bay. Note change in frequency scale. Data were weighted for analysis by giving the overlap areas a weight of 1 and the defined areas (both early and late) a weighted value of 2

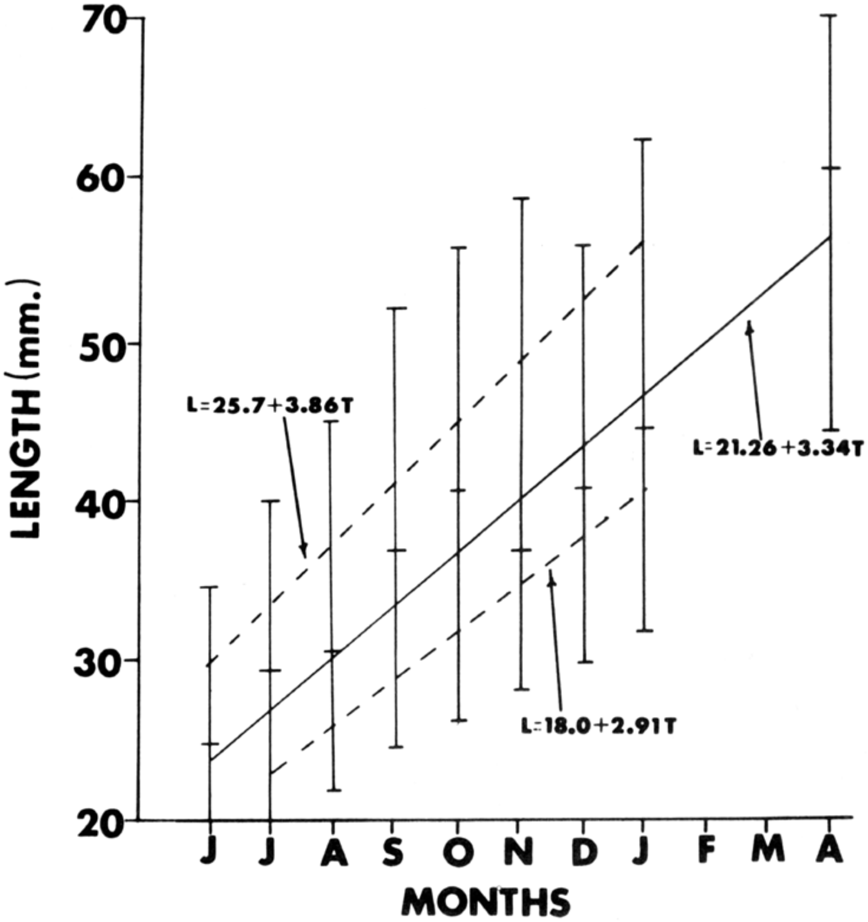

FIGURE 27—Growth of California killifish in Anaheim Bay based on mean lengths of monthly samples. L = 25.7 + 3.86T, early spawned fish; L = 18.0 + 2.91T, late spawned fish; L = 21.26 + 3.34T, combined early and late spawned fish. Long vertical line indicates range for combined data.

FIGURE 27—Growth of California killifish in Anaheim Bay based on mean lengths of monthly samples. L = 25.7 + 3.86T, early spawned fish; L = 18.0 + 2.91T, late spawned fish; L = 21.26 + 3.34T, combined early and late spawned fish. Long vertical line indicates range for combined data

11.7. SPAWNING AND FECUNDITY

California killifish spawn from April through September. Based on the time to hatching of 3 to 4 weeks (Hubbs, 1965) and monthly length-frequencies, it appears that there are three distinct periods of spawning activity occurring in April, May, and June.

While spawning was not observed there was sufficient indirect evidence that spawning occurred within the permanent pools in the grass flats. This evidence includes the presence of large numbers of post-larval fish, continuous water supply, water temperatures that were well within the thermal tolerances for development of F. parvipinnis (Hubbs, 1965), and long periods of exposure to light, a factor shown by Hubbs to increase viability of developing F. parvipinnis embryos.

Mature ova of California killifish possess adhesive strands, the function of which has not been investigated; however, Hubbs reported that ova which clumped together were more viable that those which were loose. Perhaps the strands may provide a mechanism which insures clumping. It also is possible that these strands are structures of attachment similar to those on the ova of banded killifish, F. diaphanus, as reported by Richardson (1939). This would reduce the loss of ova from pools with tidal movements. Thus these ova characteristics indicate adaptation for development in shallow, well lighted water containing substrate suitable for attachment, conditions which exist only in permanent pools.

The majority of California killifish spawn and die between the age of 11 to 18 months. Keys (1931) believed that the majority of spawners would survive the breeding season. However, of 424 fish examined during and immediately after the spawning period, only six (three of each sex) of the spawners were age Class I. All spawning fish of both sexes were larger than 46 mm (1.81 inches); a few ranged up to 91 mm (3.58 inches). Most were from 56 to 76 mm (2.20 to 2.99 inches) in length, with the mean length of spawning males being 59.5 mm (2.34 inches) and the mean length of spawning females 60.1 mm (2.37 inches).

11.8. MATURATION AND FECUNDITY

Male maturation stages were determined qualitatively. Immature male gonads are pale yellow in color, very small, and lie inconspicuously above the posterior hind gut. As maturation occurs, the testes increase in size and overlie the posterior half of the gut. The color at this stage is bluish white. Another indication of maturation is the appearance of two secondary sex characteristics, intensification of color on the body and fins, especially brassy-yellow coloration of the ventrolateral portion of the body, and the development of tubercles on scales and fins. Such characteristics were found by Newmann (1907) in the mummichog, F. heteroclitus, striped killifish, F. majalis, banded killifish, F. diaphanus, and sheephead minnow, Cyprinodon variegatus.

TABLE 10

Description of Egg Development from Preserved Specimens.

Stage no.*	Diameter of eggs (range and means in mm)	Egg description	Age of fish (months)	Standard length of fish (mm)
1	0.0 –.03	Very small golden orange	3–11	0–59
2	.07–.18 $\overline{X}$ = .12	Small orange and small white cells	8–12	48–64 $\overline{X}$ = 55
3	.14–.22 $\overline{X}$ = .18	Maturing large cells usually with thick cell wall orange	8–24 usually 11 or 12	48–81 $\overline{X}$ = 59
4	.15–.24 $\overline{X}$ = .21	Ripening large cells thin walled clear with orange spot and adhesive strands	8–18	48–76 $\overline{X}$ = 61
5	.21–.26 $\overline{X}$ = .25	Ripe, large thin walled clear cells with orange spot and adhesive strands	8–24 usually 11 or 12	48–88 $\overline{X}$ = 62
6	variable	Attretic eggs milky white	over 8	48–84

* Stages 2 through 5 are usually present in a single pair of ovaries.

TABLE 10

Description of Egg Development from Preserved Specimens.

Maturation of females was divided into six stages. These stages were subjectively based on ova appearance and diameter (Table 10). Only ova reaching Stage

2 were counted, but ova of all stages were measured. Considerable overlap was observed between the size range of fish and corresponding diameters of ova especially in Stages 2 through 5 (Table 10). This is the result of differing rates of egg maturation within the population through the spawning period and within ovaries of a single individual, yet the time necessary for development from Stage 2 to Stage 5 is regularly 1 month. Dissection of preserved ovaries showed that three portions of the ovaries undergo maturation at different times (Figure 28). The first ova to mature are those located in the posterior third of the ovaries and those located along the posterior two-thirds of the medial surfaces. This is followed by maturation of ova along lateral surfaces of the middle third of the ovaries. Finally, the ova of the anterior third of the ovaries mature. The presence of three areas of egg development explains both the three peaks in spawning and the unusual length of the spawning period.

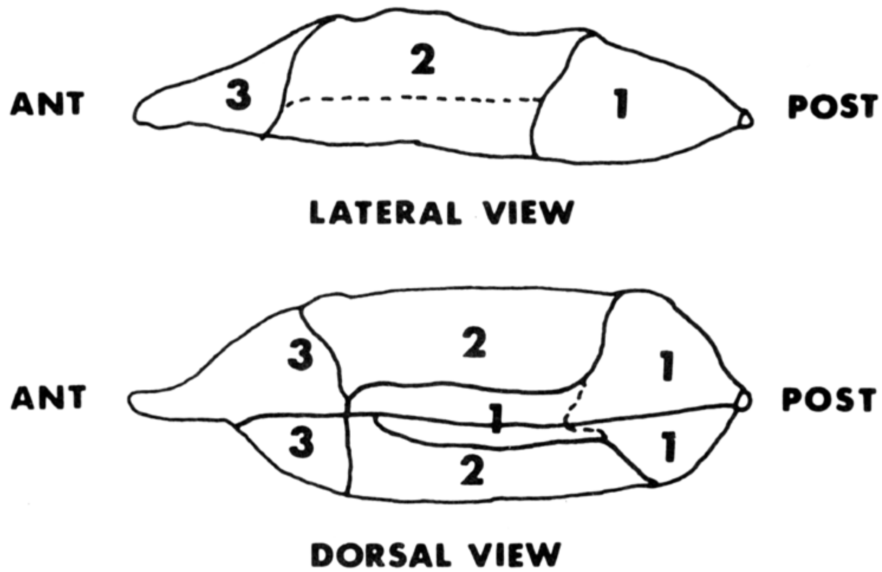

FIGURE 28—Areas of ovary with different rates of maturation, based on dissection of 100 ripe and ripening females. Designation of areas 1, 2 and 3 indicates sequence of maturation within ovary.

FIGURE 28—Areas of ovary with different rates of maturation, based on dissection of 100 ripe and ripening females. Designation of areas 1, 2 and 3 indicates sequence of maturation within ovary

The sequential maturation of three regions of ovaries suggests that female killifish spawn more than once in a breeding season. Further evidence of repetitive spawning may be derived from monthly sex ratios (Figure 29). From April to June the sex ratio of females to males is approximately unity. However, in August the ratio begins to increase. It appears that males spawn over a relatively short period and then die within 1 month of spawning. Females live somewhat longer, possibly for some time after the final spawning. Such a phenomenon would account for the decreased spawning activity from July through September; as the number of males decreased the opportunity for spawning would decrease in consequence. However, there is no positive evidence that single spawning by males is the rule.

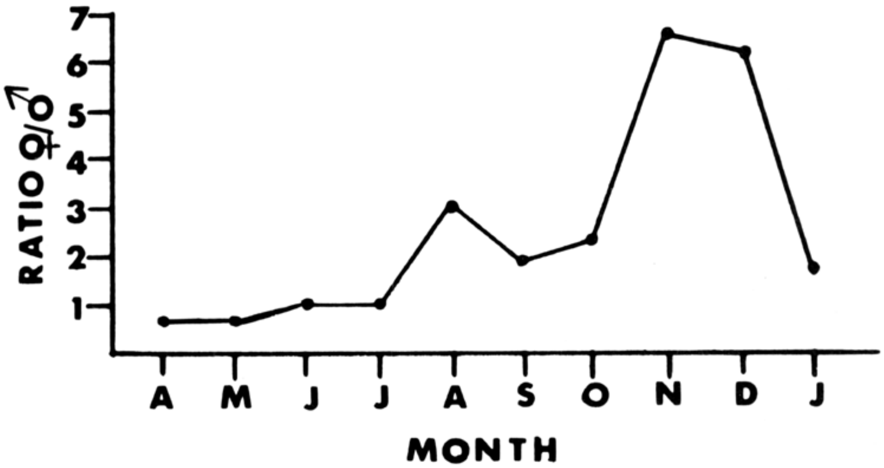

FIGURE 29—Monthly sex ratios, female/male, based on those individuals that could be sexed by dimorphic characters. Note that ratio remains close to 1 during peak spawning, then increases.

FIGURE 29—Monthly sex ratios, female/male, based on those individuals that could be sexed by dimorphic characters. Note that ratio remains close to 1 during peak spawning, then increases

The number of ova produced by F. parvipinnis ranged from 61 to 439 with a mean of 178. There appears to be a relationship between ova number and size of females. The natural logarithm of ova number is linearly related to the standard length (SL) of the fish (Figure 30). An arithmetic relationship between number

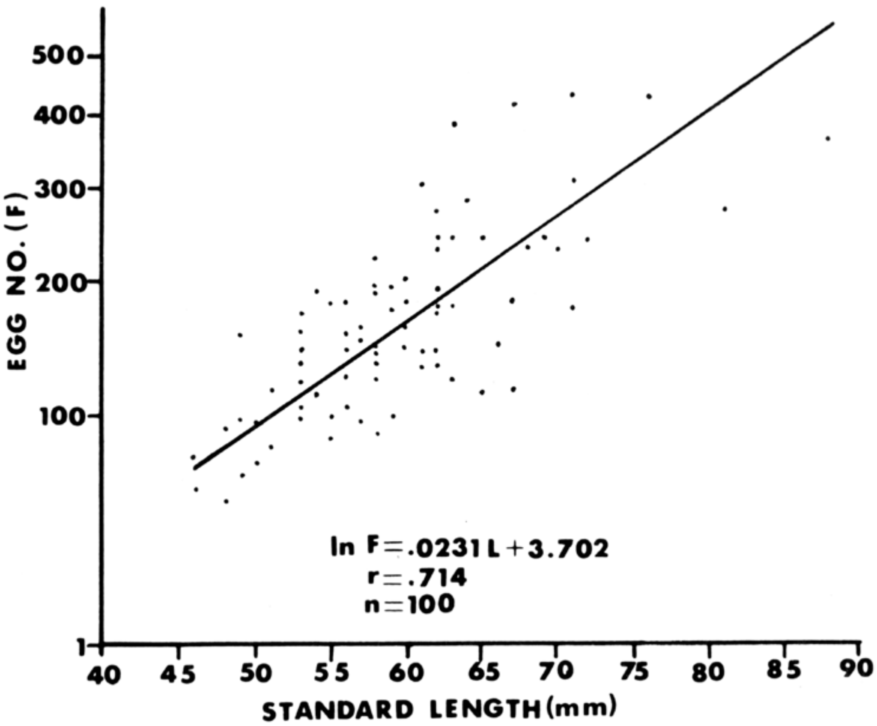

FIGURE 30—California killifish ova number (log scale) with standard length.

FIGURE 30—California killifish ova number (log scale) with standard length

of ova and length exists in the plains killifish, Fundulus kansae (Minckley and Klassen, 1969a). Lane (1967) found that a semilogarithmic relation exists in Atlantic midshipman, Porichthys porosissimus. That such a semilog relation exists is attributed to the fact that ova number is a volumetric characteristic while length is not. The equation was LnF = .0231 SL + 3.702. The coefficient of correlation (r) of these variables is 0.714. Three factors may have contributed to the low value of "r". Those females caught early in the season would have had fewer ova reaching Stage 2 than those caught at the height of the breeding season. Females collected near the completion of spawning would have had fewer ova than those which had not spawned or spawned only once. Differential rates of ova maturation also are subject to individual variation.

11.9. LENGTH-WEIGHT

The length-weight relationship of California killifish is curvilinear (Figure 31) and is described by the equation Log W = 2.899 - 10 + 4.326 Log SL where: W = weight after preservation and SL = length after preservation.

Although the regression complies with the formula $W = aL^b$ given in Ricker (1958), the power term, b = 4.326, indicates that weight increases more than that which is normally attributed to isometric growth. This deviation from isometric growth may be attributed to the long spawning period and the death of adults after spawning. Since most of the fish were caught during breeding season, increased gonadal development would cause an increase in weight. Similar situations were noted by Ricker (1958) to be common among many species. Death of adult killifish shortly after spawning would also prevent the appearance of weight reduction normally occurring in postspawning adults.

11.10. FOOD AND FEEDING

Food and feeding were determined by examining stomach contents of 300 fish. After removing the digestive tract, position of food and contents were noted. All food items were counted to determine abundance. Small food items were subjectively equated to large items by means of caloric values obtained from Cummins (1967). The presence of a single organism in a gut was considered notable as food only when found in the guts of other specimens of the same sample. Food items were identified to the smallest taxonomic group possible, and were listed along with their frequencies of occurrence (i.e., the percentage of stomachs containing a food item; Table 11).

Food of F. parvipinnis consists mainly of arthropods with annelids, gastropods, fish ova, and algae making up a minor part of the diet. Amphipods, copepods, ostracods, and dipteran insects appear to be the most important food items since they comprise the highest percentage of food items in the diet, and have a high frequency of gut occurrence throughout the study (Tables 11 and 12). Although no one family of dipteran insects occurred in more than 24.8% of the guts analyzed, different families and different life stages showed high frequency of occurrence (Table 11). Hemipteran insects make up a major portion of the diet from June to September, yet become a less important food item during cooler months.

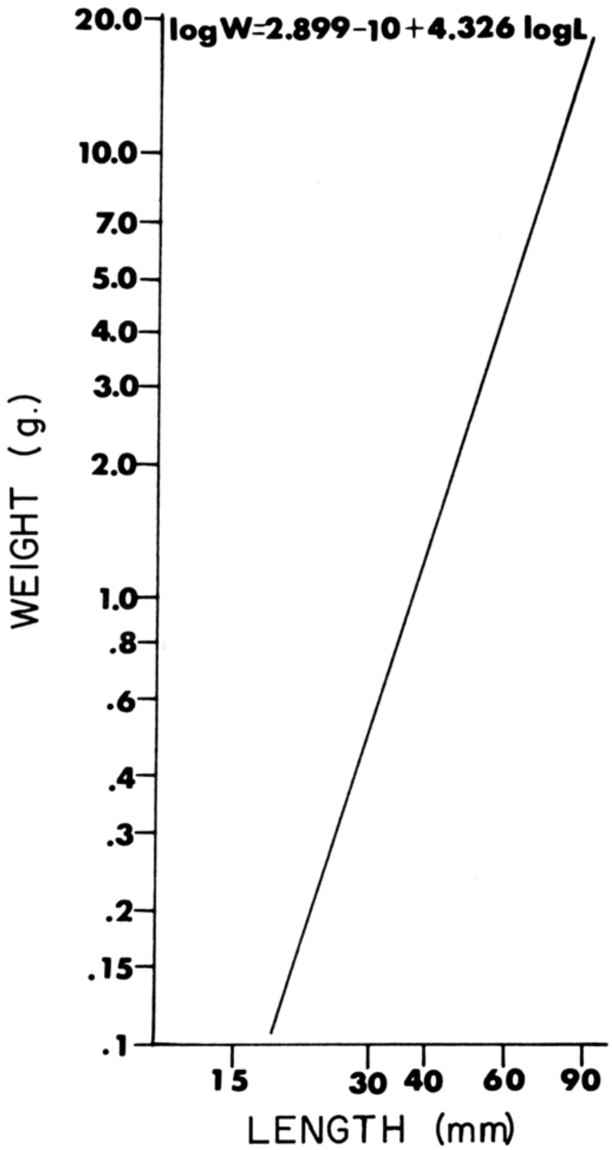

FIGURE 31—Length-weight regression of California killifish from Anaheim Bay.

FIGURE 31—Length-weight regression of California killifish from Anaheim Bay

F. parvipinnis does not change its food habits with size. A comparison between the frequencies of occurrences of food identified in 60 fish ranging in size from 22 to 40 mm (.87 to 1.57 inches) and that identified in the total sample shows that with the exception of isopods no differences were noted (Tables 11 and 13).

TABLE 11

Phylogenetic List of Food Items with Their Frequencies of Occurrence Found in 300 California Killifish.*

ANIMALS

- **Phylum Annelida**
  - **Class Polychaeta**
    - **Cirratulidae**
      - *Cirriformia* sp. (1.4%)**
    - **Ophellidae**
      - *Armandia bioculata* (0.3%)
    - **Capitellidae**
      - *Capitata ambiseta* (0.3%)
    - **Unident.** (0.3%)
- **Phylum Arthropoda**
  - **Class Crustacea**
    - **Subclass Ostracoda**
      - **Myodocopa** (47.4%)
    - **Subclass Copepoda**
      - **Harpactidae** (42%)
    - **Subclass Malacostraca**
      - **Isopoda**
        - **Ligiidae**
          - *Ligia* sp. (10.8%)
      - **Amphipoda**
        - **Corophiidae**
          - *Corophium acherusicum* (27.5%)
        - **Gammaridae**
          - *Elasmopus rapax* (32.6%)
      - **Decapoda**
        - **Callianassidae**
          - *Callianassa gigas* (1.4%)
        - **Gapsidae**
          - *Hemigrapsus oregonensis* (0.3%)
        - **Unident. zoaea** (0.3%)
  - **Class Insecta**
    - **Order Hemiptera**
      - **Heteroptera**
        - **Cicadellidae** (36.5%)
      - **Hemoptera**
        - **Saldidae**
          - *Saldida* sp. (27.5%)
    - **Order Diptera**
      - **Calliphoridae** (8.6%)
      - **Chloropidae** (2.5%)
      - **Ephydridae** (4.7%)
      - **Ephydridae larvae** (4.7%)
      - **Psychodidae** (6.8%)
      - **Psychodidae larvae** (2.5%)
      - **Psychodidae pupae** (15.5%)
      - **Unident. larvae type 1** (6.3%)
      - **Unident. larvae type 2** (8.5%)
    - **Order Hymenoptera**
      - **Apidae** (1.0%)
    - **Order Coleoptera**
      - **Hydraenidae** (1.4%)
    - **Unident egg cases** (0.3%)
- **Phylum Mollusca**
  - **Class Gastropoda** (7.9%)
  - **Class Pelecypoda** (0.3%)
- **Phylum Chordata**
  - **Class Teleostei**
    - **Cyprinodontidae**
      - *Fundulus parvipinnis* **eggs** (3.9%)
    - **Gobeidae**
      - *Clevelandia ios* (0.3%)

PLANTS

- **Phylum Cyanophyta**
  - *Oscillatoria* (5.3%)
- **Phylum Chlorophyta**
  - *Enteromorpha crinata* (1.4%)
- **Phylum Bacilariophyta** (6.0%)

MISCELLANEOUS

- **Unident. gray material**—possibly mud (18.1%)
- **Unident. chitinous tubes** (12.3%)

* Fish were both adult and juvenile, collected throughout the study area from April 1969 to January 1970.
** The percentage indicates the frequency of occurrence of a food item in 276 stomachs containing food.

TABLE 11

Phylogenetic List of Food Items with Their Frequencies of Occurrence Found in 300 California Killifish.

Feeding activity of California killifish is correlated with the tide. This phenomenon also was observed among mummichogs by Moore (1922), and by Buttner and Brattstrom (1960). By relating the phase of the tide to food position in the guts of fish caught at each phase (Figure 32a), it was found that most feeding occurs after high slack tide. The increase in numbers of fish having food in the foregut during middle rising tide indicates that some feeding occurs at this time. Fish with food in their stomachs at low tide may well have come from the grass lined side channels rather than the mud lined main channel. Food is more accessible in such side channels at all tides. Thus the evidence indicates that the relationship between tide and feeding is one of access to feeding grounds. During periods when a low high tide follows a high ebb tide, feeding appears to be continuous since water always covers a large portion of the grass flats and access for feeding is possible (Figure 32b).

TABLE 12

Monthly Lists of the Frequency of Occurrence and Proportion of the Total Diet of Food Items Eaten by California Killifish.*

	% Occ.	% of diet	% Occ.	% of diet	% Occ.	% of diet	% Occ.	% of diet
	April		May		June			
Ostracoda	30.7	21.0	37.9	16.1	41.5	15.3		
Copepoda	69.2	47.3	79.3	33.8	24.6	9.0		
Isopoda	0.0	0.0	3.4	1.4	0.0	0.0		
Amphipoda	7.6	5.2	31.0	13.2	60.0	22.1		
Hemiptera	0.0	0.0	3.4	1.4	70.7	26.1		
Diptera	15.3	10.5	27.5	11.7	30.7	11.3		
Mollusca	0.0	0.0	3.4	1.4	10.7	3.9		
Algae	0.0	0.0	0.0	0.0	3.0	1.1		
Misc.	23.0	15.7	48.2	20.5	29.2	10.7		
	July		Aug.		Sept.			
Ostracoda	31.5	12.2	5.0	1.7	26.0	8.6		
Copepoda	47.8	22.4	17.5	6.1	26.0	8.6		
Isopoda	0.0	0.0	27.5	9.6	26.0	8.6		
Amphipoda	26.3	10.2	62.5	21.9	73.9	24.6		
Hemiptera	42.1	16.3	62.5	21.9	47.8	15.9		
Diptera	36.8	14.2	32.5	11.4	47.8	15.9		
Mollusca	5.2	2.0	12.5	4.3	13.0	4.3		
Algae	10.5	4.0	22.5	7.8	17.3	5.7		
Misc.	47.3	10.7	42.5	14.9	21.7	7.2		
	Oct.		Nov.		Dec.		Jan.	
Ostracoda	51.8	18.6	66.6	16.6	57.1	15.2	53.3	21.0
Copepoda	44.4	16.0	50.0	13.6	32.1	8.5	40.0	15.7
Isopoda	3.7	1.3	33.3	9.0	17.8	4.7	6.6	2.6
Amphipoda	44.4	16.0	83.3	22.7	81.4	20.9	60.0	23.6
Hemiptera	25.9	9.3	27.7	7.5	67.8	18.0	20.0	7.8
Diptera	66.6	24.0	66.6	16.6	57.1	15.2	33.3	13.1
Mollusca	7.4	2.6	0.0	0.0	17.8	4.7	6.6	2.6
Algae	11.1	4.0	33.3	9.0	7.1	1.9	13.3	5.2
Misc.	0.0	0.0	0.0	0.0	39.2	10.4	20.0	7.8

* Percentage of diet was determined from counts of caloricly equated food items.

TABLE 12

Monthly Lists of the Frequency of Occurrence and Proportion of the Total Diet of Food Items Eaten by California Killifish.

The array of foods eaten by F. parvipinnis indicates that feeding occurs throughout the water column. Bottom feeding by the banded killifish has been noted by Forbes (1883), Pearse (1918), and Smith (1947), and by the mummichogs (Moore, 1922). The presence of adult terrestrial insects indicates the possibility of surface feeding. Surface feeding among mummichogs has been inferred by Moore (1922) and Chidester (1916) who noted that mosquito larvae and pupae made up an important part of the diet of F. heteroclitus. Surface feeding by killifish also was observed in the laboratory where 20 specimens throve on a diet of floating freeze dried tubifex worms.

11.11. BEHAVIOR

The California killifish appear to go through stages of decreasing social attraction with advancing age. Shortly after hatching, young killifish were observed to display characteristics used by Breder (1959) to describe schooling behavior. As young fish enter the adult population, schooling behavior declines. At this time interaction among fish was observably reduced to an aggregation, according to Breder's definition. The social attraction that does exist within the aggregation apparently diminishes during high tide when the fish are foraging for food.

11.11.1. Escape Behavior

When killifish are disturbed, their most obvious response is rapid swimming toward any object that might afford cover. In the natural environment the cover consists of the grasses and filamentous green algae of the area. This furtive cover-seeking behavior was in evidence in aquaria. After being disturbed the fish were observed huddling under rocks and in corners of the aquarium.

During periods of fright, when plant cover is unavailable, California killifish were noted entering either pelecypod siphon holes or shrimp holes, or burrowing directly into the mud. Burrowing and "hole entering" behavior was commonly observed among fish of intermediate size, 20 to 52 mm (.79 to 2.05 inches) SL. F. parvipinnis burrows by penetrating head first and then propelling itself forward by strong body undulation of the trunk, much in the same manner as described for the plains killifish by Minckley and Klassen (1969a, 1969b).

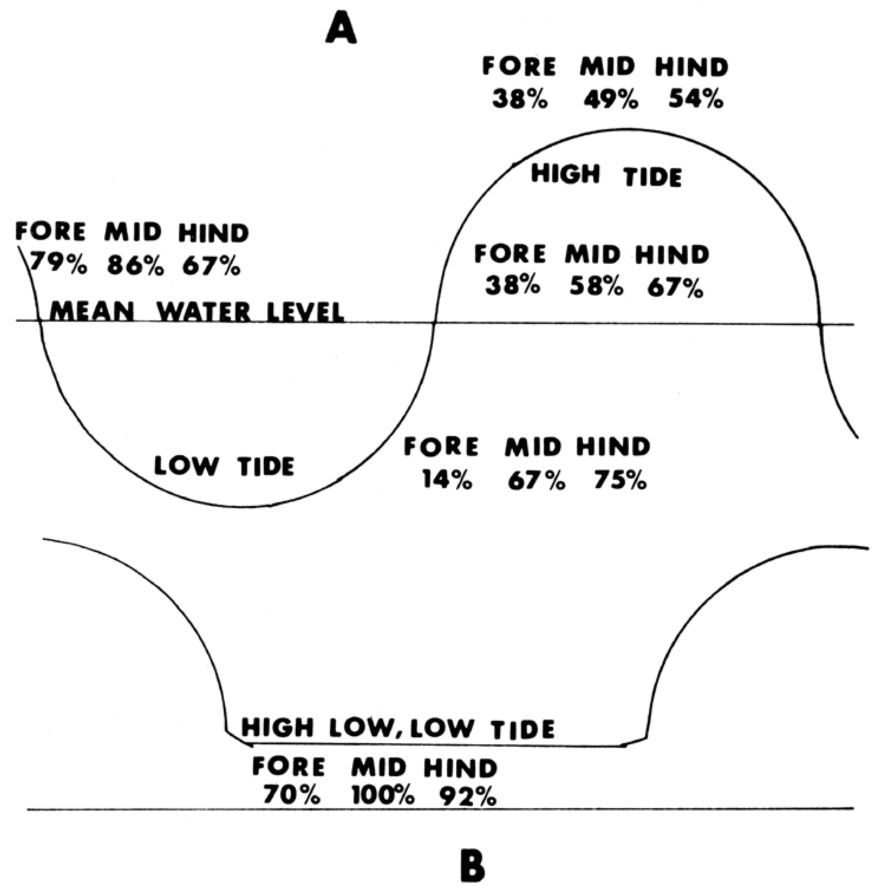

FIGURE 32—Relationship between feeding and tide indicated by fish collected throughout the study. A, feeding during normal tidal fluctuations; B, feeding during high low and low high tides. Percentages indicate the proportion of the various areas of the gut that contained food.

