

# THE ROLE OF ALGAL COVER IN DETERMINING CORAL ABUNDANCE AT VARYING DEPTHS ON A NORTH JAMAICAN FORE REEF

Kimberly A. Isaacs, Jon A. Rettman, John J. Stachowicz and Stacey A. Wooley

**Abstract.** Between 23-28 February 1992 coral and algal abundance at depths of 20', 40', and 60' were quantified at mooring 1, Discovery Bay Marine Laboratory, Jamaica. Significantly more *Lobophora variegata* and *Dictyota* spp. were found at 40' than at 20' and 60'. These algae were found to be responsible for most coral overgrowth. *Sargassum* spp. were most abundant at 20' and *Halimeda* spp. at 60'.

Corals were divided into six morphological categories. Mound and brain corals were significantly more abundant at 20' while branching and leaf corals were significantly more abundant at 60'. Total coral abundance was greatest at 60' as well. Although no significant patterns of algal overgrowth were established, mound corals seemed to exhibit the greatest evidence of algal encroachment. In support of our hypothesis, coral abundance decreased as algal cover increased.

The fate of the reef may be controlled by the future of herbivore populations. If the niche left by *Diadema* can be filled, palatable algal species should decrease and coral abundance may be restored. (SAW, KAI)

## INTRODUCTION (SAW)

Coral reefs are known to belong to the most productive natural ecosystems in the biosphere (Westlake 1963). Species diversity and abundance is great on coral reefs where competition for space and resources is intense. Overgrowth of one organism by another is common, and grazing impact seems to mediate the structure of the algal community (La Barre and Coll 1982).

In conjunction with grazing are many other factors affecting the coral reef community. Herbivory, disease, fishing pressures and invasions or extinctions of species have been shown to be important processes affecting the structural dynamics of many biological environments, and coral reefs are no exception (Woodley, et al. 1981). These processes continually affect this system, interacting with each other and the community.

Unpredictable patterns of disturbance and subsequent regeneration are the crux of species diversity. Devastating events such as recurrent hurricanes and *Diadema antillarum* mass mortality promote high diversity among species competing for space on the Jamaican coral reef. Such disturbances can cause a rearrangement of the benthic community, resulting in algal blooms and aberrations in coral diversity and relative abundance. Monopolization of space is prevented by these radical changes in the allocation of special resources, helping to maintain species diversity (Hughes 1989).

Competition between coral and algal species can also shape the community. The ability of corals to withstand high wave action may be secondary to their susceptibility to algal overgrowth, depending on the depth at which the coral is found. Algae are generally considered important competitors for space with scleractinian corals, and there is

substantial evidence that algal encroachment can limit settlement of coral larvae as well as limit coral growth (Potts 1977). Sediment entrapment and algal overgrowth may even kill certain corals (Potts 1977; Sammarco 1982).

Morphological characteristics of scleractinian corals may give a good indication of their vulnerability to external pressures and their susceptibility to overgrowth by algae. Coral growth forms include flat leaf coral, tall pillar coral, branching staghorn coral, smooth or undulating mound coral and dome shaped brain coral. All types can be found at depths offering enough protection from wave action while still allowing them to utilize the greater light intensities of the shallower depths. In any case, corals of all shapes and sizes encounter varying algal species at varying depths.

Algae must combat herbivory at all depths, especially sea urchin grazing in the shallow reef areas. Algae may be characterized by their chemical and structural defenses—leathery forms as in *Lobophora variegata* and *Dictyota* spp. and calcareous forms as in *Halimeda* spp. We noticed differences in algal cover at different depths at mooring one. We wondered if coral cover and algal cover would differ with depth? Also, are different coral morphologies more susceptible to algal overgrowth?

Given the fact that the percent cover of corals on shallow and exposed fore reef sites on the north coast of Jamaica was drastically reduced following hurricane Allen in 1980 (Woodley, et al. 1981), and that a subsequent algal bloom corresponding to the mass mortality of the sea urchin *D. antillarum* has drastically altered

this reef community, we predict the following:

1. Algae abundance will be lowest and bare substrate will be common where herbivory is highest.
2. Coral abundance will be highest where algae cover is lowest.
3. Flat leaf coral morphologies will be more susceptible to algal overgrowth than other coral morphologies (Hughes 1989).

## METHODS (KAI)

This study was conducted at the Discovery Bay Marine Laboratory on the north shore of Jamaica. All data were collected from successive depths of 20, 40, and 60 feet southwest of M1 (Mooring 1) on the fore reef of Discovery Bay. Data were collected twice daily from 23 February 1992 to 29 February 1992.

