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A DESCRIPTION

OF

THE CORAL STRUCTURE OF TUTIA REEF

(TANGANYIKA TERRITORY, EAST AFRICA),

AND ITS FISH FAUNA.

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1. INTRODUCTION.

Although the systematics of Western Indian Ocean marine fishes is tolerably well known there is very little information as yet available on the biology and ecology of fishes. In the coastal areas of Kenya and Tanganyika (Latitude 1° 35' S. - 10° 40' S.) the East African Coastal Current runs northward at all times of year, forming as the north flowing branch of the South Equatorial Current when it strikes the African mainland. As a water mass that has been for a long period of time at the surface it is low in nutrients (Newell, 1957, 1959). In addition stable upper water layers with a marked thermocline over most of the year and little or no upwelling south of the equator allows little addition of nutrients from deeper and richer water layers. This results in an area that can in no way be called quantitatively rich in animal or plant life, but the sea as a protein source plays a traditional and important role in the nutrition of the coastal races. The traditional African fishery is carried on in almost all types of habitat from mangrove swamps to deep banks of forty fathoms and over, but the main bulk of the fishery is based on those fishes on or associated with coral reefs. The complex biocoenose of the reef seems an oasis of living matter on this coastline. The present study was undertaken to describe the fish fauna of a typical coral reef and its relationships to the coral facies of the bottom. Tutia Reef in the Mafia area was chosen for study, as it had a side exposed to the open Indian Ocean,

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as well as one side completely sheltered from wave action. Three transects were pegged out down the three sides of the roughly triangular reef, and the dominant organisms on the bottom, i.e. those covering large areas, and those species determining bottom structure, were collected down these transects. Quadrats 1 yard square were laid down the transects, and the dominant corals, algae, alcyonaria and sponges noted with an estimation of the area of the bottom they covered. Collecting of fishes by a series of explosions was made down each transect, as well as from the rest of the reef and the Mafia Archipelago by explosives and other methods (see Appendix I).

Typically the East African coastline is lined by a fringing reef, usually of not great width (½ mile). All stages of the formation of a "boat channel" by erosion behind the reef crest are seen. From observations on the fringing reef of the eastern Zanzibar coastline, the southern and eastern underwater coast slopes of Tutia Reef are similar to the surf exposed fringing reef, and the description of these sides can be considered typical for much of the East African coastal area.

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Manager/

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2. TUTIA REEF, ITS ORIGIN AND CORAL STRUCTURE.

A. General Conditions Affecting the Reef:

Tutia Reef lies on the outer edge of the Mafia Archipelago, in 8° 7' South Latitude (Plates 1 & 2). Fifteen miles of shallow water (mostly 8-15 fathoms in depth) dotted with reefs and islets separate it from the mainland. The reef is separated by a narrow channel half a mile wide from Kibondo Reef to the North, to the West the reef faces the mainland across the South Mafia Channel, and to the South and East the bottom slopes fairly quickly to deep water, the 100 fathoms line being reached in about $1\frac{1}{5}$ miles. The reef therefore contains coral slopes exposed to the Indian Ocean to the South and East, and more protected slopes on its western and northern edges. The area is dominated by two main factors, the periodic monsoon winds, and the north flowing E.A. Coastal Current. From November to March the north-east monsoon winds blow, usually Force 1-3 on the Beaufort Scale, and tend to slow down the E.A. Coastal Current to $\frac{1}{2}$ - 2 knots. From May to October the stronger south-east monsoon winds blow (Force 2-5), and this, combined with a completely clockwise wind system in the northern Indian Ocean results in an acceleration of the E.A. Coastal Current up to at least 4 knots (Newell 1957).

Tidal variation in the Mafia area from mean low water springs to mean high water springs is 12.4 ft., the mean neap difference being 4.2 ft. The main current through the gap between Mafia and the mainland is northerly, but at Tutia Reef tidal rhythms dominate. In a series of 20 minute readings with an Ekman current metre (supplemented by some 24 hour readings with a Carruthers metre) at all stages/

stages of the tidal cycle at neaps and springs, Mr. B.S. Newell found no currents exceeding 1 knot around Tutia Reef. Off Mange Reef the main water current was north-westerly with a reversal to southerly (⅛th of the total current) during ebb.

On all faces of Tutia Reef there was straightforward 180° reversal of current from ebbing to flooding and vice versa, but the western face showed clockwise change and not anti-clockwise as on the northern and southern faces. Close to the reef edge this pattern becomes more complex due to run-off from the reef. The strong E.A. Coastal Current results in a northerly current of water through the whole archipelago with tidal currents to and from the shallow area super-imposed on this flow.

Salinity, turbidity and the effect of the Rufiji River. With the Rufiji River in normal flow salinities at all times of neap and spring tides were taken around Tutia Reef during June 1956. Salinities varied from 34.7 - 34.95 pts/thousand. The lower values were obtained after some hours ebbing, when water from the shallow inshore area of the southern archipelago covered the reef, and the high values were obtained after some period of flooding, when the reef was covered in water straight from the open sea. The range of salinity values from water of the E.A. Coastal Current during the year is about 34.6 - 35.30 (Newell 1959). The Rufiji Delta with its wide mangrove swamps and complex of winding channels is clearly the result of many changes of course. At present the bulk of the water enters the northern portion of the Mafia archipelago, and even in spate does not affect Tutia Reef. The writer has been able to see the area from an aeroplane with the Rufiji River in full flood, when the brown silt-laden water pours from the delta and moves northwards in a gigantic brown stream in the inner half of the northern

Mafia/

Mafia archipelago. Outside this brown water across a clear dividing line lay the typical blue tropical water, covering all the southern reefs, Niororo Island reef, Shungumbili Island Reef, and the outer reefs of the North Mafia area. During the four years of observation, even during the times of the "short rains" and the "long rains" at the changes of the monsoon winds, such muddy water was never seen off Tutia Reef. At present Tutia can be considered not to be affected by the Rufiji, but it is possible that given a more southerly entrance of the Rufiji into the area during the past ages, Tutia and the southern reefs may have periodically been affected by the Rufiji River, and suffered retarded growth or death from silt and low salinity. In this connection it must be noted that Niororo Island close to the Rufiji mouth, has a flourishing fringing reef, the dominant corals being huge beds of *Acropora hyacinthus*, much *Seriatopora hystrix*, and *Porites (Synarea) convexa*. This reef has not the variety of the outer face of Tutia Reef which is exposed to the swell, but what effect the Rufiji River may have on it at exceptional floods does not prevent a high percentage coral cover in some areas.

On Tutia Reef visibility below water is seldom less than 15 ft., and is usually in the region of 20-30 ft., and exceptionally may reach over 60 ft.

Wave action on Tutia Reef. During the south-east monsoon wind strengths of Force 5 and occasionally Force 6 occur, and the southern and eastern edges of Tutia, being unprotected from the open Indian Ocean are exposed to violent wave action. During such times it is impossible to use free diving equipment on the exposed areas of the reef, and ships cannot approach the reef with safety on the seaward side. At this time of year much coral, mostly

Acropora/

Acropora formosa and A. irregularis, is broken by wave action and masses of loose fragments wash up and down in the ridges of the outer slope. After such a storm a huge platform of Acropora spicifera, 5 ft. across was also found torn up and lying upside down. The western and northern faces of the reef are sheltered under such conditions even at high tides, and in bad storms the 120 ft. M.V. Manihino was able to lie safely at anchor in the gap between Tutia and Kibondo reefs, protected by Tutia Reef, and underwater observation was able to show that wave action was slight and no corals were being damaged on the northern and western reef edges. In the north-east monsoon the reef lies to the lee of Mafia and Kibondo islands, and wave action is negligible. As mentioned by Crossland (1902) ground swells from the Indian Ocean are unusual, and on Tutia (in the N.E. monsoon) little 2 ft. waves break on the southern and eastern faces of the reef, and the northern and western faces are flat calm.

The Tanganyika and Kenya coasts are outside the usual Western Indian Ocean cyclone area, although occasional 'freak' cyclones may strike this coast. The two most recent of these were the Zanzibar cyclone of 1872 and the Lindi cyclone of 1952 (Sansom 1953). Both were short-lived, and caused very isolated wind and sea damage. They cannot be considered to have much effect on the coastline, and the lack of large "negro-heads" is presumably due to the lack in this area of very severe winds. Smaller coral rocks, up to 3 ft. across do occur, however, and are found along the eastward reefs. These are presumably small enough to be thrown up by strong S.E. monsoon winds. On Tutia Reef a wide boulder tract is present, but as described below this is considered to be chiefly the result of erosion, and not wave thrown boulders.

B./

B. <u>The Origin of Tutia Reef:</u>

Over much of the Tanganyika, Zanzibar and Pemba coasts the present reef ends on the landward side at a cliff of coral rock 14 feet in height above the present reef flat. In an area like the east coast of Mafia the wall may run unbroken for 20 miles, with a level plain running inland above it, presenting an upper surface with small depressions and upstanding 1-3 ft. boulders. In the depressions of this very roughened surface lies a rich soil, often used for cultivating maize or paw-paws, or supporting moderately dense bush. This seems to be an older reef flat, its roughened surface caused by differential weathering, more dense corals remaining longer than the matrix between them. Crossland (1902) found many corals on the 14 ft. reef in Zanzibar in upright and growing position, and states "it is interesting that if the ocean returned to this level large areas of the eastern parts of Zanzibar and Pemba islands and of the mainland would be submerged at high tide". Gardiner (1931), after work in the Maldives and the Laccadives, the Chagos Archipelago, and the Mascarene and Seychelles Islands, found evidence for a change in sea level of at least 8 - 10 ft. and that this change was the dominant cause of formation of the isles of atolls, and also that such a change is evident over most of the islands of the equatorial belt, with indications of more complex changes of level north and south of the two latitudes 15°. Fryer (1911) found that Aldabra had over most of its islets a seaward cliff of 15 feet, and plates corals in this cliff in living positions, stating "on the top of the cliffs, so perfect were they, that it was difficult to believe that they were long dead". This was evidenced even more clearly on Astove, where the elevation was considered to be "perhaps" 18 feet, and at Assumption most of the island was 12 feet

above/

above sea level, with a ridge 18-20 foot above sea-level, with many corals in the position of growth. Sikes (1930) found raised beaches and caves at 15 foot above present sea level on the southern Kenya coast, which Caswell (1953) suggests may be due to a pause in the drop in sea level at the onset of the Gamblian pluvial, which he equates with the last (Wurm) glaciations. Caswell considers that the bulk of the elevated reefs in the southern Kenya coast were formed during the second interpluvial, for two not very convincing reasons, (a) because this was the longest of the three inter-pluvials, and (b) because the apparent maximum height of the reef is most closely matched by the second interglacial sea-level of Europe. The third interpluvial sea level he considers to have been 30 foot above the present when a thirty foot coral shelf was cut which can be seen at Mombasa, and on its retreat from this level as the following pluvial approached a pause caused the caves and beaches referred to above. Clark (1954) summarises the information on raised beaches on the northern and eastern Somaliland coasts. On the northern coast there is scattered evidence for a 5 - 25 metre raised beach at the beginning of the upper pleistocene. On the eastern coast there is an 11 - 24 metre beach, and another slight one at 2 metres. In spite of the fact that coral reefs grow on these coasts at present, there is no clear 14 foot raised coral beach described from the area. Guilcher recently (1958) describes existing and raised coral growths on Madagascar and neighbouring French ruled islands. On Madagascar raised coral reefs of any height are only found about its northern tip, where a reef of "hardly 10 metres" is present, dated before the low level of the last glaciation (Guilcher op.cit.). There is no distinctive 14 foot emerged reef here, and none on the rest of Madagascar. Guilcher describes no distinctive 14 foot beach on the Comoro group.

It is/

It is then clear that a coral bench of about 14 foot is present over a great deal of the central and western Indian Ocean, as evidenced by many islands, and that this can be clearly seen on the Tanganyika coast in the area of this survey. On the Italian Somaliland coast, and in Madagascar, such a coral bench is not clearly seen, and on the southern Kenya coast a raised beach of this height is found, but no wide coral shelf. From the extent of this older reef (East African coastline to the Maldives) and its great lengths of level aspect the emergence of this reef seems to be due to eustatic and not to tectonic movements. The date of the reef is probably upper pleistocene, and it may have been formed during the last inter-pluvial (which corresponds broadly, although probably not exactly with the last European interglacial, vide Cooke, 1957) or towards the beginning of the Gamblian pluvial.

This raised reef has played a great part in the shaping of the east coast of Mafia Island (Plate II), and forms the basis of many of the host of smaller islands. Mafia Island itself is not of coral origin, but is mostly of clays, sandy clays and subordinate limestones, all of Lower Miocene marine origin. On the landward edge of the island some small Pliocene marine detrital outcrops reach the surface. The seaward edge, however, is all composed of Pleistocene to recent coral reef, as are the small islands to the south and east (Jueni Island, Jibondo Island, Tutia Reef, Okuza Island, etc.) Although a reasonable explanation of the shallow Mafia area may be that it is due to silt deposition from the Rufiji Delta, this is not borne out by the deep hole drilled by the D'Arcy Shell Oil Exploration Company on Mafia Island, where it was found that marine detrital limestone lay from 100 ft. below the surface to 3,000 ft., the island itself being a slightly "positive" structure on

a true/

a true continental shelf (Dr. R.E. Linton, in litt.). On this shelf the smaller islands and the long eastward edge of Mafia have been formed first as reefs by upward coral growth during the Pleistocene, and later emerged by a relative drop in sea level.

Over most of the Mafia coast the width of the present reef flat averages 600 yards, with a maximum of half a mile. This is typical for much of the E.A. coastline. On the Zanzibar east coast the reef flat width is slightly greater, varying from ½ to 1½ miles. It is Crossland's view (1902, 1903) that the present reef flat is due only to erosion of the 14 foot reef, and that no growth seawards has taken place since that time. Whether this view is completely correct is doubtful, and will be discussed later. It is clear, however, that in some places much erosion has taken place, and the southern end of Mafia and its reefs present a very different picture from the typical ½ - ¾ mile flat. Here Mewe, Chole, Juani and Kibondo islands, all formed of the 14 foot coral bench, give evidence of much erosion, and the reef flat may be up to 2½ miles wide and over. There seems no reason to postulate better coral growth in this area resulting in a wider reef and the alternative, erosion of the older reef, seems evidenced by the deeply undercut cliffs, fallen rocks on the southern end of Juani and Kibondo Islands, and the few now isolated "rocks" of the older coral height that stand here and there on the reef flat between Kibondo and Tutia Reef. At Tutia reef the decay of the old coral bench has proceeded further, forming a planed flat, with the older reef present only as boulders in the boulder tract.

C. The Structure of the Reef as Exposed at Low Tide (M.L.W.S.)

The reef as exposed at spring low tide is roughly triangular in shape (Plate I), with long northern and south-eastern faces, an incurved western bay, and a short southern/

southern boulder tract.

The boulder tract:

This is 700 yards long, and up to nearly 80 yards wide at its greatest width, divided by a low neck into two portions, a shorter westerly one and a longer south-easterly one. The boulder tract averages 8-9 ft. above datum, and the highest point on the reef (10 ft. 5 ins.) occurs at about its middle. The tract is composed of a jumbled mass of boulders of coral origin, mostly 1 - 2'6" across, some 3 ft. across, those on the centre of the ridge being immovable (this portion will be called the 'backbone'), but those to seaward being loose (see Plate XII). In some places along the reef the backbone of rock has to seaward a steep and undercut little cliff of 1½ - 3 ft., seaward of which are found the loose boulders. At others the fixed boulders of the backbone and the loose boulders merge without a clear boundary. After severe storms, many of the boulders of the loose portion are moved, and even on the backbone boulders show signs of moving and breaking. On the reefward or lee side of the backbone the tract consists of smaller loose stones and dead and broken coral brash, with some sand. Although in many areas of the typical E. African fringing reefs occasional boulders are present on the crest, in no other area was such a distinctive boulder tract seen. The southerly storms and occasional hurricanes do not seem to throw up coral boulders of any large size on the reef crest to form the large and characteristic "negro-heads" of many parts of the Pacific. If the tract on Tutia is from wave thrown boulders it must be due to either greater wave action here than on the rest of the coastline or to more vigorous coral growth to provide unstable corals in times of storm, or both. There seems no reason for greater wave action on Tutia than on the rest of the Mafia coast, or on the reef on the southern tip of Zanzibar Island to take two examples, yet no such distinctive

tracts/

tracts are formed in these areas. The coral growth on Tutia is equalled in richness at many other areas visited, so an unusually large "store" of coral rocks is not the raison d'etre for the boulder tract. It is most probable that the bulk of the boulders on this tract are derived from breakdown of an older coral bench, with small additions from the existing coral reef at periods of storms. The 14 ft coral bench (which shows marked decay at Kibondo Island a few miles to the north) is the most likely source. The lower rocks on the seaward side of the boulder tract are completely covered in a felt of short, chiefly brown, filamentous algae, and above this, half way to the crest of the backbone a filmy lithothamnion is dominant, although some algae are present. The lithothamnion does not seem to be so vigorously growing as to help in cementing the boulders together, but must to a large extent protect them from erosion.

Although shingle is thrown across the boulder tract, and forms a narrow strip behind the backbone there is no indication of this widening and moving inwards, nor are any spits or tongues formed. With any wave action strong currents move behind the boulder tract scouring away loose material. Although there is loose shingle on the surface, the steep little bank that drops to the reef flat is a firm slope, not the loose overflowing type of shingle rampart that is characteristic of the moving Low Isles ramparts, for instance. (Stephenson et al, 1931; Fairbridge and Teichert, 1948).

Boulder ramparts of this type, derived from breakdown of older reef formations, are described from the Chagos Archipelago by Gardiner (1936), where similarly only few negro heads are found. From the work done by the Great Barrier Reef Expedition on Low Isles, Umbgrove's work in the East Indies (1931) and from work on Bikini Atoll (Ladd et al, 1950)/

1950 , a relationship between violent storm systems and boulder ramparts is shown, the ramparts only forming (Bikini, Low Isles) on the side of the reef where periodic, often widely spaced heavy storms or hurricanes strike, or being higher (East Indies) on such sides. Presumably decay due to solution (the ramparts lie within the tides) and boring organisms must attack the boulders of such tracts, but on Tutia the lithothamnion and probably also the algal felt that covers many of the boulders gives considerable protection, and these boulders would not decay as quickly as those on the middle of the reef flat studied by Mayor (1924a), who calculated that a five pound rock would completely distintegrate in fifteen years.

Boulder ramparts, if Gardiner's deduction and the present one are correct, can then be formed in two different ways, either being wave thrown or due to older reef decay.

The Reef Flat :

The bulk of the exposed portion of Tutia is an extremely level reef flat, which lies at about 2'-3' above datum. Just behind the boulder tract there is a slight depression, not definite enough to be called a moat, with its level about 1 ft. above datum. No living corals are present in it, but a few boulders up to 18" across lie scattered about on a rocky surface covered in thin sand, with patches of lithothamnion and occasional growths of the alga *Hydroclathrus clathratus*. The general impression is of a barren flat. From this depression the flat rises gently over 200 yards to 2' 4" and over the next hundred yards to 3' 3" above datum. Even a hundred yards from the boulder crest the typical reef flat facies

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facies is found. This is a crumbly surface, almost complete, of lithothamnion forming little nodular masses, laced with small channels up to a foot wide and 6-8" deep. These little channels are floored with solid coral rock, often sand covered. The flat seems to be protected by the lithothamnion from much decay by scouring, chemical weathering, or infauna, but the run-off from the reef top erodes the intricate channel system. The extremely level surface of the reef flat, which over hundreds of yards may only vary a few inches in height suggests a balance of the forces of decay and growth, and a relation to sea level. The lithothamnion tends to overgrow the channels, and scouring action and other factors attempt to create more channels. Time of emersion is presumably the limiting factor to further growth in an upward direction. Living coral is absent from most of the surface of the reef flat, being found only where it dips toward its edges, and in shallow pools towards these edges.

The Sandbanks

Two sandbanks, joined at their bases lie in a curve at the north-west point of the reef, the top of the westernmost and highest being 9'2" above datum, with the easternmost one slightly lower.

D. The dominant Corals of the Underwater Slopes of the Reef.

1. The Southern Edge of the Reef

This side of the reef faces on to the entrance of the South Mafia Channel, and is exposed to wave action of the open Indian Ocean, especially during the strong S.E. monsoon winds. It shows characters differing from those of the northern and western edges of the reef, both of which are sheltered from wave action. The immediately obvious differences are that this side of the reef is the only one

that/

that has a smooth seaward rock slope below low spring tides, and has "spur and groove" formations. Animal populations also show immediate and obvious differences, for example the large Turbo marmoratus, (the Green Snail shell of commerce) is common here, but is not found on the other sides of Tutia. The fish population, in particular the numbers of Lutjanus bohar, the black triggerfish Melichthys ringens, Variola louti and Aprion virescens, among others, is larger.

A transect (Plate IV) waslaid down the reef face with its first peg (S1) on the highest point of the boulder tract, and with its last peg (S6) at a depth of 21'6" below datum. Using a rectangular frame 2x1 yards (Plate XIII) quadrats a yard square were made down this transect to peg S6. Below this observations were made to 57 ft. below datum which was considered the foot of the reef proper.

As usually defined, the seaward slopes imply the area from about mean low spring tides (Manton 1935) to the end of the reef. Here this zone is divided into 3 portions, the seaward Algal Zone, the Spurs and Grouves Zone and the Lower Coral Slope.

