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Ecological Distribution of Reef Organisms at Pulau Salu

Chou L. M. and F. J. Wong

Department of Zoology, National University of Singapore
Kent Ridge, Singapore 0511

ABSTRACT

The coral reef of Pulau Salu is a sargassum-type reef. The community structure of the reef organisms was studied along 2 vertical and 4 horizontal transects. The distribution patterns of the reef-associated organisms showed well-defined zones throughout the reef from the intertidal to the subtidal levels.

INTRODUCTION

Studies on the coral reefs of Singapore and Malaysia have been on the increase especially in recent years. The earliest work was done by Purchon (1), who made a collection of corals found around Singapore. Subsequent studies by Chuang (2, 3, 4) were on the ecology as well as flora and fauna of local coral reefs. Chan (5) made a qualitative study on the effects of land reclamation on some Singapore reefs. A good quantitative study on the community structure of the fringing reef at Cape Rachado, Malaysia, was undertaken by Goh and Sasekumar (6).

Pulau Salu (1°13'N, 103°42'5''E) is a small uninhabited island 12 km south of Singapore. A luxuriant vegetation covers the hillslopes and hilltop of the island. Its coral reef is a fringing reef comprising a thin superficial layer of coral material resting on various substrate. This is typical of the reefs of Singapore and Malaysia (4). Pulau Salu, like other islands off Singapore has very gentle sloping reef flats of varying widths bordered by rather steep subtidal reef slopes.

This survey is a continuation of 2 earlier studies. The first by Tay (7) was on the biology and ecology of coral reef fishes while the second by Chou and Teo (8) was on the community structure of the hard corals. The present work is a quantitative study of the species composition of the coral reef community excluding the fishes. The abundance, density and dominance of the flora and fauna is also investigated. This study was carried out between May and December of 1982.

