taxa within natural and recolonized samples, and because the distributions were not the same between these two treatments.

Discussion

The defaunated algal tufts were rapidly recolonized over the four-day experiment by a different infaunal community than was present in natural samples. The magnitude of recolonization over the experimental period could not be assessed because tuft size measurements were not standardized, but the colonization process was probably not complete. Small copepods composed a higher proportion of the recolonized samples than the natural tufts, suggesting that they are among the first taxa to colonize algal tufts on the benthos. This may be due to the planktonic nature of many copepods, which often disperse into the water column, and settle later in a new location. Amphipods and isopods are generally larger organisms which do not always range so far, and some species may prefer to return to the same refuge. Alternatively, the predation risk on amphipods and isopods hiding in isolated clumps might be higher due to the greater exposed surface area. Smaller copepods could probably better take advantage of the three-dimensionality of even small tufts, and might be less affected by predation in these cases.

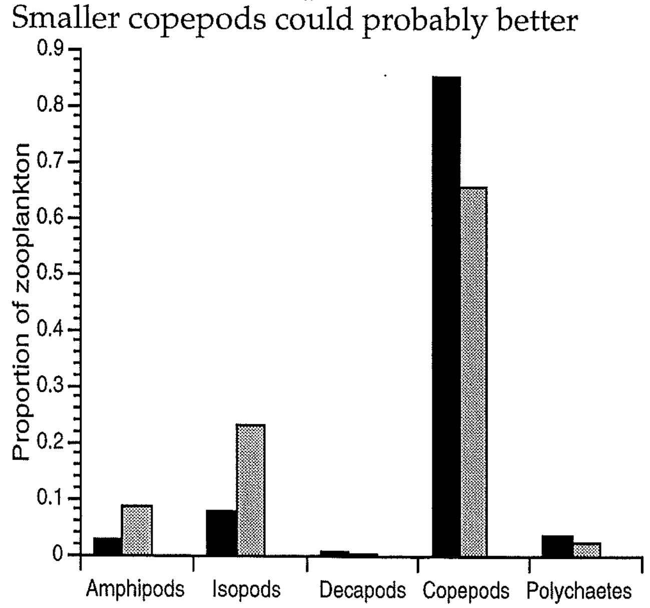

Figure 3. Relative frequency of invertebrates from day four recolonized (dark bars) and natural (light bars) algal tufts in Discovery Bay, Jamaica

The effect of the tethered and fixed treatments on species composition was minimal, as only isopods were very different between the two. Although the tethered tufts were initially quite mobile, currents and movement tangled the cords that held many of them to their weights, possible reducing the difference in the microhabitat created by the treatments.

The total defaunation of the samples with fresh water was analogous to certain kinds of natural events. For example, a big storm might bring an influx of fresh water to the back reef, dislodge some tufts of algae from the turf, and disturb them enough to cause some defaunation. Depending on the magnitude of the storm, many algal tufts could wind up defaunated and mobile, or just defaunated like the experimental treatments. In the case of a large storm event, the algal habitats available for invertebrates would shift from primarily natural, stable algal turf to loose, defaunated clumps. If such habitats are in fact less suitable or preferred habitats for amphipod and isopod invertebrates, the invertebrate community at large might shift temporarily to one of greater dominance by small, mobile invertebrates best able to use the new habitat types. In this case, that might lead to a reduction in the abundance of amphipod and isopod crustaceans. There might even be an effect on the community of fish which rely on invertebrates as a food source, as their prey community would no longer be comprised of as many large individuals.

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Covering response of normal and albino *Tripneustes ventricosus* to varying light intensities

Arthur J. Kehas and Kathleen A. Theoharides

Abstract: Tripneustes ventricosus, a Caribbean sea urchin, covers itself with pieces of shells, rocks, leaves, macroalgae and other items. Covering response may be influenced by light, UV radiation, sediment deposition, turbidity, surge and predators. We investigated the effect of light intensity on the covering response of normal and albino phenotypes of *T. ventricosus* in outdoor tub experiments at the Discovery Bay Marine Laboratory, Jamaica. Normal urchins from shallow and deep reef areas showed greater covering in response to full sunlight than partial shade or darkness. Albinos covered more than normal urchins in response to both full sun and partial shade, suggesting that lack of pigmentation may leave albinos more susceptible to sunlight stress. Field surveys supported findings from the laboratory experiments. Albinos exhibited a greater covering response than normal urchins in the west back reef, and normal urchins at shallow depth covered more than normal urchins at deeper depth. Future studies could examine threshold light intensities at which normal and albino urchins begin to cover, and also look more closely at the abundance and distribution of albino morphs within the population.

