TANGUISSON-TUMON, GUAM, REEF CORALS BEFORE, DURING AND AFTER THE CROWN-OF-THORNS STARFISH (*ACANTHASTER PLANCI*) PREDATION

by

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CHAPTER I

INTRODUCTION

Purpose and Scope of the Study

Originally the purpose of this study was to determine the species distribution of living corals, both hermatypic (reef-building species) and ahermatypic (nonreef-building species) on the fringing reefs of Guam (Fig. 1). Preliminary field work for this study began in July, 1966, at which time a general survey was started and corals were collected from all the major reef environments of Guam. This collection phase, plus the taxonomy phase, was continued until July, 1970.

In February, 1967, the sudden appearance of the coral eating "crown-of-thorns" starfish, Acanthaster planci (Linnaeus), in above normal population densities was noted along local portions of the relatively sheltered northern half of Tumon Bay (Fig. 1). The subsequent depredation and resulting death of large numbers of reef corals by A. planci predicated the intensification of coral studies and collections in this region.

During the summer of 1969 the scope of the work was changed to include, with the coral distribution work completed at Tumon Bay, a description of the first observed A. planci population explosion in this same region. In addition, large sections of reef corals along the remaining northwestern coast of Guam had been killed by A. planci (Chesher, 1969a, 1969b) and this work was modified to serve as a basis of comparison for future reef recovery studies in the area of destruction.

In September, 1969, the University of Guam was awarded a grant by the Federal Water Quality Administration (FWQA) (18050 EUK) to study various

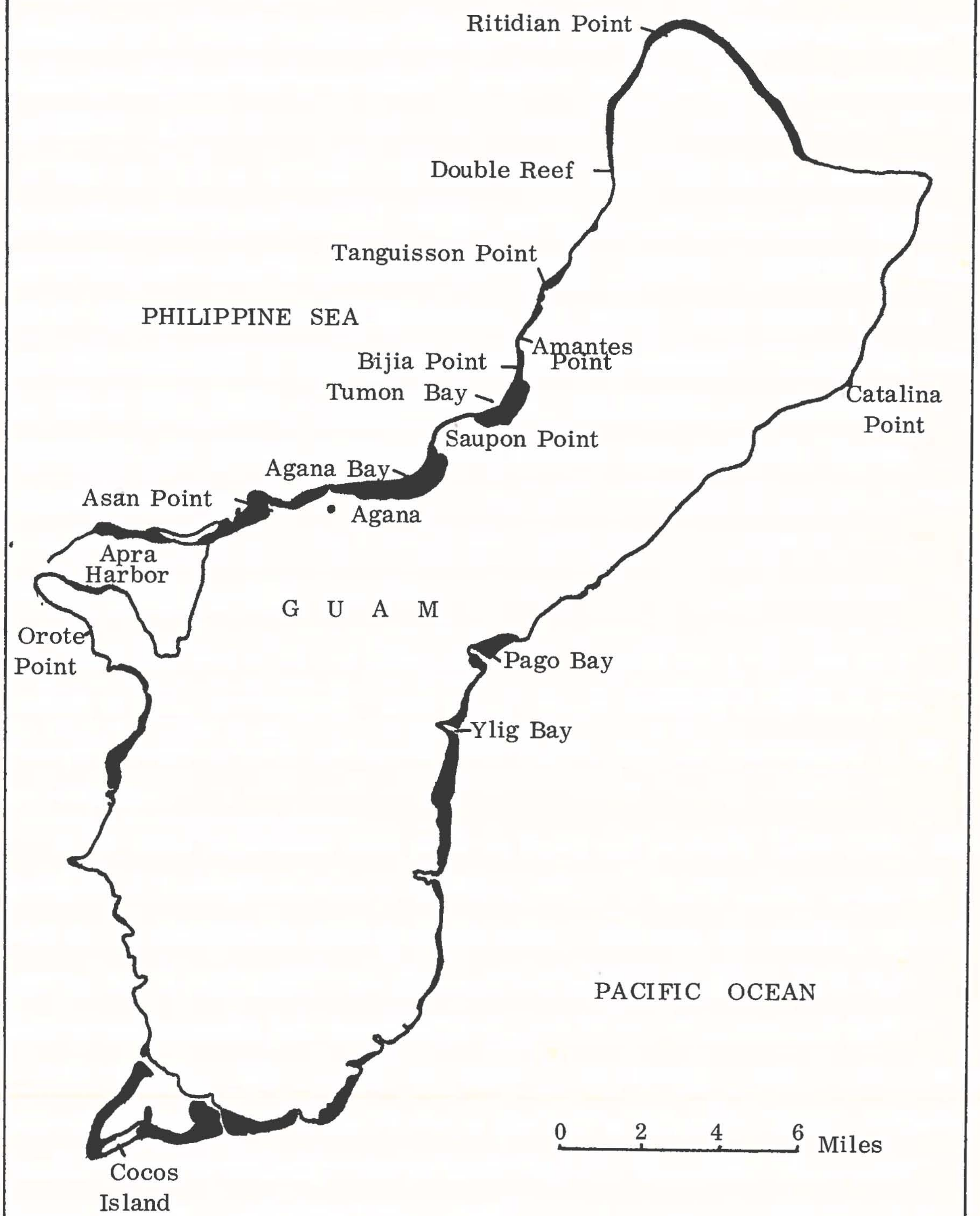


Fig. 1. Fringing reefs of Guam; reef platforms are in heavy black. Map modified from Emery (1962).

reef parameters, including reef recovery, prior to the completion and operation of a thermal steam electric power plant at Tanguisson Point. Reef recovery data obtained by the author, as a part of this grant, was incorporated into this work.

The study, thus, evolved into three major parts, with the first describing the distribution of reef corals at Tumon Bay prior to depredation by A. planci; the second describing the first observed A. planci population explosion on Guam; and the third describing coral distribution and recovery at Tanguisson Point after depredation by A. planci. Because reef environments at Tanguisson Point and Tumon Bay, where A. planci infestations had killed corals, are very similar in coral species composition and physical characteristics, the two regions were comparable.

Review of the Literature

Little previous work has been done on the fringing reefs of Guam with respect to coral distribution. Most of the studies involving these reefs are geological reports which deal mainly with various physical parameters of the reef complex.

Some coral collections were made on Guam and Saipan by Cloud (1954, 1959) during U. S. Geologic Surveys of the two islands. A list of genera compiled from this collection was made by Wells (1954). This list does not discriminate between Guam and Saipan. The above collection is deposited in the U. S. National Museum and was examined during the course of the present work.

The fringing reefs of Guam were described by Tracey (1964), who conducted transect and other reef studies during a geologic survey of the island. Physical characteristics of fringing reefs at Tumon Bay and Tanguisson Point were similar to those reported on in this study. As far as could be determined, no systematic coral collections were made during Tracey's work, but several genera were listed by reef zones from "Reef Traverse 2, at Tumon Bay." The following genera were reported: (Reef margin) Acropora, Pocillopora, Favia, and Millepora; (Reef flat) Porites in the outer part, and Acropora, Pavona, and Pocillopora in the inner part.

Other work on the reefs of Guam was done by Stearns (1940), Cloud (1951), and Tayama (1952). Coral distribution was not included in these studies. A study of the marine geology of Guam was made by Emery (1962), and includes investigation of submarine slopes, lagoon floors, channels through the fringing reefs, beaches, and rocky shores.

Previous Acanthaster planci observations on Guam were published by Chesher (1969a, 1969b). These reports deal with A. planci population movements, densities, feeding behavior, relative coral predation rates, control measures, and possible causative factors related to the sudden increase in numbers of the starfish in various Indo-Pacific regions. Chesher's observations of A. planci began during the summer of 1968, over one year after the first population increase of the starfish was noticed. The intent of Chapter V of this report is to bridge the gap between Chesher's starfish observations and the first observed population increases of A. planci on Guam.

General Description of Guam

Guam is the largest and most southerly of the fifteen small islands that make up the Mariana group in the western Pacific Ocean. The island's capital, Agana, is located at latitude 13°28' N. and longitude 144°45' E. It is 48.3 kilometers in length, and ranges in width from 6.5 kilometers at the narrow central waist near Agana to 18.5 kilometers from Orote Point on the west to Ylig Bay on the east coast. The island has a land area of 549 square kilometers.

The northern half of Guam, that includes the study area, is a limestone plateau bordered on the coasts by steep cliffs that range in elevation from more than 180 m at the north end (Ritidian Point) to less than 60 m at the centrally located, narrow waist (near Agana). The limestone is porous and no streams are found on the northern plateau. A few intermittent streams occur in the argillaceous limestones of the central waist region. The western and northern coasts are bordered by fringing reefs, whereas the more windward eastern coasts are bordered by cut benches and narrow terraces.

Climate

The following summary of climate and rainfall data is condensed from a report found in "General Geology of Guam" (Tracey, 1964). Guam has a warm, humid climate that is mainly determined by its oceanographic setting. The island lies within the belt of westward-moving, warm humid air of the tropics, which is produced between the subtropical anticyclones of the northern and southern hemispheres. Variations in the weather are caused by cyclonic eddies or whorls that form continuously, sweep westward, and dissipate. These disturbances may grow in size to become tropical storms or typhoons. The period from July to November includes the rainy months, January to May is considered the dry season, and June and December are transitional months. The mean annual rainfall on Guam ranges from less than 228.6 cm in the lee of the mountains to more than 279.4 cm in the higher mountain areas. About two-thirds of the annual rainfall occurs during the rainy season.

Sea Water Temperature

Sea water temperature at Apra Harbor, over a 10 year period, ranged between 27.2°C and 29.4°C. Months with average water temperatures above 28.9°C are July through October (Emery, 1962).

CHAPTER II

METHODS

Coral Distribution Studies

In any coral reef study that involves quantification and zonal analysis of coral species, the field method to be employed to provide an accurate interpretation of the species composition encountered is a major problem. A review of the literature describing coral distribution on tropical fringing reefs reveals that nearly as many methods exist as there are studies. Almost all studies involve the use of some type of transect lines or stations that cross the reef at right angles to the reef margin. Methods vary from casual observations at different reef zones, with a list of corals observed from each, to detailed mapping of all corals which occur within measured quadrats made across various reef zones. The former method is less time consuming, but does not yield quantifiable data. The latter method gives very detailed data, but is extremely time consuming, and so limits the number of transect studies that can be made in a specific length of time.

Tumon Bay and Tanguisson Point fringing reefs exhibit fairly distinct physiographic zones that run parallel to the reef margin, but even so, a great deal of variation occurs within these zones. For this reason, methods were selected that would allow several transects to be made and at the same time yield quantifiable data representative of the species composition of the two study regions. In view of the impending predation by Acanthaster planci at Tumon Bay, a single line transect method, which is fairly rapid, was used there.

The extended reef studies at Tanguisson Point will be continued for at least one year, and possibly longer. Since this study also involves coral growth rates, and because coral growth rate studies involve mapping and measuring of specific specimens over several time intervals, a station quadrat transect method was used. It would have been advantageous to use the same transect method at both study locations, but time limitations prevented the use of both methods at each location.

Tumon Bay

During the Tumon Bay study 27 field trips were made. From these field trips, 429 coral specimens, each with detailed habitat data, were collected; physical and biological parameters were mapped and described; and six reef transects were completed using the single-line method. Two transect study locations were selected: the first at Naton Beach, where three transects were completed, and the second at Gognga Beach, where another three were completed.

Figure 2 shows the location of the Naton and Gognga transects in relation to the various reef zones and to each other. The single line transect method used there involved the placement of a line marked at 10 m intervals across the reef section to be studies (Fig. 3). From each 10 m section of the transect line the following types of data were recorded: (1) transect line section number; (2) substratum description, including physical characteristics and sediments; (3) water depth at the seaward end of each 10 m section division; (4) specific names of all corals that lay beneath the line; (5) the diameter of the corallum and the length of line section it occupied; and (6) growth form for each recorded coral. Water depth was measured on the reef flat by using a plastic meter stick; deeper sections of the reef were measured with a depth gauge, as shown on the reef profile (Fig. 4).

During these studies at Tumon Bay, field note entries were made of <u>A. planci</u> activities. The description of the population explosion at Tumon Bay is a chronological summary of these observations. Population counts of <u>A. planci</u> were made by snorkeling over various reef zones and counting the individuals

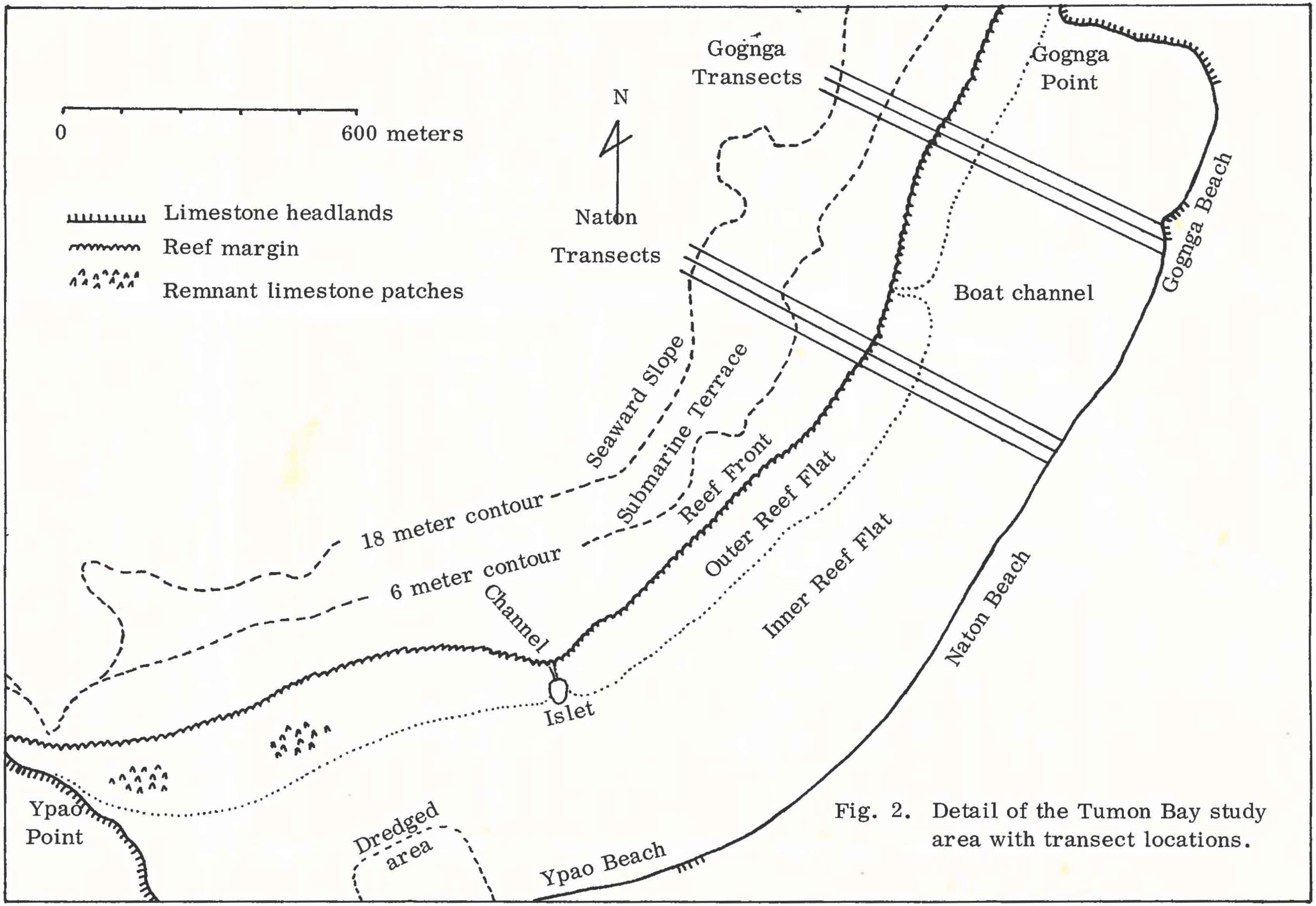


Fig. 2. Detail of the Tumon Bay study area with transect locations.

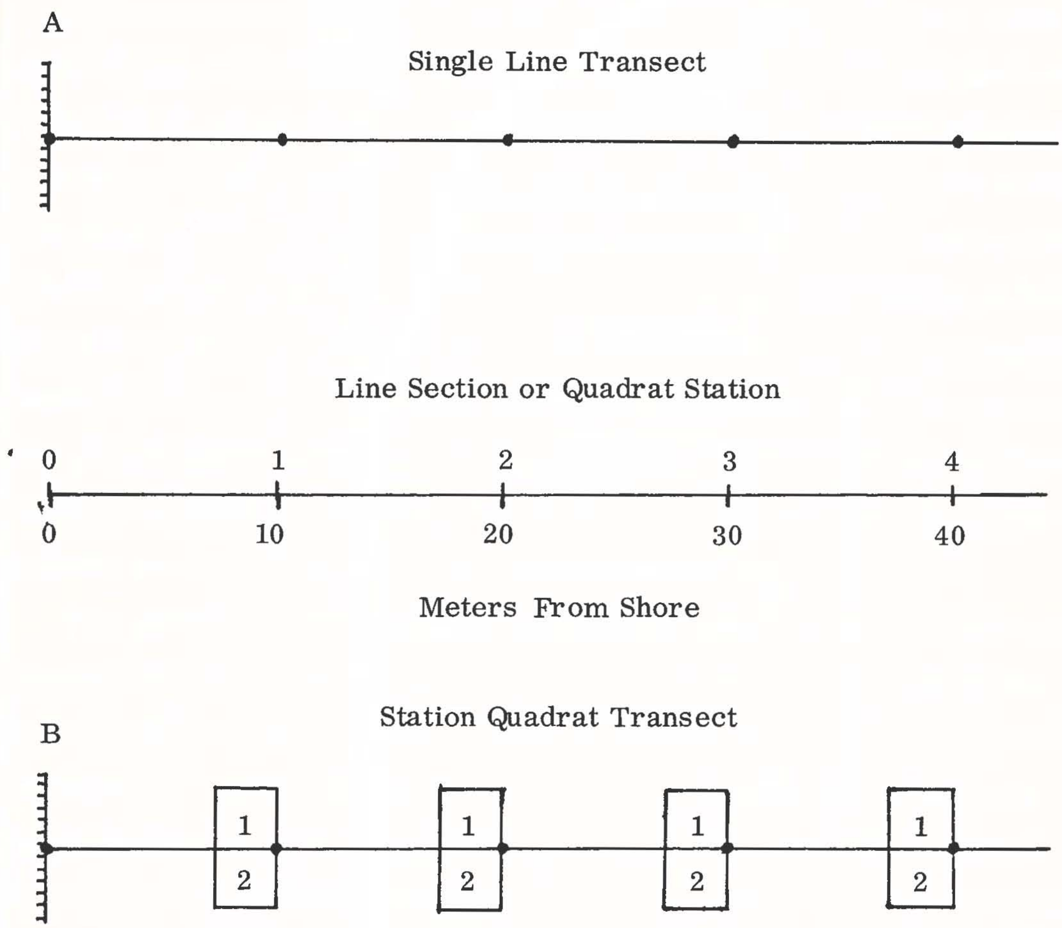


Fig. 3. A. Diagram of the single line transect method used at Tumon Bay.
B. Diagram of the station quadrat transect method used at Tanguisson Point.

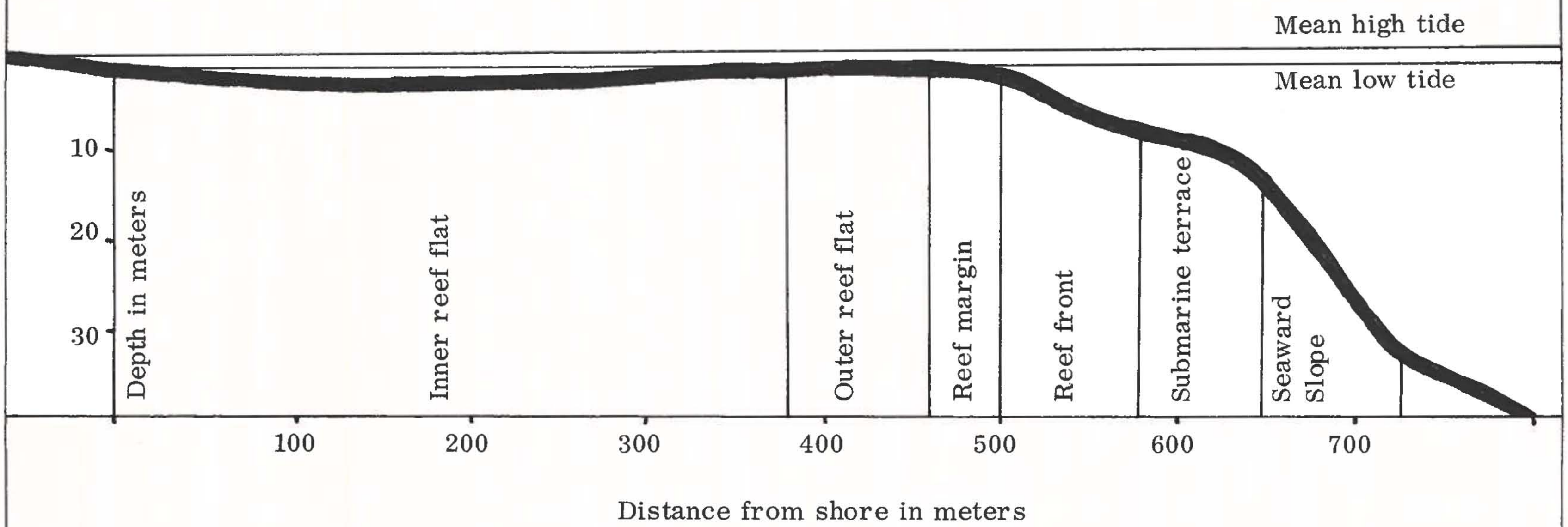


Figure 4. Reef profile of Naton Transect at Tumon Bay; Vertical exaggeration X5.

within visual proximity. Quantative data was obtained by using the single line transect method at the reef front near the Naton transect study area.

Tanguisson Point

Three permanent transects, using the station quadrat method, were established at Tanguisson Point. Figure 5 shows the location of these transects on the reef in relation to the various reef zones. Stations were established at 10 m intervals along the transects from the upper intertidal zone to a depth of 30 m on the seaward slope zone (Fig. 3). Depth measurements were determined by using the same methods as those used at Tumon Bay, as shown on the reef profile (Fig. 6). Transect stations were marked by driving a galvanized, double-headed masonry nail into the reef surface, to which a 30 cm length of red, plastic-coated copper wire was attached. Positive station identification was accomplished by attaching a plastic tag, bearing an impressed station number, to a wire loop at the end of each station wire.

Two quadrats, each 1 m^2, were laid out by placing a portable wire grid at two positions around each transect station. At each transect station the southeast and northeast quadrats were arbitrarily given numbers (1) and (2) respectively. Positioning of quadrat grids at each transect station was established by using an underwater compass to find the north reference. From each quadrat the following kinds of data were recorded: (1) transect station and quadrat numbers; and (2) specific name, growth form, and diameter of each living coral within the confines of the quadrat grid.

Growth Form and Size Determination

The various coral growth forms differentiated follow those described by Wells (1956). A columnar form was added which differentiates an intermediate mode of development between the massive and ramose forms. A subdivision of ramose forms into corymbose, cespitose, and arborescent modes of branching was made (Fig. 7 through 12).