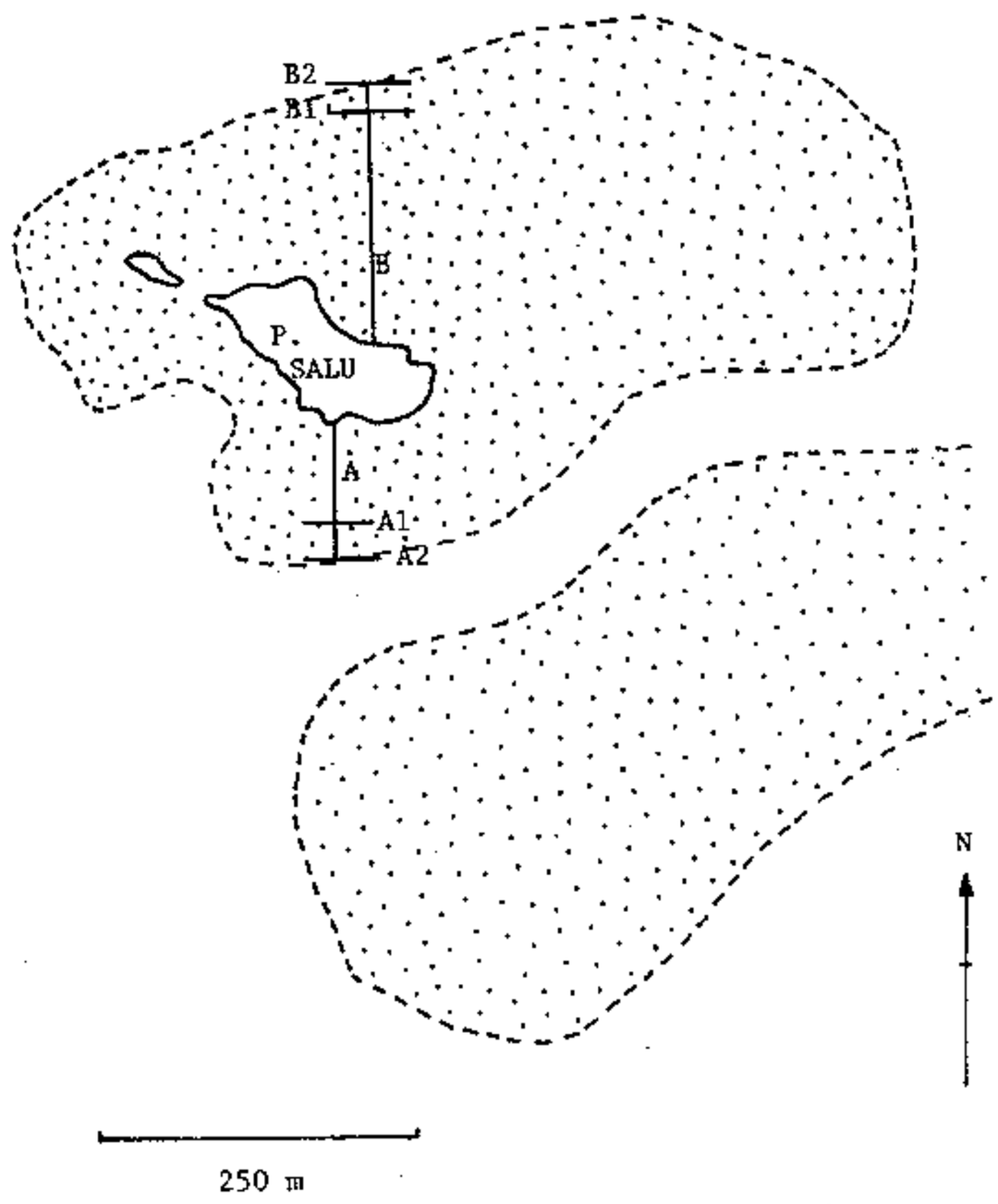

Fig. 1: Map of Pulau Salu and its fringing reefs with locations of transects.

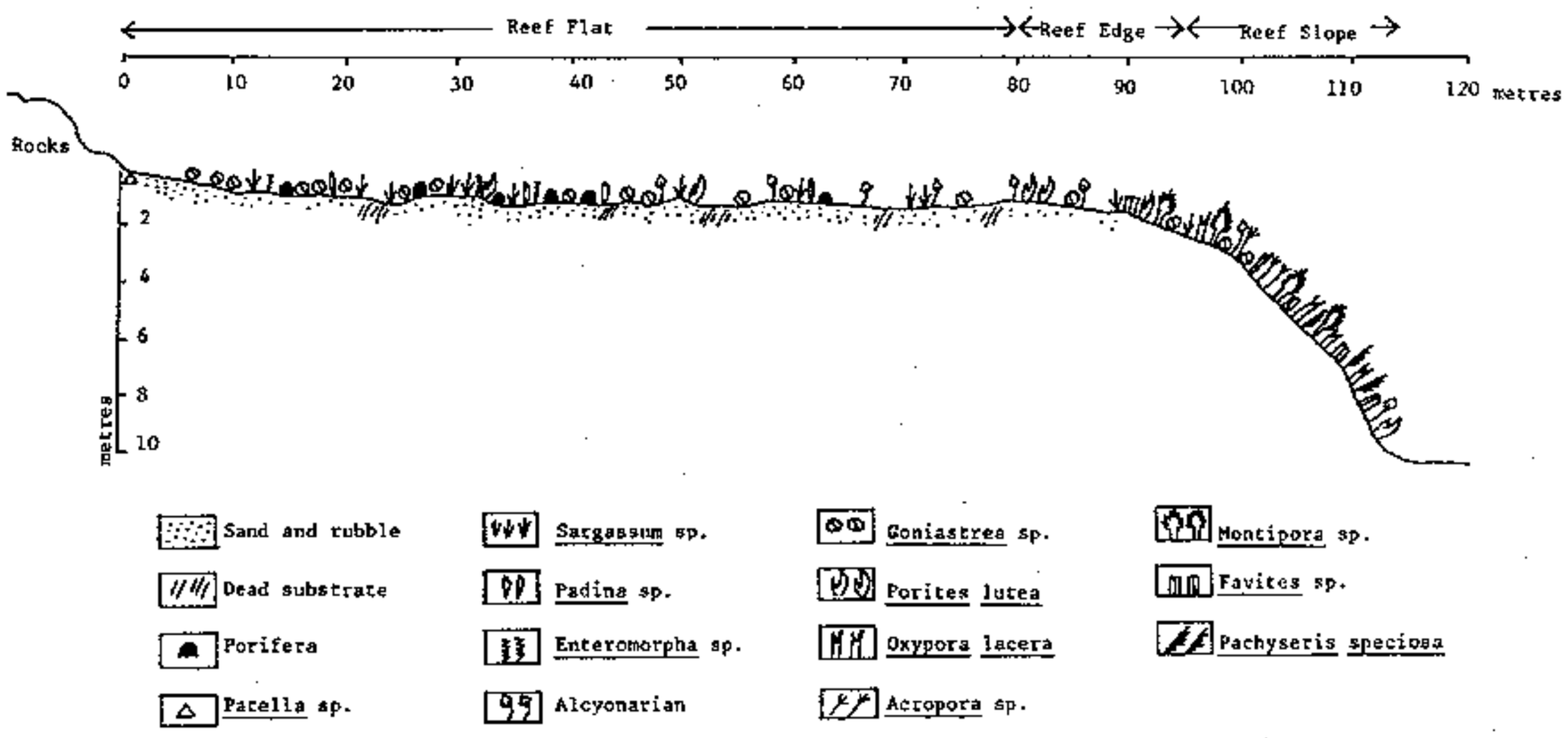

Fig. 2: General profile of Transect A (Pulau Salu).

