Reef Physiography and Distribution of Corals at Tumon Bay, Guam, Before Crown-of-Thorns Starfish *Acanthaster planci* (L.) Predation[1]

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INTRODUCTION

Preliminary field work for this study began in July, 1966, at which time a general reef survey and coral collection was started from all major reef environments of the Tumon Bay region of Guam (Fig. 1).

In February, 1967, the sudden appearance of the coral eating "crown-of-thorns" starfish, *Acanthaster planci* (Linnaeus), in above normal population densities was noted (Randall, 1971) along local portions of the relatively sheltered northern half of Tumon Bay (Figs. 1 and 2). The subsequent depredation and resulting death of large numbers of reef corals by *A. planci* predicated an intensification of coral studies and collections in this region.

Large numbers of reef corals along the remaining northwestern coast of Guam had been killed by *A. planci* (Chesher, 1969) and this work, was then, modified to serve as a basis of comparison for future reef recovery studies in the area of destruction (Randall, In Press).

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 and 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 *et al.* (1964), who conducted transect and other reef studies during a geologic survey of the island. Physical characteristics of fringing reefs at Tumon Bay are 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.

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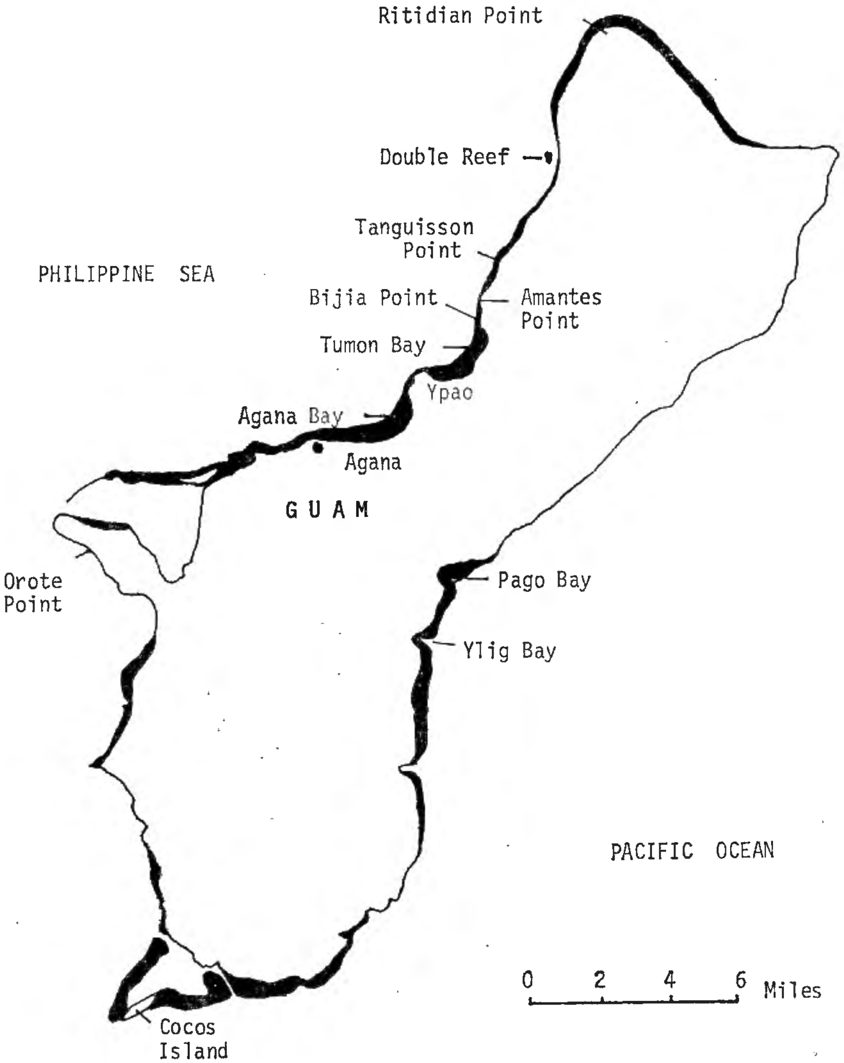

Fig. 1. Location map of Guam showing study area and fringing reef platforms. Reef platforms are in solid black. Map modified from Emery (1962).

Other works on the reefs of Guam were 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, reef flats, and rocky shores.

METHODS

Tumon Bay fringing reef exhibits fairly distinct physiographic zones that run

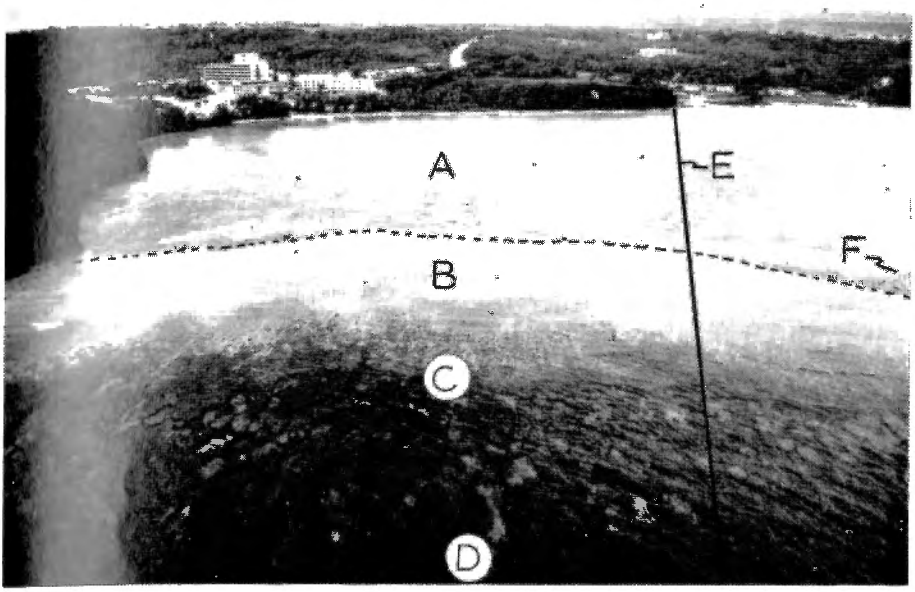

Fig. 2. Aerial view of the northern end of Tumon Bay at high tide. Dashed line divides the inner reef flat zone (A) from the outer reef flat zone (B). The dark region seaward of the outer reef flat marks the beginning of the wave-washed reef margin zone (C). The dark foreground (D) is the inner part of the reef front zone. Surge channels and buttress development is visible in zones C and D. E is the location of the Gognga Transects and F is the northern end of a large boulder track.

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 study region. In view of the impending predation by *Acanthaster planci* at Tumon Bay, a single line transect method (Fig. 3), which is fairly rapid, was used.

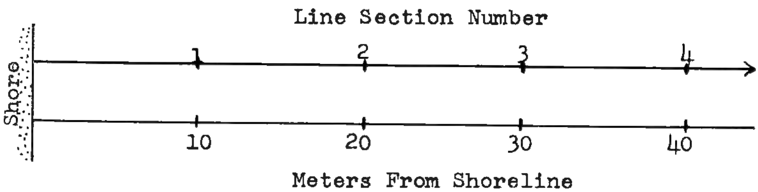

Fig. 3. Diagram of the single line transect method used at Tumon Bay.

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 4 shows the location of the Naton and Gognga transects in relation to the various reef zones. The single line transect method used there involved the placement of a line marked at 10 m intervals across the reef section to be studied (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, (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 each corallum that lay beneath the line and the length of line section it occupied, and (6) growth form for each recorded coral.