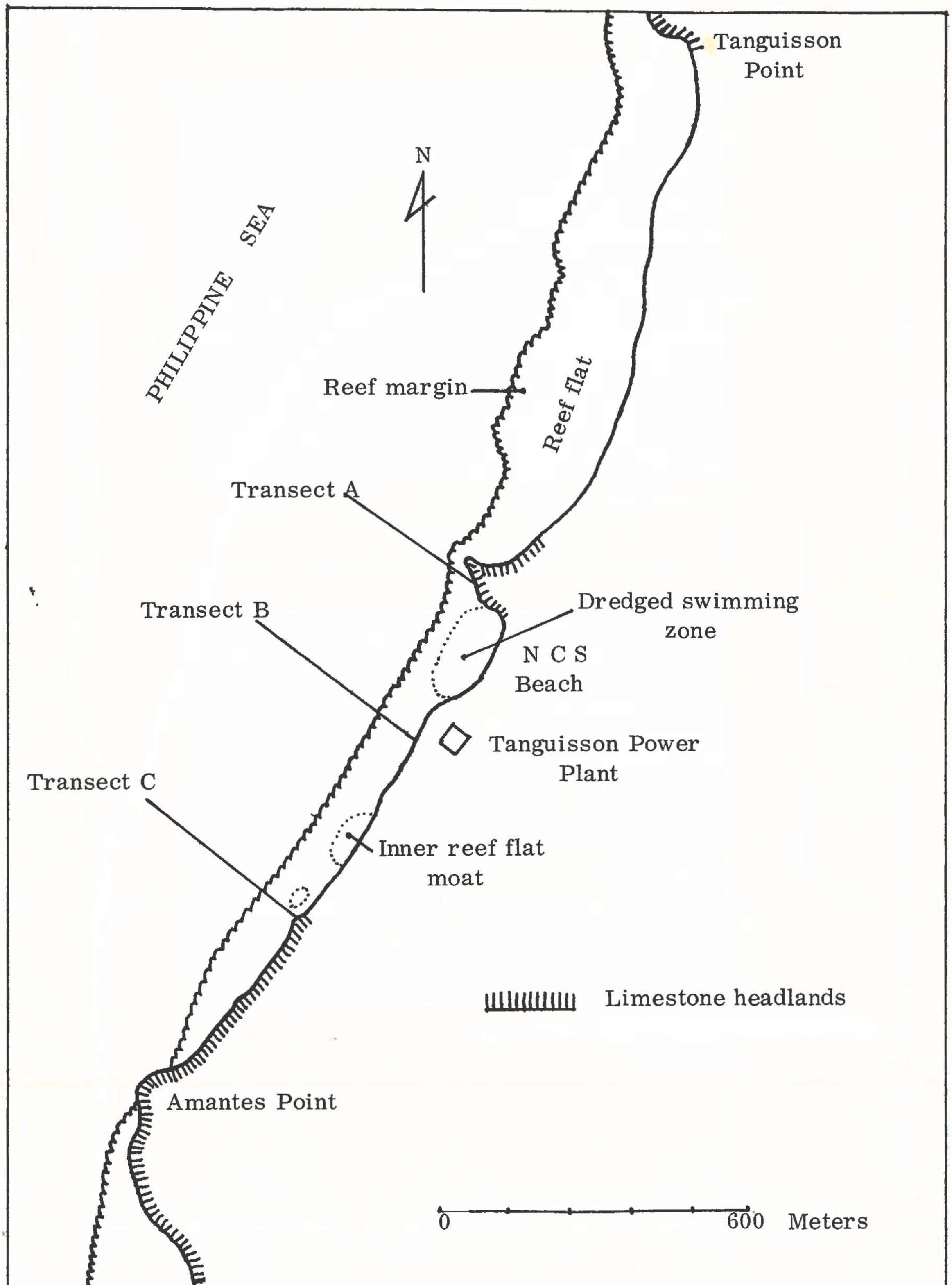


Fig. 5. Detail of the Tanguisson Point study area with transect locations.

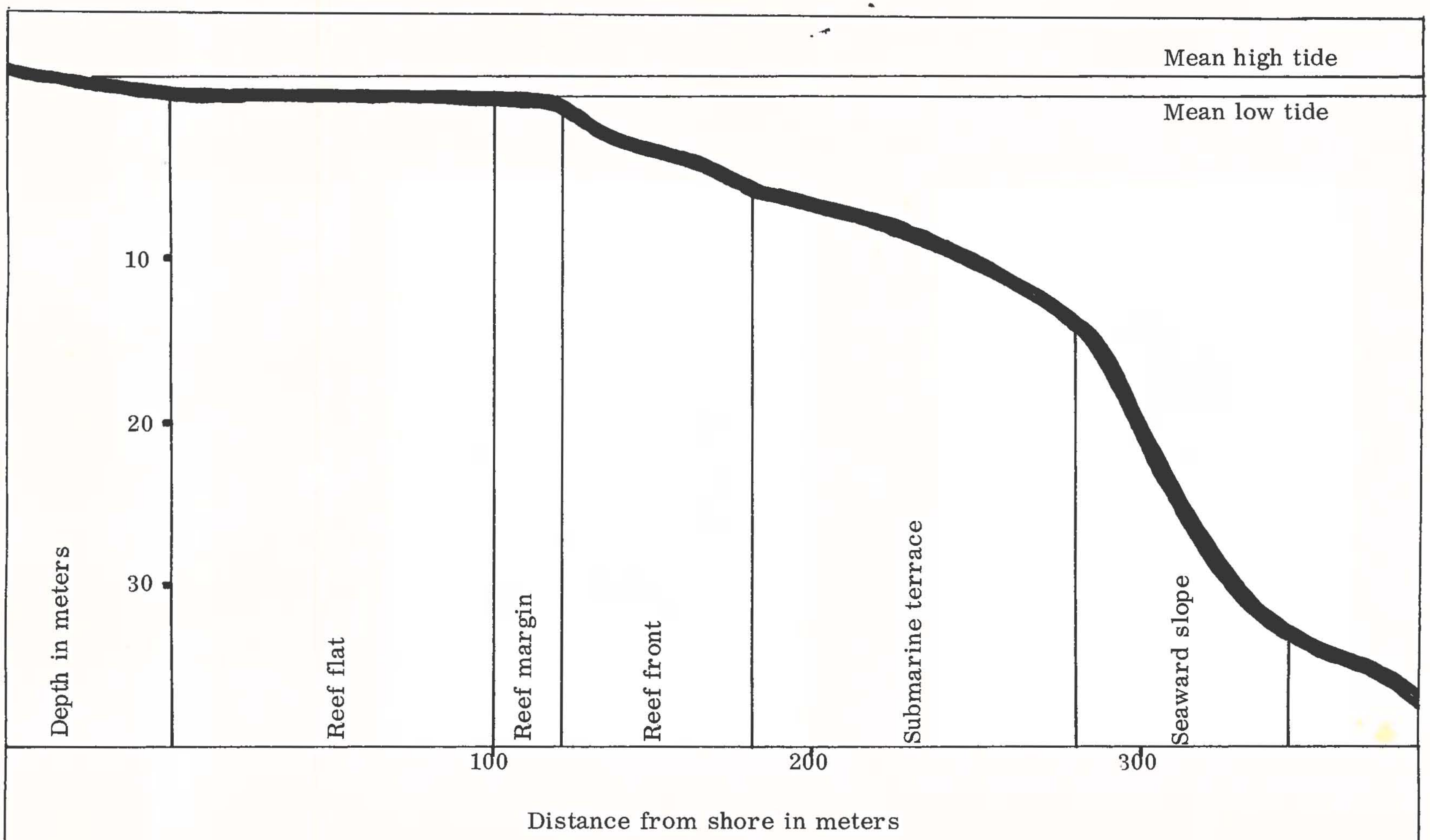
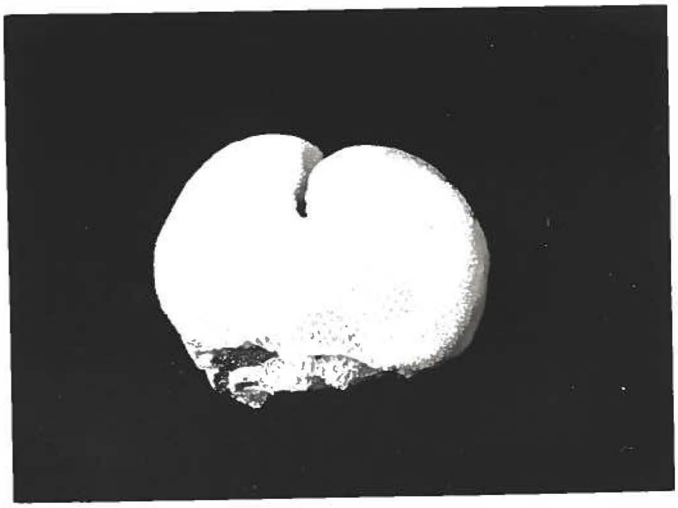


Figure 6 . Reef profile of Transect B at Tanguisson Point; Vertical exaggeration X5.



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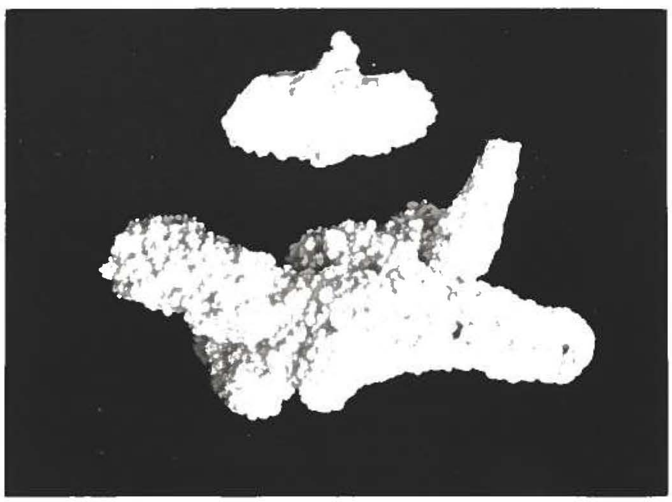
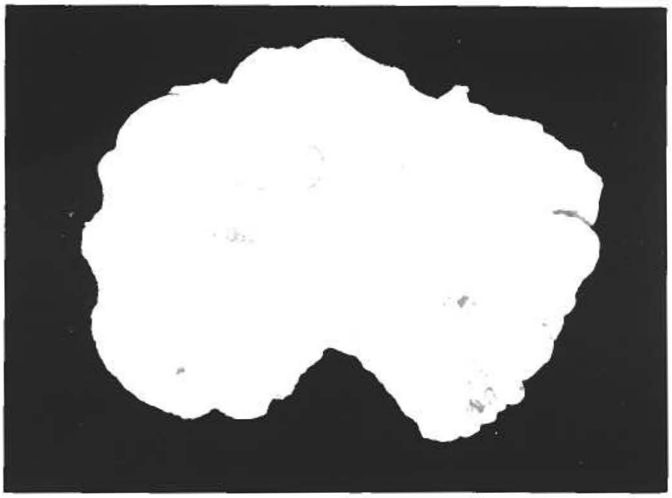


B

Fig. 7. Coral growth forms. A. Massive form of Favia stelligera. B. Encrusting form of Montipora hoffmeisteri, thin layer growing over dead Acropora branches.



A

B

Fig. 8. Coral growth forms. A. Foliaceous form of Porites (S.) iwayamaensis, plate-like expansion from the base of a large colony. B. Foliaceous form of Pavona decussata.

A

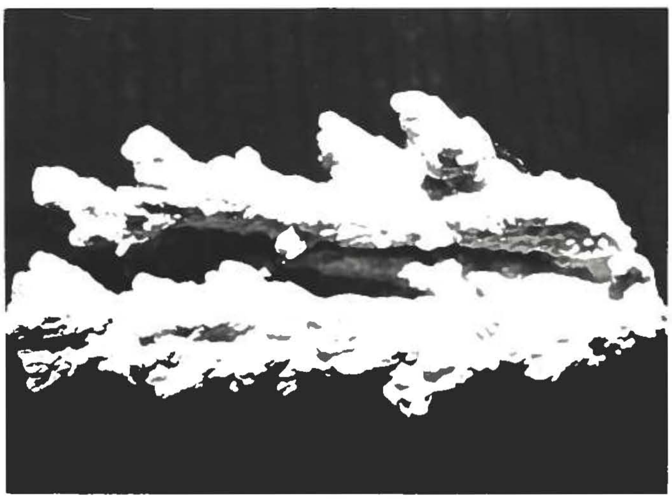


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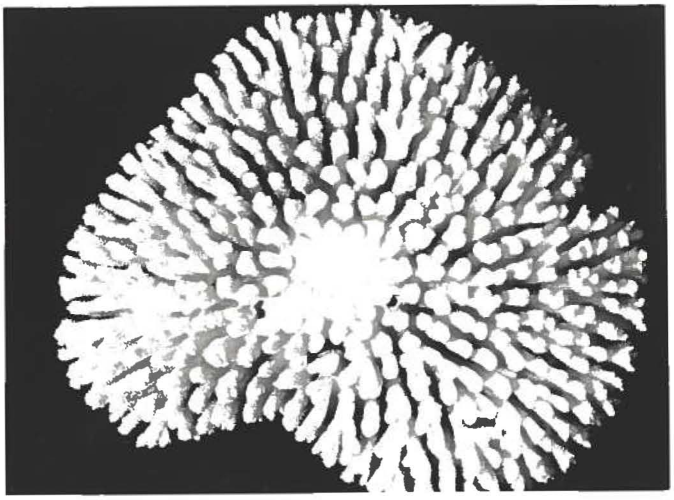
Fig. 9. Coral growth forms. A. Flabellate form of Millepora platyphylla. B. Columnar form of Porites (S.) convexa.



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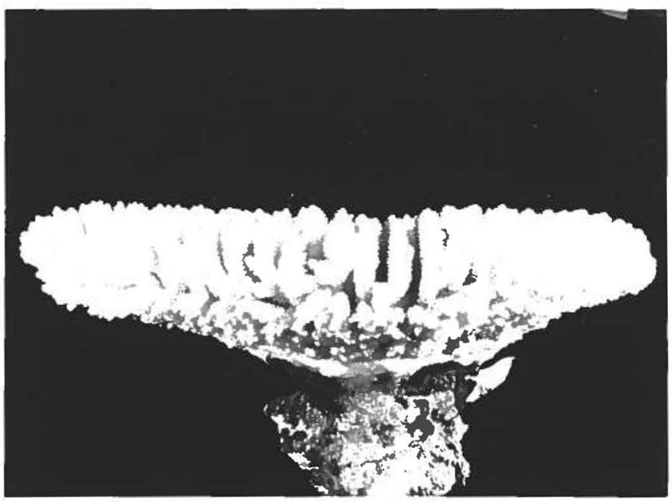
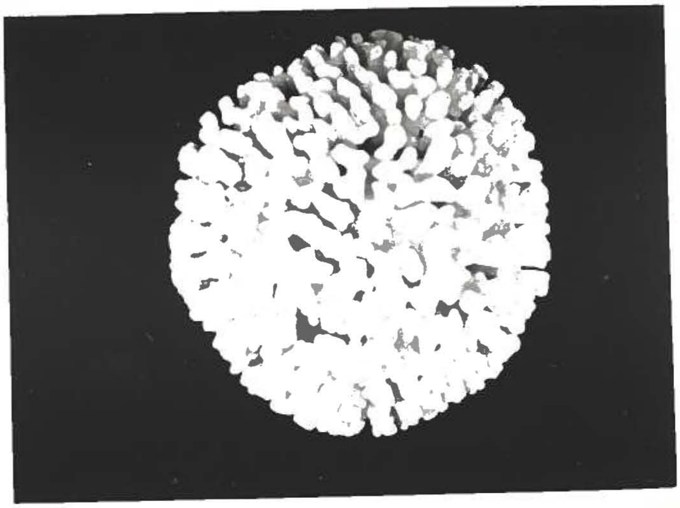


B

Fig. 10. Coral growth forms. A. Corymbose form of Acropora nasuta, dorsal view. B. Side view of A.



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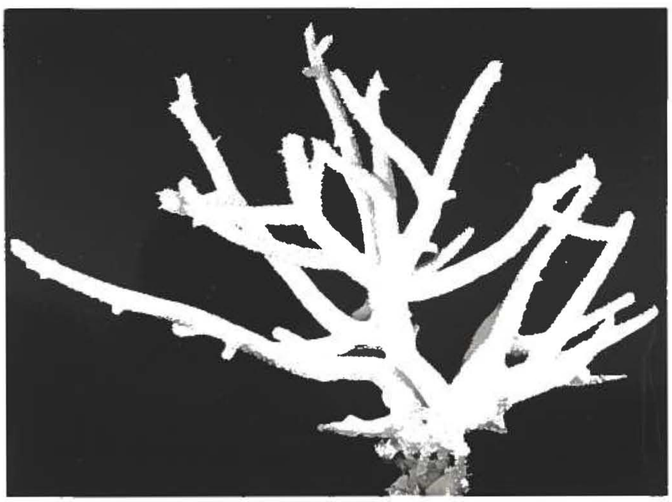
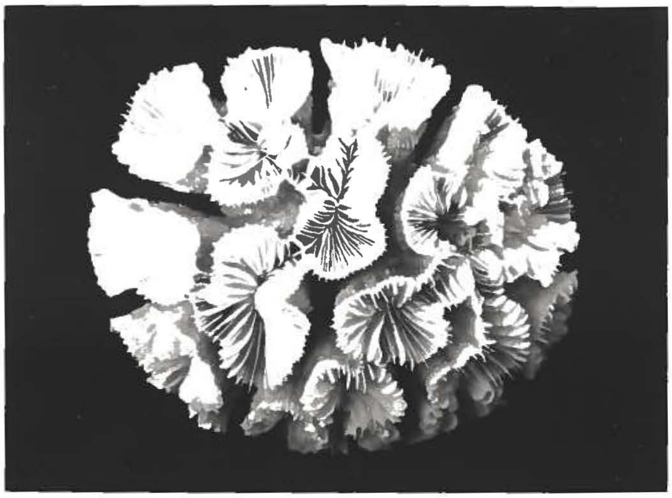


B

Fig. 11. Coral growth forms. A. Cespitose form of Porites cocosensis, dorsal view. B. Arborescent form of Acropora nobilis.



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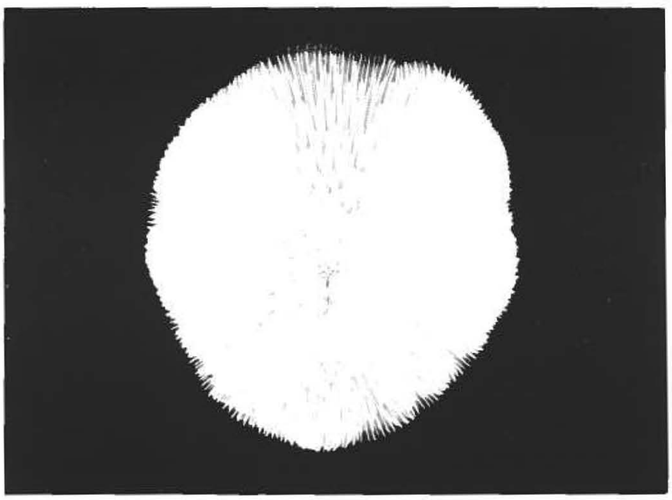

B

Fig. 12. Coral growth forms. A. Phaceloid form of Euphyllia glabrescens. B. Solitary form of Fungia fungites.

The diameter of individual coral colonies was measured with a meter stick with moveable trammel points. The colony diameter measurement was made at the widest point across the corallum. If the colony shape was not circular, its outline was sketched and several measurements of length and width were recorded.

CHAPTER III

DESCRIPTIONS OF THE STUDY AREAS

For the purpose of reef description and coral distribution studies, the reef platform and slopes were divided into several zones and subzones, based on those described by Tracey (1964). These zonal reef divisions were based on various physical parameters such as degree of reef surface exposure at high tides, degree of reef surface submergence at low tides, amount of reef slope, and reef growth and erosional structures.

The biologic parameters have deliberately been omitted from the fringing reef descriptions of Tumon Bay and Tanguisson Point. This was done because Chapters IV and VI describe reef coral distribution by zones in detail, and because future workers investigating reef recovery would experience difficulty in comparing structures and descriptions of former living coral reefs with those that have since been killed by Acanthaster planci.

The northern limestone plateau, which borders both study areas, is very porous, resulting in a well-developed Ghyben-Herzberg fresh-water lens system. Water escapes continually along most sections of the intertidal zones of both Tumon Bay and Tanguisson Point. This fresh water seepage onto the reef flat is particularly noticeable along sandy beaches at low tide, where it forms small rills. Emery (1962) measured the fresh water seepage along a 47 m section of Gognga Beach and found it to be 42.5 liters per second. Analysis of beach samples from Tumon Bay and Tanguisson Point by Emery (1962) shows that the sediments of this region are nearly 100 per cent bioclastic material. This is due to the absence of rivers and streams emptying onto the reef flats of the study areas.

Tumon Bay Fringing Reef

Tumon Bay (Fig. 2) is located along the northwest coast of Guam between Ypao Point and Lijia Point. The fringing reef flat is a broad, crescent-shaped limestone platform, 3540 m in length, measured along the concave seaward margin. It is relatively uniform in width, ranging from 460 m at Gognga Beach to 480 m at Naton Beach. According to Tracey (1964), Tumon Bay was probably formed by large scale slumping. This slumping action would provide a wide, shallow platform upon which the Tumon fringing reef could develop and explains the general absence of wide reef platforms along other sections of the northwest coast (Fig. 1). At Ypao Point and Gognga Point, the fringing reef width narrows to 50 m and 100 m respectively. At Tumon Bay, in a beach to seaward sequence, intertidal, reef flat, reef margin, reef front, submarine terrace, and seaward slope zones are recognized and described.

Intertidal Zone

This zone is the portion of the beach or shore that is covered by water at high tide and exposed at low tide. Limestone cliffs border the beach from Ypao Point to the Ypao public beach and from Gognga Point to Gognga Beach (Fig. 2). At these two locations, plus a small patch of emergent limestone located between Ypao Beach and Naton Beach, the intertidal zone consists of bare limestone with well-developed seawall indentations called "nips" (Fig. 13) along the more exposed seaward regions. The remainder of the beach consists of unconsolidated sand and coral-algal-mollusc rubble. The major fraction of the sand portion from the unconsolidated beach material consists of foraminiferan tests, which are transported from the reef flat zone by wave action and currents. Fresh water seepage is common along the intertidal zone, especially where it is backed by limestone cliffs or headlands.

Fig. 13. A "nip" at the base of a sea cliff, located about 2 m above the reef flat level at Amantes Point.

Reef Flat Zone

This is the flat limestone platform that extends from the intertidal zone to the wave-washed reef margin. At Tumon Bay, the outer seaward part of the reef flat is slightly elevated in respect to the inner shoreward section, and consequently, at low tide, is often exposed, while the inner part retains water. On this basis, the reef flat is divided into two subzones--an outer reef flat subzone that is exposed during low tide, and an inner reef flat subzone that is covered by water at low tide. The inner water mass is here called the "moat."

Inner Reef Flat Subzone

This region of the reef flat is considerably wider than the outer reef flat subzone and ranges in width from 380 m at Gognga transect to 350 m at Naton transect. Unconsolidated sediments vary in thickness from a meter or more near the beach, to a thin veneer of less than a centimeter near the outer reef flat. Local areas of bare reef-rock are common, especially where this subzone grades into the outer reef flat subzone. Sand, gravel, coral-algal-mollusc rubble, and small boulders make up the sediment composition. Sand and gravel are more common along the inner (shoreward) half, with coral-algal-mollusc rubble and boulders becoming more abundant as the outer reef flat is approached. The entire subzone is relatively flat, with a few cracks, holes, low mounds of rubble, and shallow bowl-shaped depressions, but the general relief is usually less than 50 cm. Figure 4 reef transect profile shows the water depth at high and low tides across the subzone. The depth range across this transect profile is fairly uniform for the entire length of the Tumon Reef, with the exception of the dredged swimming area at Ypao Public Beach, which is about 1 m deeper. The deepest water on the inner reef flat occurs at the mid-point, about 150 m from shore.