FIGURE 32—Relationship between feeding and tide indicated by fish collected throughout the study. A, feeding during normal tidal fluctuations; B, feeding during high low and low high tides. Percentages indicate the proportion of the various areas of the gut that contained food

If stranded on mud by the ebbing tide, California killifish display "flipping" behavior. This behavior is characterized by the fish jumping or flipping itself in the direction of water. No matter where the fish is in relation to water it always moves toward the nearest water. Similar behavior has been described for the striped killifish (Bigelow and Schroeder, 1953).

TABLE 13

Phylogenetic List of Food Items Found in Juvenile California Killifish.*

ANIMALS

Phylum Annelida (0.0%)**
Phylum Arthropoda
  Class Crustacea
    Ostracoda (38.3%)
    Copepoda (55.0%)
    Malacostraca
      Isopoda (23.3%)
      Amphipoda
        Elasmopus rapax (26.6%)
        Corophium acherusicum (25.0%)
  Class Insecta
    Hemiptera
      Cicadellidae (43.3%)
      Saldidae (15.0%)
    Diptera
      Calliphoridae (1.6%)
      Chloropidae (3.3%)
      Ephydridae larvae (1.6%)
      Psychodidae (1.6%)
      Psychodidae larvae (3.3%)
      Psychodidae pupae (20.0%)
      Unident. adults (0.0%)
      Unident. larvae type 1 (5.3%)
      Unident. larvae type 2 (6.3%)

PLANTS

Phylum Cyanophyta
    Oscillatoria (4.9%)
Phylum Chlorophyta
    Enteromorpha crinata (1.6%)
Phylum Bacillariophyta (5.3%)

MISCELLANEOUS

Unident. gray material (18.3%)
Unident. chitinous tubes (18.3%)

* Fish were collected throughout the study area from June 1969 to November 1969.
** The percentage indicates the frequency of occurrence of a food item in 60 stomachs containing food.

TABLE 13

Phylogenetic List of Food Items Found in Juvenile California Killifish.

12. THE LIFE HISTORY OF THE SHINER SURFPERCH CYMATO-GASTER AGGREGATA GIBBONS, IN ANAHEIM BAY, CALIFORNIA

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12.1. INTRODUCTION

The shiner surfperch, Cymatogaster aggregata Gibbons, is a member of the family Embiotocidae. The species ranges from Port Wrangell, Alaska, to San Quinten Bay, Baja California, encompassing the entire eastern Pacific saltwater distribution of the family Embiotocidae. Commonly taken by sportfishermen, shiner surfperch have slight commercial value, primarily as bait (Tarp, 1952). First described by Gibbons (1854), the taxonomy of the genus and species has remained constant to this date, with only one additional species, the island surfperch, Cymatogaster gracilis, described (Tarp, 1952).

Embiotocids are amphiPacific in distribution, with 21 representative species in the eastern Pacific and two species in Japanese and Korean waters. Only two other embiotocid species, the pile perch, Damalichthys vacca Girard, the striped surfperch, Embiotoca lateralis Agassiz, are as widely distributed as the shiner surfperch (Tarp, 1952).

Age and growth of shiner surfperch from Puget Sound, Washington, was discussed by Suomela (1931), while its life history in British Columbia waters was studied by Gordon (1965). Boothe (1967) reviewed food and feeding of four species of fish, including the shiner surfperch from San Francisco Bay, California, and Anderson and Bryan (1970) discussed age and growth of three embiotocids, including shiner surfperch from Humboldt Bay, California.

The viviparous mode of reproduction present in Embiotocidae has been the subject of a great deal of investigation since it was first described by Agassiz (1853). Much of this work has been done by Wiebe (1968a, 1968b, 1968c, 1968d, 1969a, 1969b), primarily on the modifications for a viviparous mode of reproduction.

Miller (1943) reported predation on shiner surfperch by Caspian terns, Hydropogne caspia, and Hubbs, Kelly, and Timbaugh (1970) record the same predation by Brandt's cormorant, Phalocrocorax penicillatus.

The objectives of this study were to define the life history of the shiner surfperch in Anaheim Bay at the more southerly end of its range, and to compare this information to that published about other areas in the range.

12.2. MATERIALS AND METHODS

Collections for this study were made between April 1970 and March 1971, during biweekly trawling operations. The collection schedule consisted of three daylight collections, followed by three night samples, covering all stages of tidal fluctuation.

Collection gear was a shrimp otter trawl. This trawl measured 4.9 m (16.08 feet) in width at the mouth, and 11.9 m (39.04 feet) from the cork line to the cod end, including a 1.2 m (3.94 feet) bag. It was equipped with a tickler chain and weighted otter boards measuring 0.4 X 0.7 m (1.31 X 2.30 feet). The trawl was constructed of 3.71 cm (1.46 inches) stretch mesh (1.85 cm bar, .73 inches) nylon netting at the throat, the cod end consisting of 2.54 cm (1 inch) stretched mesh (1.27 cm bar, .50 inch) nylon netting, protected by chafing gear. The netting was treated with "Net Set", giving it a black color. A 0.63 cm (.25 inch) woven nylon liner was added to the cod end of the trawl on May 3, 1970, after it became apparent that the smaller fish were not being adequately sampled. The trawl was towed with a 14 foot skiff powered by an 18 horsepower motor. Trawls were 3 minutes in duration at a speed of approximately 2 knots, except occasionally when net fouling shortened the time.

Specimens collected during this study were fixed for 24 to 48 hours using 4% formaldehyde (10% formalin) in seawater solution, then washed in running water and preserved in 40% isopropyl alcohol for later use.

Measurements are as described in Hubbs and Lagler (1947). These were taken before and after preservation, so the effects of preservation could be determined. Standard lengths were measured to the nearest mm and weighted to the nearest 0.1 g after blotting away all excess preservative. These specimens were used for length-weight, age structure, growth, food and feeding, sex ratio, and fecundity determinations. Further discussion of materials and methods will be given in those sections where they directly apply.

12.3. ENVIRONMENTAL DESCRIPTION

12.3.1. Study Area

The study area was located in the middle arm of Anaheim Bay, and comprised an area of approximately 102,000 m^2 (27.64 acres). Three trawl stations were established, each approximately 200 m (656.20 feet) in length (Stations 2, 3, and 4; Figure 22).

Station 2, at the mouth of the middle arm, is bounded on the east side by a shallow sandy mud area that is exposed at low tides. The western side is a mud escarpment. The center of the channel at this station varies from 2 to 5 m (6.56 to 16.41 feet) in depth. The area of this station is approximately 11,000 m^2 (2.98 acres), or about 11% of the area of the middle arm. Station 3 comprises approximately 15,000 m^2 (4.07 acres), or about 15% of the total channel area, and varies in depth from 1 to 4 m (3.28 to 13.12 feet) at the center of the channel. The channel at this station is bounded on the north by shallow mudflats, and on the south by shallow mudflats and a short mud escarpment. Station 4 is furthest from the mouth of the channel, shallowest, and smallest in area. The station encompasses approximately 5,000 m^2 (1.36 acres), or about 5% of the total area of the channel. At this station the depth at channel center varies from 0.5 to 2 m (1.64 to 6.56 feet). A mud bar is partially exposed at extremely low tides, making it impossible to trawl this station during these periods. The lower half of the station is bounded on both sides by mudflats and banks, the upper half by steep mud escarpments.

Tidal movements are generally predictable, the major source of variation being the result of high winds. Low tides expose a great number of mudflats, occasionally emptying the upper reaches of channels above the stations. Each station has a channel of such a depth that at least part of it is permanently submerged. High tides partially overflow the banks of the channels, while spring high tides flood the grassflats completely.

12.4. LENGTH-WEIGHT

The length-weight relationship of shiner surfperch was calculated using a random sample of 230 individuals. The relationship is curvilinear, and is described by the equation: $W = 4.91 \times 10^{-4} SL^{3.05}$, or Log W = 3.05 Log SL + 5.69119 - 10, (r = .99) where: W = weight after preservation SL = standard length after preservation. The equation complies with the formula $W = aL^{b}$ given by Ricker (1958), and the exponent b = 3.05 indicates isometric growth.

Parker (1963) reported shrinkage attributable to preservation in 4% formaldehyde and sea water solution to range between 2% and 4% loss in length. Shrinkage was computed for 92 fish and averaged 4.7%.

The relationship between total length (TL) and standard length (SL), is defined by the equation: TL = 1.26 SL + 1.73 (r = 0.98). The relationship between otolith length and standard length also yielded a straight line, defined by the equation: Otolith length = 0.05 SL + 0.48 (r = 0.98).

12.5. AGE AND GROWTH

Cymatogaster aggregata have been recorded to an age of 2½ years in Anaheim Bay. Age determinations were based on otolith aging and a Peterson length frequency plot (Figure 33); substantiated by aging a random sample of scales. Length grouping was performed using the criteria established by Andersen (1964). Otoliths were manually cleaned and stored in water for later use. Aging was done using the reflected light technique described by Gambell and Messtorff (1964). Otoliths were immersed in oil of anise, using the black-bottomed dish described by Schott (1965). Scales were taken from the right dorsal surface, above the lateral line, on a vertical line through the insertion of the pectoral fin. Scales were manually cleaned and mounted between two glass slides for reading. A total of 229 pairs of otoliths was aged, and compared to a sample of 50 scales, selected with a table of random numbers. Total agreement on age determinations was reached in all cases.

The presence of a birth check in shiner surfperch scales was noted by Suomela (1931) and Gordon (1965). This check was observed in all scales and otoliths of shiner surfperch studied during this investigation.

Fish in their first year ranged in length between 31 and 87 mm (1.22 and 3.43 inches) SL, the mean being 56.8 mm (2.24 inches). The second year class ranged from 68 to 115 mm (2.68 to 4.53 inches) SL, with a mean of 87.8 mm (3.46 inches). The third age class ranged between 81 and 117 mm (3.19 and 4.61 inches) SL, with a mean of 100.6 mm (3.96 inches). A logarithmic transformation of these values was made, and a line was fitted through the points. The resulting line is expressed by the equation: Log SL = 8.82 Log T - Log 17.14 (T in years). The slope of this line indicates a rapid annual growth rate for shiner surfperch in Anaheim Bay.

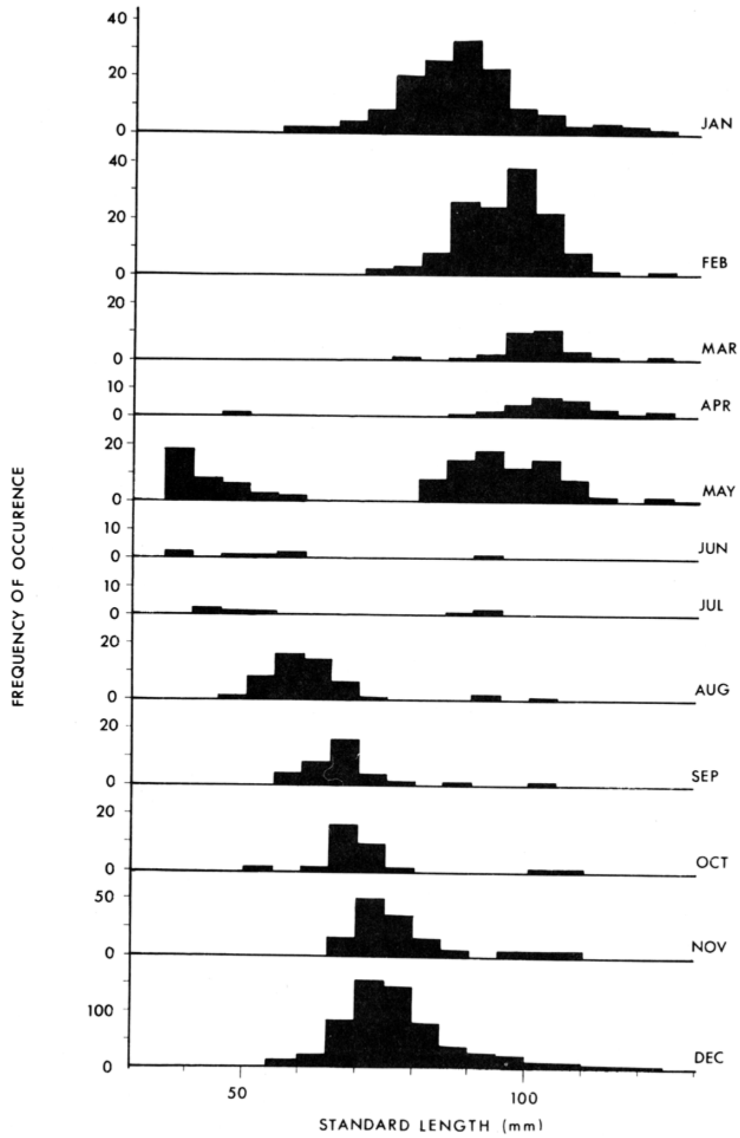

FIGURE 33—Monthly length frequency histograms of shiner surperch captured in Anaheim Bay.

FIGURE 33—Monthly length frequency histograms of shiner surperch captured in Anaheim Bay

Monthly estimates of growth were obtained by arbitrarily establishing January 1 as the date fertilization takes place in shiner surfperch. This decision was based on a published account that fertilization takes place in December (Eigenmann, 1894) and on the gonosomatic index plot for fish from Anaheim Bay (Figure 34).

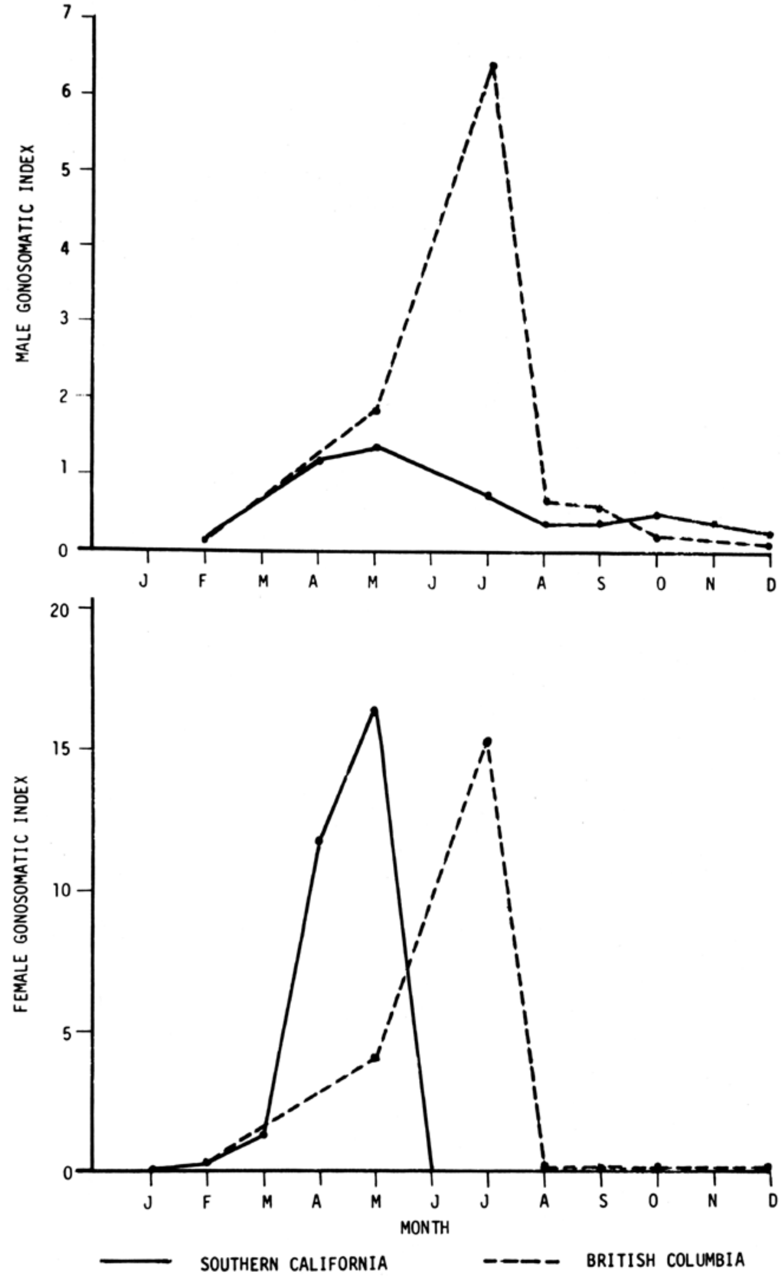

FIGURE 34—Gonosomatic Index for shiner surfperch males and females from Anaheim Bay, compared to British Columbia data from Wiebe (1968d).

FIGURE 34—Gonosomatic Index for shiner surfperch males and females from Anaheim Bay, compared to British Columbia data from Wiebe (1968d)

Each fish was given an age based on date of capture. Thus, a fish taken in August, 3 months after birth, would be termed a 0 + 8, or 8 month old fish. The mean size for each monthly period was then plotted and a line fitted to the points. This line is described by the equation: SL = 5.12 T + 33.98 (T in months). This analysis again yielded a slope indicating a high growth rate. It should be noted that there appears to be more rapid growth from June to December, the warmer time of the year, than from January to May. The different slopes found using the two methods may be due to the first being an annual rate over three age classes, and the second being a monthly rate over 1 year.

Average daily instantaneous growth rates were computed using the same methods as Gordon (1965), so a comparison between shiner surfperch from British Columbia and Anaheim Bay could be made. The instantaneous rate for fish from southern California begins at about the same level as for those from British Columbia, but remains higher over a year, whereas there is a rapid decrease in rates for the British Columbia fish. This difference may be attributable to a combination of warmer waters and possible greater food abundance in Anaheim Bay.

The use of instantaneous growth rate calculations described by Ricker (1958) showed that there is a rapidly decreasing increment of weight with increasing age. The values were derived from the equation: g = Ln (Wt/Wo) where: g = instantaneous growth rate Wo = weight at start of time, and Wt = weight at the end of the time period (1 year). These values are 0.55 for the 0–1 year period, and 0.15 for the 1–2 year period.

12.6. FOOD AND FEEDING

Food and feeding analysis was based on 138 samples, selected randomly from semimonthly collections. The digestive tract was removed from each fish, and position of food noted. The tract was divided into four distinct sections (Figure 35) as described in Gordon (1965). A visual estimate of the percentage of the total volume in the tract occupied by various food organisms in each section was noted. The contents of the entire tract were then emptied into a small glass dissecting dish and examined under a binocular microscope. The food organisms were identified and placed in the general categories; algae (Enteromorpha sp. and Ulva sp.), polychaetes, gastropods (Tegula sp. and Olivella sp.), pelecypods (Mytilus edulis) , eggs of the top-smelt, Atherinops affinis, which are associated with a benthic habitat, and zooplankton which are generally considered to be free floating organisms. The zooplankton were identified to order or subclass and placed under two general headings; the first being large zooplankton which included amphipods, mysids, ostracods, caprellids, large copepods and small shrimp. The second heading was small zooplankton under which were grouped small copepods and the larval stages of larger crustaceans. After food organisms were identified and grouped, an estimate was made of the approximate percentage each group made up of the total food volume.

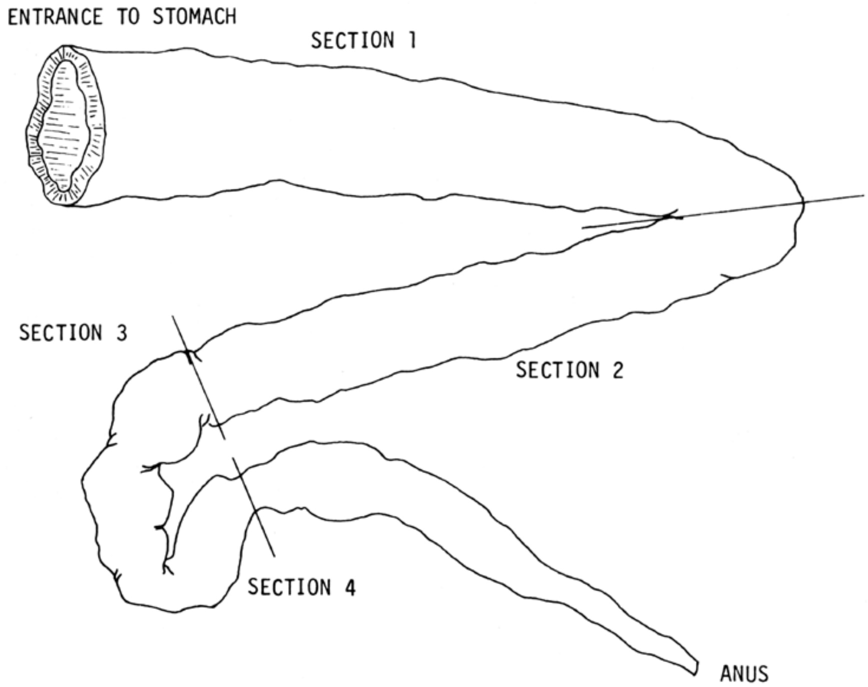

FIGURE 35—Digestive tract of shiner surfperch showing the division of the tract into sections (after Gordon, 1965).

FIGURE 35—Digestive tract of shiner surfperch showing the division of the tract into sections (after Gordon, 1965)

The data were grouped by sex and age of fish, and by season and time of day of capture. The only variation in diet appears to be seasonal in nature (Table 14). Seasons were delineated by temperature data. Thus, spring encompassed April, May, and June; and summer lasted through July, August, and September. Fall consisted of October, November, and December, while winter encompassed January, February, and March.

TABLE 14

Diet of the Shiner Surfperch by Season.

	Spring	Summer	Fall	Winter
Detritus	31.0%	18.3%	18.8%	50.1%
Empty	18.5	0.0	9.4	0.0
Zooplankton				
Large zooplankton	30.4	65.7	54.9	25.2
Small zooplankton	6.5	4.0	10.6	3.5
Total zooplankton	36.9	69.7	65.5	28.7
Benthic				
Pelecypod	1.3	5.3	2.3	8.7
Gastropod	1.1	0.0	0.9	2.8
Polychaete	1.1	0.0	1.6	5.5
Tunicate	0.0	0.0	0.0	0.8
Fish eggs	5.0	0.0	0.0	2.7
Algae	1.7	0.0	0.0	0.8
Total benthic	10.2	5.3	4.8	21.3
Diptera	3.7	6.7	1.6	0.1

TABLE 14

Diet of the Shiner Surfperch by Season.

The prime source of food for shiner surfperch in Anaheim Bay appears to be zooplankton. During summer and fall, periods of high zooplankton abundance, this item composes 60% of the diet of shiner surfperch. During winter, when plankton is less abundant, there is a diet shift and perhaps a change in feeding method. During this period the diet is more varied and 50% of the stomach contents are mud and detritus. This indicates that shiner surfperch are feeding on or in the substrate. Spring appears to be a transitional period, with the highest percentage, nearly 20% of empty stomachs. Anaheim Bay's rich environment allows shiner surfperch to feed continually, and may explain the remarkably high growth rates the species attains in this area.

12.7. BIRTH AND FECUNDITY

The sex ratio of shiner surfperch in Anaheim Bay was determined from 1,234 specimens. of these, there were 590 males and 644 females. This ratio did not significantly differ from a 1:1 sex ratio when tested by the Chi Square method.

The onset of birth for shiner surfperch in Anaheim Bay was estimated from catch data (Figure 33), and by computing the gonosomatic index. The gonosomatic index (GSI) is a measurement of gonad development, and is defined as:

$$\text{GSI} = \frac{\text{Reproductive tract weight (gms)}}{\text{Body weight (gms)}} \times 100$$

FORMULA

and thus is expressed as a percentage (Weibe, 1968d).

The first indication of the presence of young shiner surfperch was in April (Figure 33), and the bulk of the young were born in May. The plot of the GSI (Figure 34) confirms these data, and shows May as the point where birth takes place. This is in marked contrast to the time of birth in more northern waters. Wiebe (1968d) plotted the GSI for fish in British Columbia and showed July as the month in which shiner surfperch were born. This difference in time of birth can be attributed to warmer temperatures and/or higher growth rate in Anaheim Bay.

Gordon (1965) calculated the average number of embryos carried by mature females in British Columbia. He concluded that there was a tendency for the number of embryos to increase as body length increased. The same data for southern California were computed, and reflect a similar trend with between 6 and 16 embryos per female (Table 15).

TABLE 15

A Comparison of the Standard Length of the Mother and the Average Number of Embryos per Female in the Shiner Surfperch.

Mothers' Length (mm)	Southern California (Anaheim Bay)	British Columbia (Gordon 1965)
90–94	6 (1)*	--
95–99	--	7 (12)
100–104	7 (6)	9 (21)
105–109	9 (3)	9 (56)
110–114	9 (5)	10 (19)
115–119	9 (6)	10 (23)
120–124	11 (3)	13 (11)
125–129	--	12 (8)
130–134	15 (1)	--
135–139	16 (1)	--

* Number in parentheses is sample size.

TABLE 15

A Comparison of the Standard Length of the Mother and the Average Number of Embryos per Female in the Shiner Surfperch.

The shiner surfperch has been reported to be eurythermal (Tarp, 1952), with a temperature range of 4 to 21 C (39 to 70 F). The Anaheim Bay population appeared to be limited by a temperature somewhat below the recorded maximum for the species. The first indication of this limitation came from catch data for the months of June, July, and August 1970. On days when water temperatures exceeded 18.5 C (65 F), the catch in the middle arm fell off markedly.

This observation was confirmed in the laboratory, when the aquaria in which some shiner surfperch were being maintained, accidentally exceeded 18.5 C (65 F). At 18.5 C or slightly above, the fish began dying. Within 5 days, all fish in the aquaria were dead. The dissolved oxygen level never fell below 7.0 ppm. This evidence, though not conclusive, would seem to indicate the presence of a thermal barrier for the population which may be somewhat more conservative than that for the species as a whole. No attempt was made to establish the critical thermal minimum for the population.

12.8. SUMMARY

The shiner surfperch is a common species along the coast of California. It is not of great importance, although commonly taken by sportfishermen.

This species lives approximately 2½ years in Anaheim Bay, and has a very fast growth rate. The annual and monthly estimates of growth indicates slopes of 8.82 and 5.12 respectively when time is plotted against length in mm. These are extremely high, and probably the result of warm waters and a highly productive environment.

Feeding takes place continuously, with the primary source of food being zooplankton. During periods of low plankton abundance, shiner surfperch shift to a diet of benthic organisms, including pelecypods, gastropods, polychaetes, tunicates, and fish eggs.

Time of birth for shiner surfperch in Anaheim Bay is earlier than in British Columbia, again an indication of the warmer, more productive environment.

The shiner surfperch population in Anaheim Bay ranges throughout the bay and appears limited only by high temperature. Shiner surfperch left the upper reaches of the bay when the temperature began to exceed 18.5 C (65 F). This limit for the population is in contradiction to species temperature range of 4 to 21 C (39 to 70 F) as reported by Tarp (1952).

13. NOTES ON THE FAMILY GOBIIDAE FROM ANAHEIM BAY

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13.1. INTRODUCTION

Five species of gobiid fish are known from Anaheim Bay. These include the arrow goby, Clevelandia ios (Jordan and Gilbert); shadow goby, Quietula y-cauda (Jenkins and Evermann); longjaw mudsucker, Gillichthys mirabilis Cooper; cheekspot goby, Ilypnus gilberti (Eigenmann and Eigenmann); and the bay goby, Lepidogobius lepidus (Girard).

Gobies are permanent residents of both the intertidal and subtidal zones of Anaheim Bay and serve as food for many teleosts and elasmobranchs. All of the mentioned species are restricted to areas of soft substrate and most have commensal relationships with burrowing invertebrates.

13.2. MATERIALS AND METHODS

Gobies were collected monthly from February 1971 to March 1972 at five study areas (Stations 1, 2, 3, 4, and 6: Figure 22) with a 3.2 mm (0.13 inch) bar mesh bag seine 27.7 x 3.7 m (90.98 x 12.14 ft.). Other collections were made with an otter trawl (see chapter on the life history of the shiner surfperch) or by substrate sampling the intertidal zone during low tide. Specimens were fixed in the field with 5% formaldehyde and sea water, then washed and stored in 40% isopropyl alcohol.

Preserved specimens were weighed to the nearest 0.1 g and measured to the nearest mm. All lengths given in the paper are standard lengths (SL) unless otherwise stated.

Terminology describing vertical zonation of the habitat follows that of Ricketts and Calvin (1968).

Other materials and methods will be given in those sections where they directly apply.

13.3. SPECIES NOTES

13.3.1. Arrow goby, Clevelandia ios. (Jordan and Gilbert)

The arrow goby inhabits estuaries, lagoons, and tidal sloughs from San Bartolome Bay, Lower California (Hubbs, 1916) to Vancouver Island, British Columbia (Clemens and Wilby, 1961). It occupies the middle and low intertidal and subtidal zones throughout the channels of Anaheim Bay, living free and commensally in the burrows of the echiuroid worm, Urechis caupo; ghost shrimp, Callianassa sp.; and blue mud shrimp, Upogebia pugettensis.

Arrow gobies were the most abundant goby in Anaheim Bay reaching peak numbers during the summer months. Substrate sampling at low tides in January, revealed they burrowed in the middle intertidal zone at concentrations between three and four individuals per m^2 over wide areas, but as many as 20 individuals per m^2 were found burrowed in a few locations. Population densities were lower throughout the year in sandy areas, and seemingly independent of the number of invertebrate burrows in which arrow gobies could gain shelter.

Activity of the arrow goby in the intertidal zone is primarily controlled by the tidal cycle. When the tide recedes the arrow goby enters burrows of its commensal invertebrates. If a shallow film of water remains over the burrows this fish often makes short, rapid excursions from burrow to burrow.

Day and night seine catch records indicate that the arrow goby is more active at lower light intensities; however, several of the largest catches were made in turbid waters during full daylight.