Key Words: heaping, stress, sunscreen

Introduction

Several species of sea urchins display a unique behavior known as covering or "heaping," in which they use their tube feet to maneuver pieces of algae, rocks, shells, leaves onto their aboral surface. Many studies have addressed possible causes for this covering response including protection from light (Lees and Carter, 1972), UV radiation (Adams, 2001; Butcher et al., 2002; Verling et al. 2002), and sediment deposition (Richner and Milinski, 2000), response to surge (Lees and Carter, 1972), and camouflage from predators (Boon, 1925: Dayton et al., 1970).

In this study, we looked at the covering response of the salt and pepper urchin, *Tripneustes ventricosus*, to different light intensities. *Tripneustes ventricosus* is common in and around shallow tropical reefs and seagrass beds. We hypothesized that urchins would respond differently to different light intensities and predicted that there would be greater covering at greater light intensity. Results from the first experiment led us to further investigate a possible trend in covering between east back reef urchins versus west back reef urchins. We predicted that because the east back reef urchins are found at deeper depths and therefore at lower light intensities, they would cover less in response to light. Finally, we hypothesized that urchins with different phenotypes would respond to light differently, predicting that albinos would be more light sensitive and would cover more in response to light than normal urchins.

Methods

We conducted our experiments and observations at the Discovery Bay Marine Laboratory in Jamaica, W. I. from 4 - 11 March 2003. We used *T. ventricosus* from the back reef adjacent to the laboratory (west back reef) and from the east back reef across the bay. Urchins in the east back reef were located at depths of approximately 3.5 m, while urchins in the west back reef were located at depths close to 1 m.

Pilot experiment: We conducted a preliminary experiment to test urchin covering response at different light intensities. We had three light intensities: full sun, full shade, and partial shade. We set up six identical plastic tubs, 15 cm deep and 35 cm in diameter. Throughout the experiment, each tub was fed with running sea water delivered through tubing connected to the laboratory sea water system. We lined the bottom of each tub with sand and fragments of the sea grass, *Thalassia testudinum*. *Thalassia* is used preferentially by *Tripneustis* for covering (Butcher et al. 2002). Two tubs were left uncovered (full sun), two tubs were covered with black plastic material (full shade), and two tubs were covered with four layers of window screening (partial shade). We measured the diameter of each urchin test, and placed one urchin in each tub before covering the tubs according to treatment type. We left urchins in the tanks for 1 hr and then estimated percent *Thalassia* cover on each urchin.

Light intensity experiments: We conducted a modified version of the pilot experiment with urchins from the west back reef and the east back reef. We set up 6 tubs with running water and sand and added equal numbers of *Thalassia* grass blades. Each grass blade measured 7 cm and the average width of the grass blades was recorded. We set up two replicate tubs for each of the light treatments. The partial shade treatment with three layers of window screening reduced light intensity by 68% (measured using a Licor light meter model TI1000 measuring in $\mu mol/sec/m^2$). The black plastic and window screening covers were suspended so as not to touch the water surface. We measured urchin diameter and left each urchin in the tub for 30 minutes. After 30 minutes, we recorded the number of grass blades affixed to each urchin, and also the area of overlap of these grass blades to determine the total percentage of the urchin's test that was covered. We ran this experiment 5 times with different urchins from the west back reef from 10:30 to 13:20 on 5 March, 2003. We conducted the same experiment with urchins from the east back reef on 6 March, 2003 during the same time of day. We analyzed data from the east back reef and data from the west back reef separately using ANOVA because data were collected on separate days.

