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BENTHIC FORAMINIFERAL ASSEMBLAGES AT CUT CAY: A MICROCOSM STUDY OF THE EFFECTS OF WATER ENERGY AND SUBSTRATE PREFERENCE, SAN SALVADOR, BAHAMAS

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ABSTRACT

On the northeast end of the island of San Salvador, a narrow N-S eolianite peninsula known as North Point separates the open Atlantic Ocean on the east from the semi-protected, shallow waters in Grahams Harbour. A wave-cut channel at Cut Cay connects the two realms. The high-energy channel and the lagoon's seagrass beds with scattered sand flats allow the effects of water energy and substrate type to be studied in a small area. Localities were sampled in the channel (lagoon end); in the low-energy seagrass beds of the lagoon next to the ridge, both north and south of the channel; in a sand bed on the western side of the area; and in the grass bed adjacent to it. The most common plant and algae species at each site were bagged separately. Seafloor samples were taken at each site. Foraminifers on the two most common species of plants and algae per site were recorded. Sediment was screened using a 3∅ sieve, live and dead individuals were counted, and taphonomic condition was recorded.

Live foraminifers found on vegetation displayed a substrate preference, which appears to be strongly affected by the shape and relative size of the substrate. The flat, relatively wide blades of the common seagrass *Thalassia testudinum* had a low-diversity fauna dominated by the relatively large *Planorbulina* spp. *Rosalina* dominated the small, branching fibers of *Penicillus* sp. capitulae; *Planorbulina* was essentially absent. *Halimeda incrassata* hosted a more diverse fauna including mainly the genera *Rosalina, Discorbis,* and *Planorbulina.* Seafloor assemblages were largely dead tests, but live/dead ratios and taphonomic states varied with water energy and vegetation density. The highest live/dead ratios and the best test preservation were found at the protected sites on either side of the cut and within the channel. The most taphonomically altered tests were found in the lagoon's sand bed, although they appear to be derived from the adjacent grassbeds.

INTRODUCTION

Benthic foraminiferal assemblages found in the fossil record are useful in determining paleoenvironments because the distribution of modern-day species is known to be controlled by a number of environmental factors such as substrate type, nutrient availability, and water energy. (Murray, 1991). Substrate type, especially benthic vegetation, is especially important in this

regard. In a pioneering study, Brasier (1975) sampled sediment as well as several other substrates (plants, rocks, shells, and corals) from marshes, creeks, lagoons and channels in Barbuda. His results showed that similarities of phytal assemblages were dependent not only on host vegetation species, but also on the similar structure of host substrates, comparable sediment content, and physical conditions in which the substrate exists. He reported that fibrous algae provide numerous well-protected pockets in which non-cemented foraminifera may cling to the algae with little risk of detachment. In contrast, non-fibrous weeds and algae provide a higher-risk habitat in which the foraminifera are more exposed to water energy and other external agents. Changes in salinity, temperature, grain size, vegetation, and predation also affected the distribution of foraminifera.

Fujita and Hallock (1999) examined the substrate preferences of *Sorites* and *Archaias*. They collected several types of vegetation, including *Thalassia, Halimeda*, and *Penicillus*. Results showed that *Archaias* preferred vegetation with abundant epiphytic algae, and that the benthic macroalgae itself did not host a large percentage of the foraminiferal assemblage. *Sorites* preferred the flat blades of *Thalassia* without epiphytic algae, although it was a full order of magnitude less common than was *Archaias*.

In one of the few studies to include taphonomic condition, Glenn-Sullivan and Evans (2001) performed a study of the live, dead and unabraded, and dead and abraded foraminifera on vegetation and in seafloor sediment in Apo Reef, Midoro, Philippines. They aimed to provide a transition from living populations to "time-averaged sub-fossil assemblages." They found that tiny rotalliids are important in live sediment assemblages, but these are often missed in laboratory analyses because of the sieve size used. They concluded that habitat preference controls live foraminiferal assemblages on vegetation, but sediment assemblages are largely controlled by wave energy. Eventually, sediment is enriched in large,

robust tests and diminished in small, delicate tests. Taphonomic processes they cited included mechanical abrasion, dissolution, and predation.

Previous investigations focusing on or including the Cut Cay locality on San Salvador are Beck (1991), Buchan (2006), and Buchan and Lewis (2010). Beck (1991) studied various substrates in the area, reporting results at the family level and with no taphonomic data. She found that *Thallassia* beds, beach sand, and the sand flat were dominated by the Soritidae and Discorbacidae. The manatee grassbed assemblage was similar but more diverse; the rock assemblage was distinct from all others with more small taxa (e.g., Miliolidae). Buchan (2006) studied foraminiferal distribution in vegetation beds at six localities around San Salvador, including one transect at Cut Cay. This study was based on benthic foraminifera that are commonly larger than 1 mm; sediment size fractions less than 0.5 mm were not examined. Vegetation and sediment assemblages were studied at the species or species group level, as were their taphonomic states (see below). Live to dead ratios as well as the quality of preservation index (QPI), which she defined as the sum of all fractions of *live, pristine, good* tests expressed as a percentage of the total. *Sorites* and *Planorbulina* were the dominant live foraminifera found on *Thalassia* and *Halimeda*, although the assemblage at Cut Cay was based on a small number of specimens. Buchan found that, in all sites, the QPI was relatively high and was related to grassbed density (Buchan and Lewis, 2010).

