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MARINE ZONATION AND ECOLOGY OF COCOS ISLAND, OFF CENTRAL AMERICA

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by Gerald J. Bakus[2/]

During March 29 to April 8, 1972, the author participated in a cruise to Cocos Island (Isla del Coco, a Costa Rican island located at 5°N and 87°W), about 500 kilometers (300 miles) off Pacific Central America. The Janss Foundation vessel, R/V Searcher, was operating in Central America on a number of research projects, including those on the Cocos Island investigations. Although the primary purpose of the journey was to document the major nektonic groups, including crustaceans and fishes, and obtain data on holothurians that are toxic to fishes, an effort was made to gather information on the zonation of dominant marine organisms.

Earlier accounts of studies on Cocos Island are well summarized and a species list is given by Hertlein (1963). The present study is the first report on underwater zonation at Cocos Island. The following account is based on observations by eight scientists, during intertidal visits and 13 subtidal dives ranging from 0 to 31 m on the leeward side of the island, in the vicinity of Bahia de Chatham and Bahia Wafer. Station data and specific information are available from the present author or the Section of Fishes, Los Angeles County Natural History Museum, Los Angeles, California.

Cocos Island is the only portion of the Cocos Ridge appearing above sea-level. This Ridge extends in a south-westerly direction from Costa Rica almost to the Galapagos Islands and has relatively deep trenches on the north and south sides. The steep basaltic island (elevation 850 m) is covered with lush tropical vegetation (more than 200 species of plants, Dr. Manuel Murillo, personal communication), including a few patches of coconut palms (fig. 1). It has an abundant seabird population (e.g. frigate birds, boobies, terns, petrels) and 7 species of land birds (Hertlein, 1963). Feral pigs and goats roam the island. Protected bays have gentle underwater slopes covered with sand, living coral and coral

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2/ Allan Hancock Foundation, University of Southern California, Los Angeles, California 90007.

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rubble; exposed portions have gentle to moderate slopes; and offshore islets possess moderate to steep slopes. The tidal amplitude was about 2 m and water termperatures ranged from 29 to 30°C during out stay. A slight thermocline (1.1 to 1.7°C temperature change) occurred between depths of 13 and 22 m at this season (end of the tropical dry season). Underwater visibility is often 30 m, especially below the thermocline.

ZONATION OF THE LEEWARD SIDE

Protected intertidal zone (bays):

As the intertidal is approached the lush island vegetation gives way to lichen-covered rocks followed by a band of thin, black encrusting algae (Hildenbrandia or Petrocelis?). The rocky substratum is covered by Porolithon and/or Lithophyllum spp. at the very lowest tidal levels (fig. 2). The intertidal zone has a relatively low invertebrate species diversity (based on the observed numbers of species). This is characteristic of a number of tropical intertidal rocky shores or intertidal unbroken limestone reef flats (Atsatt, 1972; Paine, 1966; Risk, 1972). The snail Nerita scabricosta lives at the highest level in the intertidal; the rocks were covered with hundreds of its egg capsules, especially in small pools of water. Just below Nerita is the snail Littorina modesta followed downward by the gastropods Purpura pansa, Thais melones, Scurria mesoleuca, Planaxis planicostatus, and Siphonaria gigas at the lowest levels. Oysters (Ostrea palmula) and the large chiton Chiton stokesii are common at the level of Scurria. The shore crab Grapsus grapsus is common in the upper intertidal and supralittoral. The rock louse Ligia ranges throughout much of the intertidal.

The shallow bays contain, in addition to rocks at their edges, sand and coral rubble. A few sponges (Haliclona sp., Tethya aurantia), snails such as Mitra, Conus and Cypraea (e.g. C. moneta), abundant alpheid shrimps and some crabs (Grapsidae; Porcelanidae, Petrolisthes spp.) occur in the protection of coral rubble between 0 and 2 m in depth.

