

CORAL REEF-ASSOCIATED FLORA AND FAUNA OF SINGAPORE

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The percentage cover and distribution of reef-associated flora and fauna on two patch reefs and three fringing reefs south of Singapore were studied. Survey techniques involved the use of 100 m line transects placed at depths of 3 m and 10 m from reef crests, at two different locations for each study site. Algae made up an average 16.9% of the total benthic cover at the upper (3 m) reef slopes and 22% at the lower (10 m) reef slopes. The main proportion of algae observed was found growing on dead coral. These coral surfaces may serve as substrata affecting the distribution of algae within the reef. Non-scleractinian fauna which included alcyonaceans, gorgonaceans, sponges, zoanthids, tunicates, echinoderms and other reef organisms covered 3.8% of the 100 m transects at the upper reef slope and 7.2% at the 10 m depth.

INTRODUCTION

Early reports on the reef communities of Singapore covered, in some detail, fauna and flora found on reef flats including associated organisms (Chuang 1961, 1973, 1977). Two recent studies on reef-associated organisms dealt with the crustacean and piscean symbionts of branching corals (Goh 1987), and the echinoderm fauna (Lim 1987). However, no comprehensive study of entire reef ecosystems encompassing both qualitative and quantitative aspects of the distribution of reef organisms have been carried out in Singapore. Previous investigations into the community structure of reefs south of Singapore mainland have only covered the Scleractinia in great detail.

This study, which began in April 1986 as part of the ASEAN-Australia Coastal Living Resources Project, aims to identify (in broad taxonomic categories), as well as quantify (in terms of percentage cover) the flora and fauna living in the reefs fringing three islands and two patch reefs south of Singapore. The investigation is part of a benthic lifeform survey programme, encompassing all major macrobenthic groups found in coral reefs, namely the hard corals, algae, non-scleractinian fauna (for example, soft corals, sponges,

Zoanthidae and others), and abiotic components. Both upper (depth of 3 m from reef crest) and lower (10 m) reef slope communities were surveyed using 100 m depth line transects.

STUDY AREAS

A total of five reefs south of Singapore mainland were selected as sites for ongoing studies. Cyrene reef (1°5'N, 103°45'E) and another reef west of the island Pulau Hantu, assigned the name Hantu West (1°13'N, 103°44'E), are patch reefs with their reef flats exposed at low spring tides. The other reefs surveyed are fringing reefs surrounding the islands of Pulau (P.) Hantu (1°13'N, 103°45'E), Pulau (P.) Semakau (1°12'N, 103°45'E) and Pulau (P.) Satumu, better known as Raffles Lighthouse (1°10'N, 103°45'E). Two sample locations were allocated for each reef. The location of the reefs under study are shown in Figure 1.

MATERIALS AND METHODS

The depth-specific 100 m line transect method described in Dartnall and Jones (1986) was used to sample reef communities at depths of 3 m and

