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THE COMMUNITY STRUCTURE OF THE FRINGING CORAL REEF, CAPE RACHADO, MALAYA

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ABSTRACT

Live coral cover was low (32.9%) on a belt transect 87 meters long and one metre wide, on the coral reef at Cape Rachado, Port Dickson. Considered separately the reef edge had a live coral cover of 59.6% and the reef flat 26.5%. The abundance of soft corals (alcyonaceans) on the reef flat as compared to other reefs is probably due to their ability to tolerate turbidity and extreme low tides. High species richness, diversity, abundance and large size index at the reef edge indicate that the environment there is more favourable to the hard corals (scleractinians) than the reef flat. Macroalgae are abundant.

INTRODUCTION

Studies on coral reefs in Malaysian waters have been mainly descriptive. These include the study of Purchon (1956) which was limited to a reference collection of corals occurring around Singapore. Chuang (1961) also made a collection around Singapore and extended it with some collections in Malaysian seas (Chuang, 1973). Work by Scheer (1970) on the second Xarifa Expedition in 1958 briefly surveyed the area from Penang to the Sembilan Islands, approximately 80 nautical miles to the south in the Straits of Malacca. A description of the species found, together with ecological notes of the collection sites, is given by Pillai and Scheer (1974). This paper presents a description of the community structure in terms of species composition, zonation and diversity patterns of the fringing reef community at Cape Rachado.

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METHODS

At Cape Rachado (Fig. 1) the fringing reef extends as a reef flat almost all the way round the cape. The reef flat where this study was carried out extends from the rocky shore in a westerly direction for a distance of over 85 metres to the reef edge (Fig. 1).

The reef was first surveyed for a reference collection of corals. Hard corals were identified following Searle (1956), while soft corals were identified by Dr. J. Verseveldt (The Netherlands). The method employed for quantitative sampling of the coral distribution is the contiguous transect technique (Maragos 1974). A transect was marked by large nails hammered into coral heads at various intervals. A one metre quadrat, subdivided into a grid of 100 squares of equal size was used in sampling all along one side of a transect line (beginning with quadrat 1 located near the rocks and ending with quadrat 87 at the reef edge). A sketch of the coral colonies in each quadrat was drawn to scale on a data sheet. Any colony growing independently of its neighbour was considered an individual colony, i.e. whenever an empty space was recorded between two adjacent colonies (Loya 1972). Growth forms were noted. For growth forms more inclined to flat horizontal growth such as the laminated *Astraeopora myriophthalma,* the percentage cover was derived directly from the number of squares occupied within the quadrat. For growth forms such as those of the massive *Goniastrea retiformis* where encrusting corallites are found on the vertical face of the boulders, the depth was measured and recorded on the sketch and used to calculate the surface area. This is a better assessment of coral cover than a two dimensional accounting that was applied to the flat form. The cover of various species of macroalgae within the quadrat was also recorded. The study was carried out from April to September 1976.

RESULTS

Environmental parameters

Tidal exposure of the reef flat (calculated for August and September 1976 based on tidal data obtained from the Tide Tables) show that the reef flat was exposed 6% of the time for the above period. At extreme low spring tides the reef flat may be exposed to the air for more than 3 hours. The reef flat extends from the rocky shore for about 50 metres where it slopes gently again for a distance of 10 metres before reaching the reef edge where numerous surge channels are present (Fig. 2). These channels are trenches which are in continuity with the open sea. The reef edge extends for about 17 metres and then falls off gently to a flat muddy bottom. Corals grow on the reef slope up to a depth of 8 metres.

Turbidity readings determined at the reef edge were variable ranging from Secchi disc readings of 2 m on an overcast day with rough sea when water had a high sediment load to readings of 7 m on a clear day with calm sea and a lower sediment load.

Coral fauna

The list of the corals found in Cape Rachado with their relative abundance and morphological forms are presented in Table 1. At least 41 species were present which includes 35 scleractinian hermatypes, one milliporinid and 5 alcyonaceans. Only one genus of solitary coral, *Fungia*, was found.

The abundance, frequency and size index of coral species found on the transect are included in Table 1. Abundance refers to the percentage cover of the species with respect to the total area of the transect. The frequency of a species is the number of quadrats in which the species is present. Of the 87 quadrats in the transect, only three did not contain any coral. These quadrats had sandy substrates. Size index was calculated for individual species and quadrats. The data from the former allows comparison of colony size between species, while the latter, between quadrats. Size index for species is derived from the division of total cover of the species (for the whole transect) by the number of its colonies. This is a measure of the average size of the coral species (Table 1). Size index for quadrats is derived from the division of percentage cover in one quadrat by the number of colonies found in it (Fig. 3).

