Puerto Rico, Coastal Zone Management Plan

W.P.

INVENTORY OF THE PUERTO RICAN CORAL REEFS

BY

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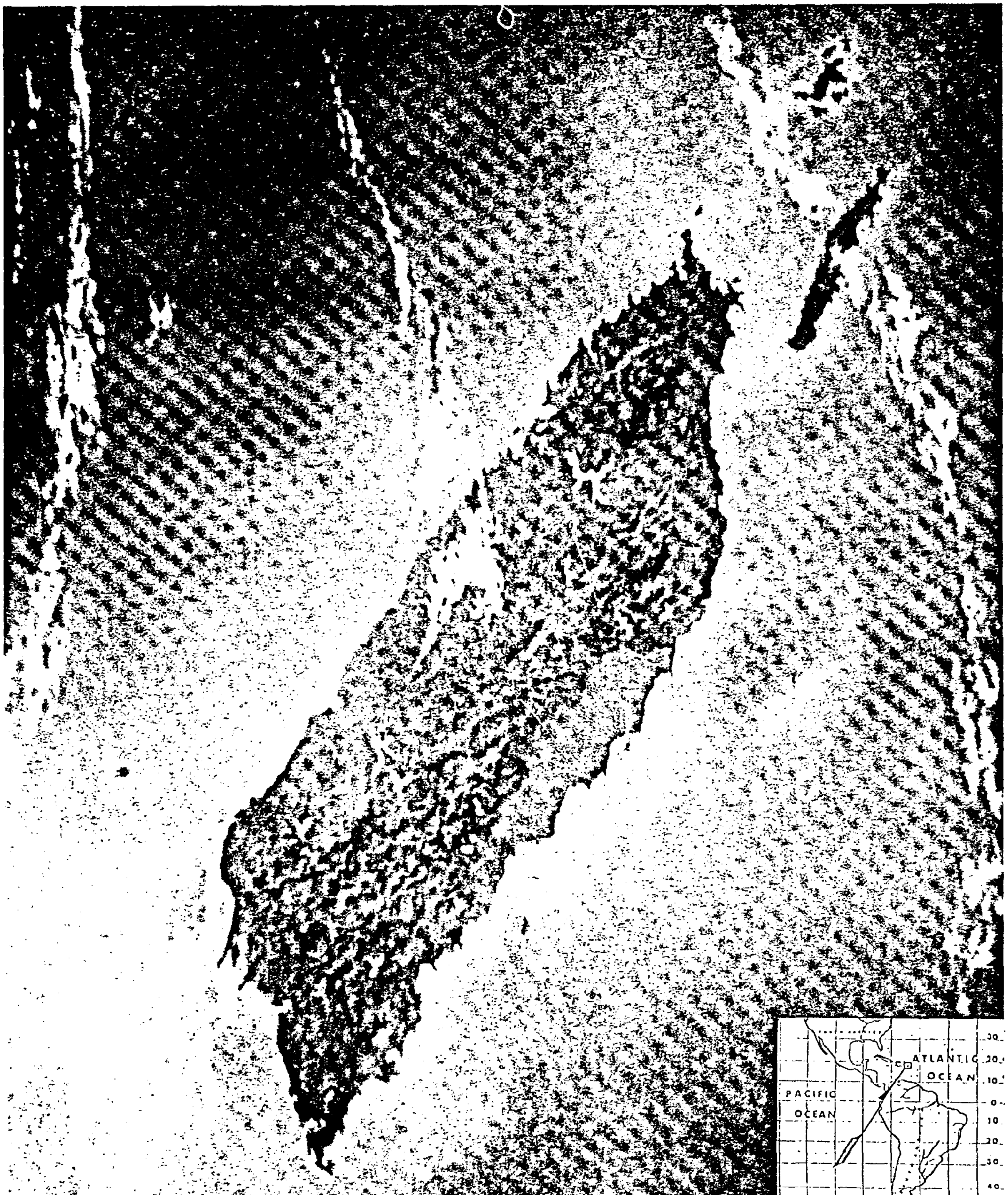
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INTRODUCTION

The importance of the coral reef ecosystem has been mentioned and documented on numerous occasions by several writers. In summary:

a) Reefs are among the most biologically productive ecosystems containing a great variety of benthic organisms and providing a habitat for large numbers of juvenile fish of many species. Reefs shelter and support the majority of fish and crustaceans that are commercially extracted from our coastal processes.

b) Reefs provide a buffer against seas pounding shorelines and moderate currents thereby influencing the deposit and maintainance of sand on beaches. As an example, the calm waters and deposited sands of Luquillo Beach would be lost if the protecting reefs were to disappear.

c) Fragments from dead coral or from other calcium carbonate producing organisms which inhabit reefs are the principal components of many Puerto Rican beach sands. Many islets are also formed by the deposition of these.

d) Many organisms inhabiting reefs, such as algae and certain soft corals, produce chemical substances with valuable medicinal properties.

e) Reefs are a recreational resource for skin and

SCUBA diving.

f) Due to the fact that reefs are the most extensive coastal communities of the earth and due to their complexity in terms of taxonomical diversity and trophic relations, these are of unlimited interest in the study of the dynamic relations of biological processes.

The interest of this report is to give a general description, status and localization of our reef resource and to stimulate in the beginner science students the curiosity and desire to initiate ecological studies of this most important and threatened ecosystem. We also attempt to create a consciousness of the alarming rate of degradation of this practically non-renewable resource in the layman and to promote their right to publicly oppose projects which may further endanger the latter. Finally, we intend to delineate guidelines, based on the analysis of our and others' observations, for the management of the coral reefs in the best social interest.

This document initially shows coral reef distribution in the world and especially in the Caribbean Sea. Following is a mention of the physical and biological conditions necessary for the development of coral reefs. Then, the most common zonation patterns and the different reef types are discussed. Reef distribution along the Puerto Rican coasts is described based on published literature, reports and personal observations. Next are our conclusions and recommendations. Included as appendices are profiles of selected reefs and tables containing detailed data.

METHODS AND MATERIALS

This reef inventory was carried out during a one year period. Observations were limited to a maximum of one day per reef and measurements were made only whenever sea conditions, e.g. high water transparency and reduced surge and wave action, permitted it.

Topographic profiles of the forereef were made with a line marked every five meters. This line was laid, perpendicular to the shore, from the closest area of the reef flat that sea conditions permitted to the windward base of the reef. Depth measurements and observations were made at five meter-intervals (or less where pertinent) and recorded on an underwater slate (Fig. 1). Self contained underwater breathing apparatus (SCUBA) was used on areas where use of a snorkel was not appropriate.

The site of the profile was chosen after analyzing aerial photography of the area and after making an underwater reconnaissance of the reef. Occasionally a diver was towed on an underwater sled to cover larger areas. The area most representative of the forereef was selected.

Coral species diversity, equitability and living cover were made with line transects according to a method designed by Loya (1972) and later modified by Rogers (1977). All transects were 10 m long and parallel to depth contours. These were run with the aid of SCUBA.

Black and white photographs were taken with a Nikonos III camera with a 35 mm lens.

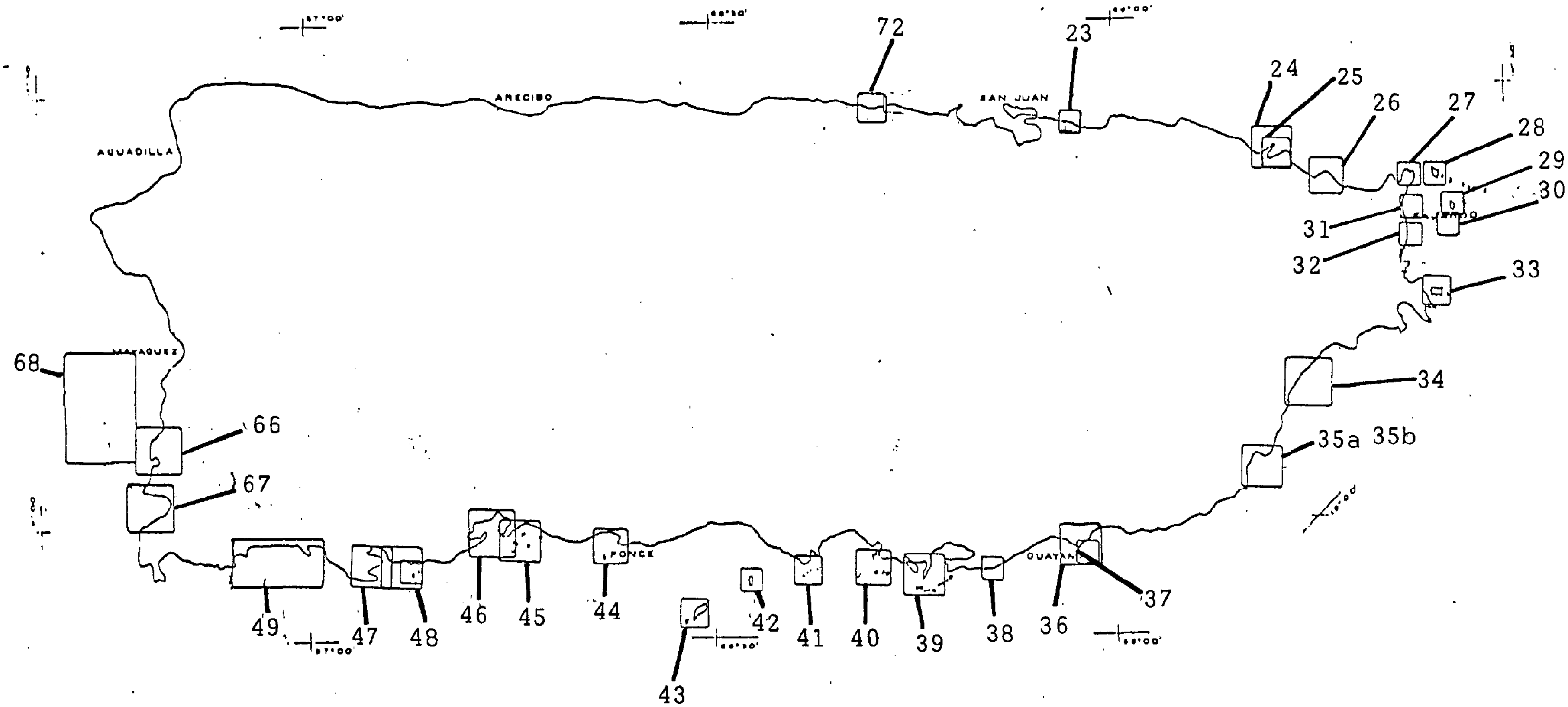

Fig. 2. Location of aerial photographs.

Reefs where profiles were not made due to diverse reasons, are described in the Coral Reef Development in Puerto Rico section.

All aerial photography is vertical unless otherwise specified. The locality and area of cover is shown in Fig. 2. The approximate areas where underwater profiles were made is shown with a line. Corresponding sections of nautical charts are included with each vertical aerial photograph.

Available north coast aerial photography was analyzed and areas where coral growth was suspected were spot-checked in the field with the aid of a boat towed underwater sled.

The section Detailed Reef Information includes:
1) The fore reef profiles showing the distribution of the most common species within each zone and 2) Tables mentioning specific details of the zones or of the reef as a whole.

The coral reef inventory does not include the islands of Mona, Vieques, Culebra and Desecheo. For information on the reef fauna of the first three the reader is reffered to Cintrón and Thurston (1975), Torres (1972) and Cintrón *et al* (1974) respectively.

WORLDWIDE CORAL REEF DISTRIBUTION

Hermatypic or reef building corals, which are the main components of the coral reef, flourish in tropical zones with seawater temperatures ranging from 25-29°C. These areas are situated within a belt roughly bounded by the Tropics of Cancer and Capricorn, imaginary lines which are drawn around the earth 23.5° north and south of the equator. Within this 4800 kilometer-wide belt, coral reefs are abundant on the eastern shores of the Americas, Africa and Australia, but far less common off the western shores of these continents. Why is this? In the Northern Hemisphere ocean currents are forced into a clockwise circular movement by the earth's rotation and associated wind distribution (Coriolis effect). The opposite is true in the Southern Hemisphere. As a result, warm water travels toward the poles along the eastern shores of the continents. On these shores, therefore, there is a much wider extension of warm water suitable for vigorous coral growth. On the western shores the reverse is true. Cold waters running toward the equator, combined with upwellings of cold water from the depths, greatly restrict the extent of shoreline favorable to coral growth.

Non hermatypic or non-reef building corals, contrary to hermatypic ones, are by no means restricted to the tropics and can be found in the cold seas lying within the Artic and Antartic circles as well as in the Norwegian fjords, the rocky shores of the United States, Canada, and the coasts of England and France. None of these cold-water corals, however, grow so actively or to such a size as the larger reef corals of the tropics. Their form is usually small and delicate rather than large and massive (Smith, 1948).

DISTRIBUTION WITHIN THE ATLANTIC OCEAN

Most coral reef development in the Atlantic Ocean is restricted to the Caribbean and adjacent areas in the southern Florida and the Bahamas. Although viable reef production is nill north of southern Florida (due to low winter temperatures), isolated hermatypic corals can survive as far north as Cape Hatteras (35 N, see average winter and summer temperatures in the Atlantic Ocean and the Caribbean in Figs. 3, 4). One notable exception is Bermuda which contains a surprisingly large number of corals, but still lacks some of the most prolific West Indian species such as <u>Acropora</u> <u>palmata</u> (Stoddart, 1969). Also, these reefs appear to be only thin encrustations over Pleistocene rock (Milliman, 1973). The Gulf of Mexico is basically an area of terrigenous sedimentation, but some scattered marginal reef growth is present near Veracruz, Mexico, together with many relict coral and algal mounds throughout much of the Gulf shelf (Milliman, 1973). The northern portion of this area, roughly that area north of a line passing through Progreso, Mexico, and Havana, Cuba, can be considered to be marginal tropics in that winter temperatures commonly fall below 22°C and coral reef development is poor as compared with the central and southern Caribbean.

Coral reef development in the Atlantic Ocean reaches its southern limit off Rio de Janeiro, Brazil. These communities are, however, biologically quite distinct from those of the Caribbean and, as in Bermuda, lack many of

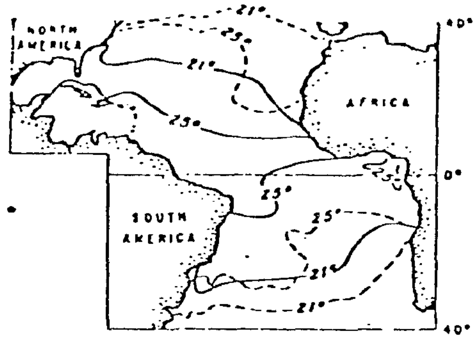

Fig. 3 Average winter (—) and summer (--) surface isotherms (°C) in the Atlantic Ocean (after Sverdrup *et al.*, 1942). Areas with prolonged exposures to temperatures less than 22°C, or with short exposures less than 18°, at best will have a depauperate coral population. Periodic influxes of cold waters from the Guinea Current have helped to severely limit reef development off tropical Africa.

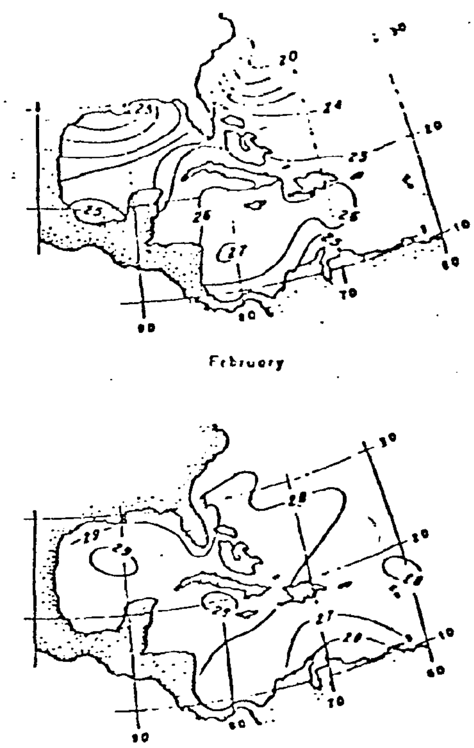

Fig. 4 Average winter (February) and summer (August) surface temperatures (°C) in the Caribbean (after Sverdrup *et al.*, 1942).

the principal constituents of the latter (Volcker, personal communication).

For a detailed summary of coral reef research in the Caribbean, the reader is referred to Colin (1978).

ECOLOGICAL ZONATION

Identifiable ecological zones are created by the degree to which the various physical and topographical factors positively or negatively affect reef organisms throughout the reef area. The characterization of each zone may, therefore, be based on the name of one key organism and/or the name of the physical factor or feature estimated to be of greatest importance to the ecology of the zone. Overlap or combination of zones may occur anywhere as a result of the varied effect of tidal currents, wave action or bottom structure.

Following is a general scheme of reef zonation (leeward to windward). It should be borne in mind that this varies from location to location and even within the same area.

(a) Reef apron -

The reef apron is the area of sediment accumulation leeward of the reef flat. It is generally a barren area in the sense of epibenthic biota although in some cases it is extensively burrowed by shrimps or holothurians (sea cucumbers) which form mounds that sometimes cover most of the barren sand areas (Mathews, 1974). It may also contain beds of marine phanerogams (flowering plants) such as turtle grass (<u>Thalassia</u>) and/or patch reefs. Sand is primarily biogenic as in the case of Cayo Enrique, La Parguera, where its principal constituents are mainly coral and coralline algae fragments (Morelock et al, 1977).

(b) Reef flat - low wave action zone

This is a shallow area of sand and rubble that lies behind the reef front. The depth may vary from 0 to 1 m. Usually, even though wave pounding is minimal, a very strong current is created by the outrushing of the water accumulated by incoming waves which come over the reef front.

During severe tropical storms, large quantities of living coral are dumped into this area forming islets of considerable heights above sea level.

As depth decreases in this area, an important littoral community, the mangrove forest, may become established creating a new habitat for many species of birds, fishes and invertebrates. Mangrove trees may, at the same time, influence the surrounding reef habitat by providing a nutrient subsidy by decomposition and exportation of leaves.

Corals present in this area are generally sturdy encrusting and small branching such as *Porites asteroides*, *Porites porites* and, to a lesser degree, *Manicina areolata*, *Favia fragum*, *Diploria clivosa*, *Agaricia agaricites*, and *Siderastrea radians*. Corals present in this zone are sometimes, as in the case of *S. radians*, very tolerant to sedimentation and their distribution is influenced by the presence of adequate substrates, such as coral fragments, which favor their establishment.

<u>Thalassia</u> beds and their associated biota are also common in this area.

(c) Reef crest; <u>Millepora</u> - zoanthid zone; Breaker zone (Figs. 5,6).

This is the zone of highest wave energy and water movement. Prominent organisms include <u>Millepora complanata</u> (fire coral) and several species of zoanthids (colonial anemones) (Fig. 7). Sometimes this zone extends above the low tide level forming emergent communities. Under slightly lower energy regimes <u>Millepora</u> may be replaced by the elk horn coral <u>Acropora palmata</u>.

Other organisms, very conspicuous in this are, include the encrusting gorgonian <u>Erythropodium caribaeorum</u>, various species of calcareous red algae and sea urchins.

Even though a discussion of this subject is out of the scope of this report, it should be mentioned that recent studies have confirmed the existence of emergent algae ridges, similar to those present in several Indo-Pacific reefs which replace the <u>Millepora</u> zone (Glynn, 1976). This algal ridge is best developed in areas of very high wave energy.

(d) <u>Acropora</u> zone

This zone extends seaward from the bottom edge of the <u>Millepora</u> zone and generally is monospecific containing, almost exclusively, the elk horn coral (Figs. 8,9, 10,11). Various forms of this coral are present depending on the degree of exposure.

Other corals and different algae species may grow on the protected substrate beneath the branches of the elk horn coral.

(e) Buttress - Montastrea annularis zone

Seaward of the Acropora zone there is usually a small drop off where massive heads or buttresses of the star coral Montastrea annularis occur (Figs. 12, 13). Very large isolated colonies of the elk horn coral are also present thus creating an area of very high relief. Soft corals or gorgonians, brain corals (Fig. 14) and pillar coral (Fig. 15) also abound here.

This area with all its steep and narrow channels, canyons, tunnels and towering coral heads provide a great variety of habitats for reef organisms (Figs. 16, 17) and is generally the area of highest biotic diversity. Large patches of A. cervicornis shelter numerous fish (18).

(f) Reef fore slope - gorgonian - head coral zone

Beyond the buttress zone, the reef flattens out towards its base. Gorgonians (Fig. 19) are usually the most frequent life form in this area, sometimes forming dense forests. Between the gorgonians encrusting coral such as Montastrea cavernosa, M. annularis, Siderastrea siderea, Diploria labyrinthiformis and Porites asteroides occur. Other corals present are Isophyllia multiflora, Isophyllastrea rigida, Mycetophyllia lamarkiana, and

Mussa angulosa. Sponges are also common here (Fig. 20). A green turtle was observed in this zone (Fig. 21). Usually, corals growing near the base of the slope are heavily silted and dead colonies are frequent.

Small patch reefs sometimes occur beyond the base of the slope. In areas where the reef base is shallower than about seven meters a contiguous sea grass bed is present. Normally a "halo" or non vegetated stripe occurs adjacent to the reef base as a consequence of reef fish grazing (see Fig. 22).

Different reef types

(a) Rock reef

Rock reefs are shallow eolianite platforms thinly veneered by stony corals. These will be discussed upon the description of Puerto Rican north coast.

(b) Fringing reef

Fringing reefs grow marginal to the coast and are separated from the latter by a shallow lagoon generally not exceeding a couple of meters and sometimes nearly exposed to the atmosphere.

(c) Patch reef

These are isolated coral colonies usually surrounded by a sandy bottom and occuring close to shore. They are irregular in shape.

(d) Bank or ribbon reefs

Bank reefs are developed on calcarenite cuestas or on drowned synclines. These will be discussed in detail in the description of the southwest coast.

(e) Barrier reef

These are usually emergent reefs separated from and by a deep and wide lagoon.

(f) Atolls

Atolls are oval shaped reefs rising from deep water and surrounding a lagoon in which there is little or no land. They develop, usually but not always, on the gradually subsiding cones of extinct volcanoes.

Barrier reefs and atolls are not found within the Puerto Rico shelf or in its vicinity although these types are found in the Caribbean. The best known and largest barrier reef in the Caribbean flanks the coast of British Honduras (Belize) which stretches for more than 200 km and has lagoon depths of more than 20 m. The best known Caribbean atolls are Hogsty Reef, Alacran Reef, Light house Reef, Glover's Reef and Serrana Bank. These are found off the coast of Honduras, Belize and the Yucatán Peninsula.

These definitions should be used carefully due to the common occurrence of intermediate forms.

ECOLOGICAL CONTROLS OF REEF GROWTH

The environmental controls of local coral growth and of general reef distribution have been summarized by Stoddart (1969).

Physical and chemical determinants

(a) Light Intensity

Most hermatypic (reef building) corals grow at depths of less than 25 m and maximum growth rates appears in depths less than 10 m. This has been explained in terms of the increasing concentration of suspended sediments with depth (Wood-Jones, 1910) but the critical control seems to be illumination (Gardiner, 1930). This decrease in light intensity with depth limits photosynthesis by the symbiotic algae present in coral endodermal tissue which play an important role in the process of calcium deposition.

It should be pointed out here that recent observations of deep reef slopes by means of submersibles have shown that certain species of hermatypic corals extend up to 100 m depth though in general, they cease to be framework constructors at about 70 m (Lang, 1974; Colin, 1974; Lang et al., 1975; Ginsburg and James, 1973, 1976; Neumann and Ball, 1970; Porter, 1973).

Light penetration is limited by turbidity as well as depth. Weak reef growth, especially in shallow waters on leeward reefs, has been explained by turbidity of the water.

(b) Temperature

The effect of cold water currents on coral reef distribution has already been discussed in the previous section.

Corals also have an upper temperature tolerance limit. Vaughan (1919) found that the highest temperature endurable by West Indian reef corals is about 36°C. Edmonson (1929) presented similar data for Hawaiian species. Temperatures close to these sometimes occur in stagnant waters of shallow reef lagoons during extreme low tides, thereby precluding coral growth or killing established corals.

(c) Salinity

Torrential rain on wide shallow reef flats or coincident with low spring tides may lower local salinities and lead to physiological damage or death. Goenaga and Canals (1979) observed mass mortalities of <u>Millepora complanata</u> (fire coral) during heavy rains on the Puerto Rican east coast.

(d) Emersion

Exposure to the atmosphere during tidal cycles, especially if coincident with midday sunshine or with rainfall, may lead to coral death (Edmonson, 1929). Duration of emersion is obviously an important factor (Stoddart, 1969). Mass mortalities of echinoids and other reef flat organisms coincident with midday, low water exposures in La Parguera, Puerto Rico, has been reported by Glynn (1968). As with other detrimental factors, coral survival varies with the species.

(e) Water turbulence

Wave turbulence and energy are certainly important controls of coral growth. Storr (1964), based on studies of the Abaco reef tract, Bahamas, concludes that wave thrust is the environmental factor which results in ecological separation of the various reef organisms. Apparently, extreme turbulence or extreme absence of it is detrimental for certain species of corals. While water movement has an important direct physical effect, it is also responsible for bringing supplies of fresh water and nutrients to corals. Removal of CO_2 is related also to degree of water turbulence (Stoddart, 1969).

(f) Sedimentation

Sedimentation as a control of reef growth in Puerto Rico has been stressed recently by workers such as Cintrón et al (1973), Kolehmainen (1974), Loya (1976), and Rogers (1977). Branching corals are relatively better able to withstand sedimentation than massive corals; others especially with large polyps, have developed efficient mucus and ciliary cleaning mechanisms (Yonge, 1935; Marshall and Orr, 1931). The role of sedimentation in island-wide coral distribution in Puerto Rico has been discussed by Kaye (1959) and Almy and Carrión-Torres (1963).

(g) Storms

The major cause of catastrophic coral mortality on reefs is destruction during tropical storms. This destruction is mostly mechanical. Colonies are uprooted, carried above sea level or into deep water or fragmented *in situ* by wave action. In some cases, though, corals may survive the storm but later succumb to changed environmental conditions resulting from it (Stoddart, 1969). Glynn et al (1965) reported on minor hurricane Edith in 1963 in Puerto Rico. Winds less than 90 km/hr. caused extensive coral destruction, especially of branching corals. During the course of this study, we observed the disastrous effects of two tropical storms (David, Frederic, Sept. 1979) on the outer east coast and especially on the southern coastal reefs. Damage was most obvious at the shallow *A. palmata* zone where these corals were ripped off and overturned causing damage at the same time to massive corals which were extensively bruised by the landing of the former.

Stoddart (1963) also reported very extensive reef damage on the British Honduras reefs resulting from another tropical storm in 1961.

(h) To this list, other not so natural environmental controls may be added. These are different kinds of man-made pollution. Johannes (1975) has given an extensive account of forms of environmental degradation caused by man which are detrimental to coral growth. Among others, erosion caused by upland deforestation, sanitary effluents, thermal effluents, dredging, chemical spills and bombing have been pointed out as unquestionable degraders of coral reef communities.

The environmental controls mentioned in this list may act in isolation (as single factors) but most frequently synergistically (in conjunction) where the sublethal effects of one are aggravated by the presence of another. The effect of these may be summarized as follows:

(1) Upland deforestation

Natural erosion is an essential process without which we would have no soil, and the delivery by rivers of nutrient-laden soil to the ocean enhances marine productivity. In excess, however, and due to excessive upland deforestation or bad land management, siltation of erosion products leads to decreased productivity of coral reef communities and, ultimately, to their destruction. Exposure of reefs to brackish, siltladen water associated with flood runoff has probably been the single greatest cause of reef destruction historically (Johannes, 1975). Undoubtedly some damage is natural, but also there can be no doubt that bad land management has greatly magnified the problem. Maragos (1972) has reported extensive reef damage in southern Kaneohe Bay, Hawaii by terrigenous sediments. Van Eepoel and Grigg (1970) report that in large areas of Lindberg Bay, St. Thomas, most corals and other sessile animals have been destroyed and conditions remain unsuitable for their establishment due to sedimentation caused by bulldozing, construction and the surfacing of land that drains into the bay. A subsequent survey (van Eepoel et al., 1971) indicated that conditions were rapidly worsening. Damage to reef communities due to accelerated terrigenous sedimentation has also been observed in Tanzania by Ray (1968) and in the Seychelles by Vine (1972).

(2) Sanitary effluents

The relation between organic or nutrient enrichment and lowered, stressful oxygen levels is well known. Johannes (1975) has pointed out that tropical marine organisms live closer, on the average, to their lower oxygen limit than biota in colder waters. Kinsey (1973) observed that oxygen levels artificially depressed only slightly below normal levels on a healthy reef caused the death of many reef inhabitants. Depressed oxygen levels in reef and near reef environments subjected to sewage effluents have been reported by Bathen (1968) and Wade et al. (1972).

(3) Thermal effluents

Tropical organisms live at temperatures only a few degrees below their upper lethal limit (Mayer, 1914). Consequently, the threat of destruction or alteration of marine communities by overheating is greatest in the Tropics. Heated effluent from a power plant in Guam led to extensive destruction of reef corals (Jones and Randall, 1973). Jokiel and Coles (1974) reported on the impact of thermal effluent on corals in Hawaii. Nearly all corals in water 4-5°C above ambient were killed.

(4) Dredging

Brock *et al*. (1966) give a detailed account of the destruction of corals and reduction of fish and echinoderm population at Johnston Island due to siltation brought about by dredging. Deterioration of reef communities continued for at least a year after dredging ceased because of continual resuspension of sediments. Grigg and van Eepoel (1970) observed the destruction of hard corals due to sedimentation associated with the release of clays brought about by the dredge removal of overlying sand in Water Bay, St. Thomas. Apart from siltation, dredging can also cause an increase in chemical oxygen demand which may constitute an additional stress (Johannes, 1975). Also, alterations of reef topography through dredging, filling or underwater construction will alter current velocity and directions which influence reef zonation and may alter settling and survival patterns (Hubbard, 1974). Examples of reef damage through dredging activities are numerous in the literature.

(5) Bombing

An account of the disastrous effect of Naval maneuvers on coral reefs off northern and southern eastern

Vieques, P.R. is given by Rogers _et al_. (1978).

Biological determinants

Bioerosion or the presence of certain organisms which bore into the reef framework have been shown to control reef growth in the deep fore reef of Bahamas, Jamaica and Belize (Lang, 1974; Colin, 1974; Neumann and Ball, 1970; Porter, 1973; Lang et al., 1975; Ginsburg and James, 1973, 1975). An example of this are the boring sponges which weaken coral skeletons and hold fasts, thus influencing the size and growth forms of corals which live at their lower depth limit (Hartman and Goreau, 1970).

Other biological processes such as competitive interactions, bioturbation (small scale distruptions) and predation also assume an increasing influence on community structure in deeper and more diverse reef assemblages (Glynn, 1976; Lang, 1973).

CORAL REEF DEVELOPMENT IN PUERTO RICO

Individual coral colonies grow almost everywhere in all four coasts of Puerto Rico. Coral reefs, as such, however, are present only where favorable conditions are present.

Reef development along the western two thirds of the north coast of the Island is poor. Kaye (1959) summarized the possible factors affecting the distribution of coral reefs on the north coast. He pointed out that the watershed of the north coast is the largest of the Island, in both area and volume of discharge, and the large volume of silt-laden waters from the north coast rivers may be the most important factor inhibiting coral growth. The importance of salinity and light penetration for coral growth has been mentioned earlier in this report. Flood discharges from the several large rivers reduce the salinity of the coastal waters near their mouths. Alter heavy rains the long plume of muddy river water off the mouths of the rivers (generally diverted to the west) may interconnect one major river mouth with the next, and form a widespread apron of turbid, low salinity water along much of the coast. The possibility that these turbid waters are responsible for inhibiting reef growth is given some support by the fact that well formed reefs occur only east of the mouth of the eastern most major river Espíritu Santo. Kaye also mentions that because of the large storm waves that rake the north coast from time to time, reefs growing on sandy or muddy bottoms in relatively shallow water have particularly unstable foundations. Most known reefs in Puerto Rico are in shallow water and a majority of them rest on a platform with depths that are within the range of large storm waves that would stir up the sand and mud and, in general, both destroy the foundation of young reefs that are struggling to establish themselves and smother them in the stirred-up sediment.

Another factor may be the possible bevelling of the shelf area by intense wave action which removed any projections above the bottom that would provide a suitable place for reef development.

It should be mentioned here that intensive upland deforestation during the last 30 years has probably increased sediment runnoff aggravating this situation.

The possible presence of "luxurious deep reefs" between 30 and 100 meters in the north coast of Puerto Rico has been mentioned by Kolehmainen and Biaggi (1975) based on the presence of these in the north coast of Jamaica. We, however, question this assumption due to the very different wave regimes and much lower precipitation on the Jamaican north coast.

East of San Juan lies a discontinuous chain of poorly developed and heavily stressed rock reefs trending in a general east-west direction and extending close to 1.5 km offshore (Fig. 23). These, from their alignment with eolianite ridges are interpreted to consist of a relatively thin coral veneer growing on a shallow eolianite platform which, in some cases (e.g. Isla Piedra, and Isla Cáncora) rise above tidal level (Kaye, 1959).

Off of Punta Las Marías reef patches occur which typically are moundlike and rise to within a couple of meters of the surface. The center of the top of these small mounds consist of head corals rimmed on its borders by the elkhorn coral (Acropora palmata) and on its lower slopes by sea fans and other gorgonians.

Northwest of Boca de Cangrejos lies what was a well developed reef system. Here, extensive coral formations were common from the surface down to 10 meters in fairly clear waters. This reef was virtually destroyed by sediments derived from extensive dredging within Torrecilla Lagoon and organic sediments discharged into this same lagoon by sewage treatment plants. At present, barely any living coral exists below approximately 1.5 m.

Stony corals are present on the rock reefs and beach rock platform at Punta Vacía Talega (Fig. 24). Most are encrusting growths and not major contributors to reef construction or maintainance. These are most abundant along the northern side of the inner reef. Millepora complanata is the most abundant coral near the surface of these rock reefs. Diploria and Isophyllia are also common on deeper areas. Soft corals are present on protected areas.

Scattered patch reefs breaking the surface are found between Punta Iglesias and Punta San Agustín (Fig. 24). Even though they do not form a continuous barrier, they have formed an effective wave energy absorbing structure. At present the patches adjacent to shore are dead probably by siltation. Water conditions here are characterized by high levels of suspended particles and low visibility. Water quality and health of corals increases offshore, living corals being present only in the shallow (1-3 m) depths of the outermost reefs. Signs of sharp erosion are evident at the base of the reefs.

Farther east, on the north and west side of Punta Miquillo and on the north and east side of Punta Picúa, are fringing reefs which average about a quarter of a mile wide (Fig. 25). It is probable that both Punta Miquillo and Punta Picúa were formerly sand cays developed from these reefs, which since have been tied to the mainland by a broad marsh and narrow sand tombolos. These two reefs, specially that of Punta Miquillo, are in very poor health situation with very low living coral cover and diversity. The Punta Miquillo reef has suffered serious perturbations and partial destruction of its components as a result of the dredging of a channel parallel to the shoreline which affected the structural integrity of the reef framework and created a silty environment, due to resuspension by wave action, which is detrimental to corals. Punta Percha is part of the same system exhibiting similar conditons but slightly higher living coral cover.

Ensenada Comezón (Fig. 25) is lined with numerous patches covered principally by algae. Stony corals cover these to a lesser extent. The patches, more than a couple of meters in relief, present no distinct zonation. Coral species present are _M. lamarckiana_, _A. agaricites_, _M. squarrosa_, _P. asteroides_, and _P. strigosa_. Surrounding waters are generally very turbid.

Two large patch reefs occur offshore from the mouth of Río Mameyes. Both are roughly circular (300-500 m in diameter) and with an exposed shoal of coarse sand (mainly _Halimeda_) and broken pieces of coral. They consist mainly of shallow grass beds incised by north-south trending sand channels. The underwater edge of the island is fringed with a narrow band of coral of which less than 20 per cent is alive. The seaward edge also contains encrusting coralline algae. The fore reef consists of a steeply sloping coral pavement, sparsely covered with living corals and terminating in a barren sand flat. Corals present are _Acropora palmata_, _Montastrea annularis_, _M. cavernosa_, and _Diploria strigosa_. The general low diversity here is apparently due to silting by the out flow of Río Mameyes. These islets and their surroundings were heavily impregnated with Bunker oil during an oil spill in December 21, 1978.

East of this reef system there is a complex of barrier, fringing and patch reefs which are responsible for the formation of Luquillo Beach (Fig. 26). Some of these probably rest on rock foundations with the exception of those northwest of Luquillo which occur at considerable distances from rock out crops and therefore may be built on sand or mud. These reefs have undergone various stages of degradation. The fringing reefs surrounding the northern and eastern end of the beach show degradation in the seaward edge where growth has been limited to the upper three meters.

East of Luquillo water transparency increases gradually and reef exhibit slightly higher living coral cover.

East of Río Juan Martín are a series of patch and fringing reefs which have been described by Torres (1973). Coral species diversity here is low, _A_. _palmata_, _S_. _siderea_, _D_. _strigosa_, and _M_. _cavernosa_ being the most common species. The areas of highest abundance, namely the outer reef flats, had 30 per cent coral coverage. Torres did not observe significant coral growth below 3 m depth. Reduced illumination, caused by silt particles in suspension, appears to be the limiting factor. The seaward edge is characterized by overhanging ledges. In some areas these ledges have collapsed creating crevices and cave-like structures. The presence of uneroded dead coral masses, mainly of A. palmata, suggest a recent death. Pumping activities of water accumulated in sand extraction pits was observed by Torres. These activities are an additional stress to these already stressed coral colonies.

A reef system fringes the area comprised between west of Cabeza Chiquita to Cabo San Juan (Fig. 27). This reef is also undergoing rapid degradation from the effects of siltation and also from systemic extraction of corals for sale. The northernmost portion of this bay has a very shallow reef platform (part of the mentioned system) which terminates at the beach after merging into a shallow Thalassia and algal bed. Corals are actively growing along an eastern channel edge and back reef. Northward of the reef crest is a steep slope terminating abruptly in a sand flat. Fire coral is very abundant in this reef's crest.

The best reef development on the northeast coast is found in the fringing reefs formed around the string of islets which overlie La Cordillera, a shallow, narrow submarine ridge approximately 18 miles long which trends east-southeast from the northeastern most tip of Puerto Rico to Culebra (Fig. 28). These reefs are of high quality, in terms of diversity, high living coral cover, and extensiveness. The islets of La Cordillera, specially Icacos and probably all (Kaye, 1959) are not reef constructions but are composed of oolitic eolianite which was deposited and partially submerged some time previous to the development of the reefs. Most of these are high islands and generally possess land and/or beach vegetation. Rock reef fringes two thirds of Icacos north shore. Corals here cover less than 50 per cent of the available surface area (Mckenzie and Benton, 1972). Off the southwestern shore of Icacos is a more protected area which exhibits fairly high coral development. South of the main line of La Cordillera reefs but still on the same platform there lie the Palominos (Fig. 29) complex and Cayo Largo (Fig. 30), two other reefs of high biotic quality and extensiveness. Between these and the mainland lie some other islets (Fig. 31) possessing highest reef development on their eastern shores. Palominos and Isla de Ramos are the tops of partially submerged hills according to Kaye (1959). Ridges of the former continue south and east as large shallow submerged banks. The degree of development appears to be related directly to the distance from the mouth of Río Fajardo. Palominitos, Isleta Marina, and Cayo Ahogado have been formed by wave deposited sand and coral fragments atop a reef platform. These rise only less than 3 m above sea level and are susceptible to occasional drastic wave erosion, especially Palominitos and Ahogado.

Fringing the mainland, an extensive but dying reef borders the coast from northeast Cabo San Juan to the north end of Punta Sardinera (Fig. 27). The entrance to Bahía Las Croabas is protected by this reef. From Playa Sardinera to Punta Barrancas there are no coral reefs fringing the coast probably because of the influence of the Río Fajardo which carries significant amounts of silt. Narrow coral reefs, however, project eastward about 450 m from Punta Barrancas and Mata Redonda (Fig. 32). There is a shallow reef in the northern Bahía Demajagua which rises abruptly from about 2 m to the reef crest (about .3 m). Coral growth and reef development is not extensive. Going westward there is a deep boulder coral zone which merges into a Acropora zone and is followed by the reef crest where fire coral predominates. Westward is a grass bed with thick mounds of P. porites and extensive zoanthid carpets. Sea fans and other gorgonians are present east of the boulder zone (McKenzie and Benton, 1972).

Off Medio Mundo, Ceiba, is Isla Piñeros (Fig. 33) with moderate coral growth on its northern and eastern coasts and Cabeza de Perro. This latter islet was used by the U.S. Navy for bombing practices and marine life is wanting.

South of this point up to Punta Lima the coast is fringed principally by Thalassia meadows although occasional small fringing and patch reefs occur.

Some of these fringing reefs of the east coast probably rest on sand or mud foundations judging from their location at the edge of tidal swamps (Kaye, 1959). These, for the most part seem to grow from a 6-7 meters deep platform. Also, many patch reefs that do not reach intertidal level occur off this stretch of coast.

The high levels of light penetration, typical of the south eastern end of the island, finds its limit at Punta Lima. West of this point the coastal waters become turbid due to a series of sediment laden rivers and creeks that sharply reduce its transparency. The first significant one is Río Antón Ruíz which is occasionally dredged and pumped. Another source of siltation is the recent development of Palmas del Mar at Humacao which has cleared the vegetation in extensive areas of steep slopes and loose soil. Erosion here has been so extensive that deep scars, which have resulted in damage to beach and coastal communities, are evident in the washed soil. Here occur several islets such as Cayo Santiago and Cayo Batata (Fig. 34) which present some coral growth specially in shallow waters and in areas open to sea (facing south). Surprisingly dense 90 per cent living elkhorn coral stands intermingled with gorgonian and head corals occur close to the surface. Coral cover diminishes drastically with depth giving way to areas of very sparse soft coral growth. It appears that water movement caused by the incoming waves is sufficient to keep coral colonies free of sediment but at the same time water transparency is too low to permit coral growth except in the shallow depths. Submerged shoals with sparse coral growth also occur occasionally off Humacao. An example of this is Bajo Parse (Fig. 34), which consists of numerous gorgonians, small head corals and extensive patches of the encrusting sponge (Anthosigmella varians. Depth is never more than about 5 m.

Adequate ecological conditions for the successful growth of corals do not exist at present in most areas of the Yabucoa Bay. The annular reef located at the southern part of the bay (Fig. 35) is not an exception and, in spite of the fact that a few living corals are found there, several other biological indices from organisms thriving there indicate that environmental conditions existing at present interfere with the normal growth of corals. These conditions seem to be the influence of fresh water coming from the rivers, ravines, and creeks which empty into the bay and resuspension of fine sediments by propellers from the heavy ship traffic. Characteristics of this annular reef are: (1) the scattered growth of A. palmata and many other dead corals, (2) the macroscopic algae colonizing the dead or dying corals, (3) the luxurious growths of large benthic marine algae among the corals, (4) the establish of marine phanerogams, mainly Cymodocea among the corals, (5) the scarcity of reef Foraminifera and the presence of Foraminifera not characteristic of coral reefs (Díaz-Piferrer, 1969, and Seiglie, 1969). About 5.5 nautical miles east of Yabucoa Bay there is a reef called La Conga by native fisherman. This reef was not visited but presumably it forms part of the submerged barrier reef which borders most of the southern shelf of the Island which I am going to describe later.

Sargeant Reef, .3 km southeastward of Punta Tuna is 1.8 miles long and .1 km wide at its widest point. Because it breaks the force of the southeast swell, the reef affords protection from the southeast for the shoreline in the vicinity of Punta Tuna where the reef is from .12 to .18 km from shore. This reef is of a high quality in terms of living coral cover and diversity. It presents a reef flat with abundant A. cervicornis thickets. Following south is an area of reduced A. palmata growth with high encrusting algal cover. This area gives way to a very dense Porites biotope (with patches larger than 100 square meters in some areas) which alternates with overwash colonies of A. palmata. Farther seaward is an area of dense, 100 per cent cover of A. palmata which is reduced gradually south merging with an area where gorgonians predominate.

A fringing reef extends almost continually for four miles along the coast between Cabo Mala Pascua to Puerto Patillas. This is exposed at low tide and protects a low sandy apron which lies at the foot of the Sierra de Guardarraya. A similar highly stressed reef is responsible for the seaward protection of Punta Figueras (Fig. 36). Partially responsible also for the protection of this area and Puerto Arroyo is Arrecife Guayama (Fig. 37) about .6 to .9 km off Punta Figueras. This reef is very extensive (nearly 5 kilometers) but is partially affected by siltation rendering an average low living coral cover. The reef flat of Arrecife Guayama is fragmented in small buttressess with fire of elkhorn coral on their tops depending apparently on the degree of exposure. The finger coral is also an important component of these structures. The _Acropora palmata_ zone has a very low cover and high mortality of standing colonies. Seaward is a zone of small sized gorgonians and dead staghorn coral (_A. cervicornis_) which increases its depth gradually up to the shelf edge. Westward of this reef are the Corona and Algarrobo patch reefs which appear relatively healthy and not much affected by siltation.

South of Las Mareas, Guayama, lies Arrecife Las Mareas (Fig. 38) which is nearly totally devoid of living coral. The death of this reef is probably due to siltation by Guamaní River east of Punta Ola Grande. Tongues of silt have been observed spreading predominantly westward from the mouth of this river (Torres, 1978). High seas and heavy surf action prevailing in this open beach maintain the silt in suspension. Furthermore, the rock jetty protecting the entrance to Puerto Las Mareas, blocks the westward movement of the silted waters retaining them on the eastern side. Extensive dredging operations took place here for the construction of the artificial harbor at Las Mareas and may have contributed to high sediment levels.

Southwest of Punta Pozuelo extends a fringing-barrier reef called Cayos Caribe for a distance of about 2.5 km. As part of the same reef system, but divided from it and each other by shallow channels are Cayos de Barca and Cayos de Pájaro (Fig. 39). These form a distinct arc that effectively protects the entrance of Bahía de Jobos. On the lee side of these reefs, specially Cayo Caribe, are a score of narrow sand cays fringed by mangrove vegetation and oriented normal to the reef margin which are separated from each other by drainage channels. These channels drain the water that washes over the higher, outer margin of the reef to the bay (Kaye, 1959). Living coral cover is moderate and increases westward.

Numerous offshore keys occur south of Salinas (Fig. 40) and Santa Isabel (Fig. 41). These are, west from Cayos de Pájaros, Cayo Morrillos, Cayos de Ratones, Arrecife Media Luna, Cayo Alfeñique, Cayos de Caracoles, and Cayo Cabuzasos. These are in very healthy state with high living coral cover and support rich benthic and nekton populations. Most of them except Media Luna have mangrove vegetation in various stages of development. Crescent-shaped Cayo Alfeñique, with its arms projecting to the northwest, shows the importance of the southeast winds and the northwest and westerly currents in the molding of these features (Kaye, 1959).

Cayo Berbería (Fig. 42), west of Cayo Cabuzasos, has an extensive fringing reef lying on its eastern and southern shores. Coral development reaches its maximum on the southern shore where the A. palmata zone reaches a 95 per cent cover and there is an extensive fish fauna. There is a relatively untouched mangrove forest on the lee side of this cay. Southeast of Berbería is a small, submerged reef called locally Las Cervezas which has extensive elkhorn coral coverage and dense gorgonian stands. Fish life is especially abundant here.

About .6 km southeast off Ponce is Isla Caja de Muertos (Fig. 43) which presents highest reef development on its northeastern shore. Specially notable of this reef is its complex high relief lagoon which supports a large variety of benthic and nektonic fauna.

Off Ponce lie numerous mangrove islets fringed by coral reef (Isla del Frío, Isla de Cardona, Isla de Ratones, and Cayo Cardona) (Fig. 44). These present stands of Acropora palmata surprisingly dense for these silt laden waters. Scleractinian coral growth, though, is sparse in deeper waters where gorgonians dominate.

About 2.5 km south of Ponce is also Bajo Tasmanian, an area of prolific coral growth. Bajo Tasmanian consists of a two leveled platform (Beach, 1975). The northern level ranges in depth from 6 to 12 meters and the southern between 18 and 24 meters. The staghorn coral (Acropora cervicornis) is particularly abundant over much of thislower level. At the shelf edge of this lower level are large shingle-like growths of various massive corals.