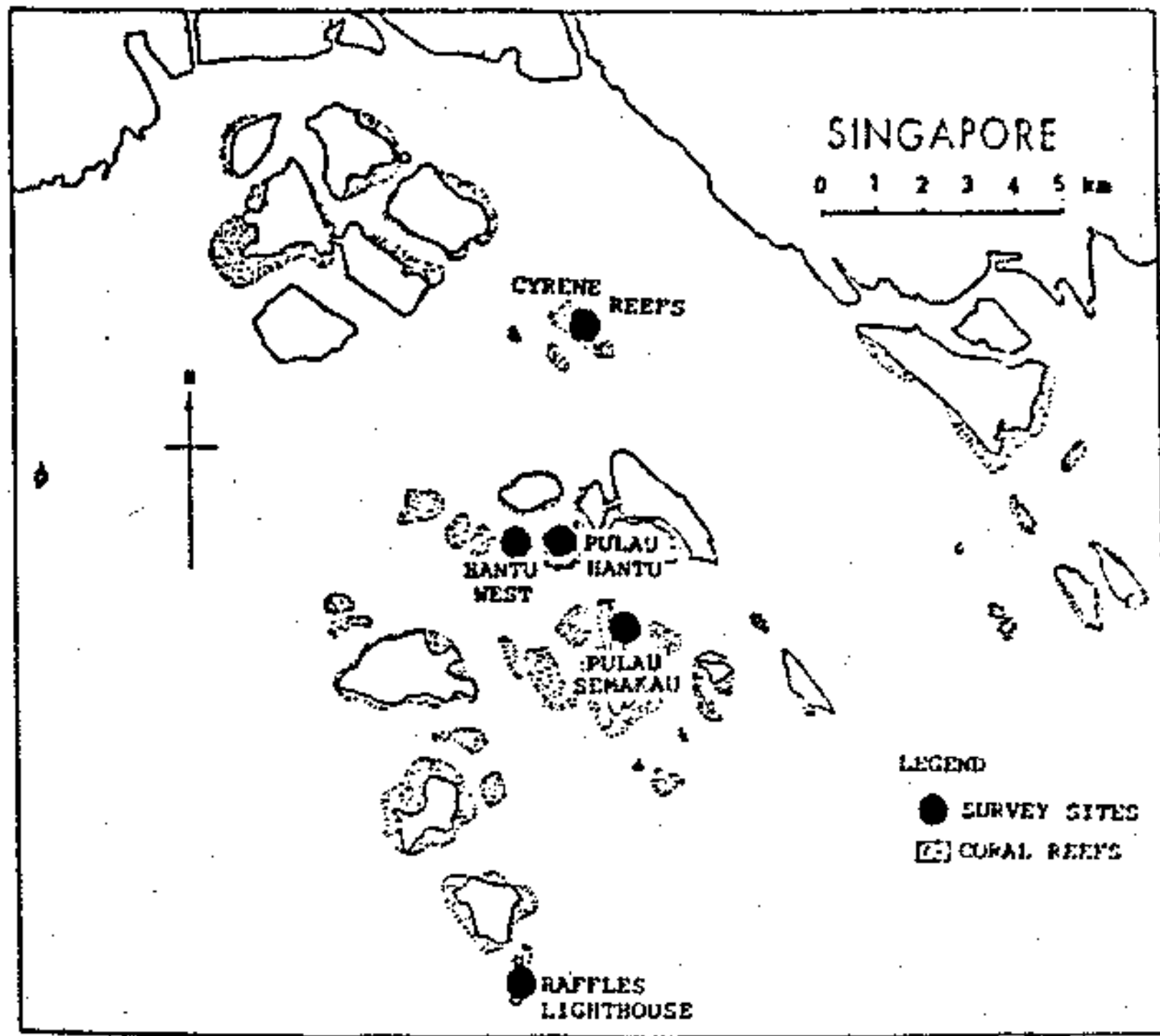


Figure 1. Map of the southern islands of Singapore showing survey sites.

10 m from the reef crests. The LIFEFORM.EXE software recommended for use in the ASEAN-Australia project and later modified by Matammu (1988) was employed in the analysis of data. The plants and animals observed were identified and classified into broad taxonomic categories.

RESULTS

The percentage cover of all benthic lifeforms sampled at the upper (3 m) and lower (10 m) reef slopes is shown in Figures 2 and 3, respectively.

Algal cover increased with depth at the two patch reefs. At Cyrene, the algal cover increased one and a half times from 26.29% at 3 m to 40.82% at 10 m at the first survey site and nine-fold (3.58% at 3 m to 33.09% at 10 m) at the second site. At Hantu West, a five-fold (8.79% at 3 m to 43.28% at 10 m) and a 3.5-fold (10.13% at 3 m to 35.19% at 10 m) increase was observed at survey sites 1 and 2, respectively. The percentage cover of algae at all fringing reefs was higher at the upper reef slopes as compared to the lower reef slopes.

