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THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME
FISH BULLETIN 146
Man-Made Reef Ecology

by
CHARLES H. TURNER,
EARL E. EBERT
and
ROBERT R. GIVEN
1969

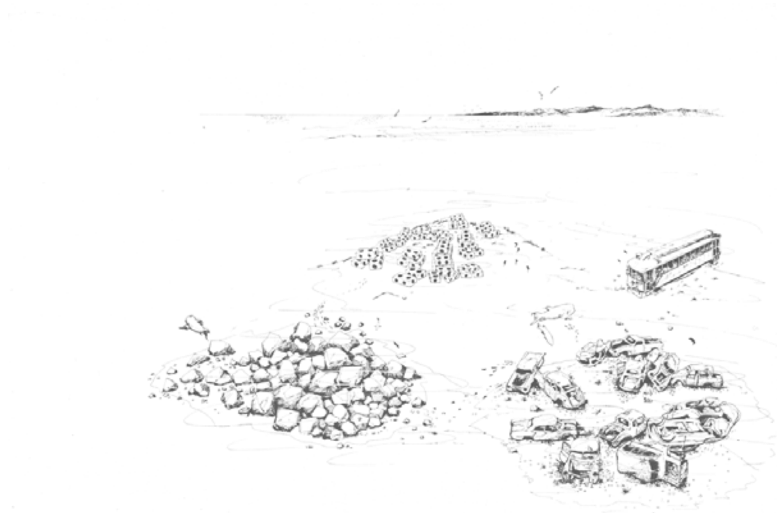

FIGURE 1 Artists concept of a multi-component study reef placed in Santa Monica Bay; 60-foot depth.

FIGURE 1 Artists concept of a multi-component study reef placed in Santa Monica Bay; 60-foot depth

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ABSTRACT

This report discusses in detail findings and observations made during more than 4 years of study on three experimental multi-component man-made reefs, and one "production" model reef, in Santa Monica Bay, California (August 1960–January 1965). The multi-component replication reefs were each constructed of 333 tons of quarry rock, one streetcar, 14 automobile bodies, and 44 concrete shelters. The "production" model reef was 1000 tons of quarry rock. The study was designed to investigate various aspects of man-made reef ecosystems and to determine the optimum material for reef construction in southern California.

Observations made and sampling conducted at each reef included: (i) enumeration (by estimate) of the fishes, invertebrates, and plants, (ii) sediment analysis, (iii) water temperature, (iv) water clarity, and (v) encrusting growths on each reef material.

Quarry rock was determined to be the preferred reef building material (based upon cost and ease of handling), even though the concrete shelters attracted the largest number of fishes. Further, quarry rock disturbed the bottom sediments less than the other three materials.

True succession, not seasonal progression, was recorded for the various encrusting organisms. During the first year, a barnacle-hydroid phase was closely followed by mollusk-polychaete, ascidian-sponge, and finally encrusting ectoproct stages. Subsequent stages involve aggregate anemones, gorgonians, and stony corals.

More than 200 invertebrates (protozoans to tunicates) were recorded during this study. Notations concerning each species occurrence, growth, importance on the reef, ecological niche, and known predatorprey relationships are presented.

Fish populations around each reef, and material, were assessed by: (i) species enumeration, (ii) estimates of size ranges, (iii) feeding habits, and (iv) general behavioral traits. Underwater tagging techniques were developed and employed to determine fish movements. In all, 78 species (35 families and 60 genera) were recorded. Embiotocid perches and serranids were dominant during the first two years of reef life. In time they decreased in dominance while resident species (e.g., cottids, gobies, damselfish, etc.) increased.

Observed fishes were classified as reef associated or non-reef associated, based upon their requirements or association to our reefs: a reef biotype being required to satisfy one or more life processes of a reef oriented species. We further subdivided the reef associated species into semi-resident (which periodically leave the reef) and resident forms (which consistently remain on the reef).

Fishing success on the reefs was two to three times that recorded for nearby natural reef areas. In some instances, due to the fish concentrating effect of these structures, angler success may be even higher.

Man-made reefs can turn "non-productive" areas of the nearshore into "productive" fishing areas. Initially, these structures attract fishes from surrounding areas. With time (about 5 years in our area) a natural situation is reached and the plant and animal populations exhibit fluctuations typical of reef ecosystems.

ACKNOWLEDGMENTS

This work was initiated, and conducted, as Dingell-Johnson Project California F-17-R, Ocean Fish Habitat Development and continued (during the preparation of this report) as part of D-J Project California F-22-R, Environmental and Behavioral Studies of Coastal Sport Fishes, supported by Federal Aid to Fish Restoration Funds.

We appreciate the help given us by the many persons and organizations interested in our reef studies: the California Wildlife Conservation Board, without whose monetary assistance the three multi-component replication (WCB) reefs could never have been built; the Los Angles County Fish and Game Commission, who financed the Redondo Canyon reef; the Redondo Beach harbor patrol, for courtesies extended us in mooring our diving boat; and Robert and William Meistrell, and Harry Pecorelli of "Dive n' Surf," Redondo Beach, who assisted by locating reef areas and kept us informed of changes in the animal populations at their favorite diving locations.

Particular thanks are due those who helped us with animal identifications: Mary Arai, University of Alberta, ceri-anthids; J. L. Barnard, U. S. National Museum, amphipods; Clinton Dawes, University of California at Los Angeles, algae; John E. Fitch, California Department of Fish and Game, fishes and mollusks; Olga Hartman, Allan Hancock Foundation, polychaetes; John Soule, Allan Hancock Foundation, ectoprocts, and Russel Zimmer, Allan Hancock Foundation, ectoprocts, mollusks and protozoans.

Many members of the California Department of Fish and Game, California State Fisheries Laboratory, Terminal Island assisted and gave encouragement during our field surveys, identification of fishes, and preparation of this manuscript. We particularly thank John L. Baxter, Glen Bickford, John E. Fitch, Janey Haugen, Constance A. Kenyon, Peter F. Major, P. Patricia Powell, Kathleen O'Rear, Alec R. Strachan, and Micaela Wolfe. Special thanks are extended to John G. Carlisle, Jr. (a former project member) for his contribution of the sportfishing catch data.

We three (authors) no longer remain with the DJ F-22-R studies. The senior author is now supervisor of the Department's Inshore Fisheries Habitat Evaluation and Monitoring Program, Ebert is in charge of the Department's new Shellfish Laboratory, Pacific Grove, and Given is Assistant Director at the University of Southern California Santa Catalina Marine Biological Laboratory.

Charles H. Turner
Earl E. Ebert
Robert R. Given
September, 1969

1. INTRODUCTION

Heavy demands are placed upon the seas by the exploding population of our modern world. The seas must receive countless tons of waste products, feed the hungry, and supply recreational tranquilizers for the multitudes attempting to escape the almost overpowering crush of advancing civilization with its foul air, noise, confusion, and worldwide crises.

Throughout the world, fishery biologists are seeking new methods of aquaculture to reap greater harvests from the sea. One method, modification of the environment, an approach long used in fresh water, is currently being evaluated as a means for obtaining conditions favoring the more desirable marine animals. One such modification is the construction of man-made fishing reefs. Various reports from countries and agencies constructing reefs indicate greatly increased catches in these areas, but most of these agencies have been unable to staff a program to observe routinely and evaluate the results of their work (Iversen, 1968; McKee, 1967; and Unger, 1966).

Volunteer diving groups who have conducted surveys in these areas frequently report "the reef abounds with life." But this phrase, no matter how descriptive, is far too general to illustrate the myriad of changes taking place.

When reporting on these reef-building programs, most authors have strongly urged a systematic investigation and evaluation of existing reefs before others were constructed.

With this in mind, California Department of Fish and Game, aided financially by Federal Aid to Fish Restoration Funds, instigated the Ocean Fish Habitat Development Project in April 1958. Its purpose was to determine: (i) the practicality of man-made reefs in southern California waters, (ii) the best materials to use, and (iii) the return to the fishermen. For this study the Department employed professional marine biologists who were also capable scuba divers.

These biologists visually observed the reefs, evaluated their findings, and made recommendations for improving reef design. Since it is an accepted fact that fishes congregate around natural reefs and sunken ships, there was no doubt that fishes would be attracted, but a multitude of questions needed answering. How many? What sizes and species? Would they remain to be caught by local fishermen? Was there a preference for a particular reef material? Were these fishes feeding at the reef or only orienting to it for shelter and feeding elsewhere? Answers to these and similar questions were obtained during a 6-year program of investigation.

During the formative period, pertinent literature was reviewed, scuba diving techniques were developed, and preliminary field observations were made. Background surveys were conducted in areas proposed for reef construction, to establish the pre-reef biota. Transect lines were swum and the animals and plants within range of vision recorded and the bottom sediments examined for suitability to support the proposed reef materials. Liaison and negotiations were carried out with all interested agencies (federal, state and local) and with the various sport and commercial fishing organizations that had vested interests in the proposed "reefs."

In 1958, two experimental reefs were constructed in Santa Monica Bay. The first, near Paradise Cove, was composed of 20 automobile bodies; the second, near Redondo Beach, used 6 streetcars. The success of these reefs, routinely observed each month for over 2 years, was based primarily on the observation of fish increases. Invertebrate and algae growths were only superficially noted.

Analysis of data obtained from these first experimental reefs (Carlisle, Turner, and Ebert, 1964) revealed wide variations in the number of fishes present on a given day. Some of these variations were explained as expected seasonal fluctuations; others concided with variations in water clarity. The remainder appeared to reflect a preference by the fishes for a given material. To evaluate this apparent preference a replication reef experiment was proposed and designed.

The present report discusses in detail our findings from over 4 years of studying these reefs. In addition, observations were made on a non-experimental ("production model") reef, and various natural areas.

Money to build the replication reefs was received from the California Wildlife Conservation Board. They allocated $18,000 for the three reefs, each composed of four different materials (Figure 1) . The reefs were placed in Santa Monica Bay offshore from Hermosa Beach, Santa Monica, and Malibu in August, 1960. Each reef was composed of 333 tons of class B quarry rock, one streetcar, 14 automobile bodies, and 44 concrete shelters; the total cubic area of each material was calculated to be nearly equal to that of any of the other materials. Each of the four materials formed a corner of each reef, and was placed from 100 to 200 feet from its nearest neighbor, to allow separate fish populations to build up around each materia. Our earlier studies (Carlisle, et al., 1964) had suggested that this separation was sufficient to keep the circulation of fishes at a minimum. Later observations indicated this held true where 200-foot distances prevailed, but not in areas separated by only 100 feet.

Our first production-model reef was constructed of 1,000 tons of class B quarry rock (stone of approximately 1,000 pounds each) deposited in four, 80-foot diameter piles in 75 to 80 feet of water. It was located near the Redondo submarine canyon, some 2,200 yards SW of the Redondo Beach fishing pier. Financing for this reef was obtained from the Los Angeles County Fish and Game Commission. The reef was built at a cost of $6,000 in January 1963.

2. REEF SITE SELECTION

Reef site selection was preceded by an on-site survey. The general area was first traversed by the diving boat and fathograms were made of the bottom. Extensive flat sand or muddy-sand areas were then visually surveyed by biologist-divers. While swimming along a 110-yard (100 m) transect line, these two- or three-man diving teams recorded the various physical and biological characteristics of the area; water clarity and temperature, bottom type, ripple marks, currents, and animals and plants. After 1963 we used a diver-held fathometer to search for rocky outcroppings or artifacts beyond our sight but still within 100 feet of the transect line (Figure 2) . By directing this unit

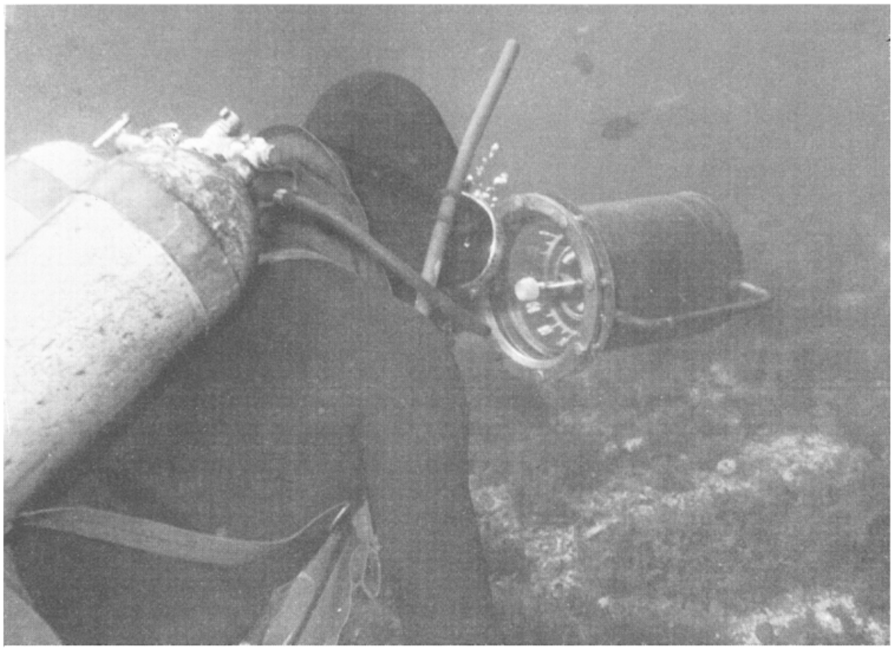

FIGURE 2 Biologist-diver Charles H. Turner horizontally surveying the sea floor with a diver-held fathometer. *Photo by Earl E. Ebert.*

FIGURE 2 Biologist-diver Charles H. Turner horizontally surveying the sea floor with a diver-held fathometer. Photo by Earl E. Ebert.

to each side of the transect line our survey area was effectively increased to some 66,000 square feet, regardless of water clarity.

Fathometer contacts were visually verified, and the potential effect of each on the proposed reef was postulated. If extensive outcroppings or large artifacts, considered as competition for the new reef, were found we recommended alternate sites. Small artifacts or single rocks were ignored.

A 60-foot depth was chosen for the multi-component reefs because this allowed the divers considerable survey time without involving prolonged decompression. Shallower depths were avoided because the increased surge could hamper our surveys and the reefs would be hazardous to navigation. Production model reefs, as yet only incidentally studied by us, were in slightly deeper water (to 90 feet). Nearshore reefs, again examined only incidentally, have been built around the periphery of fishing piers, at depths of only 12 to 24 feet.

After selection of a suitable site, permits have been obtained from the U.S. Army Corps of Engineers and the State Lands Commission or the city retaining title to the area. The U.S. Navy was also notified of our intent and the U.S. coast Guard contacted about marker buoy permits. Fishing interests, both commercial and sport, have been contacted as were any other interested agencies.

After construction, the offshore reefs have been marked with orange and white buoys inscribed ARTIFICIAL FISHING REEF (Figure 3) , in compliance with our construction permits, and to assist the small boater in finding them.

FIGURE 3 ARTIFICIAL FISHING REEF marker buoy, Redondo Canyon "production" model reef. *Photo by Charles H. Turner.*

FIGURE 3 ARTIFICIAL FISHING REEF marker buoy, Redondo Canyon "production" model reef. Photo by Charles H. Turner.

3.

3. THE STUDY AREA

Santa Monica Bay, California, is a crescent-shaped indentation of the southern California coast, lying due west of the City of Los Angeles (Figure 4) . Its extremities, Point Dume and Palos Verdes Point, are approximately 27 miles apart on a NW-SE axis, although the shoreline, due to its curvature, is 38 miles long. The Bay floor slopes gently seaward forming a shelf 3 to 6 miles wide.

The gross submarine topography of the Bay is represented by two large canyons, a basin and its accompanying slope, and a wide central

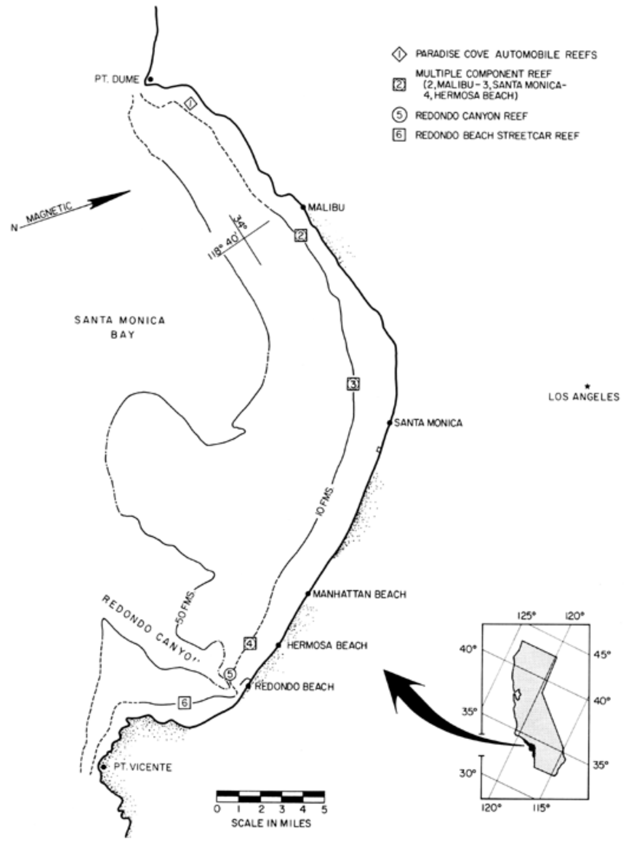

FIGURE 4 Location chart: Santa Monica Bay man-made reefs and pertinent local land marks.

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shelf. In this study, our interest was primarily with the topography of this center shelf—the site location of the three replication (WCB) and the "production model" (Redondo Canyon) reefs.

The shelf is generally characterized as being "smooth" and gently sloping seaward to approximately 50 fathoms (Figure 1). Although the term "smooth" is used, in some places local relief is extensive enough to limit the effectiveness of a man-made fishing reef. This "micro-relief," evident in the numerous fathograms made by the *Velero IV* of the Allan Hancock Foundation, University of Southern California, is categorized by the USC scientists as: (i) *smooth*—areas essentially smooth and flat, mounds or other high relief rare; (ii) *variable*—discontinuous areas of smooth topography, small mounds and undulations common; (iii) *rough*—sharp peaks and ridges projecting above an irregular bottom, relief to 40 feet high (Terry, Keesling, and Uchupi, 1956).

The WCB reefs near Malibu and Santa Monica rest upon an extensive "smooth" area, while the Hermosa Beach (WCB) and Redondo Canyon (nonexperimental) reefs are on a narrow tongue of "variable" bottom which extends along the northern edge of Redondo Canyon.

4. REPLICATION REEF CONSTRUCTION

After selecting the replication reef sites and obtaining the necessary permits, a final diving survey was conducted and temporary marker buoys placed, pin-pointing the spot for construction of the rock component of each reef.

The "bottom dump," compartmented barge, bringing the rock from a quarry on Santa Catalina Island, about 25 miles away, had only to come near this temporary buoy, open its doors, and let the rock fall (Figure 5) .

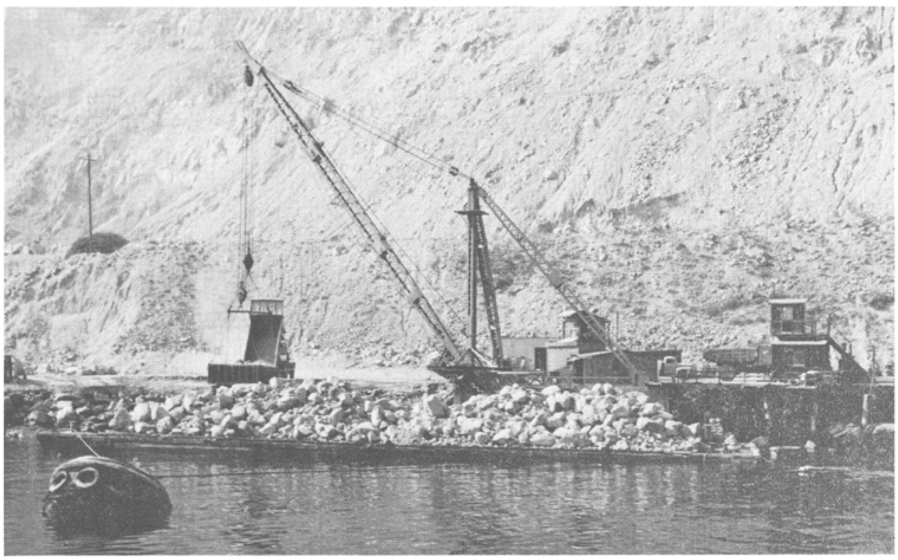

FIGURE 5 Loading the bottom dump barge at Santa Catalina Island. ***Photo by Charles H. Turner.***

FIGURE 5 Loading the bottom dump barge at Santa Catalina Island. Photo by Charles H. Turner.

After the barge departed we affixed a permanent buoy to the rock and, using it as a focal point, affixed temporary markers at the locations where a crane barge later placed the other materials. The location for each of these, with reference to the rock, was random, but the general configuration of each reef was designed to form a square (Figure 1).

The 14 automobile bodies were lashed together in groups of two, three or four (Figure 6) to prevent movement in a strong surge, and the 44 concrete shelters were made into pyramids of three, with two on the bottom and one across the top (Figure 7) to counteract "sanding-in."

At Malibu, the bargemaster was too accurate in placing the rock and it cut the temporary buoy line about 15 feet from the bottom. This buoy had drifted several hundred feet when the divers arrived and learned of the mishap. A second buoy was immediately placed and the area searched for the rock; unfortunately, our efforts at that time were futile. This second temporary buoy was then permanently anchored and the rest of the reef constructed around it.

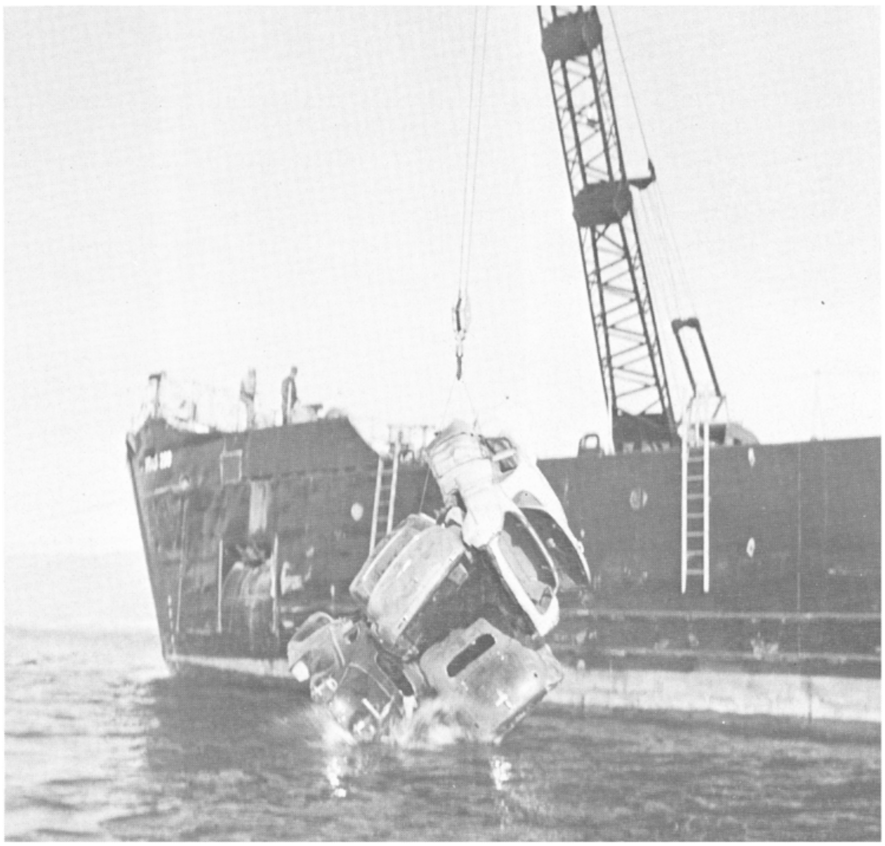

FIGURE 6 **Automobile bodies, lashed together, being lowered to the sea floor, to construct a fishing reef.** ***Photo by Charles H. Turner.***

FIGURE 6 Automobile bodies, lashed together, being lowered to the sea floor, to construct a fishing reef. Photo by Charles H. Turner.

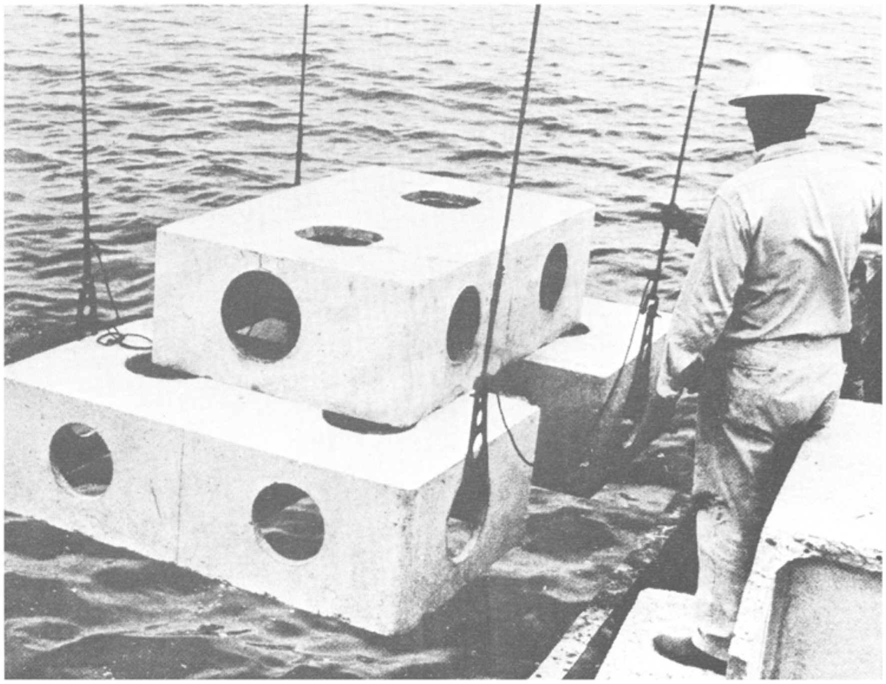

FIGURE 7 Pyramided concrete shelters being lowered to the sea floor.

FIGURE 7 Pyramided concrete shelters being lowered to the sea floor

Because of extremely murky bottom water and the lack of a diver-held fathometer until 1963, the rock component of this reef was not located, or surveyed, until April 1963, near the end of our study.

5. GENERAL STUDY METHODS

Weather permitting, routine diving surveys were conducted monthly around each component of the three replication reefs (except the Malibu rockpile), from August 1960 until November 1963. After this (until the study terminated in June 1964) the surveys became sporadic; our concern being only with new occurrences and a general notation of conditions. The majority of observations were made on the Hermosa Beach reef because of its proximity to our boat launching facilities.

The Redondo Canyon (production model) reef was constructed in January 1963 and although it too was easily accessible from our launching area, we visited it infrequently, concentrating our efforts upon the three experimental reefs.

Observations and sampling conducted at each reef included: (i) enumeration (by estimate) of the fishes, invertebrates and plants; (ii) core samples (using a diver-held coring tube) for sediment analysis; (iii) water temperatures, taken at the bottom and through the water column; (iv) horizontal visibility estimates and Secchi disc readings, taken at the bottom and through the water column; (v) general description of the bottom (ripple marks, scouring, etc.) before and after reef construction; (vi) quantitative sampling (by actual removal) of growths on the reef materials within a one-fourth meter square (0.06

TABLE 1

General Bottom Conditions and Fauna Prior to Multicomponent (WCB) Reef Construction

Area	Location	Depth (feet)	Survey* Purpose	Survey* Method	Date	Fishes	Number (size)	Invertebrates	Number (size)	Bottom Type
Hermosa Beach	AHF Station 2194–52 33° 51′ 36″ N 118° 25′ 55″ W	96	1	A	12–5–52	*Citharichthys stigmaeus* *Microstomus pacificus* *Parophrys vetulus*				Gray sand
Hermosa Beach	33° 51′ 15″ N 118° 24′ 35″ W	60	2	B	12–1–59	*Pleuronichthys coenosus* *Hypsopsetta guttulata* *Citharichthys sordidus*	15 (8–10″) 5 (7–9″) 8 (3–5″)	*Stylatula* sp. *Lytechinus anamesus* Cerianthidae *Kelletia kelleti* *Gari edentula* Nudibranchs (One *Armina californica* observed preying upon *Stylatula*.)	75 (18+″) 28 100 50 1 3 species	Sand-mud
Hermosa Beach (WCB Reef #1)	33° 51′ 15″ 118° 24′ 35″	60	3	C	8–1–60	*Citharichthys* sp.	750 (2–7″)	*Cancer gracilis* *Cancer* sp. *Renilla kollikeri* *Hemisquilla stylifera* *Kelletia kelleti* Nudibranchs *Stylatula* sp.	3 3 35 45 300+ 2 150	Sand-silty gray mud One area of red sand extending for last 63 yards (60 meters) of transect.
Santa Monica	AHF Station 3208–55	132	1	D, 1.15 cu. ft.	7–755			Ophiuroids Holothuroids Small crustaceans, Mollusca-*Listriolobus* Echiuroid Polychaetes	100+ 2 many 10+ genera 8+ 100+, at least 14 species	Fine green silty-sand
Santa Monica	AHF 3213–55 34° 00′ 00″ N 118° 32′ 28″ W	90	1	D, .84 cu. ft.	7–7–55			Ophiuroids Holothuroids Small crustaceans Mollusca—Chaetoderms and a few pelecypods Polychaetes	20+ 40 175+, at least 44 species	Fine green silty-sand
Santa Monica	AHF 3218–55 34° 00′ 03″ N 118° 30′ 20″ W	39	1	D, .51 cu. ft.	7–7–55			Ophiuroids Holothuroids Small crustaceans Mollusca—small pelecypods and gastropods Polychaetes	3 100+, at least 24 species	Fine green silty-sand

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Hermosa Beach	33° 51′ 15″ N 118° 24′ 35″ W	60	2	B	12-1-59	*Pleuronichthys coenosus* *Hypsopsetta guttulata* *Citharichthys sordidus*	15 (8-10″) 5 (7-9″) 8 (3-5″)	*Stylatula* sp. *Lytechinus anamesus* Cerianthidae *Kelletia kelleti* *Gari edentula* Nudibranchs (One *Armina californica* observed preying upon *Stylatula*.)	75 (18+″) 28 100 50 1 3 species	Sand-mud
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TABLE 1—Cont'd.

2) quadrat; (vii) removal of test blocks, monthly, during the first year of reef life; and (viii) making photographs of the conditions encountered and animals and plants observed. Details of these sampling methods are appropriately discussed in the sections dealing with each topic.

Pre-reef data were obtained from catch records, prior surveys by other organizations, and by visual observations we made during the reef-site selection surveys (Table 1).

Underwater observations were recorded, during each dive, on opaque white plastic sheets (Figure 8), using a flexible plastic pencil. This flexible pencil proved more durable than standard wooden ones.

FIGURE 8 Biologist-diver Alec R. Strachan recording fish behavior notes on a plastic slate; note the compass and collecting bag. *Photo by Charles H. Turner.*

FIGURE 8 Biologist-diver Alec R. Strachan recording fish behavior notes on a plastic slate; note the compass and collecting bag. Photo by Charles H. Turner.

Fishes, for species identification, maturity determination or food study work, were collected by spear, net, "slurp-gun," or poison.

Photographs of the reefs, the various invertebrates, and the fishes were taken underwater with Rollei-marine and Calypso underwater cameras, and on the surface with these, an Exa and a Speed-graphic. Motion pictures of reefs and survey operations were taken with both Fenjohn and Sampson-Hall 16 mm underwater cameras.

6. DIVING TIME

Excluding construction time and buoy placement and maintenance, we spent over 480 man-hours underwater conducting nearly 200 survey dives around the three replication reefs and the Redondo Canyon reef. These survey dives varied in duration from a few minutes to several hours. Although assistance was received from other divers on several occasions, one or more of the authors was present on each dive.

7. PHYSICAL OBSERVATIONS

Since a plethora of general data exists on the oceanography of the southern California shelf: the current system is discussed by Reid, Roden and Wyllie (1958) and the oceanography of Santa Monica Bay is well described by Stevenson, Tibby and Gorsline (1956), we restricted our physical data to recording and analyses of water temperatures, water visibilities (clarity) and bottom sediments. Salinity, often an important limiting factor in the sea, was not measured during this study. In the open ocean, salinity varies within narrow limits as opposed to estuarine waters where wide seasonal fluctuations may occur. For example, Stevenson, Tibby and Gorsline (1956) reported a rather constant 33.50[%] below a depth of 40 feet in Santa Monica Bay.

7.1. TEMPERATURE

Temperature is one of the most important limiting factors in the open ocean. Floral and faunal distributions, seasonal fluctuations, attachment of sessile organisms, and reproductive cycles are all contingent upon and either directly or indirectly related to temperature regimes.

During this study, temperature data were obtained with a diver-held standard bucket thermometer. Readings were taken at the bottom at the termination of each dive, then at successive 10-foot increments to and including the surface. The time of day and the months in which temperatures were recorded at each reef varied considerably. Likewise, the number of observations in any one month were not constant, ranging from zero to six.

The paucity of data from the Santa Monica and Malibu reefs, particularly in 1963, resulted from the emphasis placed on studying the Hermosa Beach reef; it was established as the standard and the others compared to it. Weather, launching facilities and travel time were all factors contributing to this decision.

Surface temperatures at the Hermosa Beach reef ranged from 13.4°C (March 1962) to 21.0°C (August 1961). The lowest bottom temperature (10.3°C) was recorded in June 1961 and the highest (17.0°C) in

November 1960. Seasonally, low surface temperatures were found from November or December through May. Low bottom temperatures prevailed from March through July.

Temperature patterns and seasonal ranges at the Santa Monica and Malibu reefs were comparable to those recorded at the Hermosa Beach reef. At each, isothermal conditions occurred in the winter and maximum stratification in the summer (Figure 9).

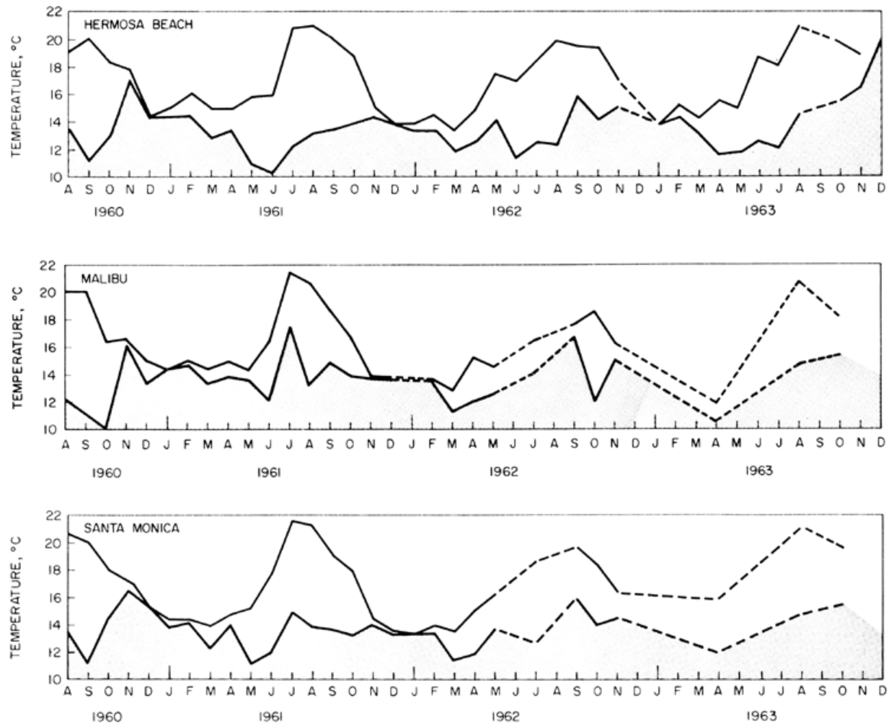

FIGURE 9 Surface and bottom water temperature patterns recorded at the three WCB study reefs; August 1960 to December 1963. The upper line reflects the surface waters, the lower line the bottom temperatures (60-foot depth).

FIGURE 9 Surface and bottom water temperature patterns recorded at the three WCB study reefs; August 1960 to December 1963. The upper line reflects the surface waters, the lower line the bottom temperatures (60-foot depth)

Sublittoral temperature patterns along the southern California coast appear to be quite similar, at least to depths of 150 feet. Typically a vertical thermal stratification initiates by late February or early March precipitated by increasing air temperatures and subsequent warming of the surface layer. This thermal gradient continues its development through spring and into early summer as prevailing westerly winds move surface water away from the coast and upwelling occurs. By May or early June, bottom temperatures along the 60-foot depth contour achieve their seasonal low—close to 10°C, as the surface layer continues to warm. In mid-summer, the surface layer attains its seasonal maximum—near 23°C. At this time, the bottom water begins to warm as upwelling diminishes. Maximum thermal stratification generally occurs in August and as fall approaches the gradient collapses. Cooling air temperatures combined with wind mixing of the upper surface layers result in nearly isothermal conditions by November or December.

Coupled with the spring thermal gradient is the development of a thermocline, which due to the density differential is frequently sharp enough to be seen by divers. During the frequent summer blooms of dinoflagellates, where a "red water" condition occurs, this thermocline acts as a barrier, restricting these dinoflagellates to the warmer surface water. Divers working beneath the thermocline during these periods often find that good visibilities, but eerie colors, prevail due to the red-filter effect from the surface concentrations of plankton.

7.2. VISIBILITY

Water clarity is indicative of the amount of organic or inorganic matter suspended in the water column and may be affected by wind, waves, bottom type, temperature and plankton.

Turbidity, resulting from suspended sediments, may be limiting for algae and many of the sessile filter feeding animals. Conversely, sedimentary tube building worms and a host of other attached animals often require these sediments to impregnate their outer layers for strength, protection and additional growth. Characteristic biotic communities thus serve as excellent indicators of the turbidity normal to an area. Additionally, reduced water visibilities limit the effectiveness of diving surveys (e.g., low fish population estimates frequently correlate with surveys conducted under turbid conditions).

We estimated water visibility on each dive to describe the general conditions under which our more-detailed biological observations were made. These estimates were the maximum horizontal distances at which most swimming fishes were recognizable. To standardize these estimates and to obtain an index which would be meaningful to other scientists, we also made horizontal Secchi disc readings. One diver held the Secchi disc while another swam out with a measured line—a right angle interpretation of the standard shipboard method. When our estimated water visibilities were plotted against the Secchi disc measurements, they revealed an approximate 2 : 1 relationship (Figure 10) .

Water visibilities fluctuated widely without apparent correlation to season or tide; although best visibilities are purported to occur during the fall, in the absence of storms.

As with temperature readings, we made fewer monthly visibility estimates at the Santa Monica and Malibu reefs in 1963.

The maximum sea floor visibility, estimated as 35 feet, occurred at the Hermosa Beach reef (June 1961), however, on several occasions bottom visibilities here were estimated at only 1 foot. Moderately good visibilities (about 10 feet) were experienced frequently at this reef but seldom at Santa Monica and Malibu (Figure 11) .

Poorest visibilities were generally encountered at Santa Monica, where only once the estimated sea floor visibility exceeded 10 feet—in August 1963, 13 feet was estimated. Here, sea floor visibilities averaged 4 to 5 feet.

Water visibilities encountered in Santa Monica Bay could generally be described as marginal for conducting diving surveys. Four-foot visibility appears minimal for properly assessing reef fish populations; with less visibility an overall perspective cannot be obtained. Some fish tend to aggregate close to the diver, following him, while other

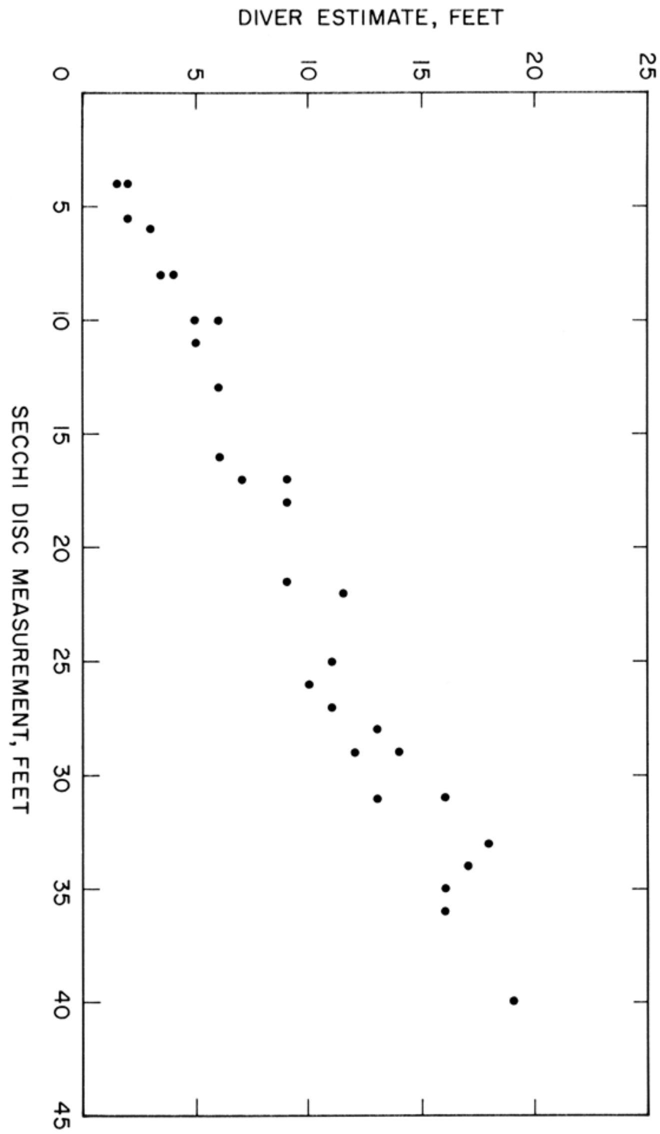

FIGURE 10 Secchi disc measurements plotted against diver estimates of water clarity.

FIGURE 10 Secchi disc measurements plotted against diver estimates of water clarity

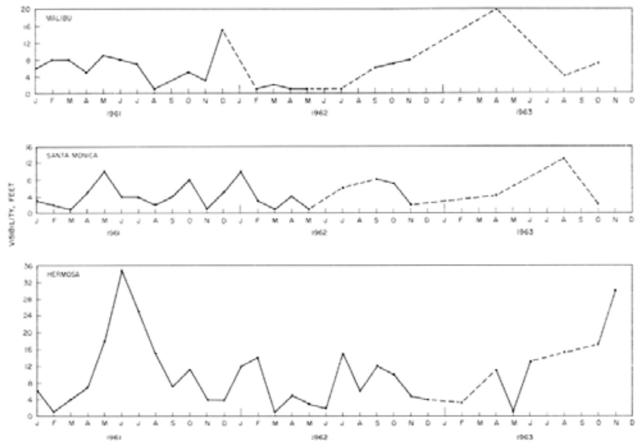

FIGURE 11 Sea floor visibilities recorded at the three WCB reefs: January 1961 through November 1963.

FIGURE 11 Sea floor visibilities recorded at the three WCB reefs: January 1961 through November 1963 species are more wary; consequently, estimates for certain species may have been double or triple, while others remained uncounted. of the 24 occasions where we estimated sea floor visibilities as less than 4 feet, 10 occurred at the Santa Monica Reef (Figure 11).

7.3. SEDIMENTS

Sediment type is important in the selection of artificial reef sites. Fine hard-pack sand is a prime base. Shifting of such sediments is minimal and objects placed on them will not "sand-in", assuming that the water depth is sufficient to negate onshore wave turbulence. Coarser sand with deep ripple marks indicating strong water action and shifting bottom sediments is less desirable due to the likelihood of materials to "sanding-in", especially those of low relief.

Any sizeable structure placed on a normally flat ocean bottom can be expected to produce certain local changes on the surrounding substrate. Such changes, even if subtle and not readily evident in general field observations, are important in assessing the value and effect of the artificially introduced reef-type structures.

Comparative analyses of bottom sediments taken from "construction" sites before and after reef placement will show the character and magnitude of any prolonged substrate alteration. Unfortunately, we made only a general analysis of the bottom sediments prior to reef placement in Santa Monica Bay. However, records of bottom sediments from areas adjoining the reef sites (Hartman, 1956; Terry, Keesling, and Uchupi, 1956) are available for comparison. In general, the Hermosa Beach reef site is an area of gray sand with an intruding tongue of "red" sand in its NW corner. At Santa Monica the bottom is green silty sand, and at Malibu it is medium green sand with much flocculent dark debris, presumably derived from nearby streams which seasonally empty into the ocean.

We made detailed analyses of sediments at two of the three multiple component reef sites near the end of our study, 3 years after reef placement. These supplemented general sediment observations made during our routine surveys.

Sediment samples were obtained using hand-held plastic tubes 18 inches long with an inside diameter of 1# inches (Figure 12) . Core penetration varied with bottom conditions. The samples were not taken randomly but plotted to give the most significant picture of the reef's effects on the substrate at varying distances from the actual structures. The core samples thus obtained were divided into two main categories: (i) cores taken for a quick visual analysis in areas obviously different from the surrounding substrate, usually to determine the depth and extent of the aberrancy and (ii) core samples for detailed analyses which were brought to the laboratory, measured, removed from the tube and allowed to dry. The dried core was then cut into three subequal parts (called "top," "middle," "bottom"), weighed and washed through a series of standard Tyler screens. Resulting fractions were again dried and weighed. The weight differential between pre- and post-washing was recorded as the silt-clay fraction—the amount passing through the 62 micron mesh screen. The approximate percentage composition of the retained sediments was calculated and the sediments were examined under a six-power binocular microscope. The various fractions were designated as coarse, fine, etc., roughly following the Wentworth nomenclature.

Because sediment samples had not been taken previous to reef placement we took cores adjacent to, and a measured distance from, the reef structures to record sediment changes resulting from the reef materials. Core samples were not taken around the streetcars or automobile bodies because we soon determined that they were unsuitable materials for long-term artificial habitat.

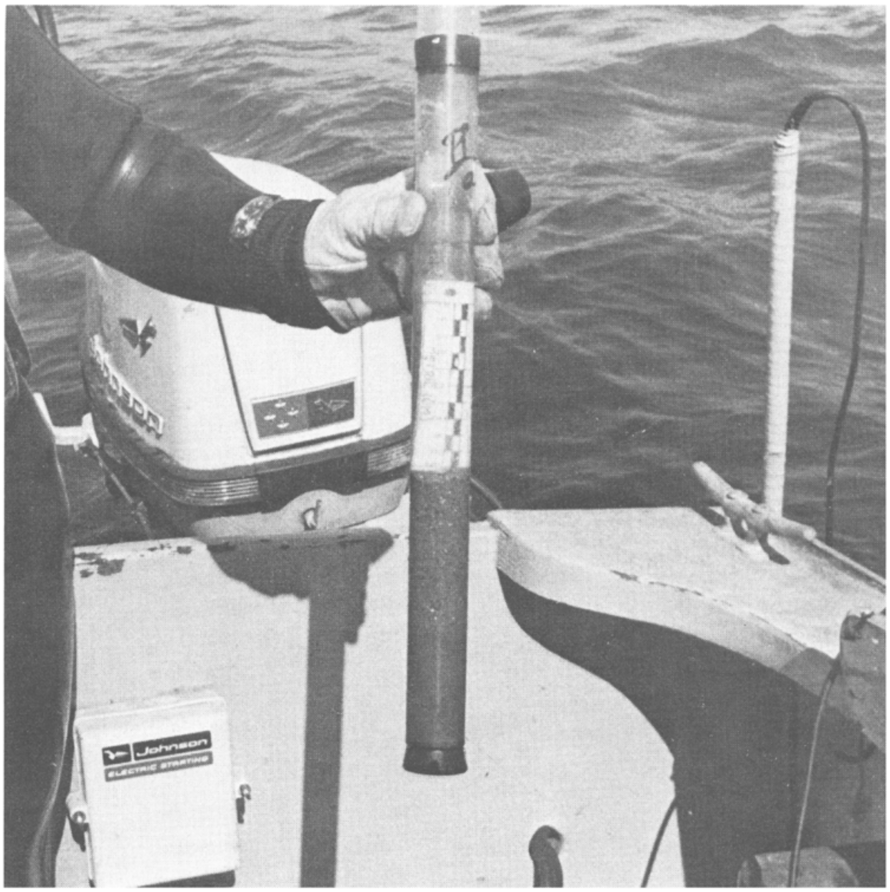

FIGURE 12 Diver-held coring tube, core in place. Above the core is a cm rule. ***Photo by Charles H. Turner.***

FIGURE 12 Diver-held coring tube, core in place. Above the core is a cm rule. Photo by Charles H. Turner.

Our diving observations, coupled with our sediment analyses, illustrated that marked alterations of the sediment composition and sea floor topography occurred adjacent to the concrete shelters, automobile bodies and the streetcars. Only negligible differences were detected around the rockpiles.

Coarser sediments were uncovered as accelerated currents, produced by openings in the materials, carried away the finer silts and clays. This scouring "dished out" the sediments, particularly those surrounding the concrete shelters, creating extensive depressions (Figure 13) . These depressions re-filled with silt during periods of minimal bottom current, often half covering the concrete shelters (Figure 14) . We suspect that single shelters may eventually "sand-in" completely due to this alternate scouring and filling process.

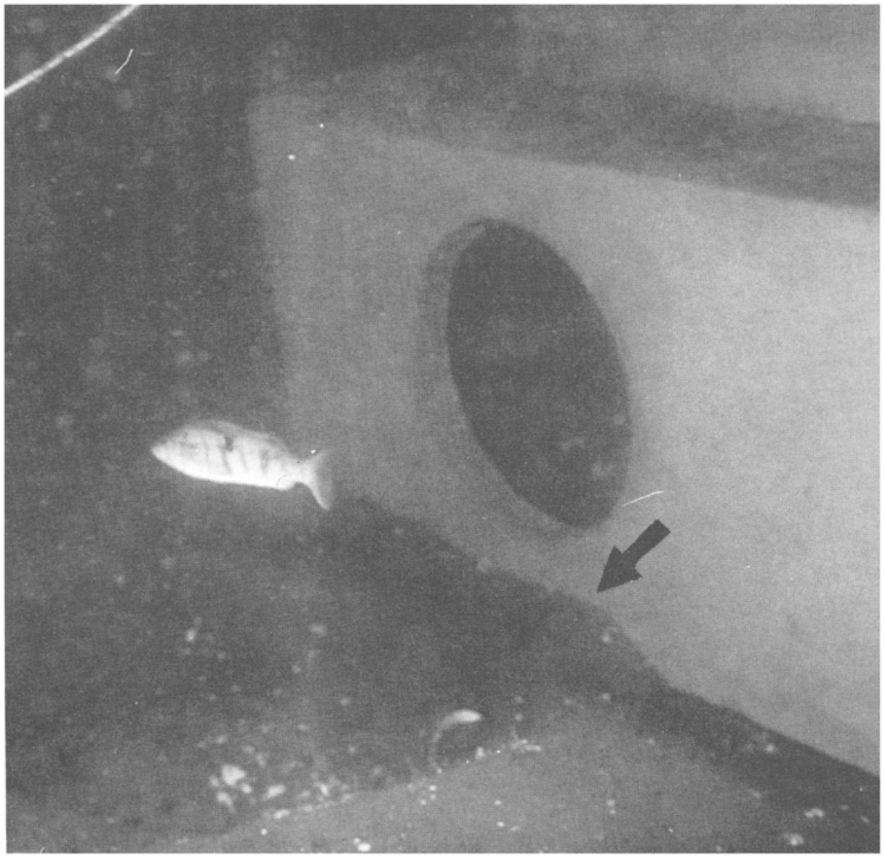

FIGURE 13 The beginning of a depression or "dished-out" area adjacent to the concrete shelters (arrow). The fish is a sand bass. *Photo by Charles H. Turner.*

FIGURE 13 The beginning of a depression or "dished-out" area adjacent to the concrete shelters (arrow). The fish is a sand bass. Photo by Charles H. Turner.

Cores taken adjacent to the concrete shelters, in scoured areas, contained coarser fractions than cores taken some distance away. Cores taken adjacent to, and a measured distance from the rock components, did not differ significantly (Table 2).

8. BIOLOGICAL OBSERVATIONS

8.1. TEST BLOCK STUDIES

The use of test blocks for studying attachment, growth, and succession of organisms along the California coast was initiated by Coe (1932) at La Jolla. Subsequent to Coe's monumental endeavors, several

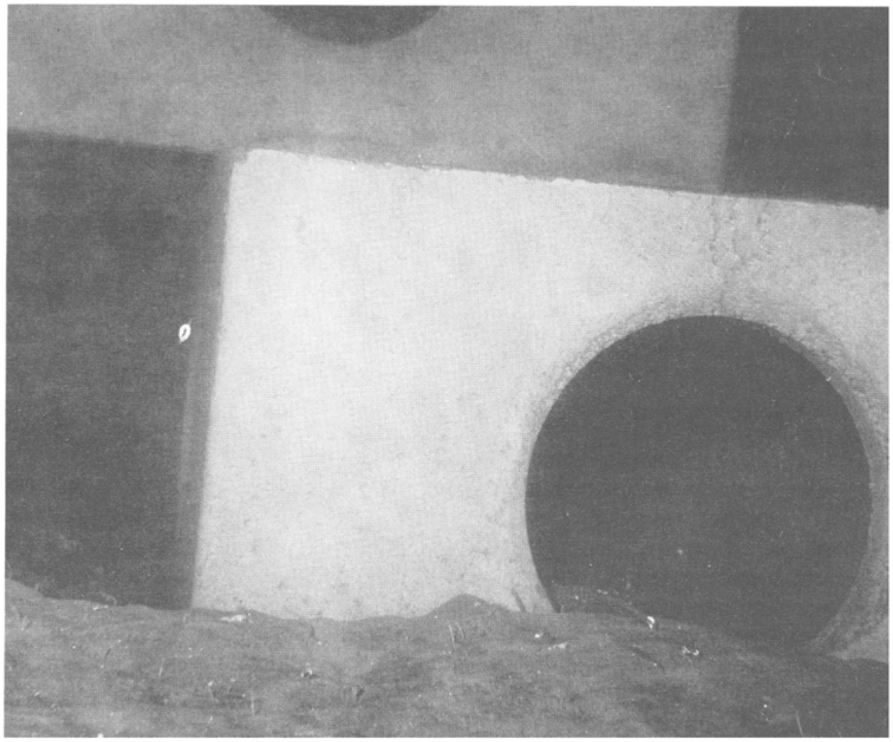

FIGURE 14 Refilling in a depression adjacent to the concrete shelters. The sediments eventually enclosed half of the 18-inch opening. *Photo by Charles H. Turner.*

FIGURE 14 Refilling in a depression adjacent to the concrete shelters. The sediments eventually enclosed half of the 18-inch opening. Photo by Charles H. Turner

workers have either used test blocks or made scrapings to collect and describe fouling communities.

In order to obtain some knowledge of attaching organisms during the first year of reef life, we placed several series of test blocks on the various reef materials. By augmenting our general observations in this manner we obtained both quantitative and qualitative measures of the biota. We assumed that settlement in the first months would be random and indicative of the larvae suspended in the water column, giving a rough indication of larval "preference" for a particular material, while in later months the speciation might be influenced more by the organisms already attached. Analysis of data obtained from these test series (Appendixes 1 and 2) indicated the early settlers caused only minor changes in speciation without appreciable change in the general successional stages encountered. The slight variations noted on the reef materials were likely a function of material texture, and were readily discernible in our general observations.

Ideally, our test blocks should have been of the same substances used for reef construction : wood, metal, rock, and concrete. We used only wooden blocks, however, due to the ease of handling and standardizing their size and shape. A series of 12 untreated white pine blocks, 6 x 1# x ¾ inches, was attached to a piece of channel iron and affixed to an exposed surface on 9 of the 12 reef components, less than 1 month after

TABLE 2

Analysis of Corings Taken at the Hermosa Beach and Malibu Multicomponent Reefs

Core number	Date obtained	Area	Core length (inches)	Core description: Top	Core description: Middle	Core description: Bottom
1	October 1963	Hermosa Beach reef; edge of rock component	15.25	Uniform gray sand; fine shelly debris; urchin spines. *Composition:* fine gray sand.....93% silt/clay.....7%	Uniform gray sand; few pieces of shell. *Composition:* fine gray sand.....86% silt/clay.....14%	Medium fine gray sand; occasional shell and urchin spines. *Composition:* fine gray sand.....100% silt/clay.....negligible
2	October 1963	Hermosa Beach reef; 32 feet from Core No. 1; directly away from rock component.	13.50	Uniform fine gray sand; sparse shelly debris. *Composition:* fine gray sand.....84% silt/clay.....16%	Uniform fine gray sand; sparse shelly debris. *Composition:* fine gray sand.....89% silt/clay.....11%	Uniform fine gray sand; sparse shelly debris. *Composition:* fine gray sand.....88% silt/clay.....12%
3	October 1963	Hermosa Beach reef; in depression adjacent to concrete shelter.	6.00	Coarse gray sand; shelly debris. *Composition:* coarse sand.....100%	Coarse gray sand; much shelly debris. *Composition:* sand.....61% silt.....39%	Fine gray sand, cobbles and pebbles. *Composition:* cobbles.....40% pebbles.....7% granules.....3% sand.....50%
4	October 1963	Hermosa Beach reef; 10 feet from concrete shelter on level, fine gray sand.	13.00	Uniform fine gray sand; small amounts of shelly debris. *Composition:* sand.....93% silt.....7%	Uniform fine gray sand. *Composition:* sand.....88% silt.....12%	Uniform fine gray sand. *Composition:* sand.....89% silt.....11%
5	October 1963	Hermosa Beach reef; 30 feet from Core No. 3; directly away from concrete shelter, level fine gray sand.	11.00	Fine gray sand; some fine reddish sand; some shelly debris. *Composition:* sand.....94% silt.....6%	Fine gray sand. *Composition:* sand.....90% silt.....10%	Fine gray sand. *Composition:* sand.....90% silt.....10%
6	October 1963	Malibu reef; adjacent to rock component.	9.00	Fine brownish-gray sand and cobble. *Composition:* cobbles.....1% pebbles.....1% granules.....2% sand.....56% silt.....40%	Very fine gray silty sand; few shells. *Composition:* sand.....41% silt.....59%	Fine gray sand. *Composition:* sand.....72% silt.....28%
7	October 1963	Malibu reef; 30 feet from Core No. 6 heading directly away from rock component.	12.50	Uniform fine gray sand. *Composition:* sand.....71% silt.....29%	Uniform fine gray sand. *Composition:* sand.....59% silt.....41%	Fine gray sand; shelly debris. *Composition:* sand.....78% silt.....22%
8	October 1963	Malibu reef; 30 feet from nearest concrete shelter.	15.00	Uniform fine gray sand. *Composition:* sand.....76% silt.....24%	Uniform fine gray sand. *Composition:* sand.....66% silt.....34%	Uniform fine gray sand. *Composition:* sand.....77% silt.....23%

TABLE 2
Analysis of Corings Taken at the Hermosa Beach and Malibu Multicomponent Reefs

reef installation (Figure 15) . In all, 108 blocks were placed in this manner.

Each month one block was removed from each series and placed in a wide-mouth quart jar, underwater. After fixing for 3 days in 10% formalin, the blocks were rinsed in fresh water and placed in 70% isopropyl alcohol to await laboratory analysis. A 0.5 mm mesh screen was utilized in all fluid exchanges, minimizing the loss of detached organisms.

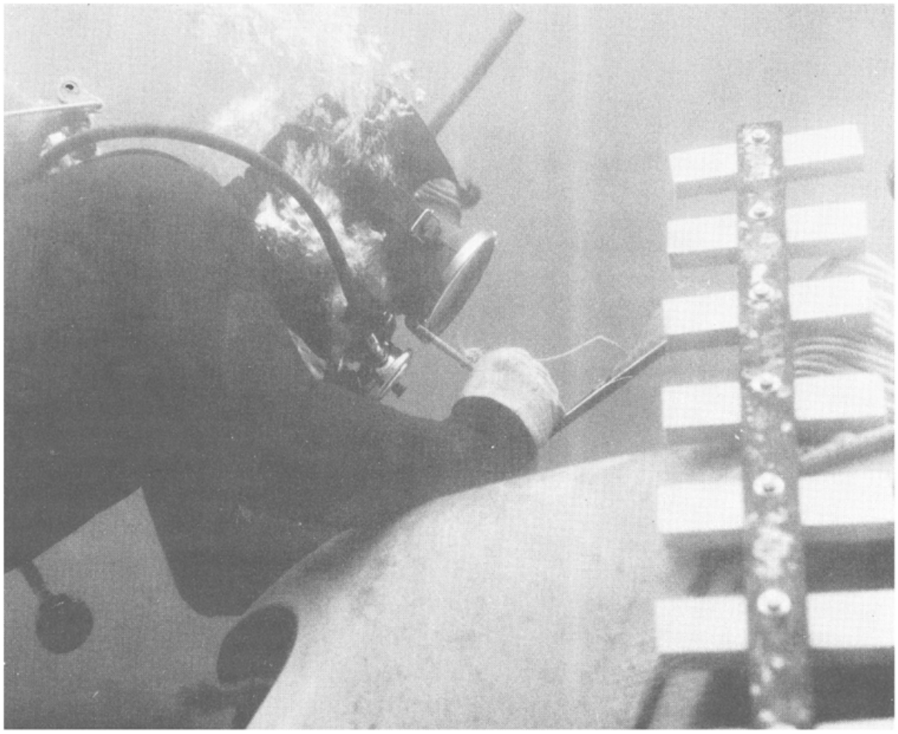

FIGURE 15 Biologist-diver Earl E. Ebert recording conditions on the reef during the first month when we affixed a test block series to 9 of the 12 reef components. *Photo by Charles H. Turner.*

FIGURE 15 Biologist-diver Earl E. Ebert recording conditions on the reef during the first month when we affixed a test block series to 9 of the 12 reef components. Photo by Charles H. Turner

Analysis included: (i) an initial cursory examination and recording of any prominent or unusual growths; (ii) photographing selected blocks; (iii) removing all attached organisms from each block and (iv) dissecting the block to expose wood-boring organisms. The various organisms were sorted into phyla and subsequently identified to lower taxons. Because of time and personnel limitations we did not identify all the organisms to generic or specific levels. Polychaete worms, for example, were diagnosed only to family, but at this level the habitat of these worms is fairly well established (sedentary or errant) and their trophic level and entry into the food chain can be postulated.

Unfortunately, wood-boring organisms severely infected the test blocks, preventing complete recovery of all the blocks for analysis. Some blocks were entirely lost, while the speciation of terminal stage blocks was often influenced, generally adversely, by the loss of wood (attachment space). The empty burrows of the wood-borers also provided a "preferred" habitat for certain organisms whose numbers might otherwise have been lower.

Wood-boring isopods, Limnoria tripunctata, occurred only at Hermosa Beach, being first recorded in December 1960. The shipworm Bankia setacea was established first at Malibu (concrete shelter series, November 1960) and then at Santa Monica (rockpile series, December 1960) and finally at Hermosa Beach (rockpile series, January 1961). Despite the earlier settlement of shipworms at Santa Monica and Malibu, we recovered a full complement of 12 test blocks from the Malibu streetcar and Santa Monica concrete shelter series. The series at Hermosa Beach lasted only 10 months from the time of placement. of the 108 blocks originally placed, only 88 were recovered for analysis : 35 from the Hermosa Beach reef, 30 from Santa Monica and 23 from Malibu (Appendixes 1 and 2).

Although several months often elapsed between the recovery of a particular block and its examination, a comparison of the species found on the blocks, particularly any first occurrences, corresponded within a few days of the dates when we first observed these animals during our more general surveys. Thus, it was soon apparent that we were not overlooking any major biotic changes during our more casual observations.

Since our data are most complete from the Hermosa Beach reef, a descriptive summary of these blocks, listed by material, is presented below, chronologically for individual blocks. These data are then compared with those from the other reefs.

8.1.1. Hermosa Beach Reef

Test blocks were attached to the Hermosa Beach reef on September 6, 1960, one series on each of the four materials. At this time, tiny acorn barnacles and sparse hydroid growths (first observed September 2, 1960, only 18 days after the reef placement) were already visible on the reef proper.

8.1.1.1. Streetcar Component Test Block Series

First test block. This was removed October 6, 1960, 30 days after placement of the series. Acorn barnacles (73 individuals) were evenly spaced on the block surfaces and were the dominant organism. Most were small, with maximum diameters of 5 mm (about 0.25-inch).

Second test block. This was removed November 7, 1960, 62 days after placement. Sixty evenly distributed acorn barnacles were noted, with maximum diameters of 1.6 cm (about 0.6-inch). Few other organisms were present.

Third test block. This was removed December 9, 1960, 94 days after placement. Shortly before this date, the test series was torn loose by a commercial fishing net snagged on the streetcar. After locating the series several feet away, on the sand, we reaffixed it to the streetcar and removed the third block. The full effect of this disturbance upon the attached organisms was not assessed. Only 3 barnacles were found on this block, but several new organisms (caprellids, polychaetes, copepods, polyclads, etc.) were present and moderate hydroid growth covered its upper surfaces. The first borers (4 surface boring gribbles, Limnoria tripunctata) were recorded.

Fourth test block. This was removed January 18, 1961, 134 days after placement. Moderate hydroid colonies were evenly distributed on all block surfaces. Eight barnacles, maximum diameters of 1 cm (about 0.4-inch), were present. The wood boring mollusk Xylophaga sp. occurred for the first time. Numerous other organisms including polychaete worms, kelp scallops (Leptopecten latiauratus) , and gammarid and caprellid amphipods were also recorded.

Fifth test block. This was removed February 10, 1961, 157 days after placement. Moderate hydroid growth covered all of its surfaces except one end where an encrusting ectoproct had established. Seven live and two dead barnacles, five small shipworms (Bankia setacea) , polychaete worms, gammarid amphipods, polyclad flatworms and a half-slipper snail (Crepipatella lingulata) were also present.

Sixth test block. This was removed March 7, 1961, 182 days after placement. The hydroid growth had decreased slightly from the previous month, and 19 live and 2 dead barnacles were present on the upper surface and sides of the block. The barnacles had presumably succumbed to predation by a polyclad flatworm found inhabiting their empty shells. Woodboring activities were extensive with some burrows exceeding 8 cm (slightly over 3 inches) in length.

Seventh test block. This was removed April 5, 1961, 211 days after placement. Speciation and total number of individuals present was considerably increased, although bare wood areas still remained. Hydroids were very sparse and only one live barnacle was present. Polychaete worms were abundant and ectoprocts were becoming conspicuous. Internally, extensive boring was noted; one Bankia setacea measured 13.5 cm (about 5.4 inches) long.

Eighth test block. This was removed May 9, 1961, 245 days after placement. This block was superficially entire, but it was soft from extensive internal boring. Only one species of hydroid was present and the ctenostome ectoproct Victorella argilla covered one-third of the upper surfaces and about one-half of the sides of the block. Polychaete worms were still abundant.

Ninth test block. This was removed June 2, 1961, 269 days after placement. Deterioration, from continued internal boring, was evident. Little boring space remained and the block could easily be crumbled. Polychaetes, ectoprocts and gammarid amphipods were still prominent, though suffering from lack of space.

By July, 1961, no test blocks on this series remained : excessive shipworm boring presumably eroded them away.

8.1.1.2. Automobile Body Component Test Block Series

First test block. This was removed October 6, 1960, 30 days after placement. Sparse hydroid growths, to 5 mm (about 0.5-inch) tall, were present on all of the block surfaces. Eighteen barnacles and two unidentified copepods were the only other organisms recorded.

Second test block. This was removed November 4, 1960, 59 days after placement. Abundant hydroid colonies to 2.5 cm (about 1 inch) tall covered all of the test block surfaces, and nudibranchs (Hermissenda crassicornis) were observed feeding on these lush growths. Copepods, amphipods and polychaete and polyclad worms were also noted.

Third test block. This was removed December 12, 1960, 97 days after placement. There were slightly fewer hydroid colonies than during the previous month. These had nudibranch egg ribbons attached to them. Twenty-seven small barnacles were evenly distributed on all the block surfaces. Polychaete worms, amphipods, nudibranchs and a polyclad worm were also recorded.

Fourth test block. This was removed March 1, 1961, 176 days after placement. The surfaces were sparsely covered with hydroid growths, but no barnacles were present. Colonies of the ectoproct Victorella argilla were beginning to appear, and 37 polychaete worms were noted.

Fifth test block. This was removed April 5, 1961, 211 days after placement. Although a few hydroid stolons remained (attesting to their former presence) no live colonies were found. A new "set" of barnacles had become established and over 500 pinhead-sized individuals were counted. The first signs of wood boring were evident, and although the block was still intact, dissection exposed 42 gribbles and 10 shipworms. Other organisms included amphipods, polyclad and polychaete worms, and small scattered Victorella argilla colonies.