The industrial development of Bahía Guayanilla and Tallaboa have significantly altered the natural coastal features and offshore reefs of the area. Reefs off Tallaboa (Fig. 45) are, at present, under high stress conditions due mainly to siltation by periodic dredging of ship channels propeller stirring (Fig. 45a) and also to the discharge of bilge water containing oily wastes into the water as well as the industrial effluents which are presently descharged into this bay. Living coral cover in shallow reef areas off Tallaboa is close to zero with some isolated heads of Acropora palmata and Millepora complanata still surviving in the seaward side. Generally these zones of dead coral are continued south by sparse gorgonian growth and then by slightly higher living, massive coral cover at the reef slope where the sediment apparently does not accumulate. Off Punta Verraco (Fig. 46) is a reef which has an extensive Thalassia and Syringodium bed on its reef flat. Stony coral cover in the shallow front reef is very reduced with the zoanthid Palythoa covering most of the $CaCO_2$ framework. In the deeper fore reef is an extensive and quite healthy community of the possibly more tolerant soft coral or gorgonians.

An extensive submerged reef surrounds the coast from Punta Ventana to Punta Vaquero, where it breaks the surface here first as a fringing reef and later as a barrier reef that protects Playa Tamarindo, Bahía de la Ballena and Playa de Caña Gorda (Figs. 47, 48). This reef is almost totally devoid of living coral and huge living carpets of the fast-growing colonial anemones Zoanthus and Palythoa lie over the dead coral framework.

West of Punta Jorobado coral reefs become more prolific and complex forming a series of provinces and breaking the surface as far as two nautical miles offshore. These are the La Parguera reefs which not only protect other important littoral communities such as mangroves and Thalassia meadows but serve as their foundation (Figs. 49-59).

Here, between the shelf edge and the coast, two elongate reef systems, aligned approximately east-west divide the shelf into an inner, middle and outer shelf.

Two theories have been presented to explain the possible origin of La Parguera reefs, these are:

(1) The major geological features of La Parguera are a result of deformation of upper Cretacous limestones (with interbedded mudstones and volcanic rocks) into a WNW-ESE trending syncline whose axis passes through Magueyes (Almy, 1969). The northern limb of the syncline is represented by the La Parguera hills, and possibly, the southern limb by the trend of coral reefs on the shelf. A longer exposure of the south limb of the syncline to attack by the surf zone at times of low sea levels would result in a lower relief. With a rise in sea level following the end of the last Pleistocene glaciation (Wisconsin), the low limestone ridges on the shelf would have been gradually submerged, providing preferred sites for coral growth and subsequent reef formation (Glynn, 1973).

(2) Kaye (1959) is of the opinion that the reefs in these areas have developed on drowned, calcarenite cuestas, which were formed as eolianite structures parallel to the shore during the Wisconsin glacial period.

Present seismic evidence (Morelock et al, 1977) fits the origin proposed by Kaye (1959) for the inner shelf provinces. However, there is no data for the outer lines of reefs and they may have formed according to the first theory presented.

These reef systems, which are considered the counterpart of the reefs of La Cordillera, Fajardo, have been subjected to comparably little pressure from industry or development. Limited amount of rainfall, minimum runnoff and great quantities of organic matter contributed by fringing mangroves nearby have also contributed to the formation of these highly developed systems. Increased inland deforestation of La Parguera limestones, proposed resort development, domestic waste discharges and closeness to heavy industrial areas, may impose in the near future, a serious threat to these communities.

At this point, I will discuss one of the most spectacular reef systems of Puerto Rico: the shelf edge reef. A well developed submerged barrier reef borders much of the shelf edge south of Puerto Rico. These systems have been most extensively studied in the southwestern shelf. The top of this reef is shallower than further inshore areas and at a depth of 17 to 25 m a sharp break in the nearly level bottom occurs, dropping away at an angle of up to 45 into the Caribbean. A buttressed spur and groove formation (Figs. 60, 61, 62) has been observed for more than 3 km on the shelf edge (Morelock et al, 1977). Sand channels up to 6 m deep with vertical walls generally less than 2 m wide and 20-30 m long are cut into the upper insular slope. These have walls covered with encrusting coral growth, algae, and boring sponges and are separated by a wide coral buttress dominated by massive coral and <u>Agaricia</u> having lushest growth at the shelf edge (Fig. 63). These appear to be some type of surge channel which allows movement of sand from the outer shelf to the slope (Morelock et al, 1977). These sands form an obvious trail down the slope below each channel and have been traced below 70 m. Coral growth is so intense on the walls that they sometimes roof over the grooves providing an excellent habitat for a great variety and number of fish. These grooves continue northward forming shallow channels (Fig. 64) containing calcareous sand and coral rubble (Quinn, 1972). They tend to branch and meander and terminate gradually in coral ridges which are aligned east to west parallel to the shelf edge. These coral ridges rise slightly to shallower depths and are covered with dense stands of gorgonians. Living coral cover is reduced here. Sand flats, also parallel to the shelf edge, occur to the north of the coral ridges. These are slightly deeper than the coral ridges and exhibit ripple marks.

The slope, south of the groove and spur system, consists of cemented or dead coral pavement with little relief below approximately 30 meters. Zonation is drastic, dense stands of gorgonians and antipatharians increasing downwards in relation to a decrease in stony hermatypic corals.

Along shelf edge surveys, Morelock _et al_ (1977) observed areas where the upper 30 to 40 meters of the slope are vertical. Where this occurs there are no grooves and the general nature of the submerged reef is similar to other Caribbean submerged reefs (MacIntire, 1972).

It is postulated that the reefs on the shelf edge built up as barrier reefs during the Pleistocene low sea stand (Goreau and Burke, 1966). The shelf edge was subjected to intermittent surface drainage of water accumulated by wave action or runoff during this periods when subaerial erosion occurred thus forming drainage channels. No growth occurred on the floor of these incisions as a result of continued scourings. As the reefs were drowned by the rapid eustatic sea level rise over the last 4,000 years, these erosional features were enhanced by coral growth forming the buttresses. Erosional processes continue at the present time, their rate being greater than accretion (by coral growth) which is also affected by boring sponges (Goreau, 1966). Currents of substantial velocity (7.5 - 13.0 cm/sec.) move through the channels preventing deposition of coral larvae (Arneson, undated). The shoreward ridges and sand flats described earlier are generally shallower than the shelf edge and probably were above the surf zone at the time of lower sea stand, therefore not affected in the same way as the shelf edge by contact with oncoming waves. They may be a more recent phenomenon of coral growth and sediment entrapment in the lower lying areas of the sand flats (Quinn, 1971). Goreau (1966) has described a similar pattern in Jamaica. Quinn (1971) also postulated that coral growth is lushiest near the shelf edge (Fig. 65) on top of the spurs due to the direct exposure to the oncoming wave trains which provide a continual supply of nutrients.

Coral reef development along the west coast of Puerto Rico can be considered from fair to moderate in relation to either the northeast or the southwest coasts. Between Cabo Rojo and Mayaguez there are various sporadic fringing reefs (Figs. 66, 67) which appear to be suffering from high turbidity of the water, unusually slight wave action and heavy land drainage. The broad bank that lies immediately offshore not only minimizes wave action against the shore by reducing wave energy but also limits the amount of ocean water available for diluting land drainage (Kaye, 1959). Siltation, due to sugar growing activities and especially, to increasing industrial and housing development and low salinities caused by the discharge of Río Guanajibo during fall are other factors threatening these reefs (Kolehmainen and Biaggi, 1975) and Morelock (personal communication).

These fringing reefs are generally wanting in stony corals but possess spectacular dense "forests" of large sized gorgonians (soft corals). Living stony corals are presently being covered by mats of macroalgae (Kolehmainen, 1974).

Offshore reef areas (Fig. 68) include Escollo Negro, Arrecife Tourmaline, Las Coronas, Escollo Rodríguez, Cayo Fanduco, Manchas Interiores, Manchas Exteriores, Arrecife Peregrina, and Gallardo.

Turbidity and sedimentation produced by resuspension of local fine calcareous sediments during heavy, long-period ground swells originating in the Atlantic Ocean mainly during winter months were found by Cintrón _et al_. (1973), Kolehmainen (1974) and Loya (1974) to be the most important factors affecting Arrecife Tourmaline during 1700 hour studies at an underwater habitat. Terrigenous suspended sediments from the Guanajibo River and the presence of seston and plankton in the water column were also found to increase water turbidity during this study. Montastrea cavernosa, a coral species equipped with many features that enable it to remove sediments from its surface, was found to be the most important reef-building coral in areas affected most by siltation. In clear water reefs, this species is an important reef-building species, but not the major one.

A low relief spur and groove system with abundant and diverse encrusting coral growth characterizes the area of Escollo Negro marked in Fig. 68. Water transparency and living coral cover are high. Shoreward, the spur and groove system diminish in relief gradually disappearing. Gorgonian cover increases, stony corals being then represented by small diameter head corals.

Las Coronas is a shallow (2-4 m) sand shoal colonized principally by large sized gorgonians and occasional massive corals. It extends east giving way to Cayo Fanduca which is constituted essentially by the same fauna.

Manchas Interiores, Manchas Exteriores, and Arrecife Peregrina also have low relief spur and groove systems sloping more or less abruptly westward giving way to a dense black coral-dominated fauna. Encrusting coral growth with large pillar coral and gorgonians dominate the shallower depths.

Escollo Rodríguez, situated about 1.6 km west of Caño Corazones is composed of a series of elongated patch reefs. Large dead coral heads, probably deposited during storms, are permanently exposed. The rest of the reef flat is exposed at low tide. This reef lacks any zonation comparable to the other reefs mentioned. There is no back reef slope or apron as characteristic of southern reefs. Instead, the reef flat drops abruptly to deeper back reef areas where large colonies of *A. palmata* occur interspersed between clusters of various gorgonians. Other stony corals are very rare or absent. *Acropora cervicornis* and *Dendrogyra cilyndricus* are common to some extent. The reef is better developed on the northern end where a large *Porites* flat occurs. Fire coral and dead *Diploria* and *Montastrea* heads overgrown by algae are common. Very notable is the presence of crinoids in rather shallow waters. To the west is also a rather abrupt slope with very patchy coral growth. Even so, this is an area of fairly high relief and fish life is abundant possibly due to the abundance of sheltered areas. The reef, in general, appears to be dying due to siltation by terrigenous clays from the Guanajibo River. These observations are based on a report by Schneidermann and Morelock (1973) and on personal observations.

Bajo Gallardo is a well developed, relatively untouched reef about 13 kilometers west of Punta Aguila, Cabo Rojo. It exhibits luxurious elkhorn coral growth and an abundant fish fauna.

North of Arrecife Peregrina to Punta Higüero the insular shelf is very narrow (less than 1 kilometer) and has well developed reefs at its outer edge where the bottom slopes steeply. Stony corals, unusual gorgonians and black corals are abundant at depths of 15 to 40 m, but water transparency is quite variable, being influenced by the local circulation and the discharge of the nearby rivers (Colin, 1978, and personal observations).

Poorly developed fringing reefs, consisting primarily of partially dead Acropora palmata (elkhorn coral) and sparse gorgonians, occur on the north side of the Rincón Peninsula from Punta Higüero to Punta del Boquerón.

North of this point only scattered, undeveloped coral growth occurs.

Off Bajura, Isabela, on the north coast there is an underwater cave system. This system is possibly related to dissolution of the Aymamón limestone which underlays a ridge of young cemented sand dunes of the area. Although not considered a coral reef, coral growth, especially by Agaricia (lettuce coral) colonies, is quite dense on the outer walls and ledges of the caves (Figs. 69, 70). There appears to be a marked biotic zonation, possibly due to changes in light and current conditions, from the various entrances to the interior of these caves.

North of the town of Dorado is an extensive but highly stressed reef fringing the shore (Fig. 72). Its reef flat is about 1-3 meters deep where sea fans (Gorgonia) are very abundant (up to 9 individuals per square meter). Predominant stony corals are Diploria strigosa and D. clivosa. The reef front is a high relief area with many dead coral promontories overgrown either by algae or by other coral species. Depth increases seaward and about 100 meters north of the reef flat are small patch reefs at a depth of 25 meters with abundant fish fauna.

Except for patchy coral growth and several minor coral assemblages in Arecibo (Torres, 1978) and submerged patch reefs off Camuy (Torres, 1978) and off Puerto de Tortuguero (Roberto Castro, personal communication), reef development on the north coast is reduced and cemented dunes are the most important feature protecting our shorelines from the severe buffeting of incoming high energy waves.

SUMMARY AND CONCLUSIONS

1. Clockwise around the Island, starting at San Juan, reefs of very high quality and extensiveness are present in: (1) La Cordillera (including Palomino and Cayo Largo), Fajardo; (2) Sargent Reef, Maunabo; (3) all offshore reefs between Bahía de Jobos and Santa Isabel (including Berbería and Caja de Muertos); (4) Ratones, Ponce; (5) offshore reefs of La Parguera, Lajas; (6) Tourmaline and El Negro reef complex, Mayaguez; and (7) submerged barrier reef at the edge of the southern and western insular shelf.

2. Extensive coral reef degradation was observed in (clockwise from San Juan): (1) all reefs from San Juan to Las Cabezas de San Juan; (2) inshore Fajardo reefs; (3) Humacao reefs; (4) annular reef off Puerto Yabucoa; (5) inshore Ponce reefs; (6) all reefs off Bahía Guayanilla and Bahía de Tallaboa; (7) all reefs off and fringing Guánica; (8) all west coast inshore reefs (from Boquerón to Rincón); (9) reefs off Arecibo; and (10) reefs off Dorado.

3. The most important stress appears to be siltation possibly due to several causes such as upland vegetation clearing which leads to accelerated runnoff, periodic inshore dredging, and alterations in sediment dynamics. Other stresses may be caused by discharge of untreated or partically treated sewage into the sea or

into streams and rivers and mechanical damage by boat anchorage. Coral extraction, though localized, presents a serious problem in the reefs off Fajardo.

4. Rapidly degrading and heavily stressed coral communities of the rock reefs of the north coast, although not nearly as complex and diverse as southern, eastern, and western reefs, are important in the sense that they, by active biological growth, protect the integrity of the structures which they overlay.

5. The underwater caves off Bajura, Isabela, are very interesting features from a biological and geological point of view. Coral communities fringing the various entrances to these caves are extensive and may play an important ecological role.

6. Present observations show that even though occurrence or distribution of certain species within the reef are related to several principal determinants (e.g. wave action, light intensity, etc.), zonation patterns are very diverse around the island and even vary within discrete locations. The principal zones of one reef can be compressed, widened or simply non existent in another. Species coverage within the same zone of two different reefs can vary widely. Zones with very low cover can be very diverse due to high equitability or equal coral distribution. Zones of very high coral

cover can and often do have very low diversities due to the almost complete dominance by a single species. Another factor that has to be taken into consideration is vertical relief. Areas of very low coral species diversity can still have high total diversity due to high relief which creates a very diverse habitat. Examples of this are the monospecific zones of A. palmata. Due to the high relief caused by extensive branching of this species, many other fish and invertebrate fauna populate the underlaying areas. This situation has been reported by Rogers (1977) for San Cristóbal reef at La Parguera. Spur and groove areas also have a high diversity due to their high relief.

7. Observed stressed reefs are characterized by a general paucity of coral species and by areas overpopulated by fast growing species such as the colonial anemones or zoanthids. A clear example are the Guánica reefs. The shallow areas of these reefs are sometimes 100 per cent covered with either Zoanthus or Palythoa. To a lesser extent Guayanilla reefs present similar conditions.

8. Another characteristic we observed in stressed reefs is the over abundance of the sea urchin Diadema antillarum. This condition is probably related to ample supplies of algae which colonize the surfaces of dead corals. Also, reduced predator populations (e.g. Balistes

vetula) related to a dying reef, may cause a *Diadema* population explosion. An example of this are the inshore reefs of Fajardo, such as Ahogado. In contrast to this, was the outer non-stressed Cayo Largo which presented a markedly reduced urchin population.

9. Colony death by bioturbation is common on healthy reefs. Various stages of this process were observed at Cayo Largo, Fajardo. Large sized parrot fish were seen accidentally knocking off branches of individual colonies of *A. palmata*. Consequently, "holes" were made on the otherwise 100 per cent *A. palmata* covered zones. These "holes" are later colonized by rapid growing species such as *M. complanata*.

10. Gorgonian populations were observed to thrive under conditions of heavy siltation and high turbidity. Apparently healthy and dense gorgonian stands were observed on the deeper zones of reefs off Guánica, Guayanilla, and Ponce.

11. Stony corals were also observed to thrive on sloping surfaces in areas with high rates of sedimentation. Due to the nature of sloping surfaces, sediments appear to flow by gravity to the reef base. This is apparent on the fore reef slope of Cayo Caribe, off Tallaboa Bay.

12. Inshore reefs of La Parguera, although apparently underdeveloped, present areas of very high coral species

diversity as shown by the fore slope of Cayo Collado, La Parguera. This, however, may be due to the development of large numbers of small-sized colonies on available, unoccupied substrates.

13. Areas of high water turbidity due to high amounts of fine sediments in suspension permit coral growth on shallow level surfaces. This is apparent in Humacao where A. palmata growth is fairly abundant. Wave action at the surface does not permit the sediments to settle over the corals. Living coral cover, though, decreases sharply with depth due to water turbidity.

14. During the end of the field data gathering period (August 30, 1979) two tropical storms, one of them (David) of considerable magnitude buffeted the island causing extensive reef damage especially in the shallower outer reefs of the east and south coast. Some of these reefs are under very heavy stress and their ability to recover in the near future is seriously questioned by several reef scientists.

15. We conclude that the acceptance of ecological principles is mandatory if the environmental integrity of the reef ecosystem is to be maintained in the face of development. Taking into account the extensive damage made by the two mentioned tropical storms, it seems reasonable to state that an additional stress may seriously

impair the natural capacity of this ecosystem to recover.

RECOMMENDATIONS

1. Pollution research has always been weighted towards public health aspects. It is not always sufficiently recognized by pollution scientists with a public health background, that waters containing levels of pollutants which do not threaten human health directly are destructive to aquatic communities (Johannes, 1975). Water pollution research in relation to benthic marine communities should be promoted and sponsored by the Department of Natural Resources in coordination with the Environmental Quality Board and the University of Puerto Rico. This research should aid in the modification, if necessary, of our water pollution laws and regulations.

2. The enactment and effective enforcement of appropriate laws, and the public censure of polluters can only be brought about when the public is made aware of their value. The most important step in deterring both the corporate and the individual polluter is thus education (Johannes, 1975). We think it should be of high priority to the Coastal Zone Management Division to prepare televised educational programs for the public in general in order to create consciousness of the importance of this and other important coastal ecosystems. Several public information booklets have already been prepared by this Division.

3. Reef areas which because of their quality and extensiveness should be included among the Natural Reserves are: (1) La Cordillera, Fajardo, (including Palomino and Cayo Largo); (2) Sargent Reef, Maunabo; (3) all offshore reefs between Bahía de Jobos and Santa Isabel (including Berbería and Caja de Muertos); (4) Cayo Ratones, Ponce; and (5) Tourmaline and El Negro reef complex.

4. The underwater caves off Bajura, Isabela, should be considered an important and potential touristic diving attraction. Safety measures, such as marking its diverse entrances and exits, should be taken by this Department.

5. Coastal Zone Management Division should prepare booklets with the following recommendations to divers and boaters:

(a) boat anchors - These never should be dropped on top of a reef. Damages by doing this are the tearing up of coral when it hits, the continued slashing of coral while the boat is anchored and the tearing of more coral when the anchor is hauled up. A Danforth-type anchor should be used by dropping it in a sandy patch and letting the boat drift over the reef.

(b) sitting and standing on coral - This not only causes breakage of branching corals but abrades and injures tissue which can then be infected by algae. Holding onto coral can have the same consequences. Dead coral and bottom rocks should be used for this purpose.

(c) <u>shell collection</u> - Pry-bars should never be used to dislodge and turn over coral heads.

(d) spear fishing - Coral injury from flying spear shafts and working a fish in a cave can be very severe.

6. Laws requiring the replanting of land cleared of vegetation have been poorly enforced in the past. We recommend that these actions be monitored by these Department in order to reduce reef siltation.

7. In summary, we recommend the active involvement of this Department in coming actions such as dredging, upland deforestation, etc. which could result in the serious impairment of the natural abilities of the reef ecosystem to repair itself and recover after the past tropical storms. The new erosion regulation being prepared by the Coastal Zone Management Division should, by all means, include the control of upland deforestation.

This active involvement is completely necessary if the policy of this Department favors the preservation of these most important and endangered Puerto Rican natural resources.

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Table 1.

Reef	Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
North east coast Cabo San Juan Coordinates Lat. 18°22.1' Long. 65°37.2'	Fajardo	Reef crest	--	--	5-10	*A. palmata* and *M. complanata*	Colonies heavily silted. Gorgonians common.
		palmata zone	--	--	--	*A. palmata*	Very sparse growth. Many dead and overturned colonies.
		Slope	--	--	--	Head corals and *Agaricia*	Colonies of the hydrocoral *Stylaster* common.

REMARKS: Heavily stressed reef probably due to discharge from Río Fajardo.

Table 2.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Isleta Marina (East) Fajardo Coordinates Lat. 18°20.6' Long. 65°37.0'	Reef crest	--	--	--	M. complanata and M. alcicornis	90% of standing coral dead. P. asteroides common.
	Mix and palmata zone	--	--	--	Massive coral and A. palmata	Zones not well defined. A. palmata and Diploria labyrinthiformis competing for space (¿?)
	Slope	--	--	--	Sparse gorgonians	Reduced cover. A. agaricites and S. siderea common.
	Reef flat	--	--	--	Thalassia	Dead coral fragments common. Many algal species present. P. porites abundant.

REMARKS: Heavily silted reef possibly due to the influence of Rio Fajardo and by construction activities on the island.

Table 3.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Zancudo Fajardo (North) Coordinates Lat. 18°20.6' Long. 65°37.2'	Reef crest	--	--	--	*A. palmata* and *M. cavernosa*	Sparse growth Small *Diploria strigosa* heads common.
	palmata zone	--	--	--	*A. palmata*	Slightly higher cover. *M. alcicornis* common.
	Mix zone and slope	--	--	--	Gorgonians	*Agaricia* sp., *Colpophyllia natans* common.
	Reef flat	--	--	--	Consolidated limestone overgrown by several species of algae.	

REMARKS: Heavily silted reef.

Table 4.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Ahogado Fajardo						
Coordinates Lat. 18°19.3' Long. 65°37.1'	Reef crest	--	--	--	M. complanata	A. palmata common.
	palmata zone	--	--	--	A. palmata	40-55 % of standing A. palmata dead. Sea urchins very abundant of top of these colonies.
	Slope	--	--	--	Gorgonians and heads	Sparse growth

REMARKS: Heavily silted reefs. Salinities close to 0‰ have been measured on the surface of the reef flat during heavy rains. Colonies of M. complanata had expulsed zooxanthellas and died (as shown by the lack of stinging properties).

Table 5.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Palominitos Fajardo (south) Coordinates Lat. 18°20.5' Long. 65°34.0'	Reef crest and palmata zone	--	--	--	A. palmata	These two zones are mixed. M. complanata common but not predominant. D. clivosa, F. fragum, D. stokesii, A. cervicornis and P. asteroides common. Very high cover although a significant number of colonies are partially broken.
	Mix zone	--	--	--	Gorgonians and M. annularis	P. porites and A. cervicornis common. This zone descends up to about 6m where there are large colonies of A. palmata at the fore edge. This is a zone of very high diversity. There is a limited groove and spur system about 2.5 m in relief.
	Slope	--	--	--	A. agaricites and head corals	Area of high competition for space. Slope very steep. Flattened growth forms. Madracis sp., P. asteroides, P. porites, Eusmilia fastigiata, Diploria, M. lamarckiana, I. sinuosa, M. angulosa common.

REMARKS: The fore reef of Palominitos is heavily damaged by what appears to be boat anchorage. The abundance of Madracis decactis is notable. For a more detailed description of the benthic communities of this and other east coast systems the writer is reffered to Mckenzie and Benton (1972).

Table 6.

Reef	Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Largo	Fajardo						
Coordinates Lat. 18°18.8' Long. 65°34.8'		Reef crest	0	0	100	*A. palmata*	Very abundant *A. palmata* with different shapes related to degree of exposure. Very occassional growth of *M. complanata* where "holes" in the dense *A. palmata* occur.
		palmata zone	--	--	75	*A. palmata*	Cover is slightly reduced. This area ends rather abruptly giving way to the mix zone.
		Mix zone	1.58	0.72	25		Area of medium relief with very high number of coral species. Diversity lower than in the slope due to patchiness of coral distribution. *M. annularis*, *A. palmata*, *P. porites*, *M. complanata* and gorgonians common.
		Slope	1.02	0.63	35	*A. cervicornis* and gorgonians	Zone of low relief dominated by *A. cervicornis* on upper slope and by gorgonians on lower slope. *P. porites* very common. Small head corals common.
		Reef flat	--	--	--	*P. porites*	Porites biotope very well developed covering extense areas. Absence of *Diadema* and other urchins is notable.

REMARKS: Reef terminates eastward with a bare sand "halo" about 8 meters wide after which a very healthy *Thalassia* bed starts. Large "halo" may be due to an extensive ichthyofauna. Numerous Queen Conch (*strombus gigas*) were present in this bed. Paucity of sea urchins in the reef flat may be due to very low coral mortality which are overgrown by algae and grazed by these echinoids. Within the reef crest sometimes is apparent the effect of bioturbation (coral breakage by fish in this case). Apertures on the dense zone are then colonized by *M. complanata* and plate-like colonies of *P. asteroides*. Several stages of this process were observed. This is a relatively untouched reef of great complexity which deserves further study.

Table 7.

Reef : Locality	Zonation	Diver-sity	Equita-bility	% Coral cover	Main Component	OBSERVATIONS
Ramos (West) Fajardo Coordinates Lat. 18°18.9' Long. 65°36.6						
	Reef crest	--	--	--	*A. palmata*	*M. complanata* absent. Small *D. strigosa* common. Large *M. annularis* colonies with dead areas on their top parts. *Colpophyllia* common.
	Slope	--	--	--	Gorgonians	High gorgonian density. *A. cervicornis* and *S. siderea* common.
	Reef flat	--	--	--	algae	Dead coral colonized mainly by several algal species. *P. asteroides* common. Sparse *A. palmata* increasing westward.

REMARKS: West of the slope are dead *A. cervicornis* patches, a "halo" about 3m wide and a *Thalassia* - *Syringodium* bed. Siltation evident. Living coral cover low.

Table 8.

Reef : Locality	Zonation	Diver-sity	Equita-bility	% Coral cover	Main Component	OBSERVATIONS
Ramos (East) Fajardo Coordinates Lat. Long.	Reef crest	--	--	--	M. complanata	Dead colonies common. Halimeda, P. asteroides and D. strigosa common.
	palmata zone	--	--	10-30	A. palmata	Overturned and dead colonies common. Gorgonian common.
	Slope	--	--	--	Gorgonians	P. asteroides and head corals present.

REMARKS: Very turbid water possibly by the outflux of Río Fajardo. The crest zone merges with the reef flat which is common to the west reef, also.

Table 9.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Piñeros Ceiba Coordinates Lat. 18°15.3' Long. 65°35.5'	Reef crest	0.55	0.51	60	*M. complanata*	Sparse growth. No abrupt separation between this zone and *A. palmata* zone.
	palmata zone	0.65	0.47	52 (live and dead but standing cover)	*A. palmata*	Many colonies dead and standing. Low living cover (about 20%). *D. strigosa* common. *M. alcicornis* common.
	Slope	--	--	--	Gorgonians	Isolated *M. annularis* heads. Barely any other coral species.
	Reef flat	--	--	--	*Thalassia*	--

REMARKS: Relatively undeveloped reef. Reef fringing the east coast less developed. From the shore to sea there is a *Thalassia* and *Syringodium* bed followed by a band, about 20m wide of 95% dead coral. Farther east is a zone of 10% live *A. palmata* (20% standing cover) increasing to 20% seaward and finally a band 13m wide of gorgonians and small head corals. Coral reef development on neighboring island Cabeza de Perro is virtually non-existent due to bombing practices by the U.S. Navy.

Table 10.

Reef : Locality	Zonation	Diver-sity	Equita-bility	% Coral cover	Main Component	OBSERVATIONS
Santiago Humacao Coordinates Lat. 18°09.5 Long. 66°44.0'	palmata zone	--	--	60-70	A. palmata	Colonies of very diverse shapes and with no definite orientation. These alternate with gorgonians. In shallower areas, M. complanata is common. Small head corals, common.
	Slope	--	--	--	gorgonians	Large heads of M. annularis common.

REMARKS: Reef terminates with an area of very sparse gorgonian growth.

Table 11.

Reef : Locality	Zonation	Diver-sity	Equita-bility	% Coral cover	Main Component	OBSERVATIONS
Guayama Arroyo Coordinates Lat. 17°56.5' Long. 66°01.5	Reef crest	--	--	--	A. palmata and M. complanata	Reef crest fragmented into numerous patches where either of the two principal components dominate according to the degree of exposure. P. porites an important reef crest component A. cervicornis and M. annularis common. 60% of A. palmata dead.
	palmata zone	--	--	35	A. palmata	Reduced cover and many colonies dead.
	Mix zone	--	--	--	Gorgonians	Gorgonians very small in height. Dead A. cervicornis common.
	Dead A. cervicornis zone	--	--	--	A. cervicornis	Very few gorgonians present.

REMARKS: Southward of the dead A. cervicornis zone the depth increases gradually to the edge of the shelf. Sparse gorgonians are present here. This reef is considered as decaying and unhealthy.

Table 12.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Cayos Caribe; Punta Pozuelo Jobos Coordinates Lat. 17°55.5' Long. 66°12.5'	Reef crest	--	--	--	M. complanata	Palythoa very common. Encrusting gorgonian Erythropodium common. Calcareous algae common. Channels of 1-2 meters of relief.
	palmata zone	--	--	39-49 (Szmant, undated)	A. palmata	Sea fan (Gorgonia) common. Large pieces of rubble encrusted with P. asteroides, Palythoa, Erythropodium and Chondrilla. M. annularis common.
	Buttress zone	--	--	63 (Szmant, undated)	A. palmata	Zone of high relief due to large A. palmata colonies. Depth varies from 5-8 meters. Rich fish and invertebrate area. *
	Fore reef slope	--	--	--	--	M. annularis, M. cavernosa, S. siderea, D. labyrinthiformis, Isophyllastrea rigida, Mycetophyllic and Mussa common. *
	Reef flat	--	--	--	P. asteroides and overwash A. palmata	Forms small channels and lagoons in some places between mangrove stands. Depth up to 1m. Usually a strong out flow current occurs. P. porites, Favia, Agaricia and siderastrea common. Sparse Thalassia.

REMARKS: Sea urchins (Diadema and Trypneustes) common in the reef flat. High cover of Palythoa and Zoanthus in this area. Size of A. palmata increases with depth. Beyond the varied relief of the buttress zone, the reef flattens out and slopes down to its base. Reef slope gradual down to about 13 m and then abrupt to 19m. Channels cut through reef slope in some areas. Agaricia common in the walls of these channels.

* based on Szmant, undated.

Table 13.

Reef : Locality	Zonation	Diver-sity	Equita-bility	% Coral cover	Main Component	OBSERVATIONS
Las Mareas Guayama Coordinates Lat. 17°55.8' Long. 66°08.5'						
	Reef flat	--	--	--	Algae	Principal algal components are Dyctiopteris, Halimeda and Dyctiota. These cover almost 95% of the available substrate. Shoreward the cover is reduced.
	Slope	--	--	--	Encrusting sponges and algae	Many over hanging ledges indicating erosional processes. Where this zone merges with the reef flat there are extensive pits made by the sea urchin Echinometra lucunter.
	"Fore reef"	--	--	--	Echinumetra lucunter	Very abundant urchin pits. Promontories of high relief overgrown to different extent. These probably represent collapsed ledges.

REMARKS: No living corals apart from Millepora squarrosa and Siderastrea radians were observed. Turbidity of the water was very high. No gorgonians were observed. Shoreward from the reef flat is a Thalassia bed followed by a Syringodium bed . Between the latter bed and the shore is a depression where large amount of broken off algal fragments collect. (Observations based on Torres 1978 and personal visits to the area).

Table 14.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Pajaros Salinas						
Coordinates Lat. 17°55.5' Long. 66°15.7'	Reef crest	--	--	--	M. complanata	Fragmented into buttressess about 3m in relief and overwash. D. clivosa and A. palmata common. Ictyofauna abundant possibly due to the highly sheltered area. Encrusting sponge Cliona common.
	palmata zone	--	--	--	A. palmata	Well developed.
	Mix zone and slope	--	--	--	gorgonians and head corals	Similar to Morrillos, Salinas.

REMARKS: The north side of this cay is highly stressed with many dead and overturned colonies.

Table 15.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Morrillos Salinas						
Coordinates Lat. 17°55.8' Long. 66°15.3'	Reef crest	--	--	--	M. complanata	Very wide zone (from north to south). Buttressess about 2m in relief present. Coralline algae a very important component of this zone. Sand channels oriented N-S between the buttressess. Dead coral present in the channels.
	palmata zone	--	--	--	A. palmata	Slightly deeper sand channels in this zone. No dead coral, just bare sand in the channels.
	Mix zone and slope	--	--	--	Head corals and gorgonians	M. cavernosa, Meandrina meandrites, S. radians, I. rigida, C. natans and D. strigosa common.

REMARKS: Mangrove vegetation present.

Table 16.

Reef : Locality Patones Salinas	Zonation Ree	Diversity	Equitability	% Coral cover	Main Component	O B S E R V A T I O N S
Coordinates Lat. 17°56.2' Long.66°17.5'	Reef crest	0.38	0.35	39	*M. complanata*	*A. palmata* common.
	palmata zone	0.36	0.22	40	*A. palmata*	*Palythoa* common. Zone of coarse bare sand between crest and *palmata* zone.
	Upper and lower mix zone	1.25 1.64	0.92 0.84	6 16	Gorgonians and massive corals	Gorgonians very abundant anddominant in upper mix zone. Massive corals dominant near reef base. *Mycetophyllia* and *Oculina* common

REMARKS: Seaward of the reef crest is an abrupt slope leading to a bare sand area with occassional isolated small head corals. Farther south depth decreases asrapidly to a zone where medium relief mounds occur. *M. complanata* grows on top of these structures.

Table 17.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Alfeñique Santa Isabel Coordinates Lat. 17°55.8' Long. 66°21.1'	Reef crest	--	--	70	*M. complanata*	Blades oriented E-W.
	palmata zone	--	--	20-40	*A. palmata* and gorgonians	Many silted colonies.
	Mix zone and slope	--	--	--	Gorgonians	*A. palmata* common. Head corals common.
	Lagoon	--	--	--	Sparse *Thalassia* and dead *Porites*	--

REMARKS: Zonation not well defined to this side (east) of the reef. *A. palmata* zone not nearly as well developed as other nearby reefs. Spur and channel system east of reef slope with orientation roughly north to south or parallel to the reef crest. Cover in this area is mainly by gorgonian in the spurs and bare sand on the bottom of the channels.

Table 18.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Cabuzosos Santa Isabel Coordinates Lat. 17°55.4' Long. 66°23.1	Reef crest	--	--	40	M. complanata	Small Diploria clivosa and D. strigosa form an important component of this area. Calcareous algae also very common. Palythoa common. About 30% of the available substrate is uncolonized
	palmata zone	--	--	45-75	A. palmata	Cover increases seaward.
	Mix zone	--	--	--	A. cervicornis and gorgonians	Both components very abundant. M. annularis, P. asteroides, Dendrogyra cilyndricus and Colpophyllia natans common.
	Slope	--	--	--	Gorgonians and A. agaricites	M. cavernosa, M. lamarckiana, Dichocoenia stokessii, I. sinuosa, P. asteroides and several sponges common.
	Reef flat	--	--	--	P. porites and Thalassia	Well developed Porites biotope and farther north a Thalassia bed mixed with Porites.

REMARKS:

Table 19.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Cayo Erio Ponce Coordinates Lat. 17°57.9' Long. 66°33.4'	Reef crest	--	--	--	M. complanata and M. alcicornis	Mounds about 1m in height with coral on top. Coralline algae abundant.
	palmata zone	--	--	--	A. palmata	D. clivosa an important component. Small M. annularis overwash mounds.
	Slope	--	--	--	Gorgonians	Large S. siderastrea heads.

REMARKS: -Due to high water turbidity the southern limit of the gorgonian community was assessed up to a depth of 5m.

Table 20.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Cardona Ponce Coordinates Lat. 17°57.5' Long. 66°38.1'	Reef crest	--	--	75	M.complanata	High cover. Low relief mounds with M. complanata growing on their tops at slightly deeper areas seaward of the crest. Palythoa common.
	palmata zone	--	--	20-45	A.palmata	High cover far high water turbidity present. Cover increases seaward.
	gorgonian zone	--	--	--	Gorgonians and occassional A. palmata	Sparse growth.

REMARKS: Gorgonian zone commences seaward of the fore reef slope and continues for an unknown distance. Small head corals occur here.

Table 21.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Ratones Ponce Coordinates Lat. 17°57.1' Long. 66°40.8'	Reef crest	--	--	--	M. complanata	Ocassional A. palmata. Patythoa abundant. Small (1m) mounds with M. complanata and D. strigosa on their tops.
	palmata zone	--	--	--	A. palmata	Many dead colonies in northern zone. Living cover increases seaward. Sporadical gorgonians and M. annularis colonies, large buttressess with A. palmata at their tops about 3 meters in relief.
	Mix zone	--	--	--	Gorgonians	A. palmata cover reduces gradually white gorgonian cover increases. Dead A. cervicornis common. M. annularis, M. cavernosa and Siderastrea common.
	Reef flat	--	--	--	Thalassia and Syringodium	Porites biotope not well developed.

REMARKS: Wide gorgonian zone (close to 100m.). Gorgonian patches south of reef slope. Mangrove vegetation on reef flat.

Table 22.

Reef : Locality	Zonation	Diver-sity	Equita-bility	% Coral cover	Main Component	OBSERVATIONS
Caribe Tallahoa Bay Coordinates Lat. 17°58.2' Long. 66°44.0'	Dead coral zone	--	--	--	Dead coral	Area consisting mainly of coral rubble with *Palythoa* and *Millepora* colonizing parts of the dead coral. Isolated *A. palmata* colonies.
	Former mix zone	--	--	--	Sporadical gorgonians	90% of zone is bare sand.
	Slope	--	--	--	Gorgonian	Gorgonian density increases in slope. *M. cavernosa*, *M. annularis*, *D. clivosa*, and *Dendrogyra cylindricus* common. Mortality reduced.
	Reef flat	--	--	--	*Thalassia* and *P. porites*	Large bare sand areas. Mangrove islet present.

REMARKS: Shallow parts of this reef are dead possibly due to neahy dredging and ship traffic which stir up the sediments thus smothering corals. The slope, however, seems normal possibly because sediment runsdown the reef base without being deposited on coral's surface. Isolated A. palmata colonies in the dead zone may signify higher individual tolerance. Fish life is sparse in the dead zone while quite abundant on slope.

Table 23.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
San Cristobal La Parguera Coordinates Lat. 17°56.7' Long. 67°04.2'	Reef crest	--	--	--	A. palmata and M. complanata	Crest not solid but fragmented into buttresses of the two predominant species.
	Palmata zone	--	--	--	A. palmata and under-laying dead coral	Northern most section with colonies having blades oriented N-S. Farther south blades are thicker and with no definite orientation. Standing partially dead colonies, common.
	Buttress zone	--	--	--	M. annularis	Other head corals, A. cervicornis and P. porites common.
	Slope	--	--	--	gorgonian and A. cervicornis	M. annularis, M. cavernosa and Diploria labirynthiformis common.
	Reef flat	--	--	--	A. cervicornis thickets and gorgonians	Thalassia mixed with Zoanthus. Dyctiota common. Patches of gorgonians and head corals.

REMARKS: North of crest follows an area of dead coral fragments cemented by coralline algae; Porites biotope; sparse Thalassia with zoanthids; area of Dyctiota; patches of heads and gorgonians. Reef flat extends to mangrove. Apron is bare sand.

Table 24.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Enrique La parguera						
Coordinates Lat. 17°57.4' Long. 67°02.8'	Reef crest	.94	.68	19	M. complanata	A. palmata common. Dead, overturned A. palmata colonies, common. Some coralline algae.
	palmata zone	.18	.12	60	A. palmata	Zone reduced due to abruptness of slope.
	Mix zone and slope	.51	.32	51	A. cervicornis and massive corals in the lower slope.	Diploria, M. annularis and A. agaricites abundant. Occasional clumps of Oculina.
	Reef flat	--	--	--	Thalassia and mangrove isled	Zoanthus common.

REMARKS: Well developed platform in the front reef at about 8 meters depth. Dead coral common in this area. Width of platform is reduced to the west until it gradually disappears.

Table 25.

Reef : Locality	Zonation	Diver-sity	Equita-bility	% Coral cover	Main Component	OBSERVATIONS
Laurel La Parguera Coordinates Lat. 17°56.6' Long. 67°03.8'	Reef crest	--	--	--	M. complanata	M. complanata blades oriented E-W. A. palmata common.
	palmata zone	--	--	100	A. palmata	Well developed zone with cover reduced south ward.
	Mix zone and slope	--	--	--	A. cervicornis and gorgonians	Head corals common.
	Micro patch reefs south of slope	--	--	--	M. annularis and Agaricia sp.	High relief area.
	Reef flat	--	--	--	--	A. palmata with dead tips of branches.

REMARKS: North of crest follows an area of A. palmata and P. porites; broader area of dead Porites with sparse colonies of P. asteroides; sparse Thalassia. Reef of considerable size and development.

Table 26.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Turrumote I La Parguera Coordinates Lat. 17°56.3' Long. 67°01.2'	Rèef crest	1.15	0.63	58	A. palmata and M. complanata	A. palmata dominates over M. complanata. Branches of the former, oriented N-S. Blades of M. complanata oriented E-W.
	palmata zone	0	0	100	A. palmata	Solid cover by this species. Some growth can be delected on the substrate beneath.
	Mix zone	1.75	0.84	24.2	M. annularis P. asteroides and gorgonians	Area of highest coral diversity even though cover is not as high.
	Buttress zone	--	--	--	M. annularis and Agaricia sp.	Zone of very high relief (over 2m).
	Reef flat	--	--	--	Sandy, some Thalassia, mangrove isledt	--

REMARKS: . Buttress zone of very high relief. East of this reef is a zone of even higher relief called locally "The Pinnacles" where there is an abundant icthyofauna.

Table 27.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
La Gata La Parguera Coordinates Lat. 17°57'54" Long. 67°2'6"	Reef crest	--	--	40%	M. complanata	Many bear substrate mainly dead A. palmata. M. complanata oriented E-W. Stoichacthys common.
	palmata zone	--	--	70-85	A. palmata	--
	Mix zone	--	--	55	M. annularis	Sparse palmata and gorgonians common.
	Slope	--	--	--	Gorgonians and head corals	M. cavernosa, D. strigosa and M. annularis, Agaricia common.
	Reef flat	--	--	--	Thalassia and dead P. porites	Zoanthus and Palythoa common.

REMARKS: ·South of the reef base is a high turbidity zone with isolated partially dead gorgonian colonies. North of crest is a zone of dead coral about 5m wide followed by sparse Thalassia which gets denser close to the mangroves.

Table 28.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Margarita La Parguera Coordinates Lat. 17°55.2' Long. 67°6.7'	Reef crest	--	--	60	M. complanata	Small sized A. palmata colonies, common. Palythoa abundant.
	palmata zone	--	--	25-75	A. palmata	Wide (100m) zone
	Buttress zone	--	--	--	M. annularis, P. porites and gorgonians	Gorgonians very abundant. Zone over 600m wide (N-S).
	Reef flat	--	--	--	Partially dead P. porites	Badly sorted sediment.
	Apron	--	--	--	Sandy; some Thalassia	--

REMARKS: A. palmata and mix zones very broad from north to south. Reef slopes gradually southward reaching a zone of dense gorgonian growth at about 130 m from the reef crest and dissipates at a depth of 16m and at a distance of over 600m from the reef flat. No mangrove present.

Table 29.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Las Pelotas, La Parguera Coordinates Lat. Long.	Reef crest	--	--	--	A. palmata	Northern reef crest wanting in M. complanata. P. porites common. Southern crest with abundant Palythoa and some M. complanata.
	palmata zone	--	--	60	A. palmata	Narrow zone
	Mix zone and slope	--	--	--	Gorgonians, A. cervicornis and M. complanata	A. cervicornis very abundant.
	Reef flat	--	--	--	Thalassia mixed with zoanthus	P. porites and A. palmata common.
	Apron	--	--	--	Bare sand with some Thalassia	--

REMARKS: Reef disipates at about 13m depth. M. annularis patches occur southward of the 13m depth contour. Mangrove islet present. South of mangrove islet is an area of large sized (3.5m diameter) A. palmata colonies. Eastward of this area, A. palmata cover is reduced and isolated heads of M. annularis of large size occur. Farther eastward is a zone of isolated A. cervicornis colonies. Subsediment dark in this area (anoxic). Gorgonians abundant. North of this area the depth is reduced and there is a dense A. palmata zone followed by a M. complanata zone and later by a dense Thalassia meadow.

Table 30.

Reef	Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Cayo Ahogado	La Parguera						
Coordinates Lat. Long.		Reef crest	--	--	--	A. palmata and M. complanata	--
		palmata zone	--	--	--	A. palmata	--
		Mix zone	--	--	--	M. annularis, M. alcicornis and gorgonians	Isolated gorgonians just north of slope.
		Slope	--	--	--	Small head corals	Many stressed colonies
		Reef flat	--	--	--	Thalassia and A. cervicornis thickets	North of the crest is a "halo" about 1m wide after which the Thalassia meadow starts.

REMARKS: Zonation not well defined. No zoanthids in lagoon. Large aggregations of sea urchin Diadema and isolated gorgonians where crest is absent. Crest dominated by A. palmata instead of M. complanata possibly due to the protection of Enrique Reef. Very turbid zone south of the slope with partially dead isolated head corals. Reef rises abruptly from sea floor.

Table 31.

Reef	Locality	Zonation	Diver-sity	Equita-bility	% Coral cover	Main Component	OBSERVATIONS
Media Luna	La Parguera Coordinates Lat. 17°56.4' Long. 67°02.8'	Reef crest	--	--	--	M. complanata and M. alcicornis	Colonies oriented E-W
		palmata zone	--	--	80	A. palmata	A. cervicornis common.
		Mix zone	--	--	--	A. cervicornis and gorgonians	--
		Slope	--	--	--	Massive corals and gorgonians	Limited spur and groove system.
		Lagoon	--	--	--	Sandy; some Thalassia	--

REMARKS: North of the crest is a zone of P. porites followed by a band where P. asteroides dominates. Density is reduced leeward where a zone of dead A. prolifera and gorgonians occur. No mangrove vegetation. A. cervicornis, P. porites, and massive corals predominate in the apron. Differences between Enrique and Media Luna aprons are due to different wave regimes (Morelock, 1977).

Table 32.

Reef	Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
La Conserva	La Parguera						
Coordinates Lat. Long.		Reef crest	--	--	--	M. complanata	Exposed at low tide
—		palmata zone	--	--	--	A. palmata	Very narrow zone
		Mix zone and slope	--	--	--	A. prolifera, dead A. cervicornis, M. annularis and gorgonians	Coverage very low. Many dead colonies of A. palmata and A. cervicornis apparently due to siltation.

REMARKS: Reef not well developed possibly due to excessive protection to wave action. Mangrove islet present.

Table 33.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Collado La Parguera Coordinates Lat. Long.	Reef Crest	1.21	0.86	38	M. complanata and Palythoa caribaeorum	Palythoa is a very important component on the inner reef flat.
	Palmata Zone	0.1	0	58	A. palmata	Zone narrow and not well developed.
	Thalassia bed	--	--	--	Thalassia	Sparse and sedimented Thalassia bed between palmata and mix zone. Thalassia thin and short-bladed on coarse biogenic sand.
	Mix zone	2.01	0.91	23	Gorgonians and massive corals	Mix zone commences drastically south of Thalassia bed. Coarse sediment. Sponges common. Colpophylia natans common.
	Reef flat	--	--	--	Thalassia, P. porites and P. asteroides	Halimeda zone divides crest and lagoon.