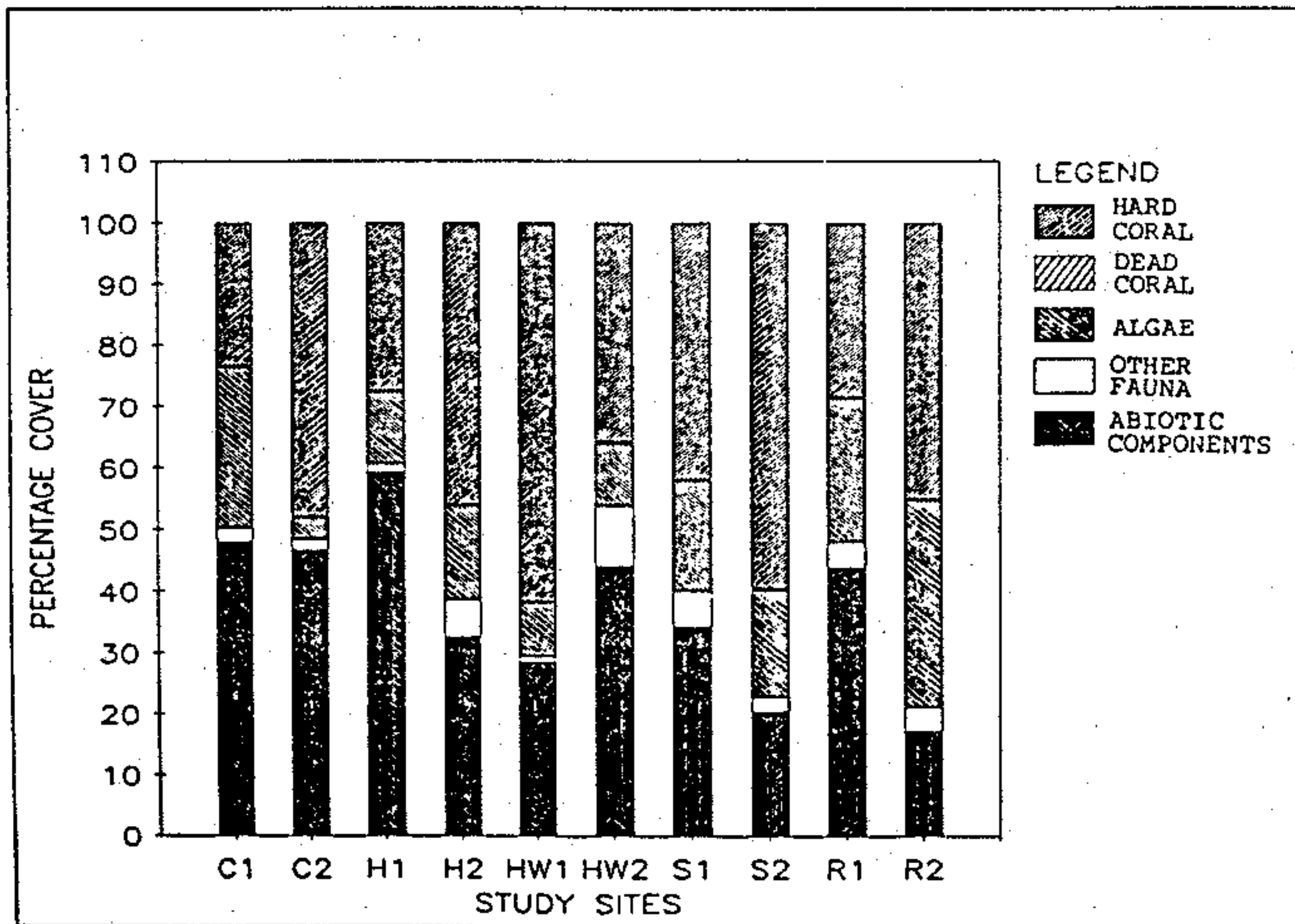


Figure 2. Percentage cover of benthic lifeforms at 3 m.