Species richness i.e. the number of species per unit area was also calculated. This was computed for quadrat sizes of 1 m^2, 2 m^2, 5 m^2 and 10 m^2 (Fig. 4). Species richness is a measure of diversity which takes into account the number of species without considering the relative proportion of each species. To include the latter parameter in the calculation, the Shannon-Weaver (1949) index was computed using

$$H_c' = - \Sigma P_i \ln P_i$$

where P_i is the proportion (percent cover) of the 'ith' species in a sample and ln refers to the natural logarithm. This index was computed for contiguous quadrats of five and is presented together with coral abundance in Fig. 5. Abundance here refers to the percentage cover of corals in the quadrats irrespective of the species composition in the quadrats.

To measure dominance of one or few species in a quadrat, the Evenness Index (Pielou, 1966) was used. This is the ratio of the observed Shannon-Weaver diversity index, H_C', to the maximum diversity index H'_{max}. The diversity index is maximal when the proportion of all species in a sample is equal. When one or few species is much more abundant than the rest, the Evenness index is low (Fig. 6). Numerical abundance of corals measures distribution of coral colonies without regard to number of species and proportion of each species (Fig. 7). For a zonation model of the reef, the coral cover of 15 contiguous quadrats are pooled together (Fig. 8). The zones are named after the dominant species.

Table 1. Abundance in terms of % cover, relative abundance, frequency and size index of corals found in Cape Rachado.
Relative abundance (percentage cover) of species on the transect are based on the following scale of quantification: Abundant (A) = 2%, Common (C) = 1 - 2%, Occasional (O) = 0.3 - 1% and Rare (R) = 0.3%. Corals not found on the transect are listed last (asterisks). Key for growth forms: B = branching; F = foliaceous; G = globular; L = laminate; M= massive.

Species	Growth forms	Abundance (% cover)	Relative abundance	Frequency (No. of quadrats)	Size Index
All corals	-	32.94	-	84	-
Lobophytum crassum Von Marenzeller	B	0.83	0	8	1.95
Lobophytum crassospiculatum Moser	B	1.49	C	5	1.71
Lobophytum pauciflorum (Ehrenberg)	B	1.06	C	4	3.85
Sarcophyton ehrenbergi Von Marenzeller	M	2.28	A	7	9.45
Astraeopora myriophthalma (Lamarck)	L	2.00	A	16	5.24
Montipora informis Bernard	L	0.87	0	12	5.03
Pavona frondifera Lamarck	F	1.33	C	17	2.89
Pavona crassa (Dana)	F	0.14	0	1	12.00
Pachyseris speciosa (Dana)	L	0.11	0	1	10.00
Fungia fungites (Linnaeus)	L	0.02	0	2	2.00
Gonipora lobata Milne-Edwards & Haime	G	0.03	0	2	0.75
Porites convexa Verrill	F	2.15	A	17	6.68
Porites nigrescens Dana	B	0.17	0	1	14.50
Porites lutea Milne-Edwards & Haime	M	7.39	A	34	13.40

Species	Growth forms	Abundance (% cover)	Relative abundance	Frequency (No. of quadrats)	Size Index
Porites eridana Umbgrove	B	0.41	0	9	2.57
Favia speciosa (Dana)	G	0.82	0	23	1.99
Favites abdita (Ellis & Solander)	M	1.71	C	24	2.29
Goniastrea pectinata (Ehrenberg)	M	2.05	A	23	3.97
Goniastrea retiformis (Lamarck)	M	2.50	A	26	3.95
Goniastrea benhami Vaughan	M	3.38	A	30	6.39
Platygyra lamellina (Ehrenberg)	M	0.22	R	3	4.88
Merulina ampliata (Ellis & Solander)	L	1.52	C	9	6.97
Galaxea fasciculatis (Linnaeus)	G	0.32	0	5	4.67
Lobophyllia hemprichii (Ehrenberg)	M	0.13	0	2	5.50
**Millepora platyphylla* Hemprich & Ehrenberg	L				
**Sinularia leptoclados* (Ehrenberg)	B				
**Psammocora togianensis* Umbgrove	G				
**Psammocora contigua* (Esper)	F				
**Pocillopora verrucosa* (Ellis & Solander)	B				
**Montipora solanderi* Bernard	L				
**Montipora laevis* Quelch	B				
**Acropora concinna* (Brook)	B				