The Seaward Algal Zone: Peg S1 to Peg S2 crosses the Boulder tract which has been previously described. Peg S2 stands on a 2'6" dead coral rock (seemingly embedded in the rock slope) two yards to seaward of the end of the Boulder Tract, the base of this boulder being at about the datum line. The Seaward Algal Zone is a 200 ft. slope extending from the foot of the Boulder Tract to 5'6" below datum. The surface of the slope is for the most part a smooth hard pavement, with little irregularity or pitting. It does not seem to be weakened by infauna, and is almost 100% covered by lithothamnia and fine brown algae. A few scattered rocks are present, being mostly flat slabs and a few well set small

boulders/

boulders. Loose stones are presumably thrown up on to the boulder zone. A few feet before peg S2 a sparse cover of small tufts of the brown algae Turbinaria ornata and T. decurrens begins, which increases in density seaward of S2 until about 12 feet from S2 there is almost complete cover, i.e. no rock can be seen through the waving fronds. Towards S3 the algae become sparse leaving flat lithothamnion-covered rock between them, and occasionally a thin surface cover of sand. The dominant alga here is T. ornata. Occasional heads of A. corymbosa (see Plate XIV) are found, with a few small heads of Porites sp. (probably P. australiensis) about 7 inches across, and occasional tufts of the mauve alcyonarian, Cespitularia sp., but the general impression is of barren, sparsely covered rock.

This Seaward Algal Zone corresponds to the 'algal ridge' of Ladd et al (1950) in their excellent description of Bikini Atoll. In both cases the level of the zone is the same, beginning where low tides just cover, and continuing some feet below this, and in both cases lithothamnia and not coral bear the brunt of the waves. At Bikini, however, the lithothamnia grow upward into folded masses forming a ridge, and not only an encrusting sheet, hence the use here of the more general 'algal zone' not 'algal ridge'. On Low Isles, Great Barrier Reef, the 'first hundred feet' of the seaward slope as described by Manton (1935) is equivalent to this zone, but at Low Isles the area, as well as algae, contained corals.

The Spurs and Grooves Zone: A few yards to seaward of peg S3 the whole aspect of the bottom changes. Abruptly the bottom becomes uneven, with a typical pattern of low longitudinal spurs, at right angles to shore line and parallel to wave action.

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They are usually 2-4 ft. high (occasionally higher), separated by grooves 3-4 ft. wide (occasionally 6 ft.). The first few yards of the spurs and the grooves are of dead lithothamnion-covered rock with a few living corals, but living coral cover increases rapidly and within a few more yards the percentage cover is 20 - 30%, with the tops of the spurs and most of their sides completely covered, but the floors of the grooves typically bare of living corals, and often with loose coral fragments or patches of sand. (Plates XV and XIII). These coral fragments are mostly of branching forms of Acropora, which seem to be extensively damaged during the S.E. monsoon, the damaged colonies regenerating during the calm period of the N.E. monsoon. At the lower end of this zone the spurs and grooves become less marked, usually with some of the spurs being lost, and others becoming lower and wider until they merge into a more even bottom described as the Lower Coral Zone. The Spurs and Grooves Zone is characterised by a great variety of corals, dominants being the shrub-like Acropora corymbosa; A. palifera, which here forms flattened encrusting sheets, and seldom the high turreted form it takes in calmer water (Plate XXIV); the regular pink shrubs of Stylophora mordax, heavy platform-like growths of Acropora secale; and especially where the spurs and grooves are flattening out branched masses of A. irregularis, A. formosa and A. florida, the last two in patches up to 50 ft. long and 15 ft. wide.

Seaward Slope : Lower Coral Zone: Below the area of spurs and grooves is a relatively smooth sloping area with a very high percentage cover of living coral. There is no distinct junction between this zone and the former one, but the grooves and spurs lie in the area of strong wave action and are not formed in deeper and calmer levels. The transition lay 60 ft. to seaward of the last peg on this transect (S6), in water of approximately four to five fathoms in depth.

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The area showed a number of differences from the Spurs and Grooves Zone in coral population. Acropora palifera is still present but no longer as abundant as in the former zone; A. secale, a dominant species in the Spurs and Grooves Zone, is almost completely absent, as is Stylophora mordax; great patches of A. formosa and A. florida are still common (Plate XVI); the delicate plate-like growths of A. hyacinthus (Plate XXV) are fairly common, but in one layer and not tiers as in sheltered N. Tutia, where the former were not seen at all in shallower water; and huge platform growths of A. spicifera up to six feet across are present (Plate XVII). Occasional hollows of broken coral brash are present, and often broken pieces are covered in encrusting coralline algae.

As the slope deepens to 60 ft. the coral thins out, and the upright tubes of the sponge Theonella swinhoedi and the large open cups of Aurora globostellata become common (Plate XVIII). A small branching Porites (close to P. mordax and to be described by Professor Wells, Plate XVIII) is common in patches a foot or two across. Seriatopora hystrix is present, as is A. diversa, and small tufts of alcyonarians are common. Porites somaliensis is fairly common, more than one head of over 6 ft. being seen (Plate XIX). This species has a low flattened form here, unlike its more upright form in shallow water, with a rugose upper surface and no vertical faces, probably due to reduced illumination. This is most probably the reason for the single plate, or rosette, form of A. hyacinthus in deeper water, with no examples of tiered growth. At this depth the coral thins out and much of the bottom is sandy (Plate XX).

No deeper observations were made than 60 ft. The coral ended here and deeper than this the bottom appeared to be a gently sloping plain, much of it sandy, with some patches of

fine/

fine tallus from the growing coral above in the form of small (1 inch) rounded fragments. The sand surface was distinctly ridged, indicating current action.

This depth limit to the living reef is typical over the area studied; it is not usual for the living reef to extend below 14 fathoms. It seems now definite that this limit is due to light, and that for flourishing reef growth bright illumination is necessary (Yonge 1940, 1958) although corals can live in poor light or darkness and have correspondingly few or no associated zooxanthellae (Duerden, 1902, Boschma 1925, Yonge & Nicholls 1931). The circumstantial evidence is strong that the zooxanthellae are the cause of the light limitation, but the physiological reasons have not yet been adequately elucidated (Nicol 1960).

2. The Western Bay: (Plate III)

A transect was laid from the base of the southernmost sandbank across the shallow western bay. The strongest wave action that affects this coral slope would be due to the violent but short-lived line squalls that sweep across from the mainland at certain times of year. These usually last for about 30 minutes with wind strengths in the region of Force 7 (Beaufort Scale). The fetch is 14 miles, and the water shallow (averaging 8 - 15 fathoms), and the resultant wave action could have relatively little strength compared with ocean swells in the S.E. monsoon, as strike the south face of the reef.

The western bay is characterised by a thin fringe of living coral ending in a sandy floor with isolated, often large coral blocks scattered about on this floor.

Peg W.1 (2'8" ab.d) was placed at the junction of the sandbank and a slightly inclined compacted rock slope covered in most places by sparse sand. A meagre growth of the alga

Padina/

Padina commersonei is scattered on the rock, which lower down becomes combined with tufts of Turbinaria ornata. Although a moderately smooth slope, the rock has sand-filled crannies and depressions and has no lithothamnia cover. It becomes increasingly covered by patches of sand towards W2 (2' below datum and 180 ft. from W1). Small heads of Porites australis 6" - 2' across were found just below datum and were fairly common near W2. Those were usually not rounded, but many had died above and grown outward, making wide flattened discs with growing edges and eroded tops. At W2 a few tufts of Turbinaria ornata are found, but Padina is not present. Isolated clumps of coral are also found, (A. palifera, and a shrub-habit Acropora, as well as the fleshy orange-pink alcyonarian Litophyton on dead coral).

Below W2 the patches of coral become more common with sand between them, some being up to six foot across, and the corals here are growing on older eroded dead coral. Acropora corymbosa, A. florida, and A. formosa were present, with A. intermedia common, a patch of the latter 25 ft. long lying just off the transect. Encrusting sheets of Montipora erythraea and small shrubs of Pocillopora verrucosa were fairly common. In spite of these attached corals the older dead coral rocks showed bare patches, and had also a number of alcyonaria attached to them. The transect between W2 and W3 (the latter 4 ft. below datum and 98 ft. from W2) lay across an elongate patch of coral starting 42 ft. from W2 and continuing to 6 ft. beyond W3. It was at its widest 15 ft. with sand surrounding it. Living coral cover averaged about 30%, the composition of the corals being similar to that of the large 'rock' at W4, described below. From W3 - W4 (120 ft., the latter 6 ft. below datum) were first fifteen yards of small coral patches interspersed with sand, then a clear

sandy/

sandy floor until a single large massive was reached (W4), an old massive Porites about 6 ft. in diameter. This massive rock is typical of many in the western bay. The original massive P.lutea, is almost completely overgrown, but a few pieces of the original colony are living (Plates XXI, XXII, XXIII). The attached corals included A. irregularis, A. humilis, A. nana, A. Florida, A. palifera, a finger-like Porites close to P. mordax (to be described by Professor Wells), Seriatopora hystrix, and at least 3 alcyonarians, Cespitularia, Lithophyton and Lemnalia.

W5 was placed on a similar massive 102 ft. away across sand in 8 ft. of water. Beyond this no more coral was seen, the sand sloping gently to the South Mafia Channel.

3. The Northern Reef Edge: (Plate III)

The reef on its northern side faces Jibondo Reef across a narrow channel reahhing 12 fathoms in depth. This portion of the reef is characterised by a steep edge, in places nearly vertical, from shallow water to four fathoms, faced with a luxuriant growth of Acropora hyacinthus and in some places Acropora formosa (Plate XXV). Lack of Porites heads also typifies this side of the reef.

A transect was marked out just east of the sandbanks, about a third of the way along the channel from its western end. Six pegs were placed.

From N1 (1ft. 6 ins. above datum) the bottom is a barren smooth sloping plain of crumbling flat rock and small (6 inch) crannies and depressions. A few small massive Porites species are present. Turbinaria is found but does not form beds. A shrub-formed Acropora, A. humilis, was found in hollows. A few specimens of the sponge Phyllospongia foliascens was present. Below N3 (5" below datum, and 86 ft. 2ins. from N1) the cover of living coral increases, and alcyonarians are also common/

common. The first patches of Acropora formosa are present and A. palifera (in its turreted form), Seriatopora hystrix and Stylophora mordax are found. Where the reef dips more markedly (just beyond N4, 11" below datum) the typical facies of the northern reef is developed, with large patches of the stagshorn, A. formosa, many yards across and patches of A. hyacinthus, with little other coral. From N5 (6' 4" below datum) to N6 (22' 1") the slope is at first steep, and then abruptly levels out, being one amazingly luxuriant bed of A. hyancinthus (Plate XXV) with no other corals finding a foothold. In some places there are also huge beds of A. formosa on the slope. At the foot of the slope the A. hyacinthus stops, and there is in some cases a thin fringe of other corals (including A. diversa and Millepora tenera (Plate XXVI)) as the sandy floor flattens out and slopes to the centre of the channel. No coral brash was seen on this sand slope.

E. Distribution of Corals on the Reef.

Although from a survey dealing only with relatively few of the dominant corals it is not possible to describe in detail the distribution of each species on the reef, certain species show definite patterns.

The very solid platform growth of A. secale (so solid it is difficult to collect a sample without a heavy hammer), is almost restricted to the southern slope, and to the shallow Spur and Groove Zone of this slope. In this area it is one of the dominant growths. It was also found and recorded as 'present' in six foot of water in the western bay, but not recorded from the northern slope.

Acropora hyacinthus is found on all three sides of the reef, but on the southern face is limited to deeper water.

On/

On the northern reef edge it is abundant and is found as shallow as about a foot below datum (it was never seen with its edges exposed as is the case with A. formosa at extreme low spring tides). In contrast to this, on the southern face the species was not seen in shallow water, but was fairly common at the lower end of the Spurs and Grooves Zone in about 20 ft. of water, and was recorded as common 20 yards below S6 in the lower coral zone. With this fragile species it is permissible to assume that the cause of this distribution is wave action. In the western bay it was present in 8 ft. of water south of the transect, but formed no abundant growths. Mayor (1924c) found that A. hyacinthus was an important element in reef formation in Samoa. He considered that conditions good for this species included freedom from silt, considerable current, and some protection from surf, all of which conditions are found on the north edge of Tutia.

The massive forms of Porites, P. australiensis, P. somaliensis, and P. lutea, were almost absent from the northern reef edge, although common in the western bay and abundant on the south-western point of the reef, and present on the southern face. These species, particularly P. somaliensis, reach huge proportions in sheltered water, individuals eight foot and over being seen in the shelter of the Zanzibar channel, and large specimens found at Nicroro Island, Boydju Island, Sefe Reef and in the boat channels of the eastern Zanzibar fringing reef. Where conditions are good for vigorous A. hyacinthus growth with their very fast growth rate compared to that of massive species (Mayor 1924b), developing heads of massive Porites would soon get smothered, and be unable to grow.

Stylophora mordax, found on all three sides of the reef

in/

in shallow water, and especially common in the Spurs and Grooves Zone of the southern seaward slopes, was limited to shallow water, and not found on the lower seaward slopes of the southern reef edge.

Millepora tenera (Plate XXVI) was found at the foot of the steep northern reef slope in the western bay in 6-8 ft. and only in deeper water of the lower end of the Spurs and Grooves Zone of the southern face. With its fragile tips it is presumably very prone to surf damage. The closely related and heavier bodied M.platyphylla (Plate XXVII) was found in shallower water, the specimen plated being photographed in very shallow water, (about three feet), in the western bay.

An interesting omission from the collecting on Tutia Reef is the subgenus Porites (Synaraea). P. (Synaraea) convexa and an undescribed species close to P.(S.) faustinoi were abundant in inner reefs like Sefo Reef, and Niororo Island, and in the Zanzibar Channel (Plate VI), and were characteristic of such sheltered reefs. It is difficult to understand their absence from the western bay and northern face of Tutia Reef.

Of the ubiquitous species on the reef mention can be made of A. formosa, A. irregularis, A. corymbosa, A. palifera Pocillopora verrucosa, Porites n. sp. aff. mordax and Seriatopora hystrix.

Although no attempt was made to make an exhaustive collection of coral species, the southern slope with its vigorous growth and large area should prove to have the greatest variety of corals. The northern face of the reef, although rich in coral growth with its huge beds of A. hyacinthus and A. formosa, is poor in species, as a few species cover such wide areas. Here only 6 species were considered/

considered to be "dominants", as opposed to 18 on the western face, and 30 on the southern reef face.

It is interesting to compare the number of *Acropora* species from Inhaca Island, Lourenco Marques, listed by Boshoff (1958) with those from this area. Boshoff lists 17 *Acroporas* after very full collecting, and here 25 species were recorded as important elements on the bottom.

3. DECAY OR GROWTH/

3. DECAY OR GROWTH OF EAST AFRICAN CORAL REEFS.

Gardiner (1936) has stated that from his work on the Maldives, Laccadives, Chagos and the Mascarene region there are indications that in the former three areas reef growth may be taking place, but that in the south-western Indian Ocean there is some evidence of decay of the existing reef systems. This he bases mainly on the presence or absence of a steep-to reef (with the 100 fathom line within 200 yards of the reef edge) in the latter region. Crossland, (1902, 1901) after spending a year on Zanzibar and Pemba, also considered that the reefs that he studied were in a state of decay, and that the existing width of the reef flat and the boat channels were solely products of the decay of the older (14 ft.) coral reef, and not due to seaward growth of the present reef. Crossland had unfortunately no knowledge of the reef below the surface except what he saw through the water from boats. His main stated reason for such lack of growth was the weakness of the surf, which would be unable to throw up coral fragments to form reef conglomerates or fissured reef edges. He was also impressed by the lack of strong nullipore growth at the reef edges (i.e. beginning of the seaward slopes), and felt the lack of cementing algae to be also an indication of the inability of the reef to grow seawards. Guilcher (1958) found, contrary to Gardiner's statement above, that both at the Comores (Mayotte Island) and at Europa Island steep-to reefs were present. He comes to the conclusion that no essential difference or hiatus is apparent between past and present reef building in the whole area considered by him. It is also of interest to note that at Inhaca flourishing living reefs (26 S., the most southerly reefs in Africa) have been/

been seen to develop within the last fourteen years (Moshoff, 1958) and growth rates of 20 cm. in *Pocillopora verrucosa* and *Stylophora pistillata* in 8 months were measured. Ladd *et al* (1950) also come to the conclusion that Bikini Atoll is growing, and see no reason to believe that the rate of growth has changed.

The type of information that has been gathered in this survey will not prove or disprove that reef growth has or has not taken place, but can supply some circumstantial evidence. As Crossland has described, the older 14 ft. reef shows much erosion. Undercut cliffs and fallen blocks at many places down the east coast, not the least in the Mafia area, support this. Isolated blocks on Jibondo Reef suggest that erosion has been considerable in places and it is clear that the present reef flats are due at least in part to erosive forces. The rock in the shallow areas of two sides of Tutia shows signs of decay, and in addition the massive *Porites* blocks in the western bay with their secondary coral and alcyonarian cover, and eroded surfaces, indicate decay. Yet on the southerly seaward slopes, which from observations made on Zanzibar's east coast seem typical of the outer edges of east coast reefs, the algal zone gives no indication of erosion and is not weakened by infauna, and coral growth is vigorous in the spurs and grooves zone and the lower coral zone. In addition cementing of brash by algae has been seen on the seaward slopes. These observations suggest that although vigorous nullipore growth is not evidenced at the edge of the seaward slopes, there is no great erosion on reefs with vigorous surf action, and probably some outward growth is taking place. Similarly Crossland's suggestion of the origin of the fringing reefs is probably an over-simplification, and the present fringing reefs are due both to cutting back of the 14 ft. fossil

reef/

reef by erosion and to the outward growth of the existing reef. Crosslands' picture of vast decaying reefs seems a very much exaggerated one, and it is probable that many reefs in E. Africa are undergoing seaward growth.

5. THE FISH FAUNA/

4. THE FISH FAUNA OF TUTIA REEF.

Collection of fishes in the Mafia Archipelago area by a number of methods (hand-lining, trolling, underwater spearing, explosives, basket traps, gill nets and trammel nets) yielded just under four thousand specimens, of which 2,152 were from Tutia Reef. 233 species were identified of which 192 were from Tutia Reef, where most of the collecting was done.

Although this list is certainly not an exhaustive one for the area, or even for the small reef at Tutia, it shows a rich and varied fish fauna, which is predominantly Indo-Pacific, with a very small (11%) endemic element. Comparing the list from Mafia with those of Inhaca Island (Smith, Gabie, 1959) it is found that 54% of Mafia fishes are also present at 26^0 S. As one proceeds southwards down the African coastline Indo-Pacific species are gradually reduced, and endemics to Africa are more important with the gradually lowering temperatures.

As an indication of the variety of such a tropical fauna it is interesting to compare this area with its 233 species with the total list in Plymouth Marine Fauna list (1957) of 175 species.

The Reef Flat:

The reef flat at low tide is dry apart from shallow pools and its winding little runnels. A few small species inhabit these pools and the eel Siderea picta (Ahl) is abundant. At high tide numbers of fishes come over the flat, and the rocks of the boulder tract show typical tooth scars from Scarid feeding where their algal covering has been scraped away. The white tipped shark Triaenodon obesus is seen over the reef top, often in shallow water of one or two foot.

The/

The Southern Transect:

In all 684 specimens of 98 species were taken on this face of the reef, including fishes trolled at the reef edge.

On the Seaward Algal Zone the fish population is sparse. Collecting by a charge of explosives brought only three species, Hanomanctus bovinus, Hemibalistes chrysoptera, and Acanthurus triostegus. Pseudopristipoma plagiodosmus has has been seen feeding in this area, and small shoals of a Lethrinid and occasional Scarids are not uncommon.

At the beginning of the Spurs and Grooves Zone the fish population makes a sudden and dramatic change. As the flat Seaward Algal Slope merges into the Spurs and Grooves Zone, with the bottom being thrown into folds, and the coral cover increasing rapidly, the fish fauna suddenly enlarges, and when the centre of the Spurs and Grouves Zone is reached it is extremely rich and varied - so much so that it is difficult to talk of "dominant" species. The bottom and mid-water is a kaleidoscope of fishes. A single explosion of the same magnitude of the charge that collected 3 fishes in the Seaward Algal Slope here (between A4 and A5, Plate IV) yielded 101 fishes of 42 species. In and about the coral heads are many of the smaller fishes: Chromis opercularis and other Amphiprionids; Abudefdufids; Chaetodontids (including C. guttatismus, C. meyeri and C. trifasizatus); Parachirrites forsteri perched on coral heads; the smaller rock cods Cephalopholis aurantius, Epinephelus summana and E. dispar in coral shelter; many Holocetrids and Acanthurids (especially A. nigrorus, Ctenochaetus striatus and A. strigosus). Scarids are common, especially Xanothon erythrodon. The larger predators Variola louti, Lutjanus bohar, Aprion virescens Plectropomus maculatus and P. marmoratus are common. Shoals of the brilliant Caesio caerulaurius and the black trigger-fish Melichthys ringens are present in mid-water, and the Carangids C. ignobilis and C. melampygus hunt along the reef.

As this zone merges into the Lower Coral Slope the population/

population remains rich, with larger predators such as Epinephelus tauvina (to 200 lbs. and over) and large specimens of P. maculatus present.