A small freshwater stream, near its entry into Bahia Wafer, contained 6 species of freshwater fishes (William Bussing, personal communication), remains of swimming crabs (Portunidae), numerous small shrimps and large snails (probably Neritina latissima).

Exposed intertidal zone:

On exposed basaltic cliffs outside the bays, lichens again grow at a high level, followed downward by a 1 to 1.5 m band of Hildenbrandia or Petrocelis (?) then a richly covered 1 m band of Porolithon and/or Lithophyllum spp. which continues

far below the water surface (fig. 3) (on the windward side of the island, Hildenbrandia or Petrocelis (?) may extend as much as 4 m high when exposed to heavy swell). The most characteristic animal is the pink barnacle, Tetraclita stalactifera, which forms a dense 1 m band that may extend as far as 3 m below the water surface. The barnacle is densest in the upper half of the exposed Porolithon band. Again, Nerita scabricosta lives at the highest tidal level followed by Purpura pansa. Thais melones, and Siphonaria gigas. Grapsus grapsus is common throughout much of the intertidal. Heavy surge prevented close observations for smaller animals.

Subtidal zone:

Outside of bays (as well as in deeper waters inside the bays), the subtidal benthic fauna is dominated by the mushroom-shaped hermatypic coral Porites californica which when well developed simulates an inverted stack of medusoid strobilae (fig. 4). Porites extends almost from the water surface downward to a depth of from 8 to at least 31 m, where it gives way to sand. Living Porites is intermixed with Porites rubble. Both the living coral and rubble are generally free of epibionts on the upper surface, due to the presence of living coral polyps and the extensive rasping habits of parrot-fishes and browsing by other fishes (fig. 5). However, at some sites, numerous, small, flat, roughly spherical, red foraminiferans live on Porites. Slits are often seen on the coral surface, evidence of burrowing barnacles or crabs. The sides and undersurfaces of Porites are often covered by oysters, vermetid gastropods and hydroids, among other animals. The coral Pocillopora robusta occurs in small, scattered patches at depths of 1-8 m; the tips of its branches are frequently bitten off by parrot-fishes (fig. 6). The burrowing sea urchin Echinometra vanbrunti is also common at these depths. The sea urchin Diadema mexicana is abundant to a depth of 10 m then common to at least 31 m. It is a constant diving hazard, as are the numerous white-tip (Triaenodon obesus) and hammerhead (Sphyrna spp.) sharks, the lattermost at depths greater than about 20 m. Small, scattered bunches of the bright orange coral Tubastrea aurea are common at various depths (fig. 7). At Isla Manuelita, between Bahia de Chatham and Bahia Wafer, Tubastrea is common at 13 m and even more dense at 30 m. Two additional species of scleractinian corals were found, one (Leptoseris sp.) from the underside of Porites at a depth of 5 m and the other, Psammocora (Stephanaria) stellata, at 18 m. Eighteen species of scleractinian corals, including 14 hermatypic species, have been reported from Cocos Island (Hertlein, 1963). Only one species of starfish (Linckia columbiae) is common. It is small and lives amongst coral rubble. The starfish Acanthaster ellisi was observed on several occasions but no abnormal effects of their feeding activities on the reef were noted. The lobster Panulirus (P. gracilis and P. penicillatus are known from Cocos Island) is common in holes and caverns under Porites.

Ophiuroids (Ophiocoma spp.; in addition, Ophionereis and Ophiocomella have been described from Cocos Island) are common under coral rubble and holothurians (11 species have been reported from Cocos Island) occur there in relatively small numbers. Balanus occurs in small, scattered patches. Sponges are relatively uncommon except as encrusting forms under coral rubble. Only one species lives exposed part of the time and this one occurs exposed infrequently. Gorgonians (Lophogorgia alba) were observed in small patches on only three occasions, at 9, 12 and 30 m. The bivalve mollusc Spondylus calcifer is common on rubble and the sea urchin Eucidaris thouarsii is common under rubble at depths of between 10 and 31 m. The slipper lobster Scyllarus was taken once at 29 m (station 515, west side of Isla Manuelita). All benthic algae observed during the dives were either thinly encrusting forms or they were grazed and browsed to within a few millimeters of the substratum.

