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Environmental Effects on the Distribution of Corallimorpharians in Tanzania

This study examined the distribution and abundance of corallimorpharians (Cnidaria, Anthozoa) in Tanzania in relation to different aspects of the coral reef environment. Five reefs under varying degrees of human disturbance were investigated using the line intercept transect and point technique. Corallimorpharian growth and the composition of the substratum were quantified in different habitats within reefs: the inner and middle reef flat, the reef crest, and at the 2 and 4 m depths on the reef slope. Corallimorpharians occurred on all the reefs and 5 species were identified: *Rhodactis rhodostoma*, *R. mussoides*, *Ricordea yuma*, *Actinodiscus unguja* and *A. nummiforme*. *R. rhodostoma* was the dominant corallimorpharian at all sites. Within reefs, they had the highest densities in the shallow habitats. While *R. rhodostoma* occurred in all habitats, the other corallimorpharian species showed uneven distributions. Corallimorpharians ranked second, after scleractinian coral, in percent living cover. Results from this study suggested that corallimorpharians benefitted from disturbance compared with other sessile organisms. They preferred inhabiting areas with dead coral, rock and rubble whilst live coral was avoided. There was a positive relationship between percent cover of corallimorpharians and water turbidity and they dominated the more disturbed reefs, i.e. reefs that were affected by higher nutrient loads and fishing.



Figure 1. Map of the study area.

INTRODUCTION

Corallimorpharians (Cnidaria, Anthozoa) are coral-like anthozoans that resemble actiniarian sea anemones in that they do not have a calcareous skeleton (1). However, they are more similar to scleractinian corals in most other aspects of their morphology. Corallimorpharians lack basilar muscles, may have tissue connections between adult polyps, lack ciliated tracts on their mesenterial filaments, and have cnidae that are similar to those of corals (1–4). They are present in most coral reef areas of the world and appear alone or in colonies, and are able to cover large parts of a reef (1, 3, 5–10). As space is a limiting factor on reefs, corallimorpharians have developed various strategies for competition including the ability to kill corals, to reproduce asexually and to move across the substratum (7–18).

Depending on water quality and other environmental factors, the distribution of corallimorpharians within a reef may vary. They are known to withstand harsh conditions such as being exposed to air during low tides, which can give them an advantage in shallow waters (10). In addition, corallimorpharians have been reported to be able to proliferate in areas with high nutrient loads and plankton populations while corals generally prefer clear water (19–23). Further, Spiegel (24) noticed that high nutrient loads had a positive effect on corallimorpharians reproduction while such changes in water content may reduce coral growth (25, 26). Thus, conditions that may be unfavorable to other reef organisms may favor the corallimorpharians. In addition, corallimorpharians are efficient in establishing themselves on shallow reefs degraded by destructive fishing or other disturbances. Consequently, they may effectively prevent coral settlement (10, 16, 17), and competitively exclude reef-building corals, especially those in the families Acroporidae, Pocilloporidae and Poritidae (13, 27). As corallimorpharians are able to withstand various disturbances that influence the reef environment, human disturbances could work in their favor.

Since 1996, the abundance of corallimorpharians appears to have increased on coral reefs in Tanzania (28). This could be the result of increased human disturbances from, e.g. sewage loads and fishing activities. The 1998 coral bleaching event in the region (29–32) further disturbed reefs as it resulted in massive coral mortality, possibly favorable to the distribution of corallimorpharians. Not only did it open up space, but corallimorpharians may also be more resistant to increased temperatures (24), which was the primary cause of the coral bleaching event 1998 (31).

The aim of this study was to examine how the distribution and abundance of corallimorpharians in Tanzania is influenced by habitat characteristics and environmental disturbance.