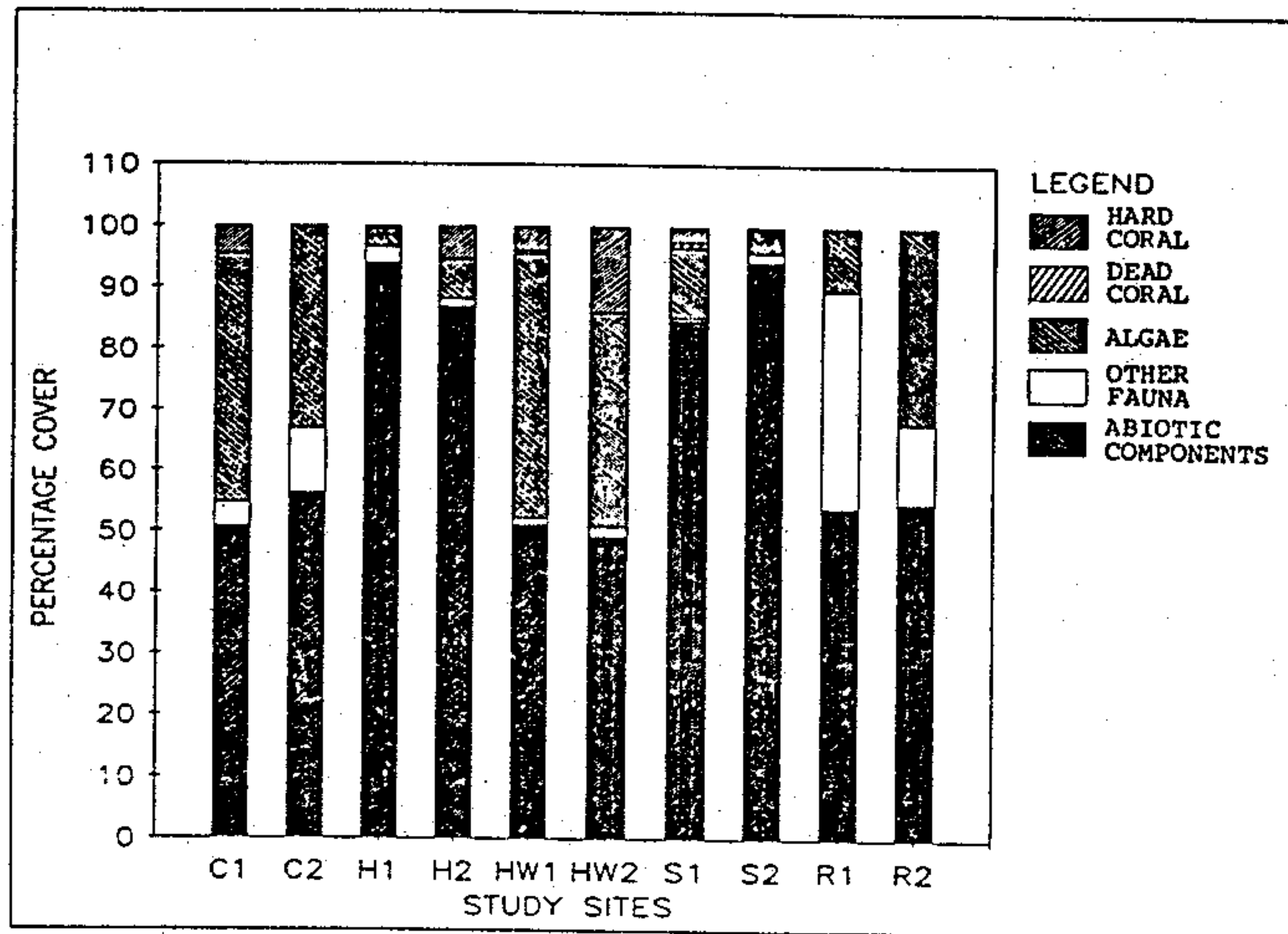


Figure 3. Percentage cover of benthic lifeforms at 10 m.

Algal percentage cover was highest (43.28%) at the 10 m depth transect of the Hantu West 1 site and lowest (3.12%) at the lower (10 m) reef slope transect at P. Hantu 1 (Fig. 3). The average percentage cover of the algal component at all five reefs was 16.9% at the upper reef slopes and 22% at the lower reef slopes.

The percentage compositions of each algal component at the two transect depths are shown in Figures 4 and 5. The bulk of algal coverage was represented by algae growing on dead coral surfaces. In particular, the algal cover at the upper reef slopes of Hantu West 1, P. Semakau 2 and Raffles 1 (Fig. 4), and the lower reef slopes of Cyrene 1, Hantu West 1 and 2, P. Semakau 1, and Raffles 1 and 2 (Fig. 5) were entirely made up of the primary algal colonisers of dead coral surfaces.

Fleshy macroalgae belonged to the genera *Sargassum* and *Padina* (in smaller quantities) and covered very small areas at the upper reef slopes of Cyrene 1, P. Hantu 1, Hantu West 2, P.

Semakau 1 and Raffles 2. Similarly, minute quantities of turf algae were recorded at the upper reef slopes of Cyrene 1, P. Hantu 2, Raffles 2 and the lower reef slopes of P. Hantu 1 and P. Semakau 2.

The percentage covers of coralline algae and *Halimeda* were also insignificant, with coralline algae occurring in small quantities in the upper reef slopes of P. Hantu 2 and P. Semakau 1, and the lower reef slopes of P. Hantu 1 and P. Hantu 2. *Halimeda* occurred at the 3 m depth transect of P. Semakau 1 and the 10 m depth transect of P. Hantu 1. Algal assemblages made up of a variety of different kinds of algae were recorded only at Cyrene, P. Hantu and P. Semakau. Apart from the component made up of algae colonizing dead coral surfaces, these other algal groups do not apparently make up a significant percentage of the total reef surface cover.

Percentage cover of the non-scleractinian fauna of the reefs under study ranged from 35.64% at the lower reef slope of Raffles