Species	Growth forms	Abundance (% cover)	Relative abundance	Frequency (No. of quadrats)	Size Index
**Acropora tubicinaria* (Dana)	B				
**Podabacia crustacea* (Pallas)	L				
**Goniopora malaccensis* Brueggemann	G				
**Alveopora excelsa* Verill	F				
**Hydnophora rigida* (Dana)	G				
**Cyphastrea chalcidicum* (Forskaal)	G				
**Mycedium tubifex* (Dana)	L				
**Pectinia lactuca* (Pallas)	F				
**Turbinaria peltata* (Esper)	L				

Macroalgae associated with corals

Both living and dead coral skeleton provide a habitat and substrate for algae and a variety of sessile and burrowing organisms. A conspicuous feature of the Cape Rachado coral reef is the abundance of macroalgae. The brown algae predominate represented by *Sargassum* sp., *Padina commersonii* and *Turbinaria* sp. Another abundant species is the red coralline algae, *Corallina* sp. The above four species were quantitatively surveyed along 70 metres of the transect (Table 2). *Padina* forms small individual bunches of pale brown, fan shape fronds with concentric rings, but cover only little space. *Turbinaria* occurs in clumps near the reef edge. *Corallina,* with biramous branching resulting in thick bushy growth occupies little space, thus its distribution, is patchy and occupied only a few squares (Table 2).

Table 2: Distribution and abundance of macroalgae on the transect.

Numbers represent the number of 10 cm squares occupied by the algae in each one metre quadrat.

	SPECIES					SPECIES					SPECIES			
Quadrat Number	*Sargassum* sp.	*Padina commersonii*	*Turbinaria* sp.	*Corallina* sp.	Quadrat Number	*Sargassum* sp.	*Padina commersonii*	*Turbinaria* sp.	*Corallina* sp.	Quadrat number	*Sargassum* sp.	*Padina commersonii*	*Turbinaria* sp.	*Corallina* sp.
1	-	-	-	-	25	38	-	-	2	49	95	3	6	-
2	-	-	-	-	26	40	-	2	-	50	100	5	8	-
3	-	-	-	-	27	30	-	1	-	51	95	2	2	1
4	2	-	-	-	28	30	-	3	-	52	100	-	-	-
5	3	-	-	-	29	30	20	-	1	53	95	-	-	3
6	15	3	-	-	30	5	-	-	1	54	80	-	4	-
7	60	-	-	-	31	10	5	-	-	55	100	6	5	-
8	70	-	-	-	32	35	-	4	2	56	97	3	5	-
9	80	-	1	-	33	46	6	-	-	57	96	3	13	8
10	85	-	-	-	34	70	5	6	2	58	98	-	-	-
11	85	4	-	-	35	10	5	-	-	59	98	-	-	2
12	15	-	3	-	36	10	4	-	2	60	100	-	-	-
13	15	4	-	-	37	50	10	-	-	61	94	-	5	-
14	10	5	-	-	38	5	5	3	-	62	96	-	3	3
15	18	-	-	-	39	15	10	-	3	63	99	5	12	-
16	7	-	5	-	40	40	8	-	-	64	98	2	5	2
17	70	-	-	-	41	50	9	-	1	65	90	-	5	2
18	60	-	-	-	42	70	10	2	-	66	87	-	8	2
19	45	-	7	-	43	85	5	1	-	67	80	2	15	3
20	35	-	-	-	44	90	4	-	4	68	50	-	-	-
21	35	-	6	-	45	95	3	4	-	69	46	-	-	-
22	78	-	-	-	46	85	-	-	5	70	20	-	25	-
23	52	9	-	-	47	-	-	-	-					
24	78	-	2	-	48	100	5	4	2					

DISCUSSION AND CONCLUSIONS

Fifty six percent of coral species found in Cape Rachado were present on the 1 x 87 metre belt transect studied. Live coral cover on the reef was low (32.9%). However, if considered separately the reef edge comprising 17 metres of the transect has a coral cover of 59.6% and the reef flat of 70 metres only 26.5%. The high coral cover at the reef edge compares favourably with the reef slope at Fanning Island, Line Islands, where Maragos (1974) obtained a value of 60%.

Size indices along the transect (beginning from quadrat 1 at rocky shore to quadrat 87 at reef edge) show extreme variability (Fig. 3), ranging from 1% to 95%. However, the two regions from quadrat 25 to 35 and 46 to 64, show significantly lower size index than the adjacent regions. The former corresponds to areas dominated by *Goniastrea retiformis* and *Lobophytum* spp. The latter an area dominated by *Astraeopora myriophthalma, Pavona frondifera* and *Porites eridani*. These two regions also show low abundance (Fig. 5) but the number of colonies between them differ greatly (Fig. 7).

