ATOLL RESEARCH BULLETIN

No. 270

HERMATYPIC CORAL DIVERSITY AND REEF ZONATION AT CAYOS ARCAS, CAMPECHE, GULF OF MEXICO

BY

TERENCE M. FARRELL, CHRISTOPHER F. D'ELIA, LAWRENCE LUBBERS, III, AND LAWRENCE J. PASTOR, JR.

ISSUED BY

THE SMITHSONIAN INSTITUTION

WASHINGTON, D. C., U.S.A.

SEPTEMBER 1983

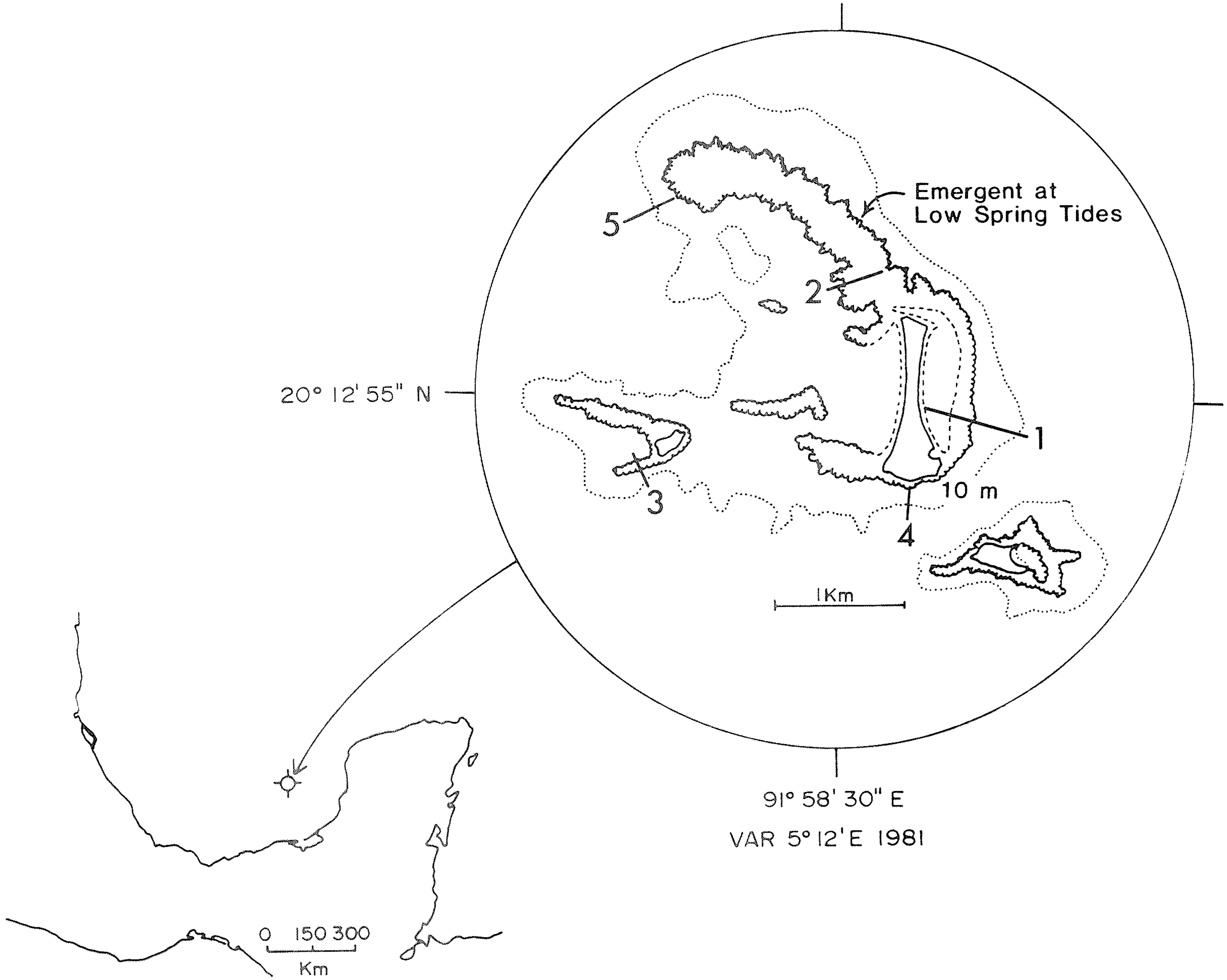

Fig. 1. Location of Cayos Arcas and survey transects.

HERMATYPIC CORAL DIVERSITY AND REEF ZONATION AT CAYOS ARCAS, CAMPECHE, GULF OF MEXICO

by Terence M. Farrell[1,3], Christopher F. D'Elia[1], Lawrence Lubbers, III[1], and Lawrence J. Pastor, Jr.[2,4]

Abstract

Ecological features of emergent coral reefs in the Campeche Bank region of the Gulf of Mexico are not well described. In a study of reef zonation and diversity of Cayos Arcas, the most southerly of these, the coral reefs surrounding three sand cays were found to exhibit a greater diversity of scleractinian coral species than has been reported previously for the Campeche Bank region. Hermatypic coral coverage was high and coral growth appeared vigorous. However, calcareous algae of the genus *Halimeda*, that are known to be abundant and therefore important producers of calcareous material in emergent reef structures to the north, were not evident. Noteworthy aspects of reef zonation included: 1) a non-emergent reef crest composed of unconsolidated coral rubble and encrusting calcareous algae, but no algal ridge, 2) extensive monospecific stands of *Acropora cervicornis* on the shallow reef flats, 3) proliferation of *Acropora palmata* at depths where one might typically find *Acropora cervicornis* in other localities, and 4) poor representation and coverage by species of the genus *Agaricia*. This zonation and the component species' growth forms suggest that high energy wave action is an important environmental factor determining community structure.

