# THE SCLERACTINIAN COMMUNITY OF SOUTHERN ISLANDS' REEFS, SINGAPORE

C.Y.Y. Chua and L.M. Chou
Department of Zoology, National University of Singapore
Kent Ridge, Singapore 0511

**The scleractinian community of Singapore's southern islands has been studied at two patch reefs and three fringing reefs, to determine the variations in hard coral cover and diversity. The use of the depth-specific 100-m line transect throughout these surveys has indicated that the live scleractinian cover at the upper reef slope ranges from 23.50% to 62.00% with a diversity of up to 42 genera per 100 m. At the lower reef slope, the live scleractinian cover was drastically reduced to a maximum of 13.96% with a diversity of 24 genera per 100 m. It was found that on the lower reef slopes, the predominant hard coral growth form was massive, whilst those at the upper reef slope were mainly foliose, encrusting and massive.**

## INTRODUCTION

Coral reefs found in Singapore are mainly located on offshore islands south-west of the mainland. Recent reclamation works on the mainland and the offshore islands have led to changes in the physico-chemical factors that are essential for coral growth (Chou 1987). Prior to 1986, quantitative studies were conducted using the perpendicular-to-shore one-meter belt transect method (e.g., Chou and Teo 1985, Chou and Wong 1985). These studies have shown that the live coral cover on both the reef flat (0.6-2.2%) and lower reef slopes were low but in contrast, the upper reef slopes were richer in coral growth (39.4-73.3%).

Under the "Coastal Living Resources Project" (ASEAN-Australia Cooperative Programme on Marine Science), surveys have been carried out since 1986 at five reefs using a rapid survey method. This paper is aimed at describing the diversity and variation in hard coral cover at both the upper and lower reef slopes zones from these surveys.

## MATERIALS AND METHODS

The depth-specific 100-m line transect method (Dartnall and Jones 1986) was employed in all the surveys. Lifeforms were classified using the system based on their structural attributes (Bradbury and Young 1981). Data collected were stored using dBASE III plus program and processed using the LIFEFORM.EXE programme. A total of five reefs were surveyed, three of which were fringing reefs and two were patch reefs (Table 1).Two sites were established on each reef and line transect surveys were carried out on both the upper reef slopes (3 m) and lower reef slopes (10 m) at the following reefs : Pulau Hantu, Pulau Semakau, Raffles Lighthouse, Hantu West and Cyrene Reefs (Fig. 1). Besides placing the benthic lifeforms into broad taxonomic categories, scleractinia were identified to species level where possible.

## RESULTS

The results of the surveys carried out on the upper reef slope (3 m) are shown in Table 2. The

In: A.C. Alcala (ed.) Proceedings of the Regional Symposium on Living Resources in Coastal Areas. University of the Philippines, Manila, pp. 41-46 (1991)