MATERIALS AND METHODS

Study Sites

The study was conducted in October and November 1999 on 5 coral reefs in Tanzania that were influenced by disturbance to varying degrees (28, 33–36) (Fig. 1). All sites were located on patch or island reefs, which generally experience calm sea conditions. Three reefs were at Zanzibar Island, Unguja, while 2 reefs were near the mainland coast close to Dar es Salaam. The reefs at Zanzibar Island were situated at various distances from Zanzibar Town. The Changuu reef was closest to Zanzibar Town (6 km) and received a higher nutrient load than the other reefs at Zanzibar (26, 28, 37, 38). The Bawe reef was 7 km away from town, and did not receive the same high concentrations of nutrients as Changuu. Both these reefs were fished, which was not the case for the third reef examined at Zanzibar, the Chumbe reef, which is a marine protected area 13 km south of Zanzibar Town (Chumbe Island Coral Park: CHICOP) (33, 35, 36). The study sites near the city of Dar es Salaam were the Bongoyo and Mbudya reefs. The Bongoyo reef is nearer the city (6 km) than the Mbudya reef (10 km). The sewage and other wastes from

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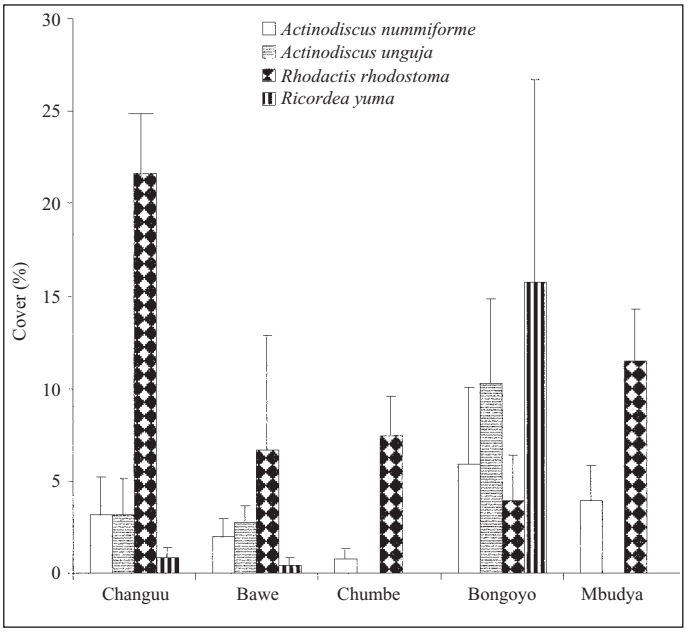


Figure 2. Percentage cover of the 4 common corallimorpharian species at each site.

the city of Dar es Salaam are carried towards these reefs by the predominantly northward East African coastal currents and hence result in increasing nutrient pollution levels (39). The reefs are also influenced by sedimentation from rivers. Furthermore, these reefs are important tourist and fishing sites, and thus affected by motor boat traffic (40).

Field Methods

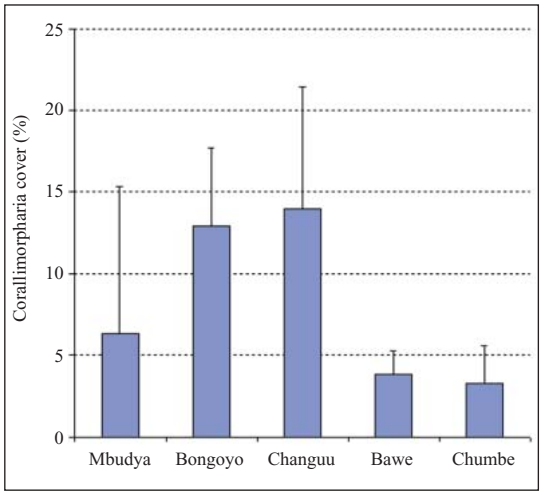
The abundance and distribution of corallimorpharians, scleractinian corals, and other benthic organisms were assessed using a combination of the line intercept transect technique (41) and the line intercept point method (33, 34, 42). At each study site, five 20-m long transects were deployed horizontally in each of the following 5 reef zones: the inner reef flat; the middle reef flat; the outer reef crest; and at the 2 and 4 m depths on the outer reef slope. Along each 20-m line transect, 5 points were randomly selected and a 2-m line-intercept transect (1 m on each side) was set perpendicularly. Thus, a total of 10 m was examined within each 20-m long transect. The types of living organisms and substrates observed to be in contact with corallimorpharians along the transects were recorded, according to categories in English et al (41). Species of corals were identified according to the method by Veron (43). Corallimorpharian species were identified at the Natural History Museum of Leiden, The Netherlands, in consultation with J.C. den Hartog.

