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Artificial Habitat in the Marine Environment

By
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,
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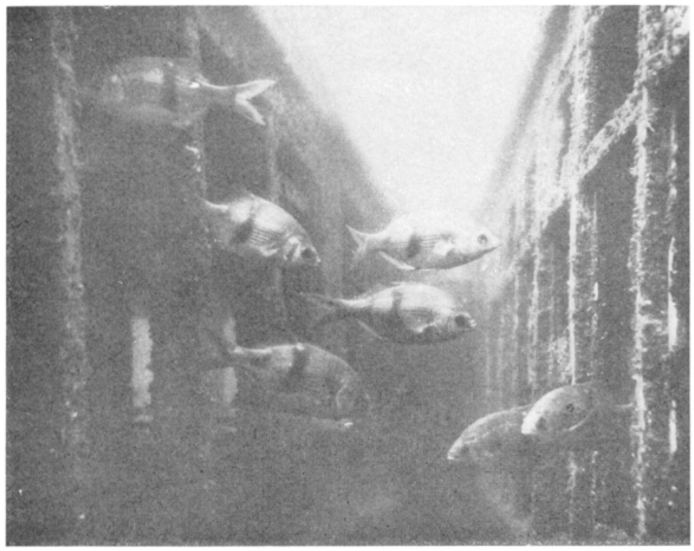
AND
EARL E. EBERT
1964



FRONTISPIECE. Large pile perch swimming between streetcars on Redondo Beach artificial reef. *Photograph by Charles H. Turner, 1958.*

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John G. Carlisle, Jr.
Charles H. Turner
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March 1963

1. INTRODUCTION

It has long been known that greater numbers and kinds of fishes inhabit rocky coasts, reefs, and banks than smooth, unbroken sandy or muddy bottoms, and that shipwrecks provide excellent fishing in otherwise non-productive areas (Figure 1).

On this basis, various state and private agencies have placed old automobile bodies and other objects in areas generally barren of sportfish. Reports have indicated greatly increased sportfish yields in these areas, but to our knowledge, no full-scale scientific evaluation of artificial reefs has been made. The Japanese have done some work in this field, but their results are unpublished. With these facts in mind, the California Department of Fish and Game instituted a study of artificial reefs in April 1958.

FIGURE 1. Biologist-diver Jeremy C. Sexsmith studies encrusting organisms and fishes on a shipwreck. *Photograph by Charles H. Turner, August 1959.*

FIGURE 1. Biologist-diver Jeremy C. Sexsmith studies encrusting organisms and fishes on a shipwreck. Photograph by Charles H. Turner, August 1959.

Many flat, sandy or muddy areas occur along the southern California coast, often near small-boat harbors. While large party, charter, and private boats can travel long distances to offshore islands and productive headlands, these fishing grounds are beyond the range of small-boat fishermen. The chief value of artificial reefs is to provide owners of small boats with good fishing near a harbor (Carlisle 1962).

With California's population increasing at a tremendous rate each year and recreation needs multiplying at an unprecedented pace, coastal fishing assumes an ever more important role. Pollution of these same waters, especially by industrial wastes, is constantly decreasing the yield of once productive areas. Kelp beds, of great importance in the ecology of the region, have diminished or virtually disappeared in the path of these pollutants, with consequent decreases in suitable fish habitat.

In addition, several successive years of above average water temperatures drastically reduced vast areas of kelp beds along our shores. Sea urchin predation on the reduced beds has been widely observed by divers (Figure 2).

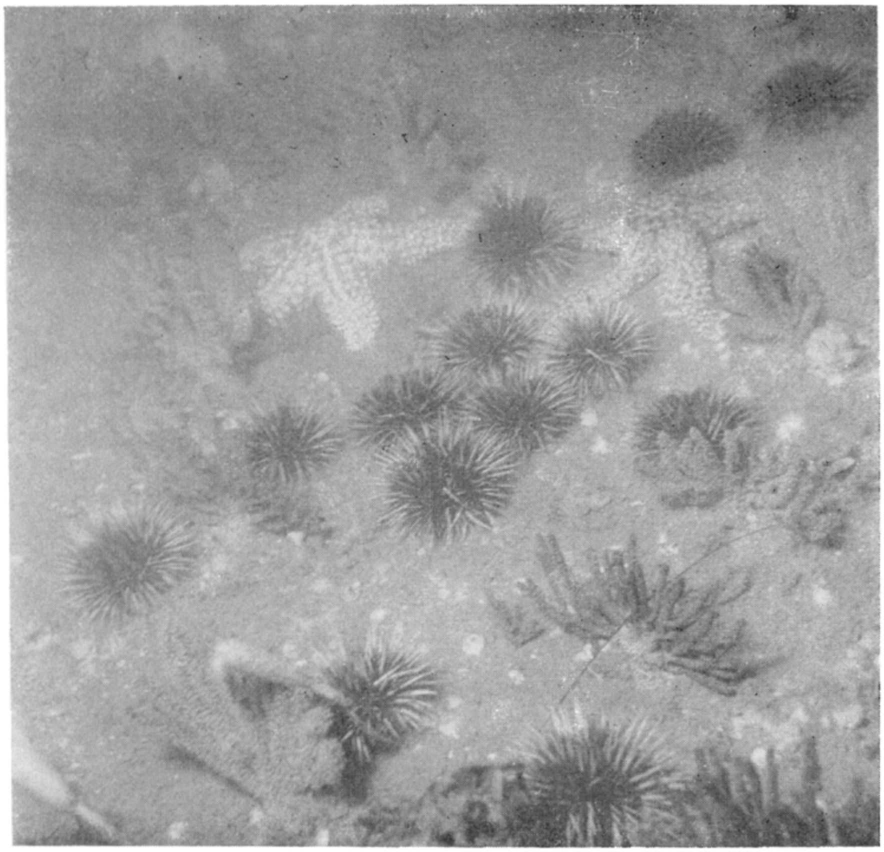

FIGURE 2. Sea urchins, starfish, and gorgonians on devastated portion of kelp bed. *Photograph by Charles H. Turner, September 1960.*

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To determine the true value of artificial reefs, we carried out routine diving so we could observe and obtain as much information as possible on the numbers and kinds of fishes occurring around artificial habitat (Figures 3 and 4). Kelp growth, numbers and species of invertebrates, animal behavior, and many other observations also have been made.

The theory of attraction of fishes to solid objects (thigmotropism) is discussed by Breder and Nigrelli (1938), and probably explains some of the success of artificial reefs in attracting and holding fishes. Observations made during the Department's Kelp Investigations Program at Scripps Institution of Oceanography (Quarterly Progress Reports), and our observations of fishes following a young giant kelp plant, Macrocystis pyrifera, drifting across a semi-barren sand bottom (Figure 5), and of fishes attracted to artificial reefs and offshore oil installations definitely support this theory.

Breder and Nigrelli (1938) described thigmotropism as the "desire" of fishes to be close to a solid object. The attraction of fishes to each other (schooling behavior) (Figure 6) also becomes a necessary explanation of reef success. Finally, availability of shelter and food help explain the attractiveness of artificial habitat.

As part of our investigation of man-made marine environment, we also undertook a study to evaluate the effects of offshore oil drilling installations.

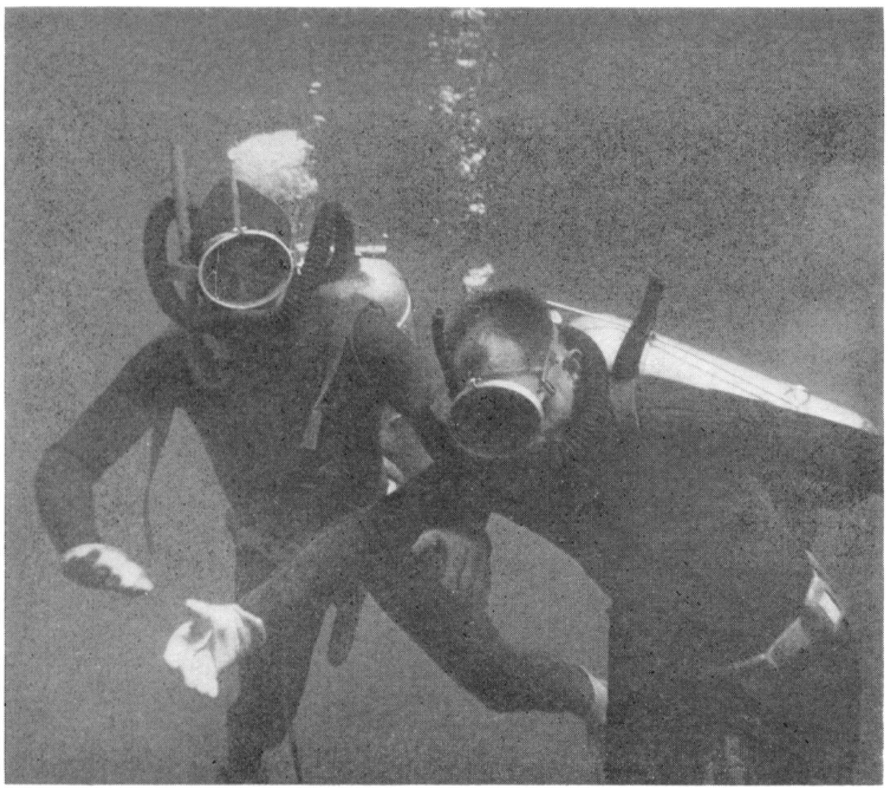

FIGURE 3. Biologist-divers Jeremy C. Sexsmith (left) and Charles H. Turner descend for diving observations. ***Photograph by John G. Carlisle, Jr., 1958.***

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FIGURE 4. Biologist-divers Charles H. Turner (left) and John G. Carlisle, Jr. take photos and record data on newly installed artificial reef. *Photograph by Gene Daniels, 1958.*

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2. METHODS

2.1. Selecting Reef Sites

Artificial reef sites were selected in flat, sandy areas (Figure 7) where fishing for semi-resident sportfishes such as kelp bass, sand bass, and sheephead was generally poor. These species, abounding in rocky areas and kelp beds, might be expected to associate with artificial reffs.

Depths between 50 and 60 feet are considered suitable for many fishes we hoped to attract and these depths are also within the optimum range for giant kelp plants which would further enhance the value of artificial habitat. Another important consideration is that fairly prolonged diving surveys can be made at these depths without employing stage decompression (stops of several minutes duration at specific depths, to allow release of excess nitrogen from the diver's system). U.S. Navy Standard Air Decompression Tables are followed in determining these diving limits. To disregard these decompression tables can result in caisson disease (bends), a serious diving illness.

Before establishing an artificial reef, we survey the tentative site. We place a 100-meter transect line along the bottom and anchor it at each end. We swim along the line just over the bottom, as far apart as visibility permits, and observe and record all life within visual range. We assume the selected bottom and water column is typical of the surrounding area.

This survey method is essentially identical to those employed by Brock (1954) and the Scripps Kelp Investigations Program.

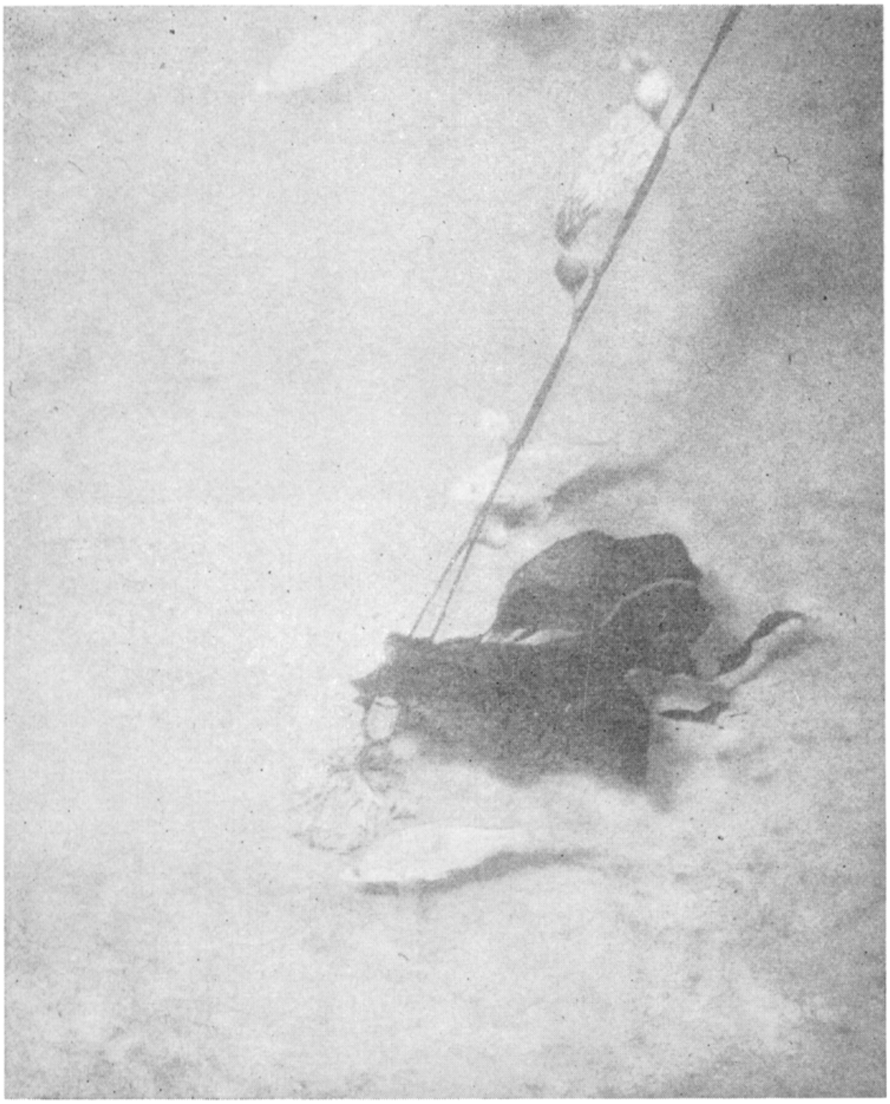

FIGURE 5. Young kelp plant drifting over barren sand bottom accompanied by embiotocid perches. *Photograph by Charles H. Turner.*

FIGURE 5. Young kelp plant drifting over barren sand bottom accompanied by embiotocid perches. Photograph by Charles H. Turner.

FIGURE 6. Fishes schooling around artificial habitat, sardines and jack mackerel in background, perch and halfmoons in foreground. ***Photograph by Charles H. Turner, February 1959.***

FIGURE 6. Fishes schooling around artificial habitat, sardines and jack mackerel in background, perch and halfmoons in foreground. Photograph by Charles H. Turner, February 1959

Selected sites are located by triangulation, using shoreside structures (generally buildings), in the event marker buoys are lost. A fathometer is used for locating unmarked reefs. Latitude and longitude are determined for use in securing permits and in describing the general location.

All reefs must be installed under permit from the U.S. Army Corps of Engineers and the State Lands Commission or city having title to the submerged lands. Clearance is also obtained from the U.S. Navy. Marker buoy permits are obtained from the U.S. Coast Guard, and fishing interests are consulted and kept informed of all reef placement. Objections from any of these agencies are fully considered and conflicting interests avoided.

It is necessary to keep artificial reefs marked with suitable buoys for several reasons. Sportfishermen must be able to locate the reefs open to fishing at the conclusion of experiments, and reefs specifically designed for fishing. Surface markers are necessary, especially for fishermen using boats not equipped with fathometers. Marker buoys are also necessary in areas open to commercial net fishing, so fishermen can avoid entangling their gear on the reefs.

On several occasions, metal buoys were shot full of holes and sunk (Figure 8), or buoy chain used to mark artificial reefs was stolen. To avoid this vandalism we had to start using unsinkable styrofoam buoys and heavy chain.

2.2. Making Fish Counts

By employing SCUBA (self-contained underwater breathing apparatus), biologist-divers are able to move freely and quickly through an area. Individual dives last from several minutes to 2 hours (Figure 9). Coordinated teams ("buddy" system) are employed at all times for maximum safety. Many dives have been made with all three project biologist-divers taking part.

FIGURE 7. Biologist-diver Keith W. Cox inspects car recently placed on barren, sandy bottom. *Photograph by Charles H. Turner, October 1959.*

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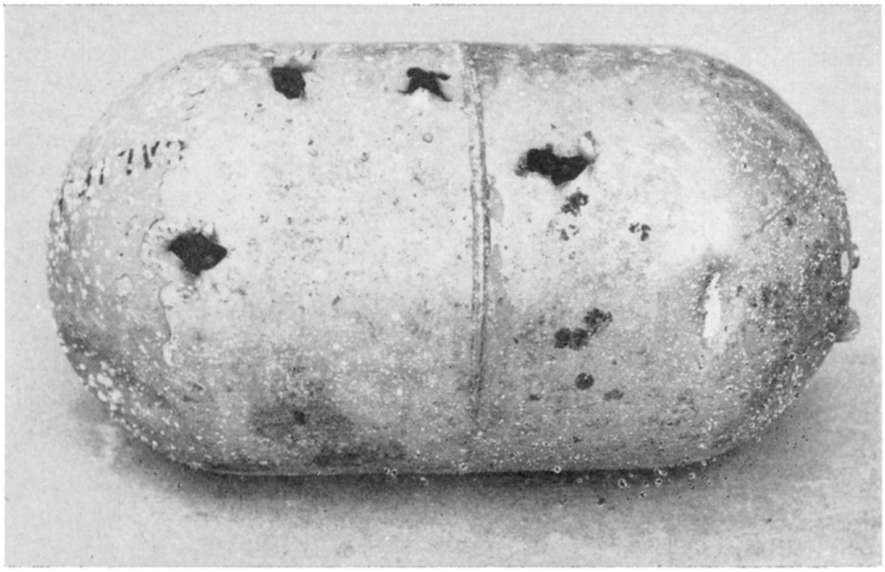

FIGURE 8. Metal buoy used to mark artificial reef shot full of holes and sunk by vandal. *Photograph by Jack W. Schott, April 1962.*

FIGURE 8. Metal buoy used to mark artificial reef shot full of holes and sunk by vandal. Photograph by Jack W. Schott, April 1962.

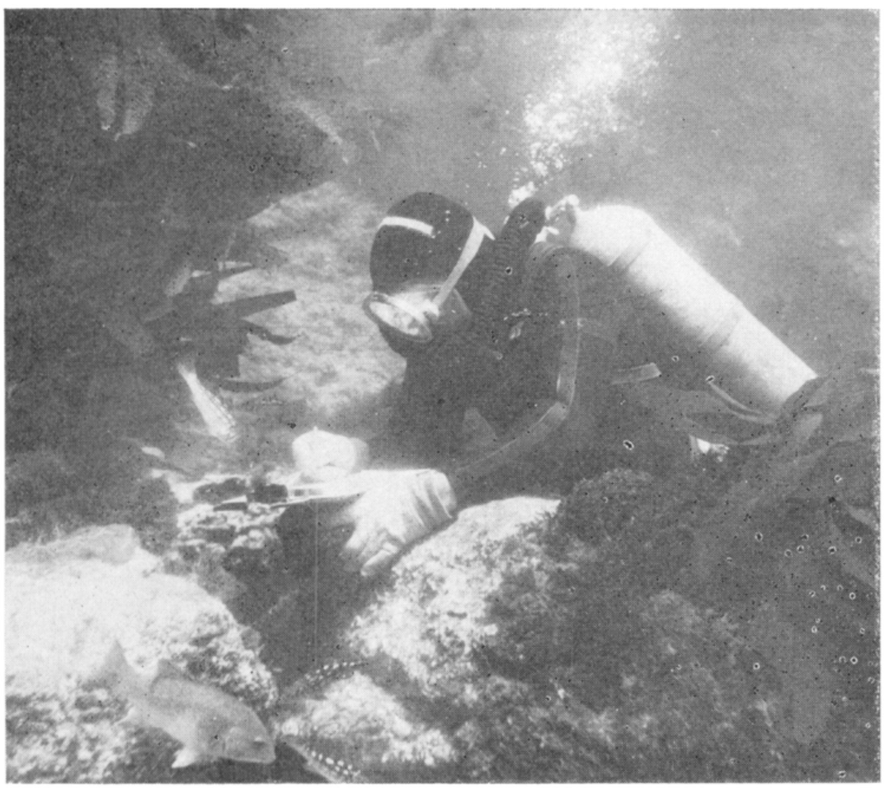

FIGURE 9. Biologist-diver Carlisle recording observations on plastic sheet. *Photograph by Charles H. Turner, April 1959.*

FIGURE 9. Biologist-diver Carlisle recording observations on plastic sheet. Photograph by Charles H. Turner, April 1959.

Each diver, using a plastic tally sheet for underwater recording, made an independent estimate of the number and kinds of fish present. One of our biologist-divers, Turner, has participated in 98 percent of the dives made since the project's inception, which we believe adds continuity and consistency to our estimates; we have achieved over 90 percent agreement. At the conclusion of each dive, notes are carefully compared before agreeing on a total fish count. Although exact counts are impossible, relative numbers and fluctuations can be demonstrated.

All fishes observed on artificial reefs and oil installations are listed in Table 1, as well as some species taken by trawling.

3. BOTTOMFISHES RECORDED BEFORE ARTIFICIAL REEF INSTALLATION

In addition to the transect surveys, we obtained some idea of the fishes normally present around potential artificial reef sites in Santa Monica Bay from data acquired by other Department studies. Fifteen species were commonly taken in these studies (Table 2).

For several years, a pollution surveillance program has been carried out in Santa Monica Bay by the City of Los Angeles. Catch data were obtained from 100 hauls with a 25-foot trawl net having 1½-inch mesh, at eight representative stations in 60 feet of water between Hermosa Beach and Paradise Cove from April 1958 to May 1961. This net catches mostly small fish. These data were analyzed by Department personnel.

Six species appeared in almost all hauls, and made up most of the catch. By far the most numerous species, the speckled sanddab, constituted 81 percent of the catch. California tonguefish and English sole made up most of the remainder, followed by plainfin midshipman, specklefin midshipman, and the yellowchin sculpin. Slightly fewer than nine individuals of these six species were taken per minute of hauling.

We obtained an estimate of larger fish present in the same area from 16 hauls made in the same depth in May and June 1957 with a 4½-inch mesh net with a 63-foot opening (Table 2). These hauls were made in conjunction with the Department's ecological studies.

Slightly more than two of these larger fish were captured per minute of hauling. Although the two nets were sampling generally different fish sizes in the same area, the catches of the two cannot be combined. However the two trawl studies do give an indication of the fish population at the 10-fathom depth on the sandy bottom typical of Santa Monica Bay before establishing artificial reefs.

4. PARADISE COVE CAR BODY REEF

An artificial reef of 20 old car bodies was placed in 50 feet of water at Paradise Cove, near Malibu, on May 26, 1958. Our selection of this site was dictated by several facts. The operators of Paradise Cove landing were willing to purchase the car bodies needed to build this experimental reef. They also provided a motorboat and an old landing float to transport the cars from the pier to the offshore area where they were dropped. The cost of the 20 cars, delivered to the pier, was $200. This was an expense for which the project had no money at that time.

The reef site selected was easily accessible by skiff from the pier, before the project acquired its own boat.

TABLE 1

Common and Scientific Names of Fishes Observed on Artificial Reefs and Offshore Oil Installations, May 1958 Through December 1960, and in Santa Monica Bay Trawling Operations

Common Name	Scientific Name
Anchovy, northern	*Engraulis mordax* Girard
Barracuda, California	*Sphyraena argentea* (Girard)
Bass, kelp	*Paralabrax clathratus* (Girard)
Bass, sand	*Paralabrax nebulifer* (Girerd)
Bass, giant sea	*Stereolepis gigas* Ayres
Blacksmith	*Chromis punctipinnis* (Cooper)
Blenny, rockpool	*Hypsoblennius gilberti* (Jordan)
Bonito, Pacific	*Sarda chiliensis* (Cuvier)
Cabezon	*Scorpaenichthys marmoratus* (Ayres)
Croaker, black	*Cheilotrema saturnum* (Girard)
Croaker, spotfin	*Roncador stearnsi* (Steindachner)
Croaker, white	*Genyonemus lineatus* (Ayres)
Croaker, yellowfin	*Umbrina roncador* Jordan & Gilbert
Electric ray, Pacific	*Torpedo californica* Ayres
Fringehead, sarcastic	*Neoclinus blanchardi* Girard
Garibaldi	*Hypsypops rubicunda* (Girard)
Goby, bluebanded	*Lythrypnus dalli* (Gilbert)
Goby, bluespot	*Coryphopterus nicholsi* (Bean)
Greenling, kelp	*Hexagrammos decagrammus* (Pallas)
Greenling, painted	*Oxylebius pictus* Gill
Guitarfish, shovelnose	*Rhinobatos productus* (Ayres)
Halfmoon	*Medialuna californiensis* (Steindachner)
Halibut, California	*Paralichthys californicus* (Ayres)
Jacksmelt	*Atherinopsis californiensis* Girard
Kelpfish, giant	*Heterostichus rostratus* Girard
Kelpfish, striped	*Gibbonsia metzi* Hubbs
Kelpfish	*Gibbonsia* sp.
Lingcod	*Ophiodon elongatus* Girard
Mackerel, jack	*Trachurus symmetricus* (Ayres)
Mackerel, Pacific	*Scomber diego* (Ayres)
Midshipman, plainfin†	*Porichthys notatus* Girard
Midshipman, specklefin†	*Porichthys myriaster* Hubbs and Shultz
Opaleye	*Girella nigricans* (Ayres)
Perch, barred surf	*Amphistichus argenteus* Agassiz
Perch, black	*Embiotica jacksoni* Agassiz
Perch, calico surf	*Amphistichus koelzi* (Hubbs)
Perch, kelp	*Brachyistius frenatus* Gill
Perch, pile	*Rhacochilus vacca* (Girard)
Perch, rainbow sea	*Hypsurus caryi* (Agassiz)
Perch, rubberlip	*Rhacochilus toxotes* Agassiz
Perch, shiner	*Cymatogaster aggregata* Gibbons
Perch, silver surf	*Hyperprosopon ellipticum* (Gibbons)
Perch, striped sea	*Embiotoca lateralis* Agassiz
Perch, walleye surf	*Hyperprosopon argenteum* Gibbons
Perch, white sea	*Phanerodon furcatus* Girard
Pipefish, kelp	*Syngnathus californiensis* Storer
Pipefish	*Syngnathus* sp.
Queenfish	*Seriphus politus* Ayres

TABLE 1
Common and Scientific Names of Fishes Observed on Artificial Reefs and offshore Oil Installations, May 1958 Through December 1960, and in Santa Monica Bay Trawling Operations

TABLE 1—Continued

Common and Scientific Names of Fishes Observed on Artificial Reefs and Offshore Oil Installations, May 1958 Through December 1960, and in Santa Monica Bay Trawling Operations

Common Name	Scientific Name
Rockfish, black-and-yellow	*Sebastodes chrysomelas* (Jordan & Gilbert)
Rockfish, blue	*Sebastodes mystinus* (Jordan & Gilbert)
Rockfish, bocaccio	*Sebastodes paucispinis* (Ayres)
Rockfish, brown	*Sebastodes auriculatus* (Girard)
Rockfish, calico	*Sebastodes dalli* (Eigenmann & Beeson)
Rockfish, flag	*Sebastodes rubrivinctus* (Jordan & Gilbert)
Rockfish, grass	*Sebastodes rastrelliger* (Jordan & Gilbert)
Rockfish, greenstriped	*Sebastodes elongatus*)Ayres)
Rockfish, kelp	*Sebastodes atrovirens* (Jordan & Gilbert)
Rockfish, olive	*Sebastodes serranoides* Eigenmann & Eigenmann
Rockfish, treefish	*Sebastodes serriceps* (Jordan & Gilbert)
Rockfish, vermilion	*Sebastodes miniatus* (Jordan & Gilbert)
Rockfish, whitebelly	*Sebastodes vexillaris* (Jordan & Gilbert)
Rockfish, unidentified	*Sebastodes* sp.
Ronquil, smooth	*Rathbunella hypoplectus* (Gilbert)
Sanddab, Pacific†	*Citharichthys sordidus* (Girard)
Sanddab, speckled†	*Citharichthys stigmaeus* Jordan & Gilbert
Sanddab	*Citharichthys* sp.
Sardine, Pacific	*Sardinops caeruleus* (Girard)
Sargo	*Anisotremus davidsoni* (Steindachner)
Sculpin (rockfish)	*Scorpaena guttata* Girard
Sculpin, mosshead	*Clinocottus globiceps* (Girard)
Sculpin, smoothhead	*Artedius lateralis* (Girard)
Sculpin, yellowchin†	*Icelinas quadriseriatus* (Lockington)
Sculpin	*Artedius* sp.
Sculpin	*Clinocottus* sp.
Sculpin	Unidentified cottid
Seabass, white	*Cynoscion nobilis* (Ayres)
Señorita	*Oxyjulis californica* (Günther)
Shark, blue	*Prionace glauca* (Linnaeus)
Shark, horn	*Heterodontus francisci* (Girard)
Shark, Pacific angel	*Squatina californica* Ayres
Shark, swell	*Cephaloscyllium uter* (Jordan & Gilbert)
Sheephead, California	*Pimelometopon pulchrum* (Ayres)
Snailfish	Unidentified cyclopterid
Sole, bigmouth†	*Hippoglossina stomata* Eigenmann & Eigenmann
Sole, Dover†	*Microstomus pacificus* (Lockington)
Sole, English†	*Parophrys vetulus* Girard
Sole, fantail†	*Xystreurys liolepis* Jordan & Gilbert
Sole, petrale†	*Eopsetta jordani* (Lockington)
Sole, rock†	*Lepidopsetta bilineata* (Ayres)
Thornback	*Platyrhinoidis triseriata* (Jordan & Gilbert)
Tonguefish, California†	*Symphurus atricauda* (Jordan & Gilbert)
Topsmelt	*Artherinops affinis* (Ayres)
Turbot, C-O†	*Pleuronichthys coenosus* Girard
Turbot, curlfin†	*Pleuronichthys decurrens* Jordan & Gilbert
Turbot, diamond	*Hypsopsetta guttulata* (Girard)
Turbot, hornyhead†	*Pleuronichthys verticalis* Jordan & Gilbert
Turbot, spotted†	*Pleuronichthys ritteri* Stark & Morris
Whitefish, ocean	*Caulolatilus princeps* (Jenyns)
Wrasse, rock	*Halichoeres semicinctus* (Ayres)
Yellowtail, California	*Seriola dorsalis* (Gill)

† Trawl-caught species not observed by divers.

