THE NON-SCLERACTINIAN COMPONENT
OF SINGAPORE REEFS: BATHYMETRIC ANALYSIS

Nigel K.C. Goh & L.M. Chou

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

ABSTRACT

This paper provides information on the relative abundance and distribution (with respect to depth) of the non-scleractinians of 12 reef sites in Singapore obtained from three surveys conducted during the two phases of the ASEAN-Australia Marine Science Project: Living Coastal Resources. Non-scleractinians make up 1.48-90.21%, 1.51-94.44%, 5.11-100% and 10.8-100% of live cover at the reef crest (0m) and 3m, 6m and 10m below the crest, respectively. Macroalgae was the dominant non-scleractinian benthos category at the 0m transect. At the 3m transect, 'others', soft corals and sponges dominated in survey 1, 2 and 3, respectively. Turf algae (survey 1) and sponges (surveys 2 and 3) shared dominance at the 6m transect. 'Others' was dominant at 10m in surveys 1 and 2, while sponges dominated in survey 3. Three zones, based on the characteristic non-scleractinian organisms are recognised: the algae-soft coral zone at the reef crest, the mixed zone between 3m and 6m below the crest where no particular organisms are characteristic, and the 'others'-sponge-coralline algae zone at 10m below the crest.

INTRODUCTION

In this paper, 'non-scleractinian' refers specifically to the categories used in the Line Intercept Transect method (Dartnall & Jones, 1986). Five broad categories are employed: Algae, Soft coral (SC), Sponges (SP), Zoanthids (ZO), and 'Others' (OT) which refers to all sessile non-scleractinian reef organisms that are not classified in the earlier categories above. Within the Algae, five sub-categories are recognised: Macroalgae (MA), Turf algae (TA), Coralline algae (CA), *Halimeda* (HA) and multi-species Algal assemblages (AA).

Non-scleractinians are an important factor in the ecology of a coral reef. Algae represent the main primary producers on a reef (Larkum, 1983), and distribution and abundance patterns have significant effects on the herbivores of the reef, especially fish and sea urchins (Foster. 1987; Hay & Taylor. 1985; Lewis, 1985). Naim (1988) reported on the association of crustaceans, polychaetes. ophiuroids and fishes with several species of *Halimeda*. Sponges are known to mediate the consolidation of loose coral rubble leading to reef growth (Wilkinson, 1983; Wulff, 1984). Gorgonians are also known to harbour many associates belonging to the Crustacea, Echinodermata. Mollusca, Bryozoa, Chordata, Annelida and Cnidaria (Bruce. 1970; Goh. 1990; Patton, 1972).

Elucidating the distributional patterns of these groups of animals is an important step towards understanding the ecology of Singapore reefs as non-scleractinian organisms comprise a large proportion of reef life here. Of the living organisms transected. up to 100% can consist of non-scleractinians. Even at the reef crest, percentage living cover of non-scleractinians can reach 90%. with means of between 30-40% for most reefs. In spite of this significant non-scleractinian component, most publications on the coral reef benthos of Singapore arising from this project (e.g., Chua & Chou. 1991; Lane. 1991; Goh & Chou. 1992) focussed on the hard corals of the reef; only one (Goh & Chou. 1991) was a quantitative study of the non-scleractinians of the reefs in Singapore. Associations of benthic organisms have also been used as environmental indicators (Konnecker. 1977). and distributional variations of non-scleractinians could reflect different environmental conditions.

MATERIALS AND METHODS

Twelve reef sites (refer to Fig. 1. Low & Chou. this volume) on 6 reefs in the islands south of Singapore were surveyed as part of the ASEAN-Australia Marine Science Project: Living Coastal Resources. Three surveys were conducted: survey 1 from 29 April 1986 to 11 April 1989: survey 2 from 7 April 1990 to 7 May 1992. and survey 3 between 8 June 1993 and 2 Nov 1993. The reefs and sites surveyed were: Cyrene Reef (C1 and C2). Hantu West Reef (HW1 and HW2). Pulau Hantu (H1 and H2). Pulau Semakau (S1 and S2). Raffles Lighthouse (R1 and R2) and Lazarus Island (L2 and L4). The depth-specific Line Intercept Transect method (Dartnall & Jones. 1986) was used in all the surveys. In the third survey. the single 100m transect was replaced by five replicate 20m transects.

Analysis was based on relative percentage cover with respect only to living organisms (non-scleractinians and scleractinians) to show the relationship between the two more clearly. The abiotic component of the transects was omitted.