Fighting, chasing, nipping, threat, and courtship displays were observed during the breeding season. When grouped in a tank, a few of the larger fish dominated the remaining fish; no further social hierarchy was evident. At high tide, arrow gobies are characteristically found resting near the entrance of an invertebrate burrow. If danger threatens one fish will impart a flash of reflected light as it turns its silver belly upwards for the headfirst dive into the burrow for protection. The sign stimulus seems to induce burrowing responses in other nearby gobies which in turn impart the sign stimulus. Within seconds the entire population over a wide area of the mudflat are in burrows.

The silver belly also appears to be used as a sign stimulus or releaser in what seems to be a courtship display by the male. When light intensities diminish to twilight levels this behavior is most frequently evident. The male with fins blackened and extended, swims a short distance forward, stops, and then with a single thrust of its tail, arcs off the bottom, rolling on its side to expose the silver belly. A flash of reflected light is imparted and the arrow goby returns upright with enough momentum to carry itself forward for one or two body lengths. This pattern was repeated in an uninterrupted fashion for as many as ten consecutive times and appeared to be an exaggerated imitation of ovideposition by females.

The prolonged breeding season of arrow gobies in Anaheim Bay is similar to that in Elkhorn Slough, California (Prasad, 1959b). Peak spawning occurred between February and June, with some spawning in December, January, July, August, and September. Ovarian development is not synchronous. Ovaries of breeding females were found in various stages of maturation during the spawning season.

Eggs of arrow gobies are benthic and adhere to the substrate with a circlet of threads. No parental care is exhibited. According to Prasad (1959b), newly hatched larva are pelagic and positively phototrophic, varying in size from 2.75 to 3.25 mm (0.11 to 0.13 inches) TL.

Plankton tows inside Anaheim Bay suggest arrow gobies leave the surface waters at approximately 8 mm (0.31 inches) length. By 10 to 14 mm (0.39 to 0.55 inches) they assume the adult behavior pattern and may be collected intertidally in the burrows of Callianassa sp. during low tide. Accompanying this behavior change the swimbladder atrophies, pelvic fins unite, and body pigment increases.

Growth from hatching until the onset of maturity appears rapid. Fish living at temperatures between 20 and 25 C (68 and 77 F) in the laboratory, grew from 11 to 24 mm (0.43 to 0.94 inches) in three months on a diet of brine shrimp eggs. Length frequency relationships for the autumn catches suggested young arrow gobies less than 29 mm (1.14 inches) SL may exhibit growth rates approaching those observed in the laboratory. After the size at first maturity, 29 mm (1.14 inches) is reached (Prasad, 1959b), the growth rate appears to decrease so that the majority of adults are between 30 and 40 mm (1.18 and 1.57 inches). Fish reach a maximum length of 45 mm (1.77 inches).

Growth for the Anaheim Bay population is nearly isometric and the length-weight relationship, excluding females with externally distinguishable ovarian development, is described by the equation. Log W = 2.99 Log SL + 5.715 - 10 where: W = weight in g after preservation SL = standard length in mm after preservation. An examination of the saccular otoliths, cleared in oil of anise and read with reflected light, suggests that many fish lived longer than 1 year. No fish appeared to live beyond the second year.

Females were more prevalent than males; sex ratios averaged 3.3:1 in the monthly catches. During the summer the imbalanced sex ratios were significantly reduced. It is unlikely that imbalanced sex ratios are the result of behavioral differences or gear bias as the entire catch for 1 month and part of the catch for 2 months were obtained by substrate sampling.

Arrow gobies greater than 14 mm (0.55 inches) are primarily benthic carnivores. Harpacticoids, ostracods, nematodes, oligochaetes, and cyclopoids are the most important food items with amphipods, caprellids, and larger oligochaetes important only to larger fish. Pelagic larvae were observed feeding almost exclusively on the callanoid copepod, Acartia tonsa. A cephalocarid was noted in several stomachs. It appears that arrow gobies from Anaheim Bay have less species diversity in their gut contents than the Elkhorn Slough population studied by Prasad (1959a). Isopods and filamentous algae were not observed. Nauplii, zoea, and ova were almost entirely absent. Even in the smallest fish examined (14 mm, 0.55 inches), diatoms and tintinnids constituted an insignificant portion of the total gut content. The author believes these organisms were not actively sought, but entered the stomachs on the setae of crustaceans.

The relationships between arrow gobies and other species in Anaheim Bay are summarized (Tables 16, 17, and 18). California halibut is probably the major predator of arrow gobies. Forty-five percent of the stomachs examined by Haaker (see chapter on the biology of the California halibut) contained gobies.

TABLE 16

Predators of the Arrow Goby in Anaheim Bay.

Paralichthys californicus (Ayres), California halibut	*Porichthys myriaster* Hubbs & Schultz, specklefin midshipman
Hyperprosopon argenteum Gibbons, walleye surfperch	*Anchoa compressa* (Girard), deepbody anchovy
Menticirrhus undulatus Girard, California corbina	*Urolophus halleri* Cooper, round stingray
Genyonemus lineatus (Ayres), white croaker	*Rhinobatos productus* (Ayres), shovelnose guitarfish
Leptocottus armatus Girard, staghorn sculpin	*Fundulus parvipinnis* Girard, California killifish
Hypsopsetta guttulata (Girard), diamond turbot	Probably a few species of birds which probe the ghost shrimp burrows during low tide.
Seriphus politus Ayres, queenfish	

TABLE 16

Predators of the Arrow Goby in Anaheim Bay.

TABLE 17

Competitors for Major Food Sources of the Arrow Goby.

Atherinops affinis (Ayres), topsmelt: nematodes, ostracods, harpacticoids	*Fundulus parvipinnis* Girard, California killifish: ostracods, harpacticoids
Seriphus politus Ayres, queenfish: ostracods	
Quietula y-cauda (Jenkins and Evermann), shadow goby: nematodes, ostracods, harpacticoids, oligochaetes	

TABLE 17

Competitors for Major Food Sources of the Arrow Goby.

TABLE 18

Indirect Competitors (Commensals and Their Predators).

Echiuroid worms	*Genyonemus lineatus* (Ayres), white croaker
Urolophus halleri Cooper, round stingray	*Menticirrhus undulatus* Girard, California corbina
Rhinobatos productus (Ayres), shovelnose guitarfish	*Rhacochilus vacca* (Girard), pile perch
Mustelus californicus Gill, gray smoothhound	*Phanerodon furcatus* Girard, white seaperch
Ghost shrimp	*Paralabrax nebulifer* (Girard), barred sand bass
Urolophus halleri Cooper, round stingray	*Paralabrax maculatofasciatus* (Steindachner), spotted sand bass
Rhinobatos productus (Ayres), shovelnose guitarfish	Numerous shore birds
Mustelus californicus Gill, grey smoothhound	Blue mud shrimp
Gillichthys mirabilis Cooper, longjaw mudsucker	No known predators in Anaheim Bay
Hypsopsetta guttulata (Girard), diamond turbot	
Hyperprosopon argenteum Gibbons, walleye surfperch	

TABLE 18

Indirect Competitors (Commensals and Their Predators).

A more comprehensive and detailed account of the life history of the arrow goby in Anaheim Bay including a meristic study of Californian populations and comments on the cephalic-lateralis system in the family Gobiidae can be found in Macdonald (1972a).

13.3.2. Shadow goby, Quietula y-cauda (Jenkins and Evermann)

The shadow goby occurs in the northern Gulf of California, and along the outer coast from Lower California to Morro Bay, California. This goby often is found in close association with the arrow goby, occupying the middle and low intertidal and subtidal zones throughout the channels of Anaheim Bay, living free and commensally in the burrows of the echiuroid worm, Urechis caupo; ghost shrimp, Callianassa sp.; and blue mud shrimp, Upogebia pugettensis. Substrate sampling suggested that unlike the arrow goby, the larger shadow gobies do not burrow in intertidal zones and are restricted to subtidal regions during low tide.

Shadow gobies grew somewhat larger than arrow gobies reaching a maximum length of 55 mm (2.16 inches) SL. An examination of the otoliths suggests that some of the larger fish lived more than 2 years. No fish caught appeared to be older than 3 years.

The shadow goby comprised approximately 5% by number of the yearly catch of gobies in the middle intertidal zone. In samples of less than 20 individuals, Quietula y-cauda occasionally constituted up to 90% of the catch.

The breeding season of shadow gobies in Anaheim Bay is prolonged like that of the arrow goby; however, the specific limits were not determined. As with arrow gobies, shadow gobies display sexual dimorphism. A prominent black band appears on the anal fin of mature males (Macdonald, 1972b), and the belly of the females is noticeably distended with eggs during the breeding season. The young assume the burrowing pattern at approximately the same size as arrow gobies.

The food of shadow gobies is similar to that of arrow gobies, but in larger fish polychaetes, oligchaetes, caprellids, and amphipods occurred in the gut contents with increased frequency.

13.3.3. Longjaw mudsucker, Gillichthys mirabilis (Cooper)

Longjaw mudsuckers are found in the northern Gulf of California southward on the west side of the Gulf to Mulege, Baja California, and on the east side to Bahía Agiabampo, Sinaloa, and on the outer coast from Bahía Magdalena, Baja California, to Tomales Bay, California (Barlow, 1961). They have been introduced to the Salton Sea (Roedel, 1953).

This is the largest goby found in Anaheim Bay. Adults and larger juveniles occupy one of the highest tidal zones inhabited by fish in the bay. At low tide they can be collected from the burrows of the yellow shore crab, Hemigrapsus oregonensis, along the steep mud banks of the channels.

Adult longjaw mudsuckers were not found in the middle intertidal zone during tidal exposure. Their large body size prevents entrance into any of the invertebrate burrows in this zone and it is presumed that these fish either occupy larger burrows in the high intertidal zone or confine their activities to subtidal regions during low tide. The longjaw mudsucker was collected subtidally with seines and otter trawls, most frequently in the upper reaches of the channels during low tide in isolated pools of trapped water.

The spawning season of the longjaw mudsucker in Anaheim Bay is protracted. Ghost shrimp, Callianassa sp., and yellow shore crabs, Hemigrapsus oregonensis, appear to be important food items for adult fish.

13.3.4. Cheekspot goby, Ilypnus gilberti (Eigenmann and Eigenmann)

The cheekspot goby occurs in the northern Gulf of California and on the outer coast from Bahía Magdalena, Baja California, to Tomales Bay, California.

Cheekspot gobies are often found closely associated with the arrow goby. Hubbs (1921a) secured cheekspot gobies with several arrow gobies in the fresh tidewater region of nearby San Gabriel River in 1916. One cheekspot goby was collected from Anaheim Bay in 1939, and is now in the Los Angeles County Museum of Natural History. No specimens were obtained from the monthly seining of the intertidal zones of the middle and west arms during the present study; however, 3 specimens were taken in the outer harbor in January 1974.

13.3.5. Bay Goby, Lepidogobius lepidus (Girard)

The bay goby is found from Cedros Island, Baja California, to Vancouver Island, British Columbia, inhabiting muddy bottoms down to 110 m (60 fathoms), (Clemens and Wilby, 1961).

One bay goby was collected by otter trawl at 10 to 20 m (4.5 to 11 fathoms) depth between the jetties at the entrance to Anaheim Bay, in a preliminary survey of the outer harbor. Extensive trawling and seining in the shallow waters of the middle and west arms failed to catch another specimen and it is assumed that the bay goby is limited to the deeper waters of Anaheim Bay.

14. ASPECTS OF THE BIOLOGY OF PACIFIC STAGHORN SCULPIN, LEPTOCOTTUS ARMATUS GIRARD, IN ANAHEIM BAY

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14.1. INTRODUCTION

Cottidae is a large diverse family represented by some 40 species in the marine waters of California (Roedel, 1953); almost 10% of California marine fishes (Bolin, 1944). Most species are small in size and are commonly found as bottom fish along the shores of northern regions, in rocky tide pools and to some extent in freshwater (Barnhart, 1936).

The Pacific staghorn sculpin, Leptocottus armatus, is the most common shallow water marine cottid found on the Pacific coast of North America (Herald, 1961). It is most frequently found in bays, estuaries, lagoons and along the coastal shore line. Boothe (1967) and Jones (1962) report the taking of specimens from the San Joaquin and Sacramento River drainage and in Walker Creek Estuary where reduced salinity was evident. Clemens and Wilby (1961) state that it is found in tide pools. Bolin (1944) records the maximum depth of capture for large, offshore staghorn sculpin at 91.44 m (50 fathoms). The staghorn sculpin ranges from Chignik, Alaska to San Quíntin Bay, Baja California.

Literature on the Pacific staghorn sculpin is quite diverse. The most comprehensive work to date is that by Jones (1962) who reported on the effects of varied salinities on hatching, growth, and development of this species along the central California coast. Porter (1964) and Boothe (1967) have written on staghorn sculpin food habits in Humboldt Bay and San Francisco Bay respectively. Morris (1960, 1961) has analyzed the distribution of this species, and other cottids, with respect to their sensitivity to temperature and salinity gradients. Staghorn sculpin meristics were studied by Hubbs (1921a) and Hubbs and Hubbs (1944).

This study covers aspects of the life history of Pacific staghorn sculpin and compares fish from the southern end of the range to those from the northern range.

14.2. MATERIALS AND METHODS

All collections were made between June 1970 and May 1971. Sampling was weekly or bimonthly, and six stations were sampled a minimum of once per month.

Collecting gear varied with the time of year. A 9.14 m X 1.22 m (30 ft X 4 ft), 12.7 mm (½ in) bar mesh bag seine was most efficient in February and March. Between April and November a 15.24 m X 1.83 m (50 ft X 6 ft), 9.65 mm (# in) bar mesh bag seine was used. During December and January, a 4.88 m (16 feet), graduated mesh shrimp trawl proved more effective than the beach seines.

The number of seine or trawl hauls varied with each sampling operation; however, no less than three seine hauls or two trawl hauls were made per station. Collecting times covered both day and night and all tidal conditions.

Staghorn sculpins retained for stomach analysis were fixed with 4% formaldehyde (10% formalin) in seawater solution, washed, and stored in 40% isopropyl alcohol. Length measurements were taken prior to fixing. All lengths are standard lengths (SL) and weights are accurate to 0.1 g. Preserved specimens were used for length, weight, sex and aging. Live fish required for experiments were brought from the field in 5 gallon plastic containers and retained in 10, 15, and 65 gallon seawater aquaria. The aquaria were housed in a thermally controlled room where water temperature was 17 ± 1C (62.6 ± 1.8 F).

Other materials and methods employed during this study will be described where appropriate.

14.3. STUDY AREA

Six sampling stations were chosen within the confines of the Naval Weapons Station, Anaheim Bay (Figure 22; Stations 2, 5, 7, 8, 9 and 10). Each of the three main channels had one station located on the lower reaches and one on the upper reaches. Preliminary sampling with seines in June 1970 yielded no staghorn sculpins at Station 8; consequently, collecting was discontinued there. This station was occasionally monitored throughout the year and staghorn sculpins were never found there.

14.4. TAXONOMY AND MORPHOLOGY

The taxonomy of Leptocottus armatus Girard has remained relatively stable. In 1880, L. armatus was recorded from British Columbia by A. Gunther and recorded as Centridermichthys armatus, and in 1901, specimens from the Queen Charlotte Islands were erroneously listed as Leptocottus maculosus (Clemens and Wilby, 1961). Bolin (1947) feels that some of the morphological characteristics of Leptocottus armatus contrast so markedly with the rest of the family that isolation of Leptocottus into a special subfamily might be advisable. Positive identification of L. armatus in Anaheim Bay was made by comparing the descriptions of Girard (1854), Jordan and Evermann (1896), and Bolin (1944).

The genus is monotypic with two subspecies having been described. Hubbs (1921a) separated the species into Leptocottus armatus armatus, which is found north of Morro Creek, California, and Leptocottus armatus australis, which is found south of this point. Separation was based on ray counts of the second dorsal and anal fins. According to Hubbs' study, L. armatus australis has 14–17 (usually 16) dorsal soft rays as compared to 16–19 (usually 17) for L. armatus armatus. L. armatus australis also possesses fewer anal fin rays, 14–16 (usually 15) rather than 15–19 (usually 16 or 17) for L. armatus armatus. An analysis of 40 specimens of L. armatus collected from Anaheim Bay between August and December 1970 showed a range of dorsal fin rays 15–17 (mean 16.2) and a range of anal fin rays 14–16 (mean 15.3). Hubbs and Hubbs (1944) report that L. armatus is "clearly right-handed" for when there is a difference in the number of rays between the two pectoral fins, the right pectoral fin usually contains the greater number.

Wildrick (1968), however, disputes this subspeciation. He states in his morphometric study of Leptocottus armatus that a south to north clinel pattern exists and that cytogenetic comparison and electrophoretic studies of eye lens proteins indicate that there is not enough genetic difference between northern and southern forms to warrant their designation as different subspecies.

The most striking morphological characteristic of L. armatus is a preopercular spine with three recurved hooks facing upwards. The gray spinous dorsal fin has an obvious black spot located distally and the pectoral fins are a golden-yellow with dark crossbars. Those fish held in laboratory aquaria have shown a remarkable ability for color variation of their dorsal surfaces. This surface has fluctuated between an olive-gray, light to dark green and light brown, blending with a variety of sandy substrates.

At the onset of the spawning season many ripening females developed a deep red tinge to their caudal fins and a light red tipping effect to the outer margin of their anal fins. This color change was not observed in all ripening females and would disappear in preserving medium. No permanent sexual dimorphism was evident.

One structural anomaly occurred rather frequently in the Anaheim Bay population. A severely underdeveloped upper jaw was observed in 0.7% of the staghorn sculpins collected. No fish captured with this condition measured more than 70 mm (2.76 in) SL or was collected later than September. When isolated in laboratory aquaria these fish were able to capture and retain small gobies, but were not able to compete favorably for food when retained in aquaria with normally developed staghorn sculpins of a similar size. A specimen with this anomaly is deposited with the Los Angeles County Museum (Catalog No. 9415-1).

The largest Pacific staghorn sculpin collected from Anaheim Bay measured 172 mm (6.77 in) SL. Barnhart (1936) reported the maximum length for the species as 305 mm (12 in).

14.5. MOVEMENT

A mark and recapture study was conducted to determine staghorn sculpin movements within the marsh. A total of 180 fish was tagged with a modified polyethylene spaghetti tag and released. Between 32 and 42 fish were marked at each station.

Ten recaptures (5.5%) were made of the 180 marked fish. Very little movement was exhibited by the majority of these fish. Eight fish were recaptured in the same station at which they had been released. One fish was captured at Station 2, about 800 m (2,624.8 ft) south of its point of release at Station 5; while another had moved approximately 300 m (984.3 ft) from Station 10 to Station 9. The recapture of the latter fish occurred 22 days after release, whereas the 800 m movement occurred over a period of 107 days. Recaptures of fish showing no movement occurred after periods ranging from 1 to 69 days.

Probably most staghorn sculpins which survive spawning leave the bay thereafter and inhabit deeper offshore waters. This conclusion is based on the fact that only one fish older than 1 year was captured and the species is known to reach an age of 3 + years (Jones, 1962).

14.6. AGE AND GROWTH

The Anaheim Bay staghorn sculpin population consists almost entirely of juvenile fish. Only a single fish, older than 1 year was captured in late November near the mouth of the bay at Station 7. It was a gravid female, 172 mm (6.77 in) SL, and nearly 2 years old. This fish probably was not a permanent member of the marsh population, but had moved in from offshore.

Age analysis was based on length-frequency (Figure 36) and substantiated by otoliths. Length groupings were based on the methods of Andersen (1964). Otoliths were removed from preserved fish and stored in oil of anise. They were read in oil of anise, over a black background, and with reflected light, (Gambell

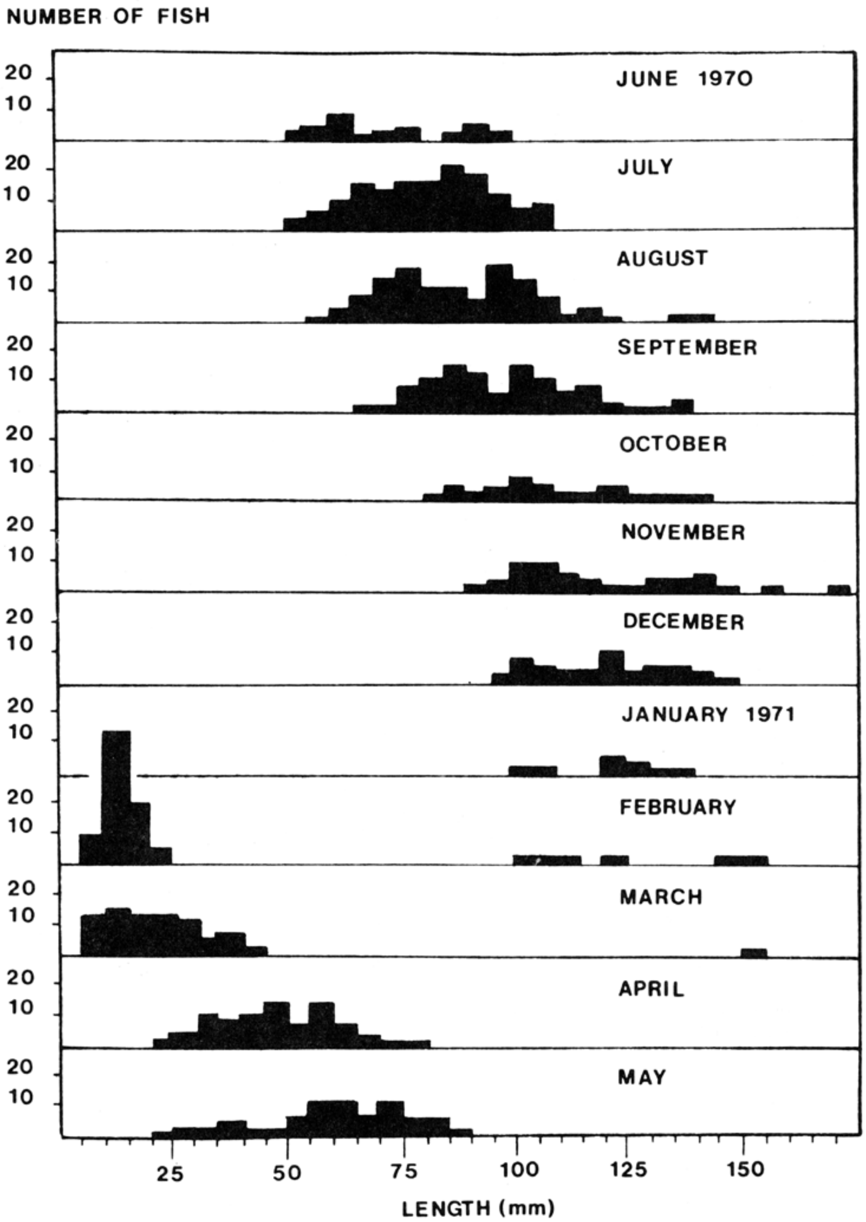

FIGURE 36—Monthly length frequency histograms of staghorn sculpin from Anaheim Bay.

FIGURE 36—Monthly length frequency histograms of staghorn sculpin from Anaheim Bay

and Messtorff, 1964). A sagittal otolith with less than 1 year's growth possessed an opaque nucleus surrounded by a translucent ring. Beginning in late November, some specimens began to develop an opaque zone at the outer margin of the translucent zone. This opaque margin has been noted to appear 2 months earlier, in September, in stagbhorn sculpins, collected from San Francisco Bay (Jones, 1962).

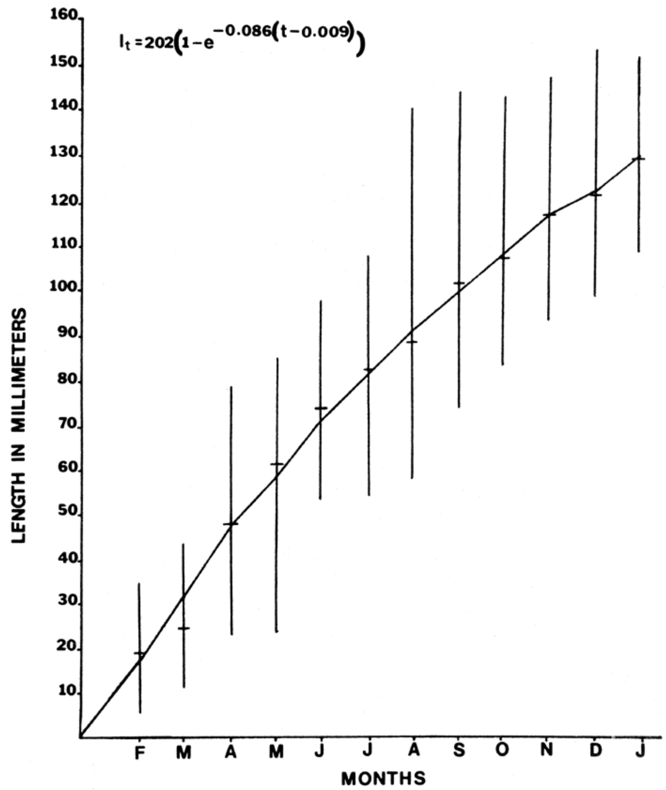

FIGURE 37—Growth of staghorn sculpin from Anaheim Bay. Vertical lines indicate ranges; horizontal lines indicate means

Growth is curvilinear and is described by the von Bertalanffy growth equation

$$l_t = L_\infty \; (1 - e^{-k(t - t_o)})$$

EQUATION

(Figure 37).

$$L_\infty$$

EQUATION

was estimated by a least squares linear regression of $l_t + 1 - l_t$ vs l_t while k and t were estimated by a least squares linear regression of t vs

$$\text{Log}_e \left(\frac{L_\infty - l_t}{L_\infty} \right)$$

EQUATION

(Gulland, 1969).

Growth for March and April as estimated from this curve is 13.5 mm (0.53 in) per month. By comparison, 10 juvenile fish, held in the laboratory during March and April at a constant 17 C (62.6 F) and fed daily with a quantity of brine shrimp which was more than they could consume in a 24-hour period, exhibited a mean monthly growth increment of 9.1 mm (0.36 in).

14.7. LENGTH-WEIGHT RELATIONSHIP

Approximately 900 staghorn sculpins were collected from Anaheim Bay. of the 326 fish measured and weighed, 212 which had been sexually identified were used in the length-weight calculation. Standard lengths (SL) and weights accurate to 0.1 g were taken prior to preservation. These measurements were recorded between June 1970 and January 1971, and length frequency and otolith analysis demonstrate that all specimens belonged to a single growth stanza. A length-weight relationship for each sex was calculated; however, no sexual differences were detectable, so the results were combined.

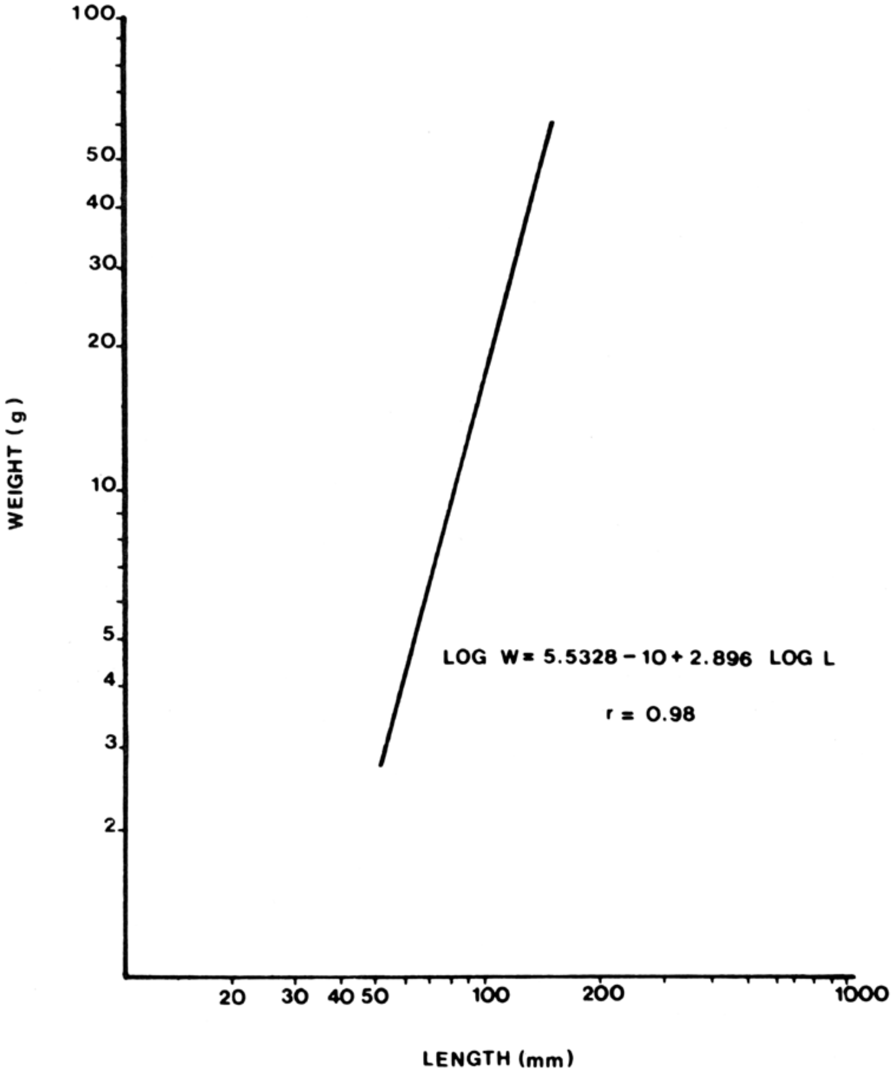

FIGURE 38—Length-weight regression of staghorn sculpin from Anaheim Bay.

FIGURE 38—Length-weight regression of staghorn sculpin from Anaheim Bay

The correlation coefficient for length-weight was r = 0.98. The staghorn sculpin length-weight relationship (Figure 38) is curvilinear and is described by the formula: $W = aL^{b}$ (Ricker, 1958) where: $W = 0.000341\ SL^{2.896}$ Log W = 5.5328 - 10 + 2.896 Log SL A 2.896 slope of the regression between length and weight indicates that growth was nearly isometric during this growth stanza. Inclusion of some ripening females in the tabulation did not increase exponent b.

