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Foraminiferal Assemblages on Sediment and Reef Rubble at Conch Reef, Florida USA

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Foraminiferal Assemblages on Sediments and Reef Rubble

at Conch Reef, Florida USA

by

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DEDICATION

I dedicate this thesis to my mother and myself. "Mom, while you are no longer with the living you are still a source of encouragement and inspiration to me throughout my life." This thesis is dedicated to two strong women, whom never let the obstacles of life get in the way of personal success.

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ABSTRACT

Benthic foraminiferal assemblages are widely used to interpret responses of the benthic communities to environmental stresses. This study compares epibiotic foraminiferal assemblages, collected from reef rubble with those from sediments, at Conch Reef, Florida reef tract, USA. Conch Reef is the site of the Aquarius Underwater Habitat research facility and includes protected areas used only for scientific studies. Although a number of studies have enumerated foraminiferal taxa from the Florida reef tract, no projects have focused on the assemblages that occur at Conch Reef.

Sediment and reef rubbles samples were collected via SCUBA from a depth range of 13 to 26 m, at Conch Reef, Florida, during October 2008. Foraminiferal assemblages were assessed and compared between the two sample types. One hundred and seventeen foraminiferal species, representing 72 genera, 37 families, and 8 orders were identified in 17 sediment samples and 21 rubble samples.

Seventy genera were identified in the rubble samples, including 12 symbiont-bearing genera representing 20% of the total assemblage, 12 stress-tolerant genera representing 6%, planktic foraminifers representing 1%, and 46 other smaller foraminiferal genera representing 73% of the total foraminiferal assemblage. The rubble samples were quite homogenous. The mean ($\pm$SD) Fisher alpha [α] diversity of genera in these samples was 12.91 $\pm$ 1.41.

Sediment samples included 60 of the same genera as the rubble samples. The same 12 symbiont-bearing genera represented 41% of the total assemblage, 10 stress-tolerant genera represented 3%, planktic taxa represented 2%, and 40 other smaller foraminiferal genera represented 54% of the total assemblage. Assemblages were somewhat more variable between sediment samples, because several samples contained very few (<100) specimens per grams. Overall, the taxonomic assemblages were similar between the sample types, with sediment assemblages alone adequately representing the local foraminiferal assemblage. The mean (±SD) Fisher alpha α for sediment samples was 11.37 ± 2.27, which is not significantly different from that found for the rubble samples.

A concentration ratio comparing relative abundances in sediment vs. rubble samples (S/R) was developed. It revealed that smaller taxa were more abundant in the rubble, while shells of larger, symbiont-bearing taxa were about 2.5-5.5 times more concentrated in the sediment, indicating winnowing of smaller taxa. Shells of *Siphonatera*, an agglutinated miliolid, and *Textularia*, an agglutinated textularid, were more abundant in sediments than in rubble, indicating high preservation potential. The concentration ratio provides a new taphonomic index that reflects the size and durability of foraminiferal taxa.

The mean FORAM Index [FI] for the sediment samples (5.57 ± 0.83) indicates that water quality at Conch Reef is suitable for calcifying symbioses. The most abundant symbiont-bearing genera were *Amphistegina*, *Laevipeneroplis*, *Asterigerina*, and *Archaias.*

INTRODUCTION

Conch Reef

Conch Reef, located within the Florida Keys National Marine Sanctuary, has been a focus of research activities since the site was chosen for placement of the Aquarius Underwater Habitat in 1991 by NOAA/NURC (National Oceanic and Atmospheric Administration/National Undersea Research Center) (**Figure 1**) (www.floridakeys.noaa.gov.com).

Located approximately 14.5 km south of Key Largo, Conch Reef considered a bank reef, with a shallow platform inshore and deeper spur and groove formations found to depths of approximately 35m. A special-use area designated as "Research Only" surrounds the Aquarius Underwater Research Laboratory (**Figure 2**) (www.uncw.edu/aquarius), is where the samples for this study were collected. The boundary of the "Research Only" area approximates the currently designated "no anchor" zone for the Aquarius facility. A detailed bathymetric map of the site is available on the Aquarius Research Facility website (www.uncw.edu/aquarius).

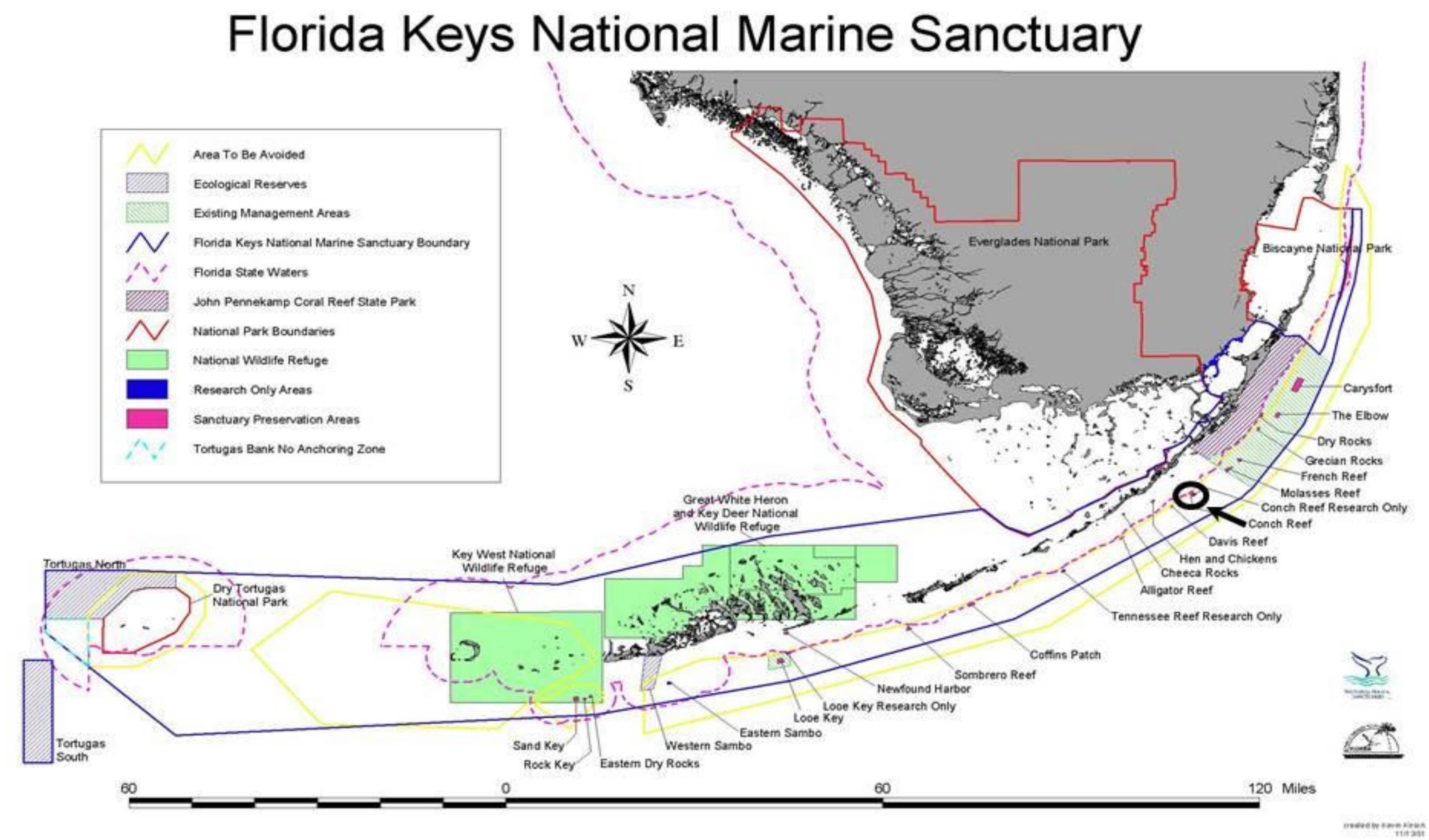

Figure 1. Florida Keys National Marine Sanctuary

www.floridakeys.noaa.gov.com

Study Site

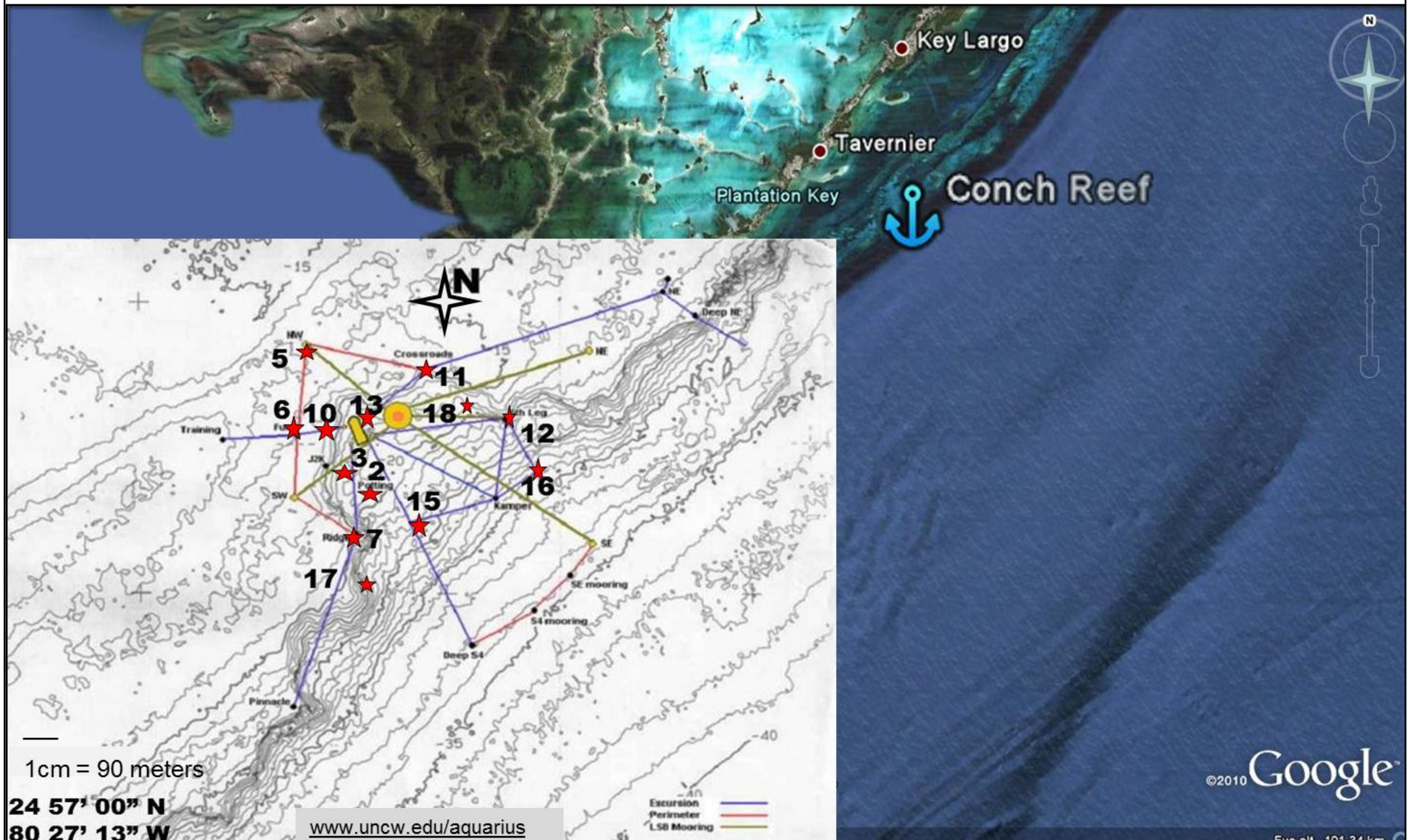

Figure 2. Conch Reef Sanctuary Preserve within the Aquarius Underwater Research Habitat.

Foraminiferal research began at Conch Reef in 1991 with the discovery of bleaching in *Amphistegina gibbosa* (Hallock and Talge 1993b). This foraminiferal population was intensively studied throughout the 1990s (Hallock *et al.* 1995) and sporadically since (Hallock *et al.* 2006a, 2006b). Baker *et al.* (2009) expanded the research focus to include other symbiont-bearing foraminifers. Although a number of studies have enumerated foraminiferal taxa from the Florida reef tract (Bock 1971; Culver and Buzas 1982; Martin 1986; Cockey *et al.* 1996), no projects have focused on the assemblages that occur at Conch Reef.

Foraminifera

Foraminifera are a class of protists in the Phylum Granuloreticulosea, and are characterized by their tests (*i.e.*, shells), which can be single or multiple chambered, organic, agglutinated, or calcareous (*e.g.*, Sen Gupta 1999). Though foraminifera are unicellular, the cytoplasm has two apparent components, with different functions. The ectoplasm, found in the outermost portion of the shell, is abundant in microtubules and is the location where the reticulopodia are produced, enabling foraminifers to feed, move, and grow new chambers. The endoplasm, found within the shell, contains the nucleus (or many nuclei) and functions to accumulate the organic matter required for reproduction (Hallock 1999). Of the 150 families of Foraminifera, fewer than 10% include members that host algal endosymbionts (Lee and Anderson 1991). Most symbiont-bearing benthic foraminifers grow larger than non-symbiont benthic foraminifers and, as such, are known as larger benthic foraminifers "LBF" (Hallock 1999).

Taxa of benthic Foraminifera that host algal endosymbionts, particularly the LBF, are characteristic of warm, shallow-shelf environments, where they are important contributors to shelf sediments. Hallock (1988) noted that shells of LBF, along with physically eroded, identifiable coral fragments, are characteristic in oligotrophic waters conducive to reef health and accretion (Hallock 1988, 2000b; Cockey *et al.* 1996). Symbiont-bearing benthic foraminifers require similar water-quality parameters as corals and are normally abundant on healthy coral reefs.

There are advantages and disadvantages to symbioses with algae. The major advantage occurs when the host lives in shallow, clear waters, where there is plenty of sunlight and the algae photosynthesize and provide the host with carbohydrates or lipids. However, if dissolved nutrients are plentiful, the symbionts can use the products of photosynthesis to grow and reproduce themselves, without providing photosynthate to the host (*e.g.*, Hallock 2000a; Wooldridge 2009).

Foraminifera as environmental indicators

Benthic foraminiferal assemblages are known to respond rapidly to environmental changes. They have been found in the geologic record since the Cambrian Period, and are used as bioindicators of countless global-change events in the geologic record, from mass extinctions to more subtle local events like volcanism (*e.g.,* Sen Gupta 1999). Foraminifers are useful bioindicators of pollution increases, the more sensitive taxa are eliminated, whereas the most tolerant genera are generally among the last organism to disappear from an impacted site (Schafer 2000; Carnahan *et al.* 2008).

Environments containing excess organic carbon, nutrients, or sunlight can cause physiological stress to the host (Hallock 1999; Hallock *et al.* 2006a; Wooldridge 2009). Due to their relatively short life cycles, which range from approximately a few weeks up to one year, and their sensitivity to environmental conditions, the foraminiferal assemblages react faster than corals to changes in water quality (Hallock 2000b; Hallock *et al.* 2003). While water samples may indicate normal nutrient concentrations, the effect of increased nutrient flux into an ecosystem typically results in a community change (*e.g.*, Hallock 1988) known as a phase shift (Done 1992; McManus and Polsenberg 2004; Palandro *et al.* 2008).

