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INSHORE MARINE HABITATS OF SOME CONTINENTAL ISLANDS IN THE EASTERN INDIAN OCEAN

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Auxiliary Cruise A of the U. S. Program in Biology, International Indian Ocean Expedition, provided the opportunity for field observations of inshore marine habitats of several groups of continental islands off the west coasts of the Malay Peninsula and Sumatra. The research vessel Te Vega left Singapore 15 October 1963 and terminated the cruise at Padang, Sumatra, 16 December 1963. During this period it was possible to devote 32 days to field study of coral reefs and other shore habitats. My main research emphasized the comparative ecology of the gastropod genus Conus in habitats supporting many co-occurring species and will be published elsewhere.

This paper, based mainly on field notebooks, lists and describes features of habitats at 15 stations in Thailand and Sumatra, most of which were on remote and very poorly known islands. I am not aware of any previous information on coastal formations of the islands west of Thailand, and none of the Indonesian sites studied are discussed in accounts of East Indian coral reefs (Kuenen, 1933; Umbgrove, 1947). Fig. 1 shows the track of Auxilary Cruise A.

Place names used are from British Admiralty charts, sometimes followed by alternate names in parentheses from U. S. Naval Oceanographic (formerly Hydrographic) Office charts and from Pilots or Sailing Directions. Coordinates refer specifically to Te Vega Stations.

Distances are in metric units, but water depths and other vertical distances are in feet to conform with tide tables and charts. Tidal data are from U. S. Naval Oceanographic Office and British Admiralty charts and U. S. Coast and Geodetic Survey Tide Tables. All sea surface temperatures recorded at nine stations ranged only from 30.0° to 32.0°C.

Particle size distributions of sand samples were analyzed by the settling tube method of Emery (1938).

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THAILAND: SINDARAR ISLANDS (CHANCE ISLANDS)

Two large, high (1100-1200 feet), densely wooded islands, Goh Sindarar Nua and Goh Sindarar Tai, are the northernmost offshore islands belonging to Thailand. They are about 90 km NNE of Goh Similan, and likewise about 65 km offshore. However, the continental shelf is wider here, and the islands lie about 40 km east of the 100-fathom line.

Goh Sindarar Nua. 9°25'30"N, 97°34'00"E. Te Vega Sta. 82. 5-7 November 1963.

A shallow, narrow channel separates the two Sindarar Islands, but the channel does not penetrate the fringing reef on the west side (Fig. 2). Both islands have irregular shorelines characteristically with large, weathered boulders above the beach and narrow fringing reefs.

Our studies concentrated in the large, southeast-facing embayment (Fig. 2). The fringing reef along the west shore near the mouth of the bay (Sta. 82A) has a substrate of patches of sand of varying particle size distribution (Table 1) and reef limestone outcrops inshore, and of reef limestone and low, dead coral heads nearer the outer edge, where living corals are also abundant. The reef flat is at about the -0.6'-+1.2' level. (Tidal datum is datum of Admiralty Chart 3052 and of Coast and Geodetic Survey Tide Tables and is 0.9' below MLWS).

The reef platform surrounding the western extremity of the bay is deeper, at about the -5' level. Large areas of sand strewn with coral rubble and isolated Porites heads about 2 m in diameter and 1-2 m high characterize the area examined (Sta. 82B, Fig. 2). Denser and more diverse corals, mainly Porites lutea and Acropora spp., occur in a band about 10 m wide along the outer reef margin.

The inshore area of the fringing reef along the northwest side of the bay (Sta. 82C, Fig. 2) is of sand (Table 1), with some truncated reef limestone covered with a thin layer of sand. Porites lutea again dominates the offshore portion, but some Acropora, Millepora, Diploastrea, Goniastrea, and other genera occur also (all coral specimens collected are presently at the Smithsonian Oceanographic Sorting Center). Living and dead coral heads are the predominant substrate, with some reef limestone, at about the -2.5' level. Some areas are paved with large pieces of Acropora rubble. Below about -3' are large areas of sand with sparse but large coral knolls, usually of several species, growing on a founder head most often of Porites.

Mangroves (Rhizophora) border the head of the bay (Sta. 82D, Fig. 2). One small stream, brackish at the time of observation, enters. Poorly sorted sand (Table 1) is the dominant substrate, but there is one outcrop of conglomerate rocks and a few dead coral heads. An enteropneust (Saccoglossus?), the gastropod Conus eburneus, and the alga Halimeda were the commonest large organisms present.

The one site visited on the reef fringing Goh Sindarar Tai (Sta. 82E) had a substrate of coral rubble and isolated Porites heads and Acropora thickets at about the -2.5' to -4.5' level.

THAILAND: SIMILAN ISLANDS (SAYER ISLANDS)

Three groups totaling nine high, wooded islands in a north-south line comprise the Similan Islands, in the Andaman Sea near the edge of the continental shelf, about 65 km west of Lem Tam Chok (Lem Tham Tjob, or Cape Dolphin) in approximately 8°28' - 8°41'N, 97°38' - 97°41'E.

Goh Huyong (South Island). 8°28'50"N, 97°39'00"E. Te Vega Sta. 77; 3-4, 8 November 1963.

Goh Huyong, the southernmost of the Similan Islands, has on its northeast side the only sand beach and coral reef mentioned in the Sailing Directions (U.S. Navy Hydrographic Office, pub. 160, 1951) as occurring in the archipelago; the rest of the island is steep-to.

The reef (Figs. 3-5) is exposed to heavy wave action, and at the highest spring tides (about +9') heavy breakers crash on the beach to the level of upper beach vegetation. Seaward of the sand beach is a band 10-20 m wide (zone 1, Figs. 3,4) of solid, rather smooth reef limestone platform covered with a thin layer of sand. Large pieces of rubble occur here; the only deeper sand patches occur inshore, where beach sand appears to be constantly rearranged by the waves. The sand is predominantly fine and medium (Table 1), entirely calcareous, and fragments of the calcareous green alga Halimeda are conspicuous in it. The sand probably scours the reef limestone, smoothing it and keeping it free of attached organisms. Zone 2, a moat, 3-8 inches deeper than the adjacent reef limestone, occurs intermittently at 20-55 m from shore. Zone 2', beginning about 40 m, is similar except that Halimeda is present. From there seaward it becomes a prominent feature of the reef; several species are abundant over the broad third zone of the reef platform (Figs. 3,5). Halimeda must contribute importantly to the beach sand, which is poorly sorted and coarser than that on the reef platform (Table 1).

Further seaward (zone 4), the reef substrate appears less influenced by sand transport; perhaps the central and outer regions are swept clear of sand by stronger water movements. "Wheels" of Porites (probably P. lutea), cemented to the reef and growing only at their peripheries, occur sparsely from about 55 m and become prominent features further seaward (Figs. 3,5). In this region also are some tide pools varying in depth from a few inches to 2-3 feet.

Beyond 140 m (zone 4), living coral is more varied. Heliopora coerulea is prominent in some areas, members of the genera Acropora, Montipora, Scaphophyllia, Psammocora, Goniopora, and Goniastrea were also noted, and more rubble is deposited on the intervening reef

limestone. However, there are no areas of sand, although sand is of course deposited at greater depths outside the zone of breaking waves. Below about -12', the sandy areas are larger, and coral heads are sparse. The slope appears to be quite gradual from this depth to about -60'.

In some regions, particularly on the east side of the reef, the seaward rampart is higher, with boulders and large pieces of coral rubble (zone 5).

Goh Similan (Great Sayer Island). 8°38'45"N, 97°39'10"E. Te Vega Sta. 85; 8 November 1963.

A brief stop at a bay on the east side of Goh Similan revealed an inshore region with a substrate of fine sand with outcrops of truncated reef limestone, and an outer region of sand with large, sparsely distributed coral heads, mainly of Porites but also including some Heliopora.

THAILAND: KO PHUKET (SALANG or JUNKSEYLON ISLAND)

Reef west of airport, Ko Phuket. 8°6'15"N, 98°18'10"E. Te Vega Sta. 90. 17 November 1963.

The reef fringes the northernmost of several bays indenting the north-south trending west coast of the island. Seaward of a shallow longshore moat with dead coral heads on rather fine sand, the main portion of the broad fringing reef is at about the 0 to -1.6' level (Datum is of soundings on Admiralty Chart 3941 and of Coast and Geodetic Survey Tide Tables and is 0.9' below MLWS).