The Porites coral reefs give way to gently sloping but micro-undulating (rippled) sand bottoms which contain numerous tubes of the polychaete Chaetopterus. On one night a few dozen of the fire worm, Eurythoe complanata (males, 0.3 m long), were attracted to the lights of the ship and spawned copious amounts of sperm after being collected.

The fish fauna is exceptionally rich in standing crop and is moderately diverse. One hundred and twenty species of fishes were collected, adding 33 new distribution records. A total of 156 species of fishes are now known to occur at Cocos Island, not including those taken by otter trawling. Among the most important pelagic fishes that are dominant and marine predators are jacks (Carangidae) and sharks (several families). A variety of tropical fish families feed on the benthic biota. Parrotfishes (Scaridae) are common, particularly Scarus ghobban and S. rubroviolaceus. Numerous toothmarks from these species are observable on benthic algae and on the corals Pocillopora and Porites (see above). Large populations of algal-browsing surgeonfishes (Acanthuridae, represented by 5 species) are present; the most abundant is Acanthurus glaucopareius. Scattered large schools of the Indo-Pacific manini, Acanthurus triostegus, also occur. There are 3 species of triggerfishes (Balistidae), and the most abundant, Melichthys niger, often occurs in large schools. Other bottom feeders include 3 species of damselfishes (Pomacentridae; Eupomacentrus arcifrons is the most abundant), 6 species of wrasses (Labridae; a species of Halichoeres is the most abundant and Thalassoma lutescens occurs in large numbers), 4 species of butterflyfishes (Chaetodontidae) including the angelfish Holacanthus passer, 4 species of snappers (Lutjanidae; Lutjanus jordani is the most abundant), 1 species of puffer (Tetraodontidae, Arothron meleagris), 1 species of porcupine fish (Diodontidae, Diodon holocanthus), 2 species of grunts (Pomadasyidae), a species of goatfish (Mullidae), 4 species of groupers (Serranidae) and the

moorish idol, Zanclus cornutus (Zanclidae). Gymnothorax flavimarginatus, a large dark-violet moray eel (Muraenidae) with light spots, is aggressive during daylight hours and will swim near divers at depths of between 8 and 30 m. The zonation of dominant marine organisms at Cocos Island is summarized in Table 1.

DISCUSSION

Cocos Island has basically the same intertidal fauna of dominant gastropods as that of mainland Costa Rica (see Bakus, 1968) but the overall species diversity of benthic invertebrates does not seem to be quite as great. This could be due to its isolation, some 483 kilometers (300 miles) southwest of Costa Rica and about 7730 kilometers (4800 miles) east of Christmas Island, directly across the East Pacific Barrier. One difference between much of the Central American continental rocky intertidal zone and that of Cocos Island is the lower standing crop of fleshy benthic algae and the development of a strong intertidal band of Porolithon and/or Lithophyllum spp. with a very dense concentration of Tetraclita on the calcareous algae at Cocos Island. The subtidal structure of Cocos Island shows Porites to be highly developed, in contrast to many adjacent continental shores or islands very close to continental shores where corals are represented by either small isolated heads (e.g. Playa del Coco, Costa Rica) or groups of up to 4 species of scleractinians occupying scattered patches no greater than about 5 by 5 meters in rough dimension (e.g. Isla Taboga, Panama). The coastal waters of Central America are often turbid, accounting for some of the differences between it and that of Cocos Island where the water is very clear (see Bakus, 1968, 1969a). However, Islas Secas (23 km from the coast) in the Gulf of Chiriqui and Isla Iguana (5 km from the coast) in the Gulf of Panama are reported to have well-developed coral reefs whereas there are only coral patches in the Islas Perlas (101 km from the coast), Gulf of Panama (Dr Charles Birkeland, personal communication). Cocos Island does not have a true reef formation in that the entire substratum is not living coral. The degree of reef development is similar to that of Lameshur Bay, St John, U.S. Virgin Islands (personal observation by the author), although the species diversity of corals is far greater in the latter region.