Water visibility was estimated at each site using a Secchi disk (41). The level of sediment resuspension was classified as high when the substrate at the base of the reef was composed of silt (fine and easily resuspended particles), and as low when the substrate was composed of nonresuspendable sand particles. A medium class was a mixture of the 2 particle sizes.

Data Analyses

The differences in corallimorpharians cover among reefs were analyzed using the 1-way ANOVA and the Student-Newman Keuls test (SNK) (44). Assumptions of ANOVA were met in terms of normality and homogeneity of variances. The latter was confirmed using the Cochran's C test ($p > 0{,}05$). The Friedmans test was used to compare differences among reef habitats. The habitat preference by corallimorpharians was evaluated using the Strauss (45) selectivity index (L) and the Spearman rank order correlation (46) was used to establish the relationship between corallimorpharian abundance and water clarity.

Figure 3. Mean percentage cover of Corallimorpharia.



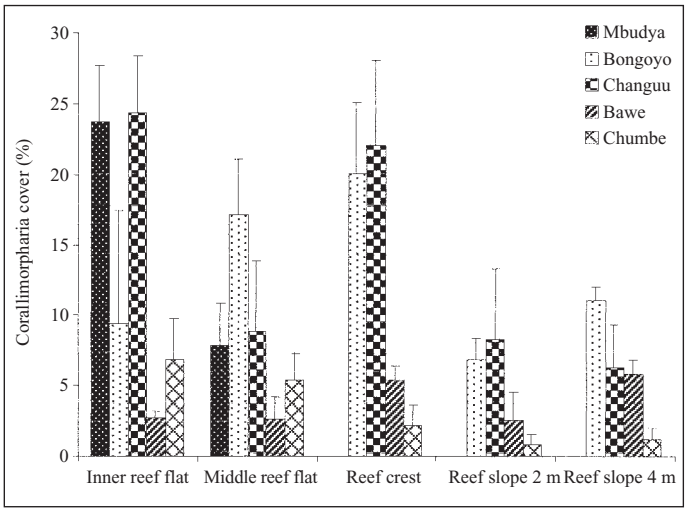


Figure 4. Percentage cover of Corallimorpharia at different depth levels at each site.

RESULTS

Corallimorpharians occurred on all the reefs. Five species were identified: *Rhodactis rhodostoma*, *R. mussoides*, *Ricordea yuma*, *Actinodiscus unguja* and *A. nummiforme*. All of them occurred at the Changuu, Bawe, and Bongoyo reefs. On the Bongoyo reef, all of the species made a relatively high contribution to the cover (Fig. 2). The number of species at Chumbe and Mbudya were limited to 2 (*A. nummiforme* and *R. rhodostoma*). *R. rhodostoma* was the dominant corallimorpharian at all sites (3.4% on reef slope; 10.9% on reef flat).

The cover of corallimorpharians varied significantly among reefs (ANOVA $F(4, 128) = 2.92$, $p < 0.05$) and it was found that the Bongoyo and Changuu reefs had a significantly higher percent cover of corallimorpharians than the Bawe and Chumbe reefs (SNK test; Fig. 3). The Mbudya site did not differ significantly from any other site (SNK test; Fig. 3). The corallimorpharians were not uniformly distributed among the reef habitats surveyed (Friedman's test, χ^2 $r = 9.25$, $DF = 4$, $P < 0.05$). A higher percent cover of corallimorpharians was observed on the reef crest and reef flat than on the reef slope at the 2-m and 4-m depths (Fig. 4). While *R. rhodostoma* occurred in all habitats examined, *A. nummiforme* was observed mostly on the reef slope. *A. unguja* was distributed from the reef crest to the reef slope and *R. yuma* on the flat.

The benthic category with the highest percent cover at all reef sites was the scleractinian corals, followed by the nonliving substrata (i.e. rock, rubble, and sand), dead coral, Corallimorpharia

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and algae (Fig. 5). Other benthic categories (e.g. soft corals and sponges) covered less than 1% of the substratum. Corallimorpharians ranked second, after stony coral, in percent cover of live benthic forms.