Reef-recovery potential following an acute event is dependent on water quality (Hallock *et al.* 2006b). Foraminiferal assemblages may indicate whether water quality can support healthy coral reefs and allow them to recover after a mortality event. How benthic foraminifers recover and colonize an area following a disturbance also depends on the hydrodynamics of the area. Small infaunal species are among the first and most successful colonizers of the soft-bottom habitats (Alve 1999; Buzas *et al.* 2002). The LBF lose dominance to those small, fast-growing herbivorous and detritivorous species, when increased nutrient loads from coastal land areas are introduced into the environment (Hallock 2000a; Carnahan *et al.* 2009). The short lifespan and large numbers of foraminifers within an assemblage allows for a differentiation between chronic reef decline and acute mortality events (Cockey *et al.* 1996; Hallock *et al.* 2003).

Cockey *et al.* (1996) assessed foraminiferal assemblages from sediments collected in 1991 and 1992 along the Florida reef tract at sites originally sampled by Rose and Lidz (1977) in the 1960s, and published in 1989 (Lidz and Rose 1989), to determine if biotic changes had occurred. Assemblage changes were consistent with increased nutrient flux from coastal sources. Indications of nutrient flux occurring to a system include the presence of smaller foraminiferal shells, unidentifiable carbonate grains, and abundant calcareous algal fragments (Hallock 1988, 2000b; Cockey *et al.* 1996). Cockey *et al.* (1996) found that family level identifications were sufficient to detect decadal scale changes in foraminiferal assemblages on the reef tract.

Indices

A variety of ecological assemblage indices are commonly used in benthic foraminiferal research, including Taxonomic Richness [S], Shannon [H], Fisher [α], Simpson [D] and Evenness [E] (Hayek and Buzas 1997, 2006).

Taxonomic richness [S] is defined as the number of different taxa of interest (*e.g.,* species or genera) identified from a sample or set of samples. The Shannon diversity [H] measures the order (or disorder) observed within a particular system, with maximum values occurring when species are evenly distributed. Fisher's alpha [α] index measures the biodiversity within a particular area, community, or ecosystem. The alpha index is based on the ratio of the number of species to the number of individuals. Simpson index of diversity [D] calculates the probabilities of picking two specimens at random that are different species, and thus ranges from 0 to 1. Evenness [E] quantifies how equally distributed the species are in the assemblage. Evenness is calculated by using the Shannon diversity and the Taxonomic Richness values. Evenness values range from 0 to 1, the higher the value the more evenly distributed the taxa are, while lower values indicate dominance by one or more taxa. All of these measures are evaluated as a function of the number of individuals in the sample (Hayek and Buzas 2010).

Various other parameters of foraminiferal assemblages have been used to define environments. Severin (1983) and Hallock and Glenn (1986), among others, used test morphology to determine biofaces. Langer (1993) subsequently developed a classification for epiphytic foraminifers. Morphotypes are used as indicators to interpret epiphytic habitats in which foraminifers live (**Figure 3**). The diversity of specific assemblages is controlled by independent factors related to temporal availability of substrates and space (substrate geometry). For each species, in variable environments, different factors may be limiting distributions both temporally and spatially (Murray 2001).

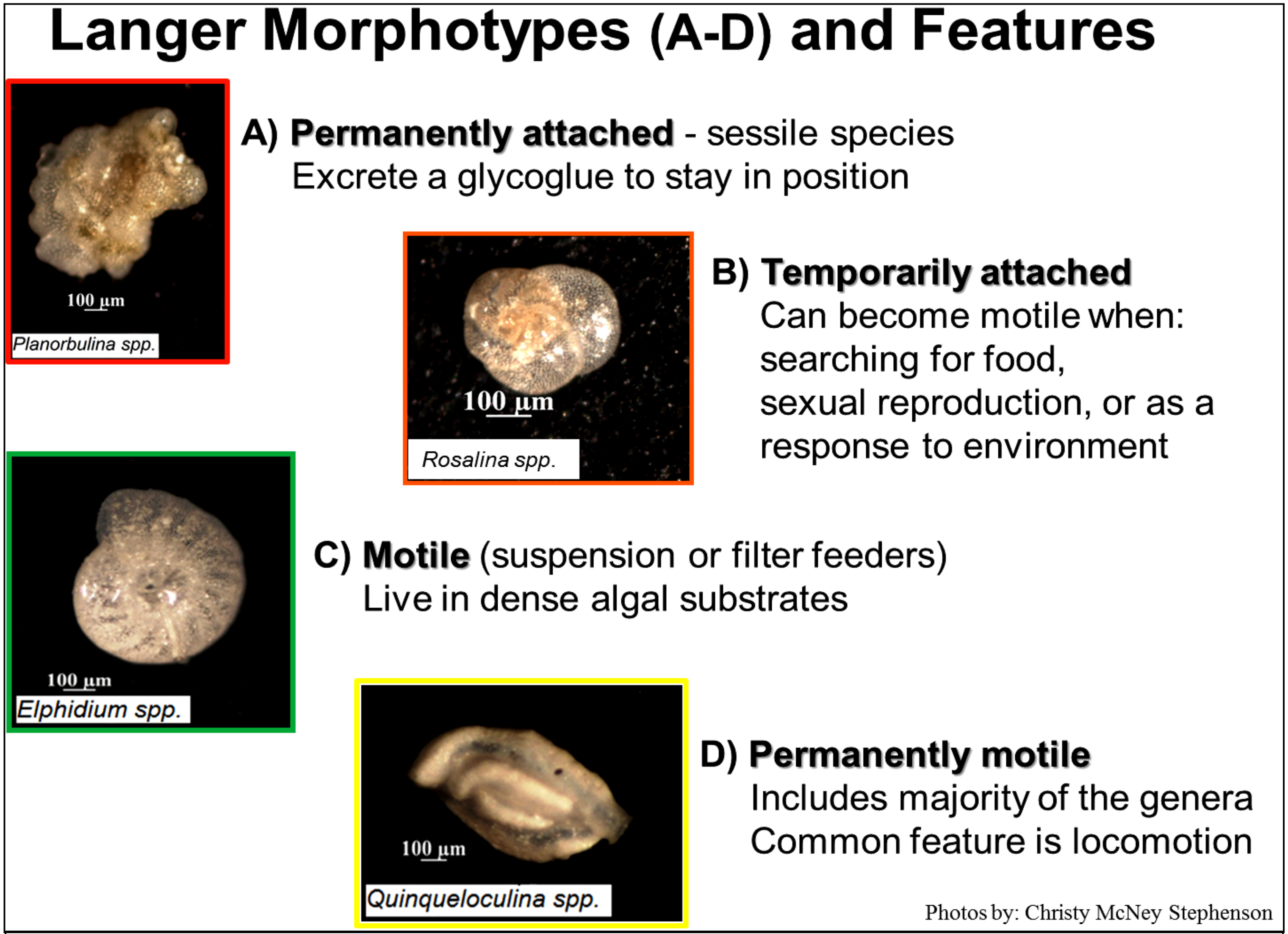

Figure 3. Langer (1993) categorization of foraminiferal morphotypes occurring on phytal substrates.

A) Morphotype A (*e.g., Planorbulina*) are permanently attached, sessile species, with a typical life span of about one year, they have relatively large or multiple aperatures. Chambers are commonly added in an orbitoidal or similar pattern for rapid growth in response to competiton for space. These benthic foraminifers secrete a substance, termed glycoglue, between the test and the substrate to give them the ability to stay in position.

B) Morphotype B (*e.g., Rosalina*) are temporarily attached, but can become motile, with a typical life span of 2-5 months. The aperatural faces are wide and interiomarginal (facing the substrate) and shell shapes are low or high trochospiral. Attachment and detachment is possible, allowing the individual to free themselves from the substrate when searching for food or for sexual reproduction. Morphotype B individuals have been known to free themselves from a substrate in response to changing environmental condition or when threatened with overgrowth by a more rapidly growing organism.

C) Morphotype C (*e.g., Elphidium*) are motile suspension or filter feeders, with a typical life span of 3-4 months. They are characterized by presence of a canal system through which they extrude pseudopods, and they have multiple aperatures. Most of these taxa prefer structurally dense algal substrates, which are ideal microhabitats for suspension feeders.

D) Morphotype D (*e.g., Quinqueloculina*) are permanently motile, grazing epiphytes, and include the majority of the species, most of which have short life-spans of weeks. The apertures are narrow to bottle-neck, with the most common feature being their method of locomotion. They all move in an upright postion on the apeartural face by extending pseudopods in the direction of movement (Langer 1993).

The FORAM Index (Foraminifera in Reef Assessment and Monitoring) is "intended to provide resource managers with a measure, which is independent of coral populations, to determine whether water quality in the environment is sufficient to support reef growth or recovery" (Hallock *et al.* 2003, p.222). The FORAM Index [FI] is based upon observations that sediments on healthy reefs have a larger proportion of symbiont-bearing foraminifers shells compared to other smaller foraminifers and stress-tolerant foraminifers (Hallock 1988; Hallock *et al.* 2003). The FI focuses on assemblage changes within foraminiferal populations, as reflected in reef sediments.

Controversy in foraminiferal research

An ongoing controversy in foraminiferal research is the practical application of live versus dead versus total assemblages. Studies of live assemblages in reef-associated sediment samples have typically identified relatively few taxa living in the sediments (*e.g.,* Martin 1986; Cockey *et al.*1996), which is why researchers (*e.g.,* Hallock *et al.*1986b; Hallock *et al.*1993a; Hallock *et al.* 2006a), have focused on sampling reef-rubble and phytal substrates when assessing live populations.

A common concern in studies of "total" benthic foraminiferal assemblages is that foraminifers living in the sediments at the time of sampling may be overrepresented. This is of serious concern in siliclastic or organic-rich sediments, where dead shells may quickly dissolve (Aller 1982), but generally not in carbonate sediments (Martin and

Wright 1988). Some researchers have argued that assessment of the accumulation of foraminiferal shells in the sediment integrates information about the general conditions more effectively than that of living assemblages (Scott and Medioli 1980; Hallock *et al.* 2003; Carnahan 2009). To form a temporal perspective on a wider community, one would need a view of the dead assemblage, which has not had substantial and selective taphonomic loss. An understanding of how a fossil assemblage might differ from the living assemblage is essential for paleoecologic reconstructions. How well the total assemblage of tests in the sediments reflects the assemblage of foraminifers living in the area is an ongoing question (Martinez-Colon *et al.* 2009).

There are differing opinions on the reliability and usefulness of total foraminiferal assemblages as environmental indicators. Some researchers (Murray and Alve 1999a, 1999b; Patterson *et al.* 1999; Murray and Pudsey 2004) have argued forcefully that only live and dead assemblages provide a sound ecological foundation for interpretation (Shifflett 1961). Hallock *et al.* (2003) and Martinez-Colon *et al.* (2009) suggested that the choice of assemblages (as well as the lowest taxonomic level to assess) depends upon the questions being addressed and the resources available to address those questions. Numerous investigations have shown seasonal changes in living assemblages (*e.g.*, Lynts 1966; Lee *et al.* 1969; Scott and Medioli 1980), but most one-time or decadal-interval assessments have focused on associated total assemblages (*e.g.*, Bock 1971; Martin and Wright 1988; Cockey *et al.* 1996; Carnahan *et al.* 2009). Scott and Medioli (1980) found that in a marsh system in Nova Scotia, living populations and assemblages were highly variable, resulting from micro-environmental changes. However, the total assemblages did not change significantly over the same period. Buzas *et al.* (2002) reported similar results in Florida's Indian River Lagoon. Both studies indicated that dead and total assemblages more consistently depicted modern environments, while the live assemblage in any given sample represented a "pulsating patch," as described by Buzas *et al.* (2002). Samples in which live assemblages differ substantially from the dead assemblages can represent local blooms, especially of taxa with fragile or readily soluble shells that are lost from the assemblage soon after death, and, therefore cannot contribute a representative amount to the total assemblages (Scott and Medioli 1980). While dead shells can be found in plankton tows, transport by suspension is not considered a common means of dispersal of live benthic foraminifers (Murray *et al.* 1982).

Abrasion, hydraulic sorting, and removal of smaller foraminifers may result in under-representation in the sediments as compared to the occurrence of living fractions of the assemblage (Greenstein 2003). Those taxa associated with fluffy sediments, (phytodetritus) have a higher dispersion potential (Alve 1999).

PROJECT OBJECTIVES

A sample set collected at Conch Reef in October 2008 provided the opportunity to examine differences between total foraminiferal assemblages from sediment and rubble samples collected from the same sites, and the variability of similar samples collected within a general reef area. Foraminiferal assemblages were evaluated using thirteen sets of samples, which included sediments and reef rubble. The goals were to evaluate inter-site assemblage variability and to determine how assemblages isolated from sediment samples differed from assemblages isolated from rubble samples at the same locations. The sediment-rubble assemblage comparison contributes data to the ongoing debate concerning whether assemblages from sediment samples are representative of live assemblages in an area and specifically what taxa tend to be under-represented in reef-sand samples. In addition, this sample set provided the opportunity to compile a species list of common Foraminifera at Conch Reef near the Aquarius Underwater Habitat. The species list will be useful to other scientists planning future research as well as contributing to the biodiversity assessments for this active research location.

Major Questions and Hypotheses

1. Are there inter-site differences in the foraminiferal assemblages on the rubble samples from Conch Reef?

H_o: No significant differences will be evident in assemblages between thirteen sites. Differences in assemblages on the rubble between sites are not significantly greater than differences between samples from the same site.

$H_{1:}$ Differences in assemblages between sites are significantly greater than differences between samples from the same sites.

2. Do the foraminiferal assemblages from rubble samples differ from assemblages in the sediment samples?

H_o: No differences will be seen in the foraminiferal assemblages from the rubble or sediment samples.

H_1: Different assemblages will be seen in different substrates.

3. Do any taxa correlate to depth or sediment texture?

H_o: No difference related to depth or sediment texture will be detected.

H_1: Differences will be observed with depth or sediment texture.

METHODS

Sample collection

Thirteen sites were sampled during October 2008 at Conch Reef. The sample sites were primarily along transect-line intersections and were chosen to facilitate future sampling from the same locations (**Figure 4**). The reef area over which the samples were collected was approximately 0.13 km^2.