Introduction

Relatively few published reports relate to the species composition and ecology of recent bioherms in the Gulf of Mexico. One reason for this is that the Gulf of Mexico does not contain extensive areas of coral reef. Nonetheless, in addition to the reefs off of Veracruz (Smith, 1954) there are six well developed emergent reef structures in the Campeche Bank region off of the western shore of the Yucatán Peninsula (Glynn, 1973; Logan, 1969). The largest and most northerly of these is Alacrán Atoll which has been the site of several geologically oriented studies (Hoskin, 1963; Kornicker et al., 1959; Kornicker and Boyd, 1962; Folk, 1967). The others are less well known, but have been

---

[1]Chesapeake Biological Laboratory, Center for Environmental and Estuarine Studies, University of Maryland, Solomons, Maryland 20688-0038.
[2]Virginia Institute of Marine Science, Gloucester Point, Virginia 23062
[3]Present Address: Zoology Department, Oregon State University 97331
[4]Present Address: Water Chemistry Division, Geomet Technologies, Inc., Environmental Consultants, 520 Broadhallow Road, Melville, New York 11747
Contribution No. 1377. Center for Environmental and Estuarine Studies of the University of Maryland.
Manuscript received Jan. 1983--Eds.

described to some extent (Agassiz, 1888; Logan et al., 1969).

We visited on two occasions the most southerly of the Campeche reef structures, Cayos Arcas. The cays comprising this structure are at the northern boundary of Mexico's offshore petroleum resources, and a deepwater oil terminal has been built in the sheltered waters south of the cays since our last visit (Orme, 1982). In the course of performing an environmental survey focusing on reef development and zonation, we found well-developed reefs with greater diversity of hermatypic corals than has been reported previously for the Campeche Bank region. In the present paper we document and discuss these and other relevant ecological observations.

Study Site

Cayos Arcas consists of three coral and sand cays on a shallow water platform about 3 to 4 sq. km. in area which rises above the Campeche Bank west of the Yucatán Peninsula, Mexico (Fig. 1). Water depth around the cays is about 40 m. The cays envelop a small, protected lagoon that is a popular refuge for local shrimp and shark fisherman located at 91° 58'30"E long. and 20° 12'55"N lat., about 300 km SW of Alacrán Atoll.

Logan et al. (1969) and Ginsburg and James (1974) have characterized Cayos Arcas and neighboring reefs and cays as isolated prominences capped by zoned reefs at the shelf margin. Kornicker and Boyd (1962) have described the geological origin of the Campeche Bank as an "underwater extension of the Yucatán Peninsula... [that is] probably Miocene limestone" with a thin cover of Pleistocene and Recent calcareous sediments. Campeche Bank reefs have apparently been able to keep pace with the Holocene transgression; this implies that reef accretion there occurred at the substantial rate of 20 to 40m during the last 9,000 years (Logan, 1969) or perhaps faster: more recently Mcintyre et al. (1977) proposed that Yucatán reefs have approached the emergent-reef status within the last 2,000 to 3,000 yrs. In any case, it is clear that accretion is rapid on the Yucatán reefs.

Easterly to northeasterly trade winds prevail and probably account for the typical northwest trend of arcuate windward reef margin characterizing Cayo del Centro (Fig. 1). Such reef orientation has been reported for other bioherms on the Campeche Bank (Kornicker and Boyd, 1962; Folk, 1967). From April to September, winds in the area are lighter and more variable (20 to 30 km/hr) than they are from October to March when speeds of 30 to 35 km/hr are common and are often associated with cold fronts or "northers" (Folk, 1967). Hurricanes are not uncommon to the area, Hurricane Allen having passed several hundred km to the north of Cayos Arcas several months before we performed our survey. The tidal range is small (~1.0 m). We do not have mean minimum water temperature for Cayos Arcas; however, we suspect it is between 20° and 22° C, close to those reported for nearby Veracruz and Progresso, Mexico (Milliman, 1973) and by the U. S. Fish and Wildlife Service (1954). Thus reefs at Cayos Arcas probably experience mean minimum temperatures near 21°C, below which optimal reef development does not occur (Milliman, 1973). Glynn (1973) reports that the thermal climate of the reefs on the margin of the Campeche Bank is probably more favorable than it is closer to shore, citing the suggestion of Logan et al. (1969) that the absence of coral reefs on the eastern sector of the shelf is due to the periodic upwelling of cold water there.

Materials and Methods

Surveys of the coral community were carried out by skin and SCUBA diving. We used a transect method keyed to changes in depth and distance offshore and selected a major topographical feature, i.e., beach, reef crest, deep trench as a benchmark for the starting point for a compass bearing traversing various zones of the benthic community. We chose the transects as being generally representative of reef zonation at Cayos Arcas.

A check list of the most abundant sessile invertebrates (primarily hermatypic corals) was developed after an intensive survey of the first transect. At this site a 30 m long chain marked at one meter intervals was laid on the bottom starting at the reef crest and moving towards deep water. We noted species composition and dominance within ten meters of this chain and estimated the total percent living coverage, depth in meters and any significant changes in topography or coral composition with distance from the starting point. Aerial photographs of the transects taken from a helicopter at an altitude of about 200 m were used to confirm our estimates of percent coverage and the representativeness of the transects chosen.

Results

Table 1 gives a summary list including all coral species identified in all five transects during our study. The list contains 20 species we identified and 5 species we suspect were present and is certainly indicative of the most common corals in the shallower (<20 m) zones of the reef. Had the study lasted longer and extended to deeper areas, more species would undoubtedly have been found (see Discussion). In fact, it would be surprising if species reported by Smith (1954) to be present off Veracruz are not also present at Cayos Arcas (Table 1). Observations along transects were completed at 5 locations (Figure 1). These data have been summarized in graphic form (Figure 2).