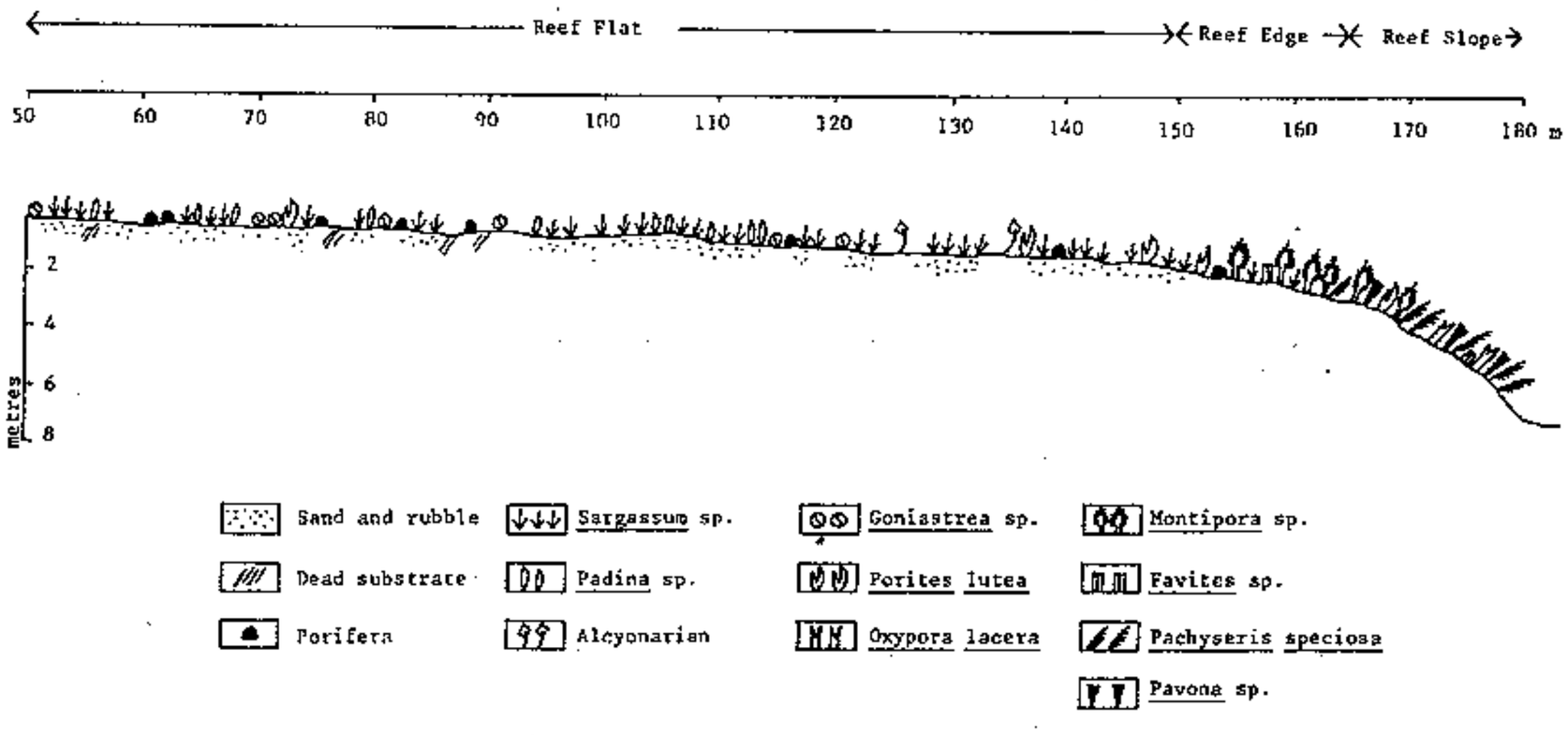

Fig. 3: General profile of Transect B (Pulau Salu).

MATERIALS AND METHOD

Two vertical transects (A & B) at opposite sides of the island were selected (fig. 1). These 2 transects were different in location to those set up by Chou and Teo (1983). At each vertical transect, two horizontal transects were made at the top (A1, B1) and at the bottom (A2, B2) of the reef slope. The Contiguous quadrat method of Maragos (9) was used along the transects, and the details have been given by Chou and Teo (8).