The present study, done as an undergraduate honors thesis (Morgan, 2008), investigates the distribution of living foraminifera and dead tests within the small geographic area and wide range of environmental variables found at Cut Cay. All taxa were identified at the species level whenever possible. Taphonomic categories were the same as in Buchan's study, but a much smaller sieve cutoff value (125mm) was used in the current study.
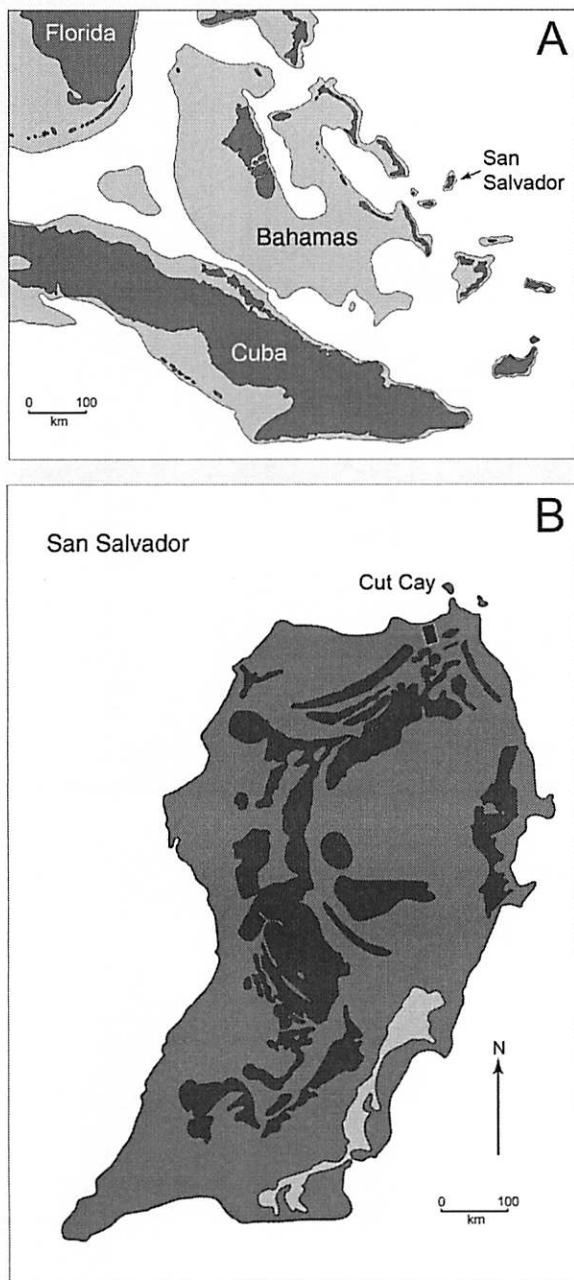
Figure 1. A. The Bahamian Islands and San Salvador. B. The Cut Cay site at North Point.

STUDY AREA

Cut Cay is located on North Point, an eolianite ridge on the northeast end of San Salvador Bahamas, 24° 07' 39.89" N, 74° 27' 26.66" W

(Figure 1). Here, a 15-meter-wide wave-cut channel links the high-energy open Atlantic Ocean to the low energy Graham's Harbour. On the Atlantic side, trade-wind generated currents and wave energy preclude the growth of vegetation. On the Graham's Harbour side of the channel within the study area, water depth is shallow, ranging from approximately 0.5 m deep near the channel to approximately 2 m deep further off shore. Grassbeds in this area are moderate to dense in percentage cover and are composed primarily of *Thalassia testudinum* and benthic macroalgae such as *Halimeda* incrassata and *Penicillus* spp. Within the channel, there is little vegetation. Only small filamentous algae grow on the cobbles that cover the seafloor.

The study locality was chosen because of the wide variety of environments that are found within a small area, only spanning approximately 40 m. This area is a microcosm of several major foraminiferal environments found elsewhere on the island. The microcosm aspect of this study was vital because physical factors such as salinity, temperature and turbidity, which vary from one locality to the next, can mask substrate preference (Brasier 1975).

