Table 1. Mean number of *T. ventricosus* found per m² at day and night along contiguous 10 m² transects perpendicular to the grass bed-back reef border at West Back Reef, Discovery Bay, Jamaica.

Habitat	Sampling time	# *T. ventricosus*/m²< 5 m from reef/ grass border (mean ± 1 SE, n = 15)	# *T. ventricosus*/m² 5-10 m from reef/ grass border (mean ± 1 SE, n = 15)
Grass bed	Day	1.65 ± 0.19	0.59 ± 0.07
Grass bed	Night	1.37 ± 0.19	0.68 ± 0.12
Back reef	Day	0.09 ± 0.03	0.007 ± 0.007
Back reef	Night	0.81 ± 0.22	0

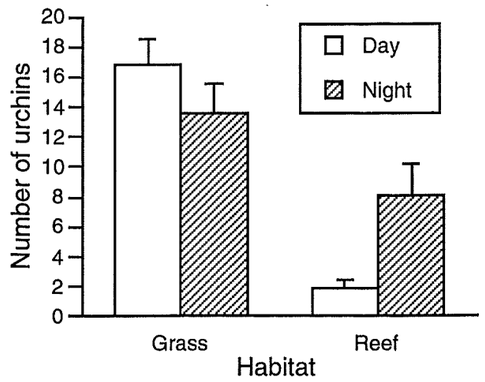

Fig. 1. Mean number of *Tripnuestes ventricosus* (± 1 SE) per 5 m transect sampled at day and at night on two adjacent habitats at Discovery Bay Marine Laboratory, Jamaica (n = 15).

Fig. 1). There was no significant difference between the number of urchins found on the reef in the morning and afternoon (t = 0.86, df = 18, P = 0.40).

Discussion

Our study suggests that *T. ventricosus* is most abundant at the grass back-reef border. Most *T. ventricosus* found were within 5 m of this border, and from our observations the majority were within 1 – 2 m of the border. Urchins seem to line the border, in the seagrass bed, by day, and then crawl up the nearby reef rocks at night.

Not all *T. ventricosus* crossed the border to the rocks. Since we did not mark any urchins to keep track of individuals, we cannot say for certain that those found on the reef at night were those closest to the reef in the day. However, since active *T. ventricosus* may travel < 10 m per day (Tertschnig 1989), we presume those found on the reef at night were within 10 m of the border during the day. Future studies could mark individual *T. ventricosus* to quantify individual migration patterns.

By sampling at only three times of day, we may not have fully quantified the diel migration pattern of *T. ventricosus*. Although our 09:30 h and 15:00 h samples showed no difference in *T. ventricosus* abundance or distribution, there may be further migration away from the reef between these hours, especially if the intensity of the noontime sun corresponds with the limit of *T. ventricosus* migration.

There was a substantial number of *T. ventricosus* found in the seagrass bed > 5 m from the grass bed-reef border both day and night. We observed that these individuals seemed fairly evenly distributed, unlike the clumping that occurred near the grass bed-reef border. Further study could determine whether the grass bed-reef border is a preferred habitat associated with greater *T. ventricosus* fitness, and if any form of intra-specific or inter-specific competition plays a role in determining which urchins occur close enough to the reef to crawl up its rocks at night.

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Invertebrate community composition differences between three macroalgae species on a Jamaican reef

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Abstract: Macroalgae provide islands of refuge for invertebrates in coral reefs, but previous research has rarely examined invertebrate community composition in macroalgal species. Different macroalgal morphologies likely create different microhabitats; thus, we hypothezised that different macroalgal species would support different communities of invertebrates. We collected samples of *Halimeda opuntia*, *Bryothamnion triquetrum*, and *Penicillus capitatus* from the West back reef at Discovery Bay Marine Laboratory, Jamaica and recorded abundance, size, and taxa of all invertebrates found in each sample. We found more total taxa and a greater mean size of invertebrates in *Halimeda* than in *Penicillus* or *Bryothamnion*. Frequencies of taxa differed significantly among the species of algae. Our results support our hypothesis and indicate that macroalgae serve as important refuge areas for invertebrates.

Key Words: Amphipoda, Copepoda, Discovery Bay, Gastropoda, Isopoda, Polychaeta

Introduction

It has long been suspected that macroalgae provide refuge for small invertebrates within coral reef and sea grass habitats. Previous research, however, has quantified invertebrate community composition in only one species of macroalgae. Stoner (1985) examined macrofauna communities in the green calcareous macroalga *Penicillus capitatus*, and found that it supported invertebrate communities at a significantly higher density than those in the surrounding sediment. Research by Richardson (1989) also showed a higher density of invertebrates in *P. capitatus* than in surrounding open water.