The diversity of fishes at Cocos Island is moderate when compared to that known for other tropical regions (see Bakus, 1969b). This might be expected considering the small size of Cocos Island and its geographical isolation. However, very large standing crops of fishes exist there and certain tropical representatives (i.e. those fishes discussed previously) produce marked effects on the benthic biota. Fishes will consume essentially all organic wastes that are deposited into the water from ships, attesting to their voracity. The incidence

of biting and rasping of the substratum is probably responsible for the relatively low density of subtidal Balanus (probably Balanus peninsularis), in strong contrast to that of Malpelo Island (see below). The large populations of acanthurids, pomacentrids, balistids and scarids result in a profound reduction in the standing crop of benthic algae, and the many predators must be responsible for the low incidence of a number of different taxa of exposed benthic invertebrates. It is evident that primary production must be very high in order to support the large populations of fishes living there (particularly top consumers) and that the turnover of energy must be very rapid.

Five of the 7 species of holothurians collected from Cocos Island are toxic to fishes. Toxic bodyparts were rejected by jacks in the natural environment whereas non-toxic portions were immediately consumed by jacks. These data continue to support the hypothesis that toxicity in certain benthic invertebrates is a chemical defense mechanism against predation by fishes (Bakus, 1971).

The Smithsonian Institution, in early 1972, made a brief but concentrated study of zonation and population densities of benthic invertebrates at Malpelo Island (Isla Malpelo, Colombia, Dr Charles Birkeland, personal communication). Diving took place at 8 stations around the island to depths of up to 51 m. It is of interest to compare the differences between Malpelo and Cocos Islands because the former is located only about 600 kilometers (400 miles) east and slightly south of the latter. Malpelo Island is a small, steep and barren basaltic rock that lacks permanent reefs except at one site. The waters are characterized by having a strong thermocline (26.5 to 19.5°C between February 29 and March 3 of 1972) between about 6 and 35 m. Balanus predominates on the rock walls and produces considerable sediment (white sand). Scarus is remarkably scarce. Pocillopora and two species of Porites predominate in shallower waters but below about 18 m Porites is replaced by two species of reef-forming corals (Pavona). In contrast, Cocos Island has predominately a one species reef (about 95% Porites). Starfishes are apparently more diverse at Malpelo Island and the two islands may lack species in common. At Malpelo Island a black sponge (Polyfibrospongia), blue bryozoan, a purple hydrocoral (Allopora) and several species of gorgonians (Lophogorgia and Pacifigorgia) were dominant animals that, excepting Lophogorgia, were not observed at Cocos Island. However, it is possible that some of these organisms may occur on the windward side of Cocos Island or in water deeper than our diving range. The fish faunas of Malpelo and Cocos Islands appear to be similar in species composition and possibly also in standing crop. There is a slightly greater incidence of Indo-Pacific fish species at Cocos Island than at Malpelo Island. The prevalent parrotfishes at Cocos Island and their very low density at Malpelo Island result in marked differences in the occurrence of certain exposed benthic plants and animals.

Algae at Malpelo Island, such as Padina, Sargassum and similar-sized species, were not observed at Cocos Island.

Clipperton Island, about 1,045 km (700 miles) southwest of southern Mexico, is an atoll that contains a reef flat, reef-front cut by channels, submarine terrace (12-18 m) and then a precipitous outer slope (Sachet, 1962). There is coral (Pocillopora verrucosa, Pocillopora meandrina and Pavona gigantea, see Squires, 1959) and algal growth on the reef front and submarine terrace. The lower edge of the submarine terrace and the outer slope are completely covered by corals. It is evident from these comparisons that major differences do exist in the components and distributions that comprise the marine biota of tropical eastern Pacific islands. Further work is needed to clarify the reasons for these differences and to incorporate the information into our knowledge of biogeography and general ecological theory.