Reef coverage was sampled by setting out 1m x 1m grids that had been subdivided into 100 (10cm x 10cm) squares. These grids were placed at 10 random locations on the reef along each depth gradient. The substrate present in each square was then recorded on a corresponding grid on an underwater slate. Four major types of algae were identified by genus: *Dictyota* (AD), *Halimeda* (AH), *Sargassum* (AS), and *Lobophora* (AL); all other types of algae were simply recorded as A0. The corals present were grouped into six classes based on morphology: Brain (CB), Mound (M), Staghorn or Branching (CS), Leaf (CL), Flower (CF), and Pillar (CP). Any barren sand in the area was noted (S), and coral rubble (R) uncolonized by algae was also recorded. Other

organisms such as sponges, urchins, and anemones were noted. If a square contained more than one type of substrate, the substrate type occupying the greatest area was recorded; if two substrates appeared equal (50:50) both were recorded.

We also quantified coral/algal interactions for each major class of coral at all three depths. For these observations we located four coral heads of each class at the appropriate depth, took their dimensions (length x width x height) and noted the presence of algal growth. If the coral was being overgrown, we recorded the genus of algae that was overtopping it, the percentage of perimeter coverage by that species, and the distance it encroached from the edge of the coral. Each genus of algae found on the coral was measured and recorded separately. We then noted the state of the coral under the algae: dead, bleached, or living. After these measurements were taken, an urchin census was taken of the area within a one meter radius surrounding the coral head. The species was recorded for the urchins found (*Tripneustes*, *Diadema*, or other).

#### RESULTS (JAR)

The percent cover of all four algal genera varied significantly between the three depths (Figure 1). Both *Lobophora variegata* and *Dictyota* spp. were significantly more abundant at 40 feet than at either 20 feet or 60 feet ( $\chi^2=61.98$ ,  $p<0.005$ ;  $\chi^2=94.48$ ,  $p<0.005$ ). *Sargassum* spp. were significantly more abundant at 20 feet than the other two depths ( $\chi^2=175.86$ ,  $p<0.005$ ), while *Halimeda* spp. made up a

Table 1. Percent covers of algal and coral types at depth.

Algae	% Cover at Depth			Type
	20'	40'	60'	
<i>L. variegata</i>	12.1	25.9	20.9	(AL)
<i>Halimeda</i>	6.5	11.8	27.9	(AH)
<i>Dictyota</i>	28.5	32.1	14.3	(AD)
<i>Sargassum</i>	15.3	1.2	4.0	(AS)
Other Spp.	1.2	0.9	3.9	(AO)
Total Algae	63.6%	71.9%	71.0%	
<b>Coral</b>				
Mound	8.6	3.0	3.5	(CM)
Brain	1.6	0.6	0.7	(CB)
Branching	1.0	0.7	8.7	(CS)
Leaf	1.7	1.0	3.6	(CL)
Flower	0.5	0	0	(CF)
Pillar	0	0.2	2.4	(CP)
Total Coral	13.4%	5.5%	18.9%	
<b>Other Substrate</b>				
Sand	5.0	11.5	3.7	(S)
Rubble	16.4	10.4	5.9	(R)
Total Other Substrate	21.4%	21.9%	9.6%	

significantly greater percentage of the total cover at 60 feet ( $\chi^2=190.68$ ,  $p<0.005$ ). Total algal cover was significantly higher at both 40 feet (71.9%) and 60 feet (71.0%) than at 20 feet (63.6%) ( $\chi^2=19.33$ ,  $p<0.005$ ).

Of the six coral morphology classes, two were too uncommon and not included in analyses (pillar coral and flower coral). The percent covers of the four other morphology classes varied significantly between the three depths (Table 1). Mound corals and brain corals were both significantly more abundant at 20 feet than at 40 feet or 60 feet ( $\chi^2=40.44$ ,  $p<0.005$ ;  $\chi^2=6.16$ ,  $p<0.05$ ). Both branching corals and leaf corals were significantly more common at 60 feet than 20 feet or 40 feet ( $\chi^2=121.78$ ,  $p<0.005$ ;  $\chi^2=17.6$ ,  $p<0.005$ ). Total coral cover was highest at 60 feet (18.3%) followed by 20 feet

(13.4%) and then 40 feet (5.5%). The differences between these values were significant ( $\chi^2=76.8$ ,  $p<0.005$ ). Rubble available for colonization was significantly less abundant with increasing depth (Table 1;  $\chi^2=57.15$ ,  $p<0.005$ ). At 20 feet, 16.4% of the cover was rubble versus 10.4% at 40 feet and 5.9% at 60 feet.