REMARKS: Anticlimactic Thalassia bed between palmata and mix zone. Isolated patches of A. cervicornis, M. complanata, Siderastrea siderea and gorgonians occur within this bed. Diadema common. "Halo" about 1m wide between this bed and palmata zone. Reef terminates gradually south of mix zone. Mangrove vegetation. Apron is bare sand.

Table 34.

Reef : Locality	Zonation	Diver-sity	Equita-bility	% Coral cover	Main Component	OBSERVATIONS
Bajo Enmedio Boquerón Coordinates Lat. 18°01.3' Long. 67°12.6'	Thalassia bed	--	--	--	Thalassia	Sparse to moderately dense.
	"Mix" zone	--	--	--	Gorgonians and A. cervicornis	Leveled platforms with very densely gorgonian growth alternating with A. cervicornis patches. M. annularis, P. porites, M. cavernosa and Colpophylia natans common.
	Slope	--	--	--	Gorgonians	Zone of high turbidity. Gorgonians of great size and abundance as sole colonizers.

REMARKS: Gorgonian "forests" most espectacular feature of this and other west coast reefs. Turbidity fairly high.

Table 35.

Reef : Locality	Zonation	Diversity	Equitability	% Coral cover	Main Component	OBSERVATIONS
Guaniquilla Boquerón Coordinates Lat. 18°02.7' Long. 67°12.3'	Reef crest	--	--	--	M. complanata and A. palmata	--
	palmata zone	--	--	--	A. palmata	Standing, dead colonies common.
	Sparse gorgonian zone	--	--	--	Gorgonians	Fine sediment and very sparse gorgonian growth. Density of the latter increases westward.
	Mix zone and slope	0.68	0.32	20	Gorgonians	Densely populated by large sized gorgonians (close to 2m.). Large heads of M. annularis. C. natans, M. alcicornis, S. siderea, M. annularis, M. lamarchiana and P. porites common. A. cervicornis common in mix zone.
	Reef flat	--	--	--	Thalassia	Seaward from shore is a Thallasia bed followed by a dead coral zone.

REMARKS: Heavily silted fringing reef possibly due to discharge of nearby rivers. West of reef slope there is a zone of fine silt with occasional gorgonian patches.

Table 36.

Reef	Locality	Zonation	Diver-sity	Equita-bility	% Coral cover	Main Component	OBSERVATIONS
Punta Ostiones	Cabo Rojo						
Coordinates Lat. 18°05.5' Long. 67°12.0'		Reef crest	--	--	--	M. complanata and D. strigosa	No A. palmata. P. asteroides common.
		Slope	--	--	--	Gorgonians	Abrupt slope. Head corals common. Gorgonians large and abundant.
		Reef flat	--	--	--	Thalassia	Small leaved (5m) Thalassia. Considerable portion of reef flat bored by urchin Echinometra. Dyctiota common. Palythoa common.

REMARKS: Reef terminates abruptly. One meter "halo" east of reef base after which starts a Thalassia bed. Slightly higher coral cover than Ratones, Joyuda.

Table 37.

Reef : Locality	Zonation	Diver-sity	Equita-bility	% Coral cover	Main Component	OBSERVATIONS
Ratones Joyuda Coordinates Lat. 18°07.1' Long. 67°11.3'	Reef crest	--	--	--	M. alcicornis	A. palmata common. M. alcicornis emergent or overwash.
	palmata zone	1.10 (lower palmata zone)	0.68 (lower palmata zone)	33 (lower palmata zone)	A. palmata	Crest and A. palmata zones intermixed. Lower palmata zone is the most diverse.
	Slope	--	--	--	Gorgonians	Colpophylia natans, M. cavernosa and M. annularis common.
	Reef flat	--	--	--	Thalassia	Sparse P. porites and overturned massive corals common. P. asteroides common close to crest.

REMARKS: Small patch reefs continue west of the fore reef slope. Fine sediment mixed with Halimeda. Islet with extensive beach vegetation.

Figure 73

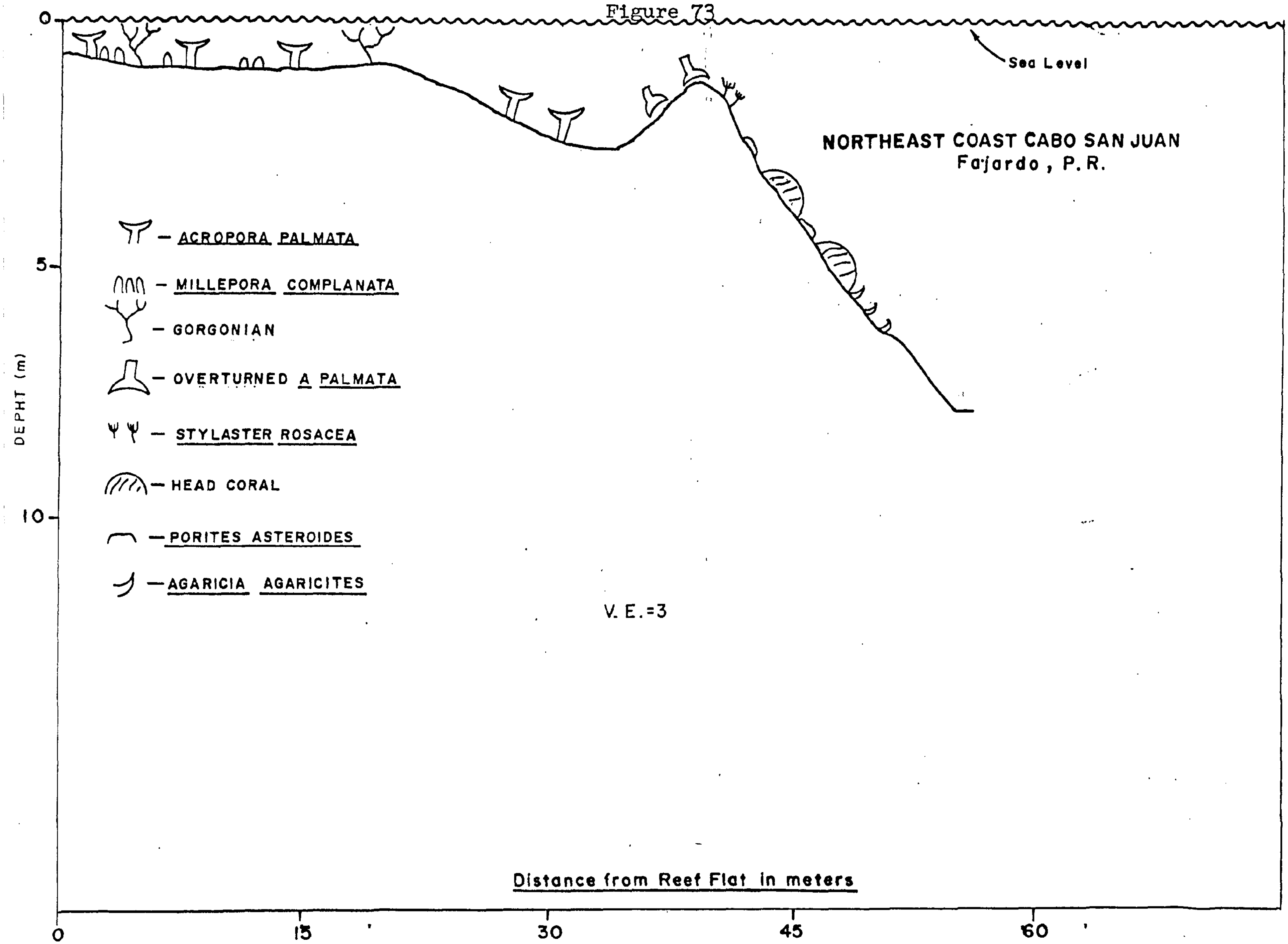

NORTHEAST COAST CABO SAN JUAN
Fajardo, P.R.
Sea Level
DEPHT (m)
0
5
10
— ACROPORA PALMATA
— MILLEPORA COMPLANATA
— GORGONIAN
— OVERTURNED A PALMATA
— STYLASTER ROSACEA
— HEAD CORAL
— PORITES ASTEROIDES
— AGARICIA AGARICITES
V. E.=3
Distance from Reef Flat in meters
0
15
30
45
60

Figure 74

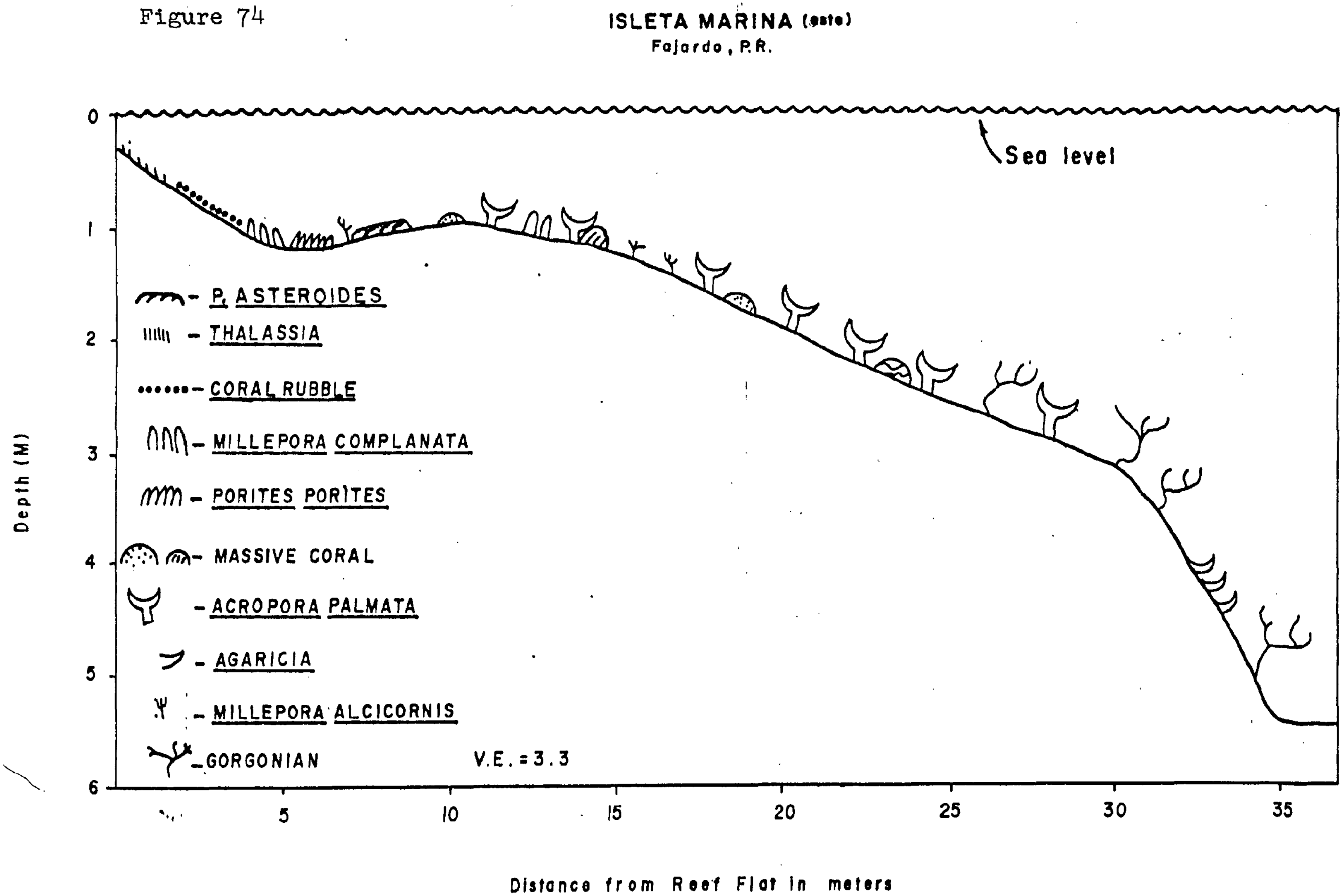

ISLETA MARINA (este)
Fajardo, P.R.
Sea level
Depth (M)
0
1
2
3
4
5
6
5
10
15
20
25
30
35
P. ASTEROIDES
THALASSIA
CORAL RUBBLE
MILLEPORA COMPLANATA
PORITES PORITES
MASSIVE CORAL
ACROPORA PALMATA
AGARICIA
MILLEPORA ALCICORNIS
GORGONIAN
V.E. = 3.3
Distance from Reef Flat in meters

Figure 75

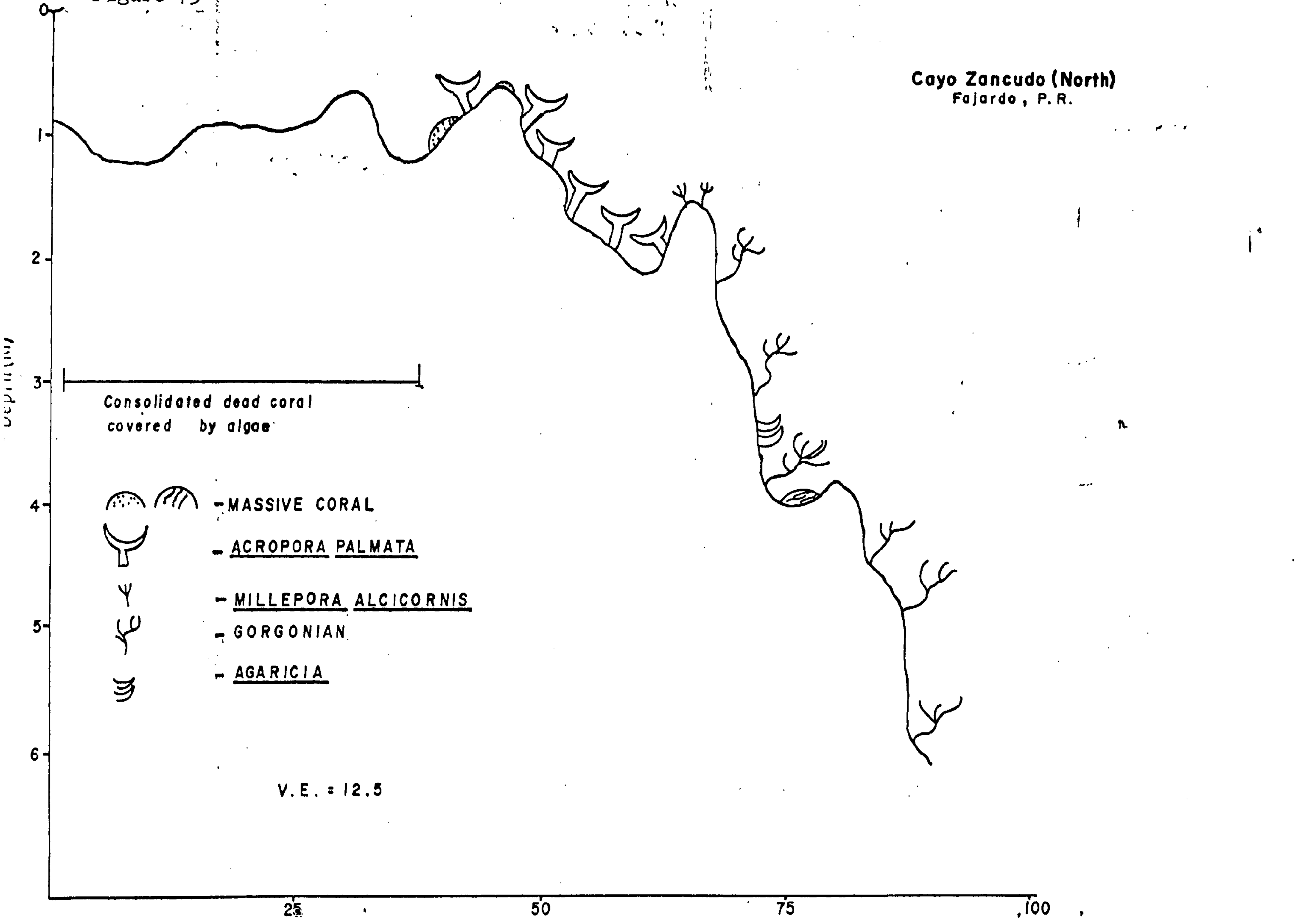

Cayo Zancudo (North)
Fajardo, P.R.
Depth(m)
0
1
2
3
4
5
6
25
50
75
100
Consolidated dead coral covered by algae
- MASSIVE CORAL
- ACROPORA PALMATA
- MILLEPORA ALCICORNIS
- GORGONIAN
- AGARICIA
V.E. = 12.5

Figure 76

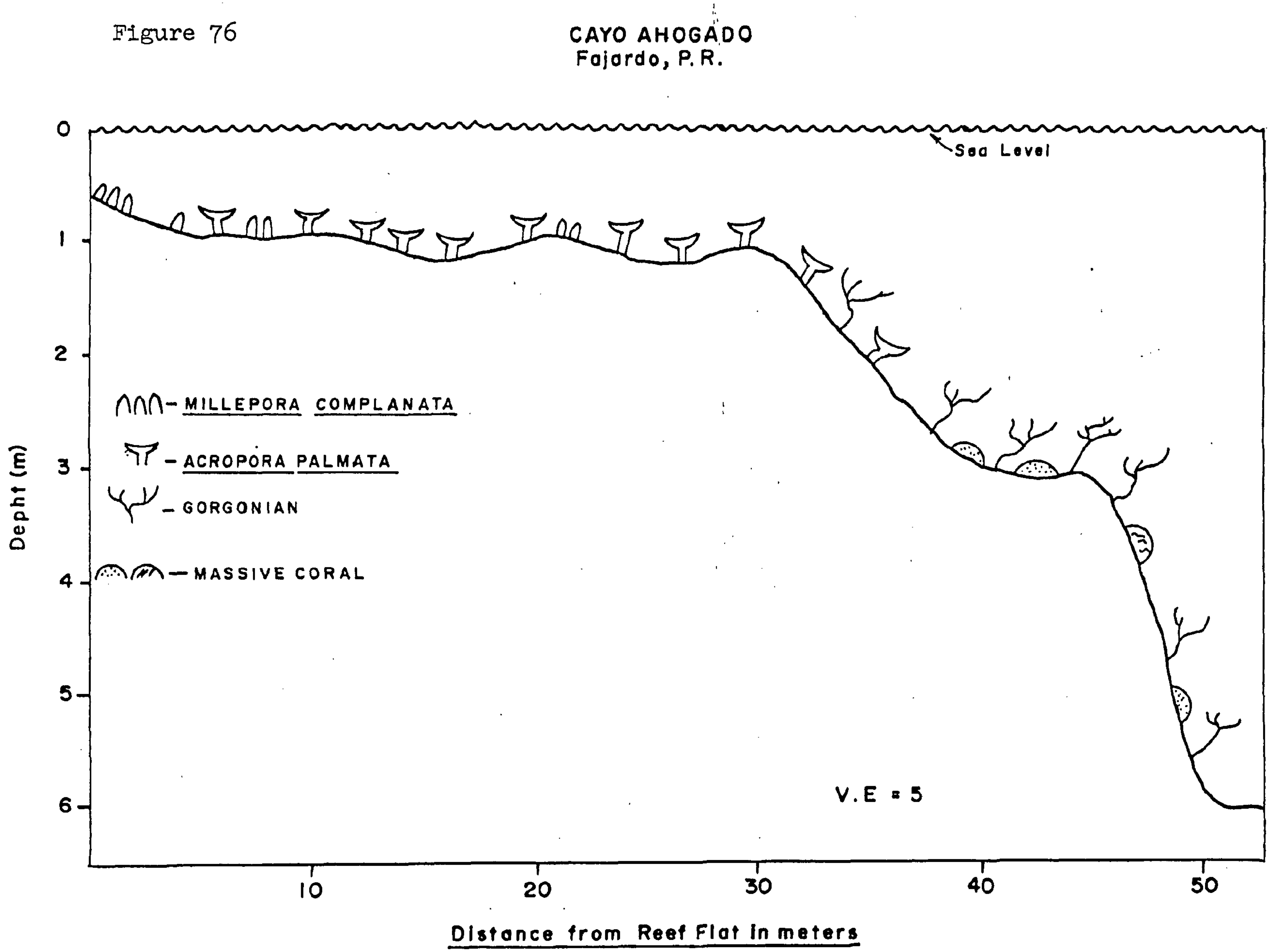
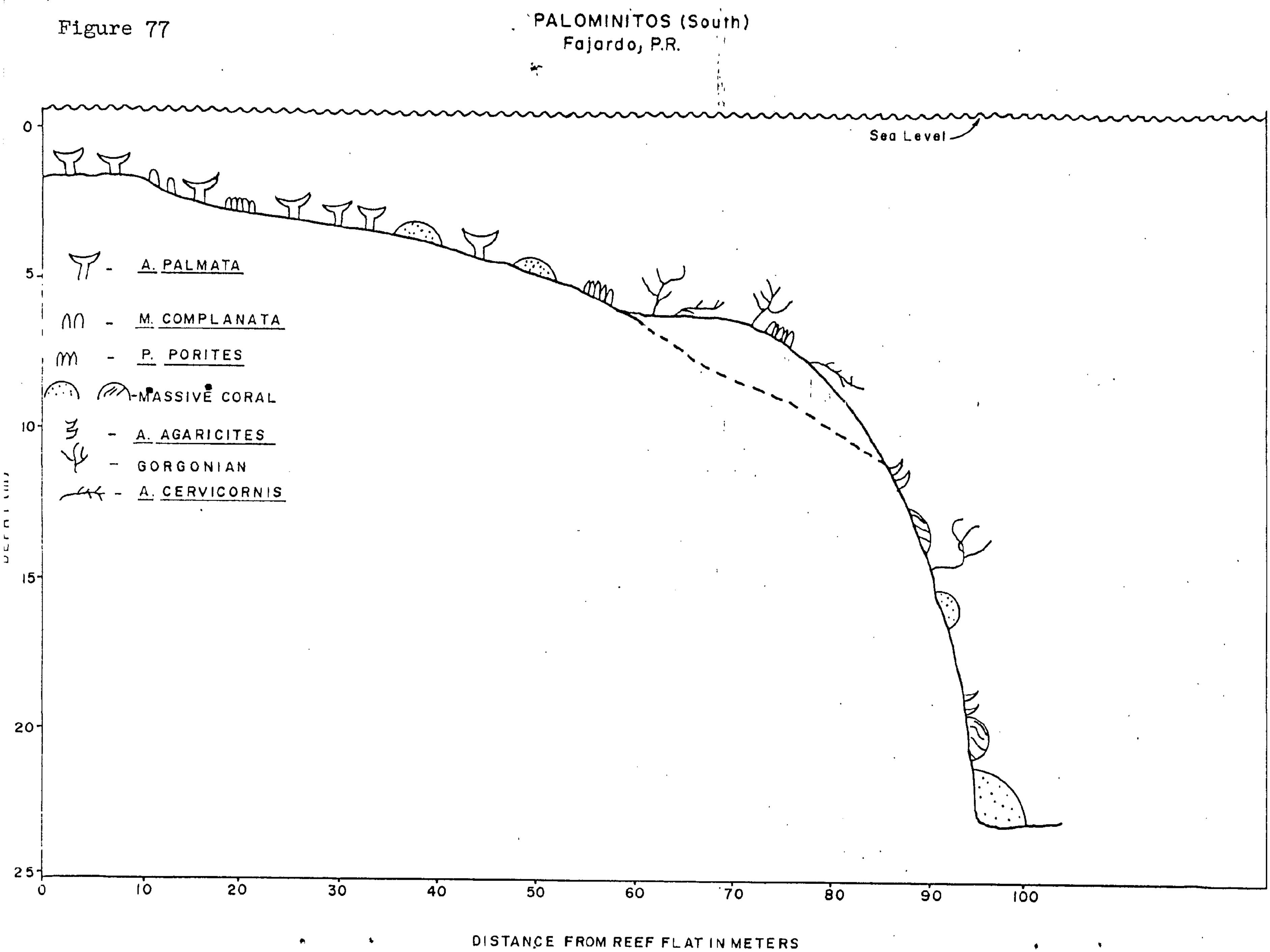
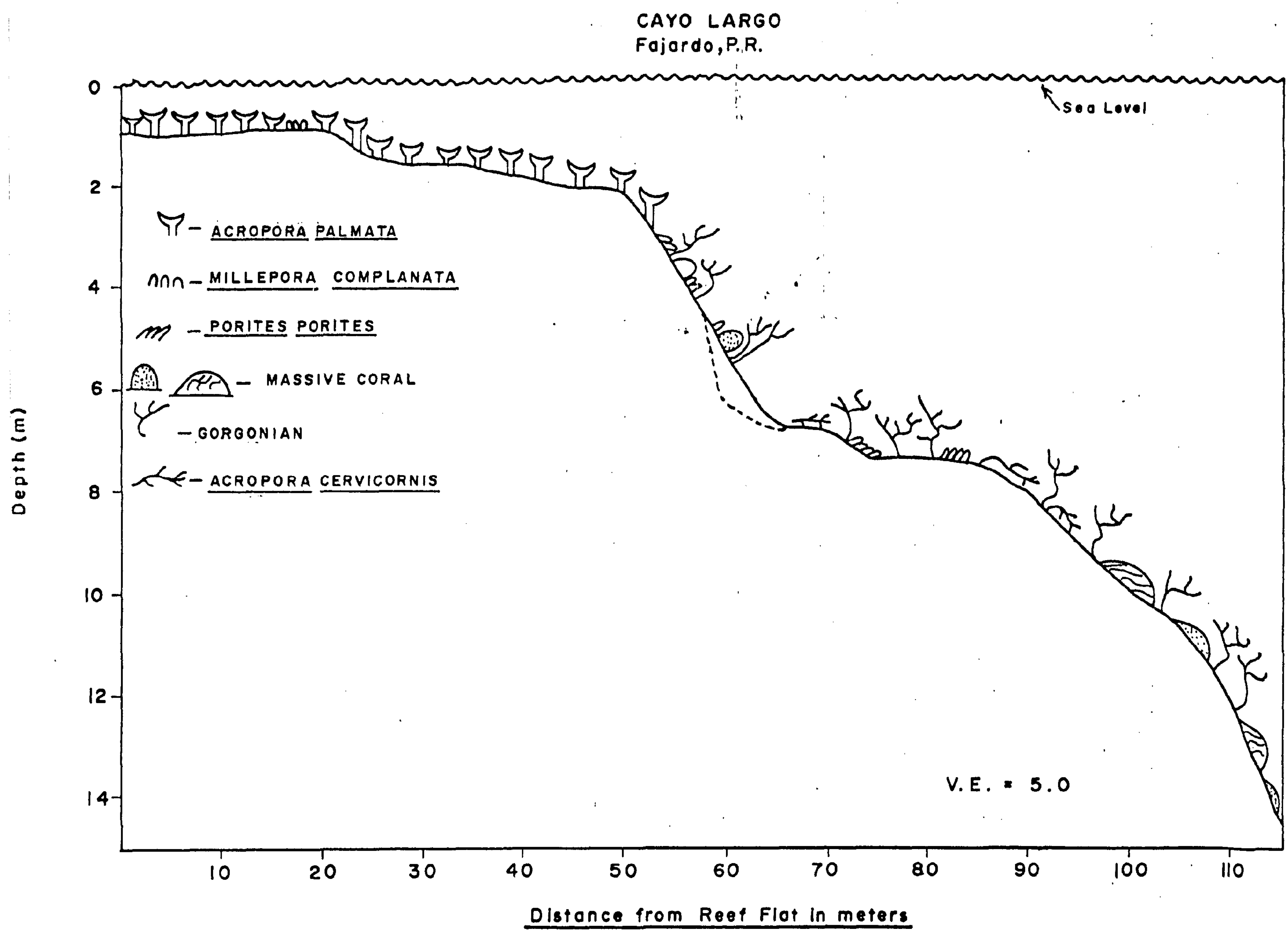
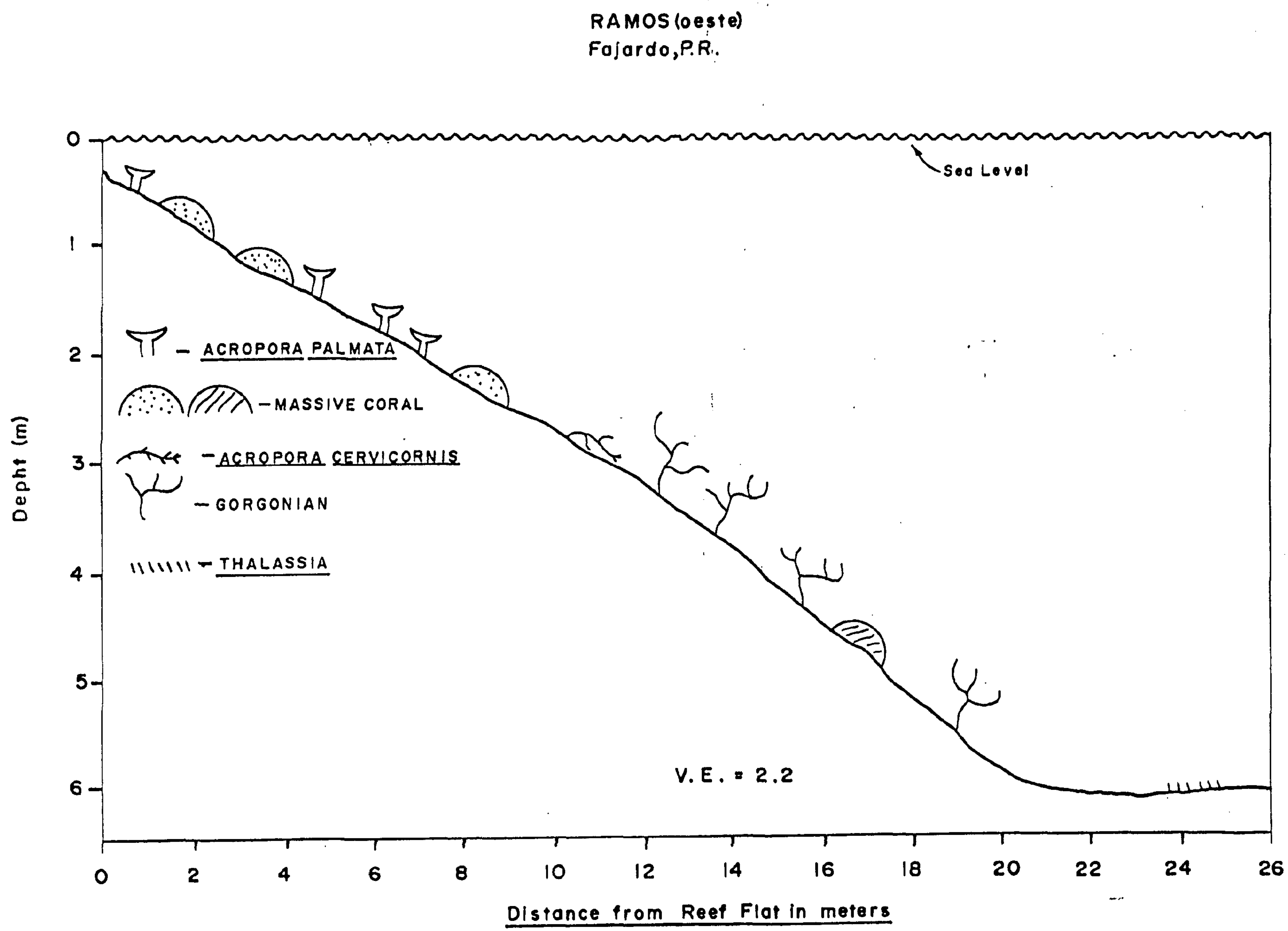
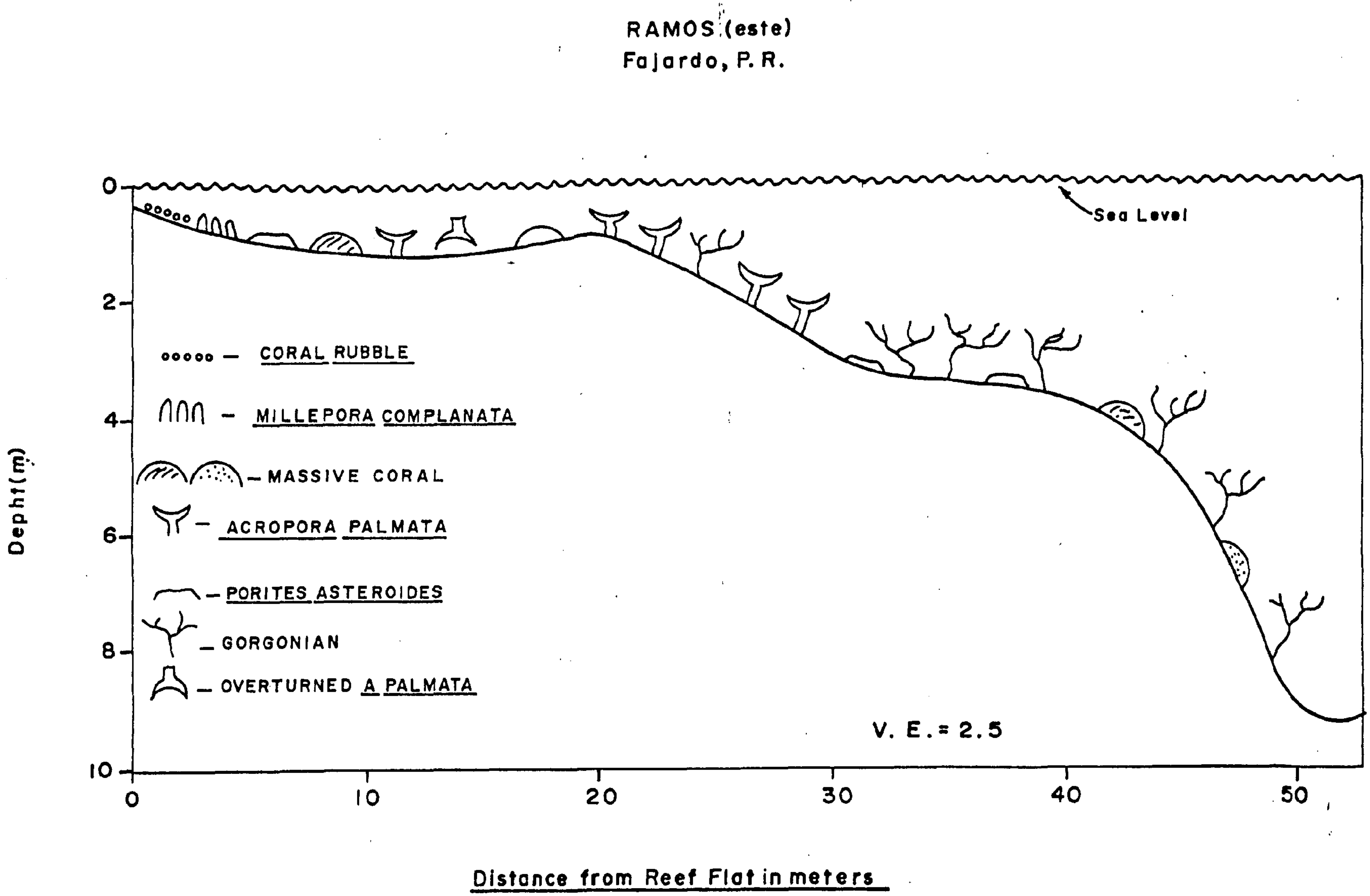

CAYO AHOGADO
Fajardo, P.R.
Sea Level
Depht (m)
0
1
2
3
4
5
6
MILLEPORA COMPLANATA
ACROPORA PALMATA
GORGONIAN
MASSIVE CORAL
V.E = 5
10
20
30
40
50
Distance from Reef Flat in meters

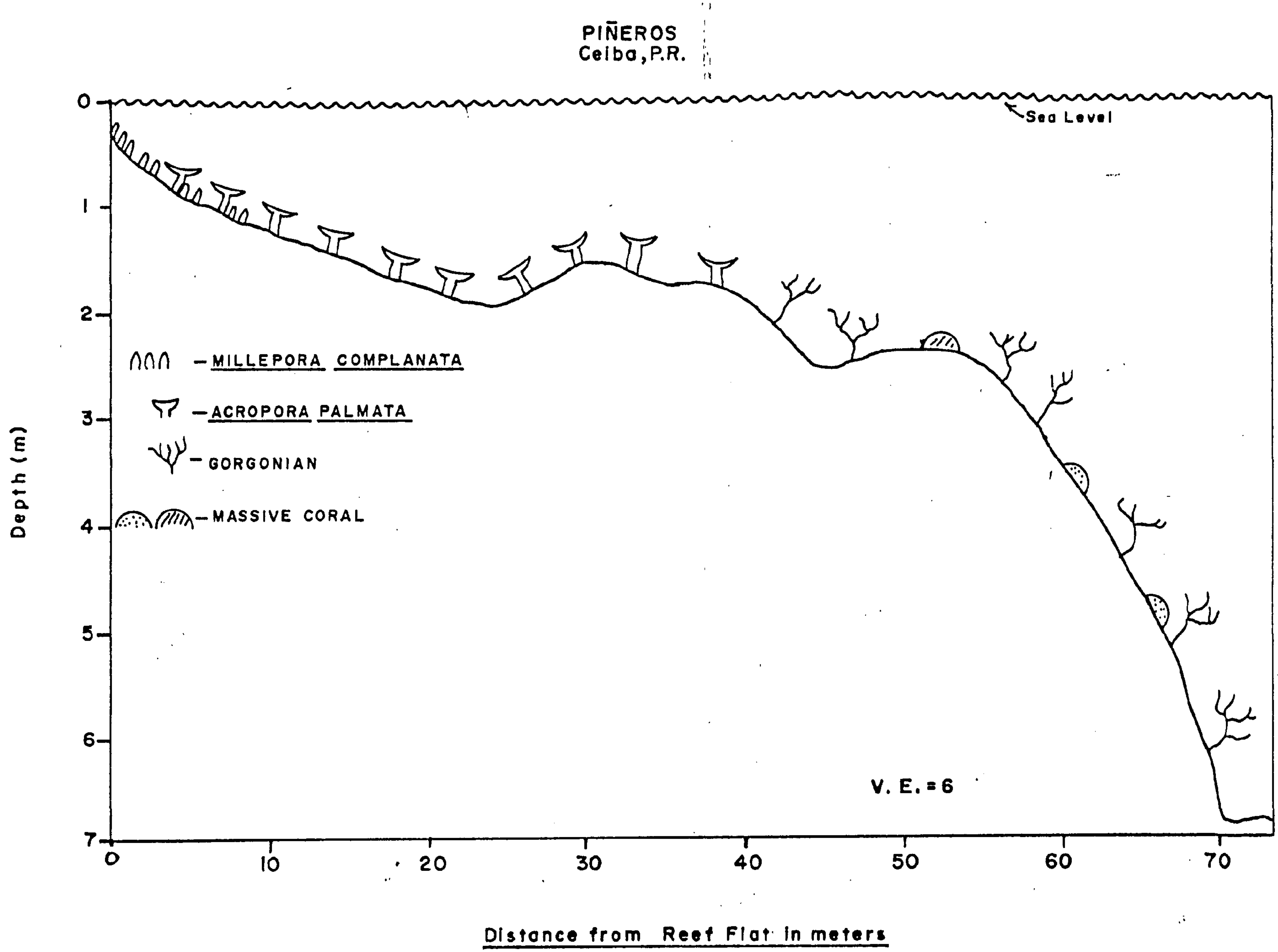
Figure 77

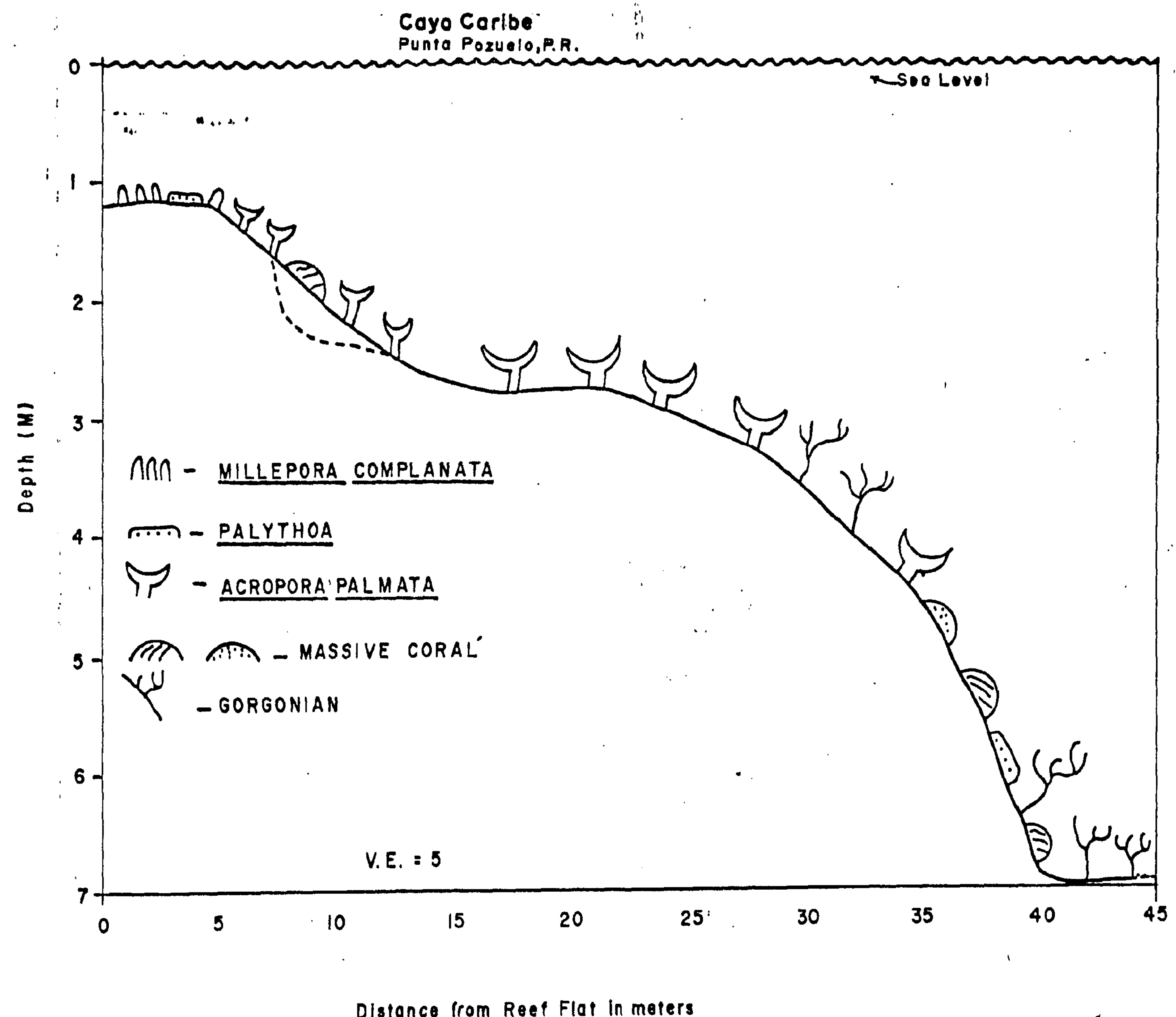

PALOMINITOS (South)
Fajardo, P.R.
Sea Level
A. PALMATA
M. COMPLANATA
P. PORITES
MASSIVE CORAL
A. AGARICITES
GORGONIAN
A. CERVICORNIS
DEPTH (m)
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
90
100
DISTANCE FROM REEF FLAT IN METERS


CAYO LARGO
Fajardo, P.R.
Sea Level
— ACROPORA PALMATA
— MILLEPORA COMPLANATA
— PORITES PORITES
— MASSIVE CORAL
— GORGONIAN
— ACROPORA CERVICORNIS
V.E. = 5.0
Depth (m)
0
2
4
6
8
10
12
14
10
20
30
40
50
60
70
80
90
100
110
Distance from Reef Flat in meters

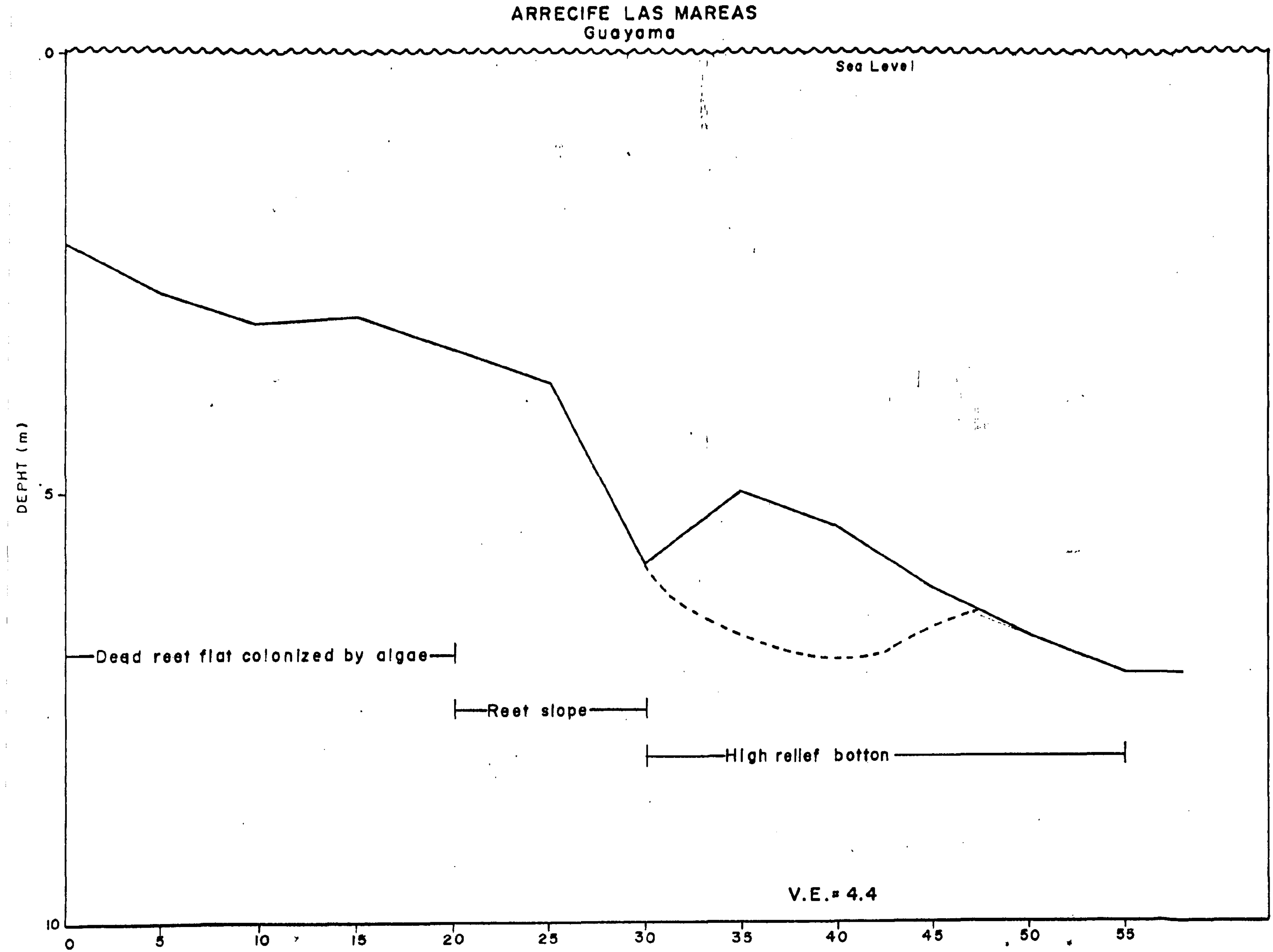

RAMOS (oeste)
Fajardo, P.R.
Sea Level
Depht (m)
0
1
2
3
4
5
6
ACROPORA PALMATA
MASSIVE CORAL
ACROPORA CERVICORNIS
GORGONIAN
THALASSIA
V. E. = 2.2
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Distance from Reef Flat in meters