The most developed reef at Cayos Arcas, in terms of physical structure and coral coverage, occurs as a three kilometer long, arcuate structure to the northwest of the central cay (Figure 1). This reef can be seen in the upper right portion of Plate 1, an aerial photograph viewing Cayos Arcas from the southeast. We investigated reef flat and lagoonal areas of this reef in Transect 2. Transect 1 encompassed the reef crest and fore reef of a nearby section of reef that was similar in physical and biological structure to the fore reef area along arcuate reef face (Plate 2). Taken together Transect 2 and the fore reef section of Transect 1 provide a good picture of the main biological and structural zones occurring on the major Cayos Arcas reef.

The most obvious feature of the reef was an extensive reef flat, over 100 meters wide, almost completely covered by a dense, monospecific stand of *Acropora cervicornis*. To the lee of this stand the bottom gradually sloped from less than one meter to three meters. On this slope a more diverse assemblage of hermatypic corals existed (predominantly members of the genera *Acropora*, *Montastrea*, and *Diploria*), in which substratum coverage ranged from 20-60% and decreased with distance from the reef flat. This back reef area gave way to sandy substrata in the lagoon that harbored numerous patch reefs not crossed by the transect.

To the windward side of the reef flat a small, non-emergent reef crest existed. The crest was composed of unconsolidated coral rubble encrusted with calcareous red algae. No true algal ridge was present. On the forereef the zoanthids *Palythoa caribbea* and *Zoanthus sociatus* were the dominant epibenthic fauna between one and three meters. Below this zoanthid zone, at depths between three and seven meters, *Acropora palmata* was the dominant scleractinian, covering nearly 75% of the substratum (Plate 3). Massive corals, dominantly the genera *Montastrea* and *Diploria* and gorgonians were abundant below seven meters (Plates 4 and 5) in a diverse community extending to approximately 350 meters from the crest, and to a depth of 18 meters where sand substratum was again encountered.

To the lee of the reef crest in Transect 1 the reef flat was absent and the back reef area consisted of a shallow (one meter) expanse of sandy substratum in front of the largest cay, in which scleractinians were scarce.

Transect 3 crossed a nearby, small, protected reef. Its zonation pattern was very similar to the previously discussed larger, exposed reef but it lacked a reef crest and its zonation was both horizontally and vertically compressed.

The remaining two transects were completed at each end of the largest reef. Transect 4, located at the more protected southern end, displayed zonation that was similar to the exposed forereef, except that it was horizontally compressed so that the *Montastrea* - *Diploria* community occurred in water several meters shallower than it did on the windward face of the reef. Transect 5, located at the northwestern end of the reef, traversed an eight meter deep channel that curved around the edge of the reef flat. In this channel the bottom was composed of unconsolidated coral rubble and sediment. The face on the far side of the channel rose to within three meters of the surface. Benthic cover on top of this rise was dominated by the zoanthid *Palythoa caribbea*. Species distributions on this crest and the slope beyond it were similar to those seen on the exposed reef face. However, the slope was more gradual and coral coverage was more extensive. Substratum coverage was 70 to 90% beyond 500 m at a depth of 20 m. Here was one of the few places we observed extensive growth of *Acropora cervicornis* below three m depth: a 30 m wide stand occurred at 8 m depth.

Four transects were located on the large arcuate reef. From these transects and less detailed observations made from a helicopter, the distribution of major reef zones on the reef have been mapped (Figure 3).

Discussion

The hermatypic scleractinian coral diversity of Cayos Arcas consists of at least 20 species from 13 genera. This diversity is greater than is believed to exist off Veracruz or has been reported for Alacrán Reef: for the former there are records of 14 to 16 species and for the latter there are records of 18 species (Glynn, 1973). Given the geographical isolation of this site, this diversity seems surprisingly high, but is not, of course, as high as has been recorded in Jamaica (Wells, 1973), in Curacao (Bak, 1974; cited in Loya, 1976), in Cuba (Zlantarzsky, cited in Loya, 1976), in Belize (Cairns, 1982), and on the Atlantic coast of Panama (Porter, 1972). Relatively little is known about reefs in the southern Gulf of Mexico, but we believe that nearshore turbid water conditions and a lack of suitable substratum affect growth; it is also likely that minimum winter temperatures are close to the lower limits at which extensive reef growth may occur, especially near the coast where occasional upwelling is believed to occur (cf. Logan et al., 1969). It is possible that seasonal temperature lows exclude species unable to tolerate them; however, the presence of species of the genus *Acropora*, which are unable to tolerate the colder temperatues encountered in Bermuda, indicates that minimum temperatures are considerably higher than in Bermuda.

Our field work was most extensive in shallow water; additional study in deeper waters could most probably increase the number of species found. Loya (1976) has discussed the increase in known species richness which occurred with increasing study in other areas.

Logan (1969), who made the only published ecological observations on Cayos Arcas that we encountered, made generally similar observations to ours about community structure. However, Logan (1969) did not report seeing the presence of a very dense monospecific stand of *Acropora cervicornis* on the shallow reef flat as we note here. Similar zonation is also found off Belize (Cairns, 1982) and off the east coast of the Yucatán peninsula (W. Adey, J. W. Porter, pers. comm.). There is no doubt that Logan (1969) would have recognized and commented on that impressive stand of *Acropora* had it been present during his study. We cannot explain this difference, but suspect that a real change in community structure occurred in the interim.