With the decrease in coral cover towards the foot of the reef the fish population drops. 19 species were taken from one explosion at the lower end of the Lower Coral Slope (60 ft. deep). The little Chromis dimidiatus is abundant at this depth, Centropyge bispinosus, Holocentrus diadema and Chromis opercularis were found. Small shoals of Lethrinus nebulosus were seen just off the foot of the reef on the tallus and sand slope. With the complete loss of coral on the plain none of the smaller fishes were found. Handlining at these depths yielded only Lethrinus waigiensis and the recently described rock cod Epinephelus leprosus Smith.

After this clear break in fauna at the foot of the living coral some handlining in deeper water showed another distinct change in population at about 40 fathoms, where the genus Pristipomoides is found in the colder water below the major thermocline (Talbot 1960). P. typus and P. microlepis were taken from this depth, and the large red snapper Lutjanus sebae is occasionally found.

The Western Transect.

This transect shows a simpler picture than that of the southerly slope. As has been described, much of the transect crosses sand, with some large patches of coral in the shallow areas, and a few very large Porites colonies sitting as isolated blocks on the sandy floor in deeper water. In the shallow eroded rock slope just below mean spring low the fish fauna is very sparse, a few of the smaller coral fishes being present about the isolated coral heads at W2 (2 ft. below datum). Below this the coral beds start. A collection by explosive charge on one of these beds yielded 66 species, the richest haul by a single charge. The coral

bed/

bed upon which this collecting was done was comprised of a variety of corals, the dominants being Acroporas (6 or more species) mostly of the stagshorn variety. In this sheltered water the corals grow as high as three feet and over, making an intertwined tangle of coral structures whose crannies house a large variety of smaller species - richer in smaller species than larger and heavier coral formations. Amphiprionids (5 species), Abudefdufidae (7 species), Acanthurids (6 species), Chaetodontids (5 species), Scarids (7 species) Labrids (7 species), Apogonids (4 species), Holocentridae (6 species) were present. Cephalopholis argus, C. aurantius and Epinephalus fasciatus were found in this area, but none of the larger predators were taken.

The populations on the deeper large Porites blocks with their secondary coral cover varies quite considerably from this. The numbers of species are very much less (36 species in one explosion) but the larger species more common, and numbers of individuals per species much higher. For example, Myripristis murdjan is usually taken in small numbers by an explosive charge, but in a single charge at 10 ft. near W5 over a hundred specimens were taken. Holocentrus sammara is also very common in this area. In the caverns below the large corals Lutjanus gibbus is common and the brilliant Holocentrus spiniferus is present. Gaterin batata, Variola louti and Monotaxis grandocularis are fairly common about these heads and shoals of the small predatory snappers Lutjanus fulviflamma and L.kasmira hang like clouds above the coral. Chaetodontids (C. lineolatus, C. strigangulus, C. guttatissimus, C. melanotus), Abudefdufids and Scarids (Xanothon bipallidus, X. erythrodon), are still common.

Beyond the last of the Porites blocks the sandy floor is almost barren, although occasionally a few shoals of Lethrinus nebulosus were seen. Handlining below this

yielded/

yielded, as on the South Transect, Epinephelus leprosus and Lethrinus waigiensis.

The Northern Transect:

At N3 the reef flat has dipped to 5" below datum, and patches of living coral are present. Collecting here yielded 24 species, mainly Amphiprionids (Chromis dimidiatus, C. ternatensis, C. opercularis), Abudefduf lacrymatus, Acanthurids (A. lineolatus, A. bicommatus, Ctenochaetus striatus and C. strigosus) and Scarids (Callyodon scaber, C. dubius, Xanothon erythrodon, X. bipallidus, Cryptotomus spinidens). In this shallow coral area Chaetodontids were only represented by one species, Lutjanids, Holocentrids and Serranidae were absent, and Labrids poorly represented.

At N4, a foot below datum the coral cover is in places 100%, mostly large areas of the stagshorn A. formosa, and the beginning of the beds of the plate-like A. hyacinthus. Here observation showed a much richer fish fauna, and a charge laid in a bed of A. formosa yielded 44 species. Chaetodontids (C. trifasciatus, C. strigangulus, C. xanthocephalis, C. unimaculatus) and Holocentrids (H. sammara, H. diadema, H. caudimaculata, Myripristis murdjan) are common. Pompheris oualensis and Holocentrus spiniferus are found in the deeper coral shelter, as well as shoals of Lutjanus gibbus. Gaterin gaterinus is fairly common. Epinephelus fuscoguttatus is found, and the Labrid Lepidaplois axillaris was also taken.

In the huge beds of A. hyacinthus the population varies little from the above and remains large. In this deeper water shoals of Caesios (C. chrysozona, C. xanthonotus Caesio sp., Pterocaesio pisang) are present, and the rock cods Plectropomus maculatus and P. marmoratus cruise above the coral. Pseudopristipoma plagiodesmus is common in small shoals moving along the channel as are Lutjanus bohar, Aprion virescens, Caranx melampygus and large specimens of

the/

the Acanthurids *A. fuliginous* and *A. lineolatus*. The shark *Triaenodon obesus* often patrols this reef edge.

At the foot of the slope the coral stops, in most cases abruptly, and the barren sandy floor of the channel is reached. Occasionally large specimens of *Epinephelus taurina* and *E. tukula* have been seen on the channel floor while diving. Handlining has yielded *Epinephelus fasciatus* and *E. tauvina* and the small Lethrinid *Lethrinus variegatus*.

From the above descriptions it can be seen that three main communities have been sampled: (a) the coral reef or bioherm community; (b) the shallow benthic community on the sand below the coral reef; and (c) the deeper benthic community below the major thermocline. Neither of the latter have been sampled adequately for their fish populations, as it has not been possible to use explosives. From observations, however, the shallow benthic community below the reef is exceptionally sparse, and the deeper benthic community gave meagre catches with deep hand lines, unlike the Lamu area (Morgans 1959). The open sea pelagic community is not considered here, although the dolphin fish *Coryphaena hippurus* belongs to this community. From stomach contents examined by Williams and Newell (1957) this species, when inshore, is feeding to some extent on fishes derived from the coral reef (post larvae and juveniles of *Siganus*, Balistids, Diodontids and other species).

Even in such a small area as Tutia Reef the environmental conditions vary enough in different areas of the reef to result in quite marked differences in population between, for instance, the exposed southern reef face and the sheltered north face. Even between the northern and western coral areas, b oth sheltered, clear differences occur. On individual transects, differences were found from shallow water to deeper water areas.

The/

The first and most marked result was the clear relation between complexity of species structure with percentage and type of cover of the bottom. This was found on all sides of the reef. It was first crudely seen by handlining over rich coral areas, where heavy catches were made, and sparse coral areas, where fishing is poor. This has also been mentioned for the Red Sea by Marshall (1952). With explosive collecting this can be more precisely shown. Plate V shows the number of species and the number of individuals taken on the southern transect compared with the percentage cover of living coral from quadrats.

The relationship is close, and also easily verifiable by observation. For example, although at high tide the Seaward Algal Zone (Southern Transect) has a small population of fishes, the multitude of small coral fishes are usually close to living coral heads, and from half a dozen species in the Seaward Algal Zone a swim of 50 yards to the Spurs and Grooves Zone will place the observer among a bewildering array of hundreds of moving fishes comprising 40 - 60 species, many of them small, making adequate assessment of the species and numbers present an almost impossible task by observation alone. Explosive collecting is essential for a reasonable picture of the fish fauna in such an area.

In the Spurs and Grooves Zone of the Southern Transect an explosive charge yielded a rich collection (101 fishes of 42 species). Coral cover of the bottom was 30%. A similar charge on the N. Transect, laid in a bed of Acropora hyacinthus, with 100% cover, yielded 140 fishes of 38 species. It is probable that the greater variety of coral species

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in the S. Transect Spurs and Grooves Zone allows for a more varied fish population than the single species in the area of the N. Transect referred to, in spite of the difference in coral cover. If this were so we would expect a 100% mixed coral floor to have a greater yield than even the S. Transect 42 species. This occurred on the W. Transect, where in a composite bed of a number of species of stagshorn *Acropora*, with 100% cover, 247 specimens of 66 species were taken.

Handlining yielded large catches of *Lutjanus bohar* on the southern face of the reef, very few on the northern, and none on the western face. *L. gibbus* was taken by hand-line on the northern face, but not on either of the other reef faces. The rock cod *Variola louti* was very much more common on the southern face than elsewhere. *Holocentrus sammara* was taken by explosives on the northern and western faces in quantity, but never on the southern. Other species, such as many of the Chaetodontids for example, are found on all sides of the reef.

The causes for the distribution of most individual species are probably highly complex, relationships between the fish and its physical environment, its feeding, its need for shelter from predators, and the pressure of competitors. For a knowledge of the reasons for the distribution of a single species it may therefore be required to know the ecology of that species in great detail. Reasons for the distribution patterns mentioned here are outside the scope of this descriptive work.

In some cases however where species were limited to obvious habitats, reasons for their distribution on the reef can be given. *Gaterin gaterinus* and *Lutjanus monostigma* are always restricted to areas with deep shelter, usually eroded coral blocks with cavities and channels. This type

of/

of bottom is typical of sheltered and not exposed reef faces, and the western face with its large eroded blocks, and the northern face with its deep shelter *Acropora hyacinthus* beds (Plate XXV) contained these species. Neither were found on the southern exposed face.

5. THE FOOD /

5. THE FOOD RELATIONSHIPS OF REEF FISHES.

If we use the definition of a major community given by Allee et al (1949): "a natural assemblage of animals which together with its habitat, has reached a survival level such that it is relatively independent of adjacent assemblages of equal rank; to this extent, given radiont energy, it is self-sustaining", how does the coral reef as a natural grouping of animals and plants fit the definition? The reef clearly derives outside nutriment from zooplankton (Yonge 1940), and has little or no attached higher algae bar the fringes in the shallow areas. Since the recent quantitative work by the Odum brothers (1955) it can, however, no longer be unquestioningly held that the reef derives the bulk of its nutriment from zooplankton feeding by the coral polyps. The Odums have shown that a coral colony has more plant than animal protoplasm (ratio 3-1) if its zooxanthellae within its cells, and the network of green filamentous algae below the animal tissue, are taken into account. Sargent and Austin (1949, 1954) and Odum and Odum (1955) give evidence to suggest that insufficient plankton from the open tropical sea reaches the corals to support the abundant life of the reef. This is also suggested in the area under discussion here, by the relative poverty of fish fauna in all other communities compared to the richness of the coral reef populations. Presumably the food production by the algae within the coral skeleton is not lost to the reef, even if it is only utilised, after eventual breakdown, by detritus and bacterial feeders. The reef is therefore being supported by primary production through its plant matter, by plankton being utilised from the surrounding waters, and perhaps to a small extent by organic detritus reaching the reef from plankton. Reef food is lost through plankton (pseudoplankton) produced by the reef itself, detritus washed from the reef and the catabolic processes

in animal/

in animal tissue. As yet no accurate assessment of the value of these various factors to give a reasonable profit and loss account for the reef has been made. The reef can, however, well fit the definition of a "major community", and closely parallels a tropical forest, in this case the corals, as do the trees, creating the gross form of the community with shelter for hundreds of other species, and being (partly) primary producers. The reef community is less of a closed system in that it gains its phosphates, nitrates, and other inorganic needs to a large extent from the water flowing past it. It is fairly closely tied to the total marine community, and enjoys less independence. This is mainly a difference of degree (the forest, for instance, lacks independence in relation to its water needs) and the parallel is a close one.

A crude model of food relationships is given in Plate XXXII. Even using three dimensions the complexity of links is too great to be fully portrayed. Here the links of decay back to bacteria have been left out, except those from coral, detritus and algae, and variety of feeding has been cut down. The system is supported by algae and plankton, if the former includes both symbionts and free living forms. If the fishes taken by explosives are considered a representative sample, and are analysed into feeding types (Appendix 5) it can be seen that algae are much more directly important to the fishes than first observations of the reef suggest. Although fixed macro-algae are rare except in the Seaward Algal Zone 25% of fishes by weight taken by explosives were predominantly algal feeders. The algae taken in most cases were filamentous and unicellular.

The remaining fishes were grouped as follows: coral feeders, 13%; plankton feeders, 15%; fish feeders, 7% and invertebrate/

invertebrate feeders, 40%. No fishes were found that were considered predominantly detritus feeders. Feeding on living coral is often seen and tooth scars of Scarid fishes on living Porites are common (Plate XXII). It is surprising that at Low Isles (Great Barrier Reef) Stephenson et al (1931) report that only dead coral was seen to be attacked by fishes, never living coral.

The percentage of fishes (by weight) that can be considered as primary consumers, those species feeding on the primary material produced on or reaching the reef (corals, algae and plankton), is 53% of the total weight of fishes collected by explosives on Tutia. Secondary(tertiary, etc.) consumers were 47% of the total weight of fish. Odum and Odum (1955), Eniwetok Atoll) using estimates made by rotenone poisoning and visual underwater counts of larger species, and converting to dry weight, found a much larger proportion of their fishes herbivores. In the present work the carnivores are probably under-estimated (Appendix I) and the proportion of these should be higher, making the discrepancy still wider. This may be due to differences between an open ocean atoll and an inshore reef. The Odums were unable also to sample the buttress (spur and groove) zone because of strong surf conditions, and much of their fishes were taken from the surface of the reef and the quiet lagoon of the atoll. Here much of the fish collected came from the exposed face of the reef.

A major component feeds mainly on the invertebrate fauna (40%), and as in the typical pyramid the fish predators at and near the top of the fodd chain are few (comprising only 7% by weight of all fishes).

In conclusion it can be said that work is badly needed, particularly quantitative work, on many aspects of the reef community. As stated by Professor C.M. Yonge, when

stressing/

stressing the need for a laboratory situated on a reef and for the study of reef problems. "In few, if any, areas in the sea could knowledge of marine biology be more rapidly extended". (Yonge 1958).

S U M M A R Y

The structure of Tutia Reef and the physical conditions affecting the reef are described. The origin of the reef is considered to be mainly from the breakdown of the older (14 ft) reef that exists over much of the East African region and the Indian Ocean Islands, and in part due to seaward growth of the present reef.

The living coral of the three sides of the reef are described, and the differences between the sides discussed. Differences in the coral growths with depth and with exposure to wave action are described.

The question of the growth or decay of present day East African reefs is considered, and it is suggested that typical seaward reefs are undergoing growth.

The fish fauna of the reef is described, and differences between the three faces of the reef shown. A relation between coral cover and fish fauna is evident, and independent of percentage coral cover, an increase in fish fauna with a more complex species structure of coral bottom is indicated.

The food relationships of the fish fauna are discussed. The percentage by weight of herbivorous fishes is found to be high (25%) in spite of lack of large algae, the fishes subsisting on filamentous and unicellular species. 53% of the fishes were found to be primary consumers, 40% to be mainly invertebrate consumers, and 7% to be fish predators.

APPENDIX I.

METHODS

At first the reef fishes were studied by hand-lining with the research ship's crew, using various hook sizes. It was soon realised however that the method was sampling a fractional portion of the fish fauna. During 360 line hours on Tutia Reef 24 species were caught by handline. Excluding species of which 5 or less specimens were taken, 9 species were left which were caught often enough to justify the method as a means of collectinbg samples for biological investigation. Even these specimens were selected for a particular size range. As seine nets cannot be used and gill and trammel nets were just as selective, it was decided that underwater work was essential. The advantages of the method for ecology have been stressed by Riedl (1958) and Drach (1958) and are fully endorsed here although it certainly has its own difficulties.

Diving equipment: Standard Siebe-Gorman compressed air squalung. For making notes a slate with a sharp pointed metal stylus was used. The impressions made were not removed by rubbing against clothing while getting into and out of the boat (Plate XXXI). Waterproof glass paper was used for erasion.

Transects and Quadrats: Mild steel pegs were driven into the coral to mark the transects, and an aluminium and wood frame 2 x 1 yards was used for yard square quadrats, and turned end over end down the transect. Corals were identified where possible, and their percentage cover in square feet estimated by eye.

Photography/

Photography: A pressurised aluminium housing made by the Physics Laboratory, University of Cape Town, was used with a 35 mm. Voigtlander Vitessa camera. For black and white photography Kodak Pan X and Plus X films were used, processed with Microdol, excepting for film taken at 60 ft., when Ergol was used. For colour photography Ektachrome film processed in the laboratory with Kodak Ektachrome kits was used, and also Kodachrome film processed by the makers. Colour prints were made from transparencies by Maxwell Deitch, Ltd., Johannesburg. Where photographs were not taken by the author they have been acknowledged.

Collection of Fishes: Experimental use of powdered Derris root for its rotenone was made. Large species are able to swim clear of the area poisoned, however, and only the smaller species were collected. Certain species also succumbed more easily than others. A course in the use of explosives was therefore taken, and a Tanganyika Blasting Certificate obtained. Geophex, a fast burning explosive manufactured by I.C.I., Nobel Division, Glasgow, was used, described as a "low freezing explosive Class III, Division I, of 60% strength". Low tension electrical detonators with 120 ft. leads were used, and fired with a six volt battery. This type of fast burning explosive with a steep shock wave is far more effective than slow burning explosives such as black-powder, where 20 - 45 lbs. do little damage to fish (vide Hubbs and Rechnitzer, 1952). On Tutia 2 lb. charges were used.

The charge was placed on the coral by hand, and the boat anchored some hundred feet away. After a 20 minute wait it was assumed that the fishes were back to normal, and the charge was fired. Collecting by scoop net on the surface and by two divers underwater with bags was then done immediately, before currents could dweep the fishes away.

As the/

As the larger predators (Carangids, Sphyraenids, Scombrids, large Serranids and Lutjanids) move along the reef, and their distribution at any one time is very discontinuous, the chance of an explosion collecting these species is not high and if it did occur would change the proportions of fish predators greatly. This group may be somewhat underestimated in the figures therefore.

Datum and Vertical and Horizontal Measurements: The datum used was Admiralty datum for Mafia, and was obtained by carefully marking a known low tide east of the boulder tract, and driving a peg at this point. Vertical heights on the reef were then made by staff from this point, using the horizon to get a horizontal sight. Vertical measurements for the lower pegs down transects were made with a graduated wire from sea level at a known height of tide. Horizontal distances between pegs were similarly measured with a graduated wire. The vertical measurements, relating as they do to tidal level, cannot be considered as precise, and are probably liable to a few inches error.

Weight of fishes taken by explosives. Larger fishes were weighed individually on board, but to assess the live weight of the fishes of each feeding group (Appendix 5) average fishes of each family, or where species varied greatly within a family of average sized members of each species, were measured for length and girth, and converted to weight by the formula $\frac{g^2 \times l}{750} = W$, where g = girth in inches, l = length in inches, and W = weight in lbs. (Smith 1953).

APPENDIX 2.

LISTS OF DOMINANT ALGAE, SPONGES, CORALS AND ALCYONARIANS FROM THE MAFIA AREA

ALGAE.

Phaeophyta

FUCALES

Turbinaria ornata J.Ag.

Turbinaria decurrens Bory

Sargassum spp.

DICTYOTALES

Padina commersonii Bory

DICTYOSIPHONALES

Hydroclathrus clathratus (Bory ex J.Ag.) Howe

Chlorophyta

SIPHONALES

Halimeda micronesica Yamada

Rhodophyta

CORALLINACEAE

Lithophyllum sp.

SPONGES.

Aurora globostellatta (Carter) = *Stellotta discolor* Bösraug.

Theonella swinhoei Gray

Phyllospongia foliascens (Pallas).

CORALS AND ALCYONARIANS/

CORALS AND ALCYONARIANS.

