APPENDIX 2. All of the color patterns of Christmas-tree worms found at four study sites. Patterns are listed as tentacle color/ tip color. Symbols indicate that a color pattern appeared at one site only.

Color Pattern	#	Color Pattern	#	Color Pattern	#
Black	10	Brown/Yellow	1‡	Red/White	22
Black/Green	4*	Fuschia/White	1†	Red/Yellow	6
Black/Green/Pink	1*	Green	1†	Rose	20
Black/Green/Red	2*	Green/Pink	4	Rose/Black	8**
Black/Green/White	1*	Green/Purple	1†	Rose/Purple	1**
Black/Orange	9	Green/Red	1†	Rose/White	7
Black/Orange/White	1*	Green/White	2*	Rose/Yellow	1**
Black/Pink	10	Green/Yellow	1†	White	11
Black/Pink/White	5*	Marroon/White	4	White/Black	7
Black/Purple	4	Orange	9	White/Black/Pink	1*
Black/Red/White	1**	Orange/Black	1**	White/Blue	1**
Black/Red	9	Orange/Red	1**	White/Green	1*
Black/White	73	Orange/White	8	White/Orange	7
Black/White/Orange	1*	Orange/Yellow	3	White/Pink	7
Black/White/Yellow	1‡	Pink	6	White/Purple	4**
Black/Yellow	75	Pink/Black	1*	White/Red	5
Black/Yellow/White	14	Pink/Blue	1†	White/Yellow	6**
Blue	2	Pink/White	7	Yellow	44
Blue/Black	1	Pink/Yellow	2	Yellow/Black	7
Blue/Pink	12	Purple	15	Yellow/Green	3
Blue/Purple	2†	Purple/Pink	5	Yellow/Orange	1‡
Blue/White	3	Purple/White	9	Yellow/Pink	3
Blue/Yellow	4†	Purple/Yellow	4	Yellow/Pink/White	1†
Brown/Orange	1‡	Red	3	Yellow/Purple	6
Brown/Red	1**	Red/Orange	1†	Yellow/Red	1**
Brown/White	2	Red/Purple	2	Yellow/White	28

* LTS 2m; ** LTS 10m; † M1 2m; ‡ M1 10m

DIEL CHANGES IN THE ZOOPLANKTON ASSEMBLAGE OVER A CARIBBEAN CORAL REEF

DEBORAH A. CHIAVELLI AND THE 1998 DARTMOUTH FSP CLASS

Abstract. Many large zooplankton exhibit diel habitat shifts in order to avoid predation by planktivores. The predominant planktivores in coral reefs are diurnally active fish. We hypothesized that large zooplankton in the back reef of Discovery Bay, Jamaica would exhibit avoidance of these predators. The nocturnal zooplankton assemblage was expected to be more abundant, more diverse and larger than the diurnal assemblage. At night, we found that, zooplankton were approximately two orders of magnitude more abundant, included five additional taxonomic categories, and were twice the average size of diurnal zooplankton. These observations suggest that this zooplankton assemblage exhibits strong predator avoidance behavior.

INTRODUCTION

Most organisms associated with coral reefs produce large numbers of planktonic larvae. Ocean currents disperse these larvae within and between reefs to find suitable habitat on which to settle. The convergence to this life history trait by many phyla of reef organisms is an indication of its adaptive value in the reef ecosystem. The two major risks faced by these planktonic larvae are a low chance of arriving at a suitable habitat, and predation by planktivores, predominantly visually feeding diurnal fish. The first risk is somewhat mitigated by the ability of many larvae to settle in response to cues from appropriate substrates, and to move into a suitable microhabitat after settling. The second risk can be reduced by being less visible to planktivorous fish. Two ways to do this are to be very small or to seek refuge during daylight hours. We hypothesized that most coral reef organisms will exhibit predator avoidance tactics. We examined zooplankton collected during the day and night over a Jamaican coral reef. We expected greater density, size and taxonomic diversity of zooplankton collected at night.

METHODS

Zooplankton were collected on 27 February 1998 near the reef crest in the back reef of Discovery Bay, Jamaica. Day samples were taken from 15:00 to 17:00; and night samples from 22:00 to 23:30. Five replicate samples were taken at each time by snorkeling twice (foreword and back) along a 22 m transect while holding a plankton net (26 cm diameter, 153 um mesh) out from the side of the body. Collected samples were immediately preserved in sea water with 10% formalin. Zooplankton were counted in gridded Petri dishes using dissecting microscopes and measured using a clear plastic ruler placed under the Petri dish. The entire sample was counted in all cases except in two night samples where 60% and 80% of the samples were examined. Length of all organisms in the following taxa were measured: copepods, decapod larvae, polychaetes, isopods, cumaceans, mollusc larvae, amphipods, fish eggs and mysids. Due to their great abundance, copepods and decapod larvae were simply placed within a size category. The categories, were < 0.5mm, 0.5 – 1.0mm, and > 1.0 mm for copepods; and < 1.0mm, 1.0 – 2.0mm, and > 2.0mm for decapod larvae. When calculating average size, the following sizes were assigned to each category: copepods < 0.5mm = 0.35mm, copepods 0.5 – 1.0mm = 0.75mm, copepods > 1.0mm = 1.25mm, decapods < 1.0mm = 0.8mm, decapods 1.0 – 2.0mm = 1.5mm, decapods > 2.0mm = 2.5mm. Nauplii and fish eggs were not measured at night because their sizes were not apparently different at night. Only the first three specimens in the first three subsamples of the following taxa were measured: fish larvae, and nauplii. We used analysis of variance (ANOVA) to test the effect of time of day on total zooplankton size and density and on size and density of each taxon. Some values were log transformed to equalize variances.