Porites lutea dominates the flat and appears to be the most important hermatypic species. Most heads are growing only at the edges, their upper surfaces evidently scoured by sand in the water. Further seaward, the coral fauna is more varied, but mainly of low growth form. Some sand-filled depressions occur among the coral heads; some of these contain Acropora.

Ao Pa Tong. 7°53'15"N, 98°17'00"E. Te Vega Sta. 91. 17 November 1963.

Ao Pa Tong is the most enclosed bay on the west side of Ko Phuket. The station, on the southern side of the bay, is an intertidal platform at about the +2.5' level, composed of very rough and irregular reef limestone outcrops with a thin layer of sand in crevices (Table 1).

THAILAND: KO PHI PHI

Ko Phiphidon. 7°46'20"N, 98°44'25"E. Te Vega Sta. 87. 9, 15 November 1963.

Little can be reported from our brief visit to Ko Phiphidon, the largest of a group of four islands about 40 km ESE of Phuket. The

island is crudely H-shaped, with sheer limestone cliffs and wooded peaks rising to 1100 feet. The bay on the north side of the isthmus of the "H" is a sandy cove, with dead reef in the center and actively growing coral reef along the outer portion across the mouth of the bay.

THAILAND: PULO TA NGAH

Pulo Ta Ngah (Tengah, Tenga). 6°34'24"N, 99°27'36"E. Te Vega Sta. 88. 10, 14 November 1963.

Pulo Ta Ngah lies about 40 km offshore and about midway between the offshore Butang Islands and Ko Terutao, just north of the boundary with Malaysia. The surrounding water is 10-20 fathoms deep. About 3 km long and 650 ft high, the island consists of north and south islets connected by a reef, which continues as a fringing reef on the east side, roughly 300 m wide at the point of examination. The following zones were distinguished:

Beach: steep; width 46 m.

1: Inner margin of reef platform: coarse sand (Table 1) with cobbles and isolated outcrops of smooth, truncated reef limestone; width about 15 m.

2: Rougher reef limestone covered with a thin layer of sand (Table 1); width 38 m.

3: Porites lutea heads and wheels, both loose on thin to deep sand (Table 1) and cemented to the reef limestone; dead coral heads and boulders also present; width 50 m.

4: The major portion of the reef platform: a plain of low growing Acropora, interspersed with a few Porites heads and dead coral rocks; width about 160 m.

Because of apparent disagreement of tidal levels with the nearest station of daily tide predictions (Pulo Lila, 24 km NW), it was not possible to estimate the level of the reef platform with respect to tidal datum.

INDONESIA: SUMATRA AND OFFSHORE ISLANDS

Pulo Boenda (Boenta). 5°33'15"N, 95°9'00"E. Te Vega Sta. 93. 20 November 1963.

Pulo Boenda is about 2.2 km long and lies offshore about 3 km northwest of Acheh Head, the northwest extremity of Sumatra. According to the sailing directions (Hydrographic Office Pub. 162, 1951), the island is covered nearly to its 778' summit with casuarina trees, but in 1963 it was covered to within 100' of the summit with coconut palms.

A heavy swell, 2-3' high, broke on the narrow (less than 100 m wide) fringing reef on the west side of the island during our visit. The following zones were distinguished:

Beach: Very narrow; sand and cobbles.

1: Moat at level of tidal datum (=MLWS); substrate of smooth truncated reef limestone pavement covered by a thin layer of sand.

2: Abundant zoanthids (colonial, sea anemone-like coelenterates) and relatively smooth truncated limestone; +2.5'.

3: A broad region dominated by Tubipora, Acropora, and zones of Acropora rubble and smooth, reef limestone pavement.

4: Seaward reef margin: slopes gently seaward, with abundant cementing calcareous red algae; heavy surf.

5: Upper portion of reef front: substrate solidly of low, growing coral colonies.

Pulo Penju. 2°50'57"N, 95°56'35"E. Te Vega Sta. 97. 22 November 1963.

Pulo Penju is one of many small coral islands around Simalur (Simueleu), the northwesternmost of the large, high islands off the west coast of Sumatra. It lies about 2.5 km off the north side of Simalur and is joined to another small island to the northeast, Pulo Kitjik, by a reef extending the mile between them. The following zones could be distinguished on the fringing reef extending about 75 m eastward from the east side of Penju:

1: Moat with coral rocks and slabs on sand (Table 1) and much terrigenous debris, mostly from coconut palms; width 3-6 m; +0.5-+1' level (Datum = LWS).

2: Inner reef margin: Acropora rubble with some dead coral slabs on rubble and sand (Table 1). Width 30-37 m; +1' level.

3: Large dead slabs and heads on rubble; some large dead coral heads cemented to reef limestone. Horizontally irregular ridges and depressions about 2' deep; width 10 m.

4: Large coral heads on rubble; some sand; width 14 m; -2.5' level.

5: Outer reef margin; width 15 m.

Along the southeast corner of the island Zone 2 is a complex region mainly of unconsolidated Acropora rubble piled up in a rampart about 2' high with scattered dead coral slabs and "coolie hats" resting on it. The highest portions were at the +1.5' level.

Pulo Pandjang, Banjak Group. 2°15'50"N, 97°24'15"E. Te Vega Sta. 98A, 23 November 1963.

The Banjak (Banyak) Group consists of more than 50 islands about 30-70 km west of Singkel, Sumatra, and between the larger islands of Simalur and Nias. Pulo Pandjak is one of the Delapan Islands, of which Ujung Batu is the largest, on the northeast margin of the Banjak Group. The Delapan Group "is nearly completely surrounded, and the individual islands are mutually connected by coast reefs, which largely dry at low water" (Hydrographic Office, Pub. 162, 1951).

Our observations were restricted to the central region of the very broad reef (900 m wide) fringing the southwest side of Pulo Pandjang. The substrate is of large areas of sand (Table 1) with scattered coral rubble and isolated living and dead coral heads.

Pulo Melila, Banjak Group. 2°15'15"N, 97°25'12"E. Te Vega Sta. 98B. 23 November 1963.

The reef area on the north and east sides of Melila, a small double islet on the reef extending from Pulo Rangit Besar to Pulo Pandjang is about 200 m wide and topographically somewhat more complex than Sta. 98A. Two zones were distinguished:

1: Inshore portion of reef platform: isolated outcrops of cemented coral heads surrounded by large areas of rather coarse sand (Table 1). Halimeda opuntia very common.

2: Offshore portion of reef platform: extensive areas of growing coral. Porites lutea prominent in some areas and Acropora in others, forming thickets to 2' above the sand (cf. Fig. 7).

Pulo Bai, Batu Group. 00°01'45"S, 98°31'15"E. Te Vega Sta. 101, 25-27 November 1963.

The Batu Islands are a complex of three large and several small islands and many reefs, straddling the equator at 98°-99°E longitude, between the larger islands of Nias and Siberut.

Pulo Bai is about 5 km long with four large, broad fringing reef areas extending from the southeast, east, northeast and north sides. The shore on the north end of the island is a vertical cliff 4-6' high of fossil-bearing siltstone. A transect of the reef extending northward from it revealed the following zones:

1: Inner reef margin: moat with substrate of silt and sand, apparently mainly of terrigenous origin. Width 16 m; +0.4' level (Datum = MLWS).

2: Sand substrate, Cymodocea (?) bed with other organisms. Holothuria atra and brown sponge common. Width 27 m; +0.9' level.

3: Halimeda sand on truncated siltstone; sponges and Cymodocea sparse. Width 4 m.

4: Rough reef limestone. 4a: reef limestone outcrops; prominent algae are Turbinaria and Caulerpa; width 35 m. 4b: reef limestone interspersed with small sand patches; algae sparser; width 11 m. 4c: reef limestone with isolated small faviid corals; very little sand; width 9 m. 4d: reef limestone with coral heads more common; Porites lutea and Pocillopora damicornis predominate; width 22 m; +0.9' level.

5: Acropora rubble. 5a: with some small faviid heads and living Acropora colonies; width 5 m. 5b: dead coral slabs on pebble to cobble size (Table 1) rubble; width 7 m (Fig. 6).

6: Outer portion of reef platform: downward slope begins; more rough reef limestone, less rubble present; width 145 m; -0.6' level at 146 m from shore (beginning Zf zone 6).

7: Reef front: gentle slope of Zone 6 continues to edge of sand at -4.5' level.