Class, Family & Species	Reef Areas					
	Tutia W	Tutia N	Tutia S-E	Sefo	Boydju	Niororo
Hydrozoa						
MILLEPORIDAE						
Millepora tenera Boschma	x	x	x			
Millepora platyphylla Hemprich & Ehrenberg	x		x			
Millepora sp. cf. M. exaesa Forskal			x			
Millepora dichotoma Forskal				x	x	
Anthozoa (Alcyonaria)						
Cespitularia sp. A						
Cespitularia sp. B (new?)						
Lemnalia sp.						
Litophyton sp. (cf. viride (May))						
Paralemnalia sp. (prob.new)						
Sinularia sp. (cf. brassica May)						
Sinularia sp. (cf. conferta (Dana))						
Sinularia sp. (cf. dissecta Tixier-Durivault)						
Sinularia sp. (cf. flexuosa Tixier-Durivault)						
Sinularia sp. (cf. gyrosa (Klunzinger))						
Sinularia sp. (cf. marenzelleri (Wright & Studer))						
Sinularia sp. (cf. polydactyla (Ehrenberg))						

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Class, Family & Species	Reef Areas					
	Tutia W	Tutia N	Tutia S-E	Sefo	Boydju	Niororo
Anthozoa (Zoantharia)						
POCILLOPORIDAE						
Pocillopora verrucosa (Ellis & Solander)	x		x	x		
Pocillopora eyedouxi Milne-Edwards & Haime	Tutia Reef - No exact locality					
Pocillopora damicornis (Linn.)			x			
Stylophora mordax (Dana)	x	x	x			
Seriatophora hystrix (Dana)			x			
ACROPORIDAE						
Acropora corymbosa (Lamarck)	x	x	x			
Acropora nana (Studer)	x		x			
Acropora hyacinthus (Dana)			x			
Acropora hyacinthus (Dana) cytherea form	x	x	x			

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Class, Family & Species	Reef Areas					
	Tutia W	Tutia N	Tutia S-E	Sefo	Boyüju	Biororo
Acropora secale (Studer)			x			
Acropora irregularis (Brook)	x		x	x		x
Acropora formosa (Dana)	x	x	x		x	
Acropora conigera (Dana)			x			
Acropora florida (Dana)	x					
Acropora palifera (Lamarck)	x	x	x			
Acropora hemprichi (Ehrenberg)	x	x	x			x
Acropora sp. cf. *A. rousseaui* (Milne-Edwards & Haime)						
Acropora clathrata (Brook)			x			
Acropora variabilis (Klunzinger)				x		
Acropora intermedia (Brook)	x		x			x
Acropora brueggemanni uncinata (Brook)	x					
Acropora massawensis von Marenzeller (same as *Forskali*?)			x			
Acropora forskali (Klunzinger)			x			
Acropora humilis (Dana)	x	x		x		
Acropora spicifera (Dana)			x	x		

Class, Family & Species	Reef Areas					
	Tutia W	Tutia N	Tutia S-E	Sefo	Boydju	Niororo
Acropora diversa (Brook)		x	x		x	
Acropora eurystoma (Klunzinger) (+ africana (Brook?)						x
Acropora reticulata (Brook)					x	
Acropora tenuis (Dana)			x			
Acropora sp. cf. A. recumbens (Brook)			x			
Montipora erythraea von Marenzeller	x					
Montipora sp. cf. M. foliosa (Pallas)	(Zanzibar Channel, not Mafia Area)					
AGARICIIDAE						
Pavona clavus (Dana)			x	x		
Pachyseris speciosa (Dana)					x	
FUNGIIDAE						
Fungia plana Studer						x
Halomitra philippinensis Studer						x
PORITIDAE						
Porites sp. cf. P. mordax Dana	x		x		x	

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Class, Family & Species	Reef Areas					
	Tutia W	Tutia N	Tutia S-E	Sefo	Boydju	Niororo
Porites australiensis Vaughan	x		x			
Porites somaliensis Gravier	x		x	x	x	x
Porites lutea Milne-Edwards & Haime	x					
Porites (Synaraea) convexa Verrill				x		
Porites (Synaraea) n.sp. aff. P.faustinoi Hoffmeister				x		
FAVIIDAE						
Favia speciosa (Dana)	x		x			
Platygyra lamellina (Ehrenberg) forma rustica (Dana)					x	
Echinopora lamellosa (Esper)						x
Echinopora hirsutissima Milne-Edwards & Haime					x	
DENDROPHYLLIDAE						
Turbinaria orator (Pallas)					x	

APPENDIX 3.

PERCENTAGE CORAL COVER FROM QUADRATS DOWN TUTIA REEF TRANSECTS.

SOUTHERN TRANSECT

Distance from S1	Peg No.	Vertical Distance from Datum	% Coral Cover Averaged for each 10 yards	Zone
0	S1	+ 10'5"	Nil	Boulder Tract
	190'8"			
190'8"	S2	0	nil	2 yds. seaward of Boulder Tract.
	190'		nil (occasionally a small coral head)	Seaward Algal Zone
380'8"	S3	- 5'6"	nil (corals rare)	A few yards within the Seaward Algal Zone.
	60'6"		22%	Spurs & Grooves Zone (sudden appearance of coral)
			25%	"
441'2"	S4	- 9'	36%	"
			29%	"
	74'			
			36%	"
515'2"	S5	-13'6"	34%	"
			63%	(large bed of *A. formosa*)
	112'6"		27%	
627'8"	S6	21'6"	33%	60 ft. from the end of the Spurs and Grooves Zone.

End of Quadrats.

Distance from S1	Peg No.	Vertical Distance from Datum	% Coral Cover Averaged for each 10 yards	Zone
690ft.	Below marked transect	- 24 ft.	± 30%	Lower Coral Zone (no ridging) Coral cover at first remains high, then progressively decreases, with increase of sand patches & sponges to - 60 ft.
1400 ft.		- 60 ft.	nil	Sand & rolled coral brash below reef foot.

WESTERN TRANSECT

Distance from W1	Peg No.	Vertical Distance from Datum	% Coral Cover Averaged for each 10 yards	Zone
0	W1	+2'8"	nil	Foot of sandbank and beginning of rock slope
	180'			This area is equivalent to Seaward Algal Zone of Southern Transect. Sparse *Padina commersoni* & *Turbinaria ornata*
			Porites australis heads present.	
180'	W2	- 2'	6%	
			24%	Beginning of coral area of Seaward Slope (Equivalent to both Spurs & Grooves Zone & Lower Coral Zone of Southern Transect)
	98'			

278 ft./

Distance from W1	Peg No.	Vertical Distance from Datum	% Coral Cover Averaged for each 10 yards	Zone
278'	W3	- 4'	29%	Coral ends below W3 in a sandy slope, except for isolated clumps and large massives.
	120'			
			8%	
390'	W4	- 6'	± 75% (on coral massive)	W4 is on a large, partly dead massive with dense cover of secondary coral growth and Alcyonaria. Sand floor from W4-W5.
	102'		nil	
402'	W5	-8'4"	±75% (on coral massive)	Peg 5 on a massive similar to W4.
			nil	Sandy floor sloping to S. Mafia Channel below W5.

NORTHERN TRANSECT

Distance from N1	Peg No.	Vertical Distance from Datum	% Coral Cover Averaged for each 10 yards	Zone
0	N1	+ 1'6"	Nil	Rock slope similar to Western Transect Fewer algae
	38'2"			
38'2"	N2	+ 11"	Nil	
	48'			Occasional corals beginning.
8·6' 2"	N3	- 5"	14%	Coral cover increases on the rock slope then dense coral beds run right to the sandy floor of the channel
	64'6"			
			51%	
150' 8"	N4	- 11"		
			39%	

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Distance from N1	Peg No.	Vertical Distance from Datum	% Coral Cover Averaged for each 10 yards	Zone
	94'		86%	Dense beds of *Acropora formosa*
			77%	
244'8"	N5	-6'4"		
			52%	*A.hyacinthus* bed
	44'		41% (averaged for 3 yds.)	
288'8"	N6	- 22'1"	nil	Sand floor of channel.

APPENDIX 4.

LIST OF FISHES TAKEN FROM THE MAFIA AREA.

Species and family	Tutia S.	Tutia N.	Tutia W.	Outer Rfs.	Inner Rfs.
TRIAKIDAE					
Triaenodon obesus (Ruppell)		1,trm.sh			2,hl,sh.
CARCHARINIDAE					
Carcharinus spallanzani (Lesueur)		1,trm			4,hl
Carcharinus albimarginatus (Ruppell)					10,hl, trm.
Carcharinus melanopterus (Quoy & Gaimard)					6,hl.
Carcharinus limbatus (Müller & Henle)					3,hl.
Carcharinus bleekeri (Gunther)					2,trm.
Carcharinus amblyrhinchus (Bleeker)		8,trm, hl			15,hl, trm, gil.
Carcharinus menisorrah Müller & Henle		2,gil			9,trm,gil
Carcharinus acutus, Ruppell					1,trm.
Galeocerda cuvier (Lesueur)	1,hl				
Scoliodon terrae-novae (Richardson)					3,trm.
ORECTOLOBIDAE					
Ginglymostoma brevicaudatum Gunther					1,hl.
RHINOBATIDAE					
Rhynchobatus djeddensis (Forskal)		1,trm.			

DASYATIDAE/

Species and family	Tutia S.	Tutia N.	Tutia W.	Outer Rfs.	Inner Rfs.
DASYATIDAE					
Taeniura lymma (Forskal)			1,sh.		23,hl,trm
Dasyatis kuhlii (Mull.& Henle)		13,trm	14,trm		116,trm, gil,sh.
TORPEDINIDAE					
Torpedo marmorata Risso			1,sh.		
ELOPIDAE.					
Elops saurus Linn.					1,hl.
CHANIDAE					
Chanos chanos (Forskal)		3,gil			
SYNODONTIDAE					
Trachinocephalus myops (Schneider)					1,trm.
TYLOSAURIDAE					
Tylosaurus crocodilus (Lesueur)					1,harpooned
HOLOCENTRIDAE					
Holocentrus caudimaculatus Ruppell	8,ex.	12,ex	7,ex		
Holocentrus spiniferum (Forskal)	3,ex,	1,ex	6,ex,sh		2,ex
Holocentrus sammara (Forskal)		24,ex	18,ex		1,ex,1,trm.
Holocentrus diademaLacepede	3,ex 5,trp	16,ex;1,trm.	2,ex		
Myripristis murdjan (Forskal)	11,ex 1,trp.	16,ex 6,trm.	110,ex 1,trm		11,ex 7,trm,hl.
Myripristis pralinius Cuvier & Valenciennes		1,ex			
Holotrachys lima (Val.)		1,ex.			
BOTHIDAE					
Bothus pantherinus (Ruppell)			4,trm		1,trm.

AULOSTOMUS/

Species and family	Tutia S.	Tutia N.	Tutia W.	Outer Rfs.	Inner Rfs.
AULOSTOMIDAE					
Aulostomus valentini (Bleeker)	1,exp.				
PRIACANTHIDAE					
Priacanthus hamrur (Forskal)					1,ex.
Priacanthus cruentatus (Lacepede)			1,ex		
PARAPERCIDAE					
Parapercis hexophthalma (Cuvier)		1,ex			
PLESIOPIDAE					
Barrosia barrosia Smith					1,ex
PSEUDOPLESIOPIDAE					
Wamizichthys bibulus Smith					1,ex.
PSEUDOGRAMMIDAE					
Aporops allfreei Smith			4,ex		
Pseudogramma polyacantha (Bleeker)			4,ex		
SERRANIDAE					
Plectropomus maculatus (Bloch)	45,1,sh, hl.	10,sh, hl	8,sh	8,hl, 1.	14,sh
Plectropomus marmoratus Talbot	16,sh, hl,1.	2,sh	7,sh	7,hl, 1.	11,hl, sh.
Variola louti	75,hl, sh,1	6,hl,trm, 3,ex	5,sh,ex	4,hl, 1.	41,hl
Chorististium susumi, Jordan & Henle		3,ex			

Cephalopholis/

Species and family	Tutia S.	Tutia N.	Tutia W.	Outer Rfs.	Inner Rfs.
Cephalopholis aurantius (Cuv. & Val.)	4,hl,ex	25,ex	1,trp		5,hl.
Cephalopholis argus (Bloch & Schneider)	3,hl,sh	2,ex	1,sh		2,hl, ex, 1,hl
Cephalopholis miniatus (Forskal)	3,ex,sh	2,sh,ex	2,ex		1,hl
Cephalopholis sonnerati (Cuv. & Val.)					1,hl.
Cephalopholis pachycentron (Cuv. & Val.)					6,ex,hl.
Cephalopholis rogaa (Forskal)	2,sh		1,sh		4,hl
Epinephelus areolatus (Forskal)					2,hl
Epinephelus salmoides (Klunzinger)			1,ex		
Epinephelus dispar (Playfair & Gunther)	35,hl,sh, ex	6,hl, trm,sh.	19,sh	4,hl	33,hl, sh
Epinephelus fuscoguttatus (Forskal)	1,ex	5,sh,ex			
Epinephelus summana (Forskal)	7,sh,hl.	2,sh,hl	9,sh		10,sh,hl.
Epinephelus leprosus Smith	9,hl				1,hl 1,seen Ch.
Epinephelus fasciatus (Forskal)	3,hl	3,hl,trm	1,seen		33,hl.
Epinephelus maculatus (Bloch)					1,trm.
Epinephelus longispinus (Kner)					3,hl.
Epinephelus caeruleo-punctatus (Bloch)					1,hl.

E. tauvina/

Family and species	Tutia S.	Wutia N.	Tutia W.	Outer Rfs.	Inner Rfs.
Epinephelus tauvina (Forsk)	3,sh,hl	5,sh,sl	4,sh		2,hl,sh, seen Niororo Chole
Epinephelus flavocaeruleus (Lacepede)				1,1	1,hl
Epinephelus malabaricus (Bloch & Schn)					3,sh,hl
Epinephelus gilberti (Richardson)				1,sh	
Epinephelus tukula Morgans		1,ex			
Anyperodon leucogrammicus (Cuvier & Val.)		2,hl,sh			3,hl,sh, seen Niororo
CIRRHITIDAE					
Paracirrhites forsteri (Bloch & Sch.)	1,ex,seen				
THERAPONIDAE					
Theraponjarbua, (Forskal)					1,trm.
ANTHIIDAE					
Anthias squammipinnis (Peters)		1,ex			
APOGONIDAE					
Cheilodipterus caninus Smith		1,ex			1,ex
Cheilodipterus lineatus (Linn.)					
Apogon bandanensis Bleeker			2,ex		3,ex
Apogon fleurieu (Lacepede)					3, ex
Apogon frenatus Valenciennes					3,ex
Papillapogon auritus (Val.)		1,ex			
Apogonichthyoides uninotatus (Smith & Radcliffe)					1,trp.

CARANGIDAE/

Family and Species	Tutia S.	Tutia N.	Tutia W.	Outer Rfs.	Inner Rfs.
CARANGIDAE					
Caranx melampygus (Cuvier & Val.)	6,hl,sh	occ.seen		12,1	5,hl,1,ex
Caranx ignobilis (Forsk)	19,1	2,1		64,1	10,1,hl, gil,occ. seen
Caranx sexfasciatus (Quoy & Gaimard)					48,1
Caranx elacate (Jordan & Evermann)	2,1	2,trm.hl		6,1	19,hl,gil
Carangoides ferdau (Forsk)			1,sh		
Carangoides fulvoguttatus (Forskal)	2,1, sh		4,sh	6,1	1,hl
Carangoides gymnostethoides Bleeker					2,hl,gil
Carangoides malabaricus (Bloch & Sch.)					2,hl
Gnathanodon speciosus (Forsk)		3,gil			
MULLIDAE					
Pseudupeneus fraterculus (Valenciennes)					1,trm.
Pseudupeneus macronema (Lacepede)		1,ex	1,ex		
Mulloidichthys auriflamma (Forskal)	5,ex				
Mulloidichthys samoensis (Gunther)			13,ex		
PLATACIDAE					
Platax pinnatus (Linnaeus)	1,sh	6,trm			2,sh

Family and species	Tutia S.	Tutia N.	Tutia W.	Outer Rfs.	Inner Rfs
POMACANTHIDAE					
Centropyge bispinosus (Gunther)	7,ex	28,ex	7,ex		1,ex
Apolemichthys trimaculatus (Cuv. & Val.)	2,ex	1,ex			1,ex
Pomacanthus semi-circulatus (Cuv. & Val.)	1,sh		4,sh		7,sh
CHAETODONTIDAE					
Chaetodon auriga Forsk.			2,ex		3,ex
Chaetodon chrysurus Desjardins	1,ex				
Chaetodon falcula Bloch		1,ex			
Chaetodon guttatissimus Bennet	4,ex	1,ex	1,ex		1,ex
Chaetodon melanotus Bl. Schn.	3,ex	4,ex			
Chaetodon meyeri Bl.Schn.	2,ex				
Chaetodon strigangulus Gmelin	3,ex	10,ex	10,ex		3,ex
Chaetodon trifasciatus Mungo Park	2,ex	12,ex	3,ex		5,ex
Chaetodon uni-maculatus Bloch		9, ex	2,ex		
Chaetodon xanthocephalus Bennet		1,ex			
Forcipiger longi-rostris (Brous-sonet)	1,ex	1 ex			1,ex
Heniochus acu-minatus (Linnaeus)	seen	2,ex			

ACANTHURIDAE/

Family and Species	Tutia S.	Tutia N.	Tutia W.	Outer Rfs.	Inner Rfs.
ACANTHURIDAE					
Acanthurus bariene Lesson					3,gil,sh.
Acanthurus bi-commatus Smith		1,ex			
Acanthurus fuliginosus (Lesson)	1,sh	11,h sh,gil	4,sh		2,gil,sh
Acanthurus leucosternon Bennet	5,ex	4,ex	1,ex		
Acanthurus lineolatus (Valenciennes)	5,ex	8,ex,sh	2,ex		
Acanthurus thompsoni (Fowler)	1,ex	4,ex			
Ctenochaetus striatus (Quoy & Gai-mard)	5,ex	24,ex	5,ex		4,ex
Ctenochaetus strigosus (bennet)	4,ex	3,ex	3,ex		
Zebrasoma scopas (Cuvier & Valenciennes)		1,trm.			
Zebrasoma veliferum (Bloch)		1,trm.			
Naso brevi-rostris (Cuv. & Valenciennes)	5,ex	11,ex			1,gil
Naso lituratus (Forster)	often seen	4,ex			
ZANCLIDAE					
Zanclus cornutus (Linn.)	2,ex	1,ex			1,ex
GERRIDAE					
Gerres oyena (Forskal)					1,trm
PEMPHERIDAE					
Pempheris oualensis Cuvier)	1,ex	2,ex			3,ex

PENTAPODIDAE/

Family and Species	Tutia S	Tutia N	Tutia W	Outer Rfs.	Inner Rfs.
PENTAPODIDAE					
Gnathodentex aurolineatus (Lacepede)	10,ex	11,ex			
Gymnocranius griseus (Schlegel)	1,hl	8,trm			1.hl
Monotaxis grandocularis (Forskal)	2,ex	2,ex	1,ex		
LUTIANIDAE.					
Lutjanus argentimaculatus					8,hl,gil, sh.
Lutjanus bohar (Forskal)	148,hl, ex	9,hl, trm	2,trp	4,hl,l	66,hl,gil sh.
Lutjanus fluviflamma (Forskal)	5,sh,ex	4,trm, hl,ex.	1,ex		143,ex,hl, trm,trp,sh.
Lutjanus gibbus (Forskal)	Seen once	34,hl,ex, trm,seen of.	14,ex, trm.	1,hl	37,hl,trm, gil,ex,seen
Lutjanus sp.	3,sh (10 seen)				
Lutjanus kasmira (Forskal)	1,hl	29,hl, trm,ex	11 ex, trp,sh		24,hl
Lutjanus lineolatus (Ruppell)			Photographed		5,hl,ex
Lutjanus monostigma (Cuv.& Val.)		2,sh,hl	6,sh		4,sh,hl
Lutjanus rivulatus (Cuv.& Val.)	1,hl	1,sh	1,sh		seen once
Lutjanus sanguineus (Cuv.& Val.)					10,hl,trm, trp.
Lutjanus sebae (Cuv.& Val.)				2,hl,sh?	5,hl,trm trp
Lutjanus vaigiensis (Quoy & Gaimard)		once seen & photogr.	1,sh		3,hl,trm
Aprion virescens Cuv.& Val.=	3,hl,l often seen	9,hl(night) occ. seen	1,sh occ. seen	8,l,hl 5,hl deep	8,l,hl, seen Niororo
Pristopomoides microlepis					

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Family and Species	Tutia S	Tutia N	Tutia W	Outer Rfs.	Inner Rfs.
Pristopomoides microlepis (Bleeker)				3,hl (deep)	
Pristipomoides typus (Bleeker)				1,hl (deep)	
NEMIPTERIDAE					
Nemipterus delagoae Smith?					3,hl
SCOLOPSIDAE					
Scolopsis bimaculatus Ruppell					1,hl
Scolopsis ghanam (Forskal)					1,trm
CAESIODIDAE					
Caesio chrysozona Cuv. & Val.		shoal 50 plus ex.			
Caesio Xanthonotus Bleeker		1,ex			
Pterocaesio pisang (Bleeker)		shoal 50 plus ex			
Caesio sp.		shoal 50 plus ex.			
PLECTORHYNCHIDAE					
Spilotichthys pictus (Thunberg)	2,sh		5,sh		4,sh
Pseudopristipoma nigris (Cuvier)					2,hl,gil
Pseudopristipoma plagiodesmus (Fowler)	3,sh	15,sh, gil,ex	1,sh		6,sh,gil
Gaterin batata Smith	2,sh	3,sh,gil	3,sh		5,sh ,gil
Gaterin gaterinus Forskal		8,ex,trm, gil	2,sh		37,ex, trm,hà.
Gaterin lineatus (Linnaeus)			1,sh		

Gaterin reticulatus/

Family and Species	Tutia S	Tutia N	Tutia W	Outer Rfs.	Inner Rfs.
Gaterin reticulatus (Gunther)	2,sh,ex		1,sh		26,sh, ex,trm.
Gaterin sordidum Klunzinger			1,sh		1,sh
LETHRINIDAE					
Lethrinus caeruleus Cuv.& Val.		2,trm.			1,trm
Lethrinus chaerorhynchus (Bloch & Schneider)		34,ex,hl, trm night			36,hl, trp
Lethrinus kallopterus Bleeker	1,hl				
Lethrinus mahsena (Forskal)					28,trm,hl, gil night
Lethrinus mahsenoides (Ehrenberg)	1,ex		2,trm		61,hl, trm,trp.
Lethrinus miniatus (Forster) Bl. Schneider		3,trm,hl			17,trm,hl.
Lethrinus nebulosus (Forskal)	2,hl	5,hl (night)	8,hl,sh, occ. seen		5,hl,trm.
Lethrinus variegatus (Cuv. & Val.)	3,hl	18,hl,trm	2,hl,trm		83,hl,trm.
Lethrinus walgiensis Cuv.& Val.	4,hl,dp.				3,hl
SPARIDAE					
Argyrops filamentosus (Valenciennes)					1,hl

AMPHIPRIONIDAE/

Family and Species	Tutia S	Tutia N	Tutia W	Outer Rfs.	Inner Rfs.
AMPHIPRIONIDAE (POMACENTRIDAE)					
Chromis dimidiatus (Klunzinger)	21,ex	14,ex	16,ex		
Chromis opercularis (Gunther)	17,ex	7,ex			7,ex
Chromis ternatensis Bleeker)		14,ex	7,ex		10,ex
Amphiprion bicinctus Ruppelli	1,ex				1,ex
Dascyllus trimaculatus (Ruppell)	1,ex				
Dascyllus aruanus (Linnaeus)		2,ex	6,ex		
Abudefduf SP.			160plus ex		

A number of Chromis and Dascyllus specimens await a group revision in the collection of Professor Smith.