The opposite ends of the transect between quadrats 5-15 (*P. lutea* zone) and quadrats 70-87 (mixed zone) show significantly higher abundance (Fig. 5). The first area (on the reef flat), exclusively colonized by *P. lutea* also showed low diversity, species richness, evenness index and frequency but large size index. Individual colonies of the species are spread over large areas, thereby excluding other species. This reduces the diversity, species richness and frequency. On the other hand, the second area is a zone equally dominated by a number of species such as *Sarcophyton ehrenbergi, Porites convexa, Merulina ampliata* and *Goniastrea* spp. (Fig. 8). Here the zone is characterised by high diversity, species richness, evenness index and frequency and also a large size index.

Generally the first and second areas reflect the characteristic coral species of the reef flat and reef edge respectively. This difference in coral species characters is a result of contrasting environmental conditions. The reef flat is subject to stress of high temperature and variable salinity. Exposure to the sun during periods of low spring tides increases the temperature considerably and subject the corals to severe desiccation. Loya (1976) reported mass mortality of corals in the Gulf of Eilat during a period of extreme low tides in 1970. In the event of rain during periods of tidal exposure, the salinity may be reduced. Regular occurrence of such fluctuations causes mortality of less hardy and competitive species; thereby reducing the diversity. Species which can tolerate such environmental conditions dominate the substrate.

Another possible factor for the difference between the reef flat and reef edge is the presence of surge channels in the latter. These surge channels probably bring in a good supply of oxygen and food. Further, the extra vertical dimension of the reef edge increases the area of substrate for the settling of planulae. This phenomenon of high abundance and diversity on the reef edge is equivalent to the 'edge effect' reported by Porter (1972).

Astraeopora myriophthalma and *Porites eridani* are the dominant corals of the region between quadrats 50 to 60, a zone that is in the trough of the reef flat. It is also a zone that shows low species richness, abundance, frequency and diversity indices. Individual colonies of *Astraeopora myriophthalma* are spread over large areas in this zone as shown by its relatively high size index and hence it has reduced the diversity by physical exclusion of other corals. The environment here is less severe as it is not subject to tidal exposure.

The seaward end of the reef flat (between quadrats 60 and 70) is covered mostly by *Porites convexa* and *Sarcophyton ehrenbergi*. *Porites convexa* is only found seaward from this region onwards which in view of its proximity with the reef edge, benefit from the food and oxygen brought in by the surge channels. Maragos (1974) described the *Sarcophyton* sp. as a soft coral characterised by a continuous spongy "corallum" that seemingly smothers other corals by growing over them. This alcyonacean may be capable of rapid growth and this may help in achieving local dominance.

Analysis of the size index of quadrats (Fig. 3) indicates that the smallest colonies existed in the middle region of the reef flat (quadrats 15 to 65) and the largest colonies occurred at both the seaward and landward ends of the reef flat. These data support the hypothesis that large colonies of *Porites lutea* and *Sarcophyton ehrenbergi* may physically exclude other corals.

Turbidity which is correlated to sediment load is very high in Cape Rachado. Visibility was limited. Compared to visibility of Fanning Island which is 50 m in terms of Secchi disc readings (Maragos 1974), the water here is indeed very turbid. Sediments which settle on the reef flat smother the corals. This leads to a significantly lower living coverage and diversity, a conclusion that is also shared by Loya (1972) concerning the Eilat coral reef flat.

Soft corals (alcyonaceans) which do not contribute to the reef skeletal framework are abundant in Cape Rachado contributing 17% of total coral cover on the transect. This is in contrast to the situation in most reefs, e.g. the Great Barrier Reef where the soft corals are negligible. Soft coral abundance in the Red Sea is due to their ability to tolerate turbidity and occasional extreme low tides better than stony corals which are more adapted to strong currents and swells (Schuhmacher 1975).

It is apparent that the abundance of soft corals in Cape Rachado is also a consequence of the same abiotic factors. The ability of soft corals to survive in turbid conditions may be due to their structural flexibility which allows them to dislodge any sediments settling on them. During extreme low tides, the soft corals droop over the substrate, reducing the exposure of polyps to direct sunlight.

They are also able to retain water in their structures which acts as a coolant to the heat from solar radiation. All these coupled with mucus secretions enable the soft corals to overcome desiccation.

