TEMPORAL PATTERNS OF ZOOPLANKTON MIGRATION

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ABSTRACT

The NOAA/NULS-1 underwater habitat facility at St. Croix was utilized during July 1982 for a study of the temporal patterns of migration into the water column by reef zooplankton. Samples were collected for 6 days at 9 daily time intervals using mesh emergence traps, diver pushed plankton nets, and surface plankton net tows. This is the first study to sample such finely spaced time intervals. Preliminary analysis from 2 days indicated that there was migration throughout the night, with increased activity found prior to sunrise as well as following sunset. This is the first time a predawn rise of zooplankton has been documented.

The cyclopoid copepod, *Oithona colcarva*, dominated most time intervals, although it was not nearly as abundant as in an earlier Caribbean reef zooplankton study. Most zooplankton taxa followed the same general pattern of activity, and the relative abundance of the common taxa generally remained the same throughout the 24 hours. The time intervals around sunset were an exception, however. For example, during the hour following sunset, calanoids, harpacticoids, polychaetes, and pagurid larvae were relatively more abundant than during the hour prior to sunset, while copepod nauplii and amphipods were less abundant during this postsunset time interval. Significantly more taxa were captured during the first hour of darkness than during any other time interval.

The effects of different trap designs and types of reef substrata on zooplankton samples also were examined. There was no significant difference in the number of individuals collected between treatments using sealed and unsealed traps or between those using unsealed traps over coral and sand substrata. This is in contrast to other studies; two possible explanations for these discrepancies relate to the types of substrata over which sealed and unsealed traps are compared and to differences in trap sealing efficiency when different substrata types are being compared.

INTRODUCTION

The zooplankton that reside within or near coral reef ecosystems have only recently begun to receive the attention of researchers. Zooplankton have been studied from various Pacific reef communities primarily by using various modifications of emergence traps (Alldredge and King, 1977, 1980; Porter and Porter, 1977; Porter, *et al.*, 1977; Hobson and Chess, 1979; Birkeland and

Smalley, 1981; McWilliam, et al., 1981; and Walter, et al., 1982). Fewer studies of reef zooplankton from the Caribbean have been conducted (Ohlhorst, 1980, 1982, 1985; Robichaux, et al., 1981; and Youngbluth, 1982). While the diel migration patterns of these zooplankton have been shown to influence the behavior of nocturnal planktivorous fish (Hobson, 1974; Hobson and Chess, 1978; Robertson and Howard, 1978) and might affect the behavior of other reef planktivores (Porter, 1974; Sebens, 1977; Liddell, 1982), few studies have investigated the diel migration patterns of reef zooplankton in detail (Alldredge and King, 1980; Ohlhorst, 1982; Walter, et al., 1982). The only study of migration by Caribbean reef zooplankton (conducted at Jamaica by Ohlhorst, 1982) suggests that there is no single pulse of migratory activity; rather zooplankton rise into the water column at variable rates throughout the night with a peak of activity during the second hour after sunset. Also, different taxa were shown to exhibit differing migratory patterns. While these observations are consistent with those from the Pacific, it is important to determine whether or not such patterns occur elsewhere in the Caribbean. Additionally, more frequent sampling than previously conducted would be of value in refining the patterns of zooplankton migration.

One of the reasons for the paucity of detailed studies addressing this question is the physiological limitation placed upon safely conducting the repeated sampling dives which are necessary for such studies. Previous studies which have addressed the question of migratory patterns of reef zooplankton have been restricted to sampling widely spaced time intervals or sampling very shallow (< 5 m) sites. Data from Ohlhorst (1985) suggests that caution should be used when extrapolating data from shallow sites to greater depths. The present study examines the migratory patterns of reef zooplankton at an intermediate (15 m) depth at St. Croix through repeated sampling of finely spaced time intervals. This sampling was made possible by saturation diving from the NOAA/NULS-1 Underwater Habitat, HYDROLAB.

METHODS

Sampling of reef zooplankton was conducted from the NOAA/NULS-1 HYDROLAB located at 15 m depth in the Salt River submarine canyon on the north coast of St. Croix, U.S. Virgin Islands (17°45' N, 64°45' W) during July 1982. Samples were collected from both reef and sand areas located approximately 15 m east of the Habitat. To eliminate biases caused by the proximity of the study sites to the Habitat, all of the external lights of the HYDROLAB remained off for the duration of the study. Saturation diving from the HYDROLAB enabled two teams of divers to collect plankton samples at closely spaced intervals over a 6-day period.