Other portions of the outer reef platform and gently sloping reef front vary considerably in substrate composition. Abundant Pocillopora damicornis, with some Porites and other genera on rough limestone, interspersed with sand patches (Table 1), characterize some areas (Fig. 7). In other portions, thickets of Acropora or patches of complex assemblages of corals separated by sand (Figs. 8-10), or more extensive areas of varied corals cemented to rough reef limestone (Figs. 11, 12) occur.

Pulo Siburu (Siboeroe), Mentawei Islands. 1°59'45"S, 99°35'00"E. Te Vega Sta. 103: 30 November - 1 December 1963.

Pulo Siburu is one of a complex of small islands extending northeastward from the north tip of the large island of Sipora and with the coast of the latter forming a protected bay, Siburu Bay.

Sta. 103, on the south coast of Pulo Siburu in the bay is an extensive area of sand mainly at the 0 to -2' level (datum = MLWS) where examined. Some outcrops of reef limestone and areas of coral rubble occur (there are reefs nearby) and the inshore, intertidal portion is a dense bed of Cymodocea growing in sand.

Unnamed island in Veeckens Bay, South Pagi Island, Mentawei Islands. 3°14'36-40"S, 100°25'54"-100°26'06"E. Te Vega Sta. 105, 2 December 1963.

Veeckens Bay, between the southwestern end of South Pagi Island and a group of islands off its southeastern point, contains a number of small islands.

Sta. 103 is a low, somewhat elliptical, unnamed island about 1.8 km long and 1 km wide, about 6.5 km east of the western shore of the bay (Fig. 13). Intertidal flats of irregular, rough altered reef rock and detrital conglomerate limestone extend from the northwest and southeast ends of the island. The former appear derived from a coral reef that was uplifted at least 2-3 feet and closely resemble the elevated reef rock ("feo") of the Tuamotu Islands described by Stoddart (1969: see especially Pl. 20). The beach is very narrow and of coarse sand and rubble (Fig. 14) or boulders (Fig. 15). The rock is deeply pitted and very hard. The southeast side of the island is most exposed to the sea; here the surf breaks heavily and there are many coral boulders on the beach (Fig. 15). On the southwest and west sides, the limestone is smoother, especially so in channels (Fig. 17) that widen to about 1-3 m and are about 1' deep. Figure 17 also shows the extensive solution pitting. Some portions of the pitted zone are relatively unweathered and show the remains of corals in position of growth (Fig. 18). Inshore, a very thin layer of algae coats the substrate only in places; it is rarely dense enough to bind any sand. Green algae become more abundant further out, and the seaward margin of the bench bears a veneer of calcareous red algae, probably Porolithon.

Mangroves appear to be encroaching on the bench (Fig. 15).

The features of the shoreline of this island suggest that land forms in Veeckens Bay are changing rapidly, a view supported by evidence of erosion of the sandy shore of an adjacent, small, also unnamed island.

Pulo Stupai (Stoepai), Sanding Island, Mentawei Islands. 3°26'50"S, 100°40'50"-100°41'00"E. Te Vega Sta. 108, 4-7 December 1963.

Sanding Island, 20 km southeast of South Pagi Island, and 110 km west of Seblat, Sumatra, is the southernmost of the Mentawei Islands. Of all the islands off the west coast of Sumatra, Sanding most closely resembles an atoll (Figs. 19, 20), and further information on its geology would be most interesting. The main island is about 5.1 x 2.4 km low and densely vegetated. It lies near the southwest margin of a broad reef platform, the rim of which is lined with 17 other small, low islets varying from densely vegetated islets to sand cays. Three channels on the east side of the reef lead to broad inlets reaching depths of 10-18 fathoms; this complex approaches a lagoonal structure.

Pulo Stupai, the second largest of the islets, is about 610 x 120 m. The reef, partially drying at low tide, fringing the north and northeast sides of Stupai is Sta. 108A. The western portion of the area examined (Fig. 19) is a platform of rough reef limestone, with some low-growing coral, chiefly Pocillopora. Its level is at +0.5 to -1.1' (datum = MLWS). A transect across the eastern portion of the Station revealed the width of the platform to be 175 m to the zone of breaking surf and the heads of surge channels at the outer reef margin. This is almost

twice the width shown in the largest scale chart of the island (Fig. 20), based on a 1917-1918 survey. The entire platform is within one foot of the +0.5' level. It is not sharply zoned, but the following regions could be characterized:

1: Inner margin of reef platform: small dead coral heads, areas of dense coral rubble, few small Porites lutea heads, narrow bands of sand (Table 1) and smooth, truncated reef limestone 1 m wide, and a band of rubble 11 m wide with dead coral slabs occur near the outer margin. Width 40 m.

2: Smooth to rough limestone bench; few live P. lutea heads, scattered dead coral boulders about 0.1 square meter in area on bench, some cemented to reef limestone; algae on smoother portions bind sand; rubble collects in shallow crevices and sand (Table 1), gravel and pebble-sized particles in many deeper depressions, to 0.5' below platform level; Conus spp. common from this zone outward. Figs. 21, 22 show this region, 85 m from shore. Width 60 m.

3: Reef limestone much rougher, making substrate topographically more complex, with more dead coral heads, both loose and cemented (Figs. 23, 24); sand and rubble (pebble to cobble size) mixed with sand in depressions. Halimeda macrophysa common, H. micronesica present. The enteropneust Ptychodera flava is common in sand pockets; mean overall density was 1-1.5 per square meter. Width 25 m.

4: Increasing irregularity and complexity of surface (Fig. 25); small living coral colonies (Pocillopora, Acropora) present. Many loose small boulders and large cobbles on sand; depressions 0.5' deep contain Halimeda sand, with gravel, pebble, and small cobble-sized rubble on sand. Halimeda macrophysa more abundant, H. opuntia common; Jania (branching calcareous red alga) present, forming small thickets. From about 130 m from shore, small colonies of Pocillopora damicornis and Porites lutea become more common. Surge increases at about 140 m from shore, which is also inshore margin of distribution of Latirolagena smaragdula, a characteristic gastropod of the outer portions of the reef. Width 30 m.

5: Seaward reef margin; Porolithon cements loose particles and forms a veneer; heavy surge. Halimeda opuntia common, H. macrophysa present, Caulerpa spp. abundant. Little rubble is present where most waves (1-1.5' high at time of observation) break at the outer edge of this zone, ca. 170 m from shore (Fig. 26). Heads of surge channel at ca 175 m from shore. Width 20 m.

6: Upper portion of reef front: surge channels ca. 1 m wide, 1.5' deep (-0.7' level) at 185 m from shore; their substrate is limestone with a thin algal turf binding sand, and a few boulders. The intervening ridges are topped with many small coral colonies, mainly Pocillopora damicornis and P. eydouxii. The cowry Cypraea caputserpentis

occurs commonly in crevices, and an unidentified black sea urchin, possibly Echinometra sp., bores rather deeply into the substratum. At about 220 m from shore, the distance between surge channels varies greatly but averages about 2 m, and they are about 3' deep (-2.2' level); the reef front slopes gently seaward from this point at about the same grade (about 1.3%) to at least the -20' level. Width examined 50 m.

Sta. 108B, 3°26'32"S, 100°40'47"E,. The islet just northwest of Pulo Stupai (Figs. 19, 20) is a small sand cay surrounded by reef. Sta. 108B, on the southeast side of the islet at the 0 to -1' level, was characterized by unusually dense growths of Halimeda micronesica, H. macrophysa, and Halimeda sp. growing in thick clumps on dead branching coral.

Mega Island, Mentawei Islands. 3°59'44"S, 101°03'02"E. Te Vega Sta. 106, 3 December 1963.

Mega lies 60 km southeast of Sanding and 100 km southwest of Seblat, Sumatra. It is low, roughly elliptical, the long axis in a southwest-northeast direction, and measures about 1.5 x 2 km. It is completely surrounded by a fringing reef 60-465 m wide, on which heavy surf breaks.

The portion of the reef platform examined, at the northeast end of the island, is about 155 m wide and resembles that at Sta. 77, but presents evidence that it is an uplifted reef now being planed down by the sea. Much of the reef platform is at about the +1' to +1.5' level (datum = MLWS) with several large dead coral heads extending to 2' above the platform. These and the higher portions of the platform are of more or less pitted reef limestone, much altered and hardened from their condition in life.

Much of the reef surface, particularly inshore, is of very rough reef limestone with some sand pockets. The outer portion is smoother limestone with an algal film. There are some level areas of coral rubble, a few loose boulders, and coarse sand and gravel derived primarily from Halimeda segments. Several species of Halimeda are abundant on the reef; it is the only alga that binds sand.