METHODS

Field Methods

The study area was visited twice, once in May of 2007 and once in March of 2008. During the first visit, a severe weather system hit San Salvador and caused two days of rough water and reduced visibility. On the first day after the storm, the research team went to Cut Cay and decided upon final locations for sample sites (Figure 2). In addition, some grab samples of algae and seagrass were collected. Manatee grass samples were collected at what would become sites J and L, but they were found not to support any foraminifera. After the water cleared three days after the storm, sampling began at the five sites selected for vege-
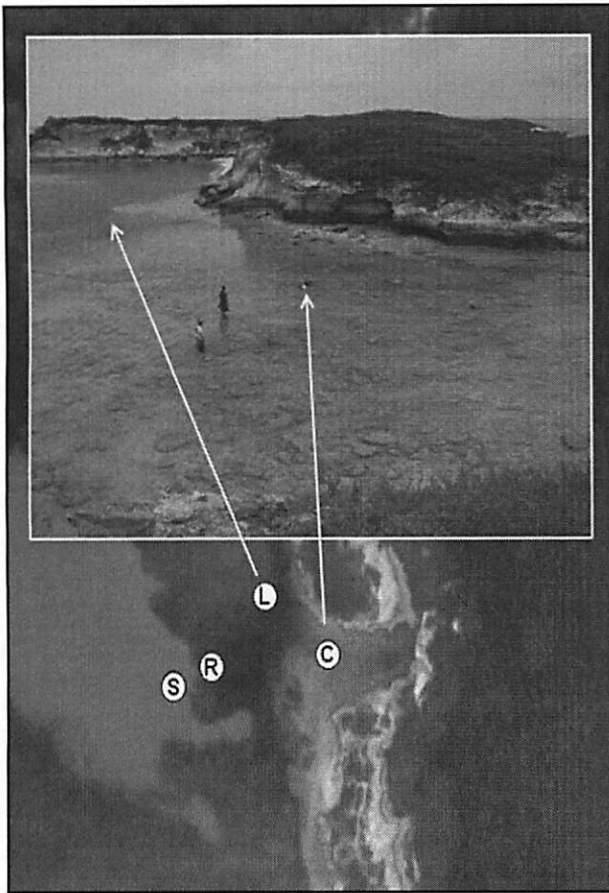
Figure 2. Sites sampled at Cut Cay. Above: Cut Cay is in background, with channel in foreground and lagoon to left. Below: areal view of study area (Google Earth).

Figure 3. Vegetation found at Cut Cay. A. Filamentous algae found on site C cobbles with Rosalina floridana (R) attached. B. Detail of Rosalina floridana. Algal filaments are approximately 0.2 mm in diameter. C. Halimeda incrassata collected at site L. D. Penicillus sp. collected at site J. E. Thalassia testudinum collected at site J.

tation and/or sediment sampling. All sampling was done in the lagoon because the substrate on the open-ocean side of the cut was nearly devoid of benthic vegetation and sand. The channel (site C) was selected because of the cobble-rich substrate as well as intermittently high water energy (wave-driven currents) present at the site. Two seagrass sites were selected as relatively low water energy as both were protected by the eolianite ridge from the channel's currents. The grassbed site north of the channel (site L) had been previously sampled by Olivia Buchan for large benthic foraminifera, and was included to provide a direct comparison
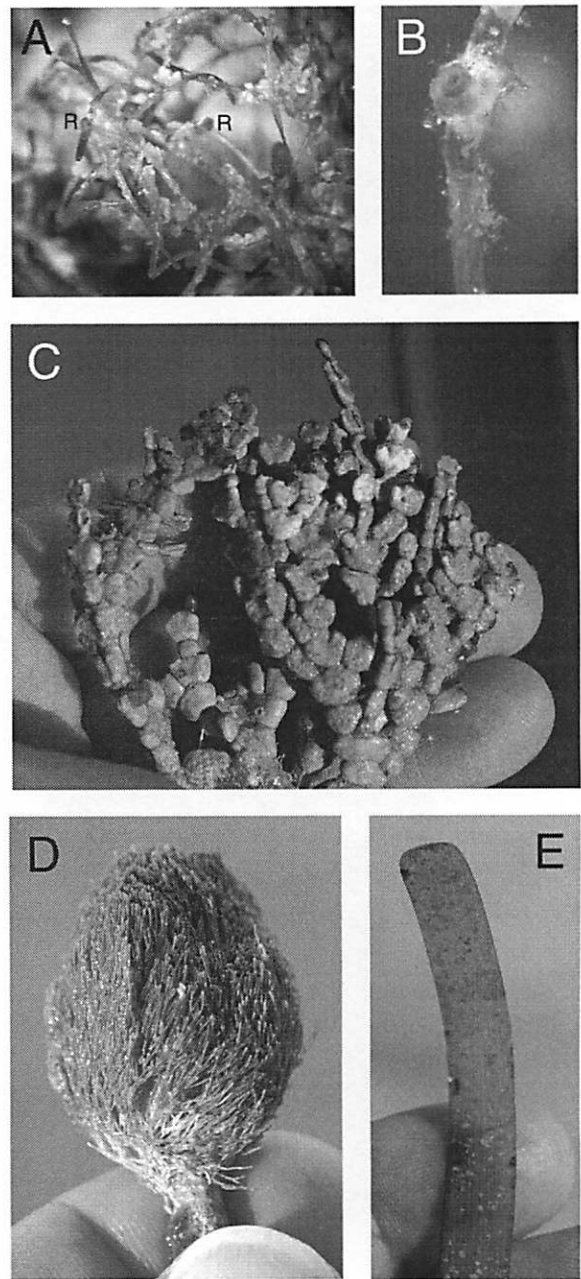
to her study (Buchan, 2006; Buchan and Lewis, 2010). The grassbed site south of the channel (site J) exhibited a different benthic macroalgae assemblage in addition to abundant *Thalassia*. Thus, the two sites were judged to be similar in setting but differed in their benthic vegetation. The sand flat site (site S) was selected in order to study the foraminiferal assemblages in an area with little to no vegetation and to study possible origins of the sediment in this area. The grassbed site (site R) adjacent to the sand flat was sampled to provide a comparison with the sand flat and with nearer-to-shore grassbeds at sites L and J. GPS waypoints were recorded at each site, as were approximate water depth, bottom water pH, and bottom water temperature (see below).