Outer Reef Flat Subzone

This subzone of the reef flat is exposed during lower tides and is bounded on the shoreward side at low tide by the impounded water of the moat and on the seaward side by the reef margin, which is constantly awash. Figure 2 shows that it varies considerably in width. In the vicinity of the Naton transects (Fig. 2), it disappears completely because of a shallow channel that occurs there. Unconsolidated sediments are nearly absent over the outer, seaward part of this region, except in small widely scattered shallow pools where boulders, sand, and gravel accumulate. The inner, shoreward part usually has scattered boulders over the surface and, in some areas large boulder tracks (Fig. 14), where it grades into the inner reef flat. The source of these boulders is the reef margin and reef front, where living corals are broken loose and worked shoreward by typhoon and other storm waves. A large accumulation of boulders have formed a small islet (Fig. 2) on the outer reef flat between Naton and Ypao beaches.

At low tide this subzone appears as a flat limestone pavement with very little relief except for shallow pools a few centimeters deep, scattered boulders, and larger pieces of reef-rock up to a meter in height broken from the margin and thrown up on the reef by storm waves. The surface of the limestone pavement is usually covered with a turf-like mat of filamentous algae. Foraminifera are abundantly distributed throughout this algal mat and are the main source of the buff-colored sand found over the reef flat and beach.

Depth of water over the outer reef flat varies due to elevation differences. The reef section between the boat channel and the shallow channel immediately seaward of the small islet (Fig. 2) seems to be depressed in respect to reef sections opposite Ypao and Gognga beaches. Since there are no streams opposite or shoreward of these channels to account for their origin, the depressed reef section between them may be due to a local faulting or slumping of the reef margin and outer reef flat.

Fig. 14. Boulder accumulations on the Tumon Bay inner reef flat where it merges into the outer reef flat.

Several patches of remnant limestone, composed of solution-pitted pinnacles and knobs, are found on the outer reef flat near Ypao Point (Fig. 15). This feature probably represents a former reef platform of higher elevation.

Reef Margin Zone

This zone is represented by the seaward edge of the reef flat platform that is constantly awash even at low tide. A poorly developed algal ridge is present along most of the Tumon Bay reef margin except at Ypao Point, where a narrow, elevated crest rises about 50 to 75 cm above the general outer reef flat level (Fig. 16). This algal ridge diminishes in height and disappears completely where the reef flat widens east of Ypao Point. The algal ridge development along this section of reef margin is probably due to its more northern exposure and subsequent greater surf and wave action.

The reef margin varies in width from 40 to 50 m along Tumon Bay. The seaward edge is very irregular and is cut at right angles by short surge channels 1 to 3 m wide, 2 to 4 m deep, and up to 30 m in length. Some surge channels coalesce and fuse at their upper margin, forming cavernous channels beneath the reef margin platforms (Fig. 17). Most of the cavernous channels open at intervals along the fusion zone, forming pools and open cracks (Fig. 18). In cross section, most surge channels are wider at the bottom than at the upper margin, which may be due partly to growth at the upper regions and abrasion at the base or floor, which contains large, rounded boulders. Most boulders, however, do not show evidence of constant movement, because most are encrusted with red algae and small coral growths. These boulders are probably moved about only during typhoons and storms. Surge channels are separated by lobate elevations called spurs that slope seaward toward the reef front zone. The upper surface of the spurs is very irregular, with knobs, pinnacles, and cracks, and in many places is honeycombed with numerous interconnecting holes.

Fig. 15. Remnant limestone patches. Solution pitted pinnacles and knobs found on the outer reef flat at Ypao Point.

A

B

Fig. 16. Algal ridge development at Ypao Point. A. An oblique view of the algal ridge looking toward Tumon Bay. B. An aerial view of A. The algal ridge is located within the breaker zone. Note the presence of the well developed submarine grooves and buttresses seaward of the algal ridge.

A

B

Fig. 17. Surge channels at Ypao Point. A. Outer (seaward) section of a surge channel. Maximum width is about 2 m. B. Inner (shoreward) section of A.

Fig. 18. Cavernous section of a surge channel which opens and widens forming a small pool 1 to 2 m in depth.

The inner half of the reef margin, like the outer surface, is irregular because of the presence of small knobs, pinnacles, holes, and pools. Shallow extensions of the longer surge channels cut through the inner half of this zone and terminate in small pools 1 to 2 m in depth.

Reef Front Zone

The reef front represents the extreme seaward edge of the reef flat platform, where the reef margin abruptly increases in depth or degree of slope. This zone is constantly covered with water. The reef front is composed of the seaward sloping extensions of the reef margin spurs and surge channels, which are here referred to as the submarine buttresses and grooves respectively. The point where the submarine buttresses and grooves terminate marks the seaward boundary of the reef front. Generally, the 6 m submarine contour (Fig. 2) coincides with the seaward limit of the reef front along Tumon Bay. The reef front slope may be contiguous with that of the seaward slope zone, but at most locations along Tumon Bay these two zones are separated by a flattened region called the submarine terrace.

Width of the reef front zone is variable and ranges from 60 m at Naton transect to 80 m at the Gognga transect location. Submarine grooves near the reef margin are 2 to 5 m in depth and commonly branch into several secondary grooves or channels. These grooves are wider at the bottom than at the top and are relatively flat-floored, with large round boulders, coarse sand, and gravel scattered along their length. Some submarine grooves widen from 5 to 15 m in diameter, with large boulders covering their floors. Submarine buttresses slope seaward from 10^{o} to 15^{o} and are extremely irregular on the upper surface due to the presence of coral-algal knobs, bosses, and pinnacles. At the seaward half of this zone, these various types of prominences may have a relief of as great as 3 to 4 m.

Submarine Terrace Zone

The first submarine terrace represents a noticeably flattened region when compared to the reef front and seaward slope zones, which at Tumon Bay begins at the 6 m contour interval and extends seaward to the 18 m contour interval, where a sharp increase in the degree of slope marks the beginning of the seaward slope (Fig. 2). Coral knobs and pinnacles are abundant on the inner seaward half of the terrace, which gives its surface a topographic relief similar to the outer reef front zone. Relief on the seaward half of the terrace is generally less, ranging from 1 to 2 m, but occasionally scattered coral knolls and knobs may have a relief up to 4 m. A few shallow grooves, about a meter in depth, are found crossing the zone at right angles and usually connect with deeper grooves found cutting through the seaward slope. The floor of these grooves is covered in places by a thin layer of sand and gravel. A large fraction of the sediments found on the terrace is derived from various species of Halimeda, which are green calcareous algae, and foraminiferan tests.

Seaward Slope Zone

At Tumon Bay this zone begins where the low angled slope of terrace abruptly increases in steepness. At the transect locations, the slope ranges from 30° to 60° and averages 50 m in width. At the 30 to 35 m depth, the slope flattens, forming a second submarine terrace. Width of the second submarine terrace was not measured, but it probably corresponds to the 32 m terrace found by Emery (1962) in several reef profile soundings around the island. Grooves and V-shaped valleys, many of which are contiguous with those mentioned on the outer part of the submarine terrace, cut across the seaward slope and terminate at the beginning of the second submarine terrace. These features are controlled by, and probably represent, remnants of a submerged groove and buttress reef front system developed during a previous glacial ocean stand. Even though the degree of slope is greater than that of the submarine terrace, accumulation of sediments is greater in pockets, holes, valleys, and grooves of this zone. Distinct linear sediment tracks can be traced from the upper part of the slope to the second submarine terrace below. Although depth of sediments was not measured at the second terrace, visual observations made with SCUBA equipment indicate a considerable accumulation at the base of the slope.

Topographic surface relief is much less on the slope than on the first submarine terrace.

Tanguisson Point Fringing Reef

Tanguisson Point study area (Fig. 1) is located north of Tumon Bay between Amantes Point and Tanguisson Point. The fringing reef platform along this section of coastline is relatively narrow (Fig. 5) when compared with Tumon Bay (Fig. 2). It ranges in width from 70 m at transect A to 110 m at transect C. This section of the coast is bordered by limestone cliffs (Fig. 19) and the fringing reef has a westerly exposure to the sea similar to the northern part of Tumon Bay.

The description of the zones here is based on the same physical parameters as is that of Tumon Bay. Distribution of coral in the above zones is discussed in Chapter VI.

Intertidal Zone

The intertidal zone bordering the transect locations is composed of bare limestone, with the exception of a sandy section at Naval Communication Station swimming beach, and another small sandy section between transects B and C. At transect B this zone is 40 m wide and consists of limestone ridges, knobs, and pinnacles, separated by numerous interconnecting channels (Fig. 20). These channels are relatively flat-floored and at about the same general level as the reef flat. The upper half of the emergent structures is exposed during high tide and is deeply solution-pitted. Relief of the emergent structures ranges from about a meter at the shoreward side to 20 cm on the seaward side,

A

B

Fig. 19. Aerial views of Tanguisson Point fringing reefs. A. A view toward the south. Tumon Bay is in the background. B. A view toward the north. NCS swimming beach is in the foreground.

Fig. 20. Intertidal zone at Tanguisson Point, transect B.

where the structures grade into the reef flat. Several smaller patches of the above structures are also found near transect C. Unconsolidated sediments are scarce along the bare rocky regions, except for local patches of coarse gravel and boulders. Sediments at the two sandy beach areas are composed mostly of sand, which is largely composed of worn foraminiferan tests. At low tide fresh water can be seen escaping from the intertidal zone and at sandy locations it forms small rills similar to those described by Emery (1962) at Gognga Beach.

Reef Flat Zone

Inner Reef Flat Subzone

The inner reef flat subzone, unlike that of Tumon Bay, is poorly developed at transects A and C and is absent altogether at Transect B. During low tide at transects A and C, a few shallow, irregular-shaped pools and a depressed zone north of transect C retain water and constitute the moat of the inner reef flat. The floors of these pools are irregular and contain coarse gravel, boulders, and scattered emergent limestone patches. At NCS Beach, water is retained at low tide, but this is partly due to dredging and blasting and does not represent natural conditions.

Outer Reef Flat Subzone

This subzone is more extensive than the inner reef flat and represents most of the reef platform (Fig. 5). At transect B, where no inner reef flat occurs, it extends from the reef margin to the intertidal zones and is 60 m wide. At transects A and C, the subzone width is 40 m and 70 m respectively.

At low tide, the exposed platform is a flat pavement with very little relief. A few small shallow pools (10 to 20 cm deep) are widely scattered over the surface. Sediments are scarce and accumulate only in the small scattered pools. An algal turf covers most of the surface and contains many foraminifera.

Reef Margin Zone

The reef margin is slightly elevated, about 30 cm above the outer reef flat level, and forms a low, poorly-developed algal ridge, however, algal ridge development is greater at transect B. Observations immediately seaward of transect B show that the degree of reef front slope is less than at transects A or C, causing greater wave agitation, thus enhancing algal ridge development. The reef margin width is fairly uniform and, at the transect locations, ranges from 20 to 30 m. Surge channel development and other features of the reef margin are similar to those described for Tumon Bay.

Reef Front Zone

The reef front at the Tanguisson transect location is quite similar in all respects to that described at Tumon Bay, with the exception of submarine buttress development. At Tanguisson the buttresses are similar in size and degree of seaward slope to those at Tumon Bay, but the upper surface has a reduced development of coral-algal knobs, bosses, and pinnacles. Relief of these features is as great as 3 to 4 m at Tumon Bay, whereas at Tanguisson it seldom is over 2 m. Reduction in size or development of these prominences gives the reef front at Tanguisson a smoother, more regular surface. Reef front width ranges from 70 m at transect A, to 50 m at transect C.

Submarine Terrace Zone

This zone ranges in width from 40 m at transect C, to 110 m at transect B. The shoreward margin of this zone begins at the 6 meter contour similar to Tumon Bay, but the seaward margin, where the steep seaward slope begins, is located at the 8 to 10 m contour. Relief of the surface features ranges from 1 to 2 m. Occasional coral mounds or pinnacles attain a relief of 3 m. Shallow channels up to a meter in width and depth cut across the surface at the same locations. The major difference between the submarine terraces at Tumon Bay and Tanguisson Point is that the former has a greater relief of surface structures such as coral-algal knobs, bosses, pinnacles, and shallow grooves. Reduced development of surface features gives the terrace surface at Tanguisson a more uniform, flattened appearance. Sediments are found in localized patches, in holes, in cracks, and in shallow channels. These sediments consist mostly of rounded boulders, coarse sand, and gravel.

Seaward Slope Zone

At the seaward margin of the submarine terrace, the degree of slope abruptly increases and sharply differentiates the seaward slope from the terrace. Degree of slope is greater at the Tanguisson study area than at Tumon Bay. Width of this zone at the three transect locations averages 60 m. The steep seaward slope flattens into a second submarine terrace at about the 30 to 35 m depth. This second terrace probably corresponds to the 32 m terrace found at Tumon Bay. Other characteristics, such as sediments and surface topographic features are like those described for the transect localities at Tumon Bay.

CHAPTER IV

DISTRIBUTION OF CORALS PRIOR TO THE ACANTHASTER PLANCI POPULATION EXPLOSION AT TUMON BAY

Coral distribution at Tumon Bay is based upon specimen collections, field observations, and transect data from Naton and Gognga reefs. By April 4, 1969, a total of six transect studies of the reef flat, reef margins, and reef front zones of northern Tumon Bay were completed prior to *A. planci* depredation of reef corals. Numerous coral collections were also made during this period of time. Another set of transect studies was originally planned for the more windward southern half of Tumon Bay (Fig. 2), but upon investigation during November, 1968, it was found that reef corals of this region were already heavily damaged by *A. planci*. Fortunately, fairly complete coral collections and reef front descriptions were made in this region during July, 1968.

A check-list of corals observed on the transects and collected from the study areas is compiled in Table 1. The classification of the scleractinian corals listed in the table follows that developed by Wells (1956). The table shows that 150 species representing 36 genera were collected and observed. Of the total number, 143 species representing 31 genera are hermatypic scleractinian corals, 2 species representing 2 genera are ahermatypic scleractinian corals, and 5 species representing 3 genera are nonscleractinian corals. The number of ahermatypic scleractinian corals collected or observed at Tumon Bay is low because collections and observations were not made to depths greater than 15 m, nor were any dredging operations carried out on the seaward slopes.

Table 1. Check list of corals that were observed on the transects and collected from the study area at Tumon Bay and Tanguisson Point fringing reefs.

[* indicates that the specimen was collected, # indicates a species which was observed on the transect, + indicates a species which was observed in the study area, ++ indicates a species which was identified from dead corals at Tanguisson Point. The locality and reef zone in which the coral was observed or collected (University of Guam catalog number is included if specimen was collected) follows the symbol. The following reef zone abbreviations are used: IRF, inner reef flat; ORF, outer reef flat; RM, reef margin; RF, reef front; ST, submarine terrace; and SS, seaward slope.]

Class ANTHOZOA

Subclass ZOANTHARIA

Order SCLERACTINIA

Suborder ASTROCOENIINA

Family ASTROCOENIIDAE

Subfamily ASTROCOENIINAE

Genus Stylocoeniella
- Stylocoeniella armata (Ehrenberg, 1834)
  - * Tumon Bay - 307, IRF; 850, 851, ORF; 464, 650, RM
  - * Tanguisson Point - 1555, RF
  - # Tumon Bay - ORF, RM, RF
  - # Tanguisson Point - RF, ST, SS

Family THAMNASTERIIDAE

Genus Psammocora
- Psammocora contigua (Esper, 1797)
  - * Tumon Bay - 39, 40, 41, 42, 43, 201, 202, 279, 325, 942, IRF
  - # Tumon Bay - IRF, ORF, RM
- Psammocora exesa Dana, 1846
  - * Tumon Bay - 30, 31, 236, 1156, IRF
  - # Tumon Bay - ORF
  - # Tanguisson Point - RF
  - ++ Tanguisson Point - SS
- Psammocora nierstraszi van der Horst, 1921
  - # Tumon Bay - ORF, RM, RF
  - # Tanguisson Point - RM, RF, ST
- Psammocora profundacella Gardiner, 1898
  - * Tumon Bay - 835, IRF; 940, ORF; 521, 522, 523, 1162, 1163, 1331, RM
  - # Tumon Bay - IRF, ORF

Table 1 continued.

Psammocora stellata (Verrill, 1866)
* Tumon Bay - 75, 76, IRF
Psammocora verrilli Vaughan, 1907
* Tumon Bay - 639, 640, 641, 1171, RM
Subgenus Stephanaria
Psammocora (S.) togianensis Umbgrove, 1940
* Tumon Bay - 1307, RF
# Tumon Bay - RF
+ Tumon Bay - ST, SS
++ Tanguisson Point - SS
Subgenus Plesioseris
Psammocora (P.) haimeana Milne Edwards and Haime, 1851
* Tumon Bay - 77, 78, 196, 272, 273, IRF; 1176, RM
# Tumon Bay - RM
# Tanguisson Point - SS

Family POCILLOPORIDAE

Genus Stylophora
Stylophora mordax (Dana, 1846)
Tumon Bay - RM, RF
Tanguisson Point - RF, ST
+ Tumon Bay - ST, SS

Genus Seriatopora
Seriatopora hystrix (Dana, 1846)
Tumon Bay - RF

Genus Pocillopora
Pocillopora brevicornis Lamarck, 1816
Tumon Bay - ORF, RM, RF
Pocillopora damicornis (Linnaeus, 1758)
* Tumon Bay - 50, 87, 88, 191, 192, 203, 204, 280, 312, 313, 314, 320, IRF; 1260, RM
Pocillopora danae Verrill, 1864
* Tumon Bay - 542, 1334, RM; 539, 540, 542, RF; 530, ST
# Tumon Bay - RM, RF
+ Tumon Bay - ST, SS
Pocillopora elegans Dana, 1846
* Tumon Bay - 1297, RF

Table 1 continued.

Pocillopora eydouxi Milne Edwards and Haime, 1860
* Tumon Bay - 10, 11, 12, 13, 14, 538, 1206, RF
# Tumon Bay - RF
# Tanguisson Point - RF
+ Tumon Bay - ST, SS
+ Tanguisson Point - ST

Pocillopora ligulata Dana, 1846
* Tumon Bay - 526, 1333, RM; 541, RF
* Tanguisson Point - 1599, 1600, RF

Pocillopora meandrina Dana, 1846
* Tumon Bay - 1336, RM; 1335, 1340, RF.
# Tumon Bay - RM, RF
# Tanguisson Point - ORF, RM, RF

Pocillopora setchelli Hoffmeister, 1929
* Tumon Bay - 1337, 1338, 1339, RF
# Tumon Bay - RM, RF
# Tanguisson Point - RM

Pocillopora verrucosa (Ellis and Solander, 1786)
* Tumon Bay - 257, 1159, 1332, RF
# Tumon Bay - RM, RF
# Tanguisson Point - RM, RF, ST, SS
+ Tumon Bay - ST, SS

Pocillopora sp. 1
Tanguisson Point - ORF, RF, ST

Family ACROPORIDAE

Genus Acropora

Acropora abrotanoides (Lamarck, 1816)
* Tumon Bay - 137, 255, 256, 831, 1164, 1173, 1174, 1175, 1341, RF
# Tumon Bay - RM, RF
# Tanguisson Point - RF

Acropora acuminata Verrill, 1864
* Tumon Bay - 210, 211, IRF; 1134, ORF
# Tumon Bay - IRF, ORF

Acropora arbuscula (Dana, 1846)
* Tumon Bay - 209, IRF

Acropora aspera (Dana, 1846)
* Tumon Bay - 73, 74, IRF
# Tumon Bay - IRF, ORF

Acropora brueggemanni (Brook, 1893)
* Tumon Bay - 832, 833, 834, ORF; 1160, 1161, RM
# Tumon Bay - ORF

Table 1 continued.

Acropora corymbosa (Lamarck, 1816)
* Tumon Bay - 1350, RM
# Tumon Bay - RM, RF
# Tanguisson Point - RF, ST
Acropora cuneata (Dana, 1846)
* Tumon Bay - 1256, ORF
# Tumon Bay - ORF
Acropora diversa (Brook, 1891)
* Tumon Bay - 620, ORF
Acropora hebes (Dana, 1846)
* Tumon Bay - 281, IRF; 1169, 1170, RF
Acropora humilis (Dana, 1846)
* Tumon Bay - 22, RM; 1558, 1566, RF
# Tumon Bay - RF
# Tanguisson Point - RF, SS
Acropora hystrix (Dana, 1846)
* Tanguisson Point - 1550, RF
# Tumon Bay - RF
# Tanguisson Point - RM, RF
Acropora kenti (Brook, 1892)
+ Tumon Bay - ST, SS
++ Tanguisson Point - SS
Acropora lutkeni Crossland, 1952
* Tumon Bay - 1259 RM
Acropora monticulosa (Bruggemann, 1879)
* Tumon Bay - 545, 1346, 1347, RF
Acropora murrayensis Vaughan, 1918
Tumon Bay - RM, RF
Tanguisson Point - RM, RF
Acropora nana (Studer, 1879)
* Tanguisson Point - 1549, RF
# Tumon Bay - IRF, RM, RF
# Tanguisson Point - RM, RF
Acropora nasuta (Dana, 1846)
* Tumon Bay - 317, 318, 319, 323, IRF; 837, 838, 1135, 1136, 1137, 1138, 1139, 1140, 1141, 1142, 1143, 1145, ORF; 263, RM
# Tumon Bay - IRF, ORF, RM, RF
# Tanguisson Point - RM, RF
Acropora nobilis (Dana, 1846)
* Tumon Bay - 1178, IRF
Acropora ocellata (Klunzinger, 1879)
* Tanguisson Point - 1559, 1560, 1561, 1562, RF
# Tumon Bay - RM, RF

Table 1 continued.

Acropora palifera (Lamarck, 1816)
+ Tumon Bay - ST, SS
++ Tanguisson Point - SS
Acropora palmerae Wells, 1954
* Tumon Bay - 1348, RF
# Tumon Bay - RM, RF
# Tanguisson Point - RM, RF
Acropora rambleri (Bassett Smith, 1890)
+ Tumon Bay - ST, SS
++ Tanguisson Point - SS
Acropora rayneri (Brook, 1892)
+ Tumon Bay - ST, SS
++ Tanguisson Point - SS
Acropora smithi (Brook, 1893)
* Tumon Bay - 133, 134, 135, 136, 1300, RF; 1342, ST
# Tumon Bay - RF
# Tanguisson Point - RF
+ Tumon Bay - ST, SS
Acropora squarrosa (Ehrenberg, 1834)
* Tumon Bay - 23, RM
* Tanguisson Point - 1553, 1557, RF
Acropora murrayensis Vaughan, 1918
Tumon Bay - RM, RF
Tanguisson Point - RM, RF
Acropora surculosa (Dana, 1846)
* Tumon Bay - 1146, 1147, ORF; 836, 1438, RM; 254, 1349, 1438, RF; 1352, ST
# Tumon Bay - ORF, RM, RF
#Tanguisson Point - RF, ST
+ Tumon Bay - ST, SS
Acropora syringodes (Brook, 1892)
* Tumon Bay - 1148, 1149, 1150, 1151, 1152, ORF: 465, 1158, 1353, RM
* Tanguisson Point - 1551, 1552, 1563, 1564, RF
# Tumon Bay - RM, RF
Acropora valida (Dana, 1846)
* Tumon Bay - 535, 536, 537, 548, 1344, RF
# Tumon Bay - RF
# Tanguisson Point - RF
Acropora sp. 1
* Tumon Bay - 1165, 1166, RM; 1167, 1168, RF
# Tumon Bay - RM, RF
# Tanguisson Point - RF

Table 1 continued.