SUMMARY

This paper describes and illustrates the surface geomorphology, zonation, and dominant benthic invertebrates and plants of coral reefs fringing the continental islands Similan, Sindarar, and Ta Ngah, Thailand, off the west coast of the Malay Peninsula; and Boenda, Penju, Pandjang, Bai, Sanding, and Mega, off the west coast of Sumatra. A few intertidal reef limestone shores and bays with sand substrate in the same region are also described.

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Table 1.

PARTICLE SIZE DISTRIBUTION OF SUBSTRATE SAMPLES FROM INSHORE HABITATS OF ISLANDS OFF WEST THAILAND AND SUMATRA

Station	Sample No.	Pebbles or Large Shell Fragments Present	Per Cent Composition of Sand Sample					Silt+ Clay
			Very Coarse 1-2 mm	Coarse 0.5	Medium 0.25	Fine 0.125	Very Fine 0.0625	0.0625
82A	6017	+	6	19	10	51	14	
82A	6021	+	27	13	10	38	12	
82A	6025	+	51	17	15	14	3	
82C	6009		2	8	18	58	14	*
82C	6010		5	17	55	17	6	
82D	6037-9	+	27	17	20	16	9	11
77	reef zone 3-4			1	27	68	5	
77	beach		4	23	43	30		
88	6080 (zone 1)	+	45	39	15	1		
88	6099 (zone 2)	+	5	27	34	24	10	
88	6090 (zone 3)	+	6	29	48	15	2	
88	6101 (zone 3?)	+	32	48	18	2		
91	6132		1	3	93	3		
97	6171 (zone 1)	+	28	26	26	18	2	
97	6172 (zone 1)	+	52	25	13	8	2	
97	6158 (zone 2)			3	23	71	3	*
97	6165 (zone 2)	+	24	21	19	26	10	
98A	6258	+	37	20	19	12	12	
98B	6241 (zone 1)	+	23	20	32	24	1	
98B	6245 (zone 1)	+	22	27	24	20	7	
98B	6246 (zone 1)	+	28	21	31	18	2	
98B	6257 (zone 1)	+	56	22	20	2		
101	6313 (zone 5)	Mainly pebbles						
101	6338 (Outer reef platform)	+	40	38	21			
108A	7274 (zone 1)	+	11	37	47	5		
108A	7272 (zone 1)		20	42	36	2		

*silt-clay fraction detectable but less than 2% of total sample

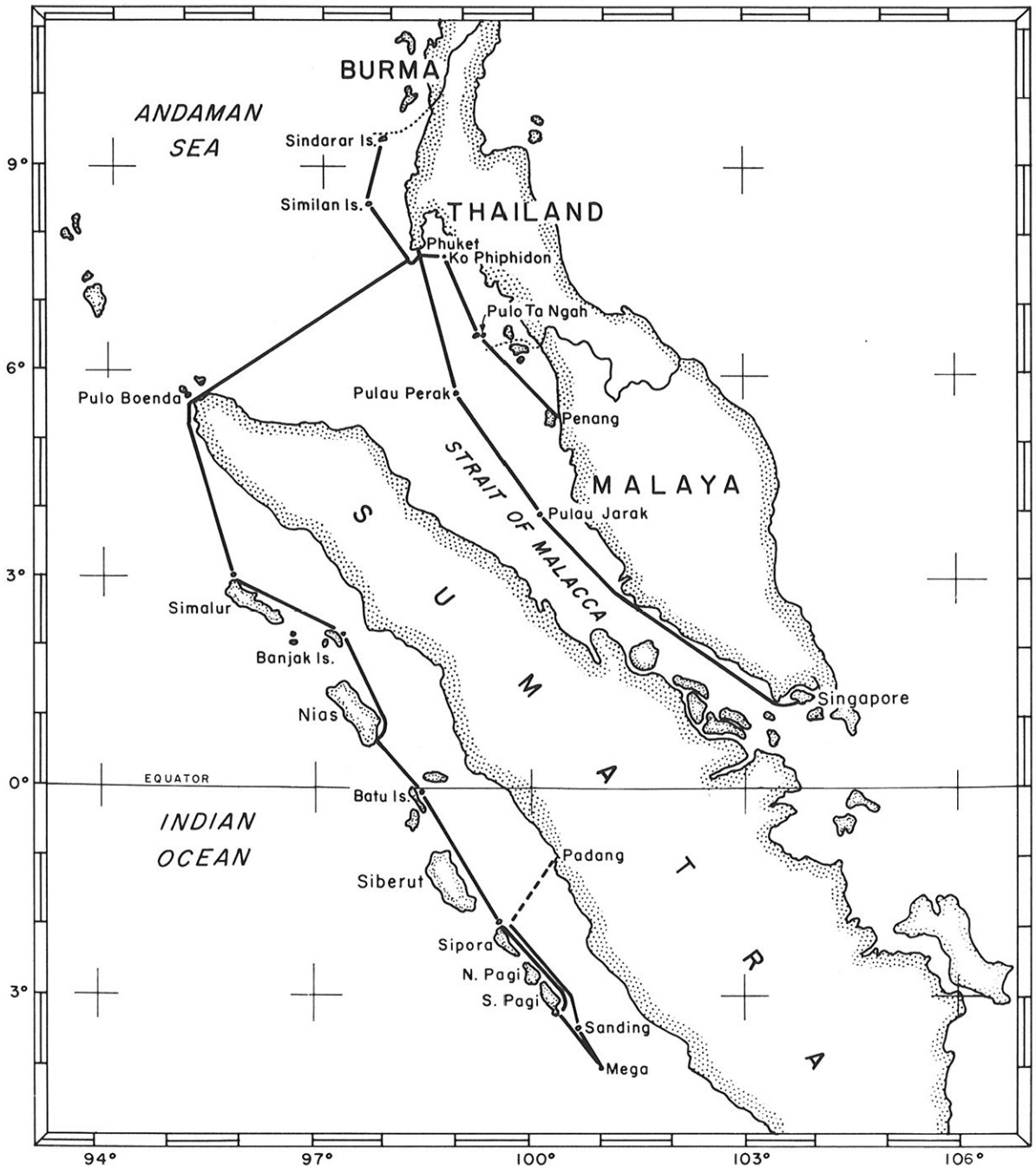


Fig. 1. Map of the southern Malay Peninsula and Sumatra, showing the track of Auxiliary Cruise A of the Te Vega, U. S. Program in Biology, International Indian Ocean Expedition, October-December, 1963.