Loya (1972) suggested that the best strategy for scleractinian corals trying to grow in areas of high sedimentation is to develop some kind of cleaning mechanism or evolve a special growth form which avoids sediment accumulation. Three out of the four most abundant species in the high sedimentation rate areas, on the coral reef in Eilat were branching corals. Roy and Smith (1971) working on Fanning Lagoon, Line Islands, also showed that ramose (branching) forms dominate the turbid water rather than the massive forms. In contrast, the most abundant species in Cape Rachado are corals with massive forms such as *Porites lutea* and the faviid species such as *Favia speciosa, Favites abdita, Goniastrea retiformis, G. pectinata, G. benhami* and *Platygyra lamellina*. These corals probably have a cleaning mechanism to remove sediments through mucus secretions or ciliary action. Large specimens of the massive faviid corals often have a dead top indicating that polyps exposed directly to sedimentation are unable to cope with the problem. It is the polyps encrusted on the vertical plane of the boulders which are able to survive as sediments do not settle there. *Porites lutea* shows essentially the same trend but large specimens have been found with short stunted projections which have less horizontal surfaces where sediments can settle. This development by *Porites lutea* towards branching or ramose forms is an adaptation to the stress of high sedimentation.

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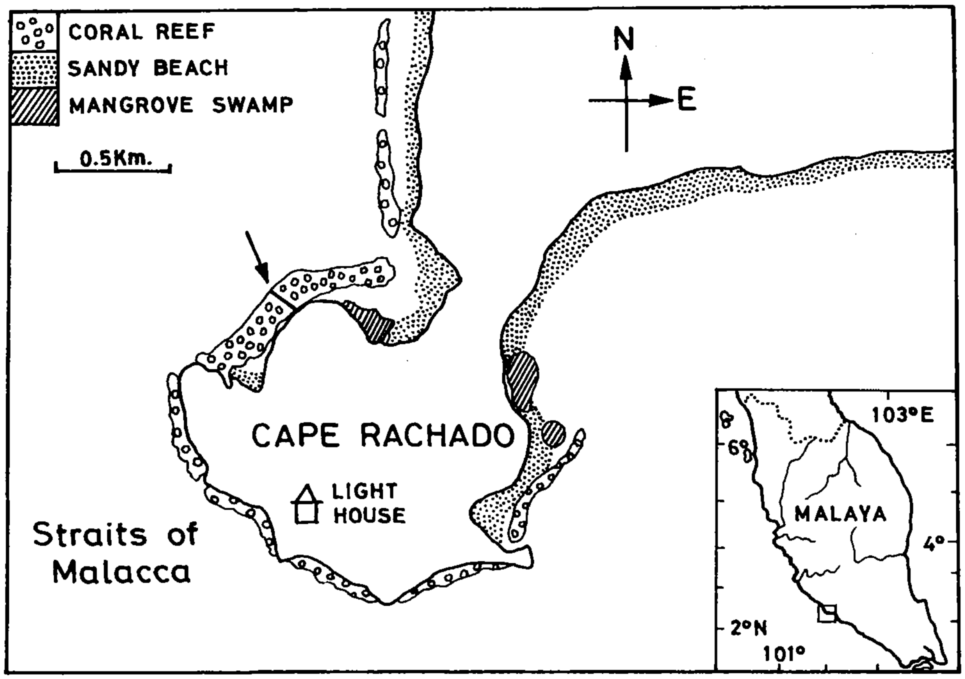

Fig. 1 Cape Rachado and surrounding coral reefs. Study transect indicated by arrow