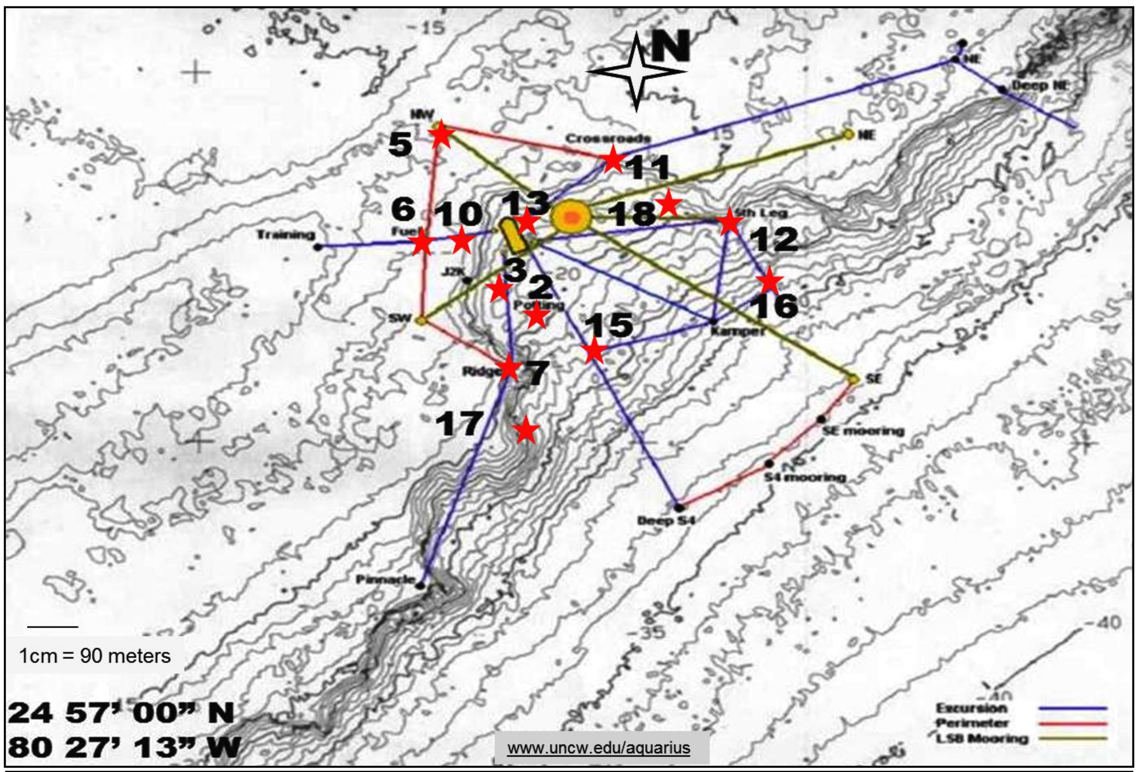

Figure 4. Conch Reef sites where sediment and rubbles samples were collected.

SCUBA divers haphazardly (*i.e.*, with no *a priori* knowledge of what foraminifers might be found in any sample) (Hayek and Buzas 1997) collected one 30ml vial of sediment and three fist-sized pieces of reef rubble from each site. Each rubble sample was placed into a re-sealable plastic bag at depth and then brought to the surface. All samples were then frozen to preserve color of those collected live (*e.g.,* Hallock 2006a).

Sample processing

Sediment samples

Each sediment sample was placed into a 63μm sieve, fitted with a container below to catch mud fractions. Deionized water was sprayed from a squirt bottle on the sediments until they were washed clean of muds. The sand-sized sediments (>63 μm) were washed into a small beaker (100 ml), water was extracted from the beaker using a thingamagigy, and the sample was placed into a drying oven ~45^{o} C. The dried sample was then weighed. The suspended mud fraction was placed in a beaker and allowed to settle until the water was clear (typically overnight); the water was then decanted. The remaining mud sample was placed into a smaller beaker (250 ml) and allowed to settle again, overnight. Once settled, the remaining water was removed and the sample was dried and weighed. The sand-sized fraction (>63 μm) was divided using a sample splitter. One-half of each sand-sized fraction was used in grain-size analysis and the other half examined to assess the foraminiferal assemblages. Subsamples were analyzed for two shallower sites (5b and 6b) and two deeper sites (15b and 16b) to determine variability within and between samples.

Grain-size analysis

To determine grain-size distribution, each dried subsample was weighed, then placed in a tower of seven previously weighed sieves (> 2 mm, 1-2 mm, 0.5-1 mm, 0.25-0.50 mm, 0.125-0.250 mm, 63 μm-0.125 mm, and pan < 63 μm) then shaken for 10 minutes. After 10 minutes on the shaker, each sieve with sediments was weighed and recorded. Any sediment that passed through the 63 μm sieve was weighed and recorded. The weight-percent of each grain size was calculated, including the mud fraction, corrected for the weight of the mud fraction originally removed by wet sieving.

Rubble samples

Each piece of rubble was thawed and carefully scrubbed with a toothbrush and rinsed with fresh water to remove foraminifers from the rock surface. Because many foraminifers adhered to tube worms, filamentous algae, and algal mats, a sonicator was used to dislodge those foraminifers attached to larger pieces. The sediment slurry removed from each rubble sample was then dried ~45^{o} C and weighed. All three reef rubble samples were analyzed for two shallower sites (5_1, 5_2, 5_3 and 6_1, 6_2, 6_3) and two deeper sites (15_1, 15_2, 15_3, and 16_1, 16_2, 16_3) to determine variability between and within sites.

The total seafloor area represented by the three rubble pieces collected per station was computed using Carl Zeiss AxioVison 4.4 software (©2002-2004), which calculated area directly from a digital image taken of the reef-rubble pieces (**Figure 5**). Using the rubble seafloor areas sampled, the number of foraminiferal shells/cm^2 was calculated.

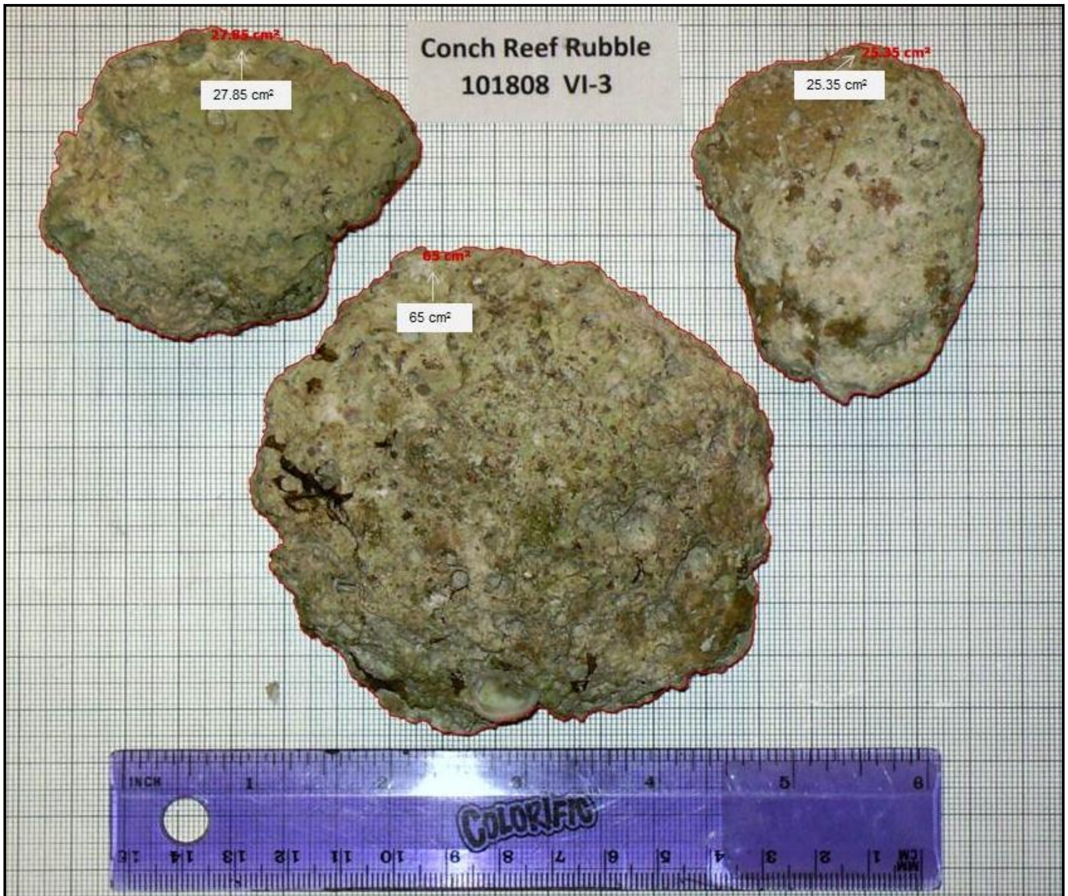

Figure 5. Rubble sample with AxioVision area (cm^2) measurements indicated.

Foraminiferal assemblages

To extract foraminifers from the samples, a weighed subsample was sprinkled over a gridded tray and examined under a stereomicroscope. The weighed subsample was picked manually with a fine paintbrush to extract approximately 150-200 foraminifers. Additional aliquots of the subsample were weighed and picked until 150-200 specimens were isolated or until 1 gram of sediment was examined. All foraminiferal specimens were picked onto a micropaleontological faunal slide coated with water-soluble glue (Ramirez 2008). Foraminifers were then sorted and identified to genus using characteristics defined by Loeblich and Tappan (1987). The abundances of each taxon were calculated using weights of the picked fraction compared to the total weight of the subsamples (Hallock *et al.* 2003). To compile the species list for the samples, the faunal slides were examined and species identified.

Data Analysis

Grain-size analysis

For each grain-size class, the raw weights were converted to weight percent for each sample using standard procedures called the phi (Φ) scale (Wentworth 1922; Blatt *et al.* 1972). Percent weights of each of the following size fractions (phi) were determined: > 2mm (-1), 1-2 mm (0), 0.5-1 mm (1), 0.25-0.50 mm (2), 0.125-0.250mm (3), 63 µm-0.125 mm (4), pan < 63 µm (>4). Median grain size for each sample was then calculated.

Foraminiferal assemblages

Foraminiferal data can be represented in either relative or absolute abundance. Relative abundance expresses each genus as a percentage of total foraminifers counted. Absolute abundance accounts for the number of foraminifers per unit mass, in grams of bulk sediment sorted, or for rubble samples, number of foraminifers per unit area of seafloor sampled. In this study data compared between sediment samples (#/g) and reef rubble samples (#/100 cm^2), are reported and analyzed as relative abundances.

Indices analysis

Several assemblage indices that are widely used in ecological research are commonly used in foraminiferal research, including Taxonomic Richness [S], Shannon [H], Fisher [α], Simpson [D], and Evenness [E] (Hayek and Buzas 1997). These indices were calculated for each sample. In addition, two indices specific to foraminiferal research, the Langer Morphotype Index described previously (Langer 1993) and the FORAM Index [FI] (Hallock *et al.* 2003; Carnahan *et al.* 2009), were also used in analysis of each sample. Each genus identified was assigned to one of the four Langer Morphotypes: A) permanently attached, B) temporarily motile, C) motile, and D) permanently motile (**Figure 3**).

To calculate the FI (**Table 1**), the genera of foraminifers were placed in one of three functional categories based on their ecological role in warm-water environments, which includes:

A) Symbiont-bearing taxa: benthic taxa that host algal endosymbionts and are generally relatively large.

B) Stress-tolerant taxa: smaller benthic taxa commonly found in naturally or anthropogenically stressed environments such as euryhaline estuaries, intermittently hypoxic environments, or environments subjected to chemical pollution.

C) Other smaller taxa: small benthic taxa that are heterotrophic, and therefore, bloom with abundant food sources in otherwise normal marine environments.

The percent abundance of each of these groups was used to calculate the FORAM Index (Hallock *et al.* 2003; Carnahan *et al.* 2009) (**Table 1**).

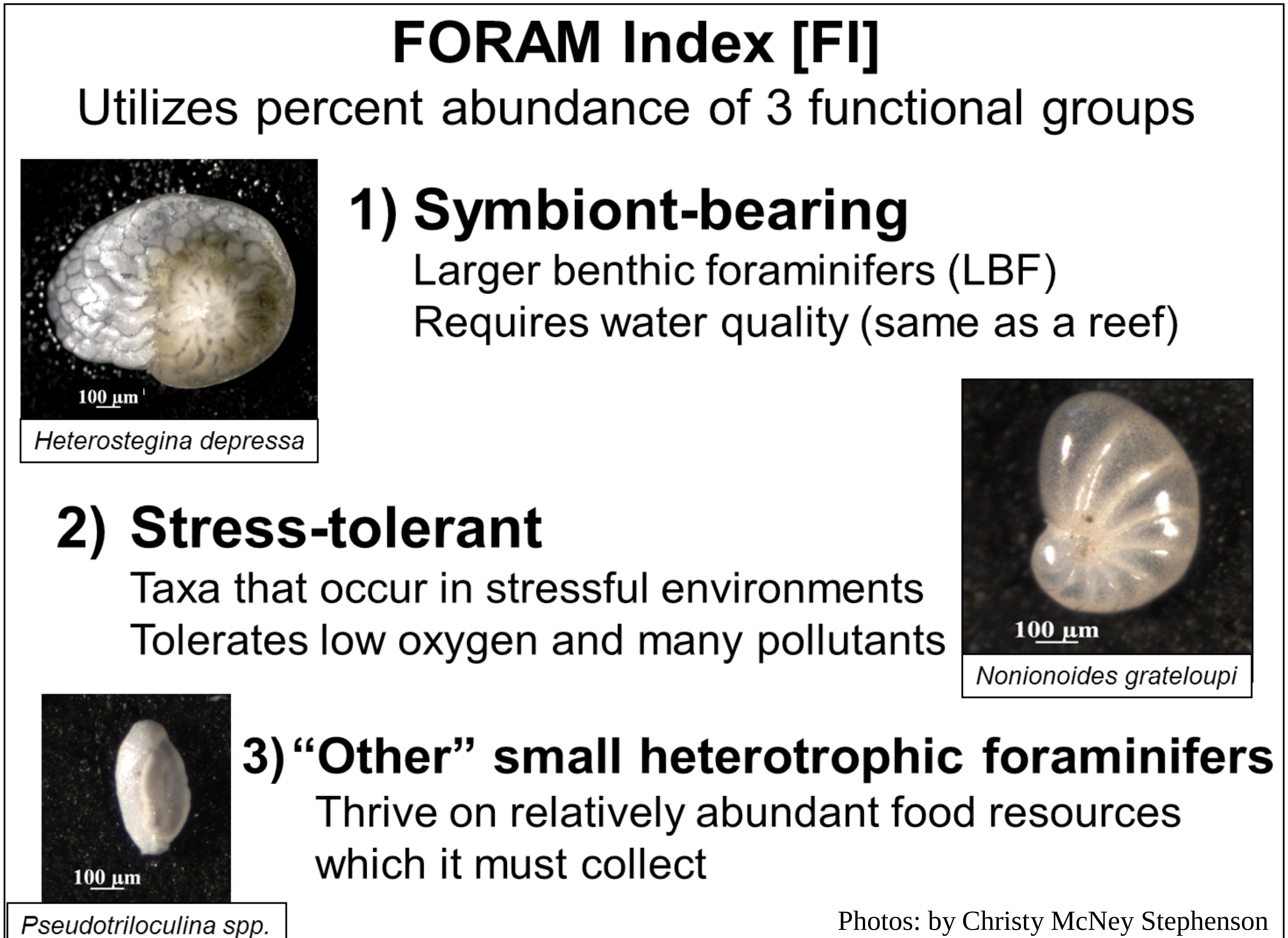

Figure 6. FORAM Index (FI) representing the three functional groupings.

Table 1. Calculation of the FORAM Index

$$FI = (10 \times P_s) + (P_o) + (2 \times P_h)$$

Where,	$P_s = N_s/T$,
	$P_o = N_o/T$,
	$P_h = N_h/T$
And,	**T** = total number of specimens counted
	N_s = number of specimens of symbiont-bearing taxa
	N_o = number of specimens of stress tolerant taxa*
	N_h = number of specimens of other small, heterotrophic taxa

“Opportunistic” as defined by Hallock *et al.* (2003) is changed to “stress-tolerant” in this Paper (Yanko *et al.* 1999; Carnahan 2005; Carnahan *et al.* 2009)

The FORAM Index resultant values can be interpreted as follows (Hallock *et al.* 2003):

- Values of <2 would result from the presence of stress-tolerant taxa with the remaining being other smaller foraminifers. This indicates heterotrophic processes dominating the reef where environmental conditions are unsuitable for reef growth and recovery.
- Values of 2-4 would result from the presence of <25% some symbiont-bearing species, indicating an environment that supports calcifying mixotrophs, although not optimal for them.
- Values of >4 would result when >25% of the foraminiferal assemblage is symbiont-bearing taxa, indicating environments suitable for reef growth and for recovery following a mortality event.

