DISTRIBUTION AND FORAGING PATTERNS OF *DIADEMA ANTILLARUM* ON THE FOREREEF OF DISCOVERY BAY

WENDY COVER, CHRIS DUMS, JOE GILBERTSON, AND ANDREW TOLONEN

Abstract. Diadema antillarum on the fore reef of Discovery Bay, Jamaica are distributed in distinct aggregations. These aggregations are much more common from the reef crest to a depth of 7 m below which very few aggregations were observed. Within these urchin aggregations, the levels of algal grazing by the urchins is extremely high and the substrate is nearly devoid of macroalgae. However, urchins do not disperse out of their aggregations to forage on the abundant macroalgae in the surrounding area during the day or night. Measurements of the ratio of demipyramid length to maximum test diameter showed that the *D. antillarum* on the fore reef are experiencing similar levels of food limitation to samples taken in 1970.

INTRODUCTION

Diadema antillarum (long-spined urchin) is a major herbivore in coral reef ecosystems. A severe die-off in the summer 1983 eliminated 93-99% of the *Diadema* populations all over the Caribbean. The subsequent decrease in herbivory by urchins has contributed to an increase in algae cover (Lessios 1988). The *Diadema* populations have not returned to the pre-die-off densities of 12.0-16.1 individuals/m2 (Hughes et al. 1985, Carpenter 1990), although they have rebounded somewhat from their post mortality density of 0-0.5 individuals/m2 (Swanson 1994). The *Diadema* that persist on the reef are aggregated into distinct clusters (Kaveeshwar et. al, 1995). Low densities of urchins have affected the dominant species in the algal communities. The algal community before the *Diadema* die-off consisted of 90% algal turf and 10% crustose coralline forms. As early as two months after the dieoff, macroalgae constituted 49% of algal cover, with algal turf reduced to 50% and crustose coralline forms reduced to only 1%(Carpenter 1990).

It has been proposed that a reintroduction of thousands of *Diadema* into Discovery Bay would reduce the algal abundance on the reef. Furthermore, a reduction in algae cover would increase coral recruitment and survivorship (Haley, pers. comm.). A successful reintroduction depends greatly upon the distribution, foraging, and dispersal behavior of *D. antillarum*. We investigated *Diadema* foraging behavior, and the effects of their foraging behavior on the algal communities.

Diadema are known to emerge from their daytime refuge in crevices to feed at night. In 1986, Carpenter found *Diadema* foraging ranges to be approximately 0.5-1 m2, although they were known to travel as far as 8m in one night (Carpenter 1984). Since the highest biomasses of algae are present outside the aggregations (pers. obs.) and there is potential intraspecific competition for food within the aggregations, we hypothesized that the urchins disperse from their patches at night into the areas of high algal cover to forage. We expected to find differences in height and percent cover of macroalgae between the aggregations and the surrounding areas.

We also hypothesized that *Diadema* are less food limited at present than they were in 1970 since mean urchin densities are lower and algal cover is greater in the forereef. Food limitation can be tested using a ratio of test size to the demi-pyramid length of the Aristotle's lantern (Levitan 1992). An urchin's Aristotle's lantern grows at a constant rate through its life time, while growth of the test is dictated by nutrition level. If the ratio of test diameter to demi-pyramid length is low, urchins have experienced low growth rates. These urchins are thus assumed to be more food limited than urchins with a high test diameter to demi-pyramid length ratio.

METHODS

We conducted our study on the west fore reef of Discovery Bay, Jamaica from 7-11 March, 1997. *Diadema* densities were measured along twelve randomly chosen 50 X 4 m transects along the fore reef north of Discovery Bay Marine Lab, Jamaica. Six of these transects were located between three to seven m depth, and six

at 7-10 m depth. Daytime densities of *Diadema* within aggregations were recorded in six randomly chosen aggregations.

In order to assess diurnal movement patterns of individuals occuring within large aggregations, urchins were counted during the day and in the night in four 4 m2 quadrats. Each quadrat was established at a randomly selected location within each of the six aggregations.

To compare the algal composition and structure within and adjacent to the *Diadema* aggregations we established ten transects, extending from the center of five aggregations (two transects per aggregation) in random directions. Three bolts were dropped along each transect: one within the aggregation, one at the edge of the aggregation, and one two meters outside the aggregation. Within a 900 cm2 quadrat surrounding each bolt, individual algae were identified to family, the length of the algae was measured, and the percent coverage of each type of algae was estimated.