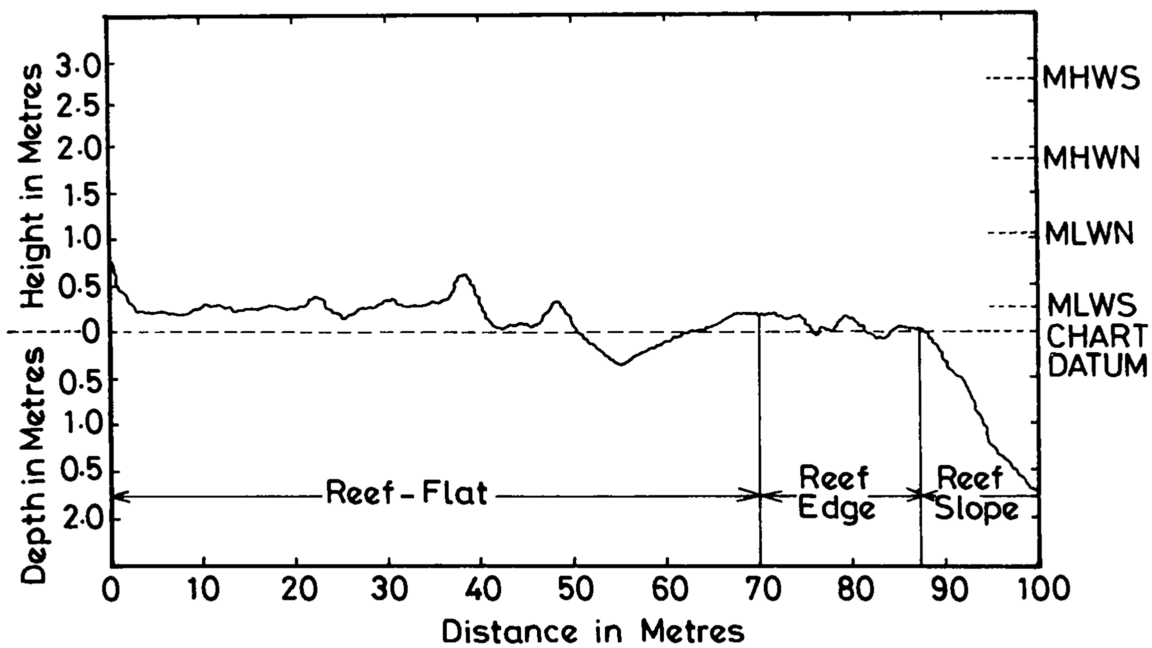

Fig. 2 Bathymetry of reef transect in relation to the various tidal levels

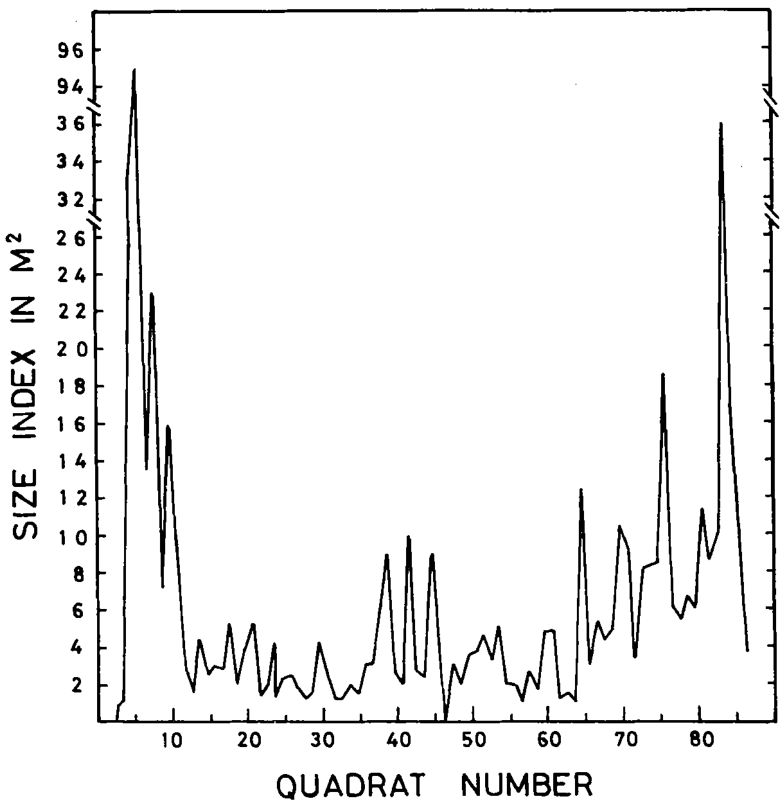

Fig. 3 Size index for quadrats (an estimate of average colony area) plotted as a function of transect location