Multivariate analyses of foraminiferal assemblages

Multivariate analyses of foraminiferal assemblages follow Carnahan *et al.* (2009). Analyses were performed on sediment samples (absolute abundances), rubble samples (absolute abundances), and both sediment and rubble samples (relative abundances) to determine how sample sites grouped based on their similarity of foraminiferal assemblages (Q-mode analysis), and how the variables (foraminiferal genera) clustered (R-mode analysis). PRIMER-e v.6 (Plymouth Routines in Multivariate Ecological Research PRIMER-E Ltd., Plymouth) was used to construct Bray-Curtis similarity matrices on square-root transformed data. This transformation down-weights the importance of the highly abundant species, so that similarities depend not only on their values, but also those of "mid-range" species (Clarke and Gorley 2006). Based on this similarity matrix, cluster analyses were performed and Multidimensional Scaling (MDS) plots were constructed. For an MDS plot, the proximity between sites represented similarity and a stress level of <0.2 was considered to be a useful representation of relationships (Clarke and Warwick 2001).

To further interpret the MDS plots, two additional analyses were applied. The ANOSIM (analysis of similarity) and SIMPER (similarity percentages) routines were performed in PRIMER. The ANOSIM test determined if there is an assemblage difference among samples, between clusters, and other factors. The ANOSIM test produces a Global R statistic between -1 and 1, where zero represents the null hypothesis or no difference among samples. Pairwise tests were run as well, with results indicating the degree of separation between groups as either indistinguishable, or variation within groups is less than the variation between groups (Clarke and Warwick 2001).

SIMPER determined the contributions of individual genera to the separation of the groups, either for an observed clustering pattern or for the differences among sets of samples. SIMPER analysis was carried out on square-root transformed data based on site groupings defined by cluster analysis. SIMPER outputs statistical parameters for each genus contributing to >90% similarity within each group or dissimilarity between groups (Clarke and Gorley 2006). Outputs included average abundance, percent contribution, and cumulative percent contribution of each genus. Analyses were performed on the rubble data and the sediment data separately and combined. The comparison of sediment and rubble samples analyses showed whether the sediment samples clustered separately from the rubble samples, the ANOSIM analysis showed if there was similarity between the samples, and the SIMPER analyses showed which genera contributed to the seperation in either type of sample.

To determine which genera tend to co-occur (i.e., R-mode analyses), a Bray-Curtis similarity matrix was constructed based on generic data for all taxa present in more than 5% of the samples. Cluster analysis and MDS plots were constructed based on this similarity matrix.

RESULTS

Grain size

Results of grain-size analysis for each sample are reported as weight-percent (**Table 2**). Median grain size, reported in phi (Φ), revealed that the majority of sites were characterized by coarse sand (82%) and the rest were medium sand (18%). No sample contained more than 2% mud (**Table 3**).

Table 2. Weight percent for each grain size class for the 17 sediment samples from Conch Reef, collected in October 2008.

Sediment Conch Reef 101808	Depth	20m	20m	13m	13m	13m	13m	20m	14m	17m	20m	18m	25m	25m	26m	26m	17m	20m
	Site number	**2**	**3**	**5**	**5b**	**6**	**6b**	**7**	**10**	**11**	**12**	**13**	**15**	**15b**	**16**	**16b**	**17**	**18**
Grain size	**Phi size**																	
>1 mm	Phi: -1 wt %	2.2%	2.6%	2.5%	2.5%	12.4%	12.4%	2.1%	3.9%	0.2%	2.4%	7.7%	11.1%	11.1%	6.2%	6.2%	6.9%	1.2%
1 mm	Phi: 0 wt. %	12.7%	12.7%	31.9%	31.9%	26.7%	26.7%	10.9%	14.3%	3.1%	14.6%	31.9%	28.3%	28.3%	26.4%	26.4%	28.0%	3.0%
.5mm	Phi: 1 wt. %	51.5%	38.7%	51.1%	51.1%	43.7%	43.7%	27.1%	36.6%	35.4%	37.2%	38.7%	27.9%	27.9%	40.9%	40.9%	39.4%	20.7%
.25mm	Phi: 2 wt. %	27.3%	24.7%	11.1%	11.1%	10.8%	10.8%	15.6%	25.6%	37.6%	22.4%	21.0%	17.4%	17.4%	15.9%	15.9%	15.0%	32.6%
.125 mm	Phi: 3 wt. %	5.9%	16.0%	2.6%	2.6%	5.1%	5.1%	10.6%	15.9%	20.2%	15.9%	0.2%	10.9%	10.9%	7.5%	7.5%	7.1%	41.2%
.063 mm	Phi: 4 wt. %	0.3%	4.0%	0.4%	0.4%	1.1%	1.1%	33.2%	0.5%	0.6%	0.6%	0.0%	0.4%	0.4%	0.3%	0.3%	0.2%	1.2%
Mud	Phi: >4 wt. %	0.0%	1.2%	0.4%	0.4%	0.2%	0.2%	0.5%	3.2%	3.0%	7.0%	0.5%	4.0%	4.0%	2.9%	2.9%	3.4%	0.2%
Median Phi		1	1	1	1	1	1	2	1	2	1	1	1	1	1	1	1	2

Table 3. Distribution of median grain size in 17 sediment samples from Conch Reef, collected in October 2008.

Size Description	Size range	Phi (Φ) size class	# of sites with median grain size
Gravel/Granule	>2mm	-1	0
Very coarse sand	1-2mm	0	0
Coarse sand	0.5-1mm	1	14
Medium sand	0.25-0.5mm	2	3
Fine sand	0.125-0.25mm	3	0
Very fine sand	63um-0.125mm	4	0
Silt/clay/mud	<63um	>4	0

Foraminiferal assemblages in sediment samples

In the 17 sediment samples examined, the shells of 62 foraminiferal genera were identified (**Table 4**). Generic abundances by station and a summary of the foraminiferal data from sediment samples by station are provided (Appendix A). A taxon accumulation curve (**Figure 6**) indicated that 90% of the genera could be found in ~10 samples. The dominant genus was *Laevipeneroplis*, representing 11%, of foraminiferal shells identified, followed by *Amphistegina* at 9%, *Asterigerina* and *Quinqueloculina* each at 8%, and *Archaias, Textularia,* and *Rosalina* each at 5% (**Figure 7**). Another 11 genera each accounted for at least 2% of the total, while 44 genera made up the remainder of the assemblage. For PRIMER analyses of sediment data, genera occurring in less than 5% of the samples, which were *Abditodentrix, Rectobolivina, Fursenkoina, Cornuspiroides, Triloculinella, Cancris,* and *Cibicoides*, were removed from data set, consistent with recommended procedures (Clark and Warwick 2001; Parker and Arnold 2002).

Key genera

Symbiont-bearing foraminifers dominated in four of the 17 samples, the other samples were dominated by other small foraminifers. Stress-tolerant genera occurred sporadically and together never accounted for 10% of any sample. In five out of the 17 sediment samples, fewer than 150 foraminiferal shells were found in a one-gram sample. Samples 5 and 5b each had fewer than 50 shells per gram. Across stations, shell abundance was quite variable, ranging from 38 to 678 foraminiferal shells per gram.

Indices analysis

The Taxonomic Richness [S] for the sediment samples was 33.59 ± 9.77. The mean (±SD) Shannon Diversity [H] for the sediment samples was 2.95 ± 0.29. The mean Fisher alpha [α] diversity for these samples was 11.37 ± 2.27. The mean Simpson's Diversity Index [D] was 0.93 ± 0.03. The mean Evenness [E] for these samples was 0.60 ± 0.09. The mean FORAM Index [FI] was 5.57 ± 0.83. A summary of the data for the sediment samples, including means and standard deviations for each assemblage parameter calculated, is listed in **Table 5**. Maximum values in Table 5 were calculated for the indices based on the total 62 genera of identified from all sediment samples.

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Table 4. All foraminiferal genera identified in samples collected at Conch Reef in October 2008. Genera are listed in functional categories defined by Hallock et al. (2003). Samples found only in sediment (*) or only in rubble (**).

Symbiont-bearing	Stress-tolerant	Other Smaller taxa	Other Agglutinates	Other Miliolida	Other Rotaliida
Amphistegina	*Abditodentrix*	*Cassidulina***	*Bigenerina*	*Adelosina*	*Cancris*
Androsina	*Ammonia*	*Floresina***	*Clavulina*	*Affinetrina*	*Cibicides*
Archaias	*Bolivina*	*Fursenkonia*	*Textularia*	*Articulina*	*Cibicoides**
Asterigerina	*Bolivinellina***	*Reussella***	*Valvulina***	*Cornuspiroides*	*Cymballoporetta*
Borelis	*Brizalina*	*Sigmavirgulina***		*Cycloforina*	*Discogypsina*
Cyclorbiculina	*Cribroelphidium*	*Spirillina*		*Hauerina*	*Discorbinella*
Heterostegina	*Elphidium*	*Trifarina*		*Lachlanella*	*Discorbis rosea*
Laevipeneroplis	*Haynesina***			*Miliolinella*	*Eponides*
Monalysidium	*Nonionella*			*Parahauerina*	*Glabratella***
Parasorites	*Nonionoides*			*Pseudohauerina***	*Gavelinopsis*
Peneroplis	*Rectobolivina*			*Pseudoschlumbergerina*	*Lobatula*
Sorites	*Reophax**			*Pseudotriloculina*	*Neoconorbina*
	*Trochammina***			*Pyrgo*	*Neoeponides*
				Quinqueloculina	*Planorbulina*
				Schlumbergerina	*Rosalina*
				Siphonaptera	*Siphonina*
				Spiroloculina	
				Triloculina	
				Triloculinella	
				Wiesnerella	

ONLY in sediment samples (*) ONLY in rubble samples (**)

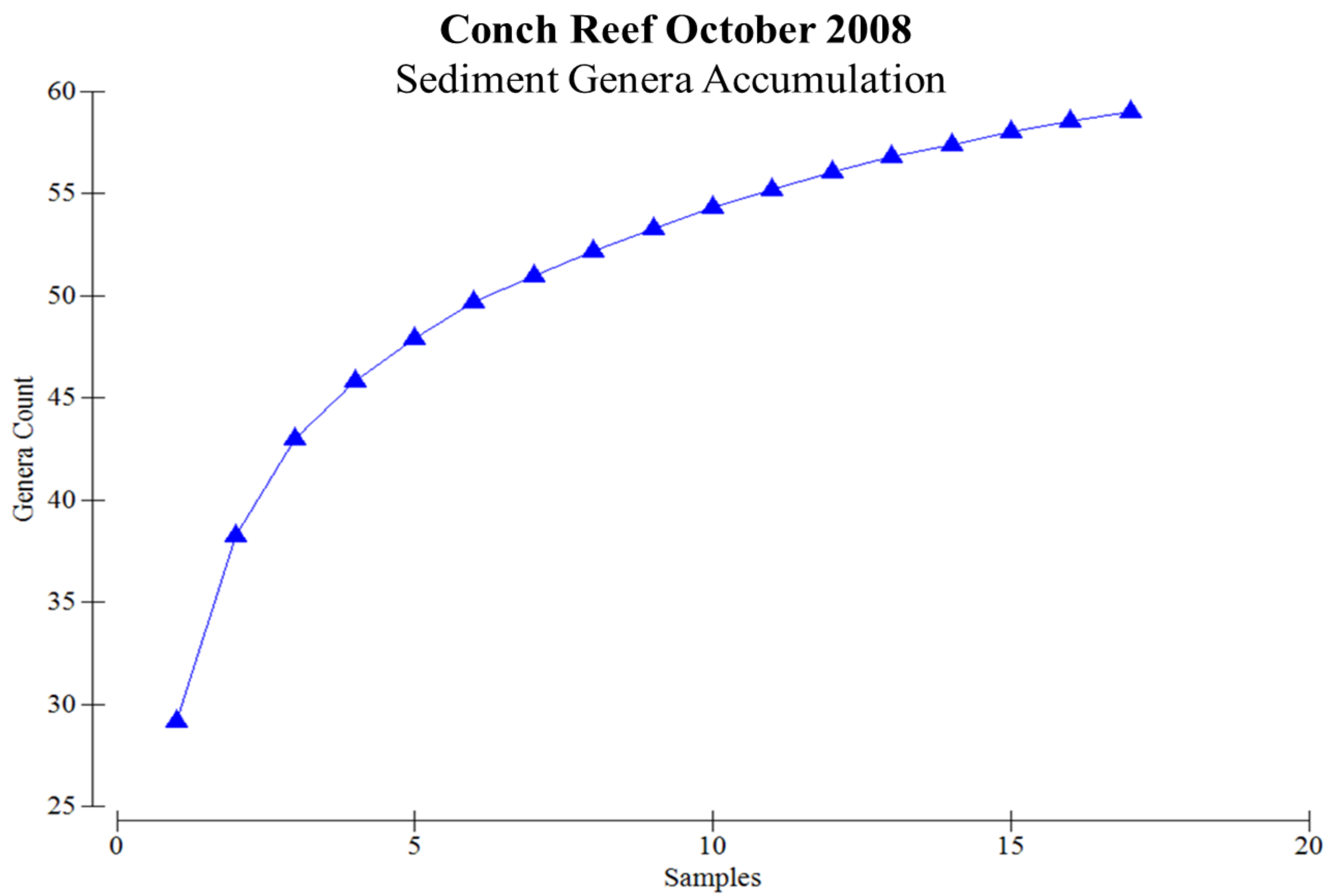


Figure 7. Randomized accumulation plot for genera in sediment samples from Conch Reef, October 2008, indicating that 90% of the genera are found in about 10 samples.