Zooplankton were sampled by three methods: (1) Emergence traps, which covered 0.5 m^2, were placed over various types of reef substrata to capture zooplankton moving from the reef site into the water column. Certain of these traps were sealed over their substrata by a skirt (Robichaux, et al., 1981), while others were affixed more loosely over their substrata. (2) Diver pushed

Table 1. Number of zooplankton captured/m^2/hour, beginning with 0030 on July 16 and continuing through 2300 on July 17, 1982. ST= Students' T test at $p \leq 0.05$, 0 = no significant difference between this and the previous time interval, + = a significant increase, - = a significant decrease; MWU = Mann Whitney U test at $p \leq 0.05$, symbols are the same as for ST.

Time Interval	#Samples	Mean (Std. Dev.)	Median	ST	MWU
0030	8	139.2 (78.0)	136.6		
0230	8	109.4 (52.0)	100.0	0	0
0500	8	176.0 (97.8)	168.0	0	0
0600	4	26.6 (20.2)	20.0	-	-
1200	8	10.6 (9.0)	8.0	0	0
1830	8	40.0 (21.8)	39.0	+	+
1930	8	246.8 (103.8)	256.0	+	+
2230	8	99.6 (60.0)	92.0	-	-
0030	8	348.0 (376.0)	202.0	0	0
0230	8	702.0 (662.0)	54.6	0	0
0500	8	306.0 (364.0)	140.8	0	0
0600	8	55.8 (22.2)	60.0	0	0
1200	8	6.2 (2.0)	6.0	-	-
1800	4	92.6 (24.2)	90.0	+	+
1930	4	399.2 (199.0)	341.4	+	0
2030	4	189.6 (144.2)	133.0	0	0
2300	4	51.0 (26.0)	40.4	-	0

zooplankton net samples were collected 1 m and 5 m above the reef. (3) A plankton net was towed at the surface from a boat to sample zooplankton just below the surface, and vertical net hauls from 15 m to the surface also were made from the boat. The emergence traps and zooplankton nets were made with 90 micron meshes. Two additional emergence traps were constructed with clear polyvinyl. The traps were modified (Ohlhorst, 1980, 1982) from those used by Porter and Porter (1977).

Five hundred and eighty samples were collected over 6 days and 9 time intervals each day (table 1). Samples were preserved in 5-10% buffered formalin immediately after collection and counted as in Ohlhorst (1982). Preliminary

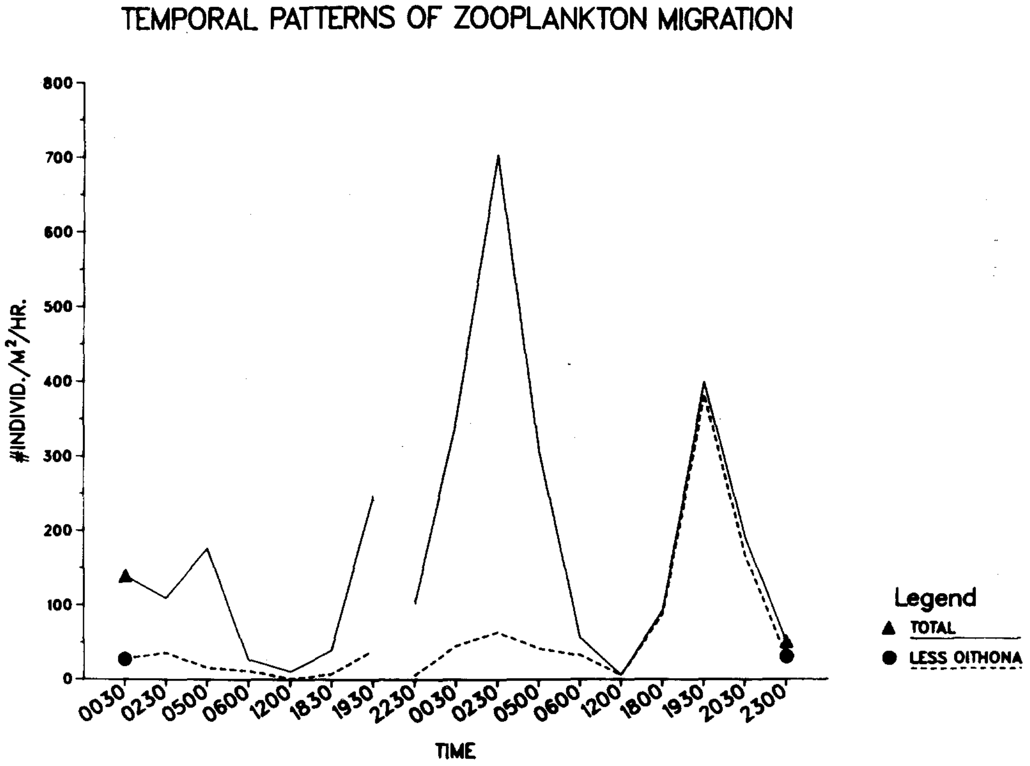

Figure 1.--The number of individuals captured per hour during the different time intervals are plotted, both with and without the copepod *Oithona colcarva*. Samples from 2030 on July 16 have not been counted. Refer to *table 1* for the means, medians, and standard deviations. Note that units of time along the x axis are unequal.

results from 148 samples from mesh emergence traps from 2 days (July 16-17) will be presented herein. During the collection period sunrise was at 0600, sunset at 1800, and the lunar phase was new moon.