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A special acknowledgment is extended to the Janss Foundation for their support of this project in tropical reef ecology. The scientific data were collected from the R/V Searcher, and to the Captain, Don Matthews, and crew (Richard McKean, Barney Schmidt, Craig Hampton) I express my thanks for their cooperation and assistance.

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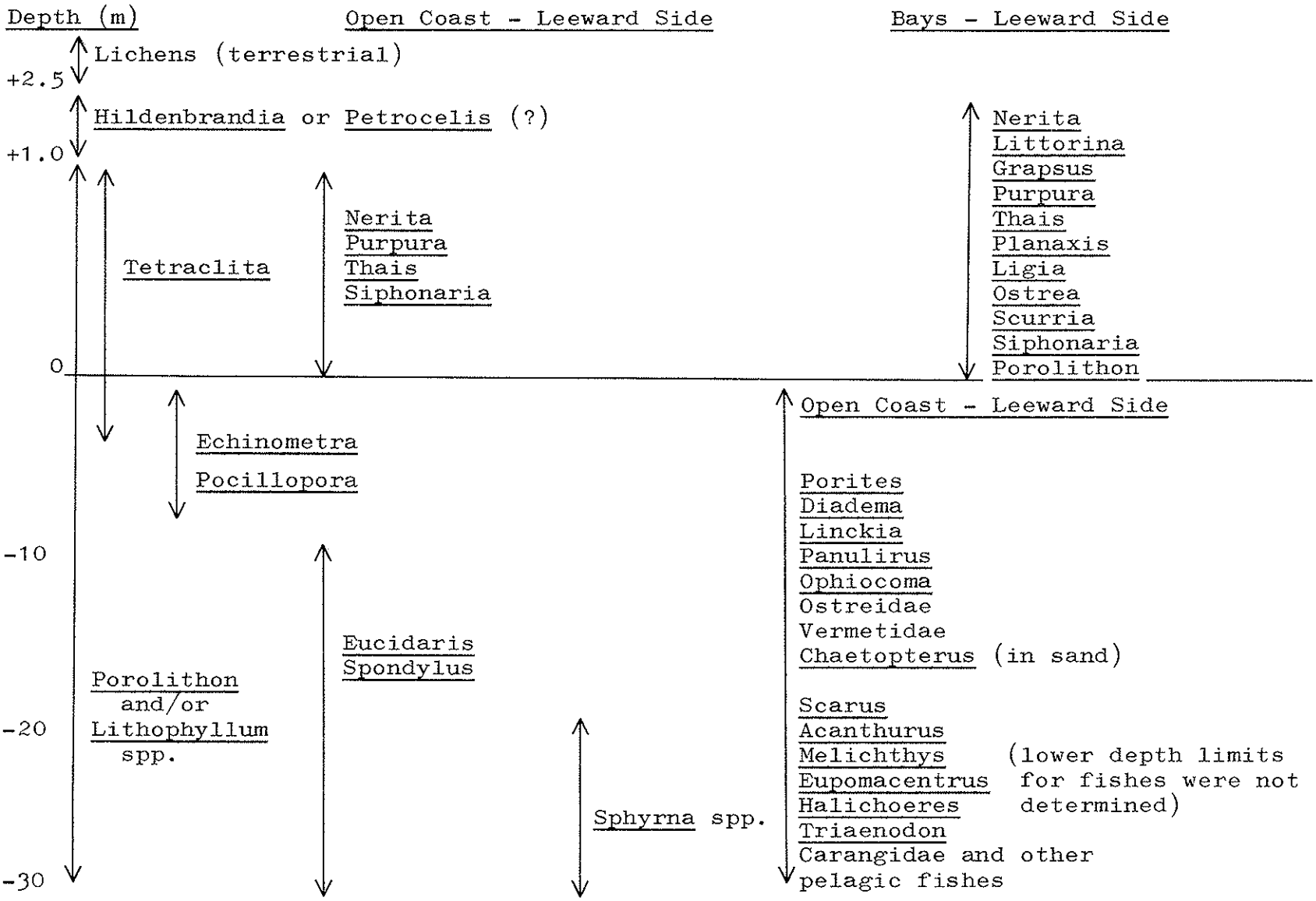
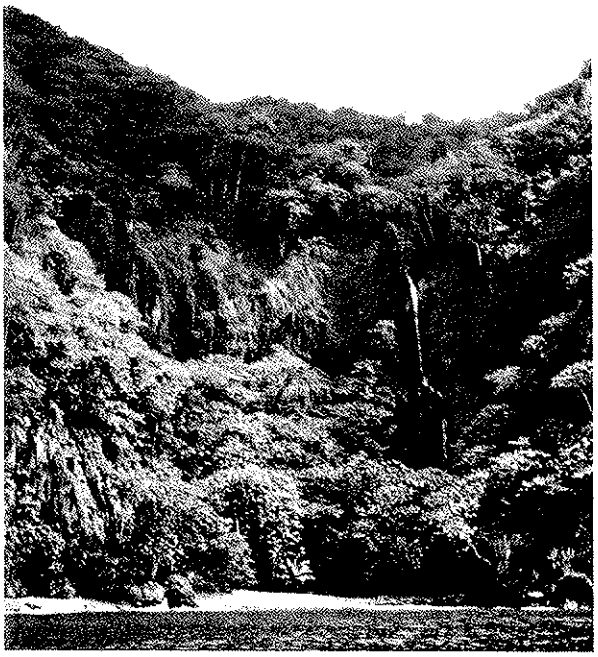
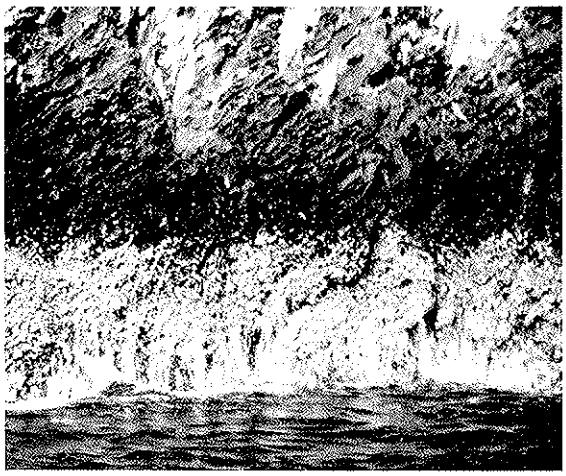
Table 1. Zonation of dominant marine organisms at Cocos Island*