RESULTS

Table 1 shows the relative percentage cover of non-scleractinians for Singapore reefs at the 0m. 3m. 6m. and 10m transects. At the 0m transect, non-scleractinian relative percentage cover across the three surveys ranged from 1.48% to 90.21%. At the 3m. 6m and 10m transects, percentage cover ranged from 1.51% to 94.44%. 5.11% to 100% and 10.8% to 100%, respectively. Looking at the mean relative percentage cover of non-scleractinians at the four transect depths for the three surveys. a depth-related trend is seen. Between the 0m and 3m transects. non-scleractinian cover decreased and then increased from the 3m through the 6m to the 10 m transect. The differences between the four transects were found to be highly significant (99% confidence level).

Table 1. Relative percentage cover of non-scleractinians on Singapore reefs (refer to text for site names).

DEPTH/SURVEY			C1	C2	HW1	HW2	H1	H2	SITE S1	S2	R1	R2	L2	L4	MEAN
0m	/	1	85.3	55.7	25.5	6.28	45	15.2	37.6	25.9	5.26	1.48	6.06	88.4	33.1
		2	63.1	41.4	18.5	6.69	54.1	24.3	37	6.81	8.25	6.77	8.27	90.2	30.4
		3	81.4	46.9	28.8	10.8	69.2	30.1	89.1	19.6	6.75	3.13	36.3	59.8	40.2
3m	/	1	19.4	6.53	1.51	23.6	5.14	27.2	25.1	3.82	12.8	8.12	8.27	94.4	19.7
		2	48.8	5.96	10.8	7.69	27.9	7.03	26.4	3.82	16	5.28	15	92	22.2
		3	57.1	23.8	10.3	6.2	34.6	6.56	27.8	4.29	10.7	6.93	6.76	85.7	23.4
6m	/	1	100	74.3	48.2	9.28	54.7	31.6	60.7	89.8	34.8	44.5	74.9	100	60.2
		2	92.1	24.6	8.93	10.8	26.5	19.5	100	18.9	26.2	59.6	65.7	91.1	45.3
		3	60.1	68	16.2	5.11	30.7	15.8	36.7	70.1	25.5	6.61	44.1	95.3	39.5
10m	/	1	46.5	100	22	10.8	93.2	27.1	16.5	100	85.6	92.9	89.7	98.4	65.2
		2	100	100	56.1	15.9	100	12	100		92.6	88.6	99.3	100	72
		3	100	96.9	76.6	51.2	100	51.6	90.3		78.6	92.7	100	98.4	78

Note: 10m transect at S2 was not carried out in surveys 2 and 3.