Neither we nor Logan (1969) observed calcareous green algae of the genus *Halimeda*. This observation was unexpected as *Halimeda* is extremely common on the nearby Alacrán reef (Hoskin, 1963; Kornicker and Boyd, 1962). We searched for this coralline algae but did not encounter living *Halimeda* nor obvious skeletal remains. However, we were unable to examine sediments microscopically to verify our field observations. *Halimeda* is the dominant producer of carbonate sediments on a reef off

Belize (Wallace et al., 1977) and presumably Alacrán (Hoskin, 1963). Its absence at Cayos Arcas may result in lowered rates of calcium carbonate deposition.

High wave energy levels may account for some of the species distributions observed on these reefs (Logan, 1969). The depth to which the forereef *Palythoa* and *Acropora palmata* dominated zones extended, and the lack of *Acropora cervicornis* and members of the genus *Agaricia* on the forereef is probably a result of intense wave action during storms. In backreef areas, where lower wave intensities predominate, the zonation was compressed so that the coral-head communities existed closer to the water surface.

Our observations indicate that well developed reef communities exist at Cayos Arcas. These communities contain the most diverse hermatypic coral assemblage found to date on the western Yucatán shelf. Further investigation will be necessary to determine if this apparent difference in diversity is real or due to the limited study most other locations in this region have received. However, we suspect that coral diversity throughout the area is richer than it is generally perceived to be. A continuing environmental monitoring program was instituted before the construction of the oil terminal, and further studies to assess the ecological impact of the facility have been discussed by Orme (1982).

References

Agassiz, A. 1888. Three cruises of the U. S. Coast and Geodetic Steamer "Blake": *Harv. Mus. Comp. Zool.*, 14:70-73.

Cairns, S. D. 1982. Stony corals of Carrie Bow Cay, Belize, pp. 271-302. In: Rutzler, K., and I. G. Macintyre, eds., *The Atlantic Barrier Reef Ecosystem at Carrie Bow Cay, Belize, I. Structure and communities*. Smithsonian Institution Press. Washington, D.C.

Folk, R. L. 1967. Sand cays of Alacrán Reef, Yucatán, Mexico: Morphology. *J. Geol.* 75:412-437.

Ginsburg, R. N., and James, N. P. 1974. Spectrum of Holocene reef-building communities in the Western Atlantic. Section 7 of *"Principles of Benthic Community Analysis,"* Zeigler, A. M., K. R. Walker, E. J. Anderson, E. G. Kaufman, R. N. Ginsburg, and N. P. James, contributors. Div. of Mar. Geol. Geophys. RSMAS. University of Miami, Fla.

Glynn, P. W. 1973. Aspects of the ecology of coral reefs in the Western Atlantic region, pp. 271-324. In: Jones, O. A., and R. Endean, eds., *Biology and Geology of Coral Reefs, Vol. II.*, Academic, N.Y.

Hoskin, G. M. 1963. Recent carbonate sedimentation on Alacrán Reef, Yucatán, Mexico, *NAS-NRC. Publ.* 1089:1-160.

Kornicker, L. S., and Boyd, D. W. 1962. Shallow water geology and environments of Alacrán reef complex, Campeche Bank, Mexico. *Am. Assoc. Petrol. Geol. Bull.* 46:640-673.

Kornicker, L. S., Bonet, F., Cann, R., and Hoskin, C. M. 1959. Alacrán Reef, Campeche Bank, Mexico. *Univ. Texas Publ. Inst. Mar. Sci.* 6:1-22.

Logan, B. W. 1969. Coral reefs and banks: Yucatán shelf, Mexico. *Mem., Am. Assoc. Petrol. Geol.* 11:129-198.

Logan, B. W., Harding, J. L., Ahr, W. M., Williams, J. D., and Snead, R. G. 1969. Carbonate sediments on reefs, Yucatán shelf, Mexico, Part I, Late Quaternary sediments. *Mem., Am. Assoc. Petrol. Geol.* 11:1-128.

Loya, Y. 1976. Effects of turbidity and sedimentation on the community structure of Puerto Rican corals. *Bull. Mar. Sci.* 26:450-466.

Macintyre, I. G., Burke, R. B., and Stuckenrath, R. 1977. Thickest recorded Holocene reef section, Isla Perez core hole, Alacrán Reef, Mexico, *Geology.* 5:749-754.

Milliman, J. D. 1973. Caribbean coral reefs, pp. 1-50. In: Jones, O. A., and R. Endean, eds., *Biology and Geology of Coral Reefs, Vol.* I. Academic, N.Y.

Orme, W. A., Jr. Cayo Arcas: New Oil Port 70 Miles Offshore. *R & D Mexico.* Vol. 2, No. 11:22-25.

Porter, J. W. 1972. Patterns of species diversity in Caribbean reef corals. *Ecology* 53:745-748.

Smith, F. G. W. 1954. Gulf of Mexico Madreporaria. *U. S. Dept. Fish and Wildlife Serv. Fish. Bull.* 89:291-295.

U. S. Fish and Wildlife Service. 1954. Gulf of Mexico: its origin, waters, and marine life. *Fishery Bulletin of the Fish and Wildlife Service, Vol.* 55.

Wallace, R. J., and Shafersman, S. D. 1977. Patch Reef Ecology and Sedimentology of Glovers Reef Atoll, Belize.--In *Reef and Related Carbonates--Ecology and Sedimentology,* Edited by S. H. Frost, M. P. Weiss and J. B. Saunders. Published by the American Assoc. of Petroleum Geologists. Tulsa, Oklahoma. pp. 37-52.

Wells, J. W. 1973. New and old scleractinian corals from Jamaica. *Bull. Mar. Sci.* 23:16-58.

Table 1. Hermatypic scleractinian coral species occurring at Cayos Arcas. "?" indicates probable identification. "*" indicates species reported found at Cayos Arcas by Logan et al. (1969) that we did not encounter. Species in parentheses were reported present at Veracruz by Smith (1954) are probably also present, but we did not observe them at Cayos Arcas in our survey.