TABLE 1
Common and Scientific Names of Fishes Observed on Artificial Reefs and offshore Oil Installations, May 1958 Through December 1960, and in Santa Monica Bay Trawling Operations

TABLE 2

Fishes Normally Present at 60-Foot Depth on Sandy Bottom in Santa Monica Bay, as Determined by Trawling

Common name	100 hauls with 1½-inch mesh net			16 hauls with 4½-inch mesh net		
	Number	Percent	Total lengths in mm.	Number	Percent	Total lengths in mm.
Speckled sanddab	7,250	81.5	29–132	27	2.8	80–122
California tonguefish	811	9.1	36–198			
English sole	588	6.6	44–394	315	32.8	160–406
Plainfin midshipman	134	1.5	25–225			
Yellowchin sculpin	61	0.7	23–89	1	0.1	79
Specklefin midshipman	54	0.6	46–339	1	0.1	310
Petrale sole	--	--	--	165	17.2	210–546
Hornyhead turbot	--	--	--	88	9.2	148–347
Curlfin turbot	--	--	--	153	15.9	118–331
C-O turbot	--	--	--	113	11.8	157–318
Pacific sanddab	--	--	--	27	2.8	83–307
California halibut	--	--	--	48	5.0	325–991
Bigmouth sole	--	--	--	8	0.8	208–369
Dover sole	--	--	--	7	0.7	160–337
Fantail sole	--	--	--	7	0.7	155–490

TABLE 2

Fishes Normally Present at 60-Foot Depth on Sandy Bottom in Santa Monica Bay, as Determined by Trawling

The area also provided an expanse of unrelieved, barren, sandy bottom needed for the experiment. It was not too far to kelp beds and natural rocky reefs where comparative observations could be carried out and kelp obtained for transplantation experiments.

The reef site was about 0.5 miles outside the pier where the bottom is sandy; some small underlying rocks and shells became visible as surge action scoured the substrate around the cars. Numerous whale bones including almost intact vertebral columns also were exposed around the cars where the sand washed away.

Our transect, prior to establishing the reef, revealed one unidentified turbot, two yellow crabs (Cancer anthonyi) , and six whelks (Kelletia kelleti) .

The fish population gradually built up on the reef, until on September 29, 1960, a high of 24,000 semi-resident fishes was counted; however, this population did not remain constant, but fluctuated continually and widely. The coming and going of pelagic species such as Pacific sardines, jack mackerel, and Pacific mackerel, caused additional fluctuations.

During the survey period (May 1958 through November 1960) which involved 29 diving observations, averaging 79 minutes each, visibility ranged from 1 to 50 feet, with an average of about 17. Low fish counts, in many instances, were correlated with poor visibility.

4.1. General Observations

During this period, 49 species representing 38 genera and 21 families were observed (Appendix A). Fishes began appearing around the car body reef within hours after dropping the cars. Among the first were embiotocid perches and sargos, followed by kelp bass and small California halibut. Shortly thereafter sheephead (Figure 10) and opaleye appeared, and somewhat later sand bass and rockfish.

FIGURE 10. Female sheephead approaching car early in the life of an artificial reef. Photograph by Charles H. Turner, October 1959.

FIGURE 10. Female sheephead approaching car early in the life of an artificial reef. Photograph by Charles H. Turner, October 1959.

A gradual population build-up and rather wide fluctuations were characteristic of this artificial reef as well as others (Figure 11). Similar fluctuations appear to characterize natural reefs and kelp beds. An average of 4,200 fishes, was noted during 29 dives.

The fish build-up is well illustrated by the population averages for the first 2½ years of the study. From June 1958 to May 1959, fishes averaged 1,415 per observation. For June 1959 to May 1960, they averaged 3,720, and for the next 6 months, June through November 1960, the average was 10,900. A peak population, counted in July 1959, was due to a sudden influx of white seaperch and shiner perch. Another peak in November 1959 was due to large numbers of kelp bass, sand bass, and white seaperch (Figure 12). Shiner perch and white seaperch occurred in large numbers again in September 1960. The peak populations in August, September, and October 1960 were due chiefly to numerous white seaperch and kelp perch. A total of 24,000 fishes, not counting 10,000 jack mackerel, was estimated on September 29, 1960.

Various perch species made up by far the greatest number of fishes on the reef, accounting for 74.5 percent of the total. These were followed by kelp and sand bass (10 percent), señorita (3.7 percent), rockfish (2.5

percent), and sheephead (1.4 percent). All other species combined made up the remaining 7.9 percent.

We could not find any correlation between water temperature and number of fishes on the reef.

4.2. The Fish Fauna

Kelp bass, an important sport species, built up steadily and reached a peak of 1,500, 1½ years after the reef was placed (Figure 13). The average count, however, was about 250. Kelp bass ranged in length from 1½ to at least 30 inches, but averaged about 11.

Sand bass reached a peak population of 2,000, 1½ years after the reef was established but averaged only about 350 for the entire period (Figure 14). Sizes ranged from 3 to 24 inches, with the average about 11.

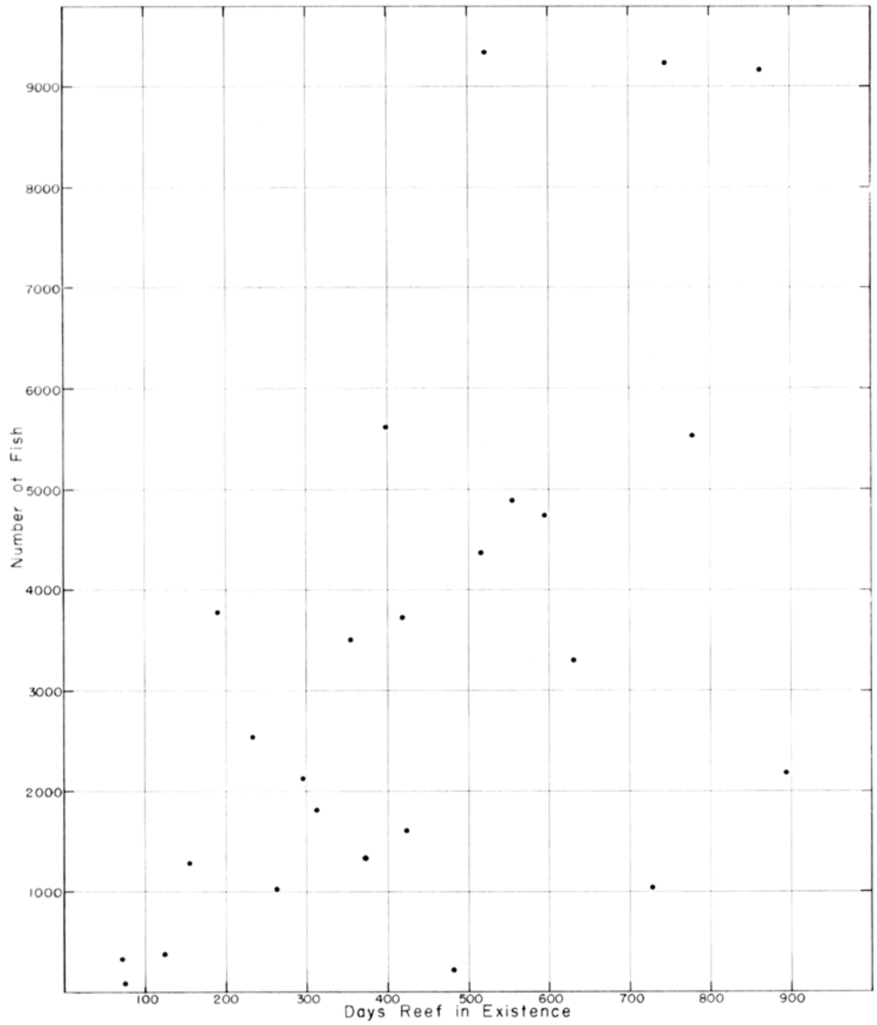

FIGURE 11. Scatter diagram indicating increase of car body reef fish population with time (15,262 fish at 525th day, and 24,021 fish at 849th day omitted).

FIGURE 11. Scatter diagram indicating increase of car body reef fish population with time (15,262 fish at 525th day, and 24,021 fish at 849th day omitted)

FIGURE 12. Sand bass, perch, and a halfmoon around giant kelp growing on Paradise Cove car body reef. *Photograph by Charles H. Turner, February 1960.*

FIGURE 12. Sand bass, perch, and a halfmoon around giant kelp growing on Paradise Cove car body reef. Photograph by Charles H. Turner, February 1960.

Sargos were present the first year but were not observed thereafter. About 80 sargos, ranging from 3 to 16 inches long (average 9), were observed per dive. A 10-inch gold-colored sargo was observed in January 1959.

Sheephead, a typical species, soon became regular inhabitants. They reached a peak population of 300 in November 1959 but the average was 66. Sheephead ranged from 1 to 36 inches, averaging about 18½.

Opaleye, although present in small numbers, were important grazers on kelp that became established on the reef. They ranged from 4 to 22 inches, averaging about 13.

White seaperch was the most numerous species observed on the car body reef. The population reached 1,000 by May 1959 and reached a peak of 5,000 in September 1960; it averaged 1,200 (Figure 15). They ranged in size from 1-inch young-of-the-year in August to 10-inch adults but the average white seaperch was 6 inches long.

Rubberlip perch were present during almost all dives and averaged 180 per observation with a maximum of 400 in August 1960. Two-inch young-of-the-year were seen in August. The largest observed was 18 inches long; about 10 inches was average (Figure 16).

Pile perch were usually present in about the same numbers as rubberlip. They averaged about 170 per observation, with a maximum of 600 in July 1959. Two-inch fish were observed in August. The largest were 18 inches long, but the average was about 10. One pile perch was bicolored, being silver anteriorly and black posteriorly. Their usual coloration is a uniform blackish- or brownish-silver with a vertical dark bar.

Black perch were regular inhabitants, averaging about 180. Peak populations of 400 were observed in January of 1959 and 1960, and 500 in November 1959 and October 1960. Three-inch fish were observed in August. Individuals up to 14 inches long were seen, with 8-inch fish being average.

Rainbow seaperch averaged about 125 per observation. They ranged from 3-inch young-of-the-year, observed in October and November, to 12 inches; 6-inch fish were about average.

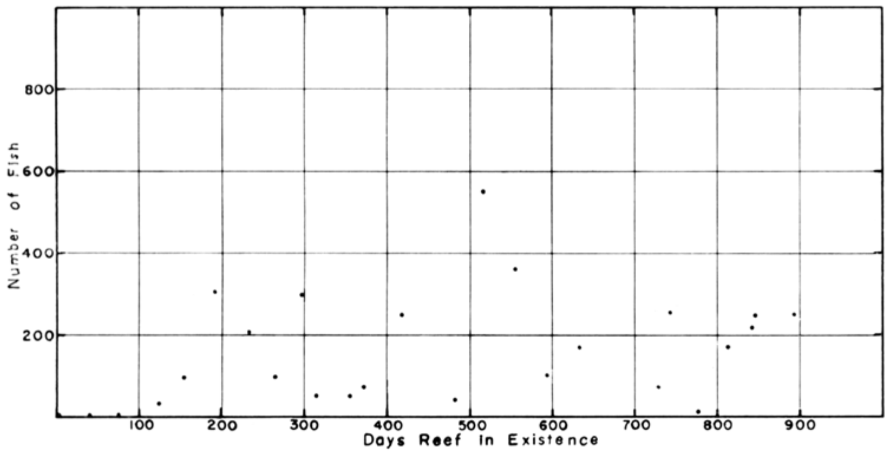

FIGURE 13. Increase of kelp bass population with time on car body reef (1,500 fish at 522nd day omitted).

FIGURE 13. Increase of kelp bass population with time on car body reef (1,500 fish at 522nd day omitted)

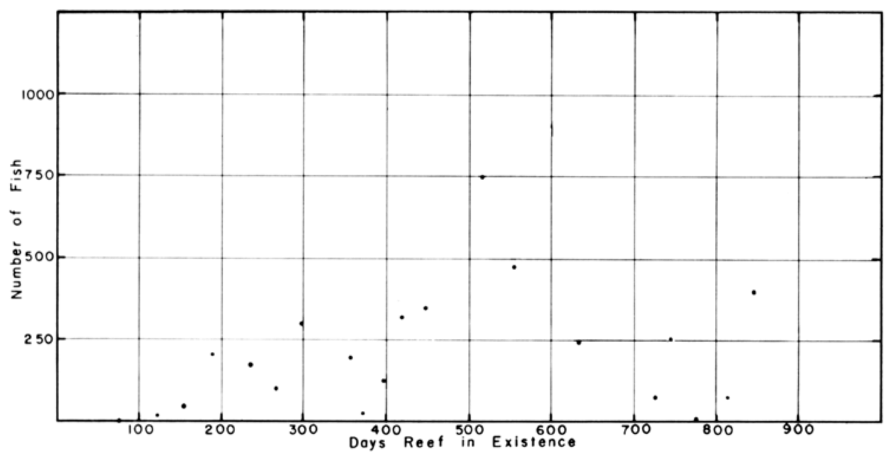

FIGURE 14. Increase of sand bass population with time on Paradise Cove car body reef (2,000 fish at 525th day omitted).

FIGURE 14. Increase of sand bass population with time on Paradise Cove car body reef (2,000 fish at 525th day omitted)

Barred surfperch, although typical and important surf fishes (Carlisle *et al*, 1960), were observed on about one-third of our dives. They were fairly numerous only during December 1959 when 200 were present. They ranged from 4 to 12 inches with the average about 7.

Walleye surfperch were seen on a few dives. They normally occur in the surf, sometimes in tremendous numbers. We observed 350, 3- to 4-inch fish in August 1960 and 500, 6- to 8-inchers in October. All other counts were low.

Shiner perch were seen on about half of our dives with a maximum of 5,000 in September 1960. They were from 2 to 6 inches long, averaging about 3½. This small species is probably an important source of food for sand bass, kelp bass, and rockfish, among others.

Kelp perch arrived after kelp became established. They were seen about half the time and occasionally were numerous. In August 1960, 5,000 were observed and in September 10,000 were estimated. They averaged about 4 inches, ranging from 2 to 7. Like shiner perch, they are important forage fish.

Cabezons occurred in small numbers except in December 1959 and January 1960 when we observed 125 and 95, respectively. Large concentrations usually are not found even when diving in natural rocky areas. Those around the reef were 6 to 36 inches long, averaging almost 18. One 5½-pound female, 490 mm (19 inches) total length, had large ovaries with maturing eggs in October 1960.

Señorita, ubiquitous in kelp beds, arrived on the reef when kelp first appeared. Occasionally up to 500 were present but the average was 170. They ranged from 2 to 11 inches long, averaging about 7. Considered a nuisance by sport fishermen, this species may be an important forage fish. Señoritas are also one of the most important of the "cleaner fish" which remove ectoparasites from such other fishes as blacksmith (Turner, 1961).

Halfmoons were seen in small numbers (averaging about 100) except in October 1960 when 800, 12 to 14 inches long were present. They ranged from 4 to 16 inches long, with 10½ about average. Halfmoons were also observed grazing on kelp on the reef.

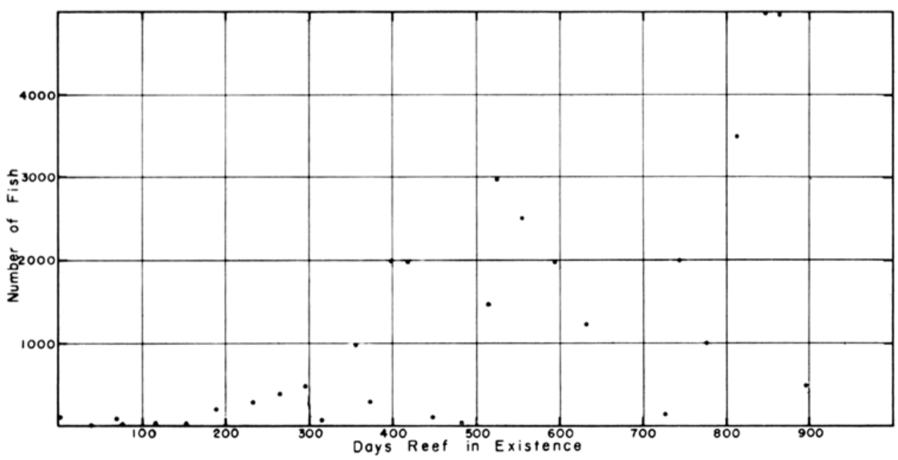

FIGURE 15. Increase of white seaperch population with time on Paradise Cove car body reef.

FIGURE 15. Increase of white seaperch population with time on Paradise Cove car body reef

FIGURE 16. Rubberlip perch orient to giant kelp fronds on Paradise Cove car body reef. Photograph by Charles H. Turner, 1960.

FIGURE 16. Rubberlip perch orient to giant kelp fronds on Paradise Cove car body reef. Photograph by Charles H. Turner, 1960.

Brown rockfish were seen in small numbers most of the time. They ranged from 4 to 16 inches, averaging almost 11.

Grass rockfish ranged in size from 7 to 20 inches with an average of 11½. They usually were in small numbers.

Olive rockfish were occasionally abundant. In both August and September 1960, 500 were observed, including about 100, 3-inch young-of-the-year. The largest were 16 inches long, but they averaged about 10.

Sculpin were seen in small numbers on about half of the dives. They ranged from 6 to 12 inches long but averaged about 10.

4.3. The Invertebrate Fauna

Although we emphasized the study of fishes, invertebrates were investigated where possible (Figures 17, 18, 19). A general listing (Appendix B) gives the common and scientific names of invertebrates we observed on the car body reef, the streetcar reef, and the various offshore oil installations.

4.4. The Flora

The Paradise Cove car body reef was installed in May 1958, and in October 1958 the first naturally seeded young giant kelp plants were discovered. Numerous ¼- to 4½-inch tall plants, were observed early in November, and by December these plants had differentiated enough to make positive identification (Figure 20). By this time there were as many as 22 plants per square foot. Some had grown to over 2 feet by the end of January 1959 and many were 6 to 8 feet tall by late March. In mid-April, fruiting fronds appeared on many of those over 4 feet tall. Some were 14 feet by this time and on each car there were 25 to 35, 2-foot plants and 10 to 15 exceeding 10 feet.

Black rot and sloughing of fronds commenced affecting the plants with the coming of warm water early in July. Growth slowed down after the tallest plants had reached about 40 feet and the surface temperature had risen to 66° F. By the end of July, the water was 71° F. By November 2, the surface temperature had dropped to 64° F, growth had resumed, and kelp had reached the surface and was about 50 feet long. The number of stipes varied from 3 to 25 per plant. In late February, some plants were 70 to 75 feet long and formed a considerable surface canopy (Figure 21). The water temperature in February was 63° F.

After reaching the surface the kelp continued to thrive, although there were periods of arrested growth and heavy sloughing during warm months.

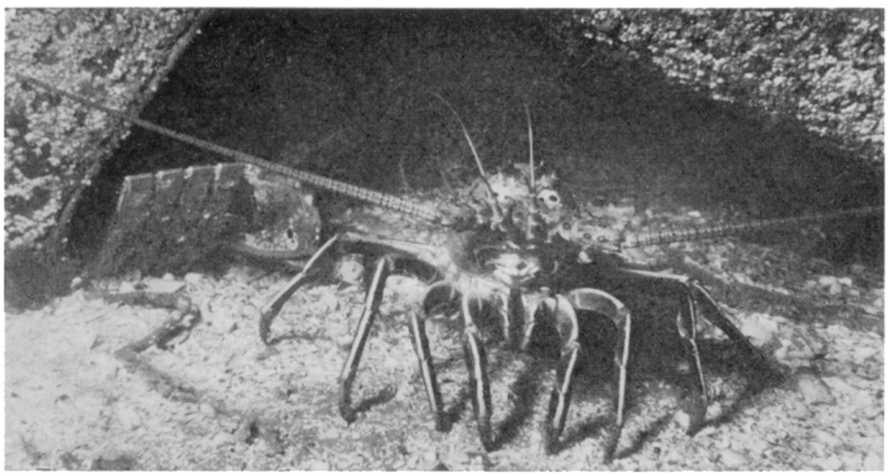

FIGURE 17. California spiny lobster under car at Paradise Cove. *Photograph by Charles H. Turner, December 1958.*

FIGURE 17. California spiny lobster under car at Paradise Cove. Photograph by Charles H. Turner, December 1958.

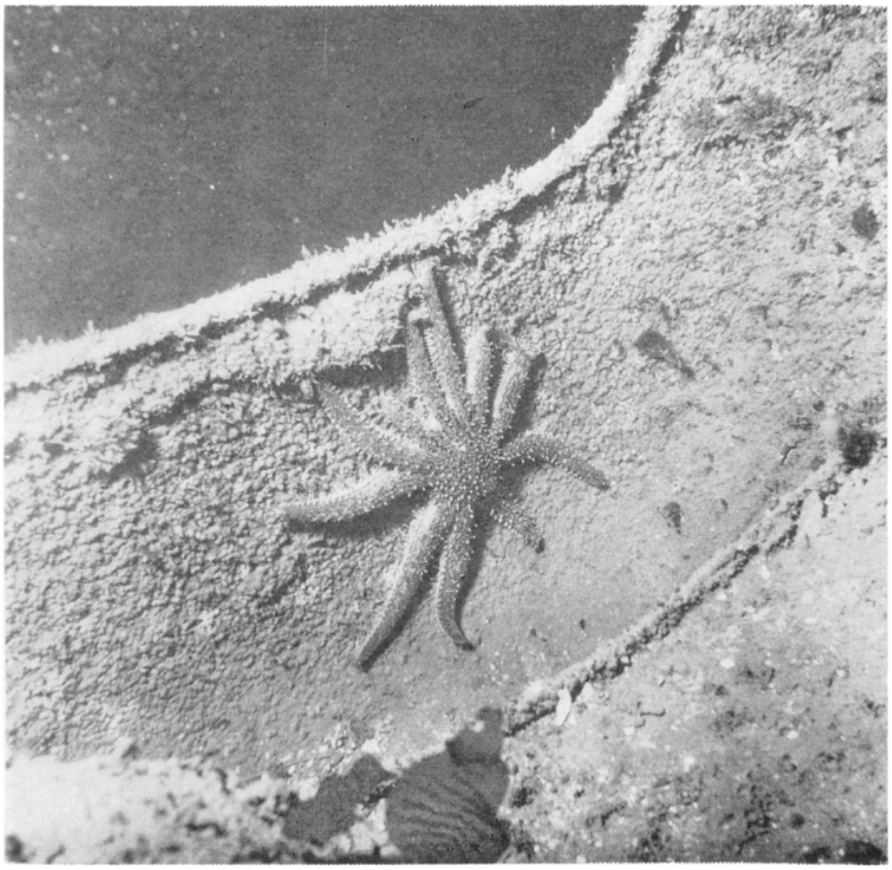

FIGURE 18. Sunburst star on car body; young kelp plants in foreground. *Photograph by Charles H. Turner, December 1958.*

FIGURE 18. Sunburst star on car body; young kelp plants in foreground. Photograph by Charles H. Turner, December 1958.

5. REDONDO BEACH STREETCAR REEF

On September 25, 1958, six wooden streetcars were placed in 60 feet of water approximately 1 mile offshore from the Redondo Beach-Palos Verdes coastline.

The streetcars were donated to further the work of the project, and the Navy furnished a 214-foot submarine salvage ship to transport them from Los Angeles Harbor to the selected site off Redondo Beach (Figures 22, 23). (Later several streetcars were purchased at $100 each. The cost for a tug and barge to transport the purchased streetcars was about $800.)

The Redondo Beach site provided an open, sandy bottom, a considerable distance from any large natural rocky habitat. Upon completion of our diving observations, when the reef was opened to fishing, its proximity (about 3 miles from Redondo Harbor) made it easily accessible to small boat fishermen.