RESULTS

The general profiles of Transects A and B are presented in figures 2 and 3. These figures show the bottom profile with the distribution of the dominant groups of flora and fauna. On the basis of dominant biological and geological characteristics, both transects can be divided into 3 distinct zones: reef flat, reef edge and reef slope. The figures give an idea of the reef community found on Pulau Salu.

The reef flat is marked by a dominance of *Sargassum* sp. and *Padina commersonii* for both transects. Transect A was characterized by another algae, *Enteromorpha* sp. *Sargassum* sp. is the most dominant of the algae and it thins out at the reef edge. Beyond this point, no *Sargassum* is recorded.

Members of the phyla, Porifera, or commonly called sponges were also found on the reef flat. Alcyonarians extend from the reef flat right to the reef slope. The reef edge and reef slope are covered with scleractinians of which the main species are indicated in the figures.

Of the 42 species of hard corals observed in the vertical transects, 28 occurred in Transect A (Table 1) and 27 occurred in Transect B (Table 2). Distribution patterns of the major corals for both transects are shown in figs. 4 and 5. Only 5 species *Goniastrea retiformis, G. pectinata, Porites lutea, Favites abdita* and *F. speciosa* in both transects occur in the shallow regions of the reef flat, while 24 species were confined to deeper regions of the slope beyond depths of 8 metres. *Montipora laevis* can be found at the deeper region of the reef flat in Transect B. The greater number of species in deeper water suggests that the environment there is more favourable for the coexistence of corals than it is in shallower waters. Fifteen coral species were common to both transects. Live coral coverage on the reef was low, being 12.05% for Transect A and 11.00% for Transect B. However, if the 3 zones of reef flat, reef edge and reef slope are considered separately, a high value of near 60% (39.37% for Transect A and 53.36% for Transect B) is obtained for the reef slopes. Tables 1 and 2 also indicate the abundance, frequency, size index and growth forms of the hard corals. No single species is prominently abundant as the cover ranges from 0.02% to 2.59% only.

Table 1. Abundance, distribution, frequency and growth forms of corals at Transect A (Pulau Salu).

Species	Abundance (% of cover)	Frequency Number of quadrats	*Growth Forms	Size Index
All corals	12.05	62		
Acropora tubicinaria	0.12	2	B	6.00
Acropora variabilis	0.06	1	B	6.00
Echinopora lamellosa	1.38	5	L	27.60
Favia favus	0.03	1	G	3.00
Favia speciosa	0.02	1	G	2.00
Favites abdita	0.16	2	G	8.00
Favites chinensis	0.04	1	G	4.00
Favites sp.	0.72	10	G	7.20
Fungia fungites	0.67	10	L	6.70
Galaxea fascicularis	0.04	1	G	4.00
Goniastrea benhami	0.03	2	G	1.50
Goniastrea pectinata	0.72	12	G	6.00
Goniastrea retiformis	2.02	37	G	5.46
Goniopora lobata	0.10	2	G	5.00
Herpolitha limax	0.04	1	L	4.00
Montipora efflorescens	0.20	1	L	20.00
Montipora informis	2.19	10	L	21.90
Montipora solanderi	0.68	5	L	13.60
Montipora sulcata	0.10	1	L	10.00
Mycedium tubifex	0.26	3	L	8.67
Oxypora lacera	0.31	10	L	3.10
Pachyseries speciosa	0.91	5	L	18.20
Pavona crassa	0.06	2	F	3.00
Pavona sp.	0.44	4	F	11.00
Pectinia latuca	0.09	1	F	9.00
Platygyra lamellina	0.08	2	M	4.00
Porites lutea	0.55	10	G	5.50
Tubastrea aurea	0.03	1	B	3.00

* Key for growth forms:

B = branching L = laminate F = foliaceous
G = globular M = massive

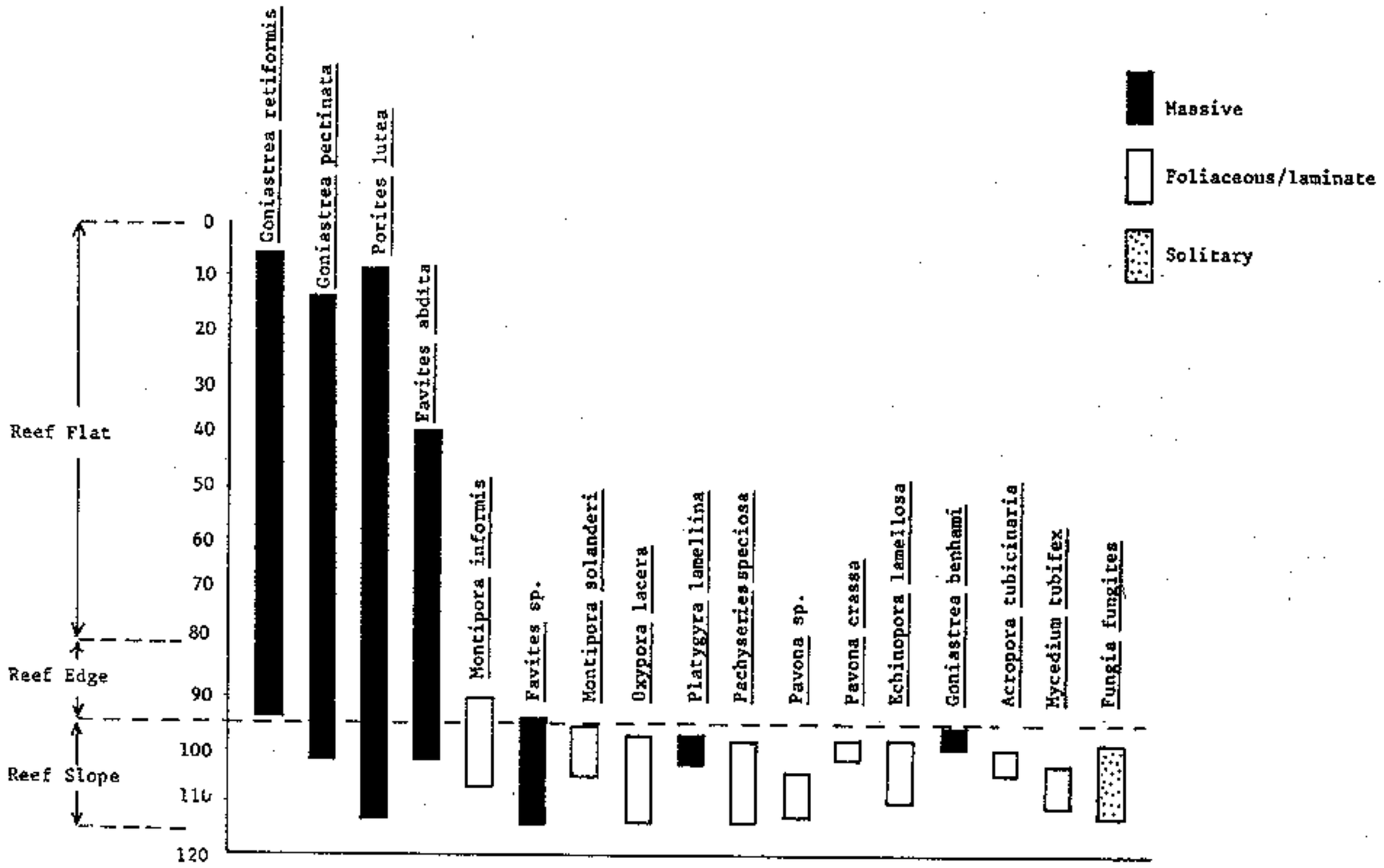

Fig. 4: Distribution of major coral species at Transect A (Pulau Salu).

Table 2. Abundance, distribution, frequency and growth forms of corals at Transect B (Pulau Salu).

Species	Abundance (% of cover)	Frequency Number of quadrats	*Growth Forms	Size Index
All corals	11.00	61		
Cyphastrea chalcidicum	0.12	1	G	12.00
Favia speciosa	0.10	4	G	2.50
Favites abdita	0.21	6	M	3.50
Favites sp.	0.17	3	M	5.67
Fungia fungites	0.05	3	L	1.25
Galaxea fascicularis	0.12	1	G	12.00
Goniastrea benhami	0.13	3	M	4.33
Goniastrea palavensis	0.02	1	M	2.00
Goniastrea pectinata	0.02	1	M	2.00
Goniastrea retiformis	0.47	19	M	2.47
Goniopora lobata	0.31	2	M	15.50
Goniopora stutchburyi	0.04	1	M	4.00
Hydnophora rigida	0.15	2	B	7.50
Montipora efflorescens	0.63	4	L	15.75
Montipora laevis	0.73	9	B	8.11
Montipora prolifera	0.18	2	L	9.00
Mycedium tubifex	0.08	2	L	4.00
Oxypora lacera	0.20	2	L	10.00
Pachyseries speciosa	2.59	13	L	19.92
Pavona frondifera	1.44	9	F	15.00
Platygyra lamellina	0.16	1	M	16.00
Porites (Synaraea) convexa	0.33	3	B	8.25
Porites lutea	1.09	19	M	5.74
Porites nigrescens	0.31	3	B	10.50
Psammocora contigua	0.70	5	F	10.33
Symphyllia nobilis	0.35	3	G	11.67
Turbinaria mollis	0.30	2	M	15.00