Within the non-scleractinians, the pie-charts in Fig. 1 show the percentage composition of the different benthos categories at the 0m. 3m. 6m and 10m transects, respectively. At the 0m transect. macroalgae (MA) dominated the non-scleractinians for all three surveys (29.1%. 32.5%. 61%). The next dominant category was shared by algal assemblages (AA, 19.3%), 'others' (OT, 23.2%) and sponges (SP, 13.8%) in surveys 1. 2 and 3. respectively. At 3m, 'others' (33%) was dominant in survey 1. soft corals (SC, 35.7%) in survey 2 and sponges (39.6%) in survey 3. Next dominant were algal assemblages (25.4%) for survey 1 and 'others' for surveys 2 (31.3%) and 3 (26.3%). At the 6m transect, dominance was shared by turf algae (TA, 23%) in survey 1 and sponges in the other two surveys (39.2%, 64.4%). At this depth, 'others' was the sub-dominant non-scleractinian category in all surveys (22.6%. 33.6%. 22.5%). In surveys 1 and 2. 'others' (45.2%. 52%) dominated at 10m while sponges (21%, 22.3%) were sub-dominant. At the same depth in survey 3. sponges (49.7%) occcurred slightly more frequently than 'others' (46.9%).
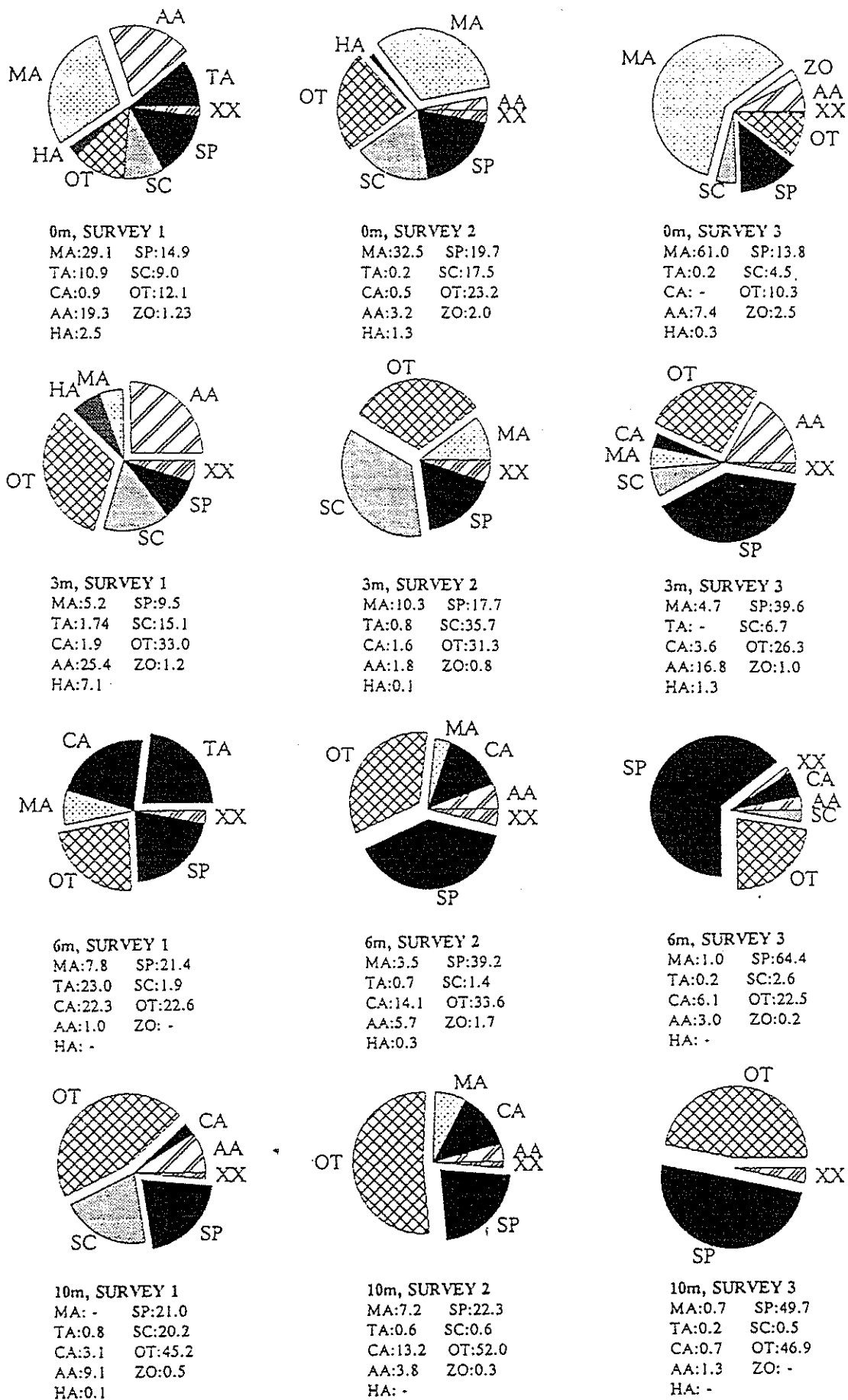
0m, SURVEY 1
MA:29.1   SP:14.9
TA:10.9   SC:9.0
CA:0.9   OT:12.1
AA:19.3   ZO:1.23
HA:2.5