Family and Species	Tutia S	Tutia N	Tutia W	Outer Rfs.	Inner Rfs.
ABUDEFDUFIDAE					
Pomacentrus trichrourus					1,ex
Abudefduf bankieri (Richardson)					4,ex
Abudefduf dicki (Lienard)	6,ex		13,ex		1,ex
Abudefduf lacrymatus (Quoy & Gaimard)	4,ex	13,ex	7,ex		4,ex
Abudefduf melas (Cuvier)	1,ex	2,ex	1,ex		
Abudefduf saxatilis (Linnaeus)			Photo.		50,ex
Abudefduf scintillans Smith		3,ex			3,ex

A number of Pomacentrus and Abudefduf specimens await a group revision in the collection of Professor Smith.

LABRIDAE/

Family and Species	Tutia S	Tutia N	Tutia W	Outer Rfs.	Inner Rfs.
LABRIDAE					
Lepidaplois axillaris (Bennet)		1,ex			1,ex
Lepidaplois hirsutus (Lacepede)					1,hl
Thalassoma hebraicum (Lacepede)			2,ex		
Thalassoma lunare (Linnaeus)					1,hl
Anampses meleagrides Cuv. & Val			1,ex		
Hemigymnus fasciatus (Bloch)	1,ex		3,ex		
Hemigymnus melapturus (Bloch)					1,ex
Halichoeres centriquadrus (Lacepede)	1,ex				
Halichoeres scapularis (Bennet)			10,ex		
Duymaeria flagellifera (Valenciennes)		1,ex			
Labroides dimidiatus (Valenciennes)		seen	seen		
Coris caudimacula (Quoy and Gaimard)		1,ex			
Coris angulata Lacepede	Shot Tutia, no definite locality				
Cheilinus fasciatus (Bloch)					2,ex
Cheilinus oxycephalus Bleeker	3,ex	3,ex	3,ex		

Pseudocheilinus hexataenia/

Family and Species	Tutia S	Tutia N	Tutia W	Outer Rfs.	Inner Rfs.
Pseudocheilinus hexataenia (Bleeker)			4,ex		
Wetmorella philippina Fowler & Bean			3,ex		
Cheilio inermis (Forskal)					1,hl
SCARIDAE					
Scarus aeruginosus Cuv.& Val.	1,ex	4,ex	1,ex		
Scarus bipallidus (Smith)	1,ex	2,ex	4,ex		2,ex
Scarus forsteri Cuv.& Val.			6,ex		
Scarus globiceps Cuv.& Val.					2,gil
Scarus guttatus Bl. & Schneider					1,trm
Scarus javanicus? Bleeker					
Scarus niger Forskal					1,ex
Scarus scaber Cuv.& Val.	2,ex	1,ex	1,ex		
Scarus sordidus Forskal	6,ex	16,ex	7,ex		
Scarus vermiculatus (Fowler & Bean)	1,ex	2,trm	1,ex		
Scarus africanus (Smith)	Tutia Reef, no definite locality				
Scarus harid Forskal	1,ex				
Scarus microrhinos (Bleeker)	Tutia Reef, no definite locality				
Scarus pectoralis (Valenciennes)	Tutia Reef, no definite locality				
Calotomus spinidens (Quoy & Gaimard)	1,ex	1,ex			

SCOMBRIDAE/

Family and Species	Tutia S	Tutia N	Tutia W	Outer Rfs.	Inner Rfs.
SCOMBRIDAE					
Euthynnus affinis (Cantor)	1,1			3,1	1,1
Gymnosarda unicolor (Ruppell)	1,1			2,1	
Acanthocybium solandri (Cuvier)	3,1			1,1 Mkumbe	
Scomberomorus commerson (Lacepede)	3,1			21,1	40,1
Scomberomorus leopardus (Shaw)					4,1,gill n.
CORYPHAENIDAE					
Coryphaena hippurus Linn				11,1	1,1
SPHYRAENIDAE					
Sphyraena toxeuma Fowler		4,hl (night)		1,1	
Sphyraena bleekeri Williams					15,1,hl,oft. night
Sphyraena jello Cuvier & Valenciennes	4,1			28,1	7,1,trm.
Sphyraena barracuda Walbaum	12,1	2,1	1,1	52,1	12,1
Sphyraena qenie Klunzinger				7,1	
Sp. chrysotaenia Klunzinger		1,ex			1,ex
SIGANIDAE					
Siganus stellatus (Forskal)		1,ex	1,ex		
Siganus oramin (Schneider)					2,ex
GOBIIDAE					
Acentrogobius sp. (nov.?)					2,ex
Gobiodon citrinus Ruppell			2,ex		

Family and Species	Tutia S	Tutia N	Tutia W	Outer Rfs.	Inner Rfs.
ELEOTRIDAE					
Eleotriodes strigatus Broussonet		2,ex			
SCORPAENIDAE					
Hypomacrus albaiensis Everman & Seale	1,ex	2,ex	2,ex		4,ex
Scorpaenodes corallinus Smith	6,ex	4,ex			
Scorpaenodes parvipinnis (Garret)			1,ex		
Parascorpaenodes hirsutus Smith			6,ex		
PLATYCEPHALIDAE					
Platycephalus indicus (Linnaeus)					1,trm
CARACANTHIDAE					
Caracanthus unipinna (Gray)		1,ex			
ECHENEIDAE					
Echeneis naucrates Linnaeus					3,hl,harp.
ECHIDNIDAE					

SIDEREA PICTA (Ahl) Common on reef flat. 2 taken by hand.

Echidna sp.			1,sh		

MONACANTHIDAE/

Family and Species	Tutia S	Tutia N	Tutia W	Outer Rfs.	Inner Rfs.
MONACANTHIDAE					
Oxymonacanthus longirostris (Bloch)	1,ex				
Hanomanctus bovinus Smith	2,ex				
Pervagor melanocephalus (Bleeker)	1,ex	4,ex			1,ex
Amanses sandwichensis (Quoy & Gaimard)			1,ex		
Amansese scopas (Cuvier)	1,ex				2,ex
ALUTERIDAE					
Osbeckia scripta (Osbeck)		1,sh			
BALISTIDAE					
Balistapus undulatus (Mungo Park)	10,ex,sh	3,ex,hl	6,ex		4,hl,ex
Balistes vetula Linn					1,hl
Balistoides conspicillum (Bloch)			1,sh		
Hemibalistes chrysoptera (Bloch)		1,trm			
Melichthys ringens (Osbeck)	3,ex,sh				
Odonus niger (Ruppell)		1,hl			
Sufflamen capistratus (Shaw)	1,hl	6,hl	2,hl		8,hl
OSTRACIODONTIDAE					
Ostracion lentiginosum Bloch	2,ex				
CANTHIGASTERIDAE					
Canthigaster valentini (Bleeker)			1,ex		

TETRAODONTIDAE/

Family and Species	Tutia S	Tutia N	Tutia W	Outer Rfs.	Inner Rfs.
TETRAODONTIDAE					
Arothron nigropunctatus (Bloch)	l,ex				

The fishes have been divided into four groups, three of which were taken from each side of Tutia Reef, one from those reefs lying inland of Mafia in sheltered water (Inner Reefs) and the fourth from the outer, or eastern edge of Mafia and the outlying reefs, excepting Tutia Reef (Outer Reef). This fourth group comprises few species, as collecting on the reefs exposed to swell was done mainly on Tutia, apart from trolling.

KEY

hl. = handling
trm. = trammel nets
sh. = shot by spear gun
gil.= gill nets.
ex.= collected by explosive
l. = taken by trolling lures
trp. = caught in basket traps.

APPENDIX 5.

FISHES TAKEN BY EXPLOSIVES FROM TUTIA REEF AND THEIR FOOD ORGANISMS.

Family	Species	Number	Food
HOLOCENTRIDAE	Holocentrus caudimaculatus	27	Crab, crust.rem.
	Holocentrus spinifer	7	Haliotis, Echinoderm rem.,whole molluscs, crab, polychaetes.
	Holocentrus sammara	42	Crab rem., amphipods, sphaeromids.
	Holocentrus diadema	20	Crust., Crab, Sphaeromid isopods.
	Myripristis murdjan	137	Crust., Polychaete bristles, Megalopa, larvae, Isopods, crabs polychaetes.
	Myripristis pralinius	1	Ostracods, isopods, crust. rem.
	Holotrachys lima	1	
AULOSTOMIDAE	Aulostomus valentini	1	-
PRIACANTHIDAE	Priacanthus cruentatus	1	-
PARAPERCIDAE	Parapercis hexophthalma	1	-
PSEUDOGRAMMIDAE	Aporops allfreei	4	-
	Pseudogramma polyacantha	4	Crustaceans.
SERRANIDAE	Variola louti	1	Fishes (including Chaetodontids and Monacanthids) crab, octopus.
	Chorisistium susumi	3	-
	Cephalopholis aurantius	32	Crab, fishes, molluscs

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Family	Species	Number	Food
	Cephalopholis miniatus	2	Fishes
	Cephalopholis argus	2	Fishes (including wrasses) also crustaceans.
	Epinephelus salmoides	1	Fishes
	Epinephelus dispar	1	Fishes, crab.
	Epinephelus fuscoguttatus	2	Fish, cepholopods.
	Epinephelus fasciatus	1	Fishes, ophinroids, crab.
	Epinephelus tukula	1	Fishes (including Scarids).
CIRRHITIDAE	Paracirrhites forsteri	1	Fish including Scarid juv.
ANTHIIDAE	Anthias squammipinis	1	-
APOGONIDAE	Cheilodipterus caninus	1	Small fishes,
	Apogon bandenensis	2	Crustaceans and sand
	Apogon frenatus	4	-
	Papillapogon auritus	1	-
MULLIDAE	Pseudupeneus macronema	2	Copepods, amphipods, other crust. rem.
	Mulloidichthys auriflamma	5	Sand
	Mulloidichthys samoensis	13	Amphipods, isopods, copepods, sand.

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Family	Species	Number	Food
POMACANTHIDAE	Centropyge multispinus	42	Much filamentous algae
	Apolemichthys trimaculatus	3	-
CHAETODONTIDAE	Chaetodon auriga	2	Algal matter, Alcyonarian polyps
	Chaetodon chrysuris	1	Mod.sized algal pieces and fil. algae.
	Chaetodon falcula	1	Algal mush
	Chaetodon guttatissimus	6	Fine algal mush 1 copepod.
	Chaetodon melanotus	7	Algae, Alcyonarian polyps.
	Chaetodon meyeri	2	Algal mush
	Chaetodon trifasciatus	17	Green brown mush (?alg), unicellular algae (incl. diatoms)
	Chaetodon strigangulus	23	Unicellular algae (including diatoms)
	Chaetodon unimaculatus	11	Crustaceans (incl. copepods). Alcyonarian polyps.
	Chaetodon xanthocephalus	1	Green mush
	Forcipiger longirostris	2	Crustacean limbs fine algae.
	Heniochus acuminatus	2	-
ACANTHURIDAE	Acanthurus bicommalus	1	-
	Acanthurus leucosternon	10	Algal filaments.
	Acanthurus lineolatus	9	Algae
	Acanthurus thompsoni	5	-
	Ctenochaetus striatus	34	Coral sand and shell, mush. Pieces of algae, foramenifera

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Family	Species	Number	Food
	Ctenochaetus strigosus	10	Sand and coral, hydroids, copepods (? scraping rocks) fine green matter.
	Naso brevirostris	16	Diatom mush Algal pieces.
	Naso lituratus	4	
ZANCLIDAE	zanclus cornutus	3	Sand and algae, mollusc remains, sponge pieces.
KYPHOSIDAE	Kyphosus cinerascens	3	Algae
PEMPHERIDAE	Pempheris oualensis	3	Crustaceans includ. isopods, copepods, amphipods and megalopa larvae.
PENTAPODIDAE	Gnathodentex aurolineatus	21	Chitons, crustaceans echinoderms, idopods, amphipods, polychaetes.
	Monotaxis grandocularis	5	Chiton, crushed bivalves, winkles, crab.
LUTJANIDAE	Lutjanus fulviflamma	3	Crustaceans, (crabs, isopods, prawns) also fish.
	Lutjanus gibbus	27	Crustaceans (crabs, prawns) also fish.
	Lutjanus bohar	15	Fishes, predominately, also crustaceans.
	Lutjanus kasmira	11	Crustaceans predominately, also squids fishes.
CAESIODIDAE	Caesio chrysozona	50+	Plankton, zoea, copepods.
	Caesio zanthonatus	1	
	Pterocaesio pisang	50+	Plankton
	Caesio sp.	50+	Zoea larvae, copepods plankton.

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Family	Species	Number	Food
PLECTORHYNCHIDAE	Pseudopristipoma plagiodesmus	8	Prawn, algae, polychaete rem. small fishes.
	Gaterin batata	1	Coral brash
	Gaterin gaterinus	5	Fishes, crabs, shrimps, ophiuroids
	Gaterin reticulatus	1	Gastropods.
LETHRINIDAE	Lethrinus chaerorhynchus	24	Crab, ostracods, polychaetes, gastropods.
	Lethrinus mahsenoides	1	Fish rem. crab.
AMPHIPRIONIDAE	Chromis dimidiatus	51	-
	Chromis opercularis	24	Plankton, copepods
	Chromis ternatensis	31	Zooplankton, copepods
	Amphiprion bicinctus	1	Mod. sized crustacean rem.
	Lepidozygus anthioides	5	Copepods
	Dascyllus trimaculatus	1	-
	Dascyllus aruanus	8	Copepods, much algae
ABUDEFDUFIDAE	Abudefduf sp.	160	-
	Abudefduf dicki	18	Algal threads & ? fish eggs Alcyonarian polyps
	Abudefduf lacrymatus	24	Ostracods, foramenifera, sand grains, algal threads.

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Family	Species	Number	Food
	Abudefduf melas	4	Alcyonarian polyps
	Abudefduf scintillans	3	Fil. algae predom. +ostracods, copepods.
LABRIDAE	Lepidaplois axillaris	1	Crustaceans (mod. sized), polychaetes, gastropods, bivalves.
	Thalassoma hebraicum	2	Bivalves, chiton, crab carapace.
	Anampses meleagrides	1	Mollusc shells, crust. rem.
	Hemigymnus fasciatus	4	Copepods, amphipods, crushed gastropods, crust. rem.
	Halichoeres centriquadrus	1	-
	Halichoeres scapularis	10	Crustaceans, incl. spaeromid isopods, copepods, crushed bivalves, ophiuroids.
	Duymaeria flagellifera	1	-
	Coris caudimacula	1	-
	Cheilinus oxycephalus	9	Chitons, mollusc shells crushed, crust. rem., a little algae.
	Pseudocheilinus hexataenia	4	Copepods, sand, formenifera, amphipods
	Wetmorella philippina	3	Crushed coral or coral sand
SCARIDAE	Scarus aeruginosus	6	Green mush and coral or coral sand
	Scarus bipallidus	7	Crushed coral, a few algal threads
	Scarus forsteri	6	Foramenifera, ostracods, sand.
	Scarus scaber	4	Broken coral and green mush.

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Family	Species	Number	Fodd
	Scarus sordidus	29	Green mush and broken coral.
	Scarus vermiculatus	2	Coral mush
	Hipposcarus harid	1	Coral mush
	Calotomus spinidens	2	
SPHYRAENIDAE	Sphyraena chrysotaenia	1	-
SIGANIDAE	Siganus stellatus	2	Sponge, algae
GOBIIDAE	Gobiodon citrinus	2	-
ELEOTRIDAE	Eleotrides strigatus	2	Copepods, ostracods, amphipods
SCORPAENIDAE	Hypomacrus albaiensis	5	-
	Scorpaenodes corallinus	10	Mod.sized crustaceans.
	Scorpaenodes parvipinnis	1	-
	Parascorpaenodes hirsutus	6	Crustaceans, prawns
CARACANTHIDAE	Caracanthus unipinna	1	-
MONOCANTHIDAE	Oxymonacanthus longirostris	1	-
	Hamomanctus bovinus	2	-
	Pervagor malanocephalus	5	Sand, algae
	Amanses sand-wichensis	1	
	Amanses scopas	1	Snapped off (not crushed) Acropora tips

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Family	Species	Number	Food
BALISTIDAE	*Balistapus undulatus*	14	Crabs, echinoids, sand, coral fragments, algae.
	Hemibalistes chrysoptera	1	-
	Melichthys ringens	1	Green algal mush
OSTRACIODONTIDAE	*Ostracion lentiginosum*	2	-
CANTHIGASTERIDAE	*Canthigaster valentini*	1	Algal pieces, broken coral or coralline algae
TETRAODONTIDAE	*Arothron nigropunctatus*	1	Stagshorn *Acropora* tips, bitten off not crushed.

GROUPING ACCORDING TO FEEDING HABITS

Coral Feeders	Algal Feeders	Invertebrate Predators
SCARIDAE	POMACANTHIDAE	HOLOCENTRIDAE
8 species, 57 fishes	2; 45	7; 235
Arothron nigropunctatus	CHAETODONTIDAE	?PRIACANTHIDAE
1; 1	12; 75	1; 1
Amanses scopas	ACANTHURIDAE	?PARAPERCIDAE
1; 1	8; 89	1; 1
	ZANCLIDAE	?PSEUDOGRAMMIDAE
Total: 10; 59	1; 3	2; 8

.../

Plankton Feeders

PEMPHERIDAE
1; 3
CAESIOIDIDAE
4; 151
AMPHIPRIONIDS
7; 121
Eleotrides strigatus
1;2

Total : 13; 277

Fish Predators

SERRANIDAE
10; 45
CIRRHITIDAE
1; 1
Lutjanus bohar
1; 15
SPHYRAENIDAE
1; 1

Total: 13; 62

Algal Feeders (cont)

KYPHOSIDAE
1; 3
ABUDEFDUFIDAE
5; 209
SIGANIDAE
1; 2

MONACANTHIDAE
5; 10
Melichthys ringens
1; 1
Canthigaster valentini
1; 1

Total : 37 ; 438

Invertebrate Predators (Cont)

ANTHIDAE
1; 1
APOGONIDAE
4; 8
MULLIDAE
3; 20

PENTAPODIDAE
2, 26
LUTJANIDAE (excl. *L. bohar*)
3; 41
PLECTORHYNCHIDAE
4; 15
LETHRINIDAE
2; 25
LABRIDAE
11; 37
SCORPAENIDAE
4; 22
Balistapus undulatus
1; 14

Total : 46 ; 454

Priacanthus cruentatus, *Parapercis hexophthalma*, and the two *Pseudogrammids* taken have been considered invertebrate predators. *Gobiodon citrinus* and *Caracanthus unipinna* have not been included.

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PLATE I.

Tutia Reef in perspective. Across Tutia channel the tip of Jibondo Reef is visible (upper centre). Vertical distance is exaggerated to indicate depth, each step representing 10 fathoms. The hundred fathom line is reached $1\frac{1}{4}$ miles eastward from the reef, the slope being very steep after 50 fathoms. The bases of the three transects are marked on the reef. the Southern Transect starting on the boulder tract, the Western at the base of the sandbanks, and the Northern facing the channel.