Samples of seagrass and benthic macroalgae (Figure 3) were cut using small scissors at the seafloor and bagged separately underwater according to vegetation species. Sampled vegetation included the most abundant taxa per site: fifty blades of the turtle grass *Thalassia testudinum* at sites J and L, twenty *Penicillus* thalli at site J, and twenty *Halimeda incrassata* at site L.

At sites C, J, R, and S, a teaspoon was used to collect approximately 5 ml of sediment from the surface of the seafloor, and these samples were placed in plastic bags underwater. Later the same day, excess seawater was poured off the sediment and vegetation samples, and 8% formalin solution with a small amount of Borax was added to preserve and buffer the samples to a pH of approximately 8.4 or above. During March of 2008, filamentous algae on the upper surfaces of cobbles at site C were removed and bagged.

Laboratory Methods

In the laboratory in Auburn University, foraminifera on vegetation were counted using a binocular microscope. The foraminifera on the fifty *Thalassia* blades from sites J and L were recorded according to species, whether they were alive or dead, and taphonomic state if dead. Ta-

phonomic stages were defined as in Buchan's thesis. Live specimens were recognized by the presence of protoplasm, colored by symbionts in some species. Pristine tests were in the same state as those of live specimens, whereas good tests had some minor damage, usually around test margins; altered had more extensive breakage and abrasion to test, and extremely altered tests showed a high degree of breakage and surface pitting (Figure 4). Ten specimens of the algae collected at sites J and L were dissected using small scissors and a scalpel into smaller, manageable pieces, and their foraminiferal populations were recorded in the above manner. The ten-specimen limit was selected because this provided approximately 200 to 250 foraminifera per algae type and was more time-efficient than picking all twenty specimens collected at each site. Individual foraminifera
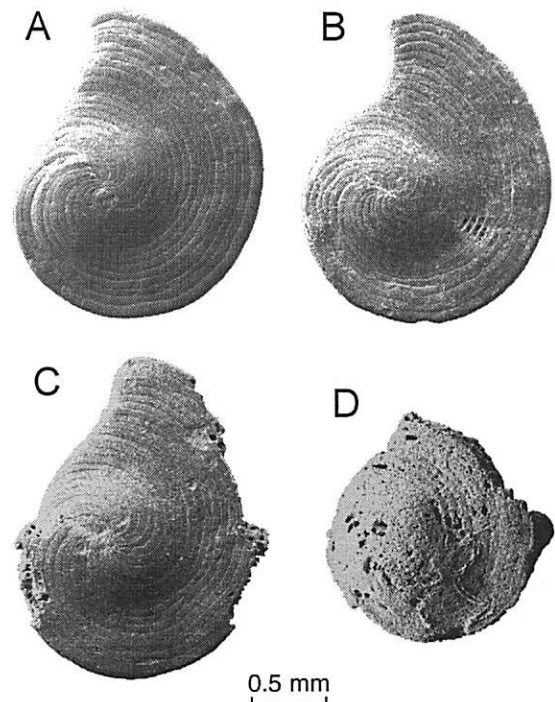

0.5 mm

Figure 4. Scanning electron photomicrographs of the taphonomic states used in this study as shown by Archaias angulatus. *A. Pristine. B. Good. C. Altered. D. Extremely altered. From Buchan and Lewis, 2010.*

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were not removed from the vegetation during this process. Those that were trapped in sediment clumps within *Penicillus* were not counted in its assemblage because they may have settled out of the water column after being picked up from the sediment by wave or current action, and thus may not represent substrate preference. Only those foraminifera still attached either by soft or hard parts were counted. Since all vegetation types were collected by cutting at the seafloor, no roots or rhizomes were present on the samples, so all foraminifera counts are only on the parts above the sediment-water interface.

Sediment samples were rinsed with fresh water and were air dried for at least 24 hours and then sieved using a 3 phi (0.125 mm) wire screen. Approximately 250 specimens per sample were picked using a binocular microscope. White or transparent tests were classified as dead, and the taphonomic state was recorded for each dead specimen based on degree of test degradation. Species picked from the sediment were stored on separate micropaleontology slides.

Two ratios indicative of the overall taphonomic state of the total assemblages were calculated for the sediment samples at each site. Live to dead ratio (L/D) was calculated by dividing the number of live foraminifera by the total number of pristine, good, altered and extremely altered foraminifera. The Quality of Preservation Index (QPI) was calculated by dividing the total number of live, pristine and good foraminifera by the total

number of foraminifera collected, and that number was multiplied by 100%, as in Buchan, 2006 and Buchan and Lewis, 2010. The unknown specimens were not included in the L/D ratio or QPI percentages because they were either too small for taphonomic state to be determined or their original surface texture was not known in order to compare and determine the extent of abrasion and polishing.

RESULTS

Plant and Algae Assemblages

Physical conditions at all sites were comparable, except for water depth and energy, which vary across the Cut Cay area. Bottom water temperature was consistently approximately 29°C and pH was approximately 8.2 (Table 1). Water depth varied from 0.5 ms and 2.5 m, generally increasing away from shore. Relative water energy was estimated based on observations made at the time field work was done, grain size of the sediment, and the physical setting of the site.