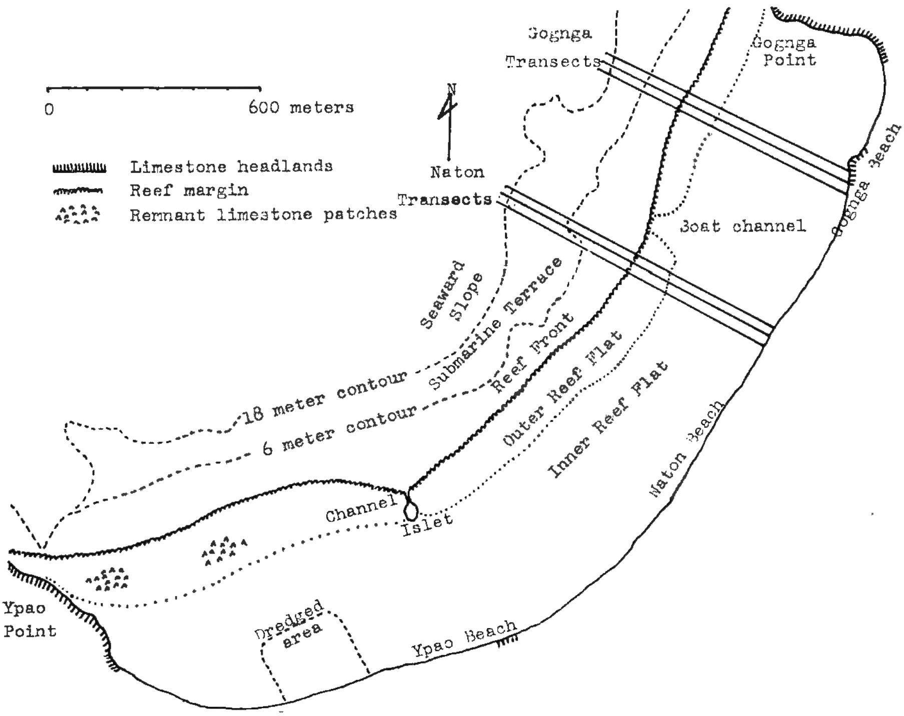

Fig. 4. Detail map of the Tumon Bay study area with transect locations.

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.

The diameter of individual coral colonies was measured with a meter stick with moveable trammel points. If circular, 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.

PHYSIOGRAPHIC DESCRIPTION OF STUDY AREA

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 (Fig. 1). 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 to less than 60 m at the centrally located, narrow waist. The limestone is porous and no streams are found on the northern plateau. The western and northern coasts are bordered by fringing reefs, whereas the more windward eastern coasts are bordered by cut benches and narrow, elevated terraces.

The northern limestone plateau, which borders the study area, is very porous, resulting in a well-developed Ghyben-Herzberg freshwater lens system. Water escapes continually along most sections of the intertidal zones of Tumon Bay. 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 by Emery (1962) shows that the sediments of this region are nearly 100 percent bioclastic material. This is due to the absence of rivers and streams emptying onto the reef flats 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 *et al.* (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. Figure 5 shows the above zones in vertical profile at the transect locations and gives the water depth range for each.

Tumon Bay (Fig. 1 and 2) is located along the northwest coast of Guam between Ypao Point and Bijia Point. The fringing reef flat (Fig. 2 and 4) 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 *et al.* (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

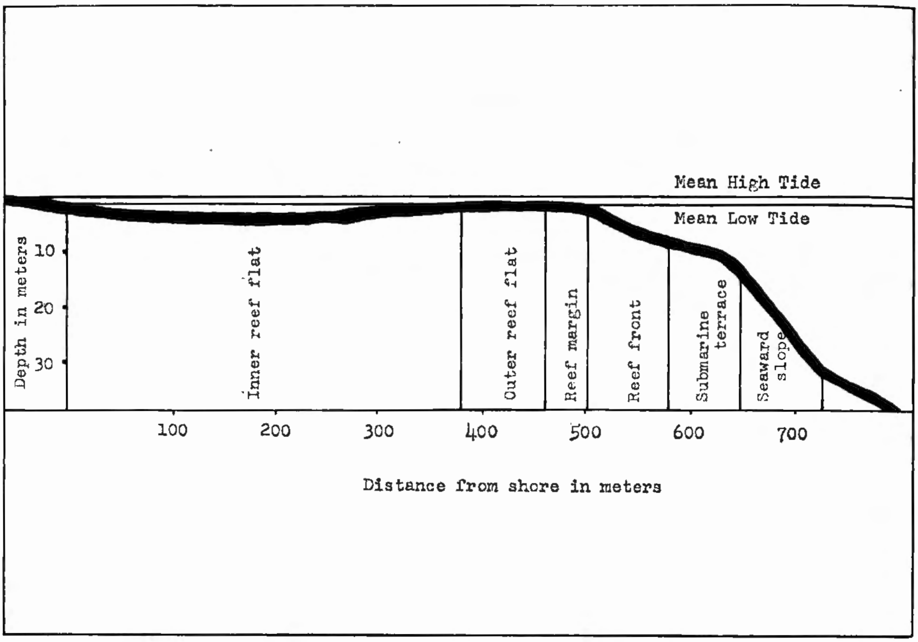

Fig. 5. Reef profile of Naton Transect, Tumon Bay; vertical exaggeration ×5. The flattened region seaward of the seaward slope is the beginning of the second submarine terrace.

narrows to 50 m and 100 m respectively (Fig. 4). 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.

INTERIDAL ZONE

This zone is the portion of the beach or shore that is covered by water at high tide and exposed at low tide. At Tumon Bay, a limestone cliff borders the beach from Gognga Point to Gognga Beach (Fig. 4). Along the more seaward exposed regions the intertidal zone consist of bare limestone with well-developed seawall indentations called "nips". The remainder of the beach consists principally of unconsolidated sand and coral-algal-mollusc rubble. A considerable 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.

REEF FLAT ZONES

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 Tumon Bay 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 reefrock 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 5 reef transect profile shows how the water at low tide forms a moat across the subzone. 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 Tumon 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 4 shows that it varies considerably in width. Near the Naton transects, it disappears completely because of several shallow channels that occur 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 form (Fig. 2), 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. 4), 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 that are broken from the margin and thrown up on the reef platform 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 buffcolored sand found on the reef flat and beach.

Depth of water over the outer reef flat varies because of elevation differences. The reef section between the boat channel and the shallow channel immediately seaward of the small islet (Fig. 4) 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. Several patches of remnant limestone, composed of solution-pitted pinnacles and knobs, are found on the outer reef flat near Ypao Point (Fig. 4). These features probably represent remnants a former reef platform of higher elevation.

REEF MARGIN ZONE

This zone is represented at Tumon Bay by the seaward edge of the reef flat platform that is constantly awash even at low tide (Fig. 2). At most places algal ridge development is absent, or very poorly developed along most of the Tumon Bay reef margin. The reef margin varies in width from 30 to 40 m along Tumon Bay. The seaward edge is very irregular and is cut at right angles by short surge channels (Fig. 2) 1 to 3 m wide, 2 to 4 m deep, and up to 20 m in length. Some surge channels coalesce and fuse at their upper margin, forming cavernous channels beneath the reef margin platform. Most of the cavernous channels open at intervals along the fusion zone, forming pools and open cracks. 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 buttresses (Fig. 2) that slope seaward toward the reef front zone. The upper surface of the buttresses is very irregular, with knobs, pinnacles, and in many places is honeycombed with numerous interconnecting holes. 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 at Tumon Bay represents the extreme seaward edge of the reef flat platform, where the reef margin abruptly increases in depth and degree of slope (Fig. 5). This zone is constantly covered with water. The reef front is composed of the seaward sloping extensions of the reef margin buttresses and surge channels, which are here referred to as the submarine buttresses and channels respectively. The point where the submarine buttresses and channels terminate marks the seaward boundary of the reef front. Generally, the 6 m submarine contour (Fig. 4) 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 (Fig. 5).