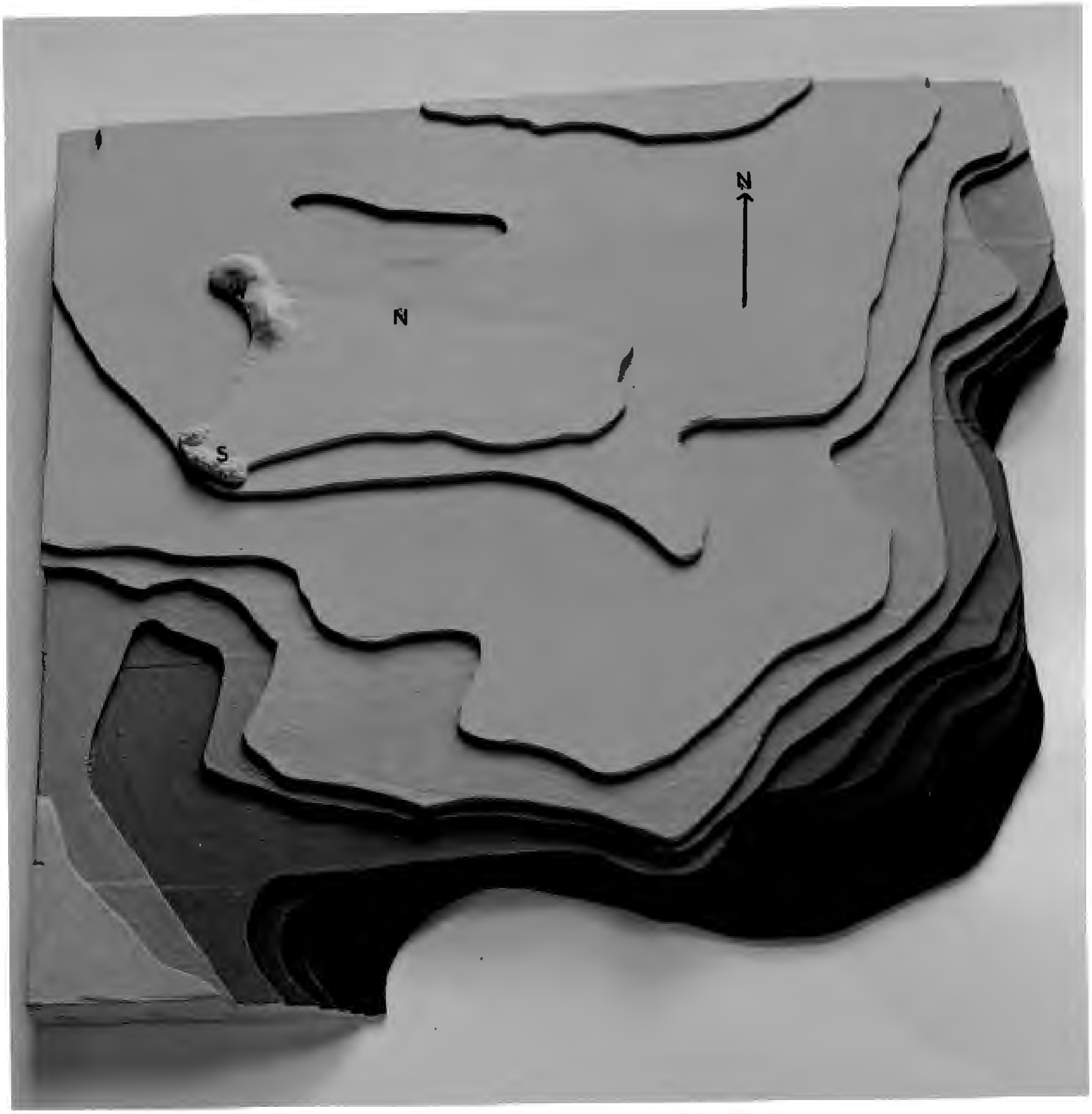
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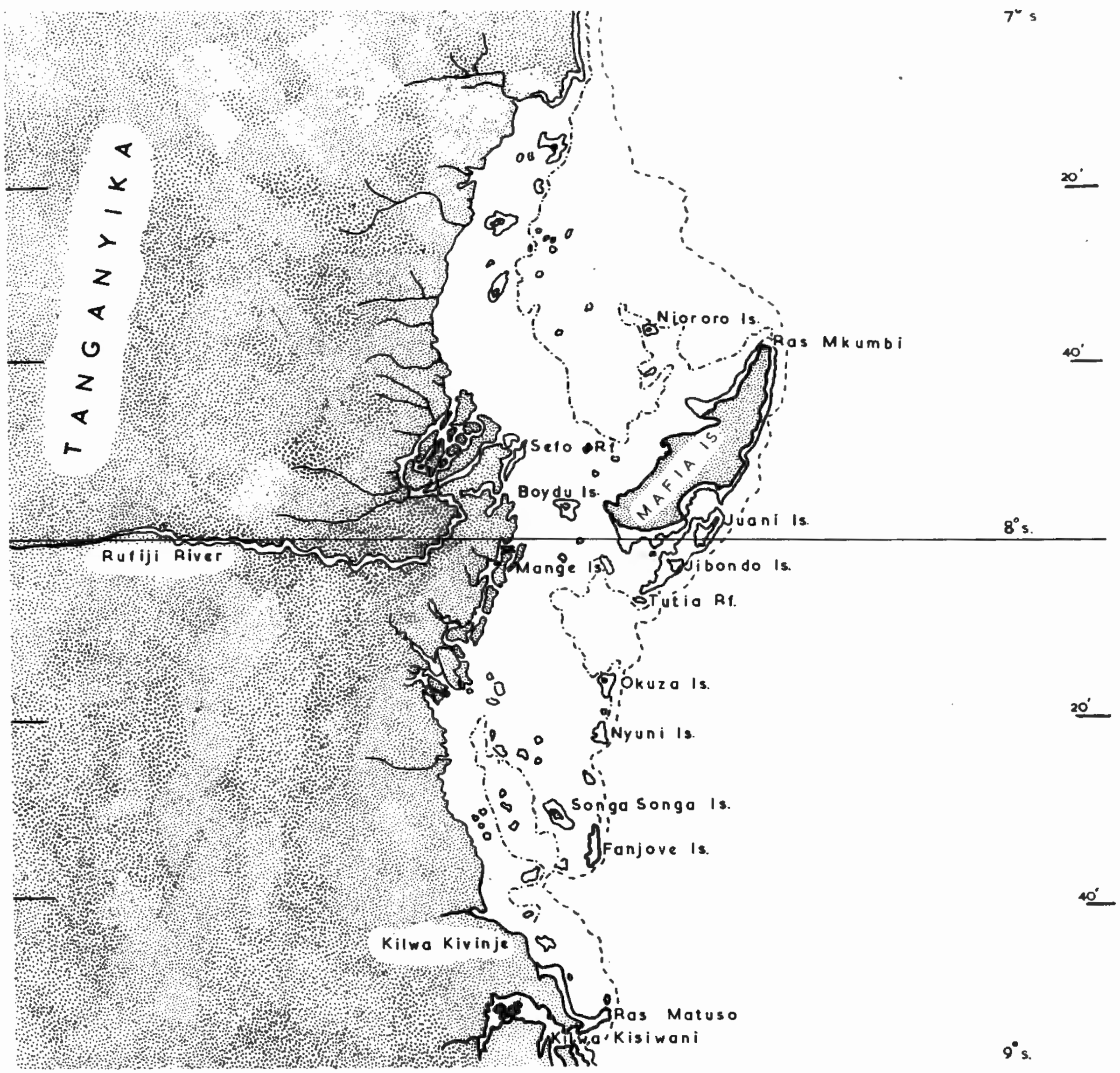
PLATE II.

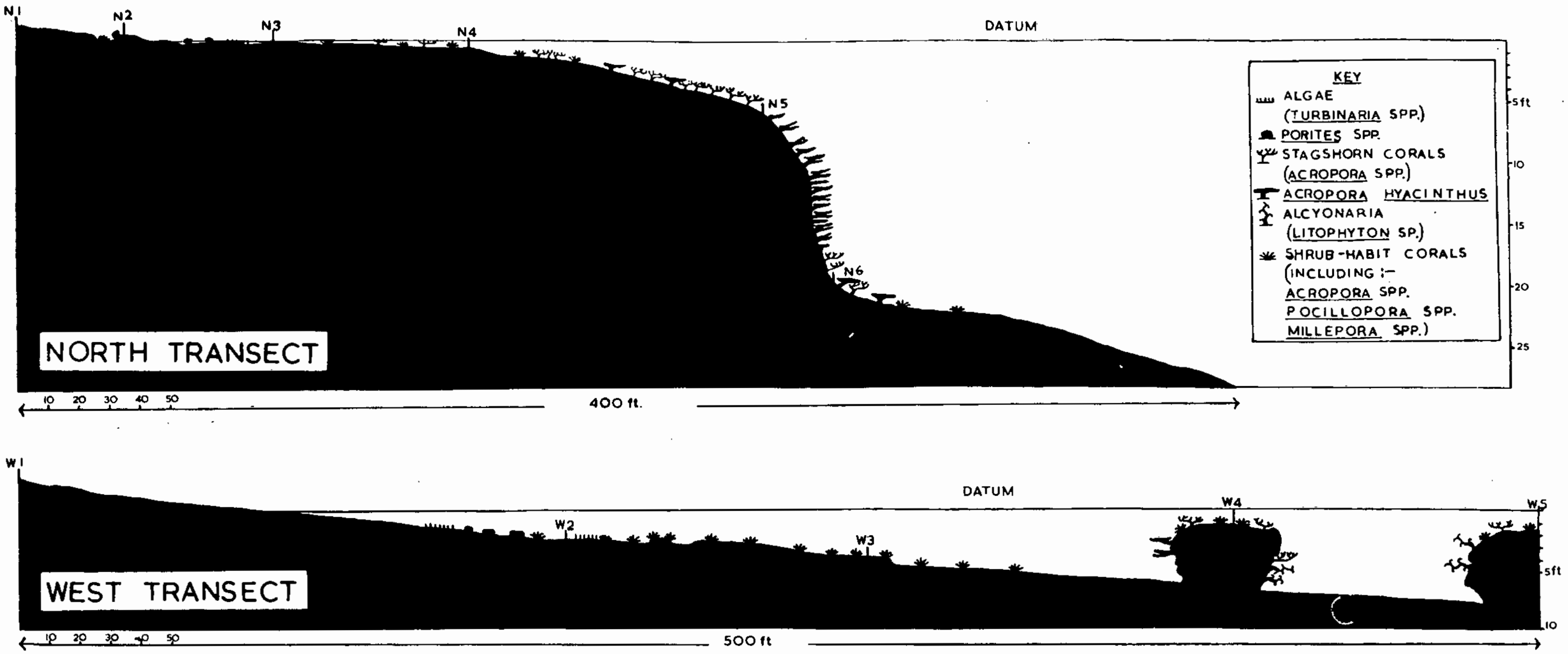
Plan of the Mafia Area.



7° S
20'
40'
8° S.
20'
40'
9° S.
TANGANYIKA
Rufiji River
Njororo Is.
Ras Mkumbi
MAFIA IS.
Sefo Rf.
Boydu Is.
Juani Is.
Mange Is.
Jibondo Is.
Tutia Rf.
Okuza Is.
Nyuni Is.
Songa Songa Is.
Fanjove Is.
Kilwa Kivinje
Ras Matuso
Kilwa Kisiwani

PLATE III.

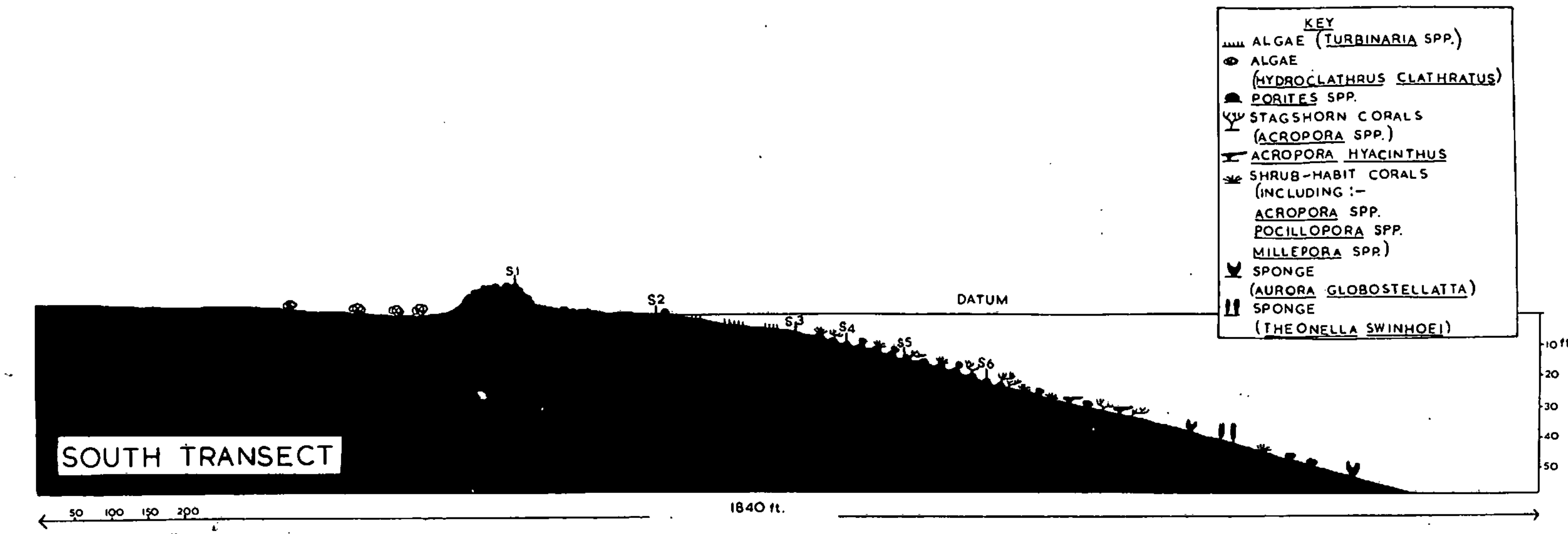
Profiles of the Northern & Western Transects



N1
N2
N3
N4
N5
N6
DATUM
KEY
ALGAE (TURBINARIA SPP.)
PORITES SPP.
STAGSHORN CORALS (ACROPORA SPP.)
ACROPORA HYACINTHUS
ALCYONARIA (LITOPHYTON SP.)
SHRUB-HABIT CORALS (INCLUDING :- ACROPORA SPP. POCILLOPORA SPP. MILLEPORA SPP.)
5ft
10
15
20
25
NORTH TRANSECT
10 20 30 40 50
400 ft.
W1
DATUM
W2
W3
W4
W5
5ft
10
WEST TRANSECT
10 20 30 40 50
500 ft

PLATE IV.

Profile of the Southern Transect.



SOUTH TRANSECT
S1
S2
S3
S4
S5
S6
DATUM
10 ft
20
30
40
50
50 100 150 200
1840 ft.
KEY
ALGAE (TURBINARIA SPP.)
ALGAE (HYDROCLATHRUS CLATHRATUS)
PORITES SPP.
STAGSHORN CORALS (ACROPORA SPP.)
ACROPORA HYACINTHUS
SHRUB-HABIT CORALS (INCLUDING :- ACROPORA SPP. POCILLOPORA SPP. MILLEPORA SPP.)
SPONGE (AURORA GLOBOSTELLATTA)
SPONGE (THEONELLA SWINHOEI)

PLATE V.

Relationship of coral cover and fish population on the Southern Transect.

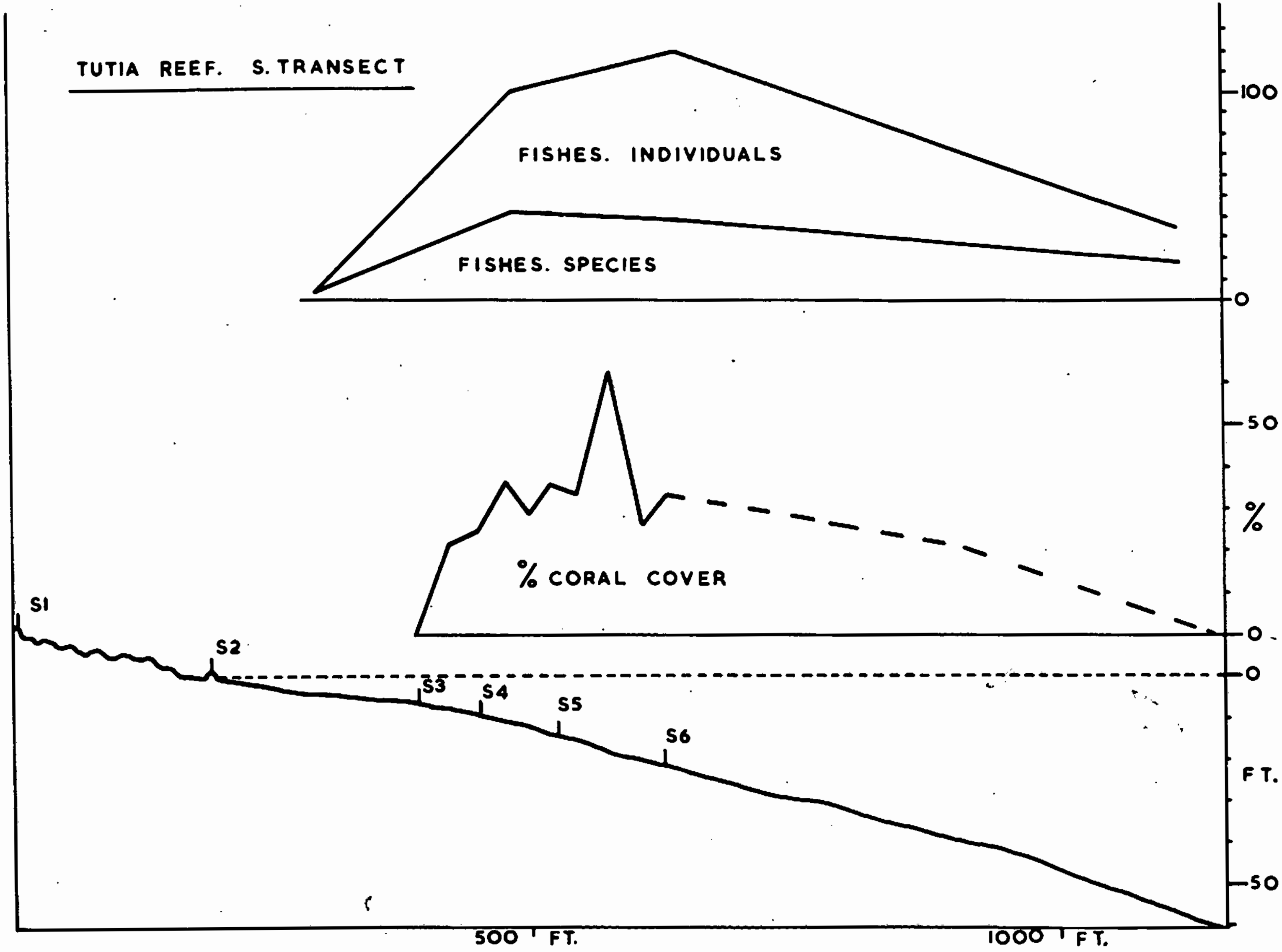

TUTIA REEF. S. TRANSECT
FISHES. INDIVIDUALS
FISHES. SPECIES
% CORAL COVER
S1
S2
S3
S4
S5
S6
100
0
50
%
0
0
FT.
50
500 FT.
1000 FT.

PLATE VI.

Sheltered water coral, typical of areas between Mafia Island and the mainland, or the Zanzibar channel. A massive *Porites somaliensis* block stands left, and a bed of *Porites* (*Synaraea*) sp. in the foreground.

PLATE VII.

Acropora formosa forming tangled masses, with Chromids keeping an eye on the photographer.

PLATE VIII.

Chaetodon melanotus, the little golden *Abudefduf scintillans*, a Scarid with characteristic pale caudal peduncle, and other fishes over dead patches of stagshorn *Acropora*.

PLATE IX.

Abudefduf scintillans and Halichoeres centriquadrus on a mixed coral bottom (Acropora shrubs, Seriatopora hystrix, Pocillopora verrucosa) in shallow and sheltered water.

PLATE X.

Dead coral, with a large Acropora shrub, Abudefduf scintillans and a golden Mullid.

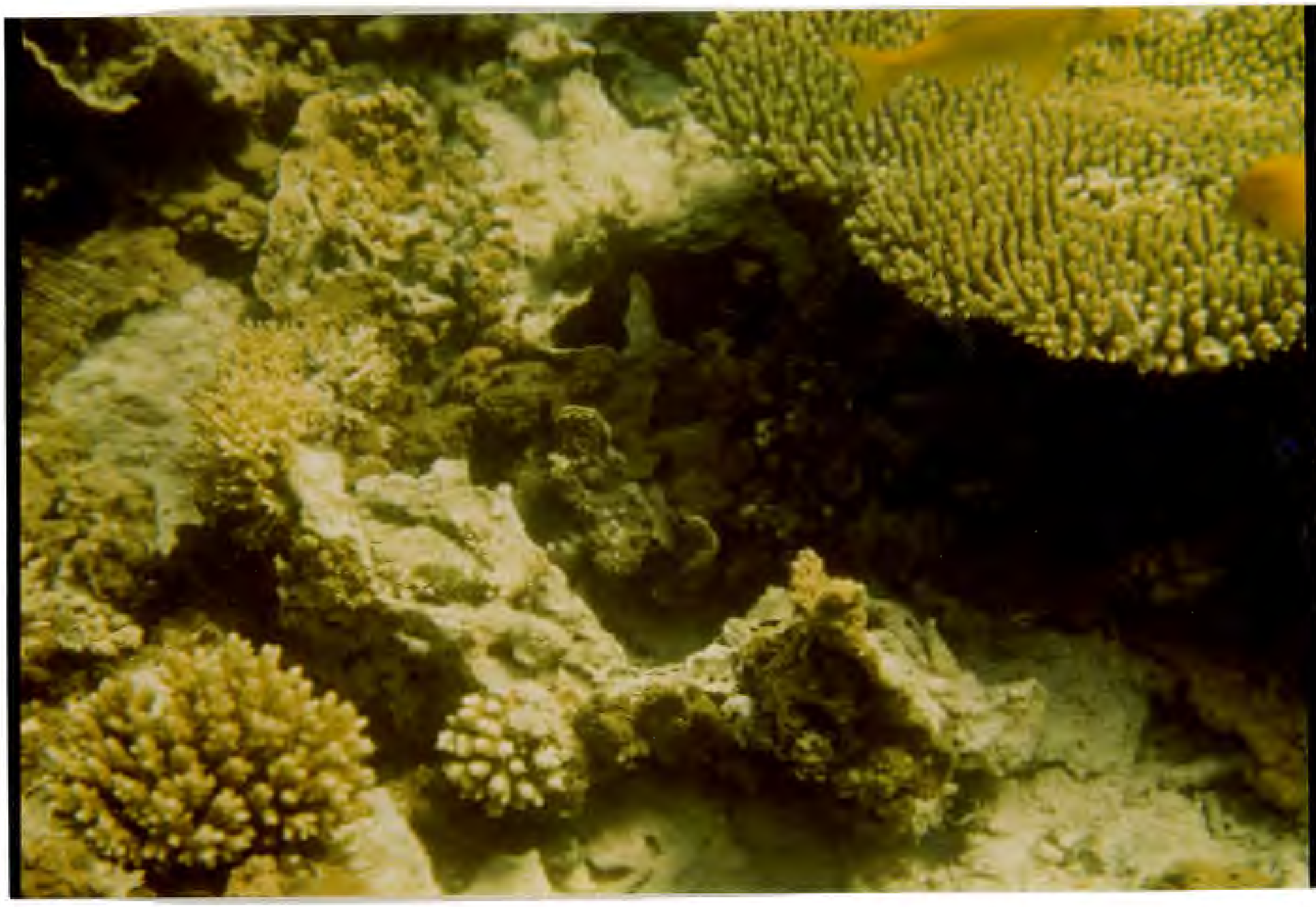


PLATE XI.