Acropora sp. 2
* Tumon Bay - 531, RF
# Tumon Bay - RF
Acropora sp. 3
* Tumon Bay - 821, 822, 823, 824, RF

Genus Astreopora
Astreopora gracilis Barnard, 1896
Tumon Bay - RF
Tanguisson Point - RF, ST
+ Tumon Bay - ST, SS
Astreopora listeri Bernard, 1896
* Tumon Bay - 218, IRF; 466, 467, ORF
Astreopora myriophthalma (Lamarck, 1816)
* Tumon Bay - 331, IRF
# Tumon Bay - IRF, RF
# Tanguisson Point - ST
Astreopora sp. 1
* Tumon Bay - 1207, IRF

Genus Montipora
Montipora acanthella Bernard, 1897
* Tumon Bay - 237, IRF
Montipora composita Crossland, 1952
* Tumon Bay - 481, 482, RF
Montipora conicula Wells, 1954
* Tumon Bay - 524, 525, 617, 618, 1356, 1358, RM
# Tumon Bay - RF
# Tanguisson Point - RF
Montipora elschneri Vaughan, 1918
* Tumon Bay - 616, 1355, RM
Montipora floweri Wells, 1954
* Tumon Bay - 549, 550, RF
Montipora foveolata (Dana, 1846)
Tumon Bay - RF
Tanguisson Point - RF, ST
Montipora granulosa Bernard, 1897
Tanguisson Point - RF
Montipora hoffmeisteri Wells, 1954
Tumon Bay - RM, RF
Tanguisson Point - RF
Montipora lobulata Bernard, 1897
* Tumon Bay - 194, 195, 276, 277, 278, IRF; 1179, ORF
# Tumon Bay - ORF, RM

Table 1 continued.

Montipora monasteriata (Forskaal, 1775)
Tumon Bay - RM, RF
Tanguisson Point - RF
Montipora patula Verrill, 1869
* Tumon Bay - 844, 845, 846, 847, ORF
Montipora planiuscula Dana, 1846
* Tumon Bay - 206, IRF
Montipora spumosa Lamarck, 1816
* Tumon Bay - 273, IRF; 635, 636, RM
Montipora stilosa (Ehrenberg, 1834)
* Tumon Bay - 528, 529, 1354, RF
Montipora tuberculosa (Lamarck, 1816)
Tumon Bay - RF
Tanguisson Point - ST
Montipora verrilli Vaughan, 1907
* Tumon Bay - 647, 648, 649, RM; 527A, 1357, RF
# Tumon Bay - RM, RF
# Tanguisson Point - RM, RF, ST, SS
Montipora verrucosa (Lamarck, 1816)
Tumon Bay - RF
+ Tumon Bay - ST, SS
Montipora sp. 1
Tumon Bay - RF
Tanguisson Point - RF, ST, SS
Montipora sp. 2
Tumon Bay - RF
Tanguisson Point - RF
Montipora sp. 3
* Tumon Bay - 1253, RM
# Tumon Bay - IRF, RM
# Tanguisson Point - ST
Montipora sp. 4
Tumon Bay - RF
Tanguisson Point - RF, ST
Montipora sp. 5
Tanguisson Point - RF
Montipora sp. 6
Tanguisson Point - RF, ST

Table 1 continued

Suborder FUNGIINA

Superfamily AGARICIICAE

Family AGARICIIDAE

Genus Pavona
Pavona clavus (Dana, 1846)
* Tumon Bay - 1359, RF
# Tumon Bay - RM, RF
# Tanguisson Point - RF, ST
+ Tumon Bay - ST, SS
Pavona decussata Dana, 1846
* Tumon Bay - 308, 309, 310, 311, IRF
# Tumon Bay - IRF, ORF
Pavona divaricata (Lamarck, 1816)
* Tumon Bay - 32, 33, 89, 326, IRF
Pavona frondifera Lamarck, 1816
* Tumon Bay - 21, 44, 45, 51, 52, 53, 54, 55, 57, 58, IRF
Pavona varians Verrill, 1864
* Tumon Bay - 215, 216, IRF; 840, 843, ORF; 637, 638, RM
# Tumon Bay - ORF, RM, RF
# Tanguisson Point - RF, ST
Pavona sp. 1
* Tumon Bay - 758, 759, 760, 855, 856, 857, RM
Subgenus Pseudocolumnastrea
Pavona (P.) pollicata Wells, 1954
* Tumon Bay - 1302, 1303, RM
# Tumon Bay - RM, RF
# Tanguisson Point - RF
Subgenus Polyastra
Pavona (P.) planulata (Dana, 1846)
* Tumon Bay - 220, 221, 222, 223, RM
# Tumon Bay - RF
Pavona (P.) obtusata (Quelch, 1884)
* Tumon Bay - 90, 212, 213, 214, IRF; 1250, 1251, ORF
# Tumon Bay - ORF
Pavona (P.) sp. 1
* Tumon Bay - 34, 35, 207, 839, IRF
# Tumon Bay - ORF, RM
Pavona (P.) sp. 2
* Tumon Bay - 198, IRF; 607, 608, 609, 610, RF
Pavona (P.) sp. 3
Tanguisson Point - RF, SS

Table 1 continued

Genus Leptoseris

Leptoseris hawaiiensis Vaughan, 1907

Tumon Bay - RF

Tanguisson Point - SS

Leptoseris incrustans (Quelch, 1886)

* Tumon Bay - 219, RM; 828, 829, 830, RF

Tumon Bay - RM

+ Tumon Bay - ST, SS

Genus Pachyseris

Pachyseris speciosa (Dana, 1846)

+ Tumon Bay - ST, SS

+ Tanguisson Point - SS

++ Tanguisson Point - SS

Family SIDERASTREIDAE

Genus Coscinaraea

Coscinaraea columna (Dana, 1846)

Tumon Bay - RF

Tanguisson Point - RM

++ Tanguisson Point - SS

Superfamily FUNGIICAE

Family FUNGIIDAE

Genus Cycloseris

Cycloseris cyclolites (Lamarck, 1801)

* Tanguisson Point - 1567, SS

Tanguisson Point - SS

Cycloseris sp. 1

* Tanguisson Point - 1568, ST

Tanguisson Point - RF, ST

Genus Fungia

Fungia fungites var. incisa Doederlein, 1902

* Tumon Bay - 442, 443, RF

Fungia fungites var. stylifera Doederlein, 1902

* Tumon Bay - 1305, RF

Tumon Bay - RF

Fungia scutaria Lamarck, 1801

* Tumon Bay - 825, 826, RF

Table 1 continued.

Superfamily PORITICAE

Family PORITIDAE

Genus Goniopora
  Goniopora columna Dana, 1846
    * Tumon Bay - 478, ST
    # Tanguisson Point - ST, SS
    + Tumon Bay - ST, SS
  Goniopora sp. 1
    * Tumon Bay - 322, IRF
    # Tumon Bay - IRF, RF
    ++ Tanguisson Point - SS
  Goniopora sp. 2
    * Tumon Bay - 1257, 1258, RM
    # Tumon Bay - RF

Genus Porites
  Porites annae Crossland, 1952
    * Tumon Bay - 269, 270, ORF
    # Tumon Bay - IRF
  Porites australiensis Vaughan, 1918
    * Tumon Bay - 1308, RM
    # Tumon Bay - RF
    # Tanguisson Point - RF, ST
  Porites cocosensis Wells, 1950
    * Tumon Bay - 17, 208, 274, 275, 332, 757, 837A, 841, 941, IRF
    # Tumon Bay - IRF, ORF
  Porites compressa Vaughan, 1907
    * Tumon Bay - 79, 80, 81, 82, 83, 84, 85, 86, 324, 513, 514, IRF
    # Tumon Bay - IRF, ORF
  Porites duerdeni Vaughan, 1907
    * Tumon Bay - 852, ORF
  Porites lichen Dana, 1846
    * Tumon Bay - 46, IRF; 1252, ORF
  Porites lobata Dana, 1846
    # Tumon Bay - RF
    # Tanguisson Point - RF, ST
  Porites lutea Milne Edwards and Haime, 1851
    * Tumon Bay - 91, 96, 97, 188, 189, 190, 193, 266, 321, 509, 510, 511, 512, 515, 516, 517, 518, 848, 849, 1153, 1154, IRF; 267, 268, 505, 506, 507, 508, ORF; 1360, RF
    # Tumon Bay - IRF, ORF, RF
    # Tanguisson Point - RM, RF, ST, SS

Table 1 continued.

Porites murrayensis Vaughan, 1918
* Tumon Bay - 532, 533, 534, RF
Porites sp. 1
* Tumon Bay - 614, 615, 1361, RM
* Tanguisson Point - 1648, RF
# Tumon Bay - RM, RF
# Tanguisson Point - RM, RF, SS
Porites sp. 2
* Tanguisson Point - 1490, 1491, SS
# Tumon Bay - RF

Subgenus Synaraea
Porites (S.) convexa Verrill, 1864
Tumon Bay - RF
+ Tumon Bay - ST, SS
+ Tanguisson Point - SS
Porites (S.) hawaiiensis Vaughan, 1907
Tanguisson Point - SS
+ Tumon Bay - ST, SS
Porites (S.) horizontalata Hoffmeister, 1925
Tanguisson Point - SS
+ Tumon Bay - ST, SS
Porites (S.) iwayamaensis Eguchi, 1938
* Tumon Bay - 234, IRF; 503, 504, RF
# Tumon Bay - RF
# Tanguisson Point - ST, SS
+ Tumon Bay - ST, SS
Porites (S.) sp. 1
* Tumon Bay - 501, IRF

Genus Alveopora
Alveopora verrilliana Dana, 1872
* Tanguisson Point - 1570, ST
# Tumon Bay - RF

Suborder FAVIINA

Superfamily FAVIICAE

Family FAVIIDAE

Subfamily FAVIINAE

Ganus Favia
Favia favus (Forskaal, 1775)
* Tumon Bay - 258, 259, 1364, 1365, 1367, RF; 1366, ST
# Tanguisson Point - RF, ST
+ Tumon Bay - ST, SS

Table 1 continued.

Favia pallida (Dana, 1846)
Tumon Bay - IRF, ORF, RF
Tanguisson Point - RM, RF, ST, SS
Favia speciosa (Dana, 1846)
Tumon Bay - RF
Favia stelligera (Dana, 1846)
* Tumon Bay - 140, 620A, RF
# Tumon Bay - RM, R F
# Tanguisson Point - RM, RF, ST
+ Tumon Bay - ST, SS
Favia valenciennesii (Milne Edwards and Haime, 1850)
* Tumon Bay - 253, IRF
# Tanguisson Point - ST

Genus Favites
Favites abdita (Ellis and Solander, 1786)
* Tumon Bay - 264, 265, ORF
# Tumon Bay - RF
Favites complanata (Ehrenberg, 1834)
* Tanguisson Point - 1601, ST
# Tumon Bay - RM, RF
# Tanguisson Point - RF, ST, SS
+ Tumon Bay - ST, SS
Favites favosa (Ellis and Solander, 1786)
Tanguisson Point - ST
Favites flexuosa (Dana, 1846)
Tanguisson Point - SS

Genus Plesiastrea
Plesiastrea versipora (Lamarck, 1816)
* Tumon Bay - 546, 547, 1362, 1363, RF
* Tanguisson Point - 1639, RM
# Tumon Bay - RM, RF
# Tanguisson Point - RM, RF
++ Tanguisson Point - SS
Plesiastrea sp. 1
Tumon Bay - RM, RF

Genus Goniastrea
Goniastrea parvistella (Dana, 1846)
Tumon Bay - RM, RF
Tanguisson Point - RF, ST
Goniastrea pectinata (Ehrenberg, 1834)
Tanguisson Point - ST, SS

Table 1 continued.

Goniastrea retiformis (Lamarck, 1816)
* Tumon Bay - 49, 94, 95, 328, 329, 330, IRF; 612, 613, 1368, RF
# Tumon Bay - IRF, ORF, RM, RF
# Tanguisson Point - RM, RF, ST

Genus Platygyra
Platygyra rustica (Dana, 1846)
* Tumon Bay - 37, 38, 235, IRF
# Tumon Bay - RF
# Tanguisson Point - RF, ST
Platygyra sinensis (Milne Edwards and Haime, 1849)
* Tumon Bay - 1369, RF
* Tanguisson Point - 1568, RF
# Tumon Bay - RF
# Tanguisson Point - RF, ST

Genus Leptoria
Leptoria gracilis (Dana, 1846)
* Tumon Bay - 36, IRF; 1372, RM
* Tanguisson Point - 1603, 1647, RF
# Tumon Bay - ORF, RM, RF
# Tanguisson Point - RM, RF, ST
Leptoria phrygia (Ellis and Solander, 1786)
* Tumon Bay - 271, 334, 827, IRF; 139, 611, 1370, RF
* Tanguisson Point - 1602, 1646, RF
# Tumon Bay - ORF, RF
# Tanguisson Point - RM, RF, ST

Genus Hydnophora
Hydnophora microconos (Lamarck, 1816)
* Tumon Bay - 543, 544, RF
# Tumon Bay - RM, RF
# Tanguisson Point - RF
++ Tanguisson Point - SS

Subfamily MONTASTREINAE

Genus Leptastrea
Leptastrea bottae (Milne Edwards and Haime, 1849)
* Tumon Bay - 92, 93, 224, 327, IRF
Leptastrea purpurea (Dana, 1846)
Tumon Bay - RM, RF
Tanguisson Point - RF, ST, SS

Table 1 continued.

Leptastrea transversa (Klunzinger, 1879)
    * Tanguisson Point - 1571-1, RF
    # Tanguisson Point - ST, SS
Leptastrea sp. 1
    # Tumon Bay - RF
    # Tanguisson Point - RF, SS
    + Tumon Bay - ST, SS

Genus Cyphastrea
Cyphastrea serailia (Forskaal, 1775)
    # Tumon Bay - RF
    # Tanguisson Point - RF
    ++ Tanguisson Point - SS
Cyphastrea sp. 1
    # Tumon Bay - RF
    # Tanguisson Point - RF, SS

Genus Echinopora
Echinopora lamellosa (Esper, 1787)
    * Tumon Bay - 479, 480, 1306, RF
    # Tumon Bay - RF
    # Tanguisson Point - RF, SS

Genus Disploastrea
Disloastrea heliopora (Lamarck, 1816)
    # Tumon Bay - RF
    + Tumon Bay - ST, SS
    + Tanguisson Point - ST, SS

Family OCULINIDAE

Subfamily GALAXEINAE

Genus Galaxea
Galaxea fascicularis (Linnaeus, 1758)
    * Tumon Bay - 56, IRF; 1254, RM
    # Tumon Bay - ORF, RM, RF
    # Tanguisson Point - RF, ST, SS
Galaxea hexagonalis Milne Edwards and Haime, 1857
    * Tumon Bay - 642, 643, 644, 645, 646, RM
    # Tumon Bay - RM, RF
    # Tanguisson Point - RF, ST, SS

Table 1 continued.

Family MUSSIDAE

Genus Lobophyllia
    Lobophyllia corymbosa (Forskaal, 1775)
        # Tumon Bay - RF
        # Tanguisson Point - SS
    Lobophyllia costata (Dana, 1846)
        * Tumon Bay - 24, 25, 26, 27, IRF; 138, 260, 261, 262, 1304, 1373, RM
        # Tumon Bay - RF
        # Tanguisson Point - RF, ST

Genus Acanthastrea
    Acanthastrea echinata (Dana, 1846)
        * Tanguisson Point - 1645, RF
        # Tumon Bay - RF
        # Tanguisson Point - RF, ST

Family PECTINIIDAE

Genus Echinophyllia
    Echinophyllia asper Ellis and Solander, 1786
        # Tanguisson Point - SS

Suborder CARYOPHYLLIINA

Superfamily CARYOPHYLLIICAE

Family CARYOPHYLLIIDAE

Subfamily CARYOPHYLLIINAE

Genus Paracyathus
    Paracyathus sp. 1
        * Tumon Bay - 640A, RM

Genus Polycyathus
    Polycyathus verrilli Duncan, 1889
        * Tumon Bay - 1386, ORF

Subfamily EUSMILIINAE

Genus Euphyllia
    Euphyllia glabrescens (Chamisso and Eysenhardt, 1821)
        * Tumon Bay - 47, 48, 205, 316, 333, IRF

Table 1 continued.

Subclass OCTOCORALLIA

Order COENOTHECALIA

Family HELIOPORIDAE

Genus Heliopora
    Heliopora coerulea (Pallas, 1766)
        * Tumon Bay - 28, 29, 306, IRF; 605, 606, 1374, RF
        # Tumon Bay - IRF, ORF, RF
        # Tanguisson Point - ST
        + Tumon Bay - ST, SS

Class HYDROZOA

Order MILLEPORINA

Family MILLEPORIDAE

Genus Millepora
    Millepora dichotoma Forskaal, 1775
        # Tumon Bay - RF
        # Tanguisson Point - RF
        + Tanguisson Point - ST
    Millepora exaesa Forskaal, 1775
        # Tumon Bay - RF
        # Tanguisson Point - RF, ST
    Millepora platyphylla Hemprich and Ehrenberg, 1834
        * Tumon Bay - 141, 519, 520, 1177, 1205, 1375, RM; 527B, 546A, 1157, RF
        # Tumon Bay - ORF, RM, RF
        # Tanguisson Point - RM, RF
        + Tanguisson Point - ST

Order STYLASTERINA

Family STYLASTERIDAE

Subfamily DISTICHOPORINAE

Genus Distochopora
    Distochopora violacea (Pallas, 1776)
        * Tumon Bay - 551, RF; 460, 461, 462, 463, ST
        # Tumon Bay - RF
        # Tanguisson Point - RM
        + Tumon Bay - ST, SS

Table 2 lists the frequency distribution of coral species that occurred by reef zones on Naton and Gognga reef transects. A total of 103 species representing 32 genera were observed on these transects.

Figure 21 shows the distribution of genera and species by 10 m transect sections and by reef zones. Zonal distribution of corals at Gognga and Naton transects was similar in number of genera and species, with the exception of the outer reef flat zone at Gognga, which had 6 species and 4 genera and two transect sections without corals. In contrast, the outer reef flat zone at Naton had a maximum of 13 species and 8 genera and had some corals in all sections. The low number of coral species at the Gognga outer reef flat zone is due to the exposure of this zone during the lower tides, whereas at Naton this zone is slightly lower in elevation and is usually covered with water.

<u>Intertidal Zone (5 meters wide)</u>

No living corals were found in this zone at the study region due to reef surface exposure during low tides, although on the windward side of the island, near Catalina Point (Fig. 1), raised bench pools located several meters above high tide level contained living corals. Several sections of coastline with similar pools are found along Tumon Bay at Saupon Point and Amantes Point (Fig. 1), but here, because of the semi-windward orientation of the shore, the pools are not constantly awash as they are at Catalina Point.

<u>Reef Flat Zone (460 to 480 meters wide)</u>

Based on reef surface exposure during low tides, this zone is subdivided into inner and outer reef flat subzones.

Inner Reef Flat Subzone (350 to 380 meters wide)

The shoreward 220 m section of this subzone is, in most places, nearly barren of corals. Living coral covering the reef surface of this section (Fig. 22) shows a range of from 0 to 5 per cent. The reef surface is

Table 2. Frequency distribution of coral species at the combined Naton and Gognga transects, Tumon Bay, by reef zones. [Species are listed in order of decreasing frequency of occurrence when all zones are combined.]

Name of Coral	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Acropora nasuta	5	.79	106	18.96	255	49.32	53	3.32	419	12.69
Acropora aspera	268	42.61	85	15.21	---	---	---	---	353	10.69
Pocillopora damicornis	133	21.14	41	7.33	19	3.68	---	---	193	5.84
Acropora acuminata	93	14.79	86	15.38	---	---	---	---	179	5.42
Psammocora contigua	62	9.86	99	17.71	5	.97	---	---	166	5.03
Pocillopora verrucosa	---	---	---	---	40	7.74	93	5.82	133	4.03
Goniastrea retiformis	7	1.11	41	7.33	11	2.13	56	3.51	115	3.48
Porites sp. 1	---	---	---	---	23	4.45	69	4.32	92	2.79
Acropora nana	2	.32	---	---	43	8.32	43	2.69	88	2.67
Porites lutea	21	3.34	39	6.98	---	---	26	1.63	86	2.60
Montipora verrilli	---	---	---	---	7	1.35	76	4.76	83	2.51
Galaxea hexagonalis	---	---	---	---	1	.19	77	4.82	78	2.36
Leptastrea purpurea	---	---	---	---	2	.39	73	4.57	75	2.27
Favia stelligera	---	---	---	---	3	.58	69	4.32	72	2.18
Acropora surculosa	---	---	1	.18	10	1.93	57	3.57	68	2.06
Porites lobata	---	---	---	---	---	---	55	3.44	55	1.67
Leptoria gracilis	---	---	1	.18	4	.77	41	2.57	46	1.36
Pavona clavus	---	---	---	---	3	.58	42	2.63	45	1.36
Acropora corymbosa	---	---	---	---	2	.39	37	2.32	39	1.18
Millepora platyphylla	---	---	3	.54	15	2.90	19	1.19	37	1.12

Table 2 continued.

Name of Coral	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Pocillopora setchelli	---	---	---	---	16	3.09	21	1.32	37	1.12
Porites (Synaraea) iwayamaensis	---	---	---	---	---	---	34	2.13	34	1.03
Pavona varians	---	---	3	.54	2	.39	25	1.57	30	.91
Millepora exaesa	---	---	---	---	---	---	29	1.82	29	.88
Acropora sp. 1	---	---	---	---	3	.58	23	1.44	26	.79
Pocillopora meandrina	---	---	---	---	5	.97	21	1.32	26	.79
Montipora sp. 1	---	---	---	---	---	---	25	1.57	25	.75
Favites complanata	---	---	---	---	1	.19	21	1.32	22	.67
Goniastrea parvistella	---	---	---	---	5	.97	16	1.00	21	.64
Pocillopora eydouxi	---	---	---	---	---	---	21	1.32	21	.64
Stylophora mordax	---	---	---	---	1	.19	20	1.25	21	.64
Acropora ocellata	---	---	---	---	6	1.16	14	.88	20	.61
Acropora humilis	---	---	---	---	---	---	18	1.13	18	.55
Acropora smithi	---	---	---	---	---	---	18	1.13	18	.55
Cyphastrea sp. 1	---	---	---	---	---	---	17	1.06	17	.51
Acanthastrea echinata	---	---	---	---	---	---	16	1.00	16	.48
Favia pallida	1	.16	3	.54	---	---	12	.75	16	.48
Pavona decussata	10	1.59	6	1.07	---	---	---	---	16	.48
Pavona (Polyastra) sp. 1	---	---	14	2.50	1	.19	---	---	15	.45
Acropora abrotanoides	---	---	---	---	1	.19	13	.81	14	.42
Porites australiensis	---	---	---	---	---	---	14	.88	14	.42

Table 2 continued.