To assess whether or not urchins can consume large macroalgae from outside the aggregation, four large rocks from outside the aggregation had their resident algal diversity, percent algal cover, and algal lengths were quantified prior to being placed in four different aggregations. The urchins were allowed to graze the algae cover from these rocks for 48 hours, after which the algae upon the rocks was assessed for any evidence of grazing.

Lastly, in order to determine whether food is a factor limiting the growth of *Diadema*, and how current levels of food stress now compare to food stress in the past, three urchins were selected from *Diadema* aggregations and dissected. The ratio of the length of the demi-pyramid to the diameter of the test (exoskeleton) was measured. This ratio has been used as an index of food limitation in a previous study (Levitan, 1992).

RESULTS

Diadema densities at 3-7 m. in the west forereef were 0.58 ± 0.18 per m2 (N=6 transects) and were 0.02 ± 0.012 per m2 (N=6 transects) at seven to ten m. depth.

In the west fore reef *Diadema* tend to aggregate in areas of high relief (with many crevices to hide in), that become highly grazed. We found mean size of *Diadema* aggregations to be 34.1 ± 7.1 m2, and mean urchin densities within these aggregations to be 2.18 ± 0.35 per m2. *Diadema* were found exclusively within these highly grazed aggregations during the day and at night, and were not found to leave the aggregations at any time. There was no difference between *Diadema* density during the day (4.75/m2 ± .73) and *Diadema* densities at night (4.875/ m2 ± .72) within the aggregations (One-way ANOVA, F=0.01, df=6, P=0.91, Fig. 1).

There were strong differences in macro-algae cover between the center of the aggregations, the edge of the aggregations, and areas two meters from the aggregations. Percent macro-algal cover was 9.4 ± 3.9 % at the center, 57.7 ± 5.9 % at the edge, and 79 ± 5.6 % two meters away from the patch of aggregated *Diadema* (One-way ANOVA, F=41.1, df=26, P=0.0000; Fig. 1). In addition, average macro algal length increased with distance from the center of the patch. Lengths were significantly different and were 2.5 ± 1.4 cm at the center, 12.5 ± 2.5 cm at the edge, and 16.4 ± 2.1 cm two m. from the patch (One-way ANOVA, F=13.2, df=26, P=0.0001; Fig. 2).

There were six algal species identified in the patch, six identified at the edge of the patch, and eight identified two meters from the patch. The two most common algal genera in terms of abundance were *Dictyota* and *Sargassum*. *Dictyota* percent cover increased with distance from the patch (One-way ANOVA, F=21.6, df=26, P=0.0000; Fig. 3), while *Sargassum* percent cover was highest at the edge of the patch (One-way ANOVA, F=12.78, df=26, P=0.0001; Fig. 2). However, there was no statistical difference between the percent cover of *Sargassum* in the edge habitat and two meters outside the patch (t=1.41, df=17, P=.1749). Both genera had lowest percent cover within the aggregations.

Although macro algae cover was lowest within the the patches, the patches did have dense coverage of young algae approximately 5mm in height. We did not identify or quantify the species of this turf-like covering, but it appeared to cover between 90 % and 100 % of the area within the patches.

In addition, algae on rocks placed in the aggregations from outside the aggregations had no visible herbivory after 48 hours. In addition, no urchins were observed feeding on these rocks at night.

Finally, we obtained a measure of urchin food limitation by comparing the ratio of demi-pyramid length to test diameter in three urchins.

This ratio was 0.3259 ± 0.0053 compared to 0.3273 ± .01786 for five urchins taken from Jamaica in 1970. This suggests that even with fewer urchins per m2 and more algal cover, *Diadema* has approximately the same food limitation now as it did prior to the *Diadema* die off of 1983.

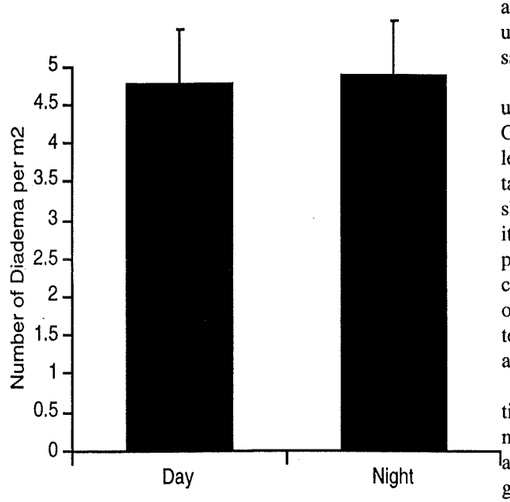

FIG 1. Density of *Diadema* in the aggregations during the day (mean ± S.E.) and during the night (mean ± S.E.).