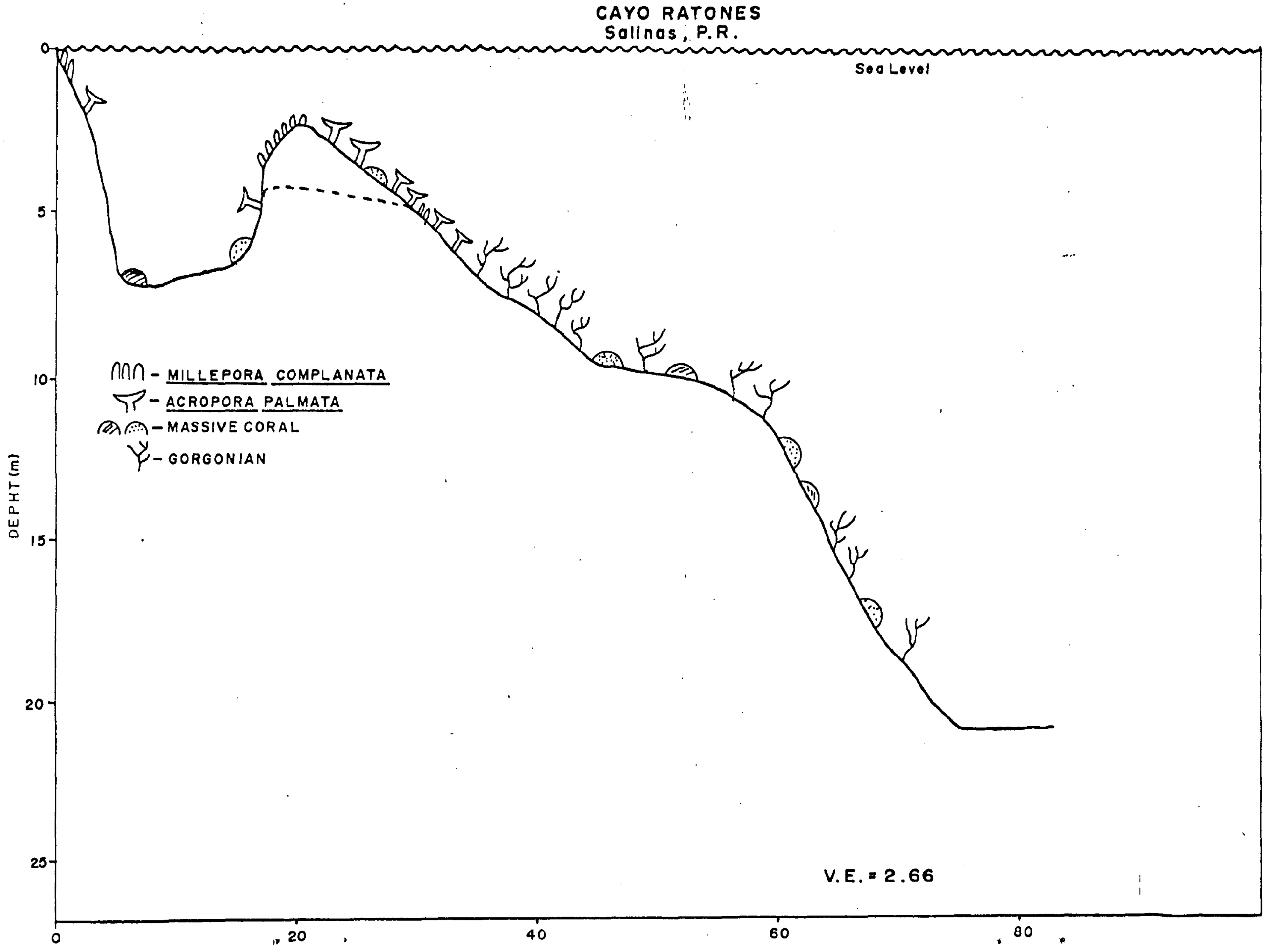

RAMOS (este)
Fajardo, P.R.
Sea Level
0
2
4
6
8
10
Depht(m)
CORAL RUBBLE
MILLEPORA COMPLANATA
MASSIVE CORAL
ACROPORA PALMATA
PORITES ASTEROIDES
GORGONIAN
OVERTURNED A PALMATA
V. E. = 2.5
0
10
20
30
40
50
Distance from Reef Flat in meters

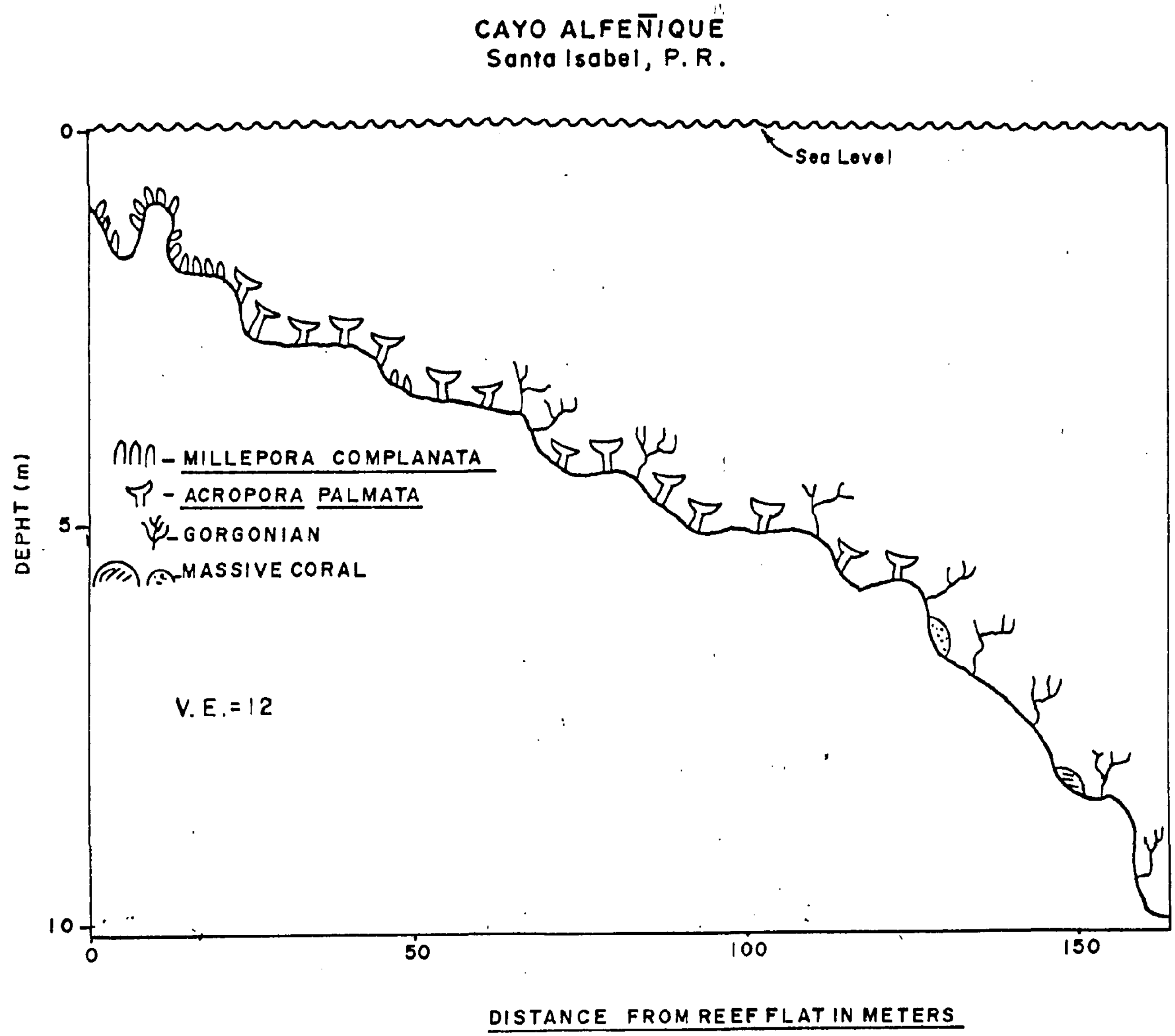

PIÑEROS
Ceiba, P.R.
Sea Level
Depth (m)
0
1
2
3
4
5
6
7
MILLEPORA COMPLANATA
ACROPORA PALMATA
GORGONIAN
MASSIVE CORAL
V. E. = 6
0
10
20
30
40
50
60
70
Distance from Reef Flat in meters



Caya Caribe
Punta Pozuelo, P.R.
Sea Level
Depth (M)
0
1
2
3
4
5
6
7
MILLEPORA COMPLANATA
PALYTHOA
ACROPORA PALMATA
MASSIVE CORAL
GORGONIAN
V.E. = 5
0
5
10
15
20
25
30
35
40
45
Distance from Reef Flat in meters

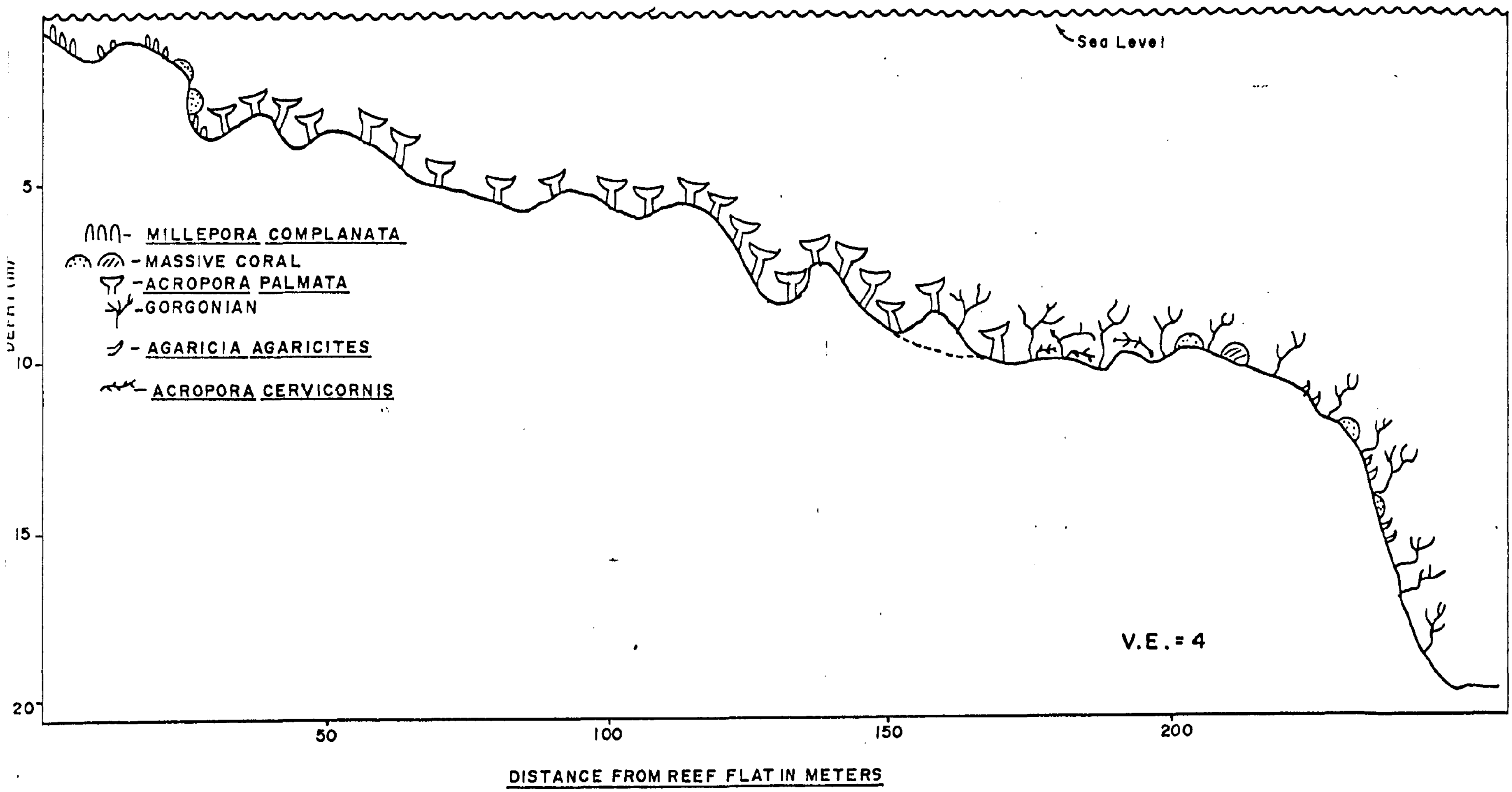

ARRECIFE LAS MAREAS
Guayama
Sea Level
DEPHT (m)
0
5
10
Dead reef flat colonized by algae
Reef slope
High relief botton
V.E.= 4.4
0
5
10
15
20
25
30
35
40
45
50
55

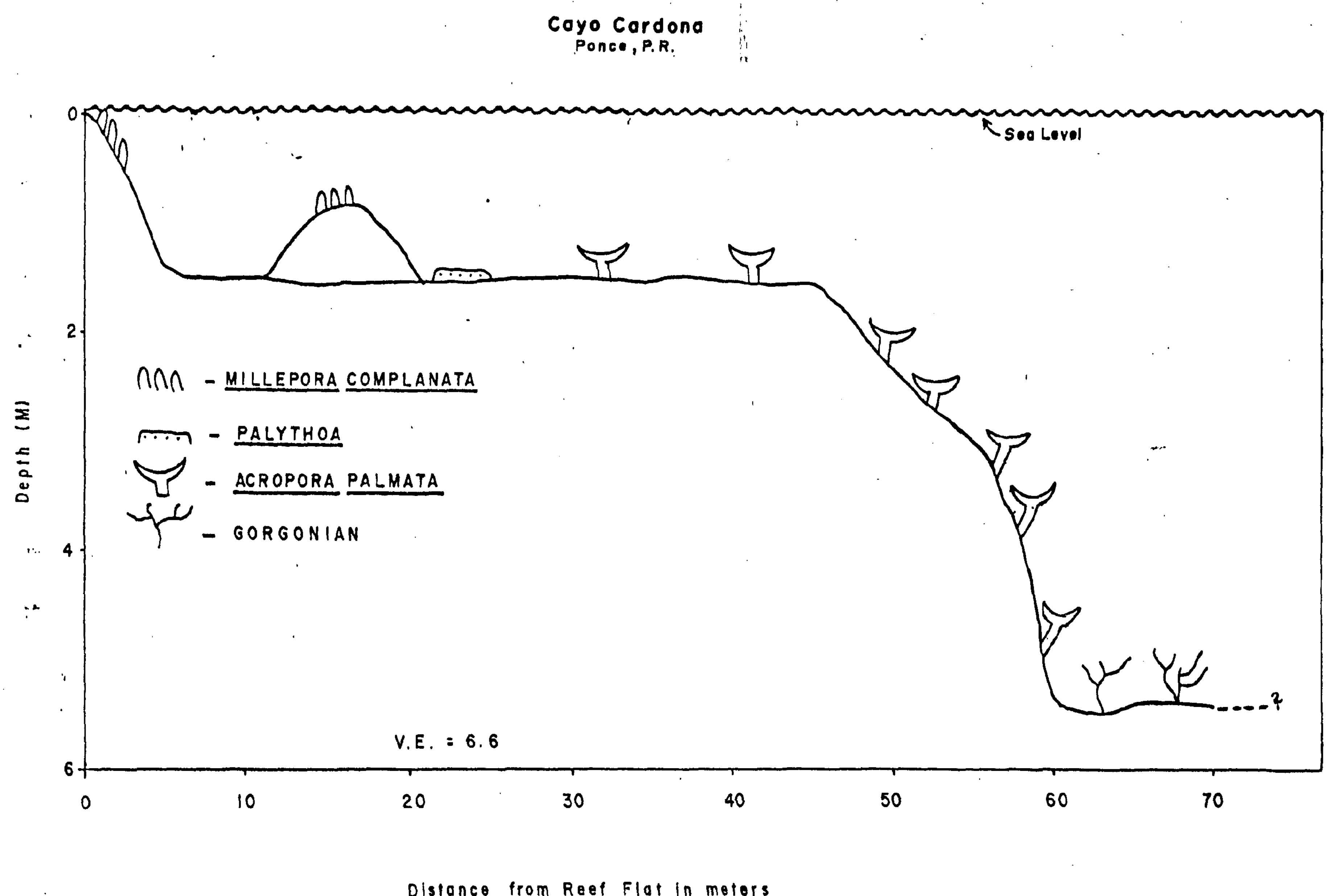

CAYO RATONES
Salinas, P.R.
Sea Level
DEPHT (m)
0
5
10
15
20
25
0
20
40
60
80
MILLEPORA COMPLANATA
ACROPORA PALMATA
MASSIVE CORAL
GORGONIAN
V.E. = 2.66

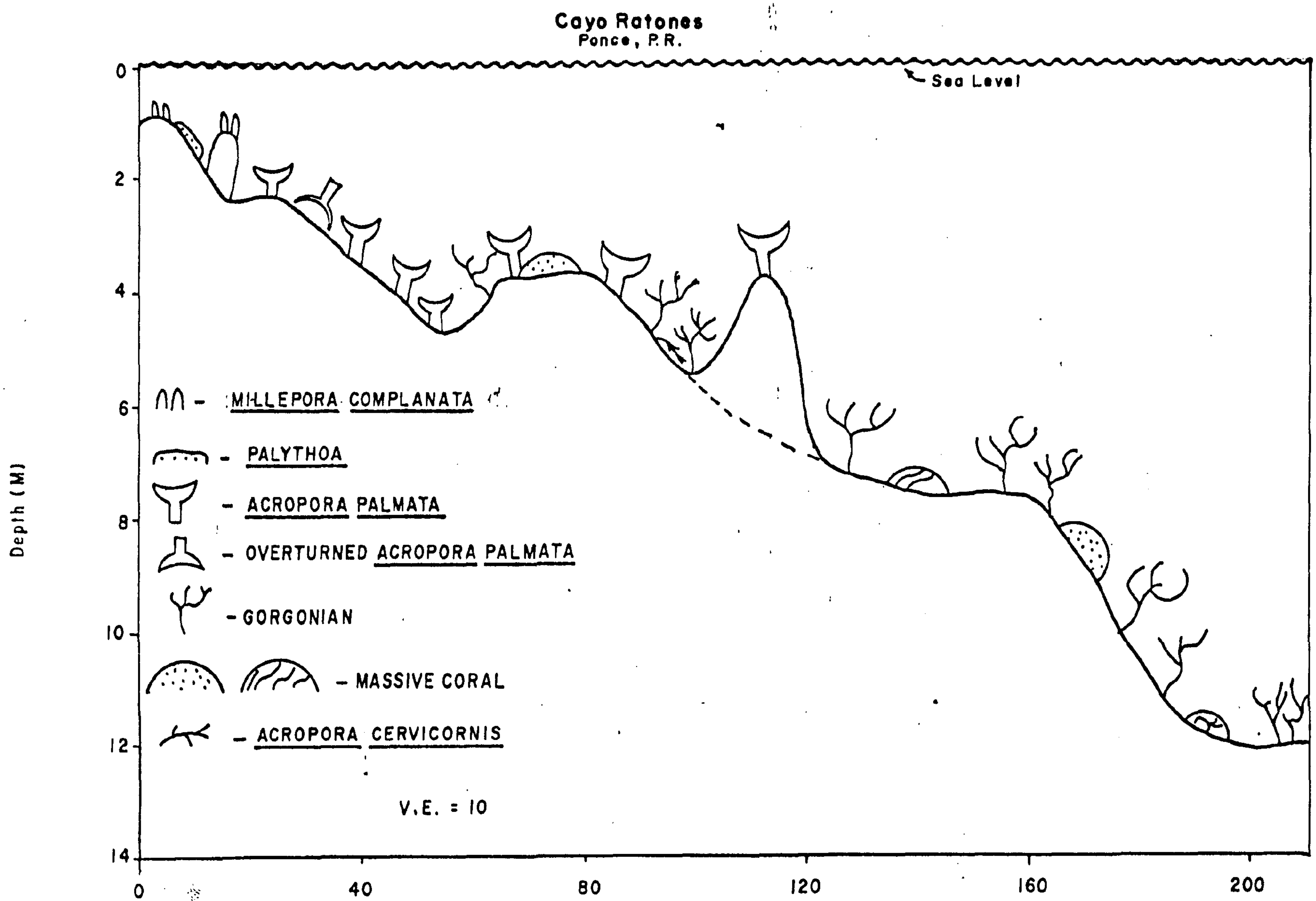


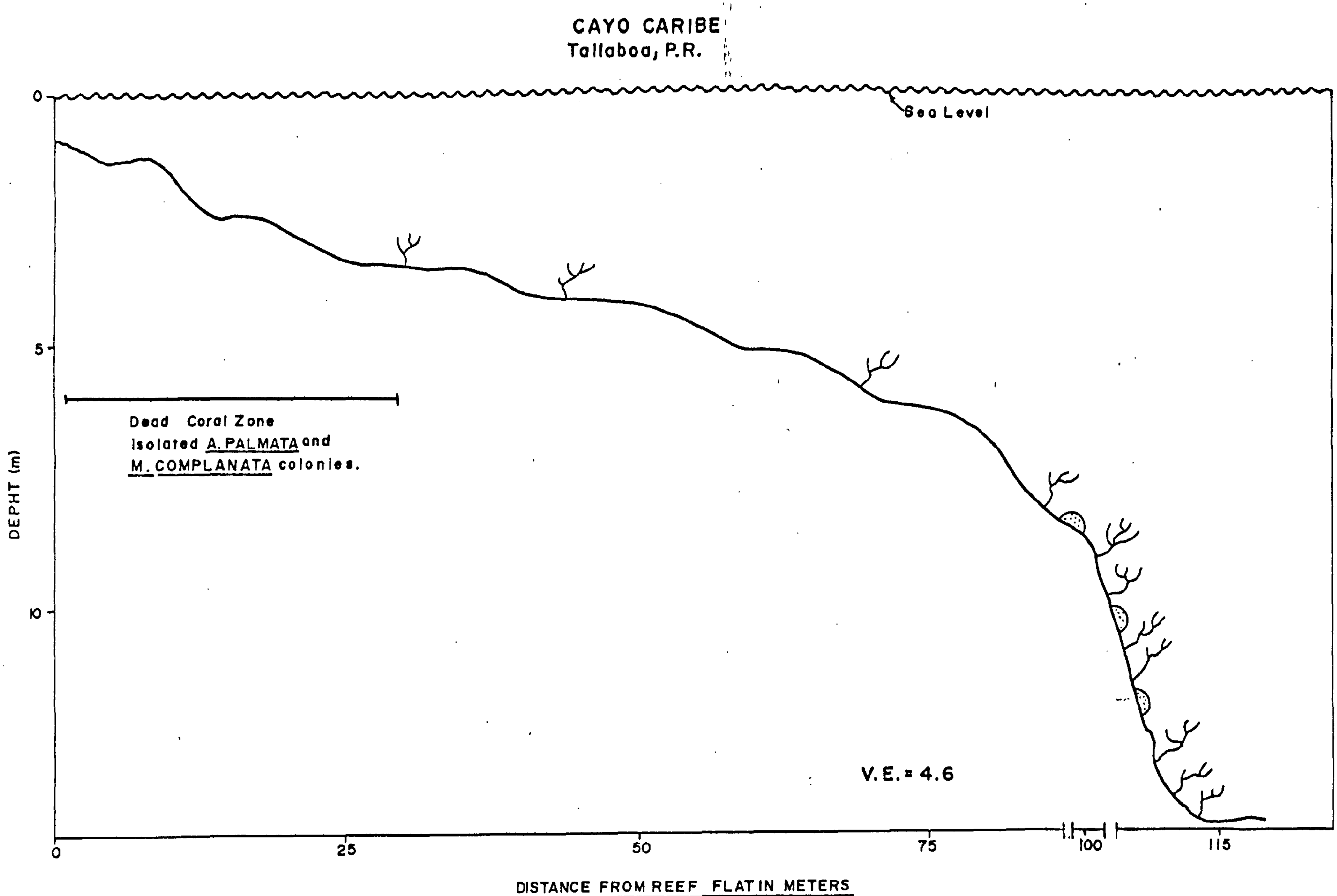
CAYO ALFEÑIQUE
Santa Isabel, P.R.
Sea Level
DEPHT (m)
0
5
10
0
50
100
150
MILLEPORA COMPLANATA
ACROPORA PALMATA
GORGONIAN
MASSIVE CORAL
V.E.=12
DISTANCE FROM REEF FLAT IN METERS

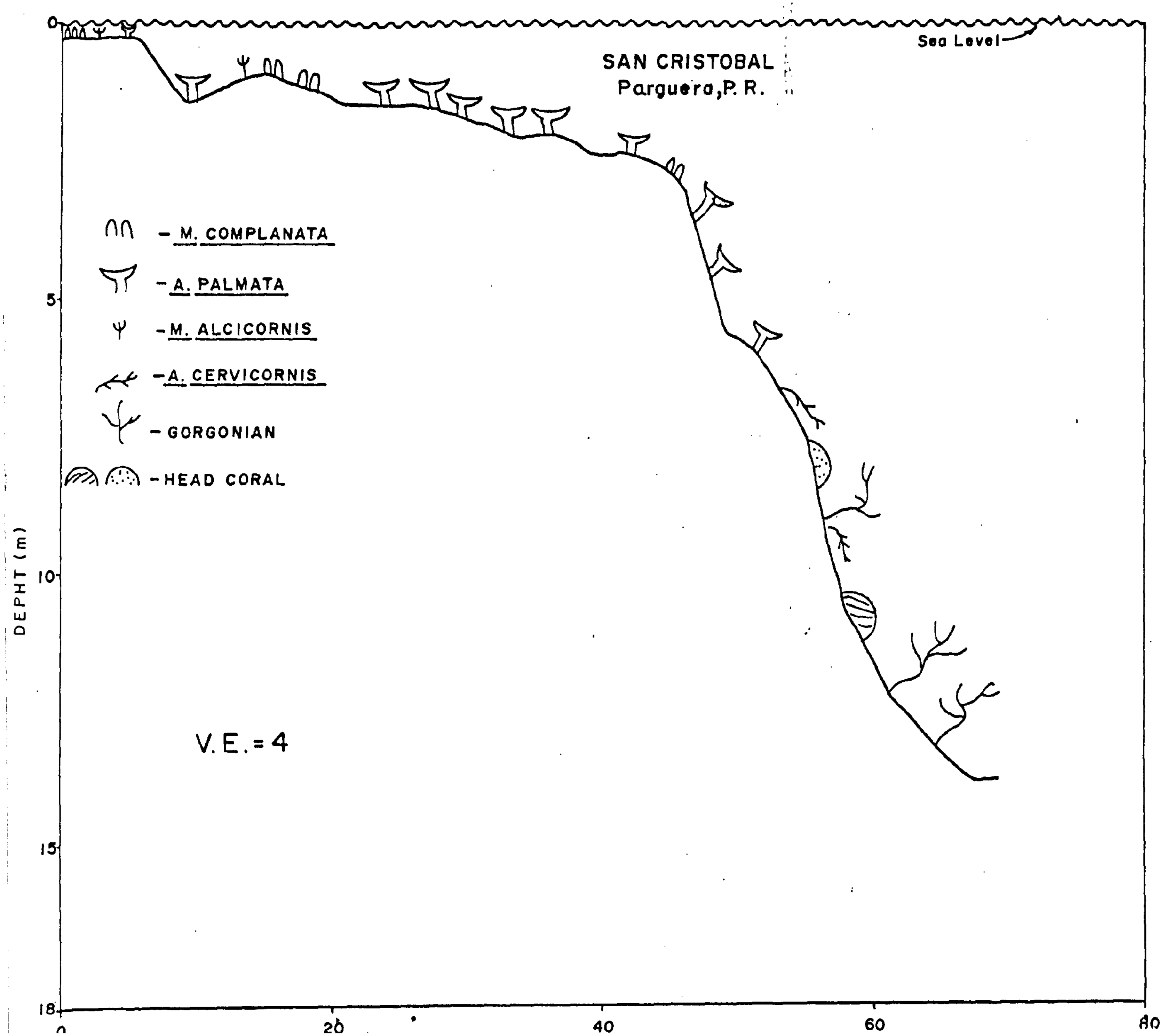
CAYO CABUZASOS
Santa Isabel, P.R.



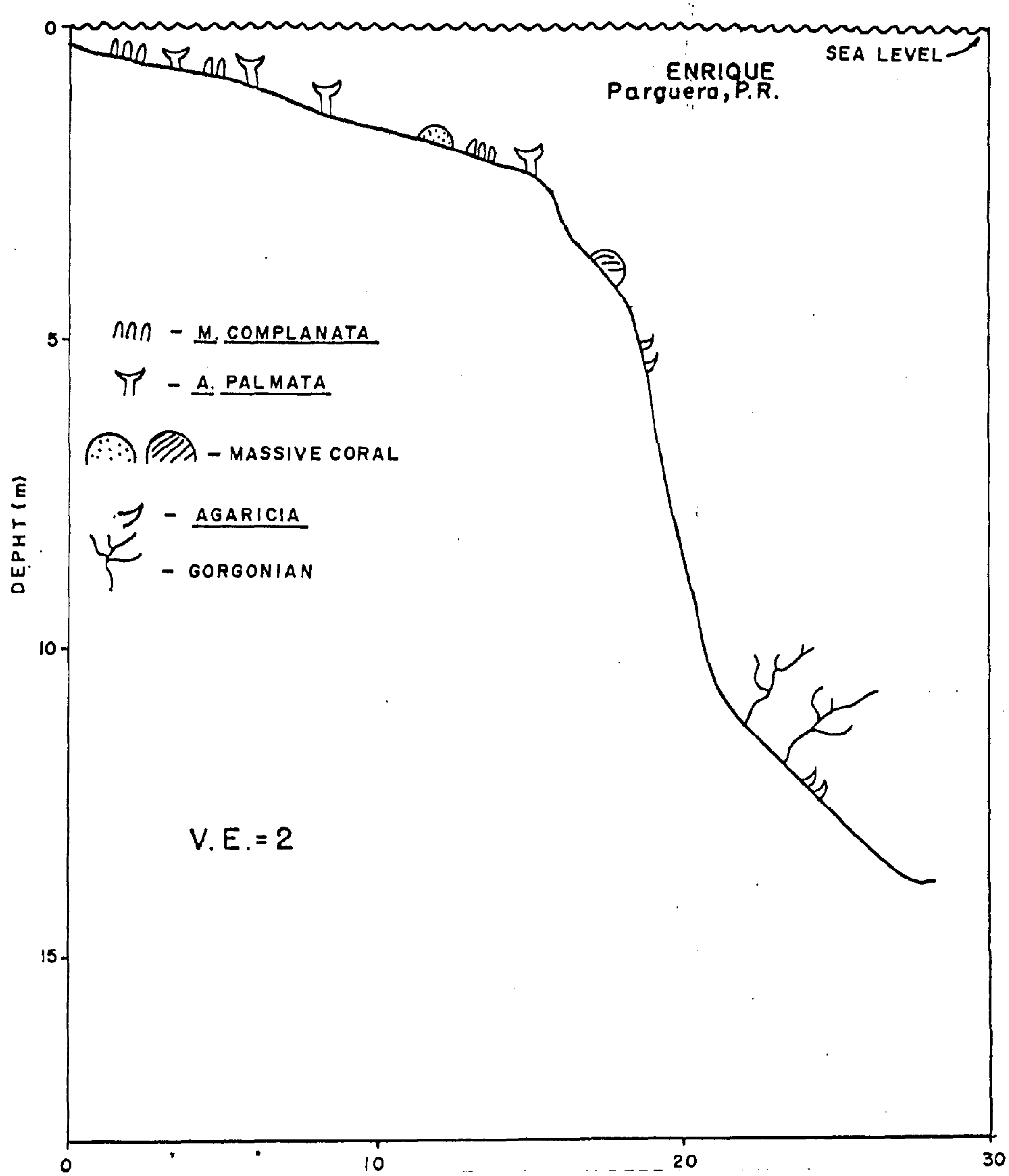

Cayo Cardona
Ponce, P.R.
Sea Level
Depth (M)
0
2
4
6
MILLEPORA COMPLANATA
PALYTHOA
ACROPORA PALMATA
GORGONIAN
V.E. = 6.6
?
0
10
20
30
40
50
60
70
Distance from Reef Flat in meters


Cayo Ratones
Ponce, P.R.
Sea Level
Depth (M)
0
2
4
6
8
10
12
14
0
40
80
120
160
200
MILLEPORA COMPLANATA
PALYTHOA
ACROPORA PALMATA
OVERTURNED ACROPORA PALMATA
GORGONIAN
MASSIVE CORAL
ACROPORA CERVICORNIS
V.E. = 10

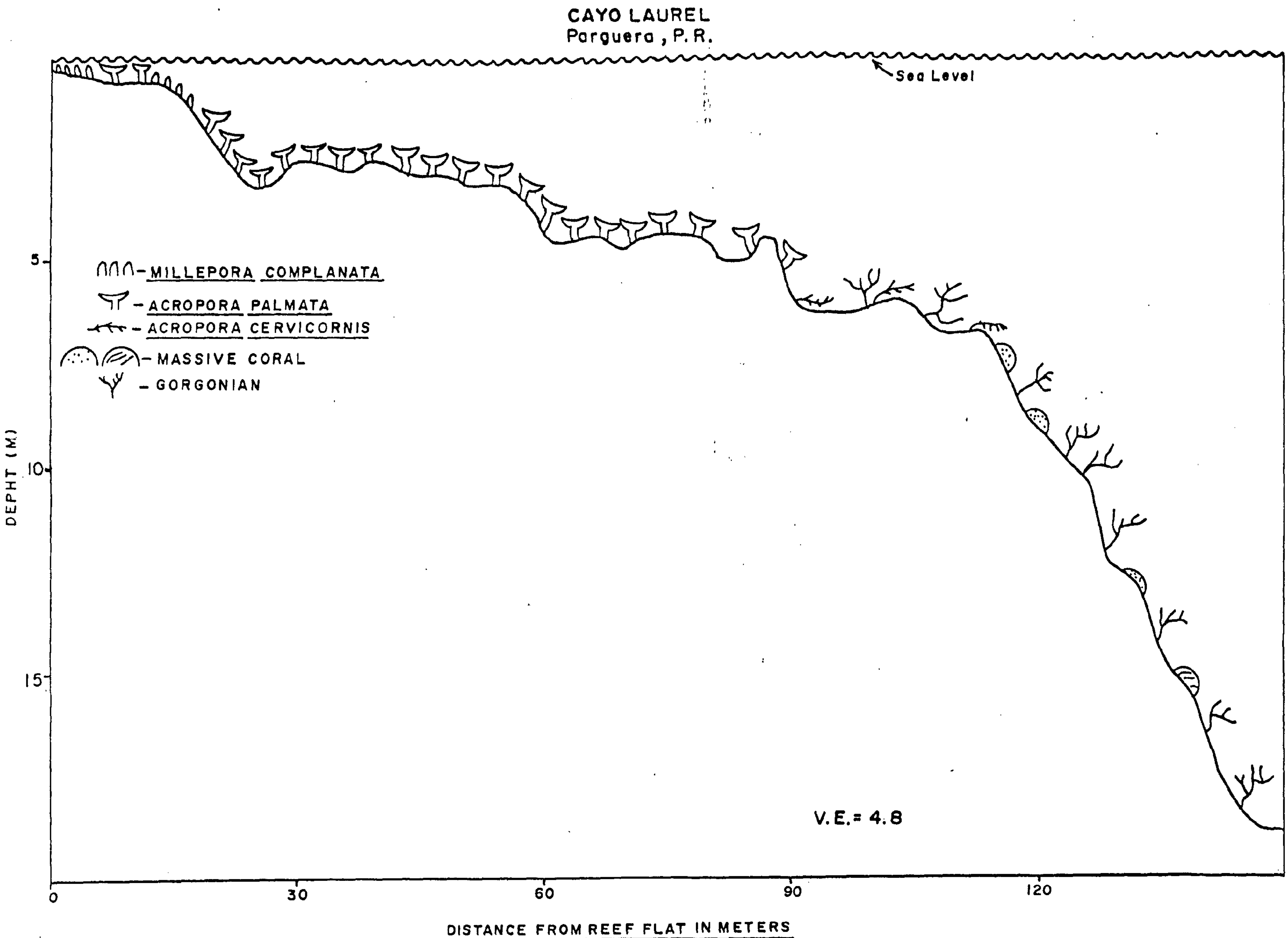

CAYO CARIBE
Tallaboa, P.R.
Sea Level
DEPHT (m)
0
5
10
Dead Coral Zone
Isolated A. PALMATA and
M. COMPLANATA colonies.
V.E. = 4.6
0
25
50
75
100
115
DISTANCE FROM REEF FLAT IN METERS

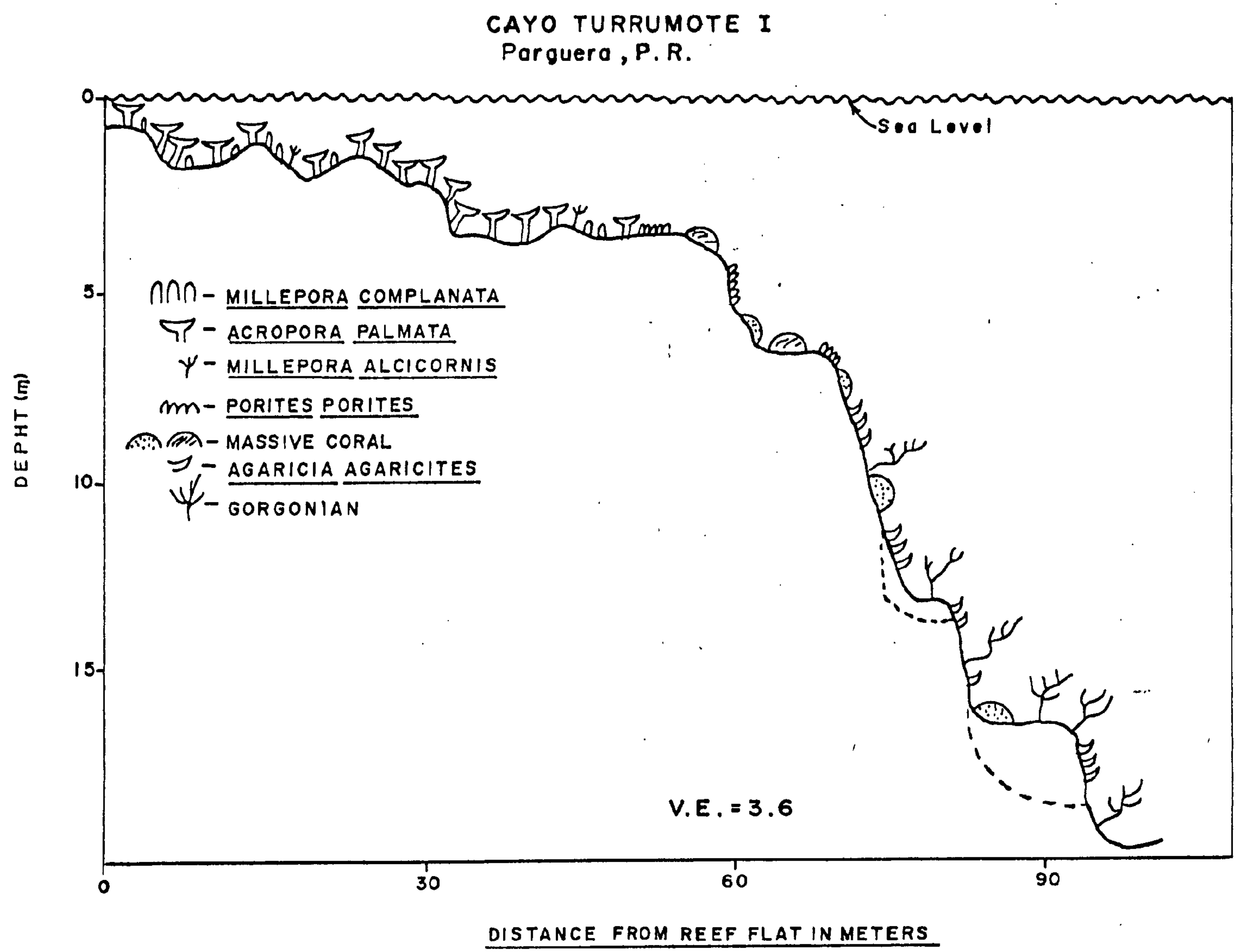


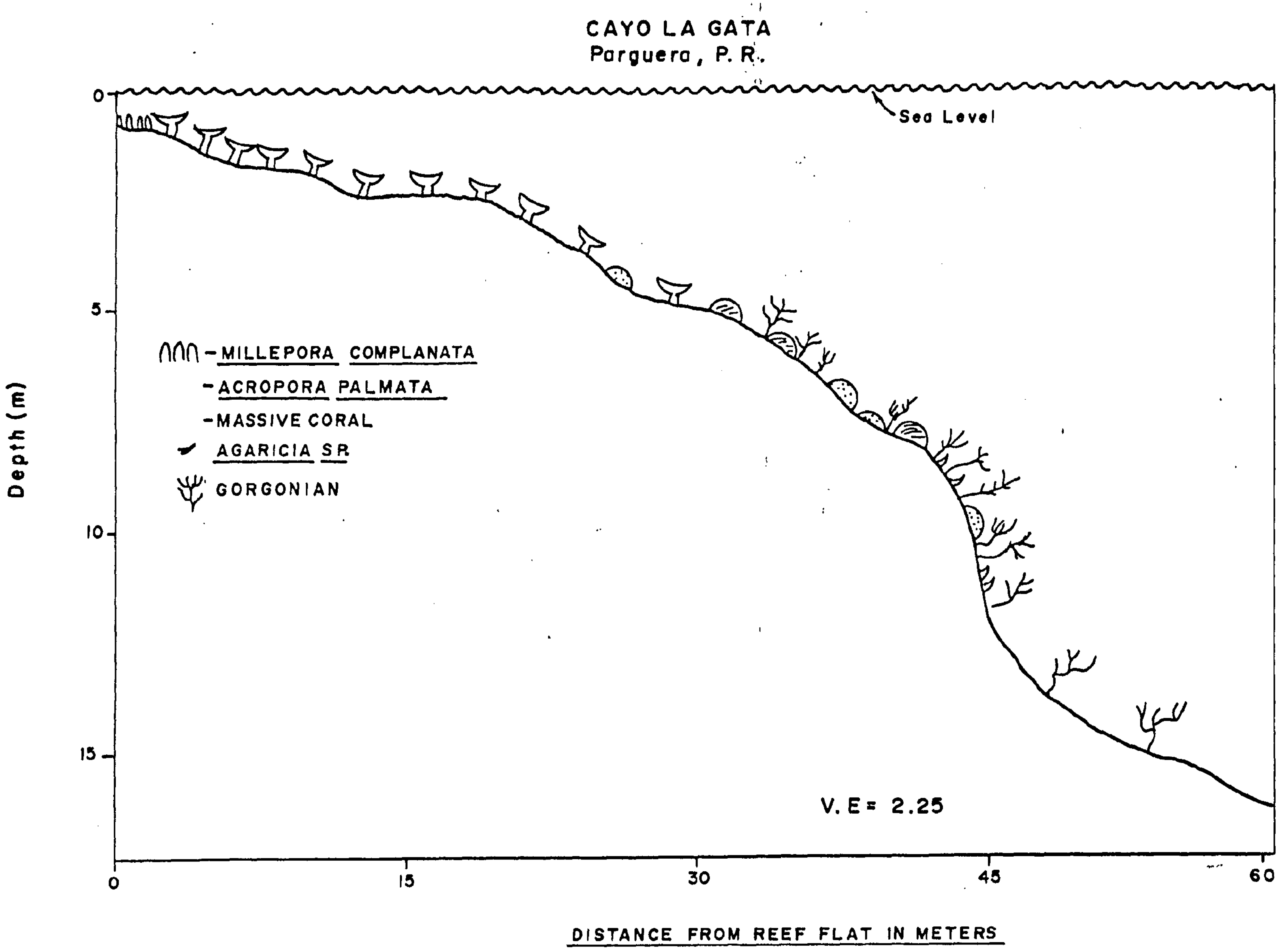
SAN CRISTOBAL
Parguera, P. R.
Sea Level
- M. COMPLANATA
- A. PALMATA
- M. ALCICORNIS
- A. CERVICORNIS
- GORGONIAN
- HEAD CORAL
V. E. = 4
DEPHT (m)
0
5
10
15
18
0
20
40
60
80

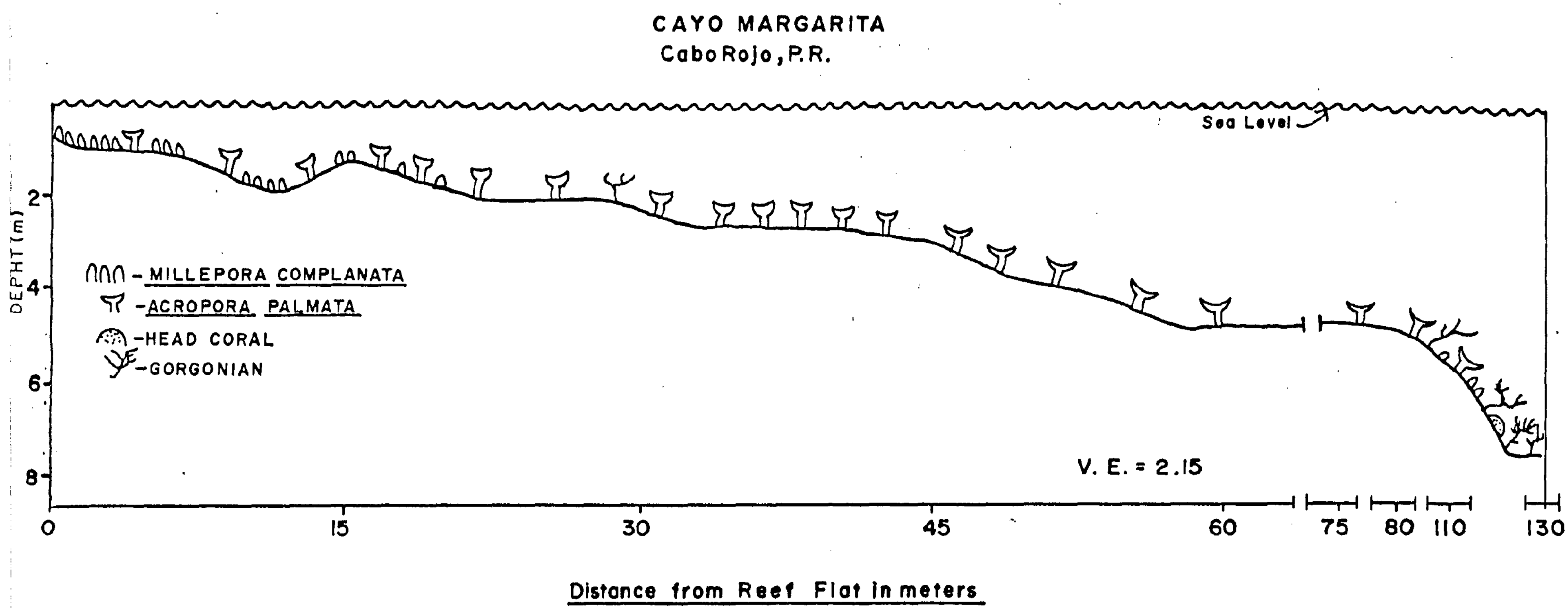


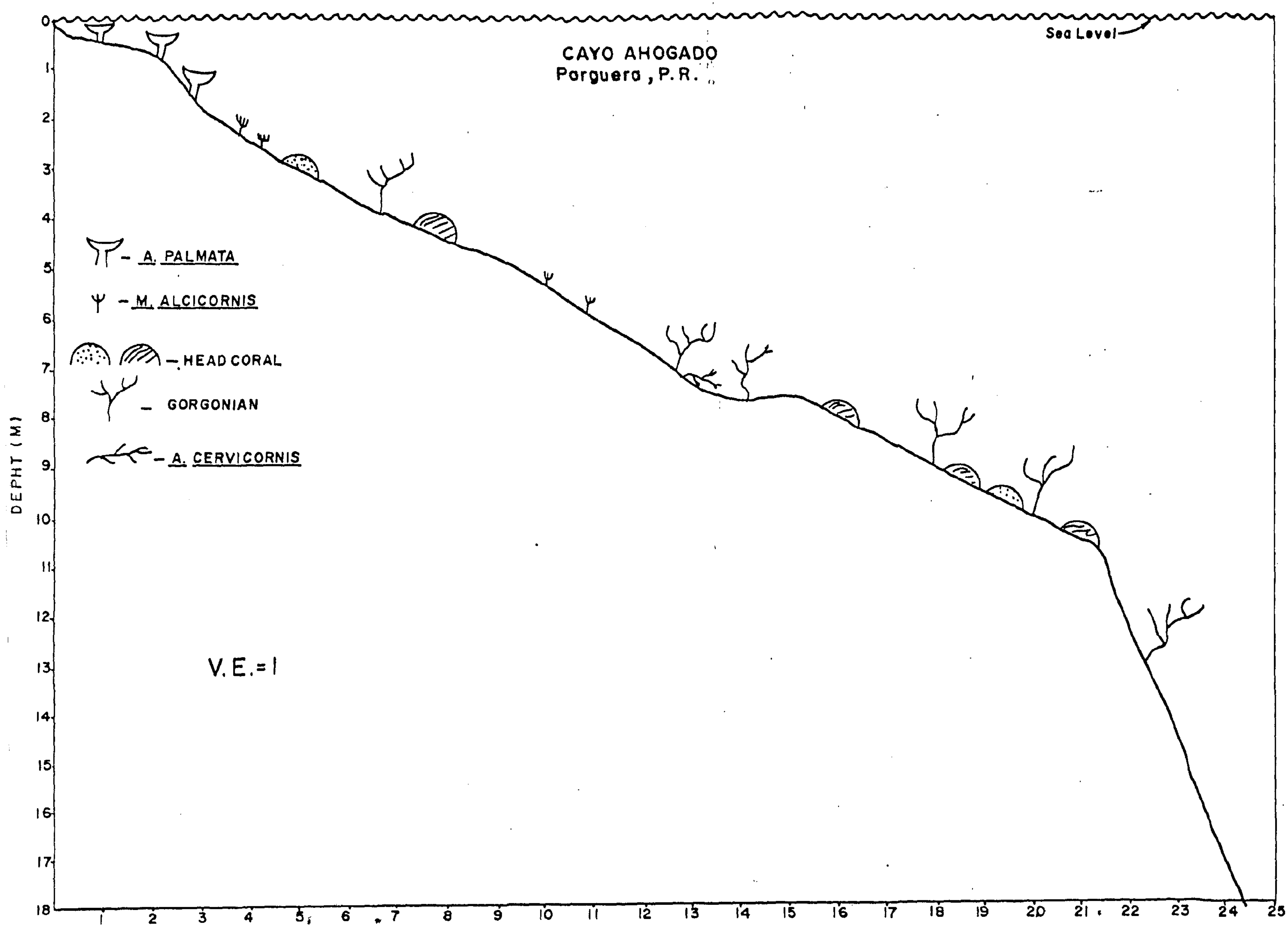
SEA LEVEL
ENRIQUE
Parguera, P.R.
M. COMPLANATA
A. PALMATA
MASSIVE CORAL
AGARICIA
GORGONIAN
DEPHT (m)
V.E. = 2
0
5
10
15
0
10
20
30