0m, SURVEY 2
MA:32.5   SP:19.7
TA:0.2   SC:17.5
CA:0.5   OT:23.2
AA:3.2   ZO:2.0
HA:1.3

0m, SURVEY 3
MA:61.0   SP:13.8
TA:0.2   SC:4.5
CA: -   OT:10.3
AA:7.4   ZO:2.5
HA:0.3

3m, SURVEY 1
MA:5.2   SP:9.5
TA:1.74   SC:15.1
CA:1.9   OT:33.0
AA:25.4   ZO:1.2
HA:7.1

3m, SURVEY 2
MA:10.3   SP:17.7
TA:0.8   SC:35.7
CA:1.6   OT:31.3
AA:1.8   ZO:0.8
HA:0.1

3m, SURVEY 3
MA:4.7   SP:39.6
TA: -   SC:6.7
CA:3.6   OT:26.3
AA:16.8   ZO:1.0
HA:1.3

6m, SURVEY 1
MA:7.8   SP:21.4
TA:23.0   SC:1.9
CA:22.3   OT:22.6
AA:1.0   ZO: -
HA: -

6m, SURVEY 2
MA:3.5   SP:39.2
TA:0.7   SC:1.4
CA:14.1   OT:33.6
AA:5.7   ZO:1.7
HA:0.3

6m, SURVEY 3
MA:1.0   SP:64.4
TA:0.2   SC:2.6
CA:6.1   OT:22.5
AA:3.0   ZO:0.2
HA: -

10m, SURVEY 1
MA: -   SP:21.0
TA:0.8   SC:20.2
CA:3.1   OT:45.2
AA:9.1   ZO:0.5
HA:0.1

10m, SURVEY 2
MA:7.2   SP:22.3
TA:0.6   SC:0.6
CA:13.2   OT:52.0
AA:3.8   ZO:0.3
HA: -

10m, SURVEY 3
MA:0.7   SP:49.7
TA:0.2   SC:0.5
CA:0.7   OT:46.9
AA:1.3   ZO: -
HA: -

Fig. 1.   Mean percentage composition of non-scleractinians at the 0m, 3m, 6m and 10m transects (Note: XX=summation of percentages =2.0 and below).

Macroalgae dominated all 3 surveys at 0m, and generally decreased in importance with depth. Coralline algae formed a small percentage (0% - 3.6%) of the non-scleractinian component at 0m and 3m. At 6m, it made up 6.1% - 22.3% of the non-scleractinians. The other algal components (TA, AA, HA) were variable in their distribution across the four depths. Soft corals were also variable in their distribution, but there was a marked paucity (1.4% - 2.6%) at the 6m transect. Zoanthids had a generally low abundance at all depths. Sponges (9.5% - 39.6%) and 'others' (10.3% - 33.0%) were important components at 0m and 3m and dominated at 6m and 10m (21.0% - 64.4% for sponges and 22.5% -52.0% for 'others').

DISCUSSION

Significant differences in relative non-scleractinian cover between the 0m, 3m, 6m and 10m transects suggest the existence of distinct environmental conditions related to depth. This is supported by the work of Goh et al. (this volume) on the depth-related distribution of coral growth forms in Singapore.

The decrease of non-scleractinian cover from 0m to 3m can be attributed largely to the decrease in macroalgae cover between the two transects (Fig. 1). Turbidity of Singapore waters decreases light levels at a depth of 4m to 40% of surface light intensity (Chuang, 1977). This would significantly reduce the ability of macroalgal species to photosynthesize, grow and hence compete with species that are less affected by reduced light intensities. At the 3m transect, hard corals constitute the major component of live cover (mean: 76.6% - 80.34%, Table 1). Predictably, hard coral cover decreases with depth (and reduced light levels). Concomitantly, non-scleractinians increasingly dominate the living fauna from the 3m transect to the 10m transect, where light levels can be less than 5% that at the surface (Chuang, 1977). The increase in non-scleractinian cover at the deeper transects is attributed mainly to sponges and 'others'. It should be noted that absolute cover of live organisms (with respect to total length transected) also decreases with depth. The non-scleractinians therefore do not replace the hard corals in the sense of occupying space on the reef vacated by the latter. They do, however, occupy an increasing proportion of the niches suitable for life at the deeper depths.

Within the non-scleractinian community (Fig. 1), different lifeform groups dominate the four depths. Three zones with characteristic (though not necessarily dominant) organisms, based on comparisons of T-values and F-ratios (Done, 1983) are distinguished: the algae (TA, AA, MA, HA)-soft coral zone at 0m, the mixed zone between 3m and 6m and the 'others'-sponge-coralline algae zone at 10m. Based on the net primary productivity of reef organisms at different depths in Singapore (Tun, 1994), a rough prediction of the capacity for primary production of communities from different zones can be made. Algae are assumed to be net producers over the depth range from 0m to 10m; sponges are producers at 0m and 3m; soft corals only at 0m. Zoanthids and 'others' are net consumers over the entire depth range studied. This information is then superimposed on the composition of the different transects. The resulting picture has a zone of vigourous production at the 0m transect, and one of net consumption at 10m. At the intermediate depths (3m and 6m), a rough balance between production and consumption is seen. This functional delineation of zones agrees well with that arrived at through comparisons of T-values and F-ratios. When considering the distribution of dominant organisms, the zonation pattern is slightly different. A macroalgae zone is distinguished at 0m, a mixed zone without any particular dominant organism at 3m, and an 'others'-sponge zone between 6m and 10 m.