East back reef vs. west back reef experiments: Our initial findings from the light intensity experiments indicated differences in the covering response of east back reef and west back reef urchins. In an attempt to elucidate these differences, we conducted a series of experiments comparing the covering response of these urchins to full sunlight at the same time. We used the revised tub set-up with the same number and size grass blades, but all tanks were left uncovered. We measured the diameter of 3 urchins from the west back reef and 3 from the east back reef, placed them individually in tubs, and recorded cover after 30 minutes. We ran this experiment three times with different urchins from 10:30 to 12:10 on 9 March, 2003.

Albino vs. normal urchin experiments: We compared the covering response of normal and albino *T. ventricosus* from the west back reef to full sunlight and partial sunlight (1 layer of screening, 34% light intensity reduction). We measured diameter of three albinos and three normal *T. ventricosus*, placed each urchin in a tub and measured percent cover after 30 minutes.

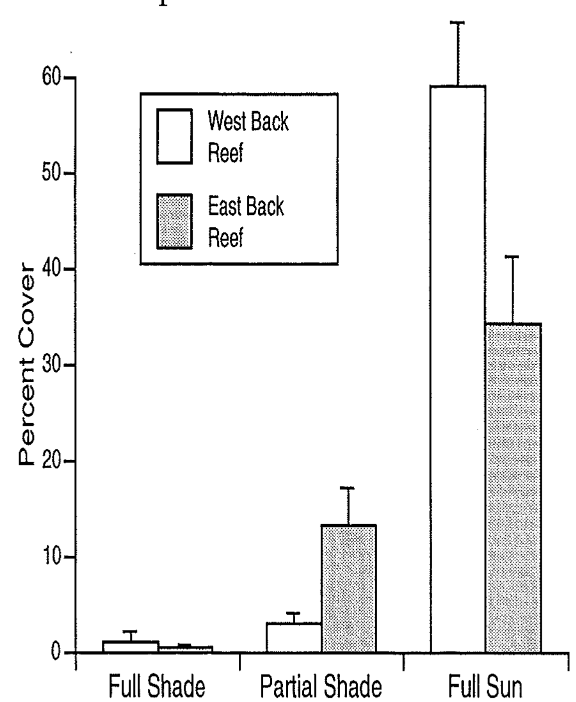

FIG. 1. Covering by *Tripneustes ventricosus* in response to varying light intensities. Data from experiments at Discovery Bay Marine Laboratory, Jamaica, W. I.

We ran this experiment six times, from 10:00 to 12:00 on 10 March 2003.

Shade vs. sun habitat choice: We ran an experiment to test habitat preference of normal urchins from the west back reef. We divided each of the 6 tubs into two habitat types: full shade with sandy bottom, and full sun with *Thalassia* grass and sandy bottom, thus forcing the urchins to make a clear choice between covering in full sun or shade and no cover. We placed one urchin in each tub and observed its location and percent cover after 30 minutes on 10 March 2003. We ran this experiment twice between 12:00 and 13:30.

Observational surveys: We conducted surveys of urchin covering behavior on the east and west back reef from 10:15 to 11:40 on 11 March 2003. At each site we measured light intensity with a Licor light meter (measures visible light wavelength) just below the water surface and on the sea floor where the urchins were found. We estimated percent cover on the first 25