RESULTS

Effects of Traps and Substrata

No significant differences [$p \leq 0.05$; Mann Whitney U (MWU), Students' T (ST) tests] in the number of individuals captured per hour were observed between mesh traps with sealed vs. unsealed bottoms over coral substrata. Additionally, no significant differences ($p \leq 0.05$) in the number of individuals captured per hour occurred between traps positioned over sand vs. those positioned over coral or rubble. For all subsequent tests, data from sealed and unsealed traps and traps located over sand and over coral or rubble were pooled. The polyvinyl traps tended to capture more zooplankton than mesh traps. Although the difference between types of trap was not significant, most of the data presented herein are from mesh traps only.

Table 2. Percent occurrence of phyla in demersal traps. Samples were collected on July 16-17, 1982 and are from both mesh and polyvinyl traps. The taxonomy is according to Barnes (1980).

time:	0030	0230	0500	0600	1200	1830	1930	2030	2230
# traps :	(20)	(20)	(20)	(14)	(20)	(16)	(16)	(6)	(16)
Phyla									
ANNELIDA	30	65	35	21	20	6	100	67	56
ARTHROPODA	100	100	100	100	100	100	100	100	100
CHAETOGNATHA	25	30	15	14	5	19	13	0	25
CHORDATA	15	15	25	7	20	19	25	33	31
COELENTERATA	0	25	25	21	25	38	56	67	44
ECHINODERMATA	0	0	0	0	5	0	0	0	0
MOLLUSCA	40	35	35	29	60	94	81	50	38
NEMATODA	0	0	0	0	5	0	13	0	0
PLATYHELMINTHES	0	5	0	0	5	0	19	0	0
SARCODINA	35	80	45	29	80	94	81	67	31
SIPUNCULIDA	25	15	10	21	40	25	63	67	25

Temporal Patterns

The number of zooplankters migrating per hour for the various sampling intervals is presented in table 1 and figure 1. Data from July 16-17 displayed significant decreases ($p \leq 0.05$; MWU, ST tests) in the total number of individuals captured per hour between 0500 or 0600 and 1200 hours, and significant ($p \leq 0.05$) increases between 1200 and 1800/1830 hours and between 1800/1830 and 1930 hours, followed by a significant ($p \leq 0.05$) decrease after 1930 hours. The pattern differed somewhat when the cyclopoid copepod *Oithona colcarva* (Bowman) was removed from analysis (fig. 1).

There was no significant ($p \leq 0.05$; MWU, ST tests) difference between the 2 days in the number of individuals migrating per hour for most time intervals (fig. 1, table 1). Significantly more individuals ($p \leq 0.05$; MWU, ST tests) were captured on July 17 than on July 16 in both the intervals from 0030-0230 and 1200-1800/1830. When the samples were considered without *O. colcarva*, numbers of zooplankters differed between days both in the intervals mentioned above and at 0500-0600.

Crustaceans made up the majority of the zooplankters captured by the traps, although representatives of 11 phyla, including foraminifera, echinoderm larvae, sipunculids, *Amphioxus*, and appendicularians also were collected (table 2). A