Sixth test block. This was removed May 9, 1961, 245 days after placement. Again hydroid colonies and a few barnacles were common on all surfaces. Amphipods had increased considerably in number and numerous polychaete worms were recorded. The block was intact but soft from the extensive internal boring; very little solid wood remained.

Seventh test block. This was removed June 2, 1961, 269 days after placement. Extensive internal boring had eroded away one corner, exposing the shipworm burrows. Some shipworm mortality had occurred, and polychaetes, polyclads and nestling clams (Hiatella arctica and Kellia suborbicularis) were living in the abandoned burrows. Hydroid colonies were sparse, but the ectoprocts, polyclads, and polychaetes were numerous.

Eighth test block. This was removed July 17, 1961, 314 days after placement. Encrusting growth was sparse, and although the block was entire, some shipworm holes were visible externally. A recent "set" of pinhead-sized barnacles, a few ectoproct colonies, amphipods, and polychaete worms constituted the majority of the surface organisms. Dissection of the block revealed extensive boring and indications of shipworm mortality (empty burrows).

This was the final block collected from this series. The others were presumably destroyed by excessive shipworm boring.

8.1.1.3. Rockpile Component Test Block Series

First test block. This was removed October 3, 1960, 27 days after placement. Three gammarid amphipods and 242 tiny barnacles were noted.

Second test block. This was removed November 4, 1960, 59 days after placement. Only 152 barnacles were recorded on this block, but their maximum diameter of 8 mm (about 0.3 inch) was greater than that recorded for the previous month. Sparse hydroid colonies were present on the upper surfaces and sides of the block. Copepods, gammarid amphipods, an unidentified shrimp, a polyclad, several polychaetes, and a few small mollusks also were present.

Third test block. This was removed December 8, 1960, 93 days after placement. Present were 126 barnacles with an average diameter of 12 mm (about 0.5 inch). Over 60% of these were attached to the upper surface of the block. Hydroid colonies were common. The remaining fauna was similar to that of the November block, with the addition of several surface-boring gribbles.

Fourth test block. This was removed January 18, 1961, 134 days after placement. Nearly half (41) of the 89 barnacles present were dead. Hydroid colonies on the upper surfaces appeared heavily grazed, while those on the undersides appeared healthy. Fifteen tiny kelp scallops were also counted. Wood boring was evident despite the solid appearance of the block; dissection exposed 26 gribbles, and 2 wood-boring mollusks.

Fifth test block. This was removed February 10, 1961, 157 days after placement. It appeared entire and solid, but numerous small pinholes indicated internal boring. of 64 barnacles counted, 23 were dead. Hydroid colonies were common and appeared healthy, but no caprellid amphipods were observed on them. Three abalone jingles (Pododesmus cepio) , 2.5 cm (1 inch) in diameter, were noted along with gammarid amphipods, polychaete worms, and kelp scallops. Dissection of the block exposed only two wood-boring mollusks.

Sixth test block. This was removed March 1, 1961, 176 days after placement. It appeared solid and entire, but dissection exposed 35 gribbles and 2 small shipworms. There were 25 medium-sized barnacles distributed over the upper surface and sides, and lush hydroid growths were seen on all surfaces. Despite this abundant growth, caprellid amphipods were again absent. Thirty-five tiny kelp scallops were using the hydroid stems for attachment. Other organisms included gammarid amphipods, polyclad and polychaete worms.

Seventh test block. This was removed April 5, 1961, 211 days after placement. It appeared nearly entire, but showed severe gribble boring on the ends and shipworm pallets were protruding from surface openings. Dissection exposed surface-boring gribbles, several shipworms, and other wood-boring mollusks. Encrustment on the block surfaces was rich and diverse. The calcareous sponge, Leucosolenia botryoides, an encrusting ectoproct, Callopora circumclathrata, and the half-slipper snail made their initial appearances. Other organisms included polychaete worms, barnacles, gammarid and caprellid amphipods, and kelp scallops.

Eighth test block. This was removed May 9, 1961, 245 days after placement. The faunal composition was similar to that seen in April, with a few notable changes: (i) the hydroid growth was more lush, (ii) more borers were noted and (iii) the amphipod population had increased to over 400 individuals.

Ninth test block. This was removed June 2, 1961, 269 days after placement. It was soft, with eroded corners due to severe boring by the numerous shipworms and gribbles. All surfaces were heavily populated with hydroids, ectoprocts, sponges, polychaete worms, and mollusks. Only a few live barnacles were noted, many others had apparently succumbed to predation by polyclad worms.

Tenth test block. This was removed July 17, 1961, 314 days after placement. Although intact, it was soft and crumbly from extensive boring. With a few exceptions speciation was similar to that seen in June. Two mollusks, Chama pellucida and Mytilus edulis, were recorded for the first time and the polychaetes had decreased in abundance. Dissection of the block revealed that some shipworm mortality had occurred and that the nestling clam, Hiatella artica, was occupying some of the empty burrows.

By August no test blocks remained, presumably due to execessive boring by the shipworms and wood-boring mollusks.

8.1.1.4. Concrete Shelter Component Test Block Series

First test block. This was removed October 3, 1960, 27 days after placement. There were no discernible organisms or encrustments on it.

Second test block. This was removed November 7, 1960, 62 days after placement. Abundant hydroid colonies covered the block, but were especially lush on its upper surface. Nudibranchs (Hermissenda crassicornis) had grazed, and deposited their egg strings on these hydroids. Barnacles (1.2 cm, about 0.5 inch in diameter), polychaete worms, copepods, small abalone jingles and kelp scallops constituted the majority of organisms present.

Third test block. This was removed December 8, 1960, 93 days after placement. It was entire and relatively clean, without sediment accumulations. Aside from moderate hydroid colonies, only a few barnacles, polychaete worms, nudibranchs, a gammarid amphipod, an abalone jingle, and an unidentified copepod were recorded.

Fourth test block. This was removed January 18, 1961, 134 days after placement. It appeared similar to the one removed in December. Moderate hydroid growths, a few kelp scallops, and an increase in the polychaete worm population was noted.

Fifth test block. This was removed March 1, 1961, 176 days after placement. Hydroid colonies were sparse, but an increase in mollusk speciation (over the previous month) was noted. of particular interest was the first occurrence of a rock scallop (Hinnites multirugosus) and a horse mussel (Modiolus capax) on the test blocks. Wood-borers infested this block: 22 gribbles, 5 shipworms and 2 other wood-boring mollusks were found. One of the shipworms was 11.2 cm (about 4.5 inches) long.

Sixth test block. This was removed April 3, 1961, 209 days after placement. This block was still intact but external signs of wood boring were discernible. Hydroid colonies were sparse but an increase in ectoproct encrustment was noted. Few barnacles were present, but one large Balanus concavus pacificus, 2.5 cm (1 inch) in diameter was particularly prominent. Dissection of the block exposed 2 gribbles, 9 shipworms and one other wood-boring mollusk.

Seventh test block. This was removed May 9, 1961, 245 days after placement. The most obvious feature on this block was the enigmatic ctenostome, Victorella argilla, which covered almost the entire upper surfaces of the block. Live hydroids were sparse, but numerous dead stems suggested their former dominance. Over 600 gammarid amphipods were counted, many of these were tube dwellers. The polychaete worm population had increased to over 200. Dissection of the block revealed that little solid wood remained. Three gribbles and 28 shipworms were recorded.

Eighth test block. This was removed June 2, 1961, 269 days after placement. It was entire, but soft in several places due to extensive internal boring. In most respects it resembled the May block where ectroprocts, polychaete worms, and gammarid amphipods were prominent. The solitary ascidian, Chelyosoma productum, was recorded for the first time on this test block.

By July, no test blocks remained; wood borers had presumably destroyed the remaining four.

As observed from the above data, close faunal relationships existed among test blocks from the individual components at the Hermosa Beach reef, and speciation developed along remarkably similar lines (with the exception of the first block removed from the concrete shelters, where no organisms were found). The poorest overall speciation occurred on the automobile body series, a maximum of 22 species being recorded on the May test block. This may be contrasted with the rockpile test series, where 27 species were recorded in May and a plateau of 37 species occurred in June.

On November 30, 1964, six microscope slides (in a plastic holder) were affixed to the Hermosa Beach reef, rockpile component, to assist us in documenting those early settlers not recorded during our test block studies. Although personnel and time limitations prevented a complete analysis of this phase of reef life, the following observations warrant reporting.

Two slides were removed after seven days, December 7. These were inhabited by various diatoms, dinoflagellates and suctorians. One week later, two more slides were removed, and suctorians were the dominant group, diatoms were abundant, and we recorded the first hydroids, barnacles, and a flatworm. The final two slides were recovered on December 16, and added copepods, an ostracod, and a nudibranch to our list (Table 3).

TABLE 3

Organisms Collected from Microscope Slides Attached to the Hermosa Beach Reef, Rockpile Component; November 30, 1964

Date slide removed	*Dec. 7*	*Dec. 14*	*Dec. 16*
Days in place	*7*	*14*	*16*
Organisms		*Number per slide **	
Chlorophyta	P		
Protozoa			
Amphora sp.	S		
Ephelotacoronata sp.	A	A	A
Foraminifera	1	--	1
Gonyaulax polyhedra	S	--	--
Gromia oviformis	--	--	2
Grammatophora marina	C–A	A	A
Licmophora abbreviata	S	--	--
Navicyla sp.	--	S	S
Nitzschia sp.	C	--	--
Porifera (spicules)	C		
Hydrozoa			
Obelia sp., cf. *dichotoma*	--	1	4
Platyhelminthes (unid.)	--	1	1
Arthropoda			
Ostracod (unid.)	--	--	1
Copepod (unid.)	--	--	2
Balanus sp. (cypris)	--	1	1
Mollusca			
Doto sp.	--	--	1
Detritus	S	C	A

* Abundance symbols
P = present on the slide but relative abundance not estimated
S = sparse—widely scattered on the slide but nowhere numerous
C = common—unevenly present on the slide and only occasionally numerous
A = abundant—numerous and evenly distributed on the slide

TABLE 3
Organisms Collected from Microscope Slides Attached to the Hermosa Beach Reef, Rockpile Component; November 30, 1964

8.1.2. Santa Monica and Malibu Reefs

Colonization of test blocks at the Santa Monica and Malibu reefs proceeded in a fashion similar to that at Hermosa Beach. Tiny barnacles were common to abundant in the initial stages, with hydroids becoming firmly established by the second month. Polychaete worms were abundant on these blocks by the fifth month, slightly earlier than at Hermosa Beach. Maximum polychaete abundance occurred at the Santa Monica concrete shelters (Appendix 2). Although numerically greater concentrations of gammarid and caprellid amphipods occurred at Santa Monica and Malibu than at Hermosa Beach, the population peaks for these two groups were concurrent. Significantly, sponges did not establish on any of the Santa Monica reef test series, while at Malibu their colonization roughly paralleled that recorded at Hermosa Beach.

In the littoral environments along the southern California coast an apparent climax is reached in the Mytilus community. We have no indication that this type of climax will be found on the reefs; in fact, along our coast, Mytilus populations are marginal at 60-foot depths and in Santa Monica Bay they are uncommon to rare, presumably because of the turbidity.

Various investigators have speculated as to whether a seasonal progression or true succession occurs: Scheer (1945) cites his study in

Newport Bay, California, as an example of true succession, whereas, Reish (1964) describes his work in Alamitos Bay, California, as an example of seasonal progression.

Most test block studies previous to ours were conducted at modest depths (shallower than 20 feet) where seasonality and environmental extremes are pronounced and thus become major factors in community structure. Our studies were conducted at 60-foot depths, where environmental extremes are minimized and animal communities are notably more stable.

From our test block studies, quadrat scrapings, general observations, and the test block studies of Carlisle, Turner, and Ebert (1964) and Vaughan (1964) we conclude that true succession, as explained by Odum and Odum (1959) does occur sublittorally.

We did not study the algal-bacterial film stage described by Aleem (1957), but began with a barnacle-hydroid phase. In our investigation this was followed by less distinct mollusk-polychaete, ascidian-sponge, and finally encrusting ectoproct stages.

Evidence that these successions occur, in this sequence, and almost independent of surrounding organisms, was seen whenever we placed semipermanent structures on the reefs (test cages, pieces of anchor chain, etc.). Biological growth on each object followed the basic pattern in approaching the complex communities associated with a mature reef.

For example, in July, 1964, we placed a series of test blocks on the Hermosa Beach rockpile to assist us in studying the enigmatic ctenostome Victorella argilla. Instead of by-passing the initial stages and quickly attaining the rich and diverse assortment of encrusting growth found on the rocks to which the series was tied, the blocks went through exactly the same successional stages as did the original test series of 1960–61. In the first month tiny barnacles appeared, followed by moderate hydroid growths. Then came the mollusk-polychaete and ascidian-sponge complexes and finally the encrusting ectoprocts.

Termination of our test block studies prevented us from defining succeeding stages, but from our general observations it was apparent that several complex associations, involving the aggregate anemone (Corynactis californica) , gorgonians, and stony corals, will follow. Aggregate anemones become important during the second and third year of a reef's life, gorgonians appear in the third and fourth, and the first stony corals in the fifth.

8.2. QUADRAT SAMPLING

Quantitative sampling during our first year of study at these multicomponent reefs was accomplished with test blocks. After removal of the final test blocks (September 1961), successional studies were continued by selective collecting and general observations, with growth estimates being made by periodic sampling. These methods were useful for following qualitative changes but did not give any quantitative data comparable to the test block results. To meet this need, quadrat sampling was conducted in 1963. Samples were taken from the upper surface of a concrete shelter at each reef. In all, six samples were taken, two from each reef, during April, June and August.

Each sample area was randomly selected by making a blind cast with a stainless steel quadrat, 0.25 m on a side ($0.06\ m^2$), onto one of the concrete shelters from a height of 5 or 6 feet. All organisms within the boundaries of the quadrat were removed with a 3-inch-wide putty knife and hammer, and immediately placed in a large-mouth plastic container. During this process some organisms, particularly the more active swimmers and crawlers, were lost; but the majority, due to their tendency to cling to the substrate even during its removal, was recovered. Samples were preserved in 5% formalin for about 24 hours and then washed through a 0.5-mm-mesh screen. Organisms that passed through this screen were not retained, and no effort was made to identify the foraminiferans, nematodes, or copepods. Amphipods were identified only as gammarids or caprellids, and dead animals, such as empty snail and barnacle shells, were not included in the species list (Table 4).

Volumetric measurements (to the nearest 0.05 ml) were made, using the displacement method. These measurements included both the soft and hard (shells, tubes, etc.) animal parts. Volumes less than 0.05 ml were not recorded. In the case of the encrusting ectoproct, Victorella argilla, the silty sand it incorporates into its structure was also included and accounts for most of its volume.

Polychaete worm volumes were not taken for individual species but were combined for the entire class (Table 4). The nature and growth form of these animals (motile or sessile, erect or encrusting) and their distribution on the substrate presents special sampling problems. It would be almost impossible for any investigator to take two or three samples from the same area and obtain exactly the same species composition and volumes. Although our sampling was limited, it was representative, and appeared to be sufficient for measuring the numbers of organisms per unit area on the concrete shelters. These numbers may also be applied, generally, to the other reef components. The samples were taken during different months, but we made no attempt to describe successional changes such as was possible with the test block studies.

Except for the aggregations of phoronid worms (Phoronis sp.), the tanaid crustacean Leptochelia sp., and a few of the minute gastropods found only in these quadrat samples, our general collections and macroscopic observations of the reef epifauna, and its changes, compare quite closely with the speciation noted in the quadrat samples, thus attesting to the validity of our more general studies.

The ctenostome ectoproct Victorella argilla and its incorporated silty sand was characteristic of the surfaces sampled. This silty mat, varying in thickness from 2 mm (less than 0.13 inch) at Malibu to 5 mm (about 0.19 inch) at Santa Monica, was responsible for killing many barnacles and hydroids. We observed it actually growing over and eventually smothering these organisms, but aggregate anemones (Corynactis californica) , once established, were apparently avoided by Victorella. Phoronids and certain polychaetes also were influenced by, and in some cases dependent upon, this silt-like layer.

Large quantities of broken and empty mollusk shells, and numerous barnacles were notable in each quadrat sample.

TABLE 4
Invertebrates and Ascidians Collected from Within a 0.06 m² Area on the Concrete Shelter Portions of the Three Replication Reefs in Santa Monica Bay, 1963

Species	Number of individuals and their volume, by reef and collection											
	HERMOSA BEACH				SANTA MONICA				MALIBU			
	June		August		April		August		April		August	
	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)
Porifera												
Haliclona sp.	--	--	--	--	--	--	--	--	Col.	*15.50	--	--
Leucosolenia botryoides	--	--	--	--	--	--	Col.	<0.05	--	--	--	--
Cnidaria												
Hydroida												
Obelia sp.	Col.	<0.05	--	--	Col.	<0.05	Col.	<0.05	Col.	<0.05	Col.	0.08
Anthozoa												
Corynactis californica	--	--	--	--	--	--	--	--	133	29.30	--	--
Platyhelminthes												
Polyclad (unid.)	1	<0.05	--	--	--	--	--	--	--	--	2	<0.05
Sipunculoidea												
Phascolosoma agassizii	--	--	1	<0.05	--	--	--	--	2	0.08	--	--
Annelida												
Polychaeta	--	0.60	--	0.50	--	<0.05	--	0.85	--	3.70	--	1.00
Chaetopteridae												
Chaetopterus variopedatus	1	--	--	--	--	--	--	--	6	--	--	--
Chrysopetalidae												
Chrysopetalum occidentale	2	--	--	--	--	--	--	--	--	--	--	--
Cirratulidae												
Cirriformia sp.	11	--	--	--	--	--	--	--	--	--	--	--
unid. cirratulid	--	--	9	--	--	--	8	--	--	--	4	--
Flabelligeridae												
Stylarioides inflata	1	--	--	--	--	--	--	--	--	--	--	--
unid. flabelligerid	--	--	5	--	--	--	7	--	--	--	12	--
Lumbrineridae												
Lumbrineris sp.	5	--	--	--	--	--	--	--	1	--	--	--
unid. lumbrinereid	--	--	2	--	--	--	7	--	--	--	1	--
Nereidae												
Nereis sp.	12	--	--	--	--	--	--	--	--	--	--	--
unid. nereid	--	--	7	--	--	--	--	--	--	--	1	--
Opheliidae	--	--	--	--	--	--	--	--	3	--	1	--
Orbiniidae	12	--	10	--	--	--	--	--	--	--	--	--
Phyllodocidae	2	--	3	--	--	--	6	--	3	--	3	--

TABLE 4
Invertebrates and Ascidians Collected from Within a 0.06 m² Area on the Concrete Shelter Portions of the Three Replication Reefs in Santa Monica Bay, 1963

TABLE 4—Continued

Invertebrates and Ascidians Collected from Within a 0.06 m² Area on the Concrete Shelter Portions of the Three Replication Reefs in Santa Monica Bay, 1963

Species	Number of individuals and their volume, by reef and collection											
	HERMOSA BEACH				SANTA MONICA				MALIBU			
	June		August		April		August		April		August	
	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)
Annelida—continued												
Polychaeta—continued												
Polynoidae												
Eunoe sp.	5	--	--	--	--	--	--	--	--	--	--	--
Halosydna sp.	--	--	--	--	--	--	--	--	1	--	--	--
unid. polynoid	--	--	2	--	--	--	28	--	--	--	61	--
Sabellariidae												
Sabellaria cementarium	7	--	--	--	--	--	--	--	--	--	--	--
unid. sabellarid	--	--	8	--	--	--	3	--	--	--	--	--
Sabellidae												
Sabella sp.	2	--	--	--	--	--	--	--	--	--	--	--
unid. sabellid	--	--	4	--	--	--	--	--	--	--	1	--
Serpulidae												
Spirobranchus spinosus	--	--	--	--	--	--	--	--	3	--	--	--
Spionidae												
Polydora sp.	3	--	--	--	--	--	--	--	--	--	--	--
unid. spionid	--	--	2	--	--	--	--	--	2	--	1	--
Syllidae	--	--	--	--	1	--	--	--	1	--	--	--
Arthropoda												
Crustacea												
Cirripedia												
Balanus aquila	--	--	--	--	28	137.50	1	10.69	8	13.00	--	--
Balanus concavus pacificus	51	57.65	45	1.80	64	62.50	15	8.70	35	5.10	4	0.80
Balanus flos	--	--	--	--	1	0.08	--	--	--	--	--	--
Balanus tintinnabulum californicus	--	--	--	--	1	0.60	--	--	--	--	--	--
Balanus trigonus	--	--	15	0.85	--	--	--	--	20	1.60	2	0.30
Tanaidacea												
Leptochelia sp.	67	0.05	185	0.15	--	--	--	--	--	--	5	<0.05
Isopoda												
valviferan	1	<0.05	--	--	--	--	--	--	--	--	--	--
Amphipoda	--	0.05	--	<0.05	--	0.08	--	--	--	--	--	--
Gammaridea	48	--	11	--	45	--	21	<0.05	3	<0.05	28	0.05
Caprellidea	12	--	2	--	4	--	--	--	--	--	10	0.05

TABLE 4
Invertebrates and Ascidians Collected from Within a 0.06 m² Area on the Concrete Shelter Portions of the Three Replication Reefs in Santa Monica Bay, 1963

Decapoda												
Alpheus dentipes	--	--	--	--	--	--	1	0.50	--	--	--	--
Cancer anthonyi	--	--	--	--	--	--	--	--	--	--	8	0.20
Cancer jordani	--	--	--	--	--	--	2	0.10	--	--	--	--
Cancer sp.	--	--	6	<0.05	--	--	--	--	1	0.10	--	--
Loxorhynchus crispatus	--	--	2	0.08	--	--	--	--	2	0.70	1	<0.05
Pycnogonida	--	--	1	<0.05	--	--	--	--	--	--	3	<0.05
Mollusca												
Pelecypoda												
Chama pellucida	--	--	--	--	--	--	--	--	4	0.90	1	<0.05
Chione sp.	1	<0.05	--	--	--	--	--	--	--	--	--	--
Hiatella arctica	34	0.08	15	0.15	3	<0.05	1	<0.05	13	0.70	12	0.20
Kellia laperousii	5	<0.05	--	--	3	<0.05	3	<0.05	3	<0.05	10	0.10
Leptopecten latiauratus	--	--	--	--	--	--	--	--	1	<0.05	--	--
Lima hemphilli	--	--	1	<0.05	--	--	--	--	--	--	--	--
Modiolus capax	1	<0.05	3	<0.05	--	--	--	--	--	--	1	<0.05
Petricola sp.	--	--	1	<0.05	--	--	--	--	--	--	--	--
Parvilucina tenuisculpta	2	<0.05	23	0.05	--	--	--	--	--	--	--	--
Pododesmus cepio	1	0.18	--	--	--	--	--	--	2	4.20	--	--
Saxidomus nuttalli	--	--	--	--	--	--	--	--	--	--	1	0.05
Gastropoda												
Acanthodoris lutea	2	<0.05	--	--	--	--	--	--	--	--	--	--
Amphissa versicolor	--	--	35	0.05	--	--	--	--	--	--	--	--
Conus californicus	--	--	4	0.08	--	--	--	--	--	--	--	--
Crepipatella lingulata	19	0.55	65	1.10	4	0.05	2	0.05	--	--	3	<0.05
Dendronotus frondosus	1	<0.05	--	--	--	--	--	--	--	--	--	--
Epitonium bellastriatum	--	--	1	<0.05	--	--	--	--	--	--	--	--
Epitonium sawinae	--	--	3	<0.05	--	--	--	--	--	--	--	--
Fusinus traski	--	--	2	0.20	--	--	--	--	--	--	3	0.20
Hermissenda crassicornis	--	--	--	--	--	--	--	--	1	0.15	--	--
Micranellum crebricinctum	--	--	1	<0.05	--	--	--	--	--	--	--	--
Mitrella tuberosa	2	<0.05	--	--	--	--	1	<0.05	--	--	--	--
Nassarius perpinguis	--	--	17	0.10	--	--	1	<0.05	2	<0.05	9	<0.05
Olivella baetica	--	--	4	0.10	--	--	--	--	--	--	--	--
Retusa sp.	1	<0.05	5	<0.05	1	<0.05	--	--	--	--	1	<0.05
Serpulorbis squamigerus	--	--	--	--	--	--	--	--	1	0.30	--	--
Turbonilla kelseyi	--	--	10	0.05	--	--	--	--	--	--	--	--
Ectoprocta												
Crisia sp.	--	--	Col.	0.30	--	--	--	--	Col.	0.80	Col.	0.30
Diaperoecia floridana	--	--	--	--	--	--	--	--	--	--	--	--
Scrupocellaria diegensis	--	--	--	--	--	--	--	--	--	--	Col.	0.40
Victorella argilla	Col.	70.75	Col.	16.60	Col.	48.45	Col.	41.60	Col.	7.10	Col.	5.10
Phoronidea												
Phoronis sp.	20	0.40	125	2.70	6	<0.05	18	0.15	--	--	225	4.50

TABLE 4—Cont'd.

TABLE 4—Continued

Invertebrates and Ascidians Collected from Within a 0.06 m² Area on the Concrete Shelter Portions of the Three Replication Reefs in Santa Monica Bay, 1963

Species	Number of individuals and their volume, by reef and collection											
	HERMOSA BEACH				SANTA MONICA				MALIBU			
	June		August		April		August		April		August	
	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)
Echinodermata												
Ophiuroidea												
Ophiothrix spiculata	--	--	--	--	--	--	--	--	1	<0.05	2	0.60
Holothuroidea												
Eupentacta quinquesemita	--	--	7	0.10	--	--	--	--	--	--	1	<0.05
Chordata												
Tunicata												
Pyura haustor	--	--	1	0.30	--	--	--	--	1	0.30	--	--
Total species	32	--	40	--	14	--	20	--	30	--	34	--
Total volume	--	129.77+	--	25.26+	--	249.26+	--	62.67+	--	83.53	--	13.93

* Col. = colony.

TABLE 4—Cont'd.

The Malibu reef samples were collected in April and August, 1963. The April sample (Table 4) was composed primarily of a thin layer of Victorella argilla (about 2 mm thick), and large clusters of aggregate anemones which were attached to the sides of the numerous barnacles. The 133 anemones present in this quadrat contributed a volume of 29.30 ml. The three species of barnacles (63 individuals totaling 19.70 ml) were of secondary importance (volumetrically). An encrusting sponge, several mollusks and polychaete worms, a few additional crustaceans, hydroids, sipunculid worms, a tunicate, a brittle star, and a cyclostome ectoproct were also present.

By cotrast, in August, we found a phoronid worm, Phoronis sp., established in large intertwining masses beneath the mat of Victorella, but sponges and anemones were absent. Tanaid crustaceans (Leptochelia sp.) were recorded for the first time. Barnacles, mollusks, and ectoproct fragments made up 35.50 ml of the 50.63 ml total volume in the sample.

The Santa Monica reef samples were also collected in April and August (Table 4). In both of these, Victorella formed a layer up to 5 mm (about 0.19 inch) thick over most of the sessile organisms. Barnacles (four species) were dominant in April, and the 94 individuals displaced 200 ml. In August only 16 barnacles (two species, volume 19.39 ml) were recorded. Hydroids were sparse in both samples, and a sponge was present only in August—a small piece of a simple ascontype calcareous sponge. Fifty-nine polychaetes, representing five families, were present in August compared with only one polychaete in the April sample.

Quadrat samples from the Hermosa Beach reef were collected in June and August (Table 4). The June sample had a 3 mm (about 0.13 inch) thick layer of Victorella covering most of the other attached growth. Sponges were absent and hydroids were sparse, but phoronids were present beneath the ectoproct layer and 63 polychaete worms, representing 12 families, were recorded. The crustaceans included 51 barnacles (one species), an unidentified isopod, 67 tanaids, and 48 gammarid and 12 caprellid amphipods. Six pelecypod and five gastropod mollusks were present.

The August quadrat contained many fragments of gastropod and pelecypod mollusks, barnacles, ectoprocts, and an otolith (ear stone) from a queenfish (Seriphus politus) . The complete Victorella—Phoronis layer was about the same thickness as that recorded in June. Sponges and hydroids were absent and an estimated 85% of the barnacles were dead—only their empty shells remained. The two species of living barnacles were all small. Additional arthropods included 185 tanaids, a small unidentified pycnogonid (sea spider), 6 tiny cancer crabs, 2 small spider crabs, and 11 gammarid and 2 caprellid amphipods. Mollusks were small but numerous, represented by 5 pelecypod and 11 gastropod species. The dominant gastropod was the half-slipper snail Crepipatella lingulata (65 individuals). of particular interest was the occurrence of small horse mussels (Modiolus capax) and juvenile cone snails (Conus californicus) , again substantiating the close correlation between our general observations and the quantitative quadrat samples.

8.3. ALGAE

We recorded four brown (Phaeophyta) and four red (Rhodophyta) algae as natural inhabitants of the three WCB reefs. A fifth red alga (Botryocladia pseudodichotoma) is common in the area near the Redondo Canyon reef, but by 1964, had not appeared on the reef proper. Two additional species, Enteromorpha intestinalis (Chlorophyta—green algae) and Ectocarpus granulosoides (Phaeophyta) were commonly observed on all the artificial reef buoys, but did not establish on the reefs proper (presumably due to depth). These recorded algae were all of minor importance on the reefs due to their limited size and number, although some furnished attachment space for ectoprocts and all were grazed upon by fishes or invertebrates.

Giant kelp (Macrocystis) was unsuccessfully transplanted onto the Hermosa Beach and Malibu reefs. Our transplanting techniques are discussed following the general species accounts.

8.3.1. Phaeophyta—brown algae

These are the large, so-called seaweeds or kelps. Some may exceed 100 feet in length, although other forms are reduced and simple and may be epiphytic. Growth rates for brown algae are phenomenal and are reputed to exceed all others in the plant kingdom. Few brown algae occur below depths of 100 feet along the southern California shelf, presumably because of insufficient illumination for photosynthesis. We have not observed them below 90 feet in Santa Monica Bay.

The four browns naturally occurring on the reefs were temporal, being present during the late summer, fall and early winter. Their growth and development were severely restricted compared to what we observed for similar species outside the Bay. Under present oceanographic conditions in the Bay we do not expect any of these to become established in large numbers on the artificial reefs.

8.3.1.1. Desmarestia munda Setchell and Gardner, 1924.—brown alga

Description. Yellowish brown to dark brown in color; pinnately branched, the branches opposite with stipitate bases. Axis and branches fringed with filaments that are particularly evident in juvenile plants but soon become deciduous. Our plants did not exceeed 20 cm (about 8 inches) in length.

Habit and habitat. Usually requires rock or other firm substrate for holdfast anchorage, although in calm water areas this species does exist on sand.

Occurrence. Hermosa Beach and Malibu reefs. Juvenile plants were first found on the concrete shelters at these reefs in September 1962 and remained through October. New thalli were again observed in August 1963 on all materials at Hermosa Beach and concrete shelter and rockpile portions at Malibu. No thalli survived beyond December.

8.3.1.2. Dictyota flabellata (Collins) Setchell and Gardner, 1924.—brown alga

Description. A small brown alga. Thallus dichotomously branched but appearing alternate because of unequal growth of the two arms of each dichotomy. Blades three cell layers thick, with smooth margins.

The thallus is blackish-brown basally, grading to a yellowish-brown distally.

Habit and habitat. Requires firm substrate for attachment. Recorded intertidal to 75 feet (Dawson, Neushul and Wildman, 1960).

Occurrence. Juvenile plants were found only once (March 1961), at the Malibu reef—not subsequently seen or recorded.

8.3.1.3. Egregia laevigata Setchell, 1896.—strap kelp

Description. A large and one of the better known brown algae. The stipe has long branches that are bladed; several of these branches bear float organs (pneumatocysts). Thalli on our reefs were all juveniles, and consisted of single blades with undulate margins. They did not exceed 10 cm (about 4 inches) in length.

Habit and habitat. Requires firm substrate, such as rock, for holdfast attachment. Seldom found below depths of 30 feet. This limited bathymetric range precludes its establishment on the man-made reefs.

Occurrence. Hermosa Beach reef rockpile in October and November 1963.

8.3.1.4. Laminaria farlowii Setchell, 1893.—brown alga

Description. Sporophytes with a single dark brown stipe and blade. Blade smoothish (in immature plants) and broadly rounded basally. Our specimens were juveniles not exceeding 10 cm (about 4 inches) in length.

Habit and habitat. Attachment by holdfast to any solid material.

Occurrence. First noted in October 1962 at the Hermosa Beach and Malibu reefs. Grazing was at least partially responsible for its demise by November. Sporophytes again appeared in October 1963 and survived until November.

8.3.2. Rhodophyta—red algae

Members of this class are pigmented either red or bluish, are of small to medium size, usually multicellular, and may be branched, unbranched, or filamentous. Filamentous types are often epiphytic.

Red algae occur intertidally to depths of several hundred feet. They are able to survive at substantial depths because of their ability to absorb and use the shorter wave lengths of light (Tshudy, 1934). Reds become the dominant algae in Santa Monica Bay below 70 feet.

Rhodophytes occurred on the man-made reefs throughout the year, but exhibited definite seasonal "blooms." Our observations in nearby natural reef areas indicated these fluctuations and abundance levels were normal for this general area.

8.3.2.1. Antithamnion occidentale Kylin, 1925.—red alga

Description. Small and delicate; our specimens did not exceed 4 cm (about 1.5 inches). Profusely branched, the branching primarily opposite.

Habit and habitat. Requires firm substrate, frequently attaches to other algae.

Occurrence. Initially collected at the Malibu reef (March 1961) and subsequently found at the Hermosa Beach reef. Although occasionally seen throughout the study it was never common.

8.3.2.2. Botryocladia pseudodichtoma (Farlow) Kylin, 1931.—sea grapes

Description. Very distinct, with disc shaped holdfast; the short branched stripe bearing cylindrical, sausage shaped vesicles; deep rose-red, almost purplish in color.

Habit and habitat. Commonly attaches to cobbles and larger rocks in waters 70 to 120 feet deep.

Occurrence. Present in the area adjacent to the Redondo Canyon reef before and after reef placement. Never observed on the reef proper.

8.3.2.3. Porphyra thuretii Setchell and Dawson, 1944.—red alga

Description. Thalli with a single reniform blade borne on a minute stipe. Although it reportedly attains lengths of 75 cm (almost 30 inches) ours did not exceed 7.6 cm (3 inches). Reddish-purple in color.

Habit and habitat. Attachment by holdfast to rocky substrate; preferring the upper surfaces.

Occurrence. Only at the Hermosa Beach reef. Thalli appeared annually, about June, disappearing by January.

8.3.2.4. Rhodymenia californica Kylin, 1931.—red alga

Description. Small bright red alga, seldom exceeding 7.6 cm (3 inches) in length. Attaches by a conical holdfast. Blades narrow and dichotomously branched.

Habit and habitat. Attaches to rocky substrate, preferring the well illuminated upper surfaces, often heavily encrusted with ectoprocts.

Occurrence. Present on the rockpiles and concrete shelters at each replication reef. Noted annually in early summer with maximum sizes and abundances occurring by October. Grazing and ectoproct encrustment severely affected Rhodymenia thereafter, and only a few unhealthy-appearing plants survived through winter.

8.3.2.5. Taenioma sp.—red alga

Description. A tiny, filamentous alga appearing moss-like underwater. The prostrate primary axis bears tiny rhizoids, and erect, freely branched shoots. The color is a deep pinkish-red.

Habit and habitat. Epiphytic, commonly attaches to the ectoproct Victorella argilla.

Occurrence. Not recorded from the replication reefs until August 1963, but because of its inconspicuous nature it may have been present somewhat earlier. This alga established on each of the replication reefs and became relatively abundant; its abundance being directly related to the amount of Victorella present.

8.3.3. Kelp Transplants

Giant kelps, Macrocystis spp., the largest known marine plants, attain lengths in excess of 165 feet. Plants are attached to the substrate by large holdfasts analogous to the root systems of terrestrial plants. Long stipes extend upward and onto the water surface often creating expansive surface canopies. Stipe flotation is provided by pneumatocysts, one of which forms the base of each lanceolate blade.

Three species are recognized from the west coast of North America: M. pyrifera, M. angustifolia and M. integrefolia (Neushul, 1959). M. integrefolia is usually found north of Monterey, California; M. angustifolia from Monterey south to near San Diego; and M. pyrifera from San Diego into southern Baja California.

Bathymetrically giant kelp ranges from the intertidal to over 100-foot depths. Generally a rocky substrate is required for holdfast anchorage, but Dawson, Neushul, and Wildman (1960) report that plants may grow on sand bottoms in certain localities and depths.

Observations in natural reef areas substantiate the importance of giant kelp in the reef ecosystem. An overall increase in reef productivity is reflected through increases in both available habitat and herbivore populations.

Giant kelp became established naturally only on the Paradise Cove car body reef (Carlisle, Turner, Ebert, 1964), presumably due to this reef's proximity to an existing kelp bed. To overcome this lack of natural seeding we attempted, unsuccessfully, to transplant giant kelp to the other reefs. In 1959 we transferred plants from the Paradise Cove car body reef to the Redondo Beach streetcar reef. These plants, transported in tubs of water on our diving boat Dolphin, and affixed with nylon line to the streetcar roof, were quickly devoured by herbiverous fishes (opaleye and halfmoon). To combat grazing activity our next transplants were protected by hardware cloth cages, open at the top, allowing the long stipes and blades to trail upward. These transplants survived a few weeks but adverse oceanographic conditions (warm turbid waters) resulted in their demise.

In February 1961, mature kelp plants were transplanted from the Paradise Cove reef to the Malibu reef concrete shelters. These plants, collected in 40- and 50-foot depths and protected from grazers by net sacks and wire cages, ranged from 3 to over 75 feet long. Only those plants whose stipes reached the illuminated surface waters (larger plants and those which we had floated above the substrate on 10- to 15-foot tag lines) survived past April. After July, warming surface waters apparently caused their destruction.

Because of the detrimental effects of warm water (summer warming) on local kelps, we endeavored to introduce a warm water resistant strain from Baja California. Plants were obtained March 19 and 20, 1961 from 25 to 50 feet of water in Bahia Tortugas, Baja California. They were placed in the bait wells of the California Department of Fish and Game research vessel Alaska and transported to the Hermosa Beach, Malibu and Paradise Cove reefs. Eight additional plants were flown to southern California, in a Department airplane, and tied to the Hermosa Beach reef March 21, 1961.

Plants shipped by air appeared healthy and in good condition when tied on the reef, while those transported in the bait well of the Alaska did not. During the 7-day trip, rough weather was encountered and most plants were cut and severely bruised. Growth was noted for some plants at each transplant location but none survived beyond July 1961—a period of only 4 months.

The ultimate failure of our giant kelp transplants was apparently the turbidity of the bay water, which severely restricted the amount of light available to the plants for photosynthesis. Grazing (by herbivorous fishes) was a minor factor, except with the unprotected plants. Sea urchins, whose grazing activities are reported by North (1963) to be a major factor in limiting the kelp at Palos Verdes Peninsula and Point Loma, were never a problem on the replication reefs. Sea urchins were recorded only twice during this study.

8.4. INVERTEBRATA AND TUNICATA

Man-made reefs are potential habitat not only for fishes and larger invertebrates but also for numerous less economically important or seemingly "insignificant" organisms. Even the most cursory life cycle study of an "economically important" species must mention its food, feeding habits, and position in the food web (trophic level). This, in itself, is sufficient justification (if such is needed) for the study of these "insignificant" forms, the lower links in food chains.

Ideally, in any ecologic investigation, every bacterium, protozoan, crustacean and worm should be counted, identified, and given a position in the ecosystem. The enormity of this task does not preclude its importance. In the present investigation no provision was made for such a detailed study, instead those animals selected by us for closer observation were judiciously chosen as representatives of their taxonomic groups at the various trophic levels.

The following species index includes all the invertebrates and ascidians recorded from our analyses of test blocks, quantitative substrate scrapings, and periodic field notations made on the artificial habitat structures during more than 3 years of study, August 1960 through November 1963. Many were identified to species, and their habitats and trophic positions easily determined. We have reported others at various higher taxa and have placed them in general ecologic groupings (i.e., tubiculous vs. errant polychaete worms; encrusting vs. amorphous sponges). The heading "Importance" with each description stresses the significance of the animal in the food web on *these* artificial reefs and not necessarily its commercial or economic status, nor its status on other reefs.

This systematic treatment of the invertebrates and ascidians that we encountered during our study will serve as an annotated reference list for their mention in the rest of the text. Unless noted otherwise, the organisms are listed alphabetically (by genus) within each phylum or class.

8.4.1. Protozoa

Acellular animals lacking tissues or organs; existing singly or in colonies of few or many individuals. Most are of small or microscopic size, from 2 or 3 microns to several centimeters in length (after Hyman, 1940).

Many protozoans were present on the artificial reef materials, but only two groups occurred regularly and in sufficient numbers to warrant our further investigation.

8.4.1.1. *Family Folliculinidae*—bottle animalcules

Description. Ciliate protozoans which secrete a bottle or vase-shaped case of **tectin** (pseudochitin), a protein-carbohydrate complex chemically similar to mucus or slime. The case, about 0.75 mm long and dark-colored, is the most conspicuous part of the animal.

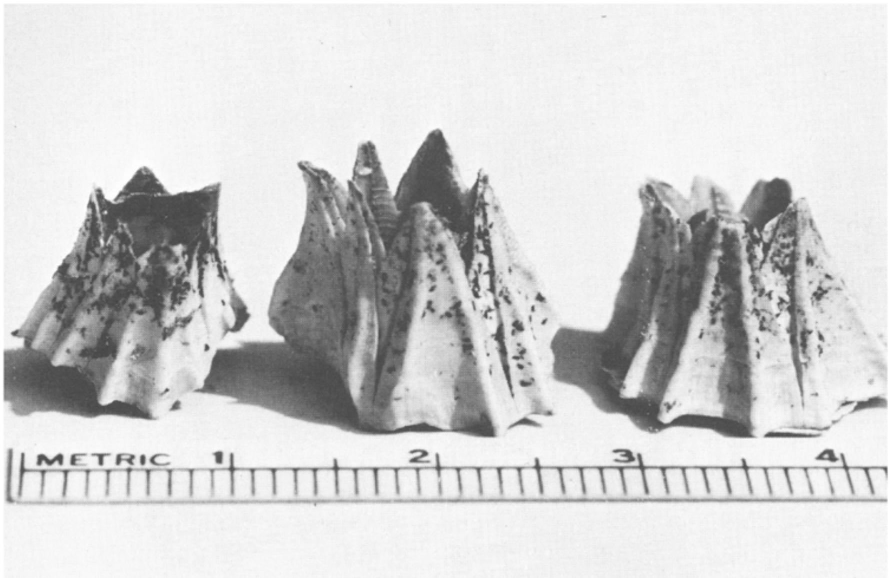

FIGURE 16 The pepper-like speckles on the barnacles (*Balanus flos*) are folliculinids, bottle animicules. *Photo by Robert R. Given.*

FIGURE 16 The pepper-like speckles on the barnacles (Balanus flos) are folliculinids, bottle animicules. Photo by Robert R. Given.

Habit and habitat. In this study folliculinids were represented by at least two genera, and were found cemented to three types of substrate: (i) on the bare wood of test blocks (Folliculina sp.); (ii) on mollusk shells and barnacle plates (Folliculina sp.); and (iii) on the pleotelson of Limnoria tripunctata (Mirofolliculina sp.).

They occurred singly but gregariously, covering large surface areas on mollusk shells and barnacles (Figure 16). Three to five folliculinids were found attached to the pleotelson of the gribble Limnoria.

Occurrence. Because we failed to recognize them as protozoans until late in the study our records of their occurrence are few but indicative of their abundance over large surface areas.

Importance. Due to the protein-carbohydrate nature of their tectin case, folliculinids can contribute significant amounts of nutrient to the food web, especially at lower trophic levels. Although we did not discover folliculinids in the gut contents of other animals, we feel that they are probably grazed upon by small crustaceans and some polychaete worms which in turn are a direct food source for reef fishes.

8.4.1.2. Gromia oviformis Dujardin, 1835.—testate protozoan

Description. Small (average 2–4 mm), spherical, light-brown, free-living, solitary amoeboid protozoans enclosed in a case or test. They are easily mistaken for fecal pellets or fish eggs (Figure 17).

FIGURE 17 The egg-like structures attached to this red algae are the testate protozoan *Gromia oviformis. Photo by Robert R. Given.*

FIGURE 17 The egg-like structures attached to this red algae are the testate protozoan Gromia oviformis. Photo by Robert R. Given.

Habit and habitat. Common to very abundant, attached to a variety of algae, the surf grass Phyllospadix and many invertebrates, particularly sponges and ectoprocts. We have recorded it from intertidal into depths exceeding 100 feet (Turner, Ebert and Given 1968).

Occurrence. As with the folliculinids these protozoans were not recognized and, hence, were not recorded until late in the investigation. During the initial 3-year scope of the project only one record (Santa Monica rockpile test block, May 1961) was made. Subsequent observations (1964), confirmed its presence on the reefs.

Importance. Similar to folliculinids since their test or case is composed of the same protein-carbohydrate complex (tectin). Its relatively large size and loose attachment to the substrate may make it an attractive morsel for smaller fishes and possibly some larger crustaceans and worms.

8.4.2. Porifera

Porifera are simple, non-motile (in adult stages), multicellular animals lacking organs or a nervous system with a symmetrical or asymmetrical aggregation of cells forming a body with canals, pores, and chambers for passage of water. Usually they are supported by a skeleton of calcareous or siliceous spicules, horny fibers, or neither or both.

These lowly animals are classified according to the presence or absence of certain spicule types and, to a lesser extent, the degree of complexity of canal and chamber construction. of interest in this study is the succession of sponge species on the reefs and their effects on associated fauna. They are sessile and feed on organisms from the water that passes through the canal systems; hence, there is no active predation or related movement.

Sponges with spicules of calcium carbonate are listed in the class Calcarea, their construction is usually simple.

8.4.2.1. Leuconia barbata (Duchaissaing and Michelotti, 1864)—calcareous sponge

Description. A large, solid, erect, amorphous white sponge. Surface texture is superficially smooth, but with many large lumps and ridges breaking any symmetry. Large excurrent openings (oscules) are characteristic. The complex structure of the inner canals and chambers provides potential hiding places for many small worms and crustaceans.

Habit and habitat. A very common shallow-water sponge along the southern California coast. We have observed it attached to various solid objects at depths of 20 to 80 feet.

Occurrence. Not seen on test blocks or reef materials during their early stages. This species appeared at Malibu a year after reef placement, at Hermosa Beach (January 1962) in small patches, and was common to abundant at Malibu later in the study (April 1963).

Importance. Spicules of this sponge were found once in the stomach of a rubberlip perch (Rhacochilus toxotes) , but probably were taken incidentally and not as food. This species' size and complex structure (Figure 18) make it important on local natural reefs. Its late

FIGURE 18 The calcareous sponge *Leuconia barbata,* attached to a mussel mass on an off-shore oil drilling platform near Santa Barbara. *Photo by Charles H. Turner.*

FIGURE 18 The calcareous sponge Leuconia barbata, attached to a mussel mass on an off-shore oil drilling platform near Santa Barbara. Photo by Charles H. Turner.

appearance on the artificial structures lessened its importance in the present study.

8.4.2.2. Leucosolenia botryoides (Ellis and Solander, 1786)—calcareous sponge

Description. One of the most simply constructed sponges known. Composed of a loose aggregation of cells and spicules forming a dirty white mass of slender upright tubes connected basally by a creeping tubular network of the same material.

Habit and habitat. Formed large, spreading masses on the bare wood of early test blocks and on other reef surfaces. First noticed as small, white isolated mounds, eventually spreading in a horizontal network giving rise to upright tubules every few millimeters.

Occurrence. The first sponge noted on any of the reef materials. It appeared at Hermosa Beach approximately 7 months after reef placement, but only on the rock and concrete components. At Malibu this species occurred only on the streetcar and rock components and was not found at Santa Monica. It grew from a few scattered mounds and tubules to a wide, thick mat in 3 months (at Hermosa Beach). At Malibu, L. botryoides was thick and abundant when first noted, so it was probably present for at least 3 months prior to our first record. The "Leucosolenia sp." we recorded from some of the test blocks might have been L. botryoides in the early stages when its characteristic upright tubules were not yet developed. It was the only sponge found on the test block series.

Importance. Probably offers little or no potential food directly to reef animals with the possible exception of some nudibranch mollusks. Its major contribution lies in its growth form. The large masses of interconnecting horizontal and erect tubules afford protection and habitat for many small motile reef dwelling amphipods and worms. Its spicules have been found in fish stomachs, but were likely the result of an attack on a hiding crustacean rather than on the sponge itself.

8.4.2.3. Leucosolenia sp., —see Leucosolenia botryoides "Occurrence"

Recorded at the generic level because the characteristic tubular structures had not formed and species identification was uncertain.

8.4.2.4. Scypha ciliata (Fabricius, 1780)—thistle sponge

Description. Vase-shaped, erect, whitish calcareous sponge. In northern California this species grows to large sizes (9 to 11 cm); our specimens were all small (2 by 10 mm).

Habit and habitat. Grows in small, neat clusters in areas protected from violent wave action and scouring. Not a large, spreading species and not common on the reef materials. Seemed to prefer flat surfaces on the concrete shelter components. Frequently overgrown by Victorella argilla.

Occurrence. Observed early (first few months), attached to guide lines running between reef materials. Not recorded on the test blocks. Recorded on the Malibu concrete shelters (September 1961); one small mass from a surface scraping. Subsequently recorded on the Hermosa

Beach reef (September 1961) in a miscellaneous collection (concrete shelters). Heaviest concentrations were noted on the rock and concrete shelter components, particularly at Santa Monica.

Importance. of undetermined importance, may supply some attachment space for small crustaceans. Probably plays a minor role in the ecology of these reefs.

The Class Demospongia is comprised of sponges with siliceous spicules or horny fibers that make up the skeletal structure. Members of this class are generally complex, relatively large, and have special morphologic adaptations for their environment. Demosponges appeared quite late in the successional picture of the artificial structures and were not recorded on the test blocks. Their importance in this study lies in this "late" appearance, large size, and their tendency to spread laterally and take over sizeable areas of substrate. They also offer potential habitat and protection for many small animals.

8.4.2.5. Aplysilla glacialis (Dybowski, 1880)—keratose sponge

Description. Encrusting up to 3 mm thick (in this study); texture soft, color rosy. Lacks spicules, the supporting structures being horny fibers and cells.

Habit and habitat. Attaches to various firm substrates.

Occurrence. One colony noted (April 1963) on the Hermosa Beach reef rock component; not recorded subsequently.

Importance. May offer slight protection to tiny crustaceans and worms. This sponge normally grows to several centimeters in height and could become a major structure on the reef.

8.4.2.6. Ficulina sp., cf. suberea lata (Lambe, 1892)—encrusting sponge

Description. Although the single specimen recorded during this study follows the description of F. suberea lata, specific identification is tentative because the growth form observed was low, encrusting, and showed no evidence of the massive subspherical form typical of the species.

Habit and habitat. Low growing and encrusting, during the study period, but may become more massive and larger with time.

Occurrence. First noted (August 1963) on the concrete shelters at Santa Monica; no subsequent observations.

Importance. Probably of little significance in reef succession at present. Its smooth, encrusting habit offers no protection for small invertebrates, but in time it may spread, grow higher, and become an important physical factor on the reef.

8.4.2.7. Haliclona permollis (Bowerbank, 1866)—amorphous sponge

Description. Soft, low-growing, lavender-colored sponge with large excurrent openings (oscules). Surface very porous (Figure 19).

Habit and habitat. First noted as small isolated clumps on the reef materials; at times covering areas up to 2 inches square. These in time enlarged and spread laterally. Usually found on the upper surfaces of

FIGURE 19 The amorphous sponge, *Haliclona permollis.* Note its soft, porous, appearance. Malibu reef, concrete shelters, April 1963. *Photo by Charles H. Turner.*

FIGURE 19 The amorphous sponge, Haliclona permollis. Note its soft, porous, appearance. Malibu reef, concrete shelters, April 1963. Photo by Charles H. Turner.

the rock material, or on the rims of holes in the concrete shelters. A brownish-tan color phase, said by de Laubenfels (1932) to be pathological, was seen in several specimens.

Occurrence. Observed on all of the Hermosa Beach concrete shelters (August 1963), covering areas 18 to 24 inches in diameter, around the holes and on the flat surfaces. Both lavender and brownish phases grew concurrently and side by side. Not recorded on test blocks or in the early observations. We subsequently found large, brownish masses of this species on the Malibu rock and concrete shelter components (August 1963).

Importance. Important physically and biologically, H. permollis covers large surface areas, competing with other encrusting forms for space, while providing potential habitat and shelter for small invertebrates.

8.4.2.8. Haliclona sp.—encrusting sponge

Description. Soft, encrusting, canal openings inconspicuous, drab. Appears similar to H. permollis, but lacks the large oscules and porous surfaces characteristic of that species.

Occurrence. Not seen on the test blocks. First noted in small, isolated patches on the rock component of Hermosa Beach reef (August 1963). Subsequently seen later the same month on other Hermosa Beach reef components and at the Santa Monica rock component; in its early "clump" stage.

Importance. Similar to H. permollis, but less prolific.

8.4.2.9. Lissodendoryx noxiosa de Laubenfels, 1930—amorphous sponge

Description. Color drab to yellowish; shape amorphous, extremely variable.

Habit and habitat. This sponge is truly amorphous, and has no characteristic shape. It seldom grows alone, but is usually found covering or growing in close proximity to other encrusting organisms. It forms a large part of the substrate "mat," and has a marked effect on the organisms it associates with or encrusts, often either killing them or changing their growth habits.

Occurrence. Not present on the test blocks. First seen on the Hermosa Beach rock components (April 1963); not recorded subsequently.

Importance. (see *Habit and habitat*). Although not a major factor in the reef ecology encompassed by this study, L. noxiosa is one of the most prolific and common sponges on the southern California coast, and will undoubtedly become more important as the reefs mature.

8.4.2.10. Mycale macginitei de Laubenfels, 1930—encrusting sponge

Description. Thinly encrusting, brownish-drab, surface smooth, excurrent openings inconspicuous.

Habit and habitat. May encrust large surface areas.

Occurrence. One record in this study, on the shell of a rock scallop (Hinnites multirugosus) ; Malibu reef rock component (August 1963).

Importance. Probably not important as food or habitat for small animals but undoubtedly affects those it encroaches upon or covers.

8.4.2.11. Zygherpe hyaloderma de Laubenfels, 1932—encrusting sponge

Description. Very smooth, thinly encrusting (up to 3 mm thick) and soft. Bright yellow; canals obvious, running beneath epidermis.

Habit and habitat. Characteristically covers large areas, spreads laterally as surface permits.

Occurrence. Found once on the Malibu rock component (August 1963); completely covered a football-sized rock.

Importance. As with the other thinly encrusting sponges it is probably only important in its effect on the organisms it covers as it spreads.

Several other sponges were incidentally recorded: a calcareous sponge, similar to Leuconia barbata in appearance and growth form, but with some major spicule differences, occurred on the Malibu rock component (August, 1963) and on the Redondo Canyon reef (October, 1963); a solitary, vase-shaped calcareous sponge was seen once on the Redondo Canyon reef (August, 1963); and a siliceous, encrusting, pale yellow sponge occurred in a scraping from the Hermosa Beach concrete shelters (October, 1963).

Identified, but not considered part of the permanent reef fauna were two other sponges: (i) Cliona celata Grant californiana de Laubenfels, 1932 (boring sponge), found in the shell of the whelk Kelletia kelleti (Hermosa Beach reef—November, 1963); and (ii) Microciona microjoanna de Laubenfels 1930 (red encrusting sponge) found on the shells of whelks other than Kelletia (Hermosa Beach reef—September and October, 1962).

8.4.3. Cnidaria

These are multicellular animals possessing tissue and organ systems, whose symmetry ranges from radial to radiobilateral. All possess stinging organelles (nematocysts).

The Cnidaria are divided into three distinct classes, two of which (Anthozoa and Hydrozoa) are well represented on our reef materials. The third class (Scyphozoa, jellyfish) is considered transient in the midwater areas around the reefs and probably has little or no influence on the reef fauna.

Members of the Class Hydrozoa on the reefs were small (up to 14 cm high) erect colonies formed of a hollow, chitinous branched stalk which supported fleshy tentacled polyps. These polyps were used as food by several small reef inhabitants (nudibranch mollusks and caprellid amphipods) which in turn were major food items for some of the reef fishes. Bits of hydroids were recovered from fish stomachs on two occasions, but were probably taken incidentally in feeding on amphipods and mollusks.

The fleshy polyps may be naked and exposed on the branch, or partially enclosed in a chitinous cup. The presence or absence of this cup forms the basis for dividing the group into suborders: those possessing the cup being **thecate** (Calyptoblastea), and those lacking it being **athecate** (Gymnoblastea). The presence or absence of the semi-protective cup is also important when considering the desirability and accessibility of the fleshy polyps to predation by other small invertebrates and fish.

The naked polyps of athecate hydroids (Gymnoblastea) are easy prey for certain small invertebrates and possibly some of the reef fishes. At times some species of gymnoblast hydroids were extremely abundant in large patches on the reefs and test blocks, but generally the volumetric proportion of gymnoblastea to Calyptoblastea was rather low. The whole group appeared to be extremely susceptible to active predation, and also to encroachment by laterally-spreading ectoprocts and sponges. The enigmatic ectoproct Victorella argilla was a particular offender. For these reasons most of the gymnoblast hydroids we encountered, except on the very early reefs and test blocks, were either dead and decimated or were lacking most of the polyps. This precluded our identifying most of them to species. The following are athecate hydroids (suborder Gymnoblastea) recorded during this study.

8.4.3.1. Bimeria sp.—athecate hydroid

Description. Colony small, straggling, only two or three branches per stem. This agrees closely with the original description of Bimeria pusilla Fraser, 1925, but those described by him were less than 5 mm high, while our specimens normally attained heights of 25 mm or more.

Habit and habitat. Seldom if ever fast spreading or lush; probably easily overcome by encrusting species. Polyps not abundant on branches, may be quickly decimated by caprellids and nudibranchs.

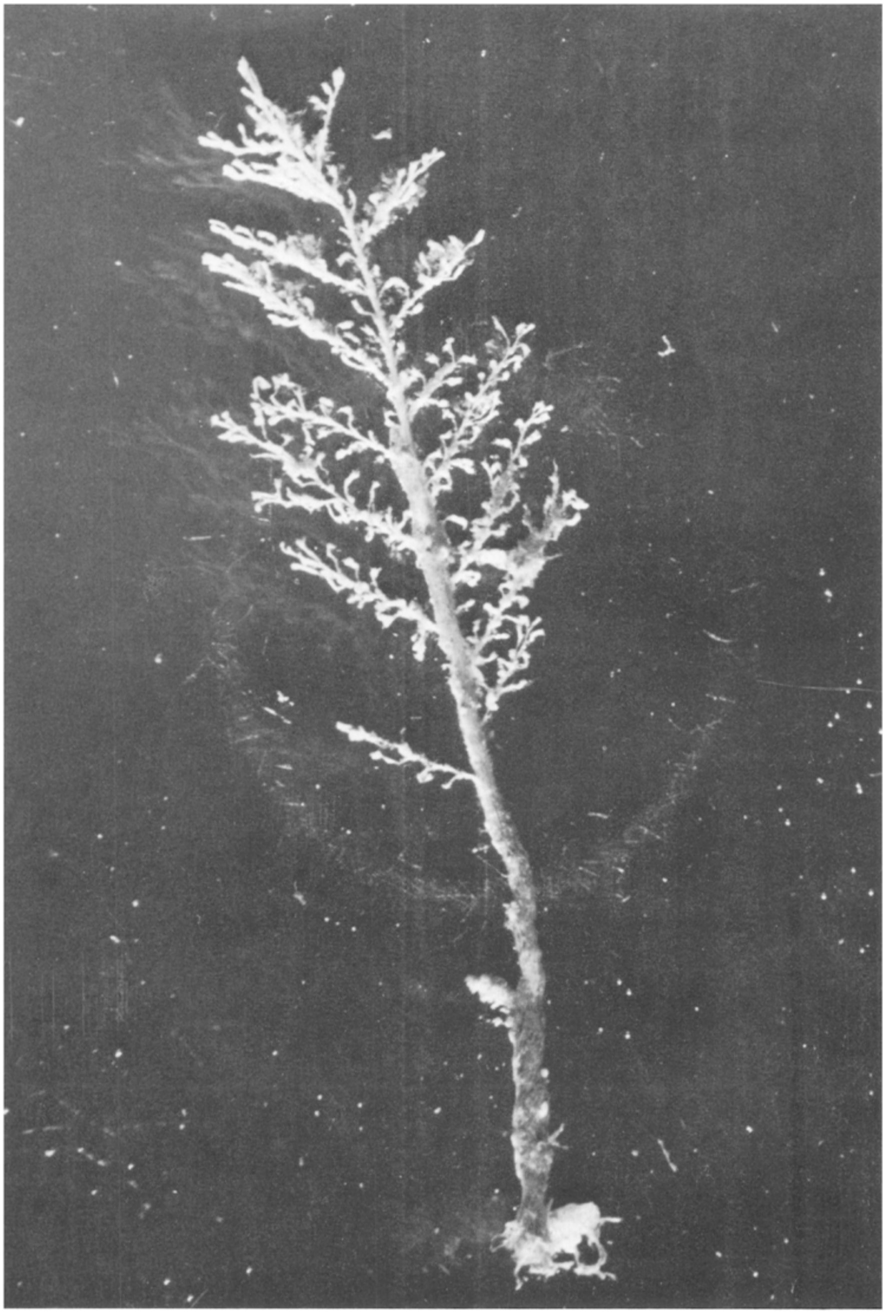

FIGURE 20 *Eudendrium* sp., an athecate hydroid. Its shape is typical of many of the athecate hydroids observed in this study. *Photo by Robert R. Given.*

FIGURE 20 Eudendrium sp., an athecate hydroid. Its shape is typical of many of the athecate hydroids observed in this study. Photo by Robert R. Given.

Occurrence. Abundant on the Malibu concrete shelter test block (March, 1961); not recorded subsequently.

Importance. Minor, due to its rarity and low-growing habit.

8.4.3.2. Bougainvillia sp., cf. mertensi Agassiz, 1862—athecate hydroid

Description. Main stem thick, branches tend to twine around it. May grow to 10 cm in height. Our specimens similar to B. mertensi, Agassiz, 1862, except for the arrangement of reproductive bodies which combined features of B. mertensi *and* B. glorietta, Torrey, 1904, but seemed nearer B. mertensi. Fraser (1937), however, places the distribution of B. mertensi as Bering Sea to San Francisco Bay; and B. glorietta as southern California and San Diego.

Habit and habitat. The few small colonies found on test blocks showed no indication of lushness or of becoming a major inhabitant of the reef.

Occurrence. One small colony was noted on a test block from the Santa Monica concrete shelters (January, 1961). Subsequently recorded on test blocks from the Malibu reef streetcar and on one test block at Hermosa Beach, (sparse to common in abundance).

Importance. Minor. May serve incidentally as habitat and food for certain small invertebrates.

8.4.3.3. Corymorpha palma Torrey, 1902—athecate hydroid

Description. A solitary, erect, fleshy "stalk" projecting above the substrate and supporting a single large, naked polyp with numerous tentacles. The stalk is usually rooted singly in soft sand or mud by filamentous processes at the base, but it may also grow on hard surfaces. Easily recognized by the large size and solitary habit. Height usually 6 or 7 cm, occasionally to 14 cm.

Habit and habitat. Attached singly (see above) but may occur in a cluster or in small groups. The upright stalk waves with water currents.

Occurrence. Common in the Hermosa Beach reef area, on substrate bounded by the concrete shelters, rock and streetcar materials (October, 1962); subsequently seen on the streetcar component (August, 1963) in large aggregations. Isolated individuals were also noted in the surrounding sand.

Importance. Minor, although the naked polyps probably offer morsels to some of the larger invertebrates and possibly some fishes. The smaller nudibranchs and caprellid amphipods so common on many colonial hydroids were not evident here.

8.4.3.4. Eudendrium sp., cf. ramosum (Linnaeus, 1758)—athecate hydroid

Description. Branching, irregular and dense, reproductive bodies separate from the polyps on short stems. Since most polyps were missing, definite species identification was not made.

Habit and habitat. Starts as small clumps, spreading moderately, but never extensively on our reefs. This species seems to be easily overcome by encrusting organisms.

Occurrence. Recorded only from test blocks. First seen on a test block from the Santa Monica concrete shelter component (May, 1961); subsequently on other blocks at this component and at Hermosa Beach; sparse to common.

Importance. Minor, due to its sparse occurrence, and its vulnerability to predation and encroachment by encrusting invertebrates.

8.4.3.5. Garveia sp.—athecate hydroid

Description. Colony with both branched and unbranched stems, up to 15 mm high. Reproductive bodies (when present) held on branched stems. Lack of polyps and general degeneration of colony made species identification impossible.

Habit and habitat. Begins as small colonies which may eventually spread laterally, but not extensively. Polyps and other protruding parts were missing in most cases during our study, indicating an apparent susceptibility to predation and grazing by other invertebrates.

Occurrence. Sparse to common. Recorded only on test blocks. First seen on a block from the Santa Monica reef rock component (February, 1961); subsequently on another block here and two from the Hermosa Beach reef.

Importance. Minor.

8.4.3.6. Tubularia crocea (Agassiz, 1862)—athecate hydroid

Description. Colony grows in large "tufts" of separate long (5 to 7 cm) stems arising from a tangled basal mat. Polyps large, stems may branch irregularly.

Habit and habitat. Growth form typical, see "Description." Usually found in relatively clean water, well above the substrate.

Occurrence. First seen on a test block (July, 1961) from the Santa Monica concrete shelters; subsequently in large tufts on the mid-water portions of the buoy chain at Santa Monica. In late 1963 this species grew in lush abundance on the roof inside the streetcar.

Importance. The large size and conspicuous growth habit of this species make it a potential direct food source for resident fishes and those inhabiting the mid-water regions. Its large size also suggests an increase in the size and quantity of the stinging cell batteries, which may lessen its desirability as food for fish. No small invertebrates were directly associated with this hydroid.

In contrast with the general lack of athecate hydroids, thecate hydroids (Calyptoblastea) were the most conspicuous organisms observed on the first test blocks and during the early life of the reefs. They grew as isolated patches (on the materials) which spread both horizontally and vertically, until they covered areas several cm in diameter and stood up to 5 cm (2 inches) high. These lush growths physically supported large populations of small invertebrates, especially nudibranch mollusks and caprellid amphipods.

These invertebrates, particularly the caprellids, were important food sources for reef fishes and undoubtedly were a factor in attracting these fishes to the artificial structures. Thecate hydroid importance, therefore, lay in their relative abundance, their general physical condition (many polyps or few polyps), and their resistance to invasion by encrusting invertebrates. For example, we believe that some species of Obelia were very important because they were found often and in significant amounts on most of the reef materials and were able to resist encroachment for a considerable time. Other genera and species were found only occasionally, in small numbers, were quickly overcome by low-growing laterally-spreading invertebrates and, hence, were of transitory and minor importance in the food web and successional picture.

Later in the study the thecate hydroids also suffered heavily from grazing by other invertebrates (and some fishes) and encroachment by encrusting animals, particularly the ectoproct, Victorella argilla. The lush hydroid growths were almost completely decimated on the oldest test blocks, and only a few sparse colonies remained. Since the classification of thecate hydroids is mainly based on the arrangement and structure of their peridermal cup (theca), the removal of these by grazing made it impossible to identify to species any but those from the early test blocks. Species affinities are proposed here, along with short descriptions of the remaining parts of the colony.

8.4.3.7. Antennella avalonia Torrey, 1902—thecate hydroid

Description. Stems unbranched, 5 to 6 mm high, arising from a **stolon** (creeping, horizontal connecting structure). Has appearance of yellowish "fuzz" over the substrate. Yellow color is characteristic.

Habit and habitat. Not an early settler on reefs, generally appeared later in the succession. Does not make thick mats but is a prolific, delicate form found mostly on the upper surfaces of the materials.

Occurrence. Abundant at Malibu (October, 1963); subsequently (early 1964) a few isolated small colonies were noted.

Importance. Minor, due to small size and late appearance on the reef. Its presence indicates a "maturing" of the reef structures.

8.4.3.8. Antennularia (?) sp.—thecate hydroid

Description. Colony stout, in poor condition on our reefs, few polyps scattered over the stems. Identification at generic level is questionable due to poor condition of specimen.

Occurrence. Collected in a "head" of the ectoproct Phidolopora pacifica on the Malibu concrete shelters (August, 1963).

Importance. Minor, due to rarity. Could become more important by contributing to solidity and integrity of the substrate mat.

8.4.3.9. Campanularia sp.—thecate hydroid

Description. Bushy, stems usually short and variously branched but not spreading laterally to any extent. Reproductive bodies usually large conspicuous sacs.