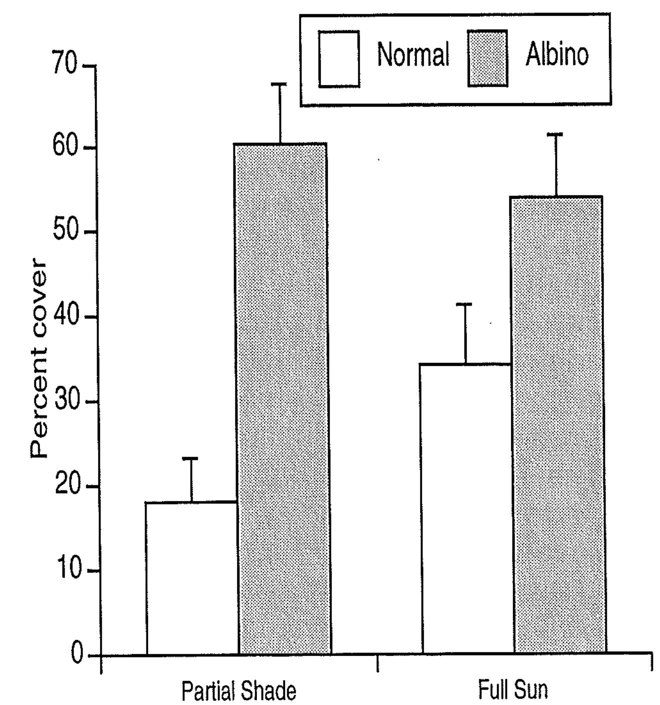

FIG. 2. Covering by normal and albino *Tripneustes ventricosus* in response to both partial shade and full sun treatments. Data from experiments performed at Discovery Bay Marine Laboratory, Jamaica, W. I.

normal *T. ventricosus* that we encountered near the site of the depth measurements. We then grouped the data into five cover categories: 0% cover, 1-24% cover, 25-49% cover, 50-74% cover, 75-100% cover. Because albino *T. ventricosus* were found mostly at the west back reef, we measured percent cover on the first 10 albinos at this reef. We also ran three 25 x 1 m transects and counted normal and albino *T. ventricosus*.

Statistical Analysis: We determined an average surface area per blade of *Thalassia* by standardizing blade length and averaging blade width from 15 blades. By counting the number of blades each urchin used for cover, and estimating the amount of overlap between the blades, we were able to calculate an estimate of percent cover, using a half sphere to approximate urchin shape. We then analyzed the experimental data using ANOVA. The categorical percent cover data from the field observations were analyzed with a G-test.

Results

Light intensity experiments: Normal urchins from both the west back reef and east back reef covered more in response to full light than full and partial shade (Fig. 1; West: $F = 66.79$, $df = 2, 29$, $P < 0.0001$; East: $F = 14.13$, $df = 2, 29$, $P < 0.0001$). Tukey-Kramer did not reveal any difference between responses to full shade and partial shade ($\alpha = 0.05$).

East back reef vs. west back reef experiment: We did not find a significant difference in covering response to full light between normal urchins form the west back reef and normal urchins from the east back reef ($F = 0.01$, $df = 1, 16$, $P = 0.92$).

Albino vs. normal urchin experiments: Albino urchins covered more in response to partial sun and full sun than did normal urchins (Fig. 2; $F = 4.06$, $df = 1, 1$, $P = 0.05$). There was no interaction between urchin type and treatment ($F = 2.74$, $df = 1,1$, $P = 0.11$).