*Arrows indicate approximate depth ranges or intertidal ranges. Intertidal species are arranged according to their respective position.

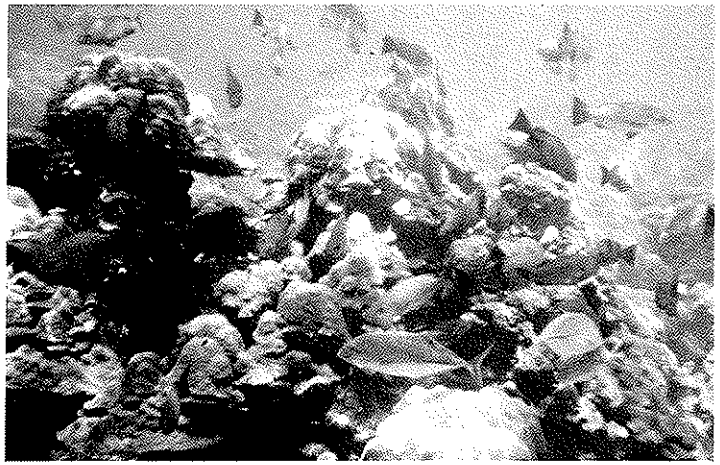




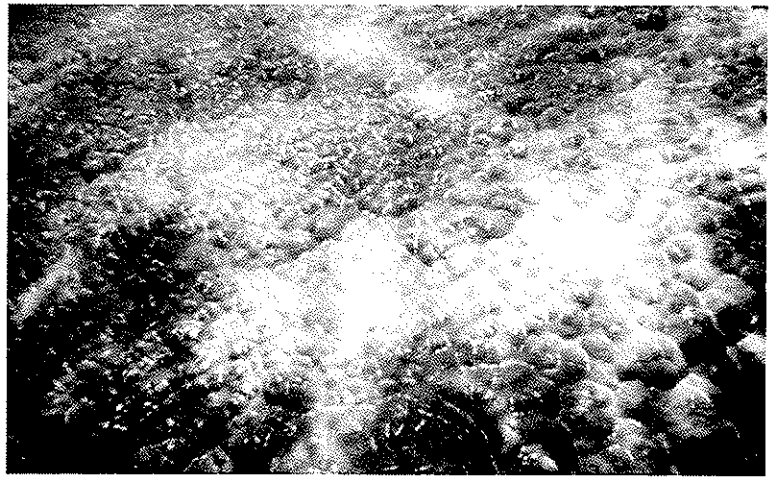
1 Leeward side of Cocos Island showing the lush vegetation and one of many waterfalls.

2 Low intertidal zone in Bahia de Wafer. Note Porolithon and/or Lithophyllum spp. on the rocks.

3 Intertidal zonation on a vertical wall, leeward side of Cocos Island. The lichen-covered basalt is followed below by the dark encrusting alga Hildenbrandia or Petrocelis (?). A veneer of Porolithon and/or Lithophyllum spp. is covered by dense aggregations of Tetraclita stalactifera at the lowest level.

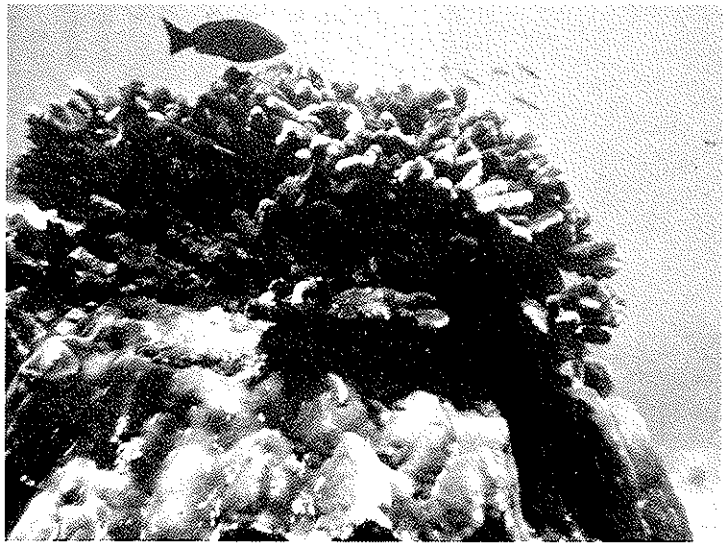


4 Porites californica at a depth of about 10 m., representing a predominantly one species coral reef at maximum development. Note the high standing crop of fishes.



5 A massive round head of Porites californica showing numerous toothmarks made by parrotfishes.

6 A colony of Pocillopora robusta growing from a mound of Porites californica. The white tips on the branches of Pocillopora indicate that they have been bitten off by parrotfishes. Note also the toothmarks on Porites.



7 Tubastrea aurea growing on dead coral substratum. Note the extent to which benthic algae have been browsed. Diadema mexicana is shown in the lower right corner.