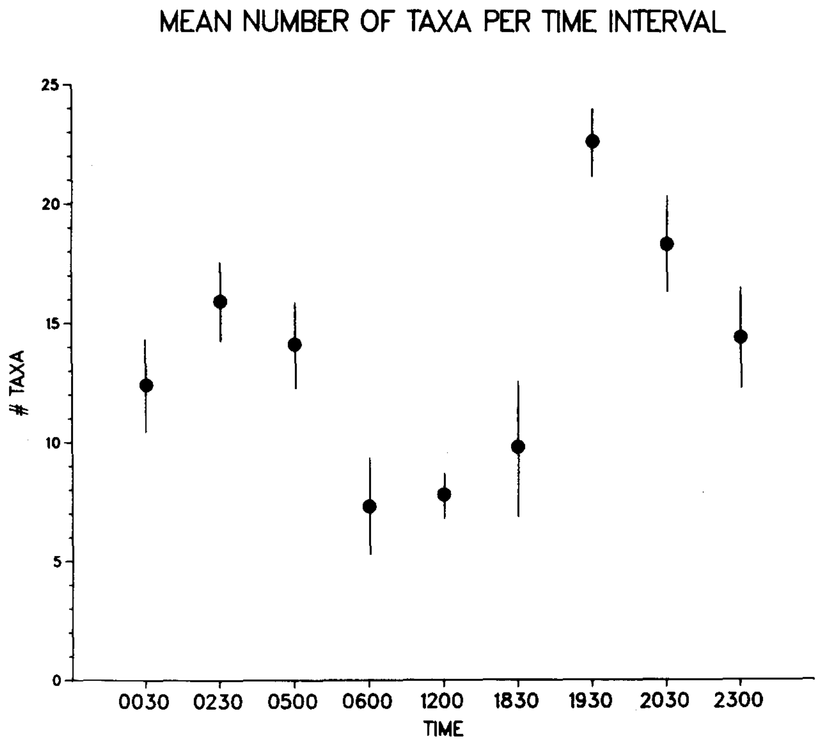

Figure 2.--The mean number of taxa captured during the various time intervals (days combined) is plotted. Vertical bars represent 95% confidence intervals. Units of time along the x axis are unequal.

total of 73 taxa were identified from these samples. Many were rarely encountered, and 27 taxa was the maximum found in a single sample (July 17, 1982). Figure 2 shows the pattern for the mean number of taxa captured during each time interval for the 2 days pooled. The only significant differences ($p \leq 0.05$, MWU, ST tests) between the 2 days in the number of taxa captured occurred at 0030 and 0600, when significantly fewer were captured on July 16. When the days were pooled, there were significant increases ($p \leq 0.05$; MWU, ST tests) in number of taxa in samples collected at 0030 vs. 0230 and in those collected at 1830 vs. 1930; in addition, significant decreases in number of taxa were observed between 0500 and 0600, 1930 and 2030, and 2030 and 2300. In general, the fewest taxa were captured during the day, the most during the first hour after sunset, and intermediate numbers during the rest of the night.

The mean and standard deviation for the abundance of the more common taxa are presented for the different time intervals in table 3. The cyclopoid copepod *Oithona colcarva* (Bowman) was the most abundant of the organisms captured at all time intervals except those between 1200-2030, although there was some variation in this pattern when the days were considered separately (fig. 1). During the morning interval (0600-1200), *O. colcarva*, foraminifera, and certain calanoid and harpacticoid species were the most abundant organisms; however, all occurred in relatively low numbers. In the afternoon (1200-1830), foraminifera

Table 3. Organisms captured at various time intervals (x̄ = mean, SD = standard deviation, * = present in 50-75% of samples, ** = present in 75-100% of samples). Only the 29 most common of the 73 taxa recorded are presented here.