Surveys made aboard sportfishing boats showed that the low-lying rubble was still providing excellent fishing for sand bass, and some returns on kelp bass and sculpins 4½ years after its placement. Low-lying

FIGURE 19. A heavy encrustation of organisms, both plant and animal, several months after installation of Paradise Cove car body reef. *Photograph by Charles H. Turner, October 1960.*

FIGURE 19. A heavy encrustation of organisms, both plant and animal, several months after installation of Paradise Cove car body reef. Photograph by Charles H. Turner, October 1960.

relief over sandy bottom appears to be the preferred habitat of sand bass.

The streetcars (50 feet long, 10 feet wide, and 11 feet high), were placed 10 feet apart, covering approximately 7,700 square feet of bottom. The top of one car was carried down-current 16 feet during a storm and its sides collapsed into rubble, effectively increasing the reef size to about 8,100 square feet (0.19 acres). The total water mass taken up by the reef approached 100,000 cubic feet (11.4 acre feet).

The substrate around the reef-site, was light gray sandy-silt. The adjacent area, 100 to 200 feet away, was composed of a coarse yellow sand sculptured by distinct current marks. Only during extreme storm conditions did the gray sandy-silt of the reef site exhibit ripple marks.

5.1. Bottom Fauna

The bottom-dwelling invertebrates observed around the reef site included: sea pansies, Renilla kollikeri; tube anemones, Pachycerianthus sp.; parchment tube worms Chaetopterus sp. (in heavy concentrations on top of the sand after a particularly severe storm in February 1960); elongate sea pens, Stylatula elongata; common sandstars, Astropecten armatus; heart urchins, Lovenia cordiformis; white sea urchins, Lytechinus anamesus; California cones, Conus californicus; San Pedro augers, Terebra pedroana; Kellet's whelk, Kelletia kelleti; Ida's miter, Mitra idae; circle-spotted sea slug, Diaulula sandie-gensis; and the pansy sea slug, Armina californica.

During our final survey prior to placement of the reef, 11 Pacific sanddabs, one Pacific electric ray, one spiny lobster, Panulirus interruptus; and two tube anemones, Pachycerianthus sp.: were observed.

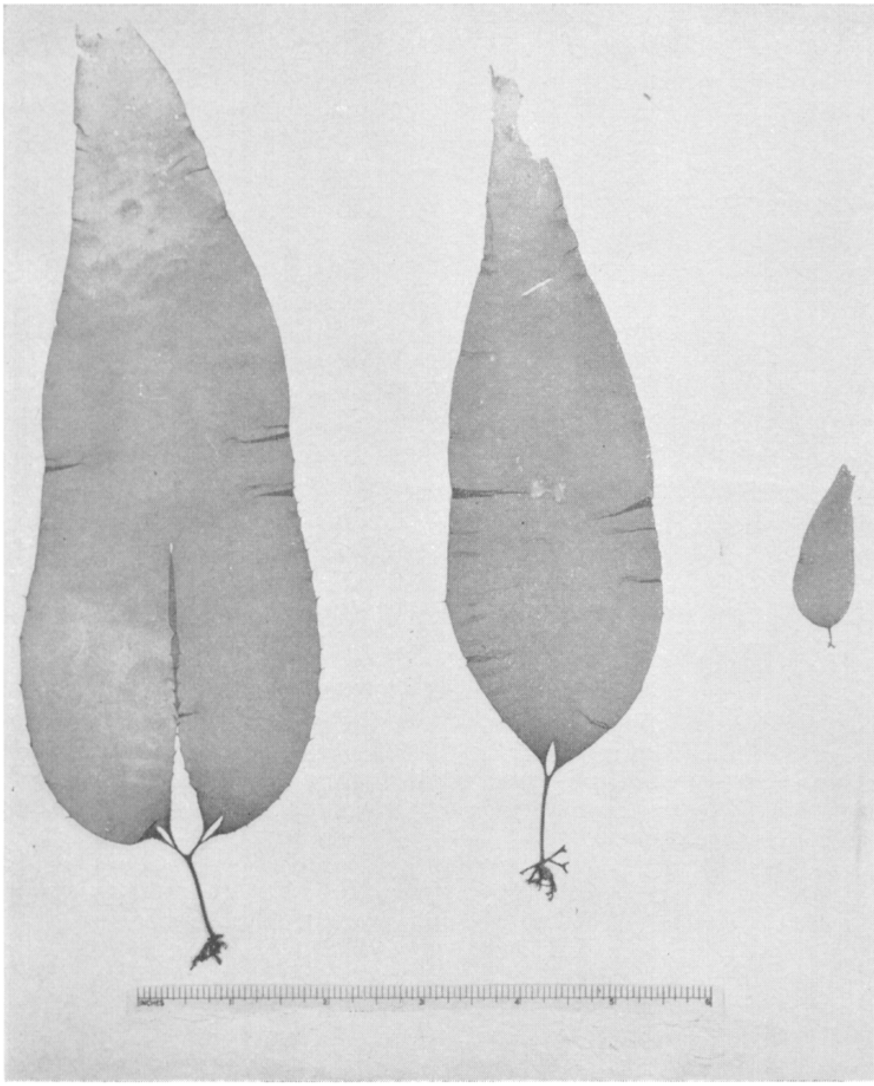

FIGURE 20. **Young kelp *(Macrocystis)* plants, showing basal frond splitting which makes identification of genus possible.** ***Photograph by Jack W. Schott, 1958.***

FIGURE 20. Young kelp (Macrocystis) plants, showing basal frond splitting which makes identification of genus possible. Photograph by Jack W. Schott, 1958.

FIGURE 21. Giant kelp on one car body at Paradise Cove; white seaperch and black perch among the fronds. *Photograph by Charles H. Turner, 1961.*

FIGURE 21. Giant kelp on one car body at Paradise Cove; white seaperch and black perch among the fronds. Photograph by Charles H. Turner, 1961.

5.2. General Observations

Into this semi-barren area, over 2,800 fishes were concentrated within 25 months, (Figure 24). High fish counts coincided with marked increases in seaperch, while very low counts, during 1959 and 1960, coincided with periods of poor water clarity. Visibility ranged from 4 to 60 feet, averaging 24.

By November 1958, juvenile kelp bass ¾ inches long were observed around the reef. Kelp bass spawn from May through August and although their eggs are pelagic, young are normally found closely associated with inshore seaweeds (Limbaugh, 1955). The streetcars gave them haven and additional nursery area. During the following 2 years, several species, including sand bass, blacksmiths (Turner and Ebert, 1962), white seaperch, pile perch, bluespot gobies (Ebert and Turner, 1962), and blue-banded gobies, spawned at the reef. The gobies spawned each year.

After 27 months, the average fish population (numerically) on the reef consisted of 35.0 percent kelp bass and sand bass, 26.3 percent miscellaneous seaperch, 11.6 percent gobies, 9.7 percent blacksmiths, and 17.4 percent all others combined.

FIGURE 22. Project personnel (Turner (left) Carlisle (center) and Ebert) inspect streetcars prior to installation of artificial reef.

FIGURE 22. Project personnel (Turner (left) Carlisle (center) and Ebert) inspect streetcars prior to installation of artificial reef

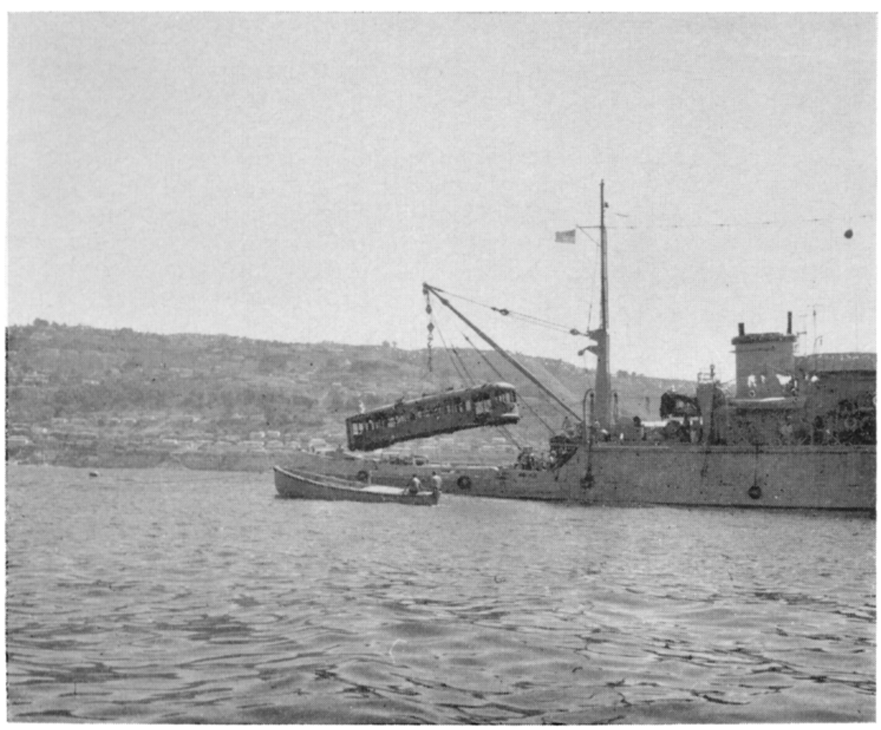

FIGURE 23. Navy submarine salvage ship *Gear* lowers streetcar on reef site off Redondo Beach—Palos Verdes coast. ***Photograph by Charles H. Turner, September 1958.***

FIGURE 23. Navy submarine salvage ship Gear lowers streetcar on reef site off Redondo Beach—Palos Verdes coast. Photograph by Charles H. Turner, September 1958.

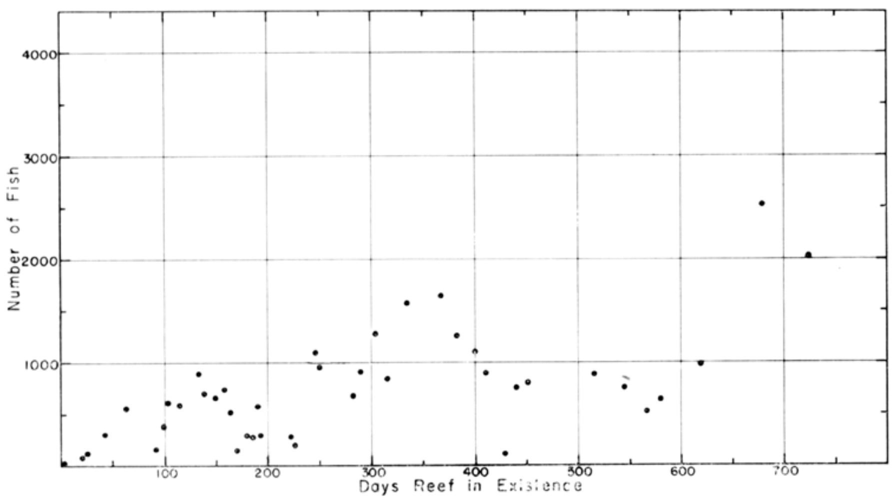

FIGURE 24. Changes in the fish population on Redondo streetcar reef.

FIGURE 24. Changes in the fish population on Redondo streetcar reef

The bass made up from 4.8 to 72.2 percent of the population. The lower range occurred during later months when sportfishing pressure became a factor (Figure 25).

Seaperch, when present, represented from 2.9 to 56.5 percent of the population. The higher percentages were usually during spawning periods when large numbers were concentrated around the reef.

There were few gobies at first but with repeated breeding they represented 42.9 percent of the total population by December 1960. Two year-classes had good survival on the reef when we terminated our studies.

Blacksmiths followed a trend similar to the gobies; surviving young having greatly increased their numbers.

During the 27 months of this study, 42 diving observations averaging 1 hour each were made. Although personnel turnover occurred during the study period, continuity was retained because the same diver (Turner) was present on 95 percent of the dives (Figure 26).

5.3. The Fish Fauna

During this survey, 47 species representing 24 families and 43 genera were noted (Appendix A). of these, four species were pelagic transients.

The total fishes observed during any one month varied markedly. For example, on February 3, 1959, only 162 fishes were seen, while on February 13, 1959, 10 days later, 623 were counted. Two major factors may have been responsible for this wide difference. On February 3, visibility was only 3 to 7 feet; on the 13th it exceeded 20 feet. Indications of heavy fishing, seen on the 3rd, were not evident on the 13th. Indications of fishing pressure include: snagged lines, empty beer bottles on the bottom, and fouled anchors. Despite our requests to local fishermen that they not fish this area, the reef was heavily fished when catches dropped in adjacent areas.

Certain species were more susceptible to fishing than others. Sand bass, kelp bass and sheephead all exhibited varying degrees of decrease during the study. Marked drops in their numbers coincided with indications of increased fishing pressure. On the other hand, the seaperch populations were little affected by sportfishing on the reef even though at least four species were large enough and abundant enough to enhance the sportsman's bag.

The possibilities of immigration, emigration, and predation are assumed relatively constant throughout the year for these semi-resident species. Our observations indicated trends and relative abundance, not necessarily exact numbers (Figure 24).

Kelp bass, thought by many fishermen to require a kelp environment, also orient with broken substrates. They were present during our earliest surveys and their numbers remained fairly constant throughout the first year, bolstered by an influx of young. During the second year, young-of-the-year increased their total (Figure 27). Large, catchable bass were fished down to a very small number. Individuals ranged from 3 to 24 inches, averaging about 10. Kelp bass were observed feeding on animals clinging to bryozoans.

Sand bass exhibited the same downward trend and the close relationship with fishing pressure observed for kelp bass (Figure 28). An influx of young fish in late winter and early spring increased their numbers. They appeared to eat more small fish than did kelp bass. Sand bass ranged from 2 to 30 inches with the average about 12.

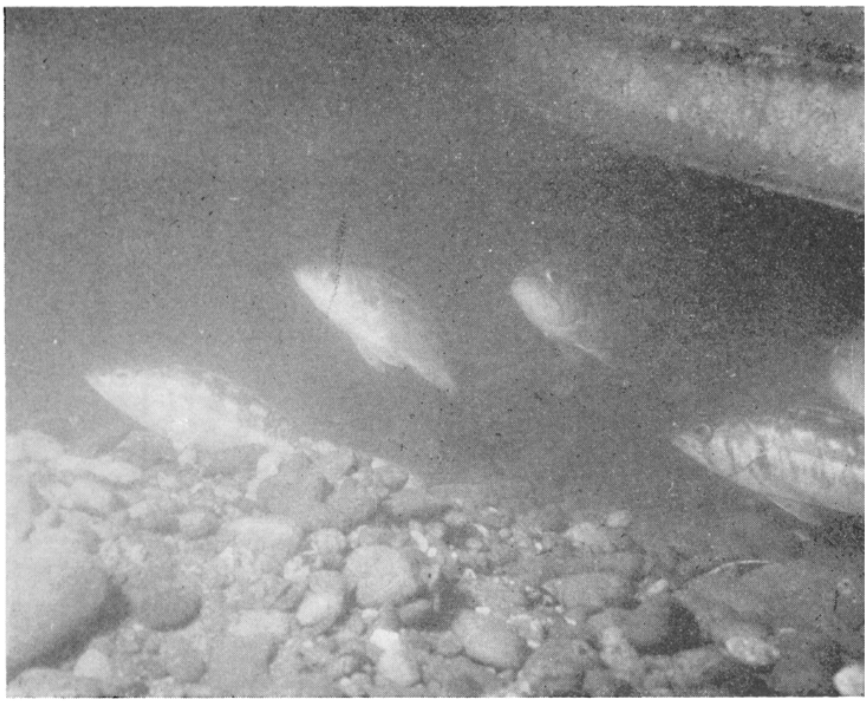

FIGURE 25. Kelp bass under the front end of a streetcar. Scouring of sand has exposed rocks previously covered. *Photograph by Charles H. Turner, December 1958.*

FIGURE 25. Kelp bass under the front end of a streetcar. Scouring of sand has exposed rocks previously covered. Photograph by Charles H. Turner, December 1958.

FIGURE 26. C. H. Turner recording observations inside streetcar over a year after reef was installed. *Photograph by John G. Carlisle, Jr., July 1959.*

FIGURE 26. C. H. Turner recording observations inside streetcar over a year after reef was installed. Photograph by John G. Carlisle, Jr., July 1959.

Black perch contributed a small but constant number of individuals to the population. They averaged about 10 inches long, ranging from 3 to 13. During kelp transplanting, black perch, pile perch, and kelp bass immediately oriented themselves to the trailing stipes.

Pile perch, with few exceptions, never exceeded 100 individuals. Like black perch, after a small initial increase, their numbers remained nearly constant. They ranged from 3 to 18 inches long, averaging 10. They fed upon mussels, clams, and various gastropods around the reef and the relatively low numbers of these food items there may have been a limiting factor.

White seaperch were observed mating, and young were seen each fall. The observed size range was 3 to 12 inches, but the average was 8. White seaperch were observed nibbling encrusting bryozoa, presumably removing amphipods and they in turn were eaten by sand bass.

Sheephead are particularly vulnerable to spearfishing which undoubtedly reduced their numbers on the reef. Their sizes ranged from 4 to 30 inches, averaging close to 14. Sheephead (Figures 29, 30) appeared early and reached a peak of 150 individuals within seven months (Figure 31). Concurrent with this peak, local diving enthusiasts entered the picture and the sheephead population dropped radically. It never recovered.

Halfmoons appeared early and continuously increased in numbers. There was a rapid influx in September 1959 and another in November 1960. A third influx was directly related to our attempted giant kelp transplant. Halfmoons were observed grazing heavily on these giant kelp plants almost immediately. Other increases coincided with their breeding season which Limbaugh (1955) reported as July to October.

Blacksmiths in dense groups of 1- to 1½-inch young were observed in and around the broken rubble of the streetcars during October and November 1960. As they grew, they became more solitary in their habits. By the following summer, when 3 to 4 inches long, they had selected individual crevices in which to hide. Although they are known to seek the services of parasite cleaners, we never observed this action on the streetcar reef. Adult blacksmiths (Figure 32) formed a moderate to dense layer at mid-depths.

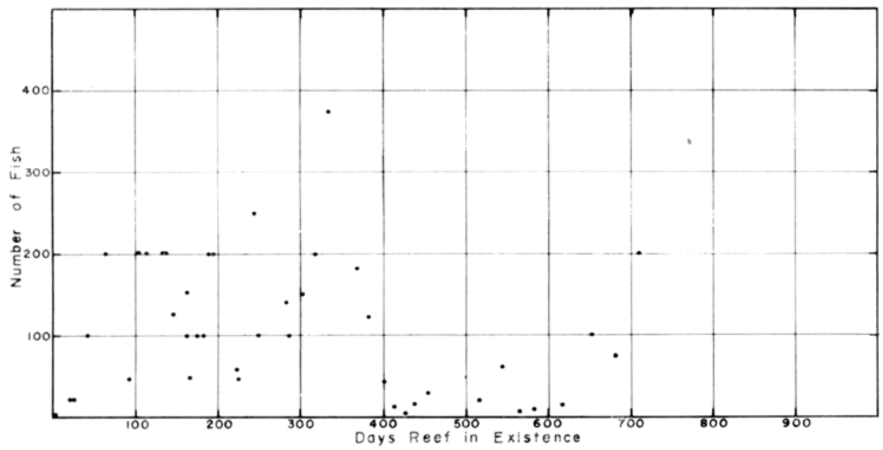

FIGURE 27. Changes in kelp bass population showing decline due to fishing pressure. Redondo streetcar reef.

FIGURE 27. Changes in kelp bass population showing decline due to fishing pressure. Redondo streetcar reef

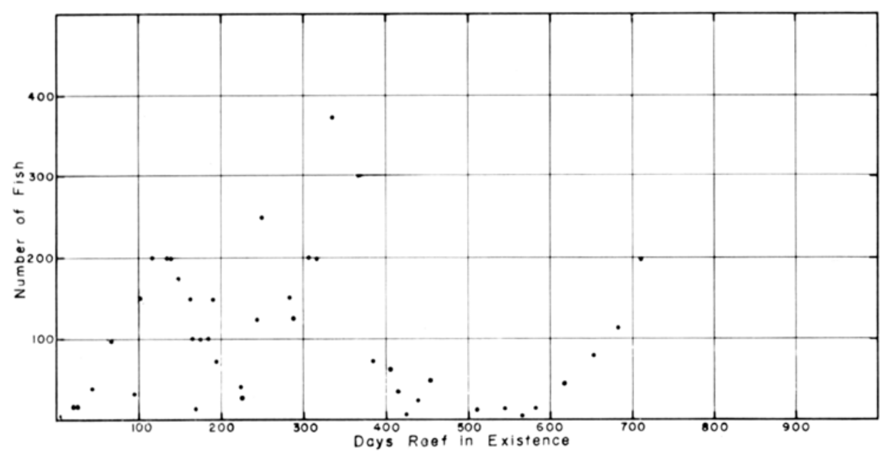

FIGURE 28. Changes in sand bass population, showing decline due to fishing pressure. Redondo streetcar reef.

FIGURE 28. Changes in sand bass population, showing decline due to fishing pressure. Redondo streetcar reef

FIGURE 29. Male sheephead on roof of streetcar. *Photograph by Charles H. Turner, March 1958.*

FIGURE 29. Male sheephead on roof of streetcar. Photograph by Charles H. Turner, March 1958

5.4. The Invertebrate Fauna

We observed the invertebrate population (Appendix B) incidentally to our fish counts, so only the more obvious species are listed. However, we anticipate placing considerably more emphasis on invertebrates in subsequent studies.

Numerous planktonic organisms including dinoflagellates, ctenophores, and salps were encountered in the waters surrounding the streetcar reef, depending upon temperature and time of year.

Various worms were observed in the encrusting mass on the streetcars, but they were treated only superficially.

Sponges of several species added their bulk to the total encrusting mass on the reef.

Several species of tube worms were present. The feather-duster worm, Eudistylia polymorpha, was scattered across the upper surfaces and colonial tube worms, Salmacina tribranchiata, shared streetcar seats with moss animals.

Pink gorgonians, Lophogorgia chilensis, were first observed in November 1959, 1 year after reef installation. These first colonies grew to 16.6 cm by the next November when several louse shells, Neosimnia sp., were found living on them. To have reached the reef, both the louse shells and the gorgonians had to have pelagic larval stages.

Rust gorgonians, Muricea fruticosa, were not recorded until March 1960, when one colony appeared in a group of more than 75 pink gorgonians.

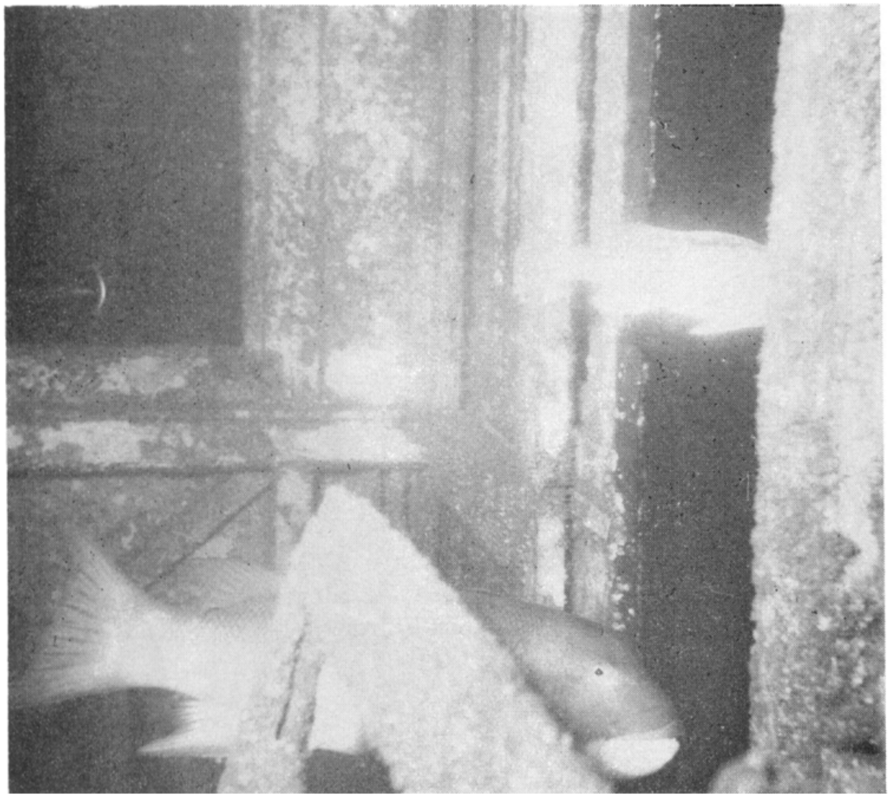

FIGURE 30. Sheephead and kelp bass inside a streetcar. *Photograph by Charles H. Turner, March 1959.*

FIGURE 30. Sheephead and kelp bass inside a streetcar. Photograph by Charles H. Turner, March 1959.

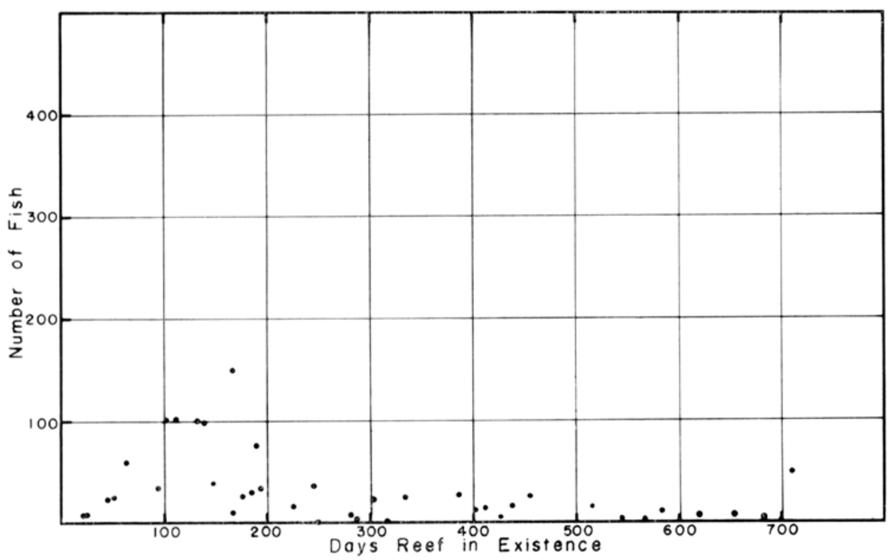

FIGURE 31. Changes in the Redondo streetcar reef sheephead population, showing decline due to fishing pressure.

FIGURE 31. Changes in the Redondo streetcar reef sheephead population, showing decline due to fishing pressure

The prolific colonial anemone, Corynactis sp., became apparent in January 1960, 15 months after reef construction. Colonies of 100 or more individuals were seen on many parts of the streetcars when the study ended.

Barnacles, Balanus sp., were observed on all of the streetcars a few days after placement of the reef. They attained a maximum diameter of ½ inch and covered nearly all sections of the cars after the first 6 months. Later, various colonial tube worms and calcareous bryozoans competed for attachment space. The most common barnacle was Balanus tintinnabulum.