The influence of the environmental factors, light and water movement on zonation patterns of reef organisms is a recognized phenomenon on coral reefs (Done, 1983). Inter-specific competition also plays a key role in determining faunal zonation (Benayahu & Loya, 1981). Both physical and biological determinants of reef zonation were considered in the work of van den Hoek et al. (1978). The reefs in Singapore are not subject to unpredictable, catastrophic events like typhoons or hurricanes; storms are usually mild and probably do not significantly afffect reef life. High sedimentation rates (Lane, 1991; Low & Chou, this volume) do however, cause significant differences in the quality and quantity of light reaching different zones. A major effect of highly sedimented waters is the compression of faunistic zones on reefs (Goh & Chou, in press; Titlyanov & Latypov, 1991). Zonation of non-scleractinians in Singapore is also light dependant and compressed, with zones separated by small vertical distances. Competition between species also plays a role in zoning patterns on Singapore reefs. This can be seen in the broad comparison of non-scleractinian and scleractinian cover (Table 1) where the latter were the dominant competitors for space at the shallower depths, although the non-scleractinians were also found at these depths (hence not limited by physical factors).

The small proportion of coralline algae at the shallow depths contrasts with recent work on the Great Barrier Reef (Klumpp & McKinnon. 1992) where coralline algae was a dominant member of the epilithic algal community in shallow water. The category, 'others' is dominant at 6m and 10m and also forms a relatively important component of the non-scleractinian community at the 0m and 3m transect. The importance of this category suggests that attempts be made to differentiate between the organisms for Singapore reefs. At least two groups of organisms have been reported to play key ecological roles on coral reefs: sea urchins (Coyer et al.. 1993; Harmelin-Vivien et al.. 1992; Robertson. 1991; Sammarco, 1980) and gorgonians (Bruce. 1970; Van den Hoek et al.. 1978). both of which are common in Singapore. A refinement of the method to include additional categories for these groups should provide a more complete ecological picture of a reef.

ACKNOWLEDGEMENTS

REFERENCES

Benayahu, Y. & Y. Loya. 1981. Competition for space among coral-reef sessile organisms at Eilat, Red Sea. Bull. Mar. Sci. 31: 514-522.

Bruce. A.J.. 1970. Report on some commensal pontoniinid shrimps (Crustacea: Palaemonidae) associated with an Indo-Pacific gorgonian host (Coelenterata: Gorgonacea). J. Zool., Lond. 160: 537-544.

Chua. C.Y.Y. & L.M. Chou. 1991. The scleractinian community of southern islands reefs. Singapore. In: A.C. Alcala (ed.). Proceedings of the Regional Symposium on Living Resources in Coastal Areas. University of the Philippines. Manila, Pp 41-46.

Chuang. S.H.. 1977. Ecology of Singapore and Malayan coral reefs - preliminary classification. Proc. 3rd. Int. Coral Reef Symp.. Miami. Florida, 1. Pp 55-61.

Coyer. J.A.. Ambrose. R.F.. Engle. J.M. & J.C. Carroll. 1993. Interactions between corals and algae on a temperate zone rocky reef: mediation by sea urchins. J. Exp. Mar. Biol. Ecol.. 167: 21-37.

Dartnall, A.J. & M. Jones. 1986. A manual of survey methods for living resources in coastal areas. Australian Institute of Marine Science.

Done. T.J.. 1983. Coral zonation: Its nature and significance. In: Barnes. D.J. (ed.). Perspectives on coral reefs. Australian Intstitute of Marine Science, Pp 107-147.

Foster. S.A.. 1987. The relative impacts of grazing by Caribbean coral reef fishes and *Diadema*: Effects of habitat and surge. J. Exp. Mar. Biol. Ecol. 105: 1-20.

Goh. B.P.L. & L.M. Chou. 1991. Coral reef-associated flora and fauna of Singapore. In: A.C. Alcala (ed.). Proceedings of the Regional Symposium on Living Resources in Coastal Areas. University of the Philippines. Manila. Pp 47-54.