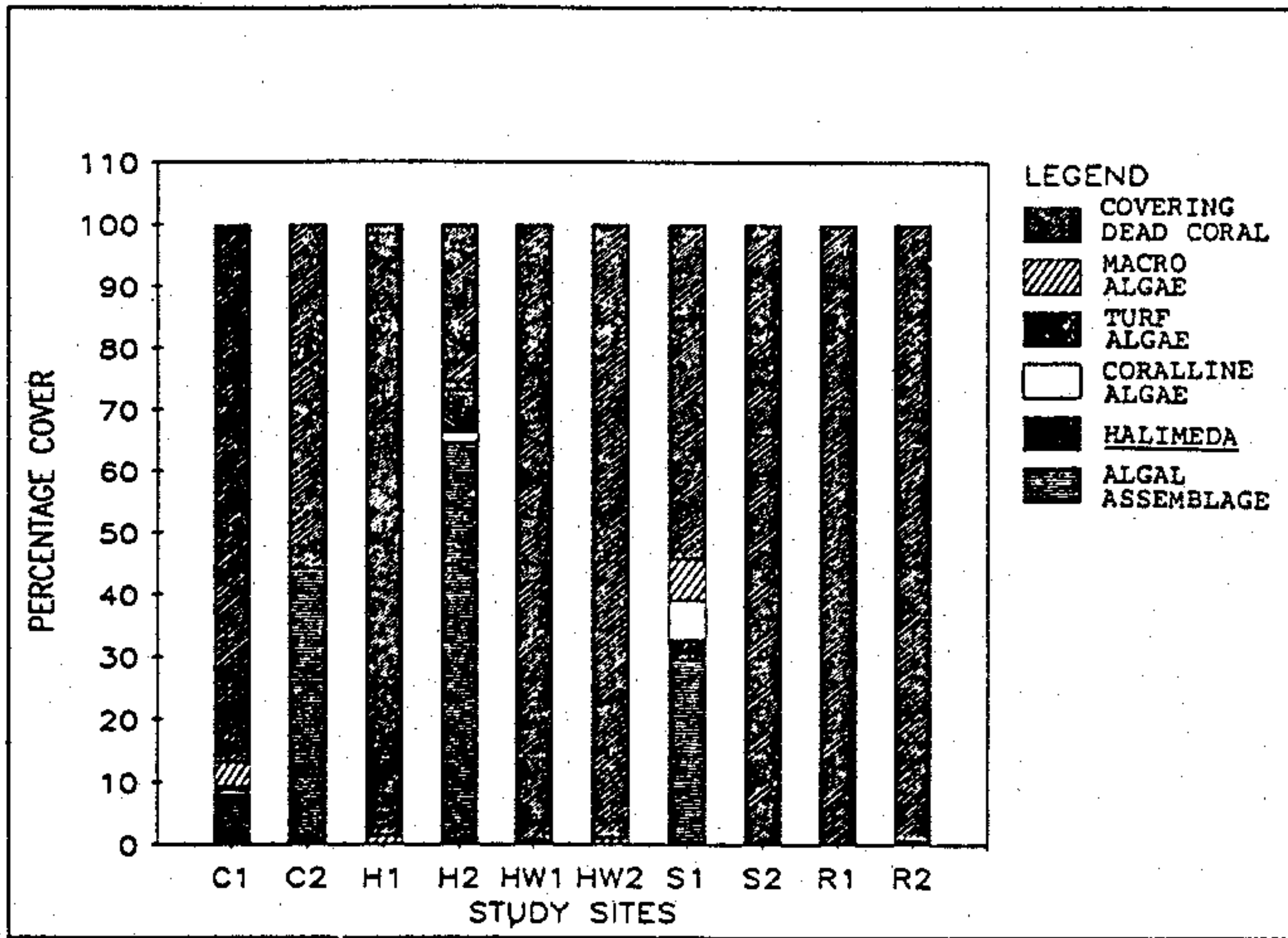


Figure 4. Percentage composition of algal components at 3 m.