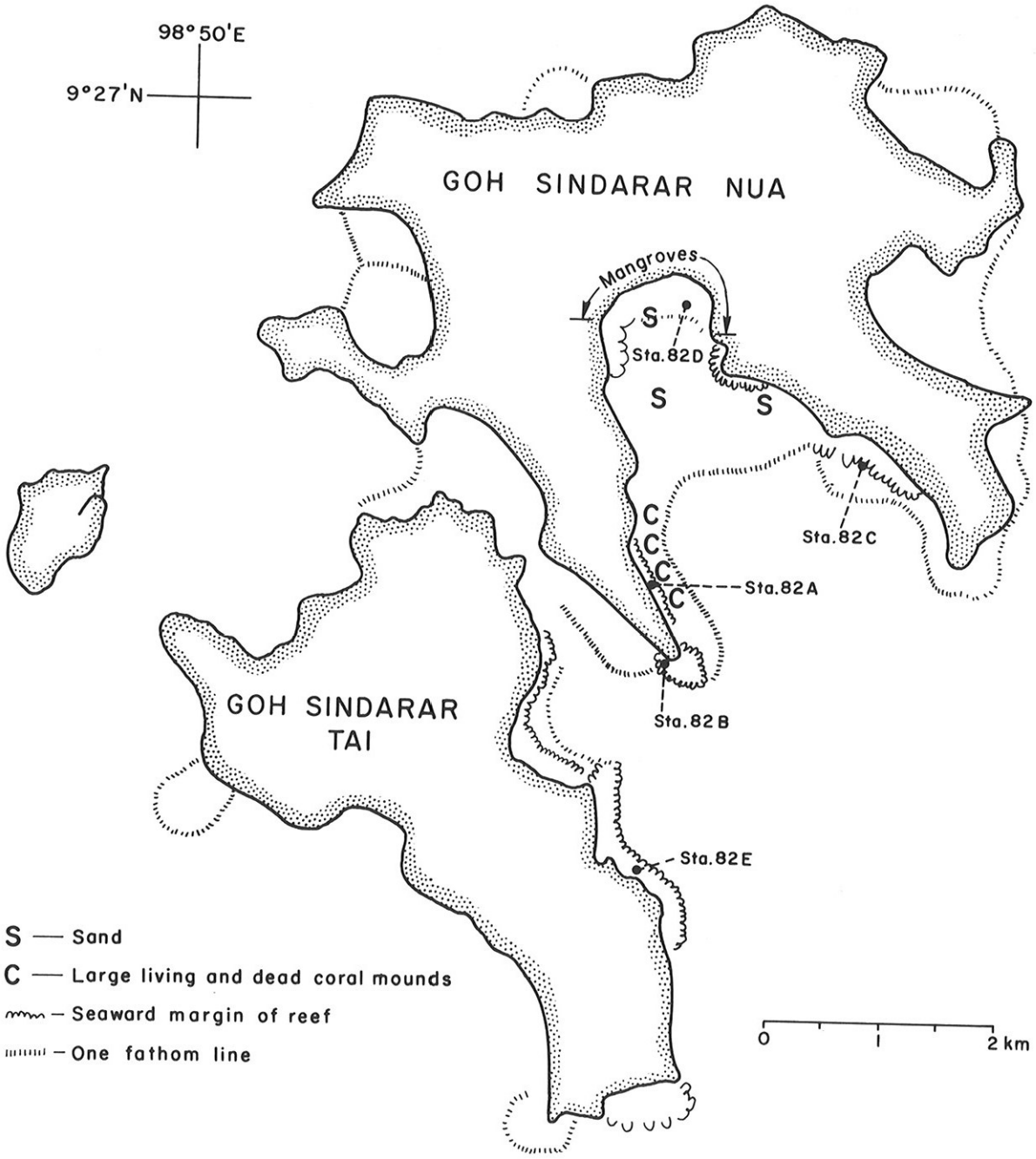
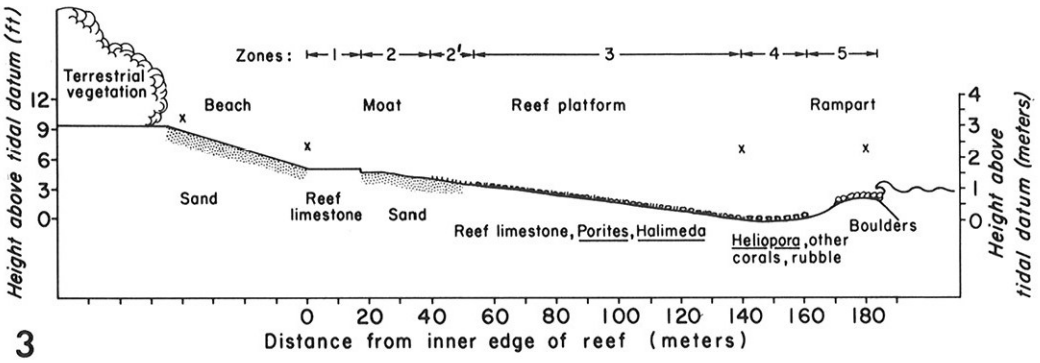


Fig. 2. Sketch map of Goh Sindarar, Thailand (Sta. 82), showing stations and shore features. Based on Admiralty Chart 3052.

Fig. 3. Profile of the fringing reef at Goh Huyong, Similan Islands, Thailand (Sta. 77). Tidal datum is datum of Admiralty Chart 3052 and of Coast and Geodetic Survey Tide Tables and is 1.1' below MLWS. For explanation of zones, see text. X, locations of substrate samples. Vertical exaggeration is 10X.

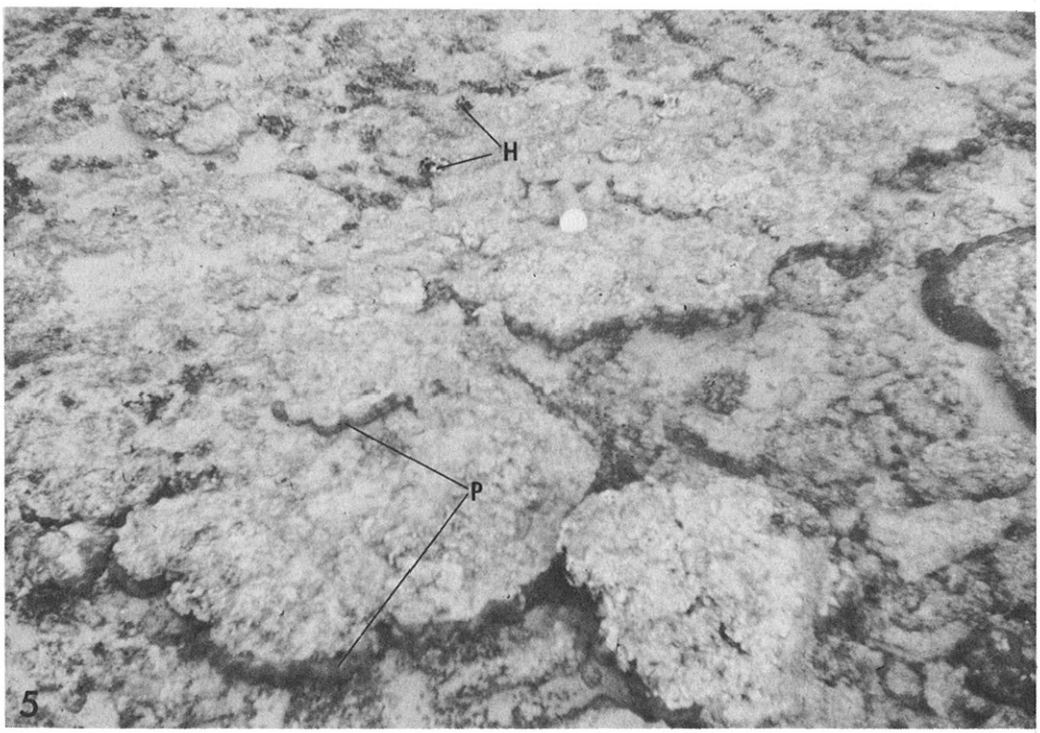
Fig. 4. Overall view of the fringing reef at Goh Huyong (Sta. 77), taken when tide level was approximately +1.5'.

Fig. 5. Detail of reef surface at Goh Huyong (Sta. 77) in Zone 3, 70 m from inner edge, showing flat, wheel-like colonies of Porites, cemented to the underlying reef limestone and growing only peripherally, and clumps of Halimeda. P, living portions of Porites colonies; H, Halimeda. The white vial cap is 40 mm in diameter.


Height above tidal datum (ft)
Zones: 1 2 2' 3 4 5
Terrestrial vegetation
Beach
Moat
Reef platform
Rampart
12
9
6
3
0
Sand
Reef limestone
Sand
Reef limestone, Porites, Halimeda
Heliopora, other corals, rubble
Boulders
4
3
2
1
0
Height above tidal datum (meters)
0 20 40 60 80 100 120 140 160 180
Distance from inner edge of reef (meters)