CAYO LAUREL
Parguera, P.R.
Sea Level
MILLEPORA COMPLANATA
ACROPORA PALMATA
ACROPORA CERVICORNIS
MASSIVE CORAL
GORGONIAN
DEPHT (M)
5
10
15
V.E.= 4.8
0
30
60
90
120
DISTANCE FROM REEF FLAT IN METERS

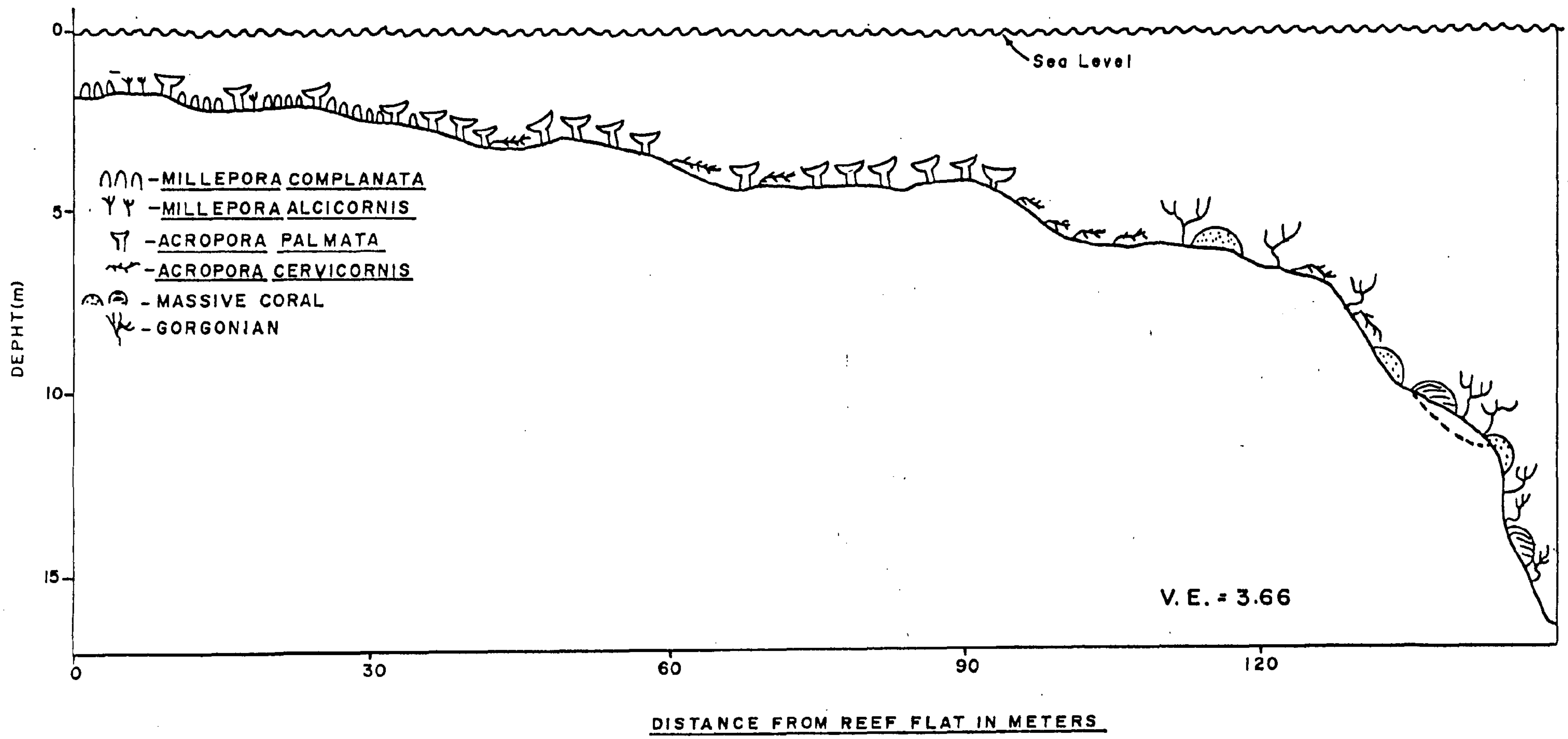

CAYO TURRUMOTE I
Parguera, P.R.
Sea Level
DEPHT (m)
0
5
10
15
MILLEPORA COMPLANATA
ACROPORA PALMATA
MILLEPORA ALCICORNIS
PORITES PORITES
MASSIVE CORAL
AGARICIA AGARICITES
GORGONIAN
V.E. = 3.6
0
30
60
90
DISTANCE FROM REEF FLAT IN METERS

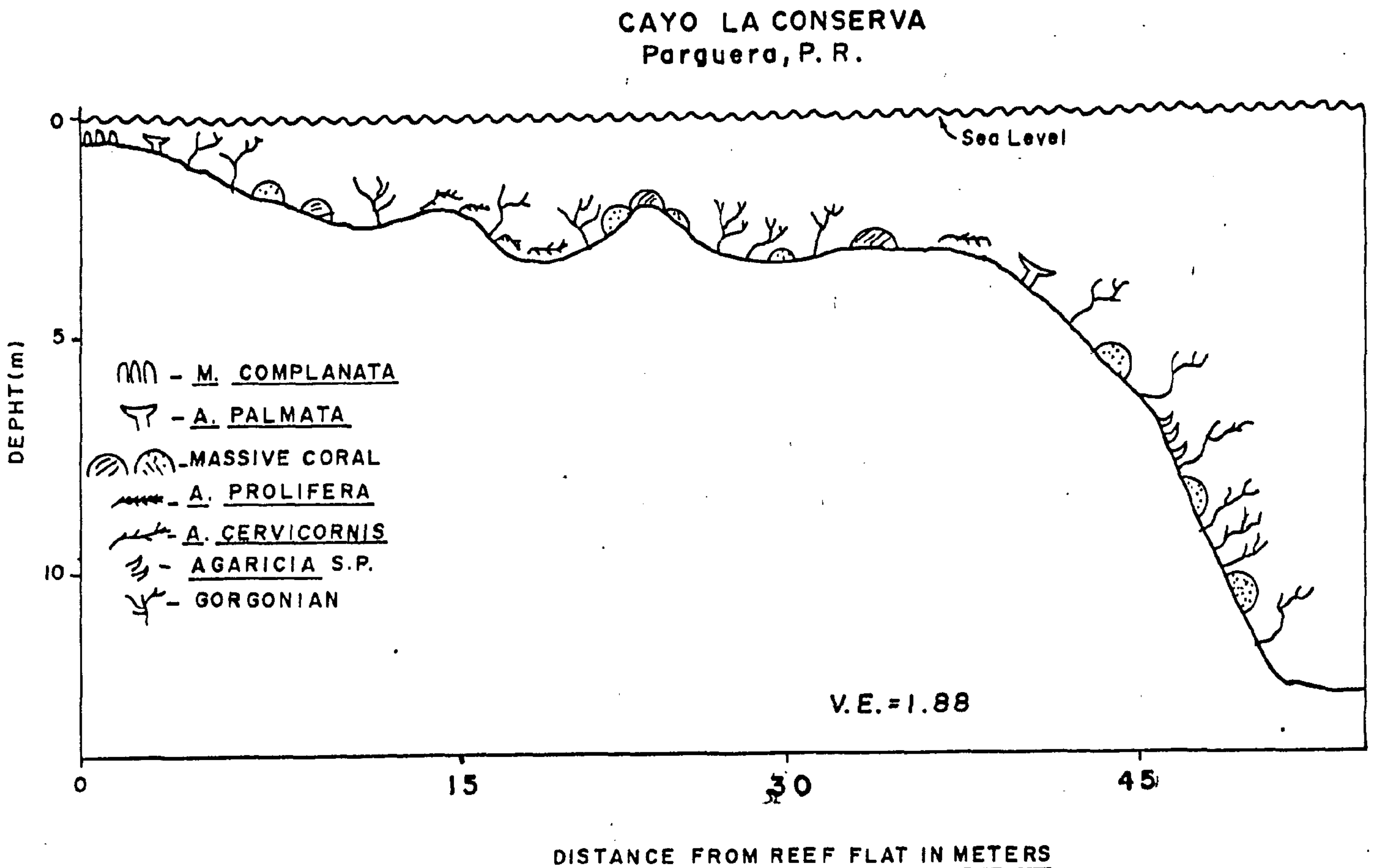

CAYO LA GATA
Parguera, P.R.
Sea Level
Depth (m)
0
5
10
15
MILLEPORA COMPLANATA
ACROPORA PALMATA
MASSIVE CORAL
AGARICIA SP.
GORGONIAN
V.E= 2.25
0
15
30
45
60
DISTANCE FROM REEF FLAT IN METERS

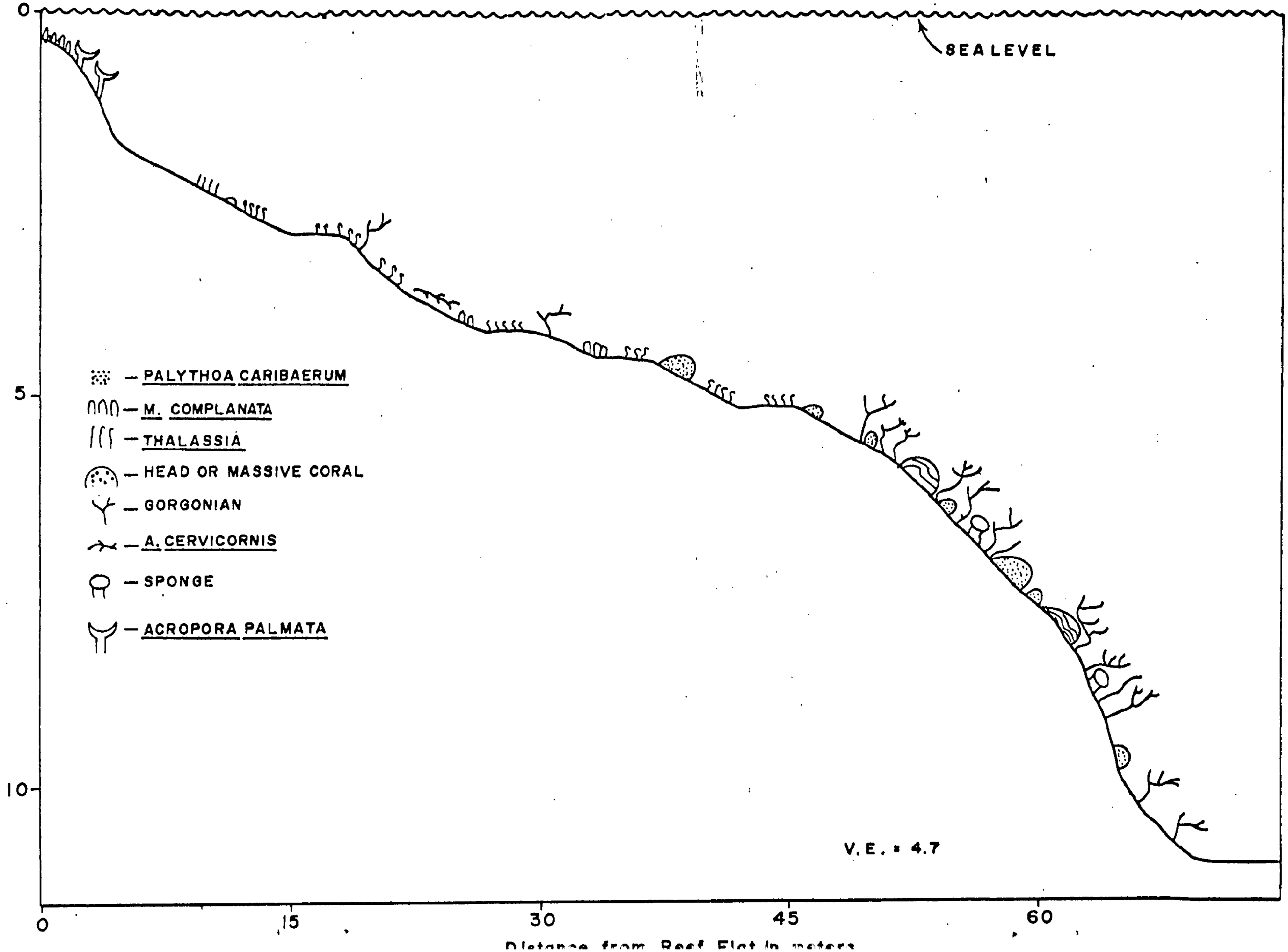

CAYO MARGARITA
Cabo Rojo, P.R.
Sea Level
DEPHT (m)
2
4
6
8
MILLEPORA COMPLANATA
ACROPORA PALMATA
HEAD CORAL
GORGONIAN
V. E. = 2.15
0
15
30
45
60
75
80
110
130
Distance from Reef Flat in meters

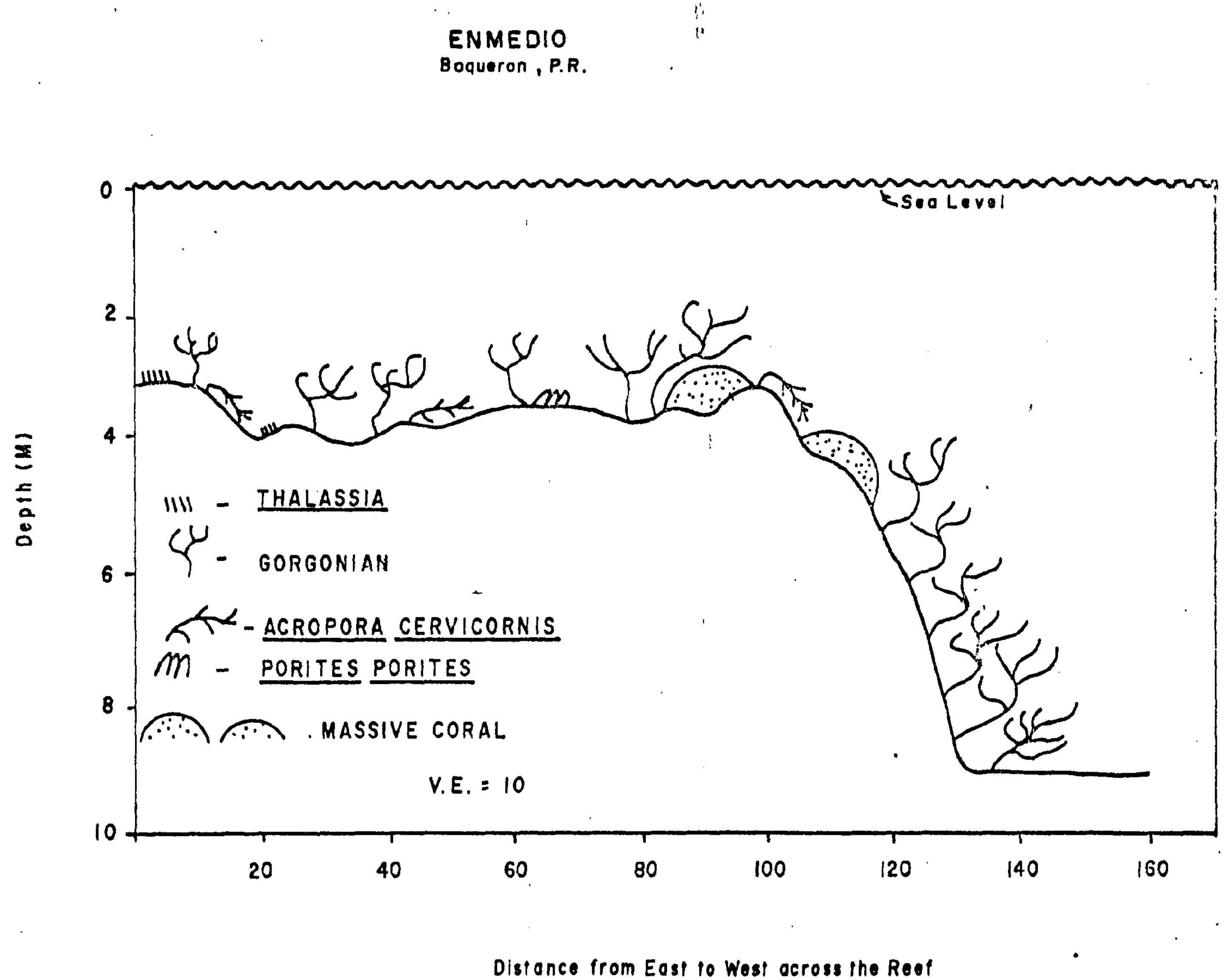

CAYO AHOGADO
Porguera, P.R.
Sea Level
DEPHT (M)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
- A. PALMATA
- M. ALCICORNIS
- HEAD CORAL
- GORGONIAN
- A. CERVICORNIS
V.E.=1

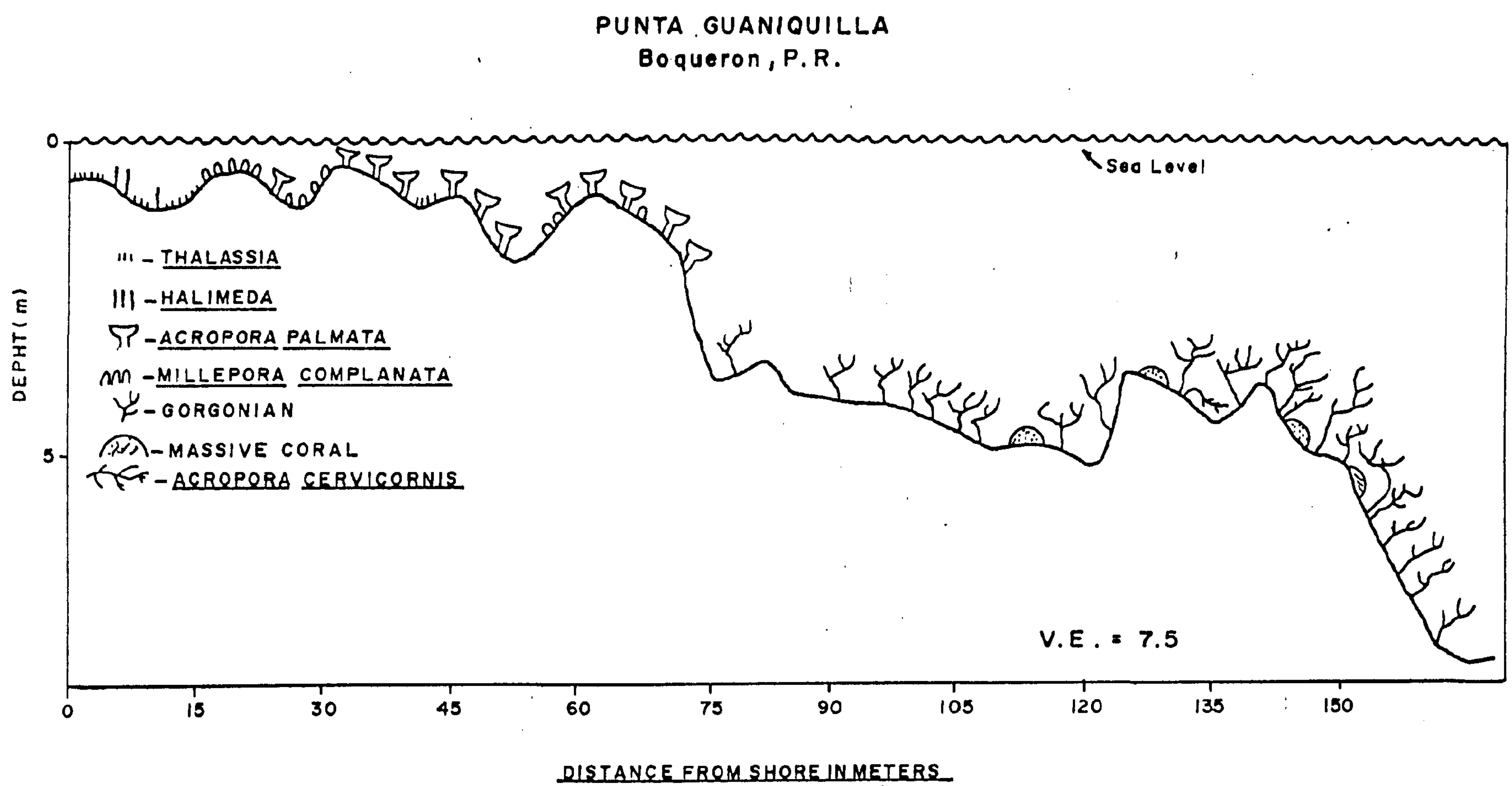
CAYO MEDIA LUNA
Parguera, P. R.



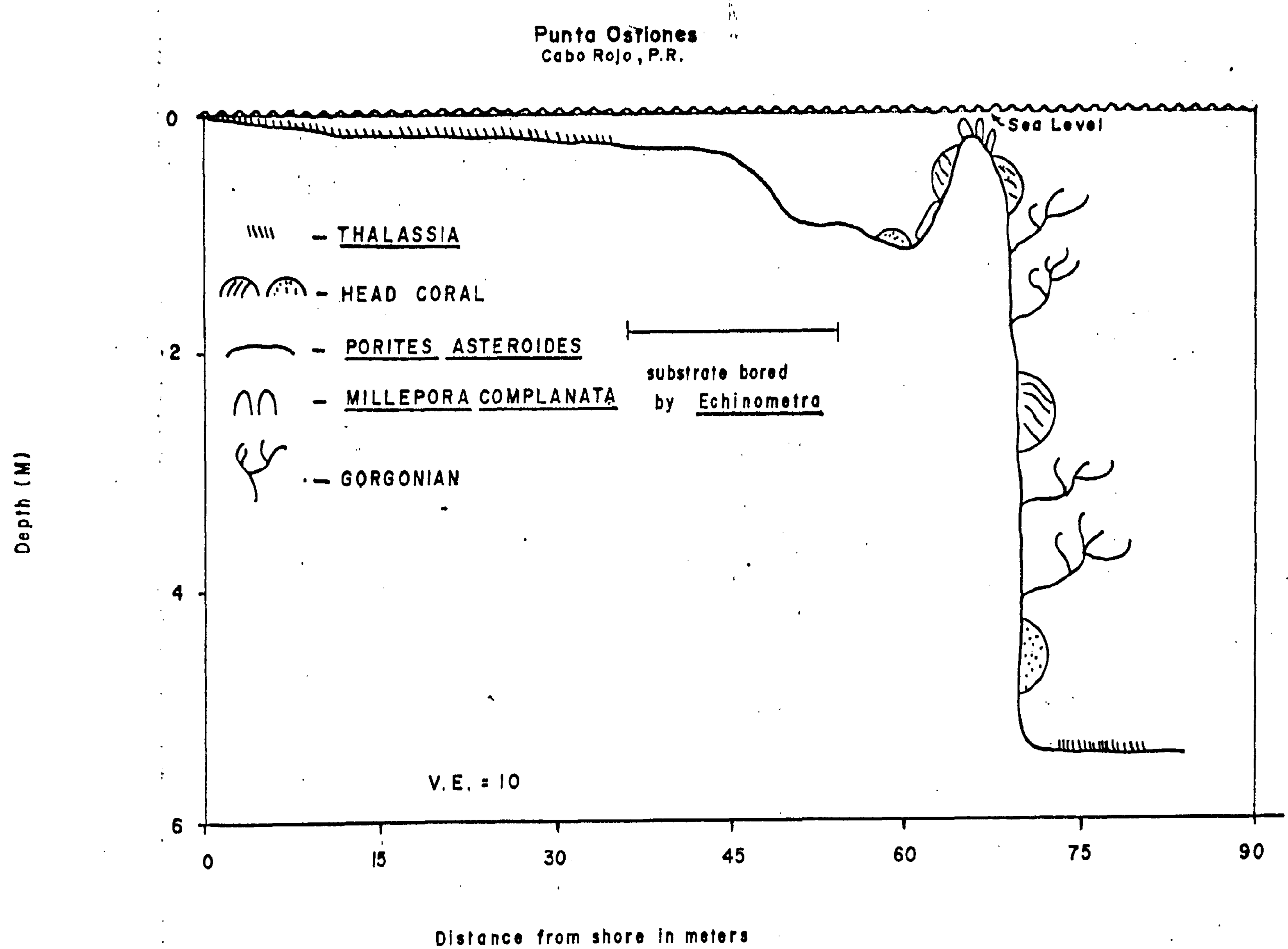

CAYO LA CONSERVA
Parguera, P. R.
Sea Level
DEPHT (m)
0
5
10
M. COMPLANATA
A. PALMATA
MASSIVE CORAL
A. PROLIFERA
A. CERVICORNIS
AGARICIA S.P.
GORGONIAN
V.E. = 1.88
0
15
30
45
DISTANCE FROM REEF FLAT IN METERS


CAYO COLLADO
PARGUERA P.R.
SEA LEVEL
0
5
10
PALYTHOA CARIBAERUM
M. COMPLANATA
THALASSIA
HEAD OR MASSIVE CORAL
GORGONIAN
A. CERVICORNIS
SPONGE
ACROPORA PALMATA
V.E. = 4.7
0
15
30
45
60
Distance from Reef Flat in meters


ENMEDIO
Boqueron , P.R.
Sea Level
Depth (M)
0
2
4
6
8
10
THALASSIA
GORGONIAN
ACROPORA CERVICORNIS
PORITES PORITES
MASSIVE CORAL
V.E. = 10
20
40
60
80
100
120
140
160
Distance from East to West across the Reef



PUNTA GUANIQUILLA
Boqueron, P.R.
Sea Level
DEPHT (m)
0
5
THALASSIA
HALIMEDA
ACROPORA PALMATA
MILLEPORA COMPLANATA
GORGONIAN
MASSIVE CORAL
ACROPORA CERVICORNIS
V.E. = 7.5
0
15
30
45
60
75
90
105
120
135
150
DISTANCE FROM SHORE IN METERS


Punta Ostiones
Cabo Rojo, P.R.
Sea Level
THALASSIA
HEAD CORAL
PORITES ASTEROIDES
MILLEPORA COMPLANATA
GORGONIAN
substrate bored by Echinometra
V.E. = 10
Depth (M)
0
2
4
6
0
15
30
45
60
75
90
Distance from shore in meters

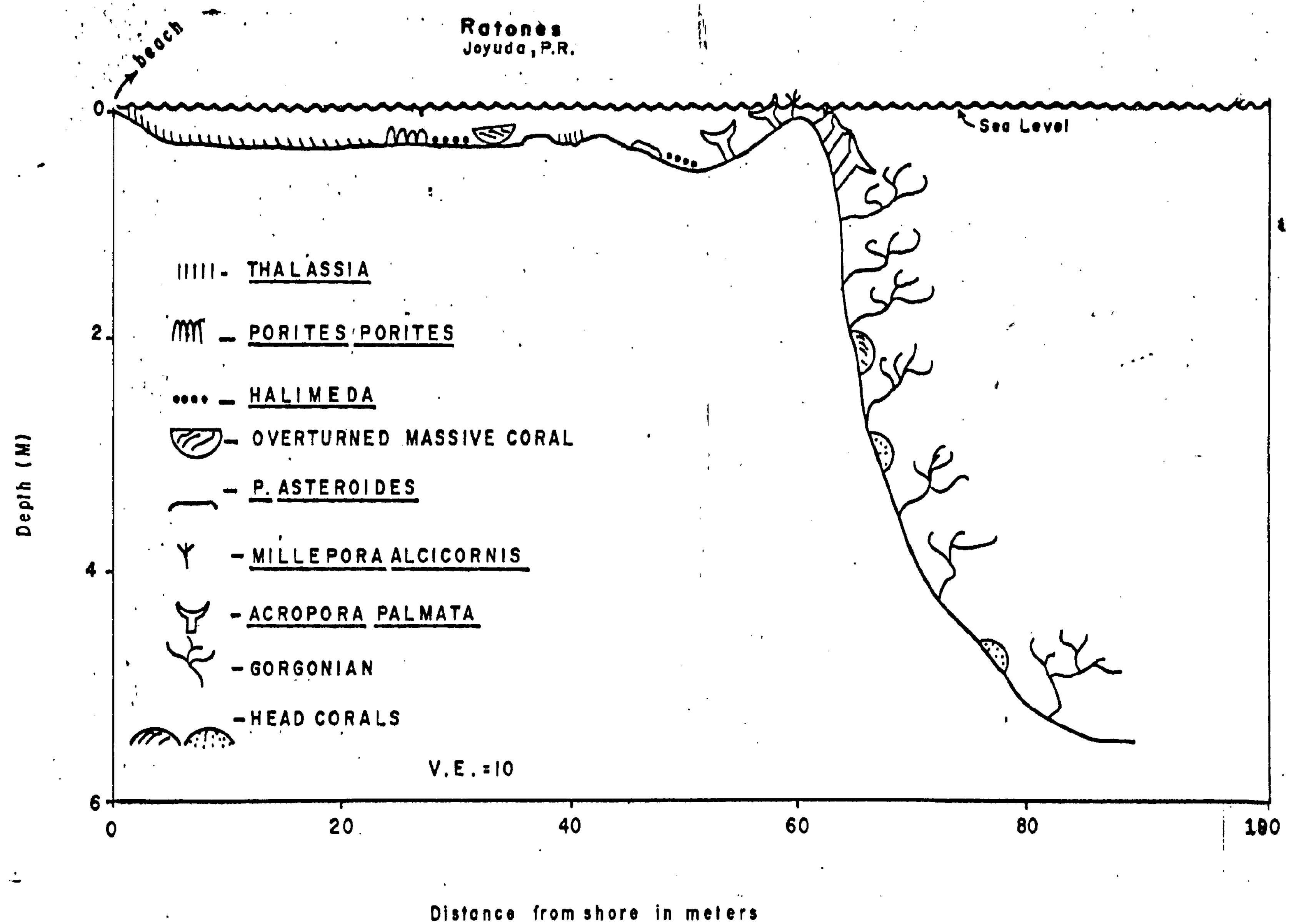

Ratones
Joyuda, P.R.
beach
Sea Level
0
2
4
6
Depth (M)
THALASSIA
PORITES PORITES
HALIMEDA
OVERTURNED MASSIVE CORAL
P. ASTEROIDES
MILLEPORA ALCICORNIS
ACROPORA PALMATA
GORGONIAN
HEAD CORALS
V.E.=10
0
20
40
60
80
100
Distance from shore in meters

Fig. 1. Diver making an underwater profile. Observe sea fans in gorgonian zone.

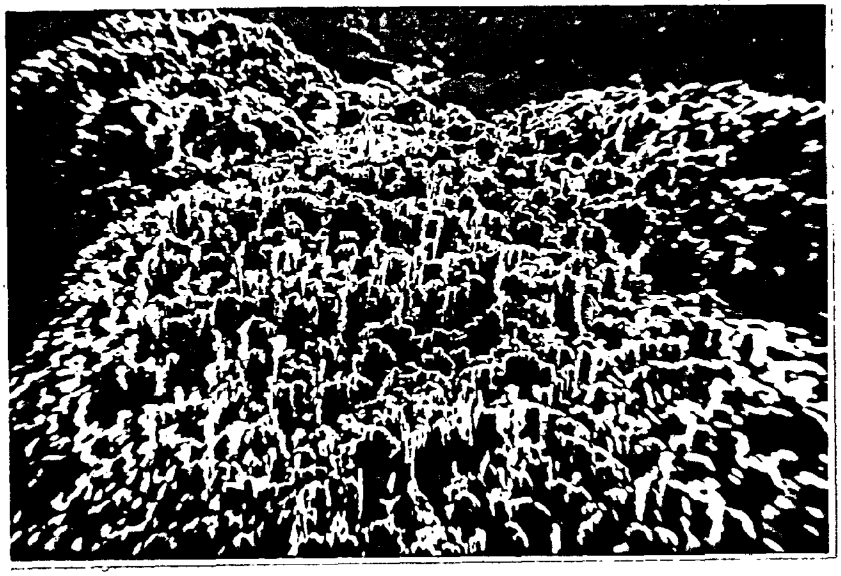
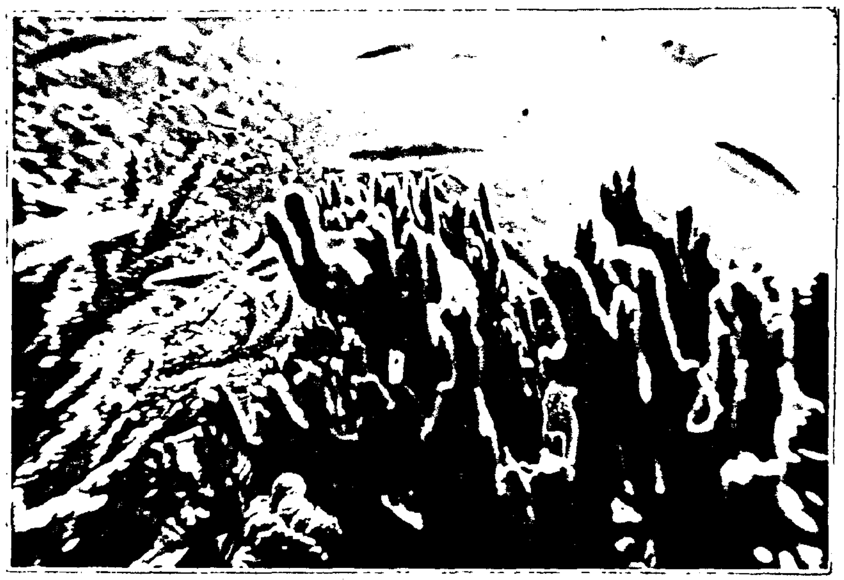


Fig. 5. Dense M. complanata on reef crest. Note beginning of reef flat in the background.

Fig. 6. Reef crest.



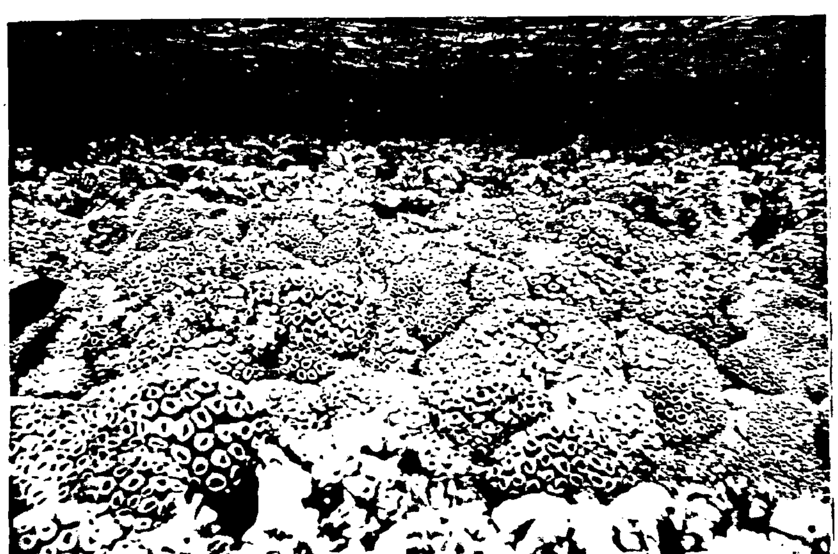


Fig. 7. Abundant colonial anemones (zoanthids) in the reef flat. Several black urchins (Diadema antillarum are present in the background.

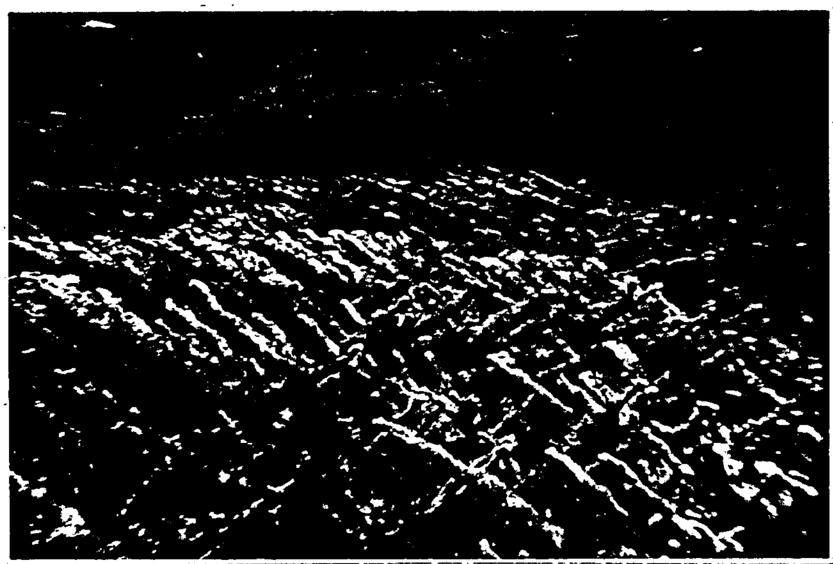


Fig. 8. A. palmata zone. Note 100% cover and high vertical relief.

Fig. 9. Large colony of A. palmata sheltering grunts (haemulon sp.) and goat fishes (Mulloidichthys sp.)

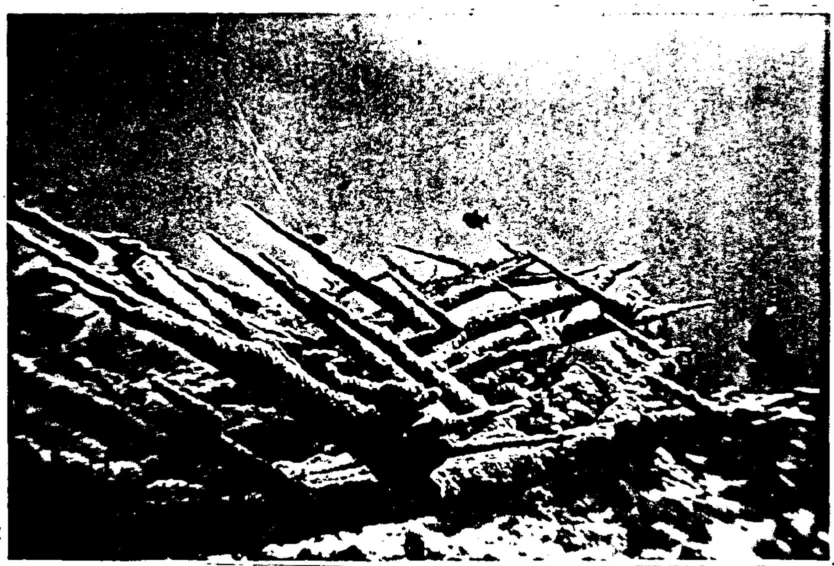


Fig. 10. A. palmata stand marginal to buttress zone.

Fig. 11. Distinct morphological shape of the staghorn coral (A. palmata).

Fig. 12. M. annularis buttress. Note large quantities of planktivorous fish. Transect line can be seen in the background.

Fig. 13. Diver making observations in buttress zone. Observe large variety of invertebrates.

Fig. 14. Brain coral in buttress zone. Observe goby lying on the coral.

Fig. 15. Colony of the pillar coral Dendrogyra cylindricus. Note large stand of the elkhorn coral (A. cervicornis) and a gorgonian to the right of the photograph.

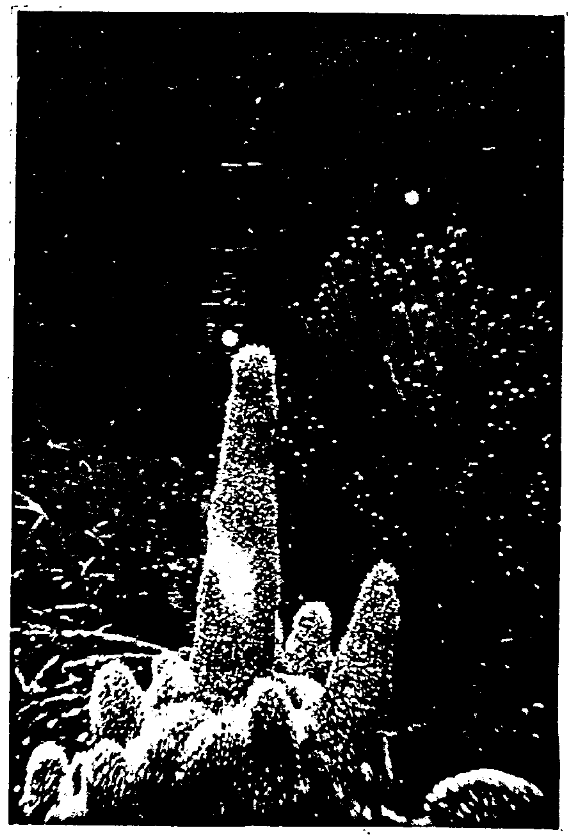


Fig. 16. School of surgeon fish (Acanthurus sp.) in the buttress zone. Observe buttress to the right of the picture.

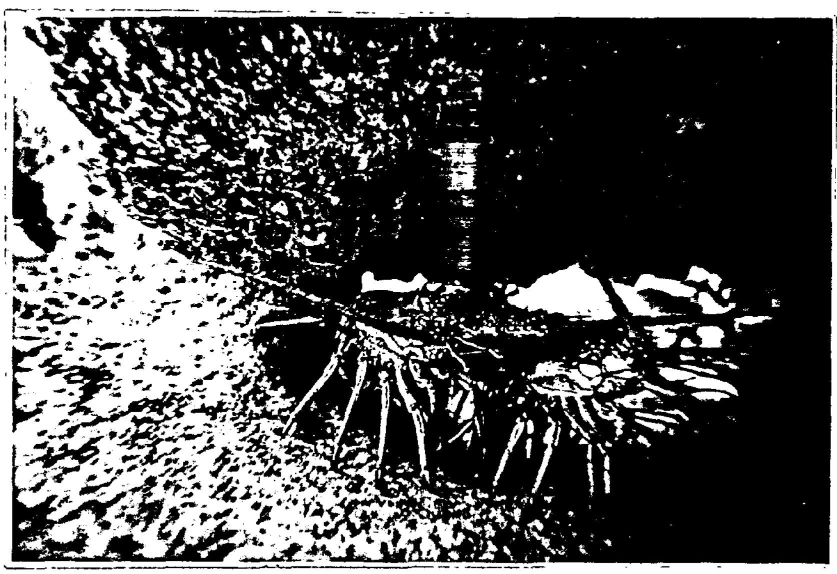


Fig. 17. Lobsters (Panulirus argus) wheltering within crevice in the buttress zone.

Fig. 18. Large staghorn colony sheltering a hamlet (Hypoplectrus sp.)

Fig. 19. Gorgonian or soft coral in the fore reef slope. Observe the dominance of gorgonians over scleractinians (hard corals) in this zone.

Fig. 20. Sponge (center) and massive corals (fore and background) in the fore reef slope.

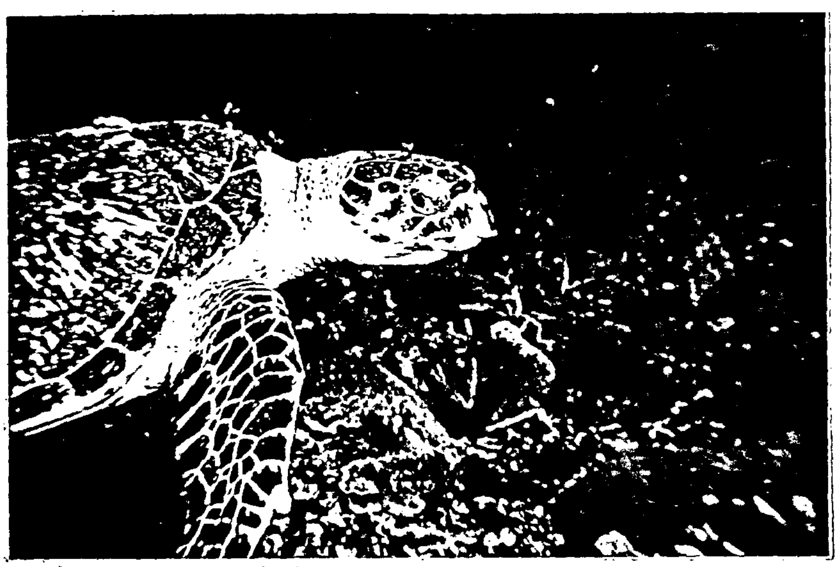


Fig. 21. Turtle (probably Chelonia mydas) in the fore reef slope.