14.8. FOOD AND FEEDING

Stomachs of 213 specimens were analyzed to determine food habits. Samples were collected at five stations throughout the year and included both day and night sampling. The entire alimentary tract was removed and stored in 40% isopropyl alcohol until analysis. Staghorn sculpin gastric digestion is relatively complete with the small intestine containing only a semifluid chyme. Consequently, only the shortened esophagus and stomach were examined for food items. Digestion is quite rapid and at 17 C (62.6 F) gastric evacuation is completed in 27 hours (D. Lindsay, Calif. State Univ., Long Beach, pers. comm.). The gravimetric and frequency of occurrence methods (Lagler, 1952) were used to determine the importance of a particular food category. All food items were identified to the lowest taxonomic group possible.

TABLE 19

Food Organisms Eaten by Staghorn Sculpin and Their Frequency of Occurrence.

- **Phylum Annelida**
  - **Class Polychaeta**
    - **Family Phyllodocidae**
      - *Eulalia* sp. (0.9%)*
    - **Family Glyceridae**
      - *Goniada littorea* (0.9%)
    - **Unident. polychaetes** (0.9%)
- **Phylum Mollusca**
  - **Class Gastropoda**
    - **Order Pectinibranchia**
      - **Family Cerithiidae**
        - *Cerithidea californica* (0.5%)
  - **Class Pelecypoda**
    - **Order Eulamellibranchia**
      - **Family Sanguinolariidae**
        - *Tagelus californi nus* (0 9%)
      - **Unident. pelecypods** (0.5%)
- **Phylum Arthropoda**
  - **Class Crustacea**
    - **Order Cyclopoida**
      - *Clausidium vancouverense* (0.5%)
    - **Order Cumacea**
      - *Oxyurostylus pacifica* (0.9%)
    - **Order Amphipoda**
      - **Suborder Gammeridea**
        - *Allorchestes* sp. (0.5%)
        - *Amphitoe plumulosa* (2.4%)
        - *Corophium acherusicum* (6.1%)
        - *Hyale plumulosus* (1.4%)
        - *Hyale rubra* (0.5%)
        - *Hyale* sp. (0.9%)
      - **Unident. gammeridians** (0.9%)
      - **Suborder Caprellidea**
        - *Caprella equillibra* (0.5%)
    - **Order Decapoda**
      - **Family Crangonidae**
        - *Crangon californiensis* (0.9%)
      - **Family Callianassidae**
        - *Callianassa* sp. (17.4%)
      - **Family Cancridae**
        - *Cancer antennarius* (0.5%)
      - **Family Grapsidae**
        - *Hemigrapsus oregonensis* (20.7%)
      - **Family Pinnotheridae**
        - *Pinnixia* sp. (21.6%)
      - **Larvae** (1.4%)
      - **Unident.** (8.9%)
  - **Class Insecta**
    - **Order Diptera**
      - **Larvae** (1.4%)
- **Phylum Chordata**
  - **Class Osteichthyes**
    - **Subclass Teleosteii**
      - **Family Atherinidae**
        - *Atherinops affinis* (0.5%)
      - **Family Cyprinodontidae**
        - *Fundulus parvipinnis* (1.9%)
      - **Family Cottidae**
        - *Leptocottus armatus* (0.5%)
      - **Family Gobiidae**
        - *Clevelandia ios* ** (10.3%)
      - **Family Pleuronectidae**
        - *Hypsopsetta guttulata* (0.5%)
      - **Unident. teleosts** (2.8%)

* The percentage indicates the frequency of occurrence of a food item in 213 stomachs containing food.
** There is some question as to the identification of *Clevelandia ios* in the stomach contents; a remarkably similar species *Quietula y-cauda* occurs in Anaheim Bay, although *C. ios* is present in much greater numbers.

TABLE 19

Food Organisms Eaten by Staghorn Sculpin and Their Frequency of Occurrence.

The staghorn sculpin is a continuous feeder. An extremely wide mouth permits the capture and ingestion of large prey organisms. Stomach contents sampled averaged 4.3% of the body weight and ranged from empty to a maximum of 11.4%. Eight percent of all stomachs examined were empty.

There is a wide variety of food items eaten (Table 19) with a concentration on decapod crustaceans. The most common decapods eaten are the yellow-shore crab, Hemigrapsus oregonensis; ghost shrimp, Callianassa sp.; and pea crabs, Pinnixia sp., the latter being a commensal in ghost shrimp burrows. Gobies were the most frequently occurring fish. These were identified as the arrow goby, Clevelandia ios, and possibly shadow gobies, Quietula y-cauda, which are known to occur in Anaheim Bay. The arrow goby is a faculative commensal of ghost shrimp, often retreating into their burrows with an outgoing tide (MacGinnitie, 1935). The occurrence of the California killifish, Fundulus parvipinnis, was not as frequent as that of the goby; however, the majority of those found in stomachs were large, weighing between 3 and 4 g (0.11 and 0.14 oz). The most common amphipods were of the gammeridian genera, Corophium, Amphitoe and Hyale. Polychaetes were taken occasionally with only Goniada littorea and Eulalia sp. being identifiable.

TABLE 20

A Comparison of the Food Habits of Juvenile and Maturing Staghorn Sculpin.*

Major food item	Juvenile†		Maturing†	
	Frequency occurrence	Proportion weight	Frequency occurrence	Proportion weight
Polychaeta	5.8	1.0	2.1	0.1
Crustacea	55.5	51.8	84.7	83.4
Decapoda	18.8	34.2	70.1	79.6
Callianassa sp.	4.4	15.7	21.5	40.7
Hemigrapsus oregonensis	1.4	2.7	30.0	26.9
Pinnixia sp.	13.0	6.3	25.0	4.4
Amphipoda	24.7	3.3	5.5	0.2
Osteichthyes	17.4	33.7	16.0	15.0
Gobiidae	11.7	25.1	9.0	3.0
Cyprinodontidae	0.0	0.0	3.5	9.9

* Comparisons indicated by frequency of occurrence in stomachs and by proportion of total stomach contents by weight of major food items. All proportions expressed as percents.

† Juvenile—less than 70 mm standard length, maturing—more than 70 mm standard length.

TABLE 20

A Comparison of the Food Habits of Juvenile and Maturing Staghorn Sculpin.

An arbitrary demarcation point of 70 mm (2.7 in) SL was established to demonstrate differences between food habits of small and larger juvenile fish. Two major differences were notable (Table 20). The smaller fish consumed fewer crustaceans and more gobies than did the larger fish. The gobies, essentially Clevelandia ios, were quite small, averaging about 200 mg (0.01 oz) per fish. There appeared to be a significant increase in the occurrence of larger decapod crustaceans as the Pacific staghorn sculpins became larger.

Fifty-one of the 213 stomachs examined were collected at night. The contents of these stomachs averaged 6.9% of the body weight as compared to 3.3% in the day caught fish. No differences in stage of digestion was found between food organisms in day caught and night caught fish. These data suggest a higher incidence of night feeding. Laboratory behavior substantiates this contention. Experimental fish subjected to a 12-hour light and 12-hour dark regime were observed to be much more active during the hours of darkness.

A comparison of major food items taken from day and night samples (Table 21) demonstrates some difference in utilization of decapods. The frequency of occurrence and weight of ghost shrimp consumed was much greater in the night samples, while the same values for yellow-shore crabs were reduced. No explanation for the increased availability of ghost shrimp is yet available. They are not known to leave their burrows during any particular time of the day. The frequency of occurrence of pea crabs was also greater in the night samples, but its percentage by weight in the diet remained relatively constant. Night values for California killifish were more than twice day values.

An analysis of the major food items by season reflects the change in size of the single age class which dominates the population. During the late winter and spring months (March to June), the occurrence of smaller organisms (Amhipoda, Polychaeta, and Gobiidae) is high. The great majority of staghorn sculpins is less than 70 mm (2.76 in) SL during these months. Larger Decapoda dominate summer and fall months (July through December) food samples when the staghorn sculpins are generally longer than 70 mm (2.76 in) SL.

A station by station comparison revealed the conspicuous absence of some food organisms at various stations. The pea crabs and arrow gobies were lacking in stomachs sampled from Station 7; ghost shrimp and representative amphipods were absent from Station 9; and Station 10 stomach samples lacked amphipods. These figures are not adequate to warrant any conclusions; however, the data suggest an unequal distribution of vertebrates and invertebrates in Anaheim Bay.

Jones (1962) reports that the most common food items for adult staghorn sculpins, collected in Tomales Bay and Walker Creek Estuary, were bay shrimps, Crago sp., and blue shrimp, Upogebia pugettensis. Juvenile fish were supported by amphipods of the genus Corophium and polychaetes of the genus Neanthes. Yellow-shore crabs were common in both adults and juvenile diets. Porter (1964) found that the juvenile staghorn sculpins in Humboldt Bay feed heavily on the amphipods Corophium and Amphitoe, while the most common adult food items were algae, bay shrimps and amphipods. From the waters of San Francisco Bay, Boothe (1967) lists the following staghorn sculpin food items in their order of abundance: pistol shrimp, Crangon sp.; the bay goby, Lepidogobius lepidus; crabs of the genera Cancer, Hemigrapsus, Pinnixia, and Scleroplax; and the callianassid,

TABLE 21

A Comparison of the Day and Night Food Habits of Staghorn Sculpin.*

Major food item	Day		Night	
	Frequency occurrence	Proportion weight	Frequency occurrence	Proportion weight
Polychaeta	1.8	0.1	3.9	0.1
Crustacea	74.1	83.4	78.4	80.3
Decapoda	51.2	78.2	60.8	77.3
Callianassa sp.	12.9	32.1	29.4	54.4
Hemigrapsus oregonensis	21.5	37.6	15.9	12.4
Pinnixia sp.	16.7	4.7	35.3	4.3
Amphipoda	12.3	0.7	9.8	0.3
Osteichthyes	17.3	14.5	13.7	17.3
Gobiidae	11.7	6.9	5.9	0.6
Cyprinodontidae	1.2	6.5	3.9	13.0

* Comparison indicated by frequency of occurrence in stomachs and proportion of total stomach contents by weight of major food items. All proportions expressed as percents.

TABLE 21

A Comparison of the Day and Night Food Habits of Staghorn Sculpin.

Upogebia pugettensis.

The staghorn sculpin apparently is an opportunistic benthic feeder. In the field, it has been observed to follow an incoming tide, most likely in pursuit of food. When tide levels were high, staghorn sculpins were commonly captured in areas as much as 15 m (49.22 ft) from the main channel; these areas were exposed at tide levels below 0.76 m (2.5 ft). In the laboratory, it consumed a wide variety of organisms, including juvenile staghorn sculpins. Laboratory fish would usually wait until a food item, such as Callianassa or Clevelandia, had landed upon the aquarium floor beside them. They would then cruise over, pursue it momentarily, and finally capture it with a few quick motions of the head. After 3 to 4 weeks of laboratory acclimation, staghorn sculpins would begin to meet food items in mid-water. A similar mid-water feeding behavior was exhibited by juveniles without prior laboratory experience. This behavior is no doubt due to the type of feeding that juveniles are accustomed to in the marsh environment. Searching for such food items as amphipods would require a more frequent use of the water column by juveniles than by larger fish which feed almost entirely upon benthic decapods.

14.9. REPRODUCTION

14.9.1. Spawning

Egg development and post-larval fish, 10 to 15 mm (.39 to .59 in) indicate spawning occurs between mid-December and mid-March and peaks in January and February. The onset of staghorn sculpin spawning in Anaheim Bay is somewhat later than in northern California. The latter populations initiate spawning in either October (Jones, 1962) or November (Boothe, 1967).

During the months of February, March, and April, juveniles measuring 10 to 45 mm (.39 to 1.77 in) were collected from five stations. Spawning apparently takes place throughout the entire bay. Numerous post-larval fish were discovered hidden in the thin, muddy surface layer of the channel banks following the retreating tide.

Absence of ripe females older than 1 year from collections made during the spawning season indicates a breeding migration of older fish into the bay does not take place. It has been speculated that staghorn sculpin spawning occurs in bays, estuaries, and offshore. Hubbs (1921a) observed that the young of the year abound in the quiet waters of the bays and estuaries, while the adults tend to be concentrated offshore. Jones (1962) reported that success of artifical hatching and rearing of staghorn sculpins from eggs collected in Walker Creek Estuary is greater in waters of lowered salinity. He also cited a report of larval forms, being collected from the offshore ocean waters of Monterey, California. Porter (1964) hypothesized the spawning location of a Humboldt Bay population as being a shallow cove at the north end of an adjoining lagoon. All available data suggest that staghorn sculpin populations breed in the same general area in which they occur as adults.

Post-spawning mortality appears very high. This is based on the absence of older fish in the population, a sharp reduction in the catch per unit effort during the breeding season, and the capture of only two spent females, both of which were suffering from severe bacterial and parasitic infections.

Male and female staghorn sculpins reach sexual maturity near the end of their first year of life. The gonads become apparent when the fish reaches approximately 50 mm (1.97 in) SL. Identification of the sexes by gonad comparison is not possible until the animal reaches about 70 mm (2.76 in) SL. Female gonadal development proceeds in three stages (Table 22). The ripening female (Stage 2) was first observed in the late November collections, and the first ripe females (Stage 3) were collected on the second of December.

TABLE 22

Description of Female and Male Gonad Development.

Stage no.	Months found	Standard length of fish (mm)	Gonad length (mm)	Gonad volume (ml)	Description of gonad*
FEMALE					
1	Feb.–Nov.	9–110	0–24	0.0– 1.2	Color: white to pink. Consistency: soft and granular. Egg: diameter 0.0–0.5 mm, transluscent, nucleus visible microscopically.
2	Nov.–Feb.	105–154	24–39	1.0– 8.0	Color: light yellow. Consistency: semifirm. Egg: diameter 0.6–1.5 mm, light yellow, nucleus not visible.
3	Dec.–Mar.	124–158	38–43	7.8–10.5	Color: yellow to gold. Consistency: firm. Egg: diameter 1.4–1.7 mm, light yellow to gold, no nucleus visible, 4–6 oil droplets.
MALE					
1	Feb.–Dec.	9–108	--	--	Two narrow, opaque bands of negligible volume, length not definite.
2	Dec.–Mar.	110–122	25–32	approximate 0.1	Soft, white finger-like projections.

* Gonads examined were from preserved specimens.

TABLE 22

Description of Female and Male Gonad Development.

The ovaries are rather short, conical-shaped structures which are joined broadly at the anterior ends. During the maturing phase (Stage 1), individual eggs are visible only microscopically and are homogeneously interspersed within the connective tissue. In the ripening phase (Stage 2), the eggs are arranged in leaves of nonuniform thickness. There are from 20 to 25 of these leaves per ovary. Two distinct sizes of eggs are evident in this stage. Large, maturing eggs, uniform in size and shape, are encompassed by many smaller, immature eggs of varying sizes. In the third and final stage of development the eggs are ready for release. The mature eggs, all of uniform size occupy the ventral portion of the ovary, while the nonmaturing eggs comprised 28.2% of the weight of the entire ovary of 11 ripe fish measured. An average of 3,200 mature eggs was found in these 11 ripe females.

The male gonad exhibited two stages of development (Table 22). Prior to ripening, the testes appeared as two thin opaque bands that run just ventral to the kidneys. During the spawning season, they enlarged with milt and took on the appearance of elongated finger-like projections.

On January 27, 1971, a ripe, aquarium housed female, in the presence of one male and another female, released two egg clusters. The eggs were adhesive, demersal, and numbered 100 to 150 per cluster. The eggs were allowed to remain in the aquarium for 5 days but no development took place. The presence of less than 300 eggs was probably the result of an incomplete release. These fish were retained for a period of 2 more months and no further spawning activity was observed.

14.9.2. Sex Ratio and Behavior

Over a 12 month period, more females than males were caught by a ratio of 1.5:1, but seasonal differences were evident. Throughout the summer the ratio was constant at 1:1. During fall and winter months there was a sharp decrease in the number of males caught, and the ratio of females to males rose to 4:1. Sex ratios during the spring months were impossible to ascertain due to lack of gonadal development in juvenile fish. No evidence was discovered to indicate either emigration by or an increase in mortality in males. Boothe (1967) noted a similar overall sex ratio in favour of the females, but indicated that there were no seasonal differences.

No spawning behavior was observed in the field. The moderately low fecundity of Leptocottus armatus suggests the possibility of egg protection after fertilization. Such egg guarding has been observed in the shorthorn sculpin, Myoxocephalus scorpius, (Ennis, 1970), which had fecundities ranging from 4,205 to 60,976. After the release of two egg clusters by the aquarium retained female in January, all three experimental fish were observed closely surrounding the eggs which were adhered to the bottom. As soon as a disturbance of the water threatened them, the fish fled from the egg masses and did not again demonstrate this apparent protective behavior in relation to the eggs. As a result of the rapid movement of the fish, the egg clusters were dislodged and, although they always remained on the bottom, never again adhered to the substrate. It is noteworthy that the adults made no attempt to eat the egg clusters.

14.10. PREDATION AND DEFENSE

Stomach analysis of major fish species in this area has failed to reveal any evidence that the staghorn sculpin is either a primary or secondary food source for fishes except as a minor constituent of its own diet. The bay does possess a large and diverse bird population, many of which are known to feed heavily on fish.

Staghorn sculpin are a prey of the Caspian tern, Hydroprogne caspia, in the San Francisco Bay area (Miller, 1943). MacGinnitie (1935), in his studies of Elkhorn Slough, California, states that staghorn sculpin is the favourite food item of the great blue heron, Ardrea herodias, and forms a large portion of the diet of loons and cormorants. Girard (1858) observed that young staghorn sculpin were common prey for large flocks of gulls and cormorants. Clemens and Wilby (1961) report that staghorn sculpins are eaten to a considerable extent by waterfowl, especially ducks. Palmer (1962) lists the western grebe, Aechmophorus occidentalis, as another predator of the staghorn sculpin.

Two distinct types of defensive behavior have been observed in staghorn sculpins under laboratory conditions. In response to threatening movements, they would quickly flee to a far corner of the aquarium and bury themselves in the sand with forceful wiggling movements of the body. On numerous occasions, with no threat involved, aquarium held specimens were found completely buried in the sand with their eyes and only a small portion of their dorsal surface exposed. This situation occurred most frequently in the daytime. In response to touch or handling, a staghorn sculpin would flatten its head and expand its operculum, extending the spine laterally and the sharp recurved hooks upward. This defensive posture probably is quite effective, for if the fish employs quick lateral movements of the head, the hooks are quite capable of cutting tissue. Although no toxins are present, secondary infections often occur.

If types of possible predators and defensive mechanisms are taken into consideration, along with seasonal distribution, numbers and growth rate, it seems highly probable that the bulk of staghorn sculpin predation occurs in spring and early summer.

14.11. PARASITISM

All preserved L. armatus specimens were checked for the presence of parasites. A small percentage of nonpreserved fish also were examined. The most frequently observed endoparasite was the common intestinal nematode Spirocamallanus pererai. This organism was observed in approximately 10% of the stomachs sampled, and was also found throughout the entire gastrointestinal tract. This parasite has been shown to be a principal parasite of the longjawed mudsucker, Gillichthys mirabilis (Noble and King, 1960); the California halibut, Paralichthys californicus (Haaker, 1971); and a great many other southern California fishes. Other noted but less obvious nematodes were coelom encysted third stage larvae of the genus Contracaecum and third stage larvae of a member of the superfamily Spiruoidea encysted in the mesentery. The nematode Contracaecum magnus has previously been found on staghorn sculpin taken from Canadian waters (Smedley, 1934).

The monogenetic trematode, Gyrodactylus sp., was a frequently found ectoparasite on the gills. A post-spawning female, captured in March, was observed to have had more than half of her gill filaments removed by this organism. Two digenetic trematodes, Tubulovesicula lindbergi and Stephanostomum sp., were found in the small intestine.

Other parasites and their observed place of attachment were: cestode plerocercoid larvae of the genus Acanthobothrium attached to the walls of the small intestine; a glossiphonid leech attached to the isthmus; and cyclopoid copepod, Holobomolochus prolixus, attached to the operculum.

15. THE BIOLOGY OF THE CALIFORNIA HALIBUT, PARALICHTHYS CALIFORNICUS (AYRES) IN ANAHEIM BAY

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15.1. INTRODUCTION

The California halibut, Paralichthys californicus (Ayres), is a member of the flatfish family Bothidae (Figures 39, 40). It occurs from the Quillayute River, Washington (Pattie and Baker, 1969), south to Magdalena Bay, Baja California, Mexico (Gilbert and Scofield, 1898); though few are caught north of San Francisco Bay. California halibut are found from the surf zone (Frey, 1971) to depths of 185m (100 fathoms), and commonly occur in bays and estuaries along the central and southern California coast.

California halibut is sought by sports and commercial fishermen. The sports catch is taken from piers, barges, jettys, and boats over sandy bottom close to shore. The commercial catch is taken in deeper waters using trawls and trammel nets.

Very little work has been published on the biology of California halibut. A summary of the existing knowledge and a brief history of the fishery can be found in Frey (1971).

15.2. MATERIALS AND METHODS

Most fish were collected with an otter trawl during semimonthly trawling operations conducted from January 1970 to February 1971. This trawl is described in the chapter on the life history of the shiner surfperch. Fewer than 2% of the California halibut were taken using seine or hook and line.

Captured individuals were treated in two ways. Those caught during tagging operations were put into a holding tank, and standard and total lengths and the side on which the eyes occurred were recorded. Each fish was fin clipped or tagged and released in the capture location. Sampling was conducted during every third trawling operation (about every 6 weeks). All sampled California halibut, except tag recaptures, were fixed in 4% formaldehyde (10% formalin) in seawater for 12 to 24 hours, washed in fresh running water for 12 to 24 hours, and preserved in 40% isopropyl alcohol. Preserved fish were measured to the nearest mm and weighed to the nearest 0.1 g. These fish were used for length-weight regression, gut analysis, age and growth, sex ratio, and fecundity studies. Lengths are standard length (SL) unless otherwise stated. Other materials and methods employed will be described in the appropriate sections.

15.3. DESCRIPTION

Comprehensive descriptions of California halibut have been given by Jordan and Evermann (1896), Norman (1934), and Ginsberg (1952). The body of the California halibut is slender and more or less eliptical in outline. The eyed side is covered with small ctenoid scales, and many accessory scales. The blind side is covered by small cycloid scales and accessory scales and in some fish ctenoid scales. The mouth is large with moderate canine teeth, gill rakers are long slender and numerous, eyes are small with a flat interorbital space, and may occur on either side of the head. The anterior part of the lateral line is arched over the pectoral fin. The dorasl fin originates over the anterior part of the upper eye and contains 63 to 74 rays and no spines. The anal fin contains 47 to 58 rays, and is without a perceptible spine. The caudal peduncle is long (Figure 39).

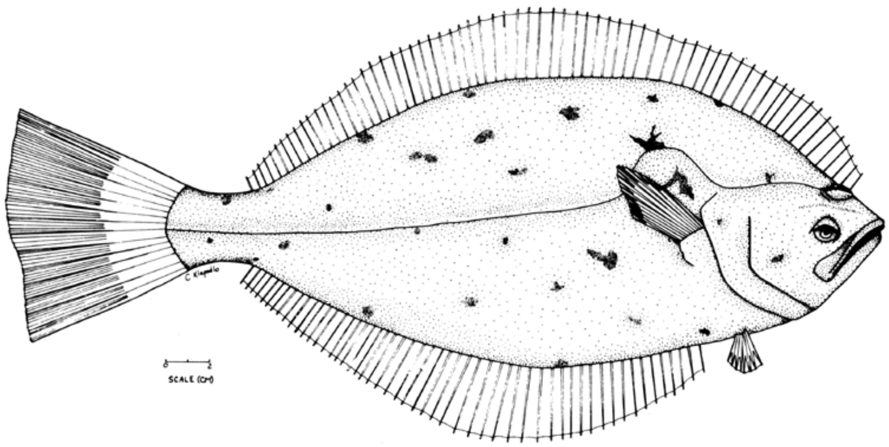

FIGURE 39—California halibut from Anaheim Bay. ***Drawing by C. Klepadlo.***

FIGURE 39—California halibut from Anaheim Bay. Drawing by C. Klepadlo.

California halibut can be distinguished from other California flatfishes by the high arch of the lateral line over the pectoral fin, and the posterior extension of the maxillary under or behind the posterior border of the lower eye.

The extreme southern range (Magdalena Bay, Baja California) of P. californicus shows a distributional overlap with P. aestuarius. These two species can be separated using dorsal and anal fin ray counts (Ginsburg, 1952). Dorsal and anal fin ray counts were made for 143 California halibut from Anaheim Bay (Table 23) and were compared with counts from Ginsburg (1952).

TABLE 23

Dorsal and Anal Fin Ray Counts of California Halibut from Anaheim Bay, Compared to the Results of Ginsburg (1952).

Dorsal count	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**	**76**
Ginsburg (n = 111)	--	--	--	4	7	13	18	15	18	20	7	6	2	1
Haaker (n = 143)	4	1	5	12	14	28	20	33	13	9	2	2	--	--
Anal count	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
Ginsburg (n = 115)	--	--	1	4	6	14	26	23	17	16	4	2	2	--
Haaker (n = 143)	1	4	6	12	25	19	30	29	12	3	1	1	--	--

TABLE 23

Dorsal and Anal Fin Ray Counts of California Halibut from Anaheim Bay, Compared to the Results of Ginsburg (1952).

15.3.1. Special Anatomical Characters

The occurrence of both eyes on one side of the head is probably the second character (after compression of the body) that is noted by most observers. In larval flatfish, an eye is located on each side of the head, but during metamorphosis one eye migrates across the dorsal region, so that both are situated on the same side of the head. Developmental processes are described by Norman (1934).

Metamorphic migration of eyes is associated with internal structural changes, as demonstrated by the sagittal otoliths. The nuclei of these otoliths is a dense concentration of calcium, presumably representing initial areas of calcium deposition. Nuclei from otoliths removed from the blind side of the fish are located approximately two-thirds back along the anterior-posterior axis of the otolith. The nuclei from the eyed side otoliths are about midpoint of this axis. This dimorphic condition was found in all California halibut examined, and probably is the result of skull structural changes occurring during eye migration.

FIGURE 40—Photograph of a California halibut in its normal habitat, note cryptic shading. *Photograph by C. H. Turner.*

FIGURE 40—Photograph of a California halibut in its normal habitat, note cryptic shading. Photograph by C. H. Turner.

The direction of anatomical rotation at metamorphosis is in many flatfishes characteristic, so that some species are right eyed (dextral) while others are left eyed (sinistral). Most species of Paralichthys are left eyed; however, P. Californicus is indifferently sinistral or dextral. of 1205 California halibut examined during this study, 782 (64.9%) were dextral; this was not related to sex. Examination of 283 males and 137 females yielded percentages of sinistral individuals of 65.7 and 70.1, respectively.

Pigmentation and anatomical anomalies were found in California halibut from Anaheim Bay and were described by Haaker and Lane (1973).

15.4. LENGTH-WEIGHT RELATIONSHIP

During this study, 498 California halibut were collected, preserved, and measured. Parker (1963) found 2 to 4% losses in length during preservation in 4% seawater solution of formaldehyde; however, the 304 California halibut measured before and after preservation demonstrated an average length loss of 1.18%.

The length-weight relationship was determined for 185 randomly selected individuals ranging in length from 42 to 455 mm (1.65 to 17.91 inches). The relationship is curvilinear and may be described by the formula: $W = 9.39 (10^{-4}) SL^{3.088}$ or $LogW = 5.03 - 10 + 3.088 \text{ Log } SL$ where: W = weight in g after preservation, and SL = standard length in mm after preservation. The correlation coefficient (r) for these data is 0.99.

The regression fits the formula $W = aL^b$ given by Ricker (1958), with the power term b = 3.088 indicating nearly isometric growth. The sexes did not differ significantly in length-weight relationship.

Regression analysis of standard length on total length (field measurements) was determined using 342 individuals and may be described by the following formula TL = 8.15 + 1.13 SL where: TL = total length in mm before preservation, and SL = standard length in mm before preservation. The correlation coefficient (r) for these data is 0.99.

15.5. AGE AND GROWTH

Ages were determined using otoliths, and were verified by scales and length frequency distribution (Figure 41). Fish were placed into 10 mm (0.39 inches) groups. This size grouping was checked by the method used by Andersen (1964). Otoliths from 350 fish of known sex were used. Otoliths were cleaned and then read with reflected light using the methods described by Gambell and Messtorff (1964). Anise oil was utilized as a clearing and reading medium. Otoliths were assigned to age groups in the following manner: (1) Otoliths having an opaque central zone, or this zone plus a translucent zone around it, were assigned to age group 0. (2) Otoliths having 2 opaque zones with a translucent zone between, or 2 opaque zones and 2 translucent zones were put into age group 1. (3) Age 2 fish had otoliths with 3 opaque zones, and 2 translucent zones. Not all bands seen in California halibut otoliths are annuli. Each annulus often appeared to be made up of numerous small bands, but these bands are close together and when combined usually form into an annulus.

The first translucent band around the nucleus of the otolith appears very early, probably before the fishes reaches 12 mm (0.47 inches). Gambell and Messtorff (1964) have described this phenomenon in whiting otoliths, naming it Bower's zone, and associating it with food changes caused by a change from pelagic to demersal habit. California halibut may develop this zone in response to metamorphosis, especially migration of the eye, but this is speculative. This inner band was not counted as the first annulus.

Scales were removed from the eyed side from the area just posterior to the lateral line arch and were mounted on slides. Scales were examined for annuli as described in Tesch (1971). Scale reading was difficult, especially in older fish, but usable data were obtained since only young aged halibut were found in Anaheim Bay. All scales and otoliths were read three times over a 6 week period.