3

4

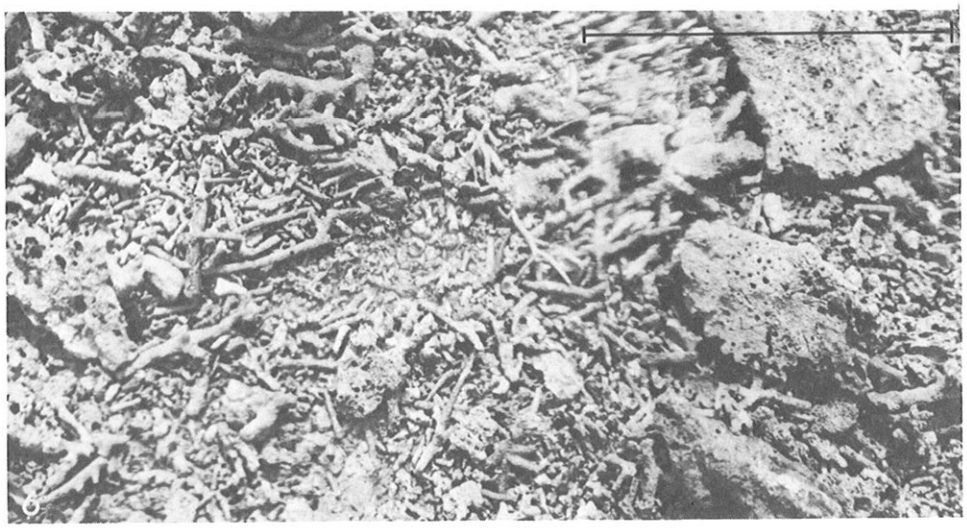

H
P

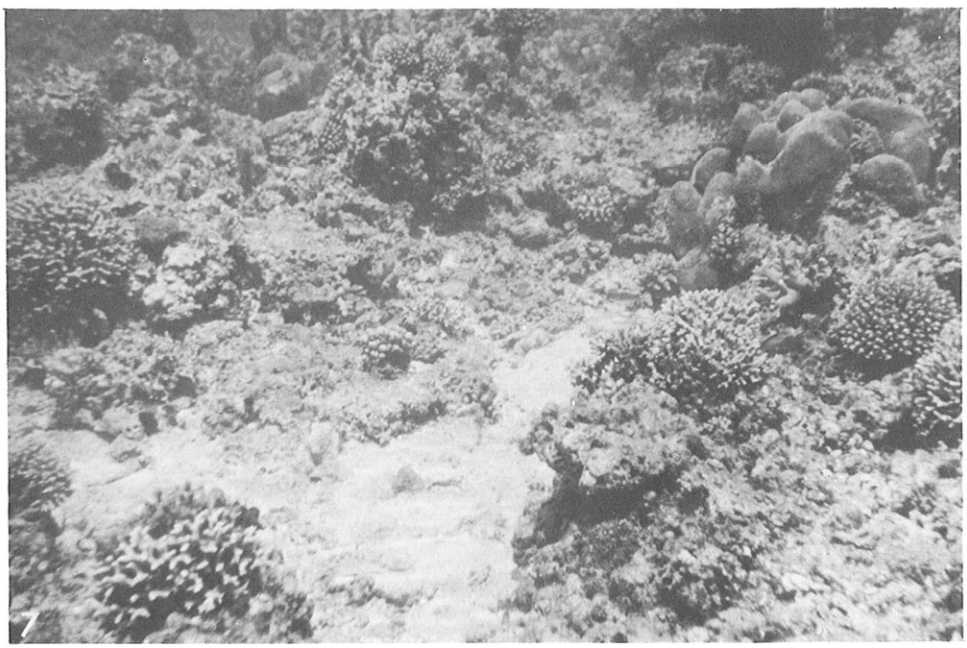
5

Fig. 6. Detail of reef surface with coral rubble and slabs of coral rock in Zone 5b at Pulo Bai, Batu Group, Indonesia (Sta. 101). The cowry Cypraea annulus is very abundant on this substrate. Scale = 0.5 m.

Fig. 7. Outer portion of reef platform at Pulo Bai (Sta. 101), showing abundant living Pocillopora, some Porites, and other corals on rough reef limestone, with sand patches.

Fig. 8. Another portion of outer reef platform at Pulo Bai (Sta. 101), showing thickets of Acropora separated by sand. Photo by Dr. J. W. Nybakken.





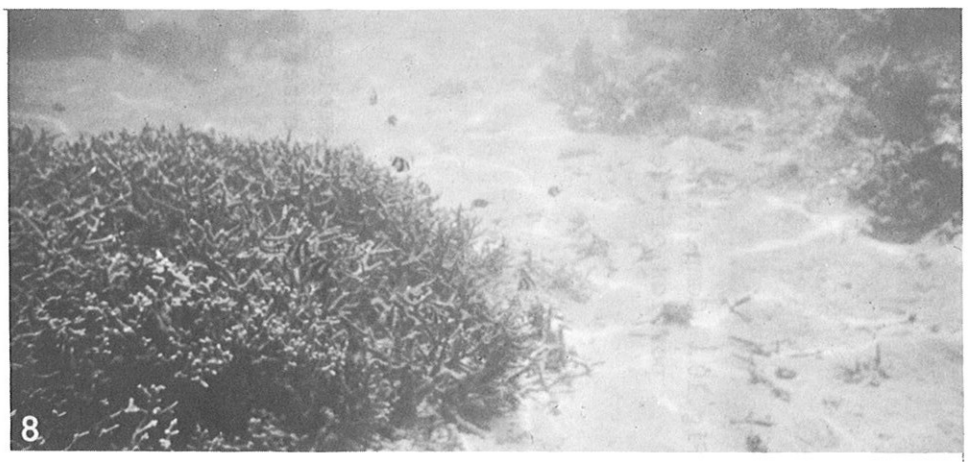
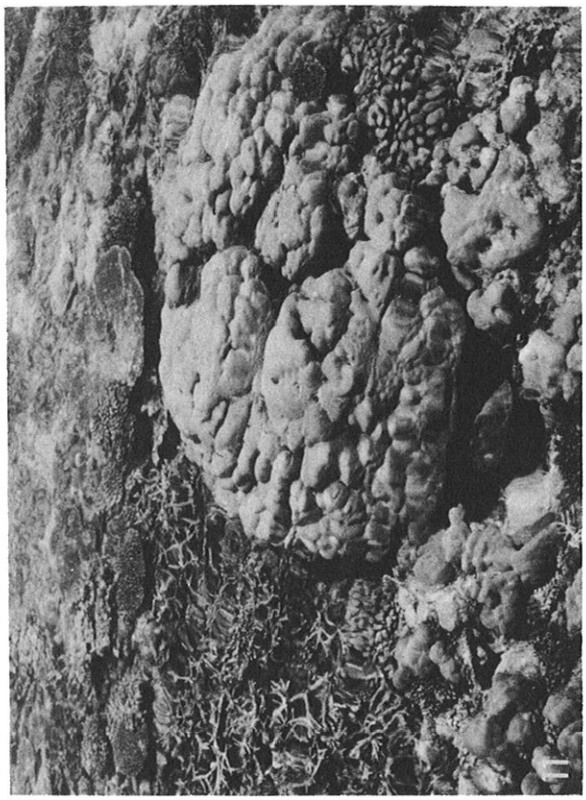


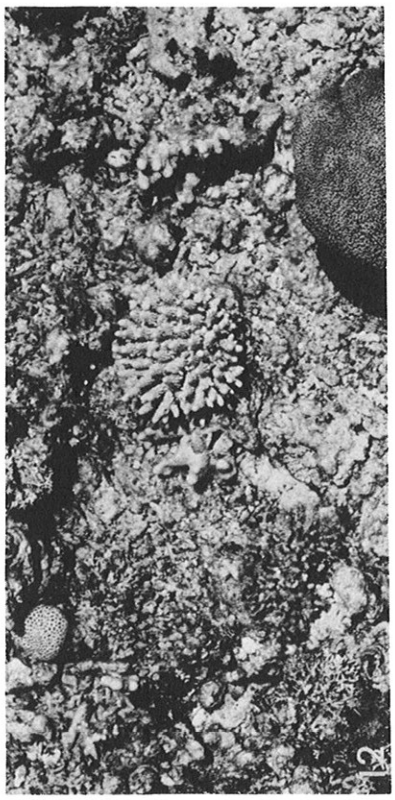
Fig. 9. Mixed thicket of Acropora and other corals bordered by sand, outer portion of reef platform at Pulo Bai (Sta. 101). Photo by Dr. J. W. Nybakken.

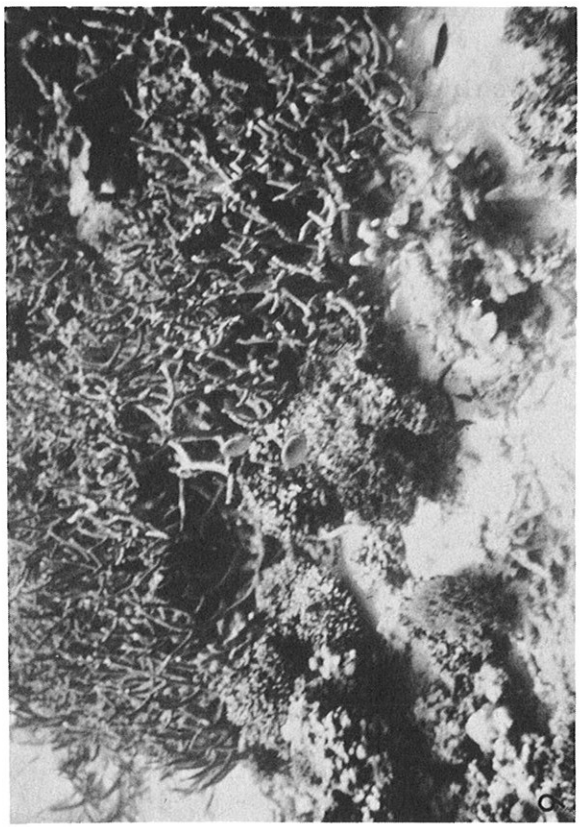
Fig.10. Complex assemblage of corals, including Psammocora and Pocillopora, bordered by sand, outer portion of reef platform at Pulo Bai (Sta. 101). Photo by Dr. J. W. Nybakken.