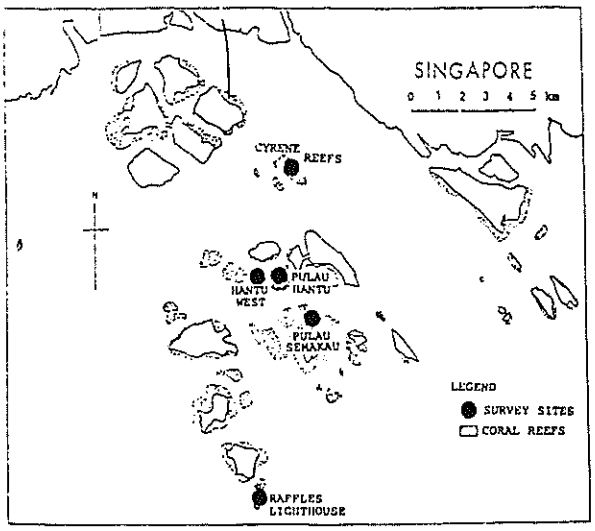


**Figure 1.** Map of the offshore islands of Singapore and their accompanying reefs.

live scleractinian cover ranged from 23.50% to 62.00%. The highest cover was located at Hantu West site 1 (HW1) while the lowest was at Cyrene site 1, (C1). The average cover throughout the ten stations was 41.90%. The dominant hard coral growth form at the upper reef slope (3 m) was foliose (18.51%), followed by encrusting (8.91%) and massive (6.70%). The only acroporid morphological form recorded was the branching type (0.18%). The live scleractinian diversity on this portion of the reef was 42 genera per 100 m (pooled results from all sites). Cyrene site 2 (C2) had the highest diversity (22 genera) while that of Hantu West site 2 (HW2) had the lowest (14 genera). Table 3 shows that the genera most widespread and found in all ten stations were *Pachyseris, Pavona, Merulina* and *Pectinia*, the latter being the most dominant. Those that occurred in at least nine of the ten sites were *Montipora, Porites, Platygyra* and *Euphyllia*. *Montipora* was dominant at three sites (R1, R2, HW2), *Merulina* at C2 and HW1, *Pectinia* at S2 and S1, and *Pavona* at H1 and H2. Diploastrea was dominant at only one site of Cyrene (C1). The contribution of acroporid corals to the live coral cover was insignificant at this depth.

At the deeper reef slopes (10 m), in contrast to the upper slope, the live scleractinian cover ranged from 0% to 13.96% (Table 4). The highest cover (13.96%) was found in the middle of the survey area at Hantu West site 2 (HW2) while the lowest was recorded at the periphery of the survey area (0% at R1, C2 and S2). The average percentage cover at this depth for all the surveyed sites was 3.09% and a total of 24 genera was recorded. The more widespread genera found at this depth were recorded at only four sites: *Pachyseris* and *Fungia* at H1, H2, HW1 and HW2; and *Dendrophyllia* at C1, R1, HW1 and HW2. In terms of areal cover, *Fungia* was more dominant than the other two. *Tubastrea* occurred at three stations (C1, R1, R2). Besides *Tubastrea* which was dominant at two sites (R1, R2), the rest of the sites were each dominated by a different genus: *Pectinia* (H1), *Mycedium* (HW1), *Goniastrea* (C1), *Favia* (HW2), *Podabacia* (S1) and *Fungia* (H2). The predominant growth forms were massive (1.19%), encrusting (0.57%) and free-living (0.49%). No live acroporid corals were found at this depth at all stations surveyed.

Coral colony occurrences ranged from 36(C1) to 186(R2) at 3 m and from 0 (C2, S2, R1) to 27

**Table 1. Location and type of reefs surveyed.**

| REEF | Type | Geographical Location |
|---|---|---|
| CYRENE | Patch | 1° 15'N, 103° 45'E |
| P. HANTU | Fringing | 1° 13'N, 103° 45'E |
| HANTU WEST | Patch | 1° 14'N, 103° 45'E |
| P. SEMAKAU | Fringing | 1° 13'N, 103° 46'E |
| RAFFLES LIGHTHOUSE | Fringing | 1° 10'N, 103° 45'E |

Table 2. Lifeforms cover at 3-m depth of reef slope and average coral cover at each reef and its relative distance from the mainland.

| Reef | Site | Lifeforms cover (%) Live coral | Average coral | Dead coral | Dead coral recent | Distance from land (km) |
|---|---|---|---|---|---|---|
| Cyrene | 1 | 23.50 | | 22.84 | - | 4.0 |
| | 2 | 48.06 | 35.78 | 2.00 | - | 4.5 |
| P. Hantu | 1 | 27.66 | | 11.69 | - | 7.5 |
| | 2 | 46.23 | 36.95 | 4.13 | - | 7.5 |
| Hantu West | 1 | 62.00 | | 8.79 | - | 7.5 |
| | 2 | 13.96 | 48.96 | 10.03 | 0.28 | 7.5 |
| P. Semakau | 1 | 42.09 | | 9.82 | - | 9.0 |
| | 2 | 59.72 | 50.91 | 17.32 | 0.32 | 10.0 |
| Raffles | 1 | 28.65 | | 23.50 | - | 15.0 |
| Lighthouse | 2 | 45.20 | 36.93 | 33.56 | 0.06 | 15.0 |

(HW1) colonies at 10 m. Figure 2 shows a size-frequency distribution of the live coral colonies found at all sites. A vast majority of the colonies (48.17% at 3 m depth and 75.63% at 10 m depth) was found to be small, measuring less than 25 cm across.