Suborder Astrocoeniida
- Family Pocilloporidae
  - *Madracis decactis*
- Family Acroporidae
  - *Acropora palmata*
  - *Acropora cervicornis*

Suborder Fungiida
- Family Agariciidae
  - *Agaricia agaricites*
- Family Siderastreidae
  - *Siderastrea siderea*
  - *Siderastrea radians*
- Family Poritidae
  - *Porites asteroides*
  - *Porites porites*
  - (*Porites furcata*)

Suborder Faviida
- Family Faviidae
  - *Favia fragum*
  - *Diploria clivosa*
  - *Diploria labyrinthiformis*
  - *Diploria strigosa*
  - *Colpophyllia natans*
  - *Colpophyllia breviserialis*
  - *Montastrea annularis*
  - *Montastrea cavernosa*
  - *Solenastrea* sp.*
  - *Manicina areolata*
  - (*Cladocora arbuscula*)
- Family Meandrinidae
  - *Meandrina meandrites*
  - *Dichocoenia strokesi* ?
- Family Mussidae
  - *Mussa angulosa*
  - *Mycetophyllia lamarckiana*
- Family Oculinida
  - (*Oculina diffusa*)

Suborder Caryophylliina
- Family Caryophylliidea
  - *Eusmilia fastigiata*

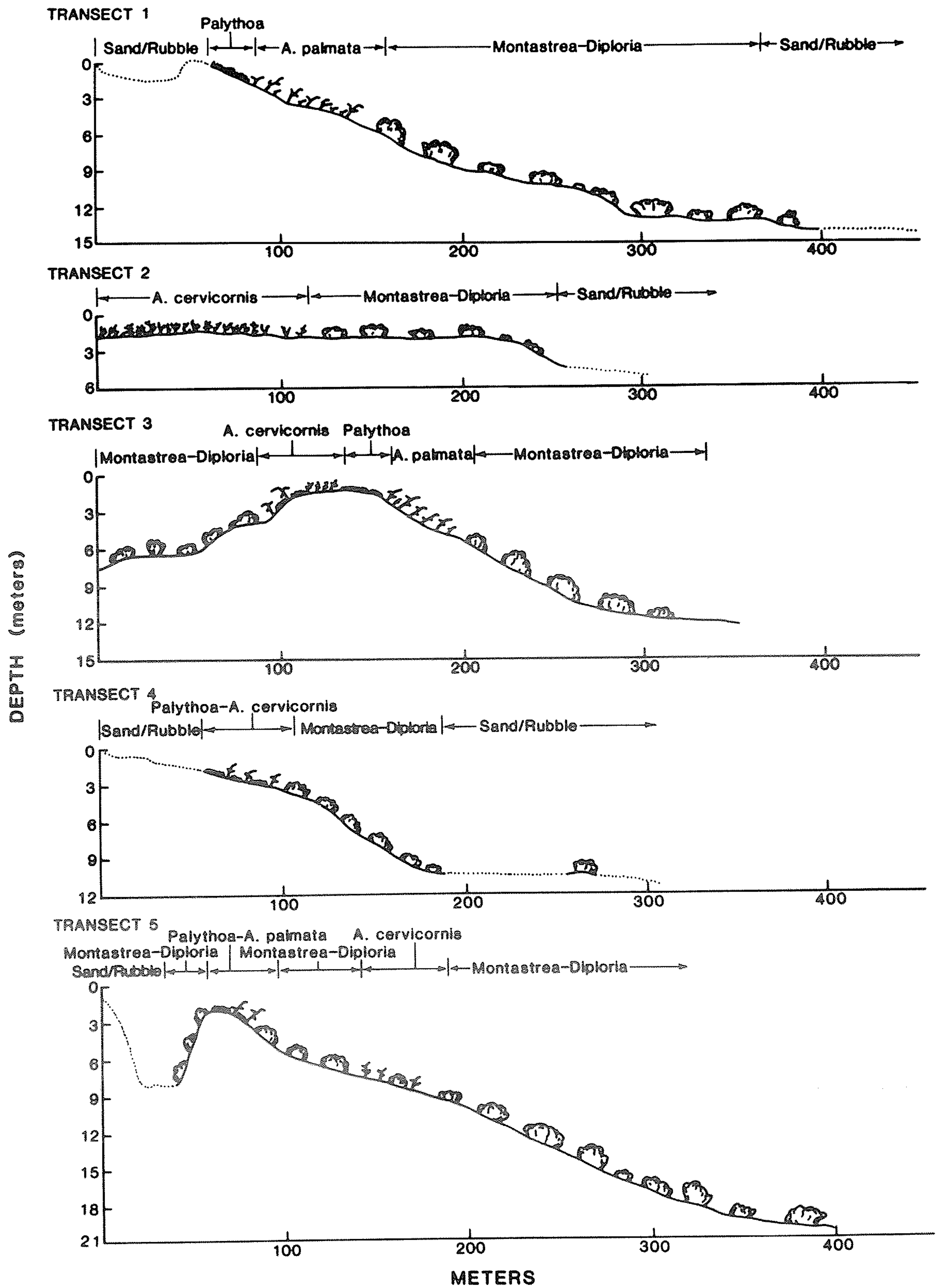

Fig. 2. Transect profiles at Cayos Arcas.