Time:	0030		0230		0500		0600		1200		1830		1930		2030		2230	
#Samples:	16		16		16		12		16		12		12		4		12	
Taxa	x̄	(SD)	x̄	(SD)	x̄	(SD)	x̄	(SD)	x̄	(SD)	x̄	(SD)	x̄	(SD)	x̄	(SD)	x̄	(SD)
Oithona colvarva	200	(272)**	354	(538)**	186	(260)**	20.2	(18.2)**	2.8	(6.6)**	3.7	(3.1)**	33.0	(38.8)**	24.0	(36.0)**	45.8	(47.4)**
Corycaeus spp.	0.5	(0.6)*	0.9	(1.0)*	1.9	(3.5)*	3.8	(4.3)**	0.1	(0.2)	0.7	(0.7)*	1.8	(2.6)*	0		0.1	(0.3)
Calanoid "A"	5.8	(9.8)**	4.1	(4.3)**	9.8	(21.4)**	2.5	(2.3)*	0.7	(0.6)**	0.5	(0.5)*	12.5	(9.9)**	4.5	(7.7)*	4.1	(5.0)**
Calanoid "B"	5.6	(9.1)*	4.5	(6.3)*	9.0	(21.8)**	0.5	(0.9)	0.1	(0.2)	0.1	(0.1)	8.8	(9.2)**	7.5	(3.0)**	0.8	(1.5)
Microsetella spp.	2.3	(2.7)*	8.2	(7.2)**	2.5	(3.5)	5.8	(11.2)*	0.4	(0.7)	5.0	(13.3)*	22.4	(37.2)	43.6	(50.2)**	0.2	(0.4)
Harpacticoid "A"	1.4	(2.4)*	2.7	(2.8)*	5.1	(5.4)*	2.2	(2.3)*	0.7	(0.9)*	1.3	(3.7)	42.8	(52.4)**	22.6	(25.2)**	5.8	(8.1)**
Harpacticoid "B"	0.2	(0.7)	0.4	(1.0)	2.0	(2.8)	0		0.3	(0.4)*	1.2	(1.5)*	4.5	(6.5)*	0		2.8	(5.3)*
Harpacticoid "C"	0.4	(0.9)	1.2	(2.2)	0.3	(1.0)	0.5	(1.2)	0		0		0.1	(0.4)	3.0	(3.5)**	0	
Copepod "A"	0.6	(0.8)	1.2	(1.3)*	0.8	(1.0)	0.7	(1.3)	0.1	(0.1)	0.1	(0.3)	5.7	(7.0)*	7.5	(4.4)**	0.4	(0.6)
Copepod nauplii	0.2	(0.4)	0.5	(0.9)	3.1	(6.9)*	0.7	(1.0)	0.1	(0.2)	0.8	(1.7)	9.1	(16.1)	5.0	(7.6)*	0.3	(0.7)
Barnacle nauplii	0		0.6	(1.0)	0.2	(0.6)	0		0.1	(0.1)	0.1	(0.2)	1.3	(1.3)*	0		0.1	(0.3)
Ostracods	0.4	(0.8)	0.3	(0.6)	0.5	(1.0)	0.3	(1.2)	0.1	(0.3)	0.1	(0.2)	3.6	(3.6)**	0		0.4	(0.8)
Amphipod "A"	4.2	(4.0)**	4.2	(4.8)**	2.9	(4.9)*	3.0	(7.9)	0.1	(0.2)	0		6.9	(6.7)**	3.0	(1.1)**	1.9	(2.0)**
Amphipod "B"	0.1	(0.2)	1.3	(1.3)**	0.2	(0.5)	0.7	(1.8)	0.3	(0.4)	0.7	(1.4)	8.0	(13.1)*	7.0	(10.1)**	0	
Isopods	0.3	(0.6)	0.2	(0.4)	0.5	(0.7)	0		0.1	(0.1)	0.2	(0.2)	2.4	(1.4)**	1.0	(1.2)*	1.4	(1.9)*
Cumacean "A"	4.8	(4.3)**	4.8	(4.0)**	4.9	(4.7)**	0		0.1	(0.1)	0.1	(0.5)	10.6	(16.2)**	24.6	(33.2)**	4.1	(4.8)**
Cumacean "B"	0.7	(1.0)	0.2	(0.5)	0.2	(0.4)	0		0		0		1.4	(2.8)	1.0	(2.0)	0.1	(0.3)
Tanaids	0.3	(0.6)	0.4	(0.8)	0.8	(1.1)*	0.2	(0.6)	0		0		1.3	(2.7)	0.5	(1.0)	0.3	(0.6)
Mysids	0.1	(0.5)	0.6	(0.9)	0.7	(1.2)	0.2	(0.6)	0		0.1	(0.1)	1.5	(2.4)	0		2.4	(4.4)**
Shrimp	0.7	(1.0)	1.1	(1.2)*	0.3	(0.7)	0		0.1	(0.2)	0.1	(0.1)	0.7	(1.6)	3.0	(2.6)**	2.0	(2.6)*
Shrimp larvae	0.5	(1.2)	0.1	(0.3)	0.4	(0.9)	0		0		0		7.9	(6.9)**	0		0.5	(0.9)
Pagurid larvae	7.0	(15.0)**	2.4	(4.1)*	1.8	(2.7)*	0.3	(0.8)	0.1	(0.1)	0.1	(0.1)	19.4	(33.2)	5.0	(5.0)**	2.5	(4.2)*
Decapod zoea	0.1	(0.3)	1.2	(1.5)*	1.8	(3.2)	0.2	(0.6)	0		0.1	(0.1)	0.7	(1.4)	0.5	(1.0)	0.1	(0.3)
Miscellaneous crustaceans	0.7	(1.3)	3.2	(3.5)**	0.4	(1.2)	0.2	(0.6)	0.1	(0.2)	0.6	(0.8)*	15.1	(18.3)**	5.5	(4.1)**	0.7	(0.8)*
Chaetognaths	0.5	(1.7)	0.4	(0.7)	0.1	(0.4)	0.3	(0.8)	0		0.1	(0.1)	0.2	(0.6)	0		0.6	(1.4)
Polychaetes	0.2	(0.4)	0.7	(0.8)*	0.3	(0.6)	0.3	(0.8)	0.1	(0.1)	0.1	(0.1)	17.7	(15.5)**	7.0	(6.6)**	0.8	(0.7)*
Gastropods	0.4	(0.6)	0.4	(0.7)	0.6	(1.0)	0.7	(1.0)	0.5	(0.7)*	18.8	(23.2)**	30.2	(27.8)**	3.0	(3.8)*	0.5	(0.7)
Sipunculids	0.3	(0.6)	0.1	(0.3)	0.2	(0.6)	0.3	(0.8)	0.2	(0.5)	0.1	(0.2)	4.8	(11.2)*	2.5	(2.5)**	0.2	(0.4)
Foraminifera	1.2	(2.0)	2.2	(2.4)**	1.9	(3.2)*	0.8	(1.6)	1.1	(1.2)**	22.8	(14.7)**	8.5	(8.1)**	3.0	(2.6)**	1.2	(2.1)