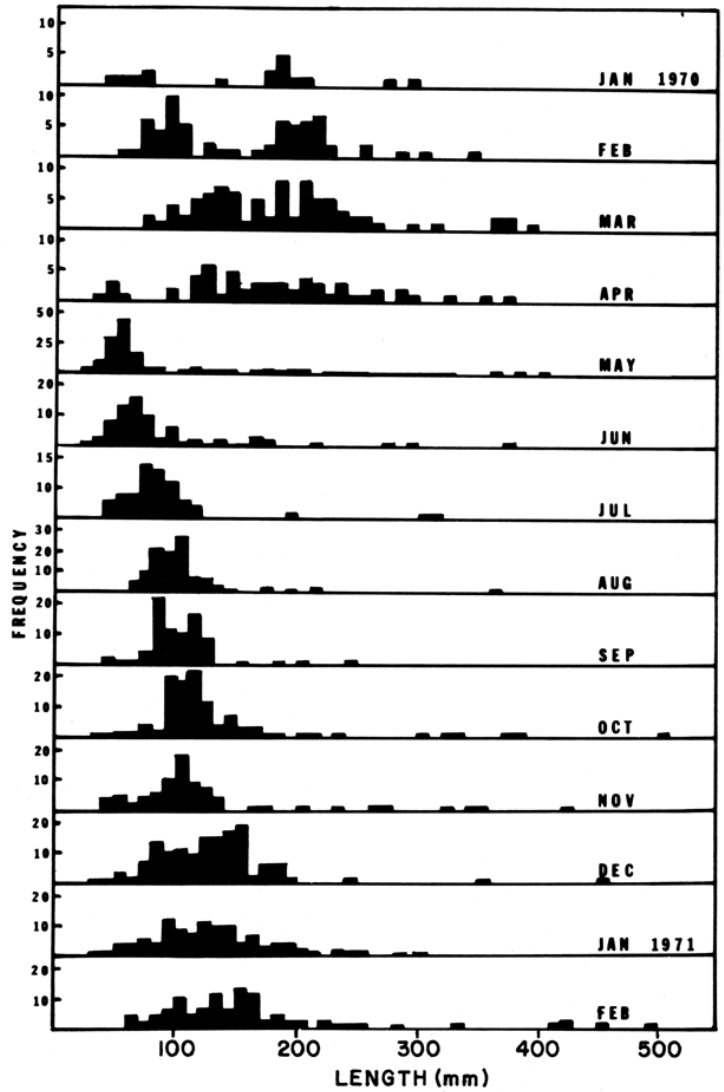

FIGURE 41—Monthly length frequency histograms of California halibut from Anaheim Bay. Note: frequency scale varies.

FIGURE 41—Monthly length frequency histograms of California halibut from Anaheim Bay. Note: frequency scale varies

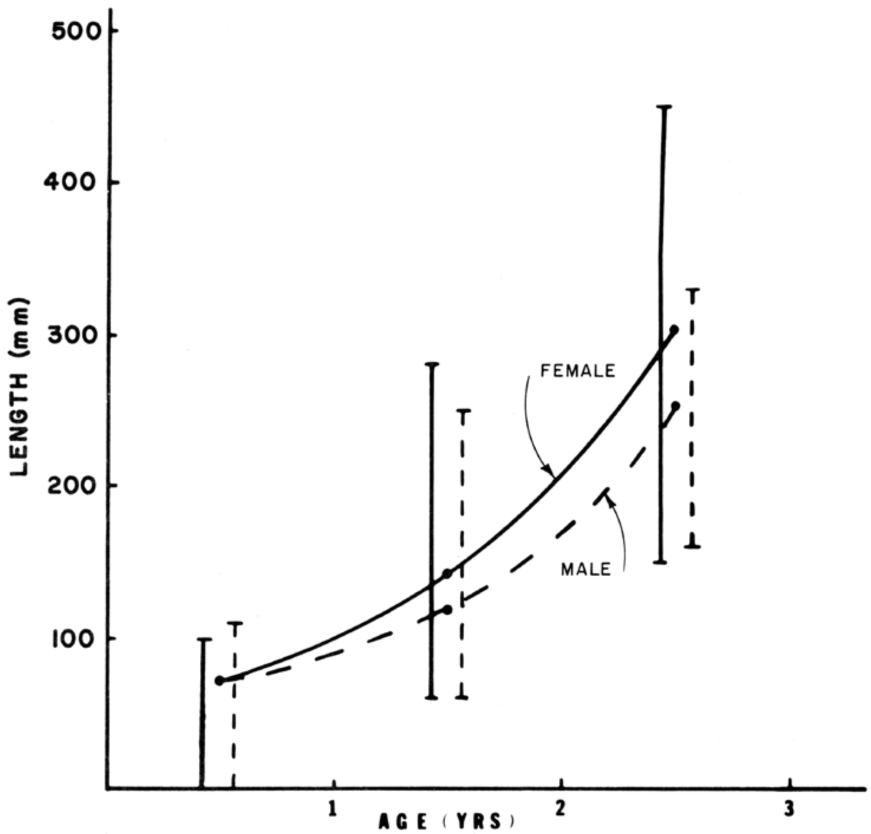

FIGURE 42—Growth curve of male and female California halibut from Anaheim Bay. Vertical bars indicate ranges.

FIGURE 42—Growth curve of male and female California halibut from Anaheim Bay. Vertical bars indicate ranges

The mean capture length of male 0, 1, and 2 year fish was 70.9, 118.6, and 250.3 mm respectively (2.79, 4.67, and 9.85 inches). Female fish of the same ages were 70.5, 146.7, and 301.3 mm (2.76, 5.78, and 11.86 inches). When mean lengths between sexes were compared using the "t" test, ages 1 and 2 were significantly different at the 5% level, females growing faster than males (Figure 42, Table 24).

TABLE 24

Mean Size at Age, in Length, Range and Annual Growth for California Halibut from Anaheim Bay, California.

Age	No. of fish examined	Range in length (mm)	Mean length (mm)	Growth per year
Male				
0+	74	30–110	70.9	--
1+	192	60–250	118.6	47.7
2+	14	160–330	250.3	131.7
Female				
0+	20	40–100	70.5	--
1+	26	60–280	146.7	76.2
2+	30	150–460	301.3	154.6

TABLE 24

Mean Size at Age, in Length, Range and Annual Growth for California Halibut from Anaheim Bay, California.

Clark (1930a) reported slow California halibut growth rates and extreme overlapping of the year classes, with overlap increasing with age. This overlapping was evident in the Anaheim Bay population (Table 24), but did not seem to make interpretation of the length frequency difficult, probably because of emigration of the fish from the bay in their second or third year.

Frey (1971) published mean total length at age for females caught throughout California. These data were converted to standard length in mm, and were compared to the growth of female fish in Anaheim Bay (Figure 43). It can be seen that the Anaheim Bay population is undergoing an increasingly rapid growth rate, as is common in very young fishes (Ricker, 1958). Since emigration seems to be associated with maturation it might be reasonable to assume the inflection point may occur when energy is shifted from body growth to gonadal development, or perhaps a shift from a highly productive environment (the bay) to a somewhat less productive environment (offshore).

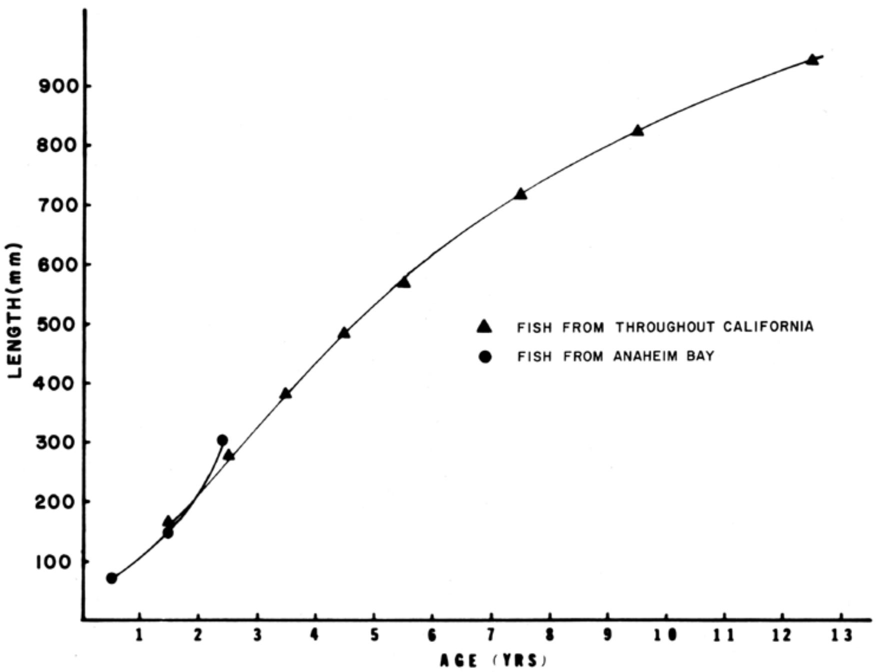

FIGURE 43—Comparison of growth curves of female California halibut from Anaheim Bay, and from throughout California (Frey, 1971).

FIGURE 43—Comparison of growth curves of females California halibut from Anaheim Bay, and from throughout California (Frey, 1971)

15.6. SEX DETERMINATION AND SEX RATIO

Sex was determined by microscopic examination of the gonads. Gonads from California halibut less than 50 mm (1.97 inches) were usually not sufficiently developed to determine sex. In fish approximately 50 to 100 mm (1.97 to 3.94 inches) ovaries and testes are similar in appearance, e.g., a pair of clear lobes which extend posteriorly into an extension of the coelom on each side of the sacrum. As fish increase in length, ovarian lobes become more acutely conical, while testes become obtusely conical. At lengths greater than 100 mm (3.94 inches) separation of the sexes is easily accomplished by macroscopic inspection.

The immature testis is characterized by many branching tubules. Ovaries of immature California halibut contain masses of spherical cells, presumably early egg cells.

The gonads of 504 California halibut were examined. of these, 288 were found to be males (67%) and 142 were females (33%). The sex of 74 fish was undetermined. Sex ratios appear to vary with size approaching a 1:1 ratio with increasing length (Figure 44).

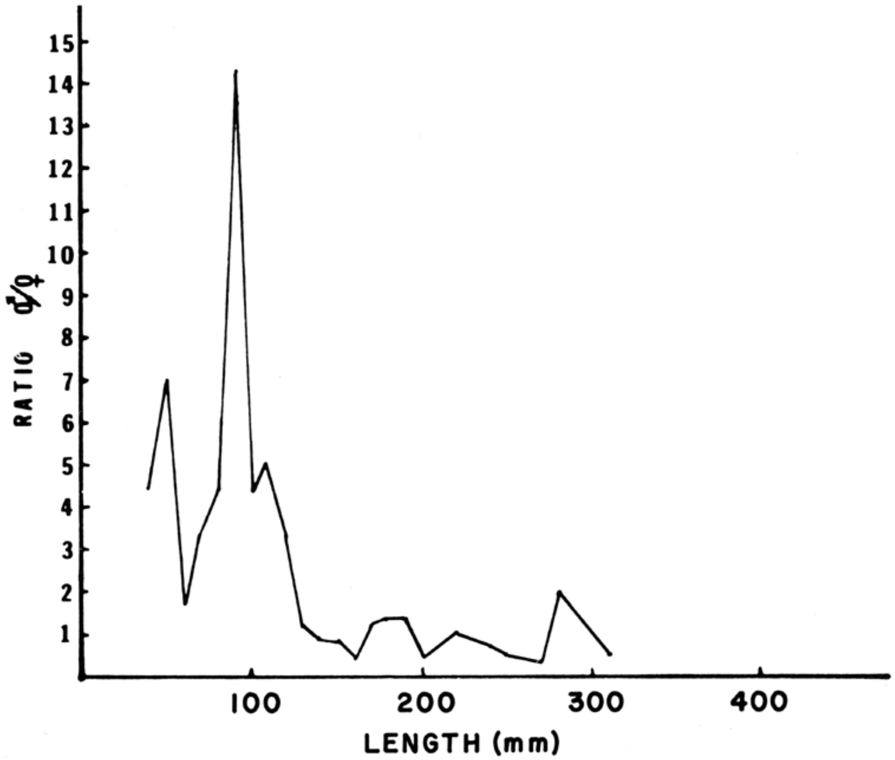

FIGURE 44—Variations in sex ratio of California halibut with fish size.

FIGURE 44—Variations in sex ratio of California halibut with fish size

Males mature at about 200 mm (7.87 inches) while females mature at about 375 mm (14.76 inches). Ovaries from fish 45 to 510 mm (1.77 to 20.08 inches) contained what seemed to be immature ova measuring 0.009 to 0.120 mm in diameter. Gonads of fish 400 mm (15.75 inches) and larger were yellow or orange in color, but subsequent examination yielded only immature ova. The largest fish examined from Anaheim Bay was a female measuring 510 mm (20.08 inches). The ovary of this fish was empty, with the exception of a few immature eggs. It is not known whether this fish was spent or immature. These data support other evidence that the California halibut population in Anaheim Bay is predominantly composed of immature individuals.

15.7. FOOD HABITS

15.7.1. Food

Feeding behavior and food of heterosomates were studied by Groot (1969) whose observations indicated that bothids were daytime feeders utilizing visual stimuli to prey on large quick prey, such as fish and shrimp. He further associated certain anatomical characters to this feeding behavior and food type. The characters, which are present in California halibut, include long heavily toothed gill rakers, an intestine with a simple loop, and possession of a brain with small olfactory and large optic lobes. The large mouth and sharp canine-like teeth are further evidence of a raptoral predator.

TABLE 25

Food Organisms Eaten by California Halibut and Their Frequency of Occurrence.

Phylum Arthropoda
Class Crustacea
Subclass Ostracoda (1.6%)*
Subclass Copepoda
Order Calanoida
Calanidae
Calanus sp. (1.1%)
Subclass Malacostraca
Order Mysidacea
Mysidae (1.1%)
Order Cumacea
Diastylidae
Oxyurostylis sp. (3.7%)
Order Amphipoda
Suborder Gammaridea
Corophiidae
Amphithoe sp. (0.5%)
Corophium sp. (15.2%)
Suborder Caprellidea
Caprellidae
Caprella sp. (0.3%)
Order Decopoda
Callianassidae
Callianassa sp. (1.1%)
Alephidae
Crangon sp. (1.1%)
Unidentified crustacea (8.0%)
Phylum Mollusca
Class Pelecypoda
Order Opisthobranchiata
Acteonidae (1.3%)
Phylum Chordata
Class Pisces
Gobiidae
Gillichthys mirabilis (0.5%)
Unidentified gobies (45.2%)**
Cyprinodontidae
Fundulus parvipinnis (1.9%)
Engraulidae
Engralis mordax (0.3%)
Atherinidae
Atherinops affinis (3.2%)
Unidentified fishes (13.6%)

* The percentage indicates frequency of occurrence in 292 digestive tracts with food, sampled from both day and night.
** This group is comprised mostly of *Clevelandia ios* with a few *Quietula y-cauda* and young *Gillichthys mirabilis.*

TABLE 25

Food Organisms Eaten by California Halibut and Their Frequency of Occurrence.

Contents of digestive tracts of 292 California halibut taken from day and night samples throughout the study period were analyzed to determine food organisms. Food organisms were identified to the lowest taxon possible (Table 25) with the aid of Miner (1950), Light (1954) and Reish (1968b).

Gut analysis was performed on fish ranging in length from 12 to 510 mm (0.47 to 20.08 inches). These data indicate a change in diet with an increase in size (Figure 45). California halibut less than 55 mm (2.17 inches) ate mostly small crustaceans; such as amphipods, cumaceans, copepods, and mysids; and small gobies, including the arrow goby, Clevelandia ios; shadow goby, Quietula ycauda; and perhaps young longjaw mudsuckers, Gillichthys mirabilis. Fish between 55 and 230 mm (2.17 and 9.06 inches) in length ate larger crustaceans and fishes. As fish length increased larger prey fish were found in the gut and included, topsmelt, Atherinops affinis; California killifish, Fundulus parvipinnis; and gobies; and the larger crustaceans, including Cragon sp. and Callianassa sp. California halibut over 230 mm (9.06 inches) long were almost totally piscivorous with very few of the larger crustaceans being found in the gut. Topsmelt; California killifish; northern anchovy, Engraulis mordax; and gobies composed the food of older California halibut found in Anaheim Bay. Frey (1971) reported the diet of California halibut was largely northern anchovies and a few other species of fish and squid.

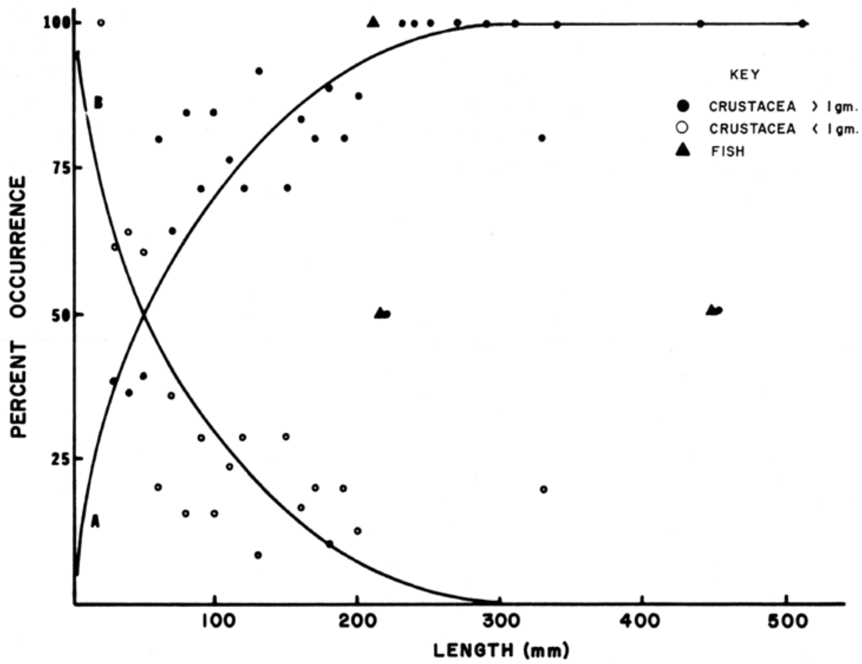

FIGURE 45—Ontogenetic progression of the occurrence of small and large food particles. A, curve of large crustaceans and fish. B, curve of small crustaceans.

FIGURE 45—Ontogenetic progression of the occurrence of small and large food particles. A, curve of large crustaceans and fish. B, curve of small crustaceans

15.7.2. Feeding

Feeding of California halibut was observed in the laboratory, and was similar to feeding habits of some east coast Paralichthys reported by Hildebrand and Cable (1930). Gobies were presented to the halibut both free and attached to a glass rod used to position the prey in any desired location. The flatfish was normally partially buried in the sand substrate, which eliminated the outline of the fish and together with close color similarity to the substrate, rendered the fish almost indistinguishable from the bottom (Figure 40). When the goby approached, the halibut's eyes turned quickly toward the prey and followed it until it left the area or arrived at a point directly in front of the flatfish, at which time the halibut usually would dart forward and slightly upward, seizing the prey. Striking distance was always less than 3 head lengths of the predator. A California halibut could not be induced to shift its position so as to bring the prey within striking distance. It is likely that in the wild such a shift would alert the prey and make any attack unsuccessful.

The position of any food was noted in all digestive tracts examined. The digestive tract was divided into four parts: esophagus and stomach, pyloris and caecae, large intestine, and rectum. Fish having food in some part of the gut numbered 174 of the 205 day-caught and 69 of the night-caught fish. Only digestible food items were counted since otoliths and bones could get caught in the rugae and caecae and remain for extended periods.

The weight of food in the stomach and the position of the food items in the digestive tract were noted in an attempt to determine the feeding period. Average percentages of body weight of food contained in the stomach of day-sampled

California halibut was 0.94% (n = 205, range from 0 to 12.00%), and for night-sampled fish was 0.61% (n = 87, range 0 to 6.54%). The difference of the average percentages is significant at the 5% level, indicating that California halibut in Anaheim Bay tends to feed more during daytime than at nighttime.

The frequency of occurrence of food in each part of the digestive tract for day and night samples was determined (Table 26). These data show a preferential diurnal feeding period.

TABLE 26

The Frequency of Occurrence of Food in Various Parts of California Halibut Digestive Tracts During Day and Night.

Sample	Stomach	Pyloris and Caeca	Large intestine	Rectum
Day*	72%†	38%	60%	66%
Night*	59%	46%	62%	67%

* Day sample n = 205, night n = 87.
† Percents indicate proportion of day or night sample.

TABLE 26

The Frequency of Occurrence of Food in Various Parts of California Halibut Digestive Tracts During Day and Night.

Neither food weight or frequency of occurrence data eliminate the possibility of nocturnal feeding by California halibut, food may be opportunistically taken when encountered, regardless of time of day. In the highly productive area of Anaheim Bay encounters may be numerous throughout the diel period.

15.8. PARASITES

California halibut in Anaheim Bay are hosts for isopod and copepod ectoparasites. An isopod of the genus Livoneca (Cymothidae) is a common parasite found on many flatfishes in California (MacGinitie and MacGinitie, 1968) and often was seen on the body and/or in the branchial cavity.

In Anaheim Bay four species of copepod parasites occur on California halibut. Lepeophtheirus bufidus was commonly seen on its body. Acanthochondria soleae and Holobomalochus prolixus were found in the branchial cavity and on the gill surfaces, and Taenicanthodes haakeri was found on the fin rays (See chapter on parasitic crustacea).

Several endoparasites were commonly found in the gut during stomach analysis. The nematode, Spirocamallanus pereirai, was found throughout the digestive tract and occurred in 140 of the 292 fish analyzed (48%).

Two species of trematodes, Tubulovesicula linbergi (Hemiuridae) and Stephanostomum casum (Acanthocalpidae), were found in 100 of the digestive tract examined (34%). The former has been found in at least 25 Pacific coast fishes including various other flatfishes. The frequency of occurrence of each of these two trematodes was not determined.

There appears to be an increase in the percentage of California halibut infested by parasites with increasing size. Since size is a function of age, increased frequency of infestation by these forms is probably a function of the age of the fish.

A larval cestode of the genus Echeneibothrum was found encysted in the mesentaries of fewer than 2% of the fish examined. However, as this parasite is small it is likely that many were overlooked and the true infestation rate is higher.

15.9. MOVEMENT AND POPULATION

15.9.1. Methods

California halibut movements were studied by fin clipping and tagging. Clipping of the eyed side pelvic fin was normally performed on fish less than 30 mm (1.18 inches) long and larger fish when tags were not available. Fish 30 to 125 mm (1.18 to 4.92 inches) long were marked with a hook tag which consisted of a size 6 (Sealey) fish hook with a piece of plastic tubing imprinted with an identification number slipped over the shank. The hook was inserted into the musculature of the eyed side just under the dorsal fin at the widest part of the fish, so that the barb passed into and back out of the skin.

Fish larger than 125 mm (4.92 inches) were tagged with an orange plastic "spaghetti" tag imprinted with the inscription "CSCLB BIOLOGY" and an indentification number. At one end of the tag a knot was tied. Insertion of the tag was performed by slipping the unknotted end of the tag on a tagging needle, making a small incision on the blind side of the fish, and pushing the needle with the tag through to the eyed side. The tag was cut just above the inscription and the knot was pulled into the fish so that the knot lodged between the blind side musculature and the neural spines. Both hook and "spaghetti" tags were inserted with an application of tetracycline in petroleum jelly mixture to prevent bacterial infection.

Fin clipping or tagging was performed on fish trawled at one of three stations (Stations 2, 3, and 4; Figure 22). At the end of each trawl the boat was beached or anchored so that the tagged fish were released in the station of capture.

Ten tagged California halibut were kept in a laboratory aquarium for approximately 4 months to determine any deleterious effects of the tag. None of the fish died as a result of the tag. One fish did not eat and died after 3 months. This fish lost its tag since its body became so thin that the musculature did not hold the knot in place. Tag loss in the field was not an important factor in population estimates since those fish which lost a tag could be identified by the scar on the blind side. Tag incisions of other aquarium kept fish healed to varying degrees. The hook tag seemed to cause least damage, especially when it was only hooked through the integument. The wound on the eyed side was susceptible to reopening if the tag was pulled or moved excessively, as sometimes occurred during handling.

Recaptured tagged fish were examined for infection and erosion of the musculature due to tagging, but no significant effects were detected. It was found that in old recaptures algae had begun to grow on the tags exposed surface. The general condition of recaptured tagged fish seemed to be no different than that of untagged fish.

To study short term California halibut movements, fish were released with balloons or styrofoam floats on 4 m (13.12 feet) of monofilament nylon line attached to the fish. Positions of the floats were noted periodically or whenever any movement was observed. Observations were made during day and night hours.

15.9.2. Movement

Clark (1930a, 1930b) reported that in the spring adult California halibut migrate from deeper offshore waters to shallower waters near the coast to spawn, after which adults return to deeper waters. Young California halibut remained in shallow water. Frey (1971) reported that young fish do not move extensively, but that larger and older fish move great distances.

A total of 521 halibut were tagged with hook or "spaghetti" tags, and 260 fish were fin clipped. Forty-six (8.8%) of the tagged and 12 (4.6%) of the fin clipped fish were recaptured at least one time. Two tagged fish were recaptured twice. These figures do not include fish recaptured on the day of original tagging.

Thirty-nine recaptures occurred in the original station of tagging while only seven were recaptured in stations other than that of tagging. One of the fish caught out of the station of original tagging was taken by a fisherman at the Seal Beach pier, Seal Beach, California. Interstation movements were not characteristic of any particular fish size.

Length of time between capture and recapture of a tagged fish in Anaheim Bay varied between 1 and 133 days and averaged 37.3 days. The fish caught at Seal Beach pier had been tagged for 153 days.

Results of the tagging experiment indicate that there is very little movement by California halibut in Anaheim Bay before emigration occurs. This is in agreement with Hildebrand and Cable (1930) who reported on the lack of movement of two east coast species of Paralichthys. Data derived from floats attached to California halibut indicate that they are not extensive daily movers or particularly active fish. A fish placed in shallow water (about 0.5 m, 1.6 feet) moved to deeper water in response to tidal ebb, and remained there. Short, slow movements of a few meters were observed during day and night hours, but were more common during daylight hours. Quick darts were observed more often during daylight hours; these were probably strikes at food organisms.

The possibility of fish moving into areas adjacent to the stations was investigated by a series of trawls including the interstation areas, without recovery of any tagged fish.

California halibut probably begin emigrating from Anaheim Bay when they are approximately 200 mm (8 inches) long, which coincides with the maturation of the males (Frey, 1971), but a definite correlation between maturation and emigration has not been established. The length frequency distribution (Figure 41) illustrates a decline in the number of individuals caught over 200 mm (7.87 inches). When the fish migrate from the bay they probably do so rapidly since there is no tendency for fish to be tagged in Station 4 and recaptured in Stations 3 or 2.

Females begin to mature a year later than the males (Frey, 1971). If emigration is maturation related a higher percentage of females would be expected to be found among the larger fish in Anaheim Bay. This higher percentage occurred. of 30 fish over 250 mm (9.84 inches) that were sexed, 23 were female.

Emigration is probably to deeper offshore waters as has been recorded for the adults (Clark, 1930a, 1930b), rather than to nearby channels of Huntington Harbour. R. A. Hardy (Calif. Dept. Fish and Game, pers. comm.) reported California halibut 87 to 325 mm (3.43 to 12.80 inches) in length from the main channel of Huntington Harbour. This length range suggests a similar length composition as is found in Anaheim Bay marsh. Movement out of the bay complex was indicated by one fish that emigrated from Anaheim Bay and was caught at the Seal Beach Pier.

15.9.3. Population

Anaheim Bay is used as a nursery area by California halibut, as illustrated by the length frequency distribution (Figure 41) which shows the appearance of young of the year fish in April and May. Large increases in the 20 to 40 mm (0.79 to 1.57 inch) size fish captured during May were probably due to the addition of a cod end liner to the trawl, which increased selectivity for smaller individuals.

California halibut spawn in water 6 to 20 m (3 to 11 fathoms) deep from about February to July (Frey, 1971). The study area probably does not constitute part of the spawning ground since the waters are of insufficient depth, and no unmetamorphosed larvae or fecund females were taken. However, the outer harbor and the dredged entrance channel of Anaheim Bay are deep enough to serve as possible spawning areas.

In February, California halibut 12 mm (0.47 inches) long were taken with seines from the shallow shore lines in the study area. It appears that spawning occurs close to Anaheim Bay since the eggs are demersal (Frey, 1971), and probably are not carried long distances by the currents. Hildebrand and Cable (1930) report that newly hatched fish (2 to 3 mm) of two species of east coast Paralichthys went quickly to the bottom and remained almost exclusively bottom dwellers. The data contradict any long movements either passive or active on the part of newly hatched fry from a distant spawning area. Two fecund females were captured in a beach seine made at Seal Beach in April 1971. Large sandy shallow areas exist in the outer harbor of Anaheim Bay inside the jetties, and for several miles on either side of these jetties; such areas might be suitable spawning grounds.

Population estimates were calculated using the method of Schnabel as discussed by Robson and Reiger (1971). Since the mean tagged period for recaptured fish was approximately a month (37.3 days), an estimate of the population was performed monthly using only tagged fish during the previous month plus any tagged during the month in question. This procedure was used in an effort to minimize any error due to recruitment, emigration, or immigration. Since California halibut did not move extensively throughout the bay, each estimate was that of the number of fish in the area of each of three stations (Table 27). In some months estimates were not made due to insufficient data.

It should be noted that the Schnabel method is not totally suited to the open system of fish populations in Anaheim Bay where emigration, immigration and recruitment occur. A full discussion of the method can be found in Ricker (1958). Since movement in and out of the bay certainly exists, the estimates are really indicators of the order of magnitude of the California halibut population in the Anaheim Bay stations rather than absolute estimates.

The California halibut population of the three stations seems to be related to the area of the stations. Station 3 generally yielded the highest estimates of population throughout the year. This was expected since the station not only was the largest in total area, but probably had the greatest food productivity to support a larger population. Although the station was bounded in part by mud flats at low tide, most of the station was always covered with water.