* Key for growth forms:

B = branching L = laminate F = foliaceous
G = globular M = massive

The reef at Pulau Salu is abundant with macroalgae. The brown algae predominate and is represented by *Sargassum* sp., *Padina commersonii* and *Turbinaria* sp. Another abundant species is the green algae, *Enteromorpha* sp. in Transect A. Other species include *Enhalus* sp. (sea-grass), *Codium* sp., *Ulva reticulata, Halimeda opunta* and *Caulerpa sertularoides. Padina commersonii* forms small individual bunches of pale brown, fan shaped fronds with concentric rings, but cover only little space. *Turbinaria* sp. occurs in small clumps near the reef edge. *Enteromorpha* sp. is quite abundant in Transect A, often seen with *Sargassum* sp. and *Padina commersonii.*

The sponges found here belong to the Class Demospongiae. There were altogether 7 species encountered in both transects. Each transect had 6 species. The abundance, distribution and frequency of the sponges as well as the other reef invertebrates are shown in Tables 3 and 4. *Suberites inconstans* was dominant on sandy patches of the reef flat. Numerous brittle stars find shelter in its cavities. Other species found here are *Dysidea* sp., *Haliclona* sp., *Hyatella clathrata, Ircinia ramosa, Spirastrella purpurea, Verongia* sp. Most of the species are found on reef flat except for *Dysidea* sp., a green spikey sponge which occurs amongst corals on the reef slopes.

Of the soft corals (alcyonarians), *Sarcophyton* sp. and *Sinularia* sp. are both quite common on the reef flat. They form rather large colonies, as they are short and low. *Lobularia pachyclados* is also very common. These have closely packed stumpy projections studded with polyps at the distal end of the short, low, massive colony.

The order Gorgonacea is represented by 2 species at Pulau Salu. These are *Gorgonia* sp. and *Junceela* sp. The former commonly called sea-fans are found often in deeper areas, beyond the reef flat. *Junceela* sp. or sea-whip is usually found in the deeper areas of the reef slope and the sea floor.