Occurrence. Seen once (March 1961), on a test block from the Malibu streetcar component, not seen subsequently on the reefs.

Importance. Minor, due to rarity. May attract caprellids.

8.4.3.10. Clytia sp., bakeri, Torrey, 1904—thecate hydroid

Description. Colony arising in clusters from a stolon network, may attain a height of 30 mm. Basal portion of stem with polyps.

Habit and habitat. Usually found attached to shells of living clams.

Occurrence. Questionable, seen on the opercle of a pile perch, Rhacochilus vacca, Hermosa Beach streetcar component (August, 1963). Positive species identification was impossible since the fish was not collected.

Importance. Incidental observation.

8.4.3.11. Clytia kincaidi (Nutting, 1890)—thecate hydroid

Description. Stem slender, unbranched; hydrothecal cup ribbed with 8 to 10 sharp teeth.

Habit and habitat. Growing in small isolated clumps on a test block.

Occurrence. One occurrence only, common on Hermosa Beach rockpile component test block (June, 1961). No subsequent records.

Importance. Minor, due to rarity.

8.4.3.12. Clytia sp.—thecate hydroid

Description. Growth patterns and general morphology like C. kincaidi but positive species determination was impossible due to mutilation of the colony.

Occurrence. Recorded solely on test blocks. Common on a block from the Hermosa Beach auto bodies (May, 1961); subsequently common on a Hermosa Beach rock component test block (June, 1961).

Importance. Minor, due to rarity. Could become more significant if established on reef materials.

The hydroid genus Obelia was well represented on most of the test blocks and its prolific growth habits made it an important part of early reef development.

The genus Obelia is characterized by the many-branched stems, the thin-walled thecal cup, and the conspicuous reproductive bodies. The colonies grow rapidly both laterally and in height and form dense bushy masses on the substrate. When the colonies are in good condition, they physically support extremely large populations of nudibranchs, caprellids and copepods, which are utilized as food by reef fishes. Since the large reproductive bodies of these hydroids are fleshy and not armed with nematocysts, they also may be tempting as food for small fishes.

Classification to species depends upon the structure of the reproductive bodies and the hydrothecal cup. Many of our specimens lacked these, so species identification must remain tentative.

We observed a larval blackeye goby (Coryphopterus nicholsi) entrapped in the hydranth of an Obelia. Obviously even so "large" an item as this 3 mm long fish was as acceptable for food as the more minute crustacean and molluscan larvae usually reported.

8.4.3.13. Obelia sp., cf. dichotoma Linnaeus, 1758—thecate hydroid

Description. See discussion of genus. Agrees with O. dichotoma in having annulation on the stems and a ridged hydrothecal cup with toothed margins. Gonangia absent in our specimens.

Occurrence. First seen on the Malibu streetcar test blocks (October, 1960); subsequently on test blocks from most components of all three reefs and on the reef materials, where it formed lush growths.

Importance. Major, due to cosmopolitan appearance and lush growth.

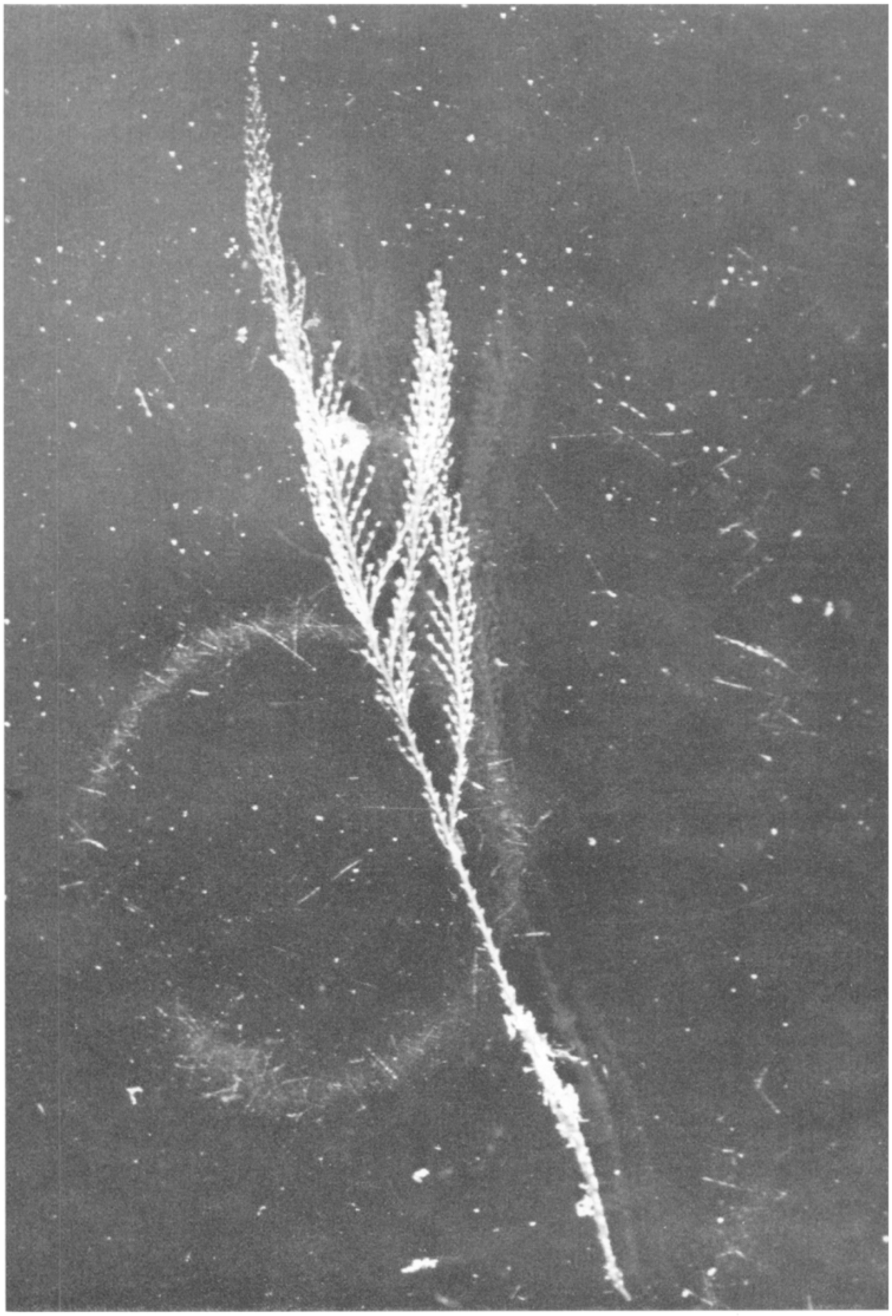

FIGURE 21 *Plumularia* sp., a thecate hydroid. Its shape is typical of many of the thecate hydroids observed in this study. *Photo by Robert R. Given.*

FIGURE 21 Plumularia sp., a thecate hydroid. Its shape is typical of many of the thecate hydroids observed in this study. Photo by Robert R. Given.

8.4.3.14. Obelia sp., cf. equilateralis Fraser, 1938—thecate hydroid

Description. Colony small (6 to 7 mm high), not extensively branched, stems long.

Occurrence. Abundant on the March, 1961 test block from Hermosa Beach rockpile. No subsequent records on our reefs.

Importance. Minor, due to rarity.

8.4.3.15. Obelia sp., cf. gracilis Calkins, 1899—thecate hydroid

Description. Colony small, slightly branched, stem slender.

Occurrence. First seen on a test block (February, 1961) from the Santa Monica rockpile; subsequently recorded at all three reefs.

Importance. Major, due to abundance.

8.4.3.16. Obelia sp., cf. obtusidens Jaderhold, 1904—thecate hydroid

Description. Colony up to 3 cm high, margin of hydrothecal cup with 12 rounded teeth.

Occurrence. On February, 1961 test block from Malibu streetcar component; no subsequent records on our reefs.

Importance. Minor, due to rarity.

8.4.3.17. Obelia sp., cf. plicata Hincks, 1868—thecate hydroid

Description. Colony heavily branched, stems and branches annulated.

Occurrence. Common on February, 1961 test block from Hermosa Beach rockpile; no subsequent records on our reefs.

Importance. Minor, due to rarity.

8.4.3.18. Plumularia alicia Torrey, 1902—thecate hydroid

Description. Stems very slender, unbranched, polyps regular and alternate along both sides of stems. Delicate, feathery appearance.

Habit and habitat. Stems usually grow singly but may aggregate in loose clumps. Generally found partly embedded in the substrate mat, giving a "fuzzy" appearance to that portion of the reef. Common on natural reefs.

Occurrence. First seen on Hermosa Beach rockpile (May, 1961) and on the same reef in late 1961 and early 1962.

Importance. Minor in the early stages of reef development. It does not seem to support other invertebrates (nudibranchs, caprellids), although nudibranch egg masses were observed on several colonies early in 1962. Interesting as an indicator of a maturing reef situation.

Anthozoans, the largest and most diverse class of cnidarians, encompass the sea anemones (order Actiniaria), octocorals (sea pens, sea pansies and sea fans) and stony corals. They differ from hydrozoans by their lack of a known medusoid stage.

The animals may live solitarily (some sea anemones and corals), colonially (sea fans, sea pansies, sea pens and corals) or in dense aggregations (some sea anemones).

Tube anemones, order Ceriantharia, live in the ocean bottom in a large tube composed of nematocyst (stinging cell) threads, slime, and

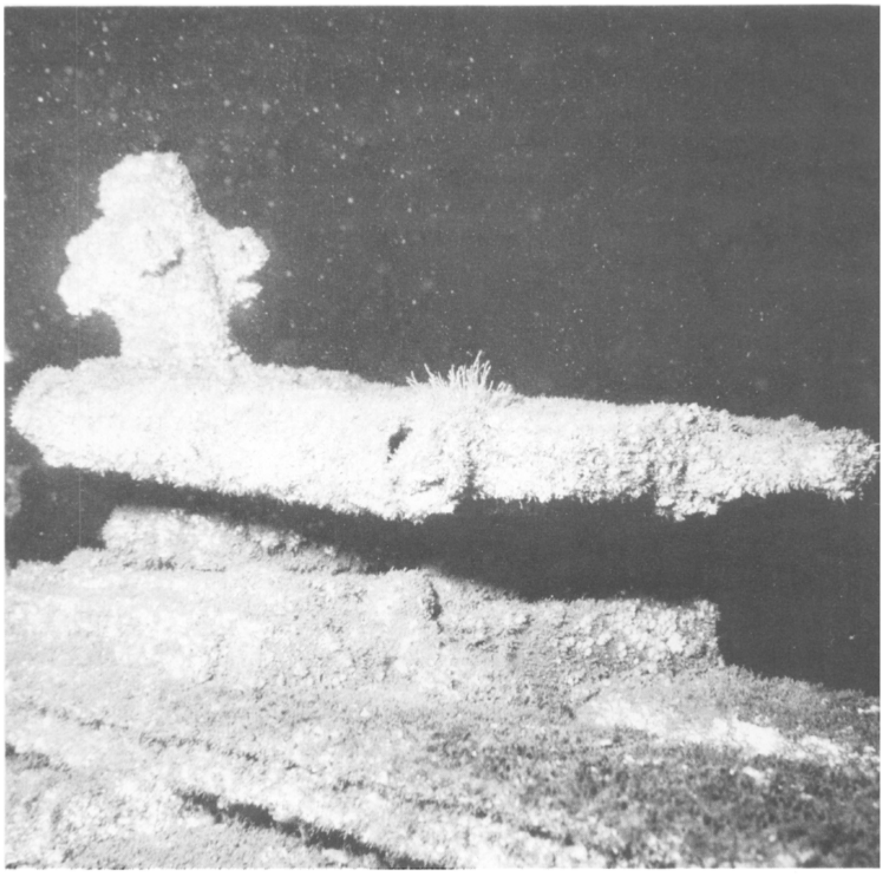

FIGURE 22 Early successional encrusting growths, barnacles and hydroids, on the trolley of a streetcar. *Photo by Charles H. Turner.*

FIGURE 22 Early successional encrusting growths, barnacles and hydroids, on the trolley of a streetcar. Photo by Charles H. Turner.

sediment. The tube is vertical in the substrate, and when active the anemone "sits" with its tentacles spread to trap falling debris or perhaps an unwary fish or worm.

They occurred in all the reef areas prior to material placement and were common around the materials during the entire study. Some time after reef construction, individuals were observed in the central sandy areas of the rockpile components (Figure 23) .

At least three genera (Pachycerianthus, Botruanthus, Cerianthiopsis) were noted, but since the taxonomy of the group is presently being revised (Mary Arai, pers. comm.) we have made no attempt at specific identification.

Fairly large size (the body minus tentacles averages 75 to 100 mm long and 12 to 37 mm in diameter) and formidable batteries of nematocysts probably precludes direct predation on ceríanthids by fishes. Sometimes the tubes harbor commensals which might attract fish, but the predator takes the chance of being caught by the outstretched tentacles of the anemone. We observed the tower snail (Megasurcula carpenteriana) depositing its egg cases on cerianthid tubes, and the close-ribbed

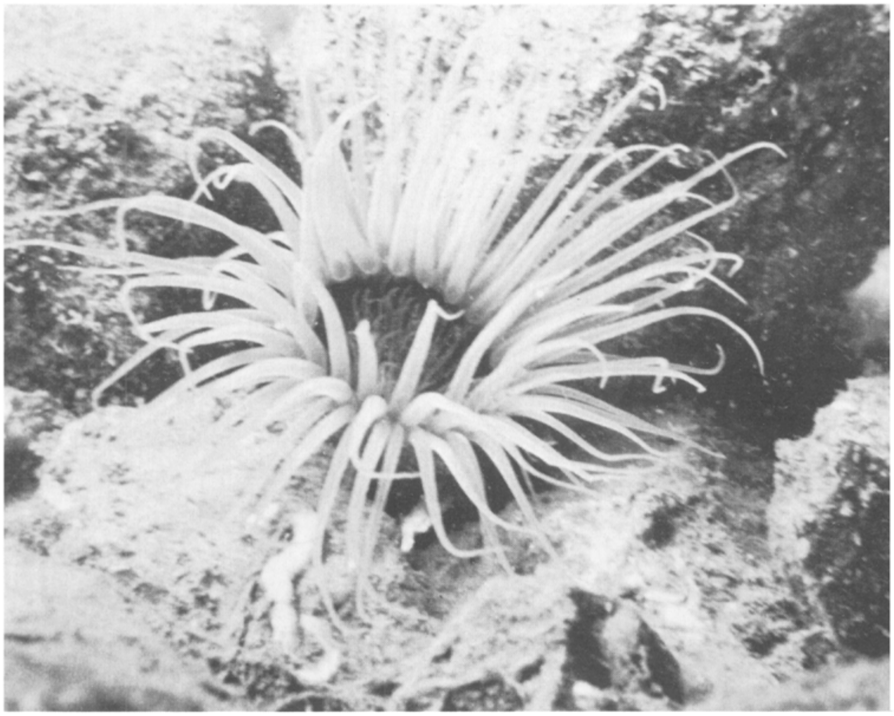

FIGURE 23 Cerianthid among the cobbles at the edge of an open area within the rockpile component at Hermosa Beach. *Photo by Charles H. Turner.*

FIGURE 23 Cerianthid among the cobbles at the edge of an open area within the rockpile component at Hermosa Beach. Photo by Charles H. Turner.

wentletrap (Epitonium sawinae) in close proximity to these anemones. Robertson (1963) reports wentletraps feeding upon sea anemones and corals.

Cerianthids play a minor and incidental role in reef succession, they apparently are neither dependent on nor affected by the reefs' construction.

Sea anemones (order Actiniaria) assume varying growth habits. They may live solitarily or they may form dense aggregations or clusters. All generally resemble a short upended fleshy cylinder which is attached by the basal end to the substrate. Their opposite end contains a central mouth surrounded by varying numbers of tentacles with nematocysts that are employed for protection and obtaining food. Some sea anemones move by creeping slowly across the substrate on their basal disk, while others seldom, if ever, move. As with the hydroids, they obtain food by entraping small invertebrates and fishes in their tentacles.

Sea anemones first appeared on our artificial reefs about 11 months after construction. Four species, representing both solitary and aggregate forms, were present. They increased rapidly in size and numbers, generally attaching on other organisms such as acorn barnacles and abalone jingles. By contrast, we did not observe other animals attaching to anemones. Their chief competitors for space were branching ectoprocts, colonial ascidians, and encrusting sponges.

8.4.3.19. Corynactis californica Carlgren, 1936—aggregate anemone

Description. A small anemone bearing numerous club-shaped tentacles arranged in radial rows; column shape variable, depending upon the state of contraction or expansion; fully extended individuals are "trumpet-shaped." Color variable and quite vivid, individuals may be white, pink, red, brown or lavender; tentacles always whitish.

Habit and habitat. Forms dense clusters or aggregations; all individuals of a cluster exhibit similar coloration. Dense aggregations and larger specimens were in areas not directly exposed to sunlight. On the concrete shelters they preferred the side walls and interior (Figure 24) , but a few small clusters were noted exteriorly on the top. In their quest for space, aggregate anemones readily grow over a host of other attached organisms.

FIGURE 24 Aggregate anemone, *Corynactis californica,* on a concrete shelter, Hermosa Beach WCB reef. *Photo by Charles H. Turner.*

FIGURE 24 Aggregate anemone, Corynactis californica, on a concrete shelter, Hermosa Beach WCB reef. Photo by Charles H. Turner.

Occurrence. Two small clusters were first noted at the Malibu reef concrete shelters in July 1961. This date coincided with their singular appearance on a test block from the Malibu reef streetcar. At the Hermosa Beach reef aggregate anemones were not observed until September 1961 when a cluster of three was found on the concrete shelters. By November 1961 they were common at these two reefs; aggregations of 50 individuals were counted. They were not observed until April 1963 at the Santa Monica reef, and there the small clusters were limited to the interior of the concrete shelters.

This species is indicative of a maturing reef; it becomes dominant during the second and third years of reef life.

Importance. Major as competitor for space.

8.4.3.20. Metridium exilis Hand, 1955—solitary anemone

Description. A small anemone; the fully extended column is slender. There are about 100 finely tapered and pointed tentacles. Gray-brown body with translucent tentacles.

Habit and habitat. Found evenly distributed on all surfaces of the reef materials. Difficult to see, its color blending well with its background (Figure 25) .

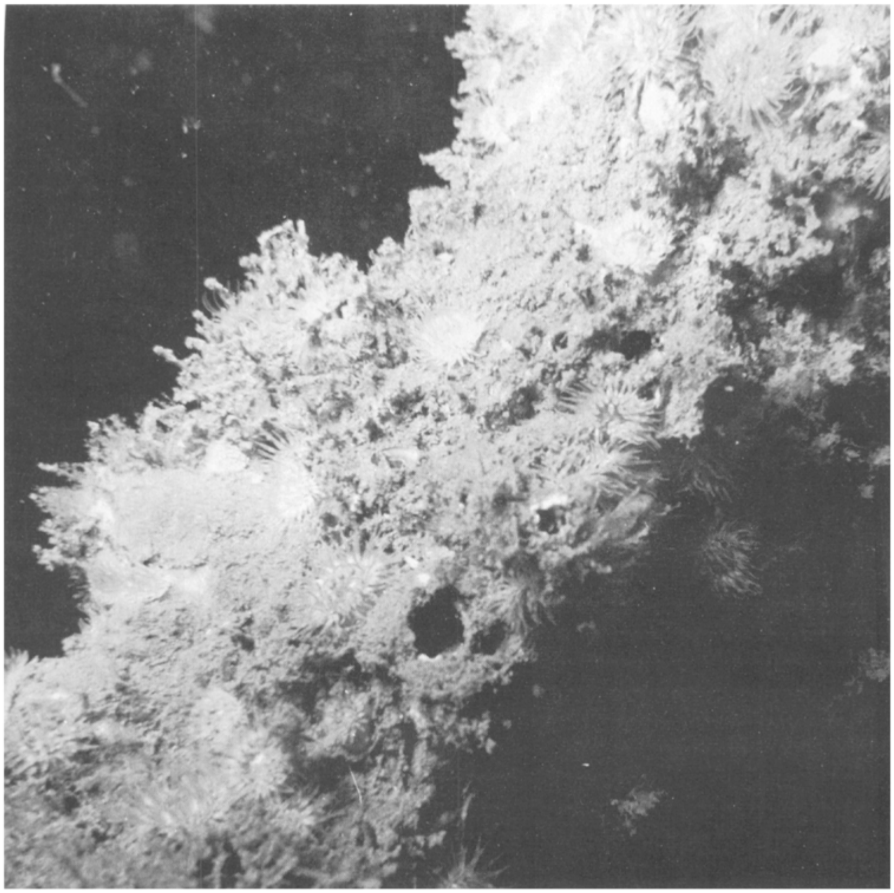

FIGURE 25 *Metridium exilis* on the upper surface of a concrete shelter, Hermosa Beach WCB reef. *Photo by Charles H. Turner.*

FIGURE 25 Metridium exilis on the upper surface of a concrete shelter, Hermosa Beach WCB reef. Photo by Charles H. Turner.

Occurrence. Not observed until November 1961 on the concrete shelters at Hermosa Beach when we estimated three on each shelter. Eventually became established on each of the replication reefs. An estimated 15 per 0.06 m^2 were at the Hermosa Beach reef concrete shelters in August 1963), but only 5 per 0.06 m^2 in October 1963.

Importance. Minor during this study.

8.4.3.21. Metridium senile fimbriatum (Verrill, 1865)—plumose anemone

Description. A large, elegant anemone with numerous short tentacles; the column when expanded is much longer than wide; the base is adherent, well developed, with a diameter greater than the column. Color variable, but only one color per specimen. We observed both white and light-brown specimens on the artificial reefs, but have found salmon and light orange-colored individuals on the structural members of offshore drilling towers near Santa Barbara.

Habit and habitat. On the man-made reefs they oriented to the concrete shelter openings, where accelerated currents were produced. They are capable of "walking" appreciable distances, although we did not record any movement for those we saw.

Occurrence. Observed only on the concrete shelters at the Hermosa Beach and Malibu reefs, at Malibu in July 1961, and at Hermosa Beach in October 1961. The population (estimated to be one per concrete shelter), once established, stabilized and maintained itself throughout the survey period.

Importance. Negligible during this study.

8.4.3.22. Tealia coriacea (Cuvier, 1798)—anemone

Description. Column tuberculated; short, its width being greater than its length, covered with adhering gravel and shell. Tentacles thick and tapering to a blunt point; cream colored. The column is a dull reddish color. Our single representative was about 5 cm (2 inches) in diameter.

Habit and habitat. Low rock slabs, close to coarse sandy substrate. Moves across gravelly substrate with ease.

Occurrence. One specimen found at the Hermosa Beach reef concrete shelters in October 1961. No subsequent observations.

Importance. No data.

In the order Pennatulacea the animal colony is fleshy, elongate (sea pen) or disk shaped (sea pansy). One end (peduncle) is submerged in the sand for attachment. Polyps are numerous and generally translucent. There may be a skeleton of limy spicules.

Sea pens and sea pansies are not known to be eaten by fishes, but are preyed upon by mollusks.

They were in the areas previous to reef placement, hence, their role in man-made reef ecology appears negligible.

8.4.3.23. Renilla kollikeri (Pfeffer, 1886)—sea pansy

Description. A flat, heart-shaped disk, fleshy, without stiff skeleton; exposed surface with numerous 8-tentacled polyps. A peduncle extends from the under side and anchors the colony to the substrate. The upper disk surface is purple and the polyps are translucent; the undersides and peduncle are cream colored. Average size of specimens around the Hermosa Beach reef was about 7 cm (almost 3 inches) in diameter.

Habit and habitat. Fine to coarse sandy substrate; generally observed lightly covered with sand, the polyps well extended.

Occurrence. Observed only at the Hermosa Beach reef in the area between the rockpile and the automobile bodies. They were present before reef construction and since they require open sand expanses they are probably adversely affected by construction of man-made reefs. No population changes nor seasonal fluctuations were noted during our study. Thirty-five were estimated in the sand around the automobile bodies in August 1963.

Importance. Negligible, preyed upon heavily by the striped nudibranch, Armina californica.

8.4.3.24. Stylatula elongata (Gabb, 1863)—elongate sea pen

Description. Rough, cream-white, elongate, slender, featherlike; axial skeleton strong and brittle with a fleshy base.

Habit and habitat. Anchors firmly into the substrate with its bulbous fleshy base. Retracts into the sand when disturbed. Favors siltysand bottoms.

Occurrence. Present around each of the artificial reefs prior to construction. We estimated one per 4 m^2 near the Hermosa Beach reef.

Importance. No data.

The order Gorgonacea (sea fans and sea whips) is one of the more conspicuous groups on any reef. They are erect, usually much branched forms attaching to the substrate by a broad base. A horny skeleton of gorgonin, covered by a mass of spiculated tissue, houses the many eight-tentacled polyps which give the colony its feathery appearance. Gorgonians are often mistaken for plants due to their branching form. At least seven species occur sublittorally along the southern California coast, three of these were recorded on the artificial reefs: Lophogorgia chilensis, Muricea californica, and M. fruticosa. These are common in 60-foot depths. During our routine study (August 1960 until November 1963) only L. chilensis had become established, but both species of Muricea (2 cm tall) were recorded by February, 1964.

Gorgonians are of interest in dating the reef's maturity. They usually appear 2 to 3 years after construction, and then steadily increase in numbers and size.

8.4.3.25. Lophogorgia chilensis (Verrill, 1868)—pink sea whip

Description. Colony tends to be extremely long and thin, spreading vertically, not laterally. The spicules are red, lending a bright red appearance to the entire colony. The polyps (when extended) are white.

Habit and habitat. These red whip-like colonies are commonly encountered in rocky areas, along the southern California coast, at depths of 10 to at least 180 feet. The colony branches tend to grow at right angles to the prevailing currents, allowing the polyps equal feeding opportunities.

Caprellid amphipods, in huge numbers, attach to these branches. A barnacle, Balanus galeatus, uses this gorgonian for attachment, and is frequently grown over by the spiculated tissue (Figure 26) .

FIGURE 26 *Balanus galeatus on Lophogorgia chilensis. Photo by Peter F. Major.*

FIGURE 26 Balanus galeatus on Lophogorgia chilensis. Photo by Peter F. Major.

A small snail, Simnia sp., feeds on the gorgonians' polyps and attaches its eggs in capsules to areas devoid of polyps (Figure 27) .

Occurrence. Present only at the Hermosa Beach reef rockpile. One colony was noted October 7, 1963 (1.3 cm, about 0.5 inch high). By

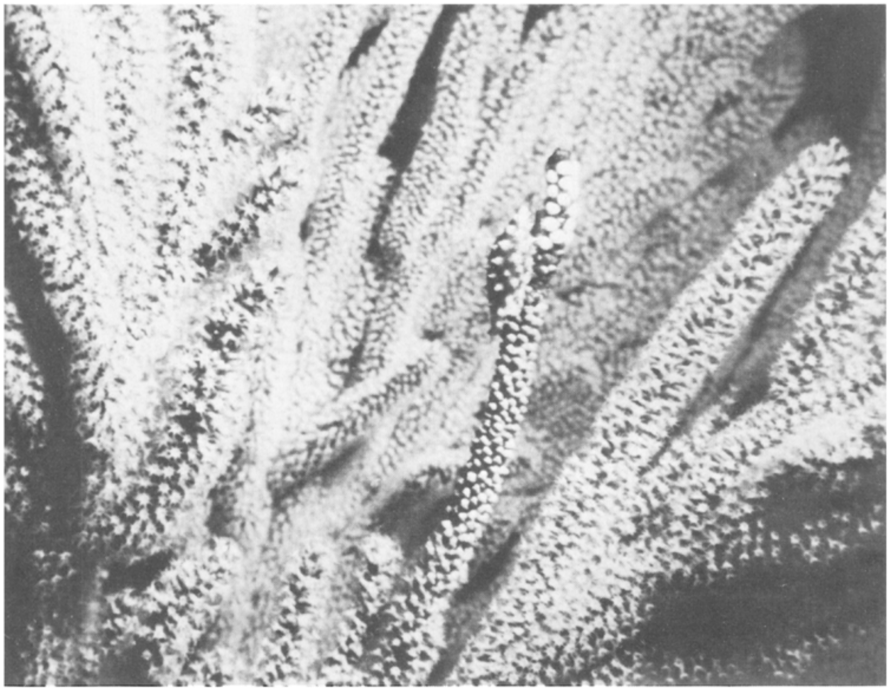

FIGURE 27 *Simnia* sp. (center) on *Muricea californica,* off Palos Verdes Point, 80-foot depth. *Photo by Charles H. Turner.*

FIGURE 27 Simnia sp. (center) on Muricea californica, off Palos Verdes Point, 80-foot depth. Photo by Charles H. Turner.

December 13, when the routine field observations terminated, its maximum length was 2.8 cm (slightly more than 1 inch), an increase of approximately 7 mm per month. Another colony exhibited 10 mm per month growth.

Importance. of major importance by increasing the habitat available to certain mollusks and amphipods which provide excellent food for fishes.

The third, and in this study the least important, class of Cnidaria are the Scyphozoa (jellyfish). None of the sessile (attached) members of this group was observed during our study. The only scyphozoan noted was Pelagia panopyra (Peron and Leseur, 1807), a large purple striped jellyfish [(Figure 28)] . It was extremely abundant during late summer and fall, mostly in midwater; it seldom approached the reef materials. This jellyfish has large and potent nematocysts which present a formidable defense against even a very hungry fish.

Juvenile slender crabs, Cancer gracilis, were observed often beneath the "bell" of this jellyfish, and we occasionally noted juvenile fish. The fish have not yet been collected for identification.

8.4.4. Platyhelminthes

This is the most primitive of the "worms," and includes parasitic flukes, tapeworms, and the free-living flatworms. Generally they are characterized by having a true "head" (anterior end with sense organs)

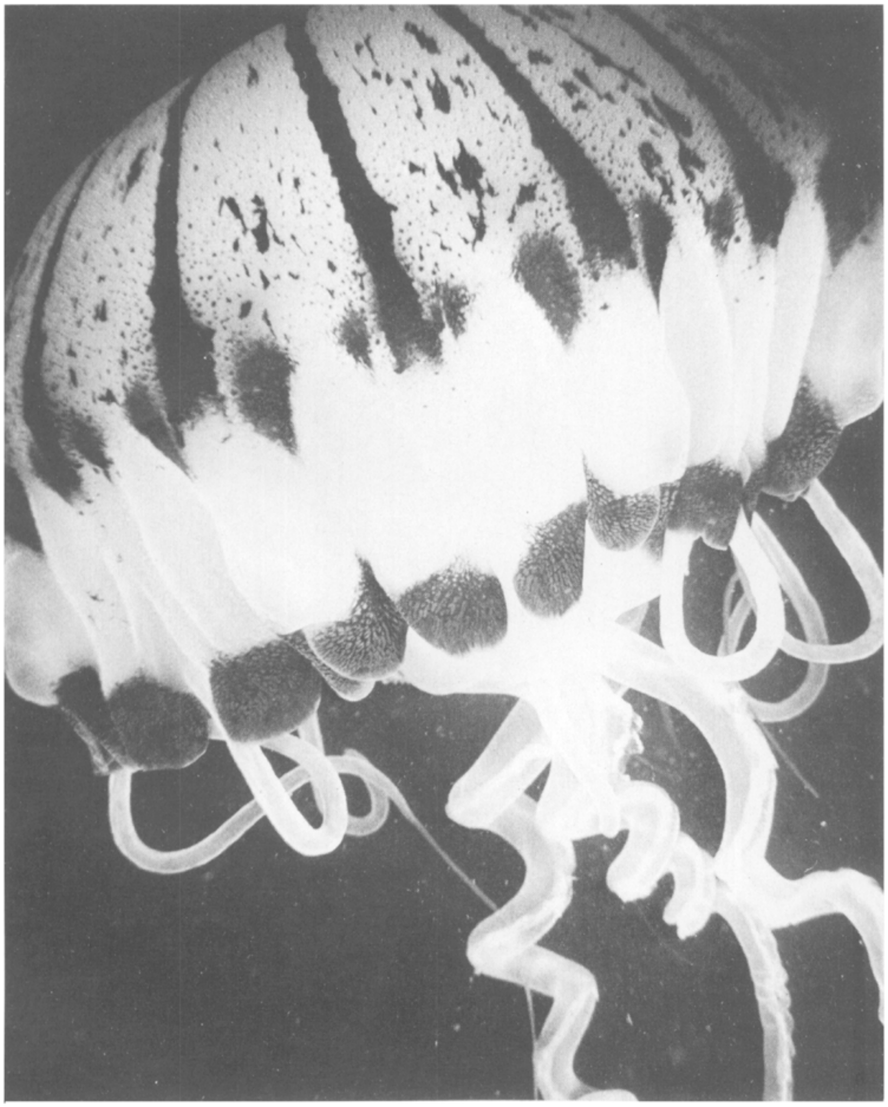

FIGURE 28 *Pelagia panopyra* recorded swimming over the Hermosa Beach reef rockpile. Photo by Charles H. Turner.

FIGURE 28 Pelagia panopyra recorded swimming over the Hermosa Beach reef rockpile. Photo by Charles H. Turner.

and by being unsegmented, bilaterally symmetrical, and usually flattened dorsoventrally; they lack circulatory and respiratory systems and an anus.

In this study our interest was in the free-living flatworms (class Turbellaria), and in particular the order Polycladida (commonly called polyclad flatworms). This order includes many species, notable for their thin, leaf-like bodies and many-branched intestines. Identification to species, or even to genus, requires careful preparation and sectioning for microscopic examination. The lack of time and facilities prevented such detailed examination, so the worms were merely counted and recorded. Cursory examination suggested at least 4 species were present.

Polyclads were recorded from 64 of the 88 test blocks examined, being noted on most series within the first months. Subsequent to the test block studies, collections and observations on the reef materials showed they were common in and around the substrate mat but never in large numbers. Although they were fairly evenly distributed on the reef surfaces, they seemed to prefer living in the protection of niches, holes, and crevices and very commonly within the empty compartments of still-attached acorn barnacles. Up to four or five small-to-medium-sized worms could be found in one shell. Possibly the barnacles were preyed upon by these worms, in a manner similar to the predation of barnacles by the flatworm Stylochus zanzibaricus (Skerman, 1960).

The soft body and lack of any formidable protective devices should make polyclads a preferred food item for reef dwelling fishes. When not hidden and inaccessible, they are slow-moving, fairly conspicuous, and could easily be taken.

8.4.5. Nemertina

These are unsegmented, bilaterally symmetrical elongate worms that possess a definite circulatory system, an anus, and an eversible proboscis enclosed in a tubular sheath (rhynchocoel).

As with the polyclad flatworms, the taxonomy and species identification of this group depends upon specialized preservation and preparation so that certain characters are highlighted for microscopic examination. These procedures were impractical in our test block study, so the worms were only counted and recorded as "nemerteans." Superficial examination during sorting, however, indicated that at least two species were present, both about 2 to 4 mm long, one with and one without a dorsal color pattern. Cursory examination for sexual maturity was not conclusive, so there was some question whether the animals we collected were juveniles or adults. With the exception of a 5 cm long Lineus sp., recorded on the Malibu reef in August 1963, in an ectoproct colony, no large specimens were found.

Nemerteans were recorded on 40 of the 88 test blocks, numbering from 1 to 19 per block. Except at Hermosa Beach, they usually appeared about the third month.

These worms are fairly large, rather plump and, as with the polyclad flatworms, tend to be secretive and slow moving. Once exposed and moving about on the reef surface, they would certainly be vulnerable to fish predation.

8.4.6. Nematoda

Nematodes are unsegmented, usually small, slender (thread-like) worms with a pinkish or flesh-colored body, sharply pointed at each end. They are commonly called thread worms.

Nematodes are extremely abundant in nearly all ecologic situations, both aquatic and terrestrial. Although best known through their parasitic forms, they are also important in the lower trophic levels in the marine environment. Most of the marine species are minute, ranging from 1 to 10 mm in length. Their classification is a highly specialized activity. Accurate counting is tedious and requires special techniques.

In most general ecologic studies it is usually considered sufficient merely to announce their presence, and if possible, their relative abundance.

In our study, we found them on the surfaces and in the cracks and holes of all the materials. They were not recorded from all the test blocks, but we assume that they were present there as well as in the subsequent surface scrapings. We found one large specimen in the stomach of the black perch (Embiotoca jacksoni) .

Excluding their presence in large numbers as an obvious influencing factor in the reef environment, nematodes probably serve as food for many reef dwellers at all but the lowest trophic levels. Some of the largest worms may actually be sought out by reef fishes.

8.4.7. Annelida

Annelids are segmented worms with complete digestive, nervous, and circulatory systems, whose true segmentation separates them from other wormlike forms.

Those in the class Polychaeta have many **setae** (bristles) and **parapodia** (simple unjointed lateral appendages), usually with a highly specialized head and sensory organs.

This is the most diverse group of invertebrates recorded from the reefs, undoubtedly forming a major portion of the diet of reef fishes.

At least 23 families were represented in the collections and observations we made during this study, and there were many species in each family. Time and facilities did not permit us to identify all the species, but family level classification is sufficient to suggest their position in the reef's successional patterns.

During the course of our study an attempt was made to analyze the stomach contents of certain resident and semi-resident reef fishes (*see* Fish Food Studies section). Although polychaete worms were among the food items present, they were unidentifiable to species because only their setae were found.

In evaluating the importance of each polychaete family we have considered their ability (or lack of it) to build tubes on the substrate, a factor directly affecting their subsequent availability as food to the reef fishes.

In the following systematic treatment, family characters are described briefly, and we have noted any tube-building habits of the specimens recovered. Many of the families mentioned are found only rarely and seem of minor importance as fish food, but they are of interest in completing the reefs' total invertebrate picture. The families are presented alphabetically.

8.4.7.1. Family Ampharetidae

Description. Body short, tapered, with numerous retractile tentacles in the mouth region.

Habit and habitat. Builds a small membranous tube which becomes covered with mud or other foreign particles.

Occurrence. Twice recorded on test blocks from the Santa Monica concrete shelters.

Importance. Minor, due to rarity.

8.4.7.2. Family Arabellidae

Description. Body smooth, cylindrical, elongate, earthworm-like. Jaws large, dark.

Habit and habitat. Mostly free-living on the reef surfaces, may occupy deserted shells and burrows.

Occurrence. On one test block from the Santa Monica streetcar, and once on the Malibu buoy chain.

Importance. Minor, due to rarity.

8.4.7.3. Family Chaetopteridae

Description. Body soft, divided into three dissimilar regions, easily broken.

Habit and habitat. Inhabits a parchment-like tube of its own construction, either U-shaped or straight; located in bottom sediments or attached by the tubes' sides to reef materials (Figure 29) . Feeds by forming a mucous net to entrap detritus, then ingesting the mucous-detritus mass. Its tubes may form large entwining masses occupying considerable space.

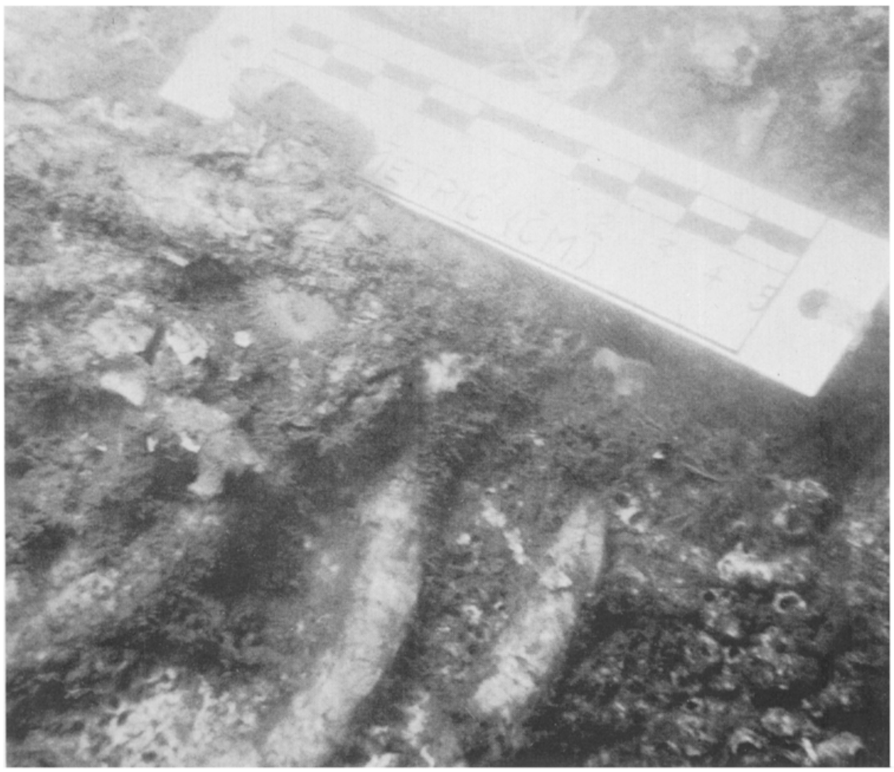

FIGURE 29 ***Chaetopterus variopedatus*** attached to the underside of rocks, Malibu WCB reef (rock overturned for photographic purposes). *Photo by Charles H. Turner.*

FIGURE 29 Chaetopterus variopedatus attached to the underside of rocks, Malibu WCB reef (rock overturned for photographic purposes). Photo by Charles H. Turner.

Occurrence. Although some of our early collection records show only an "unidentified chaetopterid" they probably were all Chaetopterus variopedatus Reiner, 1804, and those we left unidentified were too small or too mutilated for positive diagnoses. We now believe that all the members of the family we encountered were this species.

First noted on a test block from the Santa Monica concrete shelters (April 1961), subsequently on test blocks from Malibu and the other materials at Santa Monica. Later in the study it was observed on all the reefs and the reef marker buoys. In early November 1963, large masses of C. variopedatus were observed near the Hermosa Beach automobile bodies in the coarse red sand. They covered an extensive bottom area (exact perimeter unknown) forming a "crust" of sand and tubes (Figure 30) . This "crust" remained throughout November and into December, when the first winter storm broke it up. It reformed annually in late summer and fall.

FIGURE 30 ***Chaetopterus variopedatus*** **tubes in the red sands adjacent to the Hermosa Beach WCB reef automobile body component.** ***Photo by Charles H. Turner.***

FIGURE 30 Chaetopterus variopedatus tubes in the red sands adjacent to the Hermosa Beach WCB reef automobile body component. Photo by Charles H. Turner.

Importance. Fish from the reefs were seen feeding in this "crust" area. Black perch were observed to nip the parchment tube and pull out the worm; other species may do the same. Small worms (0.5 to 1 inch long) were presumably taken whole (tube and all). By pressing the tube against his palate, the fish squirted the worm out of his tube and devoured it. The tube was then spit out by the fish. The soft body and relatively large size of this worm make it a tempting morsel for many foraging fishes, but there was no evidence of the tubes being ingested along with the worms. The worms are also of some importance physically because of the large masses they form and the space they occupy. Various smaller invertebrates were observed among the entwined tube masses.

8.4.7.4. Family Chrysopetalidae

Description. Body short, broad, not obviously tapering. Color golden, caused by light refraction from the rows of modified, fanshaped flattened bristles called **paleae**. Usually small (2 to 4 mm), easily fragmented.

Habit and habitat. These free-living moderately active worms were usually found on the exposed reef or test block surfaces rather than hiding in crevices or the abandoned tubes or shells of other animals.

Occurrence. They appeared early in the study on a test block from the Hermosa Beach streetcar component (January 1961). Subsequently we noted a gradual buildup at all materials and on the test blocks with a population peak in May, June, and July of 1961. Later small numbers were seen in scrapings and on various materials.

Importance. Chrysopetalids are probably a preferred fish food due to their conspicuous coloration and free-living habit, making them easily accessible. Their numbers declined after 1961, possibly due to predation.

8.4.7.5. Family Cirratulidae

Description. Body thick, more or less cylindrical with numerous short segments. Generally characterized by branchial filaments on some body segments.

Habit and habitat. Some members of the family build calcareous tubes, but those we encountered do not. They are found in areas where the sediments are predominantly fine, but sometimes live in masses of gammarid amphipod tubes, in abandoned tubes of other worms, or in empty barnacle shells.

Occurrence. First recorded in mid-1961 on a test block from the Malibu streetcar component, subsequently on a test block from the Santa Monica reef (July 1961) and on the Hermosa Beach reef (June 1963).

Importance. Minor on the early reefs due to rarity, but the 11 specimens found at Hermosa Beach in 1963 indicated they may become significant later as a source of fish food.

8.4.7.6. Family Dorvilleidae

Description. Generally minute, characterized by the structure of the palps and antennae, and by the numerous chitinous pieces forming the jaws.

Habit and habitat. Exact habit and habitat not known, but they probably do not build permanent tubes. often found in and around muddy substrates or in the tubes and burrows of other invertebrates.

Occurrence. They were found only on the test blocks at the Santa Monica reef, first on the concrete component (April 1961), and later in small numbers from test blocks on the other materials.

Importance. Probably minor due to their small size, rarity and absence from samplings on the later, more mature reefs.

8.4.7.7. Family Euphrosinidae

Description. Body short, thick, somewhat flattened dorsoventrally; head appendages minute. Color light orange, bristles in tufts on the segments; a conspicuous groove separates the bristles down the back.

Habit and habitat. Generally free-living, fairly active, and may inhabit (temporarily) the tubes of other animals.

Occurrence. Only one large specimen was observed during our study (Malibu, August 1963), but its presence indicated a maturing reef.

Importance. The formidable bristle armament may make it undesirable as fish food.

8.4.7.8. Family Flabelligeridae

Description. Body elongate, tapering posteriorly. Characterized by long, strong spinous bristles projecting forward and concealing the anterior end of the worm.

Habit and habitat. Usually free-living, but not extremely active. May be found enclosed in a transparent gelatinous tube or with the body obscured by adhering sand grains. Not known to form permanent tubes but may be found in the burrows of other animals or buried in sandy substrate.

Occurrence. Recorded first on a test block (June 1961) from the Hermosa Beach rock component, subsequently in scrapings and on various materials from both the Hermosa Beach and Malibu reefs.

Importance. Minor due to rarity, but may form large populations on mature reefs.

8.4.7.9. Family Hesionidae

Description. Minute (2 to 4 mm) in this study. Recognized by four tiny eyes on the head and long dorsal cirri on the body segments. Those we encountered appeared to be one species; all were presumably juveniles.

Habit and habitat. Not known to build tubes, probably living on and under the substrate "mat" or in burrows and tubes of other animals.

Occurrence. Found only on test blocks, first at Hermosa Beach (January 1961), later on most of the blocks from all reefs; usually few in number (two or three per block) except the July block from the Santa Monica streetcar (31) and the April block from the Malibu concrete shelters (12).

Importance. Notable during the early faunal buildup on the reefs, and they may have provided food for some of the reef fishes at this time. Not found in scrapings and samples taken later.

8.4.7.10. Family Lumbrineridae

Description. Body superficially resembling an earthworm, being elongate and cylindrical; no head appendages except one pair of small nuchal organs. The genus Lumbrineris was tentatively identified, but more than one species was noted.

Habit and habitat. This family generally characteristic of soft, unconsolidated bottoms, and was not commonly found on the test blocks or reef components. Our species did not build tubes.

Occurrence. Recorded once from two test blocks at Hermosa Beach (January 1961) and subsequently noted in small numbers in the substrate scrapings from all reefs.

Importance. Minor during our study due to their small numbers. They may become a food source on older reefs due to their potentially large size and lack of a protective tube.

8.4.7.11. Family Nereidae

Description. Body slender, elongate, with numerous segments. Head equipped with four large eyes, an evertible proboscis with heavy jaws, and horny denticles arranged in two rings. Head appendages (tentacles, etc.) conspicuous.

Habit and habitat. Generally free-living; they were often found coiled tightly in abandoned barnacle shells or in temporary mucuslined tubes of their own secretion. This tube, actually more of a depression in the substrate "mat" with its bottom formed by the test block wood or reef's surface, may provide shelter for other small invertebrates when the worm leaves.

Occurrence. Represented by several species and many individuals on 48 of the 88 test blocks examined, and in subsequent scrapings and observations made on most of the reef materials.

Importance. of major importance in the reef succession pattern and in the diets of reef fishes. Recorded only once in a fish stomach, but polychaetes as a group are quickly digested into an unidentifiable mass with only a few setae remaining to mark their presence.

8.4.7.12. Family Onuphidae

Description. Body elongate, with conspicuous anterior tentacles mounted on an annulated base. Characteristically a difficult group to identify; the species are defined by using dentition found on certain bristles.

Habit and habitat. They build substantial mucus or debris-encrusted tubes which may be characteristic for each species, but are not entirely reliable taxonomically. The tube, usually with a thin or thick parchment like base, is smooth inside. Outside it may be covered with various foreign objects ranging from fine sand to shell fragments or bits of algae and wood. Large areas of these closely packed tubes were observed in the mud between components and also in the sediment areas protected by the concrete shelters. Where reef materials had altered the prevailing currents, large populations appeared.

Occurrence. Small individuals were first seen on test blocks from the Hermosa Beach and Malibu reefs. Later large populations were observed in the substrate between the components of these same reefs.

Importance. Their large size and abundance makes them a potential fish food. Our fish stomach analyses indicated that foraging fish may nip off the top portion of the tube to get to the worm. Their appearance coincided with an alteration of the bottom and current conditions by reef material placement. They may create a microenvironment around their closely packed tubes.

8.4.7.13. Family Opheliidae

Description. Body short, often grublike or lancet-shaped. Segmentation is obscure and the head appendages are small. Probably only one species represented here; a lancet-shaped form which never exceeded 4 mm.

Habit and habitat. Not known to build tubes; probably relatively active on the reef surfaces and under the substrate "mat."

Occurrence. Found on test blocks from all the reef components at Hermosa Beach and Santa Monica, but were at Malibu only in the later scrapings and observations.

Importance. Probably of some importance as fish food due to their free-living habit and lack of large setal armature. Their small size (at least on the test blocks) contributed little to the reef biomass.

8.4.7.14. Family Orbiniidae

Description. Body elongate, many segments, usually divided into a more or less flattened anterior and a rounded posterior portion. No visible head appendages.

Habit and habitat. Not known to build their own tubes, but may live in the abandoned tubes and shells of other animals.

Occurrence. Found in small numbers on test blocks from the Malibu reef; subsequently in small numbers on the Hermosa Beach concrete in 1963.

Importance. Their small size and rarity preclude their importance on the early reefs, but they may increase in size and numbers later.

8.4.7.15. Family Phyllodocidae

Description. Body long and slender, with many segments. Head appendages usually numerous and conspicuous, the two large eyes characteristic. The **cirri** (appendages on the body segments) are often large, globular or leaflike and very conspicuous. Active and fast-moving; secrete large quantities of mucus on stimulation.

Habit and habitat. Not known to secrete permanent tubes, but often found in abandoned barnacle shells and old tubes of other worms.

Occurrence. Phyllodocids were on 35 of the 88 test blocks analyzed, and were subsequently found on all the reefs in scrapings and by general observations.

Importance. of major importance due to their relative abundance, common occurrence, and large size—especially in older reef faunas.

8.4.7.16. Family Polynoidae

Description. Body somewhat elongate but not slender; more or less flattened. Characterized by the presence of large overlapping scales on the dorsal side (these are essential in taxonomy, but all or part of them may be lost in handling). Head appendages inconspicuous.

Habit and habitat. Active on the reef surfaces, not building tubes but taking over abandoned tubes and burrows of other animals for temporary protection.

Occurrence. Sporadic and in small numbers on all reefs during the test block study period and later studies.

Importance. Fish stomach analysis showed evidence of their use as fish food. Substantial numbers of large-sized polynoids are found on natural reefs.

8.4.7.17. Family Sabellariidae

Description. Body short, stout, circular or subquadrangular, widest anteriorly and tapering posteriorly. Sabellaria cementarium was observed more frequently than Phragmatopoma californica, but since the differences in their habits and occurrences is insignificant, they are treated together.

Habit and habitat. Sabellariids always build sand tubes generally beginning as a few isolated tubes on the reef surface, then filling in the gaps and building on each other until large sandy "hills" rise above the actual reef surface. On natural reefs, these large masses become an important physical as well as biological factor. The worms do not leave their tubes, but the operculum is conspicuous and may attract foraging fish.

Occurrence. Found on 33 of 88 test blocks, from most materials at all the reef sites, and in scrapings removed later from the reefs (including the Redondo Canyon reef).

Importance. Opercular spines from these worms are common in the stomachs of reef fishes indicating their importance as fish food. Their contribution to the physical makeup of the reef substrate is also important.

8.4.7.18. Family Sabellidae

Description. Body cylindrical, not slender or elongate, tapered posteriorly. Easily identified by the conspicuous, often colored, funnel-like plume of branchiae surrounding the mouth.

Habit and habitat. Always build tubes which may be horny, parchment-like, muddy, or sandy. Those on the test blocks were small (2 to 4 mm) and their tubes were sandy or parchment-like. They do not leave the tubes, but their branchial plume is extended most of the time (hence, their common name "feather-duster" or "plume worm") (Figure 31) .

FIGURE 31 *Eudistylia polymorpha*, the feather-duster worm (family Sabellidae), with its branchial plume extended. In the upper right corner is a cluster of aggregate anemones. *Photo by Charles H. Turner.*

FIGURE 31 Eudistylia polymorpha, the feather-duster worm (family Sabellidae), with its branchial plume extended. In the upper right corner is a cluster of aggregate anemones. Photo by Charles H. Turner.

Occurrence. Found on 44 of 88 test blocks, ranging from 1 to 146 worms per block. Ubiquitous on the reef materials, occurring on all materials at each reef site during the test block study and in later collections and observations.

Importance. No data, presumably fed upon by some fishes.

8.4.7.19. Family Serpulidae

Description. Body cylindrical or tapered, slightly flattened. Branchiae form a terminal, funnel-shaped plume around the mouth. Usually with one or two opercula (calcareous, horny or membranous), always in calcareous tubes, either cylindrical or polygonal.

Habit and habitat. The tubes, generally stout and affixed to the substrate along their entire length, present a formidable barrier to fish predation. Representative species on the test blocks formed long, wavy tubes (6 to 8 cm) on the protected side of the block near the bolt hole (Figure 32) . They do not leave their tubes but the colored branchiae which protrude most of the time may attract fish. The tubes are quite substantial and may become occupied by other animals after abandoned by the builder.

FIGURE 32 One of the test blocks placed on the WCB reefs. Note the serpulid worm tubes and the beginning mat-like layer of *Victorella argilla* (ectoproct). *Photo by* Robert R. Given.

FIGURE 32 One of the test blocks placed on the WCB reefs. Note the serpulid worm tubes and the beginning mat-like layer of Victorella argilla (ectoproct). Photo by Robert R. Given.

Occurrence. Serpulids were recorded from the test block on most materials from all three reefs. Subsequent scrapings and observations placed them on all materials at Hermosa Beach, Malibu, and the Redondo Canyon reefs, but not at Santa Monica.

Importance. Not commonly found in fish stomachs, possibly due to the fish's difficulty in removing the worm from its tube. With one exception, serpulids are not found in great numbers even on natural reefs, but their relatively large size and permanent calcareous tubes make them a notable physical factor in reef surface configuration. One small species, Salmacina tribranchiata (Figure 33) , does build large erect masses of tiny calcareous tubes, which are rather fragile and apparently unable to withstand strong currents. Salmacina was never significant on the study reefs.

8.4.7.20. Family Spionidae

Description. Body elongate, stout, not divided into distinct regions. Easily recognized by two very conspicuous elongate tentaculiform anterior palps, which are readily shed and often missing.

Habit and habitat. Some species build tubes, and those we encountered probably all build and occupy thin, parchment-like structures. They apparently remain inside the tube with their palpi protruding.

Occurrence. Spionids were noted on 34 of 88 test blocks and at various times on all materials on all reefs. They were subsequently found on the Hermosa Beach and Malibu reefs in surface scrapings.

Importance. As with other tube-builders they may be an important potential food source providing fish can remove them from their tubes.

Their protruding fleshy palpi may be occasionally nipped off by foraging animals, but the worm itself is probably saved by remaining in the tube. We recorded a spionid in one fish stomach during this study.

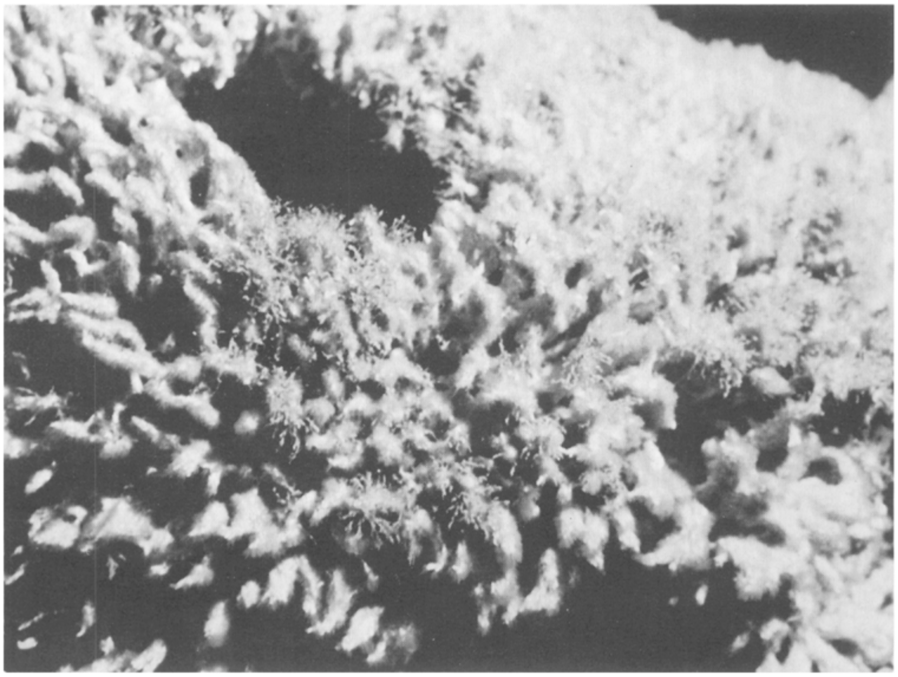

FIGURE 33 *Salmacina tribranchiata*, colonial, serpulid worm. *Photo by Charles H. Turner.*

FIGURE 33 Salmacina tribranchiata, colonial, serpulid worm. Photo by Charles H. Turner.

8.4.7.21. Family Syllidae

Description. Body slender, elongate, with two long anal cirri and relatively long cirri on the body segments. The anterior portion may be somewhat transparent, showing the dark, eversible pharnyx. Mostly small (under 10 mm) in this study.

Habit and habitat. Fairly active, free-living worms, probably living in the abandoned tubes of other animals.

Occurrence. Syllids ranging from 1 to 50 worms per block were on 39 of the 88 blocks studied, and were present at various times on all components at each reef site.

Importance. A major contributor to the fauna of the early reefs, and a good potential food source due to their abundance and availability.

8.4.7.22. Family Terebellidae

Description. Body stout, anterior section more or less inflated, posterior tapering. Very soft and fleshy with long filamentous tentacles on the head. Body often blood-red or pinkish-brown.

Habit and habitat. Some of our species constructed soft tubes in the mud or sand near the reefs. They seem to prefer being surrounded by, or living under, rocks in a muddy substrate. Their tentacles spread out over considerable areas and entrap food.

Occurrence. Found on only two test blocks (May 1961) and subsequently in small numbers during the general observations and in scrapings.

Importance. Although the worms may get quite large, they were a minor member of these reefs' fauna. They are known to inhabit mature natural reefs and, hence, may become more important in later reef succession.

8.4.7.23. *Family Trichobranchidae*

Description. Body stout, elongate, tapering somewhat posteriorly. Characterized by the large anterior lobe with numerous tentacles.

Habit and habitat. They probably do not build a permanent tube, but burrow into soft sediments leaving the tentacles exposed.

Occurrence. Found on two test blocks from the Hermosa Beach reef, but we have no subsequent records.

Importance. of minor importance due to their rarity, but may become more important as the reefs mature and the substrate "mat" builds.

8.4.8. Sipunculoidea

These are small, unsegmented, elongate, cylindrical, worm-like animals characterized by a tentacled protrusible anterior apparatus (introvert) for feeding. Their color ranges from yellowish to grayish.

8.4.8.1. Phascolosoma agassizii Keferstein, 1866—peanut worm

Description. Small to medium sized (5 to 30 mm long). The roughskinned, elongate body is pigmented with dark brown or purple spots.

Habit and habitat. One of the most common sipunculids on the southern California coast, being found both intertidally and subtidally on most rocky areas, burrowing in fine sand or mud adjacent to the rock and often in holes and crevices of the rocks. In this study we also found them in the rotted test blocks and in empty shipworm burrows.

Occurrence. Recorded on a test block from the Hermosa Beach rock component (June 1961), on the Malibu streetcar test blocks (May and June 1961), and occasionally thereafter in miscellaneous collections and during general observations.

Importance. Minor in the reef succession and ecology considered in our present study due to their relative rarity. Even in the later successional stages and on mature natural reefs their extreme secretiveness probably makes them virtually unavailable as food for reef fishes.

8.4.9. Arthropoda

The arthropod body is characteristically segmented and variously jointed externally, and is covered with a hardened external skeleton which is shed periodically. Included are the insects, spiders, crustaceans, etc. Generally, arthropods are separated into two large groups based on the presence (Mandibulata) or absence (Chelicerata) of "jaws" or mandibles. Except for the rare occurrence of a Pycnogonida (Chelicerata), all our arthropods belong to the class Crustacea (Mandibulata).

There are several opinions on the taxonomic standing of the Crustacea and consequently of the various groups included. In this study we use the scheme of classification presented by Waterman and Chace (1960). They define crustaceans as serially segmented, mandibulate arthropods with the first two pairs of appendages being antennae. The body usually has a dorsal covering (carapace), and true gills for respiration.

Crustaceans, together with the annelid worms, constituted the major fauna of the test blocks and early reef. Included are several widely separated sub-groups: some occurred in great numbers and, according to stomach analysis, were important fish foods; others occurred only rarely and were probably incidental to the main faunal picture. They are all worthy of note, however, as their presence may indicate successions to come.

The following crustaceans are presented by taxonomic sub-group, roughly following the groupings of Waterman and Chace (1960), and where appropriate, alphabetically by genus within a sub-group.

8.4.9.1. Subclass Ostracoda

Description. Usually minute, compressed crustaceans with a bivalved shell from which a few appendages may project. This shell gives the animal the appearance of a small clam.

Habit and habitat. Generally lives on or near the soft bottom, hopping about and grubbing in the substrate. Sometimes occurring in large concentrations in soft-bottom areas. Also found in the rocky environment crawling among the algae and ectoprocts.

Occurrence. Test blocks only; occasionally on test blocks from the Hermosa Beach and Malibu reefs and once at Santa Monica. Not noted in subsequent observations or scrapings.

Importance. Probably incidental during the test block study period due to their small size and numbers. As the epistrate builds they may become more abundant. We recorded one from a fish stomach. They are found in the same environment as gammarid amphipods, yet are not reported to constitute as important a part of the fishes' diet as do gammarids.

8.4.9.2. Subclass Copepoda

Description. Mostly small to microscopic crustaceans, named for and characterized by their use of oar-shaped head appendages for swimming (free-living forms only). May have a large anterior median eye; the body tapers posteriorly.

Habit and habitat. Copepods may be found in nearly every marine habitat. Most are free-swimming, but some are adapted to parasitism and others live in loose associations with other animals.

Occurrence. In small to large numbers on all materials at all three reefs during very early stages of reef development.

Importance. Along with caprellid amphipods, copepods found on test blocks may be extremely important as fish food during the early stages of faunal succession. MacGinitie (1949, p. 133) states: "Some copepods crawl freely among the tentacles of certain hydroids. Some are rather specific as to their habits, others are not so particular." He further states (p. 256), "Hydroid colonies, such as Obelia and Tubularia, will be found harboring copepods in great abundance."

Three orders in the subclass Cirripedia (barnacles), representing the two general barnacle types, "stalked" and "acorn," are recognized along the southern California coast, but only one suborder, the familiar Balanomorpha (acorn barnacles), was present during our study.

Balanomorphs occur locally from the high intertidal to depths of several hundred feet. They form extensive masses on rocks, pilings and other objects placed in the sea, often causing severe fouling. Competition for space and overcrowding results in vertical elongation of their shells; often with grotesque results (Figure 34).

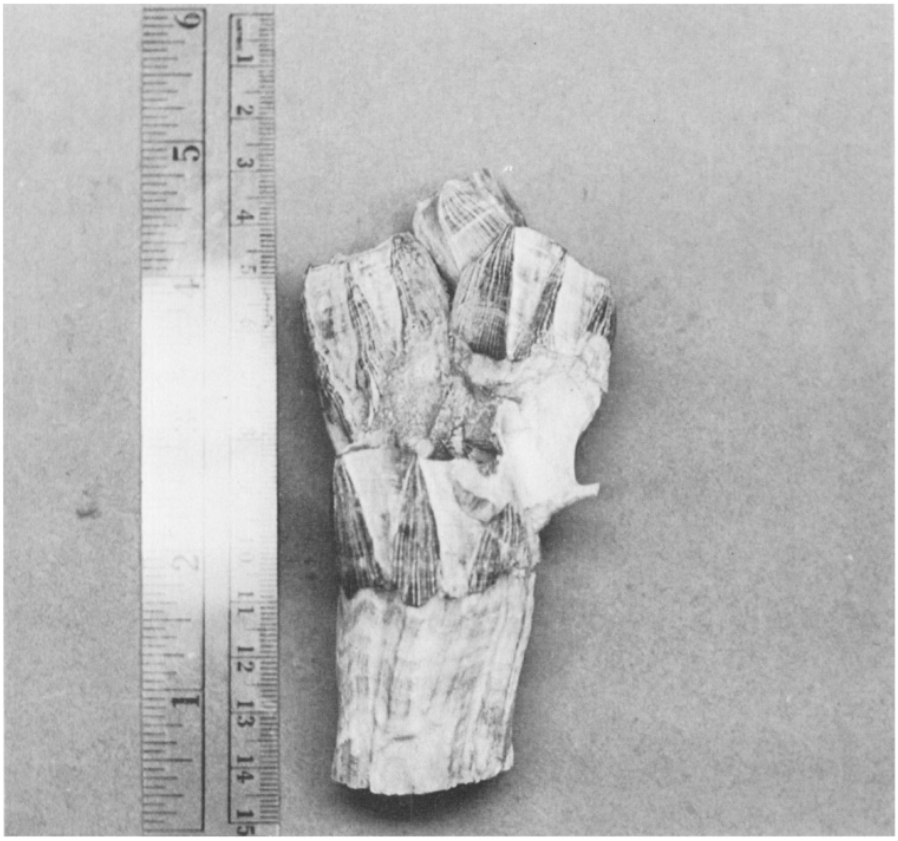

FIGURE 34 ***Balanus tintinnabulum californicus*** **showing the effects of crowding; elongation of the shell and competition for space.** ***Photo by Charles H. Turner.***

FIGURE 34 Balanus tintinnabulum californicus showing the effects of crowding; elongation of the shell and competition for space. Photo by Charles H. Turner

Acorn barnacles reproduced in all months. The juveniles metamorphose from the free-swimming nauplius stage to the cypris stage which affixes itself by its antennules to almost any firm substrate. They then undergo further metamorphosis from the bivalved to the adult form.

Barnacles were one of the first organisms to appear on man-made habitat, regardless of season. Once established they formed a large part of the biomass and were recorded in all the samples collected.

The ctenostome ectoproct, Victorella argilla, was a major cause of barnacle mortality. In laterally spreading its mat-like structure, a layer up to 6 mm (0.25 inch) thick, would extend up and over the barnacle's walls and into their apertures, eventually blocking their opercular plates (Figure 50) . Most severely affected was Balanus concavus pacificus and to a lesser extent B. trigonus. By contrast, the large B. aquila survived despite a Victorella covering on their plates and operculum. Juvenile balanomorphs settling directly onto this ectoproct "mat" were engulfed before attaining 3 or 4 mm diameters.

Frequently, empty barnacle compartments, still attached, harbored an unidentified polyclad flatworm. We strongly suspect this polyclad was predaceous on these barnacles. The manner in which these polyclads invaded the barnacles, whether as free-living larvae or adults, is not known.

Barnacle identification, is based primarily on the shape of their opercular plates, tergum, and scutum. of the six species identified during this study, five were of the genus Balanus, and the most numerous of these was B. concavus pacificus. Juveniles less than 5 mm in diameter were identified only to genus.

We collected several cypris stages on microscope slides (see Test Block Studies section) and recorded their metamorphosis into adult forms less than 18 hours later (1500 hours December 14-0830 hours December 15, 1964).

8.4.9.3. Balanus aquila Pilsbry, 1907—acorn barnacle

Description. A large barnacle with thick walls and well developed ribs; the tergal plates bear long, sharp beaks affording easy field identification. The opercular plates are pale yellow interiorly and cream-white to white exteriorly.