DISCUSSION

Although algal cover and biomass were much greater outside the urchin beds than inside, we did not observe urchins dispersing into the surrounding algae to feed. We observed no urchins in the macroalgae-rich surrounding areas during the day or the night. Nor did we observe any grazing upon rocks laden with macroalgae when they were transplanted into the urchin beds. We believe that there are two possible explanations for why the *D. antillarum* are not feeding upon the macroalgae. The urchins may be able to forage upon the macroalgae but prefer to graze upon the thin film of filamentous algae that grows within their beds. Hay (1994) wrote that *D. antillarum* may prevent the growth of tall macroalgae and maintain a lush growth of algal turf within their beds via a high level of herbivory. However, it is also possible that *D. antillarum* may not disperse into the surrounding area to forage because they simply cannot feed upon the macroalgae. Adult plants of *Dictyota* and *Sargassum*, the dominant macroalgae in our sites, produce a mixture of terpenoids, acetogenins, and terpenoid - aromatic compounds that deter herbivores (Hay and Fenical 1988). These defense compounds may reduce herbivory by *D. antillarum* on adult forms of these algae. However, our data suggests that aggregating urchins are able to reduce the cover and size of these same algae.

Levitan (1992) concluded that in 1970, the urchins he sampled from Jamaica were food limited. Over-fishing of triggerfish and other urchin predators led to high urchin densities and subsequent food limitation of *D. antillarum*. However, our results did not show that *D. antillarum* are presently less food limited than they were in 1970. Although, at present, the population of *D. antillarum* is much lower and algal cover is much greater than in 1970, our measurements of the food limitation index (demipyramid length/max test diameter) showed no differences between 1970 and 1997.

In conclusion, it appears that the current population of *D. antillarum* on the forereef is isolated into many, small island communities on grazed beds amidst large areas of seemingly unpalatable macroalgae. *D. antillarum* does not disperse from these isolated aggregations to forage upon the surrounding macroalgae. Before reintroduction of *D. antillarum* is undertaken, we believe that transplant experiments are necessary to conclude whether *D. antillarum*, if confined, are able to consume *Sargassum* and *Dictyota*. If this is the case, then a plan to transplant urchins into ungrazed areas may be a promising strategy to reduce macroalgae abundance on the coral reefs of Discovery Bay.

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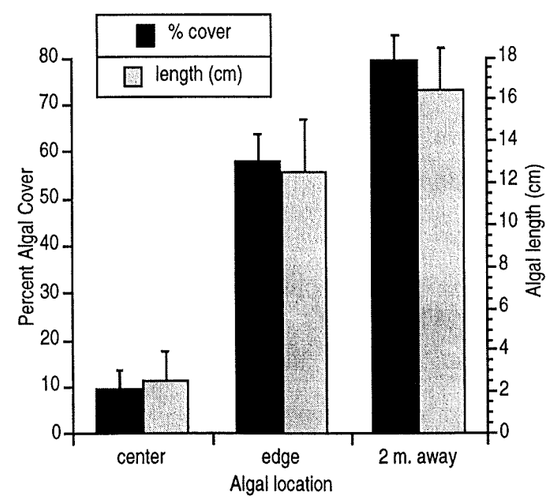

FIG 2. Macroalgae percent cover (mean ± S.E.) and macroalgae length (mean ± S.E. within, at the edge, and two m away from *Diadema* aggregations (N = 10).

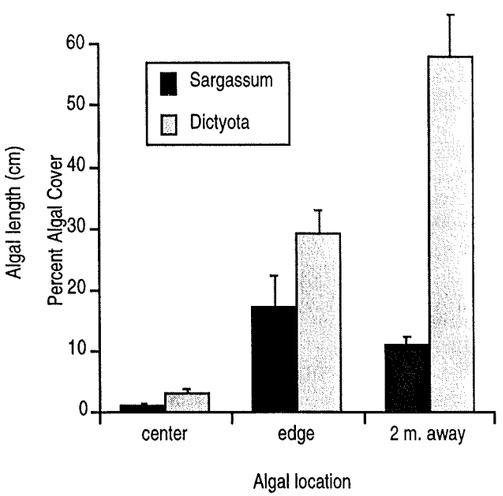

FIG 3. Percent cover (Mean ± S.E.) of Sargassum and Dictyota within, at the edge, and 2 m. away from a Diadema aggregation (N = 10).