The red rock-shrimp, Hippolysmata californica, was the most obvious of the several shrimp-like animals observed. These animals appeared

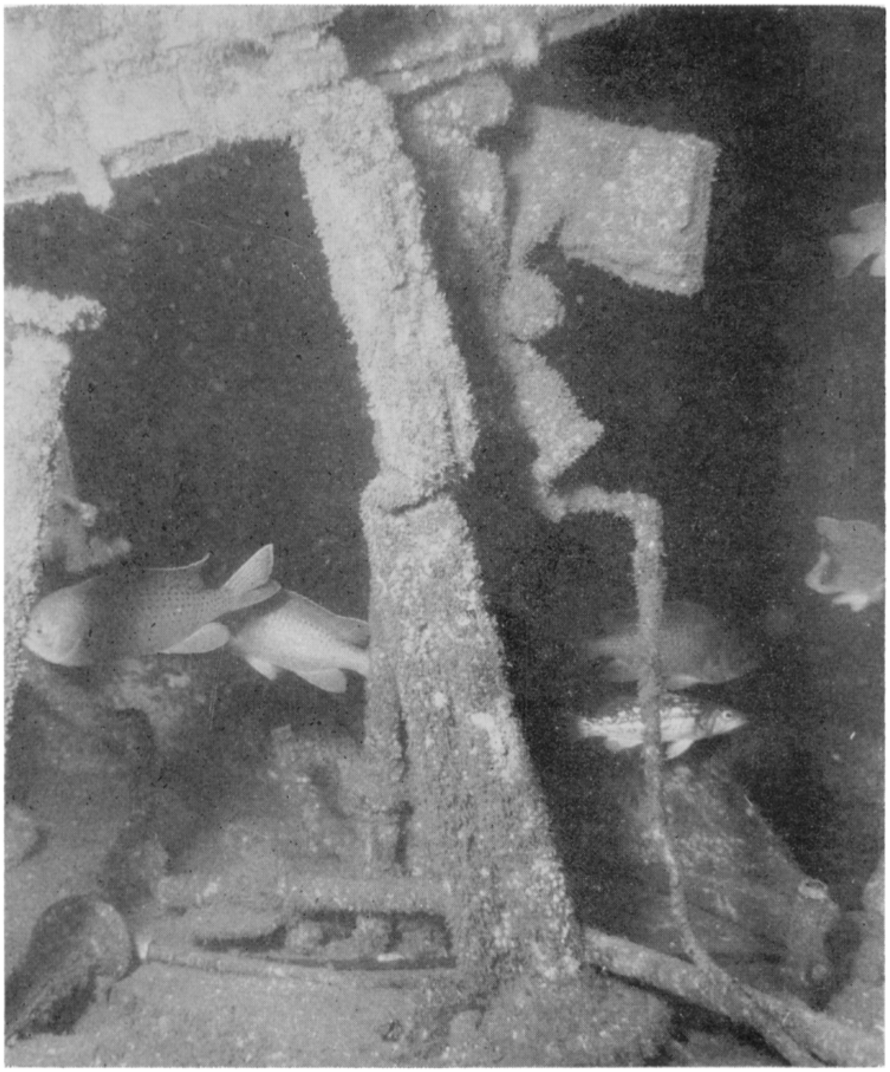

FIGURE 32. Blacksmiths and kelp bass around the seats of a streetcar. *Photograph by Charles H. Turner, March 1959.*

FIGURE 32. Blacksmiths and kelp bass around the seats of a streetcar. Photograph by Charles H. Turner, March 1959.

after 6 months and at the end of the study were living in all the crevices on the streetcars.

Spiny lobsters, Panulirus interruptus, were observed on the reef except during the summer. Individuals ranged from 4 to 16¼ inches in length, the largest weighing 6¼ pounds. They began migrating away from the reef in late April or early May and did not return until early September. When we observed them on the open sand moving away from the reef we believed they were moving into deeper waters, despite seeing numerous individuals in the shallows during this period. In September, they traveled toward the reef from deeper water.

Large spider crabs, Loxorhynchus sp., and yellow crabs, Cancer anthonyi, were observed repeatedly on the reef. Their numbers were never great, seldom exceeding 10 or 12. These crabs were more common during the spring and summer, although they were around throughout the year. Various other small crabs were noted in the bryozoans encrusting the streetcars.

A rock scallop, Hinnites multirugosus, was observed in June 1960 and kelp scallops, Chlamys latiaurata, were noted several times—in February and May 1959 and August 1960. Although they probably were carried into the area by currents they never formed an appreciable part of the reef biomass.

Abalone jingles, Pododesmus cepio, commonly attached to the sides of the streetcars. Two jingles removed in September 1959 had attained diameters of 49 and 68 mm. Their growth rate can only be estimated since their exact time of arrival is not known. They may be a food source for fishes.

One occurrence of the bay mussel, Mytilus edulis, suggests it drifted in on floating material but was unable to establish on the reef.

Two-spot octopuses, Octopus bimaculatus, and related species were frequent inhabitants of the dark, sheltered recesses of the streetcars. These animals were important in the diets of the fishes on the reef.

Several nudibranchs or sea slugs were seen, including the purple, Flabellina iodinea, the yellow-green, Hermissenda crassicornis, the yellow-margined, Cadlina marginata, and the blue-orange, Glossodoris californiensis. These species do not appear to have any relationship to the fish populations; their most important contributions would seem to be their delicate beauty.

Kellet's whelk, Kelletia kelleti, were common on the sand around the reef and on all parts of the streetcars themselves. These carnivorous snails apparently roam constantly in search of food. When they find a dead fish or crab, they attack it voraciously and make short work of the edible portions.

Louse shells, Neosimnia sp., were seen on several pink gorgonians on which they apparently graze and deposit blister-like capsules encasing their eggs.

The streetcar reef-site was a natural area for white, deep-water sea urchins, Lytechinus anamesus. They were around the streetcars in large numbers during most of the year. They would completely vacate the area for no apparent reason, particularly in the winter. When they left the area, they moved as a body, not dissimilar to a horde of ants.

The most commonly observed starfishes included giant starfish, Pisaster giganteus, purple starfish, Pisaster ochraceus, short-spined starfish, Pisaster brevispinus, leather starfish, Dermasterias imbricata, webbed-ray starfish, Patiria miniata, and sand stars, Astropecten armatus. Concealed under the sand were heart urchins, Lovenia cordiformis.

Within the first six months several tunicates, including Styela montereyensis, appeared on the reef. By 1961, the colonial tunicate, Cystodytes lobatus, was observed.

5.5. The Flora

There was never a substantial growth of algae on any part of the reef (Appendix C). We attempted several transplants of the giant kelp, Macrocystis pyrifera, without success.

Each year in late summer and early fall many tiny algae were observed. These ¾- to 1½-inch plants were identified as Laminaria farlowii, Pterygophora californica, and Gigartina sp. Within a few months all had been grazed or otherwise removed from the reef. Among the other algae we saw were Callithamnion sp., Ectocarpus sp., and Eisenia arborea. None of these was present in any quantity and all eventually disappeared.

5.6. Test Blocks

In May 1959, approximately 8 months after placement of the streetcar reef, a series of 12 white pine blocks was attached to the No. 2 car. These blocks, each ¾ by 1# by 6 inches and spaced 2½ inches apart, were bolted to a 6-foot piece of 1½-inch channel iron (Figure 33). In this manner, water circulated freely around the blocks.

Each month one block was removed and placed in a wide-mouth quart jar underwater. Later, at the laboratory, formalin was added to kill the animals. After 48 hours, the formalin was changed to 50 percent isopropyl alcohol. All changes of fluid were made while holding fine-mesh cheesecloth over the mouth of the jar to prevent animal loss.

The organisms were enumerated by major groups and their volumes recorded. These major separations were broken down into families, genera, and species where it might help to distinguish size or type (Appendix D).

The numbers of species and individuals varied with time.

Barnacles, Balanus sp., made up a high percentage of the organisms on the blocks during the early months. As time passed, they fell prey to flatworms. By the 9th and 10th months, 35 to 40 percent of the barnacles were empty tests inhabited only by large flatworms, Platyhelminthes. As boring mollusks increased, barnacles decreased, partially due to lack of attachment space. Nestling clams, Kellia sp. and jingles, Pododesmus cepio were found in minor but consistent numbers throughout the period.

A correlation is observed when the graph of total encrusting organisms is compared to the number of seaperch (Figure 34). A marked exception occurred during October and November when unusually large numbers of juvenile white seaperch were recorded; similar increases of these young fish were observed at all areas surveyed.

Seaperch are users of such encrusting animals as settled on the test blocks. Kelp bass and sand bass often eat seaperch. An indication of this food chain is evident by comparing the bass population to the seaperch and encrusting organisms (Figure 34). Discrepancies in 1960 may be due to fishing pressure which kept the bass population lower than normal.

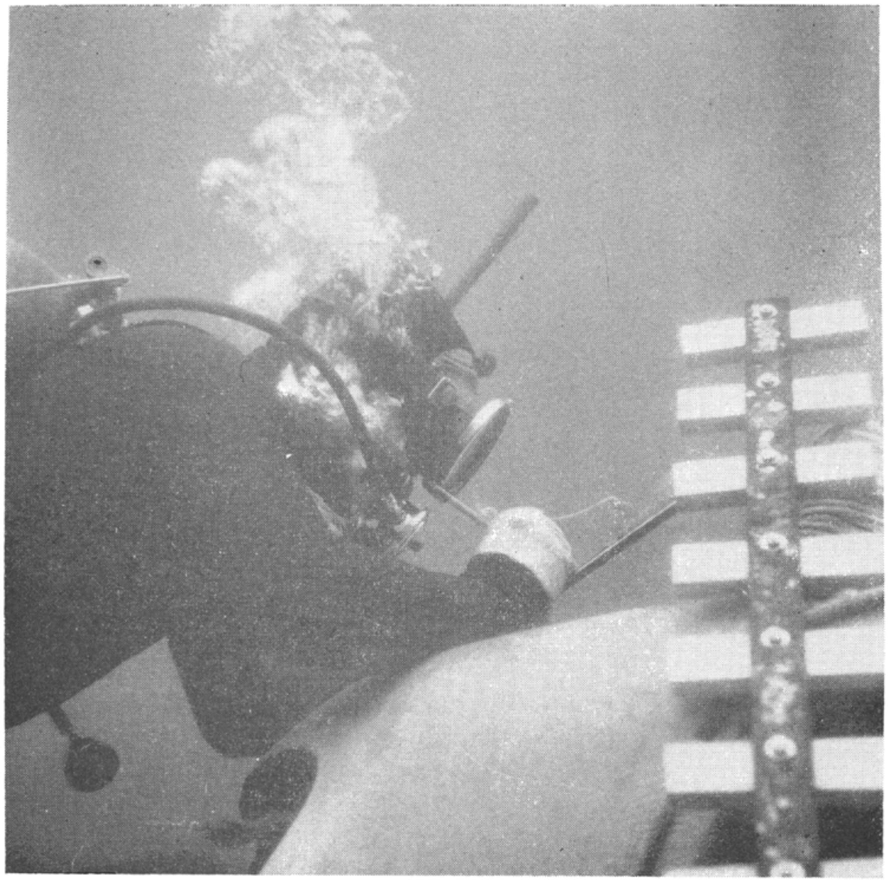

FIGURE 33. Earl Ebert making observations and checking recently installed wooden test blocks. *Photograph by Charles H. Turner, September 1960.*

FIGURE 33. Earl Ebert making observations and checking recently installed wooden test blocks. Photograph by Charles H. Turner, September 1960.

The last five blocks removed were so riddled by shipworms, predominently Bankia setacea, that only small portions remained. The other identified shipworms were: Lyrodus [=Teredo] diegensis, which was occasionally found in the blocks, and the first recorded occurrence of Xylophaga mexicana in California (Ruth Turner, pers. commun.). In January 1960, 90 percent of each remaining block was present, but, by March only 30 percent surrounded the bolt. These percentages tell only part of the story, the inside of each fractional block was honeycombed with burrows.

During the study period, several generations of borers were noted. Over 500 individuals were recorded in a single block. Using this figure, we determined that approximately 123 million borers were present in the streetcars in January 1960. A 5 mm teredo contained an estimated 100 larvae, indicating a large second generation.

Bankia setacea, the dominant borer, attained lengths of 12 to 13 inches in the wooden streetcar structures. Their destructive potential makes wooden streetcars unsuitable for constructing permanent reefs (Figure 35). Material less susceptible to boring action is recommended for reefs expected to last longer than 3 to 5 years.

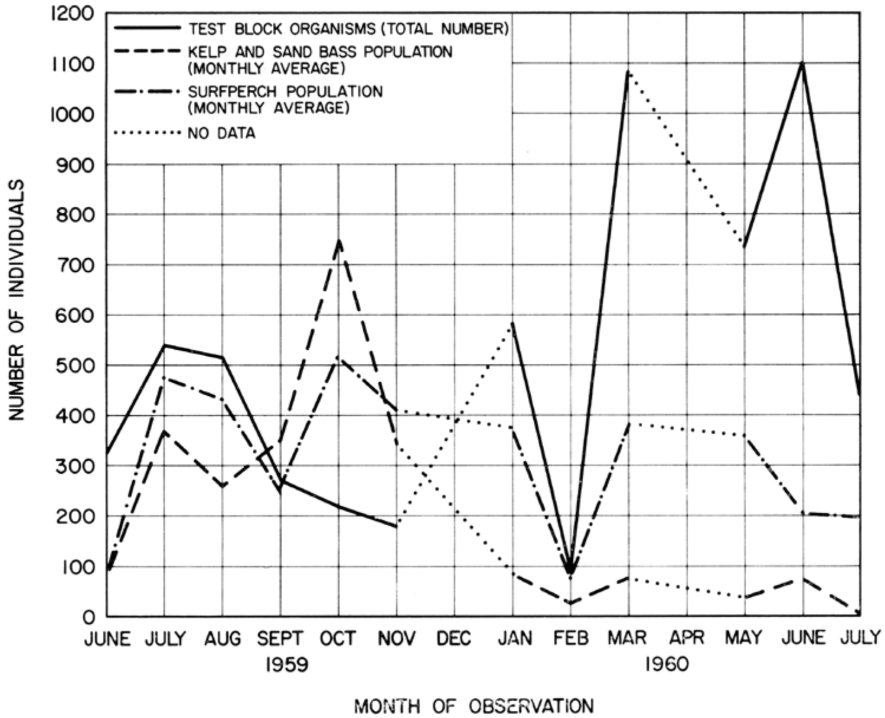

FIGURE 34. The total number of test block organisms, seaperch, and bass recorded on the Redondo Beach streetcar reef from June 1959 to July 1960.

FIGURE 34. The total number of test block organisms, seaperch, and bass recorded on the Redondo Beach street-car reef from June 1959 to July 1960

6. REPLICATION REEFS, SANTA MONICA BAY

Wildlife Conservation Board funds were made available to our project in August 1960. These funds were used to set up a replication experiment to test various materials which could be used to build artificial reefs. The two principal things we hoped to learn from the study were the relative attractiveness for fishes of various materials and the relative life of these compared to cost.

Four materials were selected for the experiment: streetcars, auto bodies, quarry rock, and concrete shelters (Figure 36). Each of the materials was used in approximately equal cubic footage for each reef, namely: one streetcar, measuring 4,400 cubic feet; 14 car bodies, measuring 4,368 cubic feet; 333# tons of quarry rock, measuring 4,444 cubic feet; and 44 concrete shelters, measuring 4,400 cubic feet.

The location of each material within a given reef was determined by chance and the materials were placed in a square with a different one at each of the four corners. Sites, each separated by several miles, were picked for these three multiple reefs off Hermosa Beach, Santa Monica, and Malibu.

The materials on the Hermosa Beach reef were placed approximately 200 feet apart, and on the Malibu and Santa Monica reefs, approximately 100 feet apart. We believed from previous underwater observations, that fish populations on each reef component would remain relatively separate and could be counted by the divers without having to worry about interchange. In practice, we found that each component of the Hermosa Beach reef developed an apparently discrete population, but some fishes circulated freely among the closer components of the Santa Monica and Malibu reefs during a diving observation. However, their movements were not great enough to negate or distort our fish counts very much.

Not enough diving observations have been made to date to draw final conclusions in this paper. However, an analysis of data covering a little over a year, September 1960 to November 1961, revealed a

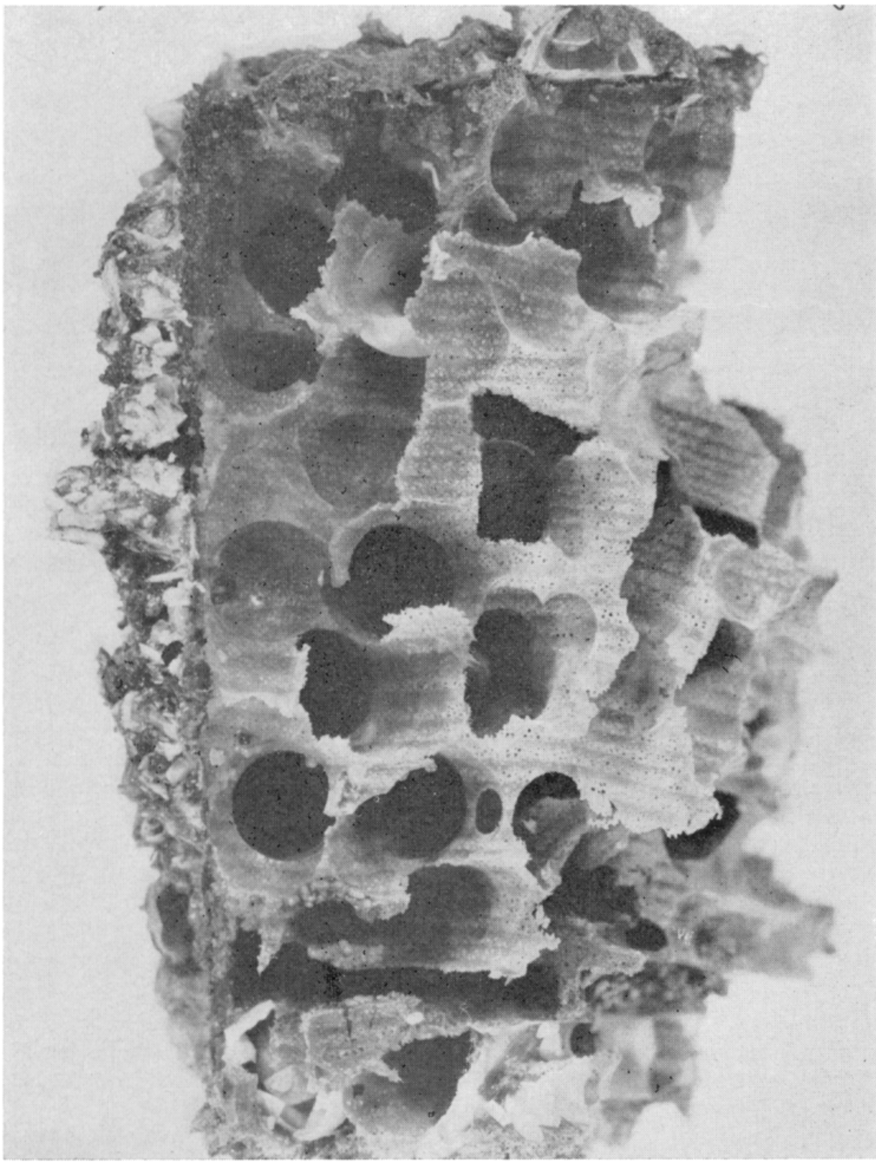

FIGURE 35. Section of 4- x 4-inch streetcar timber, encrusting organisms on the outside, left, and holes made by teredos. *Photograph by Jack W. Schott, November 1959.*

FIGURE 35. Section of 4- x 4-inch streetcar timber, encrusting organisms on the outside, left, and holes made by teredos. Photograph by Jack W. Schott, November 1959.

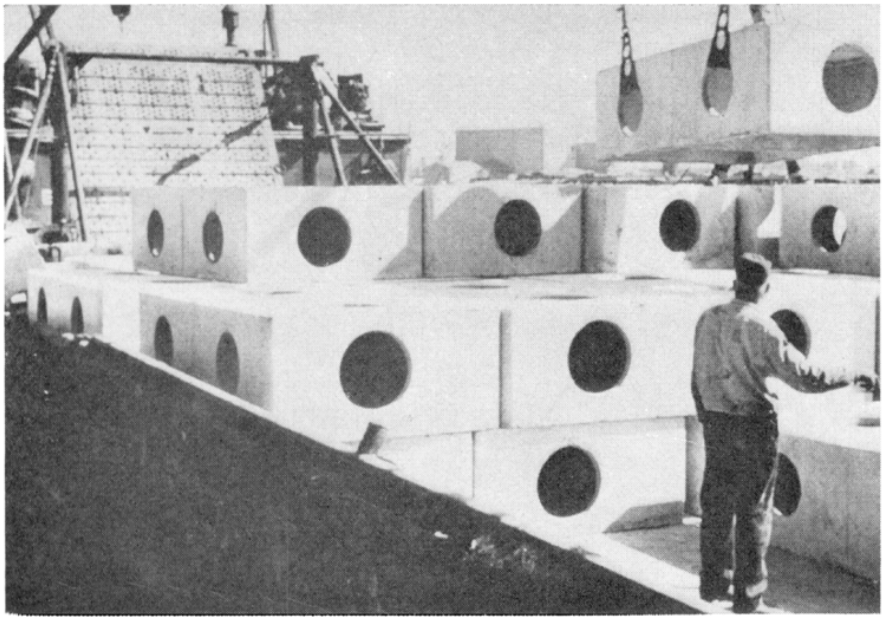

FIGURE 36. Concrete shelters being lowered to bottom off Santa Monica. *Photograph by Charles H. Turner, August 1960.*

FIGURE 36. Concrete shelters being lowered to bottom off Santa Monica. Photograph by Charles H. Turner, August 1960.

slight preference on the part of fishes for the concrete shelters. We do not feel this means concrete shelters are the best choice in reef materials. Quarry rock, which also should last forever on reasonably hard sand or flat rocky bottom, attracted almost as many fishes as concrete shelters and cost only about half as much. Recent checks on the rock component of a reef have shown catches of sand bass as high as 6.77 per angler hour.

Car bodies with a high attraction potential can provide excellent reefs at low cost for a period of about three or four years.

Up to November 1963, no sanding-in of the quarry rock had occurred, but there had been some with the other three materials. The relatively short life for car bodies and streetcars is a serious drawback to use of these materials. At Paradise Cove, where car bodies have been on the ocean floor for about 4½ years and at Redondo Beach where the streetcars have been soaking for about 4 months less, deterioration has been so bad the materials are almost entirely rubble. However, even as rubble they were attracting and holding good numbers of fishes, and the auto bodies at Paradise Cove were furnishing adequate anchorage for the kelp growing on them.

7. HUNTINGTON BEACH ARTIFICIAL ROCK REEF

One unsuccessful attempt was made to install an artificial reef in 55 feet of water off Huntington Beach in an area of completely exposed coast, frequently subjected to heavy swells.

Five artificial rocks, made of wood frames and wire mesh covered with Gunite, were donated by Marineland of the Pacific. They varied in size from a few pounds to about 1 ton. All attempts to relocate them have failed. Presumably they were either rolled out of position in heavy swells or were buried by sand.

8. OFFSHORE OIL DRILLING

On July 2, 1958, the California Department of Fish and Game and the Western Oil and Gas Association entered into a 3-year agreement, by which the Department would observe and evaluate the effects of offshore oil drilling, including the effects on marine life of man-made structures and of depositing washed drill cuttings on the ocean floor. Special attention was to be paid to the possible deleterious effects of the latter operation.

During the course of the investigation, the Department's biologistdivers made monthly diving observations on the Richfield Oil Island at Rincon and on the Standard-Humble Oil tower "Hazel" at Summerland. After its construction in August 1960, the Standard-Humble Oil tower "Hilda" was included in these observations. Several dives were made under the Monterey Oil platform off Seal Beach, and one at the tower north of Santa Barbara constructed by Texaco.

Logs were carefully maintained for all dives and monthly reports were made to the Association.

During the study, there was no evidence of deleterious effects from any part of the operation. The entire operation was very clean and the island and towers served to enhance the habitat. Many fishes have been attracted to the installations and a heavy encrustation of various organisms has developed on the structures. This encrustation includes such animals as kelp scallops, barnacles, and mussels and has added greatly to the available fish food.

9. STANDARD-HUMBLE OIL PLATFORM "HAZEL," SUMMERLAND

The first drilling tower included in this study was built by the Standard and Humble Oil Companies in July 1958, 2.2 miles off Summerland, Santa Barbara County. It stands in 100 feet of water and extends 213 feet above the surface (Figure 37). Drilling was conducted through casings which extend from the platform several feet into the ocean floor.

Washed cuttings, resulting from drilling operations, have been deposited on the ocean bottom, under the tower, through an underwater outfall pipe. The opening of this outfall pipe was 85 feet below the sea surface. After 3 years, the cuttings pile, conical in shape, extended above the pipe opening, and had a basal diameter of about 120 feet. This was in spite of the operator's attempt to jet the pile and spread it out at a lower level. Its composition was predominantly a fine silt.

The cuttings pile appeared to have had no effect on the environment; it neither added anything favorable nor greatly detracted from it. It developed as a smooth-surfaced, silty pile without holes for shelter, so it did not attract fish nor did it offer a suitable substrate for the attachment of plants or animals.

9.1. Survey Methods

Prior to Hazel's construction, a team of biologist-divers surveyed the proposed area. The bottom was dark gray silty-mud with many sea pens, Stylatula elongata, and tube anemones, Pachycerianthus sp., living in it.