Plants and algae hosted a small number of taxa of foraminifera, with a total of only eleven identified species represented in the area. The *Thalassia* assemblages at both sites J and L were limited to only four species (Figures 5 and 6). Both sites were strongly dominated by *Planorbulina*, with *Disorbis rosea* ranked second. Minor taxa included *Sorites marginalis* and *Acervulina*

Table 1. Site statistics

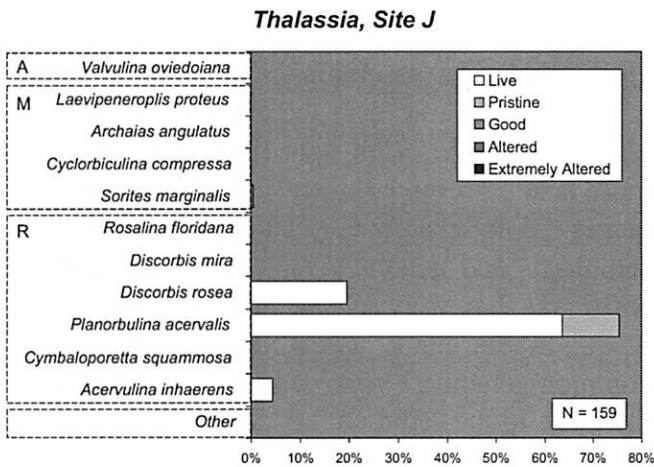| Site designation	GPS Waypoint		Approximate Water Depth	Bottom Water pH	Bottom Water Temperature
	Latitude	Longitude			
C	24.12776 N	74.45761 W	0.5m	8.3	29.0°C
J	24.12693 N	74.45789 W	1m	8.2	29.5°C
L	24.12818 N	74.45801 W	0.8m	8.1	28.7°C
R	24.12761 N	74.45851 W	1.5m	8.2	28.7°C
S	24.12773 N	74.45883 W	2.5m	8.2	28.5°C

Figure 5. Percent relative abundance of foraminiferal species found on Thalassia *at site J.*
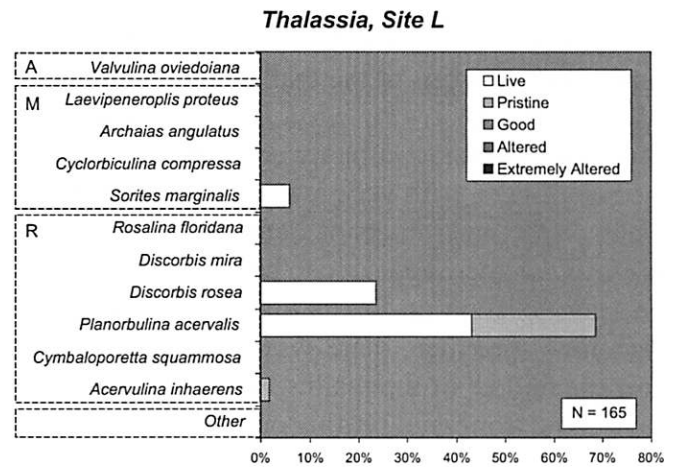

Figure 6. Percent relative abundance of foraminiferal species found on Thalassia *at site L.*
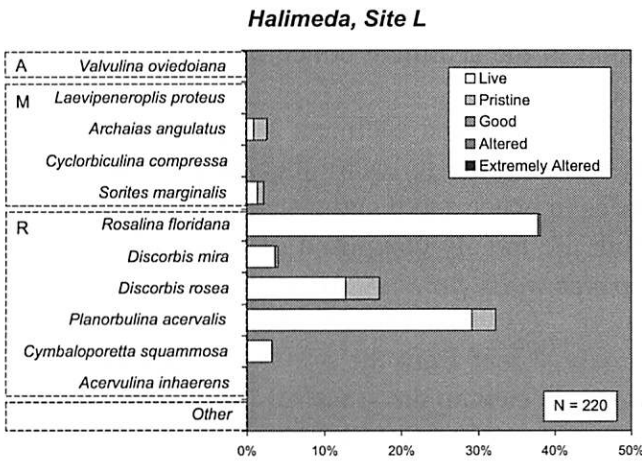

Figure 7. Percent relative abundance of foraminiferal species found on Halimeda *at site L.*
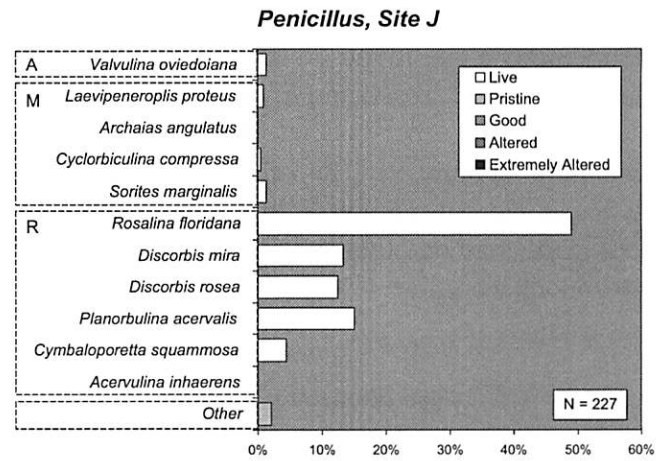

Figure 8. Percent relative abundance of foraminiferal species found on Penicillus *at site J.*

inhaerens. No textulariids were found on any of the 100 specimens of turtle grass collected. Most foraminifera were live; a minor amount of dead but pristine tests were also found. Thus, the L/D ratio was very high for the turtle grass assemblage. At site J, the ratio was 7.36; site L's L/D ratio was 2.75.