One species of sea-anemone, *Stoichactis* sp. was found

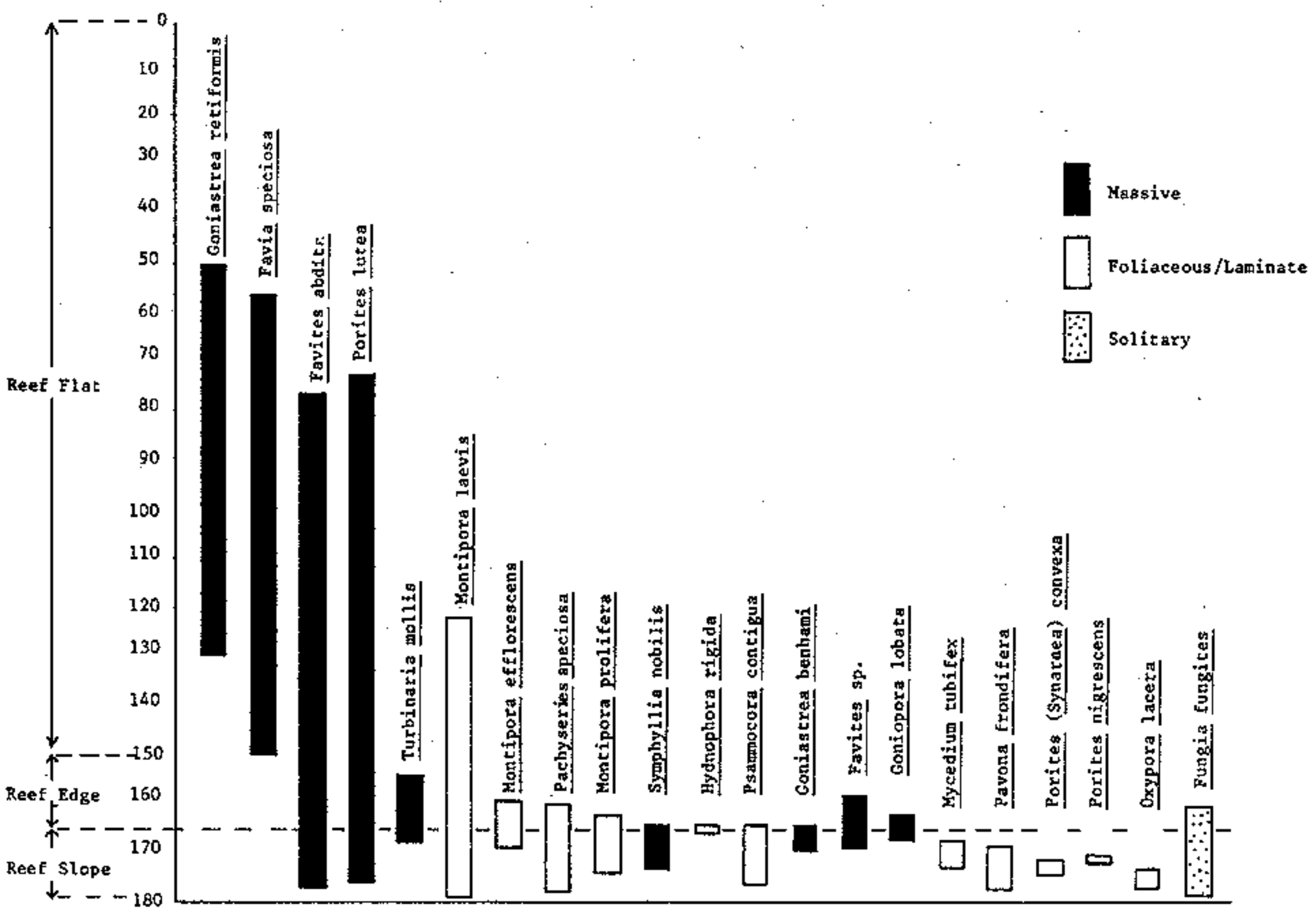

Fig. 5: Distribution of major corals at Transect B (Pualu Salu).

Table 3. Abundance, distribution and frequency of fauna at Transect A (Pulau Salu).

Species	Abundance (% of cover)	Frequency Number of quadrats	Size Index/No. of species
PHYLUM PORIFERA			
Class Demospongiae			
Dysidea sp.	0.01	1	1.00
Haliclona sp.	0.30	3	15.00
Hyattella clathrata	0.26	6	4.33
Spirastrella purpurea	0.12	4	3.00
Suberites inconstans	0.45	13	3.50
Verongia sp.	0.73	9	8.11
PHYLUM COELENTERATA			
Class Hydrozoa			
Lytocarpus sp.	—	1	1.00
Class Anthozoa			
Order Actinaria			
Stoichactis sp.	0.09	1	9.00
Order Gorgonacea			
Gorgonia sp.	0.04	1	4.00
Junceela sp.	0.06	1	6.00
Order Alcyonaria			
Lobularia pachyclados	0.56	5	11.20
Sinularia sp.	0.70	3	23.33
Sarcophyton sp.	0.60	3	20.00
PHYLUM MOLLUSCA			
Class Gastropoda			
Siphonaria sp.	—	2	40
Malleus malleus	—	5	7
PHYLUM PLATYHELMINTHES			
Order Polycladida			
Polyclad	—	1	1
PHYLUM ARTHROPODA			
Class Crustacea			
Pilumnus vespertilio	—	1	1

often on reef flats and reef slopes of both transects. This species is distinguished by its large size and numerous radiating rows of tentacles. The clown fish (*Amphiprion* sp.) was noticed in association with this sea-anemone.

The molluscs in both transects amounted to 5 species of which 2 were found in Transect A and 4 in Transect B. Along Transect A, *Malleus malleus* was noted on the reef flat, attached by byssus to coral rock or stones. The length of the shell sometimes exceeded 10 cm. Along Transect B, *Planaxis sulcatus* and *Siphonaria* sp. were found beneath rocks in the shallower regions of the reef flat. *Strombus urceus* occurred on the sandy areas of the reef flat. One species of *Tridacna* sp. was noted in shallow waters.

Other animals noted in Transect A were a polyclad and a crab, *Pilumnus vespertilio*. In Transect B, a tube-worm, *Sabella* sp. was noted together with echinoderms, *Diadema setosum* and *Stephenometra* sp.

Jaccard's coefficient was used to calculate community similarity among the 4 horizontal transects. From the coefficients obtained, it can be seen that the highest similarity occurs between Transect B1 and Transect B2 (c.c. = 0.31). This is followed by Transects B1 and A2 (c.c. = 0.28). The least similarity occurred between Transect A1 and Transect B2 (c.c. = 0.16).

Transects B1 and B2 are located on the same side of the island. The difference in depth is rather small since the slope is gradual. Therefore, these two transects are most similar. Transects B1 and A2 are similar although they were taken from opposite sides of the island. The species composition in these two transects are quite similar. Transects B2 and A1 are least similar. They are situated on opposite sides of the island and are at the top and bottom of the reef slopes respectively.