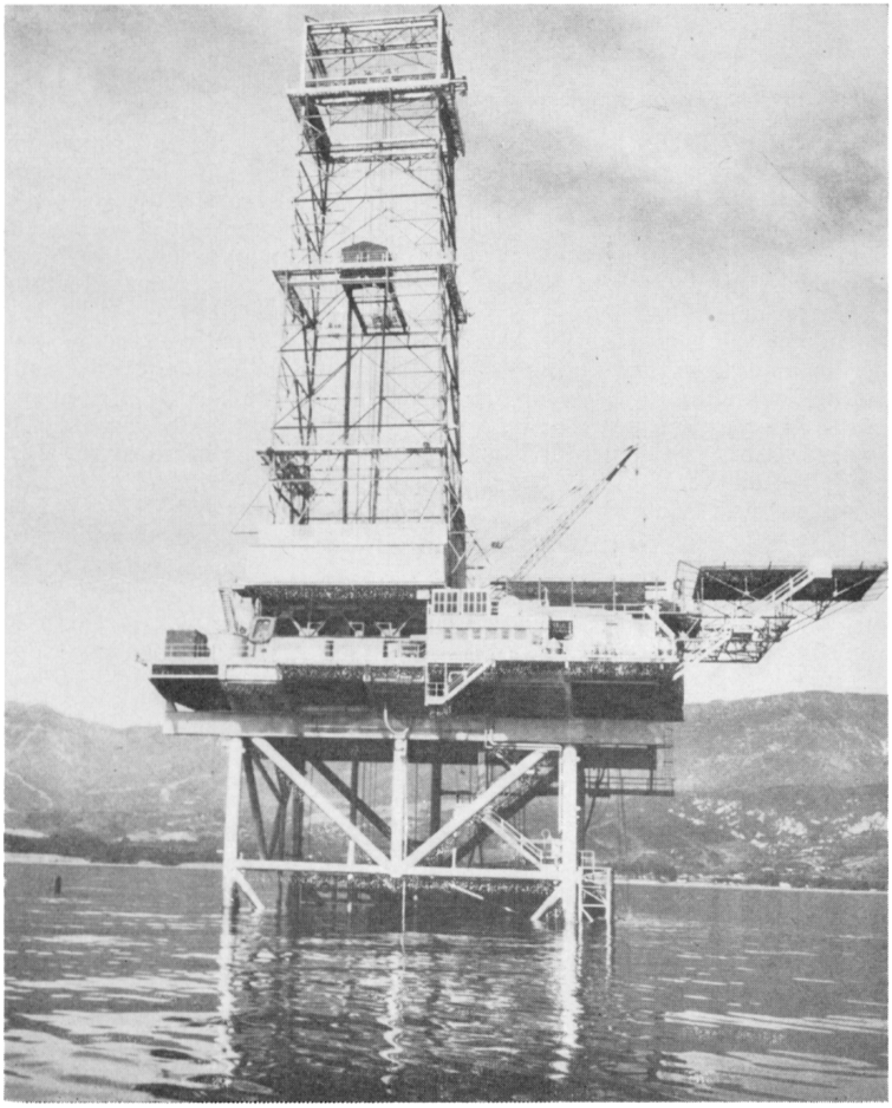

FIGURE 37. Standard-Humble Oil Tower "Hazel" off Summerland, California. *Photograph by Charles H. Turner.*

FIGURE 37. Standard-Humble Oil Tower "Hazel" off Summerland, California. Photograph by Charles H. Turner.

During each of the 29 months following construction, a diving survey was made as weather and sea conditions permitted. A total of 27 routine observations was made, each averaging 1¾ hours under water. During each dive, a descent was made to the bottom (100 feet) and that area examined as thoroughly as water clarity would permit. The diving team would then ascend some 40 or 50 feet and thoroughly survey from this point to the surface. Thus, the water mass encompassed by the four legs supporting the platform was fully covered.

9.2. General Observations

The tower is approximately 2 miles offshore and 1½ miles from the nearest known natural reef. During the first survey, made less than 1 month after completion of the tower, a single pipefish and beginning growths of hydrozoans were observed. By the second month, schools of Pacific sardines and jack mackerel swam under the platform while Pacific bonito cruised just outside the legs. The encrusting organisms included kelp scallops, Chlamys latiaurata, barnacles, Balanus spp., and hydrozoans. Nudibranchs, Hermissenda crassicornis, were observed feeding on the hydrozoans from the surface to below 70 feet. There were thousands of these nudibranchs and many were depositing egg masses on the structural members of the tower. Two other fish species, shiner perch and halfmoons were observed in the shallow upper waters.

From this beginning, over 3,000 fishes had congregated by the following February, 7 months after construction. Things remained constant until August and September 1959 when an increase in seaperch numbers resulted in a population exceeding 62,000. From this extreme, the population dropped rapidly to 5,000 and then gradually stabilized at approximately 6,000 fishes. There were five marked deviations from this average: three exceeded 6,000 when there were increases in the seaperch population and two, made during times of poor visibility (less than 7 feet) failed to attain the average.

Water clarity at the tower averaged 24 feet, ranging from 0 to over 50.

Throughout the survey period, 47 species in 20 families and 34 genera were recorded (Appendix A). Seaperch accounted for an average of 67.7 percent of the total resident fish population, ranging from 13.0 to 86.2 percent during any single dive. This is in close agreement to figures recorded at the artificial reefs in Santa Monica Bay.

9.3. The Fish Fauna

9.3.1. *The surfperches—family Embiotocidae:*

Seaperch comprised the major portion of the fish population at the platform. Conditions were similar to those noted at the artificial reefs in Santa Monica Bay, where four species, white seaperch, rubberlip seaperch, pile perch, and black seaperch were the most prevalent. Unlike the artificial reefs, shiner perch were also dominant at the tower. On one dive, these small perch accounted for 79.4 percent of the total fish population.

Seaperch were observed feeding on the mussels, kelp scallops, and hydrozoans encrusting the structural members (Figure 38).

Shiner perch, comprised from 6.5 to 79.4 percent of the total fish population; they averaged 34.6 percent. They are small fishes, 3 to 5 inches long, and form loose schools in the intermediate depths 20 to 60 feet below the surface. Occasionally they were observed as deep as 90 feet.

They were present in greatest numbers during the spring and summer, and with two exceptions, some were observed at all times of the year. During October 1959, none was seen although the water was clear; however, in May 1960, the water was so murky that they may have been present but remained outside the divers' fields of vision.

FIGURE 38. Seaperch feeding on tiny organisms attached to structural members of an off-shore drilling tower. *Photograph by Charles H. Turner.*

FIGURE 38. Seaperch feeding on tiny organisms attached to structural members of an offshore drilling tower. Photograph by Charles H. Turner.

During June and July 1959 and again in March and July 1960, there were large increases in their numbers; this coincided with their optimum breeding season. Darkened males were observed attempting to pair off with females throughout the year, indicating a prolonged breeding period.

Black perch increased slightly in numbers throughout the observation period (Figure 39) but their contribution to the population remained nearly constant. Approximately 125 fish were around the platform each month. They were from 3 to 14 inches long with the average near 8 or 9. They were often observed feeding on animals clinging to the hydrozoans that encrusted the structural members and to the kelp scallops that were present in great profusion during the first year.

The individuals around the tower appeared ready to mate throughout the year, as bright yellow marking on the anal fin, characteristic mating colors, were noted on one or more individuals every month. The young were observed predominantly in late winter and spring, but some were seen throughout the year.

Rubberlip perch reached a population peak of about 500 individuals during the observational period but there were mild fluctuations when

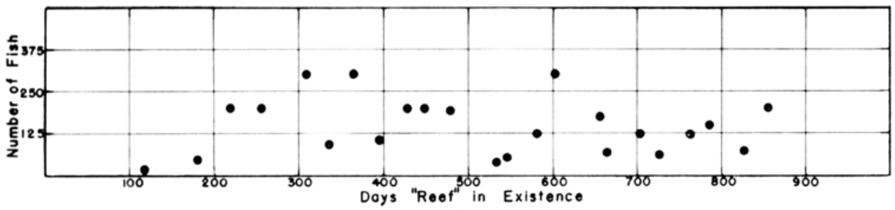

FIGURE 39. The increase of the black perch population at "Hazel" with time.

FIGURE 39. The increase of the black perch population at "Hazel" with time

fewer than 125 were seen (Figure 40). Individuals were from 4 to 18 inches long, averaging 10. Small, 4- to 5-inch fish were usually oberved during the summer. Rubberlip perch were seen at depths of 5 to 65 feet, with most 30 to 40 feet beneath the surface. Behavior indicated fall or winter mating.

Pile perch roughly paralleled rubberlip perch in abundance Figure 41). There was one abrupt rise during the late spring and summer of 1959 when kelp scallops were prevalent. This vast food source may have enticed the young to remain at the tower in large numbers. After this upsurge, the numbers of pile perch and kelp scallops decreased. The kelp scallops did not recover but the pile perch began a steady rise, and a high of 500 perch was noted in November 1960. Individuals were from 4 to 18 inches long, but the average fish was 10.

During most of the year, various individuals had yellow markings on the anal fin, similar to the breeding colors on the anal fins of black perch. The smallest (youngest) fishes were observed mainly during the summer. Some adults dissected in February contained immature embryos. Pile perch had depth preferences similar to those noted for rubberlip perch.

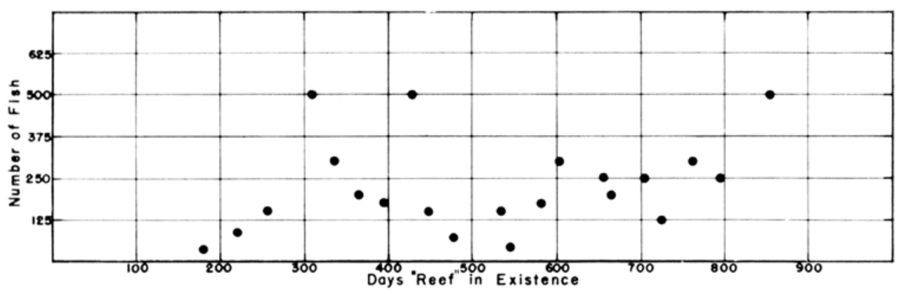

FIGURE 40. The increase of the rubberlip perch population at "Hazel" with time.

FIGURE 40. The increase of the rubberlip perch population at "Hazel" with time

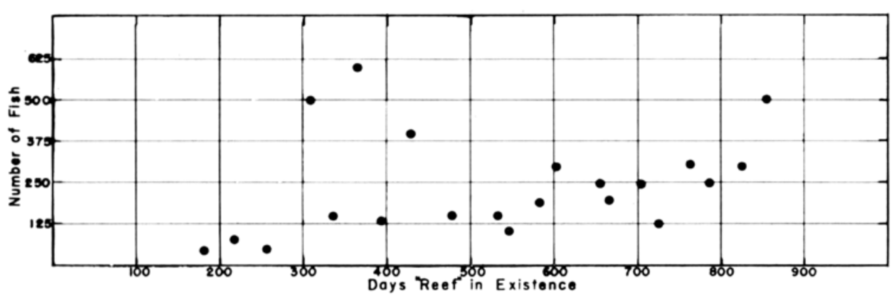

FIGURE 41. The increase of the pile perch population at "Hazel" with time.

FIGURE 41. The increase of the pile perch population at "Hazel" with time

White seaperch inhabited the waters beneath the oil tower in large numbers; they were exceeded only by shiner perch. Seldom were fewer than 500 of these loose-schooling fishes observed. Although they were most common at intermediate depths, some were observed below 90 feet. Young white seaperch were present throughout the year, particularly from July through January. Individuals were 3 to 10 inches long, but the average was about 6. This species too, grazed on encrusting organisms and in turn served as food for sand bass and various rockfish.

9.3.2. *The rockfishes—family Scorpaenidae:*

This large family of fishes, represented by 10 identified species, was second in average numbers at the platform. The six species most consistently observed were bocaccio, brown rockfish, whitebelly rockfish, olive rockfish, grass rockfish, and sculpin. By numbers, 5 of the 10 species predominated; these were olive rockfish (7,125), whitebelly rockfish (5,365), bocaccio (4,225), brown rockfish (3,374), and grass rockfish (1,218). The other five species were represented infrequently or in small numbers.

Olive rockfish were first observed in October 1959; these fish were 5 to 10 inches long. The number present each month ranged from 35 to 1,300, with an average of 356. They were from 1½ to 16 inches long, but the average was about 9.

No actual mating or courtship was noted, but young-of-the-year were observed from July through November. In July 1960, several hundred 1½-to 3-inch young were seen 80 to 90 feet beneath the surface.

This species formed loose schools at depths of 20 to 90 feet, but their average depth was around 50 feet. They often associated with various seaperches and with bocaccio.

Whitebelly rockfish were seen individually in the deeper water around the tower. Only on a few occasions did they approach to within 40 feet of the surface; they were usually encountered 70 to 100 feet down. Individuals ranged from 3 to 16 inches long, with an average length of 9. Their young were observed in the winter and early spring.

This species fed on organisms living near the bottom, as exemplified by three speckled sanddabs and an octopus found in the stomach of a 10-inch male.

Bocaccios around the tower averaged 10 inches although they were 1 to 16 inches long. Young-of-the-year were observed from July through January. Four- to 8-inch fish occurred 40 to 50 feet beneath the surface but 12- to 16-inchers preferred 70 to 80 feet. The only exception was a group of 1- to 2-inch juveniles observed 80 to 90 feet down during July 1959.

All of the stomachs examined were empty; however, the fish were in good condition, having plenty of fat deposits throughout their bodies.

Brown rockfish were on and around the cross-members at 40 feet and around the legs of the tower 20 to 60 feet beneath the surface. often they were swimming close to heavy beds of mussels. They were 3 to over 18 inches long, but averaged only 10. The largest was estimated in excess of 24 inches, a size record if it had been verified. Juveniles were observed during the summer and fall. One 12-inch male taken in May 1959 had an 8-inch greenstriped rockfish in its stomach.

Grass rockfish typically inhabit inshore areas associated with surf grasses; however, they were seen numerous times at this platform. Some were observed hiding in the fronds of a floating kelp plant, which may explain one mode of travel to the offshore tower. After the kelp became entangled with the tower's structural members, these fish re-oriented themselves with the tower. During the observational period, individuals were seen which were from 6 to 18 inches long; they averaged 10 inches. Six- to 8-inchers were observed during the winter and early spring. A large influx onto the tower added support to the "deeper" part of a theory proposed by Limbaugh (1955) that, "it seems probable that during the spawning season, which coincides with the seasonal winter storms, the species moves either into deeper or into intertidal waters." The individuals observed were usually around the guide cups at the 40-foot level, but were seen at all depths from 5 to 60 feet beneath the surface.

Although their food was not studied, they were observed chasing and eating small seaperch. It was not uncommon to see a grass rockfish with the caudal fin of a white seaperch protruding from its mouth.

9.3.3. *The silversides—family Atherinidae:*

Similar to any established kelp bed, Hazel attracted numerous silversides. Schools of these fishes were observed from the surface to 30 feet just outside the legs of the tower. Perhaps the shadow of the platform duplicated that formed by a kelp canopy. Both jacksmelt and top smelt were present. Their schooling behavior was usually independent of any other species; however, they occasionally joined schools of sardines or jack mackerel.

9.3.4. *The sea basses—family Serranidae:*

By their small numbers, bass were of secondary importance at the tower. Only occasionally were as few as 5 or as many as 500 individuals sighted; the average was 244.

Kelp bass averaging 160 individuals per observation, were more than twice as common as sand bass. They were seen from 10 to 70 feet beneath the surface with most at the 30- to 40-foot levels. They were noted eating mussels and kelp scallops and grazing on hydrozoans Figure 42). Although they ranged from 1½ to 24 inches, their average length was near 11. Young-of-the-year were seen in the fall and winter but the smallest, 1½-inch fish, were there in September 1959. Some 2-inchers were noted in both November 1958 and January 1960.

Sand bass were seen all the way from 40 to 100 feet beneath the surface but most were below 80 feet. Although seldom in large numbers, from 1 to 300 individuals were counted per observation, with an average near 80. These were from 4 to 30 inches long, averaging between 14 and 15. Small fish, 4 to 6 inches long, were seen predominantly during the spring and summer. Large fish were present in concentrated groups during the fall and winter, probably for purposes of spawning.

Shiner perch and slender crabs were suitable fare for these sand bass.

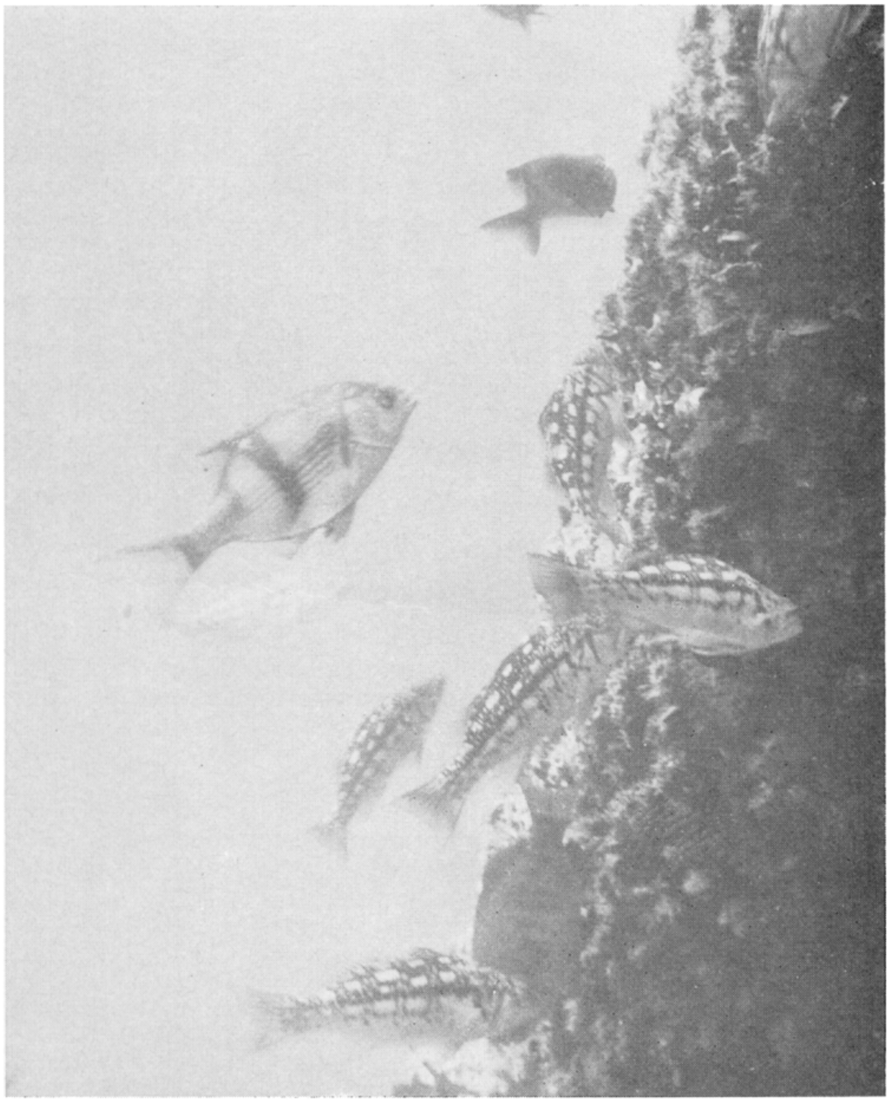

FIGURE 42. Kelp bass, pile perch, and black perch feeding on invertebrates on leg of offshore oil tower. *Photograph by Charles H. Turner, August 1959.*

FIGURE 42. Kelp bass, pile perch, and black perch feeding on invertebrates on leg of offshore oil tower. Photograph by Charles H. Turner, August 1959.

9.3.5. *Pelagic fishes of several families:*

Several schooling pelagic species were observed under the tower. Pacific sardines, jack mackerel, and Pacific mackerel were noted schooled separately as well as mixed.

Schools of them would remain in the shade under the platform and mill ceaselessly. Then, as if by a prearranged signal, a school would dart into the open where it would be attacked by yellowtail or bonito which were often cruising some 40 to 50 feet from the tower. Only on rare occasions did these predators venture under the tower. Their tenure outside the tower lasted for many months during 1959 and 1960.

During this period when numerous sportfish were present, local sportsmen almost became a nuisance to the workers on the tower. Private fishing boats would tie up as close as possible to the tower, snag a sardine or mackerel for bait and then drift a few feet away for yellowtail. At one time, 10 sardines would yield 10 large yellowtail if the bait could be gotten through the bonito.

A possible solution to the problem created by these sportfishermen would be to deposit the cuttings some distance from the tower and dump quarry rock on the pile to make good habitat. In this way, the tower would act as a reservoir for the fish populations and the sportsmen would be given an area, other than the tower, to fish. By fishing under the tower, they are in constant danger from falling metal and other objects.

9.3.6. *Miscellaneous fish:*

Two schools of queenfish were at the 85-foot level on November 13, 1959. One school was composed of 5- to 7-inch fish and the other of 7- to 9-inch fish. This species is commonly thought of as a shallow-water form.

During March 1960, numerous fishes were using a 2-foot section of pipe for a scratching post. Their scratching was perhaps to rid themselves of ectoparasites, a job usually undertaken by señoritas or kelp perch. Apparently in their absence, the pipe served just as well. This 2-foot section was polished bright and shiny, while the remaining 30 feet were well-encrusted as was all other submerged material (Figure 43).

9.4. The Invertebrate Fauna

A series of 12 wooden test blocks bolted to a 6-foot length of channel iron, was fastened to this tower. One block was removed each month to study encrusting organisms. At the writing of this report, the material had not been sufficiently worked up to make it meaningful.

A small amount of work has been done on some organisms removed from the structural members. These are discussed below and the species encountered and their distributions are shown in Appendixes E and F, illustrating the changes in the biomass from July 1959 to July 1961.

9.4.1. *The sponges:*

Large colonies of a dirty white sponge, Leucosolenia sp., encrusted many portions of the tower especially at depths of 20 to 40 feet. The larger colonies were 5 to 10 cm tall and 15 to 20 cm in diameter. The nestling clam, Hiatella arctica, was commonly found in their masses. of several other sponges, only Leucetta losangelensis and Hymeniacidon sp. have been identified.

9.4.2. *The segmented worms:*

Various segmented worms were present in the encrusting mass. Feather-duster worms, Eudistylia polymorpha, were very much in evidence on the cross-members at the 40-foot level, where their purple- or buff-colored gills stood out among the mussels. The large masses of tube worms, Salmacina tribranchiata, so common on other reefs, were lacking. Although many worms were present, only five others, Eunereis longpipes,

FIGURE 43. Drilling guide cups and cross members at 40-foot depth on "Hazel", showing pipe used as "scratching-post" by fishes. *Photograph by Charles H. Turner, March 1960.*

FIGURE 43. Drilling guide cups and cross members at 40-foot depth on "Hazel", showing pipe used as "scratching-post" by fishes. Photograph by Charles H. Turner, March 1960.

Halosydna brevisetosa, Nereis mediator, N. eakini and Paleanotus bellis, have been identified.

9.4.3. *The hydroids and sea anemones:*

Hydrozoans rapidly encrusted the submerged structural members from the surface to the bottom with heaviest concentrations in the upper 40 feet. After other organisms commenced settling in abundance, highest hydrozoan concentration appeared to be 50 to 80 feet beneath the surface. Below 80 feet, the scouring action of sand and the cutting material greatly reduced the number and size of these animals.

The most common genus was Campanularia.

Colonial anemones, Corynactis sp., were first observed in January 1960 in scattered small colonies. By December 1960, they had formed colonies of several hundred individuals on many parts of the tower and to depths of 90 feet.

Plumose anemones, Metridium senile, were first observed 45 to 80 feet beneath the surface during June 1960. Within a year several hundred large individuals were attached to the tower from 35 to 100 feet down. Both the pure white and the yellow phase were abundant.

Green anemones, Anthopleura elegantissima, very familiar to tidepool observers, were first seen in October 1960. On the tower, they attached in the areas of heaviest mussel concentration, particularly 4 to 15 feet beneath the surface. Either their planula stage had drifted a long distance or these individuals floated to the tower as adults on the holdfasts of giant kelp.

9.4.4. The joint-legged animals:

Barnacles were among the first animals to settle on the structural members of the tower. Balanus tintinnabulum and B. cariosus were the two most commonly found. B. tintinnabulum was dominant from the surface to about 60 feet, but below that it shared the substrate with B. cariosus. Our observations indicated B. cariosus was dominant below 90 feet. B. tintinnabulum were 35 mm high by 44 mm wide when 11 months old. There were 70 to 80 of this size per square foot, often one on top of another. B. cariosus, 100 to 200 individuals per square foot, had attained a maximum of 26 mm high by 44 wide after 24 months. As time progressed, bay mussels, Mytilus edulis, competed with the barnacles for space in the upper waters until late-arriving barnacles were forced to attach on the mussels. Prior to mussels taking over, the barnacles fought a similar battle for space with kelp scallops. It was not at all unusual to find a barnacle nearly covering one valve of a kelp scallop, which was still able to open its shell even with the barnacle's added weight.

A 12-inch spiny lobster, Panulirus interruptus, was hiding in a maze of pipes at the 40-foot level on October 14, 1959. No other lobster has been observed near the tower.

Yellow crabs, Cancer anthonyi, rock crabs, C. antennarius, kelp crabs, Pugettia producta, and spider crabs, Loxorhynchus sp., were observed. The numerous other small brachyurans seen on Hazel have not been identified. Crabs were most numerous during the summer.

9.4.5. The moss animals:

A sample of Membranipora savarti was removed in October 1959, but no other bryozoans have been identified. There were small concentrations of Membranipora on the tower.

9.4.6. The starfishes and sea urchins:

Purple sea urchins, Strongylocentrotus purpuratus, red sea urchins, S. franciscanus, and three starfishes, Pisaster ochraceus, P. giganteus, and P. brevispinus were all on the tower.

Purple sea urchins were first observed in September 1959 when seven 1- and 2-inch individuals were recorded at the 40-foot level. They grew to diameters of 3 and 4 inches within a 2-month period. During these 2 months, several new individuals arrived, probably on floating kelp since it is unlikely that they traveled 1½ miles across open sand and mud to reach the tower. Because of their rapid growth, they could have reached the tower as free-swimming larvae; however, if this were the case, numerous individuals should have settled there instead of the fewer than 18 that did. Only 5 months elapsed between their arrival and disappearance.

Red urchins, present for 5 months at the same depth as the purple urchins, grew from 2 or 3 inches to over 5 between October 1959 and March 1960. They were 2 or 3 inches in diameter when first noted; their mode of arrival is presumed similar to the purple urchins.

9.4.7. The scallops, mussels, clams, and snails:

Rock scallops, Hinnites multirugosus, 1½ to 2 inches across were noticed in September 1959 on the 40-foot deep crossmembers. They were in the joints between the guide cups and the cross supports. By the following July, a period of about 10 months, they were 4 to 5 inches in diameter. At this time, numerous encrusting organisms, barnacles, mussels, and kelp scallops commenced growing over them. By August, they were not visible under this heavy growth. Many months later a few tiny shells were found in scrapings taken from the structural members, but no large rock scallops were to be seen.