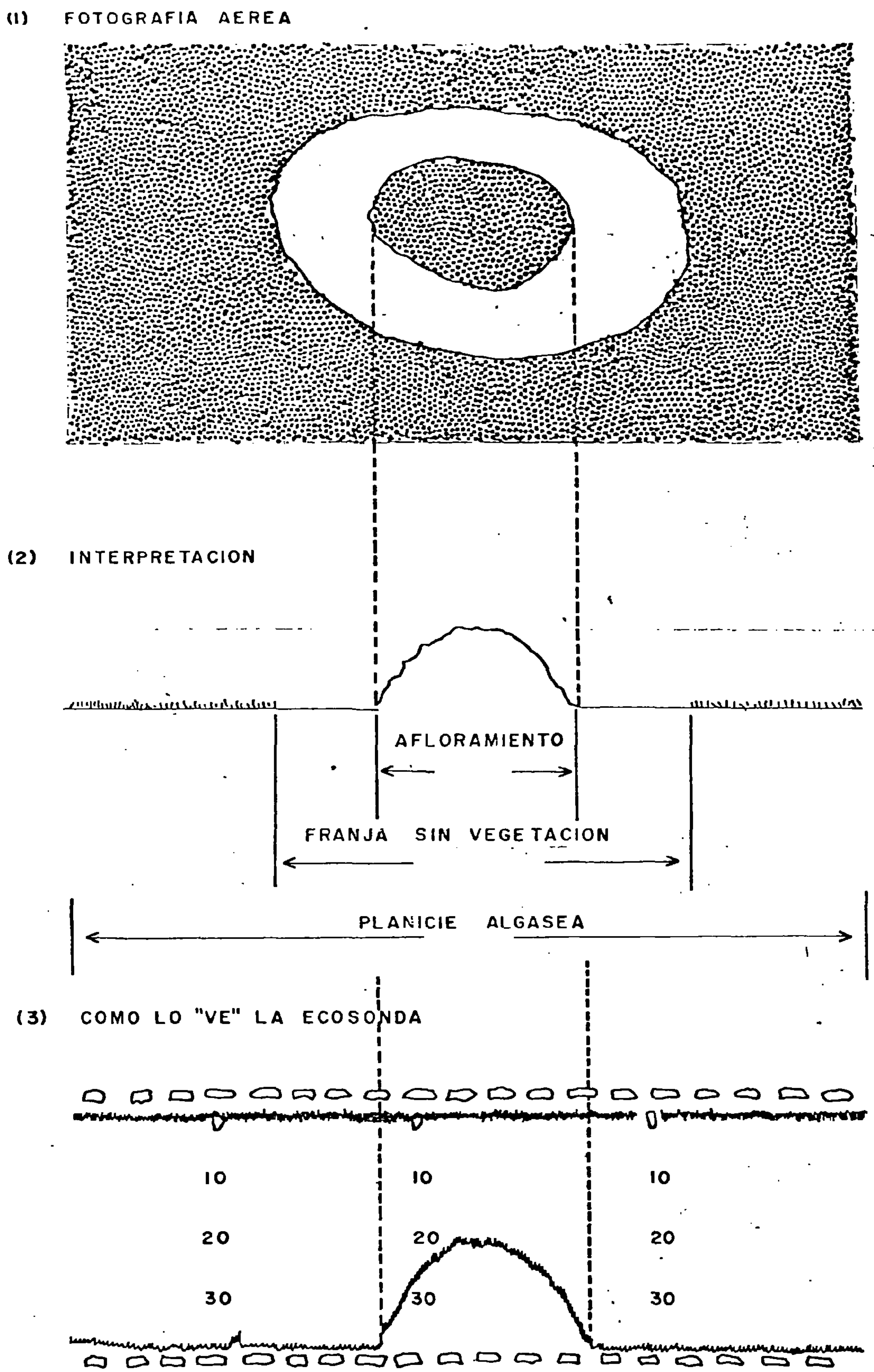


Fig. 22:
FRANJA DESNUDA DE VEGETACION ALREDEDOR DE UN AFLORAMIENTO ROCOSO SUBMARINO. FENOMENO CAUSADO POR EL- PASTOREO INTENSIVO DE LOS PECES RESIDENTES Y TURBULENCIA (after Lugo, 1978).

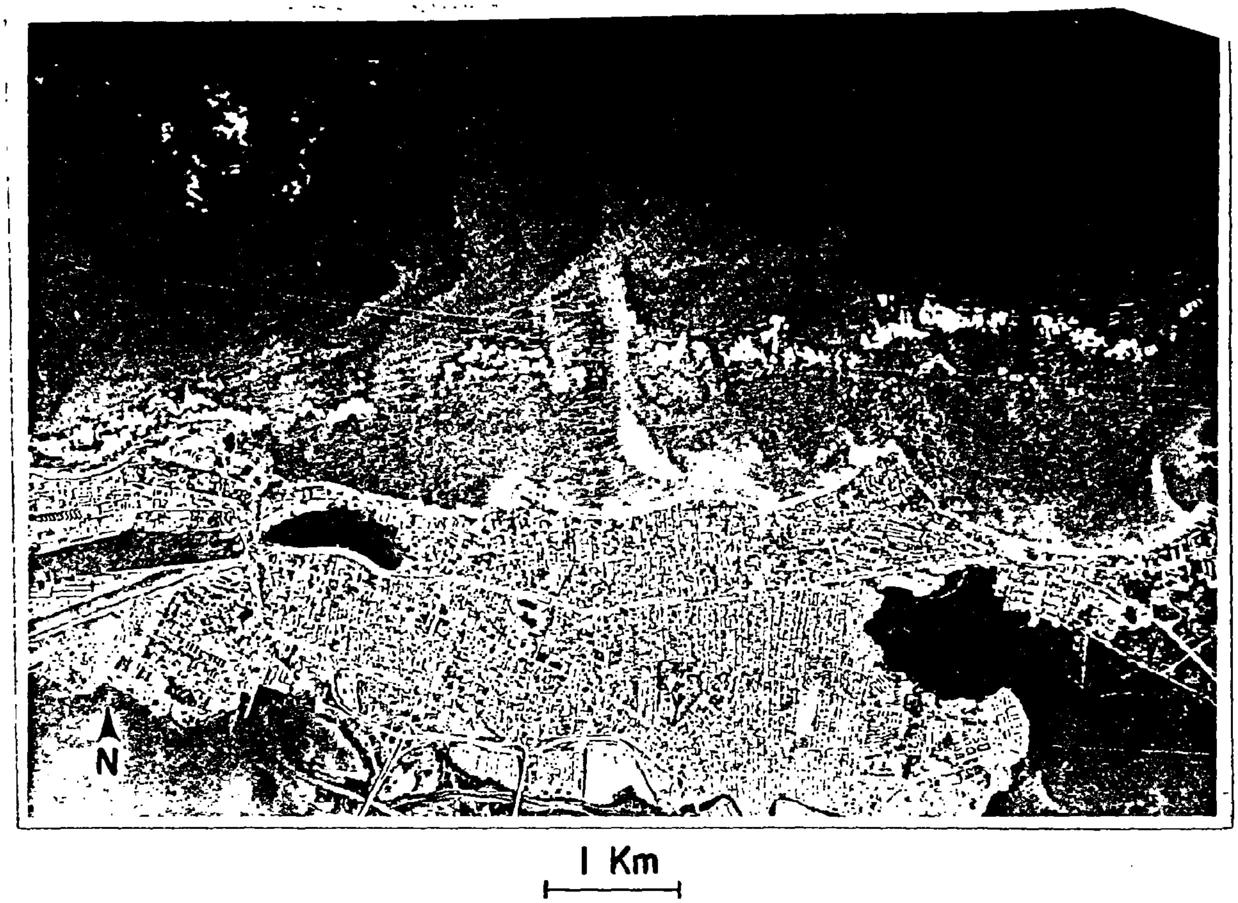


Fig. 23. Line of rock reefs (Trending east to west) offshore San Juan.

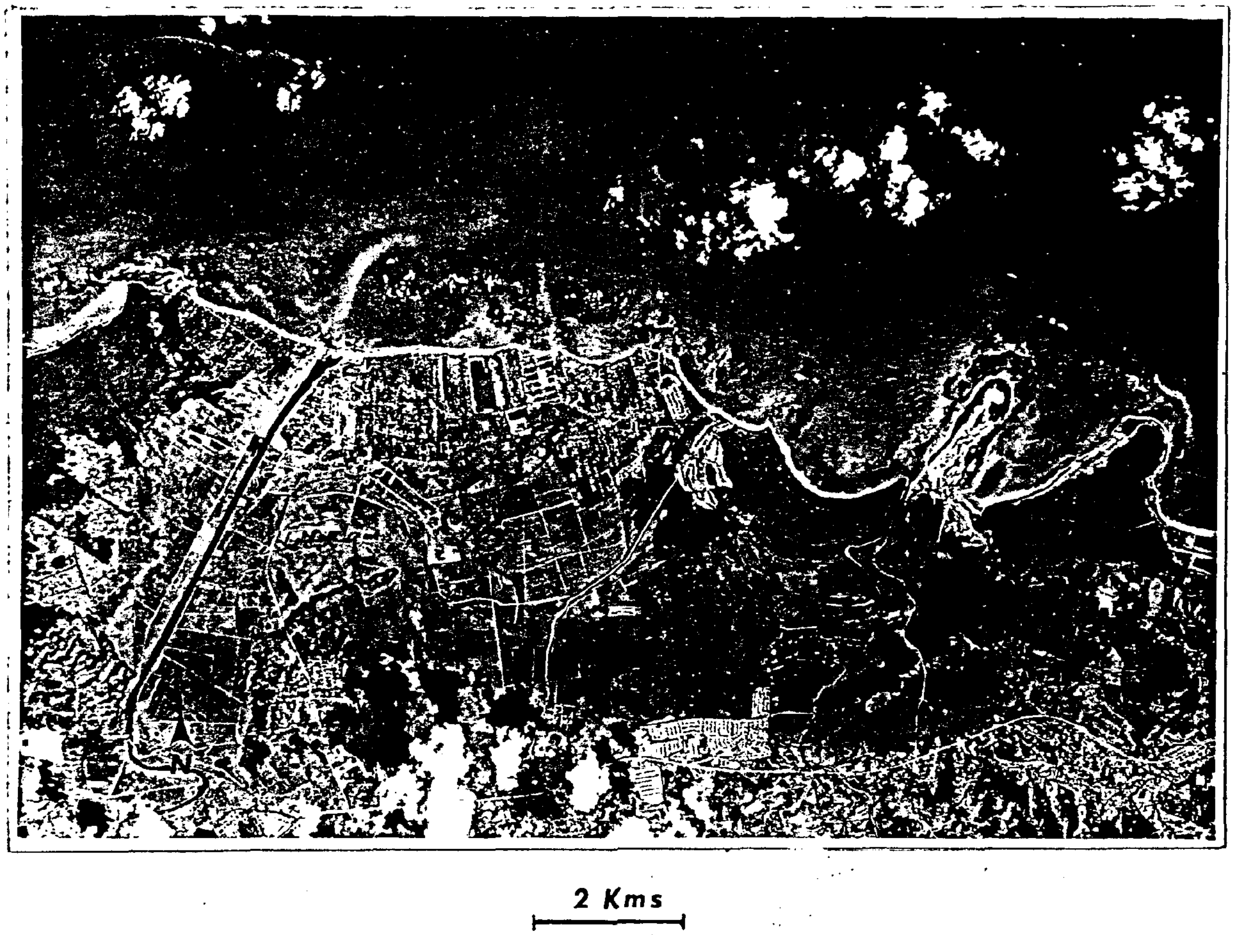


Fig. 24. Heavily silted reefs off Punta Iglesias and Punta San Agustín (center). Punta Vacia Talega can be seen at the left of the picture.

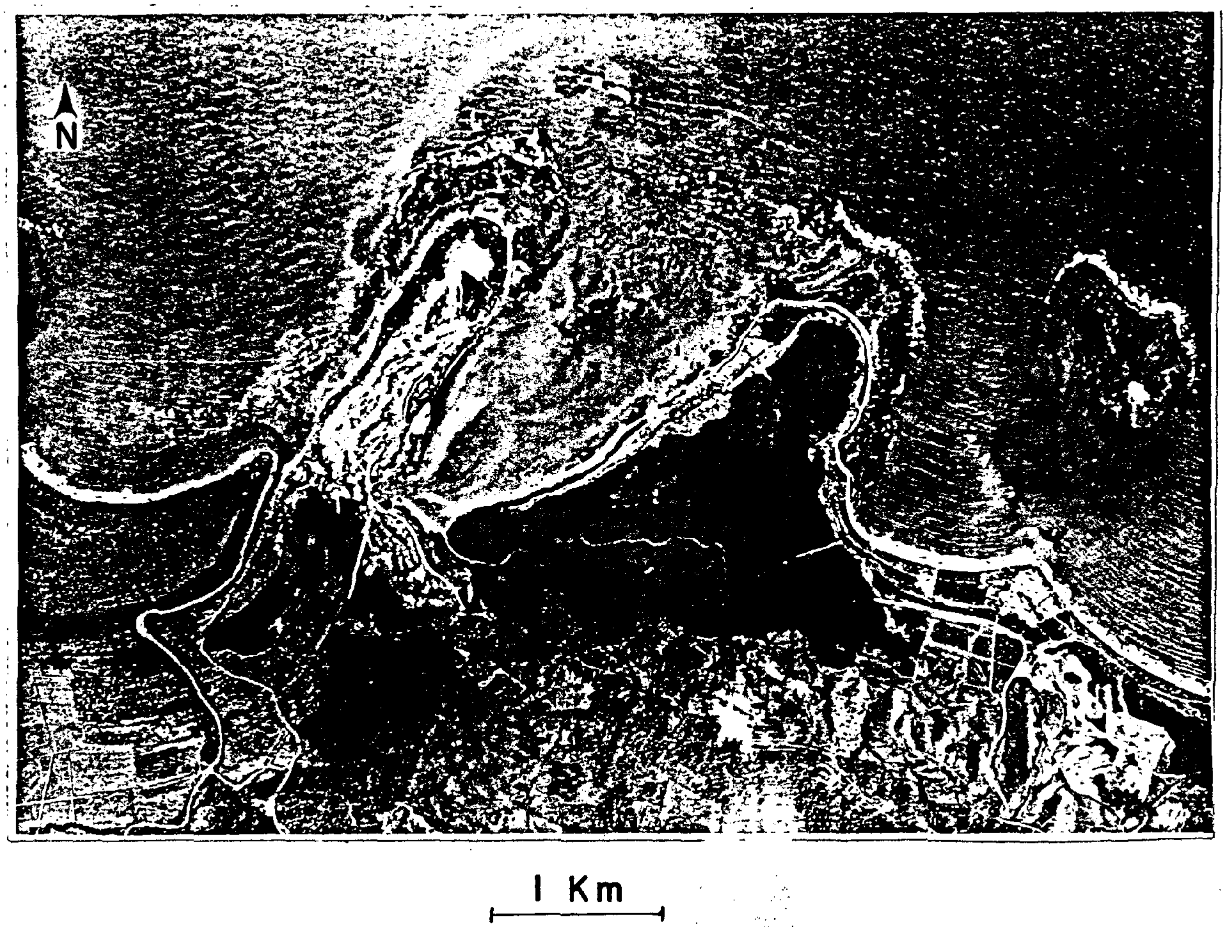


Fig. 25. Fringing reefs off Punta Miquillo and Punta Picua. Annular reef off Río Mameyes is seen to the center right of the photograph.

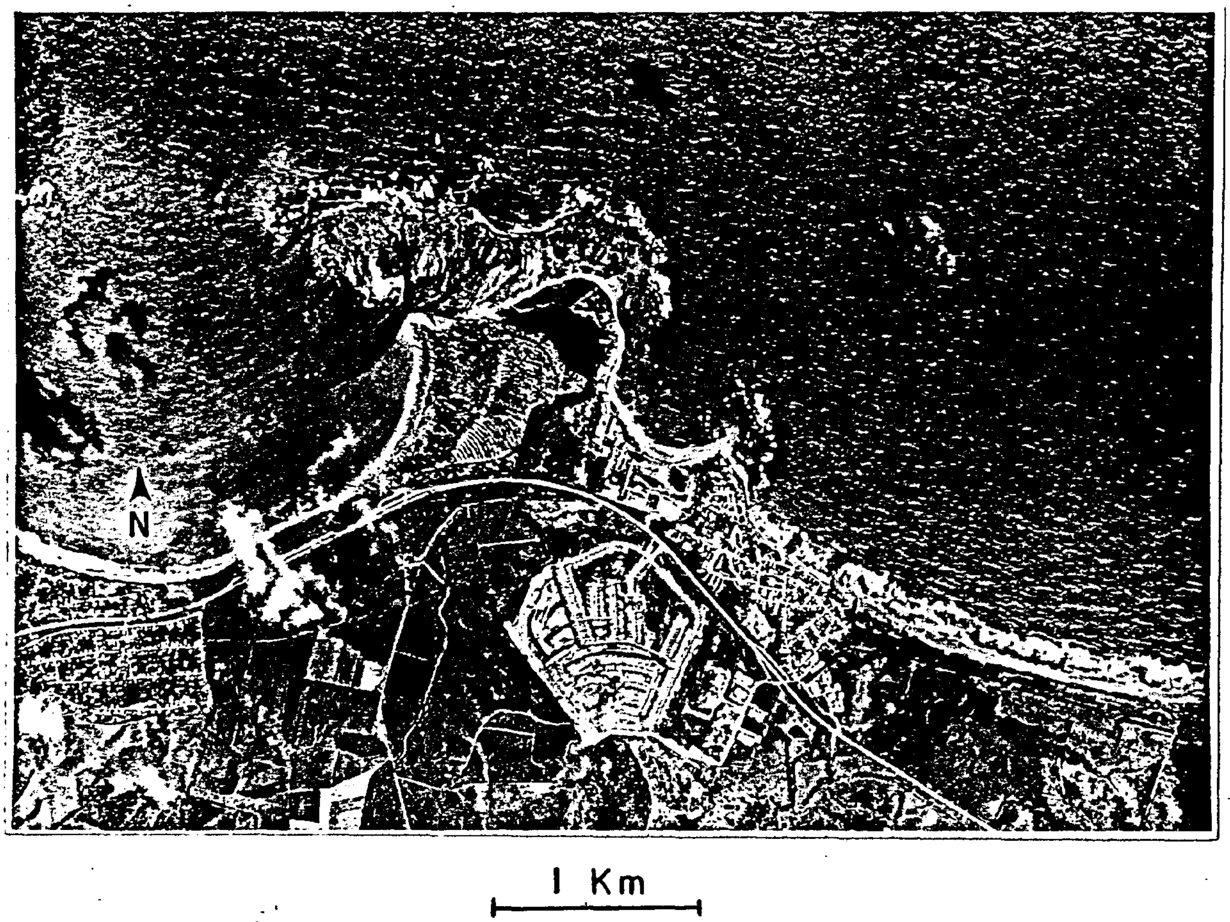
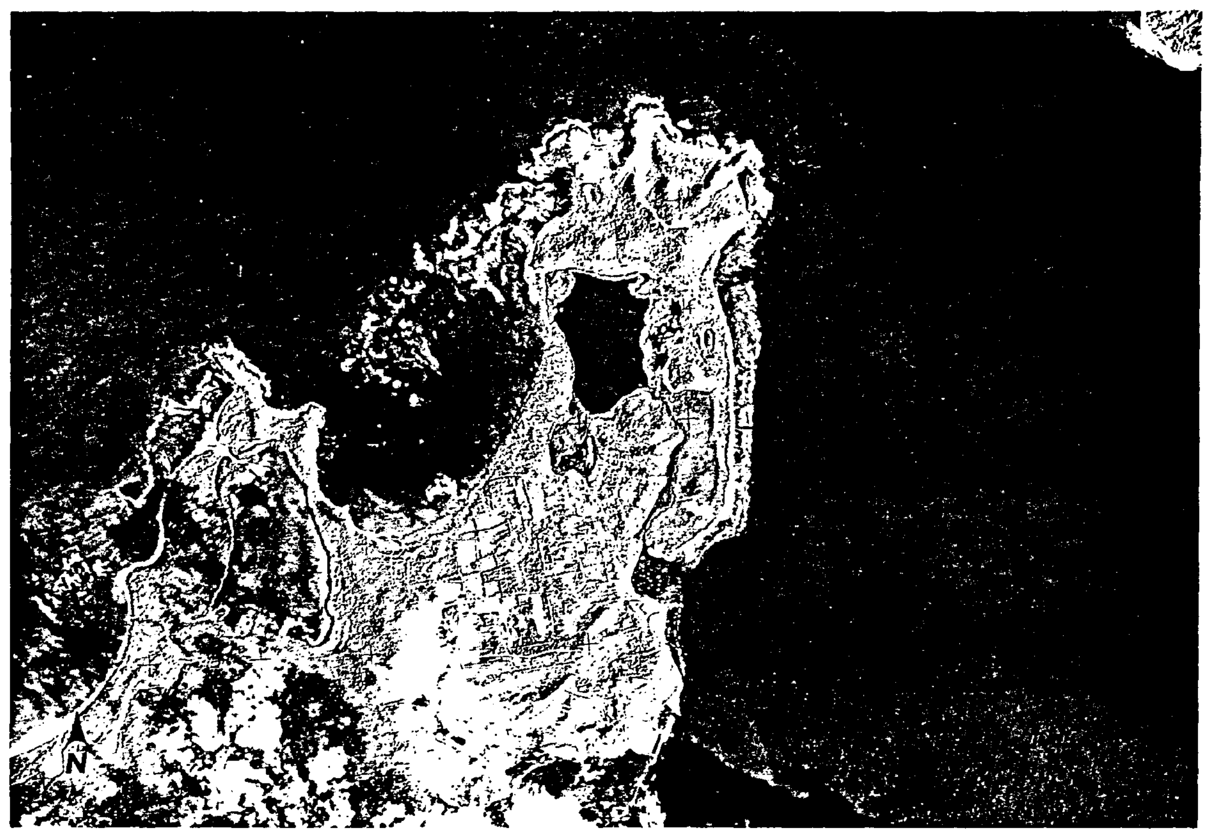


Fig. 26. Punta Percha with fringing reef protecting Luquillo Beach.



2 Kms

Fig. 27. Reef fringing area from Cabeza Chiquita to Cabo San Juan. Observe also reef fringing eastern coast of Las Cabezas.

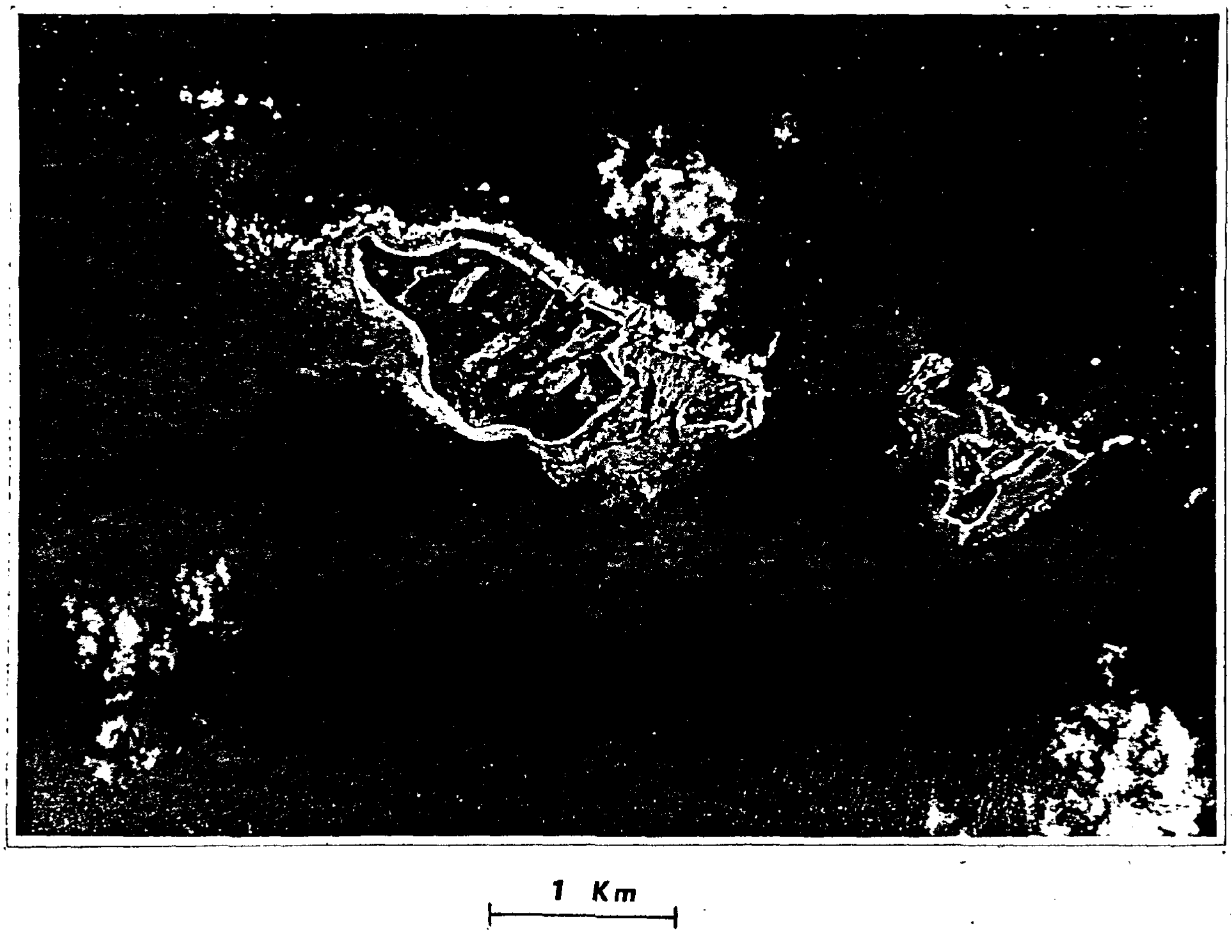


Fig. 28. Icacos, westernmost islet of La Cordillera.

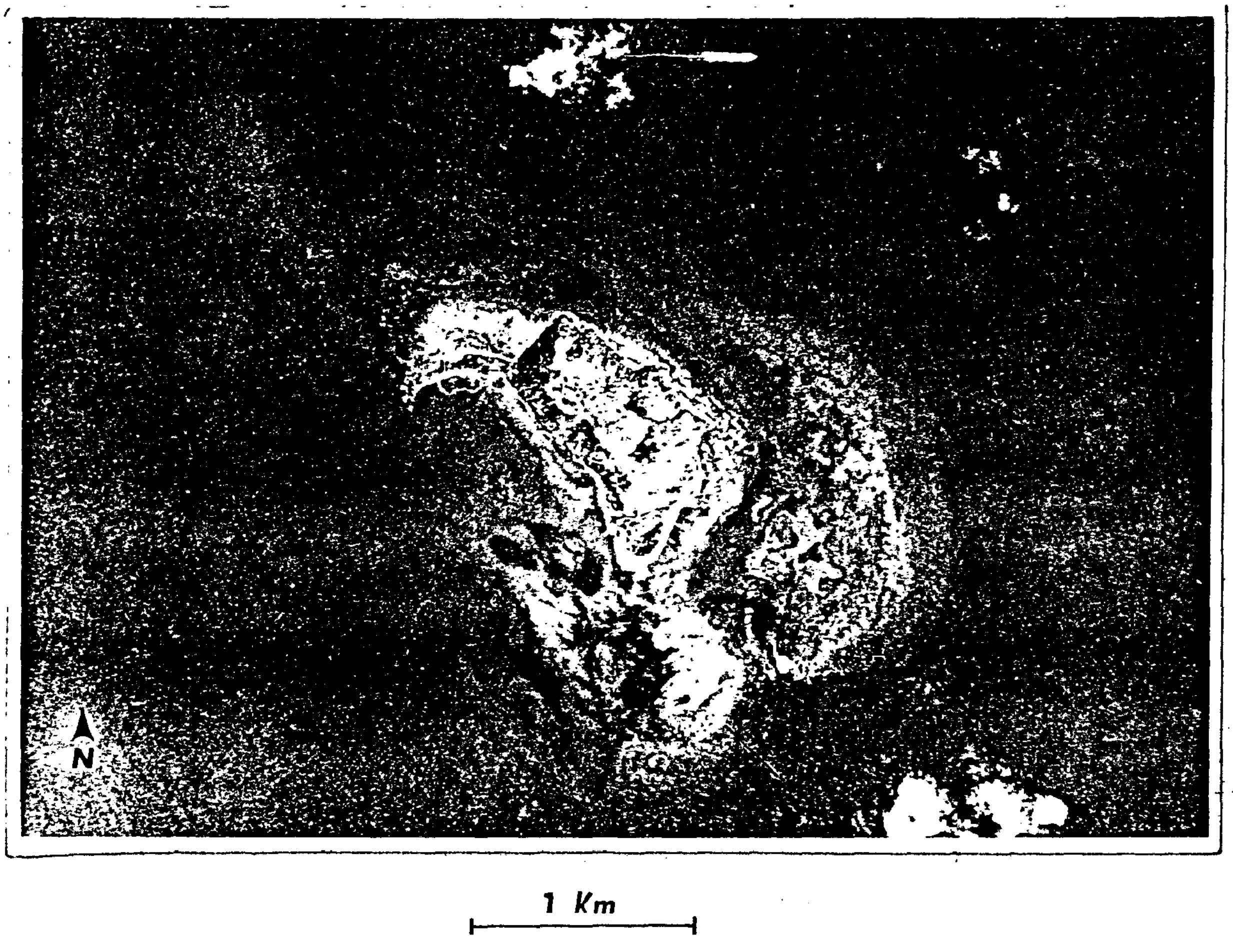


Fig. 29. Palominos and Palominitos (southern sandy islet) off Fajardo.

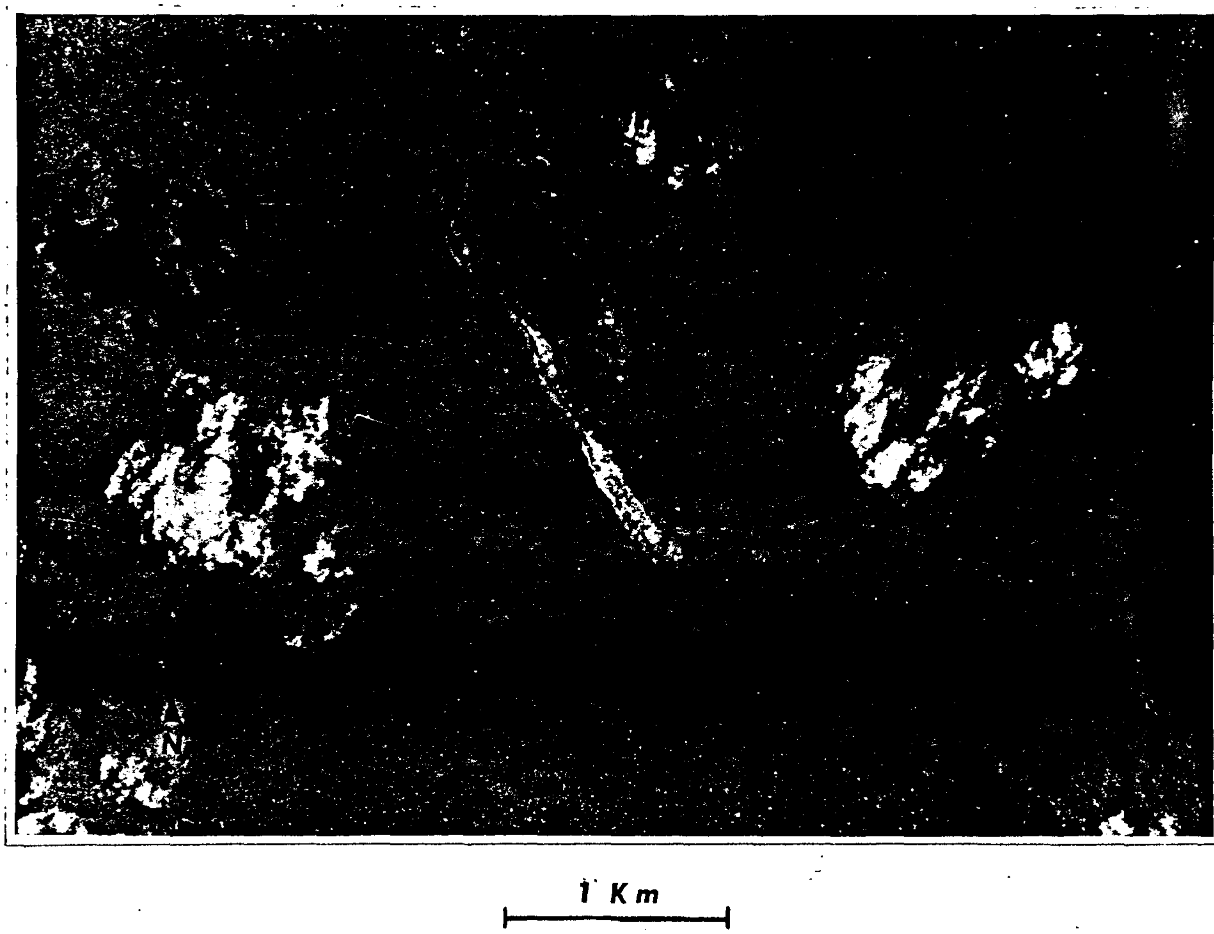


Fig. 30. Cayo Largo, off Fajardo.

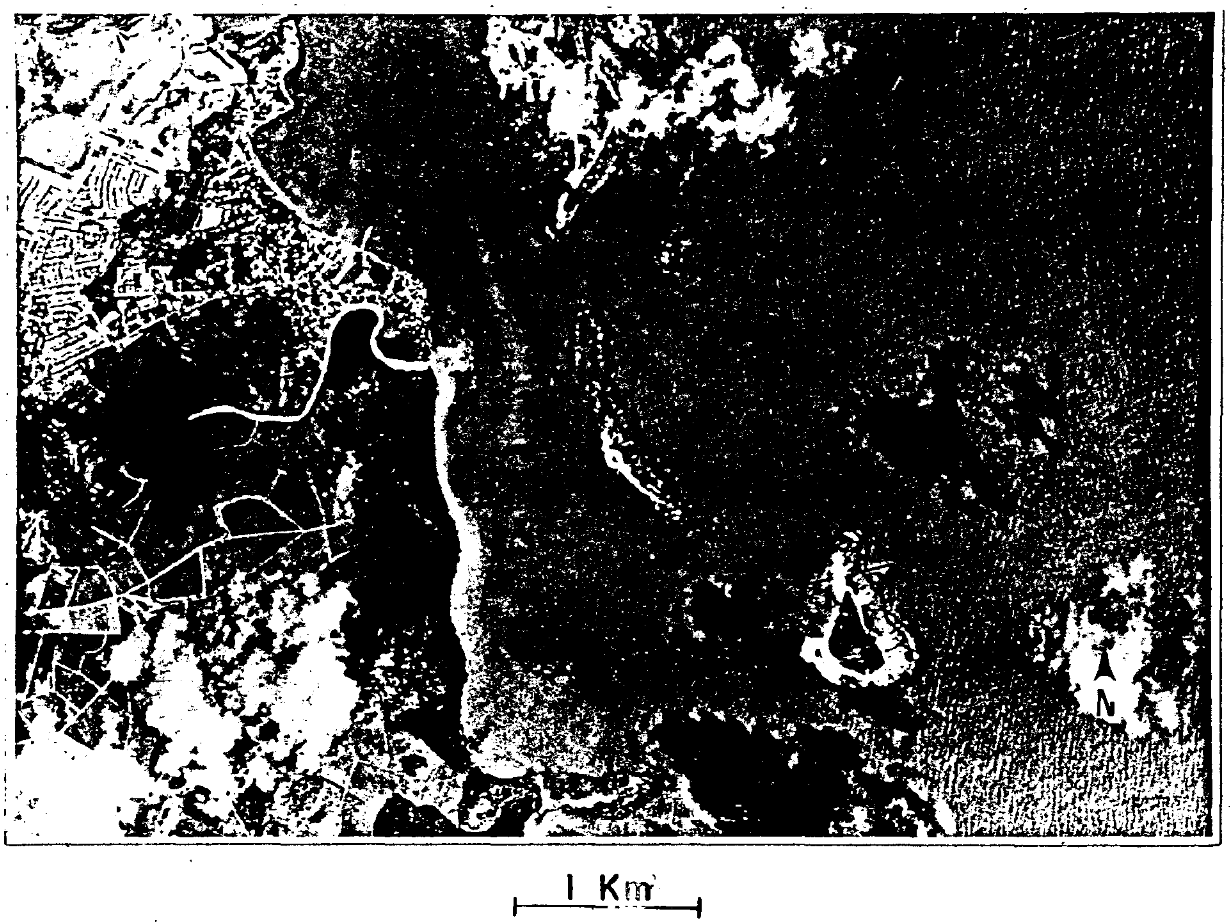


Fig. 31. Islets and reefs off Fajardo. From the bottom Isla de Ramos, Cayo Ahogado and Isleta Marina (Cayo Obispo and Cayo Zancudo) are seen.

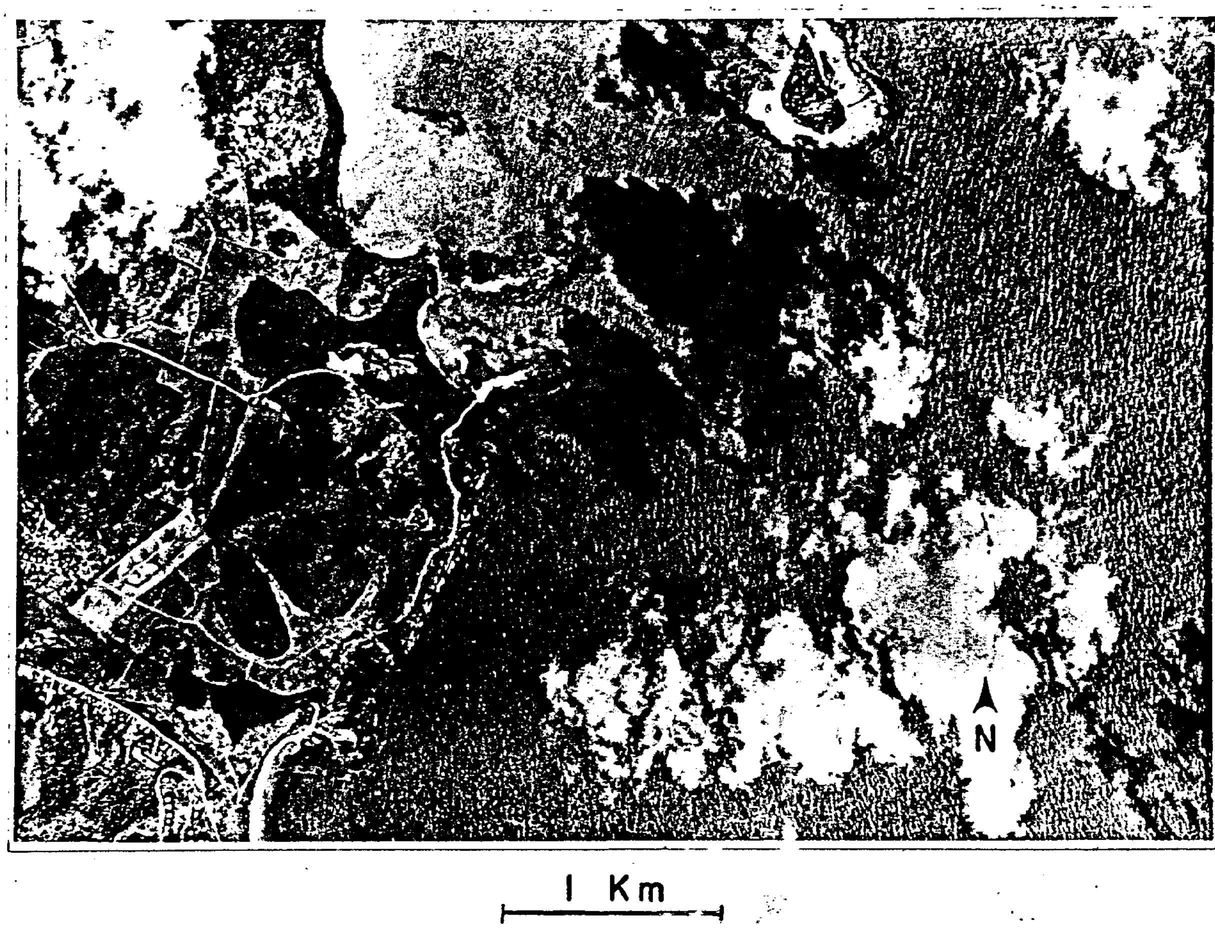


Fig. 32. Reefs projecting east of Punta Barrancas and Punta Mata Redonda.

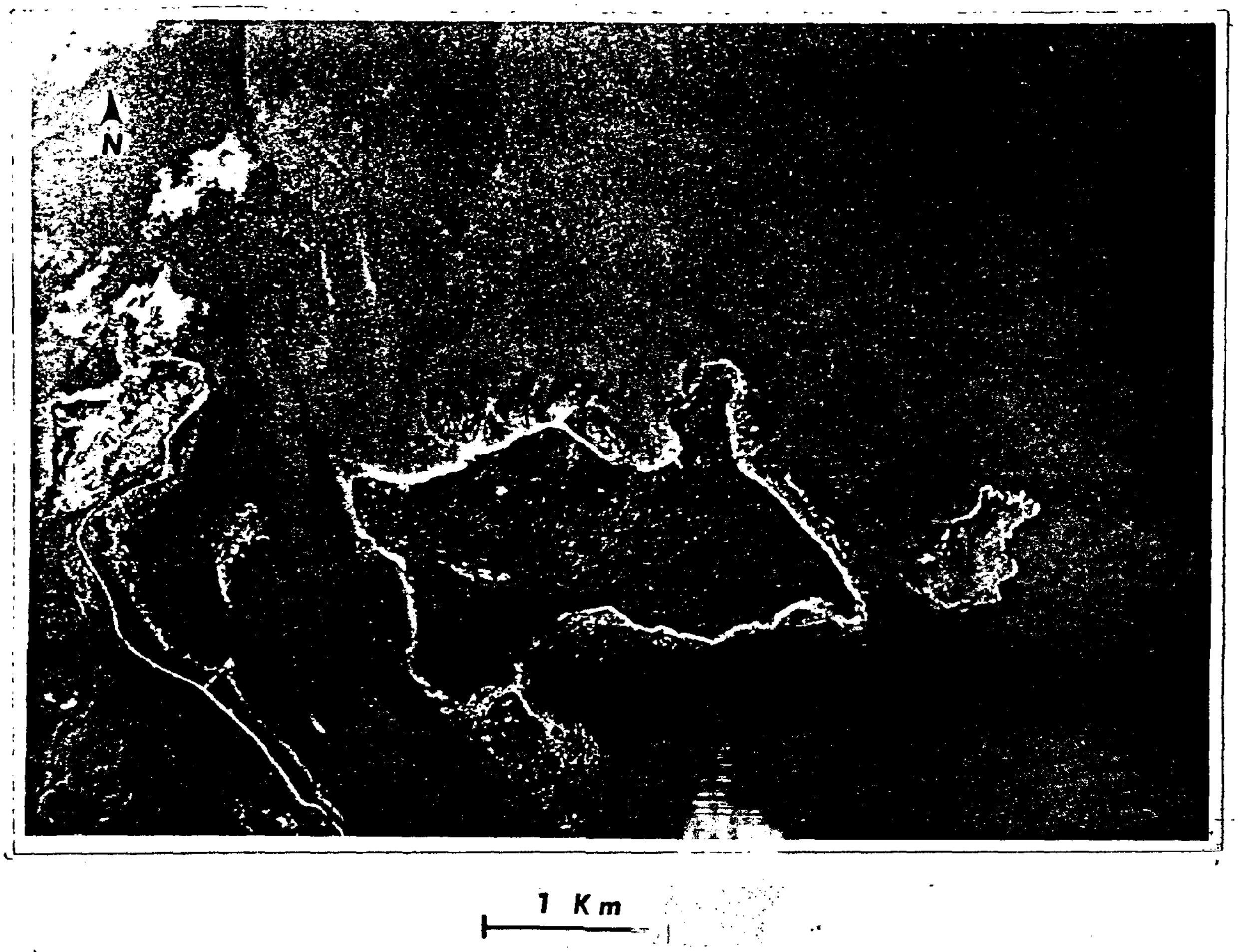


Fig. 33. Isla Piñeros and Cabeza de Perro off Medio Mundo, Ceiba.

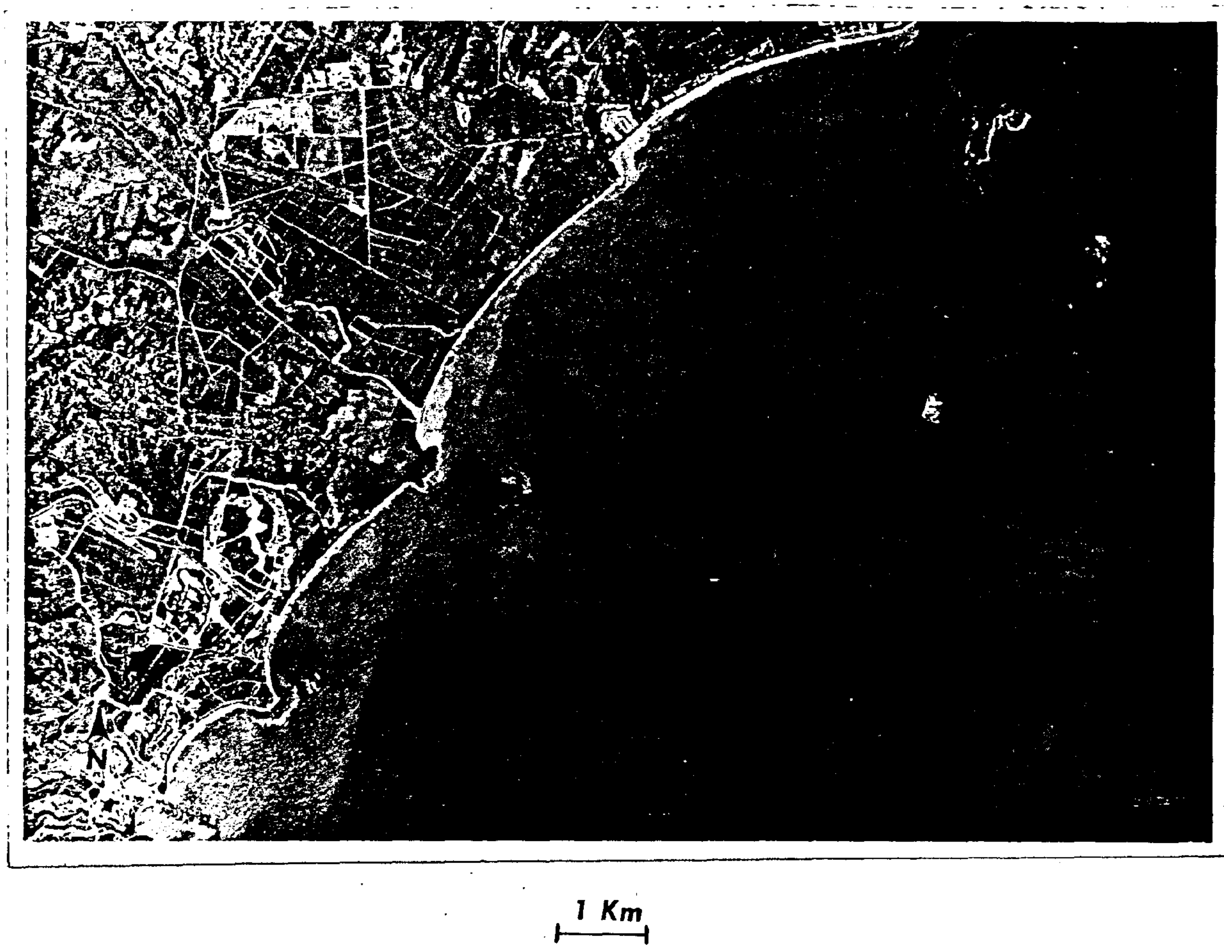


Fig. 34. Cayo Santiago (upper right) and Cayo Batata (center) off Humacao. Several submerged patch reefs, including Bajo Parse, can be seen south of Cayo Santiago.

Fig. 35a. Annular reef off Yabucoa Bay.

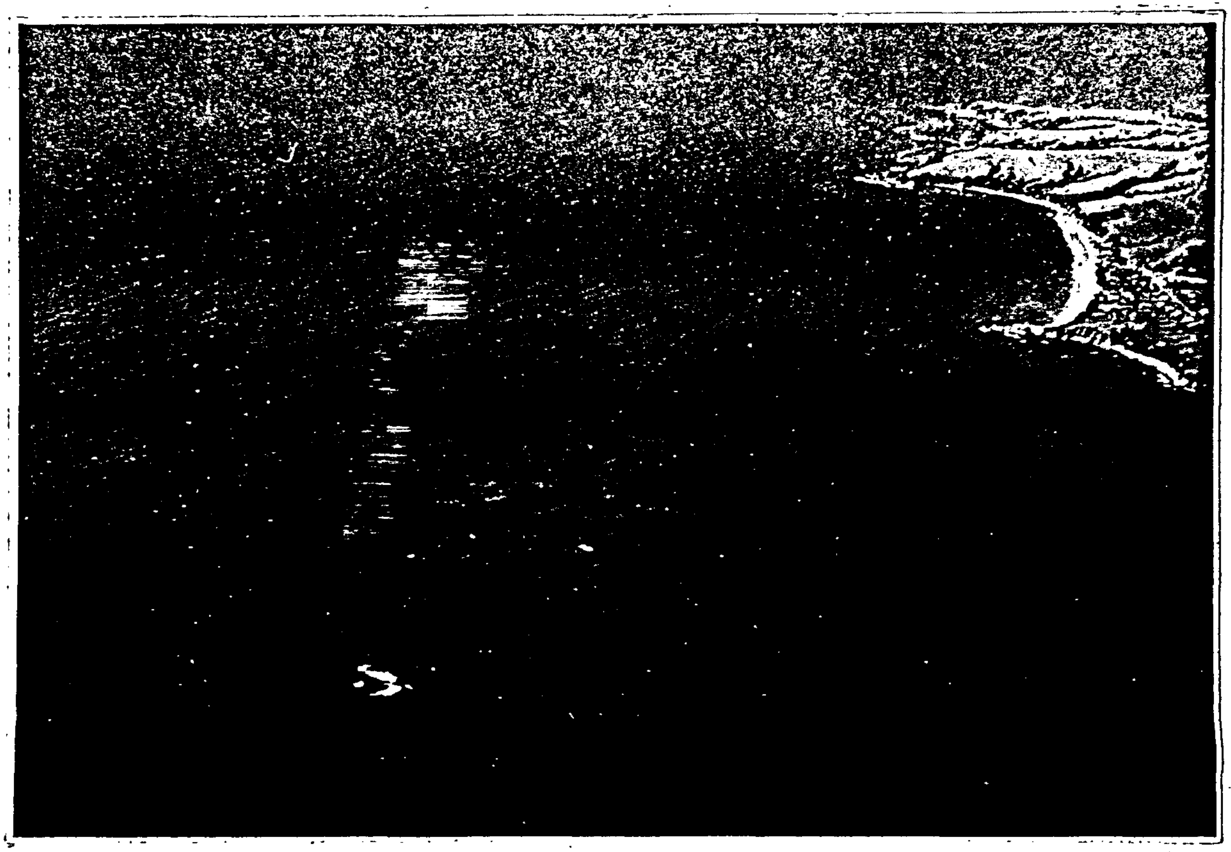


Fig. 35b. Non vertical aerial photograph of the same reef.