The *Halimeda* assemblage at Site L was among the most diverse of the vegetation assemblages (Figure 7). *Rosalina floridana* was the most

common species on *Halimeda*, ranging from immature to adult-sized individuals. There was also a larger percentage of *Planorbulina* than on any other type of algae. Once again, the L/D ratio was high for this foraminiferal assemblage, approximately 7.8.

Penicillus, which was sampled at site J, exhibited a slightly more diverse fauna (Figure 8), but the assemblage was dominated by *Rosalina floridana*. The majority of the *R. floridana*

were immature specimens, found almost exclusively near the ends of the *Penicillus* fibers and concentrated on tips of the thalli. The assemblage also included *Discorbis mira, D. rosea*, and *Planorbulina*. All foraminifera were dispersed across the outer fibers, with very few living foraminifera found on the inner fibers of *Penicillus*. Except for *R. floridana*, there appeared to be no preference for a certain location on the thallus. In almost every *Penicillus* specimen, there was a pocket of sand near the middle of the thallus, which appeared to have come from sand settling out of the water column. As in the *Thalassia* assemblage, almost all foraminifera counted were live. The L/D ratio was 44.4, much higher than that of the *Thalassia* or *Halimeda* assemblages.

The high-energy environment at site C hosted the most diverse foraminiferal assemblage on any of the plant and algae samples. The filamentous algae found on cobbles at site C was dominated by *D. rosea* and *R. floridana*, with lesser amounts of other species including *Archaias angulatus* (Figure 9). The relative abundance of *D. rosea* was conspicuously higher in the filamentous algae than on other species of vegetation. All specimens were live.

Figure 9. Percent relative abundance of foraminiferal species found on the filamentous algae at site C.

Sediment Assemblages

Sediment assemblages (Figure 10) were much more diverse than the assemblages on the plants and algae, with approximately six times more taxa represented overall. Vegetation assemblages did not exactly correlate with sediment assemblages and generally included more agglutinated taxa than were represented on vegetation.

In the site-C assemblage, the two most common genera, *D. rosea* and *R. floridana*, were the same in the sediment and vegetation. *Miliolinella*, which was relatively common in the other sediment samples and absent in the vegetation samples, is conspicuously missing at site C. The sediment at site C has the largest representation of *D. rosea*. The L/D ratio was 0.46 at this site, the highest of all the sediment samples. The QPI at site C was 84.6%, a comparable value to those found in the sediment collected in the grassbeds (Table 2).

The two grassbed sediment samples (sites J and R) were similar to each other despite the differences in water depth and distance from the shore. Both are largely composed of *R. floridana, Laevipeneropolis proteus, Miliolinella* spp., and *D. rosea. Laevipeneropolis* and *Miliolinella* were largely absent from the grassbed and algae samples collected on the grassbed vegetation. Several quinqueloculine species are also present in the sediment but absent from the vegetation samples at the grassbeds. The L/D ratio and QPI at site J were 0.35 and 84.5%, respectively. At site R, the L/D ratio was much lower at only 0.17 and the QPI was somewhat higher at 92.8%.

The sand assemblage at site S represents basically the same taxa in the same abundances as those represented in grassbed sediment assemblages. The distinguishing factor between the grassbeds and sand flat is that the tests are generally more degraded in the sand flat. There are notably more altered and extremely altered tests and fewer live foraminifera in the sand sample. The L/D ratio at site S was only 0.01, with almost no
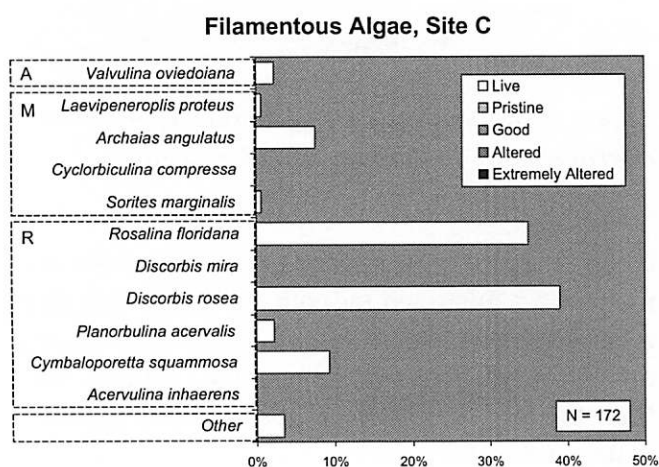
live foraminifera found. QPI was still relatively high at 79.4%, because, while the tests were dead and more degraded than those of site R, there were still few extremely altered tests.

DISCUSSION

Cut Cay provided a natural laboratory in which to study the distribution of foraminiferal assemblages within a small geographic area where environmental factors such as water temperature and salinity were nearly constant. The most important environmental variable affecting foraminifera was the nature and distribution of the vegetative substrate. The presence and type of benthic vegetation, in turn, was determined largely by water energy and depth.

Fifty-four species of foraminifera were

found in the study area. These included tests as small as 0.125 mm, whereas Buchan (2006) targeted species commonly larger than 1mm in size and used a 0.5 mm sieve to recover juveniles of these species. Because relatively few of these large foraminifera (a total of 8 individuals of *Planorbulina acervalis* / *Acervulina* spp. and *Sorites*) were found on benthic vegetation at the Cut Cay locality, Buchan was not able to evaluate the question of substrate preference in this area. Another difference in the two studies is that Buchan only examined *Thalassia* and *Halimeda*. One objective of the current research was to compare results with these two different data sets.