Gaterin gaterinus, common near deep shelter.

PLATE XII.

The Boulder Tract exposed at spring low tide.

PLATE XIII.

The quadrat frame on the floor of a "Groove" in the Southern Transect, showing broken coral brash.

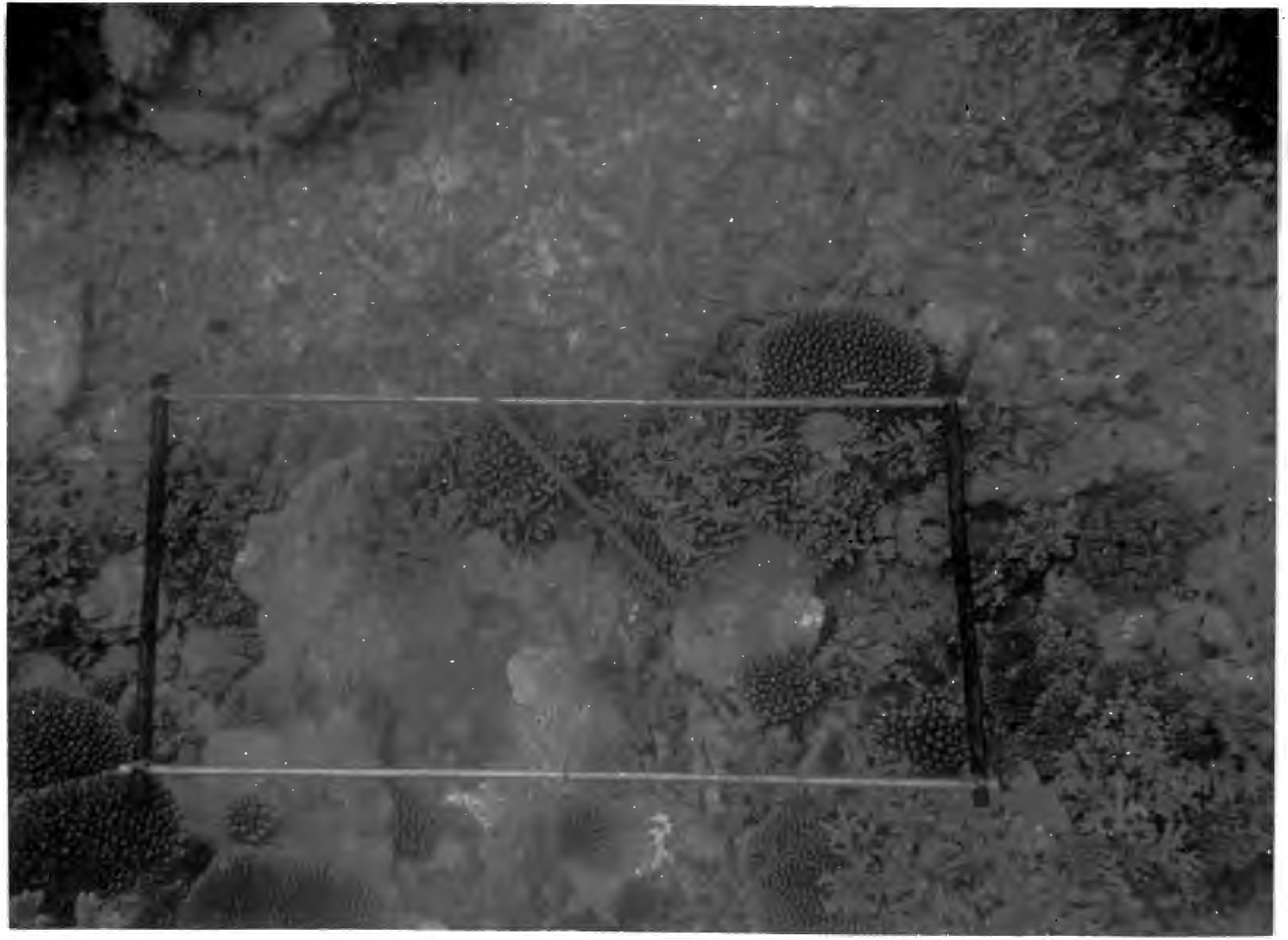


PLATE XIV.

Acropora corymbosa in shallow water on the Southern Transect. This area, at the landward end of the Spurs and Grooves Zone, is liable to strong surf action.

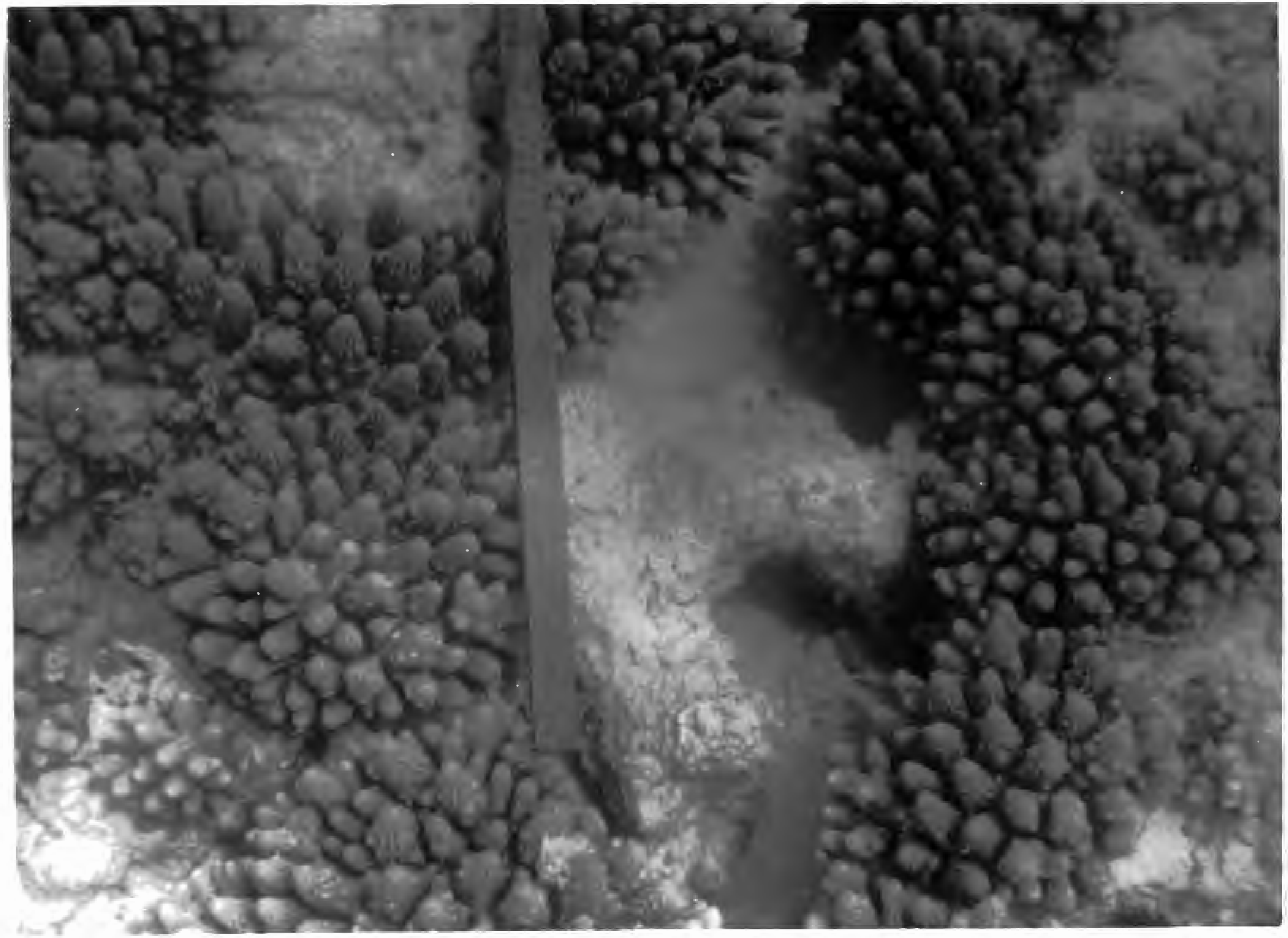


PLATE XV.

A typical "Spur", with some lithothamnion covered dead rock, <u>Acropora</u> shrubs, <u>Acropora irregularis</u> (lower left), and the symmetrical <u>Stylophora mordax</u> (left centre of metre rule). <u>Callyodon scaber</u> swims into shelter.

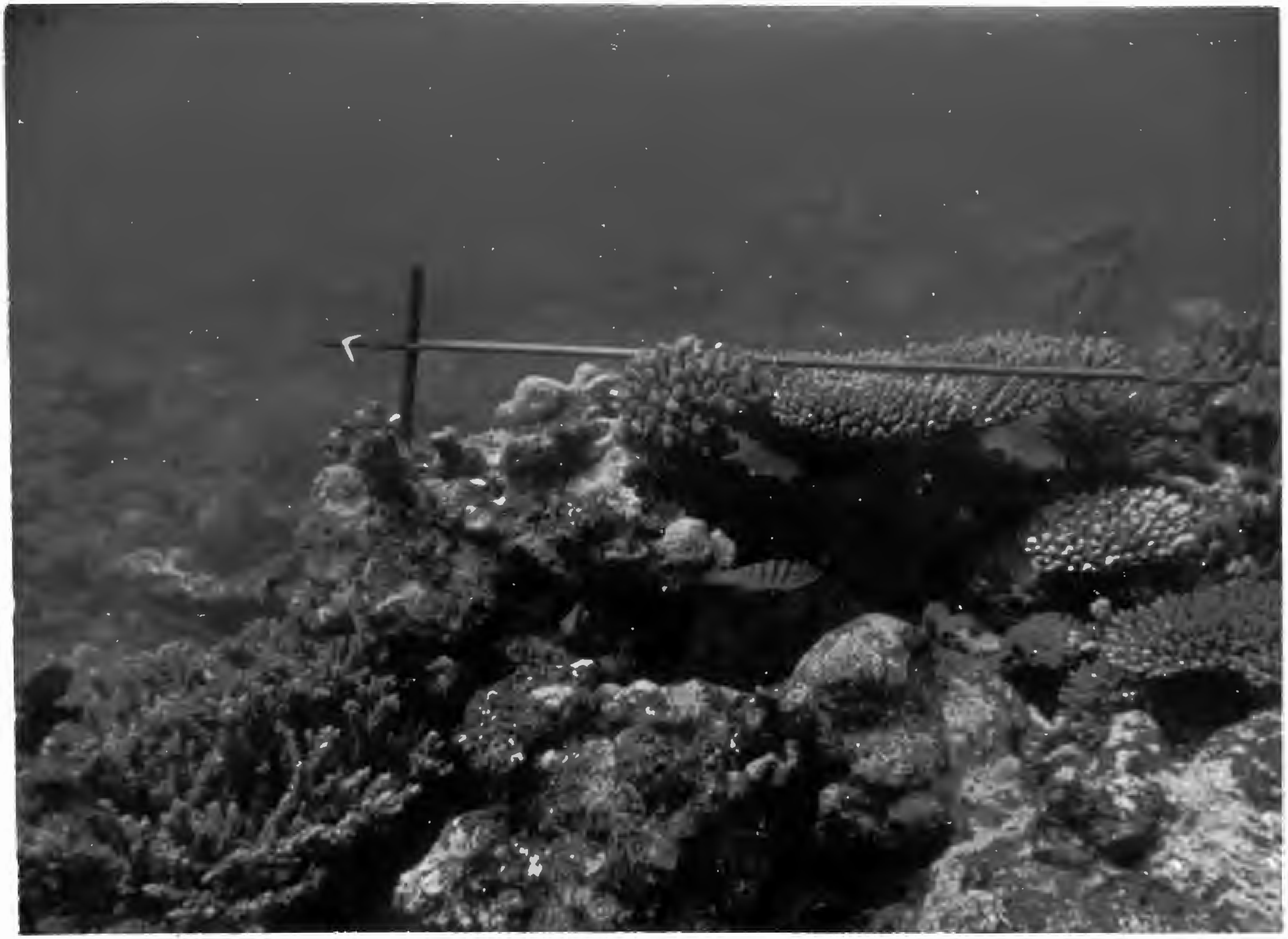


PLATE XVI

Dense beds of *Acropora formosa* and the platelike *A. hyacinthus* in sheltered water.

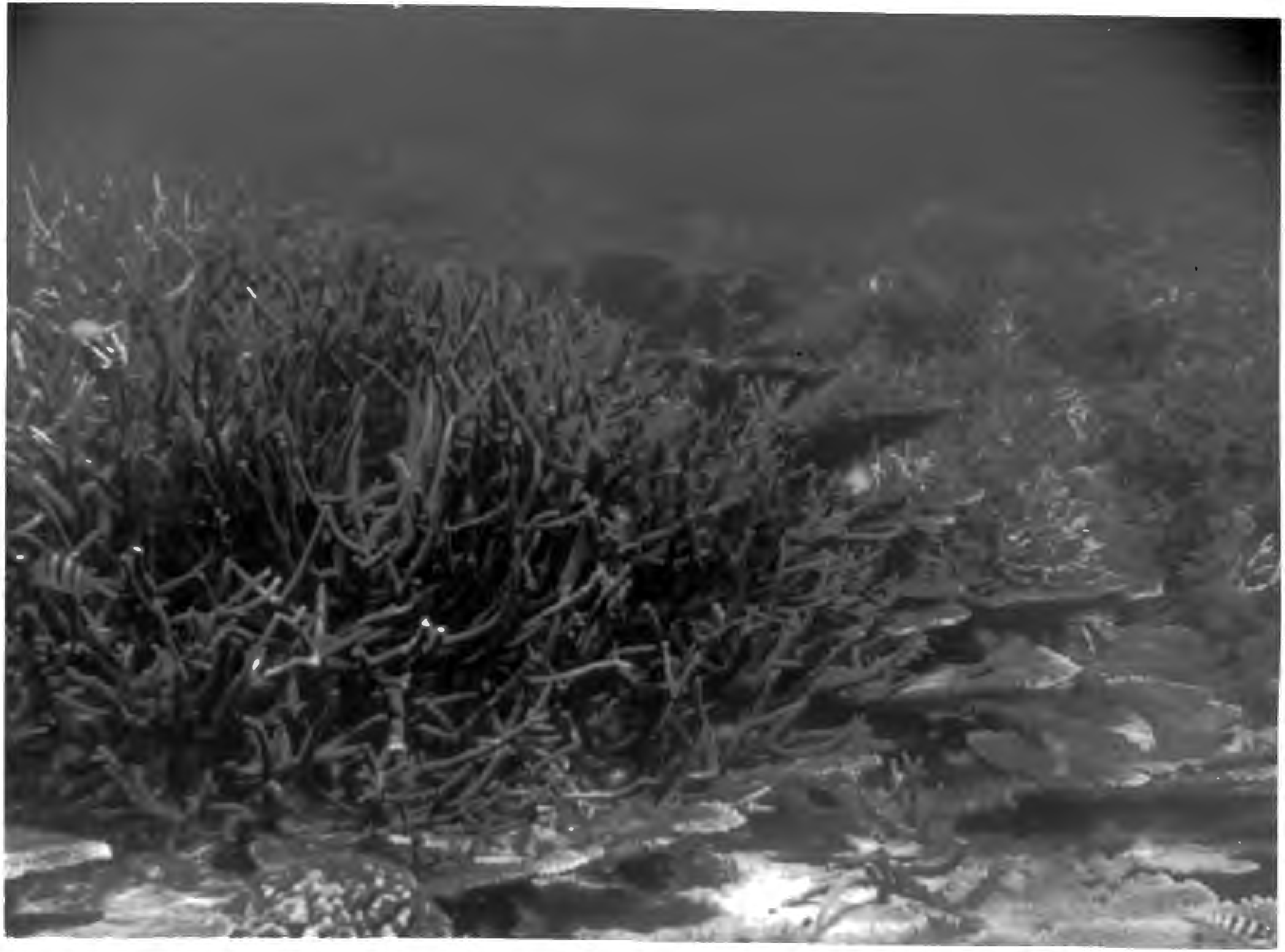


PLATE XVII

A delicate platform of Acropora spicifera growing out from a Porites somaliensis massive at 60 ft. on the Southern Transect. Zanclus sp. and Chromids swim over the coral. (See Plate XIX). Photo J.F.C. Morgans.

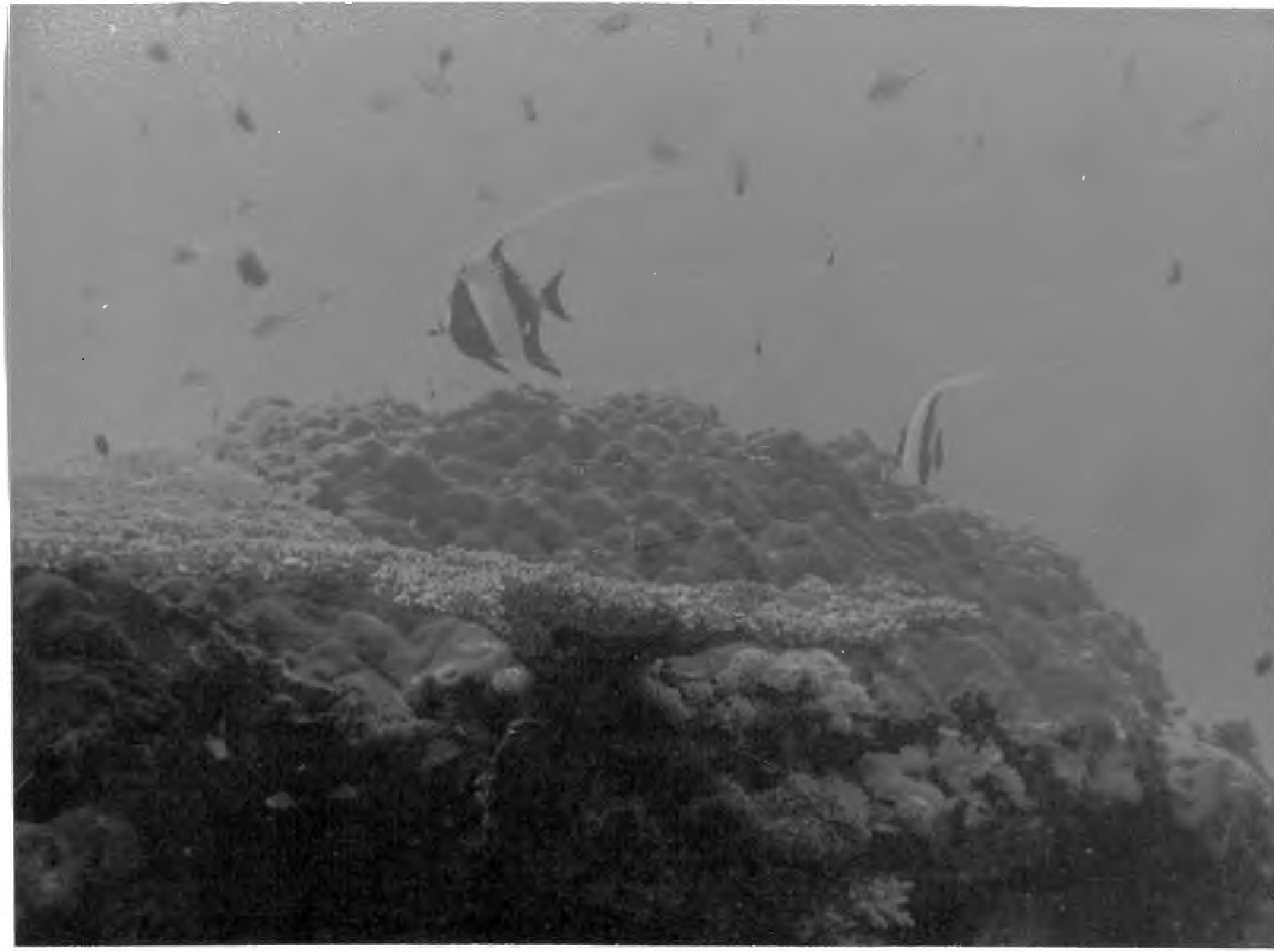


PLATE XVIII

Aurora globostellatta, a squat sponge common in the lower portion of the Lower Coral Zone Lower right are the strong "fingers" of *Porites* sp. (aff. *mordax*).