Kelp scallops, Chlamys latiaurata, first appeared in August 1958, 1 month after the tower was completed. There was no competition for attachment space or food and they grew profusely (Figure 44). They

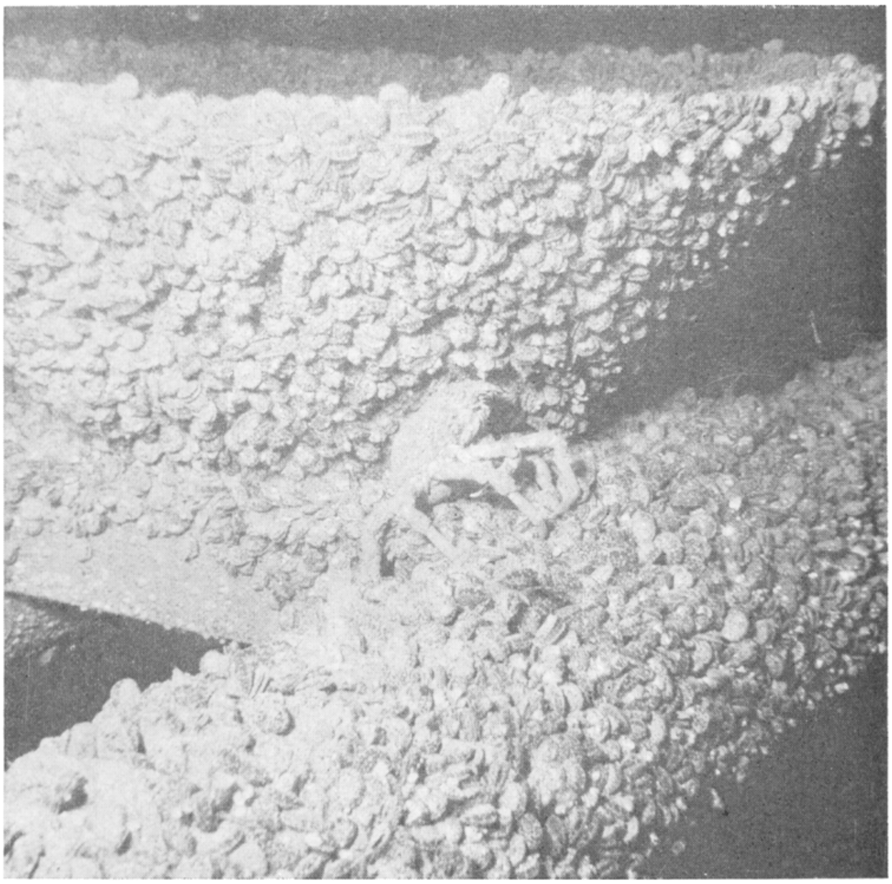

FIGURE 44. **Kelp scallops and a sheep crab on oil tower Hazel.** ***Photograph by Charles H. Turner, February 1959.***

FIGURE 44. Kelp scallops and a sheep crab on oil tower Hazel. Photograph by Charles H. Turner, February 1959

were dominant until August 1959 when bay mussels began to take over. A year later, in August 1960, the kelp scallops were non-existent except for a few hardy individuals buried several inches deep in the masses of bay mussels.

Kelp scallops were in spawning condition throughout the year and tiny scallops, less than 1 mm long were observed almost every month. The largest specimen measured 46 mm wide, 49 mm long and 33 mm along the hinge; it was collected in May 1959, roughly 9 months after the kelp scallops were first observed. Their growth was quite rapid, for within 6 months the average length was 25.1 mm and the maximum was over 31.2. These 6-month-old scallops were all mature individuals with ripe gonads. We presume their life span is at most 2 years.

During January 1959, there were 533 kelp scallops per square foot. Calculating a minimal attachment area of 15,000 feet for the structural members from the surface to 70 feet, we determined that nearly 8 million kelp scallops were present. At this same time, a new batch of 2- to 5-mm individuals having a density of 27 per square foot, increased the total population by nearly a million.

During the period of their dominance, they were heavily concentrated from 10 to 60 feet beneath the surface with scattered individuals nearer the surface and as deep as 70 feet.

The last set of any appreciable size was in November 1959, after which bay mussels completely dominated the tower.

Bay mussels, Mytilus edulis, entered the encrusting biomass within 6 months of the time the tower was completed, but because of the kelp scallop's head start, they did not become dominant (Figure 45) until July or August 1959. At that time, they completely covered the structural members from the surface to below 25 feet, and relegated the scallops to deeper water and minor importance. By January 1960, the mussels were forming heavy concentrations on all the structural members to depths of 40 feet; in shallow water the mussel masses were in excess of 3 inches thick. By August 1960, kelp scallops were gone and the bay mussels formed heavy concentrations from the surface to 60 feet. By December 1961, even the 18-inch holes in the unused guide cups were completely closed by the masses of mussels.

At the peak of their density, they extended from the turbulent surface areas to nearly 80 feet. At depths greater than 45 feet, they began to thin out and below 60 feet they were few and scattered. In the surface waters, they formed mats more than 12 inches thick.

Only one California sea mussel, Mytilus californianus, was recorded at this tower; a habitat that would usually be considered typical for this open-ocean form and less typical for bay mussels.

Agate and reversed chamas, Chama pellucida and Pseudochama exogyra, were seen in moderate numbers during March 1960. They were on the structural members 5 to 25 feet beneath the surface.

A channeled top-snail, Calliostoma doliarium, was found in September 1959; it probably floated to the tower on a raft of kelp.

Nudibranchs, Hermissenda crassicornis, were extremely plentiful at times from the surface to 100 feet. On numerous occasions they were laying great quantities of eggs.

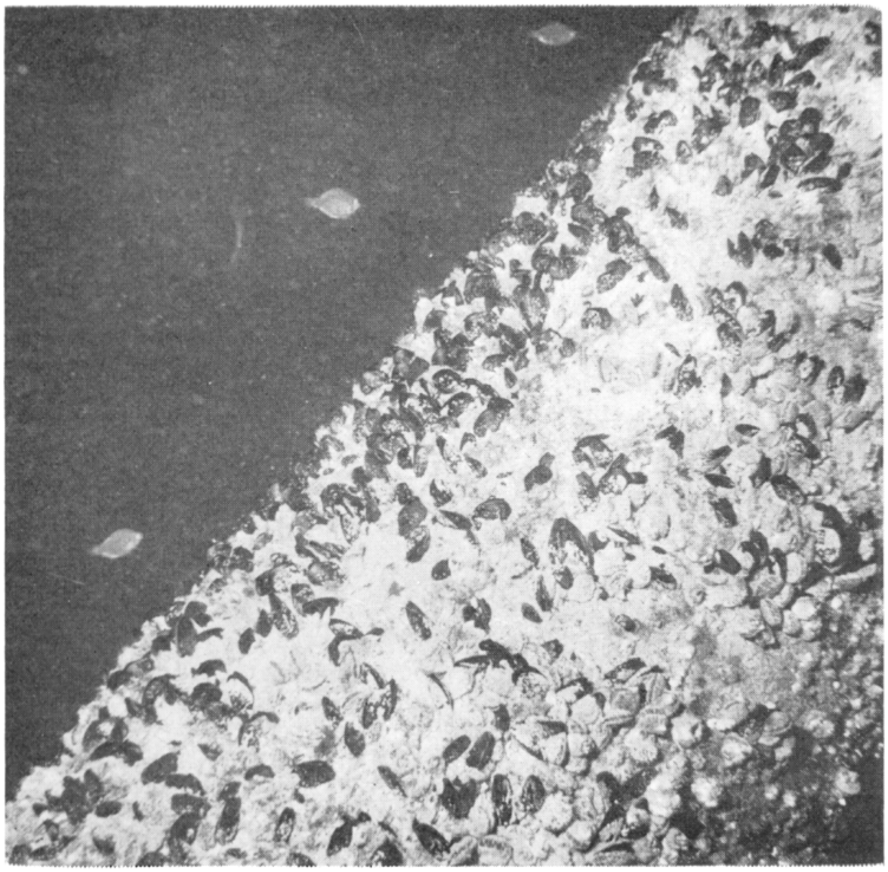

FIGURE 45. Bay mussels crowding out the kelp scallops on Hazel. *Photograph by Charles H. Turner, March 1959.*

FIGURE 45. Bay mussels crowding out the kelp scallops on Hazel. Photograph by Charles H. Turner, March 1959

9.5. The Flora

9.5.1. Algae:

Several kinds of algae were present. of those identified, giant kelp and strap kelp were most conspicuous.

Giant kelp, Macrocystis pyrifera, drifted by and became entangled in the structural members throughout the observational period. Most possessed fruiting fronds which apparently released sporophytes because in May 1959 young Macrocystis plants were growing from 10 to 85 feet beneath the surface. They survived until August and September when they succumbed to adverse environmental conditions, primarily warming of the water and intensive grazing by fishes. It was nearly 8 months later, June 1960, that several hundred ½- to 6-inch long plants were observed on a new piece of drill pipe. They had little area other than this new pipe available for attachment because of the many mussels. In fact, several mussels were observed with small plants growing on their shells. By August and September, most of these new small plants had perished. Three that survived had grown to lengths of 36 inches, and during the summer of 1961 they were the only giant kelp on the tower.

Strap kelp, Egregia laevigata, or feather boa kelp, a shallow-water species, was growing on the south side of the tower in 5 to 10 feet of water during the summer of 1961. There were two plants, one 6 feet long and the other slightly less.

9.6. The Cuttings Pile

The cuttings pile that formed below the outfall pipe had little or no effect on the fish population. Fishes were neither attracted to it nor repelled from it. Once in a while, fish were seen swimming through the cloud of cuttings falling from the pipe, but this appeared to be only an attempt to move from point "A" to point "B" in the shortest time.

When the pile became so high that it hampered further disposal of cuttings and blocked the outfall opening, a jetting operation was undertaken in an effort to disperse the pile. About all this accomplished was to level the top of the cone and to cover the encrusting organisms on the tower below 75 feet with a layer of mud. The fishes were apparently unaffected other than to lose a potential food supply. At the time of our last observations, the pile was a gently-sloping cone 120 to 150 feet across the base and 20 to 25 feet deep.

10. STANDARD-HUMBLE OIL PLATFORM "HILDA," SUMMERLAND

This platform is in 106 feet of water in the same general area as Hazel. The difference of 6 feet in depth was not great enough to affect the fauna, thus, the organisms were essentially similar to those found at Hazel.

Hilda was visited in August 1960, approximately 3½ months after completion, and then each succeeding month through December 1960. Because only these five routine observations were made, the data are too scanty for drawing valid conclusions but they are useful for considering generalities and for making comparisons with our early observations on Hazel.

10.1. The Fish Fauna

During the 5 months of observing, 32 species belonging to 16 families and 23 genera were recorded around the platform (Appendix A). At a comparable age (about 9 months), 29 species of fish belonging to 14 families and 20 genera had been seen at Hazel, ¾ mile away. On our first dive at Hilda, we tallied 2,994 fishes, a number surpassed at Hazel in February 1959, 7 months after construction when 3,195 semi-resident fishes were observed. The numerical differences in the "initial" counts at the two towers may have been due to any of several factors: distance to the nearest favorable reef-like habitat that was capable of supplying the population (Hazel could only draw from natural reefs alongshore 1½ miles away, Hilda could draw from Hazel as well as these natural reefs); time of year (Hazel was completed in July, Hilda in May); and temperature differences in 1958 and 1960 (water temperatures were warmer than usual in 1958 and about normal in 1960).

Aside from these numerical differences, the relative attractiveness of Hilda closely paralleled what had been noted for Hazel; the kinds of fishes were nearly identical, young fishes far outnumbered adults, and total numbers increased, with some fluctuations due to water clarity and influx of young.

10.2. The Invertebrate Fauna

We observed barnacles (two kinds), kelp scallops, and luxuriant growths of hydrozoans on our first visit to Hilda. At no time were the kelp scallops as abundant on Hilda as they had been on Hazel where in the early stages after construction as many as 533 per square foot were counted. It is not likely that the 20 per square foot observed on Hilda will be surpassed because at the time of our last dive (July 1961) bay mussels were taking over most of the available attachment areas. Appendix G shows the vertical distribution of the biomass in July 1961, indicating the dominance of mussels.

As on Hazel, a multitude of nudibranchs, Hermissenda crassicornis, were living on the concentrated masses of hydrozoans from the surface to the bottom. Their egg clusters were numerous, particularly during the fall.

10.3. The Flora

Giant kelp showed up early on all structural members to a depth of 35 or 40 feet. Below this, the small plants were confined to areas that had been painted white. We believe these young plants resulted from sporophytes released by kelp that floated into the platform area and became caught in the guy wires. At the time of our July dive, the plants were heavily grazed but appeared to be surviving; the largest was 5 feet long.

11. RICHFIELD OIL ISLAND, RINCON

The Richfield Oil Company's offshore drilling island is 0.5 miles off Point Gorda, Mussel Shoals, Ventura County, on a bottom of gray sandy-silt. Inshore from the island a substantial bed of giant kelp arises from a low rocky substrate partially covered by this gray sandy-silt.

The island is composed of large quarry rocks capped with huge concrete tetrapods on the seaward side. The tetrapods break up wave forces and thus protect the island (Figure 46).

Unlike our artificial reefs in Santa Monica Bay and the Standard-Humble Oil platforms, we were not able to make a preliminary survey of this area prior to construction. Without this survey, to establish baselines, the resulting changes could not be determined in their entirety.

We conducted our first survey in July 1958, 18 months after construction was begun. Many changes had already occurred : numerous fishes swam in the area, a modest kelp bed grew on all sides of the island, and numerous invertebrates and plants typical of this geographical area were observed.

Throughout the study period, August 1958 through December 1960, only subtle fluctuations in the fish populations and the appearance of new animals could be recorded. During this period, 53.4 hours were spent in the water on 26 separate dives.

Although water visibility varied from 0 to 35 feet it was usually murky, averaging 8 feet, and complete fish estimates were difficult to make. The over-all population gradually trended upward but there were many fluctuations; these may have been because of water clarity or incoming year-classes of fishes. A multitude of small, economically-Unimportant

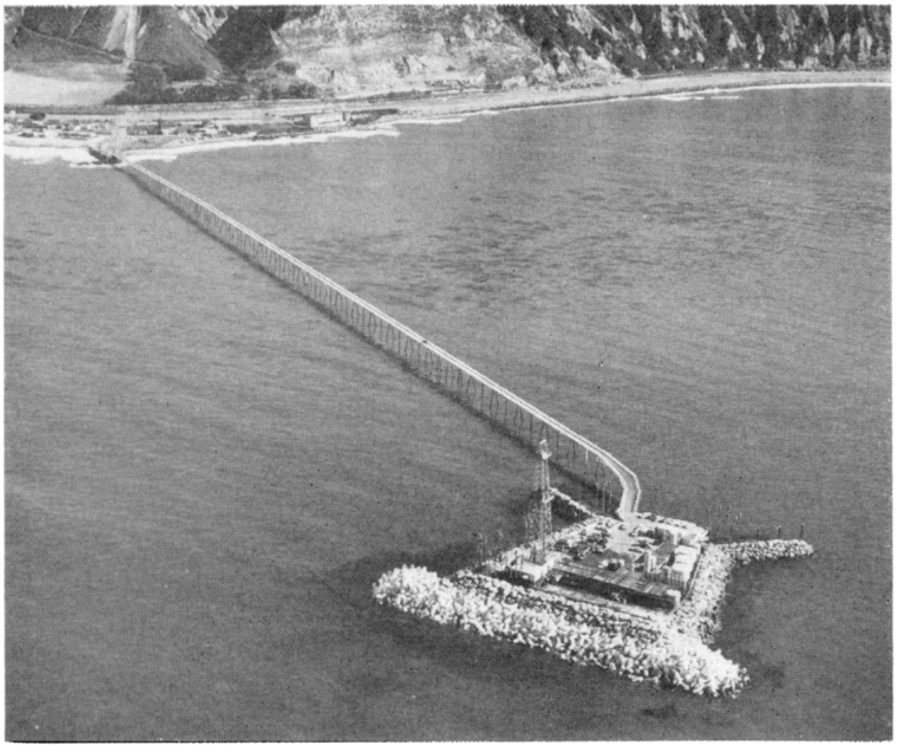

FIGURE 46. Richfield Oil Island at Rincon. *Aerial photograph by Richfield.*

FIGURE 46. Richfield Oil Island at Rincon. Aerial photograph by Richfield.

species present at the end of the survey period gave the area the look of a well-balanced animal community.

In all, we observed 53 fish species belonging to 44 genera in 22 families. The majority, 49 species belonging to 40 genera in 18 families, could be classified as semi-residents, while the remaining 4 were pelagic species with transient habits (Appendix A).

By numbers, silversides were most abundant (33.8 percent) followed by surfperches (32.3 percent), sea basses (11.6 percent), damselfishes (9.7 percent), and rockfishes and halfmoons (4.6 percent each). The other 17 fish families accounted for only 3.4 percent. These "trace amount" fishes, while usually not important to the sportsman for game, are undoubtedly essential components of the balanced reef community. Unless it could reach a condition of balance, a reef would exhibit only short-term benefits to an area.

This particular reef afforded excellent habitat for many animals and plants. In the turbulent waters on the seaward edge, there were populations of large, active fishes, while the heavy kelp beds in the lee of the island served as nursery grounds for the young of many species, especially kelp bass, blacksmiths, surfperches and rockfishes. The spaces between the rocks sheltered the more-sedentary sculpins, rockfishes, and cabezons. The upper water column and the offshore areas were used by pelagic fishes; barracuda and bonito were occasionally observed at the edges of the island.

The upper rock surfaces furnished attachment for giant kelp and other algae while the sides and crevices were covered with rock scallops, mussels, and barnacles.

11.1. The Fish Fauna

11.1.1. The silversides:

The most abundant fishes were silversides and two of the three southern California species, jacksmelt and topsmelt, were tallied on numerous occasions. These fishes formed moderately tight to loose schools in the upper waters, especially in the kelp canopies where they fed on small crustaceans living on the fronds. Silversides were eaten by some of the larger fishes such as kelp bass and yellowtail.

11.1.2. The surfperches:

This large family of fishes was represented by 11 species. Large adults were observed on the seaward side of the island and the young lived on the sheltered lee side where they were seen all during the year.

Pile perch, ranging from 3 to 18 inches but averaging 8½, were recorded during every dive. Young pile perch were observed singly or in small loose schools in the lee of the island while the larger individuals were frequently seen in the more exposed areas. Large adults, 12 to 18 inches long, schooled in groups of 25 to 50 along the turbulent front face of the island. Although the population varied somewhat, we seldom counted more than 250 individuals on any one dive, with an overall average of 140.

Rubberlip perch and black perch were the two next-most-common embiotocids at the island with maximum tallies of 400 and averages of 160 and 120 respectively. Once, when the water was extremely murky, neither species was recorded.

Rubberlip perch were from 3 to 16 inches long with an average of 9. Small ones were often by themselves while the adults formed loose schools of 25 to 50 individuals. The adults sometimes mixed with pile perch but were most often among the kelp stipes and in the lower canopy associating with their own kind. They oriented themselves to the kelp stipes in such a manner that they resembled the fronds (Figure 16).

Black perch were observed in numbers as high as 400; they were 3 to 14 inches long with the average about 7½. They usually swam independently of others and only occasionally formed a loose school. We believed that mating took place during these schooling periods, having observed mating behavior during the late summer.

Black perch commonly inhabited the lower sections of the water column. Sometimes the young would group with rainbow seaperch around the kelp holdfasts.

White seaperch, as many as 3,000 strong, were seen on occasion; however, the average population at any one time was closer to 300. Large increases in their numbers took place during the late summer and early fall when young were tightly schooled, particularly in the mid-waters and kelp canopy areas.

The white seaperch at the island ranged from 2 to 12 inches, with 6 being an average length.

Two- to 4-inch young were observed throughout the year, but were vastly more abundant during the spring and early summer. White seaperch were forage for sand bass and several kinds of rockfish. In other areas, an increase of white perch usually coincided with an increase of more-desirable game fishes.

Rainbow seaperch as long as 12 inches were seen but the smallest was only 2 inches and the average 5. Large fish were present in late spring and early summer but comprised only a small portion of the perch population.

Two other perches seen around the island, shiner perch and kelp perch, formed large schools throughout the kelp-covered areas, usually just below the canopy. Despite their small sizes they were important as forage (Figure 47). The shiner perch were 3 to 6 inches long and the kelp perch from 2 to 6. Kelp perch were observed removing ecto-parasites (sea lice) from large kelp bass.

11.1.3. The sea basses:

The two members of the sea bass family seen at the island were kelp bass and sand bass.

Kelp bass, 1½ to 24 inches long were observed during all dives around the island, but their average length was only 9.

The two highest counts showed 1,546 and 1,750 individuals present; the average for all dives was 400 Figure 48). The highest counts were made when many young were present, particularly during February and September of 1960. Based upon the number of 1½- and 2-inch fish we observed from October 1959 through September 1960, it would seem the kelp bass had spawned continuously throughout this period, which was one of higher-than-usual water temperatures. Normally, kelp bass spawn from April through September.

The area in the lee of the island, within the shelter of the kelp forests, harbored most of these young. Here, 50 to several hundred individuals formed schools just below the canopy. Adults were more solitary and sought turbulent waters on other portions of the island. In these areas, they ranged throughout the kelp beds, sometimes wandering 20 or 30 feet away from a plant. When disturbed from one of these exposed positions, they would swim to the nearest kelp stipe, rapidly descend to the bottom where they exhibited evasive action, and swim away.

Although kelp is not essential to attract kelp bass, they will swarm to it whenever it is available.

Sand bass were observed on most of the dives in the bottom portion of the water column, closely associated with rocks and sand.

Their population was never high, probably because the poor visibility encountered near the bottom kept us from seeing a lot of the fish that were there. On the average, we saw about 90 fish per dive with a high count of 400. The ones we did see were 2 to 26 inches long, 8½ being the average. The 2- and 3-inchers were present in the winter and spring, indicating summer and fall spawning.

Large adults were encountered as far as 100 feet away from the island, but when disturbed they would swim, by a circular path, back to the island's shelter. Several that were examined had eaten embiotocid perch.

The front face of the island, from 30 feet to the bottom, was always a good spot to find large sand bass.

FIGURE 47. Kelp perch in heavy kelp around Richfield Oil Island. *Photograph by Charles H. Turner, August 1959.*

FIGURE 47. Kelp perch in heavy kelp around Richfield Oil Island. Photograph by Charles H. Turner, August 1959.

11.1.4. The damselfishes—family Pomacentridae:

Blacksmiths, while edible, are seldom taken by the fishing fraternity because their size and small mouths make them difficult to catch.

The average blacksmith tally was 600, but during each spawning season several thousand newly-hatched young would be seen. Spawning took place during the summer, and ½- to 1-inch fish were observed from July through November. These young are vividly colored, blue anteriorly and yellow posteriorly. With age, the yellow fades and is replaced by the overall adult blue.

Around the island, the blacksmiths were ½ to 12 inches long, with an average of 5 or 6.

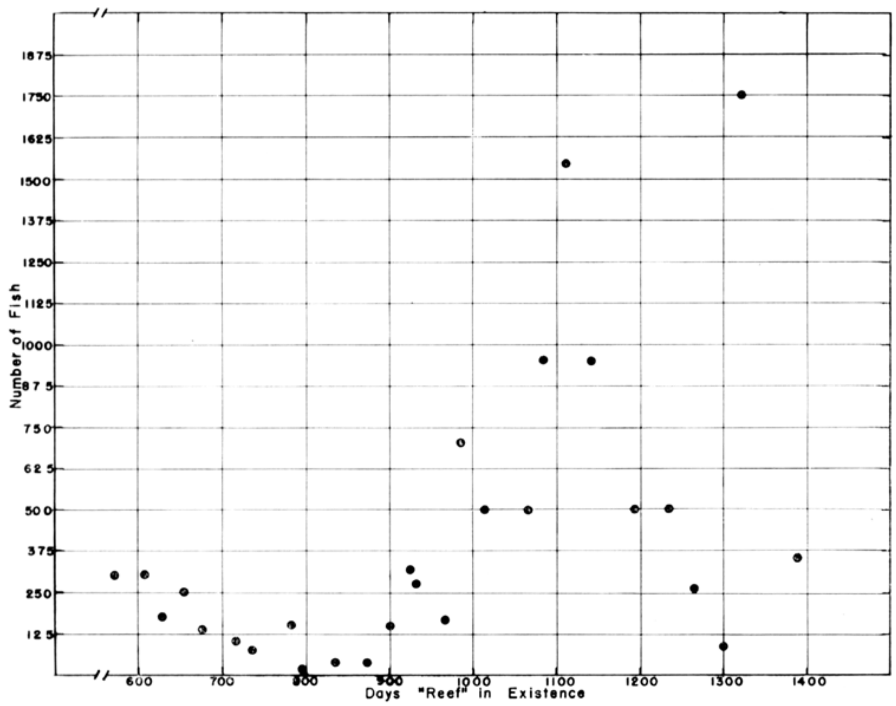

FIGURE 48. The kelp bass population increase at Richfield Oil Island with time.

FIGURE 48. The kelp bass population increase at Richfield Oil Island with time

The young schooled throughout the kelp bed, as did the adults, while fish of intermediate ages usually were more solitary and often hid in rocky crevices.

Garibaldis were observed only twice. The first, an inch long, was seen in October 1959. Although probably present, no other garibaldi was recorded until November 1960, when two were observed, each about 6 inches long.

They are a protected species and one of the more colorful of our Californian fishes. They are mentioned in this report to establish the presence of young in the Santa Barbara area.

11.1.5. The rockfishes:

At least seven species of rockfish were observed around the island. of these, blue, brown, and olive rockfish were the most common. They (the group) showed an overall increase during the study period although their numbers varied from 0 to 570, averaging 177 (Figure 49).

Brown rockfish were observed close to the rocks and in the crevices on all parts of the island. Individuals were 3 to 18 inches long, with the average about 10. Three- and 4-inchers were observed in March, September, and November.

Three adults, 343, 406 and 430 mm long, were speared and examined closely. The two largest weighed just over 1,100 grams each and one of these had the remains of a perch in its stomach.

Olive rockfish were in large numbers on all parts of the island. One-to 3-inch fish formed small schools just beneath the kelp canopy, particularly in the island's lee. The adults traveled in loose congregations

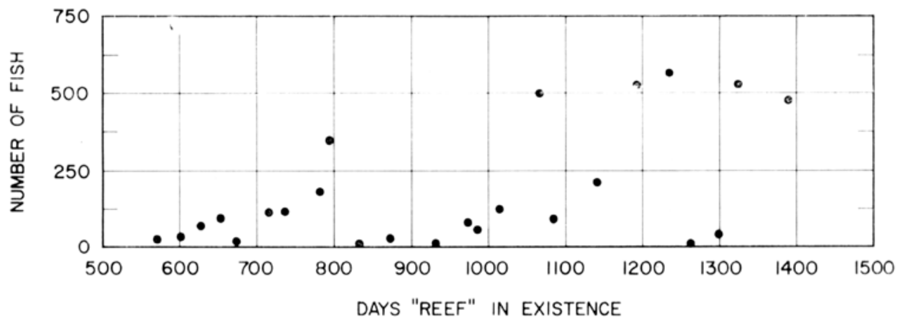

FIGURE 49. Changes in the rockfish population at Richfield Oil Island with time.

FIGURE 49. Changes in the rockfish population at Richfield Oil Island with time

throughout the water column. The largest ones were about 12 inches long, but the average olive rockfish was 8. A 9-inch adult weighed just over 4 ounces.

Several hundred 1½-inch fish were observed in May and June of 1960 and 2- to 3-inchers were present until November, indicating a late winter or early spring spawning.

Blue rockfish were always in loose school groups in the kelp bed area on the island's seaward edge. Most were small, averaging only 5 inches, although they ranged from 1 to 9. The young were present from October through February.

Bocaccios, 4 to 6 inches long, were seen hiding in rocky crevices 20 to 30 feet beneath the surface on the island's lee side in October 1959. After that, none was observed for several months but in May 1960, they were back again in the same holes between the rocks. These bocaccio were 1½ to 12 inches long. They did not mix with other species or form schools, but remained close to their shelters, darting into them if disturbed (Figure 50). This was contradictory to the schooling behavior observed on the Standard-Humble Oil platforms, but similar to what we observed at our Paradise Cove reef.