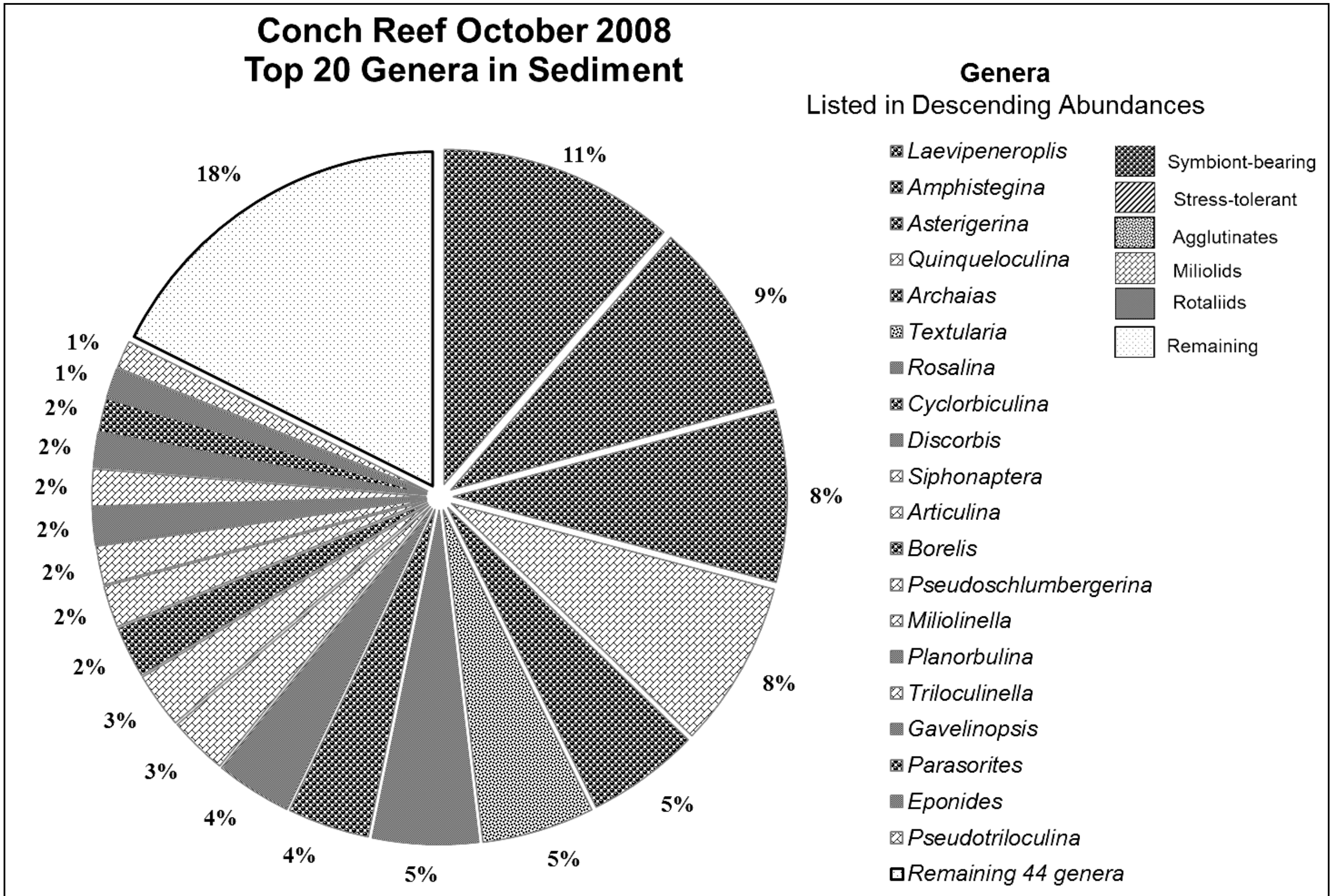


Figure 8. Twenty most abundant genera in sediment samples collected in October 2008 at Conch Reef; the 44 less abundant genera are included under "remaining."

Table 5. Summary of foraminiferal assemblage data and indices in sediment samples collected at Conch Reef, October 2008.

Abbreviations: SB= # of specimens of symbiont-bearing genera; ST = # of specimens of stress-tolerant genera; Other = # of specimens of other smaller genera; FI = FORAM index; SD = standard deviation.
See text page 7 for interpretations of diversity indices; theoretical maximum values for indices, based on 62 genera, are provided.

Station	Depth (m)	#/gram	Total Forams	Total Genera	SB	ST	Other	FI	Fishers α	Shannon (H)	Simpson (D)	Evenness (E)	Median Phi Φ	Dominant Genera
2	20	157	157	30	94	5	58	6.76	8.88	2.76	0.92	0.53	1	*Laevipeneroplis, Amphistegina*
3	20	401	168	35	82	5	81	5.88	11.21	3.02	0.94	0.58	1	*Laevipeneroplis, Quinqueloculina*
5	13	38	38	14	26	1	11	7.45	8.01	2.38	0.91	0.77	1	*Amphistegina, Archaias*
5b	13	41	42	16	25	0	17	6.76	9.43	2.59	0.94	0.83	1	*Asterigerina, Cyclorbiculina*
6	13	85	85	21	31	0	54	4.92	8.30	2.37	0.86	0.51	1	*Rosalina, Amphistegina*
6b	13	110	111	31	35	2	74	4.50	12.19	3.07	0.95	0.70	1	*Discorbis, Laevipeneroplis*
7	20	236	155	35	69	3	83	5.54	11.32	2.78	0.91	0.46	2	*Textularia, Laevipeneroplis*
10	14	286	154	35	68	3	83	5.51	10.74	2.89	0.92	0.52	1	*Quinqueloculina, Asterigerina*
11	17	425	183	36	79	2	102	5.44	10.76	3.11	0.97	0.62	2	*Laevipeneroplis, Asterigerina*
12	20	678	160	45	45	4	111	4.23	14.66	3.25	0.95	0.57	1	*Laevipeneroplis, Textularia*
13	18	51	156	24	85	6	65	6.32	8.07	2.77	0.93	0.67	1	*Amphistegina, Laevipeneroplis*
15	25	301	167	38	66	11	90	5.10	11.35	3.13	0.95	0.60	1	*Asterigerina, Textularia*
15b	25	402	196	46	63	5	128	4.55	13.42	3.31	0.96	0.60	1	*Laevipeneroplis, Quinqueloculina*
16	26	239	154	40	63	4	87	5.25	12.65	3.04	0.94	0.52	1	*Amphistegina, Laevipeneroplis*
16b	26	326	191	50	82	11	98	5.38	16.00	3.34	0.95	0.56	1	*Laevipeneroplis, Asterigerina*
17	17	274	150	39	67	5	78	5.54	13.55	3.15	0.95	0.60	1	*Amphistegina, Laevipeneroplis*
18	20	555	158	36	70	3	85	5.53	12.79	3.11	0.96	0.62	2	*Quinqueloculina, Laevipeneroplis*
Mean		271	143	33.59	62	4	77	5.57	11.37	2.95	0.93	0.60	1.18	*Laevipeneroplis, Amphistegina*
SD		178	45	9.77	21	3	29	0.83	2.27	0.29	0.03	0.09	0.38	
Maximum Values		**	**	62	**	**	**	10	>20	4.1	1.0	1.0	**	

Sample distribution

Three sample clusters were evident in cluster analyses (**Figure 8**) and the associated MDS Plot (**Figure 9**); the latter had a stress value of 0.07 which denotes a very useful representation of the data. Cluster 1 included nine samples, which exhibited no significant differences among them, and another two samples (12, 18), that were more than 60% similar to the nine samples. All of these samples had more other smaller foraminifers than symbiont-bearing taxa. The two samples that differed were primarily by higher overall abundances. Cluster 2 included two samples (2, 6b), the deeper of which had more symbiont-bearing foraminifers than other smaller taxa. The shallower site was also notable for the unusual prevalence of *Discorbis* in greater quantity than in all other sediment samples. Cluster 3 included shallower sites (5, 5b, 6, 13), which had the least number of foraminiferal shells per gram of sediment, and was dominated by symbiont-bearing foraminifers. The occurrence of sample 6 as an outlier, compared with sample 6b from the same site, indicates that differences within sites can be as great as differences among sites.

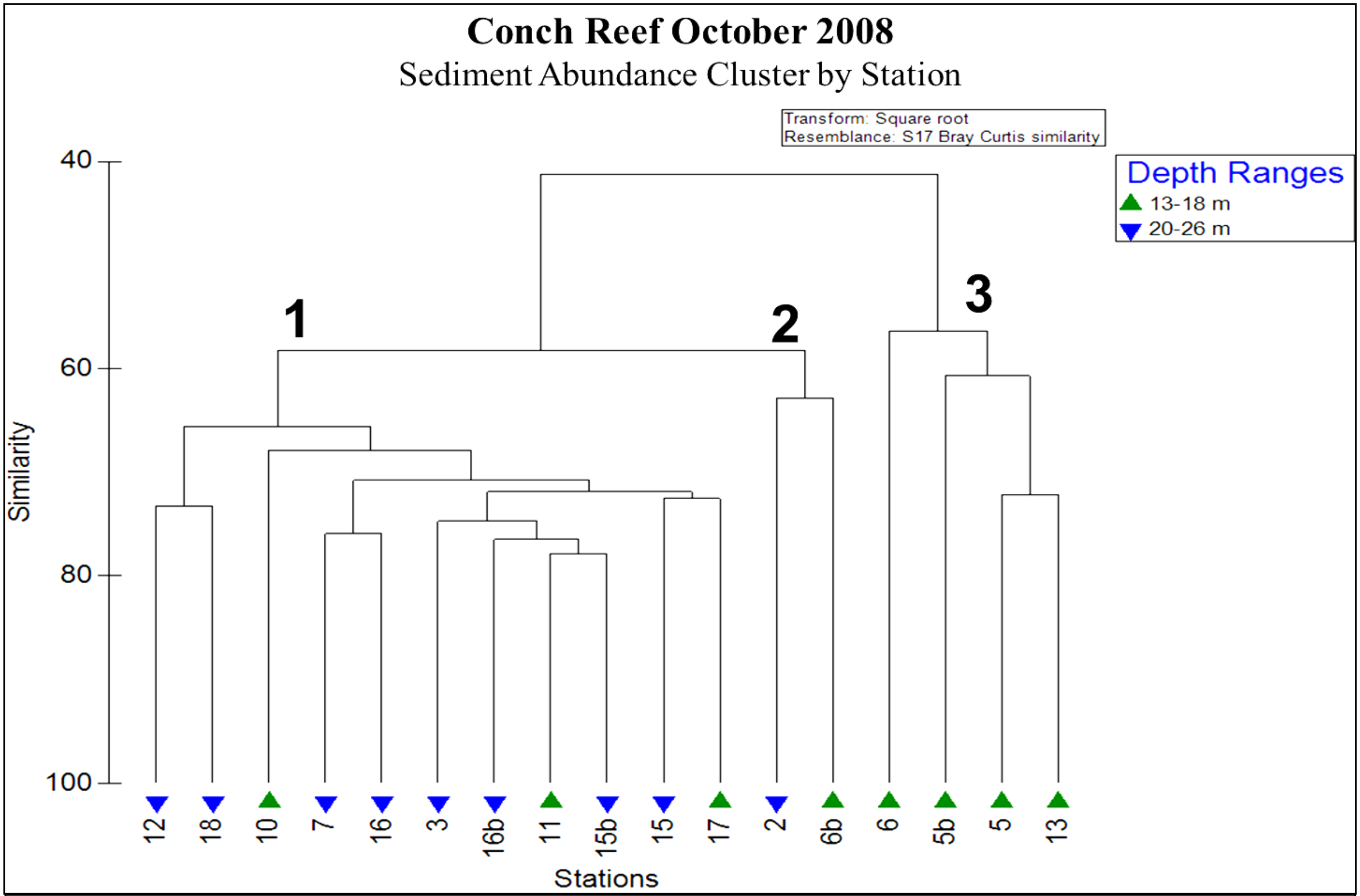


Figure 9. Sediment cluster analysis of foraminiferal assemblages by station at Conch Reef, October 2008.

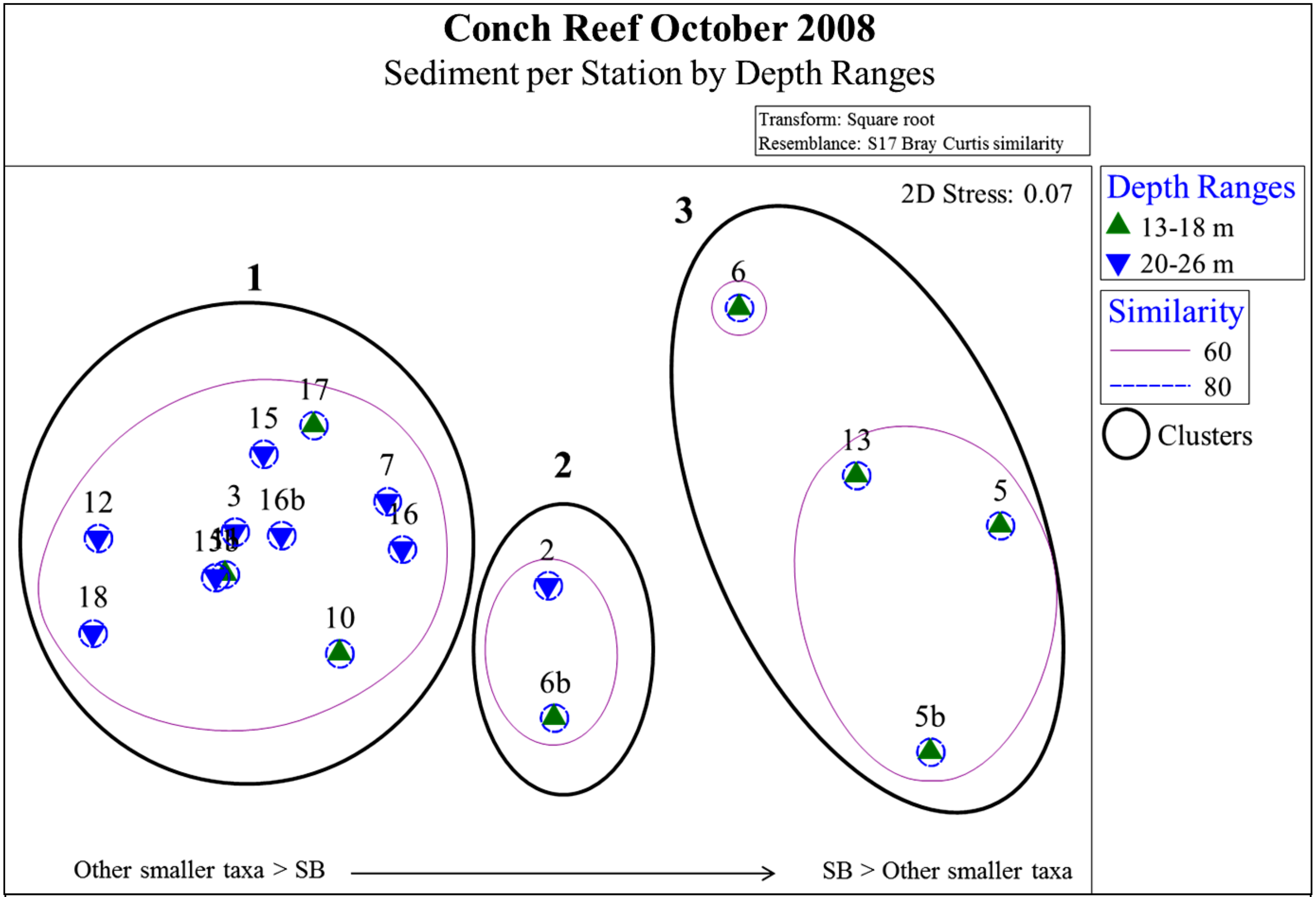


Figure 10. Bray- Curtis Multidimensional Scaling (MDS) plot of similarities of foraminiferal assemblages, in sediment samples from Conch Reef, October 2008.

SIMPER analysis via Bray-Curtis similarity (**Appendix B**), summarized in **Table 6**, revealed that the sediment samples from Cluster 1 had an average similarity of 70% with *Laevipeneroplis, Asterigerina,* and *Quinqueloculina* being the top three contributors to the similarity. Cluster 2 samples had an average similarity of 63% with *Laevipeneroplis, Amphistegina,* and *Quinqueloculina* being the top three contributors to the similarity. Cluster 3 samples had an average similarity of 61% with *Amphistegina*, *Laevipeneroplis,* and *Archaias* being the top three contributors. The dissimilarity between Clusters 1 and 2 is 42% with *Asterigerina, Parasorites,* and *Quinqueloculina* contributing most to the dissimilarity. The dissimilarity between Clusters 2 and 3 is 47% with *Rosalina, Quinqueloculina,* and *Laevipeneroplis* contributing most to the dissimilarity. The dissimilarity between Clusters 1 and 3 is 61% with *Quinqueloculina, Asterigerina*, and *Laevipeneroplis* as primary contributors.