Casual observation of the encroachment data seemed to indicate that *Lobophora variegata* and *Dictyota* spp. were responsible for the majority of overgrowth in all coral classes. Therefore, we compared total coral cover to the sum of *Dictyota* spp. and *L. variegata* cover for all plots regardless of depth. A significant negative correlation was found ( $r=-0.787$ ,  $p<0.005$ ).

As a measure of competition between algae and coral, the encroachment distances of algae on the corals were standardized by multiplying the percent of the coral perimeter covered with algae by the measured encroachment distance. Standardized encroachment distances were then compared for each coral morphology between depths. Mound corals were significantly more overgrown at 40 feet than at 20 feet ( $t=6.78$ ,  $p<0.001$ ). No other significant relationships were found.

Comparisons were also made between the standardized encroachment distances for each coral morphology class at the same depth. At 20 feet and 60 feet, branching corals had significantly larger encroachment distances than mound corals ( $t=2.37$ ,  $p<0.05$ ;  $t=2.38$ ,  $p<0.05$ ). At 40 feet, however, this trend was reversed with mound corals having a significantly large encroachment distance than branching corals ( $t=4.76$ ,  $p<0.01$ ).

Table 2. Urchin densities at each depth.

	Number Urchins/m <sup>2</sup>		
	20'	40'	60'
<i>Tripneustes</i>	2.63	0.21	0
<i>Diadema</i>	0.21	0	0
Other	0.13	0	0
Total	2.97	0.21	0

Mound corals also had a significantly larger encroachment distance than leaf corals at 40 feet ( $t=2.78$ ,  $p<0.02$ ). No other significant relationships were found.

Urchin densities were highest at 20 feet and decreased with depth (Table 2). An average of just under one urchin per m<sup>2</sup> was found at 20 feet. Low numbers of urchins were found at 40 feet and none were found at 60 feet.

Finally, the *Lobophora* and *Dictyota* covered rubble that was placed near urchins at a depth of 20 feet, was heavily grazed, while no such grazing was observed at the other depths. Although these results are highly qualitative, this indicates that *Lobophora* and *Dictyota* are palatable genera for urchins.

#### DISCUSSION (JJS)

Each algal genus studied exhibits a specific distribution that can be explained largely by two factors: herbivory and light attenuation. Herbivory was shown to be greatest at shallow depths (20 feet) coinciding with great algal consumption and urchin density. *Lobophora variegata* and *Dictyota* spp. exhibit their lowest abundances at 20 feet despite high light levels and a relatively high percentage (16%) of available substrate. This is most likely due to more intensive

grazing by *Tripneustes* and either urchin. Both these algae reach their highest abundance at 40 feet, where urchin density is low and light levels are still fairly high. As light is attenuated at depth, *Halimeda* spp. gradually increase, displacing some of the *Lobophora* and *Dictyota*, as calcareous algae like *Halimeda* are better competitors at depth (Litter, et al. 1983). *Sargassum* spp. on the other hand are found primarily at shallow depths where grazing is most intense, as its thick leathery form makes it resistant to herbivory (Litter, et al. 1983, Pfiester, et al. 1983). Total algal cover is probably a function of urchin density, as algal cover is largest where the highest urchin densities were recorded.

Coral cover seems to be governed tightly by algal cover. However, not all genera play an equally important role in the regulation. The percentage of coral cover is most closely related to the combined cover of *Dictyota* and *Lobophora*. This pattern holds well for all coral morphologies except the branching form. This apparent anomaly may be due to the fact that this growth form is dominated by *Acropora cervicornis*, which relies heavily on fragmentation for propagation (Tunncliffe, 1981). High densities will be found where currents have carried fragmented branches, usually not too far from the parent colony. Therefore, since most of the *A. cervicornis* was smashed by Hurricanes Gilbert and Allen (Woodley, et al. 1981) it grows where it was least disturbed during these events in deeper waters. Although the present *A. cervicornis* distribution may soon be independent of algal cover, in time sexual phase reproduction should

reestablish it in areas to which it is more suited.