11.1.6. The halfmoon—family Scorpidae:

Halfmoons schooled in loose aggregations throughout the kelp bed area, particularly on the seaward side of the island where they formed a modest portion of the total fish population. They are not often sought as game fish but they are excellent eating and their popularity increases every year among the State's sportfishermen. Since their diet consists of algae, bryozoans, and sponges they can be caught by using green algae for bait.

Their total contribution to the population was quite constant, averaging 175 individuals, but ranging as high as 400 (Figure 51).

11.2. The Invertebrate Fauna

A typical cross-section of the water column, on the lee side of the island, illustrates the zonation of plants and invertebrates (Appendix H). These data were obtained by sampling a 1 square-foot area at each 10-foot depth interval and by making numerous diving observations.

Only major groups have been listed along with their approximate numbers per unit of area. Slight differences were noted in the total numbers and species involved at various points on the island but the

FIGURE 50. Bocaccio, a sought after commercial species, in their natural habitat at Richfield Oil Island. *Photograph by Charles H. Turner, May 1960.*

FIGURE 50. Bocaccio, a sought after commercial species, in their natural habitat at Richfield Oil Island. Photograph by Charles H. Turner, May 1960

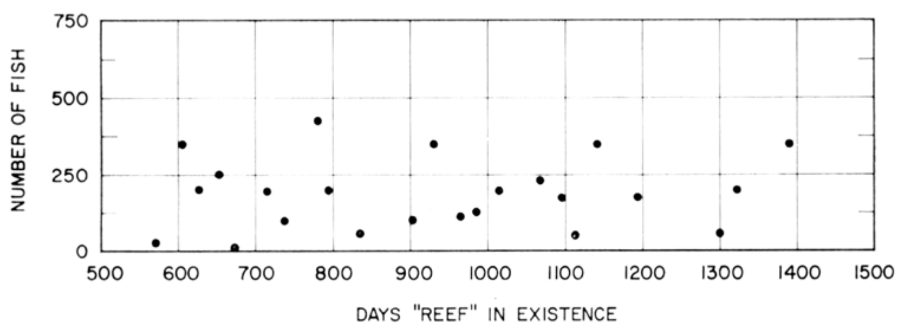

FIGURE 51. Changes in the halfmoon population at Richfield Oil Island with time.

FIGURE 51. Changes in the halfmoon population at Richfield Oil Island with time

data are insufficient to compare one area with another. This cross-sectional study was conducted on the lee side of the island because of better water clarity, reduced surge, and ease of access.

A listing of the invertebrates observed at the island follows.

11.2.1. *The sponges:*

Eleven of the numerous sponges observed on various portions of the island have been identified. These animal colonies varied in shape and size from the tiny anastomosing tubes of the urn sponge, Rhabdodermella nuttingi, to the dried-up-orange appearance of the orange puffball sponge, Tethya aurantia. The identified sponges included: thistle sponge, Leuconia heathi; urn sponge; a tube sponge, Leucosolenia sp.; orange puff-ball sponge; liver sponge, Spheciospongia confoederata; a lavender encrusting sponge, Haliclona ecbasis; leaf sponge, Hymeniacidon sinapium; geode sponge, Geodia mesotriaena; sulphur sponge, Verongia thiona; a lavender sponge, Halichoclona gellindra; and a cream sponge, Leucetta sp. Sponge colonies, and the amphipods and other organisms they shelter, serve as fish food.

11.2.2. *The hydroids, gorgonians, sea pens, sea anemones and stony corals:*

Ostrich plume hydroids, Aglaophenia sp., formed feathery colonies on the bases of rocks, on tunicates, Styela montereyensis, on moss-covered crabs, Loxorhynchus crispatus, and nearly anything else that offered attachment space. They grew at depths of 10 to 40 feet.

Encrusting hydrozoans, Campanularia spp., could be found at all times on the rocks, barnacles, and other solid materials around the island.

Rust gorgonians, Muricea fruticosa, California gorgonians, M. californica, and pink gorgonians, Lophogorgia chilensis were attached to the rocks at all depths. In the shallower waters, the two Muricea were dominant; Lophogorgia came into prominence below 25 feet. M. californica, similar in shape and size to M. fruticosa but with white instead of rust-colored polyps, was relatively rare; only a few dozen colonies were observed.

Moss-covered crabs used Lophogorgia as part of their decoration. Pink gorgonians (July 1959) were the first of these animals observed on the island; California and rust gorgonians were not seen until August 1960. By December 1960, the colonies were many-branched and over 12 inches tall. Branching occurred so that the polyps were at right angles to the water current. Gorgonians that branched randomly and appeared somewhat spherical grew in areas of changing currents with eddies or swirls.

A purple sea fan, Eugorgia rubens, was growing 20 feet beneath the surface—unusual for this species which normally lives at depths greater than 50 feet.

Sea pens, Stylatula elongata, were not living on the island proper but were growing in the sand and mud adjacent to the island.

Green anemones, Anthopleura elegantissima, were everywhere on the rocks between the surface and 20 feet down.

Colonial anemones, Corynactis sp., were late-comers to the island but by the end of the observational period they were common in depths of 10 to 30 feet. Their colonies were small, containing only a dozen or so individuals.

Prolific anemones, Epiactis prolifera, were living 15 to 25 feet beneath the surface.

Solitary tube anemones, Ceriantheopsis sp. and Pachycerianthus sp., lived buried up to their oral discs among the rocks and sand near the island's base. When disturbed, they rapidly retracted the long graceful tentacles surrounding the oral opening by drawing into their tubes. They come in a variety of colors and shapes and, while more kinds may be present, only the two genera were identified.

Stony corals had established several small basal patches at various points on the island. These patches were 5 to 10 cm across and contained 14 to 70 or more calices; the largest calyx had a columella only 2 or 3 cm long. The colonies were on the rocks 15 to 35 feet down; one colony was slightly sheltered by an overhanging rock.

11.2.3. *The free-living flatworms, Turbellaria:*

Free-living flatworms of several species were commonly observed. One inhabited empty barnacle shells.

11.2.4. *The ribbonworms, Nemertea:*

Numerous small ribbonworms were observed but not identified.

11.2.5. *The segmented worms:*

This large group of worms was well-represented at the island but only a few have been identified.

Parchment tube worms, Chaetopterus variopedatus, were very common under rocks and on the sides of materials from 20 feet beneath the surface to the bottom.

Feather-duster tube worms, Eudistylia polymorpha, were on all solid subtrate; both buff and purple-colored ones were equally represented.

Spirorbis sp. formed encrusting masses on the rocks and on kelp fronds.

Colonial tube worms, Salmacina tribranchiata, were growing in large masses on all parts of the island.

Two other segmented worms, Serpula vermicularis and Eunereis longipes, were identified among the various kinds living on the island.

11.2.6. *The moss animals:*

Several bryozoans were identified and, while numerous others probably existed, they were not collected.

Diaperoecia californica was growing on kelp holdfasts and Bugula sp., encrusted an assortment of animals and rocks.

The shrub-like bryozoan, Thalamoporella californica, formed huge masses on all substrate between the surface and 7 or 8 feet.

Two bryozoans, Membranipora membranacea and M. tuberculata formed encrusting mats on kelp fronds.

Lace coralline bryozoa, Phidolopora pacifica, formed large, lacy masses all over the island; the dimensions of some colonies exceeded 20 by 30 cm.

Purple encrusting bryozoans, Smittina sp., were growing in small patches on rocks, shells, and other solid material.

11.2.7. *The joint-legged animals:*

Numerous copepods, isopods, and amphipods (gammarids and caprellids) were observed but not identified. Most of these are quite small and some could even be considered planktonic. A number of larger organisms were identified, however.

Barnacles of four species were common to the island. Balanus cariosus ranged from the intertidal area to 30 feet; B. crenatus lived intertidally and to depths of 15 feet; B. glandula was occasionally observed intertidally; and B. tintinnabulum was extremely abundant at all depths below 5 feet.

Pistol shrimps, Crangon dentipes, were numerous in cobble areas where they hid under the smaller rocks.

Red rock-shrimps, Hippolysmata californica, are common in southern California where they have been observed removing ectoparasites from morays, Gymnothorax mordax, garibaldis, and lobsters. They make excellent fish bait and were present in quantity around the island.

Pandalus gurneyi, a retiring shrimp, lived in rock crevices on the north side at 15-foot depths.

A female bent-back shrimp, Spirontocaris brevirostris, carrying eggs was collected under a rock in a cobble area. This species is not supposed to be found south of San Francisco Bay.

Rock crabs, Cancer antennarius, yellow crabs, C. anthonyi, and red crabs, C. productus, were frequently observed in the sandy patches around the base of the island.

Moss-covered crabs, Loxorhynchus crispatus, used pink gorgonians and ostrich-plume hydroids for camouflage. They were commonly seen at all depths around the island.

Sheepcrabs, Loxorhynchus grandis, were not as abundant as mosscovered crabs but they were observed throughout the year.

Striped shore-crabs, Pachygrapsus crassipes, scurried about the intertidal area, usually out of water. They hid under ledges when approached.

Kelp crabs, Pugettia producta, were found clinging to the kelp holdfasts and in the canopy. They were abundant in the shallower water wherever giant kelp was growing. Where the kelp beds thinned out, so did these crabs.

Masking crabs, Scyra acutifrons, were abundant and used much the same materials for concealment as did moss-covered crabs.

Hermit crabs, Paguristes turgidus, were only one of several species living in dead shells.

Spiny lobsters, Panulirus interruptus, were seen only in the shallow waters, between 5 and 20 feet. There were never any large concentrations although commercial traps were observed each season. One large lobster had a 16 mm long sea urchin spine in the flesh of its tail. The external portion of the spine had worn off and the part inside the lobster's tail was encased in a heavy layer of flesh. The spine had entered at a flexture joint, not through the heavy shell.

11.2.8. *The scallops, mussels, clams, and snails:*

Several octopi were observed hiding in rocky crevices around the island, but only one, Octopus bimaculatus, was identified.

Abalone jingles, Pododesmus cepio, were attached to the sides and undersides of base rocks, where they attained a diameter of 2 and 3 inches.

California sea mussels, Mytilus californianus, were occasionally observed in the masses of bay mussels at depths to 30 feet. The heaviest mussel concentrations were between 7 and 20 feet down.

Rock scallops, Hinnites multirugosus, 4 to 5 inches across, were on all sections of the island, particularly in crevices where water currents swept through. They grew an estimated 1 to 1 ½ inches per year after first being observed in August 1959.

Kelp scallops, Chlamys latiaurata, settled in quantity in August 1959. Although there was a large die-off by October 1959 they still were abundant enough to sink the kelp stipes. By January 1960, the kelp scallops had disappeared and were not observed in any quantity after that.

Agate chamas, Chama pellucida, were prevalent on all solid substrate.

Reversed chamas, Pseudochama exogyra, were abundant on the sides of the base rock with Chama.

Sunset clams, Gari californica, were living in the broken cobble area between the large boulders.

Nestling clams, Kellia laperousii, were common among the mussels and other shell masses.

Rough nestlers, Hiatella arctica, were found in sponge masses, mussel clumps, and numerous other areas. Their shells were often disfigured if they were nestling in solid unyielding matter such as clumps of mussels.

File shells, Lima hemphilli, were attached in the kelp holdfasts and under small rocks and boulders where they nestled with the tube worm Chaetopterus.

Boring mollusks such as date mussels, Lithophaga sp.; wart-necked piddocks, Chaceia ovoidea; beaked piddocks, Nettastomella rostrata; and flap-tipped piddocks, Penitella penita, were found in the island base rock. Some of these animals had attained lengths of several inches.

Rough keyhole limpets, Diodora aspera, were living on the rocks from 5 to 25 feet deep throughout the area. Only a few hundred individuals were seen during our investigation.

Rough limpets, Acmaea scabra, were also found around the island.

Channeled top-snails, Calliostoma doliarium were living in or on the colonial tunicates and sponge masses, as was Calliostoma supragranosum, the granulose top-snail.

Gilded tegulas, Tegula aureotincta, were dominant on the north side of the island 10 to 30 feet beneath the surface, usually in areas of small rocks. These had higher spires than was previously recorded for the species.

Many wavy top-snails, Astraea undosa, were all over the island, often on rocks heavily encrusted with low-growing algae.

Scaled worm-gastropods, Serpulorbis squamigervs, were first observed on our initial dive. They were attached to rocks all the way from near the surface to the bottom. At the end of the observational period they were one of the commoner animals; some had extended their tubes 3 or 4 inches straight up to get above the mud sediment.

Eroded periwinkles, Littorina planaxis and checkered periwinkles, Littorina scutulata, were living in the splash zone between the surface and some 5 feet above the water. They were on most solid, exposed surfaces in the lee of the island.

Slipper limpets, Crepidula sp., were attached to rocks and shells in large numbers.

California cones, Conus californicus, were not common in this area but a few were observed.

Chestnut cowries, Cypraea spadicea, were observed on a few occasions as were amphissas, Amphissa sp.

Keeled dove-snails, Mitrella carinata, were very common on all rocks, plants, and shells; a scraping from any area would produce a dozen or more.

Poulson's dwarf tritons, Ocenebra poulsoni, were very common 15 to 30 feet beneath the surface. They were breeding in July and August and many would deposit their eggs in a single large mass at the edge of a cobble area.

Spotted thorn drupes, Acanthina spirata, were not common but a few were found in rock crevices 25 to 35 feet down.

Festive murexes, Jaton festivus, were very common in the rock crevices and under rocks 15 to 30 feet beneath the surface.

Three-winged murexes, Pterynotus trialatus, were observed at 20 to 30 feet. One specimen that was scarlet in the water turned pale pink when the animal died.

Smooth turbans, Norrisia norrisii, were observed only occasionally on the rocks at the bases of kelp plants at depths of 7 to 25 feet. One tiny specimen, 1 cm high, was taken in August 1961.

Louse snails, Neosimnia spp., were living on the gorgonians. Brown ones were on the rust gorgonians and pink ones on pink gorgonians.

Numerous tectibranchs and nudibranchs (sea slugs) added their brilliant colors to the undersea vistas. Many graze on hydrozoans but apparently are not a direct part of the fish food-chain. Their importance may be in replacing certain minerals back into solution after their death. Ten of the dozen or more species observed on the island were identified. These were Aplysia californica, Aplysia vaccaria, Archidoris montereyensis, Dendrodoris fulva, Diaulula sandiegensis, Glossodoris californiensis, Laila cockerelli, Triopha maculata, Flabellina iodinea, and Hermissenda crassicornis.

11.2.9. *The starfishes, sea urchins and sea cucumbers:*

Five starfishes collected on or around the island were Astropecten armatus, Patiria miniata, Pisaster giganteus, Pisaster ochraceus, and Pisaster brevispinus.

In addition to these "typical" starfishes, brittle stars or serpent stars were very common in the kelp holdfasts and in the cobble areas. None of these was indentified, however.

Purple sea urchins and red urchins were both present in a variety of shades. A few were observed in November 1958 but it was not until after August 1959 that they spread over the entire island. By February 1960, they had grazed large holes in the kelp haptera and the beds were diminishing.

Some species of sea cucumbers were very common but others were rarely seen. Four kinds were identified: Parastichopus parvimensis, Parastichopus californicus, Eupentacta quinquesemita and Cucumaria sp.

11.2.10. *The sea squirts:*

Four kinds of tunicates or sea squirts were identified. Styela montereyensis was attached to all the rocks and to numerous encrusting animals at all depths. They were even used by masking crabs as part of their festive coats.

Three or four Boltenia villosa were seen per square yard of attachment area at depths of 20 to 30 feet and a square-topped ascidian Chelyosoma productum formed large masses on the rocks between 25 feet and the bottom.

The large orange colonial tunicate, Cystodytes lobatus, was observed covering extensive areas on the south and east sides of the island. Several snails made their homes in colonies of these animals.

11.3. The Flora

Numerous red, green and brown algae were observed. The most obvious and easily recognized were the beds of giant kelp which formed moderate to heavy canopies and exhibited considerable fluctuations in density. Although there was suitable substrate for their attachment in water 40 feet deep, they were not often found at depths greater than 30. The heaviest beds were in water 20 feet deep or shallower. Turbidity and silting were undoubtedly important factors limiting their distribution.

At the first diving check in August 1958, a moderate kelp bed was present and plants were growing in 30 feet of water. By November 1959, small plants were seen on the lower rocks on the seaward side of the island and many 1- to 6-inch plants were noted in the following weeks.

The condition of this kelp bed apparently was directly related to water temperature and surge, for, within a few months, the small deep-water plants had been covered by bottom sediments and perished while the surface canopy of shallower plants suffered during heavy surge. By January 1960, kelp was growing again at 40 feet and many ¾- to 1½-inch plants were observed through June and July 1960. By July, the heavy canopy, lost during a January storm, had returned. During September 1960, heavy grazing by urchins caused a decline that lasted through November when the beds again became healthy and lush.

Several kelp plants were tagged in November 1959 and their growth was measured until July 1960. Our data are few but help to illustrate the rapid recovery that is possible for a kelp bed under favorable conditions. Growth was extremely rapid and the plants doubled in length in 17 days. The maximum daily growth, 2.86 inches, was recorded during November and December 1959.

Nine other conspicuous or easily recognized algae that were growing on and around the island were: Gigartina sp., Ulva sp., Egregia laevigata, Rhodymenia pacifica, Corallina sp., Desmarestia herbacea, Halidrys dioica, and Cystoseira osmundacea.

12. MONTEREY OIL PLATFORM, SEAL BEACH

This platform is in 55 feet of water about 3 miles southwest of Seal Beach, Orange County. It is composed of a circular, central structure protected by quarry rock on all sides. A landing stage and work area are supported by this central column and numerous pilings. On the seaward edge is an overhanging "balcony," supported by four steel girders. The surrounding bottom is gray sand.

During three diving surveys (May 1958, October 1958, and July 1959), between 1,300 and 3,000 fishes, representing 32 species belonging to 28 genera and 16 families were observed (Appendix A). Only pelagic species were seen at distances greater than 60 feet from the shelter of the platform. A well-established invertebrate fauna, characteristic of this geographic area, was also noted.

The major concentration of fishes was not over the rocky areas as might be expected, but under the "balcony." They seldom strayed outside the area bounded by the four girders; apparently this balcony-like portion supplied shade and gave the fishes a sense of security similar to what they find under a kelp canopy.

13. TEXACO OIL PLATFORM, GAVIOTA

This installation was visited roughly 3 months after its completion. It stands in 98 feet of water, on a coarse sand bottom, 4 miles west of Gaviota.

In all, 12 species representing 8 genera and 6 families were recorded. Approximately 94 percent of the 5,790 semi-resident fishes were rockfish. Most of the fishes were at depths of 80 to 90 feet. Schools of jack mackerel and Pacific sardines swam in the shallower waters.

Encrusting growth was sparse and included only barnacles (two species), kelp scallops, bryozoans, hydroids, and several species of algae. A few young giant kelp plants were attached to the tower legs in shallow water.

14. SUMMARY

Coastal fishing in southern California has assumed added importance with a great population increase and the consequent greater need for recreation. Kelp beds have decreased due to pollution, above-average water temperatures, and foraging sea urchins.

Artificial reefs are designed to improve sportfishing in coastal waters, near harbors. Thigmotropism, schooling behavior, shelter, and food are important factors in the success of reefs, artificial or otherwise.

Biologist-divers carried out an intensive study of the effects of artificial habitat in California ocean waters between May 1958 and December 1960. Reef sites were carefully selected in barren areas, and underwater surveys conducted before reefs were installed. Trawl surveys provided data on fish populations before reefs were installed.

An experimental car body reef was installed at Paradise Cove in May 1958. It was studied during 29 diving observations by two- and three-man teams. Forty-nine species of fish were observed on the reef. The fish population built up to a peak of 24,000 semi-residents, with an average of about 11,000. Species of greatest interest to sportfishermen on the reef were sand bass, kelp bass, sheephead, opaleye, cabezon and sculpin. A naturally seeded giant kelp bed became established a few months after the reef was placed and a little over a year later there was a considerable canopy with plants 70 to 75 feet long. On October 12, 1961 only low rubble remained of the reef, the kelp holdfasts were still intact on the rubble, but the fronds were heavily grazed, with the stipes almost bare. Most of the usual species of fish were present but in greatly reduced numbers.

A streetcar reef was installed off Redondo Beach in September 1958 and 47 fish species were observed there during our subsequent study which included about 42 hours of diving. Almost 3,000 semi-resident fishes were observed during one dive.

Juvenile kelp bass were present on the reef in November 1958. During the following 2 years, several species, including sand bass, black-smith, white seaperch, rubberlip perch, pile perch, bluespot gobies, and bluebanded gobies spawned on the reef. Sportfish which were an important part of the reef fish population were sand bass and kelp bass, which at times made up 72 percent of the population, and sheephead. On September 28, 1961 the last diving observation showed only one streetcar with the framework intact. The remaining five were reduced to wreckage, with only the floor areas somewhat intact. The fish population present then consisted of 1,500 semi-residents belonging to 9 species. Excellent fishing, especially for sand bass, existed after 4½ years.

In August 1960, three replication reefs were placed several miles apart in Santa Monica Bay. Each was composed of car bodies, a streetcar, quarry rock, and concrete shelters. According to our present knowledge, we believe quarry rock is the best material for constructing artificial reefs. Car bodies, although providing reefs with a high attraction potential for fish, and streetcars, somewhat less so, are limited to a life of only about 3 or 4 years.

Since large fishes appear first, an artificial reef probably acts first as a collecting station. With age it approaches a natural situation and plant and animal populations exhibit fluctuations similar to any reef eco-system.

Four offshore oil drilling installations near Santa Barbara and one near Seal Beach were visited between May 1958 and December 1960. A total of 246 man-hours was spent underwater around these rigs in 62 days of diving. The Monterey oil platform, Texaco tower and Standard-Humble tower Hilda accounted for only 9 of these 62 days. The routine monthly surveys of the Standard-Humble tower Hazel and Richfield's Rincon oil island required 27 days and 26 days respectively.

These drilling sites exhibited similar attractions for fishes. Their respective populations grew from a few scattered fishes to several thousand semi-residents. The deeper water towers attracted pelagic schooling fishes and several species of rockfish that were not associated with the inshore areas. Typical of inshore areas were kelpfishes, croakers, and small sharks. In both areas embiotocid perch were the dominant fishes.

The fish populations increased rapidly for the first year and then exhibited fluctuations apparently correlated to temperature, season, or other natural factors.

Encrusting organisms rapidly covered all exposed underwater areas and by December 1960 attachment space was at a premium. These organisms either fed the fishes or sheltered forms that did.

With regard to the two questions this investigation set out to answer, we can state that (i) the changes in habitat brought about by establishing offshore oil-drilling installations were generally beneficial to the flora and fauna, and (ii) depositing washed drill cuttings on the bottom at these sites was neither deleterious nor beneficial to the marine life in the area.

We do feel that if these cuttings were dumped several hundred feet away and capped with stones or other rubble to make suitable habitat, the result would be to establish a spot where anglers could fish without danger from falling objects or being in the way of vessels servicing the rigs.

Eighty-six species of fish were observed on all installations, as well as 142 kinds of invertebrates and 14 species of plants during 132 dives.

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APPENDIX A

Fish Occurrences Observed During 132 Dives on Various Artificial Reefs and Oil Installations, May 1958 through December 1960

	Diving sites and number of observations					
	Paradise Cove car body reef	Redondo Beach streetcar reef	Standard-Humble "Hazel"	Standard-Humble "Hilda"	Richfield Oil Island Rincon	Monterey Oil Platform Seal Beach
Common name	29	42	27	5	26	3
Anchovy, northern*	1	1	--	1	1	--
Barracuda, California*	--	--	--	–	1	--
Bass, kelp	26	42	26	4	26	3
Bass, sand	23	42	23	1	22	3
Bass, giant sea	--	2	--	--	--	--
Blacksmith	2	31	14	--	15	2
Blenny, rockpool	--	--	1	--	2	--
Bonito, Pacific*	1	3	4	1	--	--
Cabezon	20	13	17	2	13	2
Croaker, black	--	3	--	--	2	1
Croaker, spotfin	--	1	--	--	--	1
Croaker, white	--	--	--	--	--	1
Croaker, yellowfin	--	1	--	--	--	1
Electric ray, Pacific	1	--	--	--	--	--
Fringehead, sarcastic	--	1	--	--	--	--
Garibaldi	--	--	--	--	2	3
Goby, bluebanded	2	24	--	--	11	--
Goby, bluespot	21	38	3	--	5	3
Greenling, kelp	--	--	1	--	--	--
Greenling, painted	3	5	2	1	1	3
Guitarfish, shovelnose	--	1	--	--	--	--
Halfmoon	18	34	24	5	24	3
Halibut, California	6	2	1	--	1	--
Jacksmelt	--	--	8	3	10	--
Kelpfish, giant	12	--	--	--	15	--
Kelpfish, striped	--	--	--	--	2	1
Kelpfish (unident.)	--	1	1	1	2	--
Lingcod	--	1	13	--	4	2
Mackerel, jack*	14	1	20	5	5	1
Mackerel, Pacific*	1	--	5	--	--	--
Opaleye	7	37	1	--	15	2
Perch, barred surf	11	1	3	--	7	--
Perch, black	29	34	23	4	25	2
Perch, calico surf	2	--	--	--	1	--
Perch, kelp	14	--	--	--	19	--
Perch, pile	28	35	23	5	26	3
Perch, rainbow sea	22	2	18	1	21	1
Perch, rubberlip	26	34	22	4	25	3
Perch, shiner	15	1	25	3	15	1
Perch, silver surf	--	--	1	--	--	--
Perch, striped sea	--	--	--	--	1	--
Perch, walleye surf	7	2	2	--	2	--
Perch, white sea	29	33	21	5	22	2
Pipefish, kelp	1	--	1	1	1	--
Pipefish (unident.)	--	--	1	--	--	--

APPENDIX A
Fish Occurrences Observed During 132 Dives on Various Artificial Reefs and Oil Installations, May 1958 through December 1960

APPENDIX A—Continued

Fish Occurrences Observed During 132 Dives on Various Artificial Reefs and Oil Installations, May 1958 through December 1960

	Diving sites and number of observations					
	Paradise Cove car body reef	Redondo Beach streetcar reef	Standard-Humble "Hazel"	Standard-Humble "Hilda"	Richfield Oil Island Rincon	Monterey Oil Platform Seal Beach
Common name	29	42	27	5	26	3
Queenfish	--	--	4	--	--	1
Rockfish, black-and-yellow	4	--	--	--	--	--
Rockfish, blue	3	--	3	1	16	--
Rockfish, bocaccio	12	--	22	5	6	--
Rockfish, brown	18	2	21	5	18	--
Rockfish, calico	--	--	--	--	--	1
Rockfish, flag	--	--	1	--	--	--
Rockfish, grass	17	--	14	3	9	--
Rockfish, greenstriped	8	--	8	1	7	--
Rockfish, kelp	2	--	1	--	--	--
Rockfish, olive	17	--	20	5	18	1
Rockfish, treefish	1	--	--	--	--	--
Rockfish, vermilion	--	--	--	5	--	--
Rockfish, whitebelly	3	1	21	5	--	--
Rockfish (unident.)	--	--	2	--	2	1
Ronquil, smooth	--	4	--	--	--	--
Sanddab, Pacific	4	2	1	1	--	--
Sardine, Pacific*	2	--	10	3	1	--
Sargo	11	8	8	--	8	2
Sculpin (rockfish)	14	17	13	1	6	3
Sculpin, mosshead	--	--	--	--	2	--
Sculpin, smoothhead	--	--	--	--	1	--
Sculpin (unident.)	2	1	1	1	3	--
Seabass, white*	--	--	--	--	1	2
Senorita	26	1	--	--	10	3
Shark, blue*	--	--	--	1	--	--
Shark, horn	--	--	--	--	1	--
Shark, Pacific angel	--	1	--	--	--	--
Shark, swell	--	--	--	--	1	--
Sheephead, California	27	36	1	--	3	1
Snailfish (unident.)	--	--	--	1	--	--
Sole, fantail	2	7	--	--	--	--
Thornback	--	1	--	--	--	--
Topsmelt	--	--	14	2	19	1
Turbot, C-O	3	17	--	--	--	--
Turbot, curlfin	--	1	--	--	--	--
Turbot, diamond	2	6	--	--	--	--
Turbot, hornyhead	1	--	--	--	--	--
Whitefish, ocean	--	16	--	--	--	--
Wrasse, rock	2	1	--	--	1	--
Yellowtail, California*	--	3	1	---	--	--

* Indicates pelagic species—all others considered semi-reisdent.