Width of the reef front zone is variable and ranges from 60 m at Natoh transect to 80 m at the Gognga transect location. Submarine channels near the reef margin are 2 to 6 m in depth and commonly branch into several secondary channels. These channels usually 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 (Fig. 6). Some submarine channels widen into holes 5 to 15 m in diameter, with large boulders covering the floors. Submarine buttresses slope seaward from 10° to 15° and are extremely irregular on the upper surface due to the presence of coral-algal knobs, bosses, and pinnacles (Fig. 7). At the seaward half of this zone,

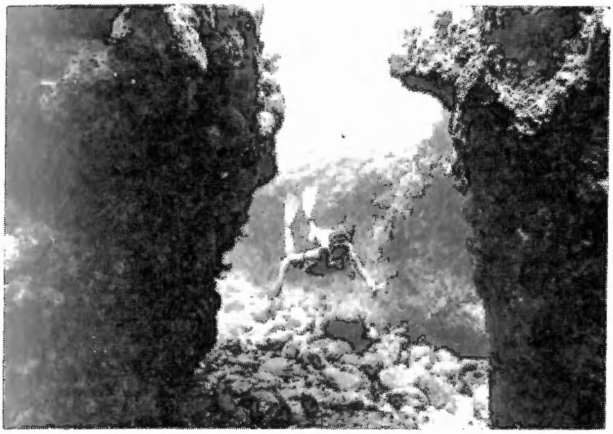

Fig. 6. Submarine channels in the reef front zone at Tumon Bay.

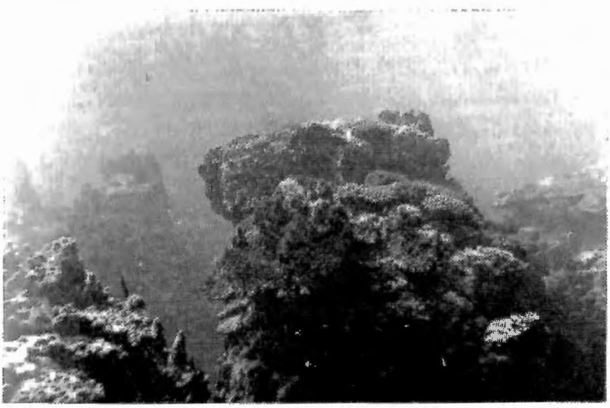

Fig. 7. Reef front zone at Tumon Bay showing coral-algal knobs, bosses, and pinnacles located on the upper surfaces of submarine buttresses. A rich growth of acroporoid species is shown growing on the large flat-topped boss in the foreground.

these various types of prominences may have a relief 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 (Fig. 5). At Tumon Bay the terrace begins at the 6 m contour interval and extends seaward, more or less, to the 18 m contour interval, where a sharp increase in the degree of slope marks the beginning of the seaward slope (Fig. 4 and 5). Coral mounds and pinnacles are abundant on the inner half of the terrace (Fig. 8) which gives its surface a topographic relief

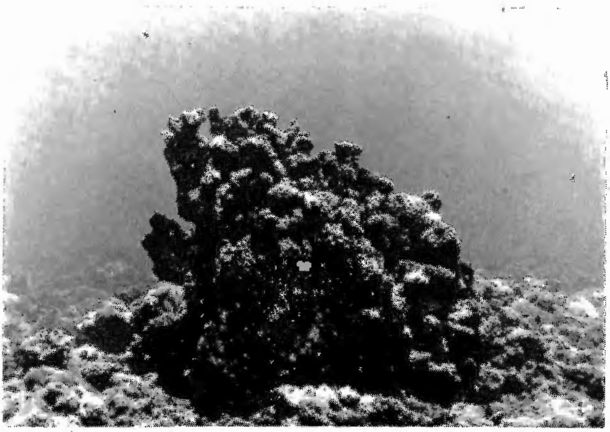

Fig. 8. Coral mound located on the submarine terrace at Tumon Bay. Relief of this mound is about three meters.

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 channels, about a meter in depth, are found crossing the zone at right angles and usually connect with deeper channels on 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*, a 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 (Fig. 5). At the transect locations, the slope ranges from 30° to 60° and averages 80 m in width. At 30 to 35 m in depth, the slope flattens, forming a second submarine terrace (Fig. 5). Width of the second submarine terrace was not measured, but it probably corresponds to the 32 m submarine 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 reef front buttress and channel system developed during a previous 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 channels 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.

DISTRIBUTION OF CORALS

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 margin, and reef front zones of northern Tumon Bay were completed prior to *A. planci* depredation of reef corals (Fig. 4). Numerous coral collections were also made during this period of time.

A check-list of corals observed on the transects and collected from the study area is compiled in Table 1. Classification of the corals listed in the table follows that developed by Wells (1956). The table shows that 146 species representing 36 genera were collected or observed. Of the total number, 139 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 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.

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
°Tumon Bay—ORF, RM, RF
+Tumon Bay—ST, SS

Family THAMNASTERIIDAE

Genus *Psammocora*

Table 1. continued

Psammocora contigua (Esper, 1797)
*Tumon Bay—39, 40, 41, 42, 43, 201, 202, 279, 325, 942, IRF
°Tumon Bay—IRF, ORF
Psammocora exesa Dana, 1846
*Tumon Bay—30, 31, 236, 1156, IRF
°Tumon Bay—ORF
Psammocora nierstraszi van der Horst, 1921
°Tumon Bay—ORF, RM, RF
+Tumon Bay—ST, SS
Psammocora profundacella Gardiner, 1898
*Tumon Bay—835, IRF; 940, ORF; 521, 522, 523, 1162, 1163, 1331, RM
°Tumon Bay—IRF, ORF
Psammocora stellata (Verrill, 1866)
*Tumon Bay—75, 76, IRF
Psammocora verrilli Vaughan, 1907
*Tumon Bay—639, 640, 641, 1171, RM
+Tumon Bay—ST, SS
Subgenus *Stephanaria*
Psammocora (*S.*) *togianensis* Umbgrove, 1940
*Tumon Bay—1307 RF
°Tumon Bay—RF
+Tumon Bay—ST, SS
Subgenus *Plesioseris*
Psammocora (*P.*) *haimeana* Milne Edwards and Haime, 1851
*Tumon Bay—77, 78, 196, 272, 273, IRF; 1176, RM
°Tumon Bay—RM
+Tumon Bay—ST, SS

Family POCILLOPORIDAE

Genus *Stylophora*
Stylophora mordax (Dana, 1846)
°Tumon Bay—RM, RF
+Tumon Bay—ST, SS
Genus *Seriatopora*
Seriatopora hystrix (Dana, 1846)
°Tumon Bay—RF
+Tumon Bay—SS
Genus *Pocillopora*
Pocillopora brevicornis Lamarck, 1816
°Tumon Bay—ORF, RM, RF
Pocillopora damicornis (Linnaeus, 1758)
*Tumon Bay—50, 87, 88, 191, 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
Pocillopora eydouxi Milne Edwards and Haime, 1860
*Tumon Bay—10, 11, 12, 13, 14, 538, 1206, RF

Table 1. continued

°Tumon Bay—RF
+Tumon Bay—ST, SS
Pocillopora ligulata Dana, 1846
*Tumon Bay—526, 1333, RM; 541, RF
Pocillopora meandrina Dana, 1846
*Tumon Bay—1336, RM; 1335, 1340, RF
°Tumon Bay—RM, RF
+Tumon Bay—ST
Pocillopora setchelli Hoffmeister, 1929
*Tumon Bay—1337, 1338, 1339, RF
°Tumon Bay—RM, RF
Pocillopora verrucosa (Ellis and Solander, 1786)
*Tumon Bay—257, 1159, 1332, RF
°Tumon Bay—RM, RF
+Tumon Bay—ST, SS

Family ACROPORIDAE

Genus *Acropora*
Acropora abrotanoides (Lamarck, 1816)
*Tumon Bay—137, 255, 256, 831, 1164, 1173, 1174, 1175, 1341, RF
°Tumon Bay—RM, 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, 281, IRF; 1169, 1170, RF
°Tumon Bay—IRF, ORF
Acropora brueggemanni (Brook, 1893)
*Tumon Bay—832, 833, 834, ORF; 1160, 1161, RM
°Tumon Bay—ORF
Acropora convexa (Dana, 1846)
*Tumon Bay—1259, RM
+Tumon Bay—ST
Acropora cuneata (Dana, 1846)
*Tumon Bay—1256, ORF
°Tumon Bay—ORF
Acropora diversa (Brook, 1891)
*Tumon Bay—620, ORF
Acropora humilis (Dana, 1846)
*Tumon Bay—22, RM; 1558, 1566, RF
°Tumon Bay—RF
Acropora hystrix (Dana, 1846)
°Tumon Bay—RF
Acropora kenti (Brook, 1892)
+Tumon Bay—ST, SS
Acropora monticulosa (Brueggemann, 1879)
*Tumon Bay—545, 1346, 1347, RF
Acropora murrayensis Vaughan, 1918