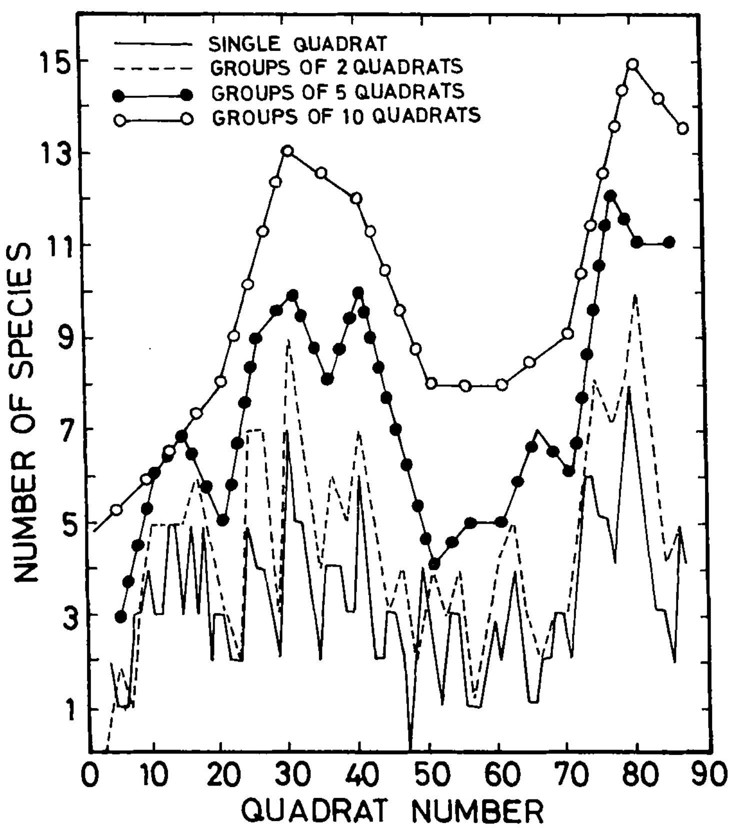

Fig. 4 Species richness plotted as function of transect location for single quadrats, for groups of 2, 5 and 10 quadrats

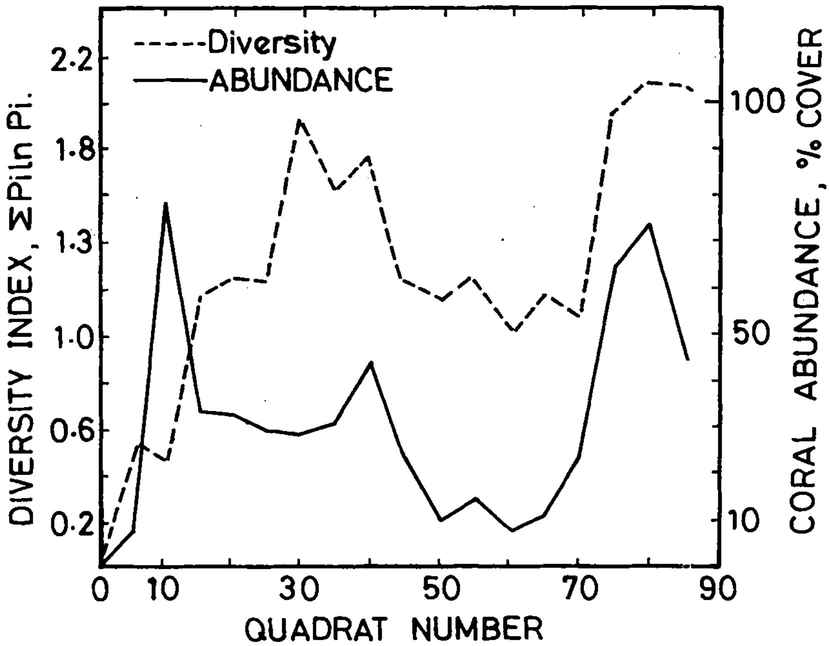

Fig. 5 Coral abundance and the Shannon-Weaver diversity index plotted as a function of transect location with values based on pooling of contiguous groups of five quadrats

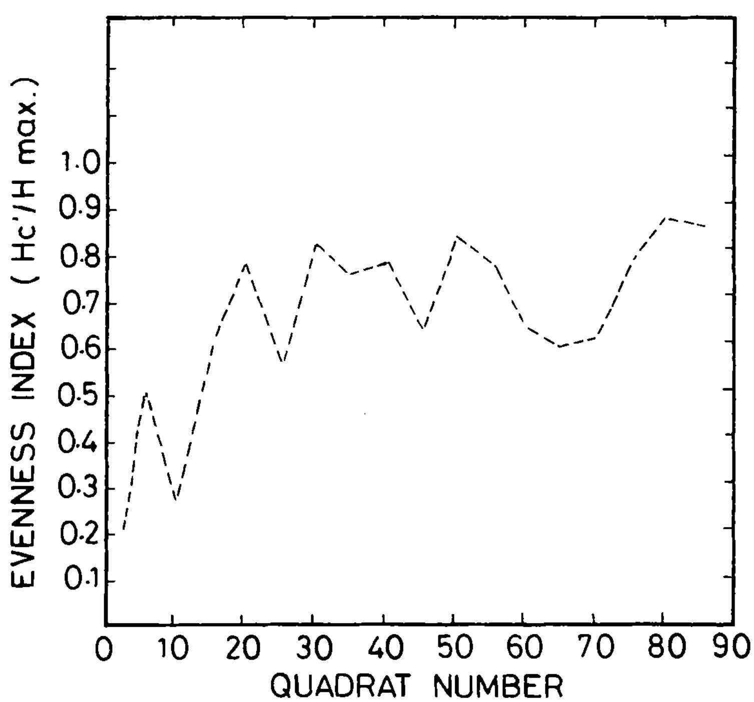

Fig. 6 Evenness Index (Hc'/H max) plotted as a function of transect location for groups of five quadrats