and gastropods dominated the samples. Samples collected in the hour following sunset were dominated by harpacticoids, with a variety of other organisms (including *O. colcarva* and gastropods) occurring abundantly. Samples taken during the second hour after sunset again were dominated by harpacticoids, although the relative abundance of the different harpacticoid species switched (table 3). *Oithona colcarva* and a species of cumacean were the other most abundant taxa during this second hour. *Oithona colcarva* dominated the other night time intervals from 2030-0500.

The relative abundance of nine common taxa (*O. colcarva*, calanoid copepods, harpacticoid copepods, copepod nauplii, amphipods, cumaceans, pagurid larvae, polychaetes and gastropods; table 3) were compared using Spearman Rank Correlations (SRC). Although the abundances were greater at night, the relative abundances (% total sample) of these taxa were correlated ($p \leq 0.05$) between pooled day samples and pooled night samples. When samples from consecutive time intervals were compared, the relative abundances of taxa in all such pairs were correlated ($p \leq 0.05$) except those from 1800/1830 vs. 1930, and 1930 vs. 2030. For example, harpacticoids, pagurid larvae, calanoids, and polychaetes were relatively more important, while copepod nauplii, amphipods, and gastropods were relatively less abundant, at 1930 than at 1800/1830. Cumaceans and amphipods increased in relative abundance between 1930 and 2030, while gastropods and pagurid larvae decreased in relative numbers over this interval. Therefore, the hours around dusk were the only ones where the relative abundance of captured organisms differed.

Differences in the relative abundances of certain taxa reflect their different temporal behavior patterns. Sixty-two percent of the 29 common taxa (table 3) were captured in greatest numbers during the first hour after sunset (1830-1930), while 17% were captured in greatest abundance during the second hour after sunset. The only taxon showing peak abundance during the day was foraminifera. Many of the taxa exhibit sustained vertical migration throughout the night following the post-sunset pulse (e.g., calanoid "A," amphipod "A," cumacean "A," pagurid larvae in table 3). A few taxa (calanoid "B," decapod zoea) were captured most frequently during the last interval of night (0230-0500), and many (28%) exhibited a pulse of migration at this time. Only the cyclopoid *Corycaeus* spp. peaked in abundance during the hour prior to sunrise (0500-0600); the harpacticoid *Microsetella* spp. also exhibited a pulse of vertical migration at this time. The behavior of *O. colcarva* was variable throughout the various time intervals (fig. 1). The mean number of this species captured for both nights combined was greatest at 0230; however, that peak reflects an especially high number captured on July 17 ($\bar{X} = 638$) and a similar pattern was not observed on July 16 (fig. 1). Migration rates for this species were high during all night hours.

DISCUSSION

The zooplankton captured by emergence traps in this study do not solely represent, either in numbers or composition, the demersal zooplankton (Hobson and Chess, 1979; Robichaux, *et al.*, 1981) living within the reef substrata over which the traps are placed. These data do, however, provide information on the temporal patterns of migration by the total reef zooplankton which is of value to studies of reef energetics and the behavior of reef planktivores.

Both Robichaux, et al. (1981) and Youngbluth (1982) addressed the question of trap design and both found differences in number and composition of zooplankton between sealed and unsealed traps. Both of these studies, however, were conducted over sandy bottoms where a complete seal was possible and zooplankton movement through the underlying substrata unlikely. In this study, both sealed and unsealed traps were placed over reef substrata; the former were sealed as well as possible through the use of sand and rubble placed over the trap skirts. No differences were observed in the numbers of zooplankton captured between the two treatments, possibly suggesting that there is more movement by zooplankton through interstices of the reef than previously thought. Analysis of differences in species composition between the two treatments is currently underway.