Habit and habitat. Lives below low tide, rarely intertidally, to at least 100 feet and probably deeper. Prefers the upper surfaces of materials where good currents prevail. Individuals 6.4 cm (about 2.5 inches) in diameter were recorded in August 1963, 3 years after reef placement. We assume these large barnacles attached sometime during the first 6 months of the reef's life.

Occurrence. Common on each of the artificial reefs. Huge numbers of juveniles were always present, but large individuals 5 cm (2 inches) or greater in diameter were sparse and scattered, averaging about 0.5 per m^2.

Importance. Eaten by several fishes including sheephead and embiotocid perch. Large individuals are preyed upon by starfish and certain carnivorous snails. Fishes were observed rubbing against them to scrape off their (the fish's) external parasites. This action against the sharp upper edges of the barnacles eventually wore them down to a smooth even surface.

8.4.9.4. Balanus concavus pacificus Pilsbry, 1916—acorn barnacle

Description. Conical, generally with straight-sided walls typically flaring slightly at the diamond-shaped orifice. Shell vertically striped with pink on a white background. Our specimens averaged about 1.9 cm (0.75 inch) in diameter and slightly less in height (Figure 35) .

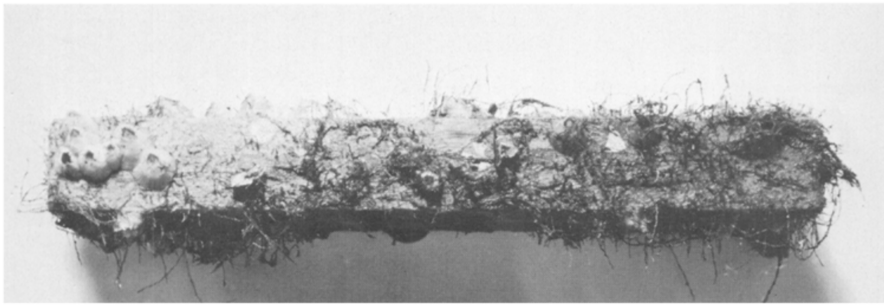

FIGURE 35 *Balanus concavus pacificus* and hydroids encrusting one of the Santa Monica WCB reef test blocks. This blocks appearance is typical for the barnacle-hydroid stage. *Photo by Glen Bickford.*

FIGURE 35 Balanus concavus pacificus and hydroids encrusting one of the Santa Monica WCB reef test blocks. This blocks appearance is typical for the barnacle-hydroid stage. Photo by Glen Bickford.

Habit and habitat. On all surfaces of any firm substrate; common just below low tide to at least 100-foot depths.

Occurrence. On all reefs and materials; juveniles appeared within 30 days of reef placement. The most common barnacle (subtidally to 80 feet) in Santa Monica Bay and possibly along the entire southern California coast.

Importance. Fed upon extensively by embiotocids and probably many other fishes and invertebrates.

8.4.9.5. Balanus flos Pilsbry, 1907—acorn barnacle

Description. Walls steeply conical, generally flaring at the aperture; orifice large; scutum concave between apex and base. Exterior walls faintly pink; opercular valves white.

Habit and habitat. Any firm substrate from the surface to depths of 338 fathoms (Pilsbry, 1916).

Occurrence. Uncommon, a single specimen collected at the Santa Monica reef concrete shelters, from the 0.06 m2 scraping (April 1963).

Importance. None in this study due to rarity.

8.4.9.6. Balanus tintinnabulum californicus Pilsbry, 1916—acorn barnacle

Description. Reddish in color with vertical white stripes; steeply conical with a large orifice. Survives when crowed by greatly elongating its shell (Figure 34). Attains diameters of at least 3.8 cm (1.5 inches) and heights of 7.6 cm (3 inches) or more.

Habit and habitat. Prefers quiet water conditions, often found just below low tide; common on floats and pilings. Its vertical distribution appears limited by turbidity.

Occurrence. Common on the undersides of the buoys marking each of the reefs. Found once on a test block at Santa Monica, once in a 0.06 m^2 sample at the Hermosa Beach reef, and infrequently in our general surveys.

Importance. Minor; the turbid waters of Santa Monica Bay prevented the development of substantial populations on the artificial reefs. In relatively clean waters (e.g., offshore oil drilling platforms near Santa Barbara) good populations flourished at depths of 60 feet and more (Carlisle, Turner and Ebert, 1964).

8.4.9.7. Balanus trigonus Darwin, 1854—acorn barnacle

Description. Flatly conical; aperture broad, diamond-shaped, hardly toothed; parietes (walls) ribbed; purplish-red, fading above to almost white. The most distinct and easily recognized character is the scutum, prominent growth ridges cross several deep longitudinal furrows, produce rows of small, deep pits that are stained a dark-brown. Our average specimens were about 8 mm (0.3 inch) in diameter and 6 mm (0.25 inch) high.

Habit and habitat. Firm substrate on all surfaces. Vertical distribution unknown.

Occurrence. On all reefs, and all materials. Like other barnacles they appeared shortly after reef placement. Common; second in abundance to B. concavus pacificus.

Importance. Typical of the group.

8.4.9.8. Tetraclita squamosa elegans Darwin, 1854—acorn barnacle

Description. Flatly conical; orifice roughly circular; outer layer of wall uneroded, ribbed; color white.

Habit and habitat. Intertidal zone.

Occurrence. On the marker buoy at the Santa Monica reef; did not establish on reef.

Importance. None on our reefs.

Crustaceans in the subclass Malacostraca have a fixed number (14) of body somites and a sharp division of the head and thorax. Most crustaceans encountered in this study (amphipods, isopods, crabs and shrimps) were in this subclass. Seven orders are reported upon: Mysidacea, Cumacea, Tanaidacea, Isopoda, Amphipoda, Decopoda and Stomatopoda.

Mysids (Mysidacea) are elongate, shrimplike crustaceans, usually found in the midwater regions. Those we encountered were generally small (5 to 8 mm long). They are commonly taken in bottom trawling operations, and are often seen by underwater swimmers as an indistinct layer floating 6 to 10 inches (15 to 25 cm) off the ocean floor. These small, near-bottom dwelling mysids presumably form an important part of the reef fish's food.

They were recorded only twice in our study, both times, in the stomach contents of rubberlip perch (Rhacochilus toxotes) collected near the reef structures.

Cumaceans (order Cumacea) are small (3 to 8 mm) benthic malacostracan crustaceans with the carapace produced anteriorly into two plates, forming a pseudorostrum. The abdomen is abruptly smaller and more slender and mobile than the thorax, ending in a characteristically forked "tail."

Cumaceans live at the water-sand interface on soft bottoms, burrowing into the top few millimeters of sediment. This makes them especially vulnerable to predation by bottom-feeding fishes.

One specimen was recovered from a test block, Hermosa Beach concrete shelter component, and others were noted during analysis of fish stomachs. Although they are found in the same substrate situations as are gammarid amphipods they apparently were not a major food item for the fishes in our study. This may have been due to their small size and relative scarcity.

Tanaids, (order Tanaidacea) have a minute, elongate, cylindrical or depressed body. The second thoracic appendage is always with a claw (chelate). The genus Leptochelia was noted. Usually, they live in mud or muddy tubes, also in rocky areas in the epifaunal mat. Generally rather secretive, they may occur in rather large numbers in some areas. In our study most were in holes or tubes.

Two specimens were found on one test block from the Santa Monica rockpile, and subsequently rather large numbers were recorded from the surface scrapings taken at the Hermosa Beach and Malibu reefs.

They are probably of some importance as fish food, if they can be caught out of their tubes. They are found occasionally in fish stomachs but never as a major food item.

Members of the order Isopoda have a usually flattened, depressed body; no true carapace; and the last seven pairs of legs are notably uniform (hence, iso-poda). Except for the gribble (Limnoria tripunctata) isopods did not appear on the test blocks and reef materials in significant numbers. An unidentified valviferan appeared in one of the substrate scrapings, and several fish stomachs contained limbs or other body parts from isopods.

8.4.9.9. Limnoria tripunctata Menzies, 1951—gribble

Description. Oval-elongate body, depressed; small, usually 2 to 3 mm long. Whitish, often with several dark patches of the ciliateprotozoan Mirofolliculina sp. on the telson. Distinguished by three small projections on the telson (hence, tripunctata) .

Habit and habitat. Wood borers, boring just beneath the surface leaving tell-tale pinholes.

Occurrence. Found only at the Hermosa Beach reef, on test blocks, at each of the materials. Individuals first appeared in December 1960, rapidly infesting the remaining test blocks. Over 400 were counted in a 1961 test block (Appendix 1). Undoubtedly they accelerated the deterioration of the predominantly wooden streetcar component at this reef.

Importance. Detrimental to wooden structures. Unlikely that they enter the food chain directly because of their inaccessibility.

8.4.9.10. Livonica vulgaris Stimpson, 1857—cymothoid isopod

Description. Oval-elongate, depressed, walking legs strongly hooked for attachment. Large specimens attain 4 cm (about 3.12 inches) in length. Color pale yellow with dark eyes and uropods.

Habit and habitat. A common ectoparasite of many teleosts, generally attaching in the branchial chamber. Juveniles are free-swimming until they find a host. During this study we observed an adult free-swimming (about 1 m above the reef material) apparently seeking a new host. They are hermaphroditic; the eggs are carried in a brood pouch beneath the abdomen. Ovigerous adults were observed from August through April and mature embryos, ready to hatch were common in January and February.

Occurrence. Common on fish at each reef. Observed parasitizing nine species (California lizardfish, Synodus lucioceps; jack mackerel, Trachurus symmetricus; lingcod, Ophiodon elongatus; olive rockfish, Sebastes serranoides; pile perch, Rhacochilus vacca; sand bass, Paralabrax nebulifer; sarcastic fringehead, Neoclinus blanchardi; sculpin, Scorpaena guttata; and white seaperch, Phanerodon furcatus) and known to occur on several more.

Importance. Heavily parasitized fishes appearing gaunt and barely able to swim were observed around the reefs; mortality seemed inevitable for these. Livonica was found in the stomach of a sand bass, possibly the result of eating an affected fish.

8.4.9.11. Mesoporcellio sp.—oniscoid isopod

The body is oval, tapering posteriorly. Our specimen was small (4 mm long, probably juvenile) and was apparently free-living on a test block (Hermosa Beach concrete shelters, April 1961). This was probably an isolated occurrence and it is doubtful that this form will become important on the reefs.

The amphipods (order Amphipoda) are small (4 to 12 mm), the body either cylindrical or laterally compressed, the abdomen flexed ventrally. Thoracic legs are separated into two groups opposing each other in articulation, allowing the animal to cling, swim, hop or spring but not to walk.

There are four suborders in the group, two of which (Gammaridea and Caprellidea) were present during our study; the other two are parasitic or pelagic. The suborders considered here are of major importance in the test block studies and reef ecology due to their abundance, diversity, and general availability as fish food. The stomachs of the reef fishes examined indicated a definite "choice" for these crustaceans as food.

In the gammarideans the body is laterally compressed and the carapace is lacking so all abdominal and thoracic appendages are visible. These are benthic animals found hopping about or grubbing in the substrate at the water-sediment interface. Some live in thin tubes of their own manufacture. Gammarids are probably the most important single food item for the fishes in and around man-made reefs; we found them in most of the fish stomachs we analyzed. They were on 73 of the 88 test blocks, in the scrapings and were observed subsequent to the block analyses. They first occurred in October 1960, less than one month after placement of the materials, their population grew from 1 to 3 per block to 1,300 per block in two cases some 9 to 10 months after reef construction. Most of those collected were small and many had built masses of tubes on portions of the test blocks and reef materials. After reaching a population peak in the spring and early summer of 1961 they declined in most areas, possibly due to the deterioration of the test block itself and the subsequent loss of space upon which to live. Their desirability as fish food, resulting in heavy predation, must also be considered as a factor in their decline.

Undoubtedly several families and many species were represented, both free-living and tube-dwelling, but their identification is a highly specialized field not undertaken in this study. All specimens from test blocks and scrapings were counted, recorded, and preserved for future study.

In members of the suborder Caprellidea (skeleton shrimp) the body is elongate, cylindrical, and stick-like; the abdomen is much reduced. Appendages are aberrant, some vestigial; those present are well-developed for grasping and clinging. Superficially they resemble "walking stick" insects. These strange crustaceans are usually found clinging to hydroids, algae, gorgonians or other upright sessile organisms. In this study, they were found almost exclusively on hydroids, their abundance being directly influenced by the amount and condition of the hydroid growth. They cling to the upright hydroid stems by their hind limbs and wave jerkily back and forth. Feeding may be directly on the hydroid polyps, on small crustaceans or diatoms living on the hydroid stems, or on small organisms in the surrounding water.

Their importance lies in their relative abundance and availability to foraging fishes. The stick-like body may be an effective camouflage when they closely adhere to the hydroid stem, but when actively waving about, clinging only by their hind limbs, they are a tempting morsel to passing fish. Fish stomach analyses showed they were common in the reef fish's diet, but not as common as the gammarids.

Caprellids were on 66 of the 88 test blocks and in four of the six subsequent surface scrapings. In general, they appeared 60 to 90 days after reef construction and they were frequently less abundant than the gammarids; however, on one of the test block series (Malibu streetcar component) a population of 900 to 1365 per block remained for the last 5 months of the 12-month study (Appendix 2).

In members of the order Decopoda (e.g. shrimps, lobsters, hermit crabs, crabs) the carapace is fused dorsally with all the thoracic segments; first three pairs of thoracic appendages modified as feeding structures, next five pairs as walking legs (thus Deca-pods = ten-foot). The first walking leg(s) may be equipped with a claw or claw-like structure.

This is the best known group of crustaceans and includes most of the edible forms. Two suborders, the shrimps and shrimp-like forms (Natantia) and the crabs and lobsters (Reptantia) were considered in our study.

The following are members of the suborder Natantia.

8.4.9.12. Alpheus (= Crangon) dentipes (Guerin, 1832)—pistol or snapping shrimp

Description. Rostrum usually short and spiniform. Characterized by a large hand or claw with the movable finger opening horizontally and capable of snapping shut with considerable force.

Habit and habitat. Rocky reef areas, especially under small rocks and in crevices.

Occurrence. Not found on test blocks, but noted later on the streetcar, rock and concrete components of the Hermosa Beach and Malibu reefs. Subsequently, at the Malibu concrete shelters (August 1963), a gravid female was collected with eggs in the eyed stage. Pistol shrimp remains were found in one fish stomach.

Importance. Minor in early reef development, they may become more abundant and thus more important with reef maturity and when more suitable substrate and habitat become available.

8.4.9.13. Hippolysmata californica Stimpson, 1896—red rock shrimp

Description. Conspicuously marked with broken longitudinal red or red-brown stripes which form an excellent protective coloration against a background of rocks and algae. Average body length 38 mm (1.5 inches), antennae extremely long. The wrist of the second pair of legs contains more than seven segments, separating them from close relatives.

Habit and habitat. Usually gregarious, found in large numbers in crevices and holes of rocky areas to depths exceeding 200 feet. Sold commercially as bait in southern California, being taken in traps fished around breakwaters.

Occurrence. Not found on test blocks, but noted around the rock and concrete shelters as early as October 1961. The population grew until May 1962, then stabilized at around 300 shrimp per material (where present). Their secretive habits, remaining deep in the darkened crevices, may have caused us to underestimate the population size.

Importance. Found in several fish stomachs. Their relatively large size would make them an important food item if they were readily accessible, but the secretive habit probably limits their availability. They are a cleaner shrimp and pick ectoparasites from fishes, especially morays, or other animals entering their crevices.

8.4.9.14. Pandalus gurneyi Stimpson, 1871—coon-striped shrimp

Description. Rostrum long, slender. curved, spiny, at least 1.5 times as long as the carapace. Body with red spots on a light background. Average size about 75 mm (3 inches) (less rostrum).

Habit and habitat. Under rocks on the man-made reefs at 60- and 90-foot depths.

Occurrence. A population of 25 to 30 individuals recorded at the Hermosa Beach rock component (September 1961). Later (October 1963) only one specimen was observed. The deeper (90-foot) Redondo Canyon reef supported 353 juveniles and adults on one of the four piles of rock in October 1963.

Importance. Minor in this study.

The genus Spirontocaris (bent-back or broken-back shrimp) is represented here by four species. They comprise a fairly homogeneous group, with subtle taxonomic differences separating the species. These differences are not immediately evident to the non-specialist and are not important in the overall ecologic position of the group. S. palpator is one of the common species, and the discussion of its habitat and behavior can be applied to the other species we saw.

8.4.9.15. Spirontocaris palpator (Owen, 1839) bent-back shrimp

Description. Body small (25 mm long) with a characteristic sharp ventral flexure of the abdomen.

Habit and habitat. A common dweller around and under small rocks. The sharp abdominal flexture enables them to bend their posterior portions suddenly downward and forward, propelling them rapidly backward. Usually seen moving about nervously on the undersides of rocks.

Occurrence. A small population was first noted (in the field) at Hermosa Beach in September 1961 (about seven individuals, scattered among the rocks and concrete). Others were subsequently identified from test blocks at all three reefs. After the test block studies ended (1961), they were noted commonly at the Hermosa Beach rock component. Females with eyed eggs were seen there in the fall of 1961, and the species was thought to be a breeding population. By 1963 their numbers had diminished somewhat but ovigerous females were still found on occasion.

Importance. Major, as food for reef fishes.

8.4.9.16. Spirontocaris brevirostris (Dana, 1852)

One specimen was seen on the Hermosa Beach rock component (December 1961).

8.4.9.17. Spirontocaris cristata (Stimpson, 1860)

One specimen was seen on the tube of a tube anemone and one on an egg collar of a moon snail (Polinices) near the Hermosa Beach reef (April 1962).

8.4.9.18. Spirontocaris prionata (Stimpson, 1864)

This species was fairly common around the Hermosa Beach reef materials in late 1961 and early 1962 and 1963.

of the nine species of cancroid crabs (suborder Reptantia) found in California, five were represented in our study. Cancer magister, the market crab and most economically important family member, is rare in southern California and was not observed, but at least three of the remaining family members, generally called rock crabs, support a limited commercial fishery in southern California.

Cancroid crabs are all similar in gross morphology and are typically "crab-like" with ovoid, flattened carapace and reduced, turned-under abdomen. Important characters used here for species identification include size differential, carapace dentition and color patterns.

We identified five species during our study. The three most common species, Cancer antennarius, C. anthonyi, and C. productus, have similar life histories and behavior patterns. The other two, C. gracilis and C. jordani, each collected only once, have slightly different behavior patterns.

8.4.9.19. Cancer antennarius Stimpson, 1856—rock crab

Description. Generally dark reddish-brown, under surfaces light yellow spotted with red, fingers on claws black-tipped; carapace smooth, widest at the eighth lateral tooth. Juveniles are very hairy but lose this as they mature. Attains a carapace width of 12.7 cm (5 inches).

Habit and habitat. Typical of the rock crab group, see this section under Cancer productus.

Occurrence. Peak concentrations of 200 or more occurred at each of the reefs during April and May throughout the study.

Importance. Minor during this study. The juveniles are a potential food item for reef fishes.

8.4.9.20. Cancer anthonyi Rathbun, 1897—yellow crab

Description. Brownish-red dorsally, under parts a uniform light yellow; black-tipped fingers on the claws. All legs quite smooth resembling the rock crab. Carapace widest at the ninth lateral tooth. Attains carapace width of at least 15.2 cm (6 inches) (Figure 36) .

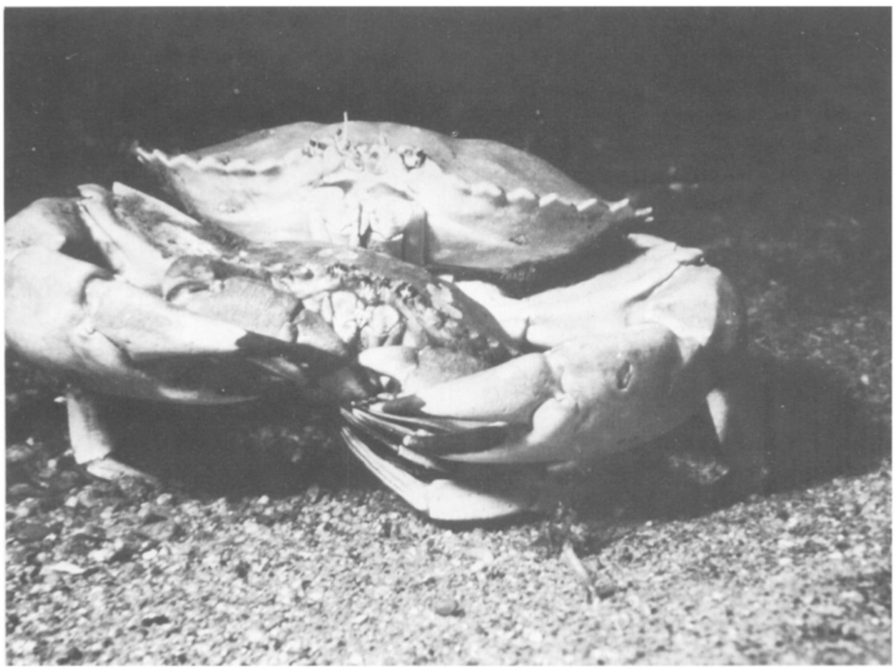

FIGURE 36 Male *Cancer anthonyi* (yellow crab) cradling a female, prior to mating; off Redondo Beach, 100-foot depth. *Photo by Charles H. Turner.*

FIGURE 36 Male Cancer anthonyi (yellow crab) cradling a female, prior to mating; off Redondo Beach, 100-foot depth. Photo by Charles H. Turner

Habit and habitat. Typical of the rock crab group, see this section under Cancer productus.

Occurrence. This was the most common adult cancer crab. Three hundred or more were frequently observed on each of the reefs during April and May throughout the study period. Carlisle (1969a) records this species into water depths of 460 feet.

Importance. Major, the adults are utilized by humans and the juveniles are eaten by various reef fishes.

We observed a Cancer anthonyi actively cleaning ectoparasites from an 18-inch sand bass. The magnitude of this behavior is open for speculation, but must be considered when assessing the importance of these animals.

8.4.9.21. Cancer productus Randall, 1839—red crab

Description. Adults are red, becoming brownish above and yellowish below with orange-red blotchings; fingers on the claws black-tipped. Juveniles vary from yellow through chocolate. Attains a width of 17.8 cm (7 inches) across the carapace.

Habit and habitat. Red crabs are commonly found in rocky crevices and under ledges, or when in open sandy expanses, half buried with only their upper carapace exposed. They congregated at the reefs during their breeding season (winter into summer). Ovigerous females restricted themselves to "rocky" areas and the crevices under other reef materials since they presumably are unable at this time to bury into the sand for protection without injury to the developing eggs attached to their swimmerets.

Their prolonged breeding season lasted from January through August with the most intense activity from April through June. Juveniles were common in the fall and winter; individuals collected in October and November had carapace widths averaging 2.2 cm (about 0.87 inch).

Occurrence. Adults were recorded in all months with peak concentrations paralleling the breeding season. Two hundred or more were present at each of the reefs during April and May throughout the study. Few adults were observed from November through February, a time when their spatial niche was filled by spiny lobsters, which compete at a similar trophic level.

Importance. Adult red crabs were not observed to be extensively preyed upon by other reef animals, possibly due to their size. Juveniles, however, were heavily fed upon during the winter months by sculpin (Scorpaena guttata) , sand bass (Paralabrax nebulifer) and kelp bass (P. clathratus) .

8.4.9.22. Cancer gracilis Dana, 1852—slender crab

Description. Carapace finely granulated. Olivaceous overlain with reddish-brown spots; fingers on the claws white-tipped. Legs slender, not flattened. Carapace width up to 10.2 cm (about 4 inches).

Habit and habitat. Adults occupy a spatial niche similar to that of other cancroid crabs. Juveniles were often observed commensal within the bell of the large jellyfish, Pelagia panopyra. Carlisle (1969a) records the adults from waters 60–570 feet deep.

Occurrence. One adult recorded at the Hermosa Beach reef in August 1960, with juveniles observed in the reef area as commensals.

Importance. No data.

8.4.9.23. Cancer jordani Rathbun, 1900—hairy cancer crab

Description. Generally smaller than the other cancroid species; adults less than 5 cm (2 inches) in carapace width. Carapace hairy; teeth sharp, alternately large and small.

Habit and habitat. Around and under rocks.

Occurrence. One specimen collected at the Malibu reef concrete shelters in March 1962.

Importance. No data.

8.4.9.24. Heterocrypta occidentalis (Dana, 1854)—elbow crab

Description. Small (averaging 3 cm across the carapace) active crabs. Carapace broadly triangular, pinkish-purple, rostrum pointed. Characterized by the long, heavy chelipeds (first walking legs, with a claw) which fold back on themselves when the animal is in repose.

Habit and habitat. Usually frequents open sandy areas, partially buried in the sand when not foraging. Probably very vulnerable to predation when not covered by sediment.

Occurrence. Recorded from fish stomachs and occasionally in the sand between various reef materials at Hermosa Beach and Santa Monica. Recorded in waters as deep as 300 feet (Carlisle, 1969a).

Importance. May be a major food item for some of the fishes that feed from both the sand bottoms around the reefs and the reefs proper.

8.4.9.25. Lophopanopeus bellus bellus (Stimpson, 1862)—black-clawed crab

Description. Small (20 mm), carapace hexagonal or subquadrate; hands smooth, fingers dark. Crimson or beet-red, sometimes with yellow.

Habit and habitat. Small specimens were found on and in the epistrate mat, the algae-sponge complex, and the large erect ectoproct "heads."

Occurrence. A few specimens were collected incidentally in 1963 on the Hermosa Beach and Malibu concrete materials.

Importance. Minor, but may become important in fish diets with reef maturity, and the thickening of the epistrate.

8.4.9.26. Lophopanopeus diegensis Rathbun, 1900—xanthid crab

Description. Small (12 mm wide); carapace with a few granulate lines; dull brown or black, occasionally reddish-brown, fingers dark.

Habit and habitat. Under small rocks.

Occurrence. Hermosa Beach rock component (December 1961 and April 1963), a few isolated specimens.

Importance. Minor, the population was too small to be important except as an incidental food item for fishes.

8.4.9.27. Loxorhynchus crispatus Stimpson, 1875—masking crab

Description. Smaller than the related spider crab L. grandis; has a heavy plush of short thick hairs on the carapace. May be completely masked with hydroids, sponges, ectoprocts or algae which subdue its crab-like appearance and cause it to blend perfectly with the substrate mat (Figure 37) .

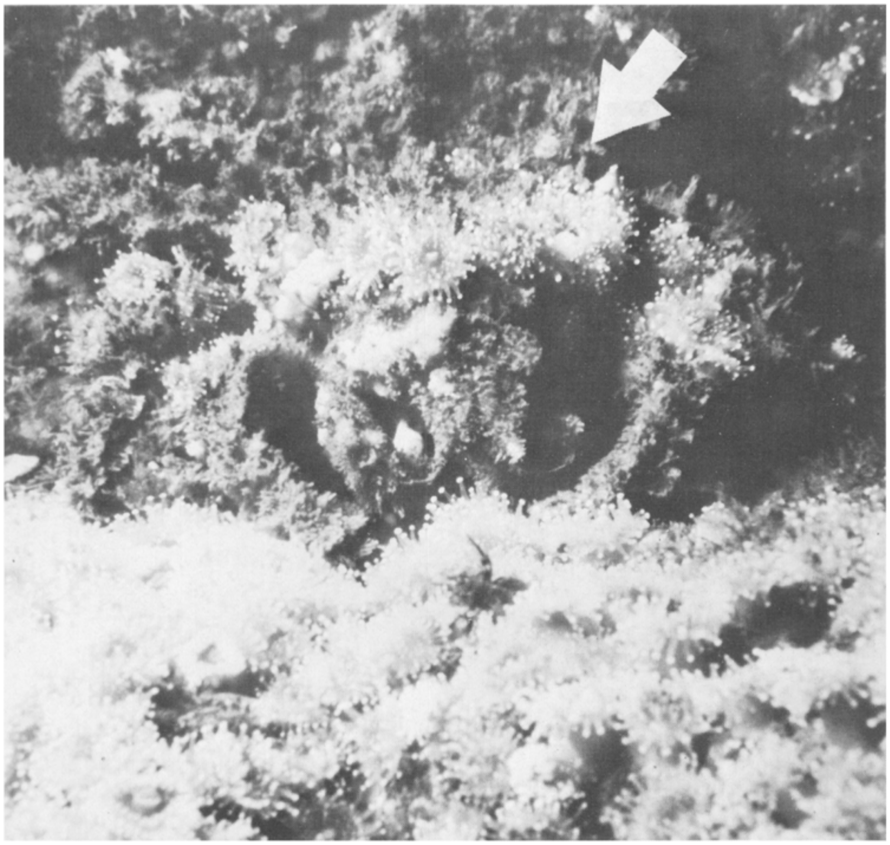

FIGURE 37 A masking crab, *Loxorhynchus crispatus* (arrow) employing aggregate anemones (*Corynactis californica*), as part of his camouflage. *Photo by Charles H. Turner.*

FIGURE 37 A masking crab, Loxorhynchus crispatus (arrow) employing aggregate anemones (Corynactis californica) , as part of his camouflage. Photo by Charles H. Turner

Habit and habitat. Lives on rocky areas where growth on the substrate is heavy. Does not secrete itself under rock but relies on carapace camouflage for protection. Slow moving.

Occurrence. Juveniles noted occasionally at the Santa Monica and Hermosa Beach reefs in 1961 and 1962; juveniles and adults seen on all reefs in late 1962 and 1963, but never in large numbers. Collected in scrapings from the concrete shelters.

Importance. Minor during this study.

8.4.9.28. Loxorhynchus grandis Stimpson, 1857—spider crab or sheep crab

Description. Characteristically large (carapace may be 10 or more inches across); carapace ovate, sparsely covered with large tubercles in the adult. Bluish-green to reddish, with worn areas of white.

Habit and habitat. On or near rocky areas, also may be seen walking across open sand bottoms. Fairly agile and fast moving, with formidable claws.

Occurrence. A few small (4 inch) specimens on the Hermosa Beach reef (July 1961). The adult population increased during 1961 and 1962, with several specimens seen on all the materials at most times of the year. Also noted on the deeper (90-foot) Redondo Canyon reef, and recorded in 126 feet by Carlisle (1969a). Mating occurred in spring and early summer, mostly among individuals with carapace widths exceeding 6 inches.

Importance. These large crabs are scavengers and may offer some competition to the reef fishes. The juveniles, possibly a minor food source for reef fishes, are camouflaged with masking hairs (as in L. crispatus) until about 3 inches across the carapace.

8.4.9.29. Pachycheles holosericus Schmit, 1921—porcelain crab

Description. Small (up to 25 mm wide); recognized by the relatively large unequal claws covered with prominent tubercles and granules on the upper surface, these in turn being covered with dense hair.

Habit and habitat. Generally around rocky areas, particularly those with small rocks and heavy substrate. They hide in this substrate or under the rocks and when flattened against the surface are difficult to detect. Also common in mussel clumps on reef marker buoys and chains.

Occurrence. Small numbers found in late 1961 and 1962, in the growths on the buoys and chains at all three replication reefs. Later in 1962 and in 1963 they were seen occasionally on the materials; some ovigerous females were noted.

Importance. Not found in fish stomachs, but may form a minor part of their diet if caught away from the protection of the rocks.

8.4.9.30. Pachycheles pubescens Holmes, 1900—porcelain crab

Description. Close to P. holosericus but with unequal chelipeds which are granulated but not tuberculated.

Habit and habitat. Same as P. holosericus, but less common on buoy chains.

Occurrence. A few seen at Hermosa Beach and Malibu in large bryozoan colonies and the heavy substrate "mat." Noted only in middle and late 1963; ovigerous females common in August 1963.

Importance. Minor during this study.

8.4.9.31. Pachycheles rudis Stimpson, 1859—big-clawed porcelain crab

Description. Similar to P. holosericus but with only a few sparse hairs on the large claws.

Habit and habitat. Hides in rocky areas in the substrate, similar to other species of Pachycheles.

Occurrence. Three specimens collected in a random scraping from the Malibu concrete shelters (October 1963).

Importance. Minor in this study.

8.4.9.32. Pachygrapsus crassipes Randall, 1839—striped shore crab

Description. Shell subquadrate, mottled reddish-green.

Habit and habitat. A very active crab, normally found in large numbers in the high- and mid-tidal rocky areas, adults rarely found in deeper water.

Occurrence. Small- and medium-sized individuals were found on the buoys and buoy chains at Malibu and Santa Monica.

Importance. Young may be picked up incidentally as fish food. Their main interest to us was their presence so far from rocky intertidal areas, indicating that an early part of their life cycle may be spent in an environment where conditions are not so harsh.

8.4.9.33. Paguristes ulreyi Schmitt, 1921—hermit crab

Description. Large sized, for a hermit crab on this coast, with the carapace measuring up to 25 mm (1 inch) wide. Reddish-orange; upper surface of claw with dark-tipped spines; eye stalks long.

Habit and habitat. Lives in abandoned shells of large gastropods, often found in sandy, flat areas of the ocean floor but also seen around reefs. Fairly active.

Occurrence. One juvenile female seen at the Hermosa Beach rockpile (September 1962).

Importance. No data.

8.4.9.34. Panulirus interruptus (Randall, 1829)—California spiny lobster

Description. Carapace longitudinally subcylindrical; rostrum consists of two short teeth; antennae large and long, exceeding the body in length; thickly set with short spines on the antennae and carapace, pleura of the abdominal somites also terminate with large spines. Weights close to 30 pounds were once recorded along the southern California coast, but, specimens exceeding 15 pounds are now quite rare. The color varies from a reddish-orange through a reddish-mahogany to deep purplish red, recently shed individuals generally having the lighter coloration. Sexual dimorphism occurs; females have bifurcate dactyls on their fifth pair of walking legs and much larger pleopods than do the males.

Habit and habitat. Found intertidally to at least 40 fathoms (about 80 m); from Monterey Bay in central California to Magdalena Bay, Baja California, in nearly all rocky areas, but uncommon north of Point Conception. They are scavengers; snails, worms and algae being common food items. Generally foraging at night, they prefer to hide in rocky ledges and caves during daylight hours. Migrations or local movements appear to be correlated with food supply, water conditions and reproductive cycles.

During these migratory periods we have observed groups of 15 or more lobsters ("bull ring") clustered closely together on the open sand apparently awaiting darkness to continue their travels. Generally an offshore migration commences about October with an onshore one beginning in February or March. The onshore migration appears to be composed primarily of ovigerous females.

Females reportedly carry from 50,000 to 800,000 eggs, depending on their size (Lindberg, 1955). We counted 120,000 eggs from a female 65 mm (2.5 inches) in carapace length and 680,000 from a female

92 mm (4 inches) in carapace length. We believe the smaller animal is near the minimum size for sexual maturity.

Mating activities on the man-made reefs commenced in January, with some ovigerous females being found from March through August. Just prior to this time, the males were observed constructing cave areas under rocks, removing sand, and facing off with females. Copulation was not observed. Temperature apparently closely regulates their breeding activities, with ovigerous females moving into the shallow, warmer water (±30 feet) presumably to accelerate egg maturation. Upon hatching the juveniles are generally presumed to be pelagic (Johnson, 1960 *a, b*), passing through about 12 instars (taking 7 to 8 months) before attaining the adult form. If a pelagic period exists, the movement of the juveniles will be dictated by the offshore water currents; greatly affecting local stocks. However, since just-settled lobsters are found intertidally and subtidally in close association with algae, we feel an inshore (non-pelagic) environment may be more typical for the instar stages. We collected a 1-inch specimen in August, at Santa Catalina Island, in a kelp holdfast in 10 feet of water, and numerous others 2 to 3 inches long in February and May, near Dana Point in beds of surfgrass in 3 to 5 feet of water. This larval-juvenile phase of the spiny lobsters life history definitely warrants further study as it appears to be the critical point for any proposed hatchery program for this species.

Occurrence. Spiny lobsters were seasonally abundant from October through March at each of the man-made reefs. Maximum concentrations of more than 300 individuals occurred at both the Hermosa Beach (Figure 38) and Redondo Canyon reefs. Scattered individuals were recorded in every month, excepting June, from at least one of the reefs. When the lobsters left the reefs en masse, about March, their niche was filled by an influx of Cancer crabs. Lobsters and crabs apparently feed at the same trophic level, and thus, tend to avoid joint tenancy of an area where intense competition for food would occur.

Importance. Spiny lobsters are scavengers and occupy an important niche in the marine ecosystem. Economically they support both a sport and commercial fishery, being highly esteemed as food and commanding a high market value. Juveniles are eaten by many reef-dwelling-fishes and the adults are preyed upon by larger fishes such as giant sea bass (Stereolepis gigas) . We have observed adult lobsters cleaning ectoparasites from fishes that enter their caves, another important consideration for explaining their value in the reef ecosystem.

8.4.9.35. Petrolisthes eriomerus Stimpson, 1871—porcelain crab

Description. Small crabs (10 mm across carapace), mottled green in color. Claws thin, elongate, broad and flattened.

Habit and habitat. Found in large numbers in mussel clumps on pier pilings, etc. Usually very secretive and fast-moving.

Occurrence. Common in the mussel and barnacle growth on the underside of the buoy marking the Malibu replication reef.

Importance. Probably a choice fish food but of minor importance here due to its absence from the reef proper, and to its secretive habit.

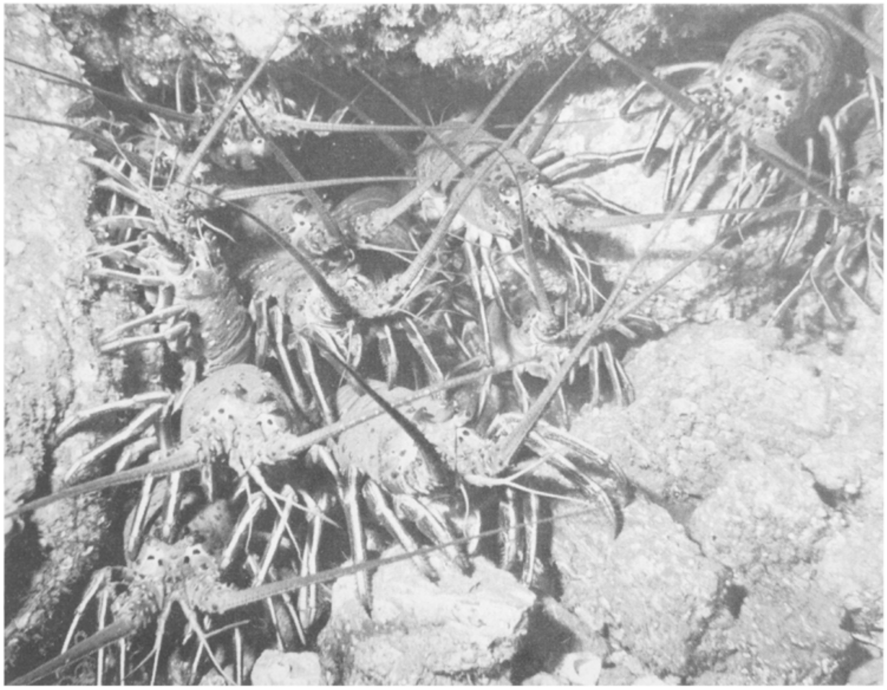

FIGURE 38 Massed spiny lobsters on the Hermosa Beach WCB reef rockpile. *Photo by Charles H. Turner.*

FIGURE 38 Massed spiny lobsters on the Hermosa Beach WCB reef rockpile. Photo by Charles H. Turner.

8.4.9.36. Pilumnus spinohirsutus (Lockington, 1877)—xanthid crab

Description. Small (28 mm wide); carapace covered with dense, long stiff hairs; claws covered with spines and hairs. A prominent ridge in the mouth area is tinged bright red.

Habit and habitat. Very secretive and retiring, found around mussel clumps and shallow rocks.

Occurrence. A few specimens were found on two occasions in the clumps of mussels and barnacles fouling the marker buoys at the Hermosa Beach and Santa Monica reefs.

Importance. Minor, due to rarity and retiring habit.

8.4.9.37. Pugettia richii Dana, 1851—sharp-nosed crab

Description. Small (up to 32 mm wide); rostrum widely forked. Carapace tuberculated, reddish; legs with light-colored bands.

Habit and habitat. Generally found in the intertidal or shallow subtidal, may mask (cover itself) with hydroids or coralline algae. Not common in our study.

Occurrence. Two ovigerous females seen at the Hermosa Beach rockpile (September 1962).

Importance. Minor due to rarity.

8.4.9.38. Pugettia producta (Randall, 1839)—kelp crab

Description. Carapace smooth, shiny, reddish-brown to tan or green.

Habit and habitat. Adults generally found in kelp beds, young in tidepools. Not secretive.

Occurrence. Seen once on the Hermosa Beach rock component (September 1962, three individuals); also found in fish stomachs on two occasions.

Importance. Minor, due to rarity.

8.4.9.39. Randallia ornata (Randall, 1839)—purple globe crad

Description. Carapace subhemispherical, nearly smooth, with a few scattered granules, dorsally marbled with red on white.

Habit and habitat. Open sandy areas, shallow or moderate depths, common in local sand dollar beds.

Occurrence. One individual observed near the Malibu reef streetcar component (November 1960).

Importance. Minor, not a reef oriented species.

8.4.9.40. Scyra acutifrons Dana, 1861—masking crab

Description. Small (18 mm wide); carapace pear-shaped, tuberculated, gray or tan with red on legs. Rostrum short with lanceolate horns. Identifying features may be covered with sponges, algae, hydroids or ectoprocts, which the crab plants on itself.

Habit and habitat. On or under rocks in areas with a fairly well-established epifaunal growth.

Occurrence. One male seen on the Hermosa Beach concrete shelters (October 1962).

Importance. Minor during our study due to its rarity, but it is common on natural reefs.

Mantis shrimps are strange crustaceans (order Stomatopoda), affiliated with the Malacostraca but having several characters which set them apart. The most notable difference is adaptation of their first five pairs of thoracic limbs for feeding (most malacostracans only have the first one, two, or three pairs so modified), these limbs being further unique in having only six segments instead of the usual seven. Another character, easily seen in the field, is the modification of the second maxilliped into a large raptorial claw. The body of the animal is elongate and flattened dorsoventrally, and depending upon the species, is often brilliantly colored. Those encountered in this study (Hemisquilla stylifera Milne-Edwards, 1837) live in burrows of their own making, in areas of sand or gravel. They are very active and often difficult to capture.

Their relatively large size (up to 34 cm long) probably precludes their being important as food for most local reef fishes, although one specimen was recovered from the stomach of a fantail sole, Xystreurys liolepis. This 16.3 cm (6.5 inch) mantis shrimp had been ingested alive and whole by the 18-inch fantail sole, without having any of its appendages disturbed. Even the large raptorial claws had not been extended.

Our species was observed in the sand and rubble surrounding the Hermosa Beach reef components before reef placement. During October 1961 we estimated their numbers as one per 3 m^2 of bottom area. In April 1962 we estimated a similar concentration and found, through general survey dives in this area, that the population extended many miles along the coastline.

Hemisquilla constructs its burrow in bottom sediments (areas of fine to medium grain size) and decorates the tunnel entrance with small shells and pebbles. They can be brought to the burrow entrance by dropping a small rock into their "home." In a few moments the mantis shrimp appears pushing the rock ahead of him and deposits it a little distance away from the hole.

They usually lie at the burrow opening waiting for food to drift by. If startled, they back into the burrow and hide. On days of turbid water or heavy cloud cover, making it dark on the bottom, we would observe them foraging many yards from their burrow. We presume this indicates their preference for nocturnal movement.

If attacked when away from the protection of their burrow, they attempt to swim away (forward), but if unsuccessful, they ball-up exposing only their uropod spines and raptorial claws to their predator. These raptorial claws are formidable weapons, capable of inflicting a nasty cut on the unwary. When traveling across the bottom, mantis shrimps usually half swim and half walk, seldom leaving the bottom by more than an inch.

Sea spiders (class Pycnogonida) are arthropods lacking true jaws or mandibles (Chelicerata). They resemble terrestrial spiders; with a large, segmented cephalothorax and a rudimentary abdomen. The four pairs of legs are slender and sometimes six or seven times longer than the body. They are extremely common in most benthic marine areas, from the intertidal (where they are usually small, even minute) out to the deep oceanic areas where the animal may be 25 cm or more broad (including legs). Their association is generally with well-developed substrate growth, particularly hydroids, ectoprocts, and seaweeds. Their presence on our study reefs was not unusual, and although their numbers may be rather large on mature reefs, their small size probably makes them of little importance as fish food.

Pycnogonids occurred on test blocks from all three reef areas a few months after placement, and in substrate scrapings from the concrete shelters at Hermosa Beach and Malibu (August 1963).

8.4.10. Mollusca

Morphologically this is a diverse phylum, but it is sharply defined and very successful. The animals are typically bilaterally symmetrical, possess soft bodies, are unsegmented, and are generally covered by a mantle that secretes a limy shell of one, two, or eight parts. An anterior head is present except in the pelecypods and scaphopods. The nervous system consists of a few paired ganglia. Sexually, mollusks may be monecious, dioecious, or protandrous.

Four of the seven molluscan classes recognized by Hyman (1967), Cephalopoda, Polyplacophora, Pelycepoda and Gastropoda, were represented on the man-made reefs. A fifth class, Scaphopoda (tooth shells) was only recognized from empty shell fragments.

Members of the class Cephalopoda all have well-developed heads, eyes, and possess radulas. Their shells are internal, external, or absent; the sexes are separate. The class is subdivided into the Tetrabranchia (not represented in this study) and Dibranchia (squids and octopuses).

No squids were observed during the study period, although egg cases of Loligo opalescens were attached to the reef materials and only two species of octopus were encountered.

8.4.10.1. Octopus bimaculatus Verrill, 1883—two-spotted octopus

Description. Characterized by a large, roundish, dark spot slightly anterior of each eye, assisting field identification. Our specimens ranged from 10 to 16 inches in length (body and arms).

Habit and habitat. Observed in crevices and under rocks, seldom venturing out by day; but foraging at night. Octopuses are carnivorous and predaceous; feeding upon mollusks, crustaceans and small fish. With their radula they can drill into mollusks and inject a toxin that causes the bivalve to gape or gastropod to expose its soft body parts.

Occurrence. Recorded only from the Hermosa Beach replication reef, concrete and rockpile components. First observed in January, 1961 and continually thereafter. The population appeared to increase slowly but steadily with a high count of 15 on the rockpile component (probably conservative) at the study's end.

Importance. A choice food item for all the larger fish species, particularly sand bass, sculpin, and various rockfish.

8.4.10.2. Octopus rubescens Berry, 1953—octopus

Description. A small octopus; our specimens did not exceed 20 cm (8 inches); averaging about 15 cm (6 inches) in total length. The distinctive reddish-brown coloration assists the field identification in shallow water, but in deeper water this coloration is not as apparent due to the water's absorption of red from the color spectrum.

Habit and habitat. This octopus usually hides completely under objects by day and is not observed unless these objects are overturned. Like other octopuses they are nocturnal foragers. Their feeding habits are similar to other octopuses. An aquarium specimen drilled and fed on three snails (Calliostoma gloriosum, C. supragranosum and Terebra pedroana) (Figure 39) . We observed their egg nests under rocks and small concrete fragments from June through December, August and September being peak months.

Occurrence. Recorded from all three replication reefs; commonly on the rock and concrete components and occasionally under the streetcars. First observed in June 1961, and thereafter, throughout the survey period. Population peaks coincided with their breeding period.

Importance. A prime food item of sand bass, kelp bass, and rockfish, being frequently recorded from their stomach contents. Sand bass were often seen deep in crevices seeking out this species.

FIGURE 39 An aquarium-held octopus, *Octopus rubescens,* drilling the top-shell *Calliostoma gloriosum.* Photo by Charles H. Turner.

FIGURE 39 An aquarium-held octopus, Octopus rubescens, drilling the top-shell Calliostoma gloriosum. Photo by Charles H. Turner.

The Polyplacophora, chitons, have elliptical bodies with shells consisting of eight (typically) wing-like dorsal plates covering most of the body. The head is reduced and tentacles and eyes are absent. A large flat foot allows them to crawl, or to cling tightly to the substrate. The dorsal plates and their usual habitat on the artificial reefs (the undersides of the reef materials) afford them good protection from predaceous fish.

8.4.10.3. Ischnochiton mertensii (Middendorff, 1846)—chiton

Description. Small, oblong, about 0.75 inch. Color variable, ours were reddish-brown with white maculations.

Habit and habitat. Found adhering to the undersides of rocks and concrete fragments.

Occurrence. Hermosa Beach reef, on the concrete shelters and rock components. First recorded in October 1961 and infrequently thereafter.

Importance. No known importance as fish food and too rare on these artificial reefs to evaluate properly.

8.4.10.4. Mopalia muscosa (Gould, 1846)—mossy chiton

Description. Oblong, about 1 inch long. Color variable, our specimen was olivaceous. The girdle has stiff hairs that appear moss-like.

Habit and habitat. Known to inhabit rocky depressions intertidally and subtidally.

Occurrence. Collected only once, from the Santa Monica replication reef buoy, April 1963.

Importance. No data.

The molluscan class Pelecypoda is generally characterized by a double or bivalve shell secreted by a mantle and a filter feeding mechanism utilizing ciliated palps. Extremes of locomotion and habitat are exhibited within the class. Various members can swim or creep; are sessile by means of cementing themselves to the substrate or attaching by byssal threads; or burrow in sand, mud, shell, wood, and stone. Taxonomically the Pelecypoda are subdivided into four orders based upon ctenidial form.

8.4.10.5. Arcuatula demissa (Dillwyn, 1817)—ribbed mussel

Description. Elongate shell with numerous radiating ribs, particularly on posterior end. Brown periostracum, interior of shell iridescent with purplish tinge. Attains length of 4.5 inches (about 114 mm).

Habit and habitat. Attaches to the substrate by byssal threads.

Occurrence. Recorded once, two specimens about 2 mm long on the July 1961 test block from the Santa Monica concrete shelters.

Importance. Minor, if the population establishes it would appear to be a desirable food item for fish.

8.4.10.6. Bankia setacea (Tryon, 1863)—shipworm

Description. Valves highly specialized for boring, gaping anteriorly and posteriorly, allowing passage for the soft worm-like body which terminates with two plume-like pallets which are useful for species identification. Large specimens in test blocks were 190 mm long (about 7.5 inches); their burrows were 8 mm (about 0.12 inch) in diameter. Those in the structural members of the streetcars often exceeded 1.5 feet (0.5 m) in length.

Habit and habitat. Bores into water-soaked wood, frequently paralleling the grain, never penetrating through the block surface or adjacent burrows. The mantle secretes a thin calcareous lining for the burrow. Siphons protrude from the entry hole for metabolic functions, but can be withdrawn and the hole covered-over by the pallets.

Occurrence. In test blocks from all materials on all replication reefs and in the wooden streetcars. First recorded from a November 1960 block (Malibu concrete shelters) the population grew rapidly; this species being primarily responsible for the decimation of terminal stage test blocks and of the streetcars. About 50 large specimens, averaging more than 100 mm (4 inches) in length, were recorded in a 3-foot section of a 2- by 6-inch timber removed from the Santa Monica streetcar. The largest Bankia in this timber was 650 mm (about 25 inches long); its burrow was 26 mm (1 inch) in diameter.

Importance. Minor, as food for fish. Destructive to all wood structures.

8.4.10.7. Chama pellucida Broderip, 1835—agate chama

Description. Shell thick, inequivalve, rough and irregular exteriorly due to concentric shingle-like frills. Juvenile shells are strongly pinkishred fading to pink or even pure white in adults. They attach to the substrate by their left valve.

Habit and habitat. Found on all surfaces of the substrate but most frequently on the sides and undersides, and in crevices. Juveniles frequently settle upon the adults, and masses several inches thick build up. The older adults, next to the substrate, usually survive even with this additional weight on their valves.

Occurrence. Juveniles slightly more than 1 mm long were recorded in July 1961 on the test block series from the Hermosa Beach rockpile and the Santa Monica concrete shelters. Field observations at the Hermosa Beach rockpile in September 1962 indicated juveniles were common; averaging 7 to 9 mm long. By the middle of 1963 they were common on all the replication reefs (300/m^2 on the Hermosa Beach rockpile) averaging 2 cm in diameter, but as yet not in large clusters.

Importance. We have no direct evidence but they appear to be a good food item for fish equipped with strong jaws and flat teeth, i.e., the California sheephead and certain sharks and rays. They add to the epistrate and make a micro-environment about their masses which is suitable for such small invertebrates as shrimps, crabs, worms, etc.

8.4.10.8. Chione sp.—chione

Description. Heavy valves, nearly circular in outline, sculptured with radiating ribs and concentric ridges.

Occurrence. Malibu replication reef, one specimen, 1.2 mm long, collected in a 0.06 m^2 scraping on the concrete blocks (June 1963).

8.4.10.9. Chlamydoconcha orcutti Dall, 1884—"naked" clam

Description. Oblong, globular, "sea slug" in appearance except for a well-developed hatchet foot. Coloration opaque-white, the bivalve shell buried in the mantle but visible externally (Figure 40) . Size range to 1.5 or 2 inches long (50 cm).

Habit and habitat. Crawling along on the undersides of the rock or concrete shelter rubble. We have found this animal under stones along the mainland from Santa Barbara to San Diego and at San Clemente, Santa Catalina, Anacapa and Santa Cruz Islands. We have recorded it into depths of 125 feet at Santa Catalina Island.

Occurrence. First collected in October 1961 at all three reefs, from the concrete shelters and rock components. Subsequently recorded commonly from these components, primarily during fall and winter (August through January), but two were recorded from the Hermosa Beach rockpile and one from the Redondo Canyon reef in April, 1963. Seasonal population peaks occurred about October. Our maximum estimate was 50 individuals (Hermosa Beach rock).

Importance. Should be an excellent food item for fish but we have no supporting evidence. Its secretive habit, remaining underneath the

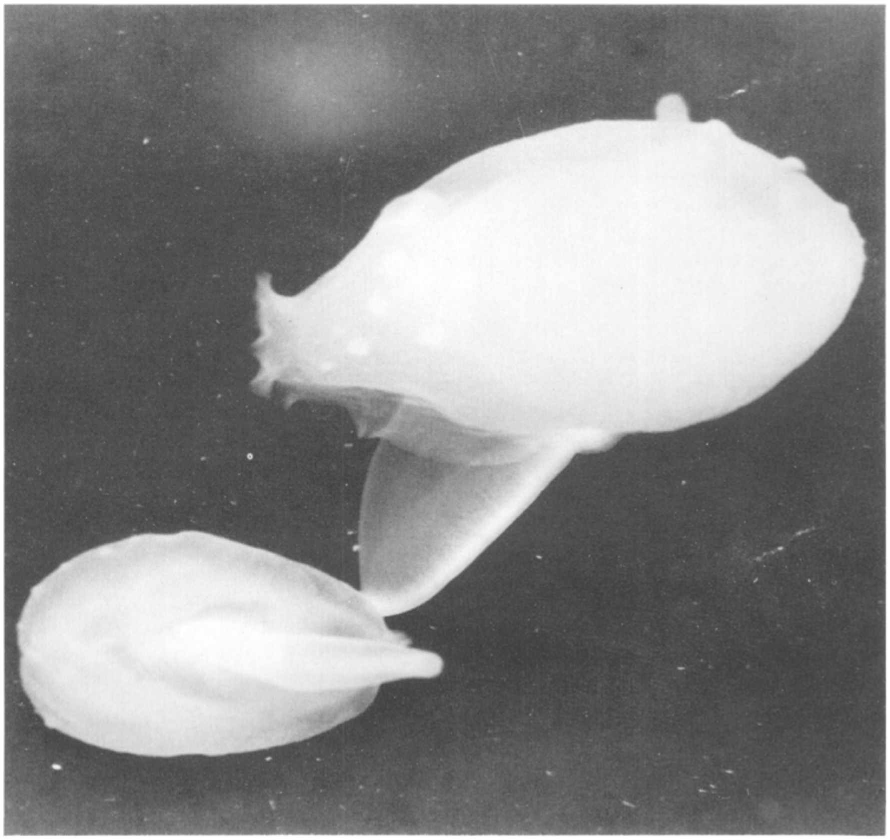

FIGURE 40 A side view (upper) and a bottom view of the naked clam *Chlamydoconcha orcutti*. A collar-like veil surrounds the anterior end. The internal shell is visible just under the anterior funnel-like vacuole on the back. *Photo by Jack W. Schott.*

FIGURE 40 A side view (upper) and a bottom view of the naked clam Chlamydoconcha orcutti. A collar-like veil surrounds the anterior end. The internal shell is visible just under the anterior funnel-like vacuole on the back. Photo by Jack W. Schott.

stones and rubble, may make it unavailable to most fishes. Fish species living within this rubble, like brotulids and cusk eels may utilize it.

8.4.10.10. Hiatella arctica (Linnaeus, 1767)—rough nestling clam

Description. Shell elongate, roughly rectangular in outline but extremely irregular due to nestling and burrowing habits. Our specimens ranged from microscopic to 1 cm long, averaging about 5 mm. Specimens less than 2 mm tend to have more regular valves with a scaled radial rib at the posterior end, and concentric growth lines. Periostracum gray-white.

Habit and habitat. Nestles in crevices, under rocks, in algal holdfasts. and among all types of sessile invertebrates and ascidians, recorded from just subtidal into 372-foot depths (Carlisle 1969*a*).

Occurrence. Initially collected on test blocks from the Santa Monica and Malibu reefs in January 1961, almost 5 months after reef installation. Subsequently collected on all materials and marker buoys at each reef; extremely common. Seventy-five were recorded from a 0.06 m^2

sample at the Hermosa Beach concrete blocks in October 1963. No seasonality apparent.

Importance. An excellent food item for perch.

8.4.10.11. Hinnites multirugosus (Gale, 1928)—rock scallop

Description. Both valves thick and heavy, numerous radiating ribs, those on the upper or left valve strongly spined. The right valve assumes the shape of the substrate to which it attaches, though the umbo region retains the shape of the free-swimming young or byssal stage. The hinge area, internally, is a vivid purple.

Habit and habitat. Adults attach in crevices and along vertical rock faces. Juveniles, prior to cementing, are found under rocks, appearing to be negatively phototactic.

Juveniles as tiny as 1.4 mm were collected in all seasons of the year. After attaching by byssal threads in a suitable location, they cement to the substrate; when 15 to 25 mm long. The mean length of Hinnites collected in October 1961 was 18 mm, by August 1962 they averaged 59 mm. One year later they had attained lengths of 96 mm. By October 1963 the larger adults had distended mature gonads and appeared ready to spawn. The mean length of several mature specimens collected at Hermosa Beach reef, rockpile component, was 124 mm (4.9 inches) in March 1966.

Occurrence. First recorded from the test block series on the concrete shelter components, Hermosa Beach in March 1961. By October 1961 populations were established on all replication reefs, primarily on the rock and to a lesser extent the concrete shelter components. They were not observed on the streetcar or automobile components.

Importance. An excellent food item; frequently preyed upon by sheephead and horn sharks. Important to sport divers who regularly seek them in natural reef areas; they are highly esteemed for their eating quality.

8.4.10.12. Kellia laperousii Deshayes, 1839—nestling clam

Description. Unsculptured, inflated shell, oval-oblong; glossy white with an olivaceous periostracum. Our specimens ranged from 1 to 6 mm in length.

Habit and habitat. Nestles wherever there is protective cover whether it be a simple recess in the substrate, a crevice, a colonial invertebrate, an algal holdfast, or an empty bottle.

Occurrence. Initially recorded from the test block series at Malibu and Santa Monica (December 1960). Appearing in test block series from Hermosa Beach by March 1961 and eventually became common.

Importance. An important food source, primarily for perch.

8.4.10.13. Leptopecten latiauratus (Conrad, 1837)—kelp scallop

Description. Valves nearly circular in outline with wing-like lateral projections on each side of the umbos and 12 to 16 radiating ribs. Their color varies from yellowish-tan through rust brown, commonly with white maculations. Specimens on the reefs ranged from less than 1 mm to about 25 mm long, averaging nearly 6 mm. We have previously recorded them as long as 49 mm (Carlisle, Turner, and Ebert, 1964).

Habit and habitat. Attaches with byssal threads to colonial invertebrates (particularly hydroids) and directly to protected areas of the substrate, or to the lush algal growths in natural areas.

Occurrence. On test blocks from all components of each reef, except the automobile bodies at Hermosa Beach. After appearing on the first or second test block (October and November 1960) the population increased for 6 months, then declined relative to the grazing of once-lush hydroids, upon which they had attached. The population fluctuated throughout the survey period, never again approaching their initial abundance. Recorded from the reef marker buoy at Santa Monica, March 1962.

Kelp scallops appeared as weak competitors for available space on the reefs, although their larvae appeared ever-present in the water column. They were one of the first mollusks to settle on new substrate regardless of season. Kelp scallops had been observed by us in heavy concentrations on offshore oil towers in the Santa Barbara area in 1958 and 1959 (Carlisle, Turner, and Ebert, 1964). After this they nearly disappeared and were never again observed in quantity. During their period of maximum concentration we recorded them from the surface to 80 feet. Because these concentrations coincided with the warm water years along the southern California coast, 1957 to 1959 (Radovich, 1961), we assume this may partially explain their reduced numbers on the reefs (1960 to 1963 were years of more normal temperatures). Turbidity may also have contributed to their lack of dominance in Santa Monica Bay.

Importance. An important food item for perch, and probably utilized to some extent by most other fishes on the reefs.

8.4.10.14. Lima hemphilli Hertlein and Strong, 1946—file shell

Description. Somewhat resembling a scallop with slight wing-like projections at the hinge; elongate shell with radial ribs crossed by concentric growth lines. Attains lengths of slightly over 1 inch; color white.

Habit and habitat. Found on the undersides of rocks generally in mucoid nests of their own construction. Free-swimming, but tending to stay in its nest, unless disturbed, at least during daylight hours. Recorded into depths of 234 feet (Carlisle, 1969*a*).

Individuals from a sample collected in September 1961 (Hermosa Beach rockpile) had a mean length of 11.8 mm; in April 1963 a similar sample measured 33.0 mm. Larger individuals appeared more senile and sluggish and their shells were crossed by many concentric growth lines. We assume the smaller individuals observed in the second sample were young of the original sample (1961); while the larger ones were adults of this original set, and about 2 years old.

Occurrence. Present on each of the replication reefs, preferring the rock and concrete shelter components. First recorded from the Hermosa Beach reef in September 1961 after which the population rapidly increased. They were observed and recorded on all subsequent survey dives and in the quadrat scrapings, but were not recorded from the test block series. A population density of 10 per 0.06 m^2 was recorded for the concrete shelters at Malibu (August 1963).

Importance. Not recorded from fish stomachs during our study but potentially an excellent food item for most species.

8.4.10.15. Macoma nasuta (Conrad, 1837)—bent-nose clam

Description. Shell smooth, rather elongate and compressed, rounded anteriorly, pointed at the posterior end and bent to the right. White in color with a thin, gray periostracum.

Habit and habitat. Prefers mud or muddy sand in sheltered bays and estuaries rather than the open coast. Lives 4 to 8 inches beneath the substrate.

Occurrence. Present previous to reef construction; their empty valves were frequently observed. One live specimen, being preyed upon by a whelk (Kelletia kelleti) , was observed at the Hermosa Beach reef in April 1962.

Importance. of minor importance; fish will nip off siphons when the opportunity presents itself.

8.4.10.16. Modiolus capax (Conrad, 1837)—fat horse mussel

Description. Thin shell covered with a heavy rich-brown periostracum bearing coarse hairs. Umbones at the anterior end. Attains lengths to 150 mm (6 inches). Our specimens were 1.5 to 26 mm long.

Habit and habitat. Juveniles to 4 mm long were found in scrapings taken on the exposed top surfaces of concrete blocks. Adults were known only from the undersides of concrete shelters where they attached solitarily by byssal threads.

Occurrence. Juveniles noted on the February 1961 test block from the Santa Monca reef streetcar and the March 1961 test block from the Hermosa Beach concrete shelters. Subsequently recorded in scrapings at both Malibu and Hermosa Beach. The first field observation was in April 1963 at Malibu (concrete shelters) where two individuals, each about 1 inch long, were collected.

Importance. Adults under rocks are available only to those fishes living in that habitat, such as brotulids, cusk eels, gobies, etc. The absence of adults on the exposed surfaces may reflect grazing by embiotocid perches.

8.4.10.17. Mytilus edulis Linnaeus, 1758—bay mussel

Description. Shell blue-black, wedge-shaped with the umbones at the extreme anterior tip. Fine, concentric growth lines, no radial ribs. Exterior glossy black, with a thin tannish periostracum that is prominent at the unbones and central valve areas. Attains lengths close to 15 cm (6 inches), we collected several 131 mm (5.1 inch) specimens in 1961 from an offshore oil drilling platform near Santa Barbara.

Habit and habitat. Usually observed in bays and sheltered, quiet water areas, attached to any submerged object at or near the low water line. Carlisle, Turner, and Ebert (1964) report massive concentrations of bay mussels on all submerged portions of oil drilling platforms offshore from Santa Barbara, California. Here they were recorded from the surface into depths of 80 feet.

Occurrence. Recorded on all reef buoys and chains. Scattered individuals extended down the buoy chains to a depth of 25 feet at Malibu, 20 feet at Santa Monica, 55 feet at Hermosa Beach and 60 feet at Redondo Canyon reef. Bay mussels did not establish on the reef proper and their depth distribution (on the buoy chains) appeared to correlate with water clarity. Juveniles settled on the test blocks at each reef but did not grow beyond a few millimeters in length except at Hermosa Beach where individuals to 21 mm were occasionally collected. Juvenile settlement occurred from January into July, with February appearing to be a "peak" month. Water temperatures ranged from 14.5°C to 19°C during this period.

Importance. Suitable food for a number of reef dwelling fishes. Bay mussels form large "mats" in which numerous other invertebrates (crabs, worms, etc.) make their homes, therefore their importance is major. In areas of less turbid water they might establish on the reef proper, otherwise they exist on only the marker buoys and chains.

8.4.10.18. Pecten diegensis Dall, 1898—San Diego scallop

Description. Shell regular in outline; wing-like lateral projections on either side of the umbones. Right valve convex, containing 22 or 23 flat-topped radiating ribs. Left valve flat or slightly concave with 21 or 22 rounded ribs radiating outward from the umbo. The right valve is pale yellow, the left or top valve is reddish.

Habit and habitat. Free-swimming just off the bottom, but generally observed settled on the bottom with only the left valve exposed. Frequently in sand channels between rocky ridges of natural reefs.

Occurrence. Hermosa Beach reef, near the rockpile, collected once (September 1961). Collected and observed at the Redondo Canyon reef in August 1963. Their empty valves are common in both areas. They are well camouflaged when buried in the sand, usually with a thin layer of sediment over them.

Importance. Suitable fare for larger reef fishes, i.e., rays, sharks, and probably sheephead. This animal contains an appreciable amount of edible biomass.

8.4.10.19. Petricola sp.—nestling clam

Description. Shape variable due to boring and nestling habits. Our single specimen was 5 mm long, oblong, with concentric irregular growth lines. White in color.

Habit and habitat. Nestles or bores in soft and hard rock.

Occurrence. Hermosa Beach replication reef, from the 0.06 m^2 quadrat taken on the concrete shelters, August 1963.

Importance. The only rock borer recorded during the study Possibly a forecast of the fate of the concrete shelters.

8.4.10.20. Pododesmus cepio (Gray, 1850)—abalone jingle

Description. Shell shape variable depending upon the configuration of the substrate to which it attaches and the available space for its growth. Right valve thin, fragile and pearly, closely applied to the substrate. The lower (right) valve is notched, allowing a byssus to pass through and affix to the substrate. The upper (left) valve is heavier with coarse, irregular radiating ribs. Gray-white to gray-green interiorly. Maximum shell diameter recorded in our study 91 mm.

Habit and habitat. Found on all surfaces of natural reef materials, preferring crevices and undersides.

Occurrence. Recorded from all reef materials, they exhibited a preference for the insides of the concrete shelters. Our earliest record was from the November 1960 test blocks, less than 3 months after reef construction. With little competition for space, they quickly increased in numbers to form a pavement-like mass on the sides of rocks and the insides of the concrete blocks, numbering up to 40 per 0.06 m^2 inside the concrete shelters by August 1961. Because of mortality and increased competition for space their population declined but still formed a major portion of the attached biomass through 1964.

Juveniles sampled at Hermosa Beach in November 1960 averaged 2 mm in diameter, by August 1961 their mean diameter was 56 mm. Our larger specimens, 80 mm or more in diameter, were recorded in June 1963, some 32 months after we first found the species.