APPENDIX A
Fish Occurrences Observed During 132 Dives on Various Artificial Reefs and Oil Installations, May 1958 through December 1960

APPENDIX B

Common and Scientific Names of Invertebrates Observed on Artificial Reefs and Offshore Oil Installations May 1958 through December 1960

Scientific name	Common name	Paradise Cove car body reef	Redondo Beach streetcar reef	Standard-Humble "Hazel"	Standard-Humble "Hilda"	Richfield Oil Island Rincon
Porifera						
Geodia mesotriaena Lendenfeld	Geode sponge	--	--	--	--	x
Halichoclona gellindra de Laubenfels	Lavender sponge	--	--	--	--	x
Haliclona ecbasis de Laubenfels	Lavender-blue encrusting sponge	--	--	--	--	x
Hymeniacidon sinapium de Laubenfels	Leaf sponge	--	--	--	--	x
Hymeniacidon sp.	Little leaf sponge	--	--	x	--	--
Leucetta losangelensis (de Laubenfels)	White sponge	--	x	x	x	--
Leucetta sp.	Cream sponge	--	--	--	--	x
Leuconia heathi (Urban)	Thistle sponge	--	--	--	--	x
Leucosolenia sp.	Finger sponge	--	--	x	x	x
Rhabdodermella nuttingi Urban	Urn sponge	--	--	--	--	x
Spheciospongia confoederata de Laubenfels	Liver sponge	--	--	--	--	x
Tethya aurantia (Pallas)	Orange puff-ball sponge	--	--	--	--	x
Verongia thiona de Laubenfels	Sulphur sponge	--	--	--	--	x
Coelenterata						
Aglaophenia sp.	Ostrich plume hydrozoan	--	--	--	--	x
Anthopleura elegantissima (Brandt)	Green anemone	--	--	x	x	x
Campanularia sp.	Campanulate hydrozoan	--	--	x	x	x
Ceriantheopsis sp.	Tube anemone	--	--	--	--	x
Corynactis sp.	Colonial anemone	--	x	x	x	x
Epiactis prolifera Verrill	Prolific anemone	--	--	--	--	x
Eugorgia rubens Verrill	Purple sea fan	--	--	--	--	x
Lophogorgia chilensis Verrill	Pink gorgonian	x	x	--	--	x
Metridium senile (Linnaeus)	Plumose anemone	--	--	x	x	--
Muricea californica Aurivillius	California gorgonian	--	--	--	--	x
Muricea fruticosa Verrill	Rust gorgonian	x	x	--	--	x
Pachycerianthus sp.	Tube anemone	--	x	--	--	x
Paracyathus sp.	Stony coral	--	--	--	--	x
Renilla kollikeri Pfeffer	Sea pansy	--	x	--	--	--
Stylatula elongata (Gabb)	Elongate sea pen	x	x	--	--	x
Platyhelminthes	Flatworms	--	--	--	--	x
Nemertea	Ribbon worms	--	--	--	--	x
Annelida						
Chaetopterus variopedatus (Renier)	Parchment tube worm	--	--	--	--	x
Chaetopterus sp.	Parchment tube worm	--	x	--	--	--
Eudistylia polymorpha (Johnson)	Feather-duster worm	--	x	x	x	x
Eunereis longipes Hartman	Nereid worm	--	--	x	x	x
Halosydna brevisetosa Kinberg	Scale worm	--	--	x	x	--
Nereis eakini Hartman	Nereid worm	--	--	x	x	--
Nereis mediator Chamberlin	Nereid worm	--	--	x	x	--
Paleanotus bellis (Johnson)	Chrysopetalid worm	--	--	x	x	--
Salmacina tribranchiata (Moore)	Colonial tube worm	x	x	x	x	x
Serpula vermicularis Linnaeus	Serpulid worm	--	--	--	--	x
Spirorbis sp.	Serpulid worm	x	x	x	x	x
Arthropoda						
Balanus cariosus (Pallas)	Acorn barnacle	--	--	x	x	x
Balanus crenatus Bruguiere	Acorn barnacle	--	--	--	--	x
Balanus glandula Darwin	Acorn barnacle	--	--	--	--	x
Balanus tintinnabulum (Linnaeus)	Acorn barnacle	--	x	x	x	x
Cancer antennarius Stimpson	Rock crab	x	--	x	x	x
Cancer anthonyi Rathbun	Yellow crab	x	x	x	x	x

APPENDIX B
Common and Scientific Names of Invertebrates Observed on Artificial Reefs and offshore Oil Installations May 1958 through December 1960

APPENDIX B—Continued

Common and Scientific Names of Invertebrates Observed on Artificial Reefs and Offshore Oil Installations May 1958 through December 1960

Scientific name	Common name	Paradise Cove car body reef	Redondo Beach streetcar reef	Standard-Humble "Hazel"	Standard-Humble "Hilda"	Richfield Oil Island Rincon
Arthropoda—Continued						
Cancer productus Randall	Red crab	--	--	--	--	x
Crangon dentipes Guerin	Pistol shrimp	--	--	--	--	x
Hippolysmata californica Stimpson	Red rock shrimp	--	x	--	--	x
Loxorhynchus crispatus Stimpson	Moss-covered crab	--	--	--	--	x
Loxorhynchus grandis Stimpson	Sheep crab	--	--	--	--	x
Loxorhynchus sp.	Spider crab	x	x	x	x	--
Pachygrapsus crassipes Randall	Striped shore crab	--	--	--	--	x
Paguristes turgidus (Stimpson)	Hermit crab	--	--	--	--	x
Pandalus gurneyi Stimpson	Shrimp	--	--	--	--	x
Panulirus interruptus (Randall)	Spiny lobster	x	x	x	--	x
Pugettia producta (Randall)	Kelp crab	--	--	x	x	x
Scyra acutifrons Dana	Masking crab	--	--	--	--	x
Spirontocaris brevirostris (Dana)	Bent-back shrimp	--	--	--	--	x
Mollusca						
Acanthina spirata (Blainville)	Spotted thorn drupe	--	--	--	--	x
Acmaea scabra (Gould)	Rough limpet	--	--	--	--	x
Amphissa sp.	Amphissa	--	--	--	--	x
Aplysia californica Cooper	Sea hare	--	--	--	--	x
Aplysia vaccaria Winkler	Sea hare	--	--	--	--	x
Archidoris montereyensis (Cooper)	Light yellow sea slug	--	--	--	--	x
Armina californica Cooper	Pansy sea slug	--	x	--	--	--
Astraea undosa Wood	Wavy turban snail	--	--	--	--	x
Bankia setacea (Tryon)	Ship worm	--	x	--	--	--
Cadlina marginata MacFarland	Yellow-margined sea slug	--	x	--	--	--
Calliostoma doliarium Holten	Channeled top-shell	--	--	x	--	x
Calliostoma supragranosum Carpenter	Granulose top-shell	--	--	--	--	x
Chacea ovoidea (Gould)	Wart-necked piddock	--	--	--	--	x
Chama pellucida Sowerby	Agate chama	--	--	x	x	x
Chlamys latiaurata (Conrad)	Kelp scallop	x	x	x	x	x
Conus californicus Hinds	California cone	--	x	--	--	x
Crepidula sp.	Slipper limpet	--	--	--	--	x
Cypraea spadicea Gray	Chestnut cowry	--	--	--	--	x
Dendrodoris fulva (MacFarland)	Yellow sea slug	--	--	--	--	x
Dialula sandiegensis (Cooper)	Circle-spotted sea slug	--	x	--	--	x
Diodora aspera (Eschscholtz)	Rough keyhole limpet	--	--	x	x	x
Flabellina iodinea (Cooper)	Purple sea slug	--	x	--	--	x
Gari californica (Conrad)	Sunset clam	--	--	--	--	x
Glossodoris californiensis (Bergh)	Blue-orange sea slug	--	x	--	--	x
Hermissenda crassicornis (Eschscholtz)	Yellow-green sea slug	--	x	x	x	x
Hiatella arctica (Linnaeus)	Rough nestling clam	--	--	x	x	x
Hinnites multirugosus (Gale)	Purple-hinged rock scallop	--	x	x	x	x
Jaton festivus Hinds	Festive murex	--	--	--	--	x
Kelletia kelleti Forbes	Kellet's whelk	x	x	--	--	--
Kellia laperousii (Deshayes)	Nestling clam	--	--	--	--	x
Laila cockerelli MacFarland	Orange-white sea slug	--	--	--	--	x
Lima hemphilli Hertlein and Strong	File shell	--	--	--	--	x
Lithophaga sp.	Date mussel	--	--	--	--	x
Littorina planaxis Philippi	Eroded periwinkle	--	--	--	--	x
Littorina scutulata Gould	Checkered periwinkle	--	--	--	--	x
Mitra idae Melville	Ida's miter	--	x	--	--	--
Mitrella carinata (Hinds)	Keeled dove snail	--	--	--	--	x
Mytilus californianus Conrad	California sea mussel	--	--	x	x	x
Mytilus edulis Linnaeus	Bay mussel	x	x	x	x	--
Neosimnia sp.	Pink louse shell	--	x	--	--	x

APPENDIX B
Common and Scientific Names of Invertebrates Observed on Artificial Reefs and offshore Oil Installations May 1958 through December 1960

APPENDIX B—Continued

Common and Scientific Names of Invertebrates Observed on Artificial Reefs and Offshore Oil Installations May 1958 through December 1960

Scientific name	Common name	Paradise Cove car body reef	Redondo Beach streetcar reef	Standard-Humble "Hazel"	Standard-Humble "Hilda"	Richfield Oil Island Rincon
Mollusca—Continued						
Nettastomella rostrata Valenciennes	Beaked piddock	--	--	--	--	x
Norrisia norrisii Sowerby	Smooth turban	--	--	--	--	x
Ocenebra poulsoni Carpenter	Poulson's dwarf triton	--	--	--	--	x
Octopus bimaculatus Verrill	Two-spot octopus	x	x	--	--	x
Penitella penita (Conrad)	Flap-tipped piddock	--	--	--	--	x
Pododesmus cepio Gray	Abalone jingle	--	x	--	--	x
Pseudochama exogyra (Conrad)	Reversed chama	--	--	x	x	x
Pterynotus trialatus Sowerby	Three-winged murex	--	--	--	--	x
Serpulorbis squamigerus (Carpenter)	Scaled worm-snail	--	--	--	--	x
Tegula aureotincta Forbes	Gilded tegula	--	--	--	--	x
Terebra pedroana Dall	San Pedro auger	--	x	--	--	--
Teredo diegensis Bartsch	Ship worm	--	x	--	--	--
Trachycardium quadragenarium (Conrad)	Spiny cockle	x	--	--	--	--
Triopha maculata MacFarland	Yellow-brown sea slug	--	--	--	--	x
Xylophaga mexicana Dall	Ship worm	--	x	--	--	--
Bryozoa						
Bugula sp.	Moss animal	--	--	--	--	x
Diaperoecia californica (d'Orbigny)	Moss animal	--	x	--	--	x
Membranipora membranacea (Linnaeus)	Moss animal	x	x	--	--	x
Membranipora savarti (Audouin)	Moss animal	--	--	x	--	--
Membranipora tuberculata (Bosc)	Moss animal	--	--	--	--	x
Phidolopora pacifica (Robertson)	Lace moss animal	x	x	x	x	x
Smittina sp.	Moss animal	--	--	--	--	x
Thalamoporella californica (Levinson)	Moss animal	--	--	--	--	x
Echinodermata						
Astropecten armatus Gray	Common sand star	x	x	--	--	x
Cucumaria sp.	Sea cucumber	--	--	--	--	x
Dermasterias imbricata (Grube)	Leather star	--	x	--	--	--
Eupentacta quinquesemita (Selenka)	Yellow sea cucumber	--	--	--	--	x
Lovenia cordiformis Agassiz	Heart urchin	--	x	--	--	--
Lytechinus anamesus Clark	White sea urchin	--	x	--	--	--
Parastichopus californicus (Stimpson)	Red-brown sea cucumber	x	--	--	--	x
Parastichopus parvimensis (Clark)	Sea cucumber	--	--	--	--	x
Patiria miniata (Brandt)	Webbed-ray starfish	--	x	--	--	x
Pisaster brevispinus (Stimpson)	Short-spined starfish	x	x	x	--	x
Pisaster giganteus (Stimpson)	Giant starfish	x	x	x	--	x
Pisaster ochraceus Brandt	Purple starfish	--	x	x	--	x
Solaster dawsoni Verrill	Sunburst starfish	x	--	--	--	--
Strongylocentrotus franciscanus (Agassiz)	Red sea urchin	--	--	x	--	x
Strongylocentrotus purpuratus (Stimpson)	Purple sea urchin	--	--	x	x	x
Tunicata						
Boltenia villosa Stimpson	Simple sea squirt	--	--	--	--	x
Chelyosoma productum Stimpson	Simple sea squirt	--	x	--	--	x
Cystodytes lobatus (Ritter)	Compound sea squirt	--	x	--	--	x
Styela montereyensis (Dall)	Simple sea squirt	x	x	x	x	x

APPENDIX B

Common and Scientific Names of Invertebrates Observed on Artificial Reefs and offshore Oil Installations May 1958 through December 1960

APPENDIX C

Algae Observed on Artificial Reefs and offshore Oil Installations, May 1958 through December 1960

Green Algae	·
Ulva sp.	–
Brown Algae	·
Cystoseira osmundacea (Turner) C. Agardh	–
Desmarestia herbacea Lamouroux	–
Ectocarpus sp.	–
Egregia laevigata Setchell	–
Eisenia arborea Areschoug	–
Halidrys dioica Gardner	–
Laminaria farlowii Setchell	–
Macrocystis pyrifera (Linnaeus) C. Agardh	–
Pterygophora californica Ruprecht	–
Red Algae	·
Callithamnion sp.	–
Corallina sp.	–
Gigartina sp.	–
Rhodymenia pacifica Kylin	–

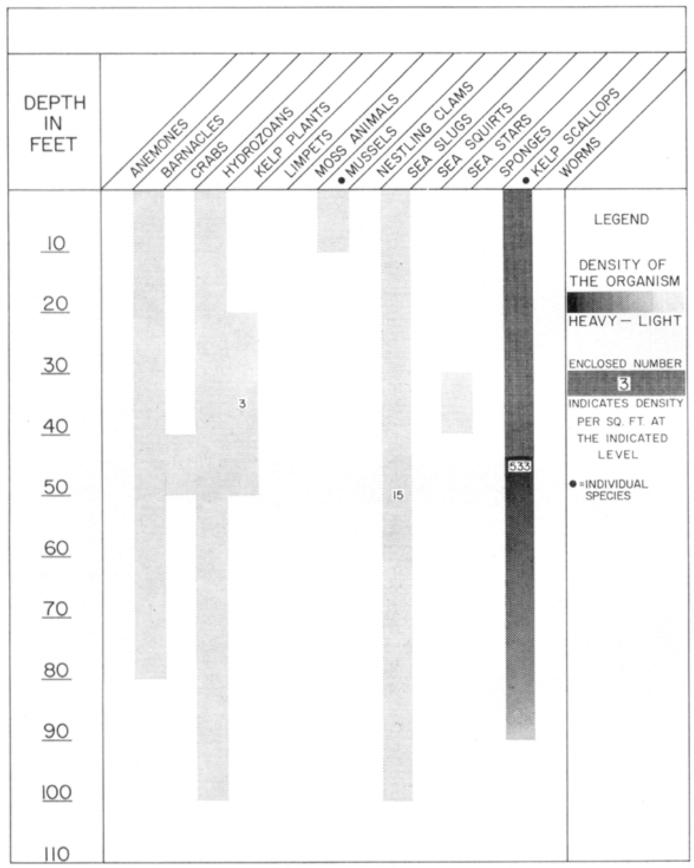
APPENDIX D

Redondo Beach Streetcar Reef—Test Block Series

Date block removed	12 June 1959	6 July 1959	6 Aug. 1959	2 Sept. 1959	2 Oct. 1959	6 Nov. 1959	8 Jan. 1960	5 Feb. 1960	28 Mar. 1960	31 May 1960	14 June 1960	12 July 1960
Days in place	37	62	93	120	150	185	245	276	327	391	435	433
Percent of block remaining	100	100	100	100	100	100	90	60	30	50	33	..
Organisms						Number per Block						
Porifera; sponges	..	n. c.*	n. c.	n. c.	n. c.	n. c.	n. c.	n. c.	n. c.	..	n. c.	..
Coelenterates; hydroids	..	..	n. c.	..	..	n. c.	n. c.	..	..	..	..	..
Platyhelminthes; flatworms	..	8	..	..	11	..	..	..	1	..	3	..
Nemerteans; unsegmented worms	..	6	..	..	3	..	..	..	8	..	8	..
Annelids; segmented worms												
Polychaete worms	..	40	37	58	..	20	14	n. c.	12	11	40	4
Sipunculids; peanut worms	..	..	3	..	..	..	..	..	..	..	1	..
Arthropods; joint-legged animals												
Copepods	..	..	..	..	..	..	..	6	6	..	..	..
Cirripedes	130	87	115	103	63	80	38	8	2	36	17	57
Isopods	2	..	..	..	..	..	..	..	..	..	..	..
Gammarids	151	350	300	61	48	35	1	60	930	640	866	950
Caprellids	..	1	1	1	2	3	1	6	28	..	..	13
Decapods	..	3	3	2	3	2	..	4	..	..	..	..
Carides	..	1	..	..	..	..	..	..	..	..	..	..
Brachyura	..	..	..	..	..	..	..	..	..	..	2	2
Pycnogonids	..	1	..	..	..	..	..	..	..	..	..	..
Mollusks												
Erycinidae	..	..	..	..	..	..	..	..	..	..	..	9
Anomiidae; rock jingles	25	15	..	12	..	14	1	10	3	6	46	14
Mytilidae; mussels	..	..	..	..	..	..	..	..	..	49	..	..
Pectinidae; scallops	3	..	..	3	..	1	..	..	53	1	5	1
Saxicavidae; nestlers	3	8	56	17	51	25	..	..	25	3	80	78
Teredinidae; ship worms	..	10	11	n. c.	42	n. c.	..	n. c.	40	n. c.	..	1
Bankia setacea	..	..	..	..	..	..	29	..	n. c.	..	20	..
Lyrodus (= Teredo) diegensis	..	..	..	..	..	..	507	..	..	..	..	..
Nudibranchs; sea slugs	3	..	..	11	1	..	..	3	9	..	1	..
Echinoderms; sea urchins												
Strongylocentrotus sp.	..	..	..	..	..	..	..	..	1	..	..	..
Lytechinus anamesus	..	1	..	..	..	..	..	..	..	..	1	..
Bryozoans; moss animals	..	n. c.	n. c.	n. c.	..	n. c.	n. c.	n. c.	..	n. c.	n. c.	n. c.
Coralline algae	..	n. c.	..	n. c.	..	n. c.	n. c.	..	..	..	..	..
Total organisms	317	531	526	270	221	189	582	97	1,085	737	1,099	429
Total volume in ml.	no vol.	no vol.	18.5	21.0	37.0	25.0	28.5 + teredos	no vol.	22.0	no vol.	no vol.	no vol.
Bottom temperature in °F	61	56	56	62	62	61	58	57	56	58	56	..

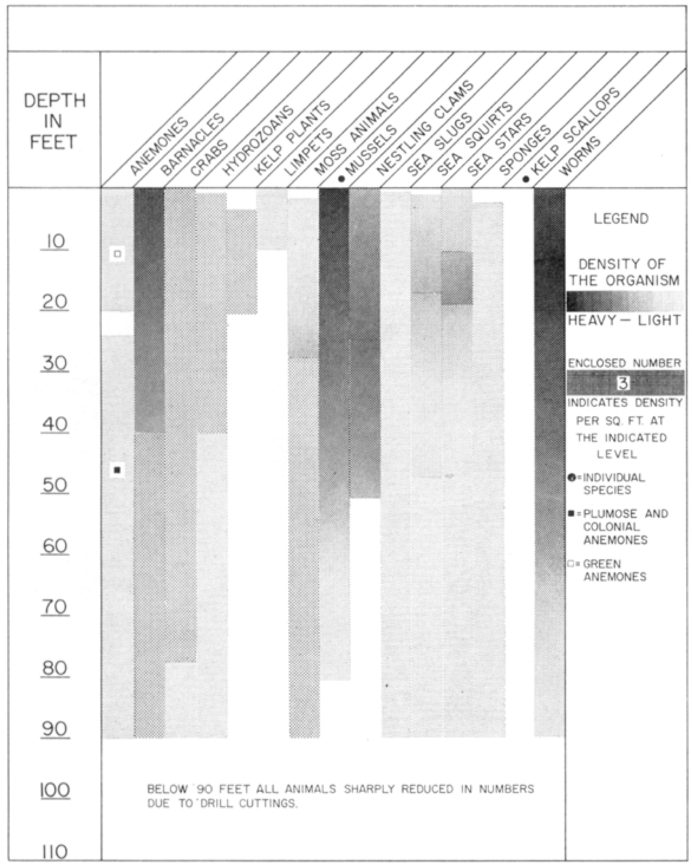
* n.c. present but not counted.

APPENDIX D
Redondo Beach Streetcar Reef—Test Block Series



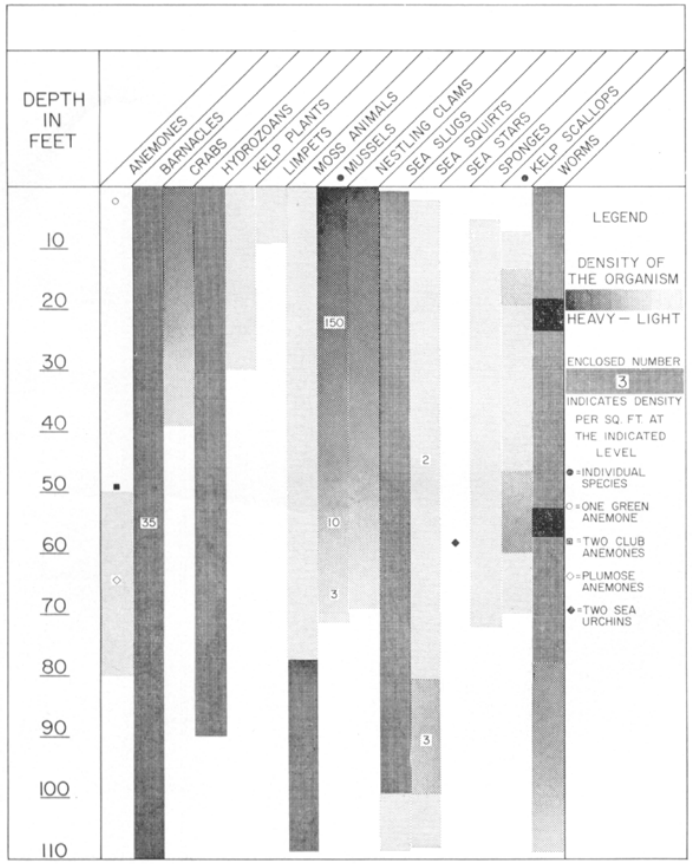
APPENDIX E. The vertical distribution of the major biomass on Hazel, July 1959, approximately 12 months after installation.

APPENDIX E. The vertical distribution of the major biomass on Hazel, July 1959, approximately 12 months after installation



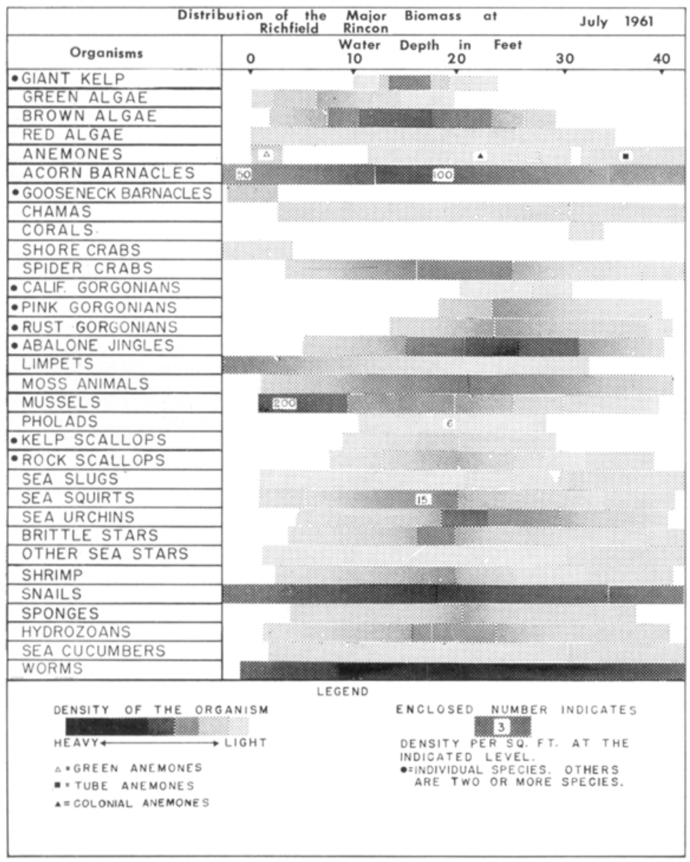
APPENDIX F. The vertical distribution of the major biomass on Hazel, July 1961, approximately 36 months after installation.

APPENDIX F. The vertical distribution of the major biomass on Hazel, July 1961, approximately 36 months after installation



APPENDIX G. The vertical distribution of the major biomass on Hilda, July 1961, approximately 14 months after installation.

APPENDIX G. The vertical distribution of the major biomass on Hilda, July 1961, approximately 14 months after installation



APPENDIX H. The vertical distribution of the major biomass at Richfield's Rincon Island, July 1961, approximately 54 months after installation.

APPENDIX H. The vertical distribution of the major biomass at Richfield's Rincon Island, July 1961, approximately 54 months after installation

INDEX TO COMMON NAMES

INDEX TO SCIENTIFIC NAMES