Station 2, which was second in estimated population had large mud flats on the east side and a mud escarpment on the west side, with a channel up to 5 m (15.5 feet) deep. This station was reduced to about half its high water area during low tide. Productivity appears very high in this station, but much of it is unavailable periodically due to tidal fluctuation.

Station 4 is the smallest, shallowest, and farthest from the bay mouth. It supports a population of California halibut slightly smaller than Station 2. At low tide an exposed mud bar partially blocks the channel at the station midpoint, and the depth of water over the rest of the station is often less than 0.5 m (1.5 feet). Productivity is high, especially in small fishes such as topsmelt and California killifish which live near the mud banks.

TABLE 27

Monthly Catch, Tagging Recapture Data, and Schnabel Population Estimates

Month	Number captured	Number marked	Marked at large	Number recaptured	Estimate ± S. E.
STATION 2					
Jan	12	0	0	0	--
Feb	12	5	0	0	--
Mar	27	22	27	2	128 ± 90
Apr	39	23	90	6	190 ± 78
May	25	22	109	4	177 ± 89
Jun	16	16	22	1	352 ± 352
Jul	39	0	16	0	--
Aug	55	32	19	1	665 ± 665
Sep	24	16	64	0	--
Oct	26	20	50	6	93 ± 93
Nov	26	13	40	1	520 ± 520
Dec	73	48	112	6	271 ± 111
Jan	54	31	99	7	382 ± 144
Feb	43	19	81	2	790 ± 559
					MEAN = 357
STATION 3					
Jan	4	0	0	0	--
Feb	23	21	4	0	--
Mar	21	17	74	0	--
Apr	18	13	66	1	367 ± 367
May	60	36	84	0	--
Jun	21	21	36	1	756 ± 756
Jul	11	60	21	0	--
Aug	35	32	18	0	--
Sep	29	16	64	1	928 ± 928
Oct	32	13	45	1	746 ± 746
Nov	33	20	26	3	143 ± 83
Dec	49	31	85	5	252 ± 113
Jan	38	20	63	1	1198 ± 1198
Feb	41	19	58	2	563 ± 398
					MEAN = 619
STATION 4					
Jan	1	0	0	0	--
Feb	8	0	0	0	--
Mar	27	22	32	5	72 ± 32
Apr	27	13	82	3	265 ± 153
May	70	45	99	2	1085 ± 767
Jun	40	33	45	0	--
Jul	22	0	33	0	--
Aug	13	12	5	0	--
Sep	27	15	24	0	--
Oct	59	27	55	4	434 ± 217
Nov	27	16	55	3	248 ± 143
Dec	33	19	58	3	210 ± 121
Jan	26	17	38	3	165 ± 95
Feb	14	6	40	3	95 ± 55
					MEAN = 322

TABLE 27

Monthly Catch, Tagging Recapture Data, and Schnabel Population Estimates

16. QUANTITATIVE ASPECTS OF THE LIFE HISTORY OF THE DIAMOND TURBOT, HYPSOPSETTA GUTTULATA (GIRARD), IN ANAHEIM BAY

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16.1. INTRODUCTION

Diamond turbot, Hypsopsetta guttulata (Girard), the most common flatfish in Anaheim Bay during the period of research, was studied with respect to the quantitative aspects of its ecology and behavior (Figure 46).

The study area was confined to the middle arm of Anaheim Bay (Figure 22; Stations 2, 3, and 4). Occasional sampling was done in the west and east arms but not at any regular interval, and only for the purpose of checking the movement of tagged fish.

Previous reports on the diamond turbot have occurred in faunal works but have been restricted to descriptions and reports of ranges (Jordan and Evermann, 1896; Bane, 1968; Miller and Lea, 1972). No comprehensive ecological work has been published to date.

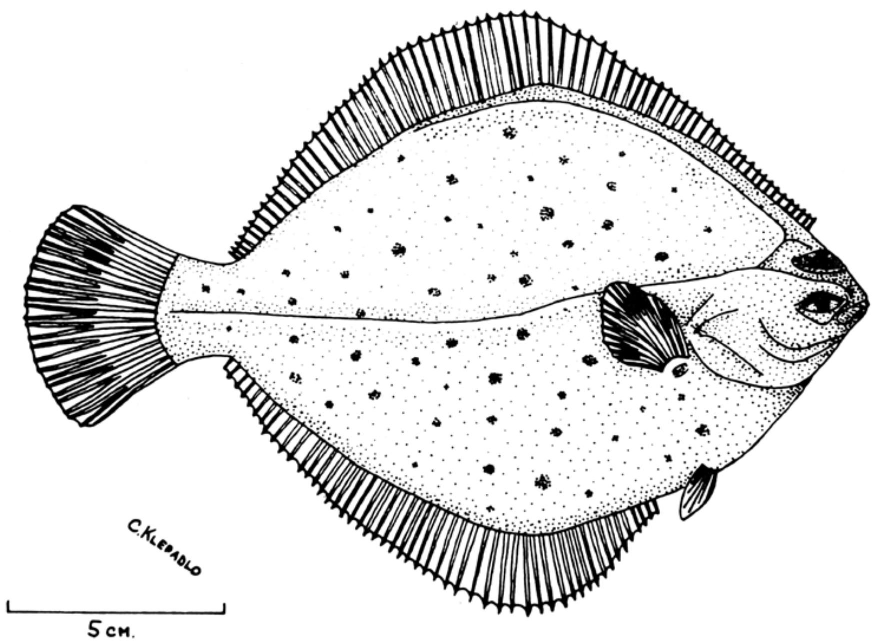

FIGURE 46—The diamond turbot, *Hypsopsetta guttulata,* from a specimen taken in Anaheim Bay. *Drawing by C. Klepadlo.*

FIGURE 46—The diamond turbot, Hypsopsetta guttulata, from a specimen taken in Anaheim Bay. Drawing by C. Klepadlo

16.2. MATERIALS AND METHODS

From January 1970 to February 1971, sampling was done every 6 weeks with two tagging cruises between each sampling. The gear is described by Odenweller (see chapter on the life history of the shiner surfperch).

All sampled fish were fixed in 4% formaldehyde (10% formalin) in sea water in the field. After 24 to 48 hours the specimens were washed in freshwater and stored in 40% isopropyl alcohol. Live fish for experiments were kept in plastic live tanks until transfer to a 65 x 235 x 30 cm (25.59 x 95.52 x 11.81 inches) laboratory experimental tank. Laboratory investigations included light preference and tagging mortality studies.

Chan and Lane presented a description of the chemical and physical aspects of the environment (see chapter on physical and chemical study of the Anaheim Bay salt marsh).

16.3. TAXONOMY AND DISTRIBUTION

The genus Hypsopsetta is closely related to Pleuronichthys (Norman, 1934), in fact the original description of the diamond turbot by Girard (1857) assigned the fish to the genus Pleuronichthys. Gunther (1862) used the genus Pleuronectes as well as Parophrys ayresi for Hypsopsetta guttulata. Gill (1863) assigned it to be genus Hypsopsetta where it has remained. The specific name guttulata has been constant except for ayresi used by Gunther.

The diamond turbot ranges from Magdalena Bay, Baja Californa, Mexico, to Cape Mendocino, California, with an isolated population in the Gulf of California (Miller and Lea, 1972). It is an inshore species and has been captured from a depth of a few centimeters (in Anaheim Bay) to about 50 m (165 ft.). It is most common in waters less than 10 m (33 ft.) in depth.

16.4. MEASUREMENTS AND MORPHOLOGY

Diamond turbot from Anaheim Bay fit previously published descriptions of the fish in other areas (Table 28). It should be noted that on the blind side around the mouth there is an area of bright chrome yellow pigment. This fades quickly in preservative and is often missing from descriptions based solely on museum specimens.

TABLE 28

A Comparison of Meristic Counts from Diamond Turbot.

Author	Number of fin rays			Number of vertebrae
	Dorsal	Anal	Caudal	
Miller and Lea (1972)	66–75	48–54	--	35–36
Norman (1934)	66–73	48–54	19	--
Jordan and Evermann (1896)	68	50	--	35
Present study, Anaheim Bay	64–70 $\bar{X} = 66.6$	47–52 $\bar{X} = 49.6$	18–20 $\bar{X} = 19.0$	33–36 $\bar{X} = 34.6$

TABLE 28

A Comparison of Meristic Counts from Diamond Turbot.

The reported maximum size is 18 inches (457 mm); however, the origin of this report was untraceable. The largest measured fish taken in this study was 295 mm (11.61 inches) SL or 358 mm (14.09 inches) TL. Although a definitely larger fish was reported taken in Anaheim Bay by a fisherman, no exact measure exists.

During the course of this study it was noted that the width of turbot, with respect to their length, varied considerably. Since this may have been a sexually dimorphic characteristic, the maximum width divided into standard length of the turbot was checked for 148 males and 151 females. While two trends were found to exist neither was statistically significant. First, there was a trend to relatively less width as the animals increased in length (Figure 47). This may be valid since it is consistent with all size groups. There was a slight trend for males to be somewhat more broad than females; however, this was not the case in all size classes and was not significant in total. It is probable that this sexual difference is due to sampling and is not biologically valid.

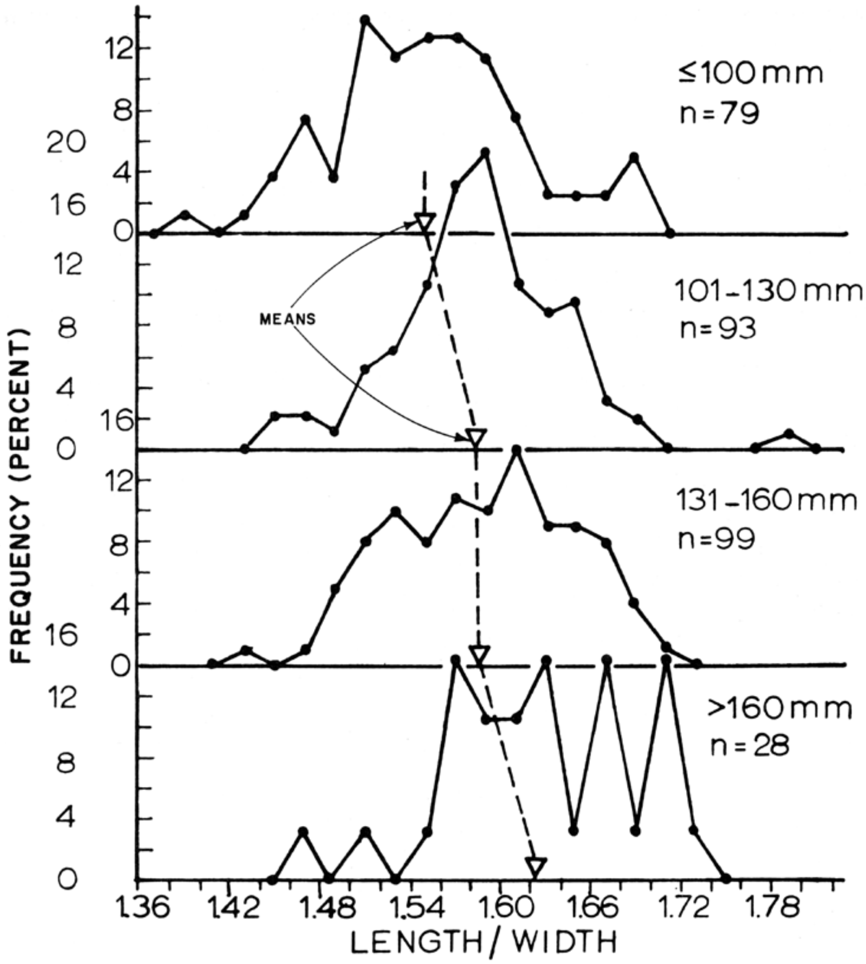

FIGURE 47—Frequency of standard length-width in different sized diamond turbot.

FIGURE 47—Frequency of standard length-width in different sized diamond turbot

Pigment and optic decussation anomalies were found in diamond turbot taken during this study; these are discussed in Haaker and Lane (1973).

16.5. LENGTH CONVERSIONS

In order to use all data on all specimens, preserved and fresh, it was necessary to compute the shrinkage factor due to preservation. Parker (1963) reported shrinkage due to preservation of 2% to 4% in length and 4% to 10% in weight, when formaldehyde and sea water solutions were used. Most of this shrinkage occurred within the first 24 hours. In this study the standard length of 207 fish was measured both before and after 48 hours of preservation. These fish varied between 21 and 200 mm (0.83 and 7.87 inches) SL.

Experimental error as shown by the considerable variation in measure (Table 29) was largely due to measuring fresh fish on board the boat. As this variation approximates a normal distribution it is expected that errors would cancel themselves out. An examination of the raw data indicates that rather than a percent correction, an addition of 2 mm (0.08 inches) to all fish greater than 40 mm (1.57 inches) in length is a usable correction from preserved to live lengths. This correction was made for growth data. The data were then grouped into 5 mm (0.20 inches) groups which were well within the acceptable statistical limits given by Anderson (1964).

TABLE 29

Shrinkage in a 48 Hour Period of Diamond Turbot Due to Preservation in 4% Formaldehyde and Sea Water Solution

Size range (standard length)	Average shrinkage (mm)	Range (mm)
21–50 mm	1.3	0 –(+2)
51–100 mm	1.8	0 –(+4)
101–150 mm	1.9	(−2)–(+10)
151–200 mm	1.7	(−4)–(+6)

TABLE 29

Shrinkage in a 48 Hour Period of Diamond Turbot Due to Preservation in 4% Formaldehyde and Sea Water Solution

Conversions from standard to total length were calculated from 150 fish selected by a random stratified method. Stratification was into groups of 0–50 mm (0–1.97 inches), 51–75 mm (2–2.95 inches), 76–100 mm (2.99–3.94 inches), 101–125 mm (3.98–4.92 inches), 126–150 mm (4.96–5.91 inches), and 151 mm (5.94 inches) and longer. The formula for conversion is: TL = 12.22 + SL (1.100) where: TL = total length SL = standard length r = 0.97 This formula describes fish 40 mm (1.57 inches) and larger; however, breaks down on very small fish.

16.6. MOVEMENT AND MIGRATION

16.6.1. Daily Movement

Two experiments were conducted in Station 3 to measure daily movement of individual fish. In March 1970, balloons were attached with monofilament nylon to four fish, then the fish were released. The balloons were observed continually from 1300 to 2030 hrs. The marked fish never wandered more than 50 m (164.0 feet) from the point of release. They did move to deeper water during ebb tide. It appeared that while the balloon seemed to have little effect on the fish, its presence probably could be felt due to the wind. A second experiment was run in November 1970. A planing, hull-shaped styrofoam float about 2.54 x 10.16 cm

(1 by 4 inches) was attached to four fish, replacing the balloon, in order to reduce the effect of drag and wind action. Observations were made from 1215 hrs. until 2215 hrs. and involved both low and high, flooding and ebbing tides. The diamond turbot never moved more than 75 m (246 feet) from the point of release. Again it was noted that the fish moved into deeper water in the center of channel with the ebbing tide. In both experiments no sudden rapid movements were noted; instead slow pace was the rule with periods of up to 4.5 hours with no apparent movement. Such slow movement would be expected from a bottom grazing fish such as the turbot.

16.6.2. Long Term Movement

No obvious migrations were observed during this study, and by far the greatest number of recaptures of tagged fish were in the same station as released (Table 30). Although trawls were made in the west and east arms, no recaptures of middle arm fish were made. Two fish were recaptured by anglers; one fish in Huntington Harbour, a distance of about 1 km (0.62 miles) from the tagging site, and one fish 2 years after tagging, at the tagging site (Station 2).

TABLE 30

Recapture Pattern of Tagged Diamond Turbot in the Middle Arm of Anaheim Bay.

	Days after Tagging					
	0–60			61 and longer		
	No. recap. in station			No. recap. in station		
Tagging Stations	2	3	4	2	3	4
2	19	2	2	4**	3	0
3	0	10	1	1*	3	0
4	2	1	11	2	2	4

* Indicates recapture below Station 2 in Huntington Harbour.
** One fish recaptured 2 years after tagging.

TABLE 30

Recapture Pattern of Tagged Diamond Turbot in the Middle Arm of Anaheim Bay.

It would appear, that there is relatively little short term movement within the bay; however, length frequency data from the stations indicates there is in fact some movement. Such movement appears to be spread out over most of the year and is therefore difficult to detect. There probably is no spawning in the inner bay; therefore, a short spawning migration is suggested (Figure 48).

The suggested migration pattern is supported by the fact that smaller fish are most frequent in Station 4 and larger fish are more common in Station 2, but all sizes were found in all stations. In addition, a few ripe adults were found within the inner bay.

The populations along the open shore do not appear nearly as dense as those in the bay and the possibility that large numbers of larva from shore populations finding the mouth of Anaheim Bay is remote. It is most likely that the dense bay population comes from spawning in the outer harbor immediately outside the bay.

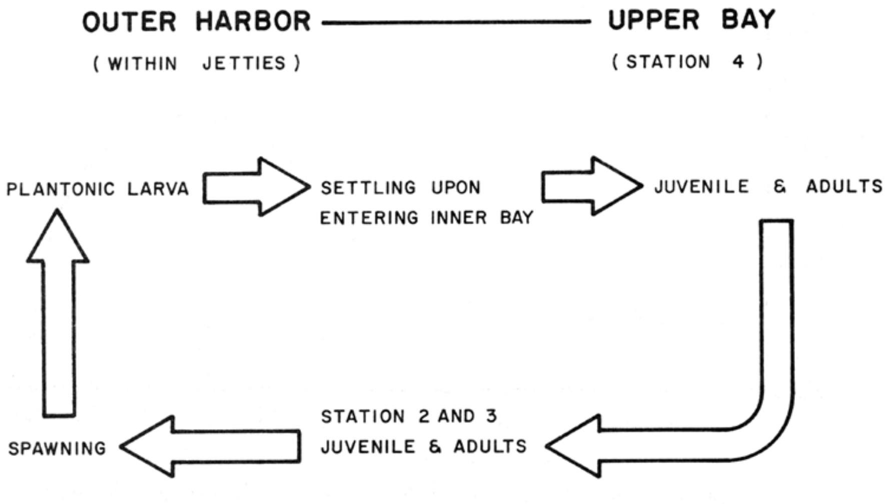

FIGURE 48—Probable migration pattern for diamond turbot in Anaheim Bay.

FIGURE 48—Probable migration pattern for diamond turbot in Anaheim Bay

16.7. SEX RATIO AND SPAWNING

Diamond turbot were sexed with a dissecting microscope. The females have gonads with distinct follicle cells even when very young, while the gonads of the males had a granular appearance with no obvious cells visible under low power (X30).

The sex ratio obtained from examining 662 fish collected over the whole year, was 1 male to 1.15 females. The slight imbalance in favor of females was consistent in most months, but is not significant and is probably the result of sampling bias. It was noted that for any given trawl catch the fish tended to be largely of one sex, with ratios usually about 4:1 or 5:1; this was especially true of fish over 125 mm (4.92 inches) in length. It was very rare to have a catch in which all fish were one sex and equally rare to have a sex ratio approaching 1:1 in any given catch. Why or how this apparent incomplete sexual separation occurs is not known.

Several methods were used to define the spawning period. A gonad-ostomic index was calculated for both males and females but no obvious trend was apparent. The largest individual index for a male (0.280%) and a female (3.217%) both occurred in January and the largest monthly mean index for adult females (0.75%) was also in January. For males the largest monthly mean index (0.066%) occurred in February. The lowest mean index occurred in October for both sexes. However, neither high nor low index values were very different from the other months and without supporting evidence little confidence can be placed on them.

Egg diameter was measured with an eyepiece micrometer for all females sexed, excluding the young fish under 100 g (3.53 oz.). The smallest average egg diameter occurred in March 0.07 mm (0.002 inches), with a steady increase until a maximum was reached 0.16 mm (0.62 inches), in December and January (Figure 49). The largest individual female egg diameter measured was in January (0.5 mm, 0.02 inches).

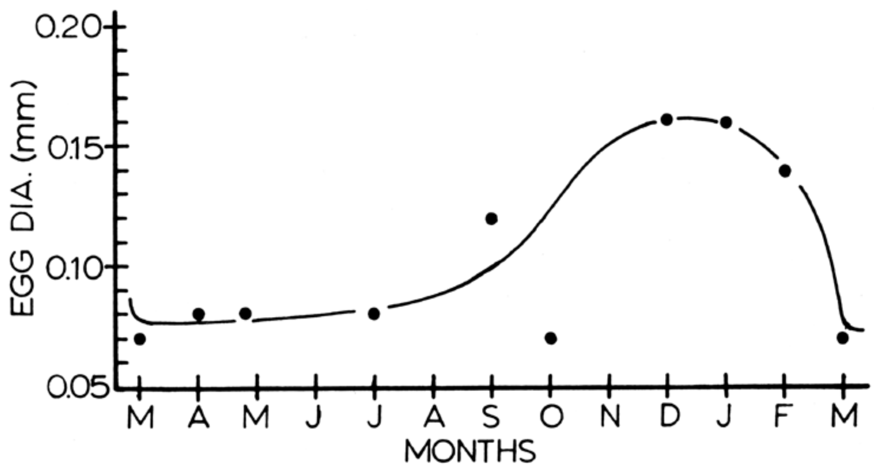

FIGURE 49—Average egg diameter throughout a year from diamond turbot over 100 g in weight.

FIGURE 49—Average egg diameter throughout a year from diamond turbot over 100 g in weight

From these data it is speculated that diamond turbot spawning starts in September and continues until late February with peak months from November through January.

The spawning area is not known. However, as previously discussed, the Anaheim Bay diamond turbot population probably spawns in or very near the outer harbor of the bay.

16.8. LIGHT PREFERENCE

The diamond turbot feeds almost totally during daylight. Light penetration in Anaheim Bay is usually to the bottom (see chapter on physical and chemical study of the Anaheim Bay salt marsh). For these reasons the diamond turbot was tested to determine if any daytime light or dark preference existed.

An aquarium measuring 65 × 235 and 30 cm deep (25.59 × 92.52 × 11.81 inches), supplied with a coarse sand substrate, was divided into three sections by covers; dark, with plywood cover; dull, with translucent plastic cover; and light, without cover. A light source was timed to turn on at 0600 hrs. and off at 1900 hrs. in two experiments. The relative amounts of light on the water surface was measured with a photometer and the results were: dark, 0.4 units; dull, 38 units; and light, 46 units. Since the dull and light were so similar, the main difference seem to be that fish under the dull cover were unable to see activity about them in the laboratory whereas those fish in the area without cover may have been disturbed by activity. The covers were moveable so that the fish did not become accustomed to one area in the aquarium. After each observation the covers were placed in different positions. The fish were tagged with different colored tags in order to observe individual movement. At the start of the summer experiment the fish were caused to move after each observation by probing them with a stick. However, it was noted that the fish moved without probing and this was discontinued.

The summer experiment was run intermittently during May, June, and July 1970 with four fish, and the winter experiment during December 1970 and January 1971 with six fish. The fish varied in length from 130 to 180 mm (5.12

to 7.09 inches) long. During the summer experiment all the fish showed a strong preference for the dull light. The summed results were: 73 times observed in dull, 30 in light, and 30 in dark. In the winter experiment all the fish showed a stronger preference for both dull and light and appeared to avoid the dark portions. The results were: 55 times observed in light, 52 in dull, and 13 in the dark portion. The summed totals for both experiments were dull, 125; light, 85; and dark, 43.

If it is assumed that in fact the difference between light and dull was a disturbance factor rather than one of light, then the fish showed almost a 2.5:1 daytime preference for light over dark. These data fit well with the observed diamond turbot feeding pattern (i.e. daylight activity). The experiments were conducted during all laboratory daylight hours, (between 0600 and 1900 hrs.) but not at laboratory night.

These data and feeding data indicate that diamond turbot is a diurnal fish in its activity.

16.9. POPULATION SIZE

Diamond turbot were marked throughout the study. Marking was done by either a blind side pectoral fin clip on fish between 50 and 125 mm (1.97 and 4.92 inches) SL or by "spaghetti tags" on fish 125 mm (4.92 inches) and larger. The "spaghetti" tag was inserted as follows: the tag was prepared by knotting one end and inserting the other end into a stainless steel tagging needle; a small incision was cut in the blind side to enable entry of the tag which was pulled through and out the eyed side so as to lodge the knot against the neural arches or neural pterygiophores. The tag was then visible on the eyed side. Each tag read CSCLB BIOLOGY and was numbered. During tagging, the needles and scalpel were kept in a vaseline and tetracycline mixture to prevent infection.

On three occasions, tagged and untagged fish were retained in the laboratory for periods up to 3 months and no tagging mortality was noted; therefore, in calculating population sizes, no tagging mortality was assumed.

Population estimates were based on 60 day periods for tagged and clipped fish. This period was chosen because initial tag return data showed that only about 28% of the tagged fish were still in the population after 2 months. Those not in the population after 1 month compensate those remaining for longer than 2 months.

Tag loss is not a factor since fish which had lost their tags were readily recognizable by a scar on the blind side where the incision had been made.

Random movement of tagged fish is assumed using Chapman's (1954) adjustment to the Schnabel multiple census (Ricker, 1958). This was not completely met in this case since the population appeared to have some movement (Figure 48), hence, the population estimates are probably somewhat low (Table 31).

All three stations are combined as a unit and estimates are given for the whole middle arm of Anaheim Bay. While the west and east arms have populations of diamond turbot, their densities are considerably lower and an estimate for the whole bay would be between 5,000 to 7,000 individuals of 50 mm (1.97 inches) and longer. Fish smaller than 50 mm were rarely taken by the gear used and hence are not included in the calculations. To check the figures, estimates based on trawl capture, assuming 100% of the fish met by the trawl were captured, showed the middle arm population to be approximately 3,000 fish. Since there is never 100% capture by any gear, this estimate is certain to be low but it does support the calculated population estimate of 3,500 for the middle arm.

TABLE 31

Population Estimates for Diamond Turbot in the Middle Arm of Anaheim Bay.*

Date	C_t	M_t	$(\Sigma C_t M_t)$	(ΣR_t)	N	95% range (Poison)
22/2/70	89	41	--	--	--	--
26/3/70	86	129	14743	3	3686	1675–24572
27/3/70	74	211	30357	7	3795	2795–10842
28/3/70	48	278	43701	12	3362	2081– 7049
5/4/70	74	321	67455	19	3373	2279– 5866
19/4/70	88	280	92095	21	4186	2878– 7084
3/5/70	82	258	109602	26	4059	2884– 6447
24/5/70	61	336	130098	33	3826	2810– 5731
31/5/70	28	198	95590	28	3296	2366– 5139
28/6/70	118	130	62536	23	2606	1818– 4283
13/7/70	95	166	57150	24	2286	1605– 3711
9/8/70	69	109	38631	13	2759	1732– 5599
23/8/70	92	175	54731	15	3421	2207– 6516
5/9/70	146	151	61437	15	3840	2477– 7314
20/9/70	131	156	66103	11	5509	3355–12241
11/10/70	116	215	83522	15	5220	3368– 9943
18/10/70	104	323	117114	20	5092	3528– 8487
1/11/70	59	233	114781	29	3825	2759– 5916
11/11/70	31	233	99938	28	3446	2402– 5151
15/11/70	56	233	112982	32	3427	2505– 5183
2/12/70	198	157	110588	36	2989	2221– 4401
13/12/70	69	52	102284	33	3008	2209– 4506
16/12/70	10	111	103394	34	2954	2177– 4400
29/12/70	77	120	79042	34	2258	1664– 3363
10/1/71	97	189	83628	28	2884	2070– 4496
24/1/71	85	137	75002	24	3000	2107– 4870
7/2/71	54	217	55634	23	2318	1617– 3811
21/2/71	74	197	65514	26	2426	1724– 3854
	Average all year = 3417					

* Method $N = (\Sigma C_t M_t)/[(\Sigma R_t) + 1]$
Time period not exceeding 60 days.
C_t = Total catch on day t
M_t = Number marked fish at larger beginning day t with a 60 day interval
R_t = Number of recaptures in sample C_t
N = Estimate of the population.

TABLE 31

Population Estimates for Diamond Turbot in the Middle Arm of Anaheim Bay.

16.10. AGE, GROWTH, AND MORTALITY

Sampled fish were aged by three methods, and agreement was excellent. Fish were aged by scale reading, otoliths, and analysis of length-frequency data. Scales were the easiest and most consistent method with only one difficulty, namely, a false annulus at 0^+ in the largest individuals of that age class, probably in those fish that metamorphosed earliest. This false annulus appeared in spring of the first year in such fish.

Diamond turbot scales are small and thin and were sandwich mounted between two slides. Otoliths were taken from the same fish, cleaned, dried, and read immersed in anise oil in the manner described by Gambell and Messtorff (1964). Better than 95% agreement was found between the scale and otolith methods; the exceptions being some fish 3 or 4 years old where the last band on the otolith was often difficult to distinguish. Fish aged in these two ways were plotted into the length-frequency histograms (Figure 50) which then could be used to age fish up to about 24 months of age. This included more than 98% of the total catch.