RESULTS

Zooplankton were approximately two orders of magnitude more abundant during the night than during the day (Table 1). The most

abundant plankton, day and night, were the copepods, but they were far more abundant at night. The next two most abundant night taxa, decapod and fish larvae, were not present in day samples (Table 1). Other taxa found only at night were cumaceans, amphipods, and mysids; mollusc larvae were found in only one day sample (Table 1). The abundance of three taxa (nauplii, fish eggs, and cnidarians) was not significantly different between times (Table 1). Considering that most of the taxonomic categories included many species, the night zooplankton assemblage was far more diverse than the day assemblage.

The average zooplankton length at night was double the day value (Table 2). This is especially striking because the most abundant organisms, the copepods, did not differ in size between the two times. If copepods are excluded from consideration, the night zooplankton are nearly three times larger than the day zooplankton (Table 2). This difference is primarily due to decapod larvae, fish larvae and polychaetes, the three most abundant night taxa after copepods, all of which were much larger than day zooplankton (Tables 1, 2). Polychaetes, isopods and cnidarians were significantly larger at night (Table 2), and the largest organisms observed were some polychaetes, which averaged approximately 20 mm.

DISCUSSION

As expected, zooplankton in Discovery Bay were more abundant, more diverse, and larger at night. This is not surprising as zooplankton exhibit predator avoidance behavior in most freshwater and saltwater ecosystems. In most of these cases, zooplankton migrate deeper into the water column, into the benthos or into microhabitats that offer protection from fish such as within macrophyte beds in ponds or damselfish territories in coral reefs. At night these organisms move out into less protected areas, which usually have more food. Future research might examine ontogenetic changes in migration. Some large zooplankton species might not migrate in their earliest stages, when they would be small enough to remain in the food rich upper water column with less predation risk.

TABLE 1. A comparison of day and night zooplankton density in the back reef of Discovery Bay. Taxa are listed in order of night abundance. ANOVA was used to determine the effect of time on density.

Taxon	Density (m^3): mean (1 SE) Day	Night	$F_{1,8}$	P
copepoda	31.1 (5.6)	521.1 (186.2)	38.45	0.0003
decapoda	0.0	423.1 (127.9)	–	–
fish larvae	0.0	71.5 (28.9)	–	–
polychaeta	4.9 (0.9)	55.0 (17.4)	26.84	0.0008
nauplii	10.4 (2.1)	10.1 (1.4)	0.02	0.9
fish eggs	4.9 (1.8)	6.6 (1.2)	1.24	0.3
isopoda	0.6 (0.3)	6.3 (1.8)	16.87	0.003
cumacea	0.0	6.0 (1.4)	–	–
mollusca larvae	0.2*	3.9 (1.3)	–	–
cnidaria	3.7 (1.2)	1.7 (0.57)	1.82	0.21
amphipoda	0.0	0.21 (0.21)	–	–
mysids	0.0	0.19 (0.12)	–	–
Total	**55.7 (6.7)**	**1105.7 (356.0)**	**65.15**	**0.0000**
excluding copepoda and decapoda	24.6 (2.0)	161.5 (45.8)	37.16	0.0003

*only found in one sample

TABLE 2. A comparison of day and night zooplankton length in the back reef of Discovery Bay. ANOVA was used to determine the effect of time on length.

Taxon	Length (mm): mean (1SE) Day	Night	F	P
copepoda	0.7 (0.03)	0.7 (0.06)	0.71	0.42
decapoda	–	1.7 (0.07)	–	–
fish larvae	–	2.2 (0.09)	–	–
polychaeta	0.97 (0.26)	2.4 (0.19)	20.49	0.002
nauplii	0.27 (0.04)	–*	–	–
fish eggs	0.51 (0.04)	–*	–	–
isopoda	1.0 (0.11)	1.8 (0.23)	6.21	0.47
cumacea	–	1.7 (0.16)	–	–
mollusca larvae	0.32**	0.33 (0.02)	–	–
cnidaria	0.54 (0.08)	1.2 (0.29)	15.34	0.006
amphipoda	–	2.1	–	–
mysids	–	2.8 (0.79)	–	–
Total	**0.6 (0.07)**	**1.2 (0.06)**	**47.61**	**0.0001**
excluding copepoda	0.6 (0.1)	1.7 (0.03)	68.74	< 0.0001

* Not measured at night; see text for explanation.
**Found in only one day sample.