## DISCUSSION

The lowest coral cover was recorded at the site nearest the mainland and the highest was recorded farther away at the Hantu West site 1, 7.5 km from the mainland. However, the farthest reef at Raffles Lighthouse 15 km away from the mainland showed a reduced live coral cover. This may be due in part to its proximity to the busy shipping lanes of large marine vessels. Waves in the wake of passing vessels probably increased the turbidity of the water in this exposed reef. Areas with the highest live coral cover (HW1 and S2) are constantly flushed by strong tidal currents within the surrounding narrow channels. However, the trends in coral cover of the lower reef slopes (10 m) are not correlated with the distance from the mainland. The low coral cover did not allow for a good comparison between sites.

At every site, the coral cover on the deeper reef slopes was found to be always lower than that of the upper reef slope. The average cover at 3 m was 41.90% and only 3.09% at 10 m. The sediment trap experiments showed that turbidity was high at 10 m depths (20 mg/cm$^2$/d), and the reduced light penetration appears to have a dampening effect on coral growth and diversity. On the other hand, the relatively higher coral cover (23.50-62.00%) and high generic diversity at the upper reef slopes are comparable to those found in clearer waters, such as Apo Reef, Philippines (Ross and Hodgson 1981).

Acroporid corals were poorly represented, with a maximum percentage cover of only 1.15%, at Raffles Lighthouse and were recorded only at four stations. The percentage of dead coral cover was always higher at the deeper reef zone than at the upper reef zone. This would indicate the importance of light penetration for corals. Recently dead corals were scarce at all transects, tending to confirm earlier reports that the corals in these reefs have adapted to the physico-chemical conditions (Chou 1987).

Table 3. Generic richness and total colony number of all surveyed sites.

| Reef | Site | Depth (m) | Generic Richness | Dominant Genus | Colony Number (All Genera) |
|---|---|---|---|---|---|
| | | 3 | 21 | *Diploastrea* | 36 |
| Cyrene | 1 | 10 | 4 | *Goniastrea* | 12 |
| | | 3 | 28 | *Merulina* | 126 |
| Cyrene | 2 | 10 | 0 | | 0 |
| | | 3 | 22 | *Pavona* | 89 |
| P. Hantu | 1 | 10 | 2 | *Pectinia* | 3 |
| | | 3 | 26 | *Pavona* | 130 |
| P. Hantu | 2 | 10 | 10 | *Fungia* | 20 |
| | | 3 | 27 | *Merulina* | 162 |
| Hantu West | 1 | 10 | 11 | *Mycedium* | 27 |
| | | 3 | 14 | *Montipora* | 102 |
| Hantu West | 2 | 10 | 7 | *Favia* | 15 |
| | | 3 | 26 | *Pectinia* | 123 |
| P. Semakau | 1 | 10 | 7 | *Podabacia* | 11 |
| | | 3 | 22 | *Pectinia* | 129 |
| P. Semakau | 2 | 10 | 0 | | 0 |
| Raffles | | 3 | 16 | *Montipora* | 89 |
| Lighthouse | 1 | 10 | 3 | *Tubastrea* | 0 |
| Raffles | | 3 | 21 | *Montipora* | 186 |
| Lighthouse | 2 | 10 | 2 | *Tubastrea* | 4 |

Hard coral growth forms at the upper reef slopes were predominantly foliose (18.51%). The steep inclination and soft substratum of the reef slopes may have affected the growth morphology of the live corals. The predominant acroporid growth form was branching. The rapid growth rate of this morphological form may have contributed to its dominance. At the lower reef slopes, however, massive forms dominate (1.19%) although not to the same extent as foliose growth forms in the upper reef slope. The reduced light penetration may also be responsible for the predominance of the foliose growth form. The dominant genera (*Montipora, Pectinia, Merulina)* are mainly foliose. The large surface area of these foliaceous corals (as compared to the other types of growth forms) may promote enhanced photosynthesis by zooxanthellae, resulting in more vigorous growth. Another fact which may help to explain the dominance of foliaceous growth forms is the location of survey sites in sheltered waters. Foliaceous forms are known to thrive in such protected conditions.