Name of Coral	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Porites (Synaraea) convexa	---	---	---	---	---	---	14	.88	14	.42
Acropora vallida	---	---	---	---	---	---	13	.81	13	.39
Montipora conicula	---	---	---	---	---	---	13	.81	13	.39
Montipora verrucosa	---	---	---	---	---	---	13	.81	13	.39
Platygyra rustica	---	---	---	---	---	---	13	.81	13	.39
Plesiastrea versipora	---	---	---	---	2	.39	11	.69	13	.39
Montipora foveolata	---	---	---	---	---	---	13	.81	13	.39
Acropora palmerae	---	---	---	---	7	1.35	5	.31	12	.36
Cyphastrea serailia	---	---	---	---	---	---	12	.75	12	.36
Porites cocosensis	10	1.59	2	.36	---	---	---	---	12	.36
Stylocoeniella armata	---	---	2	.36	2	.39	8	.50	12	.36
Hydnophora microconos	---	---	---	---	1	.19	10	.63	11	.33
Platygyra sinensis	---	---	---	---	---	---	11	.69	11	.33
Psammocora nierstraszi	---	---	2	.36	2	.39	7	.44	11	.33
Psammocora profundacella	6	.95	5	.89	---	---	---	---	11	.33
Acropora syringodes	---	---	---	---	1	.19	9	.56	10	.30
Favia speciosa	---	---	---	---	---	---	10	.63	10	.30
Montipora sp. 2	---	---	---	---	---	---	10	.63	10	.30
Pocillopora brevicornis	---	---	1	.18	4	.77	5	.31	10	.30
Astreopora gracilis	---	---	---	---	---	---	9	.56	9	.27
Lobophyllia corymbosa	---	---	---	---	---	---	9	.56	9	.27
Montipora hoffmeisteri	---	---	---	---	1	.19	8	.50	9	.27
Montipora monasteriata	---	---	---	---	2	.39	7	.44	9	.27

Table 2 continued

Name of Coral	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Plesiastrea sp. 1	---	---	---	---	1	.19	8	.58	9	.27
Acropora murrayensis	---	---	---	---	1	.20	7	.44	8	.24
Galaxea fascicularis	---	---	1	.18	1	.19	6	.38	8	.24
Heliopora coerulea	1	.16	1	.18	---	---	6	.38	8	.24
Montipora tuberculosa	---	---	---	---	---	---	8	.50	8	.24
Goniopora sp. 1	2	.32	---	---	---	---	5	.31	7	.21
Leptastrea sp. 1	---	---	---	---	---	---	7	.44	7	.21
Lobophyllia costata	---	---	---	---	---	---	7	.44	7	.21
Pavona (Pseudocolumnastrea) pollicata	---	---	---	---	3	.58	4	.25	7	.21
Acropora brueggemanni	---	---	6	1.07	---	---	---	---	6	.18
Acropora hystrix	---	---	---	---	---	---	6	.38	6	.18
Coscinaraea columna	---	---	---	---	---	---	6	.38	6	.18
Seriatopora hystrix	---	---	---	---	---	---	6	.38	6	.18
Psammocora (Stephanaria) togianensis	---	---	---	---	---	---	6	.38	6	.18
Millepora dichotoma	---	---	---	---	---	[illegible]	6	.38	6	.18
Porites compressa	3	.48	3	.54	---	---	---	---	6	.18
Astreopora myriophthalma	1	.16	---	---	---	---	4	.25	5	.15
Pavona (Polyastra) planulata	---	---	---	---	---	---	5	.31	5	.15
Pocillopora danae	---	---	---	---	1	.19	3	.19	4	.12
Alveopora verrilliana	---	---	---	---	---	---	3	.19	3	.09
Goniopora sp. 2	---	---	---	---	---	---	3	.19	3	.09

Table 2 continued.

Name of Coral	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Leptoria phrygia	---	---	2	.36	---	---	1	.06	3	.09
Montipora lobulata	---	---	2	.36	1	.19	---	---	3	.09
Distichopora violacea	---	---	---	---	---	---	3	.19	3	.09
Echinopora lamellosa	---	---	---	---	---	---	3	.19	3	.09
Montipora sp. 3	1	.16	---	---	2	.39	---	---	3	.09
Porites annae	3	.48	---	---	---	---	---	---	3	.09
Diploastrea heliopora	---	---	---	---	---	---	3	.19	3	.09
Fungia fungites var. stylifera	---	---	---	---	---	---	2	.13	2	.06
Acropora cuneata	---	---	1	.18	---	---	---	---	1	.03
Acropora sp. 2	---	---	---	---	---	---	1	.06	1	.03
Favites abdita	---	---	1	.18	---	---	---	---	1	.03
Leptoseris hawaiiensis	---	---	---	---	---	---	1	.06	1	.03
Leptoseris incrustans	---	---	---	---	1	.19	---	---	1	.03
Pavona (Polyastra) obtussata	---	---	1	.18	---	---	---	---	1	.03
Porites sp. 2	---	---	---	---	---	---	1	.06	1	.03
Montipora sp. 4	---	---	---	---	---	---	1	.06	1	.03
Psammocora exesa	---	---	1	.18	---	---	---	---	1	.03
Psammocora (Plesioseris) haimeana	---	---	---	---	1	.19	---	---	1	.03
Total	629	100.00%	559	100.00%	517	100.00%	1597	100.00%	3302	100.00%
Total species	18		29		44		84		103	
Total genera	11		14		18		32		32	

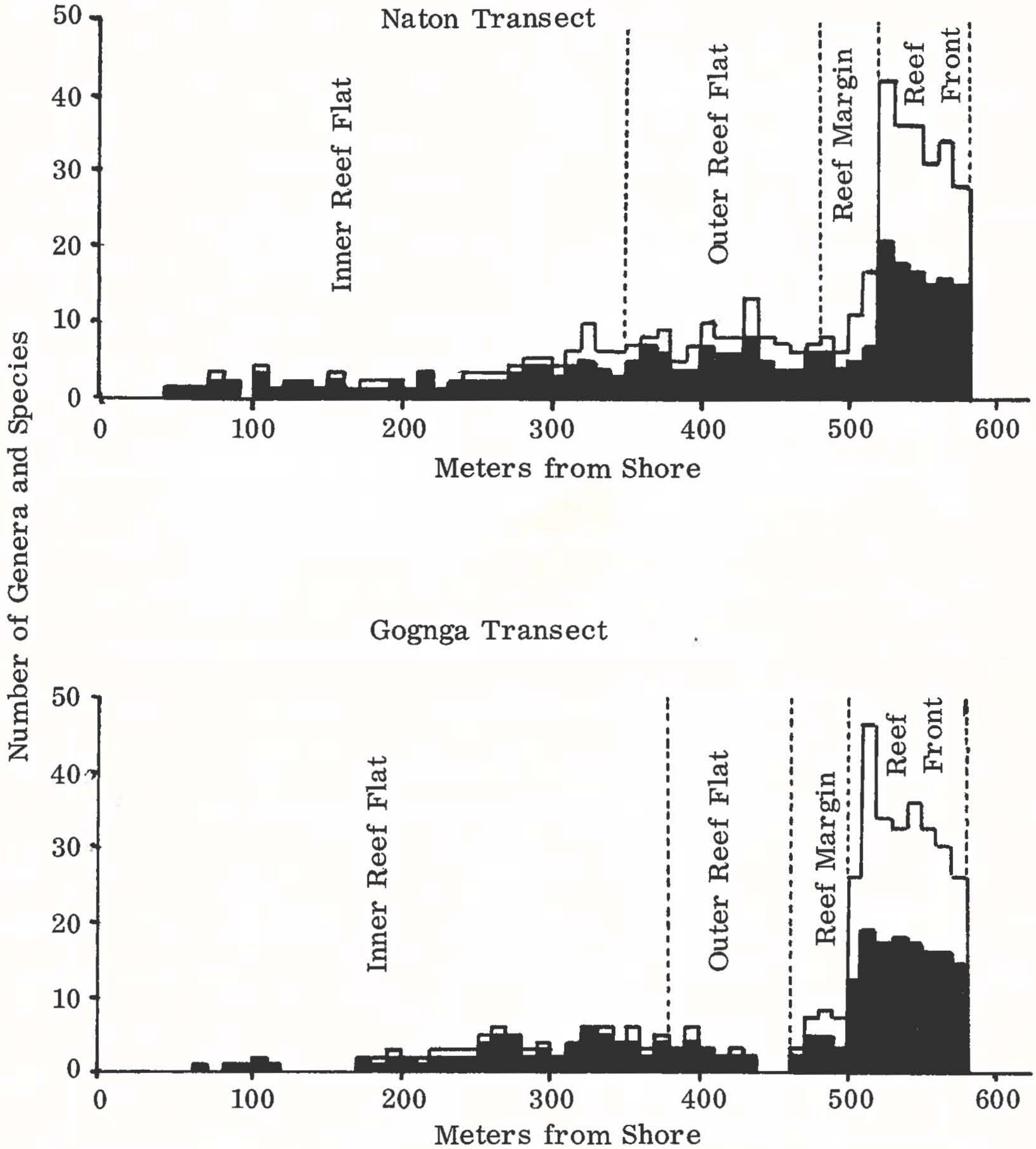

Fig. 21. Number of genera and species per 10 m transect section at Naton and Gognga, Tumon Bay. Each column represents a 10 m section of the transect. Shaded area indicates genera; unshaded indicates species.

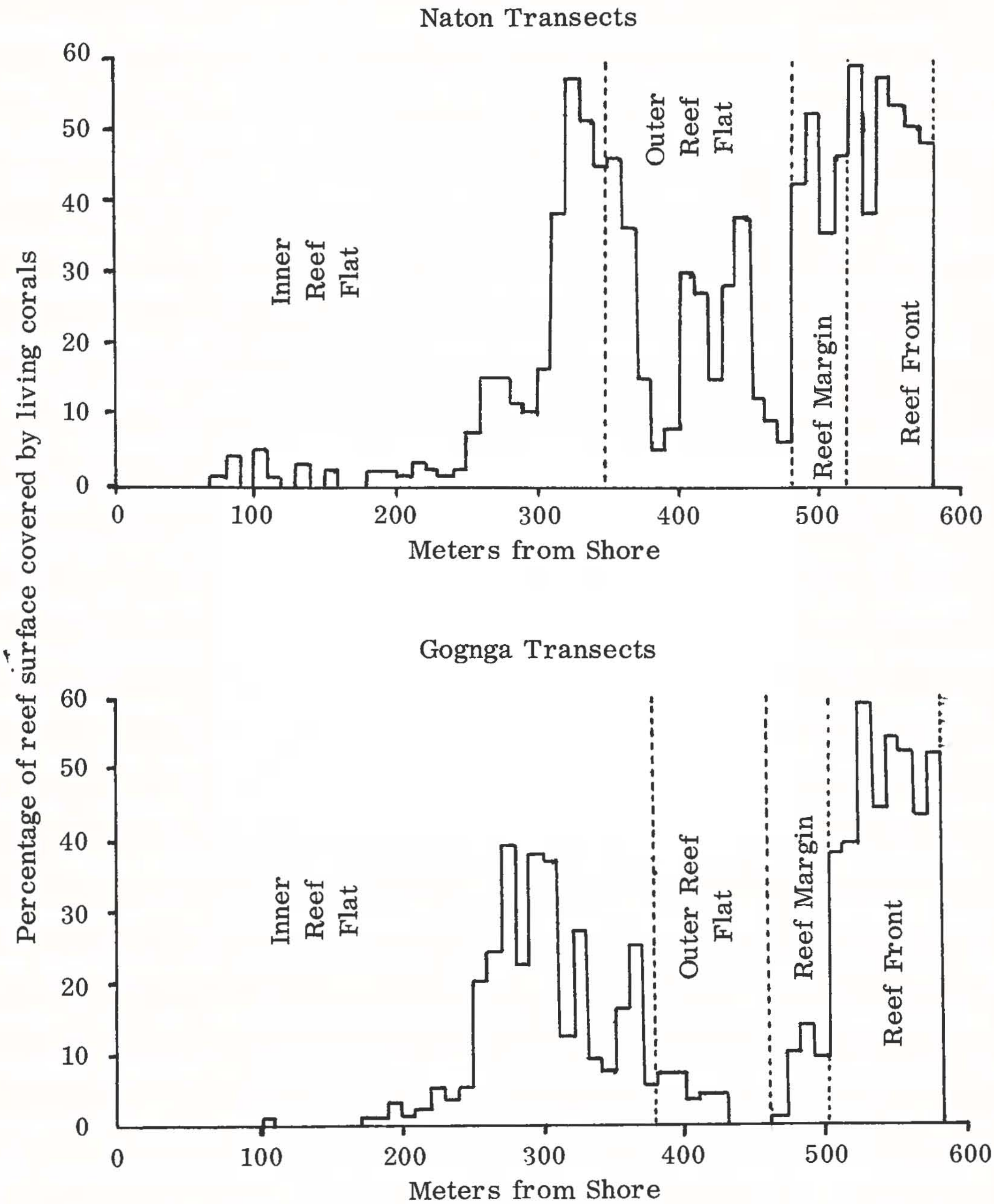

Fig. 22. Percentage of reef surface covered by living corals at Naton and Gognga transects. Each column represents a 10 m section of the transects.

characterized by widely scattered coral colonies, consisting mainly of broken fragments that have been worked shoreward by storm waves from more extensive, living beds found growing farther seaward near the outer reef flat. Porites lutea (Fig. 23), due to its massive size, is about the only coral found in this section with any degree of stability during storms. Another factor accounting for the paucity of living corals within this inner band is the presence of unconsolidated sediments that are relatively unstable and that prevent coral planula settlement. Most new colonies that do manage to settle, do so on larger pieces of coral rubble or boulders that are more stable.

The seaward 150 to 180 m section of this subzone is considerably different from the shoreward 200 m section, particularly in the percentage of reef surface covered by living corals. Planula settlement is enhanced by the presence of large areas of bare reef-rock, mounds of coral-algal-mollusc rubble, boulders, and a reduction in the quantity of unconsolidated sediments. A sharp increase in percentage of coral cover, from a maximum of nearly 5 per cent for the inner 200 m section to 57 per cent for the outer 150 to 180 m section, is found. This sharp increase in percentage of cover is not represented by a relative increase in the number of species (Fig. 21), but is due to the greater density of Acropora aspera and Acropora acuminata. These two species form large arborescent (staghorn) thickets, 1 to 20 m across (Fig. 24). Also abundant in areas between and intermixed with the above thickets are finely branched colonies of Pocillopora damicornis and Psammocora contigua. Less common are large corals of massive and anastomosing ramose growth form which produce low convex, hemispherical, and circular flat-topped colonies called microatolls (Fig. 25). These larger coralla attain diameters up to several meters, but are limited in upward growth by the depth of the moat during low tides. In order of their abundance, they are Porites lutea, Porites cocosensis, Goniastrea retiformis, Porites annae, and Porites compressa. The above corals actually cover only a small percentage of the reef surface when compared to coverage by the arborescent Acropora species, but they are conspicuous and abundant in some sites. A particularly rich growth of

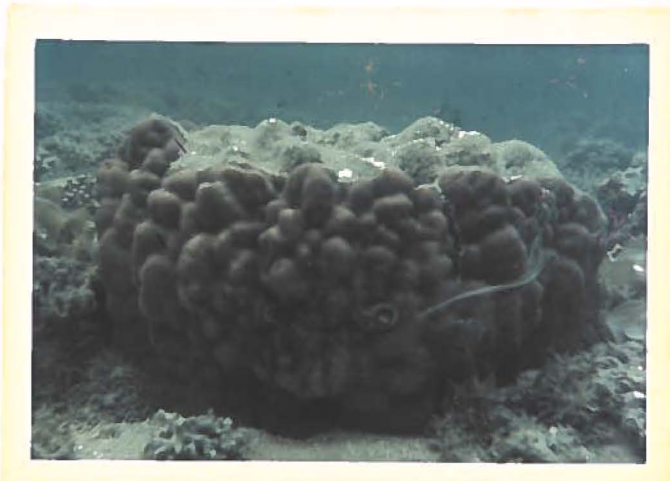

Fig. 23. Large massive colony of Porites lutea found on the inner section of the inner reef flat.

Fig. 24. A thicket of Acropora acuminata (staghorn) about 1 m across. The colony is located on the outer (seaward) section of the inner reef flat at Tumon Bay.

Fig. 25. Large microatolls of Porites lutea on the inner reef flat at Tumon Bay. The larger colony is about 4 m across and 20 to 30 cm high. Only the margin of the colony is living; the upper surface of the colony is dead because of exposure at low tide.

Pavona decussata and other corals is found along the limestone cliff at Gognga Point. Other regions with local concentrations of corals, other than Acropora species, are located between Gognga and Naton transects and the area seaward of the dredged swimming zone at Ypao Beach.

Conspicuous mounds of Acropora rubble, interspersed among luxuriant living patches, are formed when storm waves transport large quantities of coarse sediments and cover entire arborescent patches. During a tropical storm that occurred during November, 1967, numerous patches of Acropora aspera and Acropora acuminata were partially to completely covered with coarse sediments and many were killed. Growth rates of these arborescent species seem to be high, judging from observations of axial polyp regeneration which occurred within a few weeks (0.5 cm new growth) where stem tips were broken by this storm. Fast growth rates, plus recovery of the unburied branch tips, explain the presence of living coral patches interspersed with dead mounds and a general dominance of these species in unstable substrate environments.

Table 2 lists a total of 18 species representing 11 genera that were encountered on the inner reef flat subzone portions of the Gognga and Naton transects. The total number of corals from the inner reef flat is increased to 48 species and 18 genera (Table 1) when a general collection of specimens from this zone is included. Relative frequencies of coral species from Table 2 indicate that four of the 18 species from the inner reef flat, Acropora aspera, Pocillopora damicornis, Acropora acuminata and Psammocora contigua, account for 88 per cent of the 629 colonies encountered on the transects. Four of the 18 species were each represented by only one colony. The greatest number of genera and species encountered on any one transect section of the reef flat subzone (Fig. 21), was 6 and 10 respectively at Naton transect.

Outer Reef Flat Subzone (80 to 130 meters wide)

Due to reef surface exposure at low tide, this subzone is conspicuously barren of corals (Fig. 26), except where it grades into the inner reef flat and in scattered shallow reef pools. At Gognga transect, the percentage of corals

Fig. 26. Barren outer reef flat at Ypao Point during low tide.

covering the substratum (Fig. 22) drops from a high of 37 for the inner reef flat to a low of 7 for the outer reef flat. Two transect sections (45 and 46) at Gognga had no living corals present. Gognga transect is more typical of outer reef flat coral distribution along Tumon Bay than is Naton transect. At Naton transect, the reef floor is slightly depressed and a small shallow channel cuts across the outer reef at the study area, which increases the water depth there. The slightly deeper water and increased current, due to water movement in the channel, enhance coral development of this zone. This rich coral growth at Naton gives Fig. 22 a trilobed appearance and explains the major differences between the two transects.

Acropora aspera and Acropora acuminata patches are common where the subzone grades into the moat of the inner reef flat. Low tides limit upward growth of these patches, giving them a flat-topped, clipped appearance (Fig. 27). Intersperced among the Acropora beds are shallow pools which contain abundant colonies of Acropora nasuta, Goniastrea retiformis, Pocillopora damicornis, Porites lutea, and Psammocora contigua. Less common are scattered colonies of Acropora brueggemanni, Pavona decussata, Pavona (Polyastra) sp. 1, and Psammocora profundacella. Small encrusting patches of Stylocoeniella armata are common in small cavities and on the bases of larger corals. The central and outer part of this subzone is a pavement-like platform along most of Tumon Bay and has broad regions where corals are absent. Stunted growths of Porites lutea, Favia pallida, and Goniastrea retiformis occupy the margins of widely scattered pools, a few centimeters in depth, over the central region. These pools and their inconspicuous corals account for the low number of species (Fig. 21) and low percentage of coral (Fig. 22) covering the reef surface for transect sections 41 through 47 at Gognga transects.

Table 2 lists 29 species representing 14 genera from the outer reef flat subzone. Eight species were collected in this subzone that were not represented on the transects, which increases the total number of species to 37 and of genera to 16.

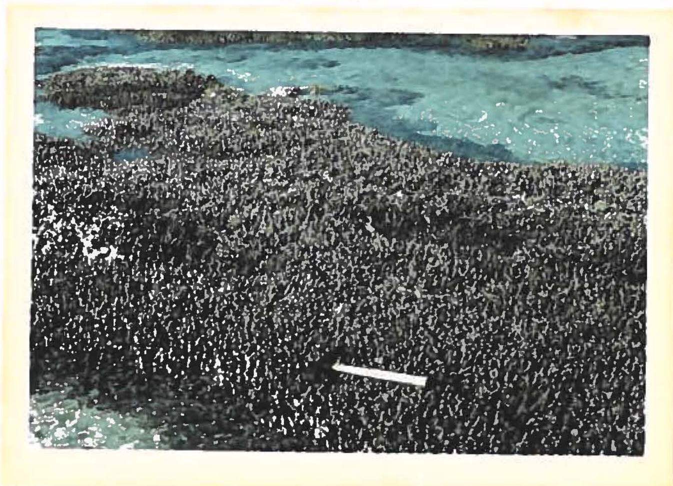

Fig. 27. Large flat-topped thicket of Acropora aspera with the dead upper surface exposed at low tide. The colony is located on the outer reef flat where it merges into the moat of the inner reef flat at Tumon Bay.

Four hundred eighty four coral colonies were recorded on the outer reef flat at Naton transect (Table 3), whereas at Gognga transect only 75 colonies were recorded in the comparable area (Table 4). The large number of coral colonies encountered at Naton transect was to be expected because of habitat characteristics which are similar to those found on the inner reef flat subzone. Another factor which increases the number of colonies occurring there is fragmentation, due to strong wave action, of ramose species of Acropora nasuta and Psammocora contigua. The deeper water at the outer reef flat at Naton enhances continued growth of numerous fragments, whereas at Gognga many of the fragments are transported to the exposed part of the outer reef flat where they are killed by exposure at low tide.

Coral diameter at Naton outer reef flat transect is similar to that found on the inner reef flat transect (Table 5), whereas at Gognga outer reef flat transect coralla size decreases considerably (Table 6). Decrease in corallum size is to be expected because of the decrease in the number of large arborescent staghorn patches that occur on the wave-washed outer reef flat (Table 3 and 4).

Reef Margin Zone (40 meters wide)

This zone is constantly awash, even during the lowest tides, and is the region of greatest water agitation. It is sharply discriminated from the barren outer reef flat by an increase in the number of coral species per transect section (Fig. 21), plus a similar increase in the percentage of living corals covering the reef surface (Fig. 22). Transition into this zone at Naton is not distinct as is that at Gognga, but luxuriant coral growth in a series of reef margin pools increases the coral covering the reef surface from 40 per cent for the outer reef flat to a high of 52 per cent for the reef margin (Fig. 21 and 22).

Three distinct habitats found in this zone are the well-lighted, upper surfaces of lobate spurs that separate surge channels, the open surge channel walls and pools, and the poorly-lighted, cavernous sections of surge channels and pools.

Table 3. Distribution of coral growth forms by reef zones at Naton Transects, Tumon Bay.

Growth form	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Massive	18	5.1	44	9.1	38	9.3	170	23.8	270	13.8
Encrusting	2	.6	12	2.5	37	9.1	121	16.9	172	8.8
Foliaceous	2	.6	3	.6	0	---	2	.3	7	.4
Flabellate	1	.3	4	.8	10	2.5	25	3.5	40	2.0
Corymbose	5	1.4	123	25.4	203	49.9	148	20.7	479	24.5
Cespitose	119	33.9	132	27.3	119	29.2	186	26.1	556	28.4
Arborescent	204	58.1	152	31.4	0	---	30	4.2	386	19.7
Phaceloid	0	---	0	---	0	---	0	---	0	---
Columnar	0	---	14	2.9	0	---	29	4.1	43	2.2
Solitary	0	---	0	---	0	---	3	.4	3	.2
Total	351	100.0%	484	100.0%	407	100.0%	714	100.0%	1956	100.0%

Table 4. Distribution of coral growth forms by reef zones at Gognga Transects, Tumon Bay.

Growth form	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Massive	23	8.3	34	45.3	1	.9	236	26.7	294	21.8
Encrusting	0	---	0	---	16	14.5	269	30.5	285	21.2
Foliaceous	8	2.9	2	2.7	0	---	0	---	10	.7
Flabellate	0	---	0	---	0	---	19	2.2	19	1.4
Corymbose	0	---	0	---	48	43.6	146	16.5	194	14.4
Cespitose	87	31.3	21	28.0	45	40.9	163	18.5	316	23.5
Arborescent	160	57.6	18	24.0	0	---	23	2.6	201	14.9
Phaceloid	0	---	0	---	0	---	2	.2	2	.1
Columnar	0	---	0	---	0	---	25	2.8	25	1.9
Solitary	0	---	0	---	0	---	0	---	0	---
Total	278	100.0%	75	100.0%	110	100.0%	883	100.0%	1346	100.0%

Table 5. Distribution of corallum diameter by reef zones at Naton Transects, Tumon Bay.