Corallimorpharians were found growing on or in contact with dead coral, rock, live scleractinian corals, dead coral, rubble, and soft coral. Scleractinian coral species that were in mesenterial contact with corallimorpharians included *Acropora* spp., *Porites annae*, *P. cylindrica*, *P. lobata*, *P. lutea*, *P. nigrescens* and *Pavona* spp. The corallimorpharians were not in contact with all benthic categories with equal frequency (Friedman test: (χ^2r = 9.25; DF = 4; P < 0.0001)). Corallimorpharian contacts were not proportional to the relative abundance of the benthic category types. The Strauss (1979) selectivity index (L) indicated that corallimorpharians preferred inhabiting dead coral (L = 0.18) and rock and rubble combined (L = 0.14), whilst live coral was either avoided or not present (L = –0.27) (Table 2). The percent cover of corallimorpharians was significantly negative correlated with water clarity (Spearman Rank correlation: r = –0.9, p < 0.05; Table 1).

DISCUSSION

This study examined the composition of corallimorpharian communities on 5 coral reefs in Tanzania influenced by different degrees and types of disturbance. Corallimorpharians occurred on all reefs with a total of 5 species encountered. Overall they were the second most dominant living cover following stony corals. However, their cover varied among reefs with the highest densities on the more disturbed reefs in turbid nutrient-rich waters.

The reefs within the marine sanctuary had the lowest cover of Corallimorpharia and together with the Bawe reef, the clearest waters. The 2 reefs with the highest abundances of corallimorpharians, the Bongoyo and Changuu reefs, had the lowest visibility and the highest readings of sediment resuspension. At Bongoyo, the poor visibility was caused by the vicinity to Dar es Salaam and its sewage effluents, the river input from the adjacent seasonal rivers as well as the frequent passage of motorboats near the reef. At Changuu, the suspended solids originated from land sources, especially the Zanzibar municipal sewage discharge system, which also increased the nutrient load (26, 28, 37, 38). Opposite to corallimorpharians, turbidity and enhanced nutrient loads are generally stressful to stony corals, which may give corallimorpharians a competitive advantage, (19–21, 47, 48).

In addition to showing high tolerance to turbidity, corallimorpharians have been noted to withstand higher temperatures (24). There are indications that the corallimorpharians have increased in abundance in Tanzania over the last few years (28). Long-term trends from other studies suggest that the abundance of corallimorpharians may increase with time as reef degradation continues (17, 24). In Tanzania, an important factor, influencing corallimorpharian densities, could be the 1998 coral bleaching event, which was induced by extraordinarily high temperatures that resulted in large-scale coral mortality (29–32).

The distribution of the corallimorpharians within the reefs further indicates that they are successful in withstanding conditions that could be stressful to corals. The highest cover of corallimorpharians was found on the shallow reef flat and reef crest. Similar results have been observed in other studies (10, 16). The reef flat areas are particularly susceptible to natural disturbances such as exposure to air and direct sunlight as well as a range of human impacts including sewage outlets (19–21) and artisanal fishing (35, 49, 50). Disturbance on coral reefs opens up space and corallimorpharians may be successful in competing for such areas. In this study, they preferred inhabiting flattened dead coral and rock and rubble combined. In other studies, they have also been noted to grow on dead coral and rock by forming large aggregations that hinder the recruitment of stony corals (10). Indeed, the corallimorpharians have developed mechanisms to occupy such areas, including the formation of large colonies of polyps sustained by asexual reproduction through fission and budding (10, 14, 15, 28, 51).

Obviously, corallimorpharians seem to have competitive advantages over many other benthic sessile organisms in being able to proliferate in environments that diverge from average conditions. In addition, they can also be strong competitors in the battle for space by direct agonistic suppression. In this study, corallimorpharians were observed to be in direct contact with living coral colonies. Closer observations showed that colonies of *Porites* spp. and *Acropora* spp. that were in contact with corallimorpharians had their contact edges bleached implying that they were stressed. Studies elsewhere have shown that corallimorpharians tend to negatively affect scleractinian coral (27), sometimes by overgrowing and killing them. They use marginal tentacles with powerful nematocysts (13, 16, 27), and may also employ mesenterial filaments, which secrete digestive enzymes (11, 13, 17, 18, 48). Among the species of corallimorpharians encountered in this study, *Rhodactis rhodostoma* was abundant on all surveyed reefs. This species is known to possess powerful mechanisms for the monopolization of space (52). Traits such as the capacity to reproduce asexually, to be mobile (24) and to damage neighboring organisms (16, 27) are successful strategies in the struggle for space (12).