The coral species composition was heterogeneous at all sites and no one genus was dominant at any one site. Differences in physico-

Table 4. Lifeforms cover at 10-m depth of reef slope and average coral cover at each reef and its relative distance from the mainland.

| Reef | Site | Lifeforms cover (%) Live coral | Average coral | Dead coral | Dead coral recent | Distance from land (km) |
|---|---|---|---|---|---|---|
| Cyrene | 1 | 4.53 | | 40.82 | - | 4.0 |
| | 2 | - | 2.27 | 29.29 | - | 4.5 |
| P. Hantu | 1 | 0.35 | | 1.09 | - | 7.5 |
| | 2 | 5.49 | 2.95 | 5.75 | - | 7.5 |
| Hantu West | 1 | 4.01 | | 43.28 | 0.50 | 7.5 |
| | 2 | 13.96 | 8.99 | 35.19 | - | 7.5 |
| P. Semakau | 1 | 2.48 | | 11.42 | 0.90 | 9.0 |
| | 2 | - | 1.24 | 0.16 | - | 10.0 |
| Raffles | 1 | 3.78 | | 10.37 | - | 15.0 |
| Lighthouse | 2 | 1.00 | 0.05 | 31.95 | - | 15.0 |

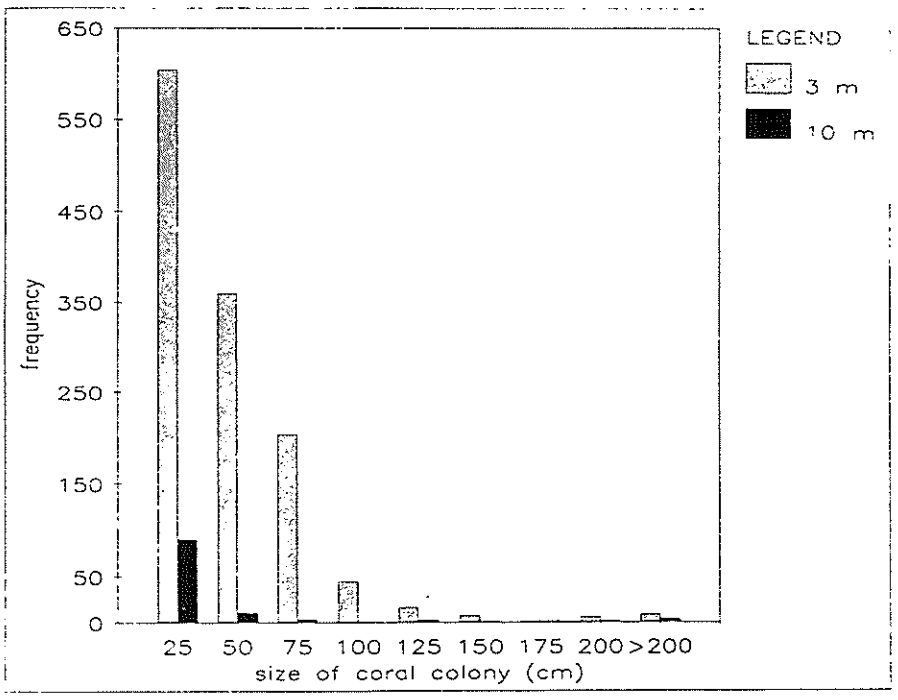


**Figure 2.** Size-frequency distribution for live coral colonies.

chemical factors among the survey sites may be a cause of such heterogeneity. For example, Cyrene Reef station 2 which had the highest generic diversity (28 per 100 m), is washed by strong tidal currents because of its proximity to a patch reef which helps to support a better coral colony (Chou and Koh 1986).

Contrary to Hill (1973) who claimed that much of Singapore reefs were already dead or dying, our findings indicate that the living scleractinia have tolerated many changes in their environment enabling them to thrive on the upper reef slopes. Efforts are underway to conduct similar studies at the reef crest and at a depth of 6 m in order to establish firmly the hypothesis.

## ACKNOWLEDGEMENTS

The "Living Resources in Coastal Areas with Emphasis on Coral Reefs and Mangroves" Project (ASEAN-Australia Cooperative Programme on Marine Science) is funded by the Australian International Development Assistance Bureau. Singapore's participation is coordinated by the Science Council of Singapore. The reef surveys were carried out by the Reef Ecology Study Team of the Department of Zoology, National University of Singapore.

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