Diameter range in cm	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
0-5	65	18.5	100	20.7	107	26.3	207	29.0	479	24.5
6-10	126	35.9	169	34.9	122	30.0	150	21.0	567	29.0
11-15	51	14.5	89	18.4	66	16.2	90	12.6	296	15.1
16-20	26	7.4	40	8.3	41	10.1	75	10.5	182	9.3
21-25	10	2.8	17	3.5	27	6.6	69	9.7	123	6.3
26-30	29	8.3	22	4.5	30	7.4	51	7.1	132	6.7
31-35	2	.6	9	1.9	4	1.0	15	2.1	30	1.5
36-40	4	1.1	5	1.0	4	1.0	12	1.7	25	1.3
41-45	2	.6	4	.8	2	.5	12	1.7	20	1.0
46-50	1	.3	4	.8	2	.5	6	.8	13	.7
51-60	9	2.6	7	1.4	1	.2	9	1.3	26	1.3
61-70	0	---	2	.4	0	---	3	.4	5	.3
71-80	0	---	3	.6	0	---	4	.6	7	.4
81-90	4	1.1	3	.6	1	.2	2	.3	10	.5
91-100	4	1.1	2	.4	0	---	3	.4	9	.5
101-150	7	2.0	3	.6	0	---	2	.3	12	.6
151-200	4	1.1	4	.8	0	---	3	.4	11	.6
201-300	4	1.1	1	.2	0	---	1	.1	6	.3
301-400	1	.3	0	---	0	---	0	---	1	.1
401-500	1	.3	0	---	0	---	0	---	1	.1
501-up	1	.3	0	---	0	---	0	---	1	.1
Total	351	100.0%	484	100.0%	407	100.0%	714	100.0%	1956	100.0%

Table 6. Distribution of corallum diameter by reef zones at Gognga Transects, Tumon Bay

Diameter range in cm	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
0-5	57	20.5	29	38.7	33	30.0	226	25.6	345	25.6
6-10	79	28.4	21	28.0	36	32.7	160	18.1	296	22.0
11-15	46	16.5	11	14.7	27	24.5	123	13.9	207	15.4
16-20	21	7.6	2	2.7	4	3.6	89	10.1	116	8.6
21-25	11	4.0	4	5.3	5	4.5	67	7.6	87	6.5
26-30	14	5.0	2	2.7	5	4.5	63	7.1	84	6.2
31-35	6	2.2	4	5.3	0	---	64	7.2	74	5.5
36-40	4	1.4	1	1.3	0	---	21	2.4	26	1.9
41-45	3	1.1	0	---	0	---	17	1.9	20	1.5
46-50	4	1.4	0	---	0	---	18	2.0	22	1.6
51-60	2	.7	0	---	0	---	13	1.5	15	1.1
61-70	2	.7	0	---	0	---	3	.3	5	.4
71-80	5	1.8	0	---	0	---	5	.6	10	.7
81-90	0	---	0	---	0	---	5	.6	5	.4
91-100	4	1.4	0	---	0	---	4	.5	8	.6
101-150	7	2.5	0	---	0	---	2	.2	9	.7
151-200	2	.7	0	---	0	---	2	.2	4	.3
201-300	8	2.9	1	1.3	0	---	1	.1	10	.7
301-400	1	.4	0	---	0	---	0	---	1	.1
401-500	0	---	0	---	0	---	0	---	0	---
501-1000	2	.7	0	---	0	---	0	---	2	.1
Total	278	100.0%	75	100.0%	110	100.0%	883	100.0%	1346	100.0%

The most common corals found on the upper surface of the spurs were: Acropora corymbosa, A. nana, A. nasuta, A. ocellata, A. palmerae, A. surculosa; Goniastrea retiformis; Millepora platyphylla; Pocillopora meandrina, P. setchelli, and P. verrucosa. Growth forms of most colonies in this habitat of agitated water are ramose and encrusting (Table 3 and 4). Ramose colonies are usually prostrate forms with stout, closely-set branches and broad, encrusting bases. An exception to this growth form adaptation is Acropora nana, which is a fragile, branched, cespitose species that thrives as well as the stouter branched species found associated with it. Encrusting Millepora platyphylla colonies sometimes cover extensive areas of the spurs and, where well developed, the upper parts of the colony form flabellate plates that anastomose into a honeycombed pattern. Also conspicuous on the surface of spurs are Acropora palmerae colonies, which form broad encrustations with mammalate projections up to several meters in diameter. Massive colonies form either low convex mounds or more commonly develop into aggregations of irregular knobs and cuneate clumps.

Common corals found associated with the open surge channels and pools were: Acropora abrotanoides; Favia pallida, F. stelligera; Goniastrea retiformis, G. parvistella; Leptoria gracilis; Millepora platyphylla; Montipora verrilli; Pavona clavus; Pocillopora setchelli, and P. verrucosa.

A few colonies of Galaxea hexagonalis, Pocillopora brevicornis, Pocillopora damicornis, and Psammocora contigua, which are normally found in less agitated water habitats, are found in some of the larger reef margin pools. Growth forms of corals are similar in surge channel habitats to those growing on the upper surface of the spurs, however, fewer ramose colonies of corymbose growth development are found. An increase in encrusting and massive colonies was observed. Growth forms in open pool habitats are similar to those found in the quieter, deeper water of the reef front. Branches of ramose forms are less stoutly developed and more laxly set and massive forms develop into rounded hemispherical colonies of larger size.

Fewer corals are found in the cavernous portions of surge channels and pools than are found in the other reef margin habitats. The more common corals found in this habitat of reduced light intensity were: Leptoseris hawaiiensis; Pavona (Pseudocolumnastrea) pollicata, P. (Polyastra) planulata; Porites sp. 1; Psammocora (P.) haimeana, P. nierstraszi; and Stylocoeniella armata. The majority of corals found in this habitat are of encrusting, or more rarely, foliaceous growth form. The upper surface of spurs, open surge channel walls, and open pools contain small cavities and holes. These microhabitats of reduced light have species compositions similar to those listed above for the cavernous regions of surge channels and pools.

Corallum size distribution (Table 5 and 6) for the reef margin is similar to that of the outer reef flat. Generally, coral colonies tend to be small, with the exception of some species of Montipora, Acropora, and Millepora, which locally may form spreading encrustations several meters in diameter. Table 2 lists a total of 44 coral species representing 18 genera that were observed on the reef margin portions of the Gognga and Naton transects. When the corals that were collected from the reef margin zone but were not observed on the transects are added to this list, the total is increased to 60 species and 21 genera.

Reef Front Zone (60 to 80 meters wide)

This zone is not well-known in most coral distribution studies and not represented in most coral collections because of the high surf and agitated water found there. The long duration of this study allowed fairly complete collections to be made in this zone during occasional periods of calms and abnormal wind direction from the south or southeast. For this zone, Naton and Gognga transects are very similar in respect to number of genera and species per transect section (Fig. 21), percentage of reef surface covered by living corals (Fig. 22), corallum size distribution (Table 5 and 6), growth form distribution (Table 3 and 4), and species composition. Coral growth is optimum in this zone, and at both transects living coral covering the reef surface ranges between 35 and 59 per cent per transect line section. The highest number of species and genera for this zone per transect section was 46 species at Gognga (line sec. 52) and 21 genera at Naton (line sec. 53) (Fig. 21). From Table 2, the total number of species from the entire reef front zone was 84 species, representing 32 genera. Table 1 shows that including the corals that were collected with those observed on the transect raises the total to 99 species, with no change in the number of genera. With the exception of the Acropora aspera and Acropora acuminata thickets found on the reef flat zone, corals reach their greatest size in this zone. Species such as Acropora abrotanoides, A. smithi; Coscinaraea columna; Diploastrea heliopora; Favia stelligera; Goniastrea retiformis; Lobophyllia costata; Millepora platyphylla; Montipora verrili; Pavona clavus; Platygyra rustica; Pocillopora eydouxi; Porites australiensis, P. (S.) convexa, P. lutea, P. (S.) iwayamaensis; and Psammocora (S.) togianensis commonly attain diameters of 1 m or more across. Millepora platyphylla forms columnar pillars several meters across and up to 3 m in height at the seaward margin of the reef front. Large colonies of Porites (S.) iwayamaensis, Porites lutea, and Porites (S.) convexa form the nucleus of large hemispherical mixed coral mounds and knolls 2 to 4 m in diameter and height. These columnar pillars, mounds, and knolls give the reef front surface most of its irregular topography and are also indicators of an older growing reef platform. Growth forms are similar for both transects (Table 3 and 4), and show a distinct increase in the relative frequency of encrusting and massive types.

The wave agitated sections of the reef margin and shoreward half of the reef front, where strong surge currents occur, constitute a distinct habitat for several species of corals that were found in no other zones. Corals found exclusively in this agitated water zone are Acropora abrotanoides, A. hystrix, A. monticulosa, A. murrayensis, A. palmerae, A. smithi, Acropora sp. 1; Pocillopora setchelli; and Porites sp. 1. These regions of heavy surf and strong surge currents also coincide with the maximum development of acroporoid species. The shoreward half of the reef front is, strangely, the principle habitat of some of the most fragile cespitose clumps of corals such as Acropora nana, A. syringodes, A. hystrix, and A. murrayensis. These corals grow beside other corymbose acroporoid species such as Acropora humilis, that respond to strong water movement by the development of stout polygonal branches which develop from a thick encrusting base.

Submarine Terrace (70 meters wide) and Seaward Slope Zone (70 meters wide)

SCUBA observations of the submarine terrace and seaward slope zones were made in the transect locations, but no systematic collections or transect studies were made beyond the reef front. Porites (S.) iwayamaensis and Porites (S.) convexa steadily increased in density and were the dominant corals on the outer part of the submarine terrace and down the seaward slope to 35 m. Other corals commonly observed in these zones were large flabellate colonies of Heliopora coerulea, columnar clusters of Psammocora (S.) togianensis and Coscinaraea columna, small rounded colonies of Astreopora gracilis, small encrusting patches of Leptastrea sp. 1 and Favites complanata, large arborescent colonies of Pocillopora eydouxi, Acropora palifera, and Pocillopora verrucosa, laxly branched colonies of Stylophora mordax, irregular nodular aggregations of Favia stelligera and Pavona clavus, large dome-like growths of Diploastrea heliopora (one colony greater than 3 m in diameter), and thick papillate encrustations of Montipora verrucosa. Down the seaward slope, conspicuous colonies of large pedicellate colonies of Acropora rambleri, A. kenti, and A. rayneri were found. At the 35 m depth several foliaceous colonies of Pachyseris speciosa and Leptoseris incrustans were observed near the base of large overhanging projections of Porites (S.) horizontalata. Small encrusting patches of Porites (S.) hawaiiensis are common in cavities, holes, and on the underside of large spreading coral colonies.

CHAPTER V

DESCRIPTION OF THE ACANTHASTER PLANCI (LINNAEUS) POPULATION EXPLOSION AT TUMON BAY

Acanthaster planci (Linnaeus) is an active predator that attacks reef corals by attaching its arms over the living portion of the corallum with its tube feet. The gastric sac is then everted through the mouth and spread over the coenosarc. A similar feeding process was observed by Mortensen (1931) in Java and Goreau (1963) in the Red Sea.

Systematic coral collections have been made from various reef habitats from early 1966 to the present. During 1966, the starfish A. planci was seen sporadically; only rarely was more than one observed on any field trip. Since the early part of 1967, the number of A. planci observed per field trip (Fig. 28) increased rapidly from three to five individuals seen during February, 1967, to several hundred seen during June, 1968.

It was found that in regions with normal populations, A. planci is usually a nocturnal feeder and is secretive at other times, being found during the daytime in holes, cracks, and on the underside of horizontally spreading coral colonies. Goreau (1963, p. 26) notes the same behavior in the Red Sea and states, "The failure of most previous investigators working in coral reefs of the Indo-Pacific area to report on extensive coral destruction by Acanthaster planci, even though the species occurs throughout the area, may be due partly to the fact that it is a nocturnal predator, and its effect may not be so noticeable in areas of more intense reef-coral growth." At Tumon Bay, however, when the populations began to increase, the starfish could be seen moving about and feeding at any time of the day.

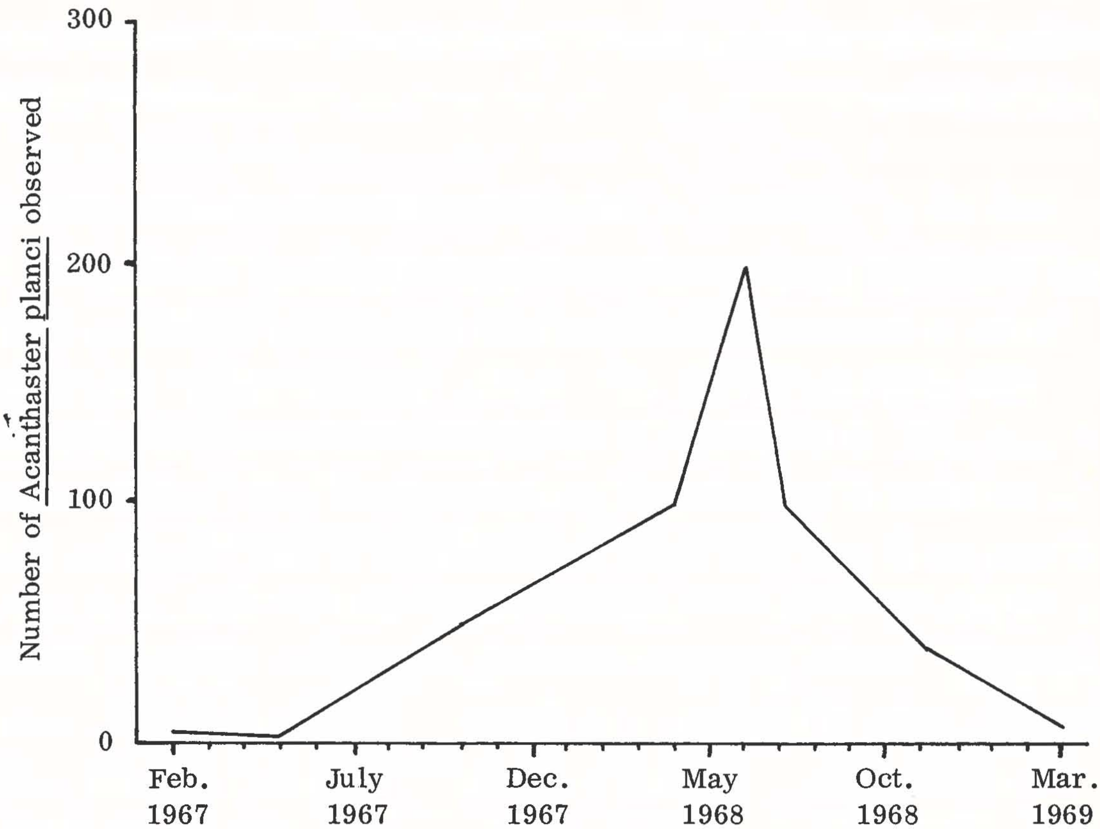

Fig. 28. Number of Acanthaster planci observed at Tumon Bay from February, 1967, to March, 1969.

The predatory nature of Acanthaster toward corals, coupled with their population explosion, has resulted in the death of nearly 100 per cent of the reef-forming corals on parts of the submarine terrace and seaward slope zones at Tumon Bay. Formerly the reefs on the northwest coast of Guam possessed very luxuriant coral growths, both in the percentage of living coral covering the reef surface and the number of species found. During a recent geological survey of Guam, Tracey (1964) also noted that this section of the coast supported rich coral growths.

Acanthaster Planci Observations at Tumon Bay

At Tumon Bay, 42 species of coral were observed during May, 1967, from several reef margin and reef front pools (Naton transect sections 52 and 53) prior to the A. planci population increase. The walls of these pools were covered with 80 to 90 per cent living corals. A resurvey of the same pools made in November, 1968, revealed less than 10 per cent of the walls covered with living corals. Only 12 living species of corals were found in the pools at the time of resurvey. In order of their abundance, the corals observed were: Millepora platyphylla, Pocillopora verrucosa, Heliopora coerulea, Pocillopora setchelli, Goniastrea retiformis, Porites sp. 1, Acropora surculosa, Acropora nasuta, Millepora dichotoma, Pocillopora eydouxi, Pocillopora elegans, and Stylocoeniella armata.

Based on field observations and transect studies, the fringing reef at Tumon Bay has undergone the following stages of A. planci predation.

Normal Density Stage

During early 1966 normal coral growth and density was observed on the reef flat, reef margin, reef front, and submarine terrace zones. An Acanthaster was observed July 15, 1966, on the reef front on a large Porites head, but there was no noticeable coral damage. No observations were made on the seaward slope zone at this time.

Infestation Stage

From late 1966 to June, 1967, an increase in the number of Acanthaster was observed on the reef front and submarine terrace zones. They were only occasionally seen on any other reef zone at this time. Usually three to five starfish were found localized in several small scattered patches, 10 to 20 m in diameter. Within these scattered patches, an estimated 25 per cent of the corals were dead and had a "bleached" white color. The starfish were not feeding during the daytime and were observed only after a search was made in the vicinity of the dead, white corals.

From the summer of 1967 to April, 1968, the number of starfish observed increased considerably and localized coral damage was more obvious. White patches of corals with larger numbers of Acanthaster were observed more frequently along the northern half of Tumon Bay. Several locations seemed to have concentrations of starfish. At Bijia Point, on October 21, 1967, a concentration of 25 starfish was observed on the reef front and submarine terrace zones. Many corals were freshly killed and others possessed a green coat of filamentous algae. A second large patch of dead corals, 50 m wide, was found on April 4, 1968, about 100 m south of Naton transect, where the reef front zone intergrades into the submarine terrace. The starfish were concentrated around the perimeter of the patch and were actively feeding during the mid-day. No actual count was made of the number of starfish present, but it was estimated to be considerably larger than the 25 counted at Bijia Point.

Population Explosion Stage

On June 1, 1968, the same region south of Naton transect was revisited. Hundreds of Acanthaster were observed on the reef front and submarine terrace zones. The infestation was localized to several strips 30 to 50 m wide, which extended from the breaker region of the reef front zone to a point 150 m seaward in the submarine terrace zone. This was the farthest point seaward that was investigated. Within the boundaries of the infested regions, 60 to 80 per cent of the corals were dead. Greatest densities of Acanthaster were observed at the living coral contact zone along both sides of the infested bands. The central portions of the infested bands had scattered clusters of starfish feeding on the few remaining patches of living corals. The Acanthaster were at this time feeding and actively moving about at all times of the day. A hemispherical colony of Porites lutea, 1 m in diameter, had eight starfish feeding on its surface at the same time. The reef margin and inner part of the reef front were relatively uninfested, although these zones contained dense coral growths.

By November, 1968, several sections of the reef front and submarine terrace along Tumon Bay, about 300 m wide, were found with 80 to 90 per cent of the corals dead and coated with various species of algae. These extensive dead regions were formed by coalescence of the expanding strips of infestation described above. Acanthaster were most abundant along the living borders of the dead regions. The central portions of these large dead areas contained some small living patches of coral, especially on the upper surface of coral mounds, knolls, and pinnacles. Patches of living coral were more numerous where the reef front grades into the reef margin zone. There was considerably more starfish predation in deeper reef areas with less water movement, than in regions of strong surge currents and water agitation.

The reef front and submarine terrace zones of Naton and Gognga transects became infested with Acanthaster in January and February of 1969. Fortunately, the transect studies of the reef front were completed before starfish infestation changed the original coral distributions there. Studies of the remaining reef zones to be carried out at the transect locations were rapidly finished, especially on the reef margin, before the starfish predation could alter the coral species composition there. The reef margin was not heavily infested at any time during the remainder of the transect study. In the reef margin zone, seven starfish were found concentrated on a single, large arborescent colony of Acropora abrotanoides, which was the highest number observed in this zone. As a result of intensified transect studies, most of the remaining starfish observations of this stage are from reef flat zones near the Naton and Gognga study areas. No Acanthaster were found in these zones at the Gognga transects, but a total of five were observed at the Naton transects where deeper water and a small channel enhance the movement of starfish onto the reef flat zones from the reef front.

Migration Stage

On April 4, 1969, a single line transect was placed across the reef margin and reef front zone at Gognga transect and all starfish occurring within visual proximity of it were counted. A total of only seven Acanthaster were observed by using this method, but at this time 80 to 90 per cent of the corals found in these zones were dead and most of the starfish had since moved out of the regions of dead corals into other areas of rich coral growth. Observations at several places along the outer reef front and submarine terrace of Tumon Bay revealed extensive coral damage, 60 to 90 per cent killed, but large concentrations of starfish were not found.

Chesher (1969a) reported a large starfish population in September, 1968, north of Tumon Bay at the Double Reef (Fig. 1) and a subsequent kill of 886 starfish by divers from 90,000 m^2 of reef surface at that locality in November, 1968. Migration out of Tumon Bay area of some starfish must have taken place before Spring, 1969, or possibly several population explosions occurred within a short period of time along the northwest coast of Guam. Possibly a combination of both of the above took place along this coastline.

Concluding Notes

During the course of reef studies at Tumon Bay, it was observed that coral attacked by A. planci usually undergoes the following changes: (1) the coral surface occupied by the starfish turned a pale tan to white color; (2) a thick mucus-like slime was secreted from the attacked portions; (3) the denuded corallum surface changed to a bleached white color; (4) recovery of the attacked region of the coral did not seem to occur; (5) filamentous algae, usually macroscopic blue-greens, were the first organisms to become established on the freshly killed areas of the corallum; (6) filamentous algae were usually followed by a succession of other algae, depending upon the reef zone or season; or (7) the dead coral may be encrusted by the surviving corals, such as Millepora or Montipora species.

Observations at Tumon Bay indicate that the quiet water of the submarine terrace zone is usually the location where A. planci populations first appear and increase in numbers. The increasing population then expands seaward to the depth limit of reef corals and shoreward to the agitated water of the reef margin zone. When the corals are killed within these limits, the population moves parallel to the reef edge, commonly forming several long sinuous herds which were also noted by Chesher (1969a). If the starfish population is contained by local barriers such as reef sections with dead corals, feeding pressure may cause them to move to unfavorable habitats such as the reef margin.

CHAPTER VI

DISTRIBUTION OF CORALS AFTER ACANTHASTER PLANCI POPULATION EXPLOSION AT TANGUISSON POINT

Coral distribution at Tanguisson Point (Fig. 5) is based upon data from three transects, general field observations, and some specimen collections. Extensive systematic coral collections were not made at the Tanguisson study region because a similar species composition was collected at Tumon Bay. The only corals collected at Tanguisson Point were those that could not be identified in the field, those that represented new growth forms, or those that were not previously collected at Tumon Bay. Field work for the study was started at Tanguisson during September, 1969, and was continued until July, 1970.

At the Tanguisson Point study area, Acanthaster planci infestation of the submarine terrace and seaward slope zones took place sometime between June, 1968, and September, 1968. Predation of corals by starfish in these zones has resulted in major changes of the ecosystem. The most obvious change in the ecosystem has been the death of many framework and reef-building corals. Many other less obvious successional changes are also taking place there. This study will, hopefully, establish a level of reef recovery, at least for the corals, and establish a baseline for future coral investigations planned in this area.