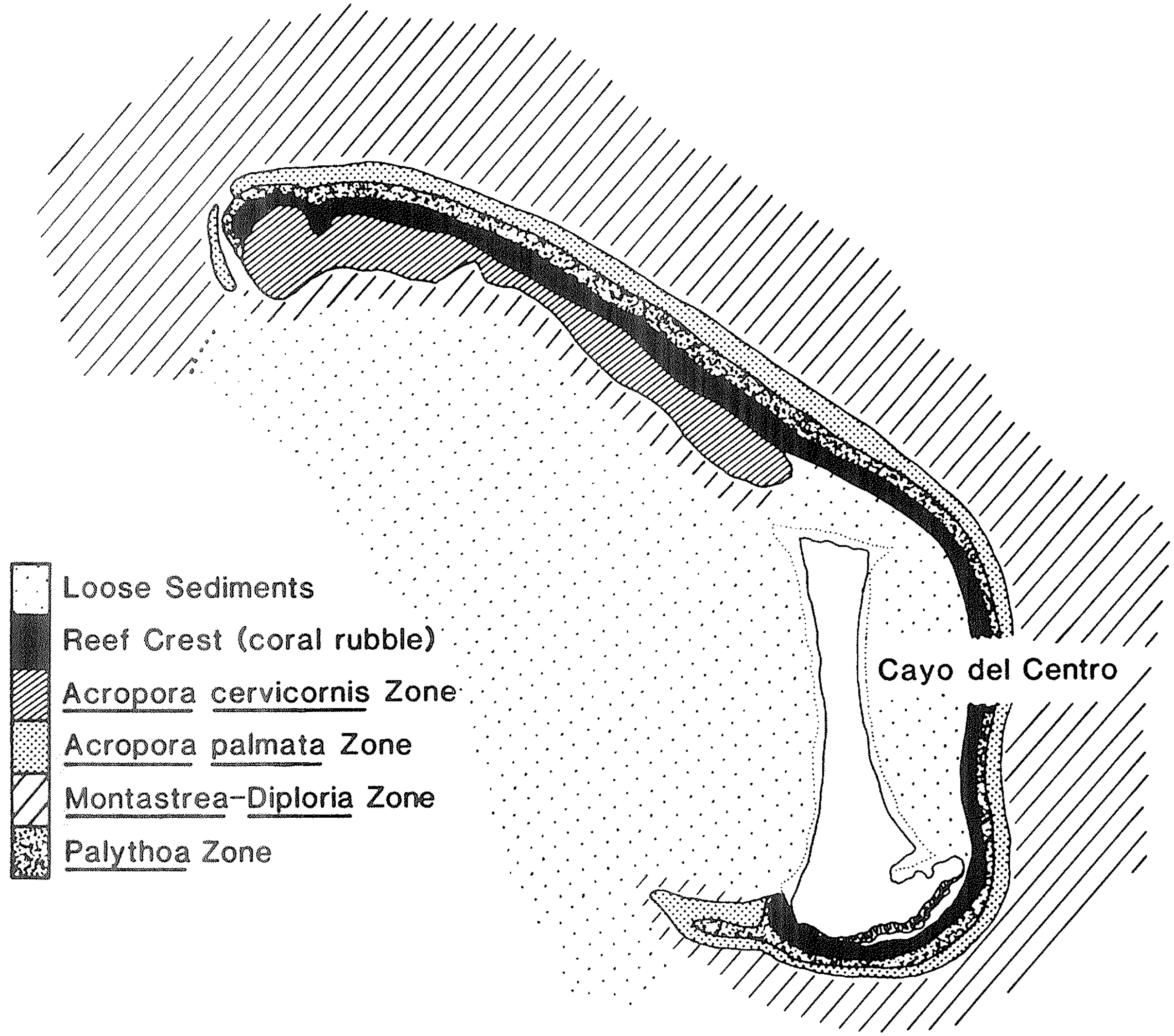

Fig. 3. An overhead drawing of the central cay and its associated reef showing the approximate distribution of the major reef zones.