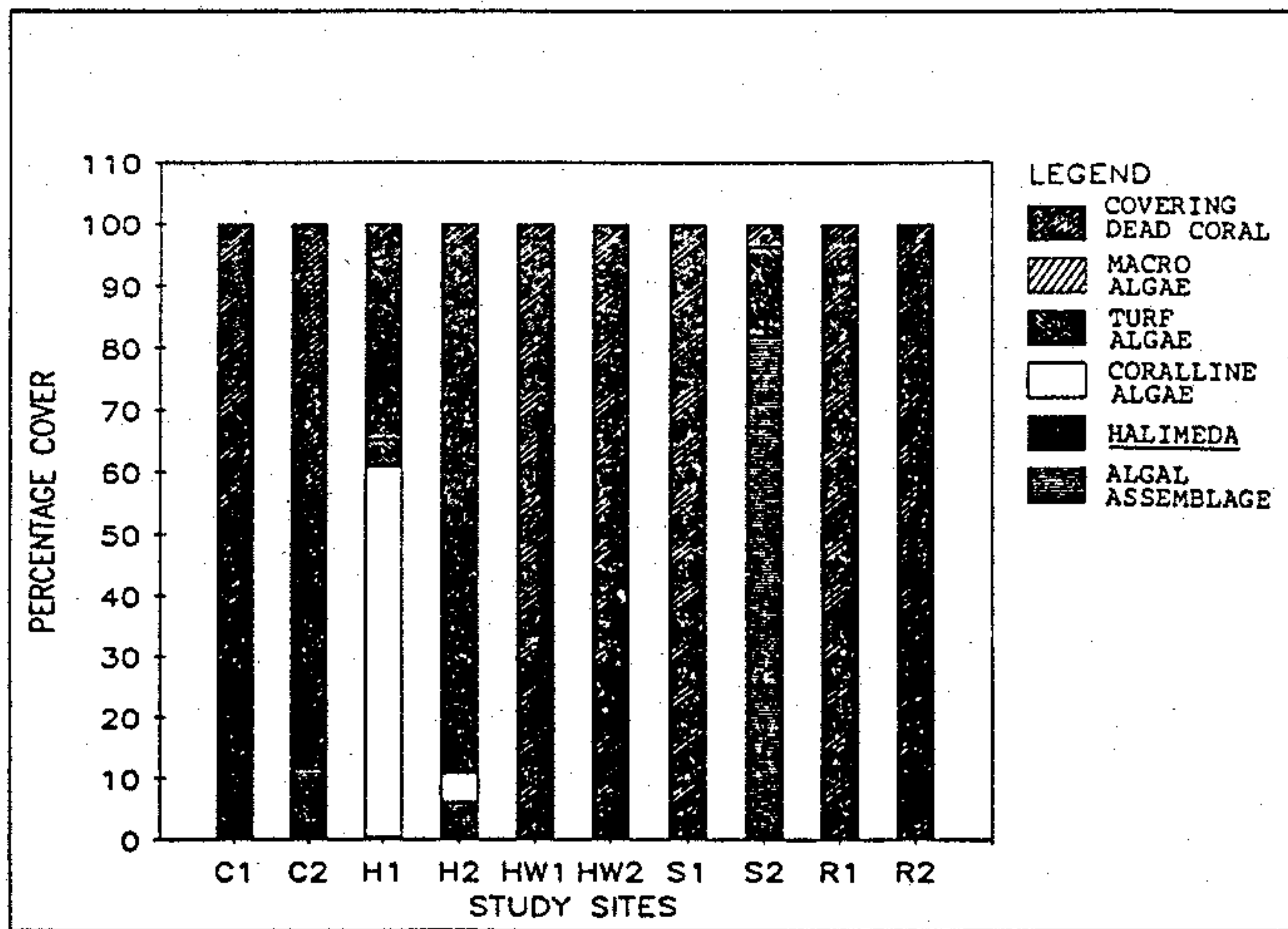


Figure 5. Percentage composition of algal components at 10 m.

Lighthouse 1 to 0.49% at the 10 m depth transect of P. Semakau 1 (Figs. 2 and 3). More realistically, the mean percentage cover of the non-scleractinia at all reefs was 7.2% at the upper reef slopes sites and 3.8% at the lower sites.

The non-scleractinians of the reefs were further categorized into smaller, albeit broad taxonomic groups, namely the soft corals (O. Alcyonacea), Porifera, Zoanthidea, and a larger group ("others" or "OT") into which the remaining percentage of the non-scleractinia was placed. This category included actinians, ascidians, the echinoid *Diadema* sp., the asteroid *Culcita* sp., crinoids, the polychaete *Sabella* sp. and other Sabellidae, hydroids and gorgonaceans.

The percentage compositions of the different components making up the non-scleractinian fauna at the upper and lower reef slopes are presented in Figures 6 and 7.

A large proportion of the non-scleractinian cover was represented by the large "OT" group. The few exceptions include the soft coral cover at the lower reef slopes of Cyrene 2 and Raffles 1 and the upper reef slopes of Hantu West 2, and the sponge cover at the 3 m depth transects of Cyrene 2 and 10 m depth transects of Cyrene 1, Hantu West 2 and P. Semakau 1. Soft corals observed were mainly of the genus *Stenularia* while sponges encompassed encrusting, branching and solitary colonies such as *Petrosia* sp..

DISCUSSION

Algal cover at the five Singapore reefs studied is apparently dependent upon the presence of uncolonized space within the reefs. The increase in algal cover made up of primary algal colonizers at the 10 m transect depths at the two patch reefs strongly indicate the availability of dead coral sur-