Table 1. continued

°Tumon Bay—RM, RF
+Tumon Bay—ST

Acropora nana (Studer, 1879)
°Tumon Bay—IRF, 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; 263RM
°Tumon Bay—IRF, ORF, RM, RF
+Tumon Bay—ST

Acropora nobilis (Dana, 1846)
*Tumon Bay—1178, IRF

Acropora ocellata (Klunzinger, 1879)
°Tumon Bay—RM, RF

Acropora palifera (Lamarck, 1816)
+Tumon Bay—ST, SS

Acropora palmerae Wells, 1954
*Tumon Bay—1348, RF
°Tumon Bay—RM, RF

Acropora rambleri (Bassett-Smith, 1890)
+Tumon Bay—ST, SS

Acropora rayneri (Brook, 1892)
+Tumon Bay—ST, SS

Acropora smithi (Brook, 1893)
*Tumon Bay—133, 134, 135, 136, 1300, RF; 1342 ST
°Tumon Bay—RF
+Tumon Bay—ST

Acropora squarrosa (Ehrenberg, 1834)
*Tumon Bay—23, RM
+Tumon Bay—ST

Acropora studeri (Brook, 1893)
*Tumon Bay—1350, RM
°Tumon Bay—RM, RF
+Tumon Bay—ST

Acropora surculosa (Dana, 1846)
*Tumon Bay—1146, 1147, ORF; 836, 1438, RM; 254, 1349, 1438, RF; 1352, ST
°Tumon Bay—ORF, RM, RF
+Tumon Bay—ST, SS

Acropora syringoides (Brooks, 1892)
*Tumon Bay—1148, 1149, 1150, 1151, 1152, ORF; 465, 1158, 1353, RM
°Tumon Bay—RM, RF
+Tumon Bay—ST

Acropora valida (Dana, 1846)
*Tumon Bay—535, 536, 537, 548, 1344, RF
°Tumon Bay—RF
+Tumon Bay—ST

Acropora sp. 1
*Tumon Bay—1165, 1166, RM; 1167, 1168, RF
°Tumon Bay—RM, RF

Acropora sp. 2
*Tumon Bay—531, RF

Table 1. continued

°Tumon Bay—RF

Acropora sp. 3

*Tumon Bay—821, 822, 823, 824, RF

Genus *Astreopora*

Astreopora gracilis Bernard, 1896

°Tumon Bay—RF

+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

+Tumon Bay—ST, SS

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

+Tumon Bay—SS

Montipora conicula Wells, 1954

*Tumon Bay—524, 525, 617, 618, 1356, 1358, RM

°Tumon Bay—RF

+Tumon Bay—ST

Montipora elschneri Vaughan, 1918

*Tumon Bay—616, 1253, 1355, RM

°Tumon Bay—RF

+Tumon Bay—ST, SS

Montipora floweri Wells, 1954

*Tumon Bay—549, 550, RF

+Tumon Bay—ST

Montipora foveolata (Dana, 1846)

°Tumon Bay—RF

+Tumon Bay—ST, SS

Montipora hoffmeisteri Wells, 1954

°Tumon Bay—RM, RF

+Tumon Bay—ST

Montipora lobulata Bernard, 1897

*Tumon Bay—194, 195, 276, 277, 278, IRF; 1179, ORF

°Tumon Bay—ORF, RM

Montipora monasteriata (Forskaal, 1775)

°Tumon Bay—RM, 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)

Table 1. continued

*Tumon Bay—528, 529, 1354, RF

Montipora tuberculosa (Lamarck, 1816)

°Tumon Bay—RF

Montipora verrilli Vaughan, 1907

*Tumon Bay—647, 648, 649, RM; 527A, 1357, RF

°Tumon Bay—RM, RF

+Tumon Bay—ST, SS

Montipora verrucosa (Lamarck, 1816)

°Tumon Bay—RF

+Tumon Bay—ST, SS

Montipora sp. 1

°Tumon Bay—RF

Montipora sp. 2

*Tumon Bay—1253, RM

°Tumon Bay—IRF, RM

Montipora sp. 3

°Tumon Bay—RF

Suborder FUNGIINA
Superfamily AGARICIICAE
Family AGARICIIDAE

Genus *Pavona*

Pavona clavus (Dana, 1846)

*Tumon Bay—1359, RF

°Tumon Bay—RM, RF

+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 fondifera 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

+Tumon Bay—ST, SS

Pavona gardineri van der Horst, 1922

*Tumon Bay—758, 759, 760, 855, 856, 857, RM

Subgenus *Pseudocolumnastraea*

Pavona (P.) pollicata Wells, 1954

*Tumon Bay—1302, 1303, RM

°Tumon Bay—RM, 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

Table 1. continued

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

Genus *Leptoseris*
Leptoseris hawaiiensis Vaughan, 1907
°Tumon Bay—RF
+Tumon Bay—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

Family SIDERASTREIDAE

Genus *Coscinaraea*
Coscinaraea columna (Dana, 1846)
°Tumon Bay—RF
+Tumon Bay—ST, SS

Superfamily FUNGIICAE
Family FUNGIIDAE

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

Superfamily PORITICAE
Family PORITIDAE

Genus *Goniopora*
Goniopora columna Dana, 1846
*Tumon Bay—478, ST
+Tumon Bay—ST, SS
Goniopora sp. 1
*Tumon Bay—322, RF
°Tumon Bay—IRF, RF
Goniopora sp. 2
*Tumon Bay—1257, 1258, RM
°Tumon Bay—RF
+Tumon Bay—SS

Genus *Porites*
Porites annae Crossland, 1952
*Tumon Bay—269, 270, ORF
°Tumon Bay—IRF

Table 1. continued

Porites australiensis Vaughan, 1918
  *Tumon Bay—1308, RM
  °Tumon Bay—RF
  +Tumon Bay—ST, SS
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
  +Tumon Bay—ST, SS
Porites lobata Dana, 1846
  °Tumon Bay—RF
  +Tumon Bay—ST, SS
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
  +Tumon Bay—ST, SS
Porites murrayensis Vaughan, 1918
  *Tumon Bay—532, 533, 534, RF
  +Tumon Bay—ST, SS
Porites sp. 1
  *Tumon Bay—614, 615, 1361, RM
  °Tumon Bay—RM, RF
Porites sp. 2
  °Tumon Bay—RF

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

Genus *Alveopora*
Alveopora verrilliana Dana, 1872
  °Tumon Bay—RF
  +Tumon Bay—ST, SS

Table 1. continued

Suborder FAVIINA
Superfamily FAVIICAE
Family FAVIIDAE
Subfamily FAVIINAE

Genus *Favia*
Favia favus (Forskaal, 1775)
*Tumon Bay—258, 259, 1364, 1365, 1367, RF; 1366, ST
+Tumon Bay—ST, SS
Favia pallida (Dana, 1846)
°Tumon Bay—IRF, ORF, RF
+Tumon Bay—ST, SS
Favia speciosa (Dana, 1846)
°Tumon Bay—RF
+Tumon Bay—ST, SS
Favia stelligera (Dana, 1846)
*Tumon Bay—140, 620A, RF
°Tumon Bay—RM, RF
+Tumon Bay—ST, SS
Favia rotumana (Cardiner, 1899)
*Tumon Bay—253 IRF
Genus *Favites*
Favites abdita (Ellis and Solander, 1786)
*Tumon Bay—264, 265, ORF
°Tumon Bay—RF
Favites complanata (Ehrenberg, 1834)
°Tumon Bay—RM, RF
+Tumon Bay—ST, SS
Genus *Plesiastrea*
Plesiastrea versipora (Lamarck, 1816)
*Tumon Bay—546, 547, 1362, 1363, RF
°Tumon Bay—RM, RF
Plesiastrea sp. 1
°Tumon Bay—RM, RF
Genus *Goniastrea*
Goniastrea parvistella (Dana, 1846)
°Tumon Bay—RM, RF
+Tumon Bay—ST, SS
Goniastrea retiformis (Lamarck, 1816)
*Tumon Bay—49, 94, 95, 328, 329, 330, IRF; 612, 613, 1368, RF
°Tumon Bay—IRF, ORF, RM, RF
+Tumon Bay—ST
Genus *Platygyra*
Platygyra rustica (Dana, 1846)
*Tumon Bay—37, 38, 235, IRF
°Tumon Bay—RF
+Tumon Bay—ST
Platygyra sinensis (Milne Edwards and Haime, 1849)
*Tumon Bay—1369, RF
°Tumon Bay—RF