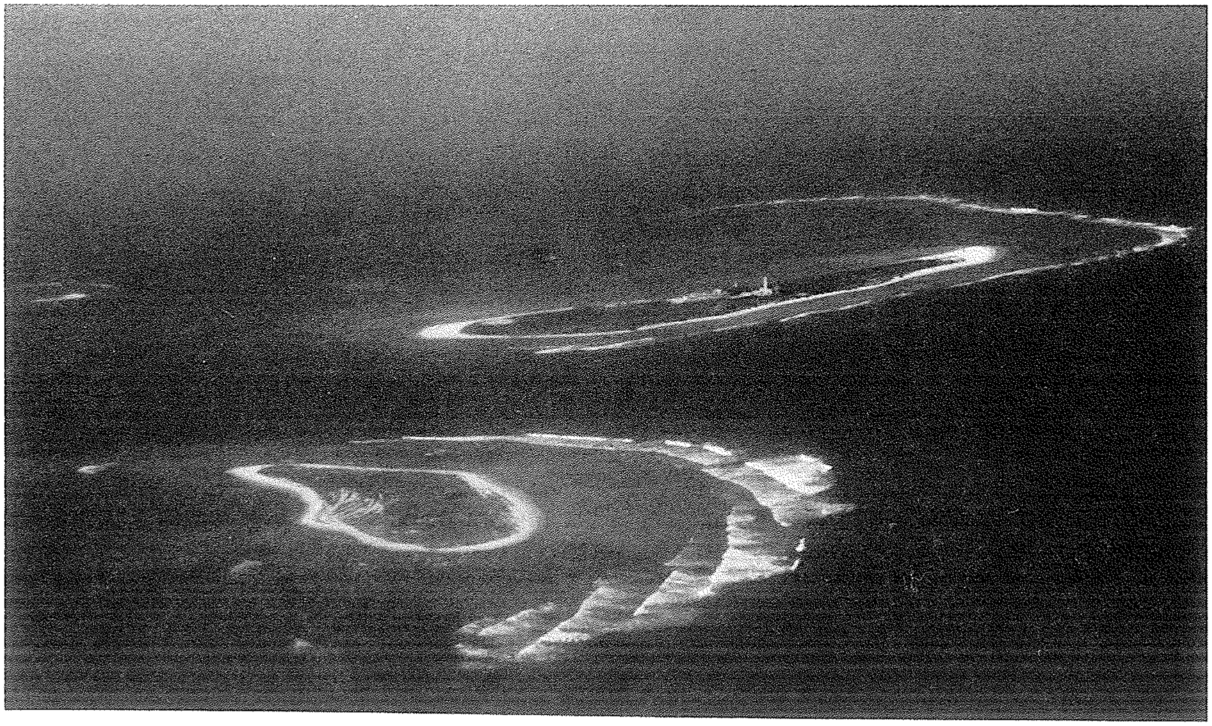

Plate 1. Aerial view of the Cayos Arcas from the southeast

Plate 2. Aerial photograph of the central cay and the reef viewed from the east

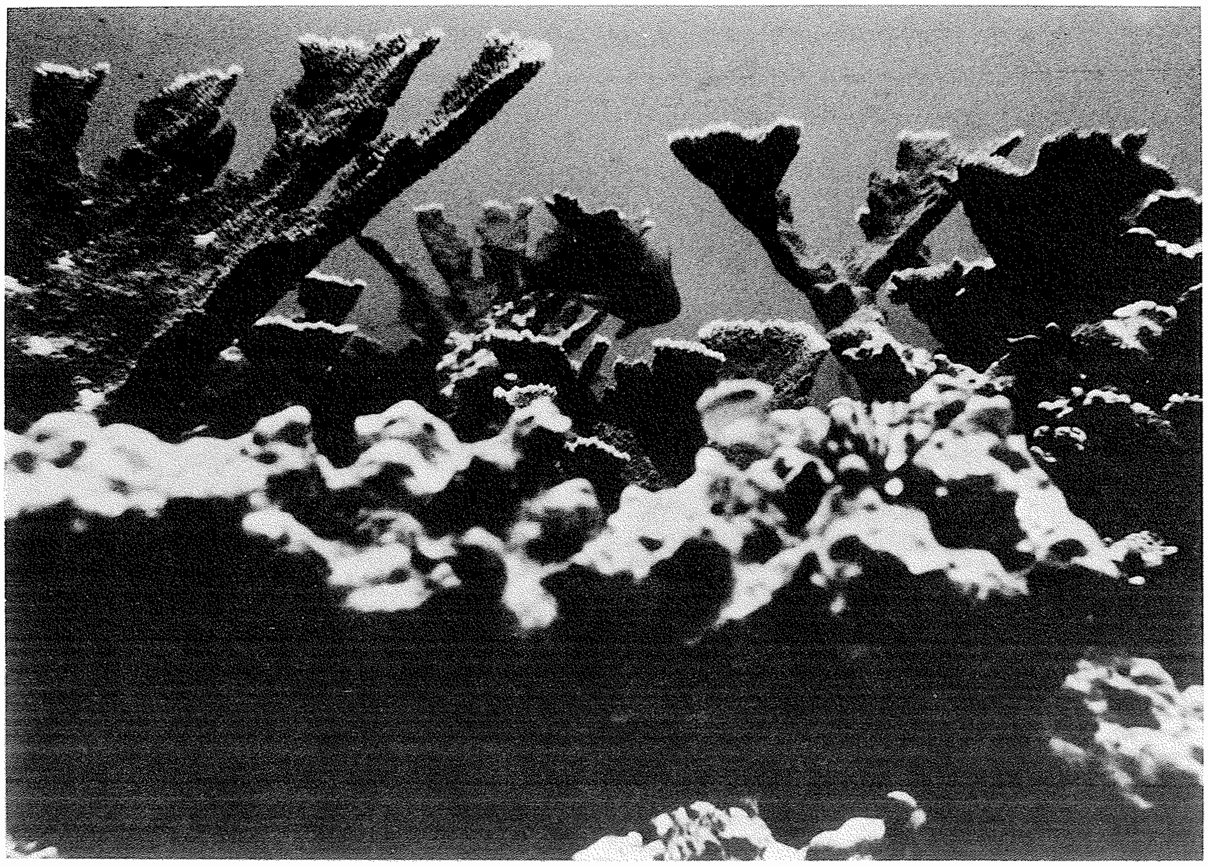

Plate 3. Underwater photograph of the *Acropora palmata* zone on Transet 1. Taken at approximately 4 m depth