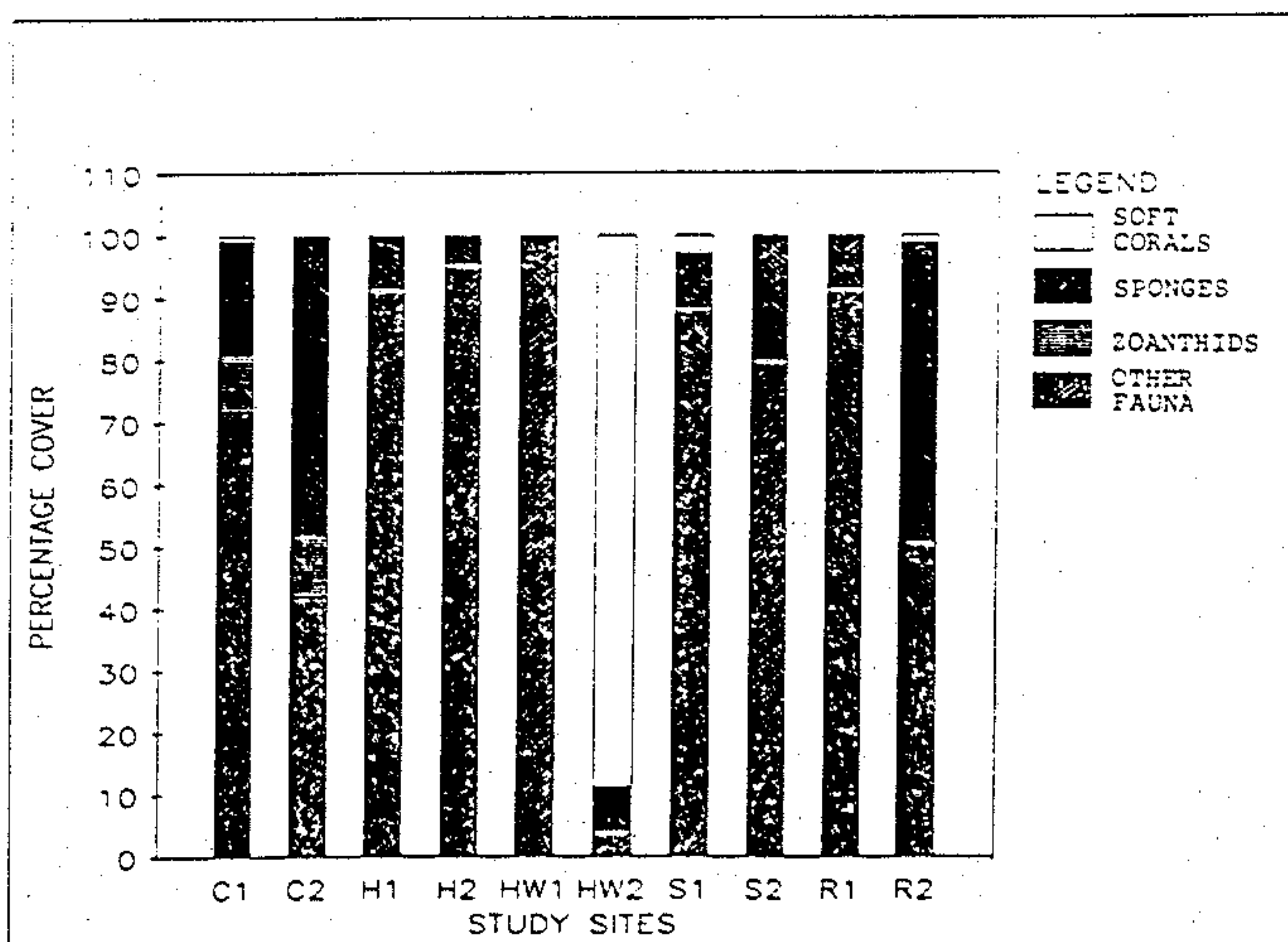


Figure 6. Percentage composition of non-scleractinian fauna at 3 m.