Table 1. continued

+Tumon Bay—ST, SS

Genus *Leptoria*

Leptoria gracilis (Dana, 1846)

*Tumon Bay—36, IRF; 1372, RM

°Tumon Bay—ORF, RM, RF

+Tumon Bay—ST

Leptoria phrygia (Ellis and Solander, 1786)

*Tumon Bay—271, 334, 827, IRF; 139, 611, 1370, RF

°Tumon Bay—ORF, RF

+Tumon Bay—ST

Genus *Hydnophora*

Hydnophora microconos (Lamarck, 1816)

*Tumon Bay—543, 544, RF

°Tumon Bay—RM, RF

+Tumon Bay—ST

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

+Tumon Bay—ST, SS

Leptastrea sp. 1

°Tumon Bay—RF

+Tumon Bay—ST, SS

Genus *Cyphastrea*

Cyphastrea serailia (Forskaal, 1775)

°Tumon Bay—RF

+Tumon Bay—ST, SS

Cyphastrea chalcidicum (Forskaal, 1775)

°Tumon Bay—RF

+Tumon Bay—ST, SS

Genus *Echinopora*

Echinopora lamellosa (Esper, 1787)

*Tumon Bay—479, 480, 1306, RF

°Tumon Bay—RF

Genus *Diploastrea*

Diploastrea heliopora (Lamarck, 1816)

°Tumon Bay—RF

+Tumon Bay—ST, SS

Family OCULINIDAE

Subfamily GALAXEINAE

Genus *Galaxea*

Galaxea fascicularis (Linnaeus, 1758)

*Tumon Bay—56, IRF; 1254, RM

°Tumon Bay—ORF, RM, RF

+Tumon Bay—ST

Galaxea hexagonalis Milne Edwards and Haime, 1857

*Tumon Bay—642, 643, 644, 645, 646, RM

Table 1. continued

°Tumon Bay—RM, RF
+Tumon Bay—ST

Family MUSSIDAE

Genus *Lobophyllia*
Lobophyllia corymbosa (Forskaal, 1775)
°Tumon Bay—RF
+Tumon Bay—ST, SS
Lobophyllia costata (Dana, 1846)
*Tumon Bay—24, 25, 26, 27, IRF; 138, 260, 261, 262, 1304, 1373, RM
°Tumon Bay—RF
+Tumon Bay—ST, SS
Genus *Acanthastrea*
Acanthastrea echinata (Dana, 1846)
°Tumon Bay—RF

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

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
+Tumon Bay—ST, SS

Class HYDROZOA
Order MILLEPORINA
Family MILLEPORIDAE

Genus *Millepora*
Millepora dichotoma Forskaal, 1775
°Tumon Bay—RF
Millepora exaesa Forskaal, 1775
°Tumon Bay—RF
+Tumon Bay—ST, SS
Millepora platyphylla Hemprich and Ehrenberg, 1834
*Tumon Bay—141, 519, 520, 1177, 1205, 1375, RM; 527B, 546A, 1157, RF

Table 1. continued

°Tumon Bay—ORF, RM, RF
+Tumon Bay—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
+Tumon Bay—ST, SS

[* indicates that the specimen was collected, ° indicates a species observed on the transects, + indicates a species observed in the study area. 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.]

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

Figure 9 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 fairly similar in number of genera and species, with the exception of the outer reef flat subzone at Gognga, which had a maximum of 6 species and 4 genera for a single transect section and two transect sections without corals. In contrast, the outer reef flat subzone at Naton had a maximum of 13 species and 8 genera for a single transect section and had some corals in all transect line sections. The low number of coral species at the Gognga outer reef flat subzone is due to the exposure of this zone during the lower tides, whereas at Naton this subzone is slightly lower in elevation and is usually covered with water.

INTERTIDAL ZONE (5 METERS WIDE)

No living corals were found in this zone at the study region due to reef surface exposure during low tides.

REEF FLAT ZONE (460 TO 480 METERS WIDE)

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 200 m section of this subzone is, in most places, nearly barren of corals. Living coral covering the reef surface of this section (Fig. 10) shows a range from 0 to 5 percent. The reef surface is 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. 11), because of its massive size, is about the only coral found in this sec-

Table 2. Relative frequency of occurrence and zonal distribution of corals at Tumon Bay. Relative frequency of occurrence is expressed as a percentage of the total number of colonies found in a transect zone or combination of zones. Data from the Gognga and Naton transects are combined. The species are listed in order of decreasing frequency when all zones are combined.

Name of Coral	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of Colonies	Rel. Freq.	No. of Colonies	Rel. Freq.	No. of Colonies	Rel. Freq.	No. of Colonies	Rel. Freq.	No. of Colonies	Rel. Freq.
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 studeri	—	—	—	—	2	.39	37	2.32	39	1.18
Millepora platyphylla	—	—	3	.54	15	2.90	19	1.19	37	1.12
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

Table 2. Continued

Name of Coral	Inner reef flat No. of Colonies	Inner reef flat Rel. Freq.	Outer reef flat No. of Colonies	Outer reef flat Rel. Freq.	Reef margin No. of Colonies	Reef margin Rel. Freq.	Reef front No. of Colonies	Reef front Rel. Freq.	All zones combined No. of Colonies	All zones combined Rel. Freq.
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 chalcidicum	—	—	—	—	—	—	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
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

Table 2. Continued

Name of Coral	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of Colonies	Rel. Freq.	No. of Colonies	Rel. Freq.	No. of Colonies	Rel. Freq.	No. of Colonies	Rel. Freq.	No. of Colonies	Rel. Freq.
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 elschneri	—	—	—	—	—	—	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
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 (Pseudocolumnastraea) 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	—	—	—	—	—	—	6	.38	6	.18

Table 2. Continued

Name of Coral	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of Colonies	Rel. Freq.	No. of Colonies	Rel. Freq.	No. of Colonies	Rel. Freq.	No. of Colonies	Rel. Freq.	No. of Colonies	Rel. Freq.
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
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. 2	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) obtusata	—	—	1	.18	—	—	—	—	1	.03
Porites sp. 2	—	—	—	—	—	—	1	.06	1	.03
Montipora sp. 3	—	—	—	—	—	—	1	.06	1	.03
Psammocora exesa	—	—	1	.18	—	—	—	—	1	.03
Psammocora (Plesioseris) haimeana	—	—	—	—	1	.19	—	—	1	.03
Total	629		559		517		1597		3302	
Total species	18		29		44		84		103	
Total genera	11		14		18		32		32	