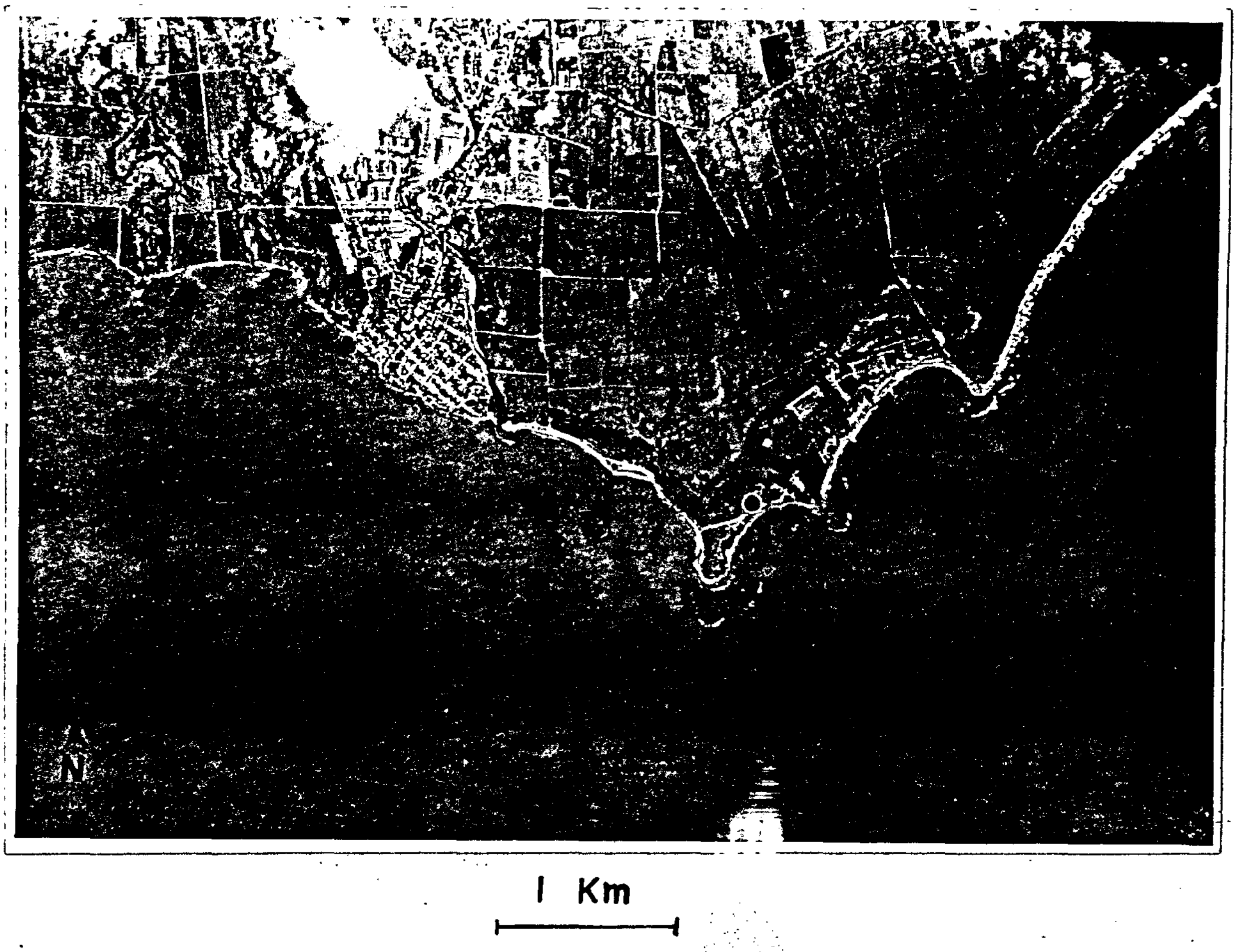


Fig. 36. Fringing reef off Punta Figueras.

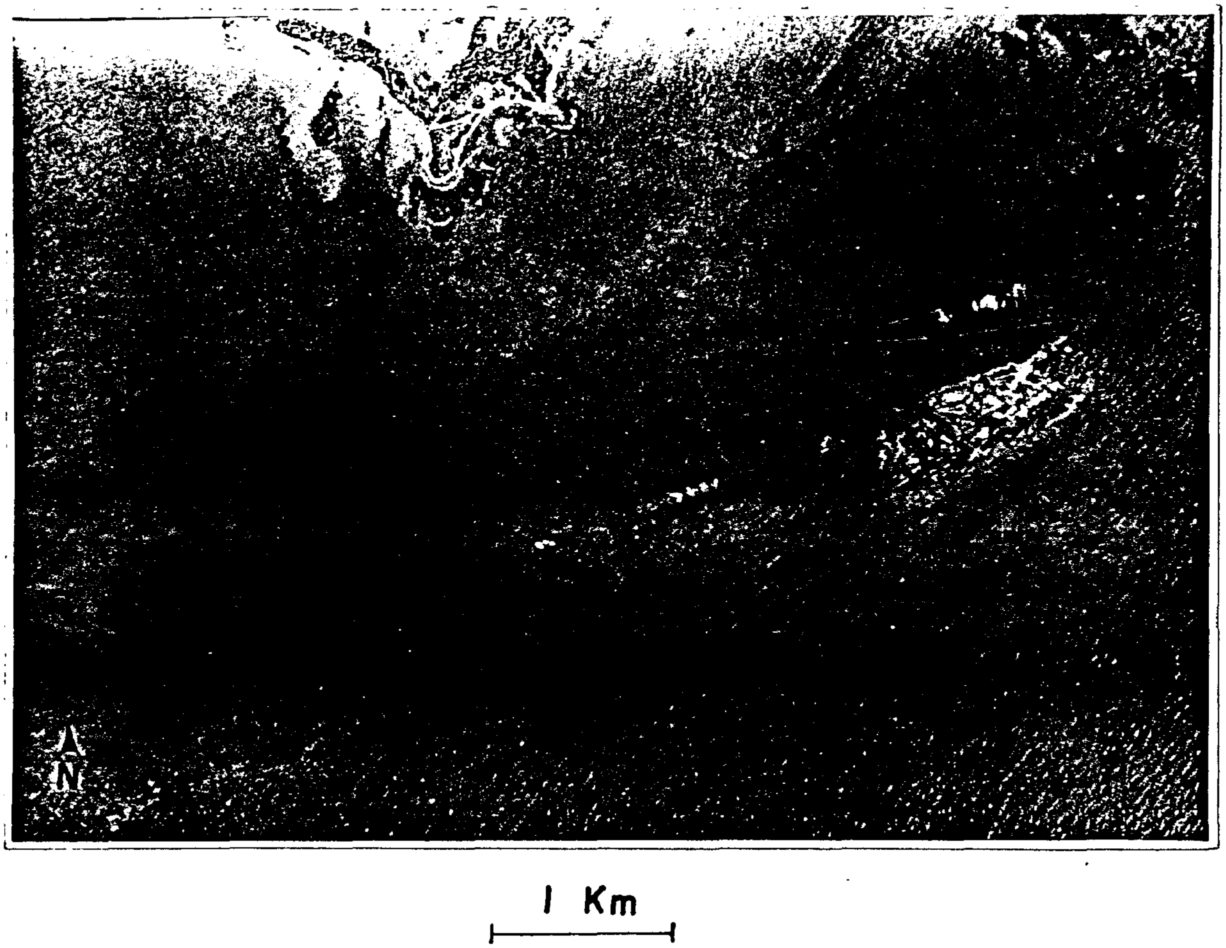


Fig. 37. Arrecife Guayama south of Punta Figueras.

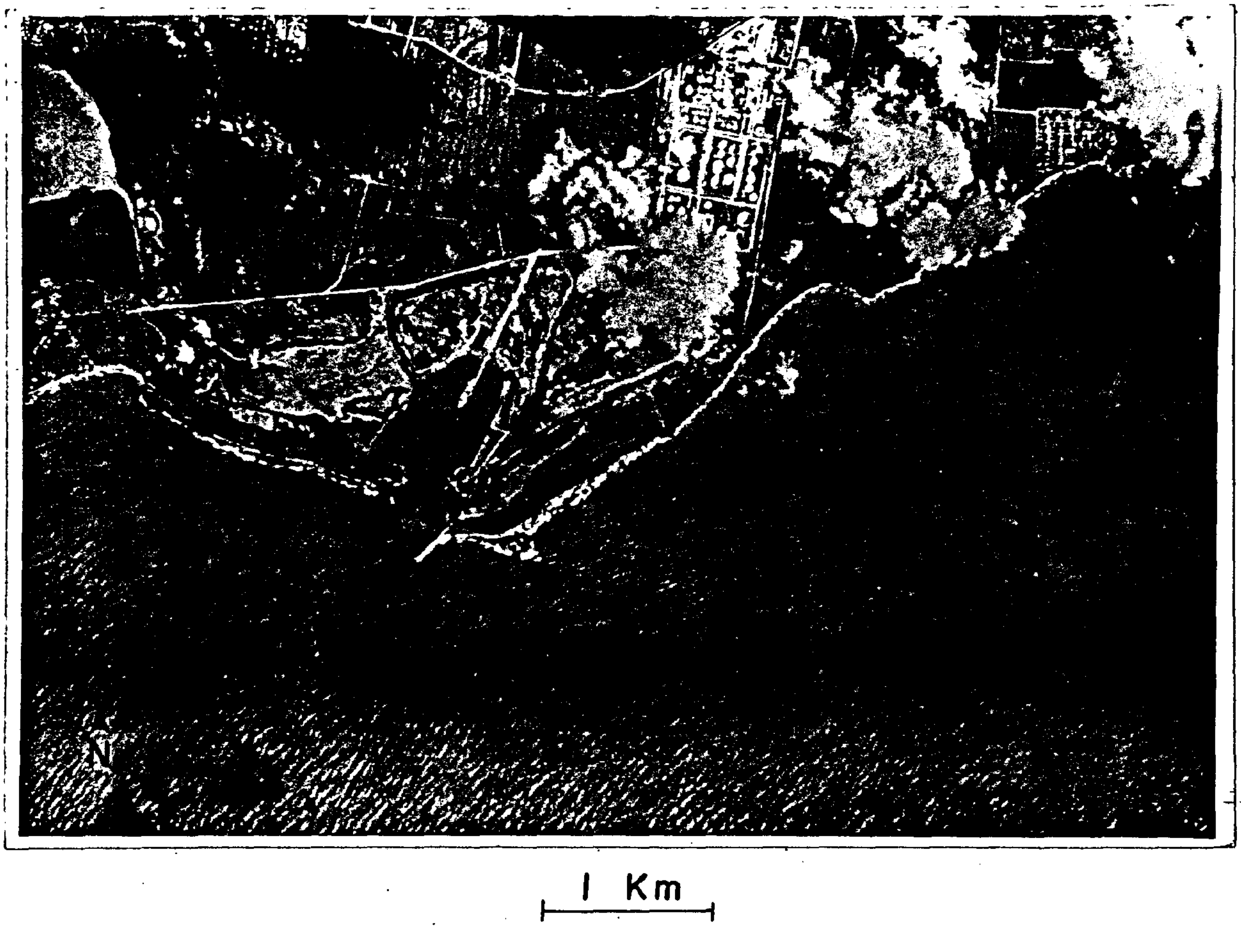


Fig. 38. Arrecife Las Mareas off Guayama (lower right).

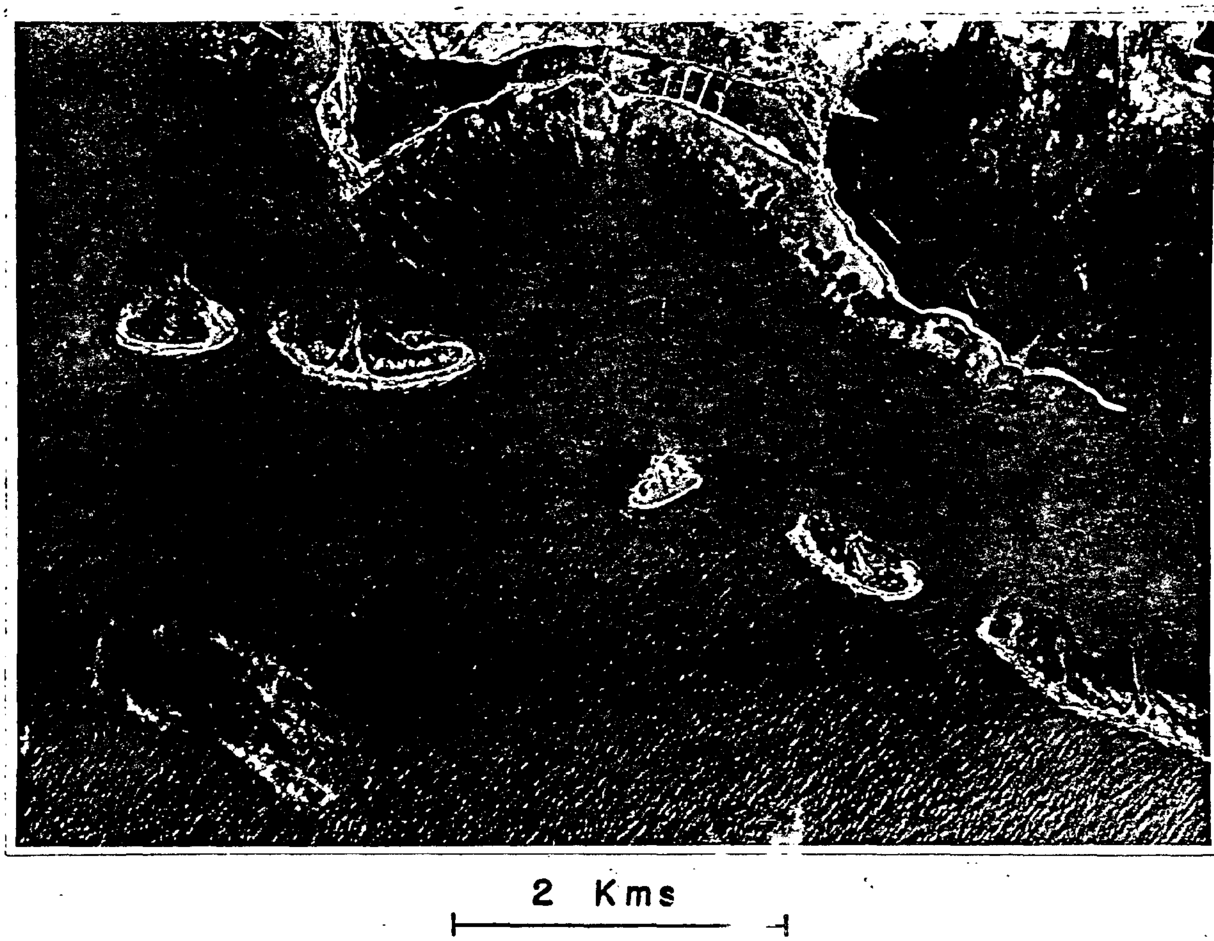


Fig. 39. Cayos de Barca, Jobos.

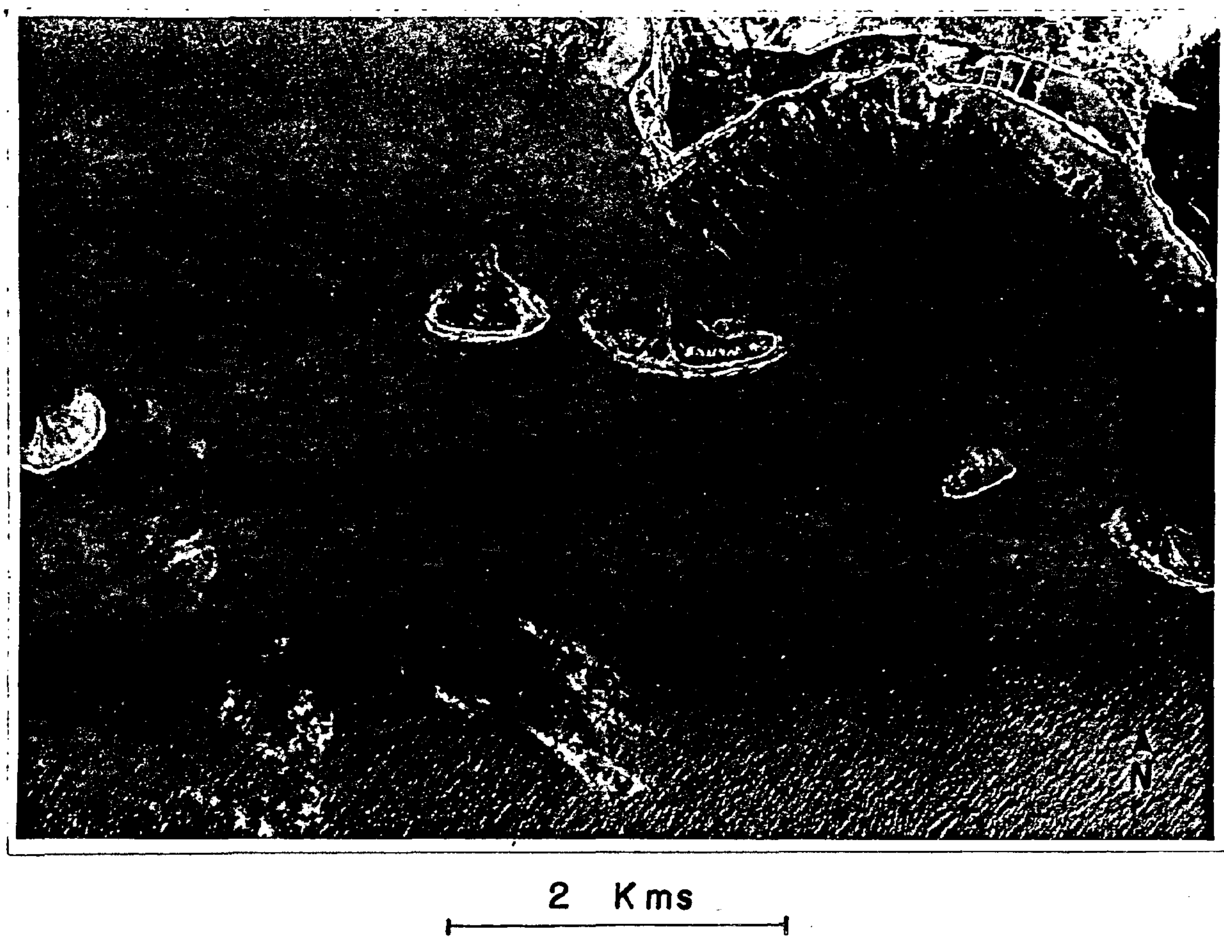


Fig. 40. Reefs off Salinas.

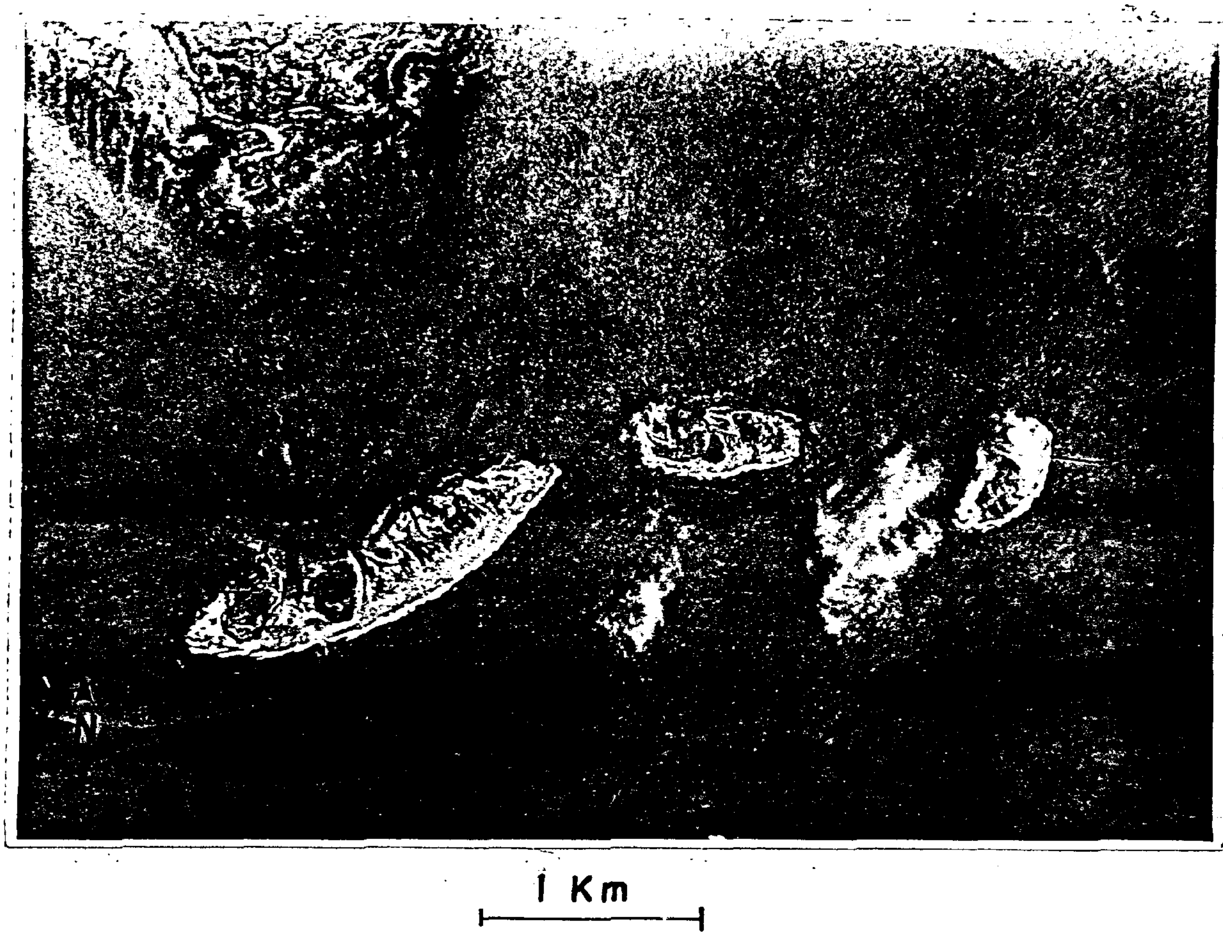


Fig. 41. Reefs off Santa Isabel.

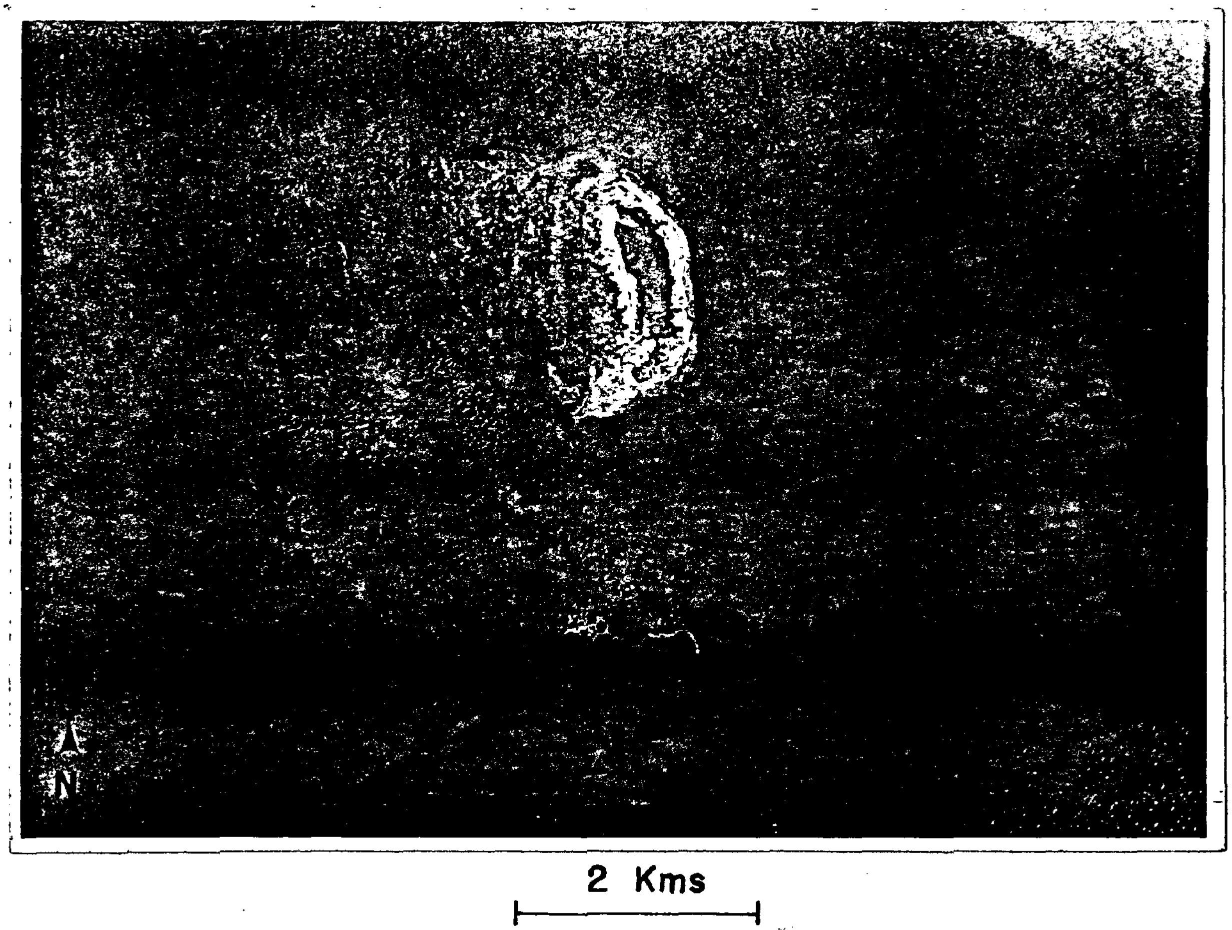


Fig. 42. Cayo Berbería off Santa Isabel. Highest reef development in south coast.

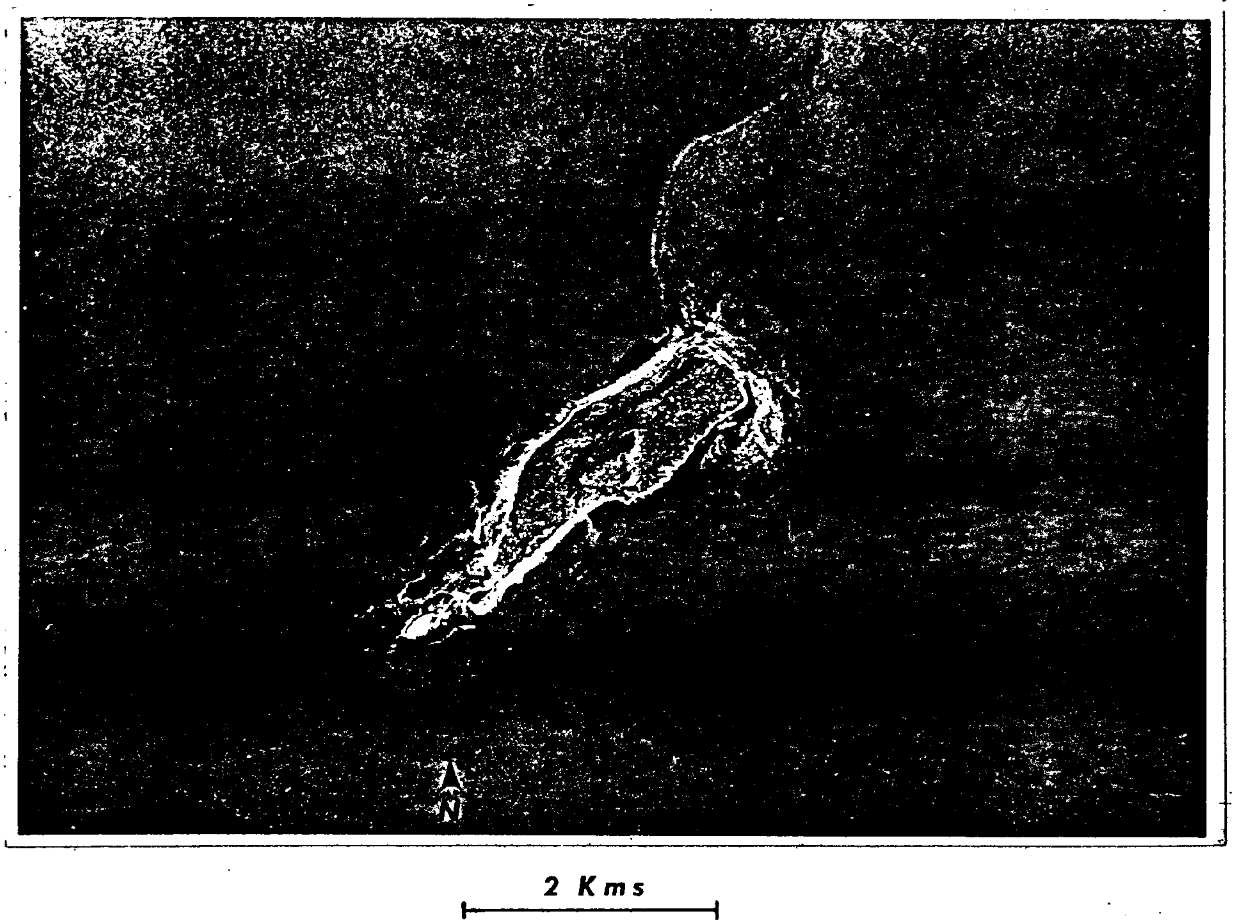


Fig. 43. Isla Caja de Muertos off Ponce. Highest reef development in eastern coast.

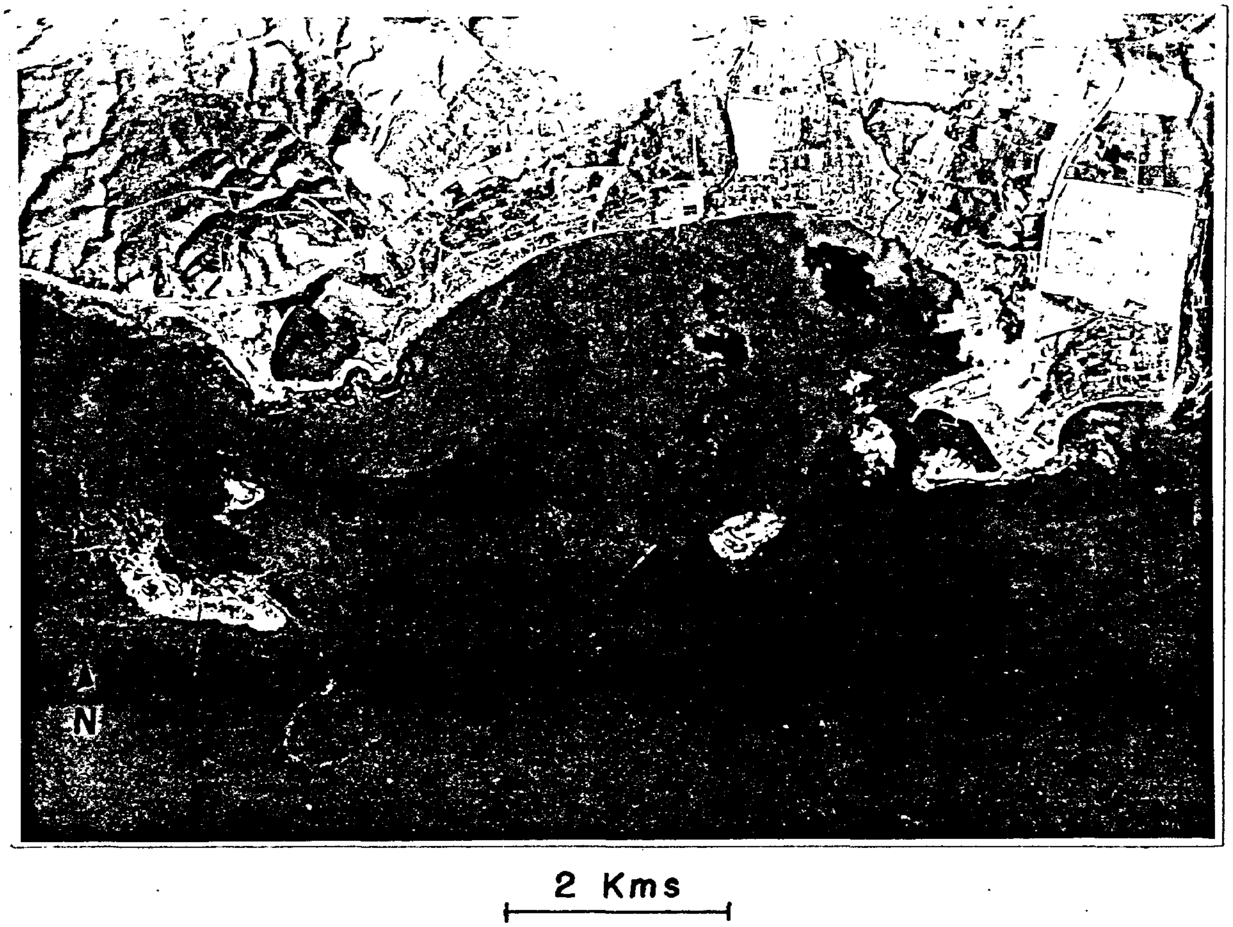


Fig. 44. Cayo off Ponce. Arrecife Ratones can be seen at left.

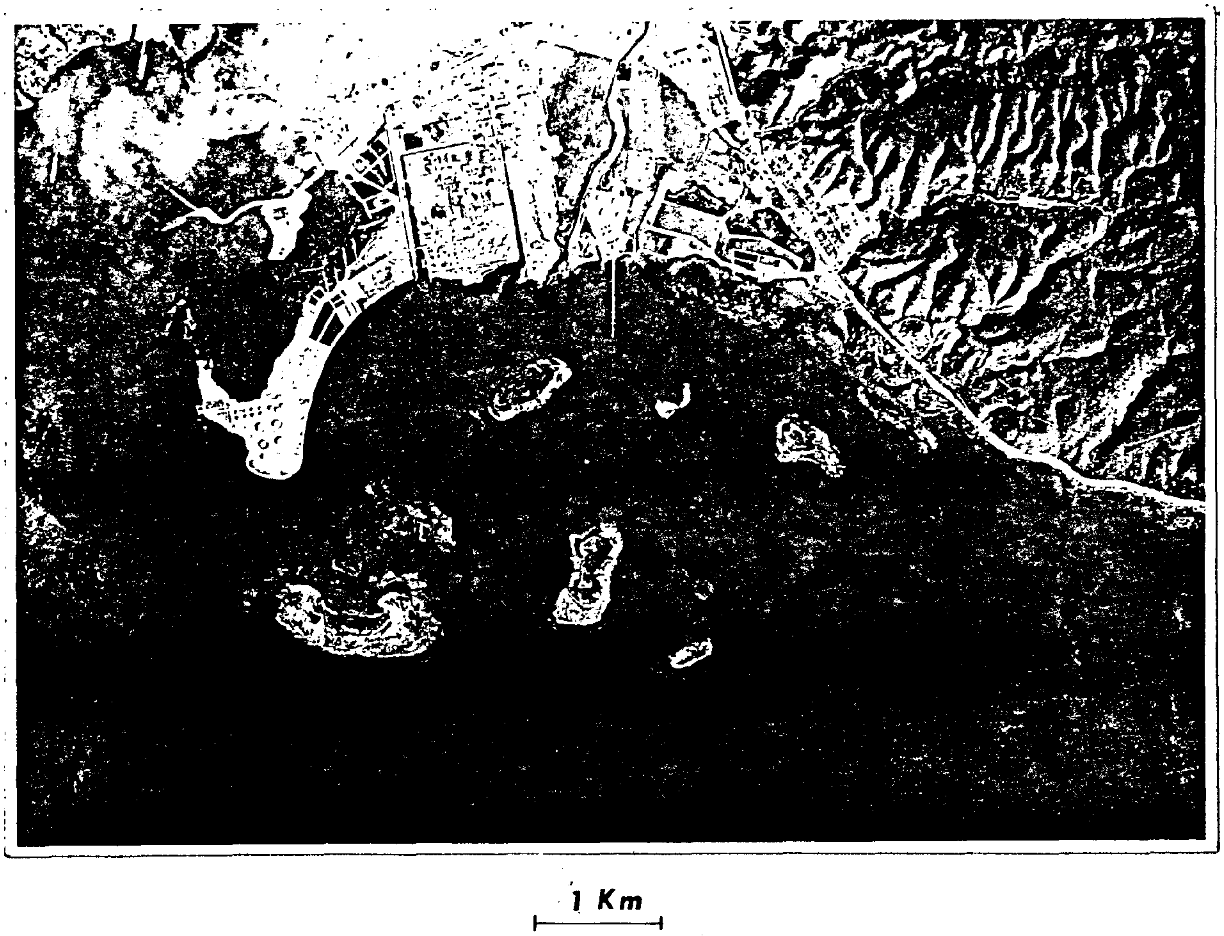


Fig. 45. Stressed reefs off Tallaboa. Note oil refining complex close to reef area.

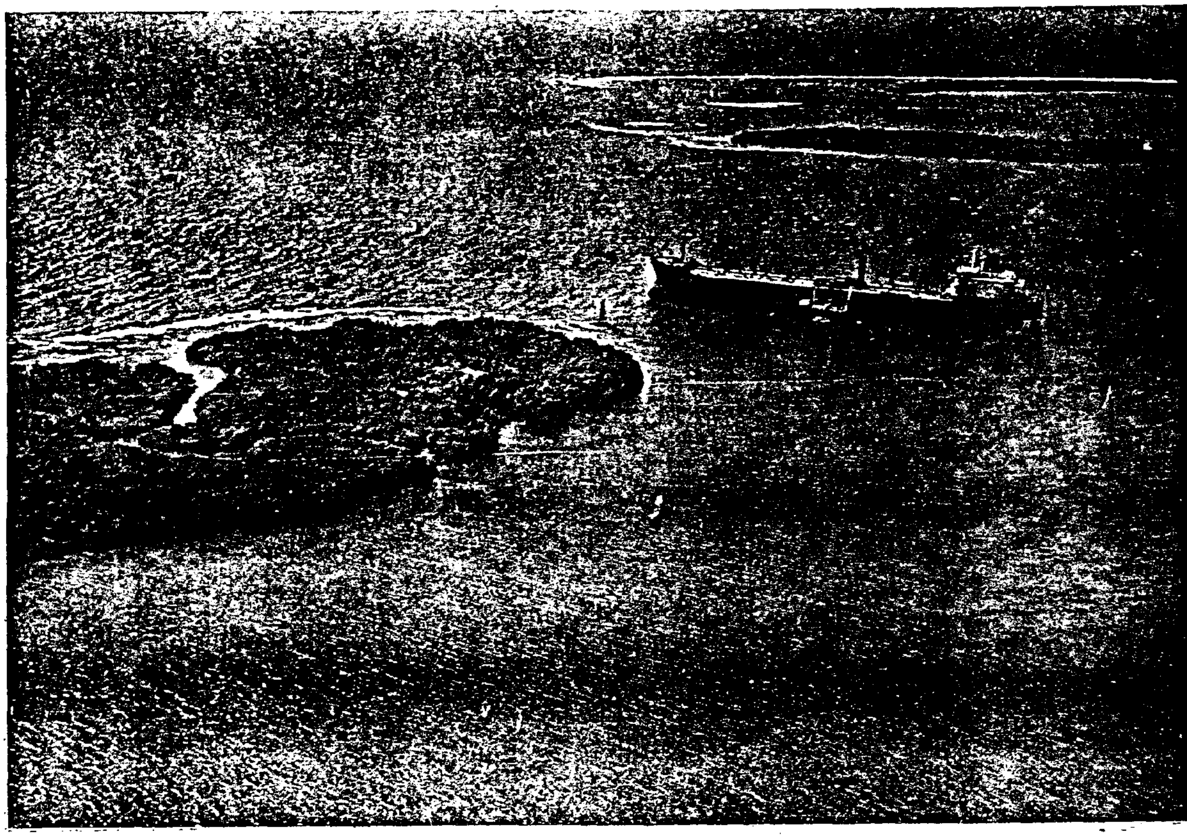


Fig. 45a. Ship stationed between Cayo Río and Cayo Palomas in Tallaboa Bay.

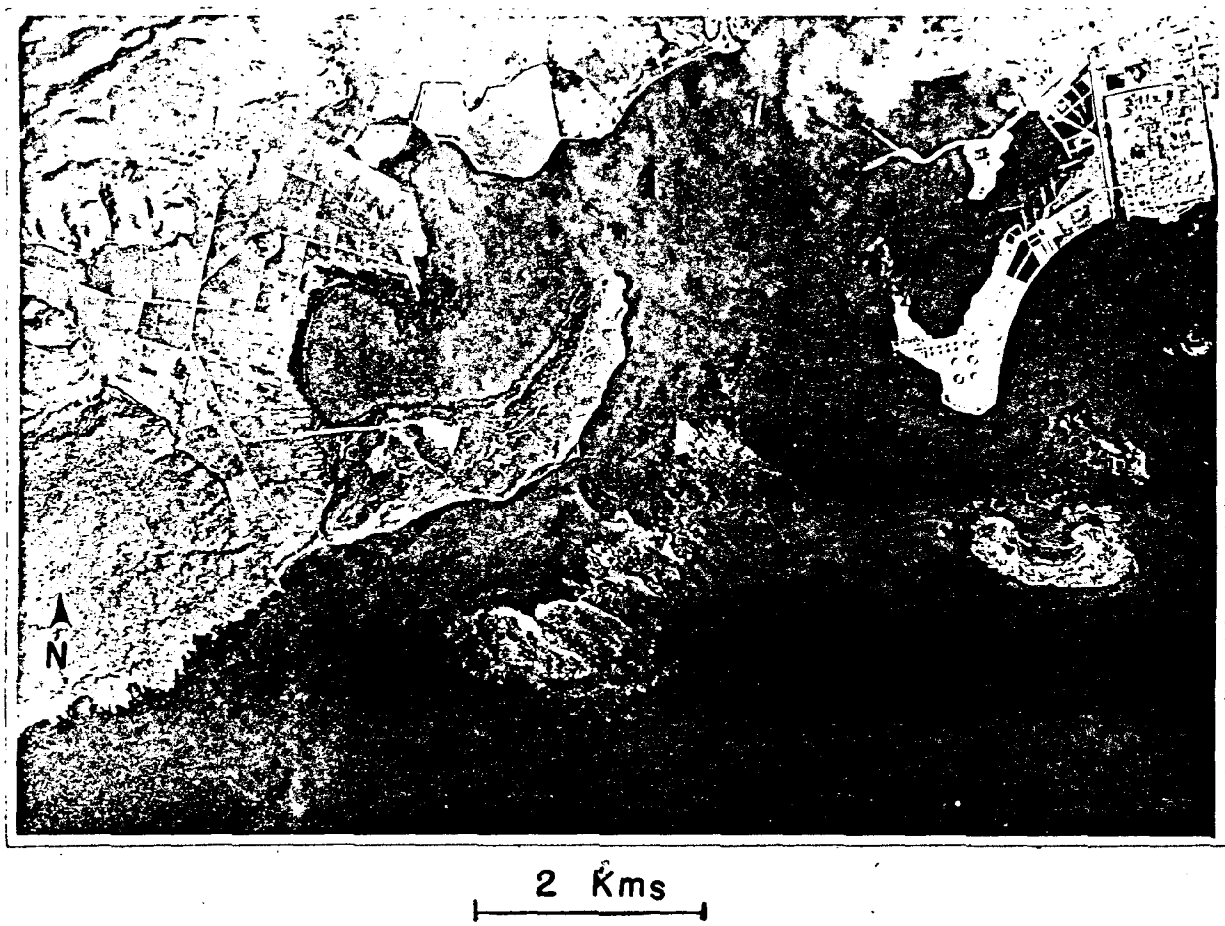


Fig. 46. Reefs off Punta Verraco, Guayanilla.

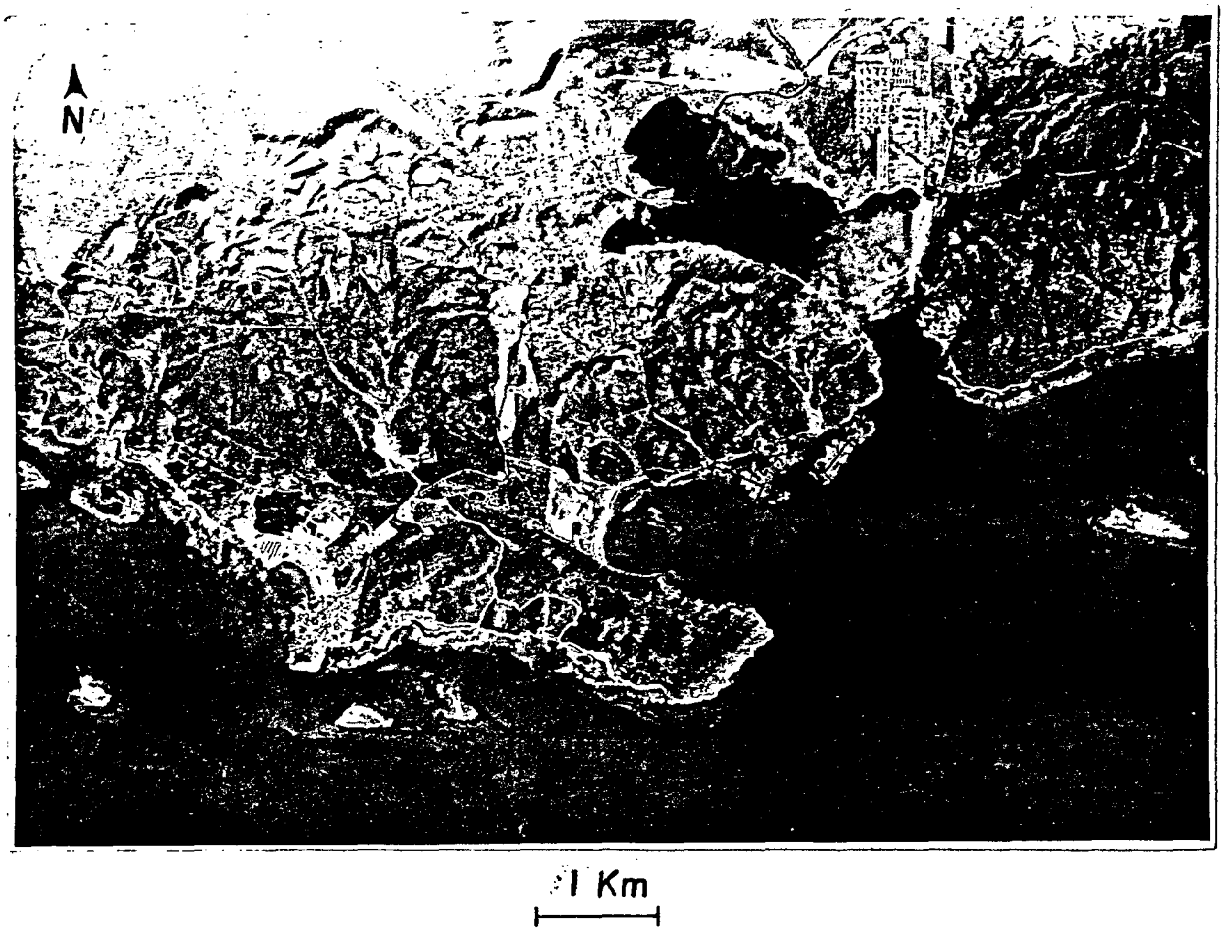


Fig. 47. Fringing and patch reefs off Guánica.