Importance. Major as a food item for California sheephead, horn sharks and probably other fishes, particularly when attached to exposed surfaces. Their shell presents suitable substrate for the attachment of a myriad of organisms, while shrimps and small crabs may hide in crevices between them.

8.4.10.21. Protothaca staminea (Conrad, 1837)—common littleneck

Description. Subovate, sculpture of radiating and concentric ribs which form beads at their junctures. Ventral margin slightly crenulate. Color variable, whitish to yellow-brown, often with brownish maculations. Attains length of 2.5 inches (62.5 mm).

Habit and habitat. Silty sand to coarse sand seldom more than 3 inches beneath the surface.

Occurrence. One small specimen, 24 mm long, collected on the Hermosa Beach rockpile, August 1962.

Importance. Minor in our study, insufficient numbers.

8.4.10.22. Saxidomus nuttalli Conrad, 1837—common Washington clam

Description. Shell oval, thick, with coarse numerous concentric ribs. Shell gapes slightly at siphonal end. Color a dull gray.

Habit and habitat. Mud to sand, 12 to 18 inches beneath the substrate; usually in bays, lagoons and estuaries.

Occurrence. One specimen collected at the Malibu replication reef in August 1963.

Importance. Negligible during our study; not its usual habitat.

8.4.10.23. Teredo navalis Linnaeus, 1758—shipworm

Description. Similar to Bankia setacea, the major difference is in pallet structure: Teredo pallets are paddle-shaped, their distal ends covered with a brownish-black chitinous material.

Habit and habitat. Similar to Bankia setaced.

Occurrence. Rare; four collected in the March 1961 test block at Hermosa Beach (concrete shelters) and a single specimen came from the May 1961 test block at Malibu (concrete shelters). About 50 small specimens, with young, were recorded from a 3-foot section of a 2- by 6-inch timber from the Santa Monica streetcar, October 1962.

Importance. Minor, constitued only a small percent of the woodborer group present. Usually considered a harbor form, and not as common in the open ocean area.

8.4.10.24. Trachycardium quadragenarium (Conrad, 1837)—spiny cockle

Description. Shell ovate, slightly higher than long, with about 40 strong radiating, squarish ribs, heavily spined at the anterior, posterior and ventral portions. Exterior yellow-white with a thin gray-tan periostracum. Attains length close to 12.5 cm (5 inches).

Habit and habitat. Lives buried just beneath the substrate in fine to muddy sand, subtidally into depths of 192 feet (Carlisle 1969*a*).

Occurrence. Empty valves were common at each of the replication reefs. Four live specimens were collected during the study, two of these were juveniles found on test blocks—one each from the March 1961 Hermosa Beach streetcar block (4 mm long), and the July 1961 Santa Monica streetcar block (1.2 mm long). The other two were adults collected from the substrate adjacent to the Malibu and Hermosa Beach reefs. We suspect a substantial population existed close to the Malibu reef but this was not investigated.

Importance. Minor, the adult population is probably little utilized. The numerous large empty valves, commonly observed, are probably the result of natural mortality or predation by octopuses (John E. Fitch, pers. comm.).

8.4.10.25. Tresus nuttalli (Conrad, 1837)—gaper clam

Description. Valves thin, oval-elongate and gaping at the posterior end. Siphons united and extremely long, covered with a thick dark epidermis. Valves chalky white covered by a thick brown periostracum. Attains a length of 8 inches.

Habit and habitat. Lives some 3 feet or more beneath the substrate in hard pack medium sand to soft silty sand.

Occurrence. Present in the general reef area at Malibu; empty valves common around reef materials.

Importance. Minor, fish reportedly feed on their siphon tips, but how much or to what extent was not observed.

8.4.10.26. Xylophaga spp.—wood-boring mollusk

Description. Shell globular, valves gape widely anteriorly, taper to a closed, sharp edge posteriorly; extremely fragile. Size to 0.9 cm (0.3 inch); color cream white.

Habit and habitat. Bores into water-soaked wood. The burrows are two to three times the length of the borer and lack the calcareous lining typical of shipworm burrows. Digested matter commonly remains within these burrows.

Occurrence. In test blocks at each of the replication reefs and in the wooden members of the streetcars. Initially found in test blocks January 1961. The population rapidly grew and was in part responsible for the deterioration of the streetcars. At least two species were observed in the various test blocks and structural members of the streetcars, Xylophaga washingtona and Xylophaga sp. near globosa. (Ruth D. Turner, Harvard Univ., pers. comm.).

Importance. Minor as food items for fish, but destructive to the wooden structures.

Members of the class Gastropoda possess spirally coiled shells that may be uncoiled, reduced or absent in adults but always present in embryonic stages. Bilateral symmetry is absent in adults due to torsion and subsequent modification or loss of certain organs giving rise to the basis of three subclasses (some authors recognize two). The Pulmonata, one of the subclasses, are air breathers which have acquired a lung; they are not included or mentioned further.

The subclass Prosobranchia is represented by the more primitive gastropods which have undergone torsion, whereby the visceral hump has rotated through an angle up to 180° in a counterclockwise direction causing the paired gills to face forward, anterior to the heart. Their shells are well developed and morphologically diverse. The members may be active, creeping rapidly over and plowing through the substrate, or sessile, cemented to the substrate in a worm-shaped tube. Active snails of this subclass are often carnivorous predators, drilling into other shelled forms with their radulae, some are herbivorous, and a great many are scavengers possessing acute olfactory senses. Primitive prosobranchs usually have free-swimming veligers; these are usually suppressed in advanced prosobranchs having encapsulated embryos that hatch at a creeping or crawling stage.

8.4.10.27. Acanthina spirata (Blainville, 1832)—muricid snail

Description. Aperture approximately one-half shell length, with a prominent spine on the lower outer lip. Sculpture weak, numerous, poorly developed spiral threads present. Our specimens measured less than 2.5 cm (1 inch). Blue-gray with brownish spots in concentric rows on all whorls.

Habit and habitat. Rocky surfaces; blending well with the surrounding encrustment. A carnivorous snail, utilizing the spine on its outer lip to pry open barnacles and small bivalves.

Occurrence. Collected April 1963 on the rockpile at Malibu. Suspected to be moderately common, but difficult to see.

Importance. No data.

8.4.10.28. Amphissa versicolor Dall, 1871—whelk snail

Description. Axial and spiral sculpturing equally prominent except on the body whorl, below the periphery, where axial ribs are absent; about seven whorls. Aperture not quite half the shell length and somewhat narrowed. Size 1.2 cm (0.5 inch) long. Surface glossy, color pinkish gray with tan to brown mottlings.

Habit and habitat. Rocky substrate, primarily in depressions, or crevices, or on the undersides of the materials.

Occurrence. Recorded only from the Hermosa Beach reef, initially in September 1962. The population rapidly increased, particularly on the concrete shelters where 35 were recorded from a 0.06 m^2 sample in August 1963. Juveniles were common in the fall.

Importance. No data; we suspect they are suitable food for perch.

8.4.10.29. Astraea gibberosa (Dillwyn, 1817)—red turban snail

Description. Shell solid, heavy, with a thick, smooth calcareous operculum. Characterized by five to six spiral, wavy cords. Base flat and nonumbilicate. Maximum length exceeds 7.3 cm (3 inches). Reddish-brown shell generally encrusted with coralline algae.

Habit and habitat. Prefers low-relief rocky bottoms or cobble areas.

Occurrence. Redondo Canyon reef; present, but not common, in the cobble area previous to reef construction.

Importance. No data.

8.4.10.30. Astraea undosa (Wood, 1828)—wavy turban snail

Description. Shell solid, heavy; similar to Astraea gibberosa. Operculum calcareous, thick, with three heavy ribs on the surface. Periostracum silky. Attains a length close to 15 cm (6 inches). Shell often encrusted with algal growth. The commensal crab Opisthopus transversus is frequently observed in the mantle cavity.

Habit and habitat. Feeds on algae. Found on rocky substrate where there is sufficient algal growth.

Occurrence. One specimen, recorded on the Hermosa Beach rockpile in August 1962, probably drifted in with seaweed.

Importance. No data.

8.4.10.31. Barleeia sp.—rissoid snail

Description. Minute, conical; nuclear whorls distinctly pitted, remaining shell surface smooth. Our specimens were almost 3 mm (0.12 inch) long. Color, tan.

Habit and habitat. Nestles among invertebrate colonies and algal growth.

Occurrence. Santa Monica reef; two specimens recorded from the April 1961 test block. No subsequent observations.

Importance. No data.

8.4.10.32. Burchia redondoensis Burch, 1944—turrid snail

Description. Turriform; eight to nine whorls with indistinct sutures. Surface bears axial ribs and fine spiral threads. Aperture long, somewhat narrow, the outer lip thin and deeply notched at the suture. Maximum size close to 5 cm (2 inches). Shell brownish-black, animal darker.

Habit and habitat. Prefers silty-sand bottoms interspersed with cobbles but also found on rocky substrate. We observed them depositing their lens-shaped egg capsules on cobbles, at 80- to 90-foot depths during June and July (Figure 41) .

FIGURE 41 *Burchia redondoensis* depositing its white lens-shaped egg capsules (arrow) on a small rock near the Redondo Canyon reef. *Photo by Charles H. Turner.*

FIGURE 41 Burchia redondoensis depositing its white lens-shaped egg capsules (arrow) on a small rock near the Redondo Canyon reef. Photo by Charles H. Turner

Occurrence. Redondo Canyon reef. Observed previous to and after reef construction. Commonly seen throughout the year.

Importance. No data.

8.4.10.33. Bursa californica (Hinds, 1843)—California frog snail

Description. Heavy shell, with six whorls, each having two varices, one opposite the other. Surface between varices with large knobby protuberances, smaller nodules are present on the varices themselves. Fine concentric sculpturing present. Large aperture, approximately one-half the shell length. Anterior (siphonal) canal and posterior canal almost equal in size. General color tan-cream, dark brown mottlings conspicuous in juvenile shells, almost absent in large adults. Maximum size close to 16.0 cm (6.25 inches).

Habit and habitat. Common on silty-sand bottoms, 60 to 387 feet deep (Carlisle, 1969*a*). We observed them attaching their egg capsules in circular masses to the concave surface of old clam valves (Figure 42) . The encapsulated eggs are incubated by the parent and at hatching the parent turns over on the substrate, lifting the eggs and clam shell above her and free from bottom sediments. The larvae escape through the now bottom portion of the capsules into the water column. We observed egg deposition and hatching in May and June at the Redondo Canyon reef and in nearby areas in depths of 80 to 100 feet.

FIGURE 42 *Bursa californica* having been removed from her "incubating" position over the egg capsules attached to a dead clam shell. In the background, California cones are depositing their egg capsules. *Photo by Charles H. Turner.*

FIGURE 42 Bursa californica having been removed from her "incubating" position over the egg capsules attached to a dead clam shell. In the background, California cones are depositing their egg capsules. Photo by Charles H. Turner

Occurrence. Redondo Canyon reef, common in the area before and after reef construction.

Importance. A scavenger, no data as to their importance in the reef food web.

8.4.10.34. Calliostoma supragranosum Carpenter, 1864—granulose top-snail

Description. Conical with six whorls. Numerous fine concentric lines, weakly beaded, particularly at the sutures. Maximum size close to 12 mm (0.5 inch) long. Tan shell with a band of brown and white dots on each whorl. Interior vividly nacreous.

Habit and habitat. Undersides of rocks at least during daylight hours, may forage nocturnally.

Occurrence. Common at the Hermosa Beach reef on the rockpile and concrete shelter components, also collected at the Malibu reef concrete shelters in October 1963. At Hermosa Beach individuals were first recorded in October 1961 and then on all subsequent dives. Concentrations occurred under some rock and concrete shelter fragments; being absent from others. Fifteen individuals were recorded under a 6- by 8-inch piece of concrete in October 1963.

Importance. No data; should be suitable food for most fish.

8.4.10.35. Calliostoma tricolor Gabb, 1865—three-colored top-snail

Description. Shell conical, periphery flattish to concave. Each whorl with one or more beaded ridges. Size to 1.9 cm (0.75 inch). Tan to yellow-brown with three spiral rows of alternately marked purple and white lines per whorl.

Habit and habitat. The undersides of rocks, may forage nocturnally. Recorded by Carlisle (1969*a*) into depths of 558 feet.

Occurrence. Hermosa Beach reef, concrete shelters. Collected on two occasions, February and November 1962. Not common.

Importance. No data; should be a suitable food item for fish.

8.4.10.36. Conus californicus Hinds, 1844—California cone snail

Description. Shell obconic, spire low, with six to seven whorls. Attains lengths close to 5.0 cm (2 inches). Covered with a dark rich brown periostracum.

Habit and habitat. Found on muddy, sandy, and rocky substrates from the shallow subtidal area into depths of 192 feet (Carlisle 1969*a*). We observed egg capsules being deposited (Figure 43) in June and July at the Redondo Canyon reef, 70- to 80-foot depths, and juveniles 3 to 4 mm long were collected in August.

Occurrence. Adults were common before and after construction of the Redondo Canyon reef. Juveniles were collected in August 1963 at the Hermosa Beach reef, concrete shelters, in the 0.06 m^2 scraping.

Importance. Minor. A predaceous snail; feeds on other mollusks.

8.4.10.37. Crepidula adunca Sowerby, 1825—hooked slipper-snail

Description. Patellate or cap shaped with an interior deck, attached along both sides. Apex sharp and recurved, often hooked. Length to almost 2.5 cm (1 inch). Brown with the interior deck white.

FIGURE 43 *Conus californicus* depositing egg capsules on polypropylene line attached to a lobster trap. *Photo by Charles H. Turner.*

FIGURE 43 Conus californicus depositing egg capsules on polypropylene line attached to a lobster trap. Photo by Charles H. Turner

Habit and habitat. Commonly found adhering to other shells.

Occurrence. Two specimens, recorded only from the June 1961 test block at the Malibu reef streetcar.

Importance. No data.

8.4.10.38. Crepidula onyx Sowerby, 1825—onyx slipper-snail

Description. Patellate, with oval margin, apex at posterior edge of shell. Large, slightly concave deck interiorly. Maximum length close to 6.0 cm (2.37 inches). Exterior is gray-brown, inside is chocolate-brown to tan-brown with pure white deck.

Habit and habitat. Attaches to any firm substrate, frequently to each other when attachment space is at a premium. Found from shallow water to 50 fathoms.

Occurrence. Juveniles were first noted on the June 1961 test blocks at Hermosa Beach (streetcar component) and the July 1961 test blocks (streetcar and concrete shelter component) at Santa Monica and Malibu. Good populations settled on each of the replication reefs and we collected adults slightly longer than 2.7 cm, by June 1963. During our August 1963 survey of the Hermosa Beach reef, we found several large empty shells, recently detached, which appeared to have been preyed upon.

Importance. Should be a choice food item, but difficult to obtain, at least by fish, because of its close application to the substrate.

8.4.10.39. Crepidula perforans (Valenciennes, 1846)—white slipper-snail

Description. Patellate or cap-shaped, low apex, large but thin deck interiorly. Maximum recorded length 4.4 cm (about 1.75 inches). Exterior with or without yellowish periostracum, otherwise pure white.

Habit and habitat. Attaches to other shells or on firm substrate.

Occurrence. Hermosa Beach reef rockpile, one specimen found on the June 1961 test block. Additional specimens collected at this reef in June 1962 and at the Malibu reef automobile bodies in October 1963. A modest population had developed by 1963–1964 at these two reefs.

Importance. No data but may be a choice food item for certain invertebrates and fishes.

8.4.10.40. Crepipatella lingulata (Gould, 1846)—half-slipper-snail

Description. Shell patellate in outline, apex near edge. Inside with a shelf attached along one side and with a central ridge. Exterior wrinkled. Maximum size close to 2.0 cm (0.75 inch). Brownish with white streaks radiating outward from apex, the shelf is shiny white.

Habit and habitat. Attaches to any firm substrate, including other mollusk shells. Found on all reef materials, on all surfaces.

Occurrence. Very common on all the reefs, forming a major portion of the encrusting matter. First recorded on the February 1961 test blocks from the Hermosa Beach and Santa Monica reefs, approximately 7 months after reef placement. By June 1962, individuals were frequently observed on all materials. Sixty-five small individuals, to 14 mm in diameter, were collected from a 0.06 m^2 scraping taken at the Hermosa Beach concrete shelters (August 1963).

Importance. Major, fed on extensively by various fishes such as embiotocid perches. Also preyed upon by invertebrates.

8.4.10.41. Cypraea spadicea Swainson, 1823—chestnut cowry

Description. Egg-shaped shell with denticulate narrow aperture extending entire length. Attains length close to 6.9 cm (2.75 inches). Glossy exterior; bluish-white ventrally, brownish dorsally, shading to dark brown laterally. Juveniles shells are bulloid and marked with a wide, brownish, spiralling band.

Habit and habitat. Rocky areas with algal growth, from low intertidal at least to 180 feet deep. Occasionally in large grazing aggregations, but usually solitary, hiding in crevices or under rocks.

We have observed their eggs during May and June in waters 40 to 60 feet deep. These capsular eggs, deposited in circular masses, under rocks or in deep crevices, are incubated by the parent (Figure 44) . Juveniles are present throughout the year, on the undersides of rocks.

Occurrence. Two juveniles were collected on the artificial reefs; they had probably drifted in with seaweed: April 1963 at the Malibu reef concrete shelters, and December 1963 at the Redondo Canyon reef.

Importance. Minor due to rarity during this study.

FIGURE 44 Chestnut cowry incubating eggs; offshore from Redondo Beach, 75-foot depth, July 1964. Above the cowry are empty *Bursa* egg capsules still attached to a scallop shell. *Photo by Charles H. Turner.*

FIGURE 44 Chestnut cowry incubating eggs; offshore from Redondo Beach, 75-foot depth, July 1964. Above the cowry are empty Bursa egg capsules still attached to a scallop shell. Photo by Charles H. Turner

8.4.10.42. Diodora arnoldi McLean, 1966—keyhole limpet

Description. Shell patellate, similar to Diodora aspera. Apical hole more centrally located and the radial sculpturing less pronounced than in D. aspera. The maximum length is close to 1.9 cm (0.75 inch). Tan with irregular white and black markings; interior white.

Habit and habitat. Clings tightly to rocky surfaces.

Occurrence. Collected once at the Hermosa Beach reef rockpile (August 1963).

Importance. No data.

8.4.10.43. Diodora aspera (Rathke, 1833)—rough keyhole limpet

Description. Shell patellate with a small oval apical hole that is about one-third back from the anterior end. Sculpture of coarse radial ribs and weaker concentric threads. Length to 70 mm (2.75 inches). Exteriorly is grayish-white with 12 to 18 purplish-black radiating bands; interior, white.

Habit and habitat. Clings tightly to rocky surfaces.

Occurrence. Collected once at the Santa Monica reef rockpile (September 1962) and occasionally at the Hermosa Beach reef rockpile and concrete shelter components during 1963. The Hermosa Beach population showed a definite increase at this study's termination.

Importance. No data, too few present to evaluate during the study.

8.4.10.44. Epitonium bellastriatum Carpenter, 1864—striped wentletrap

Description. About five whorls with 14 to 16 strong, evenly spaced, recurved varices. Distinct spiral ridges between varices separates this wentle-trap from other species. Sutures deep, spire relatively short. Length to about 1.6 cm (0.63 inch). Color, pure white.

Habit and habitat. Prefers silty-sand substrate.

Occurrence. First recorded from the stomach of pile perch, Rhacochilus vacca, at each of the man-made reefs. The wentle-trap's brilliant purple dye is absorbed into the tissue of any fish feeding on it, effecting a violet-purple hue to the fish that is readily observed in the field. A striped wentle-trap was recorded from a 0.06 m^2 scraping taken at the Hermosa Beach concrete shelters in August 1963.

Importance. A common food item of pile perch, white sea perch (Phanerodon furcatus) and to a lesser extent the other embiotocids on the reefs. Also fed upon by various flatfish (John E. Fitch, pers. comm.).

8.4.10.45. Epitonium sawinae Dall, 1903—close-ribbed wentletrap

Description. About eight whorls, each with 18 reflexed varices that form a crown at the shoulder. Sutures deep. Length to about 2.5 cm (1 inch). Color pure white.

Habit and habitat. Found on rocky and sand bottoms.

Occurrence. Hermosa Beach reef, concrete shelters; three collected from within a 0.06 m^2 quadrat (August 1963).

Importance. Probably similar to other species in this genus which are commonly recorded from perch stomachs. Robertson (1961) reported that wentle-traps feed upon sea anemones and corals. We have observed E. sawinae closely associated with tube anemones (Ceriantharia) in areas away from the reefs.

8.4.10.46. Erato vitellina Hinds, 1844—apple seed snail

Description. Pear-shaped; aperture long and narrow, outer lip denticulate within, inner lip with distinct plaits. Length to 1.2 cm (about 0.5 inch). Glossy smooth exteriorly, brownish cream to brown with a thin bluish-white line encompassing dorsal shell surface.

Habit and habitat. Rocky substrate, preferring crevices and undersides of materials.

Occurrence. Hermosa Beach reef concrete shelters, under the smaller concrete fragments. First recorded in September 1962 and frequently thereafter throughout the survey period. A modest population had developed by 1964.

Importance. No data.

8.4.10.47. Forreria belcheri (Hinds, 1844)—giant forreria

Description. Axial sculpture of 10 raised laminae, prominent on each shoulder of its six or seven whorls; body whorl large, spire rather short. Aperture large; outer lip thin, bearing a large pointed tooth. Siphonal canal moderately long; former siphonal canals also prominent to the left of the small umbilicus. Maximum size to 15.0 cm (about 6 inches). Yellow-white with subdued reddish-brown spiral bands.

Habit and habitat. Muddy sand from intertidal to moderately deep water. Predatory on other species, especially bivalves which it opens by chipping along shell margin, also suspected of drilling and relaxing prey with toxin (John E. Fitch, pers. comm.).

Occurrence. Common on the substrate around each of the man-made reefs before and after construction.

Importance. No data.

8.4.10.48. Fusinus traski Dall, 1915—spindle-snail

Description. Shell fusiform. Eight deeply sutured whorls, each with nine prominent axial ribs crossed by thick revolving cords. Anterior canal moderately long. Our largest specimens were only 7 mm long (about 0.25 inch). Yellow-brown in color.

Habit and habitat. Rocky substrate; predatory.

Occurrence. Hermosa Beach and Malibu reef, concrete components; three collected at each reef from the 0.06 m^2 samples taken in August 1963. All were juveniles, 2 to 7 mm long.

Importance. No data.

8.4.10.49. Kelletia kelleti (Forbes, 1852)—Kellet's whelk

Description. Rather large, fusiform shell, with six or seven whorls, each bearing 10 strong, rounded knobs; sutures indistinct. Aperture large, the outer lip thin and crenulate. Canal moderately long; a strong siphonal fasciole present. Maximum length 170 mm (about 6.75 inches). Color, cream-white.

Habit and habitat. We have observed them on sandy and rocky substrates from intertidal to 180 feet deep; Carlisle (1969*a*) reports them from 564 feet of water.

We observed them depositing encapsulated eggs on the reef materials from April through August (Figure 45) . Juveniles, 1.3 cm through 2.2 cm long were collected from September through November.

Occurrence. Present at each reef site before and after reef construction, with largest concentrations occurring during their breeding season. They were particularly concentrated at the Malibu concrete shelters during the spring and summer of 1961 and 1962.

Importance. Major, as a scavenger with well-developed olfactory senses. Feed upon dead animal matter, in turn falling prey to large reef fishes.

8.4.10.50. Mangelia sp.—turrid snail

Description. Small, fusiform with a short, narrow canal and a moderate posterior notch.

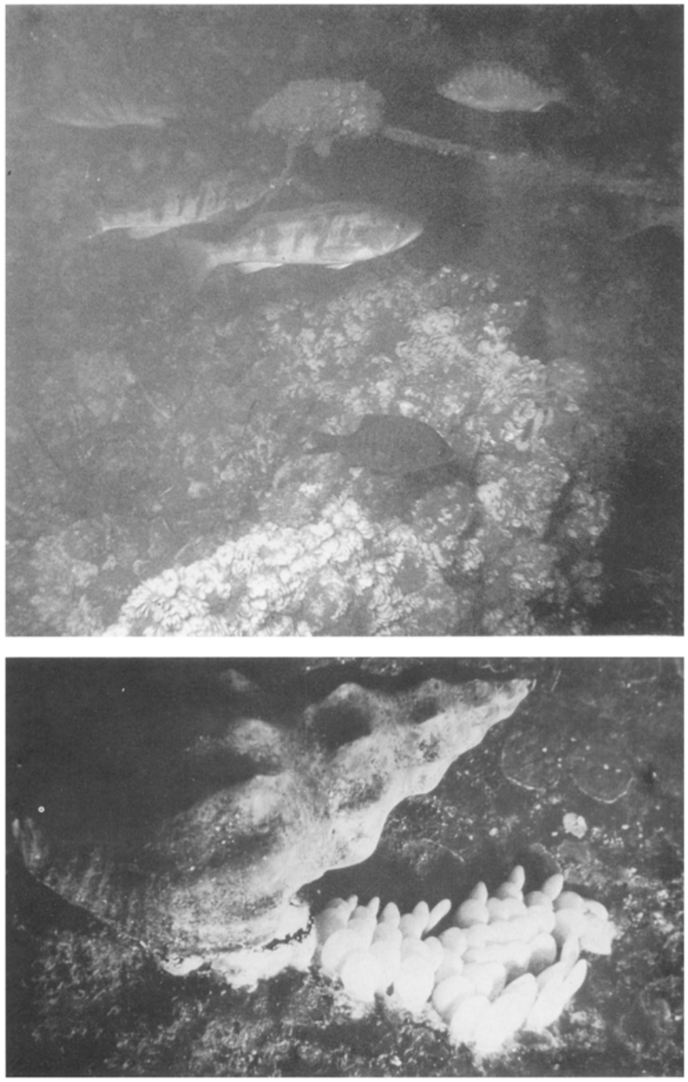

FIGURE 45 *Kelletia kelleti* and egg capsules (lower photo), so thickly deposited that they cover the concrete shelters (upper photo), Malibu reef, April 1963. The fishes are sand bass, black perch (lower) and a rainbow seaperch (upper). *Photo by Charles H. Turner.*

FIGURE 45 Kelletia kelleti and egg capsules (lower photo), so thickly deposited that they cover the concrete shelters (upper photo), Malibu reef, April 1963. The fishes are sand bass, black perch (lower) and a rainbow seaperch (upper). Photo by Charles H. Turner

Habit and habitat. Collected on the undersides of rocks.

Occurrence. Seven, 5- to 7-mm-long specimens were collected at the Hermosa Beach reef rockpile (November 1962).

Importance. No data.

8.4.10.51. Megasurcula carpenteriana (Gabb, 1865)—tower snail

Description. Fusiform, with seven to eight weakly indented whorls. Aperture long, approximately half the shell length; a slight posterior notch near juncture of first whorl. Marked with many fine growth lines, each exhibiting the posterior notch contour. Individuals average 5.0 cm (about 2 inches) long; the largest we collected was 8.2 cm long (3.25 inches). Yellow-brown shell with spiral reddish-brown lines, particularly conspicuous on the body whorl.

Habit and habitat. Silty sand, from 10 fathoms into moderately deep water (600 feet reported by Carlisle, 1969*a*).

Occurrence. Present before and after reef placement. During their breeding season, they concentrated in areas inhabited by tube anemones. We observed them attaching petal-shaped egg cases to the sides of the cerianthids during March and April, near the reefs and in adjacent areas into depths of 90 feet.

Importance. No data.

8.4.10.52. Micranellum crebricinctum Carpenter, 1864—close-ringed tube snail

Description. A simple slightly recurved tube with a spur-like apical plug, circular horny operculum and up to 100 closely set, fine rings. Length to 6 mm (0.25 inch). Pinkish brown with dark brown vermiculations.

Habit and habitat. Sandy and rocky substrate from intertidal to depths exceeding 100 feet.

Occurrence. Collected in a 0.06 m^2 sample taken on the concrete shelters (Hermosa Beach) in August 1963. Many empty and broken shells were also present.

Importance. Appears to be a good food item for small fish. Broken shells and opercula that had passed through fish digestive tracts were common.

8.4.10.53. Mitra idae Melville, 1893—miter snail

Description. Spindle-shaped, solid, five to six whorls without shoulders but well-marked sutures. Columella with three strong plaits, the largest nearest the spire. Maximum length 1.9 cm (0.75 inch). The periostracum is jet black, covering a rust brown shell; the animal is white.

Habit and habitat. Silty sand and low relief rocky substrate. We observed them depositing translucent oblong egg capsules which adhere closely to the substrate, during July in waters 70 to 90 feet deep. Cate (1968) reports egg capsule deposition by Mitra idae during July and August in waters 25 feet deep.

Occurrence. Recorded at the Redondo Canyon reef site before and after reef placement. Not affected by reef construction.

Importance. No data from this study; presumably fed upon by perch and flatfish.

8.4.10.54. Mitrella carinata (Hinds, 1844)—keeled dove-snail

Description. Shell small, fusiform, with five whorls; the body whorl bears a conspicuous keel at the shoulder. Average length about 7 mm (0.25 inch). The body whorl is tan with white flecks; noticeably darkened at the outer lip. Spire dark gray with white flecks.

Habit and habitat. Common around algae holdfasts, also found on silty substrate, under rocks, and nestling in ectoproct colonies.

Occurrence. First recorded on a test block at Malibu in August 1961. Subsequently seen at the Malibu and Hermosa Beach reefs in August 1963. At Malibu two per m^2 were estimated; at Hermosa Beach they were common on kelp drifting into the reef area. They established at the Hermosa Beach reef, and 25 were congregated beneath a small piece of concrete rubble (October 1963).

Importance. A common food item of sheephead; also recorded from perch stomachs.

8.4.10.55. Mitrella gouldi (Carpenter, 1856)—Gould's dove-snail

Description. Shell small, fusiform, with about six whorls. Similar to M. carinata but without the keeled shoulder on the body whorl. Average length 7 mm (0.25 inch). Dark gray to yellow-brown with white flecks and reddish-brown vermiculations.

Habit and habitat. Similar to M. carinata.

Occurrence. A single specimen was collected at the Malibu reef concrete shelters in August 1963.

Importance. Probably similar to M. carinata.

8.4.10.56. Mitrella tuberosa (Carpenter, 1864)—tuberculate dove-snail

Description. Small, fusiform with a slender spire. Similar to M. gouldi, but easily distinguished by a row of tubercles inside the outer lip. Average length about 7 mm (0.25 inch). Tan with white flecks.

Habit and habitat. Similar to M. gouldi and M. carinata.

Occurrence. Hermosa Beach and Santa Monica reefs; concrete shelters from the $0.06m^2$ scrapings. Two individuals were recorded at Hermosa Beach in June and one at Santa Monica in August 1963.

Importance. Probably similar to M. carinata.

8.4.10.57. Nassarius perpinguis (Hinds, 1844)—fat dog whelk

Description. Shell sculpture consists of equally-prominent spiral and axial lines giving surface a close network pattern. A distinct fossa sets off anterior canal from body whorl. Maximum length about 2.5 cm (1 inch). Color, grayish-yellow.

Habit and habitat. Sandy bottoms from intertidal to 50 fathoms.

Occurrence. Recorded at each of the replication reefs. Initially collected at Malibu in April 1963. Subsequently in the $0.06\ m^2$ samples at: (i) Malibu, April 1963, 2 individuals; and August 1963, 9 individuals;

(ii) Santa Monica, August 1963, 1 specimen; and (iii) Hermosa Beach, August 1963, 17 specimens. The reefs probably had no effect on this sand dwelling snail.

Importance. An active, carnivorous scavenger. Many fish are capable of feeding on this snail but we have no supporting data.

8.4.10.58. Ocenebra poulsoni (Carpenter, 1864)—Poulson's dwarf triton

Description. Solid shell with about six whorls; each volution bearing eight to nine nodulated axial ribs, crossed by fine spiral lines alternating with larger spiral cords. Anterior canal short, slightly twisted; outer lip with four to five small teeth within the aperture. Length to about 5.3 cm (2.1 inch). Shell with thin gray periostracum, yellowish raised spiral sculpturing and gray-white interior.

Habit and habitat. Rocky substrate.

Occurrence. Initially recorded at the Hermosa Beach reef rockpile, September 1961, and shortly thereafter at Malibu. The populations rapidly increased and this snail became common on the rockpile and concrete shelter components. We observed them depositing their egg cases on the reefs and other materials (e.g. Redondo Beach Breakwater—Figure 46) during June and July.

Importance. Active and predaceous, but we have no data on where they enter the fish food chain.

8.4.10.59. Olivella baetica Carpenter, 1864—olive snail

Description. Shell obovate, with greatly enlarged body whorl. Operculum tiny. Columella with a double-ridged spiral fold. Fasciole white, often stained brown. Maximum length about 1.9 cm (0.75 inch). Shell surface glossy, bluish to brownish, early whorls usually purplish.

Habit and habitat. Sand and rock substrate, frequently nestling with colonial invertebrates. Recorded by Carlisle (1969*a*) in waters 300 feet deep.

Occurrence. One specimen collected at the Hermosa Beach reef concrete shelters (June 1963); subsequently four were collected there from a 0.06 m^2 sample in August 1963. Apparently common but difficult to see because they frequently burrow through the sand.

Importance. A common food item of perches.

8.4.10.60. Ophiodermella incisa (Carpenter, 1865)—incised tower snail

Description. Shell turriform with seven or eight whorls, sculpture of incised spiral grooves and axial ribs; axial ribs close set, following contour of moderate posterior notch. Aperture small, outer lip thin; canal short. Maximum length about 3.9 cm (1.5 inch). Gray-brown with pale reddish bands.

Habit and habitat. Frequently observed on silty sand to medium grain sand in 20- through 100-foot depths.

Occurrence. Seasonally abundant, April through June, at the Hermosa Beach reef. Initially collected in April 1962.

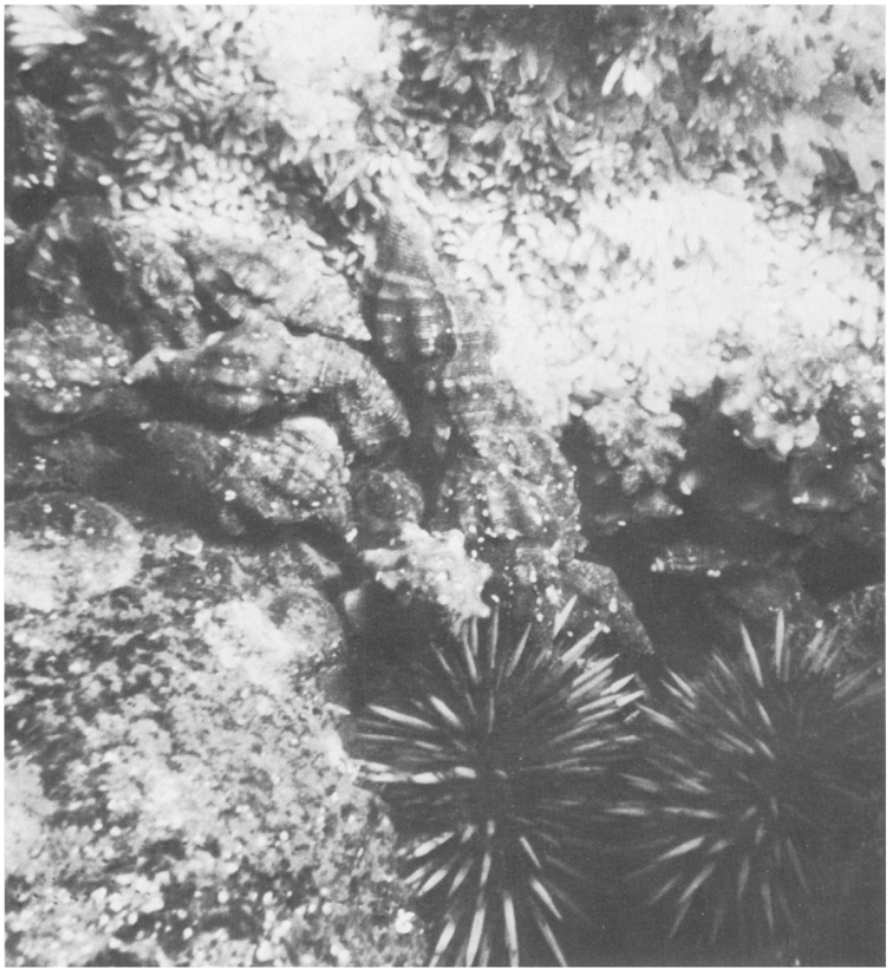

FIGURE 46 *Ocenebra poulsoni* clustered together and depositing their egg capsules, Redondo Beach breakwater, August, water depth about 5 feet. Also pictured are two purple sea urchins (*Strongylocentrotus purpuratus*). *Photo by Charles H. Turner.*

FIGURE 46 Ocenebra poulsoni clustered together and depositing their egg capsules, Redondo Beach breakwater, August, water depth about 5 feet. Also pictured are two purple sea urchins (Strongylocentrotus purpuratus) . Photo by Charles H. Turner

Importance. No data, but apparently not influenced by reef construction.

8.4.10.61. Polinices lewisii (Gould, 1847)—Lewis's moon-snail

Description. Globular and large with five or six whorls, the body whorl constitutes most of the shell. Surface smooth; umbilicus open. Maximum length close to 16.6 cm (about 6.6 inches). Color, yellow-white.

Habit and habitat. A carnivorous, active snail, feeding primarily on clams, drilling through their valves with its radular teeth. Common on sandy bottoms in shallow to moderate depths, to 126 feet (Carlisle, 1969a).

We observed their eggs, in collar-shaped mucus sheets impregnated with sand, from April through August, June being a peak month.

Occurrence. Recorded only from the Hermosa Beach reef site. Infrequently seen, except during egg laying season. Present before and after reef placement, apparently uneffected by man-made habitats.

Importance. Negligible, probably enter food chain via octopuses which drill and feed on them, and in turn are fed upon by basses and rockfish. Juveniles may be fed upon directly by fishes. John E. Fitch (pers. comm.) has recorded moon-snails in the stomachs of English sole (Parophrys vetulus) .

8.4.10.62. Pteropurpura festivus (Hinds, 1844)—festive murex

Description. Six to seven whorls, each with three prominent recurved varices; a strong vertical node between each varix. Canal closed, bent back anteriorly. Numerous, fine, dark brown spiral lines present. Maximum size close to 6.3 cm (2.5 inches). Color, yellowish-brown.

Habit and habitat. On rocks from intertidal to moderately deep water. We observed them depositing their encapsulated eggs in large masses on rocks and on each other from June through August in depths of 60 to 75 feet. Juveniles 7 to 17 mm long were recorded in October 1963 at the Hermosa Beach reef.

Occurrence. First observed in September 1961 on the rockpile and concrete shelter components of the Hermosa Beach reef; later observed at the Malibu reef rockpile. The populations rapidly increased and 10 per m^2 were recorded at the Hermosa Beach reef (rockpile), November 1963.

Importance. No data; these active, predaceous, snails feed primarily on other mollusks.

8.4.10.63. Pteropurpura macroptera (Deshayes, 1839)—muricid snail

Description. Three blade-like varices, one rounded tubercle between each varix; siphonal canal closed; varices crossed by spiral cords; anterior face of each varix with fine, crowded axial fimbriations. Maximum length about 6.4 cm (2.5 inches). Color, yellow-brown.

Habit and habitat. An active carnivorous snail, found on and beneath rocky substrate.

Occurrence. Initially recorded in November 1962 on the concrete shelters (Hermosa Beach reef), a substantial population is now established (1964).

Importance. No data.

8.4.10.64. Serpulorbis squamigerus (Carpenter, 1857)—scaled worm-snail

Description. Shell tubiculous, marked by transverse scaly ridges. Individuals start as loosely coiled shells, but grow into large intertwining masses. Aperture circular, operculum absent. Shells 5 to 13 mm (0.25 to 0.5 inch) in diameter, several centimeters long, grayish to pink-white.

Habit and habitat. Observed on most firm substrates: rocks, abalone shells, etc., from intertidal to 160-foot depths.

Occurrence. Juveniles were first noted at the Malibu and Hermosa Beach reefs in September 1962 on the concrete shelters. By April 1963, 30 per m^2 were estimated at Malibu. In December (1963) large adults were common but their tubes remained solitary—not yet intertwining.

Importance. No data, but a likely food item for several fish species.

8.4.10.65. Terebra pedroana Dall, 1908—San Pedro auger

Description. Shell slender, elongate, conical; the taper is quite regular to a sharp apex; 10 to 14 whorls, each volution bearing numerous axial ribs and weak spiral lines. Aperture small. inner lip twisted at the short, notch-like canal. Maximum length slightly more than 5 cm (about 2 inches). Bluish-white with brownish-red blotches.

Habit and habitat. Silty sand in shallow inshore waters, 60–120 feet deep, Carlisle (1969a).

Occurrence. Present at the Hermosa Beach and Santa Monica reef sites before and after reef placement. Seasonally abundant and active from June through November. Maximum counts of 10 per m^2 were recorded adjacent to Hermosa Beach reef in October 1963. Egg case deposition was observed during August.

Importance. No data; appears to be suitable food for several fish species. Not influenced by construction of reefs.

8.4.10.66. Turcica caffea Gabb, 1865—top-snail

Description. Shell outline trochoid; resembles Calliostoma but two folds on columella of Turcica easily separate these two. Whorls flattened; sutures deep and beaded; umbilicus distinct. Maximum length about 2.5 cm (1 inch). Color, gray-brown to gray-green.

Habit and habitat. Found on small rocks and cobbles.

Occurrence. Uncommon; present before and after placement of Redondo Canyon reef.

Importance. No data; the population may increase as result of manmade reef construction.

The subclass Opisthobranchia is represented by hermaphroditic gastropods. Shells are reduced, vestigial, or absent in adults and may be external or internal. A tendency toward detorsion occurs with an accompanying return to external bilateral symmetry. Calcareous spicules are often present in the dorsum of the naked forms. A great diversity in form, color, feeding and locomotion persists.

Embryos are generally born in egg strings or ribbons, attached or resting on the substrate. Veligers are often free-swimming. Generation periods apparently do not exceed 2 years. Most nudibranchs are annuals, so constant procreation is necessary during the short life span. We retained several specimens in laboratory aquaria during this study but they always died shortly after egg deposition.

The position of opisthobranchs in the food chain, or web, has always been questionable. Some, such as the tectibranch Navanax inermis, are highly predaceous (even feeding upon other opisthobranchs), while several nudibranchs feed selectively on hydroids, sponges, etc., and still others are herbivorous. Because they often possess nematocysts, garnered from hydroid feeding, or secrete acidic or poisonous substances, they are probably seldom preyed upon by individuals (fishes) at higher trophic levels. Perhaps their greatest contribution may be through their decomposition and subsequent feed-back of minerals into the food web. Beyond this our data are inadequate to evaluate properly their importance on our reefs. Therefore importance will not be discussed under each species.

8.4.10.67. Acanthodoris lutea MacFarland, 1925—dorid nudibranch

Description. Shell absent in adult; branchial plumes in a circlet on the dorsum; a pair of rhinophores anteriorly; dorsal surface covered with conical tubercles. Our specimens ranged from 8 mm (close to 0.31 inch) to 2.5 cm (1 inch). Body orange, tubercles and branchiae white, darkened rhinophores.

Habit and habitat. Rocky substrate.

Occurrence. Found at each replication reef, on all components. Initially recorded from the February 1961 test blocks at Santa Monica. This was one of the common nudibranchs, attaining an estimated population density of 75 individuals at the Hermosa Beach rockpile in November 1963. Adults abundant during fall and winter, sparse during spring and summer.

8.4.10.68. Acteon punctocaelatus (Carpenter, 1862)—barrel snail

Description. Shell obovate; four to five whorls with fine evenly spaced spiral ribs; interspaces between ribs distinctly pitted; maximum length about 1.9 cm (0.75 inch). Shell whitish with a black band of ribs revolving from the body whorl to the apex; shell base generally stained yellow-orange.

Habit and habitat. Mud to sandy bottoms; from intertidal into depths exceeding 100 feet. Observed depositing coiled egg strings (Figure 47), attaching one end firmly into the substrate, in spring and early summer in waters 20 to 100 feet deep.

Occurrence. Common on Redondo Canyon reef (July 1963).

8.4.10.69. Aegires albopunctatus MacFarland, 1905—salt-and-pepper nudibranch

Description. Shell absent in adult; animal oval-elongate; notum thickly set with short, blunt, tubercles; three tripinnate gills, arranged in a circlet, body spiculated making it quite rigid. Our specimens were about 12 mm long (close to 0.5 inch). The body is gray-white with scattered black spots—inspiring the salt-and-pepper common name.

Habit and habitat. Sand and rock substrate, from intertidal to depths of 100 feet.

Occurrence. Recorded from the Malibu and Hermosa Beach reefs each September and October during the survey period. Nine per m^2 were estimated around the concrete shelters at Hermosa Beach (October 1961).

8.4.10.70. Aglaja diomedea (Bergh, 1893)—tectibranch

Description. Animal oval-elongate, "slug shaped," with a ventral foot. Shell internal, with initial, flat, spiral whorl. Size less than 1.2 cm (0.5 inch). Body dark brown to black.

FIGURE 47. Acteon punctocaelatus and its coiled egg strings; offshore from Redondo Beach, 90-foot depth, September 1964. *Photo by Charles H. Turner.*

FIGURE 47. Acteon punctocaelatus and its coiled egg strings; offshore from Redondo Beach, 90-foot depth, September 1964. Photo by Charles H. Turner.

Habit and habitat. Creeps over silty-sand substrate, feeding primarily on nematodes.

They deposit pear-shaped egg masses in spring and summer, attached to weed or below the sand's surface, the mass itself is not buried (Marcus, 1961; Hurst, 1967).

Occurrence. Malibu replication reef area; estimated 20 to 30 per m^2 in April 1963. Subsequently observed in numerous silty-sand areas throughout Santa Monica Bay, 60- to 80-foot depths.

8.4.10.71. Anisodoris nobilis (MacFarland, 1905)—dorid nudibranch

Description. Shell absent in adult; branchial plumes posterior in a circlet on the dorsum; paired rhinophores anterior; large mantle, covering the head. Attains lengths of 20 cm (about 8 inches). Body color somewhat variable: orange-yellow to lemon yellow with brownish-black mottlings on dorsum and between tubercles; branchial plumes whitish.

Habit and habitat. Generally on rocky substrate, from intertidal to at least 100-foot depths. Observed depositing orange-colored egg ribbons in October at the Hermosa Beach reef.

Occurrence. Seasonally abundant, recorded from June through November at the Hermosa Beach and Malibu reefs, with population peaks in October.

8.4.10.72. Antiopella barbarensis (Cooper, 1863)—aeolid nudibranch

Description. Shell absent in adults. Resembles Hermissenda crassicornis in general body shape; cerata arranged in clusters of three to four along either margin of the notum; central area of notum smooth; rhinophores perfoliate and retractile. Average specimens are 3.8 cm (1.5 inches) long. Body whitish, cerata whitish basally and bluish tipped with gold band separating white from blue.

Habit and habitat. Generally observed on firm substrate, intertidally to 100 feet deep; feed on hydroids.

Occurrence. Uncommon; recorded once at the Hermosa Beach reef concrete shelters in October 1961.

8.4.10.73. Aplysia californica Cooper, 1863—sea hare

Description. Body globular, soft, and fleshy; two large parapodial flaps, nearly cover the dorsum. Anteriorly, paired tentacles and rhinophores are prominent and stand up like ears, hence, its common name "sea hare." Shell, ear-shaped, amber colored, embedded in the dorsum. Animal size, to at least 25.5 cm long (10 inches); color olivaceous gray with purple to brownish-black markings.

Habit and habitat. Kelp bed areas from low tidal to at least 100-foot depths. Exudes a purple dye. Hermaphroditic; lives 2 years, depositing large string-like egg masses during its second year.

Occurrence. Individuals observed at the Malibu reef in October 1961 and September 1962, and at the Hermosa Beach reef in January 1962. They apparently arrived with drifting seaweeds upon which they usually feed, and were only temporary residents.

8.4.10.74. Armina californica (Cooper, 1862)—striped nudibranch

Description. Shell absent in adult; branchiae ventral, beneath mantle. Attains length of 7 cm (about 2.75 inches). The mantle is dark red-brown, with longitudinal white stripes; the foot is whitish.

Habit and habitat. Feeds extensively on sea pansies Renilla kollikeri) and in turn may be preyed upon by certain tectibranchs such as Navanax inermis. Found on silty sand to muddy bottoms, subtidally to depths exceeding 250 feet.

Occurrence. Hermosa Beach reef; present throughout year; a population peak, one per m^2 occurred in October. Not influenced by man-made habitat.

8.4.10.75. Dendrodoris albopunctata (Cooper, 1863)—dorid nudibranch

Description. Shell absent in adult; animal oval-elongate; tripinnate branchial plumes in a circlet, dorsal, and near the posterior end; paired rhinophores, retractile; mantle with small papillae. Attains lengths close to 7 cm, about 2.75 inches. Mantle is rich yellow with white spots, foot and branchial plumes pale yellow, rhinophores dark.

Habit and habitat. Rocky substrate from intertidal to 150 feet.

Occurrence. On each multiple component reef from June through October each year.

8.4.10.76. Dendronotus frondosus (Assanius, 1774)—frondose nudibranch

Description. Shell absent in adult; five to eight branched cerata on either side of the notum; oral veil with three to four branched append-ages on either side with smaller ones between them; mouth a transverse slit; rhinophoral sheaths bear dendriform processes on margins. Our largest specimens were about 3.8 cm (1.5 inches) long; MacFar-land, (1966) reports they attain lengths of 10 cm (almost 4 inches). Body color variable: ours were translucent, brownish, with grayish splotches.

Habit and habitat. Feed upon the hydroids with which they generally associate. Their body shape, color, and cryptic habits are such that field observations are rare although they are found intertidally to several hundred foot depths.

An adult was noted depositing its egg ribbon in November (1961) on the Hermosa Beach reef buoy; Hurst (1967) reports their egg ribbons in March and June.

Occurrence. On each of the replication reefs from February through November. First noted on the February 1961 test block from the Santa Monica reef concrete shelters. Subsequently recorded from test blocks on the two other replication reefs and from a 0.06 m^2 scraping at the Hermosa Beach reef (June 1963). They are probably common on the reefs but almost impossible to see.

8.4.10.77. Diaulula sandiegensis (Cooper, 1862)—circle spotted nudibranch

Description. Shell absent in adult; body shape oval-elongate; branchiae retractile and arranged in a circlet; mantle covers head and foot and barely shows beyond the posterior mantle edge of the crawling animal. Attains length of 6 cm (about 2.38 inches). Body tan or beige with distinct dark brown or black rings on either side of notum.

Habit and habitat. Sandy and rocky substrate from intertidal to depth of 120 feet.

Occurrence. Recorded infrequently at the Hermosa Beach reef. Never more than three individuals noted during any survey.

8.4.10.78. Dirona albolineata Cockerell and Elliot, 1905—aeolid nudibranch

Description. Shell absent in adult. Body stout, straight sided, rounded in front and bluntly pointed posteriorly; cerata present on either side of the convex back, anteriorly they extend beyond the rhinophores. Our specimens averaged 6 mm (about 0.25 inch) in length. Translucent gray with opaque white markings on oral veil, cerata margins, and body.

Habit and habitat. Rocky substrate, from intertidal to 100-foot depths. At least one member of this genus feeds on ectoprocts (Marcus, 1961).

Occurrence. Hermosa Beach and Santa Monica reefs on test blocks. Recorded from March through August 1961; never more than three from any one block.

8.4.10.79. Discodoris heathi MacFarland, 1905—dorid nudibranch

Description. Shell absent in adult; body elliptical, flattened, rounded at both ends; dorsum covered with minute tubercles; mantle extends beyond foot except at posterior end; circlet of branchial plumes tripinnate; rhinophores retractile within sheaths. Our specimens were about 2.5 cm (1 inch) long. Body tan-yellow, somewhat darker in middorsal region; scattered brownish spots on dorsum; rhinophores darkened.

Habit and habitat. Rocky substrate, from intertidal to at least 60 feet.

Occurrence. Recorded once from Hermosa Beach reef rockpile, October 1963.

8.4.10.80. Doto sp.—dorid nudibranch

Description. Shell absent in adult; tuberculated cerata distinctive, arranged in five pairs; gills located on inner sides of cerata. Foot tapering to a point posteriorly; sheathed rhinophores prominent anteriorly. Our largest specimen was 3 mm (0.12 inch) long. The preserved color is yellowish-tan. Because of the small size and poor condition, we are uncertain of specific affiliation.

Habit and habitat. Members of this genus associate with hydroids on which they feed.

Occurrence. Found only on test blocks. One individual from the Santa Monica reef concrete shelters (February 1961), and three from the Hermosa Beach reef; one from the streetcar (May 1961) and two from the rockpile (June 1961).

8.4.10.81. Flabellinopsis iodinea (Cooper, 1862)—aeolid nudibranch

Description. Shell absent in adult; body elongate; head small; tentacles large; dorsal processes (cerata) arranged in tufts. Average length about 3.8 cm (1.5 inch). Body violet-purple with orange-red cerata and rhinophores.

Habit and habitat. Able to swim by vigorous undulations of the body. Found on both sandy and rocky substrates, often closely associated with large hydroid colonies upon which the adults feed extensively. Adults in our laboratory aquarium were eaten by the tectibranch Navanax inermis.

Pinkish egg ribbons were observed being deposited during spring and early summer.

Occurrence. Recorded from March through October at the Hermosa Beach reef.

8.4.10.82. Hermissenda crassicornis (Eschscholtz, 1831)—aeolid nudibranch

Description. Shell absent in adult; cerata prominent and profuse dorsally, arranged in about 11 groups totaling 500 or more; head large; tentacles long; body tapering to a point posteriorly. Attains lengths of 5 cm (about 2 inches). Color variable ranging from transparent bluish-gray through yellow-green (Figure 53) .

Habit and habitat. Feeds extensively on hydroids; found on any substrate supporting hydroid colonies.

We observed them depositing their white to pinkish-colored egg ribbons in all seasons; frequently attaching them to hydroid stems.

Occurrence. The most prolific nudibranch recorded on the manmade reefs, commonly observed on all reefs and materials. Maximum population estimates coincided with hydroid blooms; 50 per m^2 were recorded at the Hermosa Beach reef in June 1962.

8.4.10.83. Navanax inermis (Cooper, 1962)—tectibranch

Description. Internal shell; flat, evenly tapering, spiral; foot broad with lateral expansions (parapodia) meeting over the animal's dorsum. Length to about 17.8 cm (7 inches). Basic body color brown with dots and dashes of blue, white, and yellow.

Habit and habitat. Silty sand to mud in bays, estuaries and on the open coast. Intertidally to depths of at least 80 feet. This species preys heavily on other opisthobranchs (Paine, 1964).

Occurrence. Only one observed: Malibu concrete shelters, December 1961.

8.4.10.84. Polycera atra MacFarland, 1905—orange spiked nudibranch

Description. Shell absent in adult; body elongate, humped and slug-like; frontal veil bears four pointed processes; eight branchiae, arranged in a circlet, positioned dorsally near the body hump. Our specimens were small, being about 1.3 cm (close to 0.5 inch) long, reported to attain 2.5 cm. Blue-black longitudinal lines separated by grayish bands having numerous orange-yellow spots.

Habit and habitat. Associates with various algae intertidally to depths of 60 feet or more.

Occurrence. Two individuals recorded from Hermosa Beach reef automobile bodies (August 1963). They apparently arrived with drifting seaweeds.

8.4.10.85. Retusa sp.—barrel bubble snail

Description. Shell small, cylindrical, short spired; with a long aperture; columella without a basal fold (distinguishing this genus from Acteocina) . Length up to 5 mm (0.25 inch). Color white.

Habit and habitat. Found on mud and sandy substrates.

Occurrence. Collected from the 0.06 m^2 quadrat samples at each of the multiple component reefs. They may have been common, but are too small to be conspicuous in the field. Broken shell fragments that appear to have passed through fish digestive tracts (probably perch) were common in debris from around the reefs.

8.4.10.86. Triopha carpenteri (Stearns, 1873)—dorid nudibranch

Description. Shell absent in adult; animal elongate, sluglike; five tripinnate branchiae arranged in a circlet on the posterior dorsum; rhinophores contractile but not retractile beneath the body surface; dorsum and sides with numerous low orange tubercles, longer orange processes on the dorso-lateral margins. Our specimens averaged about 3.8 cm (1.5 inches) in length.

Habit and habitat. Found on sandy and rocky substrates; subtidally to 100 feet.

Occurrence. Recorded only at the Hermosa Beach reef concrete shelters in June 1963 (three individuals), and October 1963 (one specimen).

8.4.10.87. Turbonilla kelseyi Dall and Bartsch—Kelsey's turbonille

Description. Shell conical, semitransparent, whitish and polished; nuclear whorls heterostrophic; prominent axial ribs, except on shell base. Maximum length about 5 mm (0.25 inch).

Members of this genus and family (Pyramidellidae) are presently considered opisthobranchs although they possess several characteristics of prosobranchs.

Habit and habitat. Found on rocky substrates, members of this genus are reported to be ectoparasites, feeding on bivalve mollusks and tubiculous polychaetes (Abbott, 1967). Ours were collected in the 0.06 m^2 scrapings and we do not have evidence of their parasitic activities.

Occurrence. Hermosa Beach reef concrete shelters, August 1963; 10 specimens in a 0.06 m^2 sample. They may have been more common but are too minute to observe in the field.

8.4.11. Entoprocta

These are small (up to 4 mm high) attached animals, stalked and variously jointed. They are usually found under rocks in colonies measuring up to 50 mm (2 inches) in diameter, and give the appearance of a "living carpet" on the substrate due to their nodding or swaying movements. The body consists of a stalk attached to the substratum at one end and supporting a cuplike calyx, which holds the internal organs, at the other. They are closely related to the phylum Ectoprocta.

The only species represented in this study was Barentsia discreta (Busk 1886). It appeared only on two test blocks from the Hermosa Beach reef, but was subsequently noted in fair abundance on at least one material at each reef during later parts of the study. As the reef aged these colonies expanded laterally but did not grow in height.

Due to their under-rock habitat and small size, they are probably of minor importance as food for most of the reef fishes, but they may be grazed upon by small crustaceans or worms. Their lack of protective structures makes them extremely vulnerable to grazing.

8.4.12. Ectoprocta

Attached colonies of individually minute (1 mm or less) animals which are permanently fixed in a gelatinous or chitinous-calcareous chamber of their own secretion. They may form thin encrusting colonies which spread laterally over large areas, or erect bushy colonies up to 6 inches high. The animals, called polypides consist of an elongate body topped by a circlet of tentacles. They have the ability to retract completely into their chambers (zooecia), and thus, afford little or no food for reef fishes. What little feeding is done on them is probably incidental to picking up something on or near the colony. Despite their nonavailability as food, they are important in reef succession. Their habit of spreading laterally, encrusting hard surfaces, and competing with other encrusting forms (algae, sponges, ascidians, etc.) makes them a physical factor in competition for available surface area on the reef. They remain attached for lengthy periods after parts of the colony have died, being held together by the younger, living outer portions.

Ectoprocts are classified by external features of the colony and structure of individual zooecia. Different groups and species have characteristic growth habits and patterns. They consolidate and become intimately associated with other encrusting or low-growing invertebrates (e.g., sponges and hydroids) to form a thick epifaunal mat which is used by smaller more active animals for protection and living space. The formation of this mat is probably one of the more critical aspects of invertebrate succession on hard surfaces, making the ectoprocts a major structural consideration here.

One species of ctenostome ectoproct (Victorella argilla) was extremely important in early invertebrate succession on submarine structures. Detailed information on this species is discussed by Banta (1967). His work is based, in a major part, on collections and observations of Victorella from the Hermosa Beach reef.

8.4.12.1. Bugula neritina (Linnaeus, 1758)—ectoproct

Description. Characteristically forms large, coarse, bushy, purplish-brown colonies up to 11 cm (4+ inches) high. Ovicells are numerous and large, giving the branches a beaded appearance. This species is different from other local species in lacking modified polypides called avicularia.

Habit and habitat. Common on local wharfs, buoys, pier pilings and some natural rock reefs. Occasionally abundant in small colonies on our study reefs where the dense bushy tufts offered habitat and protection for small hydroids and caprellid amphipods.

Occurrence. Not found on the test blocks, but occurred on the Hermosa Beach rock and concrete shelter components shortly after the test block study ended (September 1961). Noted in scattered colonies at Hermosa Beach and Malibu through 1963 and on the Redondo Canyon reef in late 1963.

Importance. Although this was one of the commonest ectoprocts in the reef study it had not yet reached a size or abundance to make it important in our investigations.

8.4.12.2. Callopora circumclathrata (Hincks, 1881)—ectoproct

Description. Encrusting, loosely attached; color, light tan.

Habit and habitat. Generally encrusts shells, stones, algae, often forming lumpy areas over animals already existing on the substrate.

Occurrence. Test blocks only. Common on the several blocks from Hermosa Beach and Santa Monica during the middle of 1961.

Importance. Minor on early reefs due to small size, but may encrust large areas later.

8.4.12.3. Crisia occidentalis Trask, 1857—ectoproct

Description. Low growing, up to 25 mm (about 1 inch) high, forms large dense bushy tufts. Whitish-yellow.

Habit and habitat. Usually common on natural or well-established reefs. Does not spread laterally or encrust, but the dense tufts may provide temporary refuge for various minute crustaceans and worms.

Occurrence. Not found on test blocks, but observed at the Redondo Canyon reef, and the Hermosa Beach and Malibu concrete shelters in late 1963.

Importance. No data.

8.4.12.4. Crisia sp.—ectoproct

Description. May include several species, but the delicate upright growth form was common in all specimens observed.

Occurrence. Not found on test blocks, but appeared in small colonies at Malibu in mid-1963, Hermosa Beach in 1962 and 1963, and on the Redondo Canyon reef in 1963.

Importance. Minor, due to its small size and delicate structure. May offer temporary protection to small crustaceans or worms.

8.4.12.5. Cryptosula pallasiana (Moll, 1803)—ectoproct

Description. Encrusting, produces colonies of considerable size, sometimes forming erect leafy projections. Color, yellowish-orange.

Habit and habitat. Osburn (1953:471) states: "The zoarium is encrusting on anything that will afford attachment ..."; while Ricketts and Calvin (1968:356) say "... the encrusting Cryptosula pallasiana, also seems to be specific to wood." These two conflicting reports warrant clarification, as the artificial reefs afford many surfaces, including wood; yet we found it only on the concrete.

Occurrence. Hermosa Beach concrete component (September 1961) with up to 10 colonies measuring 2 to 3 inches in diameter on each concrete structure.

Importance. Minor as fish food, but possibly of some importance as a physical agent in taking up space, especially on the later and more mature reefs.

8.4.12.6. Diaperoecia californica (d'Orbigny, 1852)—ectoproct

Description. Erect, robust, highly branched and heavily calcified colonies. often forming subhemispherical "heads" 8 to 10 inches in diameter and 4 inches (about 10 cm) high. Color in life dirty orange; brown or tan when dried (Figure 48) .

Habit and habitat. One of the most abundant and common ectoprocts on the southern California coast. Its "heads" are extremely conspicuous on natural reefs, usually growing near the top of the reef. Like the ectoproct Phidolopora pacifica, its growth form and large, stout, anastomosing branches present an ideal microhabitat for many small crustaceans and worms. The colonies are firmly cemented to the substrate and it would be virtually impossible for any but the largest

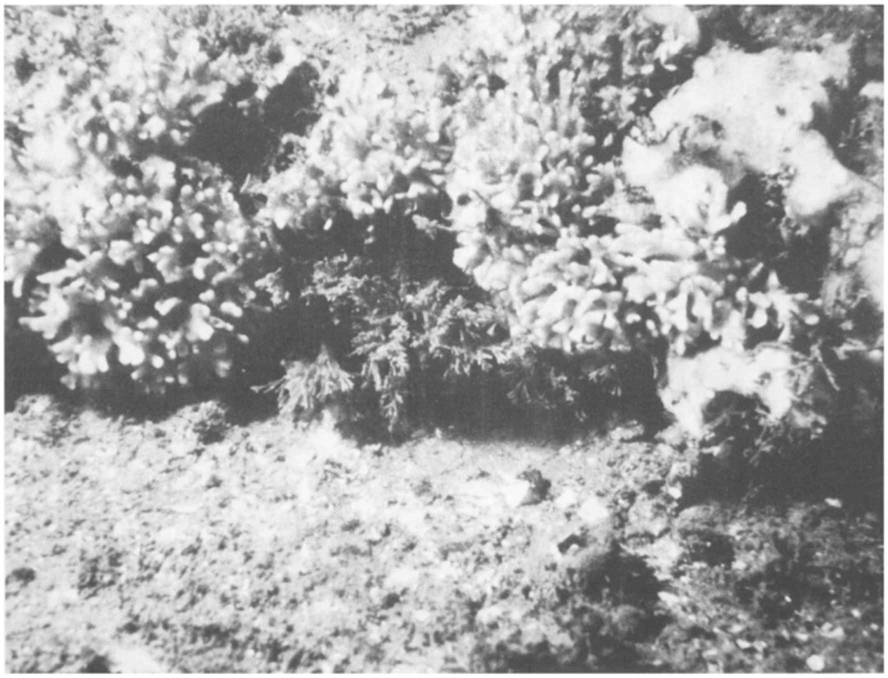

FIGURE 48 Small colonies of *Diaperoecia californica* (ectoproct) on the Hermosa Beach WCB reef concrete shelters, November 1966. *Photo by Charles H. Turner.*

FIGURE 48 Small colonies of Diaperoecia californica (ectoproct) on the Hermosa Beach WCB reef concrete shelters, November 1966. Photo by Charles H. Turner.

reef fish to dislodge them to feed on the animals sheltered within. In fact, the unique ecologic niche they afford approaches that of stony coral heads in tropical regions.

Occurrence. Not present on test blocks; appeared first at Hermosa Beach in late September 1961. The colonies became more numerous but remained small (3 cm high) during 1962 and into 1963. In mid-1963 (June) large colonies (5 by 15 cm) were noted on the sides of the concrete components at Hermosa Beach. It was not observed at Santa Monica during the study period, and only small, scattered colonies were found at Malibu in August 1963.

Importance. Major as a microhabitat, sheltering numerous smaller animals.

8.4.12.7. Diaperoecia floridana Osburn, 1940—ectoproct

Description. Colony erect, scraggly, irregularly branched, whitish. Usually no more than 2.5 cm high. Grows in small patches, high off substrate.

Habit and habitat. Grew mostly on the tops and upper side portions of low rocks and concrete shelters, without forming the large, solid-looking "heads" of D. californica. It appears more fragile and brittle than D. californica.

Occurrence. Seen occasionally during middle and late 1963 on the Hermosa Beach concrete shelter and rock components.

Importance. Minor, incidental as fish food; probably not large enough or strong enough by termination of our study to hide smaller animals or create a microhabitat.

8.4.12.8. Holoporella brunnea (Hincks, 1884)—ectoproct

Description. Encrusting; colonies form rough nodules or may rise into large gross projections. The colonies may spread to 7 cm and be 10 mm or more thick. Usually brownish in color, due to dark areas on the avicularian mandible. Colonies circular, isolated.

Habit and habitat. Seems to cover almost anything it encounters (shells, stones, algae, hydroids, etc.). One of the more common reef forms.

Occurrence. Observed on all three replication reefs and on the Redondo Canyon reef in late 1963.

Importance. None as fish food, but by encrusting fairly large areas it is an important competitor for attachment space.

8.4.12.9. Membranipora sp.—ectoproct

Description. Delicate, thinly encrusting, whitish. Not identified to species due to small size.

Habit and habitat. Typically observed as a thin, flat covering on algae stems and blades.

Occurrence. Several isolated patches on the Hermosa Beach reef (August 1961 and 1963).

Importance. Minor.

8.4.12.10. Phidolopora pacifica (Robertson, 1908)—ectoproct

Description. Colony erect, lacelike, hard and brittle (due to heavy calcification), pale orange. When uncrowded it grows in subhemispherical "heads" of varying size up to 5 inches in diameter and 2 inches high (Figure 49) .

Habit and habitat. Usually on reef material sides, rather than tops.

Occurrence. Absent during the test block study, appearing early in 1962 at Hermosa Beach in small scattered colonies. Later in 1962 it was noted at Malibu, where it soon became extremely common (averaging 3 large colonies per m^2), with about 3 to 4 inches of space between colonies. When our studies ended, small colonies were present at Hermosa Beach and it was abundant at Malibu. Its initial occurrences at these two reefs closely coincided with our transplant of Macrocystis pyrifera from Turtle Bay, Baja California. Many of the kelp holdfasts were covered with Phidolopora, suggesting a possible introduction. The lack of Phidolopora pacifica at Santa Monica supports this premise, since kelp was not transplanted there.