Table 6. Summary of ANOSIM and SIMPER results for sediment samples by clusters.

ANOSIM			**SIMPER**		
Cluster Comparison (within or between)	**R Statistic**	**Significance Level %**	**Similarity**	**Dissimilarity**	**# genera = 90%**
Cluster 1 (within)	Global R: 0.919	0.1	69.5	---	29
Cluster 2 (within)			62.8	---	19
Cluster 3 (within)			60.5	---	13
Clusters 1 & 2 (between)	0.818	1.3	---	41.8	40
Clusters 2 & 3 (between)	0.679	6.7	---	46.6	32
Clusters 1 & 3 (between)	0.997	0.1	---	61.0	37

An ANOSIM was run on assemblage distributions in the sediment samples with a one-way analysis with the cluster number as the factor of comparison. This analysis resulted in a Global R of 0.919 and a significance level (p) of 0.1%, which indicates significant differences among the clusters (**Table 6**). Results from the ANOSIM pairwise test between clusters reveals that the significant differences are between Clusters 1 and 2, and 1 and 3, but not between 2 and 3.

A two-way ANOSIM was run comparing cluster and depth ranges. The test for the differences between cluster groups across all depth ranges resulted in Global R of 0.909 with a significance level (p) of 0.1%, again showing significant differences between the clusters. The test for differences between depth ranges across all sample types had a Global R of 0.107 and a significance level (p) of 4.9%, indicating a weak but significant difference between the two depth ranges (13-18m and 20-26m).

Cluster analysis (r-mode) examining all genera which occurred in at least two samples revealed few significant associations (**Figure 10**). A one-way ANOSIM, based on samples and FI groupings, resulted in a Global R of 0.14 and significance level (p) of 6.5%. An ANOSIM pairwise test comparing the FI groups indicated significant differences between the occurrences of symbiont-bearing taxa and stress-tolerant taxa, and between stress-tolerant taxa and other smaller taxa (**Table 7**).

Table 7. ANOSIM pairwise test of the sediment samples to FI groupings.

Sediment ANOSIM	**Global R: 0.14**	**Significance: 6.5%**
FI Groups	**R Statistic**	**Significance Level %**
Symbiont-bearing vs. Stress-tolerant	0.411	0.2
Symbiont-bearing vs. Other	-0.04	62.8
Stress-tolerant vs. Other	0.308	0.9

The MDS plot with the sediment samples compared to the FI groupings visually represents the physical separation with a stress level of 0.17 (**Figure 11**).

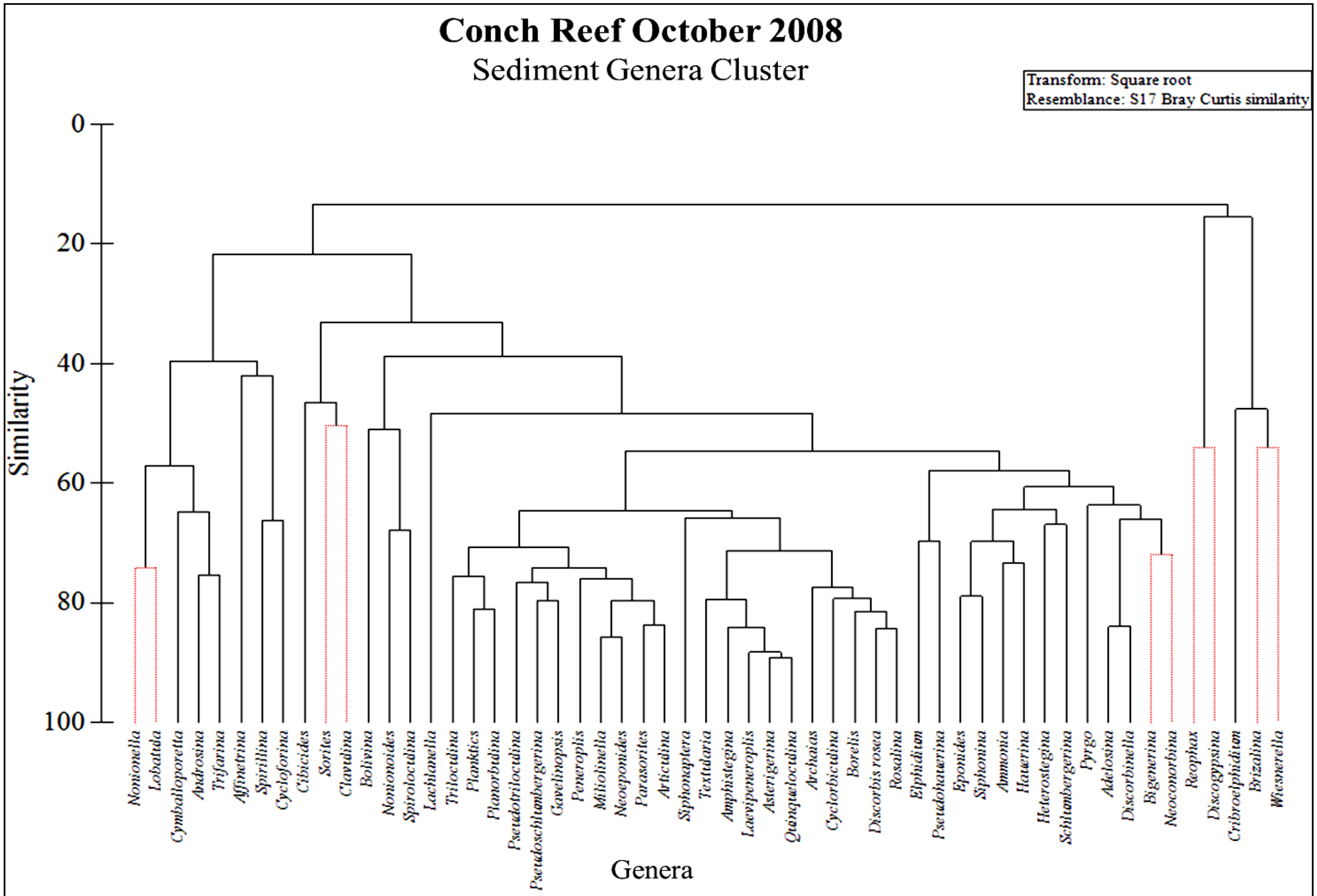


Figure 11. Cluster analysis of genera in sediment samples collected at Conch Reef, October 2008.

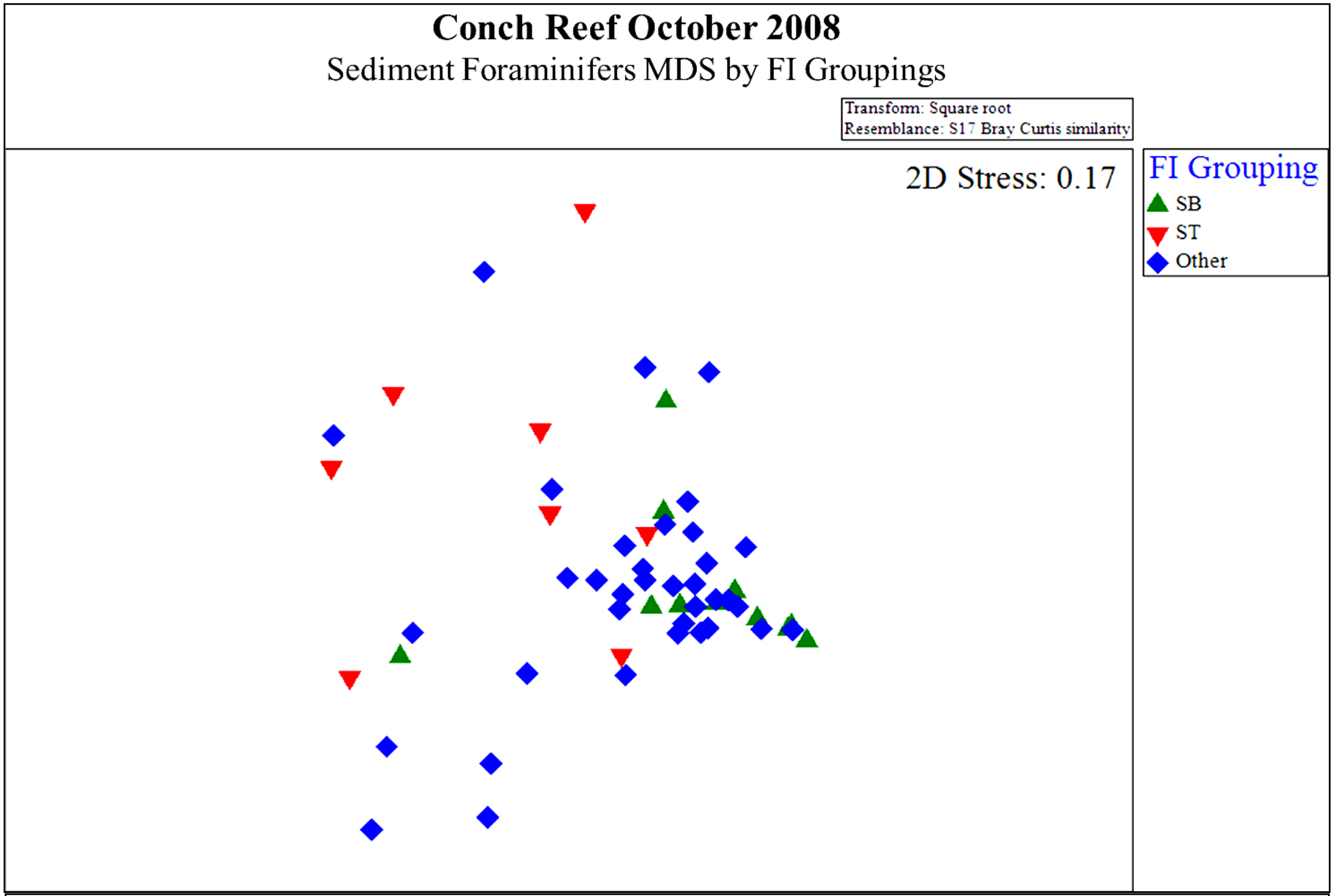


Figure 12. Bray-Curtis MDS plot of foraminifers in the sediment samples by FI groupings.
SB= Symbiont-bearing, ST= Stress-tolerant, and other = remaining smaller taxa.

Foraminiferal assemblages in rubble samples

Key genera

In the 21 rubble samples examined, shells of 70 foraminiferal genera were identified (**Table 4**). Foraminiferal abundances (100 cm^2) per station and a summary of the foraminiferal data by station are provided (**Appendix C**). A genus accumulation curve (**Figure 12**) indicates that 90% of the genera could be found in ~7 samples. The dominant genus was *Rosalina*, representing 9% of foraminiferal shells identified, followed by *Quinqueloculina* 8%, *Planorbulina* 8%, *Laevipeneroplis* 7%, *Miliolinella* 5%, and *Gavelinopsis* 5% respectfully (**Figure 13**). For statistical analyses, genera present in less than 5% of the samples, including *Bolivinellina, Trochammina, Reussella, Valvulina*, *Parahauerina*, and *Glabratella*, were removed from consideration (Clark and Warwick 2001; Parker and Arnold 2002).

Indices analysis

The mean (±SD) Taxonomic Richness [S] for the rubble samples was 49.38 ± 3.98. The mean Shannon Diversity [H] for the rubble samples was 2.97 ± 0.34. The mean Fisher alpha [α] diversity for these samples was 12.91 ± 1.41. The mean Simpson's Diversity Index [D] was 0.94 ± 0.01. The mean Evenness [E] for these samples was 0.55 ± 0.17. The mean FORAM Index [FI] was 3.60 ± 0.42. A summary of the data for the rubble samples including means and standard deviations for each assemblage parameter calculated is provided in **Table 8**. Maximum values in Table 8 were calculated for the indices based on the70 total genera identified from all rubble samples.

Table 8. Summary of the foraminiferal assemblage data and indices in rubble samples collected at Conch Reef, October 2008.

Abbreviations: SB= # of specimens of symbiont-bearing genera; ST = # of specimens of stress-tolerant genera; Other = # of specimens of other smaller genera; FI = FORAM index; SD = standard deviation.
See text page 7 and for interpretations of diversity indices; theoretical maximum values for indices, based on 70 genera, are provided.

Station	Depth (m)	#/100cm^2	# Genera	#/g	Seafloor area (cm2)	SB/100 cm^2	ST/100 cm^2	Other/100 cm^2	FI	Fishers α	Shannon (H)	Simpson (D)	Evenness (E)	Dominant Genera
2_1	20	28996.2	47	1503	99.86	6700	970	21326	3.82	8.22	3.26	0.95	0.64	*Miliolinella, Quinqueloculina*
3_1	20	15586.1	48	1923	107.80	3824	981	10782	3.90	12.94	3.20	0.95	0.67	*Rosalina, Quinqueloculina*
5_1	13	67354.8	45	1030	44.60	11636	3775	51943	3.33	12.30	3.19	0.95	0.64	*Rosalina, Planorbulina*
5_2	13	28451.0	45	2148	76.04	4902	1850	21698	3.31	13.30	3.25	0.95	0.68	*Rosalina, Pseudoschlumbergerina*
5_3	13	26782.6	49	1111	53.24	4874	2163	19746	3.38	14.99	3.21	0.95	0.63	*Rosalina, Planorbulina*
6_1	13	30116.6	49	1101	20.06	5037	1412	23667	3.29	12.06	3.16	0.95	0.61	*Planorbulina, Rosalina*
6_2	13	30105.7	49	1746	46.74	5614	1880	22612	3.43	11.72	3.08	0.93	0.57	*Planorbulina, Rosalina*
6_3	13	20272.1	49	1225	118.20	4397	1936	13939	3.64	13.04	3.06	0.94	0.63	*Discorbis, Quinqueloculina*
7_2	20	13234.4	50	1899	82.62	2850	1348	9035	3.62	12.70	3.15	0.95	0.73	*Laevipeneroplis, Rosalina*
10_3	14	7402.4	48	1450	94.64	1510	360	5532	3.58	13.66	3.20	0.95	0.68	*Planorbulina, Rosalina*
11_2	17	55084.3	54	2790	104.23	7431	7306	40347	2.95	13.53	3.14	0.95	0.64	*Rosalina, Quinqueloculina*
12_1	20	29659.5	55	1649	91.31	5223	3381	21056	3.29	13.12	3.07	0.96	0.54	*Rosalina, Quinqueloculina*
13_3	18	6014.1	45	578	52.85	1493	346	4175	3.93	12.53	3.13	0.95	0.72	*Rosalina, Archaias*
15_1	25	111558.8	43	2540	42.28	24944	7244	79371	3.72	11.51	3.18	0.95	0.71	*Quinqueloculina,Planorbulina*
15_2	25	53398.2	51	2318	31.16	11092	2221	40086	3.62	14.71	2.43	0.93	0.27	*Quinqueloculina, Rosalina*
15_3	25	108628.0	50	2134	57.93	21235	5992	81401	3.51	13.01	2.67	0.96	0.33	*Quinqueloculina, Rosalina*
16_1	26	105945.5	54	1316	44.47	25453	5095	75397	3.87	15.15	2.64	0.95	0.31	*Rosalina, Amphistegina*
16_2	26	131990.5	53	1331	50.19	28548	9058	94385	3.66	13.53	2.53	0.95	0.30	*Quinqueloculina, Planorbulina*
16_3	26	109405.2	57	1711	40.22	17171	7384	84850	3.19	13.08	3.20	0.95	0.57	*Quinqueloculina, Planorbulina*
17_3	17	64442.8	54	1303	45.19	11642	3407	49393	3.39	12.29	1.97	0.93	0.16	*Quinqueloculina, Planorbulina*
18_2	20	19849.2	42	594	37.37	7723	477	11649	5.09	13.78	2.66	0.91	0.57	*Laevipeneroplis, Planorbulina*
Mean		50679.9	49.38	1590	63.86	10157	3266	37257	3.60	12.91	2.97	0.94	0.55	*Rosalina, Quinqueloculina*
SD		38958.5	3.98	574	28.09	8155	2619	28742	0.42	1.41	0.34	0.01	0.17	
Maximum Values		**	72	**	**	**	**	**	10	>20	4.2	1.0	1.0	