Fig.11. Complex assemblage of corals including Porites, Montipora and Acropora spp. cemented to rough reef limestone, outer portion of reef platform at Pulo Bai (Sta. 101). Photo by Dr. J. W. Nybakken.

Fig.12. Complex assemblage of low-growing corals, including Acropora, Goniastrea, and Pocillopora cemented to rough reef limestone, outer portion of reef platform at Pulo Bai (Sta. 101). Photo by Dr. J. W. Nybakken.







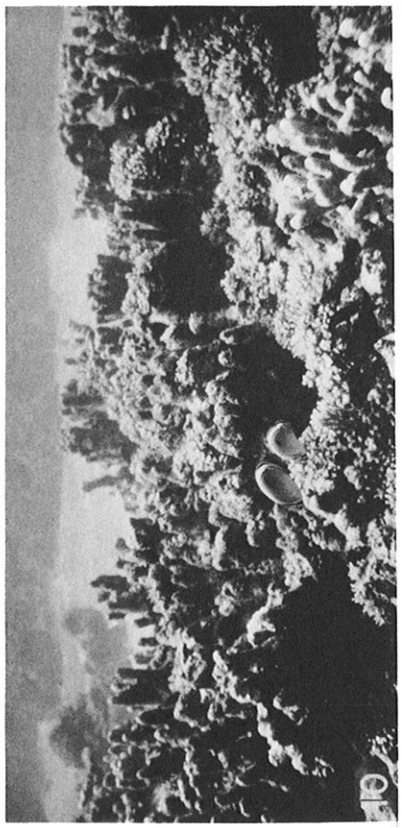


Fig.13. View of island in Veeckens Bay, South Pagi Is., Indonesia (Sta. 105), from the north. South Pagi in right background. Figs. 14-18 show details of shore topography of this island.

Fig.14. Raised reef and detrital limestone bench on south side of island, with narrow, steep beach of sand and coral rubble. Water at about +1.8' level.

Fig.15. Inshore edge of bench and boulder beach on south side of island, showing detrital limestone and mangroves advancing on flat.

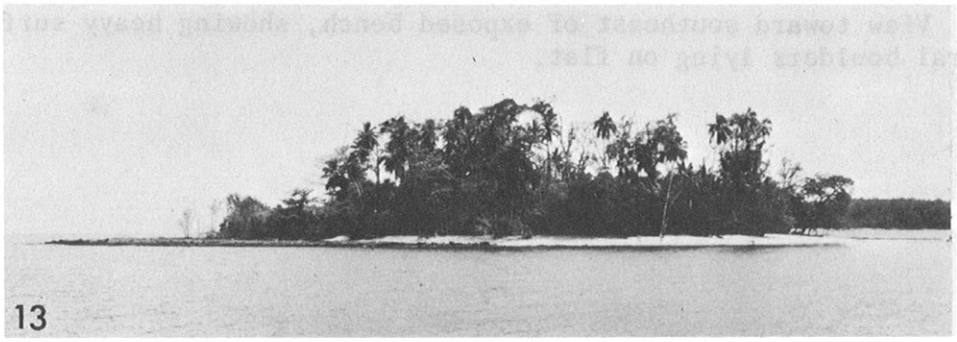


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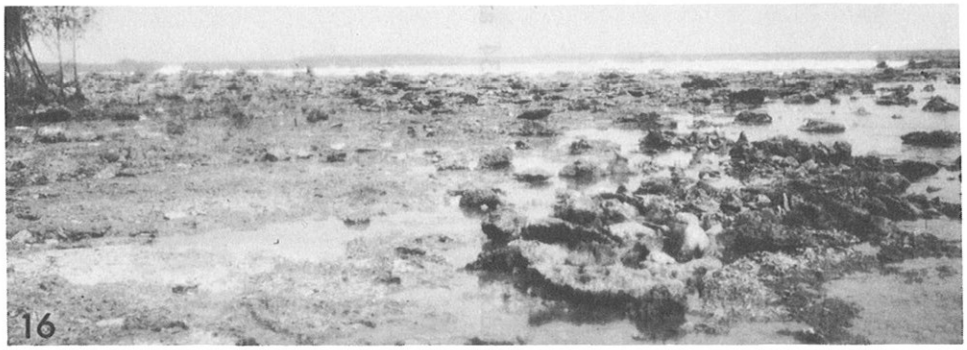
Fig.16. View toward southeast of exposed bench, showing heavy surf and coral boulders lying on flat.

Fig.17. Bench on southwest side of island, showing surge channels and pitted limestone. Foreground is 45-50 m from shore.

Fig.18. Details of relatively unweathered section of pitted zone, showing remains of truncated reef corals. 22 m from shore. The pick is 0.3 m long.



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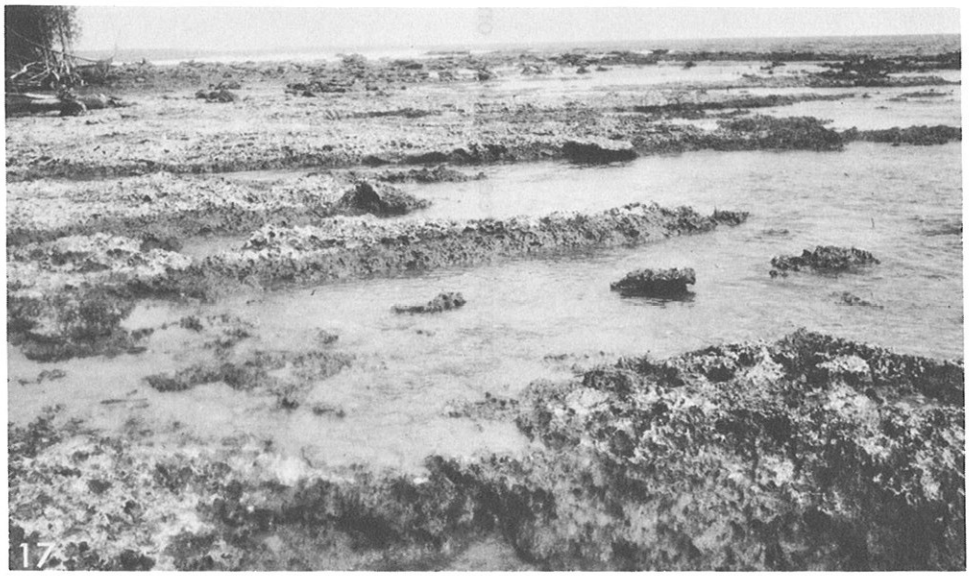

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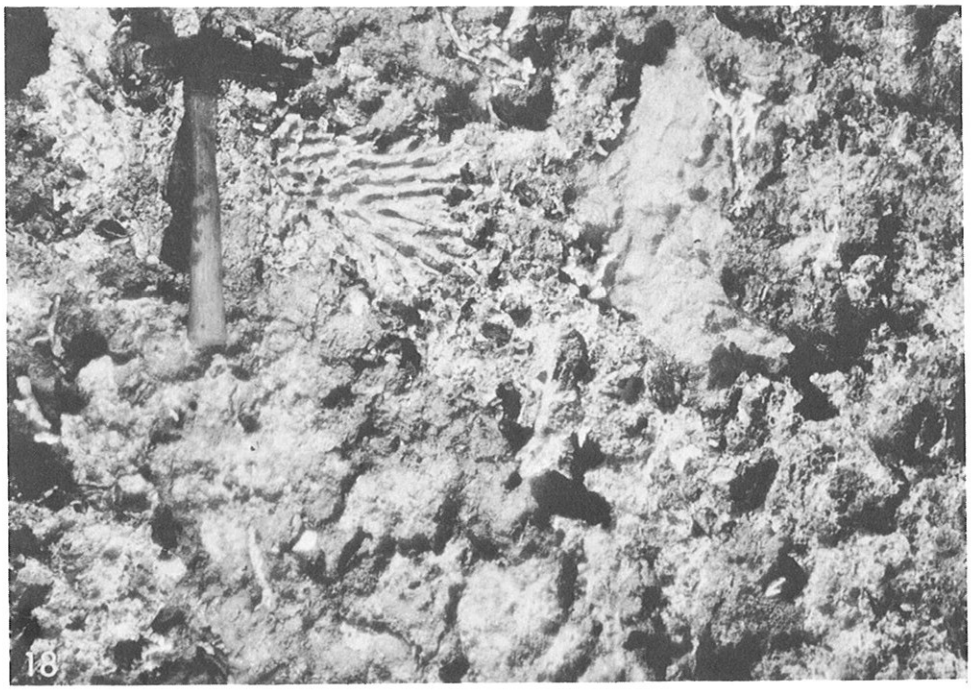

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Fig.19. Photograph of Pulo Stupai, Sanding Island, Indonesia (Sta. 108) from the northeast. Sta. 108A is in front of the right side of the island, Sta. 108B, the sand cay at far right. Sanding Island in background.