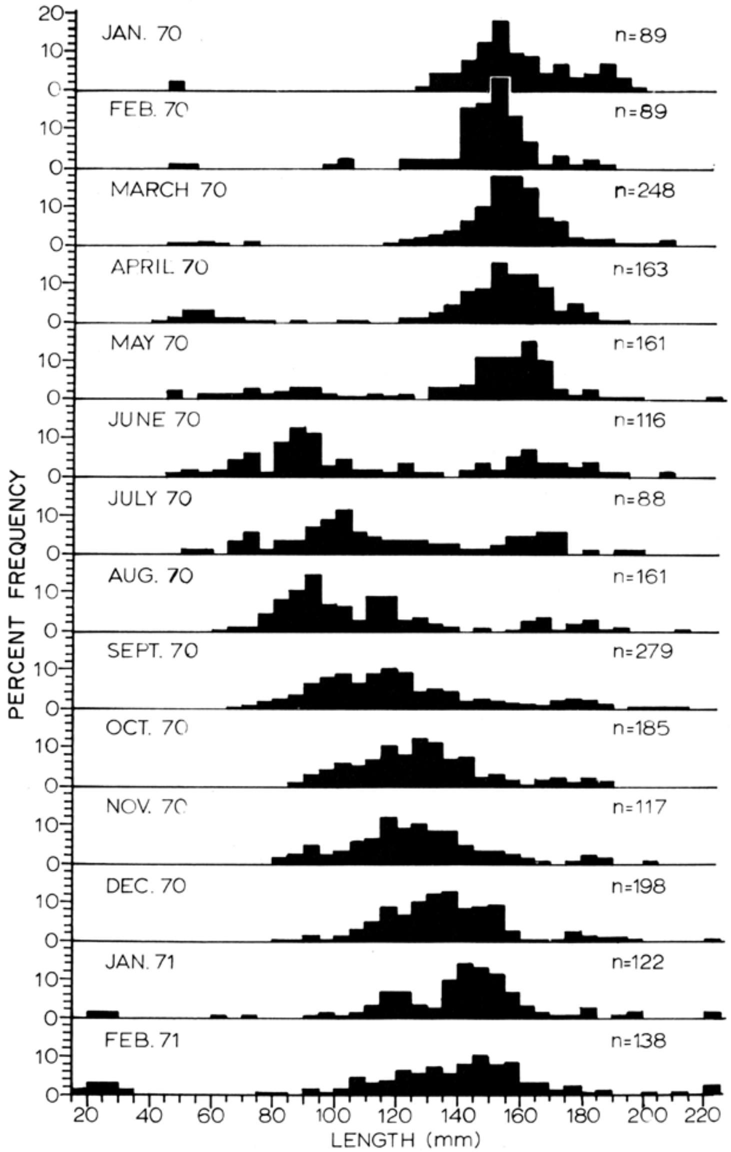

FIGURE 50—Monthly length frequency histograms of diamond turbot from Anaheim Bay. Frequencies are percentages, n = total catch used during the month indicated.

FIGURE 50—Monthly length frequency histograms of diamond turbot from Anaheim Bay. Frequencies are percentages, n = total catch used during the month indicated

The oldest fish was one tagged during the study and at that time determined to be 4 years old (January 1971). It was recaptured by a fisherman, L. C. Drenon, in January 1973, making it 6 years old at the time of final capture.

16.10.1. Mortality

Mortality was estimated by two methods, both using the equation: $N_{t2} = N_{t1} e^{-Z(t_1 - t_2)}$ where: N_{t2} = Number at time t_2 N_{t1} = Number at the beginning of time period $t_1 - t_2$ Z = instantaneous coefficient of mortality $t_1 - t_2$ = length of time involved.

The monthly catch per unit effort data from the 1969 year class during their second year of life (i.e. 12 to 24 months) was used. The estimated average monthly instantaneous mortality using these data was 0.22 and the average annual instantaneous mortality (Z) was 2.62. Using catch data on all fish from all years classes, and lumping them to compare all fish from 9 to 15 months of age with those of age 21 to 27 months; the average annual instantaneous mortality (Z) was 2.65. The average annual instantaneous mortality (Z) included both mortality and emigration, and was affected by the fact that larger individuals may have been better at escaping the trawl. Both emigration and escape would tend to indicate that the present estimate of Z from 2.62 to 2.65 is somewhat high. However, two indicators tend to substantiate the hypothesis that movement and escape is limited. One, larger sized fish are not found to any great extent in catches from other areas (where they would presumably migrate to). Secondly, the only tagged individual recaptured after a long time period (2 years) was taken in the station of tagging. The fish that emigrate to spawn probably die thereafter with few returning to the inner bay. Therefore, estimates of the average annual instantaneous mortality (Z) are probably close to the true Z. In terms of percentage, the mortality between ages 1 and 2 years is estimated to be between 94.2 and 94.3% with the survival rate of 5.8 and 5.9%.

No estimates were determined for fish in their first year of life since such fish were not fully vulnerable to the trawl and were immigrating to the inner bay during this time.

16.10.2. Length-Weight Relationships

Fish were stratified into size groups and a random sample of 25 fish was drawn from each group. Size groups were 20–74, 75–99, 100–124, 125–149, 150–174, 175–199 and 200 and greater mm (0.79–2.91, 2.95–3.90, 3.94–4.88, 4.92–5.87, 5.91–6.85, 6.89–7.83 and 7.87 inches) SL (maximum 277 mm, 10.91 inches). A total of 158 fish was used.

The length-weight relationship was: log W = 5.348 - 10 + 3.044 log SL or W 2.213×10^{-5} SL $^{3.044}$

The co-efficient of correlation "r" for these data was 0.995 where: W = weight after preservation and SL = length after preservation The power term (3.044) is very close to 3 and indicates growth is isometric from 20 to 277 mm (0.79 to 10.91 inches) SL.

16.10.3. Growth

Calculations of growth were made on diamond turbot up to the age of 24 months, assuming January 1 to be the birthday. This assumption is reasonable since it is estimated that the spawning peak occurs from November to January, and when the data are checked by extending the growth curve, age 0 months occurs very near January 1.

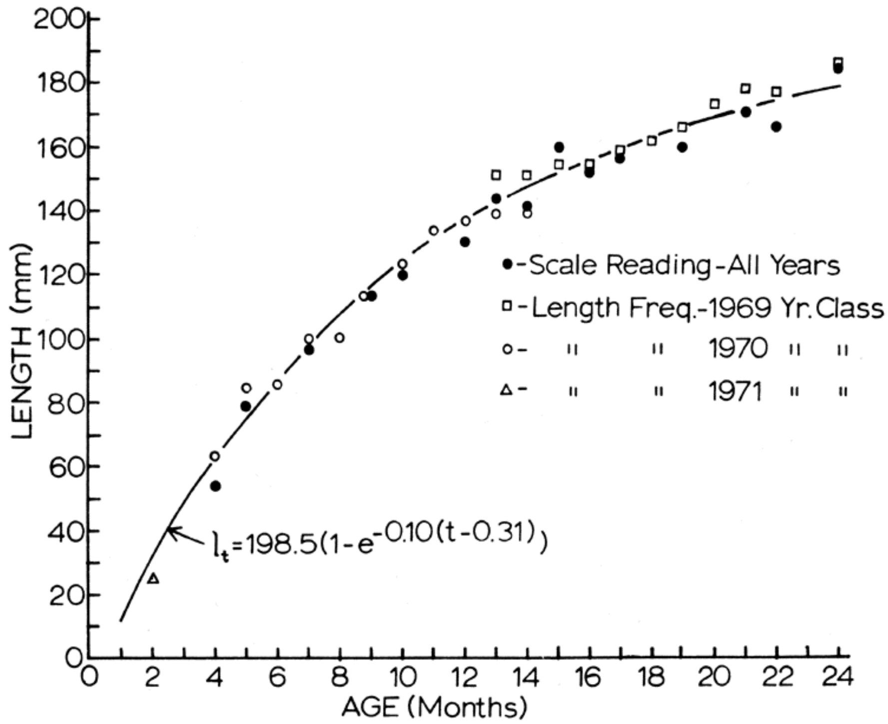

FIGURE 51—Observed growth curve of diamond turbot fitted to the von Bertalanffy (1938) model

Growth from 1 to 24 months was found to approximate a von Bertalanffy (1938) growth curve (Figure 51). The parameters of the equation:

$$l_t = L_\infty\left(1 - e^{-K(t - t_o)}\right)$$

EQUATION

are:

$$L_\infty \text{ (asymptotic length)} = 198.3$$

EQUATION

K (proportionality constant) = 0.10 t_o (parameter of the simple von Bertalanffy model) = +0.31 A regression analysis of $l_t + 1$ and l_t from a Ford-Walford plot (Figure 52) yielded estimates of

$$L_\infty$$

EQUATION

and K. The t_o was estimated using the average t_o between ages 4 and 20 months (Gullard, 1965).

The analysis of $l_t + 1$ and l_t gave: $l_t + 1 = 19.43 + 0.902\, l_t$ hence:

$$L_\infty = 198 \text{ (i.e., where } l_t + 1 = l_t)$$

EQUATION

then:

$$e^{-K} = 0.902 \therefore K = 0.10$$

EQUATION

t_o was estimated from t = 4 to t = 20 (months) by the formula

$$t_o = t + \frac{1}{K} \ln \left(\frac{L_\infty - l_t}{L_\infty} \right)$$

EQUATION

By this method, mean t_o = +0.31.

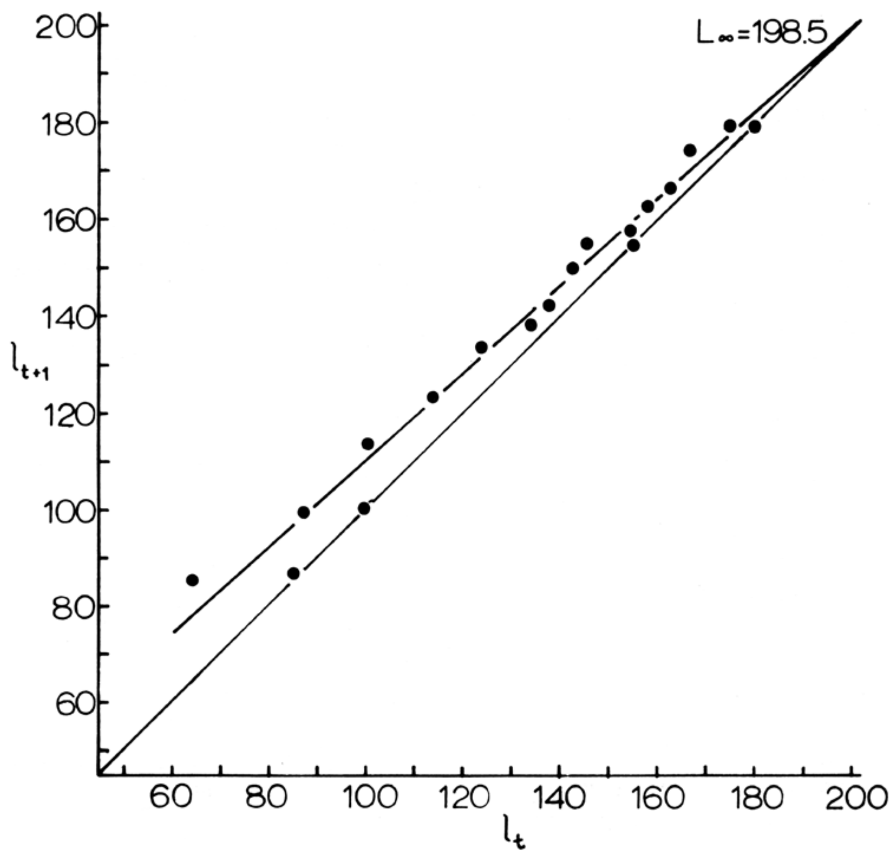

FIGURE 52—Ford-Walford plot, using t in months, for the diamond turbot over the first 2 years of life.

FIGURE 52—Ford-Walford plot, using t in months, for the diamond turbot over the first 2 years of life

The instantaneous growth on a monthly basis was calculated between age 2 and 23 months (Tesch, 1971). It decreased with time as would be expected (Table 32). A mean monthly instantaneous growth from age 7 months to age 24 months, was 0.108.

A few individuals lived beyond 2 years (less than 2% of the adult population). Such fish were aged and the oldest was estimated to be 6 years. These older fish were larger than the calculated asymptotic length ([L8]) which was based on fish aged 0 to 24 months old. It appears that at some time between 25 and 35 months of age the fish increase their growth rates and undergo a second stanza of rapid growth. There were, however, too few fish in these age groups to draw any meaningful conclusions. Perhaps the faster growing fish are all that survive the first spawning or alternately some fish do not spawn during their second year of life and live longer. There is a shift in diet in larger fish toward much larger food items and this may allow the second phase of rapid growth. At any rate such fish were not a significant part of the population in terms of numbers or biomass.

TABLE 32

Means of Length and Weight * and Estimated Instantaneous Growth Rate in Diamond Turbot from Anaheim Bay.

Age (months)	Average Length (mm)	Uncorrected average weight (g)	Corrected average weight (g)	G (monthly)†
2	25.00	0.41	0.45	
3	--	--	--	1.56
4	63.64	7.42	8.98	
5	85.21	17.08	20.75	0.84
6	86.59	18.01	20.34	−0.02
7	99.92	27.86	30.95	0.42
8	100.23	30.11	32.77	0.06
9	113.70	41.34	45.36	0.32
10	123.57	53.16	55.92	0.21
11	133.67	67.53	71.80	0.25
12	137.93	74.34	77.50	0.08
13	141.97	81.11	84.60	0.08
14	145.42	87.29	90.51	0.07
15	155.03	106.05	108.14	0.18
16	154.69	105.27	107.28	0.00
17	157.58	111.47	113.17	0.05
18	162.45	122.23	124.80	0.10
19	166.39	131.54	133.59	0.07
20	174.55	152.18	153.79	0.14
21	179.58	165.90	166.74	0.08
22	178.97	164.21	166.54	0.00
23	--	--	--	0.07
24	187.83 L_{∞} = 198.30	190.12	190.98 W_{∞} = 225.07	

* Uncorrected average weight calculated from length-weight regression. This was corrected by the method of Pienaar and Ricker (1968).
† $G = (\ln W_t - \ln W_0)/\Delta t$

TABLE 32

Means of Length and Weight and Estimated Instantaneous Growth Rate in Diamond Turbot from Anaheim Bay.

16.11. FOOD AND FEEDING

16.11.1. Methods

Stomachs of 389 diamond turbot caught over the entire year and at all hours of day and night were examined. These stomachs were taken from preserved fish and stored in 40% isopropyl alcohol. During analysis the total stomach content and the individual items were wet weighed to the nearest 0.01 g. Wet weights were standardized in the following manner. Stomach contents were removed and placed on paper laboratory towels for approximately 5 minutes, then weighed. Records were kept on total weights, individuals weights, and occurrences. The method of feeding with respect to the diet was ascertained from skulls which were prepared by boiling and picking the flesh from them.

16.11.2. Food

Mollusca, Polychaeta, and Crustacea form the major portion of the diet of the diamond turbot (Figure 53, Table 33). often studies report food by occurrence; however, a comparison of occurrence and wet weight estimates of the diet shows that the better measure is weight. Occurrence of a given item can be very high when its importance is relatively low. This is especially notable in comparing the polychaetes and clam siphons (Figure 54). Polychaetes almost always have a higher frequency of occurrence than siphons whereas siphons are the more important food source by weight. It also can be seen that the occurrence of polychaetes drops in larger fish while the proportion in the diet by weight increases slightly. This is due to a shift from small polychaetes to large polychaetes with increasing fish size. Another problem with using occurrence data is illustrated by the small crustacea. In this case diamond turbot between 50 and 200 g (1.76 and 7.05 ounces) had an occurrence level of about 20% while the diet by weight was always 1% or less (Figure 55). If one had access only to occurrence data, it would appear that small crustacea are an important food item, while on a weight basis it is apparent that the food is of little importance in the fish diet. At best, diet as measured by occurrence can only be considered as an indication of importance of any given food.

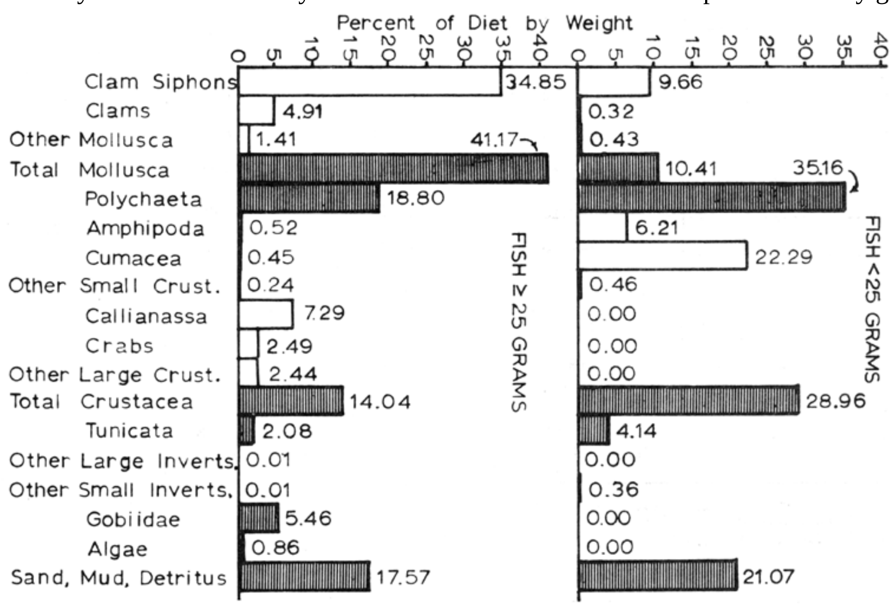

FIGURE 53—Diet of large and small diamond turbot expressed as percent of total food intake.

FIGURE 53—Diet of large and small diamond turbot expressed as percent of total food intake

TABLE 33

Food of Diamond Turbot Expressed as a Percentage of the Total Weight of All Food in Five Size Classes of Fish.

Fish size (g)	Crustacea						Tunicates	Polychaetes	%
	Misc. small	Cumacea	Amphipods	Misc. large	*Callianassa*	Crabs			
0– 24.9	0.83 29.7	22.19 67.6	5.84 64.9	0.00 0.00	0.00 0.00	0.00 0.00	4.14 16.2	35.16 94.6	By weight By occurrence
25– 49.9	0.47 23.5	2.17 38.2	1.52 47.1	0.00 0.00	6.62 8.8	0.94 8.8	1.37 23.5	27.52 94.1	By weight By occurrence
50– 99.9	0.74 10.4	0.15 14.6	0.11 8.3	1.66 5.2	3.46 6.3	2.43 18.8	1.90 17.7	19.15 85.4	By weight By occurrence
100–199.9	0.16 16.3	0.17 21.7	0.14 10.9	4.40 13.0	0.13 15.2	2.72 21.7	2.74 27.2	15.05 90.2	By weight By occurrence
200 and up	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	47.44 55.6	6.78 33.3	0.00 0.00	20.44 44.4	By weight By occurrence

Fish size (g)	Mollusca				Misc. small Invert.	Misc. large Invert.	Goby	Algae	Mud, sand, plant fragments	%
	Misc.	Clams	*Tagelus* siphons	Misc. siphons						
0– 24.9	0.43 21.6	0.32 13.5	9.19 35.1	0.47 24.3	0.36 2.7	0.00 0.00	0.00 0.00	0.00 0.00	26.90 --	By weight By occurrence
25– 49.9	0.49 11.8	5.82 41.2	25.50 64.7	1.32 32.4	0.00 0.00	0.00 0.00	2.71 8.8	0.00 0.00	23.56 --	By weight By occurrence
50– 99.9	1.72 11.5	3.85 29.2	33.07 75.0	1.25 31.3	0.00 0.00	0.03 2.1	8.24 21.9	1.53 3.1	20.72 --	By weight By occurrence
100–199.9	1.57 16.3	6.05 42.4	38.76 88.0	1.64 42.4	0.00 0.00	0.00 0.00	4.12 18.5	0.55 2.2	12.78 --	By weight By occurrence
200 and up	0.00 0.00	0.89 22.2	11.50 44.4	2.67 22.2	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	10.28 --	By weight By occurrence

TABLE 33

Food of Diamond Turbot Expressed as a Percentage of the Total Weight of All Food in Five Size Classes of Fish.

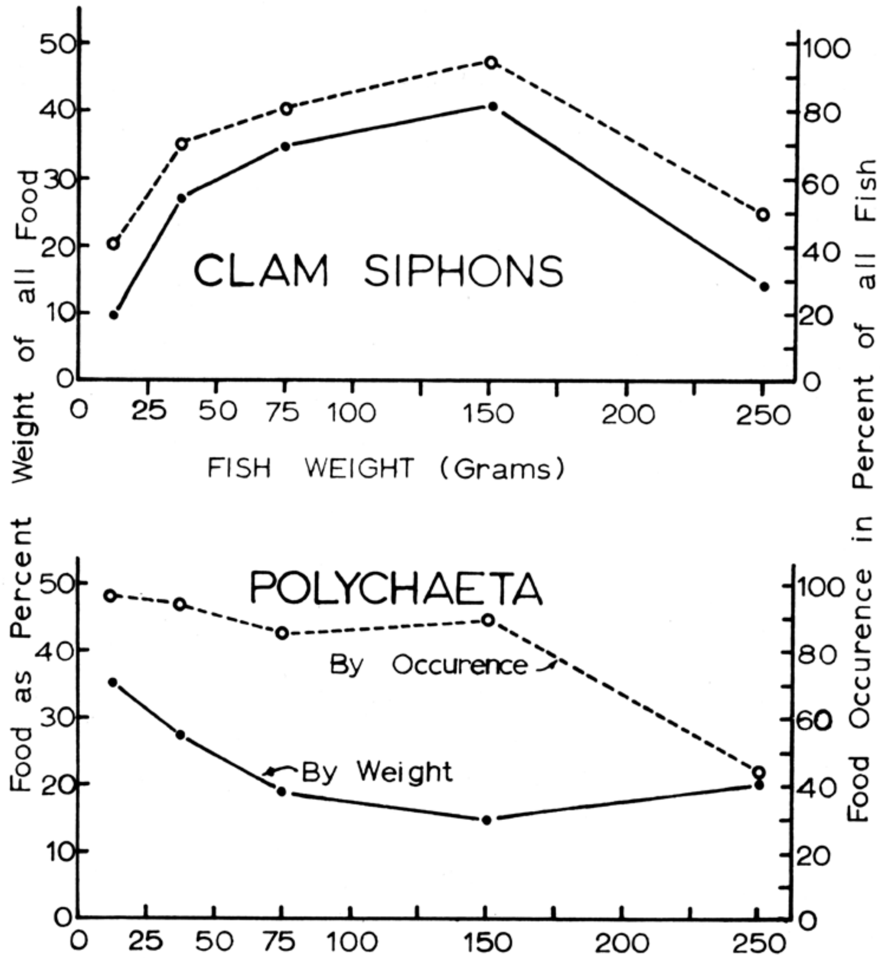

FIGURE 54—Comparisons of amounts, measured by occurrence and weight of clam siphons and polychaeta, eaten by diamond turbot of various weight classes.

FIGURE 54—Comparisons of amounts, measured by occurrence and weight of clam siphons and polychaeta, eaten by diamond turbot of various weight classes

There were no major seasonal dietary trends except that in spring and early summer there was an increase in the frequency of clams in the diet. These clams were all very small, usually not more than 3 mm (0.12 inches) in length. During this period, there was also a slight decrease in the amount of clam siphons in the diet. A marked day-night diet pattern was noted during this study with the fish ceasing to feed at night and starting to feed again in the morning, with continual feeding all day.

The food items were considered in major food divisions. These major divisions and included organisms are: miscellaneous small crustacean—including an array of largely larval decapods as well as the skeleton shrimp, Caprella spp.; miscellaneous large crustacea—including mostly pistol shrimps, Cragon spp.; crabs—including a few shore crabs, Hemigrapsus spp., young Cancer, but mostly pea crabs (Pinnotheridae); tunicates—including, as far as could be ascertained, only one species, Eugyra arenosa; polychaetes—including many families (see chapter on a quantitive study of the benthic polychaetous annelids); miscellaneous mollusca—including largely small olive snails, Olivella spp., and a few Bullidae Corithiidae, Naticidae, one nudibranch and a few unidentified mollusca feet; clams—including young clams with the following families identified, Cardiidae, Veneridae, Tellinidae and Garidae; clam siphons—including largely Tagelus spp. siphon tips with a few other siphons represented; miscellaneous large invertebrates—including Urechis caupo; Gobiidae—including mostly the arrow goby Clevelandia ios, and probably a few shadow gobies, Quietula y-cauda. All other major groups are self-explanatory

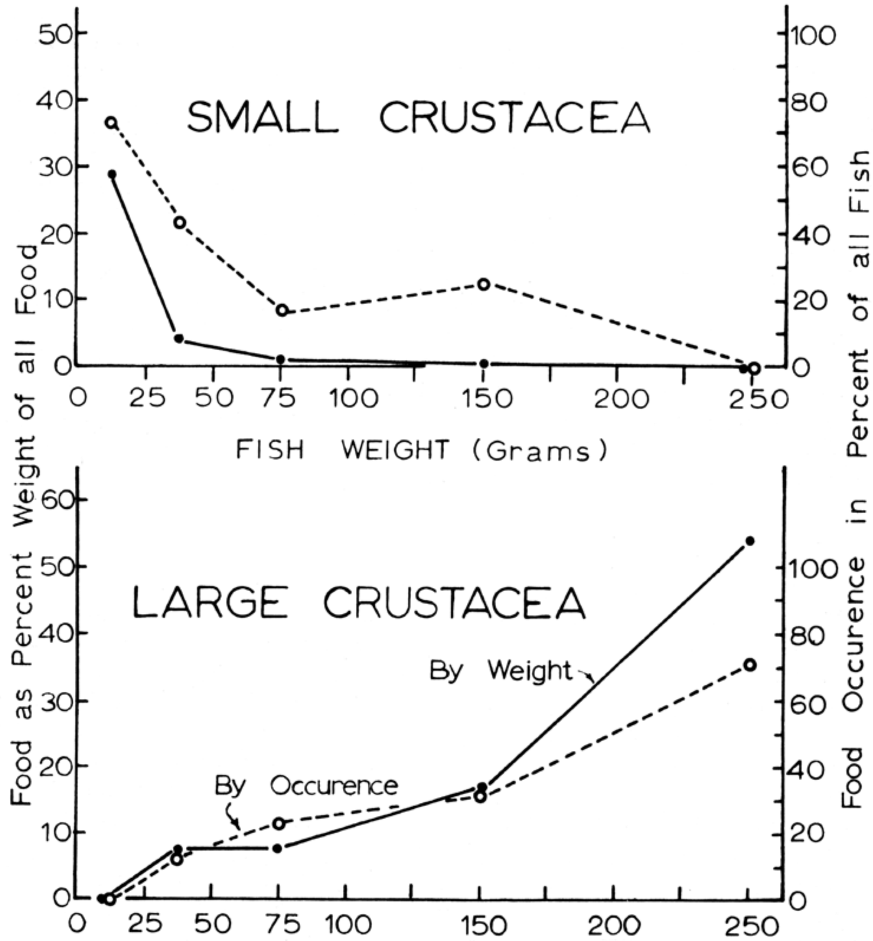

FIGURE 55—Comparisons of amounts, measured by occurrence and weight of large and small crustacea, eaten by diamond turbot of various weight classes.

FIGURE 55—Comparisons of amounts, measured by occurrence and weight of large and small crustacea, eaten by diamond turbot of various weight classes

There is a great change in diet with size (Figures 53, 54, and 55). The very young fish (less than 25 g, 0.88 oz.) rely heavily on small crustacea (29% by weight) and polychaetes (35% by weight) with a relatively low reliance on clam siphons. Small crustacea are defined as those whose weight was less than 0.01 g and large crustacea 0.01 g or greater, usually much greater. With growth there is a rapid decrease in the importance of small crustacea with a corresponding increase in the importance of large crustacea. The latter is the major food of very large turbot (over 200 g, 7.05 oz.). Polychaetes are reduced in importance with increasing size although they always made up 15% and 20% of the diet. Among fish between 50 and 200 g (1.76 and 7.05 oz.) in weight, clam siphons are the main food. Arrow gobies, although never a major food, are important to the mid sizes of turbot. No other food item is of any great importance at any fish size.

16.11.3. Feeding

Anaheim Bay has high populations of two species of flatfish; the California halibut and diamond turbot. Haaker (see chapter on the biology of the California halibut) has described the halibuts' feeding. It appears that the California halibut feeds either on or above the substrate whereas the diamond turbot feeds either on or in the substrate. Thus the two species are ecologically separated insofar as competition for food is concerned. The eyed and blind side gapes of the jaw of the California halibut were measured from five prepared skulls. The larger three skulls had the eyed side gape larger than the blind side gape (105%, 106%, and 110%). In the smaller two skulls both gape measurements were equal. This gape pattern appears adapted to feeding above the substrate. Diamond turbot, on the other hand, have a jaw with a much smaller gape which is angled slightly down toward the substrate, adapted for feeding in the substrate. The teeth of California halibut are large while those of diamond turbot are small. The diets of both fish reflect these adaptations. The California halibut would fit Groot's (1969) group within Bothidae. The diamond turbot fits Groot's Pleuronectid group in all characteristics except diet where it combines elements of both the Soleidae and Pleuronectidae groups.

16.12. ENVIRONMENTAL COST

The environmental cost, or how much food the environment must provide to maintain status quo can be calculated from estimates of food eaten and population numbers. The method of calculation has been devised by E. David Lane and D. E. Thornton, and will be published elsewhere. The model is based on the assumption that: the animal eats periodically, the rate of intake of food is a constant during the eating period, and the rate of digestion is a function of the amount of food in the stomach. Using this model an estimation of food intake for diamond turbot over 25 gm (0.88 oz.) weight was made. Smaller fish were eliminated because they ate different foods and had somewhat different diet feeding patterns.

The calculations of daily ratio is a matter of integrating the curve in Figure 56. The observed points (Table 34) closely fit the theoretical curve (Figure 56) hence, the model is considered to fit this situation. The daily ration (R) is estimated at 3.76% of fish body weight per day. The calculation of this daily ration then allows an estimate of food necessary to keep the population of diamond turbot in a status quo situation. The method is: mean fish weight X 3.76/100 X population. In this population, mean fish weight was 95.5 g (3.37 oz.); therefore, the average fish ate 3.59 g/day (0.13 oz.). If the population is approximated in the middle arm as 3,500, then the population eats 12.57 kg/day (27.72

lbs.), or 4587 kg/year (10,114.34 lbs.). This can be better appreciated by breaking this amount of food down by groups (Table 35).

TABLE 34

Average Amount of Food Found in the Stomachs of Diamond Turbot Throughout the Day.