While Alldredge and King (1977) and Porter and Porter (1977) found the most zooplankton over structurally complex coral substrata, this was not found by Ohlhorst (1980) or Birkeland and Smalley (1981). In the present study, there also was no difference in the number of individuals captured over different substrata. One contributing factor may be the differential ability to seal traps over sand and coral substrata. Robichaux, et al. (1981) and Youngbluth (1982) both found that more zooplankton were captured by unsealed traps than by sealed traps when both were placed over sand substrata. Youngbluth (1982) observed that a gap of 1 cm between trap and substratum resulted in capture of significantly greater numbers of zooplankton than a total seal, while there was no difference between samples from traps with gaps of 1 and 10 cm. Therefore, differences in number of zooplankton collected over different types of substrata might be expected when certain treatments are well sealed and others not. If the sand traps of Alldredge and King (1977) and Porter and Porter (1977) were well sealed in contrast to those over coral substrata, it may be difficult for these researchers to compare their substratum treatments. Birkeland and Smalley (1981) compared coral substrata to algal turf pavement and probably were able to sample both treatments similarly, since in either habitat a total seal is unlikely. Ohlhorst (1980) and this study used unsealed traps to sample both coral and sand substrata. These traps captured the zooplankton moving along the reef bottom over both types of substrata, and the data indicated that the numbers of zooplankton available to planktivores were comparable in both habitats. Analysis of the species composition of zooplankton over various reef substrata is in progress.

Fewer zooplankton were captured per hour in this study than in previous Caribbean studies by one of the authors (Ohlhorst, 1980, 1982, 1985). The most probable explanation lies in the sole use of polyvinyl traps in the previous studies. In this study, two polyvinyl traps were used in addition to mesh traps (details will be discussed elsewhere); and, while no statistically significant differences were found in abundance of plankton between these treatments (due to high variance and small sample size of polyvinyl traps), the polyvinyl traps usually captured considerably more zooplankton. Both this study and the earlier work by Ohlhorst (1980, 1982, 1985) found considerable variability between nights sampled.

The bimodal emergence pattern (post-sunset, pre-sunrise) suggested by Glynn's (1973) data from plankton tow nets appears to be supported by this study (fig. 1), although more complete information will be available when all the samples have been analyzed. The present study provides the first documentation of a presunrise emergence of zooplankton and has considerable implications for reef bioenergetics and planktivore feeding behavior.

As in the previous work where plankton were collected over Caribbean reef substrata at different time intervals (Ohlhorst 1982), *Oithona colcarva*, various calanoids and harpacticoids, copepod nauplii, amphipods, and polychaetes were important components of the fauna. The relative abundances of these organisms from the two studies are correlated ($p \leq 0.05$, SRC). There are, however, differences in the behavior of certain taxa between these studies. In Jamaica, for example, the harpacticoid *Microsetella* spp. migrated in greater numbers during the day than at night, while at St. Croix the peak migration was during the first and second hour after sunset. Also, isopods were an important component of the Jamaican fauna but were relatively rare at St. Croix. *Oithona colcarva* was less abundant at St. Croix than in Jamaica, and its activity pattern differed. At Jamaica *O. colcarva* was captured in the greatest numbers during the second hour after sunset, while at St. Croix the capture rate of this copepod was highest from midnight to just prior to sunrise. The sample size needs to be increased at both reef locations to determine if these differences are real.

The differences between this study and those over primarily sand substrata in the Caribbean (Robichaux, *et al.*, 1981; Youngbluth, 1982) may be related to habitat differences and/or trap design. The relative abundance of nine common taxa from this study and the unskirted traps of Robichaux, *et al.* (1981) were positively correlated ($p \leq 0.05$, SRC). There was no correlation, however, between the relative abundance of taxa in this study and that from any of the treatments of Youngbluth (1982). While harpacticoids were a very important component of the reef zooplankton in St. Croix, they did not dominate to the degree reported by Robichaux, *et al.* (1981) and Youngbluth (1982) in the Bahama Islands. The St. Croix samples usually were dominated by the cyclopoid *Oithona colcarva*. This is a swarming meroplanktonic species unlikely to be captured in traps sealed over sand. Cumaceans and calanoids were important over St. Croix reefs, as was found with certain trap designs over sand by Youngbluth (1982) but not by Robichaux, *et al.* (1981).

This preliminary analysis of data collected from St. Croix is consistent with earlier diel studies (Walter, *et al.*, 1981; Ohlhorst 1982) which indicated that zooplankton move up into the water column throughout the night with a pulse in activity following sunset. Although zooplankton are therefore available to planktivores throughout the night, the indication that there are predawn (this study) and postdusk peaks of migration is consistent with the hypothesis that fish predation is an important selective factor upon zooplankton behavior since these dawn and dusk peaks of emergence coincide with periods when there are few fish predators (Hobson, 1975).

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LITERATURE CITED

Alldredge, A. L., and J. M. King. 1977. "Distribution, Abundance, and Substra Preferences of Demersal Reef Zooplankton at Lizard Island Lagoon, Great Barrier Reef." *Mar. Biol.* 41:317-333.