Importance. Insignificant as fish food, but extremely important in its physical presence on the reefs. The subhemispherical growth pattern, and hard, resistant nature of the colony make it available as habitat and protection for a myriad of small crustaceans, mollusks, and worms. These animals live near the base of the colony and move

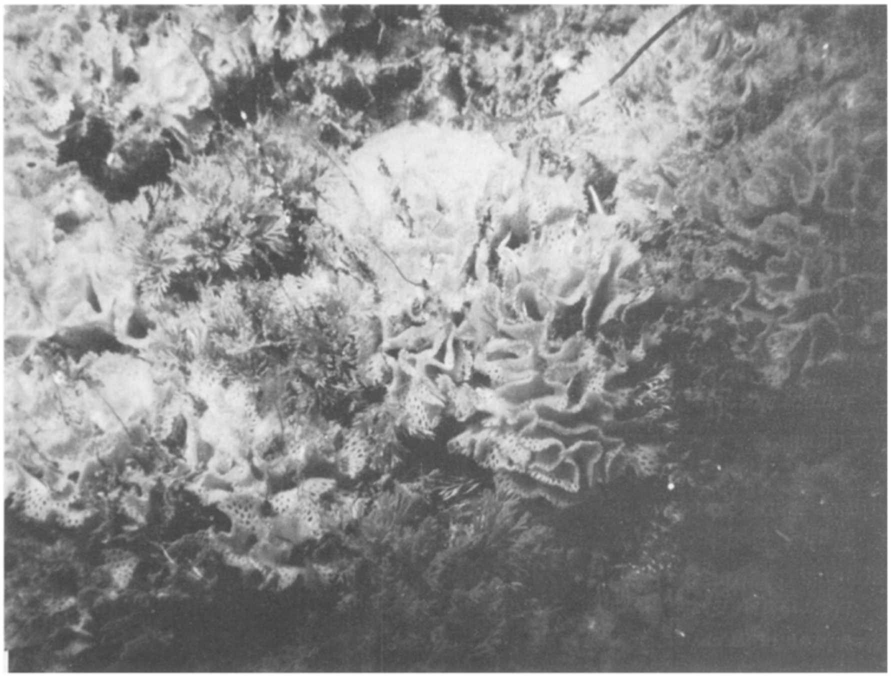

FIGURE 49 Colonies of *Phidolopora pacifica* (ectoproct) encrusting the Malibu WCB reef concrete shelters, October 1963. *Photo by Charles H. Turner.*

FIGURE 49 Colonies of Phidolopora pacifica (ectoproct) encrusting the Malibu WCB reef concrete shelters, October 1963. Photo by Charles H. Turner.

about within the interstices in the lacy calcareous network, completely protected from any but the largest foraging reef fishes.

8.4.12.11. Rhynchozoon rostratum (Busk, 1856)—ectoproct

Description. Rough, encrusting, may form into small nodes. Dark yellow.

Habit and habitat. Seems to grow only in protected areas, such as the inner surfaces of concrete shelters.

Occurrence. Incidental observations on the Hermosa Beach concrete shelters (October 1963) where colonies up to 4 cm in diameter were seen on attached pelecypod shells and on exposed concrete surfaces.

Importance. Spreads laterally with some facility; may be a physical consideration in the more mature reef fauna by competing for space.

8.4.12.12. Scrupocellaria diegensis Robertson, 1905—ectoproct

Description. Colony stiff, coarse, bushy, highly branched; may be over 50 mm high. Color in life dirty orange-tan.

Habit and habitat. One of the common bushy species on our reefs. Grows in tufts all over tops and sides of rocks and less commonly under overhangs (Figure 54) . Does not spread laterally, but in abundant bushy colonies on the rocks and concrete shelters. May afford temporary attachment space for small crustaceans or worms.

Occurrence. Not seen on test blocks; appeared on the reefs in July 1962. A moderate number of colonies was found on most materials at Hermosa Beach and Santa Monica through 1963. It flourished at Malibu and was one of the dominant species in late 1963.

Importance. Not significant in the fish food cycle, but large colonies may afford temporary habitat and protection for small crustaceans and worms. The fact that it does eventually form large bushy colonies, however, probably makes it important as a competitor for available space.

8.4.12.13. Thalamoporella californica (Levinsen, 1909)—ectoproct

Description. Encrusts at first, then rises to an erect, branching, jointed growth form. Color, whitish.

Habit and habitat. Grows up to 6 inches (15 cm) high on algae, rocks, etc.

Occurrence. Young, low-growing colonies were found only at the Malibu reef: once on test blocks, and several times on the marker buoy.

Importance. Minor, may form large bushy masses on later reefs.

8.4.12.14. Tubulipora admiranda Osburn, 1953—ectoproct

Description. Colonial, forming small, rounded patches usually about the size of a dime (18 mm). The zooecial openings are borne on the ends of erect calcareous tubules arising from the low-growing mass of horizontal tubes. Whitish-gray in color. Does not spread laterally for any distance.

Habit and habitat. Encrusts algae and various firm substrates.

Occurrence. An early reef species, found on test blocks only: from all materials at Hermosa Beach during May through July 1961, at Malibu during February through June 1961.

Importance. Minor, due to its small size and non-spreading growth habit.

8.4.12.15. Victorella argilla Banta, 1967—encrusting ectoproct

Description. Basically encrusting but with a noticeable elongation of the peristome (projecting end of the tubule which opens into the main body area of the polypide). The individuals bud off from a creeping basal portion and spread over the surface of test blocks and reef materials, with the tubules upright and perpendicular to the flat surface. These extend horizontally as the main tubule grows vertically, and eventually interdigitate with those of their immediate neighbors. This tubule network incorporates sediment in its meshes and forms a thick (up to 3 mm) adhesive mat completely covering the reef surfaces (Figure 50).

Habit and habitat. Found on nearly every exposed surface on all reef materials at all locations. Due to its strange growth habits and camouflage by the sediment it was not recognized as anything but a thick, tightly adherent sedimentary accumulation of non-animal origin until June 1962. Its presence as a "sediment layer" or "muddy mucous layer" was noted early in the study.

FIGURE 50 *Victorella argilla* (ectoproct) covering barnacles (*Balanus* sp.) and other attached organisms on the Santa Monica WCB reef concrete shelters, April 1963. *Photo by Charles H. Turner*

FIGURE 50 Victorella argilla (ectoproct) covering barnacles (Balanus sp.) and other attached organisms on the Santa Monica WCB reef concrete shelters, April 1963. Photo by Charles H. Turner

Occurrence. Its first appearance on the reefs is vague, since our recognition of it as an ectoproct was not made until late in the study and because the very young colonies are not conspicuous. We first recorded this "thin, muddy layer" in December 1960 from the streetcar component of the Santa Monica reef. The next diver record was in August 1961, also at Santa Monica. It was noted subsequently on all materials of all reefs in our study up to 1964, but appeared to be more abundant and thicker at Santa Monica than on the other two study reefs, possibly due to the increased sediments in suspension at this reef.

Importance. It is obviously not tempting to fish as food, but was recorded on two occasions in fish stomachs, presumably taken incidentally with some other invertebrate. As a biological and physical consideration in reef succession and ecology, however, it was probably the most important species studied (at least in Santa Monica Bay). Its encrusting growth habit and ability to encroach upon and cover everything in its path made it a major contender for surface space on the reefs.

The apparent importance of this species in reef ecology prompted us to initiate a detailed and thorough investigation of its habits, resulting in its description as a new species (Banta, 1967).

8.4.13. Phoronida

A small phylum of tube-dwelling animals, wormlike in appearance, whose tubes are secreted by their body wall and often are covered with sand grains. Their outstanding phylogenetic character, the lophophore, is a horseshoe-shaped, double spiral, bearing two rows of ciliated tentacles.

8.4.13.1. Phoronis sp

Description. Tubes small, parchment-like, intertwining, forming large spaghetti-like masses; tentacles whitish but translucent when fully extended (Figure 51) .

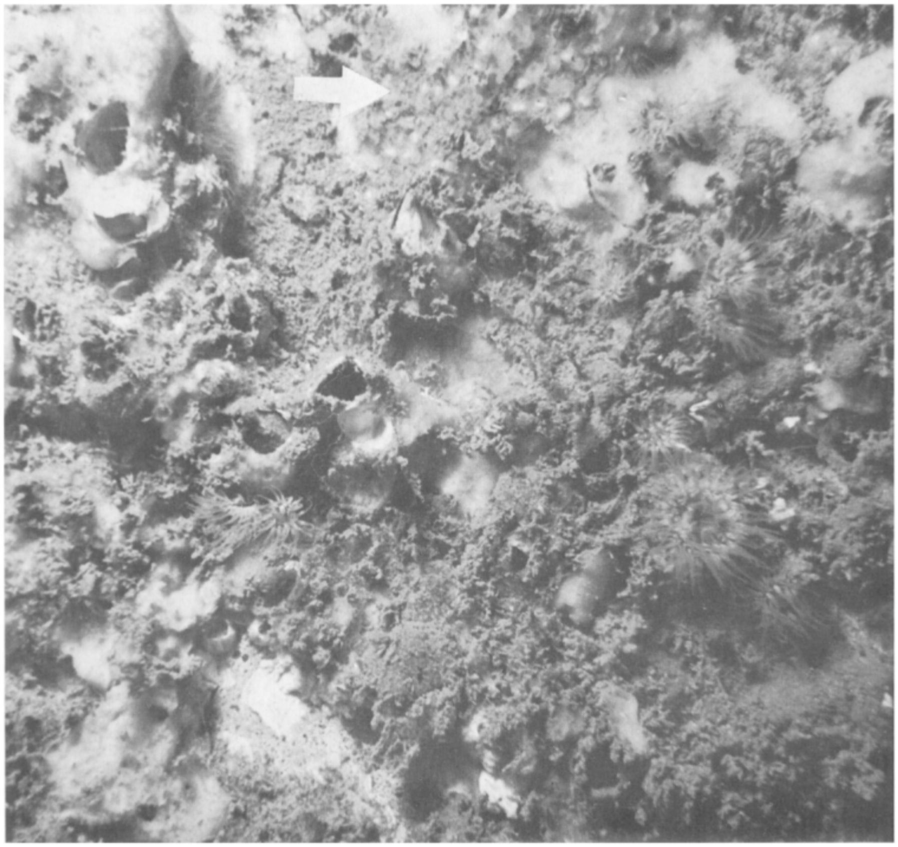

FIGURE 51 *Phoronis* sp. (arrow) joining *Metridium exilis* as major encrusting organisms on the Hermosa Beach WCB reef concrete shelters, February 1964. *Photo by Charles H. Turner.*

FIGURE 51 Phoronis sp. (arrow) joining Metridium exilis as major encrusting organisms on the Hermosa Beach WCB reef concrete shelters, February 1964. Photo by Charles H. Turner.

Habit and habitat. On the man-made reefs they formed large compact aggregations beneath the ctenostomaceous ectoproct Victorella argilla, their tentacles projecting through the mat-like layer in small clusters.

Occurrence. First recorded in April 1963 from the Santa Monica quadrat samples. At this time they were quite common on that reef. They probably established late in 1961, after the test block study, or sometime early in 1962. They were abundant on the concrete shelters at each of the replication reefs where their tubes were protected from predators by the Victorella layer. This protection appears to be a prerequisite for their establishment.

Importance. Needs further evaluation. May be important as a physical consideration, affecting the encrusting growth on the reefs, i.e., their tube masses becoming sufficiently large to cause dislodging of the above encrustment.

8.4.14. Brachiopoda

Small animals, with a clam-like two-valved shell; in most species a stalk or peduncle protrudes through one valve. The resemblance to pelecypod mollusks is extremely superficial, and many internal and external differences exist. The only species represented in our study is the inarticulate brachiopod Glottidia albida (Hinds). It is seldom seen in shallow water but is generally found in depths of 60 to 100 feet or deeper. The peduncle is inserted into the sand where it attaches to some solid object (e.g., small rock, shell fragment, etc.), keeping the animal in a vertical position just above the substrate. This particular species resembles a large (2 cm long) elongate, flattened kernel of corn. The yellowish-white valves are commonly found on the sand but the living animal is seldom seen.

Its importance as fish food or in the ecology of these reefs is incidental but our records are interesting. One live specimen was collected (Malibu, April 1963) in close association with a tube anemone (Ceriantharia). Another specimen was in the stomach of a black perch, Embiotoca jacksoni. John E. Fitch, California Department of Fish and Game (pers. comm.), has observed that Glottidia are fed upon heavily by various flatfish (e.g., fantail sole, some turbots and English sole).

8.4.15. Echinodermata

A very distinctive invertebrate group composed of five large classes, one of which (class Crinoidea) was not represented in this study. The other four are extremely common and well known, and although not present on the test blocks and in the early reef fauna, they were important in later reef development and in the diets of some of the reef fishes.

Echinoderms as a group are characterized by an internal supporting skeleton of calcareous plates covered by thin epidermal tissue (thus "echino-derma" = "spiny-skin"). These plates are especially evident in the sea urchins and starfish and to a lesser extent in the sea cucumbers and brittle stars. Their symmetry is generally five-parted, and the presence of their unique water vascular system (a complex of tubules through which circulation, excretion and movement are accomplished) is sufficient to define the phylum.

Since the four groups represented in our study (Asteroidea, Holothuroidea, Echinoidea, and Ophiuroidea) are so different from each other, and each group is generously treated in the available literature, only short descriptions emphasizing the pertinent forms are presented. Echinoderms as a group do not lend themselves as fish food because there is so little available protein in relation to the vast amounts of calcareous body plates. There are exceptions, however, sea urchins are known to be favored as food by some of the local labrids while the brittle stars are consumed in large quantities by several of the perches, various flatfishes (particularly English sole) and to a lesser extent by the serranids (basses). The other echinoderm classes are present on and around the study reefs and are important as competitors for available food and space.

In the class Asteroidea the body is flattened, usually star-shaped, and consists of a central disk area and typically five tapering arms. The disk area may be obscure in some species, while in others it may be most of the animal with the arms being short and immovable.

Their importance lies in their voracious appetites and ability to attack and devour large mollusks and worms. They are probably the most significant and active competitor of reef fishes for these food items.

Some of the large sea stars have sucker disks on their tube feet, enabling them to cling to reef surfaces and assisting them in opening the shells of pelecypod mollusks. Other species do not have these suckers and live on the sandy bottoms around the reefs, moving actively through the soft substrate in search of food.

8.4.15.1. Astropecten brasiliensis armatus Gray, 1840—sand star

Description. Large (average arm length 15 cm), body very symmetrical; color light purplish-gray. Arms tapered, margins heavily spined. Tube feet lack suckers.

Habit and habitat. Almost obliged to live on the sand, due to the absence of suckers on the tube feet. Very motile on sandy areas and capable of burying itself rapidly in the substrate. Feeds on sand-dwelling clams, snails, and worms. Swallows mollusks whole, so sand star stomachs often yield treasures to shell collectors.

Occurrence. Found at all three reef locations before construction. Subsequently noted (estimated 1 per square meter) around and between the reef materials. The presence of the reef structures apparently had no effect on the resident populations of this species.

Importance. Minor. May compete with the bottom-fishes to some extent for food, but does not feed or take up space on reefs. Young sand stars are seldom seen; may be incidental food for some reef fishes.

8.4.15.2. Henricia leviuscula (Stimpson, 1857)—slender-armed star

Description. Disc obscure; arms long and tapering, almost cylindrical. Surface appears granulated and reticulated but not spiny. Color varying from light orange to deep maroon.

Habit and habitat. Common on mature natural reefs. Strictly a rock dweller, probably a relatively light eater.

Occurrence. Seen on two occasions at the Redondo Canyon reef in late 1963.

Importance. Minor at termination of study, due to rarity.

8.4.15.3. Patiria miniata (Brandt, 1835)—sea bat, bat star, orange peel star

Description. One of the most common species on this coast. Characterized by its five-rayed symmetry, the high inflated disc, and the short broad arms. Surface superficially smooth; color variable, shades of red predominating but ranging from yellow to blue; mottled or solid.

Habit and habitat. An active and voracious feeder, found on both rock and sand. The short arms are not flexible, but the stomach is highly evertible and can enter and digest large mollusks.

Occurrence. Abundant on all materials at the Santa Monica reef site from late 1961 until the study ended in 1963. During this time, except for one occurrence at Malibu (August 1963), it was not recorded on the other two reefs.

Importance. Potentially an active competitor for surface space and for certain types of fish food. The young, usually observed on the undersides of stones and rubble, are very secretive but may be an incidental source of food for certain reef fishes.

8.4.15.4. Pisaster brevispinus (Stimpson, 1857)—short-spined sea star

Description. Large (arms may be 12 inches long or more), surface spiny and reticulated, tube feet with suckers. Noted for its large size and light, sickly pink color.

Habit and habitat. Usually found around piers and shallow rocks, may also be on open sand. A ravenous eater and active predator, it is often seen devouring large masses of mussels and chamas.

Occurrence. Seen in moderate numbers on all reefs and all materials shortly after placement. The population established early and did not fluctuate significantly during the study period.

Importance. Noteworthy as a competitor with fish for large mollusks and worms around reefs. Its large size also makes it a consideration as a physical "space-taker." The empty shells left in the wake of large feeding starfish are utilized by small fishes, shrimps and various encrusting growths, forming micro-habitats.

8.4.15.5. Pisaster giganteus (Stimpson, 1857)—giant sea star

Description. Usually large (arms average 10 inches long); color bluish-brown; large blunt spines on upper surface.

Habit and habitat. Common on local piers, jetties, and natural reefs where it feeds actively on mussels, barnacles, and snails.

Occurrence. Noted on all three reefs during 1962 and 1963, in small numbers (possibly due to the lack of a large mollusk population at this early stage of reef development).

Importance. Relatively minor at termination of study, may compete for food and temporary space.

8.4.15.6. Pisaster ochraceus (Brandt, 1835)—ochre sea star

Description. Large (arms average 8 to 10 inches long); surface rough and pitted, with white tubercles but not large spines. Color variable, from yellow to blue, usually solid.

Habit and habitat. Extremely abundant in shallow water, on jetties, piers, and rocky headlands. Large congregations may be seen feeding on mussels in the spray zone.

Occurrence. One specimen was noted at Santa Monica (April 1963) and one at Malibu, on two occasions (October, 1962 and 1963).

Importance. Incidental, probably never becoming a major competitor at these depths; it is primarily an intertidal species.

Holothurians are elongate, soft-bodied, cylindrical echinoderms, which may or may not have tube feet and large papillae on their bodies. They feed by collecting debris in tentacles and passing it to the mouth, or by ingesting large quantities of mud and passing it through the digestive tract, extracting the organic material. Probably of little or no significance to our reef fishes, and not known to be specifically preyed upon by other animals. Does not compete strongly with fish for food. In tropical waters various fishes (carapids) utilize holothurians for housing.

8.4.15.7. Eupentacta quinquesemita (Selenka, 1867)—white sea cucumber

Description. Small (1 to 2 inches long), with non-retractile tube feet on the sides of the body, giving it a bristly appearance. Oral tentacles long, branched, yellowish.

Habit and habitat. Found attached to the undersides of small rocks and cobbles in the reef areas. Not common.

Occurrence. At Hermosa Beach reef on two occasions (October, 1961 and 1963), one small specimen each time.

Importance. Minor, due to rarity and secretive habit. May be eaten by fish if exposed.

8.4.15.8. Parastichopus californicus (Stimpson, 1857)—California sea cucumber

Description. Adults large (12 inches or more in length), with redtipped conical papillae on the body. Color golden tan. Differs from the more common P. parvimensis in being lighter in color and having more numerous body papillae, all tipped with red. Normally found in deep (100-foot or more) water.

Habit and habitat. Commonly a deeper-water species in southern California, not abundant anywhere in shallow depths. Adults live on muddy bottoms.

Occurrence. Two small specimens were collected on the buoy at the Malibu reef in November 1962 and one juvenile (25 mm long) recorded at Hermosa Beach in October 1963.

Importance. Incidental to the ecology of these reefs. Interesting in that the adults are in deep water while the young apparently frequent the shallow, midwater zone. Typically the various errant sea cucumbers are most numerous in areas of organically rich sediments. Their use as an indicator of these conditions is of some importance.

Among the members of the class Echinoidea the skeleton is of large fused plates forming a rigid, globular or flattened body covered by a thin epidermis and armed with long and short spines. Inside this globular body, or test, are the viscera and gonads. The globose sea urchins are easily recognized. The occur on both sandy and rocky areas, eating mostly vegetable matter (algae). Some species are overwhelmingly abundant in certain areas, where they may decimate the existing algae. In this study, however, they played a minor role and are considered incidental to the ecology of the reefs at these early stages of reef development. Various fishes are known to eat them, but their present abundance precludes this consideration.

8.4.15.9. Strongylocentrotus purpuratus (Stimpson, 1957)—purple sea urchin

Description. Body depressed, globular, with short purplish-green spines.

Habit and habitat. Abundant locally in natural rocky areas from intertidal to depths over 100 feet. On our reefs the few that were found probably drifted in on floating kelp; no population has established.

Occurrence. Noted at Malibu in small numbers on two occasions (several in October 1961 and one in September 1962).

Importance. Minor, being incidental at this stage. Their presence, and especially their means of arrival, is worthy of note as a possible means for their eventual establishment as permanent reef inhabitants. The gonads of this and a closely related species (S. franciscanus) are considered a delicacy by some people.

8.4.15.10. Lovenia cordiformis Agassiz, 1872—heart urchin

Description. Body somewhat flattened, heart-shaped. Spines long, flexible and usually folded down along the body.

Habit and habitat. A common resident of sandy areas, burrowing several inches below the sand surface eating detritus.

Occurrence. Malibu rockpile area (April 1963), one seen in the substrate. Probably common in sand around the reefs, but not recorded as part of the study.

Importance. Minor, no effect on reef ecology and not affected markedly by reef placement.

Ophiuroids are characterized by long, slender, snaky arms attached to a clearly defined disc. The arms are very flexible and easily broken (hence, "brittle star"). They are ravenous eaters that can pursue, catch, and manipulate small invertebrates with their arms. Ophiuroids are extremely abundant in both sandy and rocky areas. Only one of many local species was of major importance in this study, although remains of several other unidentified forms were found in fish stomachs.

8.4.15.11. Ophiopteris papillosa (Lyman, 1875)—brittle star

Description. A large, brownish-tan ophiuroid with broad flattened spines on its arms.

Habit and habitat. often found in moderate to large numbers under rocks and reefs, also under some large sea urchins.

Occurrence. Two specimens were noted on the marker buoy at Malibu (November 1962).

Importance. Minor as fish food, but interesting in their occurrence near the surface on a buoy. They generally characterize mature reefs.

8.4.15.12. Ophiothrix spiculata Le Conte, 1851—brittle star

Description. Arms up to 5 inches long, spines on arms with secondary spinelets. Arms may be banded dark and light; disc variously colored.

Habit and habitat. This is the most common brittle star in shallow subtidal regions. It may live partially buried in the sand with two or three arms protruding to catch floating food; under rocks where they are active predators; or down deep in large "heads" of ectoprocts, again with the arms extended above the surface of the ectoproct colony to catch food.

Occurrence. First noted on the Hermosa Beach reef (September 1961). Common in the sand around the Redondo Canyon reef; in fact, common around and on all reefs where there is any potential hiding place or temporary protection.

Importance. Serves as a major food item for reef fishes, particularly pile perch. May also compete with smaller fishes and invertebrates for food.

8.4.16. Chordata

The Chordata are characterized (at least in the larval stages) by the presence of a dorsal tubular nerve cord, a dorsally located supporting structure (notochord) and pharyngeal clefts (gill slits). This large phylum encompasses several widely separated subphyla, only two of which are pertinent to this study: (i) Vertebrata (e. g. birds, mammals, fishes, etc.), and (ii) Tunicata (ascidians and salps).

The Vertebrata are the most familiar chordate group and will be treated as a separate section (Fishes) of this report. The Tunicata are usually studied along with the invertebrates because of their similar growth habits and behavior. The distinction between the two subphyla, however, must be clearly made. The tunicates conform to all the characters of the Chordata, but only in their larval stages. Their adult morphology, growth habits, and ecology are those of invertebrates.

Two of the three classes of Tunicata are pelagic. The third (Ascidiacea, or sea squirts) are attached, sac-shaped animals that occur singly or in low-growing, laterally spreading colonies. The body is encased in an outer cover (tunic) and is provided with a pair of apertures (inhalent and exhalent) for passage of water from which food is obtained and respiratory exchanges made. They are commonly seen on the sides and bottoms of rocks, piers, pilings, and floats and are often intimately associated with algae, sponges, hydroids, and ectoprocts. As a group they are not eaten by any other invertebrates, but are used for temporary shelter or habitat by some small crustaceans.

8.4.16.1. Amaroucium californicum Ritter and Forsyth, 1917—compound ascidia n

Description. Low-growing, colony spreading laterally for great distances. Color of colony usually bluish-white, translucent. Does not become embedded with sand, so surface remains smooth and gelatinous. Forms great irregular sheets covering large areas of rocks and other surfaces. Very conspicuous.

Habit and habitat. First noted as small isolated colonies which grew rapidly and spread laterally into large lumpy colonies covering areas up to 1 foot in diameter. The lumps and convolutions in the surface of the colony will shelter many small animals.

Occurrence. Present in small to medium-sized patches at the Hermosa Beach rockpile (December 1961). Subsequently observed at Malibu in small colonies. Not seen at Santa Monica, possibly due to the adverse water quality in that area. During 1962 and 1963, it continued to proliferate, and at the termination of the study (1964) formed a conspicuous part of the reef ecology, covering large surface areas and competing with other encrusting forms for space (Figure 52) .

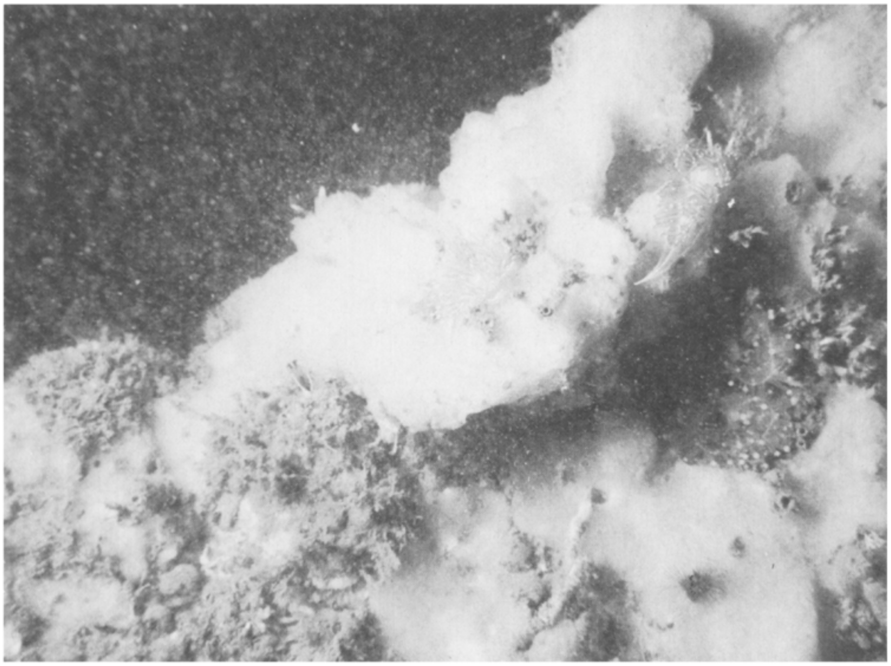

FIGURE 52 *Amaroucium californicum* (compound ascidian) becoming a major encrusting organism at the Hermosa Beach WCB reef concrete shelters, June 1962. Crawling on its surface are nudibranchs, *Hermissenda crassicornis*. Photo by Charles H. Turner.

FIGURE 52 Amaroucium californicum (compound ascidian) becoming a major encrusting organism at the Hermosa Beach WCB reef concrete shelters, June 1962. Crawling on its surface are nudibranchs, Hermissenda crassicornis Photo by Charles H. Turner.

Importance. Major. Not used as food by fishes or invertebrates but is a major contender for surface space and provides habitat and protection for other small animals. Its presence apparently indicates a maturing reef; its absence presumably indicates adverse water quality.

8.4.16.2. Ascidia ceratodes (Huntsman, 1912)—solitary ascidian

A solitary form with a translucent, cartilaginous greenish-colored test through which the internal organs are visible. It attaches to rocky surfaces and was observed on one occasion (Hermosa Beach reef, August 1961) attached to the shell of an abalone jingle (Pododesmus cepio) . of no apparent major importance in these reefs' ecology.

8.4.16.3. Chelysoma productum Stimpson, 1864—solitary ascidian

Description. Solitary, translucent greenish color; average width of individual 10 to 15 mm. Body somewhat flattened, characterized by the presence of six distinct triangular plates arranged in a ring around each aperture.

Habit and habitat. Fastens to the substrate by a broad base usually not in company with other individuals of the species.

Occurrence. Two recorded on the June 1961 test blocks from Hermosa Beach (concrete and rock), and one from Santa Monica (May 1961). Also observed on the rock and concrete materials occasionally during 1962 and 1963. The populations were never large (averaging three or four per concrete component); their sizes ranged from 5 to 8 mm.

Importance. Negligible as fish food and takes up very little surface space on the reef. Interesting in that it is the only ascidian recorded from the test blocks and as a part of the early reef fauna.

8.4.16.4. Distaplia sp.—compound ascidian

Many tiny individuals (zooids) growing in a gelatinous matrix covered by a cellulose tunic. The whole mass is translucent orange. A colony was collected on the Hermosa Beach rock component (September 1962). Interesting in its occurrence, indicating progression of the reef fauna toward "maturity."

8.4.16.5. Pyura haustor (Stimpson, 1864)—solitary ascidian

Description. Solitary; body elongate, bag-shaped; siphons long and pink-tipped. Test very thick and leathery, usually covered with a heavy growth of algae, ectoprocts, sponge and hydroid. May grow to 10 cm long.

Habit and habitat. Common on mature reefs, often harboring small crustaceans in its internal cavity. Attaches to rocks in crevices and cracks.

Occurrence. Appeared on the Hermosa Beach reef late in 1962, and by late 1963 the population was estimated at one individual per 4 m^2. A few isolated specimens were also noted on the Redondo Canyon Reef in late 1963.

Importance. Possibly none as fish food. May offer some slight competition for space, provide substrate for some invertebrates, and harbor and protect some small crustaceans.

8.4.16.6. Salpa (= Thetys) vagina (Tilesius, 1802)—salp

Description. In its solitary stage this species is barrel-shaped, with incurrent and excurrent openings at opposite ends, the circular muscle bands visible. Body 8 to 10 inches long with two greenish "tails" at the aboral end. Free-swimming in the midwater regions.

Habit and habitat. Pelagic, usually solitary. Its life cycle is complex, producing alternately solitary forms and aggregates of individuals in long chains (Figure 53). often found seasonally in great numbers in the local bays and inshore areas, as well as far out to sea. Not considered a part of the reef fauna.

Occurrence. Noted particularly during the summer months in 1962 and 1963, around the Hermosa Beach and Redondo Canyon reefs.

Importance. Minor, since they are part of the pelagic environment. Occasionally fed upon by the reef fishes (perches, sand bass and kelp bass) and more frequently by molas.

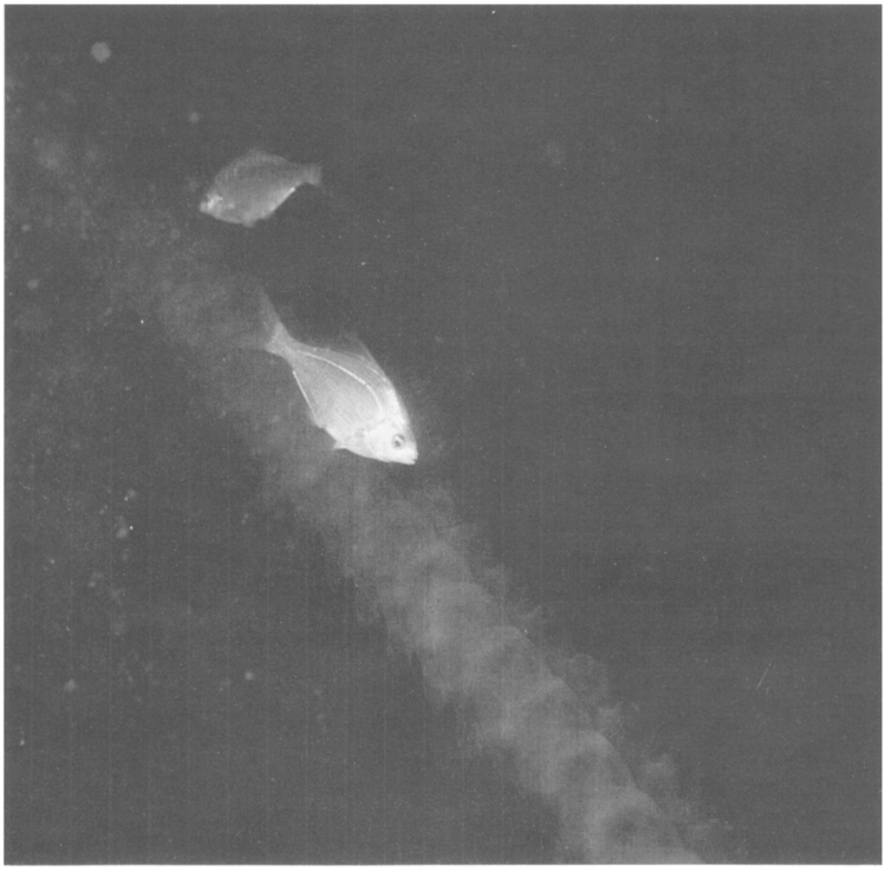

FIGURE 53 A long chain (aggregation) of salps being fed upon by white sea perch, *Phanerodon furcatus.* Photo by Charles H. Turner.

FIGURE 53 A long chain (aggregation) of salps being fed upon by white sea perch, Phanerodon furcatus. Photo by Charles H. Turner.

8.4.16.7. Styela montereyensis (Dall, 1872)—solitary ascidian

Description. Body an elongate, leathery sac tapering to a narrow stalk by which it attaches. The outer tunic has longitudinal folds and grooves and is usually well covered by algae and hydroids (Figure 54).

Habit and habitat. Grows erect and solitary, often in loose aggregations on pilings, jetties, and subtidal reefs.

Occurrence. First noted in small numbers, up to 3 inches long, on the Malibu reef components (June 1961). Subsequently common on all materials of all reefs, with lengths to 12 cm (5 inches).

Importance. Minor, apparently not used as fish food. Does not occupy much space for attachment on the substrate, but may provide additional surfaces for growth of hydroids, algae, etc.

8.5. VERTEBRATA (Fishes)

We assessed the fish populations around the man-made reefs by: (i) species enumeration; (ii) estimates of size (lengths); (iii) feeding habits; and (iv) general behavioral traits. Underwater tagging

FIGURE 54 *Styela montereyensis* attached to the submerged rock forming the Richfield Oil Island, near Santa Barbara. In the background are colonies of the ectoproct *Scrupocellaria diegensis.* Photo by Charles H. Turner.

FIGURE 54 Styela montereyensis attached to the submerged rock forming the Richfield Oil Island, near Santa Barbara. In the background are colonies of the ectoproct Scrupocellaria diegensis. Photo by Charles H. Turner.

techniques (Ebert 1960) were developed and employed to determine fish movements.

During our survey dives from August 1960 through November 1962, each member of the survey team independently estimated the numbers and kinds of fishes present on each reef component visited. These estimates were tallied underwater on plastic slates and later compared before inclusion in our diving logs. Although precise population numbers are impossible to obtain, we found an 80% to 90% agreement when comparing our individual estimates, assuring us that relative population changes were adequately depicted. Estimates of the more mobile fishes were made while quickly swimming across and around an entire component. Less active species were subsequently tallied by carefully searching in crevices and grottos. Due to the relatively limited bottom area covered by each component and its isolation from the rest of the reef, we were able to "live" with the fishes during each dive, estimating their numbers and observing their behavior. After November 1962, we noted only new occurrences and changes in the fish population structure.

Only one species, a red brotula (Brosmophycis marginatus) was so secretive as to avoid detection completely until after we suspended the routine fish counts. It was first collected during a small-scale poisoning of the Hermosa Beach reef, rock component, November 5, 1963. Subsequently on July 10, 1964 we observed a second specimen hiding beneath more than a foot of rock rubble.

A total of 78 species (representing 35 families and 60 genera) was recorded during our routine study (Table 5).

The total fishes present at each material (on a given survey) ranged from 2 (Hermosa Beach streetcar, September 1960) to 2,707 (Malibu streetcar, September 1960), averaging 846 fishes per observation, for all materials and observations (Figures [55], [56], [57], and [58]).

The Malibu materials attracted an average of 999 fishes, ranging from 900 for the streetcar to 1,140 for the concrete shelters. The Hermosa Beach materials were next with an average of 800 fishes, ranging from 411 (streetcar) to 1,070 (concrete shelters). The Santa Monica reef was least attractive, as an average of only 741 fishes ranging from 593 (streetcar) to 948 (concrete shelters), were recorded.

By material, the majority of the fishes were attracted to the concrete shelters, averaging 1,053 fishes per observation; the streetcar attracted the least, 635. Between these extremes were the automobile bodies, 826, and the quarry rock, 870.

The greatest diversity was recorded at the Hermosa Beach reef: 66 species. This high was followed by Malibu (40), Santa Monica (35) and finally the "production model" Redondo Canyon reef with 27 species. We attribute the lack of species diversity at the Redondo Canyon reef to its relative newness; it was only 8 months old at the termination of the surveys. Also, fewer and less detailed observations were conducted here. We attribute speciation differences between the other reefs in part to our unequal number of observations (Hermosa Beach 93, Santa Monica 70, and Malibu 62) but primarily to reef location and surroundings.

Both Malibu (40 species) and Hermosa Beach (66 species) are near the Bay's extremities, within a few miles of natural reefs, and in areas of relatively clean waters and active currents. By contrast the Santa Monica reef lies in the middle of the Bay, a considerable distance from natural reefs and in a "stagnant" area of eddy currents and very turbid waters.

Comparison of species lists for the invertebrates and plants (discussed in detail in other sections of this paper) and the fishes point out the effects of location and currents. Twenty-three fish species

TABLE 5

Fishes Observed During the Routine Monthly Surveys of the WCB Reefs, September 1960 Through November 1962, with Additional Occurrences Noted Through August 1963

Species (by family)	Classification*	Location, Material and Number of Observations: Hermosa Beach WCB reef #1				Santa Monica WCB reef #2				Malibu WCB reef #3				Redondo Canyon Reef
		Rock (27)	Streetcar (22)	Automobiles (21)	Concrete (23)	Rock (17)	Streetcar (22)	Automobiles (14)	Concrete (17)	Rock **	Streetcar (24)	Automobiles (17)	Concrete (21)	†
Heterodontidae														
Heterodontus francisci (Girard)	S	1	--	--	--	--	--	--	--	--	--	--	--	--
Scyliorhinidae														
Cephaloscyllium ventriosum (Garman)	S	1	--	--	--	--	--	--	x‡	--	--	--	--	--
Squatinidae														
Squatina californica Ayres	B	x	--	--	--	--	--	--	--	--	--	--	--	--
Rhinobatidae														
Platyrhinoidis triseriata (Jordan & Gilbert)	B	--	1	1	--	--	--	--	--	--	--	--	--	--
Rhinobatos productus (Ayres)	B	--	--	1	--	--	--	--	--	--	--	--	--	--
Torpedinidae														
Torpedo californica Ayres	B	1	2	2	3	--	--	--	2	--	--	--	--	--
Dasyatidae														
Urolophus halleri Cooper	B	x	--	--	--	--	--	--	--	--	--	--	--	--
Myliobatidae														
Myliobatis californicus Gill	S	x	--	1	--	--	--	--	--	--	--	--	--	--
Engraulidae														
Engraulis mordax Girard	P	--	--	--	--	--	--	--	--	--	--	--	1	--
Synodontidae														
Synodus lucioceps (Ayres)	B	--	--	--	x	1	2	1	1	--	9	6	4	--
Serranidae														
Paralabrax clathratus (Girard)	S	24	20	19	20	14	17	10	15	x	22	16	21	--
Paralabrax nebulifer (Girard)	S	25	20	19	21	16	21	14	17	x	23	16	21	x
Stereolepis gigas Ayres	S	1	--	--	1	--	--	--	--	--	--	--	--	--
Branchiostegidae														
Caulolatilus princeps (Jenyns)	S	20	5	13	12	--	--	--	--	--	1	--	--	x
Carangidae														
Seriola dorsalis (Gill)	P	--	--	x	--	--	--	--	--	--	--	--	--	--
Trachurus symmetricus (Ayres)	P	1	--	--	2	--	4	--	--	--	4	1	2	--
Sciaenidae														
Cynoscion nobilis (Ayres)	S	--	--	1	--	--	--	--	--	--	--	--	1	--
Genyonemus lineatus (Ayres)	B	--	--	--	--	--	§	--	--	--	--	--	--	--
Scorpidae														
Medialuna californiensis (Steindachner)	S	8	13	13	6	--	--	--	--	--	2	--	3	--
Girellidae														
Girella nigricans (Ayres)	S	3	--	--	--	--	--	--	--	--	2	3	1	x
Embiotocidae														
Cymatogaster aggregata Gibbons	I	--	--	--	--	1	1	1	1	--	--	--	--	--
Embiotoca jacksoni Agassiz	S	19	13	16	14	15	20	13	15	x	24	16	21	x
Hyperprosopon argenteum Gibbons	B	--	--	--	--	--	--	--	--	--	--	--	1	--
Hypsurus caryi (Agassiz)	S	13	5	11	12	6	8	7	6	x	23	15	20	x
Phanerodon furcatus Girard	B	23	17	17	17	16	21	14	7	x	24	16	21	x
Rhacochilus toxotes Agassiz	S	24	17	17	18	15	18	13	16	x	23	16	20	x
Rhacochilus vacca (Girard)	S	25	17	17	18	17	21	13	16	x	24	16	21	x
Pomacentridae														
Chromis punctipinnis (Cooper)	R	14	8	10	8	1	1	--	--	x	1	1	2	x
Labridae														
Oxyjulis californica (Gunther)	S	--	--	10	1	--	--	--	--	--	--	--	--	x
Halichoeres semicinctus	S	x	--	--	--	--	--	--	--	--	--	--	--	--
Pimelometopon pulchrum (Ayres)	S	2	2	6	4	4	4	4	7	x	20	14	20	x
Scombridae														
Scomber japonicus Houttuyn	P	--	--	--	--	--	--	--	--	--	1	--	1	--
Sarda chiliensis (Cuvier)	P	--	--	--	--	--	--	--	--	--	--	--	x	--
Gobiidae														
Coryphopterus nicholsi (Bean)	R	23	12	11	17	--	--	--	--	x	--	--	--	x
Lythrypnus dalli (Gilbert)	R	8	--	1	x	--	--	--	--	--	--	--	--	--
Lythrypnus zebra (Gilbert)	R	x	--	--	--	--	--	--	--	--	--	--	--	--
Scorpaenidae														
Scorpaena guttata Girard	S	22	15	13	15	11	10	9	6	x	19	12	17	x
Sebastes atrovirens (Jordan & Gilbert)	R	1	1	--	1	--	--	--	--	--	1	--	1	--
Sebastes auriculatus (Girard)	R	11	4	2	3	4	1	3	--	--	8	1	10	x
Sebastes chrysomelas (Jordan & Gilbert)	R	1	--	--	--	--	--	--	--	--	--	--	--	--
Sebastes dalli (Eigenmann & Beeson)	R	1	--	--	3	1	--	--	--	--	--	--	--	x
Sebastes miniatus (Jordan & Gilbert)	S	4	--	--	--	--	--	--	1	--	--	--	--	x

TABLE 5

Fishes Observed During the Routine Monthly Surveys of the WCB Reefs, September 1960 Through November 1962, with Additional Occurrences Noted Through August 1963

TABLE 5—Continued

Fishes Observed During the Routine Monthly Surveys of the WCB Reefs, September 1960 Through November 1962, with Additional Occurrences Noted Through August 1963

Species (by family)	Classification*	Location, Material and Number of Observations												
		Hermosa Beach WCB reef #1				Santa Monica WCB reef #2				Malibu WCB reef #3				Redondo Canyon Reef
		Rock	Streetcar	Automobiles	Concrete	Rock	Streetcar	Automobiles	Concrete	Rock	Streetcar	Automobiles	Concrete	
		(27)	(22)	(21)	(23)	(17)	(22)	(14)	(17)	**	(24)	(17)	(21)	†
Scorpaenidae--Continu^e														
Sebastes mystinus (Jordan & Gilbert)	R	1	--	--	--	--	--	--	--	--	--	--	--	--
Sebastes paucispinis (Ayres)	S	--	--	1	--	--	--	--	--	--	--	--	--	--
Sebastes rastrelliger (Jordan & Gilbert)	R	--	--	--	--	--	--	--	--	--	1	--	1	--
Sebastes serranoides Eigenmann & Eigenmann	S	19	10	15	17	7	8	9	7	x	13	9	11	x
Sebastes serriceps (Jordan & Gilbert)	R	--	--	--	--	--	--	--	--	--	--	--	--	x
Sebastes vexillaris (Jordan & Gilbert)	R	3	--	--	--	--	--	--	--	--	--	--	1	x
Sebastes sp.	I	--	--	--	1	--	--	--	--	--	--	--	--	--
Hexagrammidae														
Ophiodon elongatus Girard	S	x	--	--	--	--	--	--	--	--	--	--	--	x
Oxylebius pictus Gill	R	16	10	7	12	3	4	--	--	x	1	1	--	x
Cottidae														
Artedius creaseri (Hubbs)	R	2	--	--	3	1	--	--	1	x	--	--	--	--
Artedius notospilotus Girard	R	1	--	--	--	--	--	--	--	--	--	--	--	--
Scorpaenichthys marmoratus (Ayres)	S	11	2	1	2	1	1	1	--	x	3	2	6	--
Agonidae														
Agonopsis sterletus (Gilbert)	I	--	--	--	1	--	--	--	--	--	--	--	--	x
Bathymasteridae														
Rathbunella hypoplecta (Gilbert)	R	2	--	x	2	x	--	--	--	--	--	--	--	x
Clinidae														
Alloclinus holderi (Lauderbach)	R	--	--	1	--	--	--	--	--	--	--	--	--	--
Neoclinus blanchardi (Girard)	R	1	1	--	1	--	--	--	--	--	--	--	--	--
Neoclinus uninotatus Hubbs	R	1	1	--	--	--	--	--	--	--	--	--	1	--
Blenniidae														
Hypsoblennius gilberti (Jordan)	R	--	--	--	--	--	--	--	1	--	--	--	--	--
Brotulidae														
Brosmophycis marginatus (Ayres)	R	x	--	--	--	--	--	--	--	--	--	--	--	--
Ophidiidae														
Otophidium taylori (Girard)	B	x	--	--	1	1	--	--	--	--	--	--	--	--
Sphyraenidae														
Sphyraena argentea (Girard)	P	--	--	--	--	--	1	--	--	--	--	--	--	--
Atherinidae														
Atherinops affinis (Ayres)	P	--	--	--	--	--	--	--	1	--	--	--	--	--
Atherinopsis californiensis Girard	P	--	--	--	--	--	--	--	--	--	--	--	--	x
Bothidae														
Citharichthys sp.	B	5	6	4	7	2	2	2	2	--	2	1	2	--
Hippoglossina stomata Eigenmann & Eigenmann	B	1	--	--	1	--	--	--	--	--	--	--	--	--
Paralichthys californicus (Ayres)	B	2	2	1	2	--	1	--	--	--	1	1	1	x
Xystreurys liolepis Jordan & Gilbert	B	6	5	5	8	1	--	--	--	--	3	2	2	x
Pleuronectidae														
Eopsetta jordani (Lockington)	B	--	--	1	--	--	--	--	--	--	--	--	--	--
Hypsopsetta guttulata (Girard)	B	3	2	2	4	1	--	--	1	x	2	1	4	--
Parophrys vetulus Girard	B	--	1	--	--	--	--	--	--	--	--	--	1	--
Pleuronichthys coenosus Girard	B	7	2	5	6	x	1	--	--	--	3	4	2	--
Pleuronichthys decurrens Jordan & Gilbert	B	1	1	2	1	--	--	--	--	--	1	--	1	--
Pleuronichthys verticalis Jordan & Gilbert	B	2	1	1	2	--	--	--	--	--	--	--	--	--
Gobiesocidae														
Gobiesox rhessodon Smith	R	--	--	--	1	--	--	--	--	--	--	--	--	--
Molidae														
Mola mola (Linnaeus)	P	1	1	--	--	--	1	--	--	--	--	--	--	--
Batrachoididae														
Porichthys notatus Girard	R	--	--	--	--	3	--	--	--	--	--	--	--	--

* Classification symbols
P = pelagic
B = benthic
S = semi-resident
R = resident
I = indeterminate, too rare in this study to be classified.
** Surveyed after termination of monthly fish counts.
† Constructed after termination of monthly fish counts.
‡ Observed after termination of monthly fish counts.
§ Caught on hook and line during surveys—not actually observed underwater.

TABLE 5
Fishes Observed During the Routine Monthly Surveys of the WCB Reefs, September 1960 Through November 1962, with Additional Occurrences Noted Through August 1963

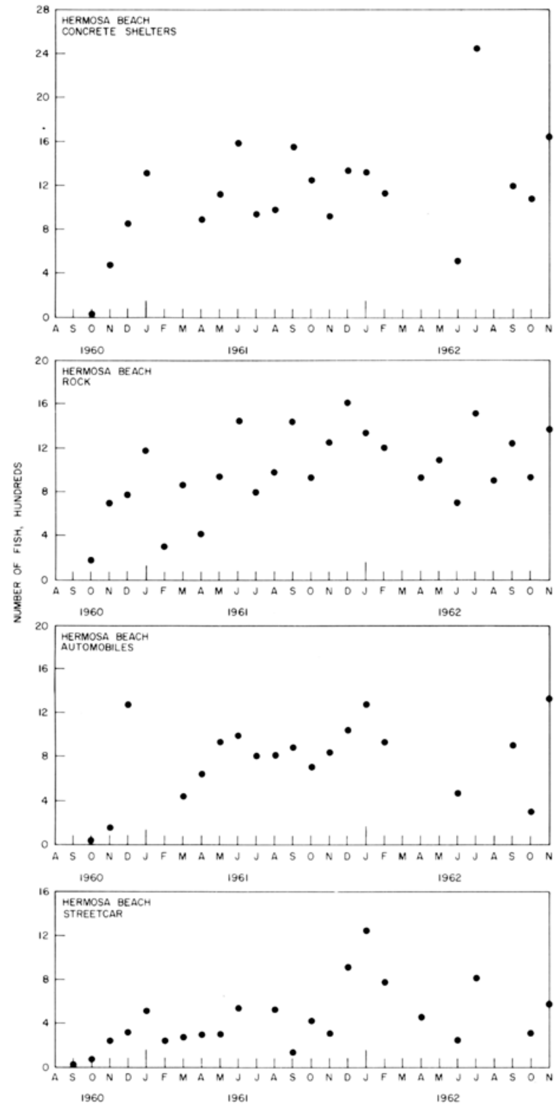

FIGURE 55 Changes in the total fish population at the Hermosa Beach WCB reef with time, by material.

FIGURE 55 Changes in the total fish population at the Hermosa Beach WCB reef with time, by material

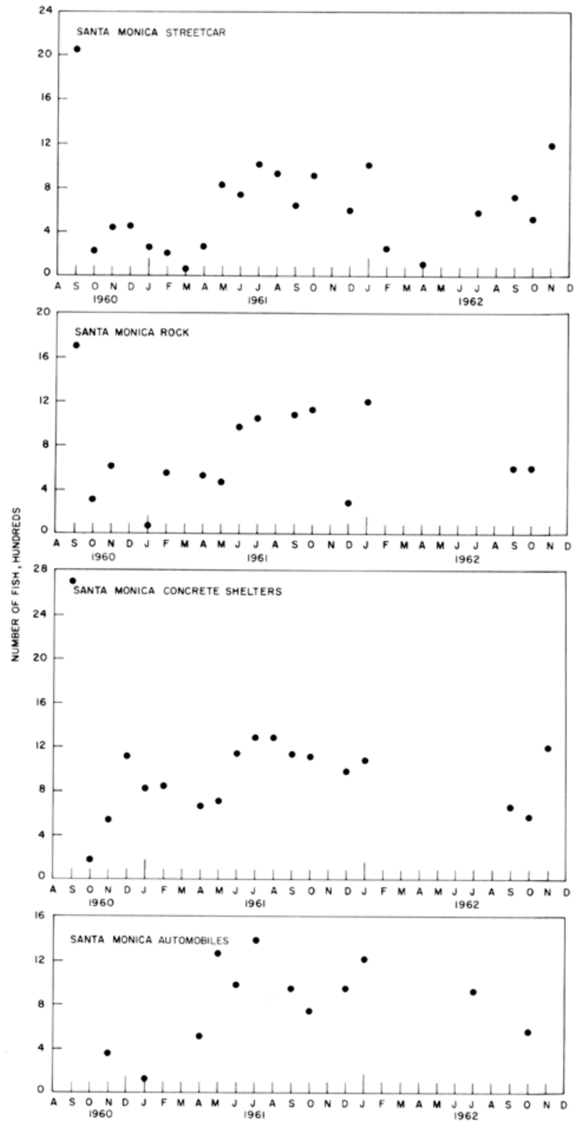

FIGURE 56 **Changes in the total fish population at the Santa Monica WCB reef with time, by material.**

FIGURE 56 Changes in the total fish population at the Santa Monica WCB reef with time, by material

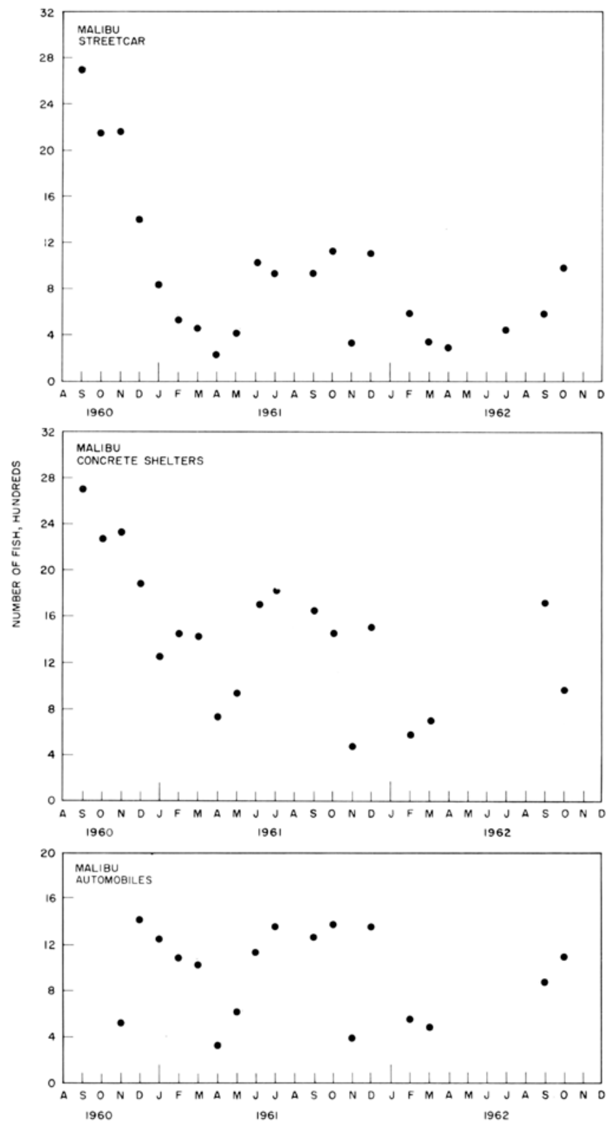

FIGURE 57 Changes in the total fish population at the Malibu WCB reef with time, by material.

FIGURE 57 Changes in the total fish population at the Malibu WCB reef with time, by material

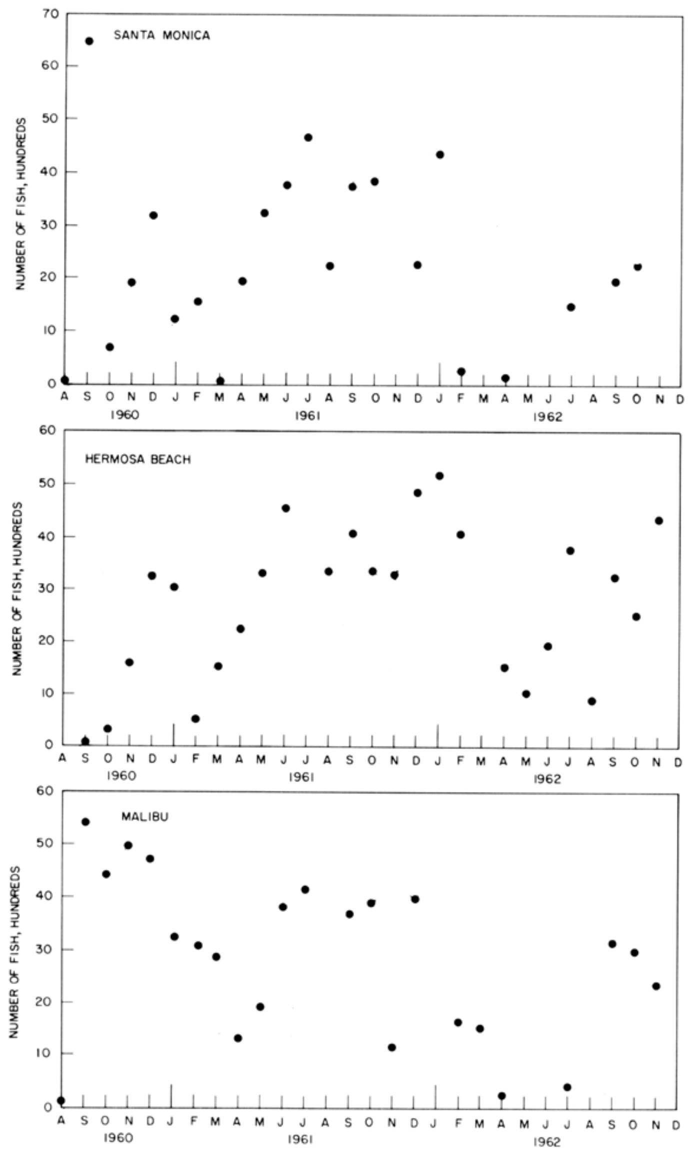

FIGURE 58 Changes in the fish populations at the three WCB reefs with time.

FIGURE 58 Changes in the fish populations at the three WCB reefs with time were observed on 10% or more of the dives at Hermosa Beach, 18 at Malibu and only 13 at Santa Monica. At Hermosa Beach blackeye gobies (Coryphopterus nicholsi) , ocean whitefish (Caulolatilus princeps) , blacksmiths (Chromis punctipinnis) , halfmoons (Medialuna californiensis) , and señoritas (Oxyjulis californica) , were observed on at least 10% of the dives; they were seldom, if ever, recorded at the other reefs. Eighteen species were common to all four study reefs, five others were common to the three replication reefs, and in time presumably would be observed at the Redondo Canyon reef (Table 6).

At Hermosa Beach, 11 species (two serranids, four embiotocid perches, two rockfishes, one goby, one tilefish, and one greenling) were present on 45 (about half) or more of the diving surveys. The dominant species here, present 85 and 83 times during the 93 observations, were sand bass (Paralabrax nebulifer) and kelp bass (P. clathratus) .

By contrast, at Santa Monica only seven species (two serranids, four embiotocid perches, and one rockfish) were present on 36 (about half) or more of the survey dives. Sand bass were also dominant here, but embiotocid perches were second, with kelp bass relegated to sixth.

The Malibu reef, similar in many respects to the Hermosa Beach reef, had 10 species (two serranids, five embiotocid perches, two rockfishes and one labrid) present on 22 (about half) or more of the survey dives. Unlike the other reefs, embiotocid perches were first in frequency of occurrence with sand bass and kelp bass falling to fourth and fifth. California sheephead (Pimelometopon pulchrum—the labrid) were seldom numerous but generally present (54 times) at this reef, while only occasionally recorded at the others (Table 6).

During the first year of reef life, embiotocid perches and serranids dominated each reef's fish population. When present they accounted for more than 90% of the fishes recorded.

During the second year, a slight decrease in their dominance was recorded at Santa Monica (89.9%) and Malibu (86.0%) while at Hermosa Beach they declined to 67.6%. As the Hermosa Beach reef aged this percentage decreased even further, being 55.7% during the last 4 months; considerably higher than that observed at nearby natural reefs. At Santa Monica (86.4%) and Malibu (87.0%) the percentages of serranids and embiotocids combined remained high, reflecting even more the effects of reef location, and isolation on sand flat areas, and showing that more time is required for isolated reef fish populations to reach the natural reef's equilibrium.

By its third year, a Santa Monica Bay reef, covering approximately 25,000 square feet of bottom area, will support a total fish population of approximately 3,400. Included will be some 1,900 embiotocid perches (56.2%) and 1,100 serranids (31.9%). The remainder will be composed of several resident species: gobies, damselfishes, cottids, and several rockfish including a few hundred sculpin (scorpionfish). Although many of these, particularly the sport species, are semi-resident forms (leaving the reef for short periods), to construct such a reef will add to the amount of acceptable habitat available to them and their progeny. Thus, although difficult to assess, their total numbers eventually are increased by reef construction.

TABLE 6

Species Observed on Ten Percent or More of the Survey Dives; Ranked by Frequency of Observation

Hermosa Beach reef		Santa Monica reef		Malibu reef		TOTAL FOR ALL REEFS	
Common name	Times obs. in 93 dives	Common name	Times obs. in 70 dives	Common name	Times obs. in 62 dives	Common name	Times obs. in 225 dives
Sand bass	85	Sand bass	68	Black perch	61	Sand bass	213
Kelp bass	83	White seaperch	68	Pile perch	61	Pile perch	206
Pile perch	78	Pile perch	67	White seaperch	61	White seaperch	203
Rubberlip perch	76	Black perch	63	Sand bass	60	Kelp bass	198
White seaperch	74	Rubberlip perch	62	Kelp bass	59	Rubberlip perch	197
Sculpin	66	Kelp bass	56	Rubberlip perch	59	Black perch	186
Blackeye goby	63	Sculpin	36	Rainbow seaperch	58	Sculpin	150
Black perch	62	Olive rockfish	31	California sheephead	54	Rainbow seaperch	127
Olive rockfish	61	Rainbow seaperch	27	Sculpin	48	Olive rockfish	125
Ocean whitefish	50	California sheephead	19	Olive rockfish	33	California sheephead	87
Painted greenling	45	Brown rockfish	8	Brown rockfish	19	Blackeye goby	63
Rainbow seaperch	42	Sanddab	8	Lizardfish	19	Painted greenling	54
Blacksmith	40	Painted greenling	7	Cabezon	11	Ocean whitefish	51
Halfmoon	40			C-O turbot	9	Brown rockfish	47
Fantail sole	24			Diamond turbot	7	Blacksmith	46
Sanddab	22			Fantail sole	7	Halfmoon	45
C-O turbot	21			Jack mackerel	7	Sanddab	35
Brown rockfish	20			Opaleye	6	Fantail sole	32
Cabezon	16					C-O turbot	31
California sheephead	14					Cabezon	30
Diamond turbot	11					Lizardfish	24
Señorita	11					Diamond turbot	20
Bluebanded goby	9					Jack mackerel	14

TABLE 6
Species Observed on Ten Percent or More of the Survey Dives; Ranked by Frequency of Observation

8.5.1. Underwater Tagging Studies

Despite the limited time and effort expended on our tagging program, March 1962 until November 1964, we successfully marked 17 species (representing 10 families and 12 genera) with yellow streamer tags. Underwater tagging, as discussed by Ebert (1964), was conducted at all three WCB reefs, the Redondo Beach streetcar reef and at nearby wrecks and natural reefs along the Palos Verdes Peninsula (Figures [59] and [60]).

FIGURE 59 Gun and fish (sculpin) in position for tagging. In the foreground is a calico rockfish *(Sebastes dalli). Photo by Charles H. Turner.*

FIGURE 59 Gun and fish (sculpin) in position for tagging. In the foreground is a calico rockfish (Sebastes dalli). Photo by Charles H. Turner

We observed or recovered 36 (16%) of the 224 tags used. Fourteen of these (about 6%) were found loose on the bottom; one day to six months after tagging.

The tag recoveries (Table 7) indicated movements of up to 6 miles for a vermilion rockfish (Sebastes miniatus) , and two sculpin (Scorpaena guttata) , but other sculpin, a lingcod (Ophiodon elongatus) , and an olive rockfish (Sebastes serranoides) , did not travel from the place of tagging. Movement, or lack of it, varied considerably with season and species indicating a necessity to continue and expand these underwater tagging studies.