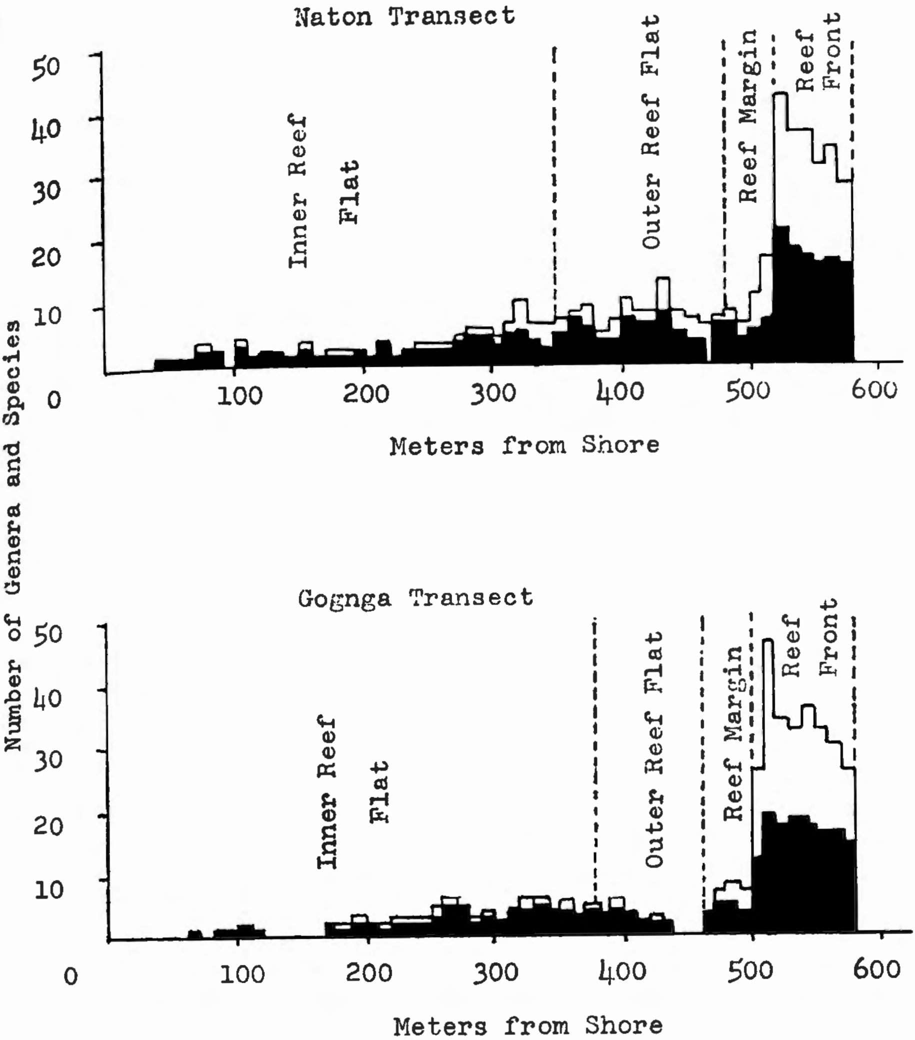

Fig. 9. Number of genera and species per 10 m transect line section at Naton and Gognga Transects. Each column represents a 10 m section of the transects. Shaded area indicates genera and unshaded area indicates species.

tion 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 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 greater percentage of reef surface covered by living corals (Fig. 10). Planula settlement is enhanced by the

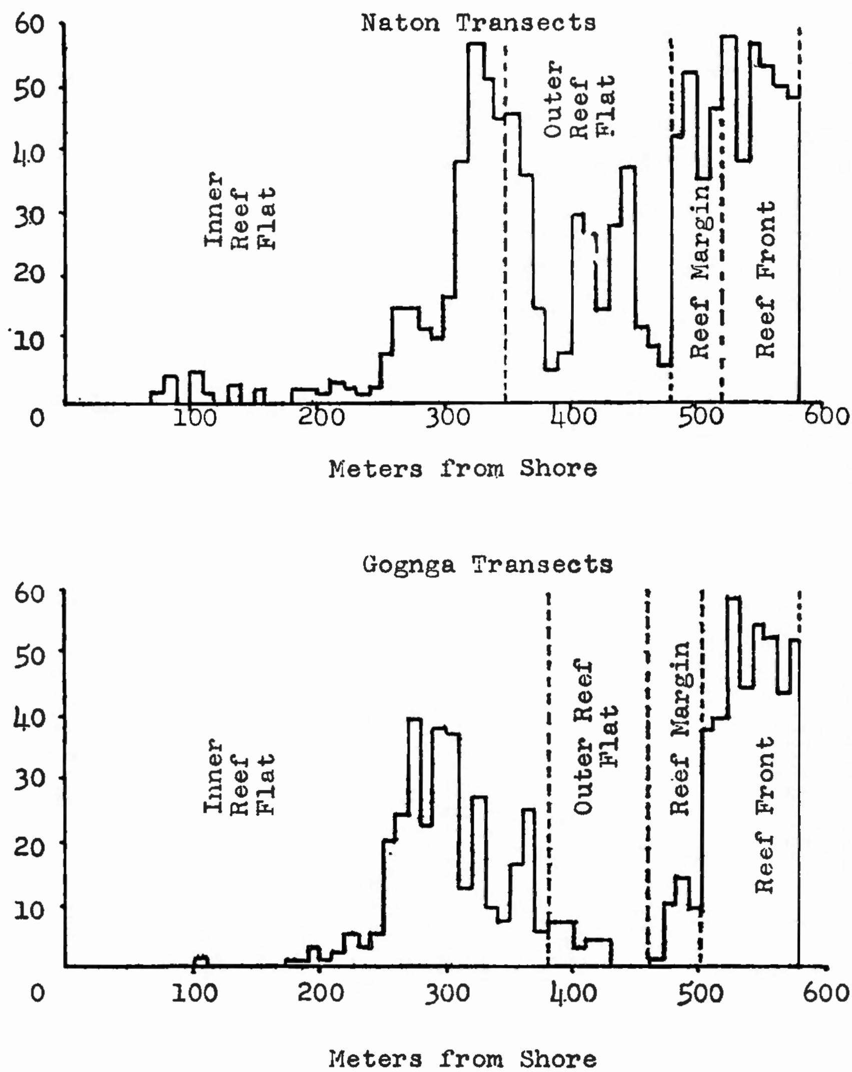

Fig. 10. Percentage of reef surface covered by living corals at Naton and Gognga Transects. Each column represents a 10 m section of the transects.

present 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 5 percent for the inner 200 m section to 57 percent for the outer 150 to 180 m section, is found (Fig. 10). This sharp increase in percentage of cover is not represented by a relative increase in the number of species (Fig. 9), but is because of the greater density of *Acropora aspera* and *Acropora acuminata.* These two species form large arborescent (stag-horn) thickets, 1 to 10 m across (Fig. 12). Also abundant in areas between and

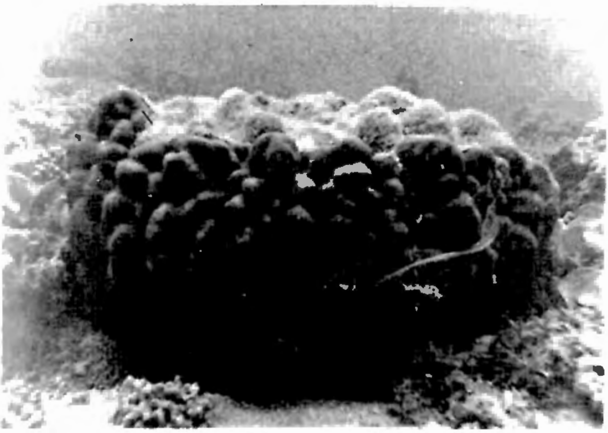

Fig. 11. Massive colony of *Porites lutea* growing on a sand and rubble surface of the inner reef flat zone at Tumon Bay. The upper surface of the colony is dead due to exposure at low tide.

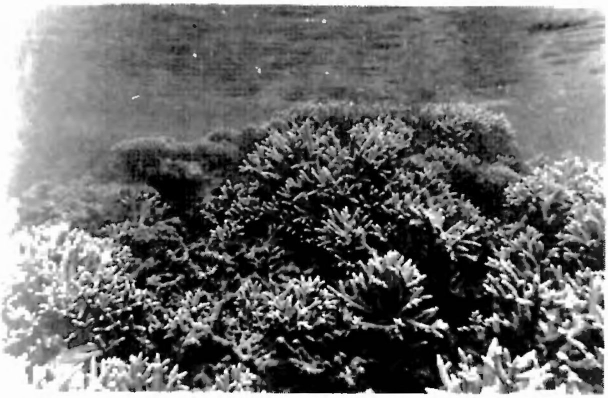

Fig. 12. Thicket of *Acropora acuminata* (staghorn coral) and scattered clumps of *Pocillopora damicornis* located on the inner reef flat zone at Tumon Bay.