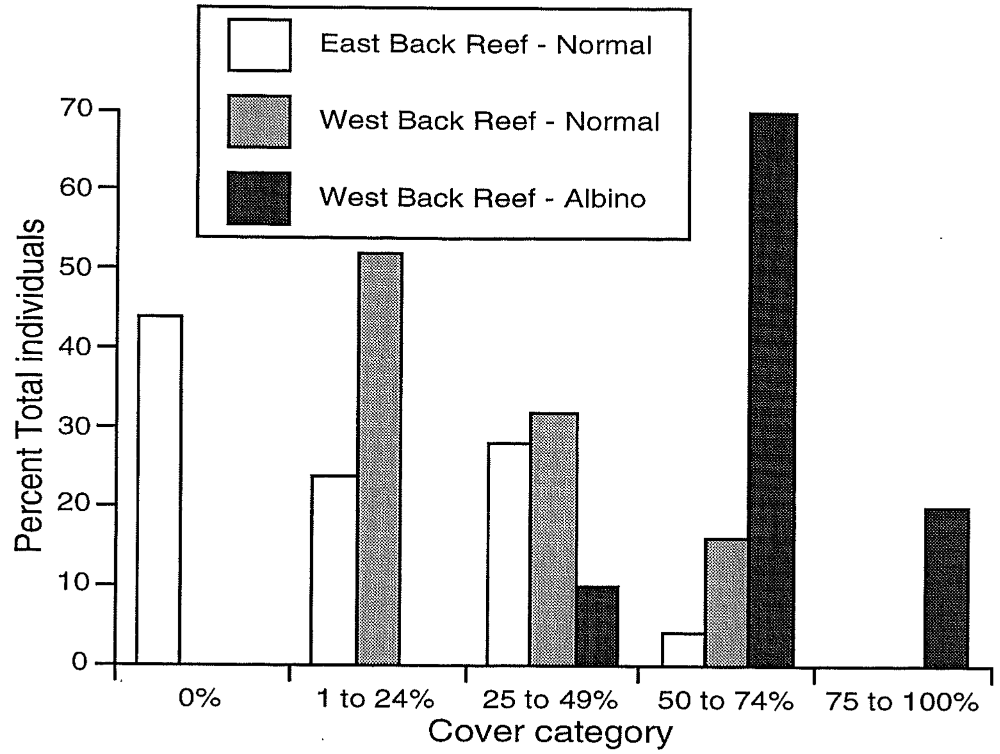

FIG. 3. Survey of percent-cover categories for *Tripneustes ventricosus*. Depth at west back reef was 1 m (high light intensity). Depth at east back reef was 3.5 m (low light intensity). Survey conducted from 10:15 to 11:40 on 11 March 2003 at the Discovery Bay Marine Laboratory, Jamaica, W. I.

Shade vs. sun habitat choice: In this experiment providing shade or full sunlight and grass, 10 out of 12 of the normal urchins chose shade. Those in grass covered less than 15% of their exposed surface area, and those in shade had no cover.

Observational surveys: Albinos in the west back reef covered the most (Fig. 3; $G = 21.18$, $df = 4$, $P < 0.005$), and the normal phenotype in the east back reef covered the least (Fig. 3; $G = 19.88$, $df = 4$, $P < 0.005$). In the west back reef, albino abundance was roughly 1 individual per 10 m^2 and normal urchin abundance was roughly 24 individuals per 10 m^2. We did not measure albino abundance in the east back reef because they were scarce. At 1 m depth in the west back reef, light was reduced to 86% of the intensity just below the surface. At 3.5 m depth in the east back reef, light was reduced to 58% of the intensity just below the surface.

Discussion

Urchins with a normally-pigmented phenotype from both areas of the reef showed significantly less covering in response to partial and full shade, suggesting that high light intensity induces the urchins to cover. Although results from our initial experiment with varying light intensities suggested that normal urchins from the east back reef may cover less than those from the west back reef, these findings were not supported by our second experiment testing the covering response of urchins from these locations to full light at the same time. Interestingly, albinos covered more in response to light than did normal urchins. Albinos may be more susceptible to damage from intense light due to their lack of pigmentation, necessitating a more marked covering response. However, in our survey, we found more albinos at shallower depths

where light is at a greater intensity. This may be the result of competitive interactions or resource exploitation. Further research into the abundance and distribution of albino *T. ventricosus* may provide an explanation for these findings.

Our preliminary test of urchin preference for shade or full sunlight with grass cover suggested that normal *T. ventricosus* prefer shade. Five minutes after the start of our experiment, all urchins were in the shade. When we returned to record the results at the end of the experiment, two urchins were in full sun with very little cover. This may possibly be because they had been in the shade and recently entered the sun towards the end of the experimental period. Repeating this experiment with a larger sample size might produce a significant result.

Our survey of urchin covering is consistent with our experimental results, supporting our methodology. Due to increased depth, urchins at the east back reef experienced a light intensity less than that used in our partial shade treatments, which generated a low covering response. Therefore, because the need to cover may be reduced at depth, these urchins exhibited the lowest cover. Urchins at the west back reef experienced higher light intensity as a result of being at shallower depths and, consequently, would be expected to cover more. Also, at the west back reef sites, albino urchins covered more than normal urchins. Further research could determine the threshold light intensity at which normal and albino urchins begin to cover.

Our results are consistent with those of other urchin covering studies. Lees et al. (1972) found increased covering with *Lytechinus anamesus* in response to light. A similar covering response to light was also found with *Paracentrotus lividus* by Verling et al. (2001). A third urchin species, *Strongylocentrotus droebachiensis*, also covers in response to light (Adams 2001). Our study was the first to explore the covering response of *Tripneustes ventricosus* to varying intensities of light or shade and was also the first to test the covering response of an albino phenotype, an area in need of further study.

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