2 Kms

Fig. 48. Reefs protecting Playa Caña Gorda, Guánica.

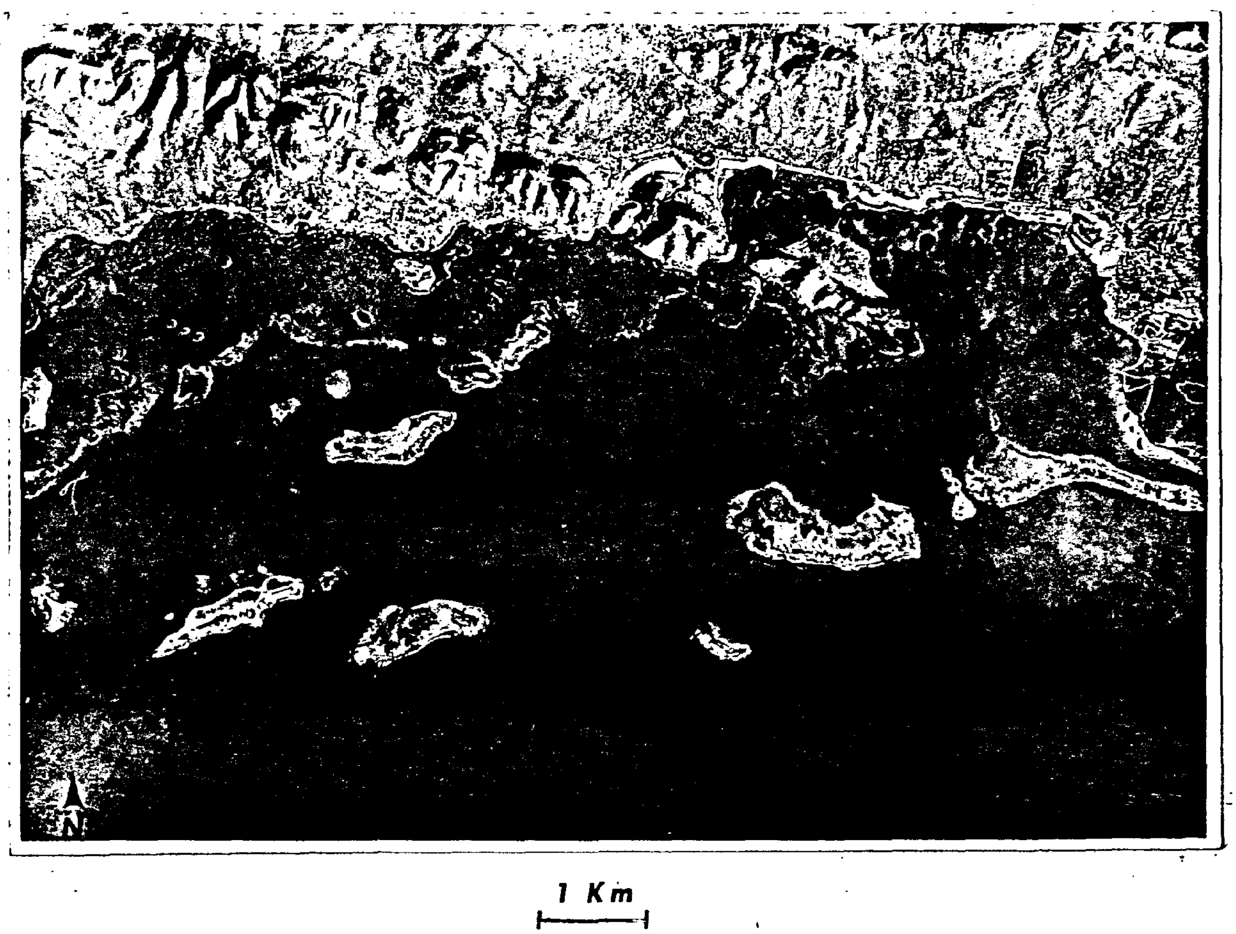


Fig. 49. La Parguera.

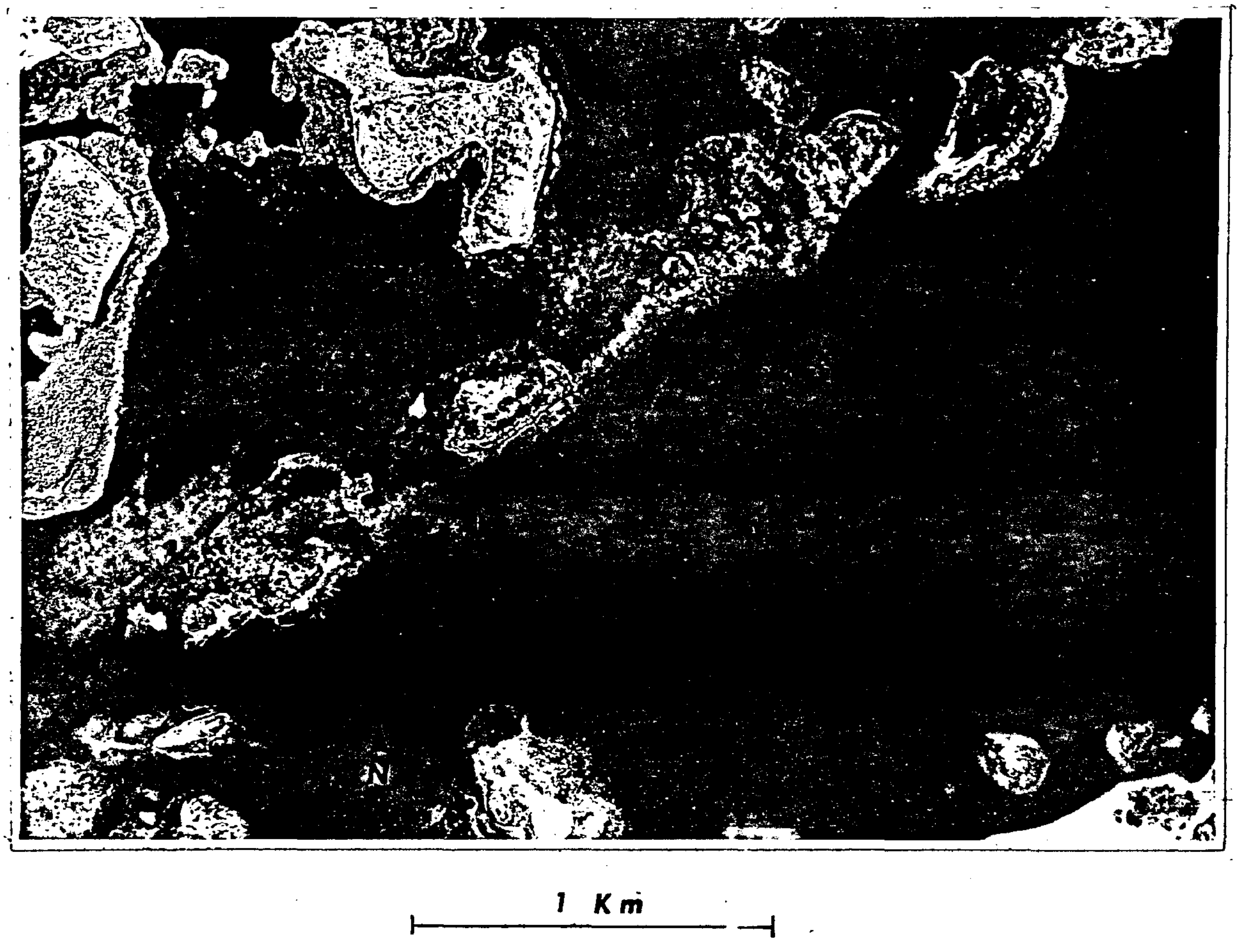


Fig. 50. Patch reefs off Isla Cuevas.

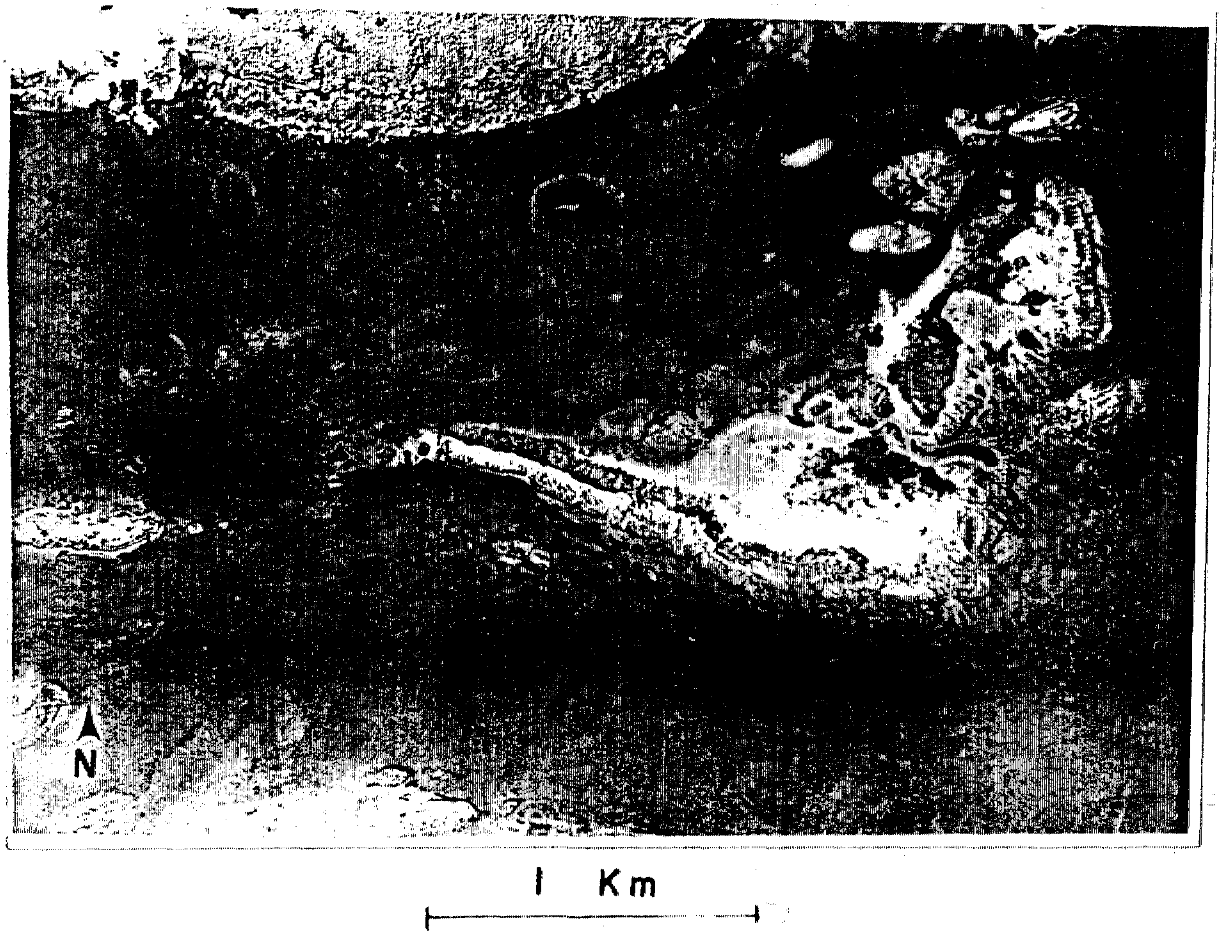


Fig. 51. El Palo - Atravesado reef.

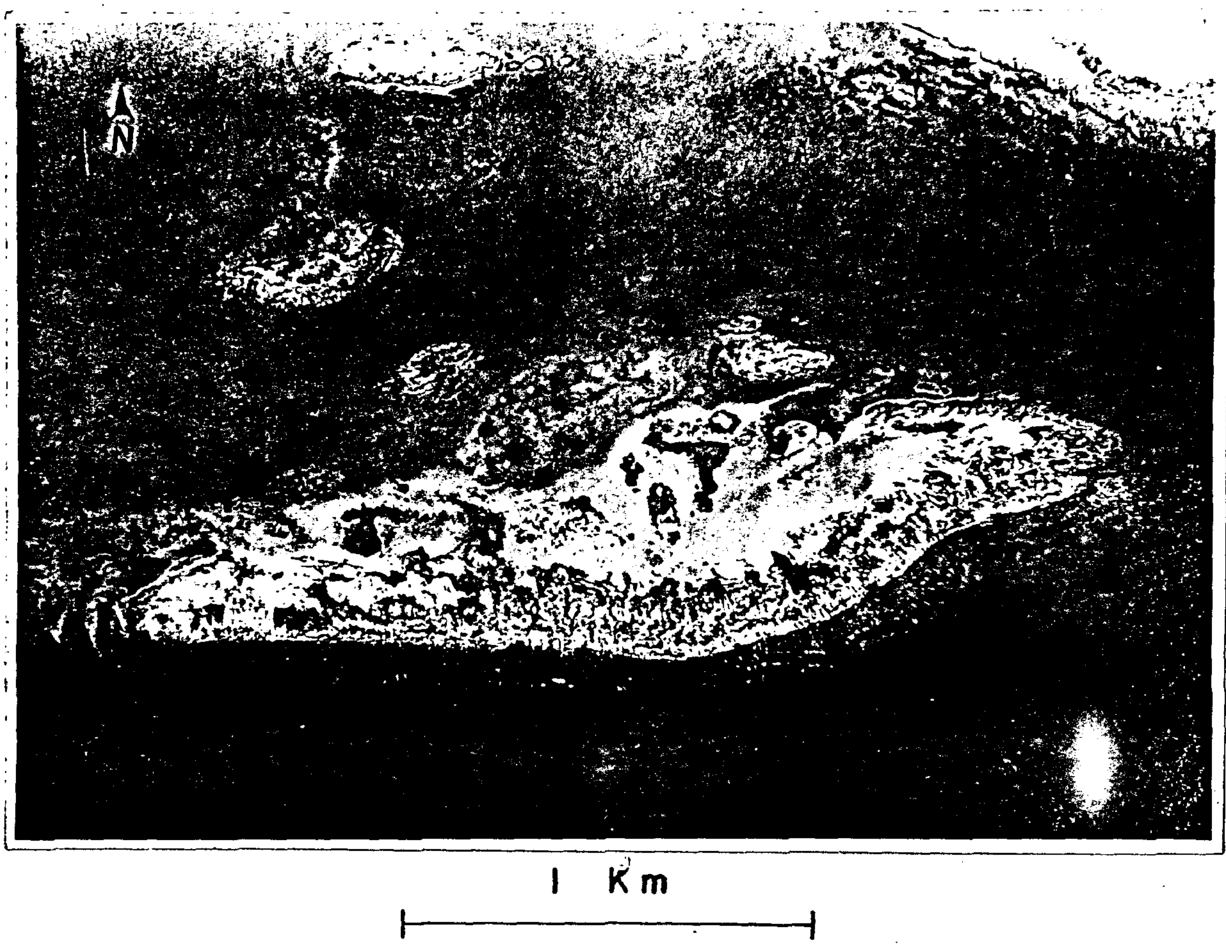


Fig. 52. Margarita reef.

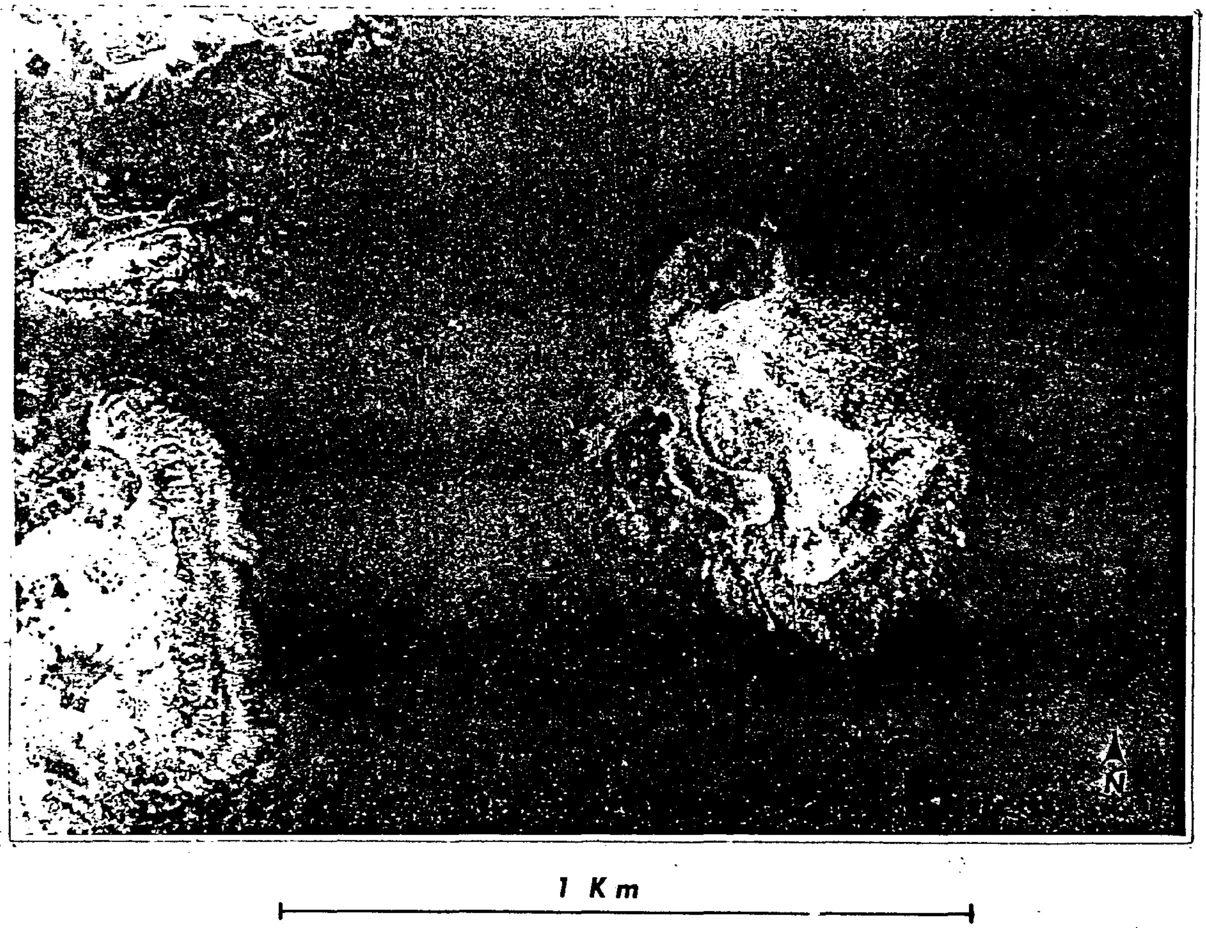


Fig. 53. San Cristobal reef.

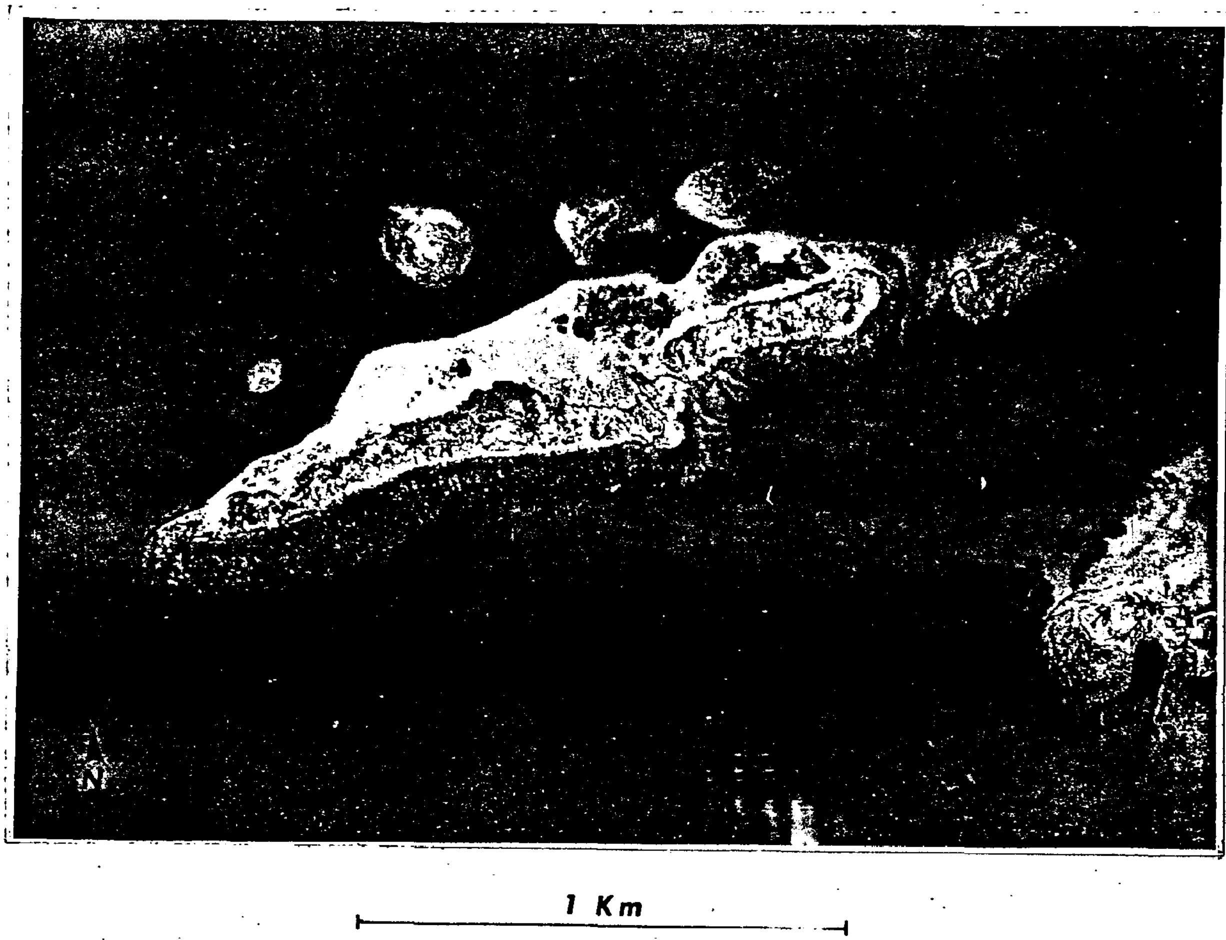


Fig. 54. Laurel reef.

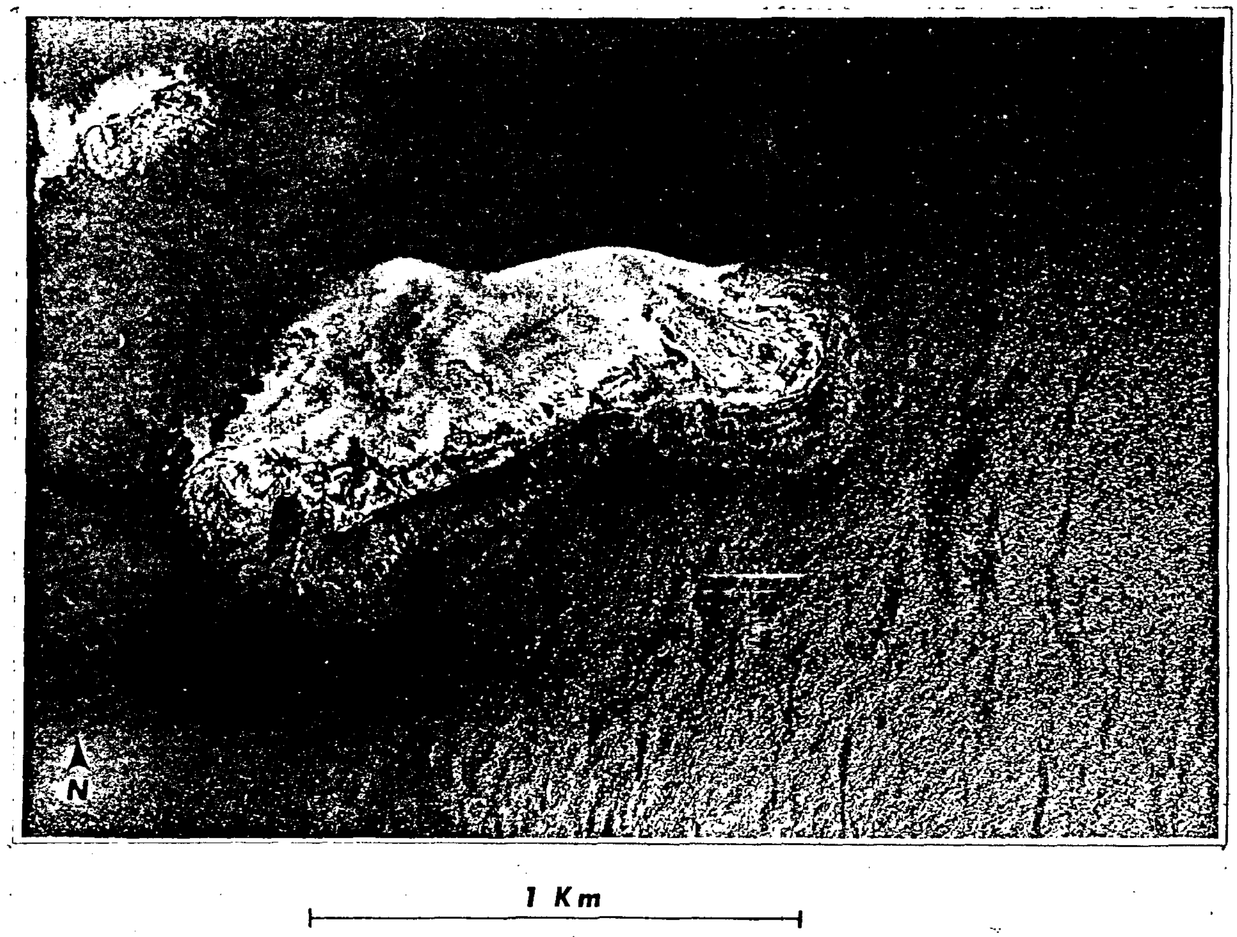
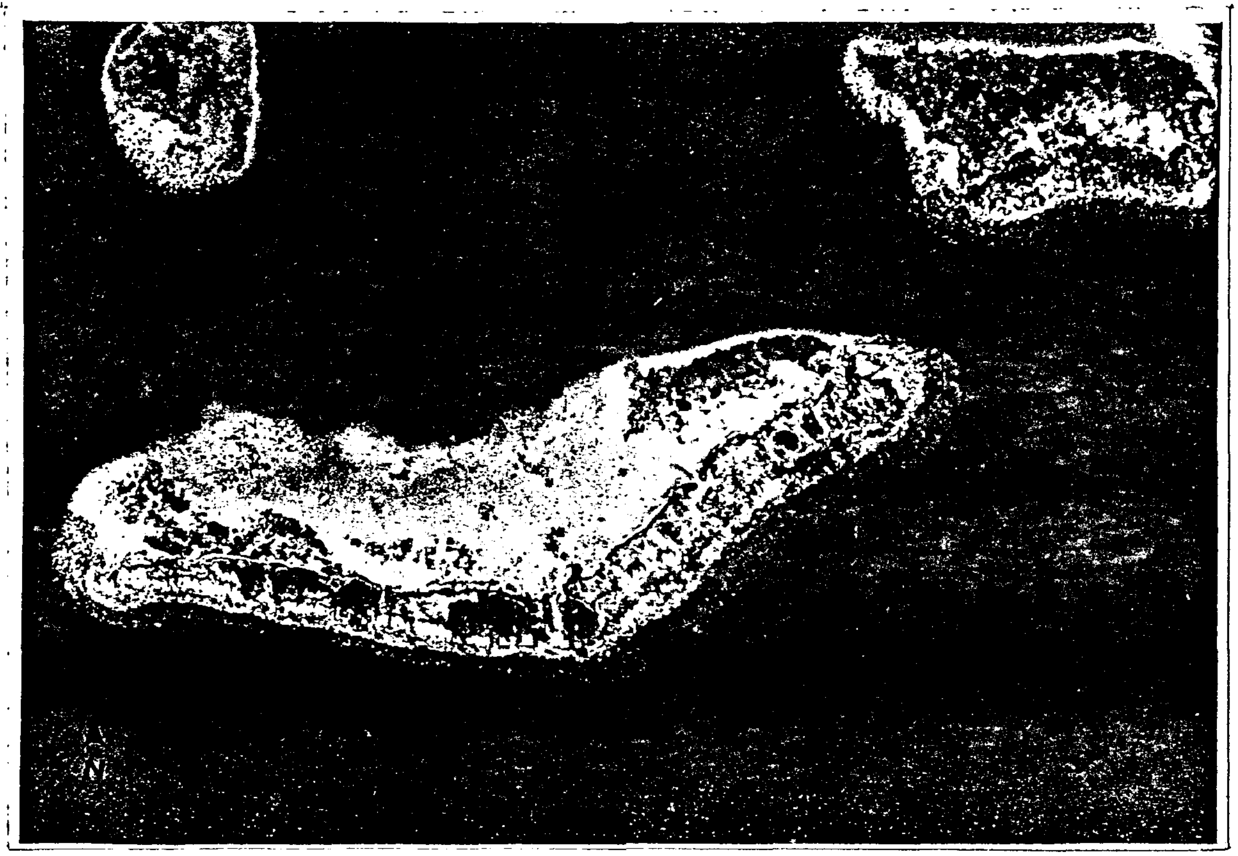


Fig. 55. Media Luna reef.



1 Km

Fig. 56. Enrique reef.

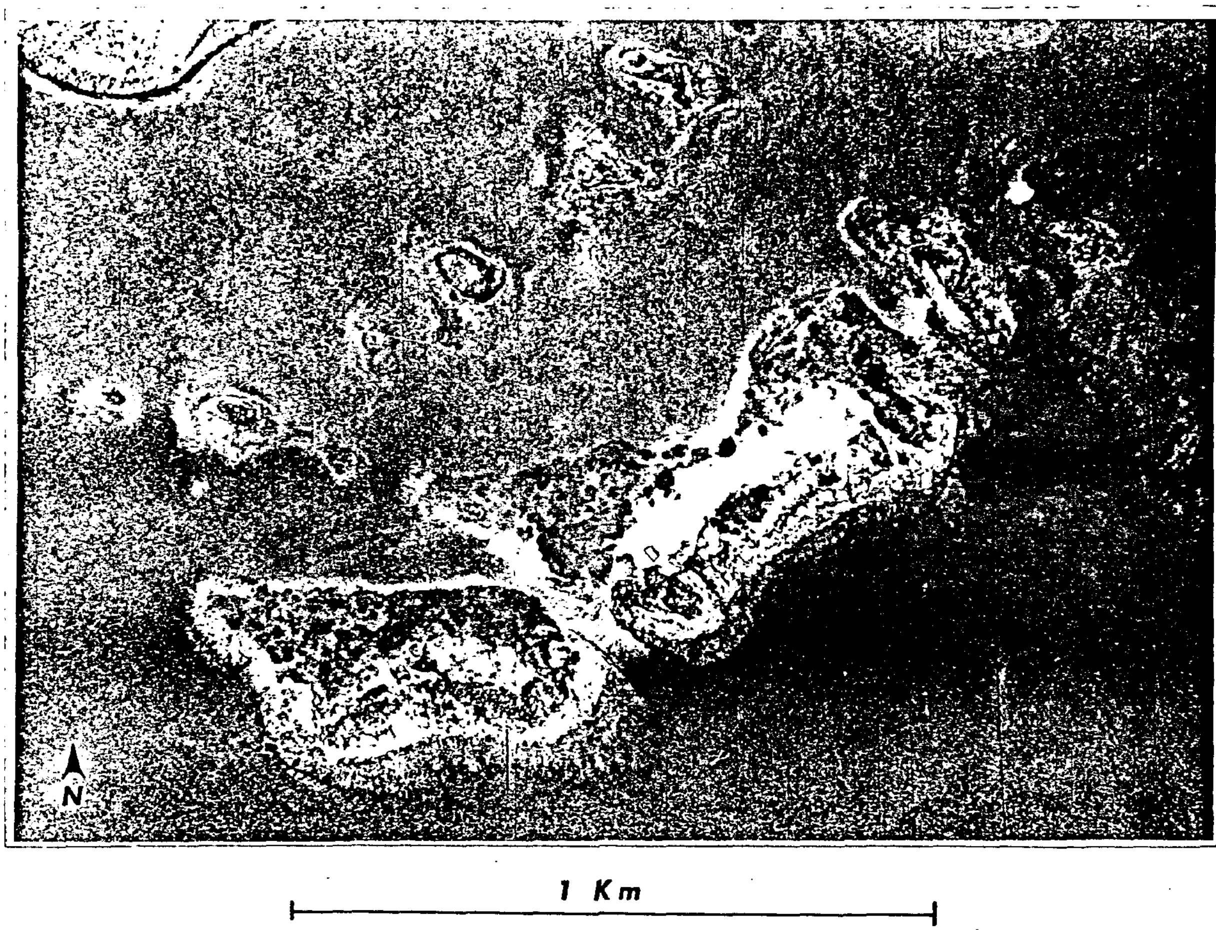
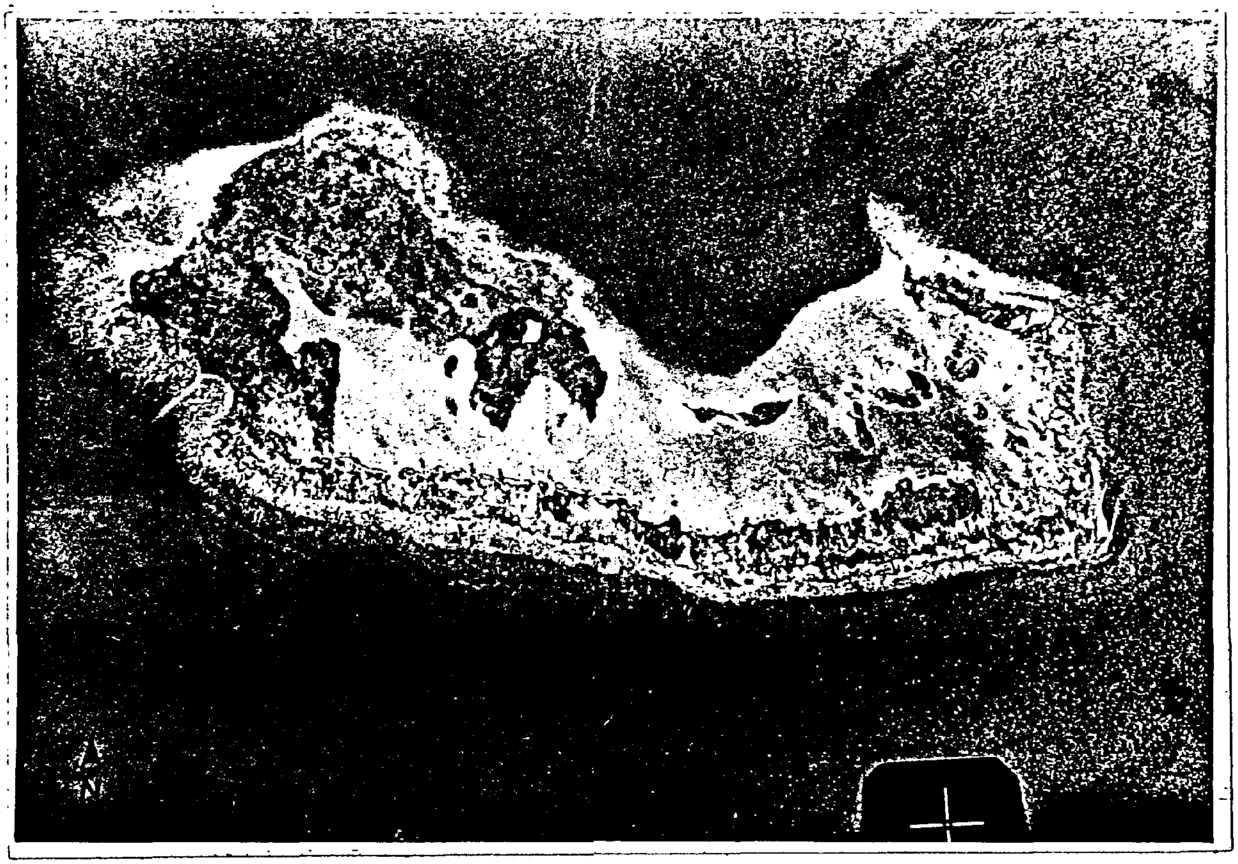


Fig. 57. La Gata - Caracoles reef.



1 Km

Fig. 58. Enmedio reef.

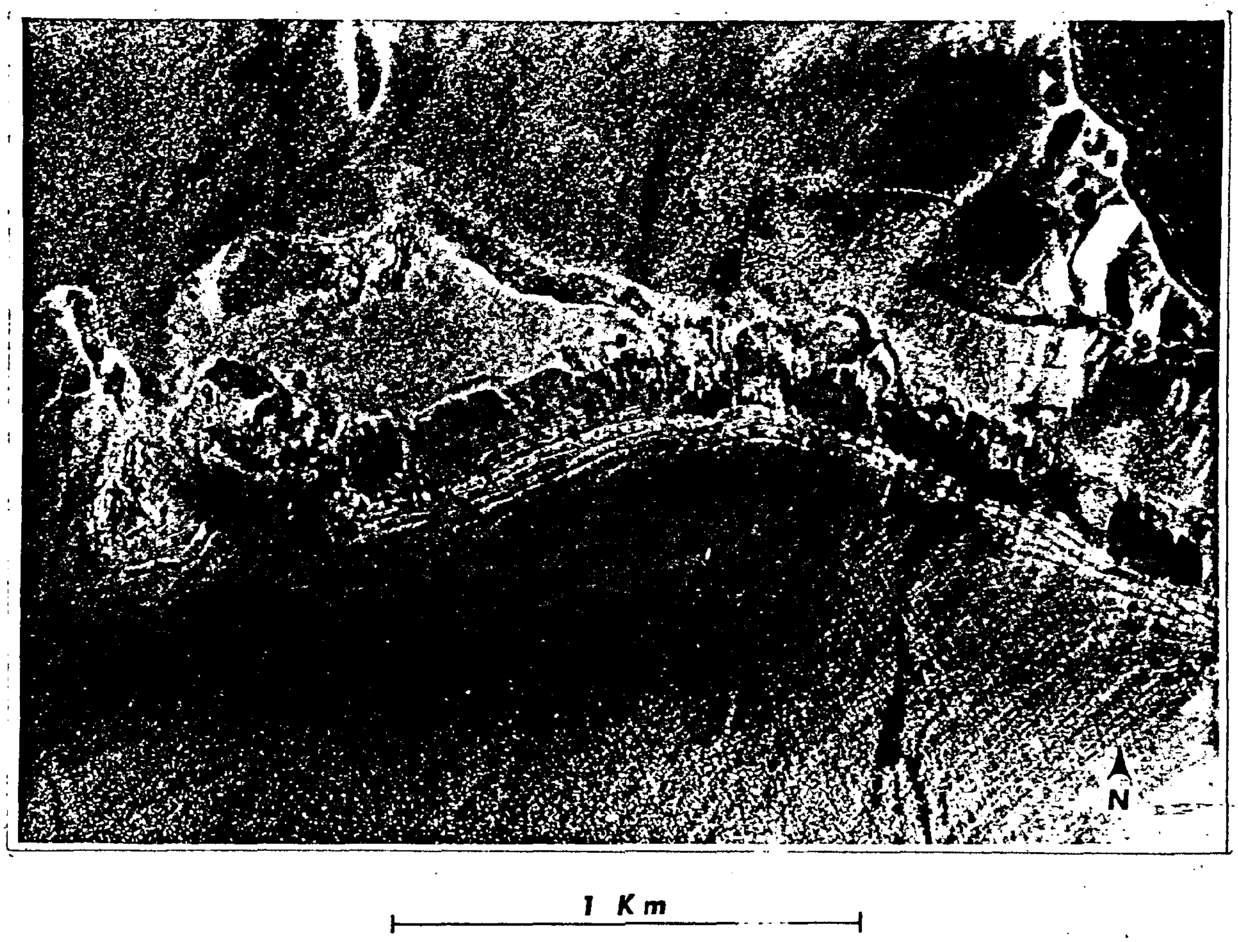


Fig. 59. Mario reef.

Fig. 60. Spur and groove system. Observe high coral cover.

Fig. 61. Idem. Spur and groove system. Note high coral cover, specially Agaricia sp., lining the sides of the grooves.

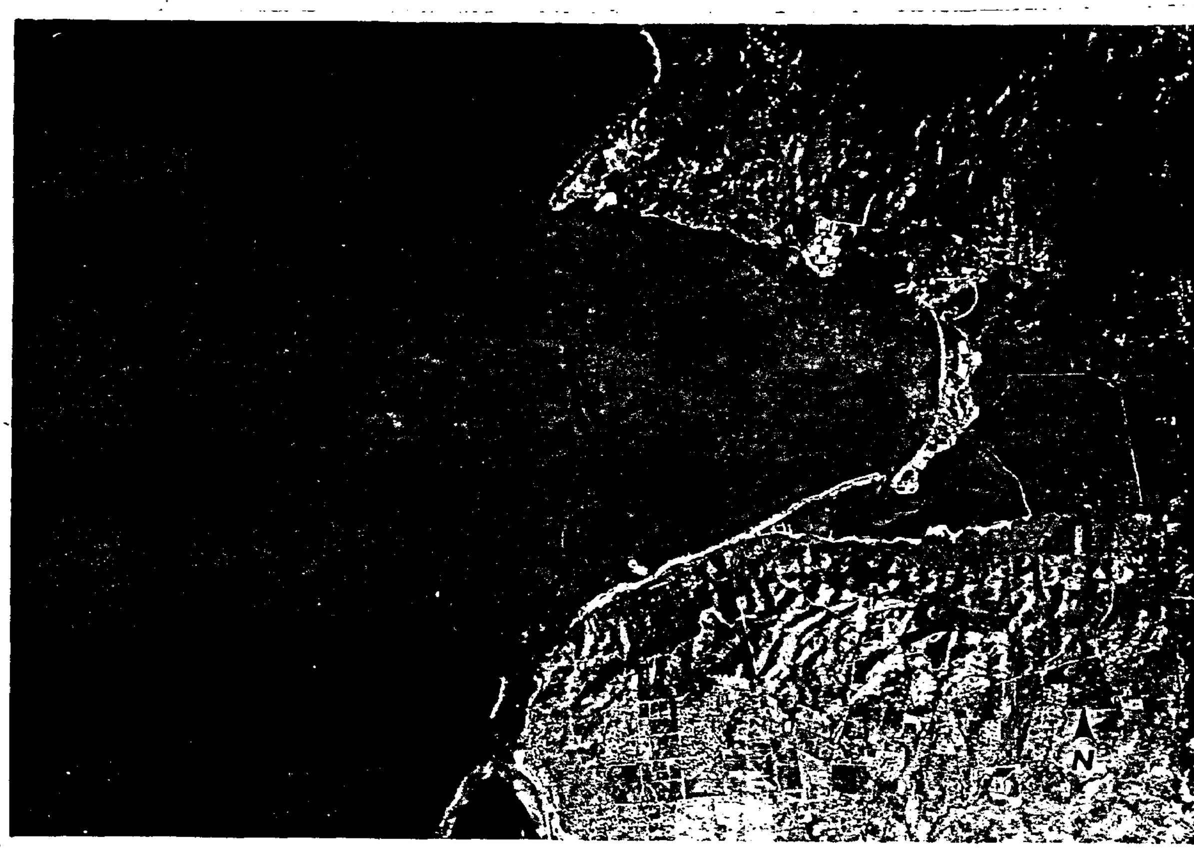
Fig. 62. Idem. Note whip antipatharians (black coral). Spur and groove system. Note whip coral (<u>Stichopathes</u> sp.) in the foreground. Accumulated sand can be seen between spurs.

Fig. 63. Diver working at the shelf edge. Note insular slope.

Fig. 64. Low relief sand channels north of the shelf edge.

Fig. 65. Shelf edge. Note high coral cover. Insular shelf edge. Note high coral cover.

Fig. 66. Fringing reefs of the west coast. Also note Cayo Ratones west of Joyuda Lagoon (upper right).



2 Kms

Fig. 67. Fringing - barrier reef off Boquerón.

Fig. 68. Offshore reefs of the west coast. Square marks off spur and groove system.

Fig. 69. Bajura caves.

Fig. 70. Outer walls of the Bajura caves. Observe dense *Agaricia* growth.

Fig. 71. Large dead *A. palmata* colony inside cave. Its origin remains to be studied.

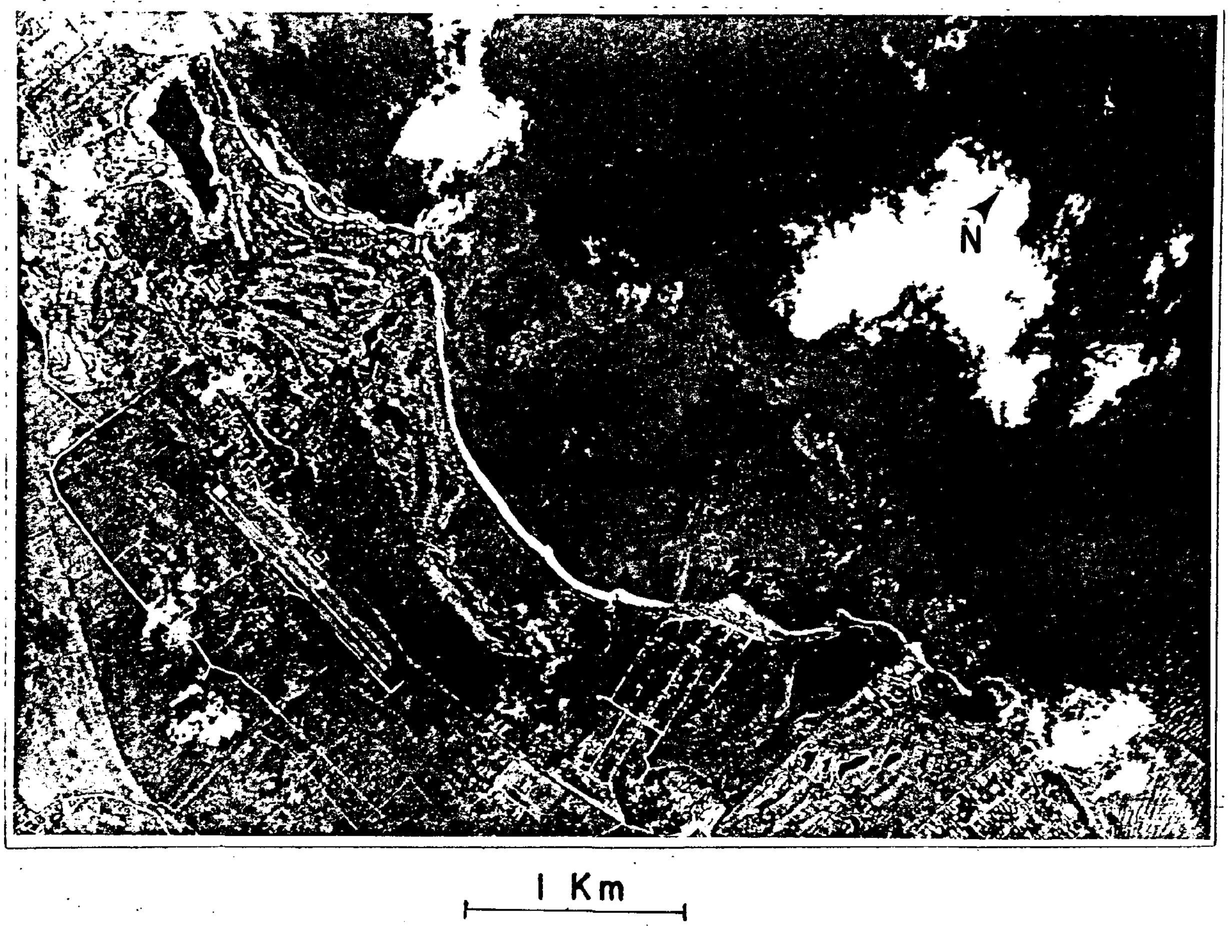


Fig. 72. Reef off Dorado.