PLATE XIX

Porites somaliensis at 60 ft., Southern Transect. Zanclus sp. pose over the massive, Acropora spicifera in foreground. Photo J.F.C. Morgans.

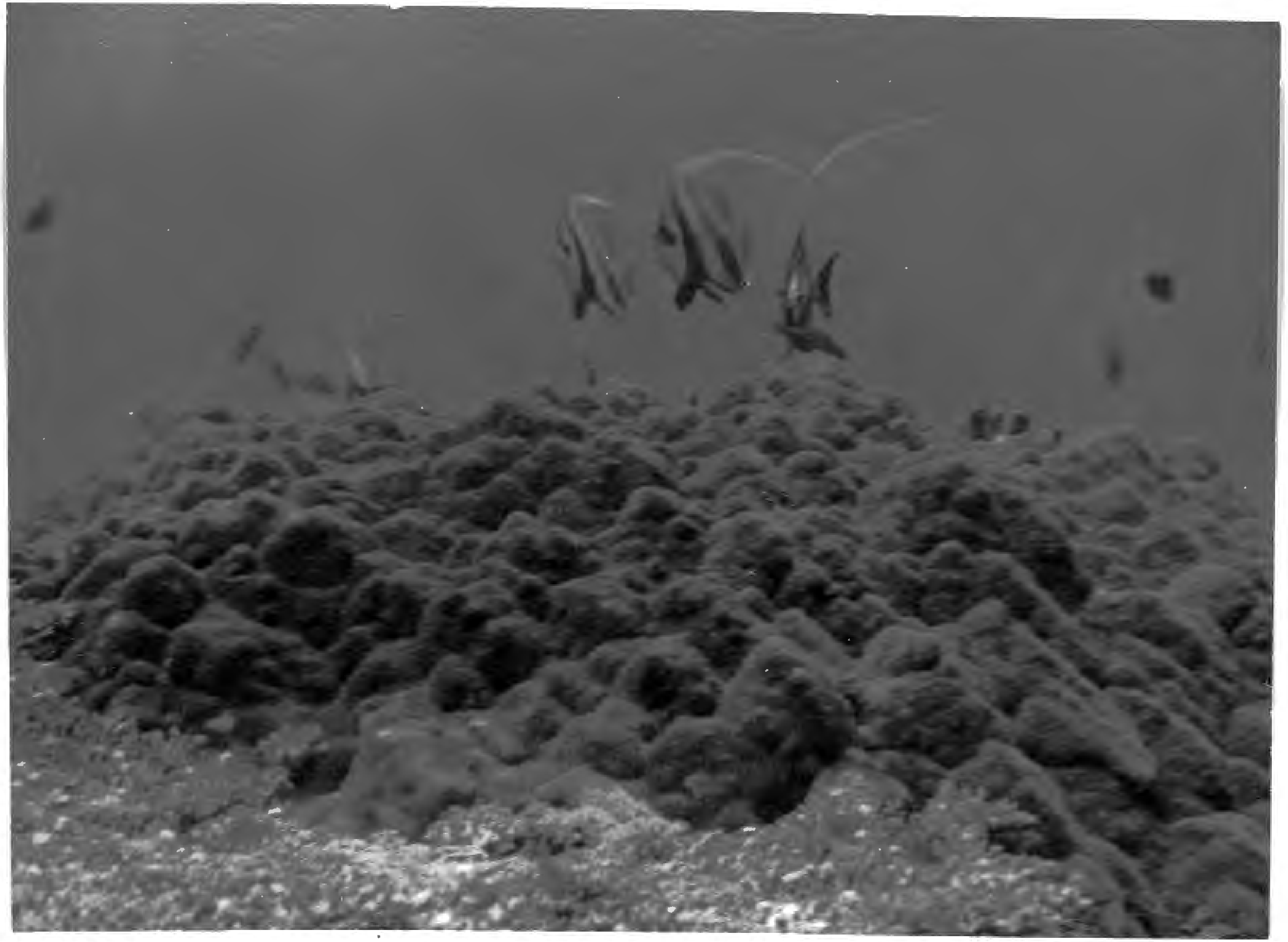


PLATE XX.

Aurora globostellatta and a sparse growth of alcyonaria at the reef foot. 60 ft. Southern Transect.

PLATE XXI

Lithophyton growing on an eroded Porites somaliensis block in the Western Bay. Parts of the original massive are still growing.

PLATE XXII

Porites somaliensis, in part dead and with secondary cover of alcyonarians and other corals. Scarid tooth marks show clearly on the living *Porites*. Western Bay.

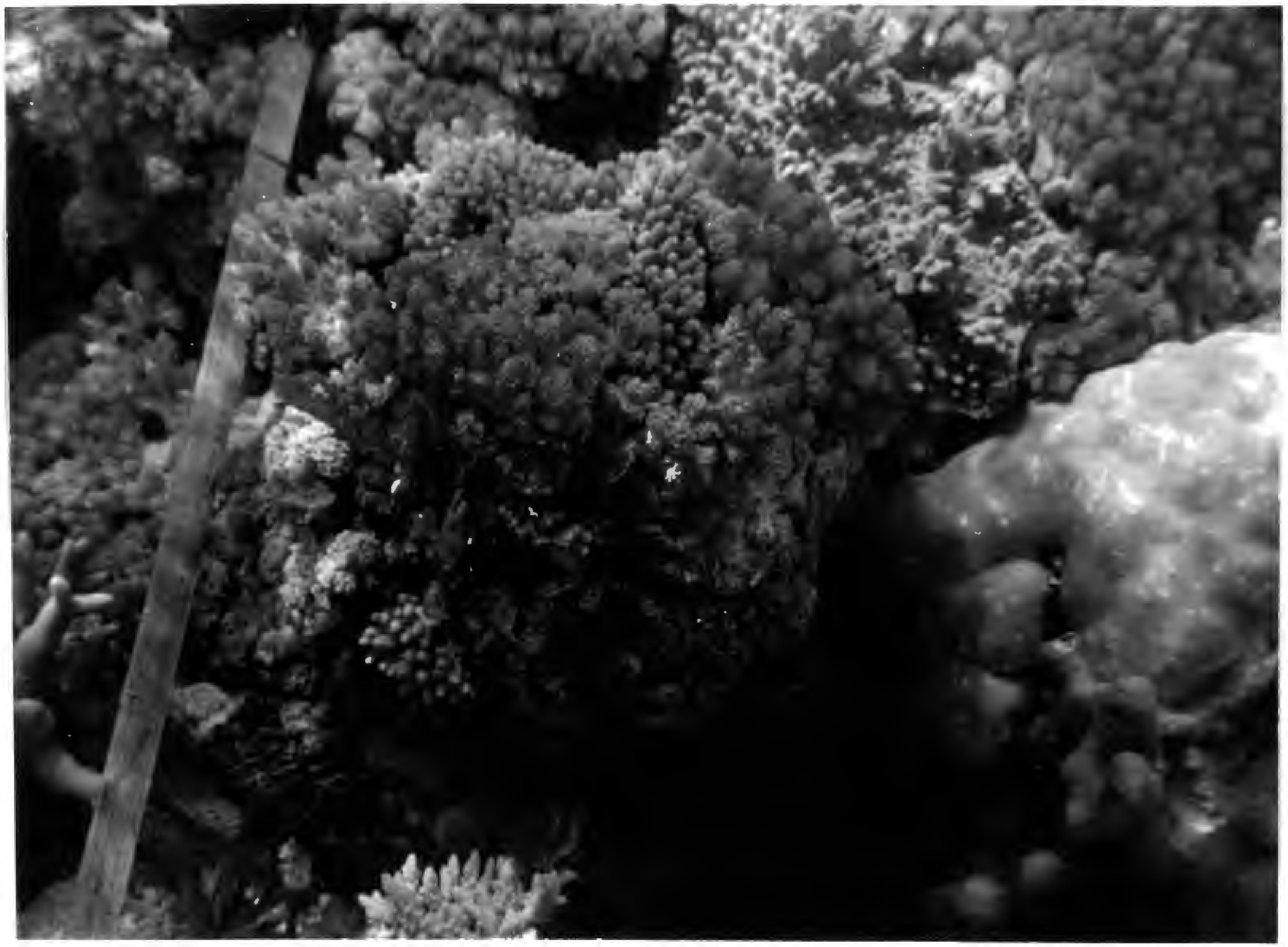


PLATE XXIV

Acropora palifera in its typical turreted form growing with shrub-formed Acropora and alcyonarians on an older dead coral block in the Western Bay. Abudefduf saxatilis (centre foreground) and other coral fishes swim about the coral.

PLATE XXIII

A <u>Porites</u> sp. massive completely covered in secondary coral growth, including <u>A. corymbosa</u> (left) sturdy "fingers" of Porites (n.sp.aff. <u>mordax</u>)(centre left), fragile twigs of <u>Seriatopora hystrix</u> (centre), a tangle of <u>A. irregularis</u> (right), and alcyonarians (<u>Cespitularia</u> sp.). Western Bay.

PLATE XXV

Acropora hyacinthus, *cytherea* form, in tiers on the sheltered northern edge of Tutia Bay.

PLATE XXVI.

Millepora tenera forming a rounded shrub in the shelter of the northern reef edge.

PLATE XXVII.

Millepora platyphylla in shallow water of the Western Bay. Swell is throwing up sand at the foot of the coral.

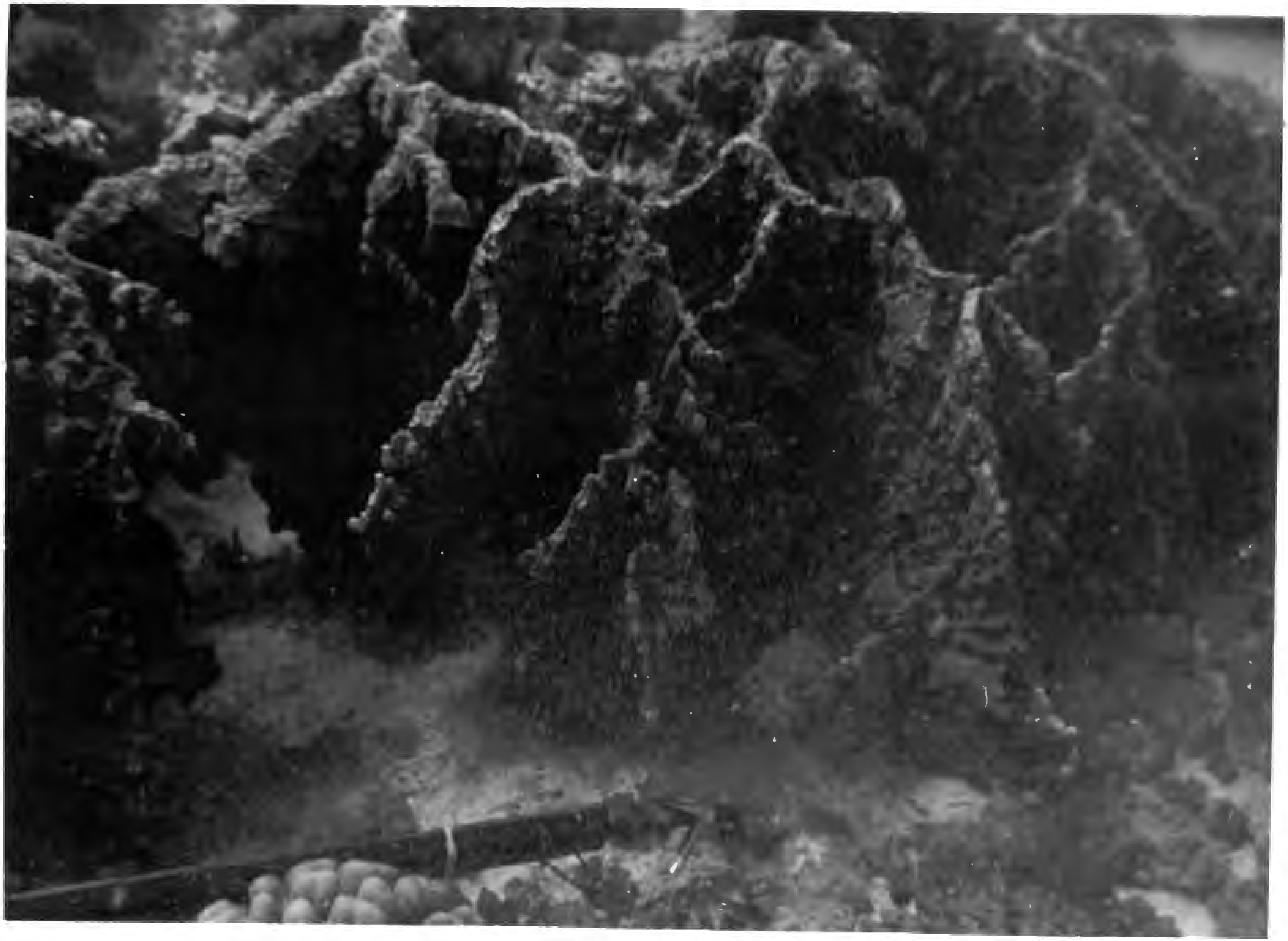


PLATE XXVIII.

Epinephelus dispar, showing a striking blotched pattern not present in death, moving over *Acropora* and *Stylephora mordax* (right lower corner) shrubs, but staying near deep shelter.

PLATE XXIX

Acanthurus leucosternon over the Acropora hyacinthus, forma cytherea beds of the northern reef edge.

PLATE XXX.

A school of Chromid fishes about dense coral growth in Western Bay.

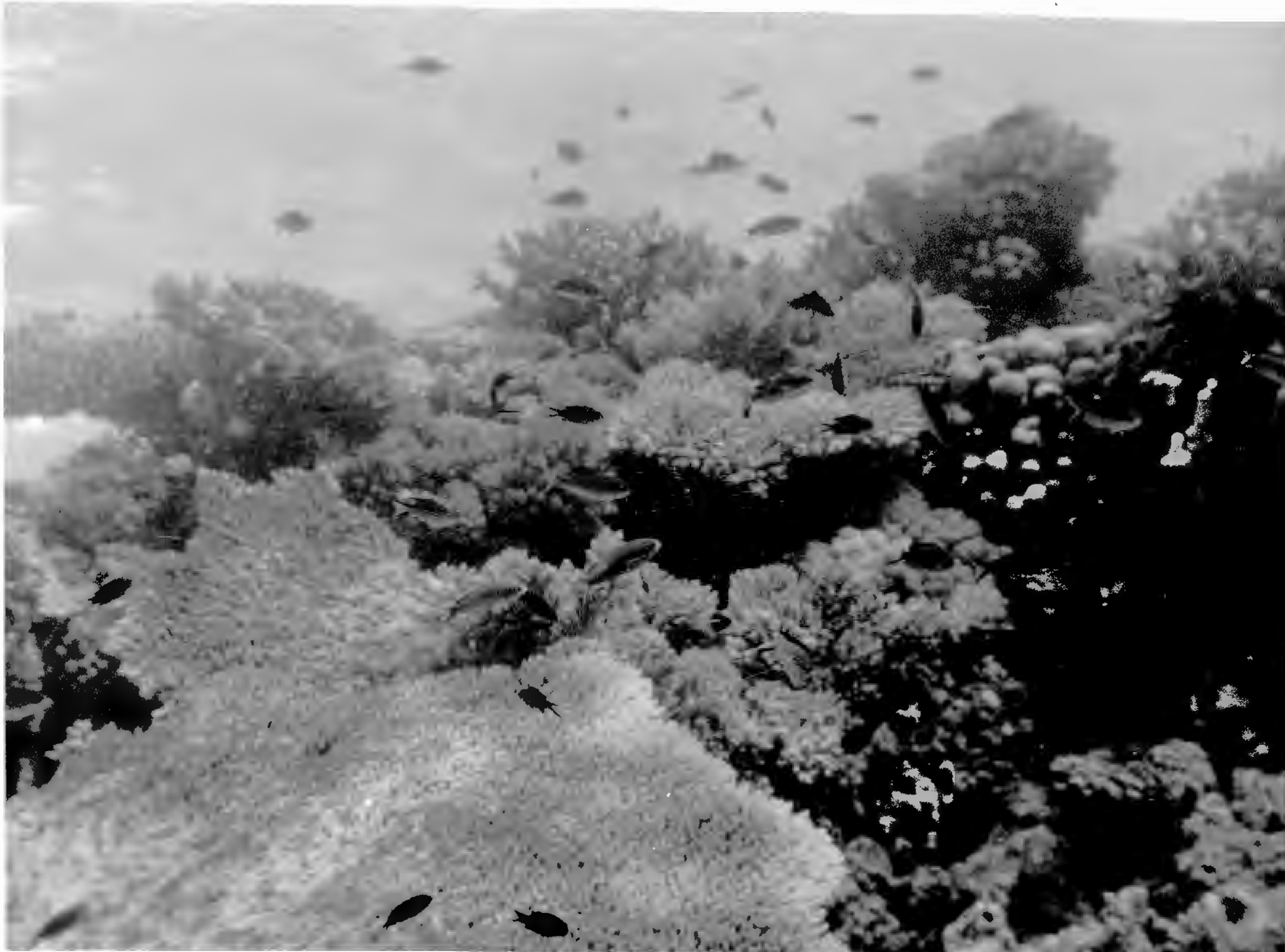
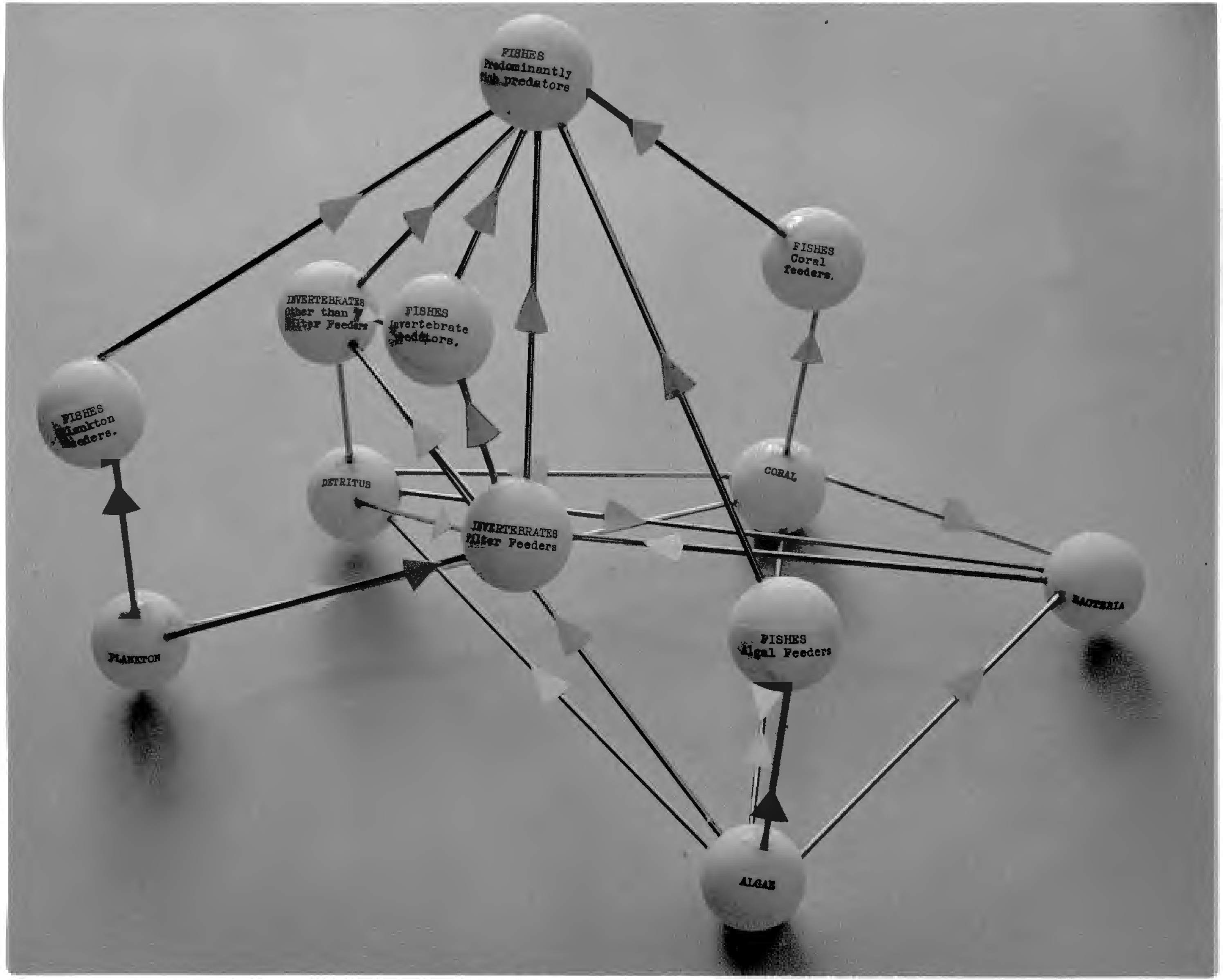


PLATE XXXI.

Collecting at 60 ft.   Photo J.F.C. Morgan.

PLATE XXXII.

A three dimensional representation of reef food relationships.


FISHES
Predominantly
predators
FISHES
Coral
feeders.
INVERTEBRATES
Other than
Feeders
FISHES
Invertebrate
FISHES
DETRITUS
CORAL
INVERTEBRATES
Feeders
PLANKTON
FISHES
Feeders
BACTERIA
ALGAE