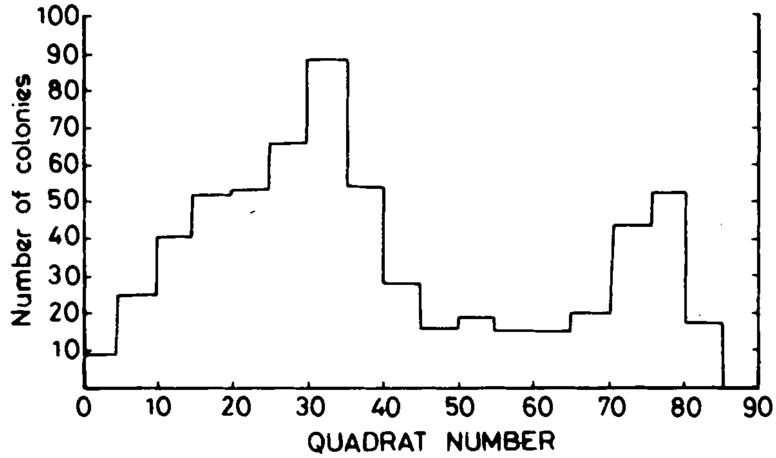

Fig. 7 Number of quadrats at 5 meter intervals along transect

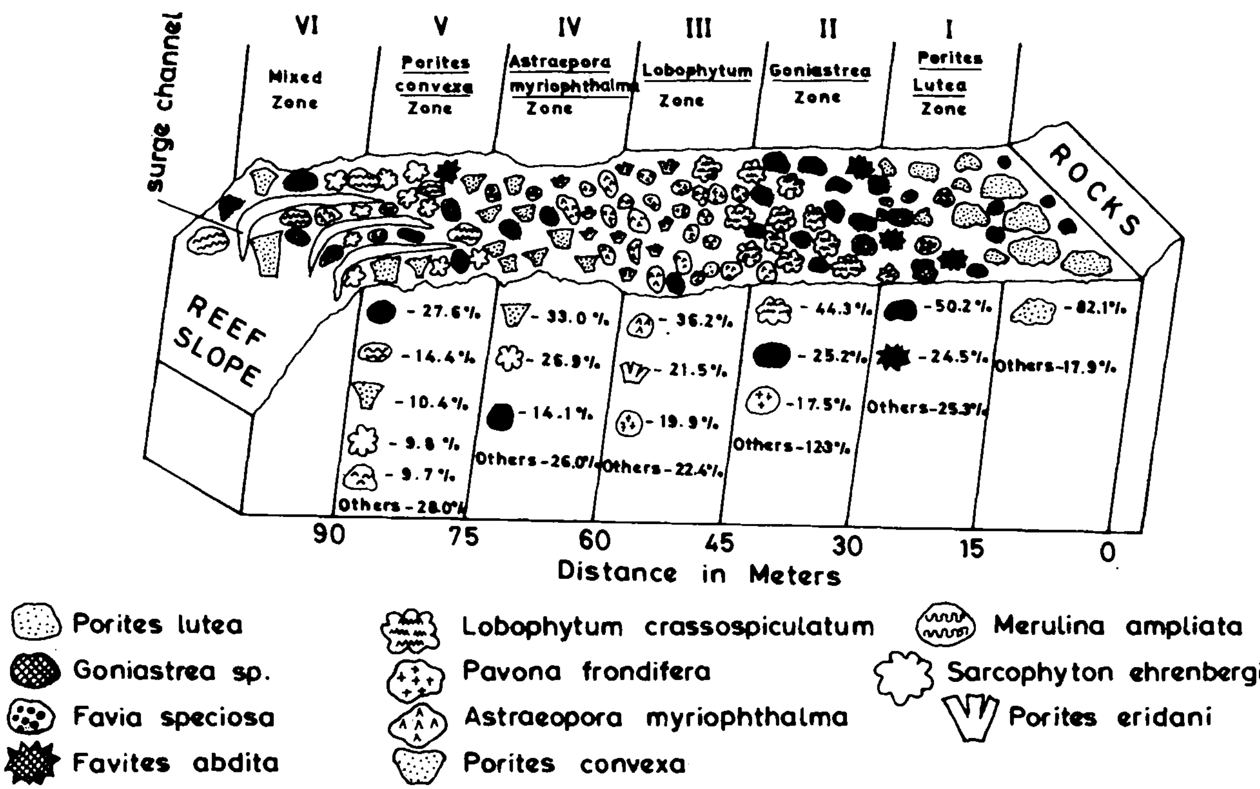

Fig. 8 Zonation model of coral reef transect at Cape Rachado