Time of day	Percentage of food* found in fish 0–24 grams in size	Percentage of food* found in fish 25 grams and over
00:00–02:30	0.00	0.16
03:00–06:00	0.00	0.08
07:00–09:30	--	0.42
10:30–13:30	0.95	0.84
13:31–16:30	3.05	0.85
17:30–20:30	4.27	0.86
21:00–23:30	1.06	0.51

* Percentage of food is the amount of food expressed as a percent of fish body weight.

TABLE 34

Average Amount of Food Found in the Stomachs of Diamond Turbot Throughout the Day.

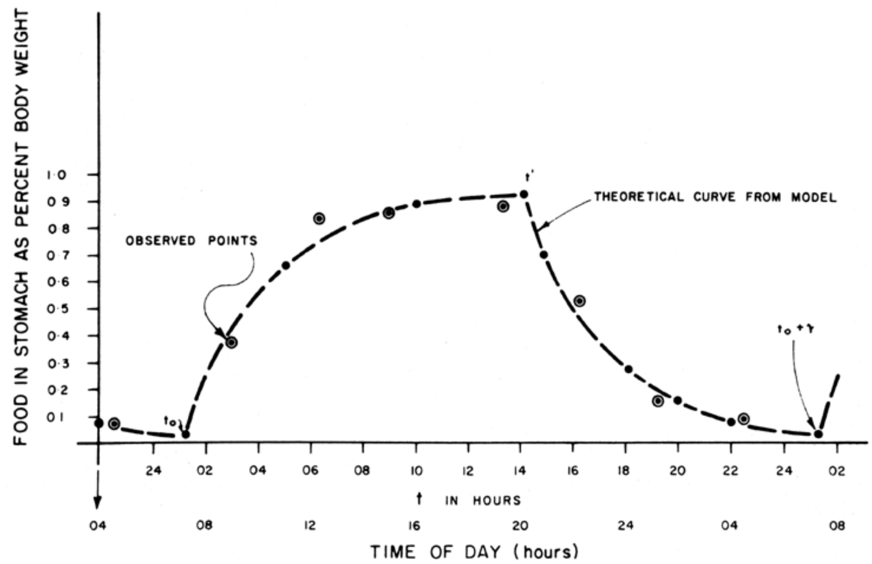

FIGURE 56—Theoretical and observed diel food curves for diamond turbot over 25 g weight taken during the study. t_o indicates the theoretical time feeding starts and t' the time feeding ceases.

FIGURE 56—Theoretical and observed diel food curves for diamond turbot over 25 g weight taken during the study. t_o indicates the theoretical time feeding starts and t' the time feeding ceases

16.13. PRODUCTION AND GROWTH EFFICIENCY

The mean monthly instantaneous growth rate of fish over 25 g (0.88 oz.) was 0.108 (Table 32). Therefore, the average fish in the population grew from 95.5 g (3.37 oz.) to 106.4 g (3.75 oz.) in a month, for an increase of 10.9 g/month (0.38 oz.) or 130.8 g/year (4.61 oz.). If again the rounded off population estimate for the middle arm of 3,500 fish is used, it is estimated that the annual production of diamond turbot protoplasm is 457.8 kg/year (1,009.45 lb.).

Growth efficiency may now be readily calculated since it took 4,587 kg (10,114.34 lbs.) of food to produce 457.8 kg of fish; therefore, the gross growth efficiency for the population is 10.0%. Nevertheless, 17.57% of the diet is sand, mud, etc. (Table 35) and if this is removed as part of the food, then efficiency rises to 12.1%. These figures compare well with Birkett's (1970) value for laboratory kept plaice, for which he obtained a growth efficiency of 16%. Birkett's laboratory raised fish may have a higher growth efficiency due to the limited possibility for movement in aquaria and the lower metabolic expense in food search.

TABLE 35

Estimates of the Amount of Food Eaten by the Population of Diamond Turbot in the Middle Arm of Anaheim Bay *

Diet	Percent of diet by weight	g/day	kg/year
Misc. small crustacea	0.44	55.3	20.18
Cumacea	0.45	56.6	20.64
Amphipods	0.32	40.2	14.68
Misc. large crustacea	2.44	306.7	111.92
Callianassa	7.90	993.0	362.37
Crabs	2.49	313.0	114.22
Total crustacea	14.04	1764.8	644.01
Tunicates	2.08	261.5	95.41
Polychaetes	18.80	2363.2	862.36
Misc. mollusca	1.41	177.2	64.68
Clams	4.91	617.2	225.22
Clam siphons	34.85	4380.6	1598.57
Total mollusca	41.17	5175.1	1888.47
Misc. small invertebrates	0.01	1.3	0.45
Misc. large invertebrates	0.01	1.3	0.45
Fish—gobies	5.46	686.3	250.45
Algae	0.86	108.1	39.45
Sand, mud, etc.	17.57	2208.5	805.94

* Data excludes fish under 25 grams.

TABLE 35

Estimates of the Amount of Food Eaten by the Population of Diamond Turbot in the Middle Arm of Anaheim Bay

16.14. PARASITES

The ectoparasites found on the diamond turbot are discussed by Ho (see chapter on parasitic crustacea). Both nematods and trematods were found in a very high percentage of the digestive tracts.

The trematod is located almost exclusively in the stomach. The two nematods were most commonly found in the small intestine but occasionally found in the stomach.

17. A CHECKLIST OF THE ELASMOBRANCHS AND TELEOSTS IN THE OUTER HARBOR OF ANAHEIM BAY

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17.1. INTRODUCTION

Although study of Anaheim Bay fish fauna has been in progress almost continually since 1969, no work was attempted on those fish inhabiting the outer harbor until April 1972. At that time two preliminary surveys were made, one during the day and one at night, to determine the feasibility of a faunal study in the area of the recreation beach (Figure 21, Station L). In June 1972 a 1 year study was initiated using seines and trawls for sampling. The seines used during the study included a 15.2 m (50 foot) bag seine (see chapter on the annotated checklist of the elasmobranchs and teleosts of Anaheim Bay), and a 30.4 x 1.8 m x 18.1 mm (100 x 6 foot x 0.75 inch) bar mesh seine. The shrimp otter trawl was similar to that used by Odenweller (see chapter on the life history of the shiner surfperch).

The study area consists of a sandy beach, approximately 365 m (1,198 feet) in length (Figure 21, Station L). The beach is bounded on the north by a rocky jetty and on the south by the channel into the inner harbor area. The beach is of artificial construction and extends about 6 m (20 feet) offshore at mean low tide. The natural substrate within the study area consists of very fine, hard-pack sand while that of the beach is of a much coarser, more loosely packed consistency. offshore, intermittent beds of eel grass, Zostera sp. extend the length of the beach. The maximum water depth in the area seined was about 3.6 m (2 fathoms). Mean water temperature was found to vary from a high of 21.5 C (70.7 F) in August to a low of 14.6 C (58.3 F) in January. The salinity was relatively constant at 33[o/oo].

Sampling was conducted at least once a month from June 1972 through June 1973 with seining being the predominant method. Trawls were made the length of the whole beach, both inside and outside the eel grass beds, three times during the study period. The majority of the seinings were such that 2 day and 2 night collections were made during a 24 hour period using both seines per collection. Once in each season, sampling was done every 2 hours throughout a 24 hour period, alternating small and large seines. At these times six 30 m (100 foot) wide stations were set up along the length of the beach and sampled in a stratified random order so that at the end of a 24 hour period each station was sampled once with each of the seines. All fish lengths are standard lengths (SL).

Various seasonal and day and night patterns were noted during this study, these are discussed in the text with the species involved and are summarized in data form (Table 36).

TABLE 36

Capture Data for Fish from Outer Anaheim Bay.

SPECIES	SUMMER		FALL		WINTER		SPRING		Total
	Day	Night	Day	Night	Day	Night	Day	Night	
Heterondontus francisci	--	1	--	3+	--	--	--	--	4+
Mustelus californicus	2	1	--	--	--	--	--	--	3
Myliobatis californica	--	2	1	1	--	1	--	--	5
Urolophus halleri	3	1	--	4	--	--	--	2	10
Anchoa compressa	--	3	--	--	--	--	--	--	3
Engraulis mordax	--	40	--	25	--	1	--	19	85
Porichthys myriaster	--	--	1	--	--	--	--	3	4
Otophidium scrippsi	--	--	--	11	--	--	--	--	11
Fundulus parvipinnis	--	--	--	1	--	--	--	--	1
Atherinops affinis	many*	many	many	many	many	many	many	many	many
Syngnathus leptorhynchus	6	6	--	--	22	1	--	--	35
Paralabrax clathratus	4	--	--	--	--	--	--	--	4
Paralabrax maculatofasciatus	9	7	--	5	--	4	1	3	29
Paralabrax nebulifer	--	--	--	1	--	--	--	--	1
Anisotramus davidsoni	--	1	--	--	--	1	--	--	2
Cheilotrema saturnum	--	1	--	2	--	1	--	--	4
Cynoscion nobilis	--	--	--	5	--	--	--	--	5
Genyonemus lineatus	--	3	--	23	--	3	--	--	29
Menticirrhus undulatus	42	19	6	7	--	3	8	7	92
Roncador stearnsi	--	5	--	--	--	--	--	--	5
Seriphus politus	2	82	--	12	--	6	--	6	108
Umbrina roncador	2	3	1	--	--	--	--	--	6
Girella nigricans	83	2	1	--	--	--	2	4	92
Amphistichus argenteus	--	--	--	--	--	1	--	--	1
Cymatogaster aggregata	508	90	10	27	--	3	6	21	665
Damalichthys vacca	1	3	1	9	--	9	--	5	28
Embiotoca jacksoni	88	18	18	95	1	75	--	33	328
Hyperprosopon argenteum	28	136	23	141	1	225	--	107	661
Micrometrus minimus	24	6	8	3	3	--	--	--	44
Phanerodon furcatus	148	11	77	62	12	72	20	25	427
Mugil cephalus	3	2	6	--	12	1	2	1	27
Heterostichus rostratus	36	6	2	1	2	1	--	4	52
Hypsoblennius gilberti	--	--	--	--	--	1	--	--	1
Sarda chiliensis	1	--	--	--	--	--	--	--	1
Sebastes pinniger	15	1	--	--	--	--	--	--	16
Leptocottus armatus	3	6	--	2	2	1	--	1	15
Paralichthys californicus	11	5	--	1	2	2	6	7	34
Hypsopsetta guttulata	1	2	--	4	--	4	4	8	23
Pleuronichthys ritteri	1	--	3	--	--	1	1	1	7
Pleuronichthys verticalis	1	--	--	--	--	--	1	--	2
Symphurus atricauda	--	--	--	9	--	--	--	--	9
Totals	1025	460	158	432	57	421	51	258	2883

* Numbers estimated at being between 1,000 to 3,000.

TABLE 36

Capture Data for Fish from Outer Anaheim Bay.

17.1.1. Family Heterodontidae

17.1.1.1. Heterodontus francisci (Girard)

The horned shark has been recorded in the outer harbor twice. One was captured in a gill net during June 1973 and several were observed by divers in October 1973 (E. D. Lane, Environment Canada, pers. comm.). Both occurrences took place at night and adjacent to the north jetty.

17.1.2. Family Carcharhinidae

17.1.2.1. Mustelus californicus Gill

Although the grey smoothhound is a common constituent of the bay fauna it has been recorded only once in the outer harbor. During June 1973 a total of three specimens were captured in a night gill net set near the north jetty.

17.1.3. Family Myliobatidae

17.1.3.1. Myliobatis californica Gill

In the summer and late fall of 1972 four bat rays were collected in the seines. Two were collected in late August and one each in mid-September and early December.

17.1.4. Family Dasyatidae

17.1.4.1. Urolophus halleri Cooper

As in the inner bay, the round stingray was the most commonly captured elasmobranch in the outer harbor. A total of ten was taken during the study period, six of which were taken by seine and four by trawl. Two of the specimens captured in November 1972 were juveniles.

17.1.5. Family Engraulidae

17.1.5.1. Anchoa compressa (Girard)

According to Klingbeil (1972), the deep body anchovy is quite abundant in the bay particularly during the months from March to November and most frequently caught by trawl. Only three specimens were taken; two in August 1972 and one in June 1973. All were caught at night by seine and ranged in size from 70 to 92 mm (2.8 to 3.6 inches) SL.

17.1.5.2. Anchoa delicatissima (Girard)

Three slough anchovies were taken by seine in January 1974. These are the first specimens from Anaheim Bay to be positively identified since the 1920's.

17.1.5.3. Engraulis mordax Girard

A total of 85 northern anchovies was taken throughout the study period by seine. of those 57 were adult and were taken during summer and fall. The remaining 28 juveniles were captured during winter and spring, 1973. All specimens were captured at night and varied in size from 27 to 137 mm (1.1 to 5.4 inches) SL.

17.1.6. Family Batrachoididae

17.1.6.1. Porichthys myriaster Hubbs and Schultz

Five specklefin midshipmen were collected in the outer harbor and all but one (a juvenile) were taken by seine. of the adults, one was collected in October 1972 and three in March 1973. One of the latter was a gravid female and it appears that spawning may take place in late March or early April. The juvenile was collected in a trawl in November and measured 37 mm (1.5 inches). The adults ranged in length from 214 to 366 mm (8.4 to 14.4 inches) SL, with the largest being the gravid female. All specimens were captured at night.

17.1.7. Family Ophidiidae

17.1.7.1. Otophidium scrippsi Hubbs

Nine basketweave cusk-eels were captured in a night trawl in November 1972. It is probable that at the time of capture they were feeding since they are burrowing nocturnal fish and only leave the substrate at night (Greenfield, 1968). They ranged in size from 198 to 265 mm (7.8 to 10.4 inches) SL.

17.1.8. Family Cyprinodontidae

17.1.8.1. Fundulus parvipinnis Girard

Although California killifish are a common member of the inner bay fauna only one specimen was taken in the outer harbor. This individual was collected at night in October 1972 with a siene and was 90 mm (3.5 inches) SL.

17.1.9. Family Atherinidae

17.1.9.1. Atherinops affinis (Ayres)

The topsmelt was the most abundant species in the outer harbor. Topsmelt were collected in large numbers throughout the year and exhibited no seasonal or diel variations. Although well over 10,000 were taken by seine, none was collected in trawls. Only 665 specimens were kept for examination, and they varied in length from 33 to 175 mm (1.3 to 6.9 inches) SL. Examination of the gonads indicated that spawning occurred in spring.

17.1.10. Family Syngnathidae

17.1.10.1. Syngnathus leptorhynchus (Ayres)

There were 35 bay pipefish taken during the study period. All were collected by seine, and the majority (28) during the day. Some males captured during the latter part of the summer were laden with eggs, so spawning probably occurs early in summer.

17.1.11. Family Serranidae

17.1.11.1. Paralabrax clathratus (Girard)

Four kelp bass were collected, two each during summer 1972 and 1973. All were taken by seine in the daytime. At present there is a rapid increase in the Sargassum sp. in the harbor area with an associated increase in kelp bass juveniles and other species associated with the rooted algae (E. D. Lane, Environment Canada, pers. comm.).

17.1.11.2. Paralabrax maculatofasciatus (Steindachner)

The spotted sand bass appears to be a permanent resident of the outer harbor with 29 captures being more or less evenly distributed throughout the year. Nineteen specimens were taken at night. Sizes ranged from 116 to 310 mm (4.6 to 12.2 inches) SL.

17.1.11.3. Paralabrax nebulifer (Girard)

One barred sand bass was taken in the outer harbor. This specimen was caught in a night seine during September 1972, and was 132 mm (5.2 inches) SL.

17.1.12. Family Pomadasyidae

17.1.12.1. Anisotremus davidsoni (Steindachner)

Two sargo were captured, both in night seine hauls. One specimen, 246 mm (9.7 inches) SL was collected in August 1972, the other, 240 mm (9.5 inches) SL, in February 1973.

17.1.13. Family Sciaenidae

17.1.13.1. Cheilotema saturnum (Girard)

Four black croaker were taken during the study period. These fish were all caught by seine at night and ranged in size from 203 to 235 mm (8.0 to 9.3 inches) SL. Black croaker appear to be more numerous in the outer harbor than indicated by this study. In late June 1973 several were taken in a gill net during the day (E. D. Lane, Environment Canada, pers. comm.).

17.1.13.2. Cynoscion nobilis (Ayres)

Five juvenile white seabass were captured in a night trawl during November 1972. They varied from 47 to 73 mm (1.9 to 2.9 inches) SL. Thomas (1968) mentions that juveniles have been taken in Newport Bay and Long Beach-Los Angeles Harbors. Bays may serve as nurseries for young white seabass.

17.1.13.3. Genyonemus lineatus (Ayres)

All 29 white croakers collected were taken at night by seine. The majority (23) were captured in October 1972. Gill net collections along the south jetty during 1973 captured large numbers of white croaker (E. D. Lane, Environment Canada pers. comm.). The seine captured fish varied in size from 80 to 229 mm (3.2 to 9.0 inches) SL.

17.1.13.4. Menticirrhus undulatus (Girard)

The California corbina appears to be one of the dominant sciaenids in the outer harbor, 92 were collected during the study period. Although Baxter (1966) states this species moves offshore during summer months to spawn, and Klingbeil, et al (see annotated checklist of elasmobranchs and teleosts of Anaheim Bay) mention that corbina are scarce in the inner bay at this time, the majority of the specimens taken in the outer harbor were taken from May through August (23 during the summer of 1972 and 38 during the summer of 1973). All were caught by seine and most (56) were taken in daytime. They ranged in size from 185 to 535 mm (7.3 to 21.1 inches) SL.

17.1.13.5. Roncador stearnsi (Steindachner)

Five spotfin croaker have been taken in the outer harbor. All were taken at night, four by seine in October 1972, and one by gill net in late June 1973. The size range was 120 to 415 mm (4.7 to 16.3 inches) SL.

17.1.13.6. Seriphus politus Ayres

Queenfish appear to be year-round residents of the outer harbor, but are present in greatest numbers during late spring and summer. All but two of the 108 individuals collected were caught at night. Their sizes ranged from 69 to 200 mm (2.7 to 7.9 inches) SL with the majority appearing to be juveniles. All were collected by seine.

17.1.13.7. Umbrina roncador Jordan and Gilbert

Five yellowfin croaker were taken during the year, four in August and one in October 1972. They varied from 128 to 223 mm (5.0 to 8.8 inches) SL.

17.1.14. Family Girellidae

17.1.14.1. Girella nigricans (Ayres)

A total of 92 opaleye was collected, 80 of which were taken in sunrise and sunset seines during June 1973. A single juvenile was captured in December 1972 (32 mm, 1.3 inches SL). Adult sizes ranged from 168 to 264 mm (6.6 to 10.4 inches) SL.

17.1.15. Family Embiotocidae

17.1.15.1. Amphistichus argenteus Agassiz

A single female barred surfperch was captured in a night seine during February 1973. It measured 170 mm (6.7 inches) SL.

17.1.15.2. Cymatogaster aggregata Gibbons

Although the shiner surfperch is the most common surfperch, based on total number of specimens taken, it is rather seasonal in its appearance on the beach of the outer harbor. of the 665 specimens taken, 599 were captured during the summer. There appears to be some variation in the diel rhythms of this species throughout the year with most of those caught during summer months taken in daytime while the three specimens taken in winter were caught at night. Fall and spring were transition periods. Most females taken during the late spring and early summer were in advanced stages of pregnancy, indicating that they may move into shallows to give birth to young (see chapter on the life history of the shiner surfperch, and Gordon, 1965). of the total catch only 238 were kept for examination, they ranged in size from 35 to 112 mm (1.4 to 4.4 inches) SL. The sex ratio of the specimens was 37% male and 63% female.

17.1.15.3. Damalichthys (= Rhacochilus) vacca Girard

Although the pile surfperch is one of the most common embiotocids encountered in the inner bay only 28 specimens were taken in the outer harbor. They were collected sporadically throughout the study period, with the majority (18) being taken during fall and winter. All but two were taken at night, and the size range was 81 to 280 mm (3.2 to 11.0 inches) SL.

17.1.15.4. Embiotoca jacksoni Agassiz

The black surfperch, along with most other embiotocids encountered during this study, is a permanent resident of the outer harbor. of the 328 black surfperch collected, 221 were taken at night; however, large numbers were observed among the rocks along the north jetty by divers during the day (A. Wells, California State University, Long Beach, pers. comm.). The fish collected ranged in size between 53 and 215 mm (2.1 and 8.5 inches) SL. A preliminary examination of the size of the uteri of pregnant females, indicates the young are born during late spring.

17.1.15.5. Hyperprosopon argenteum Gibbons

This very common embiotocid was encountered in the study area all year. All 661 specimens collected were taken by seine, and all but 52 of them at night. They ranged in size from 43 to 164 mm (1.7 to 6.5 inches) SL. The young are probably born in late spring.

17.1.15.6. Micrometrus minimus (Gibbons)

Forty-four dwarf surfperch were taken. All but three were collected during summer and early fall, 1972. They were captured diurnally and ranged in size between 50 and 103 mm (2.0 and 4.1 inches) SL.

17.1.15.7. Phanerodon furcatus Girard

The white surfperch is another permanent resident of the outer harbor. A total of 427 specimens was taken during the year. As with shiner surfperch there appears to be a variation in diel rhythm with season. In summer the species was diurnal with 148 of 159 captures being during the day. In winter the white surfperch appeared nocturnal with 72 of 84 specimens taken at night. There was also a seasonal variation, the fewest fish were taken in late winter and early spring. the smallest fish was 54 mm (2.1 inches) and the largest 200 mm (7.9 inches) SL. The young are born in late spring to early summer.

17.1.16. Family Mugilidae

17.1.16.1. Mugil cephalus Linnaeus

Twenty-seven striped mullet were captured during the study period. All were taken by seine and all but four were caught in daytime. A male, captured in January 1973, was observed to extrude milt during handling. This was not unexpected, since it was the peak of the spawning period (Hendricks, 1961). All but one of the specimens taken were adult and ranged in size from 383 to 492 mm (15.1 to 19.4 inches) SL. The single juvenile, collected in December 1972, measured 28 mm (1.1 inches) SL.

17.1.17. Family Clinidae

17.1.17.1. Heterostichus rostratus Girard

Fifty-two giant kelpfish were taken intermittently throughout the study period with most being captured during the day (40). This inhabitant of kelp and eel grass (Roedel, 1953) is probably a permanent resident of the area. Juveniles collected indicates that spawning occurs during late spring and early summer. The largest specimen measured 295 mm (11.6 inches) and the smallest 33 mm (1.3 inches) SL.

17.1.18. Family Blenniidae

17.1.18.1. Hypsoblennius gilberti (Jordan)

A single rockpool blenny measuring 77 mm (3.0 inches) SL was taken in a night seine during January 1973. It is expected that this fish is fairly common in the rocky jetties bordering the harbor.

17.1.19. Family Scombridae

17.1.19.1. Sarda chiliensis (Cuvier)

One Pacific bonita was collected in a day seine in late June 1973. It measured 390 mm (15.4 inches) SL.

17.1.20. Family Scorpaenidae

17.1.20.1. Sebastes serranoides (Evermann and Evermann)

Sixteen juvenile olive rockfish were captured by seine during June 1973. All but one were taken in daytime. They ranged in size from 49 to 60 mm (1.9 to 2.4 inches) SL.

17.1.21. Family Cottidae

17.1.21.1. Leptocottus armatus Girard

Fifteen staghorn sculpin were collected with a size range from 67 to 145 mm (2.6 to 5.7 inches) SL. At night sculpin were observed to lie buried in the sand with only their eyes exposed. All were caught by seine.

17.1.22. Family Bothidae

17.1.22.1. Paralichthys californicus (Ayres)

California halibut were taken sporadically throughout the year in both seines and trawls. The 55 specimens collected varied in length from 26 to 492 mm (1.0 to 19.4 inches) SL.

17.1.23. Family Pleuronectidae

17.1.23.1. Hypsopsetta guttulata (Girard)

Twenty-three diamond turbot were taken by seine and trawl during the study period. These fish ranged in size from 163 to 231 mm (6.4 to 9.1 inches) SL.

17.1.23.2. Pleuronichthys ritteri Starks and Morris

The size range of the seven spotted turbot taken was from 83 to 192 mm (3.3 to 7.6 inches) SL. They were taken in both seines and trawls.

17.1.23.3. Pleuronichthys verticalis Jordan and Gilbert

Two hornyhead turbot were collected in March and April 1973. The March fish was taken in a day seine and measured 159 mm (6.3 inches) SL. The other fish was captured in a night trawl and measured 103 mm (4.1 inches) SL.

17.1.24. Family Cynoglossidae

17.1.24.1. Symphurus atricauda (Jordan and Gilbert)

All 11 California tonguefish were taken in a single night trawl during November 1972. The specimens ranged in size from 130 to 158 mm (5.1 to 6.2 inches) SL.

17.2. CONCLUSION

The fish fauna of the outer harbor consists of at least 24 families, of which only three are dominant: Atherinidae, Sciaenidae, and Embiotocidae.

Atherinidae was represented in our study by one species, Atherinops affinis. A. affinis is by far the dominant species along the beach in the outer harbor. Over 10,000 were taken during the study with no observable seasonal or diel variations.

Embiotocidae and Sciaenidae are most dominant with respect to the number of species in the area, both having seven.

Embiotocids found in the outer harbor are Amphistichus argenteus, Cymatogaster aggregata, Damalichthys vacca, Embiotoca jacksoni, Hyperprosopon argenteum, Micrometrus minimus, and Phanerodon furcatus. Most of these species are permanent residents of the outer harbor. C. aggregata and P. furcatus both show diel and seasonal variations, being found in the catches during the day in summer and at night in winter. C. aggregata decreased in numbers in the winter, probably because they were in the inner bay, while P. furcatus was scarce in late winter and early spring. D. vacca, E. jacksoni, and H. argenteum are found year-round and were caught at night, only D. vacca showed any seasonal variation, with a majority being taken in fall or winter. M. minimus were captured primarily in summer and fall and are diurnal.

Sciaenids are represented by Cheilotrema saturnum, Cynoscion nobilis, Genyonemus lineatus, Menticirrhus undulatus, Roncador stearnsi, Seriphus politus, and Umbrina roncador. Only three were taken in numbers sufficient to draw any conclusions. G. lineatus were taken at night, with the most being taken in

October. S. politus is another species that is onshore at night. It was present all year but was captured in greatest numbers in late spring and summer. M. undulatus were taken mostly in daytime and from May through August.

Seven species of fish found in the outer harbor exhibited observable movements. These can be divided into three types: spawning, seasonal, and undetermined onshore-offshore. Four species are in the spawning group. Porichthys myriaster appears to move inshore for spawning; Cynoscion nobilis used the inshore area as a nursery area and during spawning; Menticirrhus undulatus appears in greatest numbers in the outer harbor at probable spawning time, and may spawn there; and Micrometrus minimus moves out of the bay to spawn (A. Wells, California State University, Long Beach, pers. comm.). Cymatogaster aggregata and Phanerodon furcatus exhibit seasonal movement patterns by being along the beach during summer. Girella nigricans appears inshore during summer, but the purpose of this movement was undetermined. Other species (embiotocids and sciaenids) exhibit inshore-offshore movements as previously discussed.

There is a probability that some species can avoid the nets, Mugil cephalus, Sarda chiliensis, and Leptocottus armatus appear capable of this. M. cephalus and S. chiliensis avoid the net by rapid swimming, while L. armatus, and perhaps some flatfish evade nets by burrowing.

Species that could be adequately sampled during this study were limited due to use of seines as the predominant sampling tool and the choice of the recreation beach as a study area. Occasional trawls and gill net sets did provide supplementary information for the study.

18. SPECIES ADDENDA AND RANGE EXTENSION

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Family Gerreidae

Eucinostomus argenteus Baird & Girard

On August 20, 1974, four large adult silver mojarra, Eucinostomus argenteus (141, 144, 150, 174 mm SL) were taken with a seine from Anaheim Bay, California. The fish were taken in the outer harbor region along a sandy beach in association with white surfperch, Phanerodon furcatus, and walleye surfperch, Hyperprosopon argenteum.

This is a northern range extension for the species which was reported from San Diego bay by Eigenmann in 1891 as "Gerres cinereus. " Several years ago a few more specimens were taken from the intake of the power plant in San Diego bay (C. Hubbs, Scripps Institution of Oceanography, pers. comm.).

Identification of the specimens was confirmed by Carl Hubbs (S.I.O.) and are now deposited at the Los Angeles County Museum of Natural History (34039-1).

19. DISCUSSION

Salt marshes are very common on the eastern (Atlantic) and southern (Gulf of Mexico) coasts of the United States, but occupy a much smaller area on the west coast. Those marsh areas that do occur on the west coast have been greatly reduced by human development and only a few pristine marshes are in existence. Anaheim Bay is one of these pristine marshes and is presently protected by having been designated a National Wildlife Refuge in 1972.

Salt marshes are areas of extremely high biological productivity (Teal and Teal, 1969). In Anaheim Bay this is exhibited by the high growth rates in fishes and dense populations of invertebrates. A great diversity of fauna is also found. The bay serves as an important refugium for many forms limited to the now scarce salt marsh habitat.

Anaheim Bay is a nursery area for some fish species (California halibut), a spawning area for others (midshipmen, various surfperches), and the primary habitat for many fish (diamond turbot, California killifish) and invertebrates (ghost shrimp, clams, polychaetes).

Birds, as well as fish and invertebrates extensively utilize the bay, both as residents and as migratory visitors. A preliminary report on the bird use may be found in Romero (1972).

This bulletin represents research conducted in the bay from 1969 to 1973 and does not constitute the final work on this area. Presently, further studies are being pursued on the fish and invertebrates, both in the bay itself and in the outer harbor.

That Anaheim Bay is a National Wildlife Refuge and has remained pristine is due to effort on the part of many citizen groups; California Department of Fish and Game; California State University, Long Beach; Congressman Craig Hosmer; and a very active role played by the Seal Beach Naval Weapons Station base command.

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