A major finding of our study was that the smaller foraminifera, most of which are rotaliids, are important and show that living foraminifera at Cut Cay do, indeed, have a strong substrate pref-
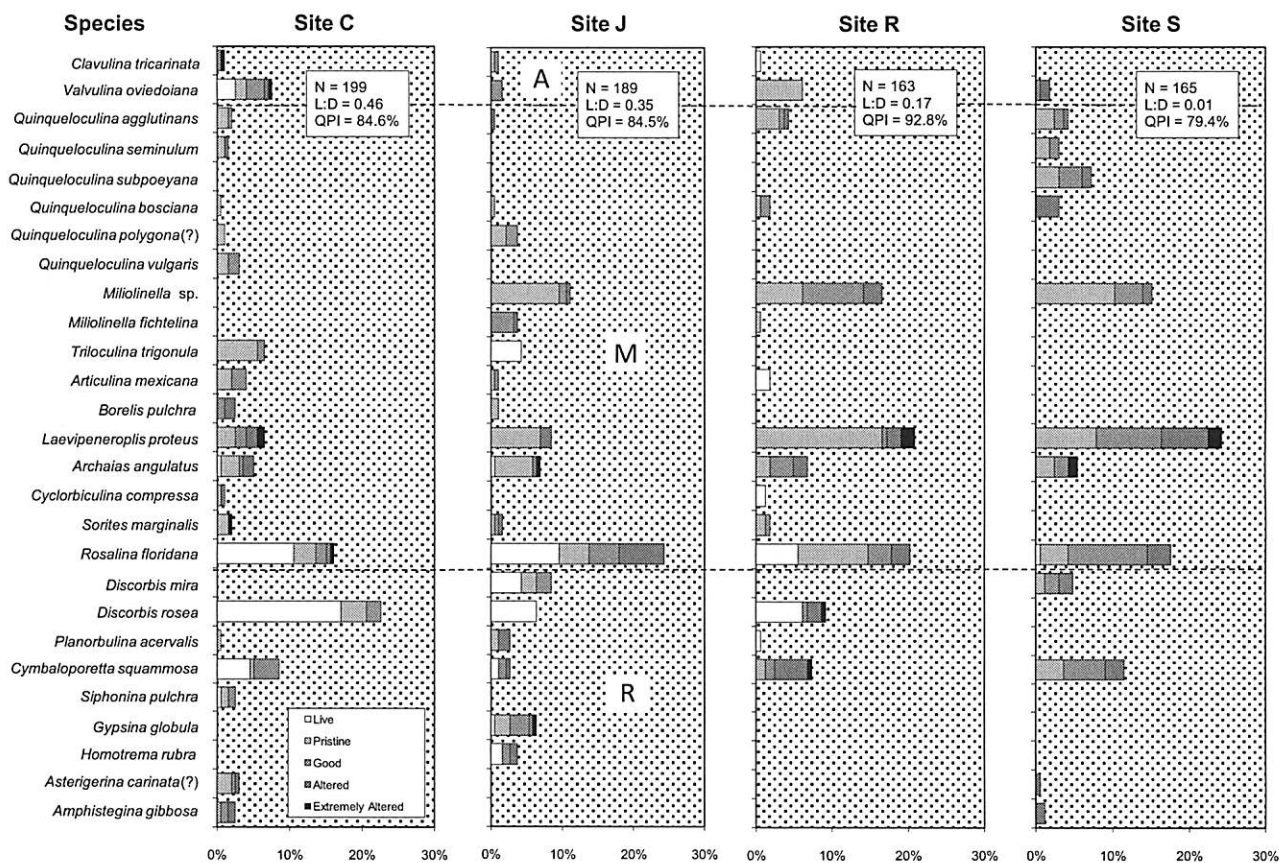

Figure 10. Percent relative abundance of select foraminiferal species found at all sediment sites.

Table 2—Sediment data statistics.

Sediment site	Number of foraminifera counted	Live to dead ratio	Quality of Preservation Index (QPI)
C	248	0.46	84.6%
J	269	0.35	84.5%
R	261	0.17	92.8%
S	261	0.01	79.4%

erence. The foraminiferal assemblages on vegetation appear to have been determined in large part by the specific shape of the plant or algal substrate. This is consistent with Brasier's (1975) conclusion regarding the importance of "substrate structure and detrital content" in phytal assemblage preference. Plants and algae with broad, flat surfaces, such as *Thalassia* and *Halimeda*, host larger attached foraminifera, such as *Planorbulina*. These foraminifera, Langer's Morphotype A, attach firmly and are able to remain attached to these unprotected substrates, whereas non-cementing varieties would be washed off in bad weather (Brasier 1975; Langer 1993). According to Fujita and Hallock's (1999) description of the preferred substrate of *Planorbulina* and *Sorites*, these taxa prefer a flat surface without the presence of epiphytal algae, whereas *Archaias* is better suited to filamentous algae.

The preference of immature *R. floridana* for the tip of the *Penicillus* thallus was the only instance of a preference for a certain area of a substrate in this study. This is similar to Wilson and Ramsook's (2007) conclusion that foraminifera are more abundant on the bushy heads of *Penicillus* than on the stems, although there is no mention of a preference for a certain section of the head in their study.