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. 13). 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 *Pavona decussata, Psammocora contigua*, 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 (Fig. 4)

Fig. 13. Microatoll of *Porites lutea* on the inner reef flat zone at Tumon Bay. The larger colony is about 4 m across and 30 cm high. Only the outer margin of the colony is living, the upper surface is mostly dead because of exposure at low tide.

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, distribution by fragmentation, plus recovery of the unburied branch tips, explain the 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 and observations from this subzone are 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 percent of the 629 colonies encountered on the transects. Four of the 18 species were represented by only one colony each. The greatest number of genera and species encountered on any one transect section of the reef flat subzone (Fig. 9), was 6 and 10 respectively at Naton transect.

Outer Reef Flat Subzone (*80 to 130 meters wide*). Because of reef surface exposure at low tide, this subzone is conspicuously barren of corals except where it grades into the inner reef flat and in scattered shallow reef flat pools. At Gognga transect, the percentage of corals covering the substratun (Fig. 10) drops from a high of 37 for the inner reef flat to a high of 7 for the outer reef flat. Two transect sections (45 and 46) at Gognga had no living corals present at all. 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. This slightly deeper water and increased current, in the channel, enhance coral development of this subzone. This rich coral growth at Naton gives Fig. 10 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. 14). Interspersed 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 *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 coral. The central and outer part of this subzone is a pavement-like platform along most of Tumon Bay and has long stretches where corals are absent. Stunted growths of *Porites lutea, Favia pallida*, and *Goniastrea retiformis* occupy the margins of widely scattered reef flat pools, a few centimeters in depth, over the central region. These pools and their inconspicuous corals account for the low number of species (Fig. 9) and low percentage of coral (Fig. 10) covering the reef surface for transect sections 41 through 47 at Gognga transects.

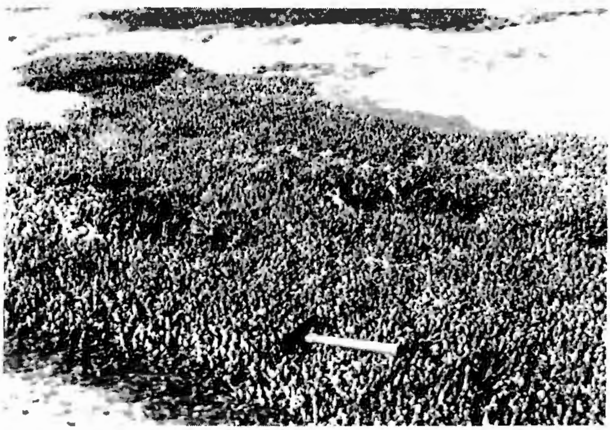

Fig. 14. Large flat-topped thicket of *Acropora aspera*. Low tides limit the upward growth of the colony giving it a flattened clipped-like appearance. The upper tips of the branches are mostly dead.

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 the genera to 16.

Four hundred eighty-four coral colonies were recorded from the outer reef flat at Naton transect, whereas at Gognga transect only 75 colonies were recorded in the same comparable area. The large number of coral colonies encountered at Naton transect can be explained because the depressed platform there, tends to create habitat characteristics which are similar to those found on the inner reef margin zone. Another factor which increases the number of colonies on the Naton transect is fragmentation, due to strong wave action, of ramose species of *Acropora nasuta* and *Psammocora contigua*. The deeper water on the outer reef flat at Naton enhances continued growth of these living coral fragments, whereas as Gognga many of the fragments transported to the outer reef flat are killed by exposure at low tide.

Colony diameter on the outer reef flat subzone is similar to that found for corals on the inner reef flat subzone (Table 3), except for the number of coralla 50 cm and above. Decrease in the number of large coralla is to be expected in the sub-

Table 3. Distribution of coral colony diameter by reef zones at Tumon Bay, 1969. Relative frequency of occurrence is expressed as a percentage of the total number of colonies found in a transect zone. Data from Naton and Gognga Transects are combined.

Diameter range in cm	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of Corals	Rel. Freq.	No. of Corals	Rel. Freq.	No. of Corals	Rel. Freq.	No. of Corals	Rel. Freq.	No. of Corals	Rel. Freq.
0—5	122	19	129	23	140	27	433	27	824	25
6—10	205	33	190	34	158	31	310	19	863	26
11—15	97	15	100	18	93	18	213	13	503	15
16—20	47	7	42	8	45	9	164	10	298	9
21—25	21	3	21	4	32	6	136	9	210	6
26—30	43	7	24	4	35	7	114	7	216	7
31—35	8	1	13	2	4	1	79	5	104	3
36—40	8	1	6	1	4	1	33	2	51	2
41—45	5	1	4	1	2	1	29	2	40	1
46—50	5	1	4	1	2	1	24	2	35	1
51—60	11	2	7	1	1	1	22	1	41	1
61—70	2	1	2	1	0	0	6	1	10	1
71—80	5	1	3	1	0	0	9	1	17	1
81—90	4	1	3	1	1	1	7	1	15	1
91—100	8	1	2	1	0	0	7	1	17	1
101—150	14	2	3	1	0	0	4	1	21	1
151—200	6	1	4	1	0	0	5	1	15	1
201—300	12	2	2	1	0	0	2	1	16	1
301—400	2	1	0	0	0	0	0	0	2	1
401—500	1	1	0	0	0	0	0	0	1	1
501—up	3	1	0	0	0	0	0	0	3	1
TOTAL	629		559		517		1597		3302	

zone because of the fewer numbers of large arborescent staghorn patches that occur on the wave-washed outer reef flat (Table 4).

Table 4. Distribution of coral growth forms by reef zones at Tumon Bay, 1969. Relative frequency of occurrence is expressed as a percentage of the total number of colonies found in a transect zone. Data from Naton and Gognga Transects are combined.

Growth Form	Inner reef flat		Outer reef flat		Reef margin		Reef front		All zones combined	
	No. of Corals	Rel. Freq.	No. of Corals	Rel. Freq.	No. of Corals	Rel. Freq.	No. of Corals	Rel. Freq.	No. of Corals	Rel. Freq.
Massive	41	7	78	14	39	8	406	25	564	17
Encrusting	2	1	12	2	53	10	390	24	457	14
Foliaceous	10	2	5	1	0	0	2	1	17	1
Flabellate	1	1	4	1	10	2	44	3	59	2
Corymbose	5	1	123	22	251	49	294	18	673	20
Cespitose	206	33	153	27	164	32	349	22	872	26
Arborescent	364	58	170	30	0	0	53	3	587	18
Phaceolid	0	0	0	0	0	0	2	1	2	1
Columnar	0	0	14	3	0	0	54	3	68	2
Solitary	0	0	0	0	0	0	3	1	3	1
TOTAL	629		559		517		159		3302	

REEF MARGIN ZONE (40 METERS WIDE)

This zone is constantly awash, even during the lowest tides, and is the region of greatest water agitation (Fig. 2). It is discriminated from the barren outer reef at Gognga by an increase in the number of coral species per transect section (Fig. 9), plus a similar increase in the percentage of living corals covering the reef surface (Fig. 10). Transition into this zone at Naton is not as distinct as is that at Gognga. Luxuriant coral growth in a series of reef margin pools at Naton increases the coral covering the reef surface from 40% for the outer reef flat to a high of 52% for the reef margin (Fig. 10).

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

The most common corals found on the upper surface of the buttresses were: *Acropora studeri, A. nana, A. nasuta, A. ocellata, A. palmerae, A. surculosa; Goniastria retiformis; Millepora platyphylla; Pocillopora meandrina, P. setchelli,* and *P. verrucosa.* Growth forms of most colonies in this habitat of agitated water are various ramose forms (Table 4). Ramose colonies are usually prostrate forms with stout, closely-set branches and broad encrusting bases. An exception to this rough water 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 buttresses 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 buttresses are *Acropora palmerae* colonies, which form broad encrustations up to several meters in diameter with mammalate projections on the upper surface. 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* are found in some of the larger reef margin pools. Growth forms of coral differ somewhat in surge channel habitats compared to those growing on the upper surface of the spurs. Fewer ramose colonies are found in the surge channels, but 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 (Pseudocolumnastraea) pollicata, P. (polyastra) planulata; Porites* sp. 1; *Psammocora (Plesioseris) 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 contains 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 3) for the reef margin is similar to that of the outer reef flat, except for the near absence of colonies 50 cm and above in diameter. Generally, coral colonies tend to be small, with the exception of some species of *Montipora, Acropora*, and *Millepora*, which locally may form spreading encrustations a meter or more in diameter. Table 2 lists a total of 44 coral species representing 18 genera that were found on the reef margin portions of the Gognga and Naton transects. When the corals that were collected from the the reef margin zone but not found on the transects are added to this list, the total is increased to 59 species and 21 genera.