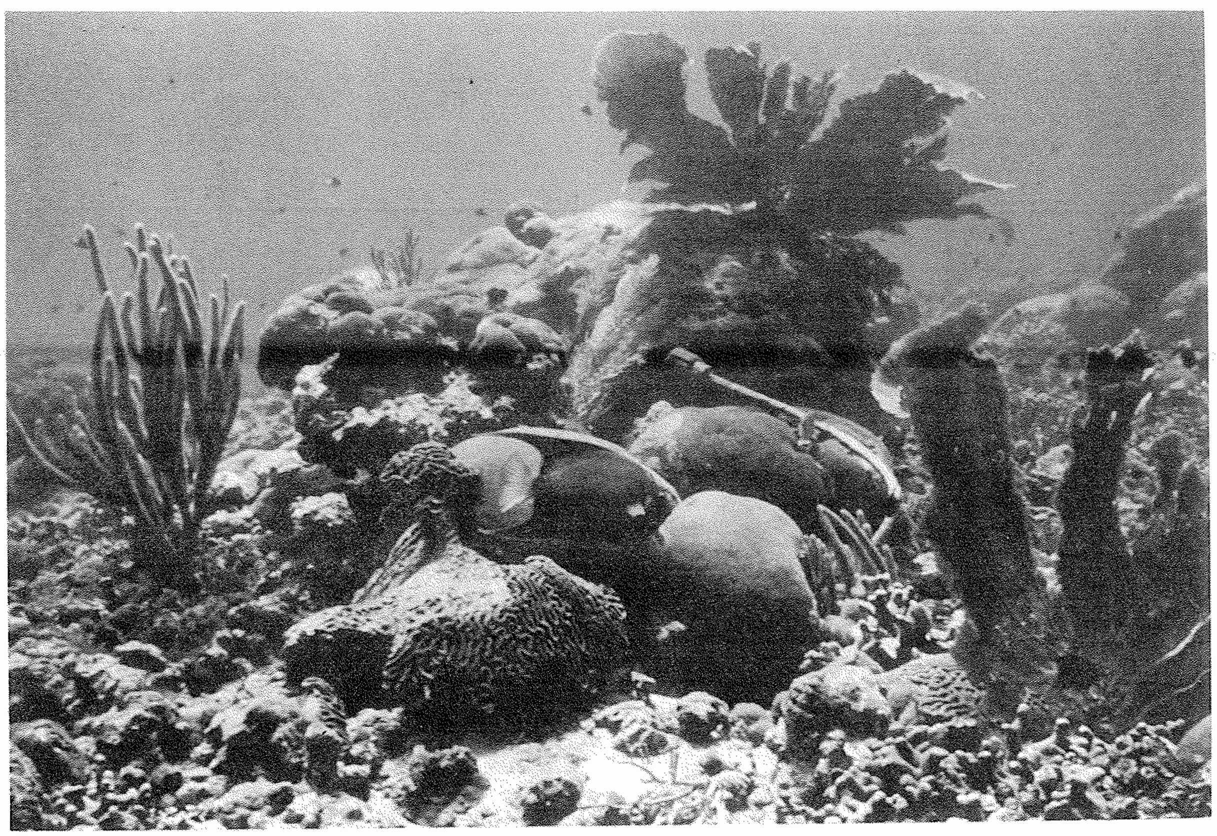

Plate 4. Photograph of the *Montastrea-Diploria* zone taken in water 10 m deep (Transect 1)

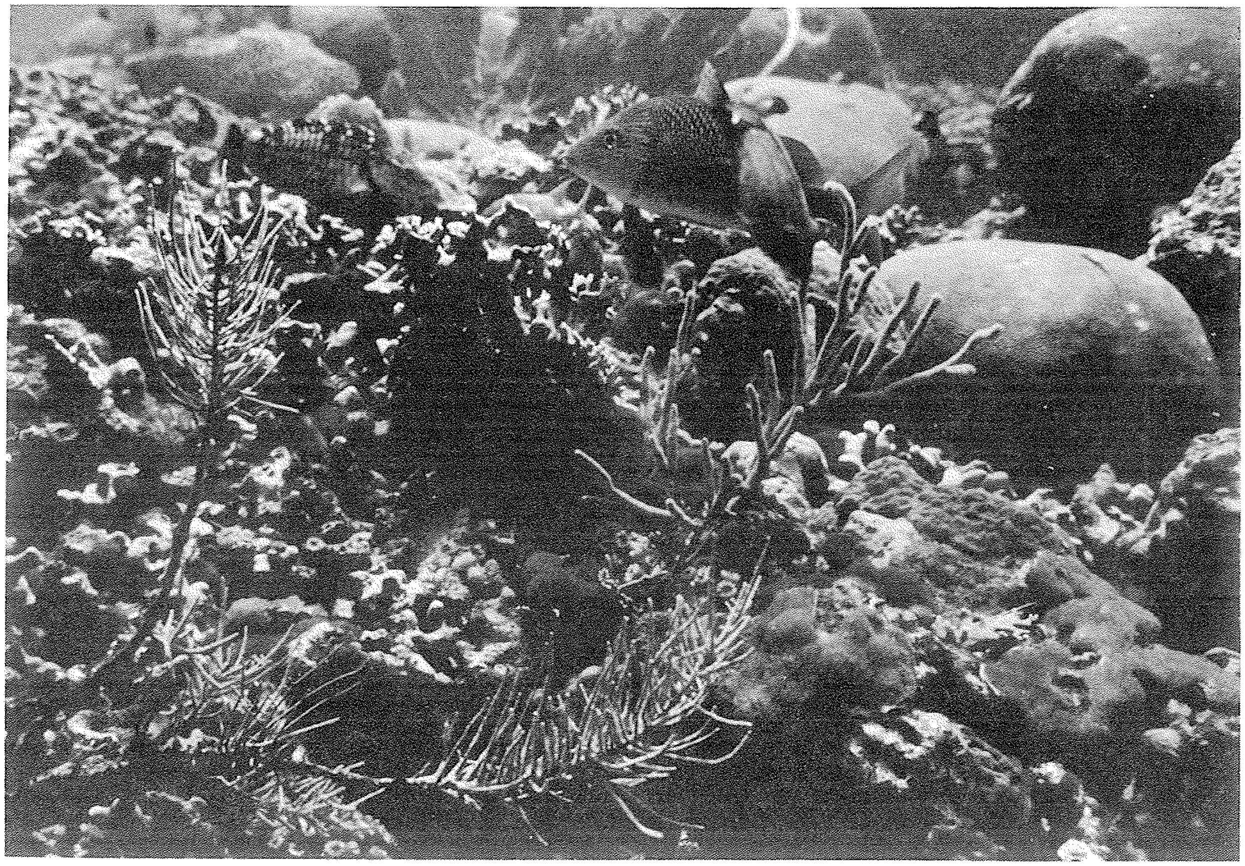

Plate 5. Photograph of the *Montastrea-Diploria* zone taken in water 10 m deep (Transect 1)