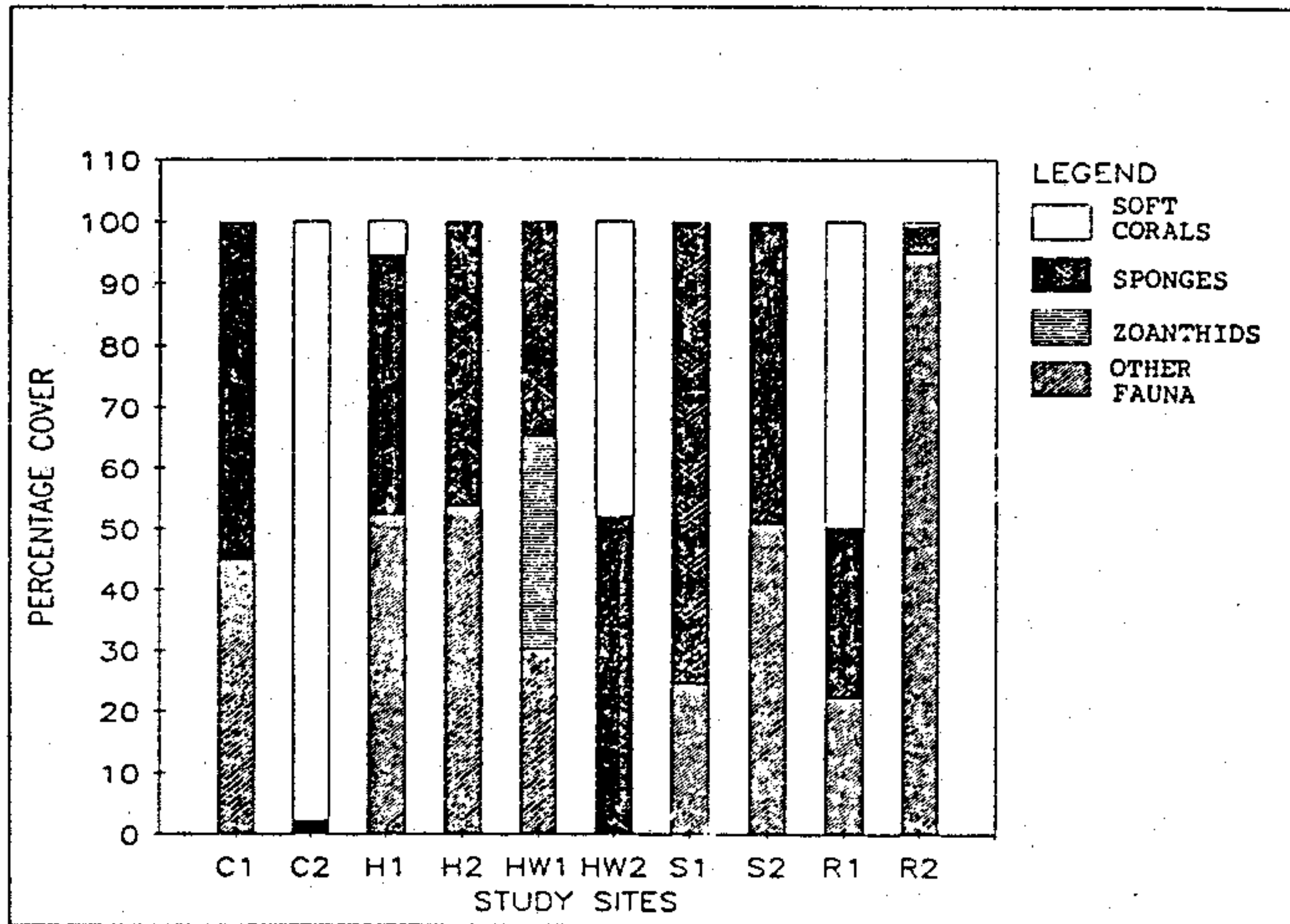


Figure 7. Percentage composition of non-scleractinian fauna at 10 m.

faces. At all other sites except Raffles 2, percentage algal cover corresponding to dead coral surfaces decreased at the lower reef slopes. At Raffles 2, percentage algal cover remained relatively constant (33.78% at 3 m, 31.95% at 10 m).

Chou (1987) stated that poor coral cover and high percentages of dead coral at the 10 m depths of four reefs south of Singapore mainland may be attributed to the reduction in light penetration due to the high sedimentation level in Singapore's waters. The observations concerning algal coverage on the two patch reefs may indicate that the lower reef slopes originally supported high percentages of hard coral communities that were smothered by sedimentation caused by more than two decades of land reclamation activities. This was apparently not so at the fringing reefs, where algal cover decreased with depth. It may be that the topographies and profiles of these fringing reefs do not allow as high percentages of hard coral coverage at their lower reef slopes as the patch reefs. However, this needs further investigation.

The percentage cover of the non-scleractinian fauna of the reefs studied was not apparently significant at the upper and lower reef slopes, apart from the 10 m depth transects of Cyrene 2 and Raffles 1 where soft corals mainly represented the 10.67% and 35.64% of non-scleractinian coverage, respectively. Although the non-scleractinian fauna of Singapore's reefs represent a small proportion of the total reef cover only, it is believed to play a significant role in the reef ecosystem through the many inter-specific interactions. Research into this field is forthcoming.

The depth specific line transect method used in this study gives a fair representation of the sessile lifeforms on the reef. It does not, however, fully describe the distribution of free-living lifeforms (a large proportion of which are organisms inhabiting coral reefs), especially if their distribution patterns are patchy. Examples of such organisms would be the echinoderms, crustaceans and molluscans which inhabit crevices and cavities. Lim's (1987) study on the distribution of the echinoderm fauna of Singapore reefs

revealed a patchy but wide distribution of the sea urchin, *Diadema setosum*. In this study, however, the species was only recorded at the P. Hantu fringing reef and the upper reef slopes of P. Semakau and Raffles Lighthouse. Additional quadrats and belt transects used to quantify free-living, non-scleractinian fauna in particular, may complement the present line transect method.

In summary, the flora of the upper and lower reef slopes of Singapore's reefs is made up entirely of algae. Percentage cover of this algal component is more significant at the lower reef slope than the upper and is composed mainly of early algal colonizers of dead coral surfaces. The non-scleractinian fauna, though apparently not significant in terms of percentage cover, is believed to be an important component of the reef ecosystem. A survey method incorporating the use of the line and belt transects, and quadrat methods could possibly give a more accurate quantitative representation of reef organisms with patchy distributions.

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 within the framework of the ASEAN-Australia Economic Cooperative Programme. 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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