In conclusion, results from this

Figure 5. Percentage of benthic community categories in surveyed reefs.

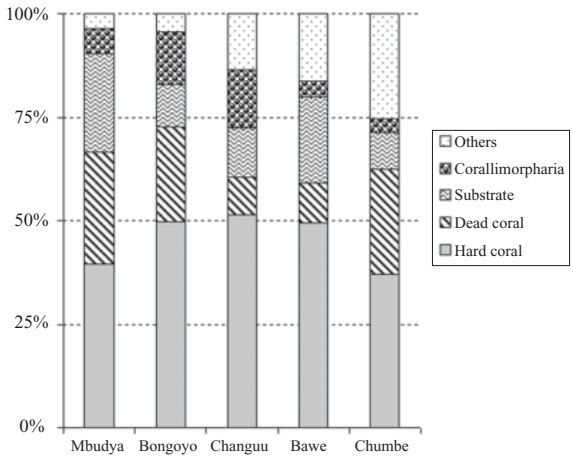


Table 2. Proportions of corallimorpharians in contact with benthic categories (R), the relative contribution of the benthic categories (all sites pooled) (P), and the Strauss (45) Linear selectivity index (L). NB: Selectivity index (L) values range from –1 to 1, with positive values indicating preference and negative values indicating avoidance or inaccessible; Dead coral = dead coral + dead coral with algae; ns = L not significant from 0; * = significant; ** = very significant.

	R	P	L = R-P	L = 0
Hard coral	0.184	0.455	-0.271	**
Dead coral	0.372	0.189	0.183	*
Rock and rubble	0.339	0.203	0.136	*
Algae	0.004	0.045	–0.041	ns
Soft coral	0.100	0.005	0.095	ns
Sponges	0.000	0.008	–0.008	ns
Others	0.000	0.014	–0.014	ns

Table 1. Water visibility (Secchi disk reading), sediment resuspension levels, and corallimorpharian cover on surveyed reefs in Tanzania.

Site	Secchi disk (m)	Sediment resuspension	Corallimorpharia (%) cover
Changuu	3.3	High	14.0
Bawe	10.5	Low	3.8
Chumbe	10.5	Low	3.3
Bongoyo	3.0	High	12.9
Mbudya	4.8	Medium	6.3

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study suggest that corallimorpharians may have competitive advantages in water conditions that are stressful to corals. One factor that seemed to be an important determinant in corallimorpharian presence was water turbidity and nutrient content. There are also reasons to believe that the 1998 coral bleaching event had a positive effect on the populations of corallimorpharians. Reefs with high densities of corallimorpharians were also affected by other disturbances such as fishing. In addition, the corallimorpharians were strong aggressors in the struggle for space by attacking corals. Thus, their abilities to proliferate in poor water conditions and their capacity to occupy substratum opened up by physical disturbance as well as their aggressive behavior can make corallimorpharians successful on disturbed coral reefs.

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53. This study was supported by CORDIO (the Coral Reef Degradation in the Indian Ocean project) and the Sida/SAREC Bilateral Marine Science Programme between Sweden and Tanzania for research in marine zoology (Sida = Swedish International Development and Cooperation Agency). We appreciate the field assistance provided by E. Evans, M.N. Mohammed and J. Katomanga. The Director of the Institute of Marine Sciences in Zanzibar provided SCUBA equipment used in the surveys. Logistical support was also given by the Department of Zoology and Marine Biology, University of Dar es Salaam, as well as the Kunduchi Fisheries Institute. We also acknowledge J.C. den Hartog for advice in identifying corallimorpharian species and K. Bergman, N.E Chadwick-Furman, M. Gullström and M.D. Richmond for comments on the manuscript.

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