Different macroalga morphologies likely create different microhabitats. We hypothezised that different macroalgal species would support different communities of invertebrates. We examined the invertebrates inhabiting three different species of macroalgae representing a range of structural densities: high (*Penicillus capitatus*), medium (*Halimeda opuntia*) and low (*Bryothamnion triquetrum*). We expected to find many small invertebrates in the dense filaments of *Penicillus*, large invertebrates in the less dense but structurally complex *Halimeda*, and few invertebrates in the very open *Bryothamnion*.

Methods

On 24 February 2001 (14:00-15:00) we collected samples of *Halimeda opuntia*, *Bryothamnion triquetrum*, and *Penicillus capitatus* from the West back reef at Discovery Bay Marine Laboratory, Jamaica. We chose an area (roughly 40 m² and no greater than 2 m deep) of patch reef and sand that contained all three species. We haphazardly selected three clumps of each alga, covered each with a plastic bag, tore them from the substrate, and sealed the bags. In the laboratory, each clump was rinsed in salt water and again in freshwater, and the rinse water was poured through a 153 µm filter after each rinse. The filtered samples were then preserved overnight in a 1:1 ratio of fresh water and 10% formalin, and were rinsed again through the filter with salt water just before counting. We measured the wet weight of each algal clump after patting it dry with a paper towel. We recorded the class of each invertebrate found (or order when possible) and recorded its length to the nearest mm.

We performed ANOVAs to compare mean number of invertebrates and number of taxa per gram algae, as well as the mean size of invertebrates for the three algae. We used a Chi-square analysis to compare the frequencies of the five most abundant taxa in the three algae.

Table 1. Invertebrate taxa represented and number of individuals per taxa found in three algal species collected from the West Back Reef, Discovery Bay, Jamaica.

Species	Rep	Wet Weight (g)	# Taxa	# animals present
Bryothamnion	1	25.9	8	880
	2	59.4	8	996
	3	65.4	6	357
	Mean (1 SD)	50.3 (21.3)	7.33 (1.15)	744 (340)
Halimeda	1	14.5	9	282
	2	21.6	11	373
	3	39.5	14	372
	Mean (1 SD)	25.2 (12.9)	11.33 (2.52)	342 (52)
Penicillus	1	4.5	7	146
	2	6.4	7	307
	3	7.0	8	159
	Mean (1 SD)	5.97 (1.3)	7.33 (0.58)	204 (89)

Results

We recorded a total of 3869 individuals in the nine samples (Tables 1 & 2). The mean number of invertebrates per gram algal wet weight did not differ significantly beween the three algae (ANOVA, $F = 2.34$, $df = 2, 6$, $P = 0.18$). There were more total taxa represented in the *Halimeda* samples (15) than in the *Penicillus* (10) or *Bryothamnion* (8) samples (ANOVA, $F = 6.00$, $df = 2, 6$, $P = 0.037$; Table 1, Fig. 1).

Composition of the samples differed among algae (Fig. 2, Table 2). In particular, the frequencies of the five most common invertebrate taxa (Amphipoda, Copepoda, Gastropoda, Isopoda and Polychaeta) were significantly different in the different algae ($\chi^2 = 2296.5$, $df = 8$, $P < 0.0001$). There were many more copepods in the *Bryothamnion* than expected from a uniform distribution, and fewer in the *Penicillus* and *Halimeda*. Isopod numbers were high in the *Penicillus* and low in the *Bryothamnion*. Polychaete numbers were highest in the *Halimeda*.

Table 2. Total number of invertebrates per order found in clumps of three different species of macroalgae in the west back reef of Discovery Bay, Jamaica.

Order	*Bryothamnion*	*Halimeda*	*Penicillus*
Amphipoda	36	139	15
Anthozoa	3	2	37
Copepoda	2012	296	47
Decapoda	0	10	1
Foraminifera	0	19	5
Gastropoda	46	28	61
Holothuroidea	2	11	0
Isopoda	91	394	423
Mysida	0	1	0
Nauplii	0	1	0
Ophiurodea	0	5	0
Ostracoda	20	11	2
Platyhelminthes	0	9	0
Polychaeta	23	97	20
Polyplacaphora	0	0	1
Scyphozoa	0	4	0
Total Individuals	2233	1027	612
Number of Orders Present	8	15	10

The mean size of the invertebrates in *Halimeda* was significantly greater than that of the invertebrates in *Penicillus*, which was in turn significantly greater than that of the invertebrates in *Bryothamnion* (Welch's ANOVA, $F = 67.95$, $df = 2, 3866$, $P < 0.0001$; Fig. 3).