Fig.20. Map of Sanding Island and associated islets on fringing reef, based on Indonesian Chart 134 and 242.

Figs. 21 and 22. Detail of smooth limestone bench in Zone 2, 85 m from shore, Pulo Stupai (Sta. 108A), showing Halimeda and one Porites head. The lines in Fig. 21 mark a 4 x 4 m quadrat on the transect across the bench.

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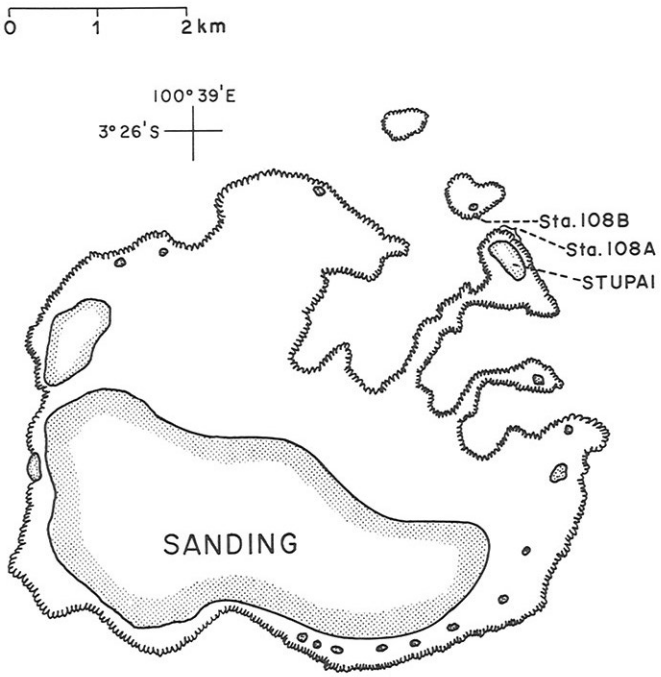

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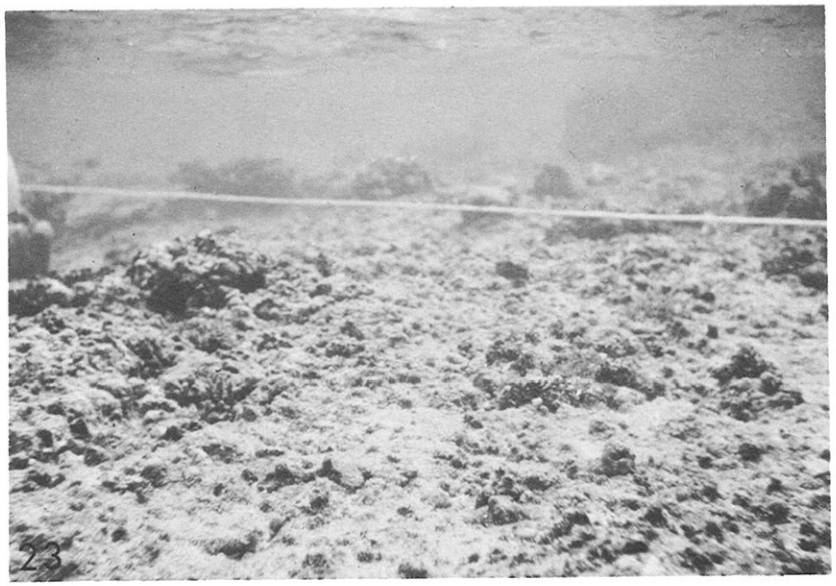
Figs. 23 and 24. Detail of topographically more complex substrate of rougher reef limestone bench, about half way across the reef platform (about 115 m from shore) at Pulo Stupai (Sta. 108A), showing dead coral boulders, Halimeda, and small sand pockets.

Fig.25. View along reef from a point 125 m from shore, Pulo Stupai (Sta. 108A). Increasingly complex substrate, with many cobbles and small boulders and abundant Halimeda.

Fig.26. Seaward reef margin at Pulo Stupai (Sta. 108A), about 165 m from shore, showing abundant Halimeda clumps (H), living Acropora (A), cemented to rough reef limestone veneered by Porolithon (P). There is little loose rubble in this region of breaking waves and heavy surge.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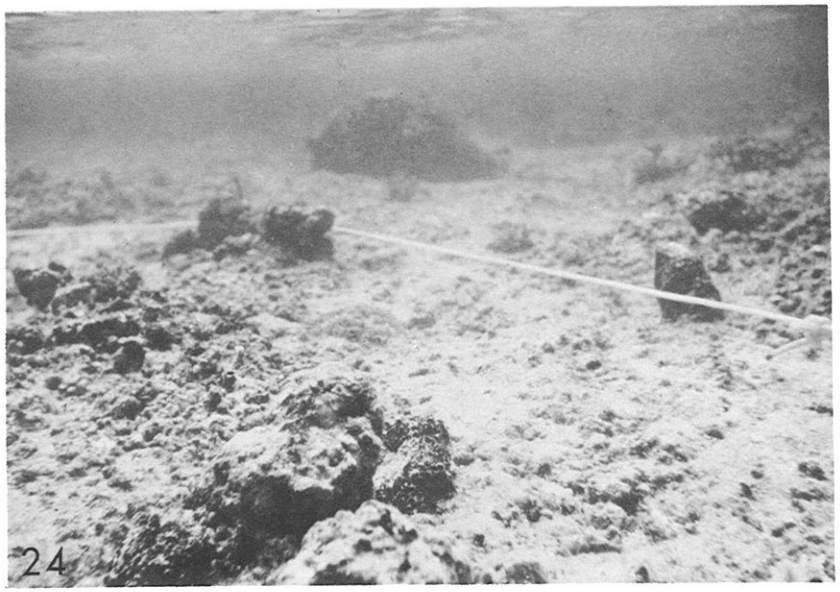
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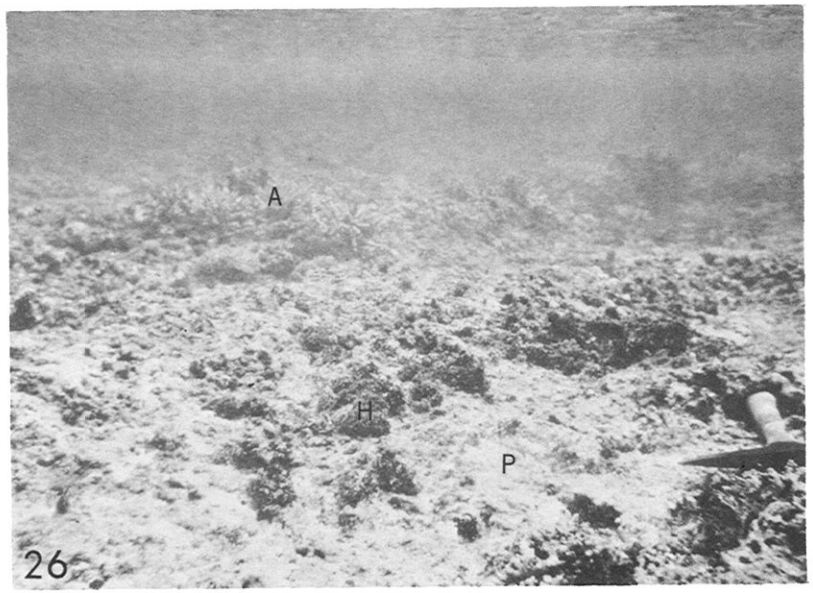

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