Alldredge, A., and J. M. King. 1980. "Effects of Moonlight on the Vertical Migration Patterns of Demersal Zooplankton." *J. Exp. Mar. Biol. Ecol.* 44:135-156.

Barnes, R. D. 1980. *Invertebrate Zoology*. 4th Edition. Saunders, Philadelphia. 1089 pp.

Birkeland, C., and T. L. Smalley. 1981. "Comparison of Demersal Plankton From Comparable Substrata From a High Island and an Atoll." *Proc. 4th Int. Coral Reef Symp.* 1:437-442.

Glynn, P. M. 1973. "Ecology of a Caribbean Coral Reef. The *Porites* Reef Flat Biotope: Part 2. Plankton Community With Evidence for Depletion." *Mar. Biol.* 22:1-21.

Hobson, E. S. 1974. "Feeding Relationships of Teleostean Fishes on Coral Reefs in Kona, Hawaii." *Fish. Bull.* 72:915-1031.

Hobson, E. S. 1975. "Feeding Patterns Among Tropical Reef Fishes." *Amer. Sci.* 63:382-293.

Hobson, E. S., and J. R. Chess. 1978. "Trophic Relationships Among Fishes and Plankton in the Lagoon at Enewetak Atoll, Marshall Islands." *Fish. Bull.* 76: 133-153.

Hobson, E. S., and J. R. Chess. 1979. "Zooplankters That Emerge From the Lagoon Floor at Night at Kure and Midway Atolls, Hawaii." *Fish. Bull.* 77:275-280.

Liddell, W. D. 1982. "Suspension Feeding by Caribbean Comatulid Crinoids," pp. 173-182. *In*: J. M. Lawrence (ed.), *Echinoderms: Proceedings of the International Conference, Tampa Bay*. A. A. Balkema, Rotterdam.

McWilliam, P. S., P. F. Sale, and D. T. Anderson. 1981. "Seasonal Changes in Resident Zooplankton Sampled by Emergence Traps in One Tree Lagoon, Great Barrier Reef." *J. Exp. Mar. Biol. Ecol.* 52:185-203.

Ohlhorst, S. L. 1980. "Jamaican Coral Reefs: Important Biological and Physical Parameters." Ph.D. thesis, Yale University. 147 pp.

Ohlhorst, S. L. 1982. "Diel Migration Patterns of Demersal Reef Zooplankton." *J. Exp. Mar. Biol. Ecol.* 60:1-15.

Ohlhorst, S. L. 1985. "Reef Zooplankton Collected Along A Depth Gradient at Discovery Bay, Jamaica," pp. 101-116. *In*: M. L. Reaka (ed.), *The Ecology of Coral Reefs*, Symp. Ser. Undersea Res., *Vol.* 3(1). NOAA *Undersea Res. Progr.*, *Rockville*, Md.

Porter, J. W. 1974. "Zooplankton Feeding by the Caribbean Reef-Building Coral *Montastrea cavernosa*." *Proc. 2nd Int. Reef Symp.* 1:111-125.

Porter, J. W., and K. G. Porter. 1977. "Quantitative Sampling of Demersal Plankton Migrating From Different Coral Reef Substrates." *Limnol. Oceanogr.* 22:553-556.

Porter, J. W., K. G. Porter, and Z. Batac-Catalan. 1977. "Quantitative Sampling of Indo-Pacific Demersal Reef Plankton." *Proc. 3rd Int. Coral Reef Symp.* 1:105-112.

Robertson, A. I., and R. K. Howard. 1978. "Diel Trophic Interactions Between Vertically-Migrating Zooplankton and Their Fish Predators in an Eelgrass Community." *Mar. Biol.* 48:207-213.

Robichaux, D. M., A. C. Cohen, M. L. Reaka, and D. Allen. 1981. "Experiments With Zooplankton on Coral Reefs, or, Will the Real Demersal Plankton Please Come Up?" *Mar. Ecol.* 2:77-94.

Sebens, K. P. 1977. "Autotrophic and Heterotrophic Nutrition of Coral Reef Zoanthids." *Proc. 3rd Int. Coral Reef Symp.* 1:397-404.

Walter, C., L. Tulane, and J. N. Pasamonte. 1982. "A Preliminary Quantitative Study on Emergence of Reef Associated Zooplankton From a Philippine Coral Reef." *Proc. 4th Int. Coral Reef Symp.*, 1:443-451.

Youngbluth, M. J. 1982. "Sampling Demersal Zooplankton: A Comparison of Field Collections Using Three Different Emergence Traps." *J. Exp. Mar. Biol. Ecol.* 61:111-124.