Discussion

Invertebrate communities differed markedly among the three algae. The differences may be driven by the physical structure of the algae. The large numbers of copepods found in our *Bryothamnion* samples may be explained by the fact that *Bryothamnion* is more open than the other two species, thus providing room for swarms of copepods but leaving larger invertebrates exposed to predation (resulting in a low mean size of the invertebrates). *Penicillus* tops are too dense to allow inhabitation by very large invertebrates, but they provide a great deal of protection for smaller invertebrates. *Halimeda* provides spaces of an intermediate size, allowing for

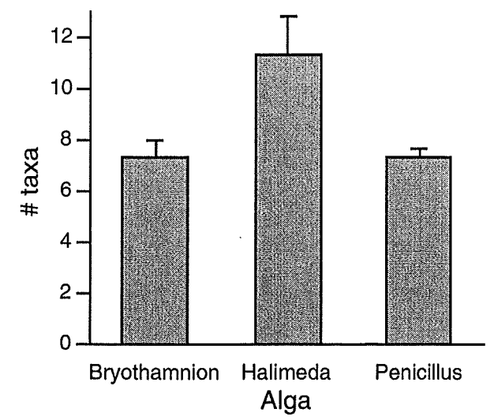

Fig. 1. Mean number of invertebrate taxa (± 1 SE) in three types of macroalgae in the west back reef, Discovery Bay, Jamaica (n = 3). The mean for *Halimeda* was significantly higher than the means for *Bryothamnion* and *Penicillus* (P = 0.037).

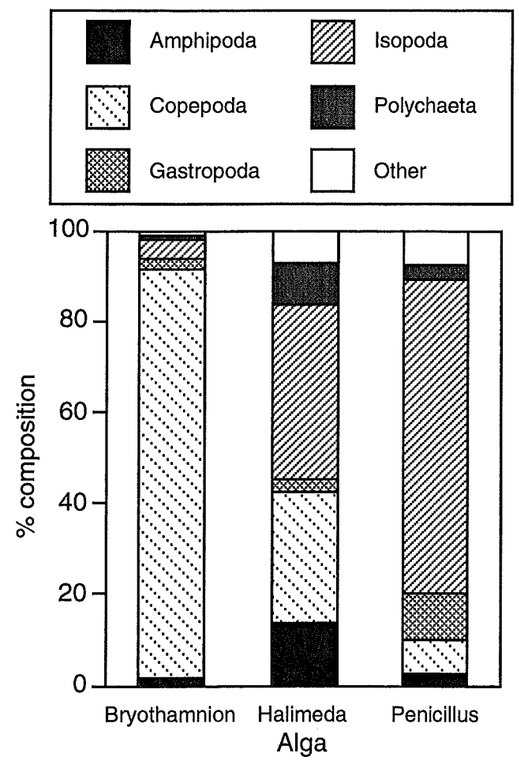

Fig. 2. Composition of invertebrate communities in three algae in the west back reef, Discovery Bay, Jamaica (n = 2233 for *Bryothamnion*; n = 1027 for *Halimeda*; n = 612 for *Penicillus*).

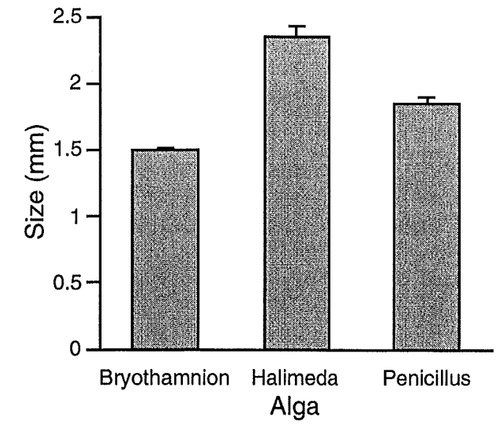

Fig. 3. Mean size (± 1 SE) of invertebrates found in three different algae in the west back reef, Discovery Bay, Jamaica (n = 2233 for *Bryothamnion*; n = 1027 for *Halimeda*; n = 612 for *Penicillus*).

the inhabitation by and protection of large invertebrates like crabs and brittle stars, as well as smaller animals.

The tremendous number of invertebrate individuals found in our samples, and the number of taxa represented by these individuals, indicate that macroalgae are indeed important refuges for invertebrates. The degree to which an alga serves as a refuge may depend on its morphology, and on other factors such as depth, wave action, fish predation, or edibility of the alga (or the likelihood of the alga to be eaten by an herbivore). In addition, an examination of changes in these communities over time (such as the effect of diel vertical migration of zooplankton residents of the algae, or the timing of larval recruitment of different organisms, on community composition) would be of interest.

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