REEF FRONT ZONE (60 TO 80 METERS WIDE)

This zone is poorly-known in most coral distribution studies, and is not well 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. 9), percentage of reef surface covered by living corals (Fig. 10), corallum size, growth form, 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 percent (Fig. 10) per transect line section. The highest number of species and genera for this zone per transect section was 46 species at Gognga (line section 52) and 21 genera at Naton (line section 53), (Fig. 9). From Table 2, the total number of species from the entire reef front zone was 84 species, representing 32 genera. Tabulation from Table 1 shows that, by including the corals that were collected with those observed on the transects, it raises the total to 98 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, many corals reach their greatest size in this zone (Table 3). Species such as *Acropora abrotanoides, A. smithi; Coscinaraea columna; Diploastrea heliopora; Favia stelligera; Goniastrea retiformis; Lobophyllia costata; Millepora platyphylla; Montipora verrilli; Pavona clavus; Platygyra rustica: Pocillopora eydouxi; Porites australiensis, P.* (*Synaraea*) *convexa, P. lutea, P.* (*Synaraea*) *iwayamaensis*; and *Psammocora* (*Stephanaria*) *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* (*Synaraea*) *iwayamaensis, Porites lutea*, and *Porites* (*Synaraea*) *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 (Fig. 7). Growth forms are similar for both transects and show a distinct increase in the relative frequency of encrusting and massive types when compared to the reef margin (Table 4).

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 channel 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

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* (*Synaraea*) *iwayamaensis* and *Porites* (*Synaraea*) *convexa* steadily increased in density and were the dominant corals found 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* (*Stephanaria*) *togianensis* and *Coscinaraea columna*; small rounded colonies of *Astreopora gracilis* and *Goiopora* sp. 1; 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 vasiform and tabulate 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* (*Synaraea*) *horizontalata.* Small encrusting patches of *Porites* (*Synaraea*) *hawaiiensis* are common in cavities, holes, and on the underside of large spreading coral colonies.

SUMMARY AND CONCLUSIONS

SPECIES DIVERSITY

At Tumon Bay a well-developed fringing reef with a diverse assemblage of corals is found living on both the wide reef flat platform and offshore slopes. The following data, summarized from Table 1, list the number of genera and species for the major divisions of corals at Tumon Bay.

	Genera	Species
Hermatypic Scleractinians	31	139
Ahermatypic Scleractinians	2	2
Non-Scleractinians	3	5
Total	36	146

Following is a reef zone analysis of the number of genera and species tabulated from Table 1, from Tumon Bay.

Reef Zone	Genera	Species
Inner reef flat	18	48
Outer reef flat	16	37
Reef margin	21 (14)	59 (26)
Reef front	32	98
Submarine terrace	28	73
Seaward slope	26	57

Most of the fringing reef flat platforms along the coasts of Guam are rather barren of corals because of exposure during low tides. At Tumon Bay the high number of species found in the inner reef flat zone is due to the rather well developed moat that is present at low tide. Except for times during the lowest tides and periods of calms, wave transport moves water across the reef margin and outer reef flat into the moat. This mass transport of water generates several longshore currents that flow from Ypao Beach and Gognga Beach toward the boat channel where they converge and then flow seaward (Randall and Jones, 1973). The shallow lagoon-like conditions of the moat plus the longshore currents in this zone provide conditions very favorable for growth of coral. Coral species predominate in this zone which can withstand and are adjusted to the higher water temperatures that are occasionally encountered when mass transport of water over the reef margin ceases. Preliminary thermal stress data from Jones and Randall (In Press) show that corals from reef flat environments, where seawater temperatures are commonly higher, can survive in water 2° to 3°C above the more constant ambient seawater temperature of the offshore coral communities. Conversely many offshore coral species have a narrower thermal tolerance range and are not commonly found on the reef flat platform. This could be a factor accounting for the 20 species (Table 1) that are more or less restricted to the reef flat platform.

Corals are not equally distributed across the inner reef flat zone. The shoreward half of the zone has sandy unstable substrates that are unfavorable for coral growth, whereas the seaward half has substrates of coral-algal-mollusc rubble, boulders, and stretches of bare reef rock which are favorable for coral development. Many coral colonies on the reef flat platform are derived by mechanical fragmentation and distributed to other locations by storm waves.

Species diversity is high for the outer reef flat zone when data from the rich coral growth at Naton transects is combined with that from Gognga transects. When presented separately the outer reef flat zone at Gognga is rather depauperate (data from above table in parentheses). The number of species rises sharply at the reef margin and is highest at the reef front zone.

The most conspicuous features of the reef front is the dominance of acroporoid species. Eighteen species of *Acropora* were found in this zone and a greater percentage of reef surface was covered by this genus than by any other. Fourteen species of *Acropora* were found in the reef margin zone but pocilloporid species account for more reef surface coverage than any other genera except at Naton transects. At Naton transects the reef channel and depressed platform there favor the development of *Acropora nasuta*, which accounts for over 50 percent of the colonies occurring in this zone. Species diversity is high also on the submarine terrace which is due mainly to the persistance of acroporoid corals (13 species) into the shoreward half of this zone from the reef front. Lower species diversity in the seaward slope zone is due primarily to the dropping out of acroporoid species, as only five were encountered there. Of these five species three were restricted to this zone at Tumon Bay.

PERCENTAGE OF CORAL COVER

The following data, summarized from Figure 9, shows the mean percent of living coral, per transect section, covering the reef surface from the Naton and and Gognga transects. Data for the submarine terrace and seaward slope zones was obtained from six 4 m^2 random sample points at each zone.

Reef Zone	Percent of Coverage
Inner reef flat	5.4
Outer reef flat	14.9
Reef margin	43.8 (9)
Reef front	49.1
Submarine terrace	59.5
Seaward slope	50.1

The percentage of cover for the inner reef flat is low because of the unfavorable substrate habitat found on the inner part of the subzone. The outer reef flat zone is quite low for Gognga transects (data in parentheses) because of reef surface exposure there at low tide. At Naton transects the percent of cover increases considerably which is a reflection of the rich coral growth found on the depressed reef platform and reef channel found there. The reef front, submarine terrace, and seaward slope (down to 30 meters) zones are quite similar in the percent of coverage by living corals. Below 30 to 35 meters coral density and percentage of coverage drop rapidly for the seaward slope.

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 "stag-horn" *Acropora* species. 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.

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 these zones. These growth forms become more abundant in the deeper water found on the seaward slope. In this deeper zone *Porites (Synaraea) horizontalata* forms tiers of plates, which may develop into large contiguous masses. At Tumon Bay *Porites* (*Synaraea*) *convexa* and *Porites* (*Synaraea*) *iwayamaensis* typically form large columnar coralla, which at the base develop large, reniform, foliaceous plates. These two species account for nearly half of the living coral coverage at some locations on the submarine terrace and seaward slope zones.

Encrusting 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 *Lobophyllia* species on the reef front, submarine terrace, and seaward slope 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.

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

CORALLA SIZE DISTRIBUTION

Acropora (staghorn) thickets in the reef flat zone account for the large coralla encountered there. In this study, a circular contiguous patch of arborescent *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. Other parameters indicating growth are the presence of a buttress and channel system (growth features) at the reef margin and reef front zones instead of a spur and groove system (erosional features). A high degree of topographic irregularity due to local growth of corals forming knobs, pinnacles, bosses, and mounds is another indicator of reef growth. Using the above criteria to estimate relative age, the coral reef communities at Tumon Bay appear to be in a developmental stage and growing seaward onto the shallow submarine terrace found there.

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