8.5.2. Fish Classification Schema

Based on their requirements or associations to our reefs we readily separated the fishes into two broad ecological classes: (i) reef associated, and (ii) non-reef associated. Reef associated fishes require a

TABLE 7
Underwater Tagging Data; March 1962 Through December 1964

TAGGING DATA					RECOVERY DATA					
Tag no.	Species	Estimated size (inches)	Date	Area	Date	Area	Size (inches)	Estimated growth (inches)	Days at liberty	Movement
G-2157	Sculpin	8	3-26-62	Malibu WCB Reef—Concrete Shelters.	8-15-63	Malibu WCB Reef—Concrete Shelters.	10	2	507	None
G-2192	Sculpin	6	4-19-62	Malibu WCB Reef—Streetcar.	10- 2-62	Same location; Tag loose on bottom.	--	--	166	--
G-2182	Sculpin	13	5- 9-62	Hermosa Beach WCB Reef—Rock.	10-29-62	Same location; Tag loose on bottom.	--	--	173	--
G-2183	Sculpin	10	5- 9-62	Hermosa Beach WCB Reef—Rock.	10-11-62	As above.	--	--	155	--
G-2196	Sculpin	7	5- 9-62	Hermosa Beach WCB Reef—Rock.	10- 3-62	As above.	--	--	147	--
G-2131	Sculpin	7	7-19-62	Hermosa Beach WCB Reef—Rock.	9-18-62	As above.	--	--	164	--
G-2230	Sculpin	6	7-19-62	Hermosa Beach WCB Reef—Rock.	9-18-62	As above.	--	--	161	--
G-2233	Sculpin	15	7-19-62	Hermosa Beach WCB Reef—Rock.	3-31-63	Tag ret'd by sport landing, Paradise Cove, approx. 20 mi. west of tag area.	No catch data			
G-2131	Sculpin	7	9-25-62	Santa Monica WCB Reef—Streetcar.	11-11-62	Santa Monica WCB Reef.	8.6	1.6	47	None
G-2245	Sculpin	10	7-19-62	Hermosa Beach WCB Reef—Rock.	9-23-62	Hermosa Beach WCB Reef.	10	--	66	--
G-2201	Sculpin	8	8-15-62	Hermosa Beach WCB Reef—Rock.	8-16-63	Tag found loose on bottom.	--	--	1	--
G-2204	Sculpin	9	8-15-62	Hermosa Beach WCB Reef—Rock.	9-23-62	Hermosa Beach WCB Reef.	9	--	39	None
G-2210	Sculpin	11	8-15-62	Hermosa Beach WCB Reef—Rock.	9-23-62	As above.	11.75	0.75	39	None
G-2211	Sculpin	6	8-15-62	Hermosa Beach WCB Reef—Rock.	9-18-62	Tag loose on bottom.	--	--	34	--
G-2216	Sculpin	9	8-15-62	As above.	9- 4-62	Hermosa Beach Reef.	9	--	21	None
G-2239	Sculpin	12	9-18-62	As above.	9-23-62	As above.	11.75	--	5	None
G-2211	Sculpin	12	9-24-62	Malibu WCB Reef—Concrete Shelters.	11- 9-62	Observed in same area.	Not collected		46	None
G-2253	Sand bass	17	9-24-62	As above.	10- 2-62	Observed at Streetcar component (Malibu).	Not collected		8	None
G-2257	Sculpin	7	9-24-62	As above.	1-22-63	Malibu WCB Reef.	Tag returned by fish market		120	None
G-2262	Sculpin	8	9-24-62	Malibu WCB Reef—Concrete Shelters.	10- 7-62	Malibu WCB Reef.	9	--	13	None
G-2263	Sculpin	15	9-24-62	As above.	10-31-62	Malibu WCB Reef.	Notified of tagged fish by commercial fisherman; specimen not observed.		37	None
G-2289	Sculpin	8.5	9-28-62	Redondo Beach Streetcar Reef.	5-25-63	Redondo Beach Streetcar Reef.	9.25	0.75	240	None
G-2315	Sculpin	7.5	11-16-62	Hermosa Beach WCB Reef—Automobiles.	1- 5-63	Observed in same area.	Not collected		50	None

TABLE 7
Underwater Tagging Data; March 1962 Through December 1964

TABLE 7—Continued
Underwater Tagging Data; March 1962 Through December 1964

TAGGING DATA					RECOVERY DATA					
Tag no.	Species	Estimated size (inches)	Date	Area	Date	Area	Size (inches)	Estimated growth (inches)	Days at liberty	Movement
G-2333	Vermilion rockfish	8	7-24-64	"Deephole" off Redondo Beach.	7-29-64	Rocky Point—Palos Verdes Peninsula.	Caught by sport fisherman; specimen not observed.		5	5 to 6 miles south.
G-2370	Lingcod	14	4- 5-63	Hermosa Beach WCB Reef—Rock.	4-10-63	Hermosa Beach WCB Reef.	14	--	5	None
G-2371	Sculpin	12	4- 5-63	Hermosa Beach WCB Reef—Rock.	7-20-63	"South Bank."	12.3	0.3	105	6 miles west.
G-2372	Sculpin	12	4- 5-63	As above.	7-20-63	As above.	12.3	0.3	105	6 miles west.
G-2383	Olive rockfish	10	7-28-64	Wreck of AVALON, Palos Verdes Peninsula.	8-26-64	Wreck of AVALON, Palos Verdes Peninsula.	10	--	29	None
G-2384	Sculpin	10	10- 9-64	Hermosa Beach WCB Reef—Rock.	12-16-64	Tag loose on bottom, Hermosa Beach WCB Reef—Rock.	--	--	68	--
G-2387	Sculpin	10.5	10- 9-64	As above.	12-16-64	As above.	--	--	68	--
G-2392	Ocean whitefish	15	10- 9-64	As above.	12-16-64	As above.	--	--	68	--
G-2397	Sculpin	10	11-30-64	As above.	12-16-64	As above.	--	--	16	--
G-2398	Sculpin	9	11-30-64	As above.	12-14-64	As above.	--	--	14	--
G-2399	Sculpin	9	11-30-64	As above.	12- 7-64	Observed Hermosa Beach WCB Reef—Rock.	Not collected		7	--
G-2678	Sculpin	10	11-30-64	As above.	12-14-64	Tag loose on bottom, Hermosa Beach WCB Reef—Rock.	--	--	14	--
G-2679	Sculpin	10	11-30-64	As above.	12- 7-64	Observed Hermosa Beach WCB Reef—Rock.	Not collected		7	--

TABLE 7
Underwater Tagging Data; March 1962 Through December 1964

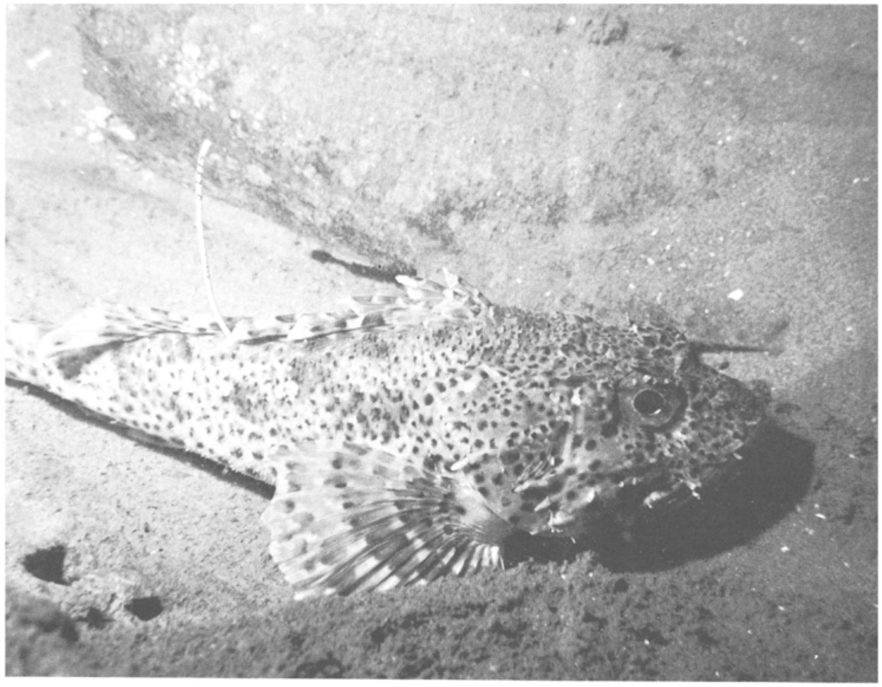

FIGURE 60 A recently tagged sculpin (*Scorpaena guttata*). The yellow streamer tag is readily visible to the divers and in many instances the legend can be read without handling the tagged fish. *Photo by Charles H. Turner.*

FIGURE 60 A recently tagged sculpin (Scorpaena guttata) . The yellow streamer tag is readily visible to the divers and in many instances the legend can be read without handling the tagged fish. Photo by Charles H. Turner

reef biotype to satisfy one or more life processes (i.e. feeding, breeding, spawning, protection, etc.) while the non-reef associated fishes, though frequently seen in our reef areas, are independent of reefs in both their habits and requirements. We further divided the reef associated fishes into semi-resident and resident forms. The non-reef associated fishes were subdivided into pelagic and benthic forms—recognized ecological classifications.

This classification (Figure 61) has proved quite useful for defining the fish assemblages around our man-made reefs and was established solely for this purpose; however, with modifications it may adapt to natural reef areas and prove useful for other fishery scientists.

8.5.2.1. Pelagic Fishes

Those occupying the mid- or upper-water column; generally schooling fishes, represented by nine species (Table 5). Most frequently seen were jack mackerel, northern anchovy (Engraulis mordax) , Pacific bonito (Sarda chiliensis) , and mola (Mola mola) . These species were more commonly observed in late summer, fall and winter. Because they are not intimately connected with reef ecosystems their bearing upon our reef's ecology is slight. Only two were observed with sufficient frequency to warrant further comment.

8.5.2.2. Trachurus symmetricus (Ayres, 1855)—jack mackerel

This was the most common pelagic species, particularly in the latter portion of the study period. Large schools of 8- to 9-inch fish were observed

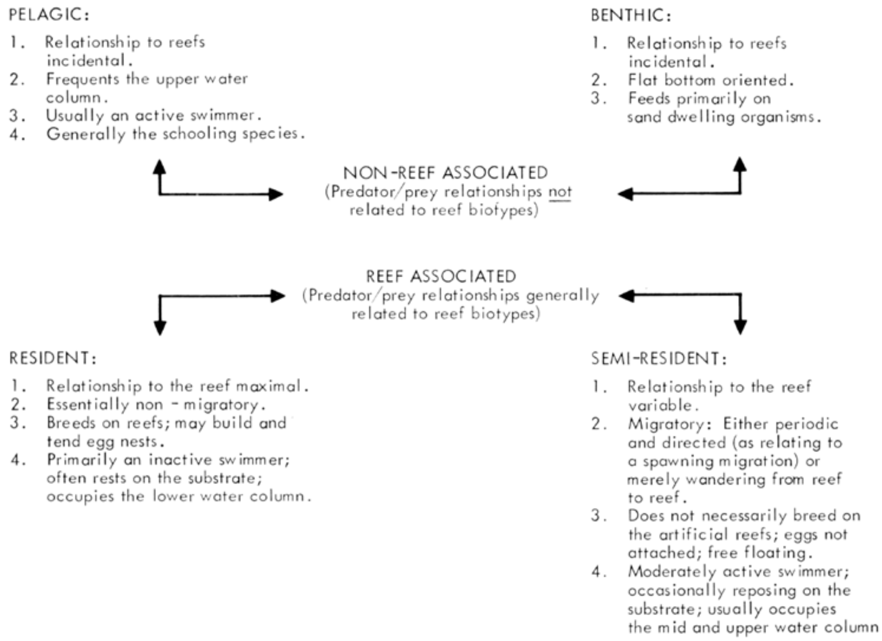

FIGURE 61 Schema of fish classification and parameters as designed from man-made reef studies.

FIGURE 61 Schema of fish classification and parameters as designed from man-made reef studies

throughout Santa Monica Bay in 1963 and 1964, frequently being preyed upon by Pacific bonito, and occasionally by California yellow-tail (Seriola dorsalis) .

Jack mackerel swim in compact, horizontally distributed schools, generally in the mid- or upper-water column.

Mola mola (Linnaeus, 1758)—mola (or ocean sunfish). Molas were particularly numerous in late summer and fall when several dozen were recorded near each reef material. During this period we observed them from the surface to depths of 90 feet. Seasonal population increases coincided with abundant salp populations, presumably one of their major food items.

Contrasting with other pelagic species they are weak swimmers, usually observed at or near the surface. When migrating, they swim rapidly in small groups of 10 to 15 individuals, 15 to 30 feet beneath the surface. Señoritas, Oxyjulis californica, (reef associated fish) are frequently observed "picking" copepods (ectoparasites) from them (Figure 62) . Their ability to seek-out purposefully the reefs and señoritas is conjectural.

8.5.2.3. Benthic Fishes

In this group we include typical bottom dwellers (flatfish, several sharks and rays and the lizard fish) and three atypical species: (i) white croaker, (ii) walleye surfperch, and (iii) white seaperch. These three are not bottom dwellers but orient to and generally feed on bottom

FIGURE 62 Señoritas (*Oxyjulis californica*) cleaning an ocean sunfish (*Mola mola*) near the Redondo Canyon reef. *Photo by Don Morrison.*

FIGURE 62 Señoritas (Oxyjulis californica) cleaning an ocean sunfish (Mola mola) near the Redondo Canyon reef. Photo by Don Morrison.

organisms. Their whitish or silvery coloration is indicative of, and better adapts them to, an "open-water" non-reef environment.

Most of these benthic species were present previous to reef construction and their populations did not alter perceptibly. One species, the white seaperch, appears relatively important to the reef ecology, being a food item for some of the reef fishes. Although not observed prior to reef placement, they undoubtedly were present in the general area. Their recorded arrival nearly coincided with reef placement.

We recorded 20 benthic species, including 10 flatfish. Only one, the white croaker (Genyonemus lineatus) , was never observed underwater during our dives. These are apparently quite wary and remained just out of our range of vision. We have observed fishermen catching them at the reefs while we conducted our surveys.

Torpedo california **(Ayres, 1855)—Pacific electric ray.** This species was observed around all components at the Hermosa Beach reef and twice at the concrete shelter portion of the Santa Monica reef. They were usually half buried in the sand (Figure 63) adjacent to the material. Occasionally they were seen swimming 1 to 4 feet above the sand, and once, 15 feet above the bottom.

When approached by divers, this particular ray (swimming 15 feet off the bottom) became aggressive, faced the divers and with its pectoral fins curled downward moved toward one in a challenging manner. If disturbed while on the sand, electric rays normally swam quickly away. If prodded with a spear or short pole, these rays turn toward the irritant, not away from it as do most fishes.

Although Limbaugh (1955) reports them as common throughout the year in southern California, we observed them at the reefs only from August through January.

FIGURE 63 Pacific electric ray (*Torpedo californica*) lying half buried in the sand between the Hermosa Beach WCB reef rock, and concrete shelter components; November 1960. *Photo by Charles H. Turner.*

FIGURE 63 Pacific electric ray (Torpedo californica) lying half buried in the sand between the Hermosa Beach WCB reef rock, and concrete shelter components; November 1960. Photo by Charles H. Turner.

Synodus lucioceps **(Ayres, 1855)—California lizardfish.** California lizardfish were abundant in the Malibu area, less abundant at Santa Monica, and were recorded only once at Hermosa Beach. We observed them in December and January at Santa Monica and throughout the year at Malibu.

They were often seen resting on their pelvic fins, at a slight angle to the substrate in the sand areas between or around the reef materials. Occasionally they would bury in sandy depressions, covering themselves with 0.25 to 0.50 inches of sand; either as protective cover or concealment to await some unwary prey.

The Hermosa Beach specimen, a 2- to 3-inch juvenile, was observed in June 1963. Those observed at Malibu and Santa Monica were up to 20 inches (about 50 cm) long.

Because of their habits and coloration they are difficult to see. When startled, they break from the sand, stirring up a cloud of sediment and swim rapidly away.

Hyperprosopon argenteum **(Gibbons, 1854) — walleye surfperch.** These perch were only observed at the Malibu concrete shelters September 24, 1962. This large school of 4- to 5-inch fish swam close to the shelters. They usually frequent the inshore surf-swept areas of the open coast, although we have occasionally observed them in kelp beds and around offshore drilling platforms (Carlisle, Turner and Ebert, 1964). Their silvery coloration adapts them to open sand, non-reef areas and we have not observed any close relationship to the reef biotypes. John E. Fitch, California Department of Fish and Game (pers. comm.) reports they may be "barred" when in rocky habitat with other embiotocids.

Phanerodon furcatus **(Girard, 1854)—white seaperch.** Although this species ranked third in frequency of times observed, they are considered non-reef oriented. Ubiquitous in the littoral zones, they swim in loose schools or aggregations. They formed a major portion of each reef's fish population; varying from 5 to 1,500 when present and averaging about 211 per observation. They preferred the sandy areas adjacent to the reef materials and often ventured 25 to 100 feet away, regardless of water clarity. Reef oriented species were always more closely associated with the reef materials.

Typical of the surfperch family they are seemingly incessant feeders. They stand on their heads, a foot or so above the bottom and scull horizontally with their pectorals, searching the sand for agreeable food items (Figure 64) . They were not observed feeding from the reef proper until its second year. They frequently feed upon a tiny snail, Epitonium bellastriatum, a habit readily apparent without examining the fish's stomach. The snail's brilliant purple dye is readily absorbed by the fish's tissues imparting a striking violet cast to the fish, particularly in the snout areas. At 60-foot depths this coloration appears bluish.

Citharichthys **spp.—sanddabs.** Sanddabs were present before and after reef placement. They avoided the reef materials entirely and remained on the sandy bottom. Specimens observed ranged from 3 to 5 inches long.

Xystreurys liolepis **(Jordan and Gilbert, 1880)—fantail sole.** Fantail sole were seen around each of the artificial reefs, most commonly in the fall and winter. A squid was found in the stomach of one and a 6-inch mantis shrimp in the stomach of an 18-inch specimen. These too remained on the sand, between or away from the materials.

8.5.2.4. Semi-Resident Fishes

We categorize these as reef-oriented fishes requiring a reef situation for many of their life requirements. Some leave the reefs to spawn

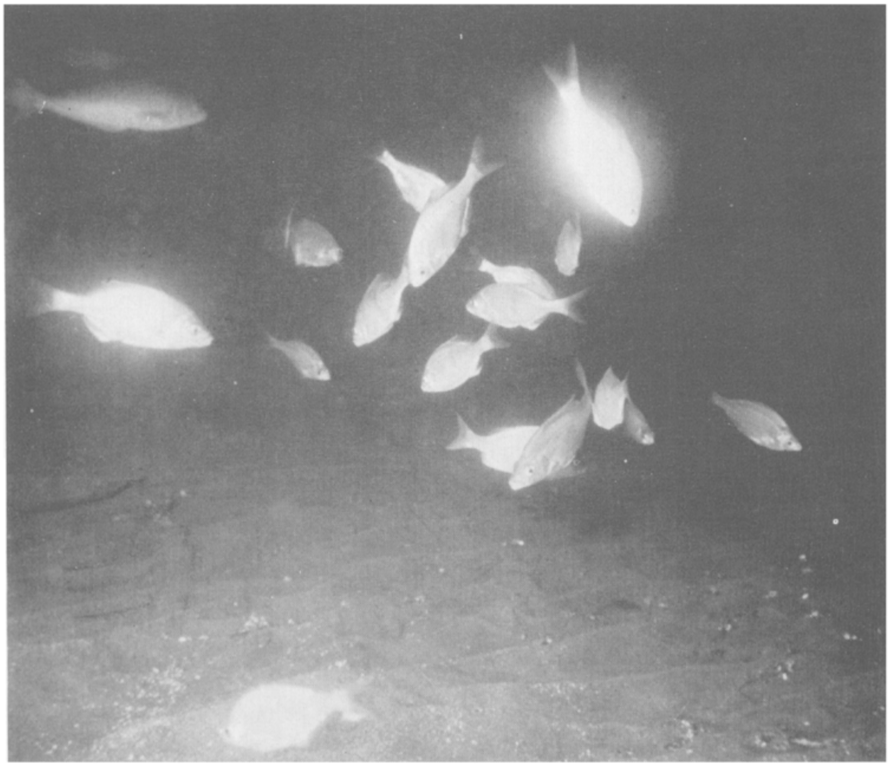

FIGURE 64 White seaperch (*Phanerodon furcatus*) and rubberlip perch (*Rhacochilus toxotes*) searching the sand for suitable food items. *Photo by Charles H. Turner.*

FIGURE 64 White seaperch (Phanerodon furcatus) and rubberlip perch (Rhacochilus toxotes) searching the sand for suitable food items. Photo by Charles H. Turner.

over flat sandy bottoms (e.g., serranids) while others may migrate offshore to deeper reefs (e.g., scorpaenids). Typically these species wander extensively, throughout adjoining reef areas or from reef to reef, often across vast sand (open) areas.

We include two sharks and a ray, the basses (family Serranidae), the wrasses (family Labridae), most of the surfperches (family Embiotocidae), and some of the rockfishes (family Scorpaenidae) in this category.

Semi-residents appear to constitute the most important link, both ecologically and economically, to reef success. Primary, secondary and tertiary consumers are represented and most are desirable sport species.

We obtained sufficient information to comment further about 14 of the 23 species observed.

Cephaloscyllium ventriosum **(Garman, 1880)—swell shark.** Swell sharks were observed only once at Hermosa Beach, were commonly found inside the concrete shelters at Santa Monica during 1963, after our routine fish counts were suspended. Limbaugh (1955) reports observing them in the summer and fall and in waters to 50 feet deep. We have observed them irregularly throughout the year and at depths exceeding 75 feet; they have been trapped in over 2,000 feet. of a retiring nature, they rest in crevices or protected areas, and when closely approached by divers exhibit almost no outward concern, but if touched or handled they vigorously swim away.

On natural reefs (Santa Catalina Island) we observed them being harassed by other fishes whenever they left their crevices or ledges. In one instance (Figure 65) blacksmiths (Chromis punctpinnis) swarmed around the swell shark in a manner similar to crows chasing an owl. Apparently foraging only at night, this shark's appearance during the day causes considerable consternation among the other reef inhabitants.

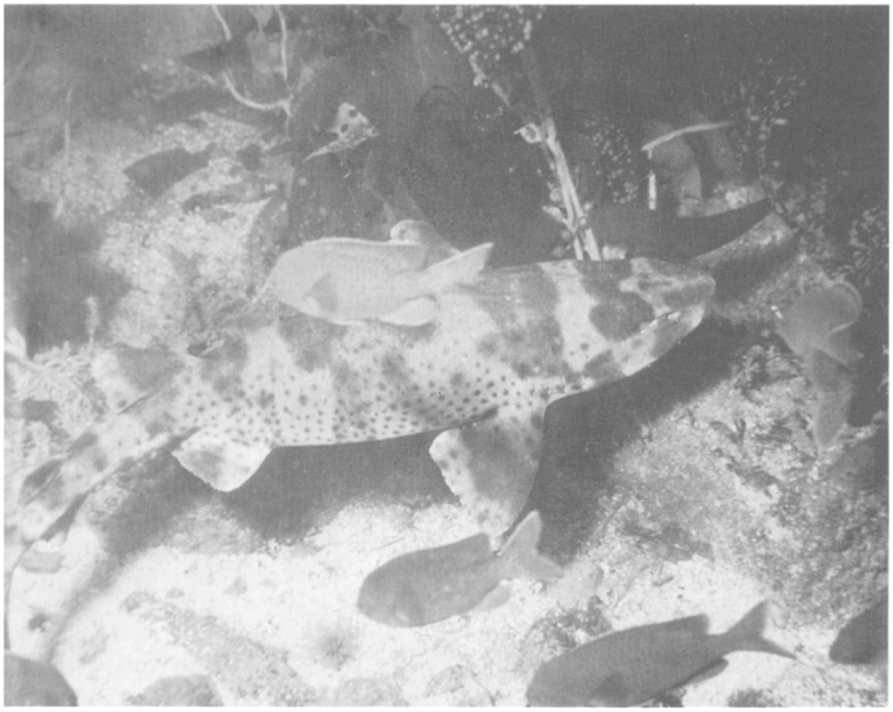

FIGURE 65 A swell shark (*Cepholoscyllium ventriosum*) being harassed by blacksmith (*Chromis punctipinnis*); Santa Catalina Island, March 1963. *Photo by Charles H. Turner.*

FIGURE 65 A swell shark (Cephaloscyllium ventriosum) being harassed by blacksmith (Chromis punctipinnis) ; Santa Catalina Island, March 1963. Photo by Charles H. Turner.

Paralabrax clathratus **(Girard, 1854)—kelp bass.** Kelp bass are an important sport species in southern California. They formed a substantial segment of each reef's fish fauna, being present on all materials. We noticed them on 80% of our dives at Santa Monica and 95% at Malibu, and counted from 2 to 300 individuals, averaging 99. They were usually more numerous at the Malibu reef.

From Quast's (1968) and our own observations in kelp bed areas, kelp bass are evenly distributed throughout the water column, irrespective of any thermocline. On our reefs, they typically inhabited the water column directly above the reef materials, foraging downward, often into crevices and only occasionally ranging upward into the surface waters. In kelp beds, they usually orient to the kelp stipes when ascending or descending through the water column. The absence of kelp on the man-made reefs appears to have slightly altered this behavior.

Kelp bass swim in loose groups or aggregations, demonstrating little schooling behavior, except during their breeding season. Then the population forms into rather compact schools, noticeably more concentrated, which "balloon" well above the substrate into the surface waters. In these clusters they are very aggressive and strike at any bait or object thrown into their midst, making them extremely susceptible to harvest.

As the spawning time approaches, aggressiveness increases and the schooling clusters circulate more freely. At the height of the breeding period kelp bass were absent from one or more of the study reefs.

During the breeding season, April through October (Young, 1963) their normally pale silvery-gray chin becomes bright yellow. We observed this condition from February through September, but it was most prevalent during summer months.

Larval and juvenile kelp bass, smaller than 3 inches, were not seen or collected on the study reefs. Presumably a shallow inshore or kelp bed area is necessary for them. The observed kelp bass ranged from 3 to 24 inches in length, and were from 1 to more than 16 years old (Young, 1963).

Although kelp bass exist in many areas without kelp, our surveys indicate these are a less desired habitat; putting them at a disadvantage in competing with other species. At the reefs, a sand bass, an obvious competitor at the same trophic level, is definitely favored by the rock-sand ecotone.

Paralabrax nebulifer **(Girard, 1854)—sand bass.** Sand bass were the most frequently observed species, forming a major and very important portion of each reef's fauna. They were recorded on 91% and 97% of the surveys at Hermosa Beach and Santa Monica, respectively. They numbered from 1 to 500 per sighting, averaging 160 for all reefs and materials. Sand bass were most numerous at the Santa Monica components, averaging 180 individuals per sighting, followed by Hermosa Beach (161) and Malibu (135).

Population declines were evident during the breeding season, summer and fall, when they formed breeding aggregations which left the reefs to spawn over flat sandy bottom areas. The observed breeding aggregations, in water approximately 60 to 70 feet deep, contained fish which were frenzied and quite aggressive. They took any bait or lure offered them by anglers and were unaffected by divers swimming through their schools. After breeding, sand bass return to the reefs, possibly the same one they had previously frequented, and rest upon the sand or reef materials, stacked like cord wood (Figure 66) . When so dispersed they are gaunt and outwardly inactive. This listless behavior lasts for a period of several weeks.

Although juvenile sand bass 4 to 6 inches long apparently prefer sheltered bays or harbors, particularly around breakwaters, we did collect a 0.5-inch specimen on the Hermosa Beach rockpile (October, 1963). This small striped fish closely resembled a juvenile calico rockfish (Sebastes dalli) in the field.

Sand bass observed on the study reefs averaged 12 to 14 inches long. They ranged from 0.5-inch to greater than 30 inches. A 630-mm

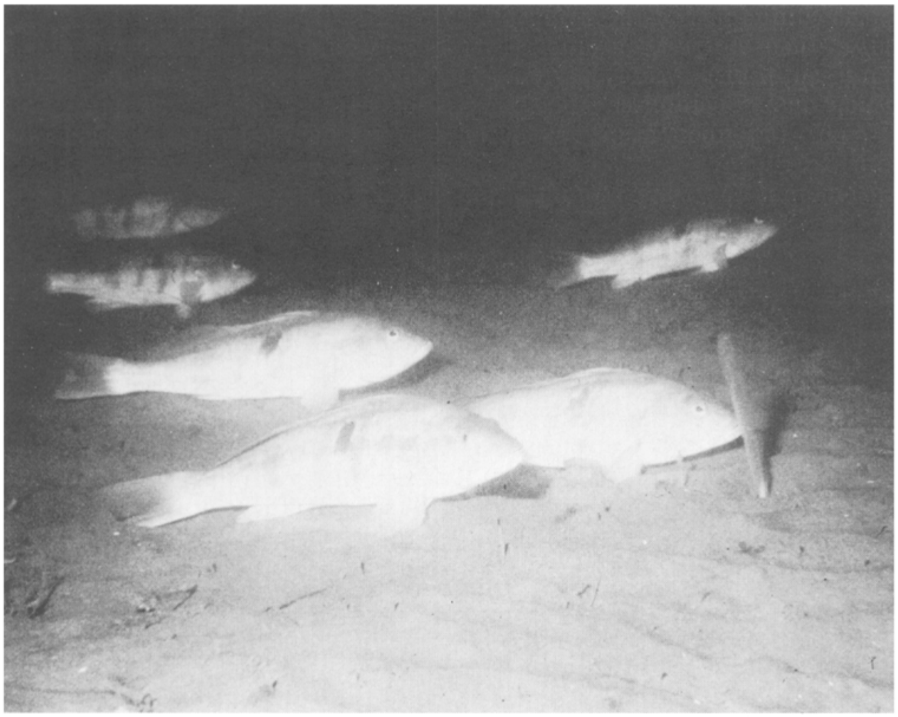

FIGURE 66 The past breeding behavior of sand bass (*Paralabrax nebulifer*) at the Hermosa Beach WCB reef, October 1961. In the foreground is a sea pen (*Stylatula*). *Photo by Charles H. Turner.*

FIGURE 66 The past breeding behavior of sand bass (Paralabrax nebulifer) at the Hermosa Beach WCB reef, October 1961. In the foreground is a sea pen (Stylatula) . Photo by Charles H. Turner.

(24.75-inch) specimen was in its 20th winter. This fish weighed 3,500 g (7.75 lbs) and had just eaten a sarcastic fringehead (Neoclinus blanchardi) and a white seaperch.

On the reefs, sand bass occupy much the same habitat as kelp bass, the two species often intermingling. Sand bass feed on motile species (e.g., anchovies or jack mackerel) and more sedentary forms (e.g., crabs or octopuses). Their feeding habits appear to be dictated in part by availability, but primarily by season. It is doubtful, for example, that sand bass feed extensively on motile species during their post breeding "listless" period. Motile species appear to be sought predominantly during their more active times.

Because sand bass prefer sand-rock ecotones and avoid kelp biotypes, they are perhaps the most valuable species, sportswise, to the man-made reef community.

Stereolepis gigas **(Ayres, 1859) — giant sea bass.** Giant sea bass were recorded only once, a 14-inch juvenile seen at the Hermosa Beach reef. Two others (6 and 12 pounders) were caught by fishermen at the Malibu reef during March and April 1963. Their occurrence at any of the man-made reefs was rare, an incidental stop in their normal meandering.

Embiotoca jacksoni **(Agassiz, 1854) — black perch.** Black perch were present on all reefs and materials. Maximum numbers occurred at the Malibu and Santa Monica reefs. They exhibited a slight preference for the concrete shelters.

Black perch swim solitarily or in small groups just above the reef materials, but pair off during their breeding season.

Generally they feed on attached reef organisms (barnacles and tube worms) but occasionally they venture beyond the reef's perimeters seeking sand-flat animals.

Black perch are the only embiotocids we have observed which readily respond to background colors. When they form loose aggregations over the sand they often become pale and are easily misidentified by inexperienced observers. Instead of their usual dark-brown to olive coloration with darker vertical barring they bleach out to a pale gray-white, with pale golden-brown to golden bars. This color often remains after they return to the darker background reef areas. If speared or frightened they quickly darken. In this pale phase, they are frequently mistaken for barred surfperch. (Amphistichus argenteus) .

We observed a bi-colored individual under the Standard-Humble Oil drilling platform "Hazel," off Summerland, near Santa Barbara, California. Its anterior half was pale gray and the posterior coal black. No barring was visible posteriorly, although pale bars were discernible anteriorly.

Hypsurus caryi **(Agassiz, 1854)—rainbow seaperch.** These perch were observed at all reefs and materials, but were most prevalent at Malibu; particularly around the concrete shelters. Excepting Malibu, where they averaged 90 individuals per sighting, rainbow seaperch did not contribute substantially to the reef's fish populations. They usually swam in small groups of 5 to 15 individuals directly above the materials, frequently intermingling with other perch species.

Rhacochilus toxtoes **(Agassiz, 1854)—rubberlip perch.** Rubberlip perch formed a major population segment at each reef on all materials. Maximum concentrations occurred at Malibu, particularly around the concrete shelters. They formed small groups directly above the reef materials and were frequently seen grazing on attached growths.

During our kelp transplanting experiments, at Malibu, they quickly oriented along the kelp stipes in mid-water. The presence of kelp (on these concrete shelters) attracted an estimated 300 individuals, compared to 150 on the car-bodies and 60 around the streetcar. These, and additional observations from our previous studies (Carlisle, Turner, Ebert, 1964), support Limbaugh's (1955) statement that they prefer the mid-kelp biotype.

Rhacochilus vacca **(Girard, 1855)—pile perch.** This perch ranked third in total observations for fish species and they were common and nearly equally represented on all reefs and materials. Peak concentrations occurred in late summer, fall and early winter.

Pile perch occur solitarily or in small aggregations which freely intermingle with other species. They usually remained close to reef materials, actively foraging along the crevices or overhangs.

Large (14-inch) specimens fed upon octopuses, crabs, and shrimps while smaller individuals fed upon more typical perch food: gammarid and caprellid amphipods, small crabs, worms, ectoprocts, mussels and tiny snails, including the wentletrap (Epitonium sp.) which stains their flesh violet (see white seaperch section, above).

When breeding the pelvic and anal fins are bright yellow and the males have intense black spots on their snouts. These colors were most apparent in the summer and fall although occasionally they were seen throughout the year.

We removed 12 young from each ovary of a 318 mm (14.75-inch) fish and 8 young from each ovary of a 276 mm (11-inch) fish in February 1961. Limbaugh (1955) observed breeding in October and November, and juveniles from June through October.

Oxyjulis californica **(Günther, 1861)—señorita.** Although this species was not common, they were recorded at all reefs except Santa Monica. These orange, cigar-shaped fishes are well known for their habit of feeding upon ectoparasites infesting other fishes. We have observed them "cleaning" rockfish (Sebastes spp.), molas, topsmelt (Atherinops affinis) , jack mackerel, jacksmelt (Atherinopsis californiensis) , California yellowtail, and blacksmith (Chromis punctipinnis) .

Adults swim in the mid-waters, solitarily or in aggregations, but seldom venture close to the reef materials, contrasting with the juveniles who remain close to protective cover. The adults burrow into the sand at night and sleep (Limbaugh, 1955). About 50 juveniles, 0.5- to 0.75-inch long, were observed in late fall at the Hermosa Beach reef automobile bodies. They remained close to the automobile bodies for almost a year, growing to an estimated 2 to 3 inches.

Halichoeres semicinctus **(Ayres, 1859) — rock wrasse.** Only one rock wrasse was observed, at the Hermosa Beach reef, a large 14-inch male (Figure 67) that circulated freely among reef components.

Juvenile rock wrasse, 1 to 3 inches long, are orange-yellow in color with a broad cream-white horizontal midline. A dorsal extension of this line proceeds from the snout regions, over the eye and posteriorly along the dorsal fin base (Figure 68) . When 3 to 5 inches long this midline blends into their now overall cream-white ventral coloring; black speckling appears on the greenish-orange scales, and the white line extending along the dorsal fin base becomes less distinct. At 6 inches their dorsal line is quite faint and sexual dichromatism initiates in the form of a blue-black bar posterior to the pectoral fins on the males.

Mature rock wrasse are readily influenced by background coloration. Males in particular exhibit blue, yellow and reddish hues when over rocky areas, but over sand they are basically light yellow-orange or orange-brown with short pale white bars dorsally, and whitish ventrally.

The young are common in natural reef areas during fall and winter, gravid females are seen during the summer.

Pimelometopon pulchrum **(Ayres, 1854) — California sheephead.** This species was observed at all four study reefs. Most, and the largest individuals, were at Malibu where several large females exceeded 800 mm (31.5 inches) in length and 9,300 gms (20.5 pounds) in weight. These large sheephead were noticeably infested with ectoparasitic copepods (Figure 69) ; a common occurrence throughout their range.

Sheephead generally swam in and among the reef materials rather than venturing up into the mid-waters. In kelp beds they are found

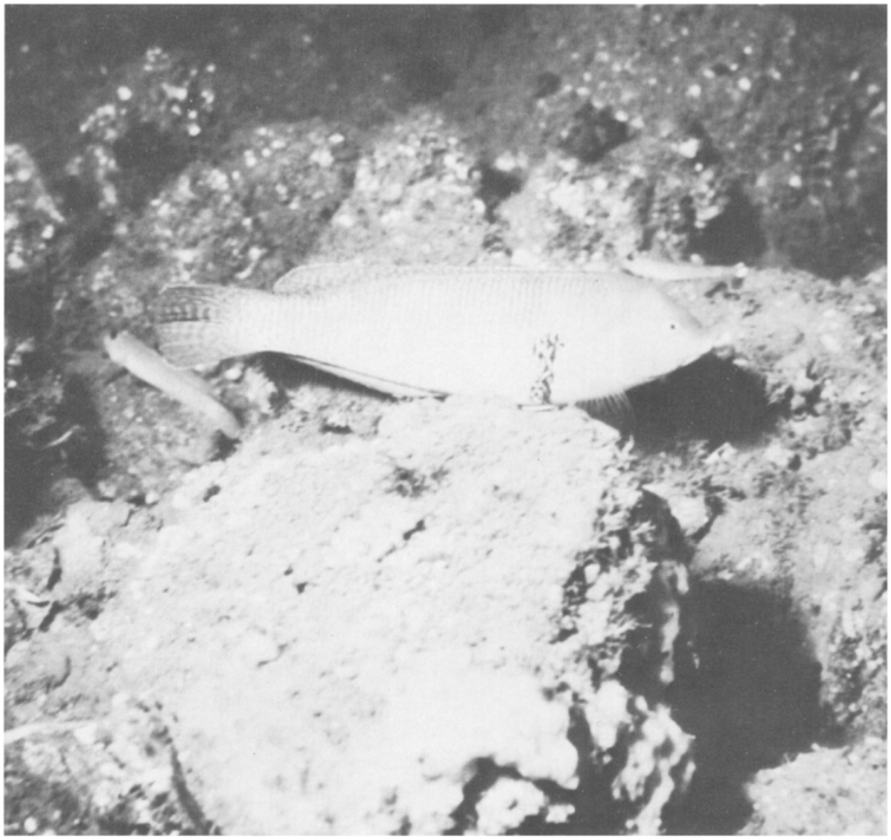

FIGURE 67 Adult rock wrasse (*Halichoeres semicinctus*), Hermosa Beach WCB reef rock. The small fish in the picture are blackeye gobies (*Coryphopterus nicholsi*). *Photo by Charles H. Turner.*

FIGURE 67 Adult rock wrasse (Halichoeres semicinctus) , Hermosa Beach WCB reef rock. The small fish in the picture are blackeye gobies (Coryphopterus nicholsi) . Photo by Charles H. Turner

throughout the water column, but here also they favor areas near the substrate.

They fed upon crabs, barnacles, clam siphons (where possible the whole clam), octopuses, and the shipworms infesting the wooden streetcars. Shipworms were obtained by crunching the bored wood in their jaws, then spitting out the assorted wood and shell fragments. Their large canine-like teeth are highly suited to this feeding behavior.

Young of the year were observed in October 1963 and June 1964 on our reefs. These small 2- to 3-inch fish are bright orange or dull red with dark chocolate spots on their fins, and a brilliant white horizontal stripe at the midline (Figure 70) They hid among the drifted-in seaweed. On natural reefs they seek gorgonians where they build protective shelters of a slimy mucus-like substance. At night they retire into these mucus sacks and sleep. Adults sleep in crevices and under rock ledges, their vivid daytime colors fading or turning blotchy.

Ages of three female sheepheads, 800, 730, and 555 mm total length (approximately 32, 29 and 22 inches) were determined (by counting the annuli on their opercles) as 37, 27 and 15 years, respectively.

FIGURE 68 Juvenile rock wrasse, about 2 inches long. *Photo by Charles H. Turner.*

FIGURE 68 Juvenile rock wrasse, about 2 inches long. Photo by Charles H. Turner

Scorpaena guttata **(Girard, 1854)—sculpin (or California scorpionfish).** Large populations of sculpins formed at Hermosa Beach and Malibu (predominently each fall and winter), but few individuals were recorded at Santa Monica (Figure 71) .

Sculpins are extremely sedentary and rest directly on the substrate, often in crevices or under rock overhangs. They are rarely observed swimming, unless disturbed, and even then they swim only a short distance and re-settle. We did not investigate their nocturnal behavior when they may be considerably more active. Their protective coloration and poisonous spines provide an adequate defense from most predators.

Sculpins fed almost exclusively upon juvenile Cancer crabs during fall and winter. During other periods they fed upon octopus or fish.

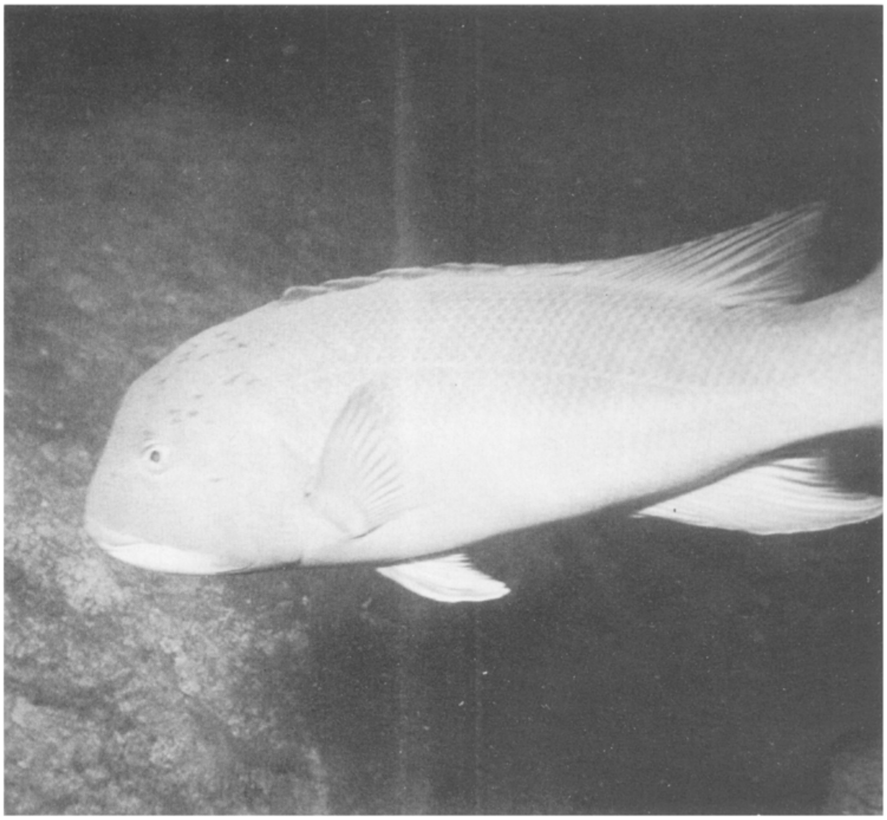

FIGURE 69 Large female sheephead (*Pimelometopon pulchrum*) infested about the head with ectoparasites. Redondo Canyon reef, March 1963. *Photo by Charles H. Turner.*

FIGURE 69 Large female sheephead (Pimelometopon pulchrum) infested about the head with ectoparasites. Redondo Canyon reef, March 1963. Photo by Charles H. Turner

An offshore migration occurs in summer, closely correlated with water temperatures. Adult sculpins (10 inches or larger), forming the breeding population, concentrate on offshore banks in 150 to 200 feet or deeper water. Commercial sculpin fishermen locating these offshore banks are provided with excellent fishing, but of short duration. Adults reappear on the inshore reefs, widely dispersed, after only 5 to 6 weeks. Immature sculpin (less than 10 inches) appear to remain in relatively shallow water (on the reefs) throughout the year.

Two, 12-inchers tagged underwater at Hermosa Beach in April 1963, moved about 6 miles offshore into 180-foot water where they were caught by a commercial fisherman in July. An 8-incher tagged at the Malibu concrete shelters remained on this portion of the reef for nearly 17 months, growing an estimated 2 inches. On many occasions during this period we were able to approach the fish and read the tag number directly without disturbing him.

Sebastes miniatus **(Jordan and Gilbert, 1880)—vermilion rockfish.** Vermilion rockfish were observed once at Santa Monica, several times at Hermosa Beach and frequently at the Redondo Canyon reef. All were juveniles or sub-adults, 3 to 6 inches long.

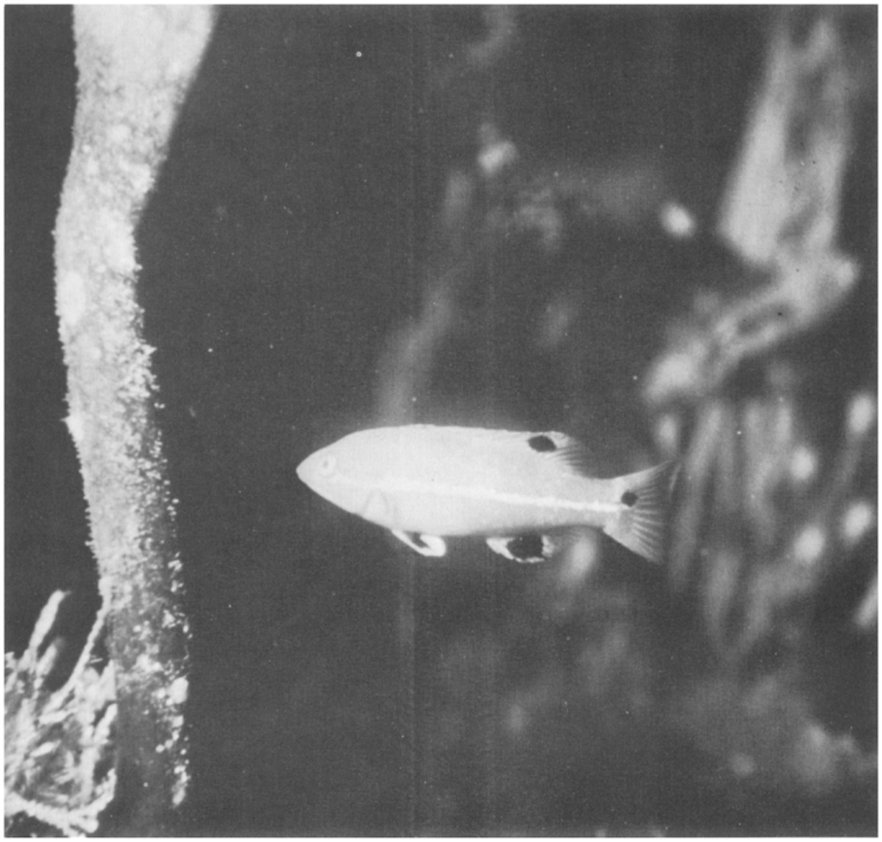

FIGURE 70 Juvenile sheephead, about 1.5 inches long. *Photo by Charles H. Turner.*

FIGURE 70 Juvenile sheephead, about 1.5 inches long. Photo by Charles H. Turner

This is a deeper water species, having been taken from as deep as 110 fathoms (Phillips, 1957). Sub-adults, 8 to 12 inches long, frequent water as shallow as 80 feet, with an occasional juvenile observed slightly shallower, but adults restrict themselves to deeper water.

We have observed that the 80-foot depth break for sub-adults (8- to 12-inch fish) is quite real. During our surveys of offshore drilling platforms near Santa Barbara, California (Carlisle, Turner, Ebert, 1964), vermilion rockfish formed large concentrations around the platform supports from the bottom (106 feet) upward to the 80-foot level, none was observed at shallower depths.

An 8-incher, tagged by us underwater off Redondo Beach, traveled nearly 6 miles in 5 days. After crossing extensive areas of open sand and the Redondo submarine canyon, it was caught at a natural reef area, south of its tagging location, but at a similar depth: 100 feet.

Sebastes serranoides **(Eigenmann and Eigenmann, 1890)—olive rockfish.** This species was common on all reefs and materials except in the late fall and winter. During these months, their probable breeding season, the few observed were retiring, hiding in crevices or caves, and extremely wary of divers. Adult population increases were especially notable each spring.

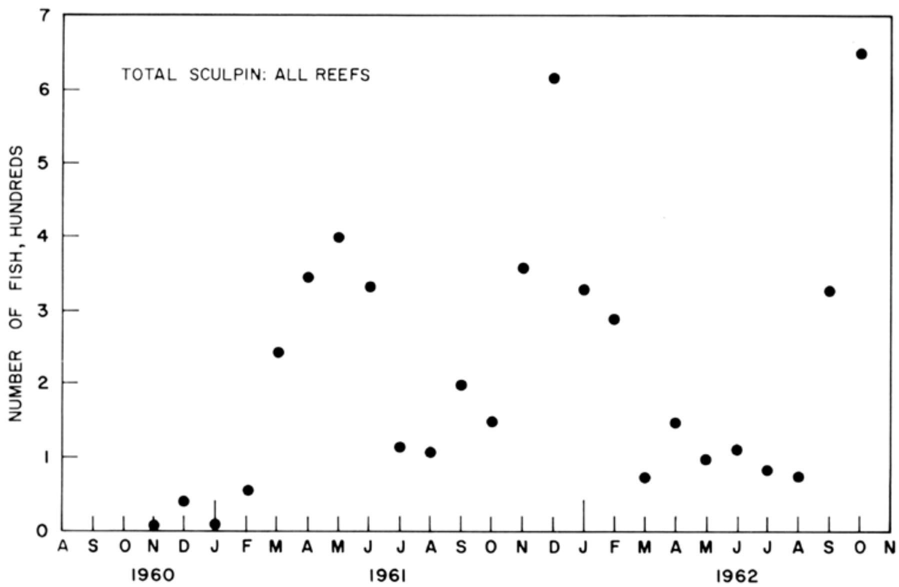

FIGURE 71 Changes in the sculpin (Scorpaena guttata) population on the three replication reefs with time. Increases in the sculpin populations occurred in fall and winter; decreases in summer

Olive rockfish occupy spatial positions in the water column similar to kelp bass and are frequently associated with them. Around some of the southern California Channel Islands they often dominate the large schools of fishes in the kelp beds. Because of their habits, shape, and coloration, they often are mistaken for kelp bass.

Juveniles, 1.5 to 2 inches long, were seen in the late spring and early summer. In kelp bed situations these young reside in the upper water column, schooling near the kelp canopy.

Portions of kelp canopies torn loose and cast adrift during storms often carry several species of rockfish (including the olive rockfish) along with them. The degree to which this mode of migration exists and its effect upon fish distributions warrants further investigation.

8.5.2.5. Resident Fishes

These include fishes that require a reef biotype for all their life functions. Some may construct and guard egg-nests while others merely cement their eggs to the substrate. In general, these are inactive swimmers usually found resting on the substrate. Many restrict themselves to limited reef areas, exhibiting almost no tendency for extensive movement. Most employ cryptic coloring for protection.

Gobies (Gobiidae), damselfishes (Pomacentridae), true sculpins (Cottidae) and several rockfishes are typical representatives.

The relationship of these several resident species in artificial reef ecology is not clearly understood. Specifically, we have found no evidence that gobies and cottids, secondary consumers which have exhibited steady population increases since their first appearance, are being utilized higher in the food web. If this is the situation then a tremendous energy loss exists. Only a few of the resident rockfishes contribute directly to fishing success on the reefs.

of the 23 resident species seen during the study, we have specific notes concerning 11.

Chromis punctipinnis (Cooper, 1863)—blacksmith. This was the only pomacentrid recorded on the study reefs. They were observed frequently at the Hermosa Beach and Redondo Canyon reefs, rarely at Santa Monica or Malibu. Blacksmiths may occur in small groups of three to five or form large schools of many hundreds. Adults prefer midwaters while the bicolored juveniles (blue anteriorly and yellow posteriorly) remain close to the substrate, often hiding in crevices. We recorded a bicolor adult (dark blue-black posteriorly and light blue-gray anteriorly) at Santa Catalina Island.

Egg-nests, constructed beneath rocks during late summer and fall, are guarded by the male (Turner and Ebert, 1962).

We observed blacksmiths removing ectoparasites from molas. They in turn were "cleaned" by señoritas, spiny lobsters (Panulirus interruptus) , and red rock shrimp (Hippolysmata californica) . The shrimp were observed removing ectoparasites from nest-guarding adult males.

Coryphopterus nicholsi (Bean, 1881) — blackeye goby. Blackeye gobies were present on the Hermosa Beach and Redondo Canyon reefs and at the rockpile component at Malibu. They prefer the sand-rock junctures occurring at the reef's periphery. They often forage out onto the sand (3 to 5 feet), but seldom venture far from protective cover.

Blackeye gobies are nest builders, typical of their family. An elaborate courtship precedes breeding, and the nests are tended by the males (Ebert and Turner, 1962). Their protracted breeding season and nesting habits assisted them in becoming abundant, particularly at the Hermosa Beach reef rockpile where 41 were collected from a 6- by 8-foot area. They attain a maximum size of about 6 inches and although appearing to be a suitable food item for larger predaceous fish, none was recorded from the stomachs examined.

Lythrypnus dalli (Gilbert, 1890)—bluebanded goby. This species established a substantial population at only the Hermosa Beach reef rockpile. A few others were seen at the Malibu reef rockpile and on the Redondo Canyon reef in 1964, after termination of our routine study. We expect them eventually to establish on all of the study reefs.

We have observed them on natural reefs along the mainland from Santa Barbara to San Diego and at Santa Catalina, San Clemente, Anacapa, Santa Cruz, Santa Rosa, and San Miguel Islands. Their depth range is intertidal to at least 180 feet.

This 2- to 2.5-inch fish, bright orange-red with iridescent blue cross bars, lives in crevices on the sides or upper surfaces of reefs.

Their eggs, attached to empty shells during the spring and early summer, are tended by the males. We collected gravid females and their deposited eggs during August 1962.

Courtship and nest building was observed during February 1963 in a home aquarium containing three gravid females and a male. After first cleaning an area beneath a shell to receive the eggs, the male rushed at one female, nipping her genital area and jaws. Finally they locked jaws and drifted, leaf-like, about the tank. Actual entry of the female into the "nest area" and egg deposition on the shell was not observed.

Lythrypnus zebra (Gilbert, 1890)—zebra goby. These gobies were observed at only the Hermosa Beach reef rockpile. This goby, similar in shape to the bluebanded goby, but dull brick red with numerous pale blue vertical stripes, is quite retiring, preferring to live under rocks, in caves, or far back in deep crevices. Although infrequently seen by most observers, when an area is intensively collected they are almost as numerous as the more obvious bluebanded goby.

Sebastes atrovirens (Jordan and Gilbert, 1880)—kelp rockfish. Kelp rockfish were seen at both the Malibu and Hermosa Beach reefs but never in significant numbers. This light tan to whitish colored fish often associates with large algal growths (Figure 72) where it "hangs" upside down or side-ways as if without any sense, perhaps inspiring the often-used common name "dumb bass." In the absence of kelp it is seen resting directly on the substrate.

On natural reefs, 10 to 40 feet deep, we observed mature females about to release prolarvae during late winter and early spring. At this time they hid far back in crevices or caves.

Sebastes auriculatus Girard, 1854—brown rockfish. These occurred at each of the artificial reefs but in small numbers. Juveniles, 1.5- to 2-inches long, were observed at the Redondo Canyon reef in August, hiding in small crevices. This rockfish normally remains close to the substrate, frequenting caves and crevices.

Sebastes dalli (Eigenmann and Beesons, 1894) — calico rockfish. Calico rockfish were common on the Redondo Canyon reef, occasionally seen at Hermosa Beach, and were recorded once at Santa Monica. Observations on natural reefs in southern California indicate this rockfish prefers depths exceeding 60 feet, becoming common below 90-foot depths.

This relatively small, maximum size of about 8 inches (Phillips, 1957), rockfish resides at the rock-sand junctures, rarely swimming higher than 6 to 8 feet above the bottom, preferring to rest upon the substrate (Figure 73) . They occur solitarily or in aggregations but do not exhibit schooling.

We observed mature females, in 100-foot depths, about to release prolarvae during winter and spring. The young are apparently released in protective caves or crevices. Numerous juveniles, 0.5 to 1 inch long, were present on the Redondo Canyon reef during spring and summer. They remain in or near crevices and caves until 3 to 4 inches long, when

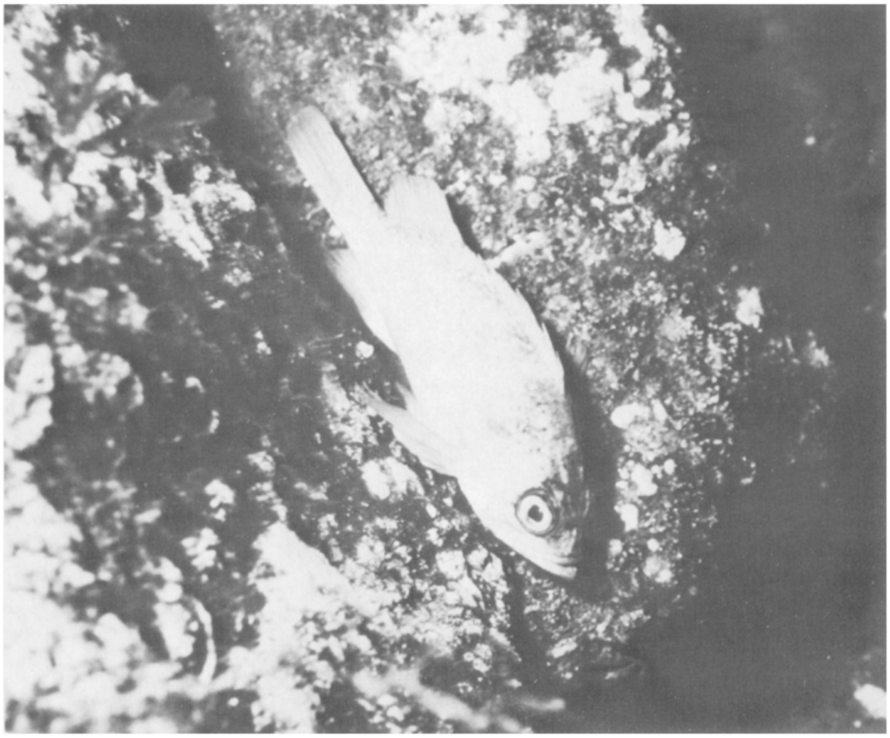

FIGURE 72 Kelp rockfish (*Sebastes atrovirens*) resting on the substrate. *Photo by Charles H. Turner.*

FIGURE 72 Kelp rockfish (Sebastes atrovirens) resting on the substrate. Photo by Charles H. Turner.

they behave as adults, venturing several feet from the rock cover to forage.

Sebastes vexillaris (Jordan and Gilbert, 1880)—whitebelly rockfish. This species was observed at the Malibu, Hermosa Beach, and Redondo Canyon reefs. Their general behavior approximates that of the brown rockfish. Those observed were small, 6 to 7 inches long. One observed off Redondo Beach, 100-depth, in February was estimated to be only 2 inches, indicating a fall and winter spawning—typical for the genus.

Oxylebius pictus (Gill, 1862)—painted greenling. Painted greenlings were commonly observed at the Hermosa Beach and Redondo Canyon reefs, but infrequently at the others. They typically rest on the substrate moving only when disturbed or to forage.

Courtship was observed in February, egg masses (containing some 2,200 eggs), attached to the reef materials, were found in March, August, and November indicating a protracted breeding season. Young, 1 to 2 inches long, were seen on the sand at the edge of the reef materials in fall and winter. During this study several different year-classes were recognized on the reefs.

Artedius creaseri (Hubbs, 1926)—roughcheek sculpin. These species became ubiquitous on the undersides of the reef materials after 1962. Because this small 1- to 3-inch sculpin resides on the undersides of reef materials an estimate of the total population is difficult, but 12

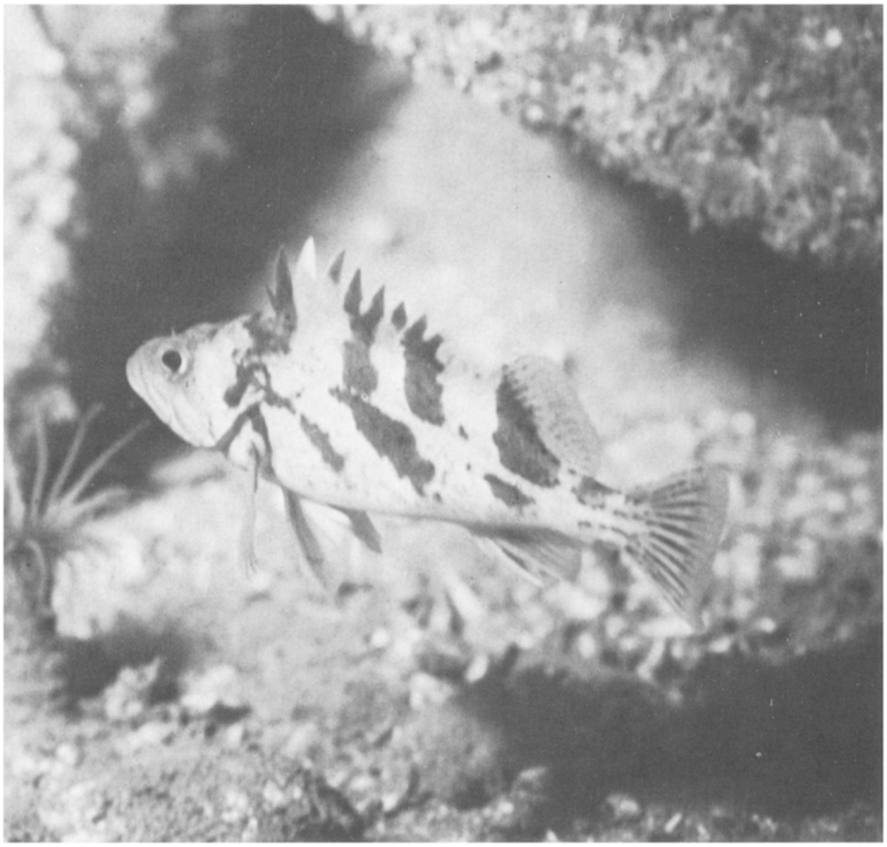

FIGURE 73 Calico rockfish (*Sebastes dalli*) just above the substrate. *Photo by Charles H. Turner.*

FIGURE 73 Calico rockfish (Sebastes dalli) just above the substrate. Photo by Charles H. Turner.

were collected from a 4- by 6-foot area of the Hermosa Beach reef rock-pile. Limited stomach analyses indicate shrimp are the prevalent food item. A 47-mm (1.75 inch) sculpin contained a 23-mm (1 inch) bentback shrimp (Spirontocaris palpator) .

Rathbunella hypoplecta (Gilbert, 1890)—smooth ronquil. Smooth ronquils were seen at each reef's rockpile, and the automobile bodies and concrete shelters at Hermosa Beach. They were also quite numerous on the Redondo Canyon reef. In natural reef areas we find them at 80-foot or greater depths. They typically rest directly on the substrate (Figure 74) or burrow into silty sand, exposing only their head.

We collected gravid females on natural reefs during March 1964 and 1965. Juveniles, less than 1 inch long, were common at the Redondo Canyon reef in summer, with 3- to 5-inchers numerous in the fall and winter. The largest specimen seen, 9.5-inches, was collected in September.

Porichthys notatus (Girard, 1854)—plainfin midshipman. Plainfin midshipmen were observed in small numbers at the Santa Monica reef and once at Malibu. They typically rested on the substrate, either on

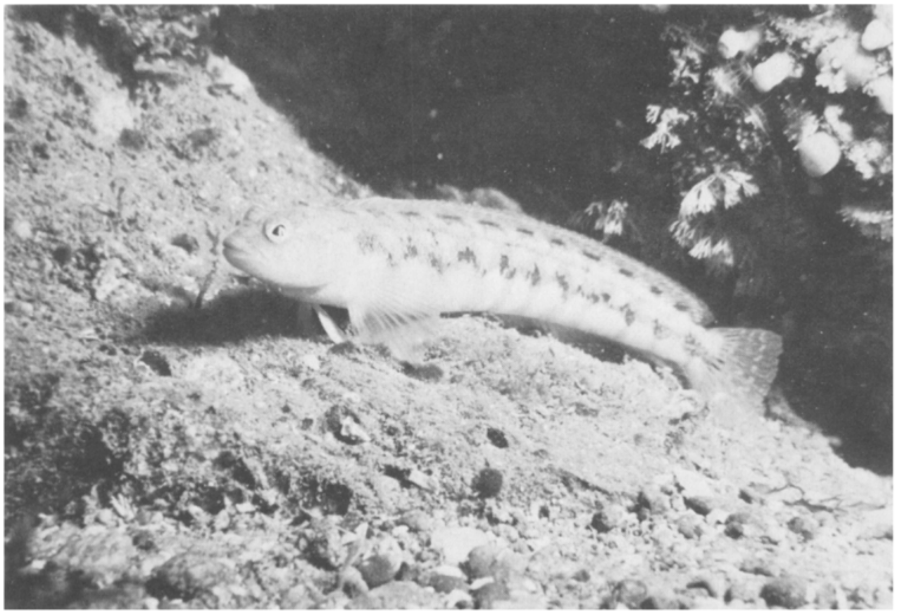

FIGURE 74 Smooth ronquil (*Rathbunella hypoplecta*) resting on one of the rocks forming the Redondo Canyon reef, August 1967. *Photo by Charles H. Turner.*

FIGURE 74 Smooth ronquil (Rathbunella hypoplecta) resting on one of the rocks forming the Redondo Canyon reef, August 1967. Photo by Charles H. Turner.

open sand or in the rocky areas and were seldom observed swimming in the mid- or surface waters. Characteristically they are found burrowing into the bottom.

Breeding occurs during the fall. The large, yellowish eggs are attached to the undersides of rocks previously cleaned by the males. The males remain at these nest sites, caring for the eggs. Male midshipmen, tending eggs, exhibit a progressively emaciated appearance directly correlated with egg-larval development. As the larvae approach "term" the adult male has become progressively more emaciated, portions of his fins have eroded away and patches of necrotic tissue are apparent. In one instance a dead, adult male was found still with the larvae. These fully developed larvae were in the process of freeing themselves from their yolk sac attachment on the rock. This mortality of egg-tending males appears quite extensive and it may account for some of the mass die-offs reported for the species.

8.5.3. Fish Food Studies

Although we have not carried out an extensive study to determine the food habits of the artificial reef fishes, we did sample a few selected species to determine their general feeding behavior. A total of 120 fishes was collected, representing 14 of the more common resident or semiresidents.

Before a fish was collected, by spearing, we attempted to observe it in the field for a short time and note its feeding pattern and the specific reef areas on which it fed. After collection, length-weight-sex-condition data were obtained, then the stomach and most of the esophagus were removed, opened, and the contents, if any, examined. Most of the detailed gut-content analyses were performed under considerable magnification enabling us to make, in many cases, specific identification of broken animal parts.

of the 120 stomachs examined, 31 were completely empty, the remaining 89 contained one or more representatives of the 73 different food items recorded (Table 8). These food items included algae, small fish, worms, sponges, mollusks, crustaceans, and echinoderms. Crustacean remains were identified more often than any other invertebrate group, suggesting they are a "preferred" food, a hypothesis which may be biased due to the relative resistance of the crustacean exoskeleton to rapid digestion, allowing the "food animal" to maintain its integrity and be identifiable longer than the less resistant, soft-bodied forms.

Next in importance (total number of occurrences) were small mollusks, again readily identified from intact hard parts. Fish, echinoderms, and octopuses were considered incidental and "seasonal" food items for the resident fishes but of importance for the semi-resident and transient groups.

Four of the embiotocids (black perch, rainbow seaperch, white seaperch, and rubberlip perch) showed a decided preference for worms, small crustaceans, and small mollusks. The pile perch (another embiotocid), however, did not eat any worms, and the crustaceans and mollusks it ate were large, possibly indicating it is a more selective feeder. Further, its pharyngeal teeth are more capable of handling these food items than are those of the other perches.

of particular interest was the food of sand and kelp bass. Young kelp bass reportedly feed on small crustaceans and the adults on free swimming fishes and cephalopods (Limbaugh, 1955; Quast, 1968; Young, 1963). In addition to these items, we found brittle stars and pelagic ascidians in their stomachs, and on several occasions observed them feeding on chains of salps which floated near the reefs. They apparently preferred the gut portion of the ascidians and would bite it out of the surrounding tunic. Only after all the salps were thus "gutted" would they consume the tunics. Small salps, however, were ingested whole. In natural reef areas (San Clemente Island), we observed 20-inch kelp bass which had recently devoured large California flyingfish (Cypselurus californicus) .

Sand bass, though closely related to kelp bass, fill a slightly different niche in the reef ecosystem and appear favored by the rock-sand areas, feeding principally on small fishes, octopuses, shrimps, crabs and brittle stars. The small fishes fed upon included: white seaperch, northern anchovy, shiner perch, southern spearnose poacher, and sarcastic fringehead. Some of these are relatively fast swimmers, while others are slow-moving bottom-dwellers, inhabitants of sand bottoms or rock crevices. Sand bass were observed actively searching out food from crevices and holes in the reef materials.

The painted greenling, a true reef dweller, depends entirely upon the reef bios for food, grazing and picking items from the sides and tops of the materials. The bulk of their diet is small crustaceans, although hydroid and gastropod remains were noted occasionally.