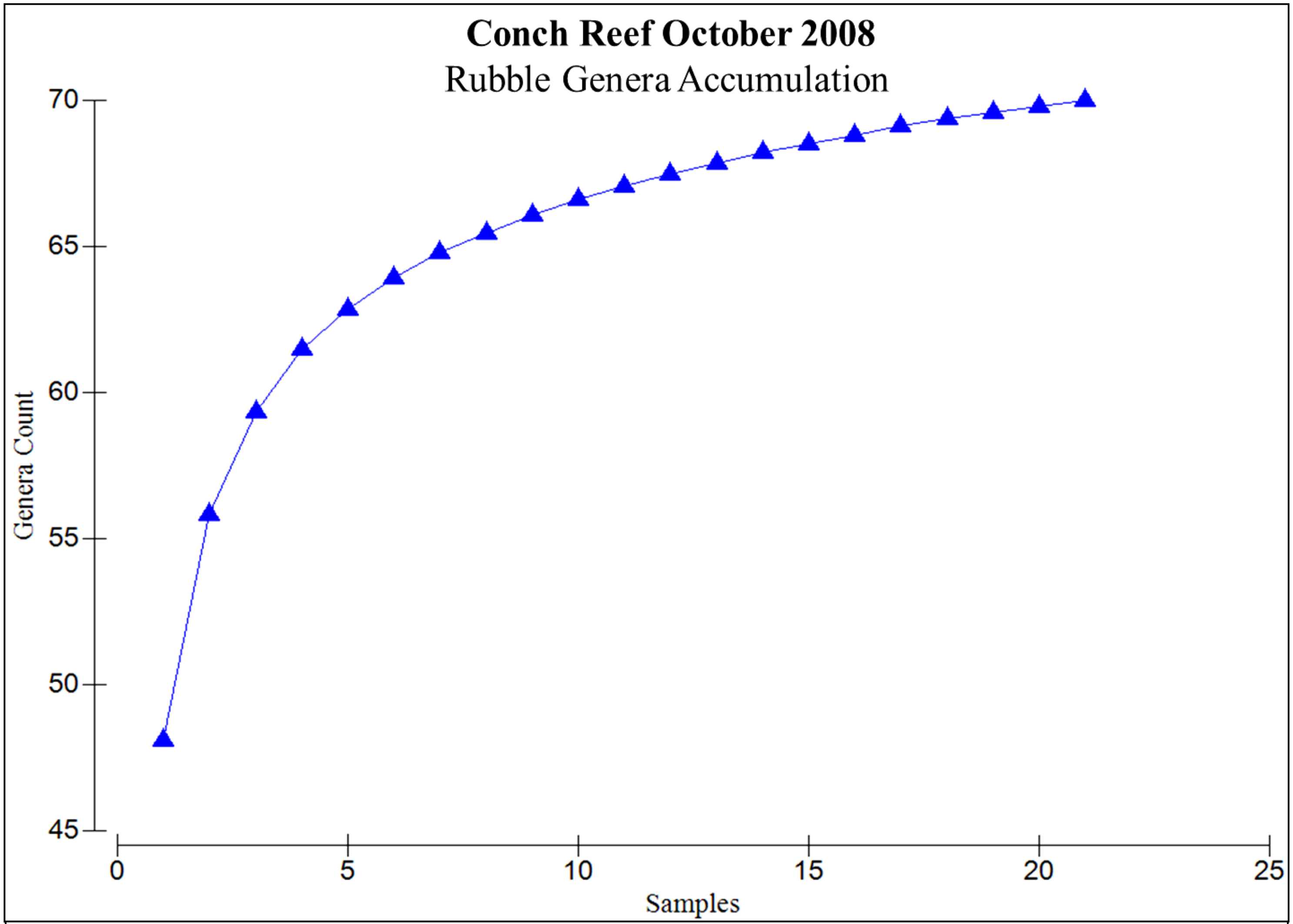


Figure 13. Randomized accumulation plot for genera of rubble samples from Conch Reef in October 2008 indicating that 90% of the genera are found in about 7 samples.

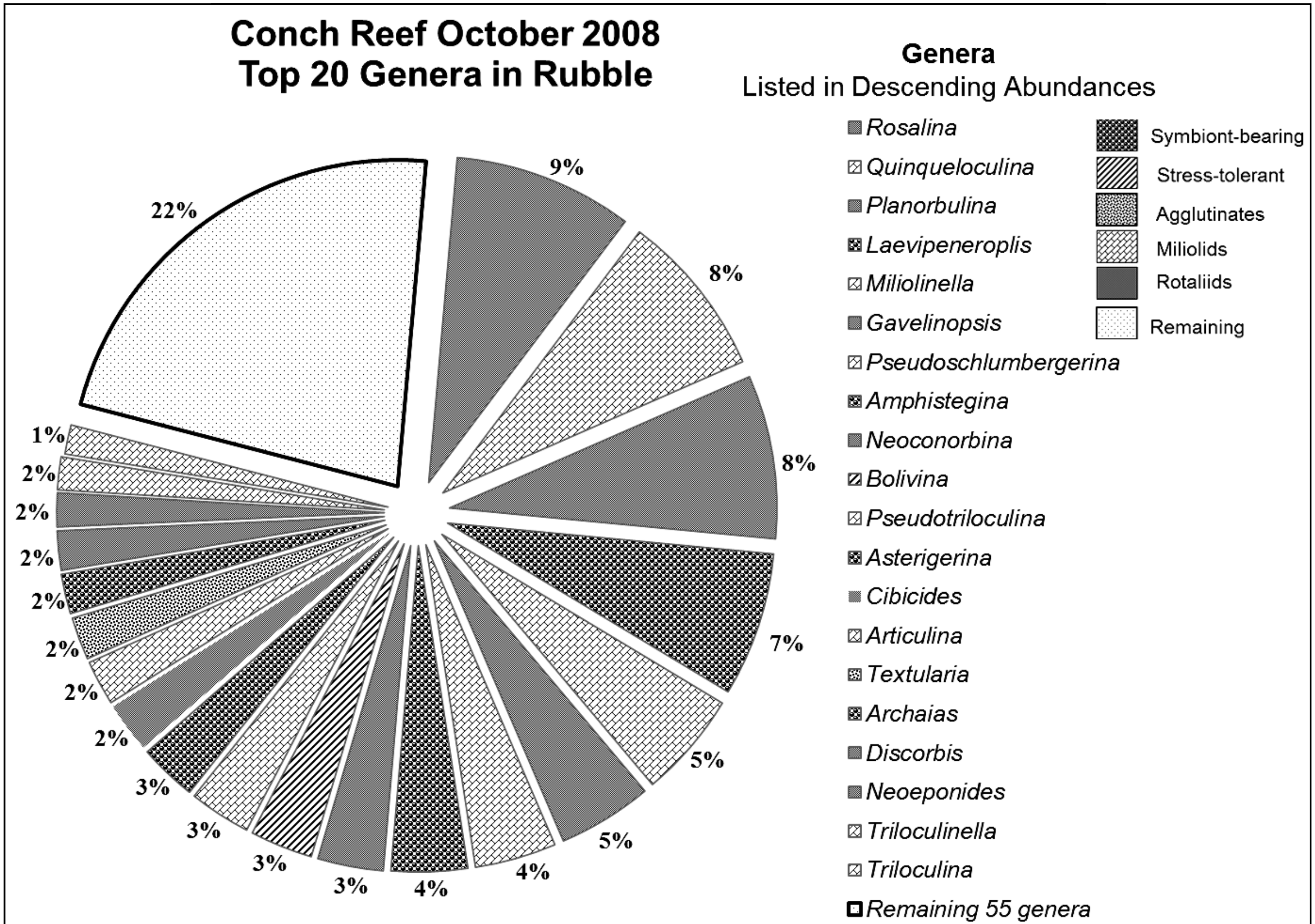


Figure 14. Twenty most abundant genera in rubble samples collected in October 2008 at Conch Reef; the 55 less common genera are included under “remaining.”

Sample distribution

Cluster analysis (q-mode) revealed three main clusters of samples (**Figure 14**). Nineteen of those samples exhibited greater than 60% similarity. The MDS plot comparing the rubble assemblages had a stress value of 0.06 (**Figure 15**), which denotes an excellent representation of the data set. The driving difference among the sample clusters is the quantity of stress-tolerant foraminifers and the relative abundances of other smaller taxa as compared with the symbiont-bearing taxa.

Cluster 1 is made up of two samples (10_3, 13_3) that had the fewest stress-tolerant foraminifers; the other smaller foraminifers were approximately three times more abundant than symbiont-bearing foraminifers. Cluster 2 includes 10 samples that had approximately four times smaller foraminifers than symbiont-bearing foraminifers. Subcluster 2a included 6 samples that did not differ significantly from each other and had four times more other smaller taxa than symbiont-bearing taxa. Subcluster 2b included 4 samples that did not differ significantly from each other, in which other smaller foraminifers were 1.5 times more abundant than symbiont-bearing taxa. Cluster 3 included samples in which other smaller foraminifers substantially exceeded that of symbiont-bearing taxa. Subcluster 3a contained one sample in which symbiont-bearing taxa were the least common. Subcluster 3b contained three very similar samples, which had 3.5-4.5 times more other smaller foraminifers than symbiont-bearing and approximately three times more symbiont-bearing than stress-tolerant taxa. Subcluster 3c included five samples that did not differ significantly, which had 3-4 times more other taxa than symbiont-bearing taxa, and stress-tolerant taxa were more common than in other samples. Rubble samples from the same collection site clustered together (*e.g.*, 16_1, 2, and 3), or in different clusters (*e.g.*, 5_1, 2, 3), demonstrating that within-site differences could be as great as among sites at this location.

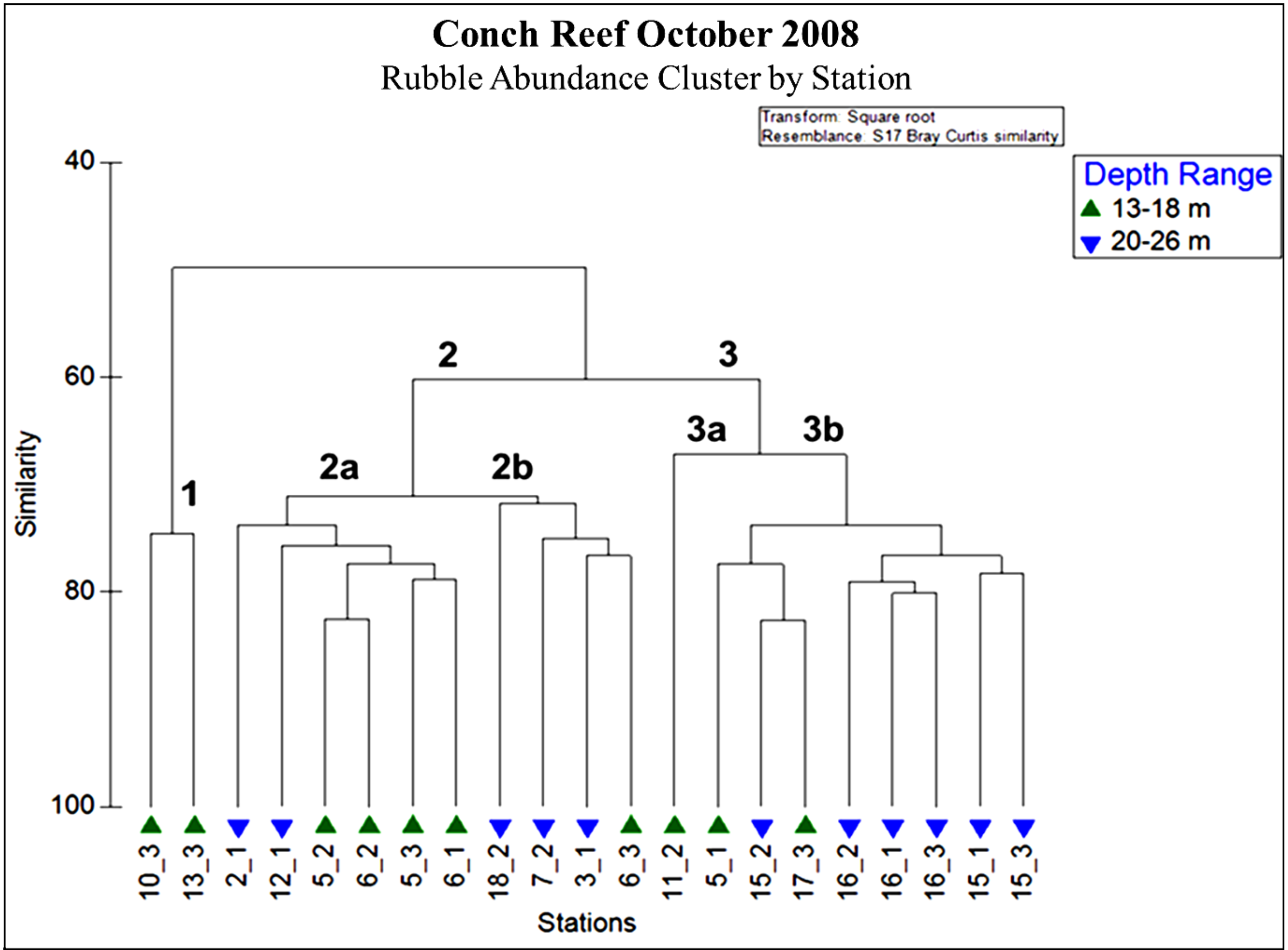


Figure 15. Cluster analysis of rubble samples, based on foraminiferal assemblages, with depth range of sampling sites indicated.