Table 7 lists the frequency distribution of coral species observed on the transects by reef zones. This table shows that 86 species representing 30 genera occurred on the three transects. Combining the number of species shown on Table 1 that did not occur on the transects, the total number of species is raised to 96 species representing 33 genera. From the total number of species

Table 7. Frequency distribution of coral species by reef zones at Tanguisson Point transects. [Species are listed in order of decreasing frequency of occurrence by combining all reef zones. Inner reef flat and outer reef flat subzones were omitted because only two species with a frequence of occurrence of one each were found there. These two species are indicated with the symbol *.]

Name of Coral	Reef margin		Reef front		Submarine terrace		Seaward slope		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Galaxea hexagonalis	---	---	85	15.60	4	1.67	1	1.75	90	9.80
Goniastrea retiformis	6	8.11	69	12.66	2	.83	---	---	77	8.39
Favia stelligera	1	1.35	39	7.16	20	8.33	---	---	60	6.54
Pavona varians	---	---	13	2.39	39	16.25	---	---	52	5.66
Pocillopora verrucosa	12	16.22	21	3.85	8	3.33	1	1.75	42	4.58
Favia pallida	1	1.35	18	3.30	18	7.50	4	7.02	41	4.47
Montipora verrilli	1	1.35	31	5.69	7	2.92	1	1.75	40	4.36
Porites lutea	2	2.70	9	1.65	17	7.08	8	14.04	36	3.92
Leptastrea purpurea	---	---	4	.73	16	6.67	8	14.04	28	3.05
Leptoria phrygia	3	4.05	16	2.94	9	3.75	---	---	28	3.05
Acanthastrea echinata	---	---	24	4.40	1	.42	---	---	25	2.72
Leptoria gracilis	1	1.35	20	3.67	1	.42	---	---	22	2.40
Millepora platyphylla	10	13.51	9	1.65	---	---	---	---	19	2.07
Acropora hystrix	7	9.46	9	1.65	---	---	---	---	16	1.74
Millepora exaesa	---	---	5	.92	10	4.17	---	---	15	1.63
Montipora sp. 1	---	---	6	1.10	6	2.50	3	5.26	15	1.63
Psammocora nierstraszi	2	2.70	10	1.83	2	.83	---	---	14	1.53
Goniastrea parvistella	---	---	2	.37	11	4.58	---	---	13	1.42
Favites complanata	---	---	6	1.10	4	1.67	1	1.75	11	1.20

Table 7 continued.

Name of Coral	Reef margin		Reef front		Submarine terrace		Seaward slope		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Acropora murrayensis	6	8.11	4	.73	---	---	---	---	10	1.09
Acropora nana	7	9.46	3	.55	---	---	---	---	10	1.09
Acropora nasuta	4	5.41	6	1.10	---	---	---	---	10	1.09
Pavona clavus	---	---	8	1.47	2	.83	---	---	10	1.09
Stylocoeniella armata	---	---	7	1.28	2	.83	1	1.75	10	1.09
Goniastrea pectinata	---	---	---	---	8	3.33	1	1.75	9	.98
Montipora sp. 2	---	---	8	1.47	1	.42	---	---	9	.98
Plesiastrea versipora	1	1.35	8	1.47	---	---	---	---	9	.98
Acropora corymbosa	---	---	5	.92	3	1.25	---	---	8	.87
Galaxea fascicularis	---	---	3	.55	1	.42	4	7.02	8	.87
Montipora sp. 4	---	---	8	1.47	---	---	---	---	8	.87
Pocillopora meandrina	2	2.70	5	.92	---	---	---	---	8	.87
Stylophora mordax	---	---	4	.73	4	1.67	---	---	8	.87
Acropora surculosa	---	---	7	1.28	1	.42	---	---	8	.87
Favia favus	---	---	2	.37	6	2.50	---	---	8	.87
Porites australiensis	---	---	3	.55	4	1.67	---	---	7	.76
Acropora abrotanoides	---	---	6	1.10	---	---	[illegible]	---	6	.65
Cyphastrea sp. 1	---	---	4	.73	---	---	2	3.51	6	.65
Montipora sp. 3	---	---	---	---	6	2.50	---	---	6	.65
Platygyra rustica	---	---	5	.92	1	.42	---	---	6	.65
Platygyra sinensis	---	---	4	.73	2	.83	---	---	6	.65
Porites lobata	---	---	1	.18	5	2.08	---	---	6	.65
Porites sp. 1	2	2.70	2	.37	---	---	1	1.75	6	.65

Table 7 continued.

Name of Coral	Reef margin		Reef front		Submarine terrace		Seaward slope		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Lobophyllia costata	---	---	4	.73	1	.42	---	---	5	.54
Montipora foveolata	---	---	4	.73	1	.42	---	---	5	.54
Montipora sp. 5	---	---	5	.92	---	---	---	---	5	.54
Pavona (Polyastra) sp. 3	---	---	4	.73	---	---	1	1.75	5	.54
Astreopora gracilis	---	---	1	.18	3	1.25	---	---	4	.45
Leptastrea sp. 1	---	---	1	.18	---	---	3	5.26	4	.45
Echinopora lamellosa	---	---	2	.37	---	---	1	1.75	3	.33
Montipora monasteriata	---	---	3	.55	---	---	---	---	3	.33
Montipora tuberculosa	---	---	---	---	3	1.25	---	---	3	.33
Montipora conicula	---	---	3	.55	---	---	---	---	3	.33
Porites (Synaraea) iwayamaensis	---	---	---	---	1	.42	2	3.51	3	.33
Acropora palmerae	2	2.70	1	.18	---	---	---	---	3	.33
Leptastrea transversa	---	---	---	---	1	.42	2	3.51	3	.33
Favia valenciennesii	---	---	---	---	2	.83	---	---	2	.22
Cycloseris cyclolites	---	---	---	---	---	---	2	3.51	2	.22
Cycloseris sp. 1	---	---	1	.18	1	.42	---	---	2	.22
Lobophyllia corymbosa	---	---	---	---	---	---	2	3.51	2	.22
Montipora granulosa	---	---	2	.37	---	---	---	---	2	.22
Montipora sp. 6	---	---	1	.18	1	.42	---	---	2	.22
Pocillopora setchelli	2	2.70	---	---	---	---	---	---	2	.22
Goniopora columna	---	---	---	---	1	.42	1	1.75	2	.22
Pocillopora eydouxi	---	---	2	.37	---	---	---	---	2	.22

Table 7 continued.

Name of Coral	Reef margin		Reef front		Submarine terrace		Seaward slope		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Pocillopora sp. 1	---	---	1	.18	1	.42	---	---	2	.22
Psammocora exesa	---	---	2	.37	---	---	---	---	2	.22
Acropora humilis	---	---	1	.18	---	---	1	1.75	2	.22
Acropora sp. 1	---	---	1	.18	---	---	---	---	1	.11
Acropora smithi	---	---	1	.18	---	---	---	---	1	.11
Acropora valida	---	---	1	.18	---	---	---	---	1	.11
Astreopora myriophthalma	---	---	---	---	1	.42	---	---	1	.11
Coscinaraea columna	1	1.35	---	---	---	---	---	---	1	.11
Cyphastrea serailia	---	---	1	.18	---	---	---	---	1	.11
Echinophyllia aspera	---	---	---	---	---	---	1	1.75	1	.11
Distichopora violacea	1	1.35	---	---	---	.42	---	---	1	.11
Favia favosa	---	---	---	---	1	---	---	---	1	.11
Favites flexuosa	---	---	---	---	---	---	1	1.75	1	.11
Heliopora coerulea	---	---	---	---	1	---	---	---	1	.11
Hydnophora microconos	---	---	1	.18	---	---	---	---	1	.11
Leptoseris hawaiiensis	---	---	---	---	---	---	1	1.75	1	.11
Millepora dichotoma	---	---	1	.18	---	---	---	---	1	.11
Montipora hoffmeisteri	---	---	1	.18	---	---	---	---	1	.11
Pavona (Pseudocolumnastrea) pollicata	---	---	1	.18	---	---	---	---	1	.11
Porites (Synaraea) hawaiiensis	---	---	---	---	---	---	1	1.75	1	.11

Table 7 continued.

Name of Coral	Reef Margin No. of coralla	Reef Margin Relative per cent	Reef front No. of coralla	Reef front Relative per cent	Submarine terrace No. of coralla	Submarine terrace Relative per cent	Seaward slope No. of coralla	Seaward slope Relative per cent	All zones combined No. of coralla	All zones combined Relative per cent
Porites (Synaraea) horizontalata	---	---	---	---	---	---	1	1.75	1	.11
Psammocora (Plesioseris) haimeana	---	---	---	---	---	---	1	1.75	1	.11
Totals	74	100.00%	545	100.00%	240	100.00%	57	100.00%	918	100.00%
Total species	21		65		45		28		86	
Total genera	12		24		22		19		30	

and genera occurring at Tanguisson Point, 91 species represented by 30 genera are hermatypic scleractinians and the remaining 5 species representing 3 genera are nonscleractinians. No ahermatypic corals were observed or collected at Tanguisson Point, even though investigations were made to a depth of 35 m.

Intertidal Zone (5 to 10 meters wide)

In most places the intertidal zone is either bare reef-rock or an irregular emergent strip of solution-pitted limestone. Cut benches with pools that might contain corals are not found along this region as they are occasionally found on the windward eastern coast.

Reef Flat Zone (70 to 100 meters wide)

The fringing reef platform along Tanguisson Point is divided into inner and outer reef flat subzones, but the inner reef flat is very poorly developed. At low tide the impounded water or moat, which delineates the inner reef flat subzone, represents a very small percentage of the reef platform and is not contiguous along the entire study region.

Inner Reef Flat Subzone

This subzone is represented by several small pools (Fig 5) at transects A and C. No corals occurred on the transects, but several small colonies of *Porites lutea* were observed in a small pool near transect C.

Outer Reef Flat Subzone

This subzone is, in most places, a flat limestone pavement with very little relief. Only two colonies of corals were encountered, *Pocillopora meandrina* and *Porites lichen*, on the transects. These two colonies were found occupying a shallow pool near the reef margin zone. Coral observations along other parts of the outer reef flat are similar to those found near the transect regions.

Reef Margin Zone (20 to 30 meters wide)

This zone is awash constantly and represents a condition favorable for coral development. Figures 29 and 30 reflect this abrupt change in habitat, at transects A and B, by significant increases in the percentage of reef surface covered by living corals and the number of species and genera per transect station.

Transect C (Fig. 30) is atypical in respect to coral density because of conditions at stations 11 and 12, both of which occur on the upper surface of a rather barren spur. Visual observations there, though, reveal normal coral growth and densities adjacent to these barren stations.

The reef margin environment, like that at Tumon Bay, can be divided into three separate habitats, the well-lighted, strongly-agitated water region found on the upper surface of spurs that separate surge channels, the open surge channels and open pools, and the poorly-lighted, cavernous regions of surge channels and pools. On the upper surface of the spurs, the most common corals were: Acropora palmerae; Goniastrea retiformis; Millepora platyphylla; Pocillopora meandrina, P. setchelli, and P. verrucosa (Fig. 31). In the surge channel and open pool habitats the more common corals encountered were: Acropora hystrix, A. murrayensis, A. nana, A. nasuta; Favia pallida, F. stelligera; Goniastrea retiformis; Leptoria gracilis, L. phrygia; Millepora platyphylla; Plesiastrea versipora; Pocillopora verrucosa; and Porites lutea. Growth forms in the surge channels were similar to those observed on the upper surface of spurs at Tumon Bay. In open pools the growth forms are more like the forms encountered on the shoreward half of the submarine terrace. Corals encountered in cavernous regions of surge channels and pools were mostly encrusting forms of Psammocora nierstraszi, Porites sp. 1, and an encrusting growth form of Coscinaraea columna. Cespitose growth forms are predominant in the reef margin zone, with nearly 48 per cent at transect A and 70 per cent at transect B (Table 8 and 9).

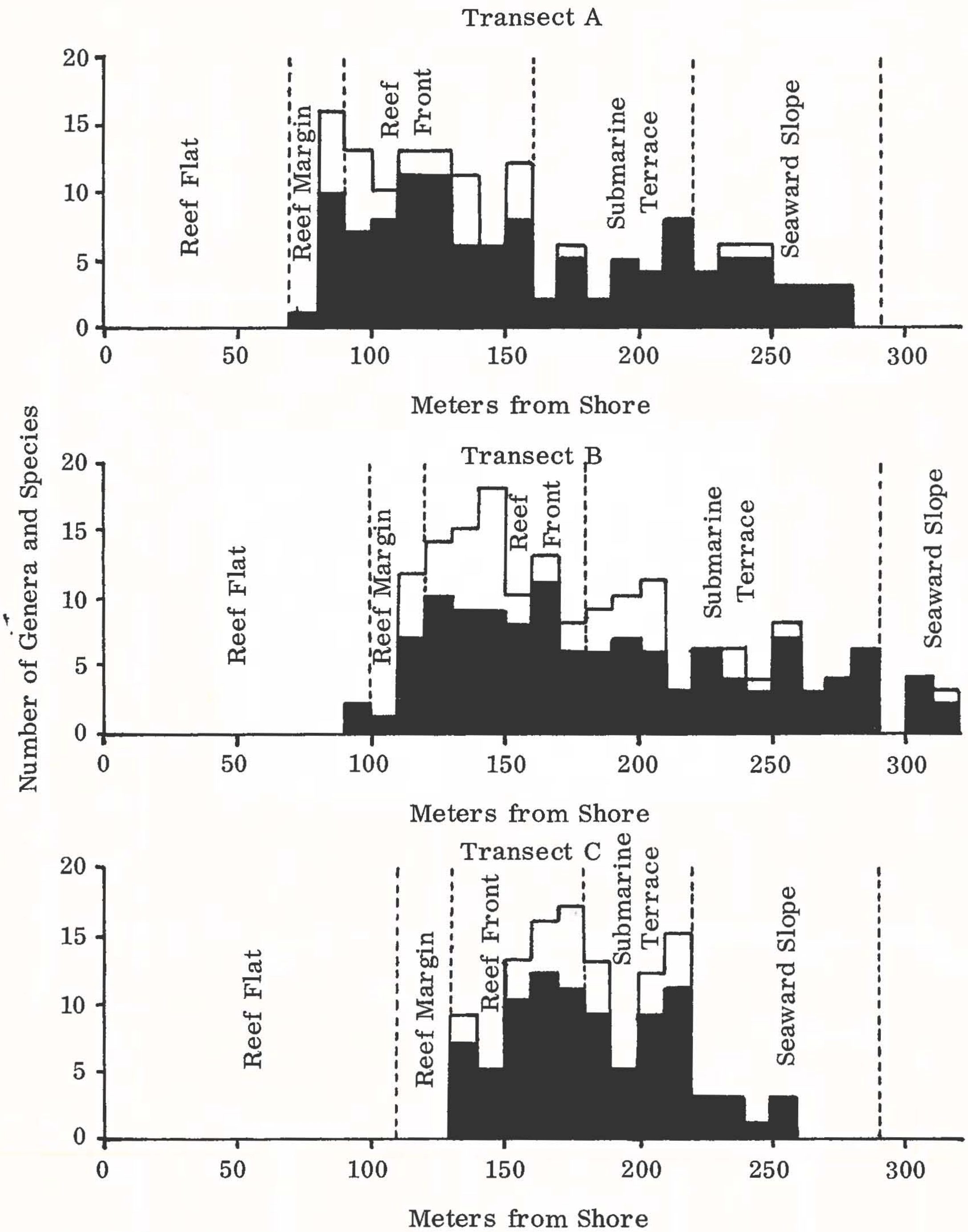

Fig. 29. Number of genera and species per transect station at Tanguisson Point. Shaded area indicates genera; unshaded indicates species.

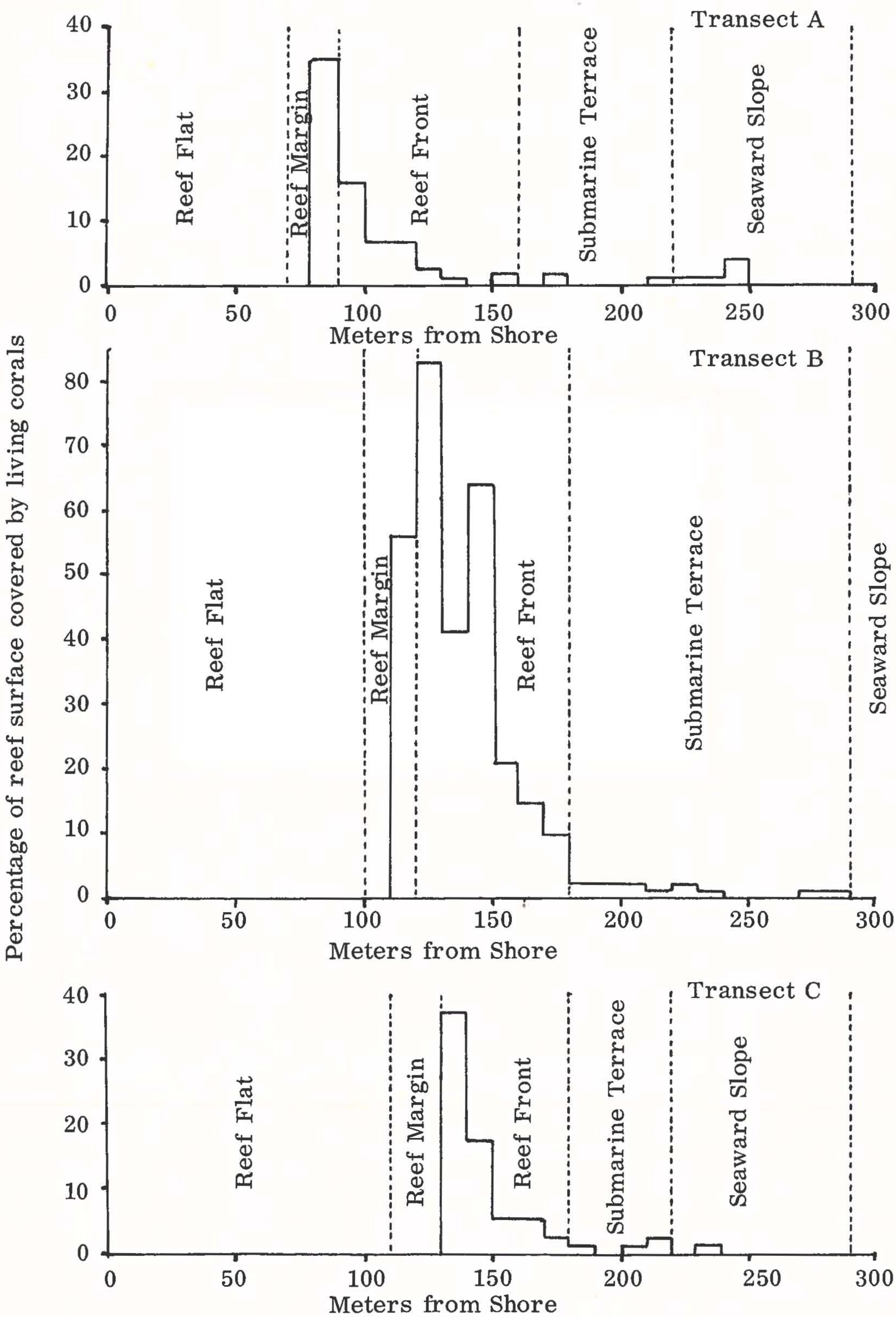

Fig. 30. Percentage of reef surface covered by living corals at Tanguisson Point.

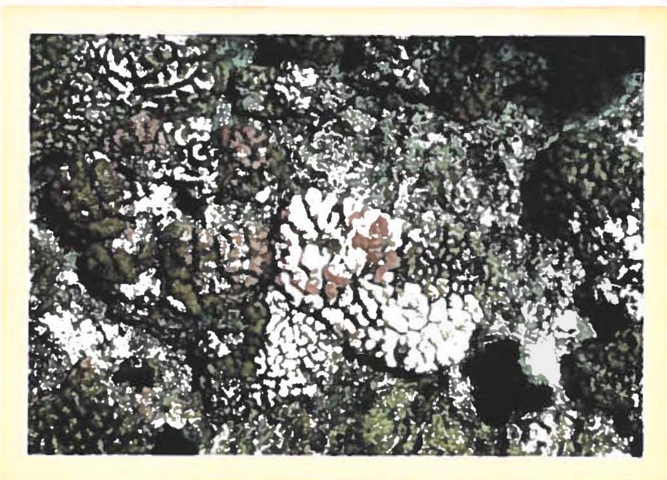

Fig. 31. Coral growth on upper surface of a reef margin spur.

Table 8. Distribution of coral growth forms by reef zones at Transect A, Tanguisson Point.

Growth form	Outer reef flat		Reef margin		Reef front		Submarine terrace		Seaward slope		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Massive	0	---	6	13.6	46	25.0	2	5.6	0	---	54	18.7
Encrusting	0	---	10	22.7	97	52.7	72	75.0	20	80.0	154	53.3
Foliaceous	0	---	0	---	0	---	0	---	2	8.0	2	.7
Flabellate	0	---	5	11.4	7	3.8	0	---	0	---	12	4.1
Corymbose	0	---	1	2.3	5	2.7	0	---	0	---	6	2.0
Cespitose	0	---	21	47.7	26	14.2	5	13.8	1	4.0	53	18.3
Arborescent	0	---	1	2.3	0	---	0	---	0	---	1	.4
Phaceloid	0	---	0	---	3	1.6	1	2.8	1	4.0	5	1.7
Columnar	0	---	0	---	0	---	0	---	1	4.0	1	.4
Solitary	0	---	0	---	0	---	1	2.8	0	---	1	.4
Total	0	00.0%	44	100.0%	184	100.0%	36	100.0%	25	100.0%	289	100.0%

Note: Inner reef flat not included because no corals were found there on any transect.

Table 9. Distribution of coral growth forms by reef zones at Transect B, Tanguisson Point.

Growth form	Outer reef flat		Reef margin		Reef front		Submarine terrace		Seaward slope		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Massive	0	---	3	10.0	52	23.3	25	18.3	3	14.3	83	20.1
Encrusting	1	50.0	4	13.3	144	64.6	105	76.6	16	76.1	270	65.5
Foliaceous	0	---	0	---	0	---	0	---	1	4.8	1	.2
Flabellate	0	---	0	---	0	---	1	.7	0	---	1	.2
Corymbose	0	---	2	6.7	7	3.1	0	---	0	---	9	2.2
Cespitose	1	50.0	21	70.0	12	5.4	6	4.4	0	---	40	9.7
Arborescent	0	---	0	---	7	3.1	0	---	0	---	7	1.7
Phaceloid	0	---	0	---	1	.5	0	---	0	---	1	.2
Columnar	0	---	0	---	0	---	0	---	0	---	0	---
Solitary	0	---	0	---	0	---	0	---	1	4.8	1	.2
Total	2	100.0%	30	100.0%	223	100.0%	137	100.0%	21	100.0%	413	100.0%

Note: Inner reef flat not included because no corals were found there on any transect.

Table 10. Distribution of coral growth forms by reef zones at Transect C, Tanguisson Point.

Growth form	Outer reef flat		Reef margin		Reef front		Submarine terrace		Seaward slope		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
Massive	0	---	0	---	20	14.5	3	4.5	1	9.1	24	11.1
Encrusting	0	---	0	---	102	73.9	60	89.5	8	72.7	170	78.7
Foliaceous	0	---	0	---	0	---	0	---	0	---	0	---
Flabellate	0	---	0	---	0	---	0	---	0	---	0	---
Corymbose	0	---	0	---	6	4.4	0	---	0	---	6	2.7
Cespitose	0	---	0	---	9	6.5	3	4.5	1	9.1	13	6.0
Arborescent	0	---	0	---	1	.7	0	---	0	---	1	.5
Phaceloid	0	---	0	---	0	---	0	---	1	9.1	1	.5
Columnar	0	---	0	---	0	---	1	1.5	0	---	1	.5
Solitary	0	---	0	---	0	---	0	---	0	---	0	---
Total	0	00.0%	0	00.0%	138	100.0%	67	100.0%	11	100.0%	216	100.0%

Note: Inner reef flat not included because no corals were found there on any transect.