Both *Lobophora* and *Dictyota* form relatively dense colonies which can encrust and overtop the perimeter of coral colonies. Their high turnover rates make individual leaves disposable and therefore makes the plant as a whole less vulnerable to the effects of coral defenses such as sweeper tentacles (De Ruyter van Steveninck, et al. 1988). *Halimeda* and *Sargassum* are usually more erect species which occupy a lesser horizontal area, moving with wave action, and therefore pose less of a threat to most species of coral. In fact, qualitatively the data suggest most coral encroachment is a result of *Lobophora* and *Dictyota* competition.

The data collected regarding encroachment of algae were insufficient to make claims with statistical certainty, but some trends are apparent. Encroachment distances for both mound and brain forms very closely mirror *Lobophora* and *Dictyota* cover and these corals were most abundant where competition with these algae was least. There were no significant trends in either leaf or branching forms, so little can be said about the relationships between encroachment distance and algal cover for these groups. However, it is interesting to note that branching coral is distributed fairly randomly with respect to competition from algae (as measured by encroachment distance). It is possible that fast growing branching corals attempt to out compete algae by growing over them rather than attempting to beat back algal advance. Most bleached and dead coral of branching form was observed to occur low to the ground, and little algal en-

croachment was observed in the new sections of a branch. However, a more accurate assessment of overgrowth is necessary before trends can be firmly determined.

This could be accomplished by sampling all coral within a transect to obtain a larger and more representative sample. In addition, future studies should measure encroachment as a percentage of coral colony surface area covered by algae. However, this probably would not have helped our data due to the large standard deviations in encroachment distance.

Competition is not a static event, and showed vary with time and other factors. Ideally, encroachment should be measured by regularly photographing permanent quadrats and comparing changes in percent cover with time. To assist further researchers, we suggest that this program establish permanent plots on the fore reef to be sampled annually by FSP students. This would prove a valuable asset to both further studies and FSP students. The future of the reef may be determined by herbivore (urchin) abundance. If the empty niche left by the *Diadema* crash at 1983 can be filled by some other grazer such as the *Tripneustes*, coral numbers eventually may be restored to their prior abundances.

#### LITERATURE CITED

- Hughes, T. P. 1989. Community structure and diversity of coral reefs: The role of history. *Ecology*, 70(1), 1989, pp. 275-279.
- La Barre, S.C., J.C. Coll and P.W. Sammarco: Defensive strategies

of soft corals (coelenterata: Octocorellia) of the Great Barrier Reef. II. The Relationship Between Toxicity and Palatability. *Biol. Bull. Mar. Biol. Lab.*, Woods Hole 171, 565-576 (1986).

- Littler, M.M., D.S. Littler and P.R. Taylor. 1983. Evolutionary strategies in a tropical barrier reef system: functional groups of marine algae. *J. Phycol.*, 19: 229-239.
- Potts, D.C. Suppression of coral populations by filamentous algae within down selfish territories. *J. Exp. Mar. Biol. Ecol.*, 28: 207-216 (1977).
- Pfister, C.A. and M.E. Hay. 1988. Associational plant refuges; convergent patterns in marine and terrestrial communities result from diff. mechanisms. *Oecologia* 77: 118-129.
- Sammarco, P.W. 1982. Echinoid grazing on a structuring force in coral communities: whole reef manipulations. *J. Exp. Mar. Biol. Ecol.*, 61: 31-55.
- Tunncliffe, V. 1981. Breakage and propagation of the stony coral *Acropora cervicornis*. *Proc. Natl. Acad. Sci. USA*, 78(4): 2427-2431.
- Westlake, D.F., 1963. Comparisons of plant productivity. *Biol. Rev.*, 38: 385-425.
- Woodley, J.D., E.A. Chornesky, P.A. Clifford, J.B.C. Jackson, L.S.



Kaufman, N. Knowlton, J.C.  
Lang, M.P. Pearson, J.W. Porter,  
M.C. Rooney, K.W. Rylaarsdam,  
V.J. Tunnicliffe, C.M. Wahle,  
J.L. Wulff, A.S.G. Curtis, M.D.  
Dallmeyer, B.P. Jupp, M.A.R.  
Roehl, J. Neigel, and E.M. Sides.  
1981. Hurricane Allen's impact  
on Jamaican coral reefs. *Science*  
214: 749-755.

De Ruyter van Steveninck, E.D., L.L.  
Van Mulekan and A.M.  
Brennan. 1988. Growth  
inhibition of *Lobophora*  
*variegata* by scleractinian corals.  
*J. Exp. Marine Biology and*  
*Ecology* 115: 169-178.