Goh. N.K.C.. 1990. Taxonomy. distribution and ecology of the Gorgonacea (sub-class Octocorallia) of Singapore reefs. Unpublished B.Sc. (Hons.) thesis. Department of Zoology. National University of Singapore. 114pp.

Goh. N.K.C.. C.Y.Y. Chua & L.M. Chou. this volume. Depth related morphology of scleractinian corals on Singapore reefs.

Goh. N.K.C. & L.M. Chou. in press. Distribution and biodiversity of Singapore gorgonians (sub-class Octocorallia) - A preliminary survey. Hydrobiologia.

Goh. N.K.C. & L.M. Chou. 1992. A comparison of benthic life-form characteristics of a reef (Cyrene) nearest to and a reef (Raffles Lighthouse) furthest from mainland Singapore. In: Chou. L.M. & C.R. Wilkinson (eds.). Third ASEAN Science and Technology Week Conference Proc.. Vol. 6. Marine Science: Living Coastal Resources. National University of Singapore and National Science and Technology Board. Singapore. Pp 55-62.

Hay. M.E. & P.R. Taylor. 1985. Competition between herbivorous fishes and sea urchins on Caribbean reefs. Oecologia (Heidelberg) 65: 591-598.

Harmelin-Vivien. M.L.. Peyrot-Clausade. M. & J-C Romano. 1992. Transformation of algal turf by echinoids and scarid fishes on French Polynesian coral reefs. Coral Reefs 11: 45-50.

Klumpp. D.W. & A.D. McKinnon. 1992. Community structure. biomass and productivity of epilithic algal communities on the Great Barrier Reef: Dynamics at different spatial scales. Mar. Ecol. Prog. Ser. 86: 77-89.

Konnecker. G.. 1977. Epibenthic assemblages as indicators of environmental conditions. In: B.F. Keegan. P.O. Ceidigh & P.V.S. Boaden (eds.). Biology of benthic organisms 5. Pergamon Press. Pp 391-395.

Lane. D.J.W.. 1991. Growth of scleractinian corals on sediment-stressed reefs at Singapore. In: A.C. Alcala (ed.), Proceedings of the Regional Symposium on Living Resources in Coastal Areas. University of the Philippines. Manila. Pp 97-106.

Larkum. A.W.D... 1983. The primary productivity of plant communities on coral reefs. In: Barnes. D.J. (ed.). Perspectives on coral reefs. Australian Intstitute of Marine Science. Pp 221-230.

Lewis. S.M.. 1985. Herbivory on coral reefs: Algal susceptibility to herbivorous fishes. Oecologia (Heidelberg) 65: 370-375.

Low. J.K.Y. & L.M. Chou. this volume. Sedimentation rates in Singapore waters.

Naim. O.. 1988. Distributional patterns of mobile fauna associated with *Halimeda* on the Tiahura coral reef complex (Moorea. French Polynesia). Coral Reefs 6: 237-250.

Patton. W.K.. 1972. Studies on the animal symbionts of the gorgonian coral. *Leptogorgia virgulata* (Lamarck). Bull. Mar. Sci. 22: 419-431.

Robertson. D.R.. 1991. Increases in surgeonfish populations after mass mortality of the sea urchin *Diadema antillarum* in Panama indicate food limitation. Mar. Biol. 111: 437-444.

Sammarco. P.W.. 1980. *Diadema* and its relationship to coral spat mortality: Grazing. competition. and biological disturbance. J. Exp. Mar. Biol. Ecol. 45: 245-272.

Titlyanov. E.A. & Y.Y. Latypov. 1991. Light-dependance in scleractinian distribution in the sublittoral zone of South China Sea Islands. Coral Reefs 10: 133-138.

Tun. K.P.P.. 1994. Productivity of reef flat organisms in a sediment stressed environment. Unpublished B.Sc. (Hons.) thesis. Department of Zoology. National University of Singapore. 76pp.

Van den Hoek, C., Breeman, A.M., Bak, R.P.M. & G. van Burt. 1978. The distribution of algae, corals and gorgonians in relation to depth, light attenuation, water movement and grazing pressure in the fringing coral reef of Curacao, Netherlands Antilles. Aquatic Botany 5: 1-46.

Wilkinson, C.R., 1983. Role of sponges in coral reef structural processes. In: Barnes, D.J (ed.), Perspectives on coral reefs. Australian Intstitute of Marine Science, Pp 263-274.

Wulff, J.L., 1984. Sponge-mediated coral reef growth and rejuvenation. Coral Reefs 3: 157-164.