TABLE 8

Items Found in the Stomachs of Fishes Speared Around the Multicomponent (WCB) Reefs, 1962 and 1963

Item	Occurrence by species of fish examined														
	Kelp bass	Sand bass	Black perch	Rainbow seaperch	White seaperch	Rubberlip perch	Pile perch	Blackeye goby	Sculpin (rockfish)	Vermillion rockfish	Olive rockfish	Painted greenling	Cabezon	Fantail sole	Total times occurring
Sponge (unid.)	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1
Leuconia barbata	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
Hydroid (unid.)	--	--	1	--	--	--	--	--	--	--	--	1	--	--	2
Nematode (unid.)	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1
Polychaete (unid.)	--	--	6	1	1	8	--	--	--	--	--	2	--	--	18
Diopatra sp.	--	--	--	4	1	--	--	--	--	--	--	--	--	--	5
Polynoidae	--	--	--	--	1	--	--	--	--	--	--	--	--	--	1
Phragmatopoma californica	--	--	--	--	1	--	--	--	--	--	--	--	--	--	1
Sabellaria cementarium	--	--	3	--	1	1	--	--	--	--	--	--	--	--	5
Sabellaria sp.	--	--	--	1	--	--	--	--	--	--	--	--	--	--	1
Spirorbis sp.	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
Spionidae	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1
Crustacean (unid.)	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
Ostracoda	--	--	--	1	--	--	--	--	--	--	--	--	--	--	1
Balanus concavus pacificus	--	--	1	1	--	--	--	--	--	--	--	--	--	--	2
Balanus tintinnabulum californicus	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1
Balanus sp.	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
Lepas sp.	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1
Hemisquilla stylifera	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1
Mysidacea	--	--	--	--	--	2	--	--	--	--	--	--	--	--	2
Hemilamprops californica	--	--	1	--	1	--	--	--	--	--	--	--	--	--	2
Tanaidacea	--	--	1	1	1	--	--	--	--	--	--	--	--	--	3
Isopoda (unid.)	--	1	2	2	--	2	--	--	--	--	--	--	--	--	7
Livonica sp.	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1
Gammarid amphipods	--	--	9	10	11	12	--	--	--	1	--	3	--	--	46
Caprellid amphipod	--	--	1	--	--	1	--	--	--	--	--	3	--	--	5
Decapoda (unid.)	--	--	3	--	--	--	--	--	--	--	--	--	--	--	3
Decapod zoea (unid.)	--	--	1	1	2	1	--	--	--	--	--	--	--	--	5
Caridean shrimp (unid.)	--	1	--	--	3	1	1	--	--	--	--	--	--	--	6
Alpheus dentipes	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
Hippolysmata californica	--	1	--	--	--	--	--	--	--	--	--	1	--	--	2
Spirontocaris sp.	--	--	--	--	--	1	--	--	--	--	--	3	--	--	4
Brachyura (unid.)	--	--	--	--	--	--	1	--	--	--	--	--	--	--	1
Cancer antennarius	--	1	--	--	--	--	--	--	--	--	--	--	--	--	1
Cancer sp.	--	--	6	9	3	14	--	--	1	--	--	3	--	--	36
Heterocrypta occidentalis	--	--	--	1	1	2	--	--	--	--	--	--	--	--	4
Lophopanopeus sp.	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
Loxorhynchus sp.	--	--	--	--	--	--	--	--	--	--	--	1	--	--	1
Oxyrhyncha (unid.)	--	--	--	2	--	2	--	--	--	--	--	--	--	--	4
Pugettia producta	--	--	--	--	--	1	--	--	1	--	--	--	--	--	2
Anomura (unid.)	--	--	--	--	--	--	1	--	--	--	--	--	--	--	1
Octopus sp.	--	4	--	--	--	1	--	--	3	--	--	--	1	--	9
Loligo opalescens	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
Chiton (unid.)	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1
Bankia setacea	--	--	2	--	--	--	--	--	--	--	--	--	--	--	2
Hiatella arctica	--	--	--	2	1	--	--	--	--	--	--	--	--	--	3
Kellia sp.	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
Nuculoid clam (unid.)	--	--	3	1	--	1	--	--	--	--	--	--	--	--	5
Amphissa sp.	--	--	--	--	--	2	1	--	--	--	--	--	--	--	3
Gastropod (unid.)	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
Crepidula sp.	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1
Crepipatella lingulata	--	--	1	--	1	--	1	--	--	--	--	--	--	--	3
Epitonium sp.	--	--	--	--	1	1	1	--	--	--	--	--	--	--	3
Mitrella carinata	--	--	--	--	--	--	--	--	--	--	--	--	1	--	1
Nassarius sp.	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
Ocenebra sp.	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
Olivella pedroana	--	--	1	1	1	3	--	--	--	--	--	--	--	--	6
Victorella argilla	--	--	--	1	--	--	1	--	--	--	--	--	--	--	2
Ectoprocta (unid.)	--	--	--	--	--	--	1	--	--	--	--	--	--	--	1
Glottidea albida	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1
Ophiothrix spiculata	1	--	--	--	--	--	4	--	--	--	--	--	--	--	5
Ophiuroidea (unid.)	--	1	2	--	--	--	1	--	--	--	--	--	--	--	4
Echinoidea (unid.)	--	--	--	--	1	--	--	--	--	--	--	--	--	--	1
Salpa vagina	1	--	--	--	--	--	--	--	--	--	--	--	--	--	1
Agonopsis sterletus	--	1	--	--	--	--	--	--	--	--	--	--	--	--	1
Cymatogaster aggregata	--	1	--	--	--	--	--	--	--	--	--	--	--	--	1

TABLE 8

Items Found in the Stomachs of Fishes Speared Around the Multicomponent (WCB) Reefs, 1962 and 1963

TABLE 8—Continued

Items Found in the Stomachs of Fishes Speared Around the Multicomponent (WCB) Reefs, 1962 and 1963

Item	Occurrence by species of fish examined														
	Kelp bass	Sand bass	Black perch	Rainbow seaperch	White seaperch	Rubberlip perch	Pile perch	Blackeye goby	Sculpin (rockfish)	Vermillion rockfish	Olive rockfish	Painted greenling	Cabezon	Fantail sole	Total times occurring
Engraulis mordax	--	2	--	--	--	--	--	--	--	--	1	--	--	--	3
Neoclinnus blanchardi	--	1	--	--	--	--	--	--	--	--	--	--	--	--	1
Otophidium scrippsi	--	--	--	--	--	--	--	--	1	--	--	--	--	--	1
Phanerodon furcatus	--	1	--	--	--	--	--	--	--	--	--	--	--	--	1
Rathbunella hypoplecta	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1
Miscellaneous fish parts	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
Rhodophyta	--	--	--	1	--	1	--	--	--	--	--	--	--	--	2
Miscellaneous debris, sand, rock, wood	--	--	6	10	3	7	1	--	--	--	3	3	--	--	33
Total number of items	2	11	27	18	18	32	11	1	4	1	2	9	2	1	
Number of stomachs examined	4	18	13	13	16	20	7	1	15	1	4	4	1	3	120
Number of stomachs empty	2	5	2	3	4	1	0	0	9	0	3	0	0	2	31

TABLE 8

Items Found in the Stomachs of Fishes Speared Around the Multicomponent (WCB) Reefs, 1962 and 1963

Sculpin (scorpionfish) are semi-resident reef fishes observed to eat octopuses, crabs and, in one case, a cusk-eel. The number of sculpins on the reef varied throughout the year, with their population peaks coinciding with the population peaks for juvenile Cancer crabs. In spring and summer, the sculpin's departure for deep water, presumably to spawn, coincides with the replacement of these young crabs, in part, with immigrating berried female crabs.

It is obvious that further studies on all phases of the reef food web are necessary. Our preliminary work, however, suggests certain basic patterns and helps explain some of the behavioral activities recorded during diving observations.

8.5.4. Sportfishing Success

When the three WCB replication reefs (Hermosa Beach, Santa Monica and Malibu) were placed and buoyed (August 1960), we asked that sportsmen refrain from fishing them for at least 2 years. This would allow us to observe the fish population growth, natural fluctuations, and abundance levels without undue influence or fishing pressure. At the termination of this 2-year period, we planned to evaluate angler success on the study reefs, comparing it to data obtained on nearby natural reefs.

By January 1962, it was apparent that the reefs were being subjected to moderate to heavy fishing pressure: our diving observations revealed snagged fishing gear on many of the components. In view of this situation we decided to open the reefs to fishing and initiate a limited program aimed at measuring fishing success.

Sampling of fishing effort and success was achieved through the cooperation of sportfishing landings at both Redondo Beach and Malibu.

Catch data were gathered at the Hermosa Beach and Malibu replication reefs and the Redondo Beach streetcar reef.

The species caught were the same, in general, as those observed by the divers. The exceptions were two giant sea bass caught at Malibu, and white croaker, Pacific mackerel (Scomber japonicus) , California barracuda (Sphyraena argentea) , and a spiny dogfish (Squalus acanthias) , caught at Hermosa Beach.

Angler success was measured on 15 occasions at the Hermosa Beach reef from September 1962 through June 1963 (Table 9). From 1.6 to 10.75 fish were caught per angler hour at this reef, with an average of 4.32.

On one occasion a sport boat fished both a study reef and a nearby natural reef on the same day. The natural reef yield was 2.22 fish per angler hour, compared with 5.68 fish from the artificial reef.

At Malibu reef, a sportfishing barge anchored between the streetcar and rockpile components during portions of 1962 and 1963. Catch records were tabulated here on seven different occasions (Table 10), but catch per angler hour was indeterminate as fishermen arrived and departed at irregular intervals throughout each 9-hour fishing day. We did calculate their success as averaging 6.77 fish per angler, ranging from 2.63 to 13.67.

Sculpin were most frequently caught, followed closely by Pacific bonito. The absence of kelp bass in these landings reflected the time of year. Sampling was conducted in March and April, prior to their breeding season, when this species is notably inactive on the reefs. Similarly, at Hermosa Beach, kelp bass were caught infrequently except during the summer.

Fishing success was censused on four occasions at the Redondo Beach streetcar reef during October and December 1962 (Table 11). Although the six streetcars had deteriorated appreciably, primarily due to woodboring shipworms, they were nevertheless providing fair to good sport-fishing and were a regular stop for local boats. The catch-per-angler-hour averaged 6.77 fish at this reef, ranging from 3.75 to 12.00.

Although our data are insufficient to depict fishing success fully on the man-made reefs, fishing success appears to be substantial, possibly two to three times that recorded on similar sized nearby natural reefs. In some instances, probably due to the fish-concentrating effect of these reefs, angler success may be even higher.

Our diving observations and reports from anglers fishing the experimental, and early production model reefs indicate that these (25,000–50,000 square feet) reefs are minimal in size to allow sustained harvest. They quickly concentrate fishes for easy harvest, but in turn are rapidly "fished-out." They remain fished out until new adult fishes swim in; they are unable to reach an equilibrium. If the reefs were to cover at least 200,000 square feet of ocean floor they could reach a proper equilibrium and allow propagation by the reef fishes, thus permitting recreational harvest over a much more extended period.

TABLE 9

Sportfishing Catch Records for the Hermosa Beach Replication Reef September 1962 Through June 1963

Date	Number of anglers	Time expended (minutes)	Number of fish	Fish per angler hour	Species														
					*Spiny dogfish	Kelp bass	Sand bass	**Kelp and sand bass	Ocean whitefish	*White croaker	Pacific bonito	*Pacific mackerel	Sculpin (rockfish)	Olive rockfish	Rockfish (unid.)	Lingcod	Cabezon	*California barracuda	California halibut
9-21-62	13	42	41	4.71	1	2	31	--	--	--	4	--	1	1	--	--	--	--	1
9-26-62	20	40	45	3.40	--	--	45	--	--	--	--	--	--	--	--	--	--	--	--
10- 4-62	8	40	20	3.78	--	--	20	--	--	--	--	--	--	--	--	--	--	--	--
11-13-62	9	37	60	10.75	--	2	35	--	--	--	--	--	--	--	--	--	--	--	--
12- 3-62	4	90	27	4.50	--	2	23	--	--	--	--	--	1	--	1	--	--	--	--
12-31-62	23	45	49	2.84	--	--	6	--	--	--	--	--	43	--	--	--	--	--	--
3-19-63	23	25	25	2.59	--	--	19	--	--	--	--	--	4	--	--	--	--	--	2
4- 4-63	13	50	28	2.59	--	--	19	--	2	--	3	--	4	--	--	--	--	--	--
4-10-63	39	70	350	7.48	--	8	300	--	6	--	--	--	35	--	--	1	--	--	--
4-11-63	20	15	8	1.60	--	--	--	--	--	--	--	--	8	--	--	--	--	--	--
4-18-63	5	30	12	4.80	--	--	1	--	--	6	--	--	5	--	--	--	--	--	--
5-30-63	34	60	106	3.12	--	--	40	--	--	--	1	2	48	--	--	--	2	1	12
6- 8-63	76	80	278	2.75	--	--	--	225	--	--	6	8	6	--	6	--	--	24	3
6-20-63	30	80	227	5.68	--	160	50	--	--	--	--	--	15	--	--	--	--	2	--
6-28-63	64	120	544	4.25	--	540	--	--	--	--	--	--	--	--	--	--	--	4	--

* Not observed during the diving surveys.
** Species not differentiated.

TABLE 9
Sportfishing Catch Records for the Hermosa Beach Replication Reef September 1962 Through June 1963

TABLE 10

Sportfishing Catch Records for the Malibu Replication Reef March and April 1963

Date	Number of anglers	Number of fish	Average fish per angler	Species				
				Sand bass	*Giant sea bass	Pacific bonito	Sculpin (rockfish)	California halibut
3–24–63	48	398	8.29	145	--	210	25	18
3–30–63	120	446	3.72	88	1	200	112	45
3–31–63	111	292	2.63	110	--	70	74	38
4– 6–63	98	838	8.55	160	--	400	270	8
4– 7–63	92	1,110	12.06	150	--	300	650	10
4– 8–63	24	328	13.67	45	1	160	120	2
4– 9–63	42	507	12.07	55	--	150	300	2

* Not observed during the diving surveys.

TABLE 10

Sportfishing Catch Records for the Malibu Replication Reef March and April 1963

TABLE 11

Sportfishing Catch Records for the Redondo Beach Streetcar Reef October and December 1962

Date	Number of anglers	Time expended (minutes)	Number of fish	Fish per angler hour	Species						
					Shovel-nose guitar-fish	Kelp bass	Sand bass	White croaker	Pacific bonito	Sculpin (rock-fish)	Cali-fornia halibut
10– 2–62	11	90	76	4.61	--	40	10	--	--	25	1
10– 4–62	8	40	20	3.77	--	--	20	--	--	--	--
10– 9–62	4	120	52	6.50	--	10	30	--	--	12	--
10–19–62	8	60	56	7.00	1	--	52	--	1	--	2
12–19–62	10	30	60	12.00	--	--	25	30	5	--	--

TABLE 11

Sportfishing Catch Records for the Redondo Beach Streetcar Reef October and December 1962

9. SUMMARY AND CONCLUSIONS

An increasing world population has forced the further exploitation of certain heretofore untouched natural areas, primarily in the ocean. One method currently under investigation is marine environmental modification by the construction of man-made fishing reefs in areas where little or no natural bottom relief exists. In April 1958, California Department of Fish and Game, (aided financially by Federal Aid to Fish Restoration Funds) initiated its Ocean Fish Habitat Development Program. This program was designed to determine: (i) the practicality of artificial (man-made) reefs in southern California waters, (ii) the best materials to use, and (iii) the return to the fisherman. This study was conducted by competent marine biologists who were also capable scuba divers.

Data obtained from this first study (Carlisle, Turner, and Ebert, 1964) revealed wide variations in the numbers of fishes present on a given day, around a particular reef. Some of these variations were explained as expected seasonal fluctuations, others coincided with variations in water clarity (influencing the visibility of the fishes to the divers). The remainder appeared to reflect a preference by the fishes for a given material.

During August 1960, the Department constructed three replication reefs in Santa Monica Bay, offshore from Hermosa Beach, Santa Monica, and Malibu, in an effort to document and define this apparent preference for material type. Each reef was composed of 333 tons of class B quarry rock, one streetcar, 14 automobile bodies, and 44 concrete shelters; the total cubic area of each material was calculated to be nearly equal to that of any of the other materials. A diving survey and sampling program was conducted monthly at each reef from August 1960 until November 1963. After this, until the end of the study in January 1965, our surveys were somewhat sporadic. During this period, we studied various aspects of this man-made reef ecosystem. Observations and sampling conducted at each reef included: (i) enumeration (by estimate) of the fishes, invertebrates and plants; (ii) core samples of the bottom substrates for sediment analysis; (iii) water temperatures; (iv) horizontal visibility estimates and Secchi disc readings; (v) general description of the bottom, before and after reef construction; (vi) quantitative sampling of growths on the reef materials; (vii) removal of test blocks, monthly, during the first year of reef life; and (viii) photographing the conditions encountered and the animals and plants observed.

Pre-reef data were obtained from catch records, prior surveys by other organizations, and by our visual observations during the reefsite selection surveys.

Excluding construction time and buoy placement and maintenance, we spent over 480 man-hours underwater conducting nearly 200 survey dives around these study reefs.

We limited our taking of physical data to recording and analyses of water temperatures, water visibilities (clarity) and bottom sediments. We recorded similar temperature patterns and seasonal ranges at all three replication reefs. At each, isothermal conditions occurred in the winter and maximum stratification in the summer. Surface water over the reefs ranged from 13.4°C (March 1962) to 21.0°C (August 1961). Bottom waters, on the reef (60-foot depth), varied from 10.3°C (June 1961) to 17.0°C (November 1960). Seasonally, low surface temperatures were found from November or December through May. Low bottom temperatures prevailed from March through July.

The water visibilities encountered in Santa Monica Bay could generally be described as marginal for conducting diving surveys. Four-foot visibility appears minimal to assess reef fish populations properly; any less and an overall perspective cannot be obtained. The maximum sea floor visibility, estimated as 35 feet, occurred at the Hermosa Beach reef (June 1961), however, on several occasions bottom visibilities here were estimated at only 1 foot. Moderately good visibilities (about 10 feet) were experienced frequently at this reef, but seldom at either Santa Monica or Malibu.

Comparative analyses of bottom sediments, taken from construction sites before and after reef placement, illustrated that marked alterations of the sediment composition and sea floor topography occurred adjacent to the concrete shelters, automobile bodies, and streetcars. Only negligible differences were detected around the rockpiles. Coarser sediments were uncovered as accelerated currents, produced by water passing through openings in these three materials, carried away the finer silts and clays. This scouring created extensive depressions around the materials. During periods of minimal bottom currents these depressions would refill, often half covering the material.

Wooden test blocks were affixed to the multiple component reefs to study the attachment, growth, and succession of encrusting organisms. Test blocks were removed monthly during the reef's first year. Analyses of the test-block data disclosed that speciation among the various reef materials and reefs developed in a similar fashion. of particular note, however, was the lack of sponges on any of the Santa Monica reef test blocks; at both Malibu and Hermosa Beach the colonization by sponges was roughly parallel.

The ubiquitous presence of wood boring organisms in the test blocks points out the inadvisability of using wooden materials for other than short term reef construction.

From analysis of our test block and quadrat scraping data and from our general observation, we felt that true animal succession rather than seasonal progression occurred among the species encrusting these reefs. During the reef's first year we could define a barnacle-hydroid phase, followed by less distinct mollusk-polychaete, ascidian-sponge, and finally encrusting ectoproct stages. Subsequently, aggregate anemones became important (during the second and third years), followed by gorgonians (in the third and fourth). The first stony corals appeared in the fifth year.

Four brown and four red algae were recorded as natural inhabitants of the three replication reefs. Because of their limited size and numbers, they were of negligible importance during our study.

Giant kelp transplants onto the reefs proved unsuccesful, apparently due to the turbid waters.

The invertebrates identified from test blocks, quantitative substrate sampling, and our general reef surveys are presented systematically in a species index, which includes notations of their occurrence, growth, importance on the reef, ecological niche and known predator-prey relationships.

of particular interest was our finding Victorella argilla (encrusting ectoproct) on all of the reef materials. As a biological and physical factor in reef succession and ecology, it is probably the most important species studied. It is obviously not a tempting food item for fishes, but its encrusting growth habit and ability to encroach upon and cover everything in its path makes it a major contender for surface space on the reefs.

Fish populations around the man-made reefs were assessed by : (i) species enumeration; (ii) estimates of size ranges (lengths) for individual species; (iii) feeding habits; and (iv) general behavioral traits. Underwater tagging techniques were developed and employed to determine fish movements.

A fish classification scheme to define the fish assemblages around the man-made reefs was established. It discusses reef asociated and non-reef associated fishes and describes the semi-resident and resident form.

Fishes (particularly embiotocid perches and serranids) appeared within *hours* after construction of each reef. These were adult fishes that had moved in from other areas. During the first year of reef life, embiotocid perches and serranids dominated each reef's fish population. When present they accounted for more than 90% of the fishes recorded during each survey.

During the second year, a slight decrease in their dominance was recorded. A further decrease was noted in the third year, as resident species (i.e., gobies, cottids, and rockfishes) increased in numbers and the reefs approached a natural equilibrium.

By material, most of the fishes were attracted to the concrete shelters, averaging 1,053 individuals per observation; the streetcar attracted the least, 635. Between these extremes were automobile bodies, 826, and quarry rock, 870.

Although our data are insufficient to depict fishing success fully on the man-made reefs, this success appears to be substantial, possibly two to three times that recorded on similar sized nearby natural reefs. In some instances, probably due to the fish-concentrating effect of these structures, angler success may be even higher.

From the information presented here and gathered from the literature, it is apparent that certain "non-productive" areas of nearshore ocean floor can be made "productive" by installation of relief structures. Initially, these structures attract fishes from surrounding areas and present a substrate suitable for development of the complex biotic assemblages typical of natural reefs. As these new reefs mature, biological succession occurs and fishes which may have been initially attracted only to the structures are incorporated into the reef community in response to the increasingly available food and shelter. Ultimately (in about 5 years) a natural situation is attained, and the plant and animal populations exhibit fluctuations typical of reef ecosystems.

Based upon ease of handling and cost considerations we have concluded that of the four materials tested, quarry rock is the preferred reef building material in southern California. Local considerations in other areas (availability of material, transportation charges, etc.) may alter this finding.

In any event, reef units should be moderately large (with numerous holes and crevices), durable (rock, concrete rubble, tires, etc.), inexpensive, easily handled at sea, and sufficiently large to preclude or minimize sanding-in or silting-over.

Man-made reefs should be constructed upon firm, relatively flat, "barren" sand or mud bottoms, at considerable distances (0.5-mile or more) from natural reefs. They should be in areas free from pollutants and should be well marked with lighted buoys or large floats.

The overall reef should cover a broad area (no less than 200,000 sq. ft.) and incorporate into its configuration large open spaces 50 to 60 feet in diameter.

Water depth over the reef can vary considerably with the construction site and local considerations. Productive man-made reefs have already been placed in southern California waters 10 to 80 feet deep, the shallower reefs being at the periphery of fishing piers.

Reefs must not be installed without adequate biological and physical data for each area in question. These data are necessary to determine the need for such a reef, and the proper material and design for its construction.

Although funding may be from public subscription, federal or state conservation agencies must be actively involved in each reef's construction. Other groups, no matter how well intended, are all too prone to consider only their own special interests. Without basing a reef's construction upon proper scientific parameters, it becomes at best a temporary high relief area of questionable value, or at worst an ocean junk pile whose major value has been as a promotional gimmick publicizing a special interest group.

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APPENDIX 3

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Scientific Name	Common Name
ALGAE	
Antithamnion occidentale Kylin	red alga
Botryocladia pseudodichotoma (Farlow) Kylin	seagrapes
Chlorophyta	green algae (division)
Desmarestia munda Setchell and Gardner	brown alga
Dictyota flabellata (Collins) Setchell and Gardner	brown alga
Ectocarpus granulosoides (J. E. Smith) C. A. Agardh	brown alga
Egregia laevigata Setchell	strap kelp (feather boa)
Enteromorpha intestinalis (Linnaeus) Link	green alga
Laminaria farlowii Setchell	brown alga
Macrocystis angustifolia Bory	giant kelp
Macrocystis integrifolia Bory	giant kelp
Macrocystis pyrifera (Linnaeus) C. Agardh	giant kelp
Macrocystis sp.	giant kelp
Phaeophyta	brown algae (division)
Porphyra thuretii Setchell and Dawson	red alga
Rhodophyta	red algae (division)
Rhodymenia californica Kylin	red alga
Taenioma sp.	red alga
INVERTEBRATES AND ASCIDIANS	
Acanthodoris lutea MacFarland	
Acanthoptilum scalpellifolium Moroff	dorid nudibranch
Acanthina spirata (Blainville)	muricid snail
Acteon punctocaelatus (Carpenter)	barrel snail
Acteocina sp.	snail
Actinaria	sea anemones (order)
Aegires albopunctatus MacFarland	salt-and-pepper nudibranch
Aglaja diomedea (Bergh)	tectibranch
Alpheus dentipes Guerin	pistol shrimp
Amaroucium californicum Ritter and Forsyth	compound ascidian
Ampharetidae	polychaete worm (family)
Amphipoda	amphipods (crustacean order)
Amphissa versicolor Dall	whelk snail
Amphissa sp.	whelk snail
Amphora sp.	protozoan
Anaitides medipapillata (Moore)	phyllodocid worm
Anisodoris nobilis MacFarland	dorid nudibranch
Annelida	worms (phylum)
Anomura	crab (tribe)
Antennella avalonia Torrey	thecate hydroid
Antennularia sp.	thecate hydroid
Anthozoa	anthozoans (cnidarian class)
Antiopella barbarensis (Cooper)	aeolid nudibranch
Aplysia californica Cooper	sea hare
Aplysilla glacialis (Dybowski)	keratose sponge
Arabella semimaculata (Moore)	arabellid worm
Arabellidae	polychaete worms (family)
Arcuatula demissa (Dillwyn)	ribbed mussel
Armina californica (Cooper)	striped nudibranch
Arthropoda	arthropods (phylum)
Ascidiacea	ascidians (class)
Ascidia ceratodes (Huntsman)	solitary ascidian
Asteroidea	sea stars (class)
Astraea gibberosa Dillwyn	red turban snail
Astraea undosa (Wood)	wavy turban snail
Astropecten brasiliensis armatus Gray	sand star
Astropecten californicus Fisher	sand star
Balanomorpha	acorn barnacle (sub-order)
Balanus aquila Pilsbry	acorn barnacle
Balanus concavus pacificus Pilsbry	acorn barnacle
Balanus flos Pilsbry	acorn barnacle
Balanus galeatus (Linnaeus)	acorn barnacle
Balanus tintinnabulum californicus Pilsbry	acorn barnacle
Balanus trigonus Darwin	acorn barnacle
Balanus sp.	acorn barnacle
Bankia setacea (Tryon)	shipworm
Barentsia discreta (Busk)	entoproct
Barleeia sp.	rissoid snail
Bimeria pusilla Fraser	athecate hydroid
Bimeria sp.	athecate hydroid
Botruanthus sp.	tube anemone
Bougainvillia glorietta Torrey	athecate hydroid
Bougainvillia sp., cf. *mertensi* Agassiz	athecate hydroid
Bougainvillia sp.	athecate hydroid
Brachiopoda	brachiopods (phylum)
Brachyura	crab (sub-class)
Bugula neritina (Linnaeus)	ectoproct
Burchia redondoensis Burch	turrid snail

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APPENDIX 3—Continued

Scientific and Common Names of Plants and Animals Discussed During the Study of Three Multi-Component Man-Made Reefs in Santa Monica Bay; August 1960–January 1965

Scientific Name	Common Name
INVERTEBRATES AND ASCIDIANS—Continued	
Bursa californica (Hinds)	California frog snail
Calcarea	sponges (class)
Calliostoma gloriosum Dall	trochid snail
Calliostoma supragranosum Carpenter	granulose top-snail
Calliostoma tricolor Gabb	three-colored top-snail
Callopora circumclathrata (Hincks)	ectoproct
Callopora sp.	ectoproct
Calyptoblastea	hydroids (sub-order)
Campanularia sp.	thecate hydroid
Cancer antennarius Stimpson	rock crab
Cancer anthonyi Rathbun	yellow crab
Cancer gracilis Dana	slender crab
Cancer jordani Rathbun	hairy cancer crab
Cancer magister Dana	market crab
Cancer productus Randall	red crab
Cancer sp.	cancer crab
Caprellidea	skeleton shrimp (sub-order)
Caridea	caridean shrimp (section)
Cephalopoda	mollusk (class)
Cerianthiopsis sp.	tube anemone
Ceriantharia	tube anemone (order)
Chaetoderma sp.	worm-like mollusk
Chaetopteridae	polychaete worm (family)
Chaetopterus variopedatus (Renier)	parchment tube worm
Chama pellucida Broderip	agate chama
Cheilostomata	ectoproct
Chelyosoma productum Stimpson	solitary ascidian
Chione sp.	chione
Chlamydoconcha orcutti Dall	"naked" clam
Chordata	chordates (phylum)
Chrysopetalidae	polychaete worm (family)
Chrysopetalum occidentale Johnson	polychaete worm
Cirratulidae	polychaete worm (family)
Cirripedia	barnacles (sub-class)
Cirriformia sp.	polychaete worm
Cliona celata Grant *californiana* de Laubenfels	boring sponge
Clytia sp., cf. *bakeri* Torrey	thecate hydroid
Clytia kincaidi (Nutting)	thecate hydroid
Clytia sp.	thecate hydroid
Conus californicus Hinds	California cone snail
Cnidaria	coelenterates (phylum)
Copepoda	copepod (crustacean sub-class)
Corymorpha palma Torrey	athecate hydroid
Corynactis californica Carlgren	aggregate anemone
Crepidula adunca Sowerby	hooked slipper-snail
Crepidula perforans (Valenciennes)	white slipper-snail
Crepidula onyx Sowerby	onyx slipper-snail
Crepipatella lingulata (Gould)	half-slipper snail
Crinoidea	basket stars (class)
Crisia occidentalis Trask	ectoproct
Crisia sp.	ectoproct
Crustacea	arthropods (class)
Cryptosula pallasiana (Moll)	ectoproct
Ctenostomata	ectoprocts (sub-order)
Cumacea	cumacean crustacean (order)
Cypraea spadicea Swainson	chestnut cowry
Decapoda	crustacean, order
Demospongia	sponges (class)
Dendrodoris albopunctata (Cooper)	dorid nudibranch
Dendronotus frondosus (Ascanius)	frondose nudibranch
Diaperoecia californica (d'Orbigny)	ectoproct
Diaperoecia floridana Osburn	ectoproct
Diaulula sandiegensis (Cooper)	circle spotted nudibranch
Diodora aspera (Rathke)	rough keyhole limpet
Diodora arnoldi McLean	keyhole limpet
Diopatra ornata Moore	polychaete worm
Diopatra sp.	polychaete worm
Dirona albolineata Cockerell and Eliot	aeolid nudibranch
Discodoris heathi MacFarland	dorid nudibranch
Distaplia sp.	compound ascidian
Dorvilleidae	polychaete worms (family)
Doto sp.	dorid nudibranch
Echinodermata	echinoderms (phylum)
Echinoidea	urchins (class)
Echiuroidea	echiuroid worms (phylum)
Ectoprocta	bryozoan (phylum)
Entoprocta	pseudocoelomates (phylum)
Epitonium bellastriatum Carpenter	striped wentletrap
Epitonium sawinae (Dall)	close-ribbed wentletrap

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Scientific Name	Common Name	Scientific Name	Common Name
Epitonium sp.	wentletrap snail	*Ischnochiton mertensii* (Middendorff)	chiton
Erato vitellina Hinds	apple seed snail	Isopoda	isopod (crustacean order)
Eudendrium sp., cf. *ramosum* (Linnaeus)	athecate hydroid	*Janolus barbarensis* (Cooper)	aeolid nudibranch
Eudistylia polymorpha Johnson	feather-duster worm	*Kelletia kelleti* (Forbes)	kellet's whelk
Euneris sp.	nereid worm	*Kellia laperousii* Deshayes	nestling clam
Eunoe sp.	polynoid worm	*Kellia suborbicularis* Montagu	nestling clam
Eupentacta quinquesemita (Selenka)	white sea cucumber	*Kellia* sp.	nestling clam
Ephelota coronata Kent	suctorian	*Lacuna* sp.	chink snail (bivalve)
Euphrosinidae	polychaete worm (family)	*Lepas* sp.	gooseneck barnacle
Ficulina sp., cf. *suberea lata* (Lambe)	encrusting sponge	*Leptochelia* sp.	tanaid
Flabelligeridae	polychaete worm (family)	*Leptopecten latiauratus* (Conrad)	kelp scallop
Flabellinopsis iodinea (Cooper)	aeolid nudibranch	*Leuconia barbata* Duchassaing and Michelotti	calcareous sponge
Folliculinidae	bottle animalcules (family)	*Leucosolenia botryoides* Ellis and Solander	calcareous sponge
Folliculina sp.	ciliate protozoan (attached)	*Leucosolenia* sp.	sponge
Foraminiferida	foraminifera (protozoan order)	*Licmophora abbreviata* Agardh	diatom
Forreria belcheri (Hinds)	giant forreria	*Lima hemphilli* Hertlein and Strong	file shell
Fusinus traski Dall	spindle snail	*Limnoria tripunctata* Menzie	gribble
Gammaridae	amphipod (sub-order)	*Lineus* sp.	nemertean worm
Gari edentula (Gabb)	deepwater gari clam	*Lironeca vulgaris* Stimpson	cymothoid isopod
Garveia sp.	athecate hydroid	*Lissodendoryx noxiosa* de Laubenfels	amorphous sponge
Gastropoda	snails (class)	*Listriolobus* sp.	tongue worm
Glottidia albida (Hinds)	brachiopod	*Livoneca vulgaris* Stimpson	cymothoid isopod
Gonyaulax polyhedra Stein	dinoflagellate	*Loligo opalescens* Berry	squid
Gorgonacea	gorgonians (order)	*Lophogorgia chilensis* (Verrill)	pink sea whip
Grammatophora marina (Lyngbye) Kietzing	diatom	*Lophopanopeus bellus bellus* (Stimpson)	black-clawed crab
Gromia oviformis Dujardin	testate protozoan	*Lophopanopeus diegensis* Rathbun	xanthid crab
Gymnoblastea	hydroids (sub-order)	*Lophopanopeus* sp.	crab
Haliclona cinerea (Grant)	encrusting sponge	*Lovenia cordiformis* Agassiz	heart urchin
Haliclona permollis (Bowerbank)	amorphous sponge	*Loxorhynchus crispatus* Stimpson	masking crab
Haliclona sp.	encrusting sponge	*Loxorhynchus grandis* Stimpson	spider crab
Halosydna brevisetosa Kinberg	polynoid worm	*Loxorhynchus* sp.	spider crab
Halosydna sp.	polynoid worm	Lumbrineridae	polychaete worm (family)
Hemilamprops californica Zimmer	cumacean	*Lumbrineris* sp.	polychaete worm
Hemisquilla stylifera (Milne-Edwards)	mantis shrimp	*Lytechinus anamesus* H. L. Clark	urchin
Henricia leviuscula (Stimpson)	slender arm star	*Macoma nasuta* (Conrad)	bent-nose clam
Henricia sp.	sea star	Malacostraca	crustaceans (sub-class)
Hermissenda crassicornis (Eschscholtz)	aeolid nudibranch	*Mangelia* sp.	turrid snail
Hesionidae	polychaete worms (family)	*Megasurcula carpenteriana* (Gabb)	tower snail
Heterocrypta occidentalis (Dana)	elbow crab	*Membranipora* sp.	ectoproct
Hiatella arctica (Linnaeus)	rough nestling clam	*Mesoporcellio* sp.	isopod
Hinnites multirugosus (Gale)	rock scallop	*Metridium exilis* Hand	solitary anemone
Hippolysmata californica Stimpson	red rock shrimp	*Metridium senile fimbriatum* (Verrill)	plumose anemone
Holoporella brunnea (Hincks)	ectoproct	*Micranellum crebricinctum* Carpenter	close-ringed tube snail
Holothuroidea	sea cucumber (echinoderm class)	*Microciona microjoanna* de Laubenfels	red encrusting sponge
Hydrozoa	hydroid (cnidarian class)	*Mirofolliculina* sp.	bottle animalcule

APPENDIX 3—Cont'd.

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Scientific and Common Names of Plants and Animals Discussed During the Study of Three Multi-Component Man-Made Reefs in Santa Monica Bay; August 1960–January 1965

Scientific Name	Common Name
INVERTEBRATES AND ASCIDIANS—Continued	
Mitra idae Melville	miter snail
Mitrella carinata (Hinds)	keeled dove snail
Mitrella gouldi (Carpenter)	Gould's dove snail
Mitrella tuberosa (Carpenter)	tuberculate dove snail
Modiolus capax (Conrad)	fat horse mussel
Mollusca	mollusks (phylum)
Mopalia muscosa (Gould)	mossy chiton
Muricea californica Aurivillius	sea fan
Muricea fruticosa Verrill	sea fan
Mycale macginitiei de Laubenfels	encrusting sponge
Mysidacea	mysid (crustacean order)
Mytilus edulis Linnaeus	bay mussel
Mytilus sp.	mussel
Myxicola infundibulum (Renier)	polychaete worm
Nassarius perpinguis (Hinds)	fat dog whelk
Nassarius sp.	whelk
Navanax inermis (Cooper)	tectibranch
Navicula sp.	protozoan
Nematoda	nematode worm (phylum)
Nemertina	nemertean worm (phylum)
Nereidae	polychaete worms (family)
Nereis sp.	polychaete worm
Nitzschia sp.	protozoan
Nucula sp.	nut clam
Nudibranchia	nudibranchs (order)
Obelia sp., cf. *dichotoma* Linnaeus	thecate hydroid
Obelia sp., cf. *equilateralis* Fraser	thecate hydroid
Obelia sp., cf. *gracilis* Calkins	thecate hydroid
Obelia sp., cf. *obtusidens* Jaderhold	thecate hydroid
Obelia sp., cf. *plicata* Hincks	thecate hydroid
Obelia sp.	thecate hydroid
Ocenebra poulsoni (Carpenter)	Poulson's dwarf triton snail
Ocenebra sp.	triton snail
Octopus bimaculatus Verrill	two spotted octopus
Octopus rubescens Berry	octopus
Octopus sp.	octopus
Olivella baetica Carpenter	olive snail
Olivella pedroana Conrad	olive snail
Onuphidae	polychaete worms (family)
Opheliidae	polychaete worms (family)
Ophiodermella incisa (Carpenter)	incised tower snail
Ophiopteris papillosa (Lyman)	brittle star
Ophiothrix spiculata Le Conte	brittle star
Ophiuroidea	brittle star (class)
Opisthopus transversus Rathbun	pea crab (commensal)
Opisthobranch	mollusk (sub-class)
Orbiniidae	polychaete worm (family)
Ostracoda	ostracods (crustacean sub-class)
Oxyrhyncha	crab (super family)
Pachycerianthus sp.	tube anemone
Pachycheles holosericus Schmitt	porcelain crab
Pachycheles pubescens Holmes	porcelain crab
Pachycheles rudis Stimpson	big-clawed porcelain crab
Pachygrapsus crassipes Randall	striped shore crab
Paguristes ulreyi Schmitt	hermit crab
Pandalus gurneyi Stimpson	coon-striped shrimp
Panulirus interruptus (Randall)	California spiny lobster
Parastichopus californicus (Stimpson)	California sea cucumber
Parastichopus parvimensis (H. L. Clark)	sea cucumber
Parvilucina tenuisculpta Carpenter	lucina clam
Patiria miniata (Brandt)	bat star
Pecten diegensis Dall	San Diego scallop
Pelagia panopyra (Peron and Lesueur)	purple striped jelly-fish
Pelecypoda	clam (class)
Pennatulacea	sea pens (order)
Petricola sp.	nestling clam
Petrolisthes eriomerus Stimpson	porcelain crab
Phascolosoma agassizii Keferstein	peanut worm
Pherusa capulata (Moore)	flabelligerid worm
Phidolopora pacifica (Robertson)	ectoproct
Phoronida	phoronid (phylum)
Phoronis sp.	phoronid
Phragmatopoma californica (Fewkes)	sabellariid worm
Phyllodocidae	polychaete worm (family)
Pilumnus spinohirsutus (Lockington)	xanthid crab
Pisaster brevispinus (Stimpson)	short-spine sea star
Pisaster giganteus (Stimpson)	giant sea star
Pisaster ochraceus (Brandt)	ochre sea star
Platyhelminthes	flatworm (phylum)

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Scientific Name	Common Name
Plumularia alicia Torrey	thecate hydroid
Pododesmus cepio (Gray)	abalone jingle
Polinices lewisii (Gould)	Lewis' moon snail
Polinices sp.	moon snail
Polycera atra MacFarland	orange spiked nudibranch
Polychaeta	worm (class)
Polycladida	flatworm (order)
Polydora sp.	spionid worm
Polynoidae	polychaete worm (family)
Polyplacophora	chiton (class)
Porifera	sponge (phylum)
Protothaca staminea (Conrad)	common littleneck
Protozoa	protozoans (phylum)
Pteropurpura festivus (Hinds)	festive murex
Pteropurpura macroptera (Deshayes)	muricid snail
Pugettia producta (Randall)	kelp crab
Pugettia richii Dana	sharp-nosed crab
Pugettia sp.	kelp crab
Pycnogonida	sea spider (class)
Pyramidellidae	snail (family)
Pyura haustor (Stimpson)	solitary ascidian
Randallia ornata (Randall)	purple globe crab
Renilla kolliberi (Pfeffer)	sea pansy
Retusa sp.	barrel bubble snail
Rhynchozoon rostratum Busk	ectoproct
Sabellariidae	polychaete worms (family)
Sabellaria cementarium Moore	sabellariid worm
Sabellaria sp.	sabellariid worm
Sabella sp.	sabellid worm
Sabellidae	polychaete worms (family)
Salmacina tribranchiata (Moore)	serpulid worm
Salpa (=Thetys) *vagina* (Tilesius)	salp
Saxidomus nuttalli Conrad	common Washington clam
Scaphopoda	mollusks (class)
Scrupocellaria diegensis Robertson	ectoproct
Scypha ciliata (Fabricius)	thistle sponge
Scyphozoa	scyphozoan (Cnidarian class)
Scyra acutifrons Dana	masking crab
Serpula vermicularis Linnaeus	serpulid worm
Serpula sp.	serpulid worm
Serpulidae	polychaete worms (family)
Serpulorbis squamigerus (Carpenter)	scaled worm-snail
Simnia sp.	snail
Sipunculoidea	peanut worm (phylum)
Spionidae	polychaete worms (family)
Spirobranchus spinosus Moore	serpulid worm
Spirobranchus sp.	serpulid worm
Spirontocaris brevirostris (Dana)	bent-back shrimp
Spirontocaris cristata (Stimpson)	bent-back shrimp
Spirontocaris palpator (Owen)	bent-back shrimp
Spirontocaris prionota (Stimpson)	bent-back shrimp
Spirontocaris sp.	bent-back shrimp
Spirorbis sp.	serpulid worm
Strongylocentrotus purpuratus (Stimpson)	purple sea urchin
Styela montereyensis (Dall)	solitary ascidian
Stylarioides inflata (Treadwell)	flabelligerid worm
Stylatula elongata (Gabb)	elongata sea pen
Stylatula sp.	sea pen
Stylochus zanzibaricus (Skerman)	flatworm
Syllidae	polychaete worms (family)
Tanaidacea	tanaid (crustacean order)
Tealia coriacea (Cuvier)	anemone
Terebra pedroana Dall	San Pedro auger
Terebellidae	polychaete worms (family)
Teredo navalis Linnaeus	shipworm
Tetraclita squamosa elegans Darwin	acorn barnacle
Thalamoporella californica (Levinson)	ectoproct
Thelepus crispus Johnson	terebellid worm
Trachycardium quadragenarium (Conrad)	spiny cockle
Tresus nuttalli (Conrad)	gaper clam
Trichobranchidae	polychaete worm (family)
Triopha carpenteri (Stearns)	dorid nudibranch
Tubularia crocea (Agassiz)	athecate hydroid
Tubularia sp.	athecate hydroid
Tubulipora admiranda Osburn	ectoproct
Tunicata	ascidians (sub-phylum)
Turbonilla kelseyi Dall and Bartsch	Kelsey's turbonille
Turbellaria	flatworm (family)
Turcica caffea Gabb	top snail
Valvifera	isopod (sub order)
Victorella argilla Banta	encrusting ectoproct
Xylophaga washingtona Bartsch	wood-boring mollusk
Xylophaga sp.	wood-boring mollusk
Xylophaga sp., cf. *globosa* Sowerby	wood-boring mollusk
Zygherpe hyaloderma de Laubenfels	encrusting sponge
VERTEBRATES	
Agonidae	poachers (family)
Agonopsis sterletus (Gilbert)	southern spearnose poacher

APPENDIX 3—Cont'd.

APPENDIX 3—Continued

Scientific and Common Names of Plants and Animals Discussed During the Study of Three Multi-Component Man-Made Reefs in Santa Monica Bay; August 1960–January 1965

Scientific Name	Common Name
VERTEBRATES—Continued	
Alloclinus holderi (Lauderbach)	island kelpfish
Amphistichus argenteus Agassiz	barred surfperch
Artedius creaseri (Hubbs)	roughcheek sculpin
Artedius notospilotus Girard	bonehead sculpin
Atherinidae	silversides (family)
Atherinops affinis (Ayres)	topsmelt
Atherinopsis californiensis Girard	jacksmelt
Bathymasteridae	ronquils (family)
Batrachoididae	toadfishes (family)
Blenniidae	combtooth blennies (family)
Bothidae	lefteye flounders (family)
Branchiostegidae	tilefishes (family)
Brosmophycis marginatus (Ayres)	red brotula
Brotulidae	brotulas (family)
Carangidae	jacks (family)
Carapidae	pearl-fishes (family)
Caulolatilus princeps (Jenyns)	ocean whitefish
Cephaloscyllium ventriosum (Garman)	swell shark
Chromis punctipinnis (Cooper)	blacksmith
Citharichthys sordidus (Girard)	Pacific sanddab
Citharichthys stigmaeus Jordan and Gilbert	speckled sanddab
Citharichthys sp.	sanddab
Clinidae	clinids (family)
Coryphopterus nicholsi (Bean)	blackeye goby
Cottidae	sculpin (family)
Cymatogaster aggregata Gibbons	shiner perch
Cynoscion nobilis (Ayres)	white seabass
Cypselurus californicus (Cooper)	California flying fish
Dasyatidae	stingray (family)
Embiotocidae	surfperches (family)
Embiotoca jacksoni Agassiz	black perch
Engraulidae	anchovy (family)
Engraulis mordax Girard	northern anchovy
Eopsetta jordani (Lockington)	petrale sole
Genyonemus lineatus (Ayres)	white croaker
Girella nigricans (Ayres)	opaleye
Girellidae	nibblers (family)
Gobiesocidae	clingfishes (family)
Gobiesox rhessodon (Rosa Smith)	clingfish
Gobiidae	goby (family)
Halichoeres semicinctus (Ayres)	rock wrasse
Heterodontidae	horn sharks (family)
Heterodontus francisci (Girard)	horn shark
Hexagrammidae	greenlings (family)
Hippoglossina stomata Eigenmann and Eigenmann	bigmouth sole
Hyperprosopon argenteum Gibbons	walleye surfperch
Hypsoblennius gilberti (Jordan)	rockpool blenny
Hypsopsetta guttulata (Girard)	diamond turbot
Hypsurus caryi (Agassiz)	rainbow seaperch
Labridae	wrasses (family)
Lythrypnus dalli Gilbert	bluebanded goby
Lythrypnus zebra (Gilbert)	zebra goby
Medialuna californiensis (Steindachner)	halfmoon
Microstomus pacificus (Lockington)	dover sole
Mola mola (Linnaeus)	mola (ocean sunfish
Molidae	molas (family)
Myliobatidae	eagle rays (family)
Myliobatis californicus Gill	bat ray
Neoclinus blanchardi Girard	sarcastic fringehead
Neoclinus uninotatus Hubbs	onespot fringehead
Ophidiidae	cusk-eels (family)
Ophiodon elongatus Girard	lingcod
Otophidium scrippsi Hubbs	basketweave cusk-ee
Otophidium taylori (Girard)	spotted cusk-eel
Oxyjulis californica Günther	señorita
Oxylebius pictus Gill	painted greenling
Paralabrax clathratus (Girard)	kelp bass
Paralabrax nebulifer (Girard)	sand bass
Paralichthys californicus (Ayres)	California halibut
Parophrys vetulus Girard	English sole
Phanerodon furcatus Girard	white seaperch
Pimelometopon pulchrum Ayres	California sheephead
Platyrhinoidis triseriata (Jordan and Gilbert)	California thornback
Pleuronectidae	righteye flounders (family)
Pleuronichthys coenosus Girard	C-O turbot
Pleuronichthys decurrens Jordan and Gilbert	curlfin turbot
Pleuronichthys verticalis Jordan and Gilbert	hornyhead turbot
Pomacentridae	damselfishes (family)

APPENDIX 3
Scientific and Common Names of Plants and Animals Discussed During the Study of Three Multi-Component Man-Made Reefs in Santa Monica Bay; August 1960–January 1965

Scientific Name	Common Name	Scientific Name	Common Name
Porichthys notatus Girard	plainfin midshipman	*Sebastes serranoides* (Eigenmann and Eigenmann)	olive rockfish
Rathbunella hypoplecta (Gilbert)	smooth ronquil	*Sebastes serriceps* (Jordan and Gilbert)	treefish
Rhacochilus toxotes Agassiz	rubberlip perch	*Sebastes vexillaris* (Jordan and Gilbert)	whitebelly rockfish
Rhacochilus vacca (Girard)	pile perch	*Sebastes* sp.	rockfish
Rhinobatidae	guitarfish (family)	*Seriola dorsalis* (Gill)	California yellowtail
Rhinobatos productus (Ayres)	shovelnose guitarfish	*Seriphus politus* Ayres	queenfish
Sarda chiliensis (Curvier)	Pacific bonito	Serranidae	sea bass (family)
Sciaenidae	croakers (family)	*Sphyraena argentea* Girard	California barracuda
Scomber japonicus Houttuyn	Pacific mackerel	Sphyraenidae	barracudas (family)
Scombridae	mackerel (family)	*Squalus acanthias* Linnaeus	spiny dogfish
Scorpaena guttata Girard	sculpin (California scorpionfish)	*Squatina californica* Ayres	California angel shark
Scorpaenichthys marmoratus (Ayres)	cabezon	Squatinidae	angel shark (family)
Scorpidae	halfmoons (family)	*Stereolepis gigas* Ayres	giant sea bass
Scyliorhinidae	cat shark (family)	Synodontidae	lizardfish (family)
Sebastes atrovirens (Jordan and Gilbert)	kelp rockfish	*Synodus lucioceps* (Ayres)	California lizardfish
Sebastes auriculatus Girard	brown rockfish	Torpedinidae	electric ray (family)
Sebastes chrysomelas (Jordan and Gilbert)	black-and-yellow rockfish	*Torpedo californica* (Ayres)	Pacific electric ray
Sebastes dalli (Eigenmann and Beeson)	calico rockfish	*Trachurus symmetricus* (Ayres)	jack mackerel
Sebastes miniatus (Jordan and Gilbert)	vermilion rockfish	*Urolophus halleri* (Cooper)	round stingray
Sebastes mystinus (Jordan and Gilbert)	blue rockfish	Vertebrata	vertebrates (sub-phylum)
Sebastes paucispinis Ayres	bocaccio	*Xystreurys liolepis* Jordan and Gilbert	fantail sole
Sebastes rastrelliger (Jordan and Gilbert)	grass rockfish		

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APPENDIX 1

Invertebrates and Ascidians Recorded from the Hermosa Beach Reef Test Block Series; 1960–61

Component and abundance*	Streetcar									Automobile bodies								Rockpile										Concrete shelters							
Date block removed	Oct '60	Nov '60	Dec '60	Jan '61	Feb '61	Mar '61	Apr '61	May '61	Jun '61	Oct '60	Nov '60	Dec '60	Mar '61	Apr '61	May '61	Jun '61	Jul '61	Oct '60	Nov '60	Dec '60	Jan '61	Feb '61	Mar '61	Apr '61	May '61	Jun '61	Jul '61	Oct '60	Nov '60	Dec '60	Jan '61	Mar '61	Apr '61	May '61	Jun '61
Organisms / Days block in place	30	62	94	134	157	182	211	245	269	30	59	97	176	211	245	269	314	27	59	93	134	157	176	211	245	269	314	27	62	93	134	176	209	245	269
Porifera																																			
Leucosolenia botryoides	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S	S	S	C	--	--	--	--	--	--	S	C
Cnidaria																																			
Hydrozoa																																			
Bougainvillia sp., cf. *mertensi*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	C	--	--	--	--
Eudendrium sp., cf. *ramosum*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S	--
Garveia sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S†	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S
Clytia kincaidi	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	C	--	--	--	--	--	--	--	--	--
Clytia sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	C†	--	--	--	--	--	--	--	--	--	--	C	--	--	--	--	--	--	--	--	--
Obelia sp., cf. *dichotoma*	--	--	--	--	--	--	--	--	--	--	A†	--	--	--	--	--	--	--	--	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Obelia sp., cf. *equilateralis*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	--	--	--	--	--	--	--	--	--	--	--	--
Obelia sp., cf. *gracilis*	--	--	--	--	--	--	--	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Obelia sp., cf. *plicata*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	C	--	--	--	--	--	--	--	--	--	--	--	--	--
Obelia sp.	--	--	--	C	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	C	--	A	C	A	--	--	--	--	--	S	S	--	S	--
hydroid (unid.)	--	--	C	--	--	C	S	--	--	S	--	C	S	--	--	S	S	--	S	--	--	--	--	C	--	--	C	--	A	C	--	--	S	--	--
Platyhelminthes																																			
Polycladida	--	--	1	--	2	6	53	7	9	--	4	1	--	12	25	29	3	--	7	1	1	1	2	2	1	3	3	--	1	--	--	--	--	16	--
Nemertina	--	--	--	--	--	--	1	2	8	--	--	--	--	--	5	1	--	--	--	--	--	2	--	--	10	3	--	--	--	--	--	--	--	1	7
Annelida																																			
Polychaeta																																			
Chrysopetalidae	--	--	--	P	--	--	40	136	83	--	--	--	5	19	56	14	10	--	--	--	--	3	5	P	P	39	9	--	--	--	1	3	--	97	99
Flabelligeridae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--
Hesionidae	--	--	--	--	--	--	5	--	2	--	--	--	4	3	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	1
Lumbrineridae	--	--	--	P	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--
Nereidae	--	--	--	--	--	--	20	43	33	--	--	--	12	4	30	11	9	--	--	--	--	--	2	--	8	8	10	--	--	--	3	--	2	28	28
Onuphidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--
Opheliidae	--	--	--	--	--	--	18	--	3	--	--	--	3	--	1	2	--	--	--	--	--	--	4	--	--	14	--	--	--	--	--	--	--	1	--
Phyllodocidae	--	--	--	--	--	--	8	14	15	--	--	--	--	2	2	9	2	--	--	--	--	--	--	--	--	15	5	--	--	--	1	1	--	16	15
Polynoidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	P	--	--	--	--	--	--	--	1	97	26
Sabellariidae	--	--	--	--	--	--	40	27	25	--	--	--	1	1	--	1	2	--	--	--	--	--	1	3	--	20	8	--	--	--	--	--	--	--	--
Sabellidae	--	--	--	--	--	--	21	22	10	--	--	--	8	2	15	4	--	--	--	--	--	--	--	--	--	22	5	--	--	--	1	--	2	19	30
Serpulidae	--	--	--	--	--	--	1	5	3	--	--	1	--	--	4	--	--	--	--	--	--	1	--	6	17	7	1	--	--	--	1	--	6	4	1
Spionidae	--	--	--	--	--	--	3	21	9	--	--	--	--	1	7	2	--	--	--	--	--	--	1	--	--	8	--	--	--	--	--	--	3	8	24
Syllidae	--	--	--	--	--	--	3	3	9	--	--	--	4	1	8	1	4	--	--	--	--	5	4	--	--	5	--	--	--	--	1	2	2	3	21
Terebellidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--
Trichobranchidae	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--
polychaete (unid.)	--	--	4	--	--	20	7	2	5	--	15	9	--	--	--	--	--	--	21	8	3	--	--	62	--	--	--	--	23	6	--	--	--	--	--
Sipunculoidea																																			
Phascolosoma agassizii	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--
Arthropoda																																			
Crustacea																																			
Ostracoda	--	--	--	5	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	1	--	--	1	10	--	--	--	--	--	--	--	--	--	--
Copepoda	--	--	17	7	--	7	--	--	--	2	250	--	--	--	--	--	--	--	38	27	12	--	--	--	15	--	--	--	48	1	--	--	--	--	--
Cirripedia																																			
Balanus concavus pacificus	--	--	3	3	7	19	--	3	2	--	12	27	--	52	12	10	100	--	--	--	20	35	24	7	11	4	1	--	--	--	2	--	2	2	1
Balanus trigonus	--	--	--	3	--	--	1	4	2	--	--	--	--	--	3	--	--	--	--	--	28	6	1	4	1	3	5	--	--	--	--	--	--	4	--
Balanus sp., cf. *concavus pacificus*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	152	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Balanus sp.	73	60	--	2	--	--	--	--	--	18	--	--	--	450	--	--	--	242	--	126	--	--	--	5	--	--	--	--	16	4	1	--	--	--	--
Cumacea	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--
Isopoda																																			
Limnoria tripunctata	--	--	4	--	--	3	--	--	--	--	--	--	--	42	30	4	2	--	--	9	26	--	35	148	410	250	180	--	--	--	--	22	2	3	9
Mesoporcellio sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--
Gammaridea	1	35	3	8	39	113	117	190	138	--	2	4	--	32	93	49	65	3	11	2	3	12	7	50	104	64	49	--	2	1	1	5	--	625	295
Caprellidea	--	--	1	1	1	--	6	46	--	--	3	2	--	2	78	102	60	--	--	--	--	--	--	16	300	150	170	--	1	--	3	--	--	10	11
Decapoda																																			
Spirontocaris palpator	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
shrimp (unid.)	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cancer sp.	--	--	--	--	--	--	1	--	--	--	--	--	--	--	2	3	--	--	--	--	1	--	--	--	3	1	2	--	--	--	--	--	--	--	--
Loxorhynchus sp.	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--
crab (unid.)	--	--	1	--	--	1	--	--	1	--	3	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--
Pycnogonida	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	2	--	--	--	--	--	--	--	--	--
Mollusca																																			
Pelecypoda																																			
Bankia setacea	--	--	--	--	5	5	15	72	170	--	--	--	--	10	152	18	25	--	--	--	1	--	2	6	28	24	25	--	--	--	--	5	9	28	58
Chama pellucida	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--
Hiatella arctica	--	--	--	--	--	8	1	4	1	--	--	--	--	--	--	P	--	--	--	--	--	--	--	1	2	5	7	--	--	--	--	2	1	2	6
Hinnites multirugosus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
Kellia laperousii	--	--	--	--	--	21	--	--	--	--	--	--	--	--	--	P	--	--	--	--	--	--	--	--	6	2	2	--	--	--	--	4	--	--	--
Leptopecten latiauratus	1	--	--	3	--	31	1	--	--	--	--	--	--	--	--	--	--	--	4	3	15	7	35	18	3	--	6	--	3	--	4	23	1	--	--
Modiolus capax	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--
Mytilus edulis	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--
Pelycepod (unid.)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
Pododesmus cepio	--	--	3	--	--	--	--	3	1	--	--	--	--	--	--	--	--	--	2	2	1	3	--	--	6	1	1	--	7	1	--	--	--	1	1
Teredo navalis	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	--	--	--
Xylophaga sp.	--	--	--	1	--	--	1	2	2	--	--	--	--	--	1	--	--	--	--	--	1	2	--	3	1	2	5	--	--	--	--	2	1	--	5
Gastropoda																																			
Acanthodoris lutea	--	--	--	--	--	--	--	3	9	--	--	--	--	--	--	2	1	--	--	--	--	--	--	--	--	4	1	--	--	--	--	1	--	6	9
Crepidula onyx	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Crepidula perforans	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--
Crepipatella lingulata	--	--	--	--	1	--	1	--	1	--	--	--	--	--	--	--	2	--	--	--	--	--	--	4	3	3	4	--	--	--	--	--	--	--	3
Dendronotus frondosus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
Dirona albolineata	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	2
Doto sp.	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--
Hermissenda crassicornis	--	--	--	--	--	--	--	1	--	--	6	--	--	--	--	--	6	--	--	--	--	--	--	--	--	1	--	--	4	3	--	1	--	--	--
nudibranch (unid. aeolid)	2	1	--	--	--	2	--	--	--	--	--	3	--	--	--	--	--	--	1	--	--	--	--	4	3	--	--	--	--	--	--	--	--	--	--
nudibranch (unid. dorid)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	1
Ectoprocta																																			
Callopora circumclathrata	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6†	8†	--	1†	--	--	--	--	--	--	--	2†
Callopora sp.	--	--	--	--	--	--	--	--	1†	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tubulipora admiranda	--	--	--	--	--	--	--	--	1†	--	--	--	--	--	--	1†	2†	--	--	--	--	--	--	--	--	1†	1†	--	--	--	--	--	4†	A†	2†
Victorella argilla	--	--	--	--	--	--	2†	C†	C†	--	--	--	P†	P†	S†	--	1†	--	--	--	--	--	--	--	P	C	A	--	--	--	1†	--	P†	A†	A†
Entoprocta																																			
Barentsia discreta	--	--	--	--	--	--	P†	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S†	--	--	--	--	--	--	--	--	--
Chordata																																			
Ascidiacea																																			
Chelyosoma productum	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	1

* Abundance symbols

P = Present but relative abundance not estimated.
S = Sparse—widely scattered on the block but nowhere numerous.
C = Common—widely scattered on the block but only occasionally numerous.
A = Abundant—numerous and evenly distributed on the block.
† = Colony.

APPENDIX 2

Invertebrates and Ascidians Recorded from the Santa Monica and Malibu Reefs Test Block Series; 1960–61

Component and abundance*	Santa Monica																														Malibu																						
	Streetcar										Rockpile								Concrete Shelters												Streetcar												Concrete Shelters										
Date block recovered	Oct '60	Nov '60	Dec '60	Jan '61	Feb '61	Mar '61	Apr '61	May '61	Jun '61	July '61	Oct '60	Nov '60	Dec '60	Jan '61	Feb '61	Apr '61	May '61	Jun '61	Oct '60	Nov '60	Dec '60	Jan '61	Feb '61	Apr '61	May '61	Jun '61	July '61	Aug '61	Sep '61	Oct '61	Oct '60	Nov '60	Dec '60	Jan '61	Feb '61	Mar '61	Apr '61	May '61	Jun '61	July '61	Aug '61	Sep '61	Oct '60	Nov '60	Dec '60	Jan '61	Feb '61	Mar '61	Apr '61	May '61	Jun '61	July '61	Aug '61
Organisms — Days block in place	26	62	85	130	153	204	210	244	266	317	26	62	85	130	153	210	244	266	26	62	85	130	153	210	244	266	317	337	365	402	30	64	83	122	149	170	205	237	262	310	329	357	30	64	83	122	149	170	205	237	261	310	329
Protozoa																																																					
Gromia oviformis	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Folliculina sp.	--	--	--	--	--	A	--	--	--	--	--	--	--	--	--	--	P	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Porifera																																																					
Leucosolenia botryoides	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Leucosolenia sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S	--	--	--	S	S	--	--	--	--	--	--	--	S	C	C	C
Cnidaria																																																					
Hydroza																																																					
Bimeria sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	--	--	--	--	--
Bougainvillia sp., cf. *mertensi*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S	--	--	--	--	--	--	--	--	--	--	--	S	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Eudendrium sp., cf. *ramosum*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S	--	--	S	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Garveia sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S	--	--	--	--	--	--	--	--	--	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tubularia crocea	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Campanularia sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Obelia sp., cf. *dichotoma*	--	S	S	S	--	--	--	--	--	--	--	A	A	--	--	--	--	C	--	--	--	--	S	--	--	--	--	--	--	--	S	--	--	--	--	--	--	--	A	--	--	--	--	--	S	C	S	--	--	--	--	--	--
Obelia sp., cf. *gracilis*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	C	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	C	--	--	--	--	--	--	--	--	--	--	S	--	--	--	--
Obelia sp., cf. *obtusidens*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Obelia sp.	--	--	--	--	--	S	S	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S	--	--	S	S	--	--	S	S	--	--	--	--	--	C	S	--	--	S	A	A	--	--	--	--	--	--	--	--	S	--	S
hydroid (unid.)	--	--	--	--	--	--	--	--	--	S	--	--	--	--	--	--	--	--	--	C	C	--	--	--	--	S	--	--	--	--	--	C	C	C	--	--	--	--	--	--	--	--	--	S	--	--	--	--	S	S	S	S	--
Anthozoa																																																					
Corynactis californica	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Platyhelminthes																																																					
Polycladida	--	--	2	--	--	5	3	3	2	2	--	1	2	--	5	14	--	7	1	11	1	--	1	4	17	10	1	1	2	7	1	--	--	5	1	1	22	25	5	18	7	12	2	--	8	2	1	2	4	--	4	3	3
Nemertina	--	--	1	--	--	6	4	14	--	8	--	--	2	--	--	4	19	6	--	5	--	--	1	5	15	16	6	5	--	4	--	--	--	4	2	--	4	10	12	6	5	6	--	--	--	--	2	2	1	10	2	--	--
Annelida																																																					
Polychaeta																																																					
Ampharetidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Arabellidae	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chaetopteridae	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	14	1	6	--	--	--	--	--	--	--	--	3	--	--	6	--	--	--	--	--	--	--	--	3	--	--
Chrysopetalidae	--	--	--	--	9	26	13	55	97	62	--	--	--	--	--	3	77	40	--	--	--	--	9	45	130	107	161	162	23	108	--	--	--	--	5	2	--	140	16	--	--	--	--	--	--	--	5	8	2	P	2	--	--
Cirratulidae	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dorvilleidae	--	--	--	--	--	--	--	--	1	4	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hesionidae	--	--	--	--	--	1	--	8	1	31	--	--	--	--	--	4	1	2	--	--	--	--	1	2	1	2	--	3	2	3	--	--	--	--	--	4	--	1	--	--	--	--	--	--	--	--	--	12	--	P	--	--	--
Nereidae	--	--	--	--	15	20	31	23	30	5	--	--	--	--	--	12	47	32	--	--	--	35	24	2	47	45	17	19	1	6	--	--	--	--	38	6	7	27	17	P	--	P	--	--	--	--	30	38	29	100	2	5	5
Onuphidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	P	--	5	--
Opheliidae	--	--	--	--	--	--	1	--	5	79	--	--	--	--	--	2	2	3	--	--	--	--	--	--	--	2	14	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Orbiniidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	P	--	P	--	--	--	--	--	2	--	P	--	--	--
Phyllodocidae	--	--	--	--	1	7	3	29	27	30	--	--	--	--	--	2	2	2	--	--	--	--	1	--	8	5	13	22	3	22	--	--	--	--	--	--	--	11	1	P	--	--	--	--	--	--	--	--	1	--	4	5	--
Polynoidae	--	--	--	--	--	--	--	1	5	5	--	--	--	1	--	--	1	1	--	--	--	--	--	1	4	1	4	9	1	2	--	--	--	--	--	--	--	4	3	P	--	1	--	--	--	--	--	--	1	P	--	--	--
Sabellariidae	--	--	--	--	4	34	12	29	28	4	--	--	--	--	--	2	37	19	--	--	--	--	--	62	54	68	40	8	8	4	--	--	--	--	1	--	--	6	3	--	--	--	--	--	--	--	1	--	4	--	3	--	--
Sabellidae	--	--	--	--	26	90	93	49	26	2	--	--	--	1	--	6	67	8	--	--	--	--	26	93	146	14	14	5	1	17	--	--	--	--	5	1	--	29	21	P	--	2	--	--	--	--	5	6	8	12	8	7	3
Serpulidae	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	1	1	2	--	--	--	5	--	--	3	1	--	--	--	--	--	--	--	--	--	--	--	--	--	P	--	--	--	2	--	--	--	1	2	5	--	13	13
Spionidae	--	--	--	--	1	4	2	5	--	4	--	--	--	--	--	11	10	9	--	--	--	--	2	10	3	27	3	1	1	3	--	--	--	--	1	--	--	2	5	--	--	--	--	--	--	--	1	4	73	--	5	--	--
Syllidae	--	--	--	--	23	27	18	11	--	3	--	--	--	1	--	20	23	15	--	--	--	--	16	29	32	13	6	3	1	8	--	--	--	--	34	--	--	7	5	--	--	--	--	--	--	--	50	--	5	--	5	--	--
Terebellidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
polychaete (unid.)	--	9	4	46	--	1	1	2	--	5	1	15	11	4	--	1	1	7	5	25	12	1	--	2	--	3	--	--	--	--	--	9	9	32	--	22	28	--	--	75	97	67	21	19	95	90	--	--	--	--	--	--	75
Sipunculoidea																																																					
Phascolosoma agassizii	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Crustacea																																																					
Ostracoda	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	13	--	--	--	--	--	--	20
Copepoda	--	31	--	4	--	--	--	--	--	--	--	258	42	--	--	--	--	--	--	2	3	--	--	--	--	--	--	--	--	--	--	7	48	--	--	--	--	--	--	5	12	63	--	--	--	--	--	--	--	--	--	--	--
Cirripedia																																																					
Balanus concavus pacificus	--	--	--	--	3	5	11	--	18	2	--	--	--	--	21	2	5	4	--	--	--	--	--	6	11	5	6	6	--	14	--	--	--	--	2	--	50	50	--	5	--	--	--	--	228	19	4	30	25	7	60	2	2
Balanus tintinnabulum californicus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Balanus trigonus	--	--	--	--	5	3	--	--	7	1	--	--	--	--	9	3	1	4	--	--	--	--	--	--	--	7	1	1	5	1	--	--	--	--	20	100	100	10	--	62	--	7	--	--	--	--	1	25	5	--	2	--	3
Balanus sp., cf. *concavus pacificus*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	71	--	--	--	--	--	--	--	--	--
Balanus sp.	30	42	45	40	--	--	--	--	--	2	179	139	57	117	1	--	--	--	174	56	71	24	1	--	--	--	--	--	35	--	540	27	42	462	--	81	--	--	--	78	315	63	808	--	--	--	--	--	--	--	--	--	225
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Gammaridea	--	1	--	11	--	365	24	1,300	15	44	--	--	--	3	18	382	221	17	--	--	4	--	85	102	22	301	75	33	13	48	--	11	96	84	133	266	50	1,300	53	490	600	805	3	--	1	8	82	45	12	23	20	4	18
Caprellidea	--	5	25	21	--	40	14	80	4	31	--	2	16	5	25	160	143	180	--	2	2	51	1	14	215	200	209	98	11	48	2	26	18	9	16	35	35	1,150	1,200	925	900	1,365	3	--	--	2	4	14	82	22	12	3	38
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* Abundance symbols
P = Present on the block but relative abundance not estimated.
S = Sparse—widely scattered on the block but nowhere numerous.
C = Common—widely scattered on the block and only occasionally numerous.
A = Abundant—numerous and evenly distributed on the block.
† = Colony.