Although *Archaias angulatus* was present in small amounts on several of the vegetation samples, it was much more common in the sediment at all sites. Tests are resistant to abrasion and tend to accumulate in the sediment compared to species with more fragile tests (Martin, 1986). Even with the larger percentage of *A. angulatuss* in the sediment, this genus comprised a smaller amount of the assemblage than was anticipated. Hallock et al. (1986) described *Archaias* as the "dominant foraminifer in the Florida-Bahamas carbonate province." The highest abundances of this robust foraminifer in Hallock et al. (1986) were in mixed macro-algal-seagrass substrates, similar to the grassbeds at Cut Cay. The Hallock et al. (1986) study concentrated on larger benthic foraminifera, which made up a very small percentage of the overall foraminifera assemblage at Cut Cay. Therefore the prominence of *A. angulatus* may have been overstated in such studies.

In contrast, *Planorbulina* was one of the most common genera on the vegetation samples but was almost completely absent in the sediment samples. Just as *A. angulatus* is preferentially accumulated in the sediment because of its robust test, *Planorbulina* may be preferentially decreased in sediment populations because of its delicate, thin-walled test. Wilson and Ramsook (2007) inferred that the lack of planorbulinids in their sediment study was due to breakage after death.

Small foraminifera such as *Rosalina floridana, Disorbis mira,* and *D. rosea* are well suited

to live on algae with thin, fibrous texture such as that found in *Penicillus* and the filamentous alga on cobbles. These fibrous algae protect the small, uncemented foraminifera and allow them to cling to thin fibers and shield them from external forces (Brasier, 1975). Suspension feeding foraminifera thrive in this microhabitat because they may suspend their pseudopodia between the small fibers on the algae (Langer, 1993), but were not found on vegetation in this study.

Sorites is largely absent from all assemblages. The near absence of *Sorites* at Cut Cay on the plants and in the sediment is consistent with previous work done at the site (Buchan, 2006). In general, nutrient enrichment from anthropogenic sources can lower *Sorites* populations. This fragile foraminifer may be forced out by the increased growth of epiphytic algae that nutrient enrichment can bring (Fujita and Hallock, 1999). At Cut Cay though, little epiphytic algae was found, and the unpopulated nature of San Salvador makes anthropogenic nutrient enrichment unlikely. It is more likely that the intermittent high energy of the Cut Cay locality precludes *Sorites* from becoming well established there. In her study of six different localities at the island, Buchan (2006) concluded that *Sorites* was more common in low-energy environments, whereas, *Planorbulina* was usually more common in high energy settings. She also noted that *Sorites* was easily removed from vegetation samples with a brush in the laboratory, while *Planorbulina* was more difficult to remove (Buchan, 2006). This is consistent with the findings of Kloos, 1980.

Foraminiferal assemblages from the sediment at the grassbed sites J and R were similar to each other despite the differences in water depth and distance from the shore. This similarity would seem to confirm the notion that substrate preference is a major controlling factor in foraminiferal assemblages and that sediment assemblages are largely controlled by vegetation assemblages as opposed to other environmental variables (Brasier 1975).

The near absence of living foraminifera within the sand body at site S indicates that the sand flat is not a viable habitat for foraminifera; thus, the foraminiferal tests found there must be transported from the sites of living foraminifera. Based on similar taxonomic compositions, the source of sediment within site S appears to be the adjacent grassbeds (e.g., site R) and not the channel. There is little overlap with the site C sediment assemblage despite the apparent spatial correlation of the channel and the small sand tongue extending from the large sand bed. The grassbed signature is most apparent in the high abundance of *Miliolinella* and *Laevipeneroplis* at both sites, but what is perhaps most convincing is the total lack of *D. rosea*, the most abundant foraminifer within the channel. This is not to say that there is no sediment transported from the channel to sand bed, but that during fair weather and mild storms sediment transport is usually more localized. It is likely, however, that one or more hurricanes or other major storms formed the sand flat initially by removing the seagrass cover as strong currents and high waves surged through the channel.

The QPI for all of these sites was remarkably high. This is consistent with the findings of Buchan (2006; Buchan and Lewis, 2010). Even within the sand bed, where the L/D ratio was low, QPI was still above 70%. The highest QPI at Cut Cay was found at site R, where it exceeded 90%. The tests that were categorized as altered or extremely altered at all sites were generally affected by abrasion and minor breakage. This damage appeared to come from mechanical grain-to-grain impacts. Dissolution and polishing played a minor roll, even in the sand bed.

CONCLUSIONS

1. The shape of vegetation largely determines foraminiferal assemblages found on the seagrass and benthic algae. Sediment assemblages are strongly influenced by vegetation assemblages, but have much higher species diversity. The

sediment is preferentially enriched in robust tests and depleted in fragile tests.

2. The relatively large benthic foraminifera studied by Buchan (2006) do not provide as much information as complete benthic foraminiferal assemblages at all localities. Cut Cay had very few of these larger taxa, but the site still provides information about substrate preference and foraminiferal habitats.

3. QPI was remarkably high for all sites the Cut Cay locality. The lowest QPI was found within the sand body where living foraminifera were largely absent. These findings are consistent with those of Buchan (2006).

ACKNOWLEDGEMENTS

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