The faunal distribution at Pulau Salu is quite constant

Table 4. Abundance, distribution and frequency of fauna at Transect B (Pulau Salu).

Species	Abundance (% of cover)	Frequency Number of quadrats	Size Index/No. of species	
PHYLUM PORIFERA				
Class Demospongiae				
Dysidea sp.	0.01	1	1.00	
Haliclona sp.	0.06	3	2.00	
Hyattella clathrata	0.16	5	3.00	
Ircinia ramosa	0.11	4	2.75	
Spirastrella purpurea	0.13	4	3.25	
Suberites inconstans	0.53	18	3.00	
PHYLUM COELENTERATA				
Class Anthozoa				
Order Actinaria				
Stoichactis sp.	0.09	1	9.00	
Order Alcyonaria				
Lobularia pachyclados	0.27	4	7.67	
Sarcophyton sp.	0.08	2	4.00	
PHYLUM ANNELIDA				
Sabella sp.	0.01	1	1.00	
PHYLUM MOLLUSCA				
Class Gastropoda				
Planaxis sulcatus	—	2		9
Siphonaria sp.	—	2		6
Strombus urceus	—	3		3
Class Bivalvia				
Tridacna sp.	0.02	1	2.00	
PHYLUM ECHINODERMATA				
Class Echinoidea				
Diadema setosum	0.02	1	2.00	
Class Crinoidea				
Stephanometra sp.	0.02	1	2.00	

with depth. The transects of A1, B1 and A2, B2 were found to have nearly the same value (0.25 and 0.24). These transects were located on opposite sides of the island but are located at similar depths.

DISCUSSION

The reef coral community may be divided subjectively into the three zones, reef flat, reef edge and reef slope. At greatest depths on the transect (around 8 metres), physical factors such as sediment and low light density may limit both the growth and dominance of corals. However, the environment is too deep to be periodically disrupted by storm waves and therefore may allow a greater coexistence of specialized and different forms. It is on the reef slope that there is a great increase in the diversity and species richness.

At intermediate depth, the environment may be both stable with respect to storm waves and optimal with respect to light conditions. A stable and favourable environment may allow biological interactions to determine the nature of the community. For example, a few forms may find conditions optimal and dominate reef substrates as do *Sarcophyton* sp., *Lobularia pachyclados, Porites lutea* and *Goniastrea retiformis.*

At shallower depths the environment does become periodically disrupted by wave action but light conditions are optimal for development of a variety of small forms. In Pulau Salu, most of the shallower depths were occupied by small heads of *Goniastrea retiformis, Porites lutea, Goniastrea pectinata, Favites abdita* and *Favia speciosa.* In the shallowest depths, above the reef flat, breaking waves, diurnal variations in temperature, salinity changes, light and exposure result in unpredictable and suboptimal conditions. The diversity and development of corals is negligible. The coral community is replaced by other organisms such as coralline algae.

The sandy patch of Pulau Salu can be referred to as the *Sargassum* zone. This zone starts from the level of the low water neap downwards and extends to the margin of the reef edge. *Sargassum* cover in this zone is seasonal, with maximum cover during the cooler months (between August and January) and is sparse during the warmer months (between February and July) (4). The study was carried out during the cooler period, thus the readings are relatively high. During this cycle of growth and decline, the animals associated with them are also affected. During their period of luxuriance, food and shelter are in abundance for the herbivores. Some examples of herbivores that feed on the brown algae are *Lambis lambis, Thais echinulata, Trochus gibberula* and *Turbo* sp.

Padina commersonii is also abundant here. This algae tends to appear more prominent at the shore and where *Sargassum* becomes less luxuriant. Other prominent algae occurring here are *Turbinaria ornata* and *Enteromorpha* sp. The majority of macroalgae occur on sandy patches of the reef flat. Little macroalgae is found beyond the reef edge.

The results of the horizontal transects give an indication that some genera may be localized although most coral species appear to colonize all parts of the slope indiscriminately. There are, however no consistent signs of zonation. It is difficult to compare community similarity because the opposite sides of Pulau Salu are different. They may be exposed to different salinity, temperature, wave action or currents. It appears, however that the same depth at opposite sides of the island may have the same amount of similarity.

The lower margin of the reef slope is marked by an abrupt change from a rich coral community to a sparsely populated one. The sandy floor has only occasional gorgonids, sea whips (*Junceela*) and *Rumphella* sp. Light here is the limiting factor as it is essential for photosynthetic zooxanthellae. These have a symbiotic relationship with madreporarian reef-building corals and thus no corals appear where photosynthesis cannot take place. This explains the total absence of coral growth beyond the critical depth, which is the reef slope.

ACKNOWLEDGEMENTS

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