Corals that were not encountered on the reef margin quadrat stations, but were observed there were: Acropora abrotanoides, A. smithi, A. surculosa; Hydnophora microconos; Pavona clavus, P. (Pseudocolumnastrea) pollicata; and Stylocoeniella armata. Porites sp. 1 and Stylocoeniella armata were found in all three reef margin habitats in small holes, cracks, and on the underside of large spreading coralla.

Corallum diameter was small, with most colonies measuring less than 15 cm. Coral diameter distribution (Table 11 through 13) was about the same for all three transects and was similar to that found at Tumon Bay before A. planci infestation.

Several major differences of coral distribution between this zone at Tanguisson Point and that at Tumon Bay were revealed when a comparison of data was made. The first major difference was the occurrence of numerous Acropora nasuta colonies, nearly 50 per cent relative frequency, at Tumon Bay, (Table 2) compared to a relative frequency of 6 per cent Acropora nasuta at Tanguisson Point (Table 7). Secondly, frequency distribution Table 7 shows that 21 species representing 12 genera were found on the reef margin, which is less than half the number of species encountered at Tumon Bay for the same zone (Table 2). These differences were caused by the rather atypical luxuriant coral growth found at Naton transects, which weights the relative frequency table when combined with the data from the more typical Gognga transects. The total number of genera and species for the Gognga reef margin is 14 and 27 respectively, which is similar to the number found at Tanguisson.

Reef Front Zone (50 to 70 meters wide)

Major differences in coral distribution begin to emerge at the reef front zone because of prior A. planci activity. Comparison of Figure 30 from Tanguisson Point with Figure 22 from Tumon Bay points out the major differences in the percentage of reef surface covered by living corals at the two study regions. Percentage of reef surface covered by living corals is similar to that found at

Table 11. Distribution of corallum diameter by reef zones at Transect A, Tanguisson Point.

Diameter range in cm	Outer reef flat		Reef margin		Reef front		Submarine terrace		Seaward slope		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
0-5	0	---	19	43.2	124	67.4	32	88.9	21	84.0	196	67.8
6-10	0	---	17	38.6	40	21.7	4	11.1	3	12.0	64	22.1
11-15	0	---	3	6.8	12	6.5	0	---	0	---	15	5.2
16-20	0	---	1	2.3	6	3.3	0	---	1	4.0	8	2.8
21-25	0	---	2	4.5	2	1.1	0	---	0	---	4	1.4
26-30	0	---	0	---	0	---	0	---	0	---	0	---
31-35	0	---	0	---	0	---	0	---	0	---	0	---
36-40	0	---	0	---	0	---	0	---	0	---	0	---
41-45	0	---	1	2.3	0	---	0	---	0	---	1	.3
46-up	0	---	1	2.3	0	---	0	---	0	---	1	.3
Total	0	00.0%	44	100.0%	184	100.00%	36	100.0%	25	100.0%	289	100.00%

Note: Inner reef flat not included because no corals were found there on any transect.

Table 12. Distribution of corallum diameter by reef zones at Transect B, Tanguisson Point.

Diameter range in cm	Outer reef flat		Reef margin		Reef front		Submarine terrace		Seaward slope		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
0-5	2	100.0	3	10.0	53	23.8	117	85.4	19	90.5	194	47.0
6-10	0	---	9	30.0	100	44.8	20	14.6	2	9.5	131	31.7
11-15	0	---	10	33.3	29	13.0	0	---	0	---	39	9.4
16-20	0	---	3	10.0	10	4.5	0	---	0	---	13	3.1
21-25	0	---	2	6.7	8	3.6	0	---	0	---	10	2.4
26-30	0	---	1	3.3	9	4.0	0	---	0	---	10	2.4
31-35	0	---	0	---	2	.9	0	---	0	---	2	.5
36-40	0	---	0	---	6	2.7	0	---	0	---	6	1.5
41-45	0	---	0	---	2	.9	0	---	0	---	2	.5
46-up	0	---	2	6.7	4	1.8	0	---	0	---	6	1.5
Total	2	100.0%	30	100.0%	223	100.0%	137	100.0%	21	100.0%	413	100.0%

Note: Inner reef flat not included because no corals were found there on any transect.

Table 13. Distribution of corallum diameter by reef zones at Transect C, Tanguisson Point.

Diameter range in cm	Outer reef flat		Reef margin		Reef front		Submarine terrace		Seaward slope		All zones combined	
	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent	No. of coralla	Relative per cent
0-5	0	---	0	---	93	67.4	58	86.6	10	90.9	161	74.5
6-10	0	---	0	---	30	21.7	7	10.4	1	9.1	38	17.6
11-15	0	---	0	---	9	6.5	2	3.0	0	---	11	5.1
16-20	0	---	0	---	2	1.5	0	---	0	---	2	.9
21-25	0	---	0	---	1	.7	0	---	0	---	1	.5
26-30	0	---	0	---	1	.7	0	---	0	---	1	.5
31-35	0	---	0	---	0	---	0	---	0	---	0	---
36-40	0	---	0	---	0	---	0	---	0	---	0	---
41-45	0	---	0	---	2	1.5	0	---	0	---	2	---
46-up	0	---	0	---	0	---	0	---	0	---	0	.9
Total	0	00.0%	0	00.0%	138	100.0%	67	100.0%	11	100.0%	216	100.0%

Note: Inner reef flat not included because no corals were found there on any transect.

Tumon Bay only for the first one to three quadrat stations immediately seaward of the reef margin zone. This similarity at first indicates that starfish predation was absent or at least nearly so along this narrow one to three quadrat band. However, when parameters other than percentage of reef surface covered are compared, it is apparent that coral distribution changes have indeed taken place. Comparisons between Figure 21 and Figure 22 reveal higher numbers of species per transect line section at Tumon Bay than per transect quadrat station at Tanguisson Point. There was also a major shift in growth forms (Table 3 and 4 and Table 8, 9, and 10) for this zone at Tanguisson Point. Corymbose and cespitose growth forms had been reduced in relative frequency, whereas encrusting types had increased. Observations and collections at Tanguisson Point reveal, however, that ramose and cespitose growth forms were previously more abundant, indicated by the many dead acroporoid corymbose and cespitose coralla which had been overgrown by various encrusting _Millepora_ and _Montipora_ species. Breaking waves and accompanying surge seems to cause selective feeding by _A. planci_ on corymbose and cespitose _Acropora_ growth forms in this section of the reef front. During the earlier _A. planci_ infestation and predation period some starfish were observed feeding in this part of the reef front zone. Chesher (1969a) also reported some starfish activity in this zone, but noted that they had difficulty in attaching their tube feet to smooth, rounded coralla. From the above data and observations, it would seem that selective feeding behavior by _A. planci_ has changed the distribution of corals in this narrow band of surge and wave-assaulted reef front, but, because of coral resuccession by different species and growth forms, the percentage of corals covering the surface has remained nearly the same.

Common corals observed in the above reef zone were: _Acanthastrea echinata_; _Acropora abrotanoides_, _A. corymbosa_, _A. hystrix_, _A. murrayensis_, _A. nasuta_, _A. surculosa_; _Favis stelligera_; _Galaxea hexagonalis_; _Goniastrea retiformis_; _Leptoria gracilis_; _Millepora platyphylla_; _Montipora verrilli_, Montipora sp. 1, Montipora sp. 2; Pavona varians; Platygyra sinensis; Pocillopora verrucosa; Porites lutea; and Stylophora mordax.

Seaward of the narrow wave and surge section of the reef front, the percentage of living corals covering the reef surface (Fig. 30) drops rapidly as deeper water is encountered, to less than 1 per cent for some quadrats near the submarine terrace. The reef front zone at transect B is shallower than that at transects A and C. This extends the wave-assaulted section of transect B farther seaward and explains the presence of a fairly high percentage of living coral covering the reef surface for the outer part of the zone. Observations of dead coralla indicate that species composition, colony diameter, and growth forms were very similar to those found living at Tumon Bay. Even though slightly less relief of topographic growth structures such as coral-algal knobs, bosses, and pinnacles was noted at Tanguisson Point, it is still obvious that nearly similar reef development was taking place as that at Tumon Bay.

Most living colonies encountered are either small, regenerated parts of larger, older, dead coralla or small encrusting coralla from new planulae settlement. Prior A. planci predation did not, in many cases, kill the entire corallum. Some small, inaccessible sections of the corallum, especially if of irregular lobate or cuneate growth form, survived the predation. These surviving sections resume growth by growing upward and spreading outward over old dead parts of the parent corallum and appear as small encrusting patches. Most young colonies established from newly settled planulae also appear as small encrustations, even though later growth development may be of ramose or massive form. Corallum diameter is, therefore, small and the number of encrusting growth forms is high because of patchy regeneration and the presence of newly settled corals. Some corals observed to be regenerating from older colonies were: Cyphastrea serailia; Favia stelligera; Goniastrea parvistella, G. retiformis; Leptoria gracilis; Lobophyllia corymbosa, L. costata; Pavona clavus; Plesiastrea versipora; Porites australiensis; and P. lutea. Corals that were developing from newly settled planulae were: Acropora corymbosa, A. humilis, A. surculosa; Astreopora sp. 1;

Favia favus, F. pallida; Favites complanata; Leptastrea purpurea, Leptastrea sp. 1; Millepora platyphylla; Montipora foveolata, M. granulosa, M. verrilli, Montipora sp. 1, Montipora sp. 3, M. conicula; Pavona varians; Pocillopora sp. 1; and Porites lutea.

Table 7 lists 65 species representing 24 genera for the reef front zone. Added to this list those species collected but not observed at the transect stations (Table 1), increases the total species for the zone to 70 species representing 24 genera.

Submarine Terrace Zone (40 to 110 meters wide) and Seaward Slope Zone (50 to 70 meters wide)

These zones were not quantitatively studied at Tumon Bay prior to A. planci predation. Some SCUBA observations on these zones at Tumon Bay were made prior to and after the starfish infestation, therefore, some qualitative comparisons of similar zones at Tanguisson Point can be made. The submarine terrace and seaward slope zones were the most heavily infested with A. planci during the initial invasion, and as a result nearly all the original coral populations were killed. Regeneration of small sections of larger colonies and resettlement of some corals has taken place as described for the reef front, but to a lesser degree, especially on the seaward slope. About 84 to 90 per cent of the corals were less than 5 cm in diameter (Table 11, 12, and 13) and 73 to 89 per cent were of encrusting growth form (Table 8, 9, and 10). The average percentage of living coral covering the reef surface on these zones (Fig. 30) was less than one. At transect A, station 25, the highest percentage of coral coverage (4%) was found, caused by a single patchy living colony of Porites (S.) horizontalata.

For the submarine terrace zone, 45 species represented by 22 genera (Table 7) occurred within the quadrat stations. Specimen collections made in this zone increased the number of species and genera to 47 and 24 respectively. The most common corals encountered on the submarine terrace were:

Favia favus, F. pallida, F. stelligera; Goniastrea parvistella, G. pectinata; Leptastrea purpurea; Leptoria phrygia; Millepora exaesa; Montipora verrilli, Montipora sp. 1, Montipora sp. 3; Pavona varians; Porites lobata, and P. lutea.

The total number of species occurring on the seaward slope zone, including one collected specimen, was 32 species representing 21 genera. This was a considerable reduction when compared to the submarine terrace and was related to little regeneration from older colonies and the lack of many new corals developing from planulae settlement. Dead coralla of some species were encountered on the seaward slope that were not observed as living species. This again indicates that not all the original species were regenerating at this zone, nor had resettlement of many new colonies taken place. Some of the dead coralla that could be identified in the field and that were not observed as living on the seaward slope transect stations were: Acropora rayneri, A. trambleri, A. kenti, A. palifera: Coscinaraea columna; Cyphastrea serailia; Goniopora sp.; Hydnophora microconos; Pacyseris speciosa; Psammocora exesa, P. (S.) togianensis; Plesiastrea versipora; plus some tuberculate Montipora species. Common living corals observed on the seaward slope were: Favia pallida; Galaxea fascicularis; Leptastrea purpurea, Leptastrea sp. 1; Montipora sp. 1; and Porites lutea.

Observations of the submarine terrace and seaward slope zones at Tanguisson Point and from other reefs of Guam indicate that some coral species are not usually preyed upon by A. planci. Some of these corals observed at Tanguisson Point were: Acanthastrea echinata; Diploastrea heliopora; Galaxea fascicularis, Goniopora columna, G. hexagonalis; Heliopora coerulea; Millepora dichotoma, M. exaesa, M. platyphylla; Pocillopora eydouxi; Porites lutea, and various Porites species of the subgenus Synaraea.

Species composition for these two zones at Tumon Bay seems to be fairly homogeneous with that found at Tanguisson Point. The major difference between the two study regions seems to be in the better development of topographic growth features as pointed out in Chapter III.

CHAPTER VII

DISCUSSION AND CONCLUSIONS

Comparison of Coral Reef Communities at Tumon Bay and Tanguisson Point

The following data summarize the number of genera and species, for the major divisions of corals, at Tumon Bay and Tanguisson Point reefs.

	Tumon Bay		Tanguisson Point	
	Genera	Species	Genera	Species
Hermatypic Scleractinians	31	143	30	91
Ahermatypic Scleractinians	2	2	0	0
Non-Scleractinians	3	5	3	5
Total	36	150	33	96

The totals listed from Tumon Bay represent the number of genera and species found in the reef community before Acanthaster planci predation killed most of the corals there. The totals listed from Tanguisson Point represent the number of genera and species found living in the reef community after A. planci predation of the reef corals had taken place there. Comparisons of physical reef characteristics (Chapter III) and coral distributions (Chapter IV and VI) indicate that the reef margin, reef front, submarine terrace, and seaward slope reef zones at Tumon Bay and Tanguisson Point were similar, except for slightly less topographic relief at the latter, in reef development before starfish predation took place. The only zones not comparable at the two locations are the subzones of the reef flat, which were not initially infested with starfish during the population explosion stage. Based on the above assumptions, a comparison can be made of the coral communities between the two study locations.

The data above shows that the total number of living coral genera surviving the A. planci predation is nearly the same as that found before predation. The only genera not found at Tanguisson Point, after the starfish predation, but that were earlier found at Tumon Bay before the starfish predation were Euphyllia, Paracyathus, and Polycyathus. The high number of genera surviving A. planci predation, even though of low density, may be essential in the recovery of devastated reefs if diversity of seed populations is an important prerequisite.

The number of species found on the Tanguisson reefs after A. planci predation is 35 per cent less than that at Tumon Bay. The number is reduced to 27 per cent if those species that are specific for the reef flat moat, which is well developed only at Tumon Bay, are discounted.

Comparisons of Coral Distribution by Reef Zones

The number of coral genera and species that were observed or collected from the various reef zones at Tumon Bay and Tanguisson Point are as follows:

	Tumon Bay		Tanguisson Point	
Reef Zone	Genera	Species	Genera	Species
Inner reef flat	18	48	0	0
Outer reef flat	16	37	2	2
Reef margin	21-(14)	60-(27)	12	21
Reef front	32	99	24	70
Submarine terrace	8	28	24	47
Seaward slope	18	28	21	32

Specific differences between Tanguisson Point and Tumon Bay inner and outer reef flat subzones are not due to A. planci predation. Differences in physical parameters, discussed earlier, account for the near absence of corals in these two subzones at Tanguisson Point.

Some A. planci predation occurred in the reef margin zone, but not to the extent that coral distribution was greatly changed there. When data from Naton and Gognga transects, Tumon Bay, are combined, a considerable difference in the number of species occurs between Tumon Bay and Tanguisson Point. Naton transect data is atypical for the reef margin zone at Tumon Bay and is biased by the presence of rich coral growth because of factors which are discussed in Chapters IV and VI. If only the data from Gognga transects, indicating 27 species representing 14 genera (above data within parentheses), is compared with that from Tanguisson Point, a similar coral distribution is found between the two regions.

A. planci predation has caused extensive damage in the reef front zone. A 29 per cent reduction in the number of species and a 25 per cent reduction in the number of genera has occurred in this zone. Coral damage to the reef front zone is not uniformly distributed across it. A comparison of Figure 22 with Figure 30 shows that the inner (shoreward) sections of the reef front zones at Tanguisson Point have normal pre-starfish percentage of reef surface covered by living corals, while the outer (seaward) sections show a reduction. However, other data from the same inner (shoreward) part of the reef front indicate that a change in coral species distribution has taken place, even though the percentage of living coral coverage has not changed. Upon close inspection of this zone, it was found that A. planci predation had selectively killed many of the ramose growth forms of corals, especially the acroporoid species. This selective predation resulted in lowering the percentage of reef surface coverage, but subsequent resettlement and regeneration of encrusting coral growth forms has restored the normal percentage of coral cover found there. This section of the reef front is located in a zone of wave agitation where starfish have difficulty in remaining attached to coralla other than ramose forms and, as a result, selective predation occurs. Future assessment of coral damage caused by A. planci on the wave-assaulted regions of the reef front zones, and possibly the reef margin as well, must, therefore, be made with care. It is within this section of the reef front where near optimum coral reef development takes place and probably optimum coral growth rates as well. Many regions on Guam and other parts of the Indo-Pacific possess reefs that have undergone

A. planci predation in the past several years. Resettlement and regeneration of specific fast growing corals may by now have obscured coral damage in certain reef zones.

Quantitative transect data for the submarine terrace and seaward slope zones at Tumon Bay was not recorded before *A. planci* predation there, but visual observations of these zones were made. These observations indicated nearly the same species composition and reef development as was found at the outer part of the reef front. The number of major coral species and genera observed in these zones is shown above. These totals are not high because complete species lists were not obtained, and therefore, the low number of species reported does not mean that reef development and surface coverage was not originally high there. Observations of dead coralla found in this zone at Tanguisson Point indicate a similar degree of development as that which was previously found at Tumon Bay. The number of species found living on the submarine terrace and seaward slope at Tanguisson Point is somewhat higher than at Tumon Bay because of the detailed transect study used there, but the total reef surface occupied by them averages less than 1 per cent of surface coverage. It was in these two zones that *A. planci* predation was the most intense. It was astounding to see such large areas of previously living coral killed in less than a year's time by *A. planci*.

Coral Growth Form Distribution

Arborescent growth forms of corals are abundant on the inner reef flat subzone at Tumon Bay, where the quiet waters of the moat support large thickets of "staghorn" *Acropora* species. This growth form is not present at Tanguisson Point on the reef flat zone because the reef surface is exposed at low tide. Stoutly branched arborescent species such as *Acropora abrotanoides* and *A. smithi* are found on the reef margin and reef front zones.

Solitary corals, represented by *Fungia fungites*, were found in large clusters (over 100 individuals) in reef margin and reef front pools at Naton transect, and by Cycloseris species in deeper parts of the transects at both study locations. Nearly all of the Fungia populations were later killed by the June and July, 1968, peak Acanthaster infestation period.

Foliaceous growth forms of Pavona species were found widely scattered over the reef flat zones at the Tumon Bay transects. Foliaceous growth forms are not usually found on the reef margin and reef front zones, except in sheltered pools, holes, and cavernous regions of the reef margin. These growth forms become more abundant in the deeper water found on the seaward slope. In this deeper zone Porites (S.) horizontalata forms tiers of plates, which may develop into large contiguous masses. A dead colony of this species, measuring 6 m across, was observed on transect A at Tanguisson Point. At Tumon Bay Porites (S.) convexa and Porites (S.) iwayamaensis typically form large columnar coralla, which at the base develop large, reniform, foliaceous plates which account for nearly half of the living reef surface area at some locations. Dead coralla with this same development were observed at Tanguisson Point.

Encrusting, cespitose, and massive growth forms are best developed on the reef front and submarine terrace zones. These forms also tend to be adaptable to most habitats and consequently are fairly abundant in all zones.

Large colonies of Millepora platyphylla and Heliopora coerulea commonly develop a flabellate growth form. Millepora platyphylla is most common in the reef margin and reef front zones, where encrustation by basal parts of the flabellate colonies may cover extensive areas. Heliopora may be found in any zone, but is more common where the submarine terrace merges into the seaward slope.

The phaceloid growth form develops in Euphyllia glabrescens on the reef flat at Tumon Bay and by Lobophyllia species on the reef front and submarine terrace zones.

The cespitose growth form is common in all zones, even in the wave agitated inner reef front and reef margin, where some of the most fragile colonies of this growth form are to be found.

The corymbose growth form is most common in the reef margin and reef front zones, where it is represented almost exclusively by Acropora species.

Comparison of Table 3 and 4 with Table 8, 9, and 10 shows an increase in the number of encrusting forms and a reduction in the number of corymbose and cespitose forms where A. planci predation occurred. In fact, a major shift in coral growth forms of this nature has occurred at Tanguisson Point on all reef zones that were infested with A. planci.

Coralla Size Distribution

There has been a shift in coralla size in all reef zones, where corals were killed by Acanthaster, except where predation was less intensive at the reef margin and inner part of the reef front. At Tanguisson Point nearly 90 per cent of the coralla found in zones of previous starfish predation were less than 10 cm in diameter, whereas at Tumon Bay less than 50 per cent were in this size range for the same zones. Reduction in coralla size in regions of starfish predation is due to the small size of newly established coralla and the small size of regenerating sections of older, larger coralla that survived the initial A. planci predation.

The Acropora (staghorn) thickets on the reef flat at Tumon Bay account for the large coralla encountered there. In this study, a circular contiguous patch of Acropora is considered as a single corallum, since it probably originated from a single progenitor.

At Tumon Bay many large colonies (1 to 4 m) found in the reef front, submarine terrace, and seaward slope zones are represented by massive growth forms that take many years to develop, possibly as many as 100 years (personal communication with T. F. Goreau). The number and size distribution of these larger coralla is a good index by which to estimate the relative age of a coral community. If a reef community contains a high number of large coralla (1 to 4 m diameter) with massive growth forms of genera such as Porites, Diploastrea, Platygyra, Leptoria, Goniastrea, Favia, and Pavona, it indicates relatively long, uninterrupted growth. If a reef community is composed of small, uniform colonies of the massive growth form of the above genera, its relative age is probably much less. Using these criteria to estimate relative age, the coral reef communities at Tumon Bay and Tanguisson Point were, prior to A. planci predation, about the same age.

Resettlement and Regeneration

At Tanguisson Point, starfish predation was intensive on the submarine terrace and seaward slope, and the resulting predation has left less than 1 per cent of the reef surface covered with living coral growth. Resettlement and regeneration has not taken place in these two zones to the extent that it has in the wave agitated parts of the reef front, possibly because of the following factors: (1) more intensive predation in these zones has left fewer seed populations of corals to initiate coral resettlement and regeneration, (2) less optimum coral growth parameters occur at these two zones, (3) low level A. planci predation is in equilibrium with coral regeneration and development in these zones, or (4) the standing crop of various seasonal species of algae is greater on seaward reef zones where corals have been killed by A. planci that it is on seaward reef zones where luxuriant coral development is found (personal communication with R. T. Tsuda), which may prevent planulae settlement or retard and kill newly developing patches of coral.

Acanthaster predation at a low level is still occurring at Tumon Bay and Tanguisson Point fringing reefs. A. planci are observed on nearly every field trip to these locations in numbers slightly above the normal population density level established by Chesher (1969b). This low level persistence of starfish predation may be just keeping pace with the re-establishment by coral planulae and regeneration of small corallum sections that have survived earlier predation. If low levels of starfish infestation continue, re-establishment of the luxuriant coral reefs that were once found along the northwest coast of Guam may take a longer time than anticipated.

A continuation of reef resettlement and regeneration studies at Tanguisson Point during the next few years will, hopefully, provide data that will be useful in the assessment of some of the above, or other, factors controlling reef recovery at these two zones.

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