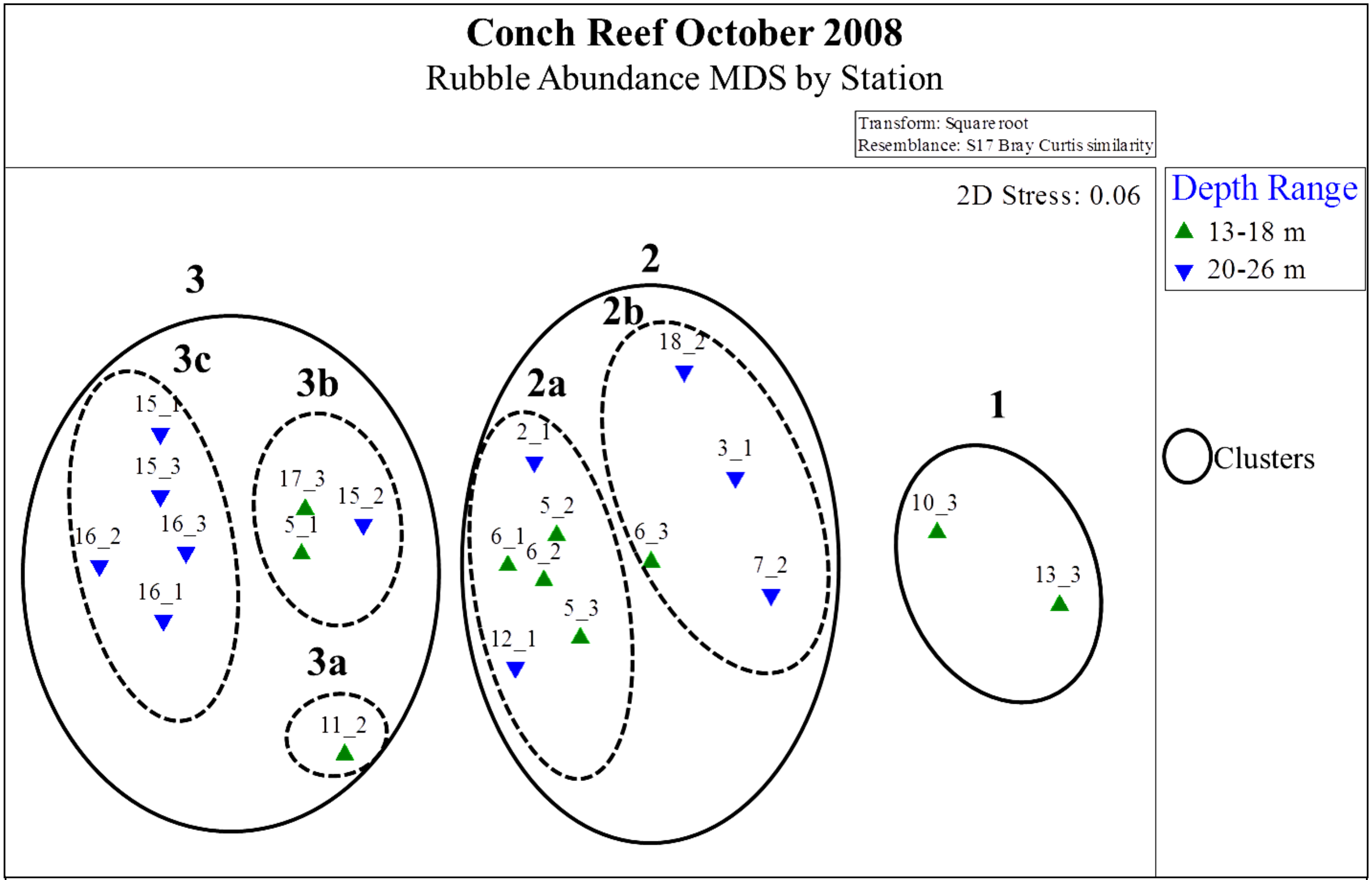


Figure 16. Bray-Curtis MDS plot of rubble samples based on foraminiferal assemblages at Conch Reef.

An ANOSIM was run on assemblage distributions in the rubble samples with a one-way analysis with the cluster number as the factor of comparison. This analysis resulted in a Global R of 0.887 and a significance level (p) of 0.1%, which indicates significant differences among the rubble-sample clusters.

SIMPER analysis via Bray-Curtis similarity (**Appendix D**), summarized in **Table 9,** showed that the samples from Cluster 1 had an average similarity of 75% with *Rosalina*, *Laevipeneroplis*, and *Planorbulina* being the top three contributors to the similarity. Cluster 2 samples had an average similarity of 73% with *Laevipeneroplis, Rosalina,* and *Planorbulina* being the top three foraminifers contributing to the similarity. Cluster 3 samples had an average similarity of 74% with *Quinqueloculina, Rosalina*, and *Planorbulina* being the top three foraminifers contributing to the similarity. The dissimilarity between Clusters 2 and 1 is 40% with *Gavelinopsis, Miliolinella*, and *Planorbulina* contributing to the dissimilarity. The dissimilarity between Clusters 2 and 3 is 40% with *Quinqueloculina*, *Rosalina*, and *Planorbulina* contributing to the dissimilarity. The dissimilarity between Clusters 1 and 3 is 61%, with *Quinqueloculina*, *Miliolinella*, and *Rosalina* contributing most to the dissimilarity. ANOSIM and SIMPER results from a pairwise test between clusters are shown in **Table 9**, indicating significant differences between each cluster pair.

Table 9. Summary of ANOSIM and SIMPER results for rubble samples by clusters.					
ANOSIM			**SIMPER**		
Cluster Comparison (within or between)	**R Statistic**	**Significance Level %**	**Similarity**	**Dissimilarity**	**# genera = 90%**
Cluster 1 (within)	Global R: 0.887	0.1	74.6	---	31
Cluster 2 (within)			73.2	---	34
Cluster 3 (within)			73.9	---	37
Clusters 2 & 1 (between)	0.885	1.5	---	40.2	48
Clusters 2 & 3 (between)	0.864	0.1	---	39.8	50
Clusters 3 & 1 (between)	1	1.8	---	61.2	46

Cluster analysis (r-mode) examining all genera present in at least two samples revealed few significant associations (**Figure 16**). An MDS plot with the rubble samples compared to the FI groupings visually represented the physical separation with a stress level of 0.15 (**Figure 17**). A one-way ANOSIM was run with the samples and FI groupings, which resulted in a Global R of 0.043 and significance level (p) of 30%, which means the sample group as a whole is relatively homogeneous. The pairwise test comparing the FI groups again indicated significant differences between symbiont-bearing and stress-tolerant taxa, and between stress-tolerant taxa and other smaller taxa, but not between symbiont-bearing and other smaller taxa (**Table 10**).

Table 10. ANOSIM pairwise test of the rubble samples to FI groupings.		
Rubble ANOSIM	**Global R: 0.043**	**Significance: 30.2%**
FI Groups	**R Statistic**	**Significance Level %**
Symbiont-bearing vs. Stress-tolerant	0.411	0.2
Symbiont-bearing vs. Other	-0.04	62.8
Stress-tolerant vs. Other	0.308	0.9

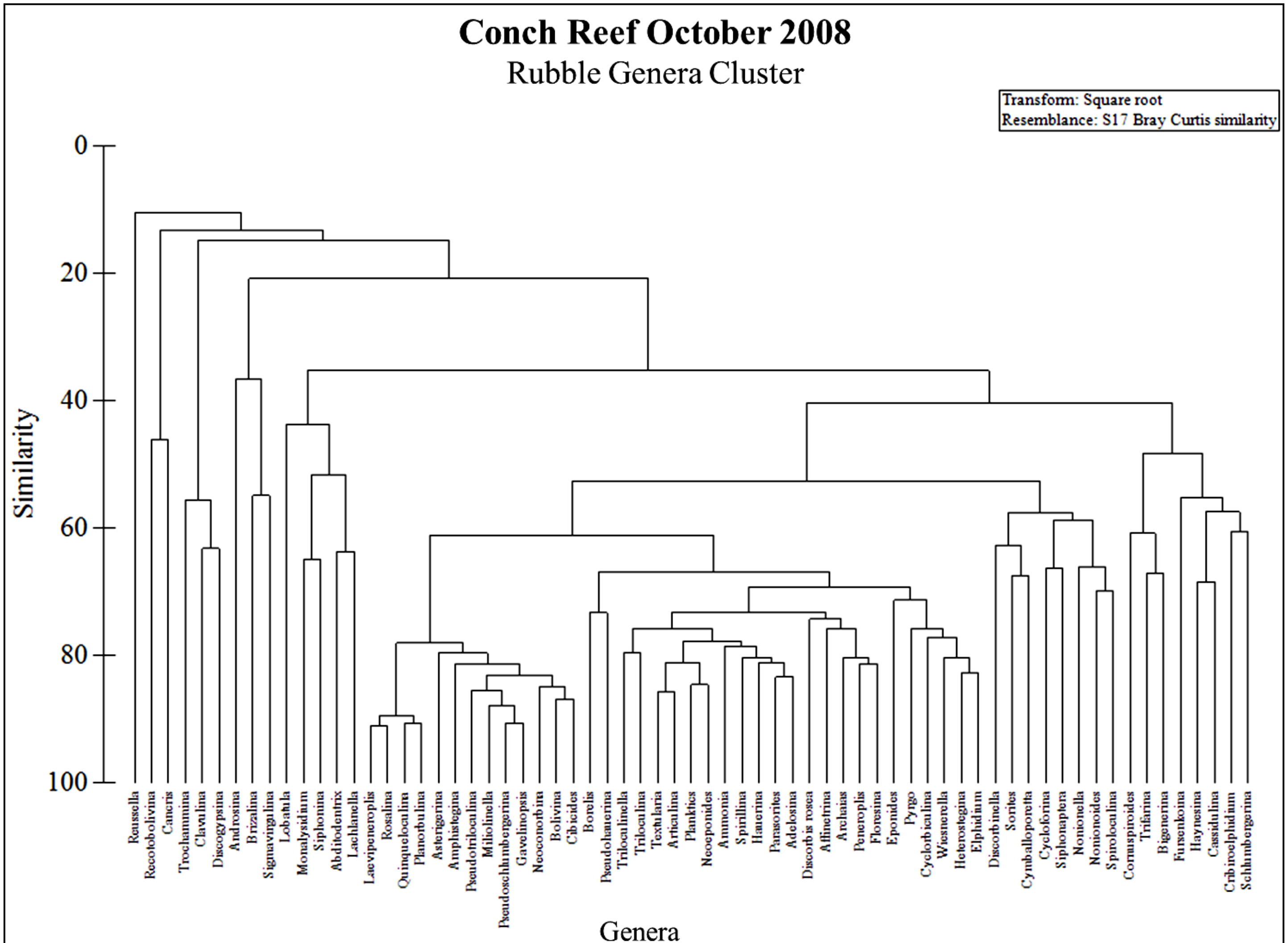


Figure 17. Cluster diagram by foraminiferal genera from rubble samples collected at Conch Reef.

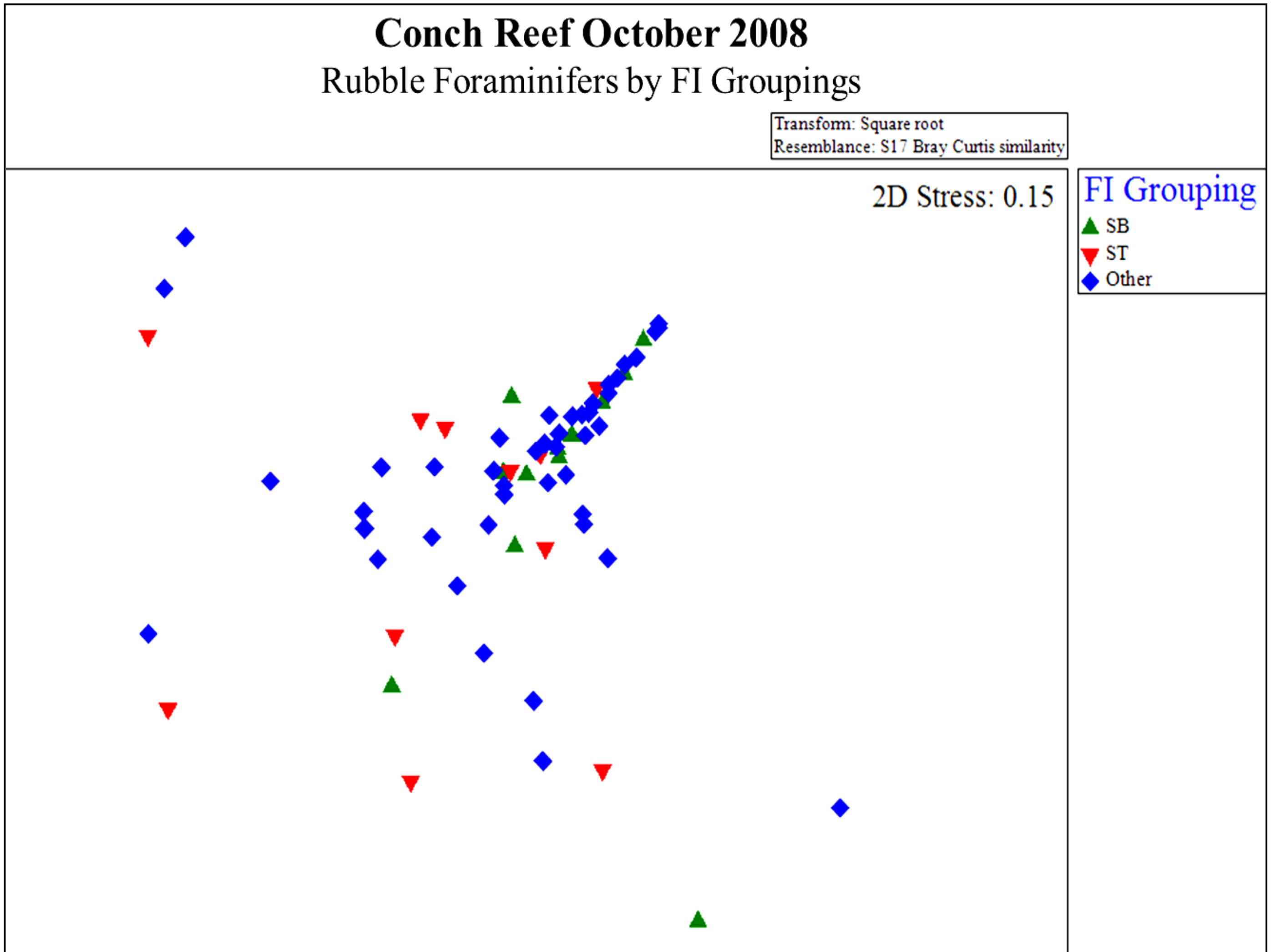


Figure 18. Bray-Curtis (r-mode) MDS plot of rubble samples by FI groupings. SB= Symbiont-bearing, ST= Stress-tolerant, and other = remaining

Comparison of foraminiferal assemblages in sediment and rubble samples

Key genera

In all sediment and rubble samples collected from Conch Reef in October 2008, 72 foraminiferal genera in total were identified (**Table 4**). Those genera found in sediment samples, but not in rubble, were *Reophax* and *Cibicoides;* both were rare. Genera that were observed in the rubble, but not in the sediment were *Bolivinellina, Cassidulina, Floresina, Glabratella, Haynesina, Parahauerina, Reussella, Sigmavirgulina, Trochammina,* and *Valvulina.* Again, none of these was particularly common in the samples.

Indices analysis

Assemblage indices showed that there were more genera per sample in the rubble than in the sediment. The FI was lower in the rubble samples, while the Fishers [α] was slightly higher, both reflecting the greater abundance and diversity of other smaller foraminifers in the rubble samples. The Shannon Diversity [H], Simpson's Diversity Index [D], and mean Evenness [E] were very similar between sediment and rubble samples.

Species richness by order as an indicator of biodiversity can be seen in **Figure 18**. Most species belong to the order Miliolida with 57, followed by Rotalida with 34, and Bulminida with 15. In total there were 117 species representing 72 genera, 37 families, and 8 orders (**Appendix E**).

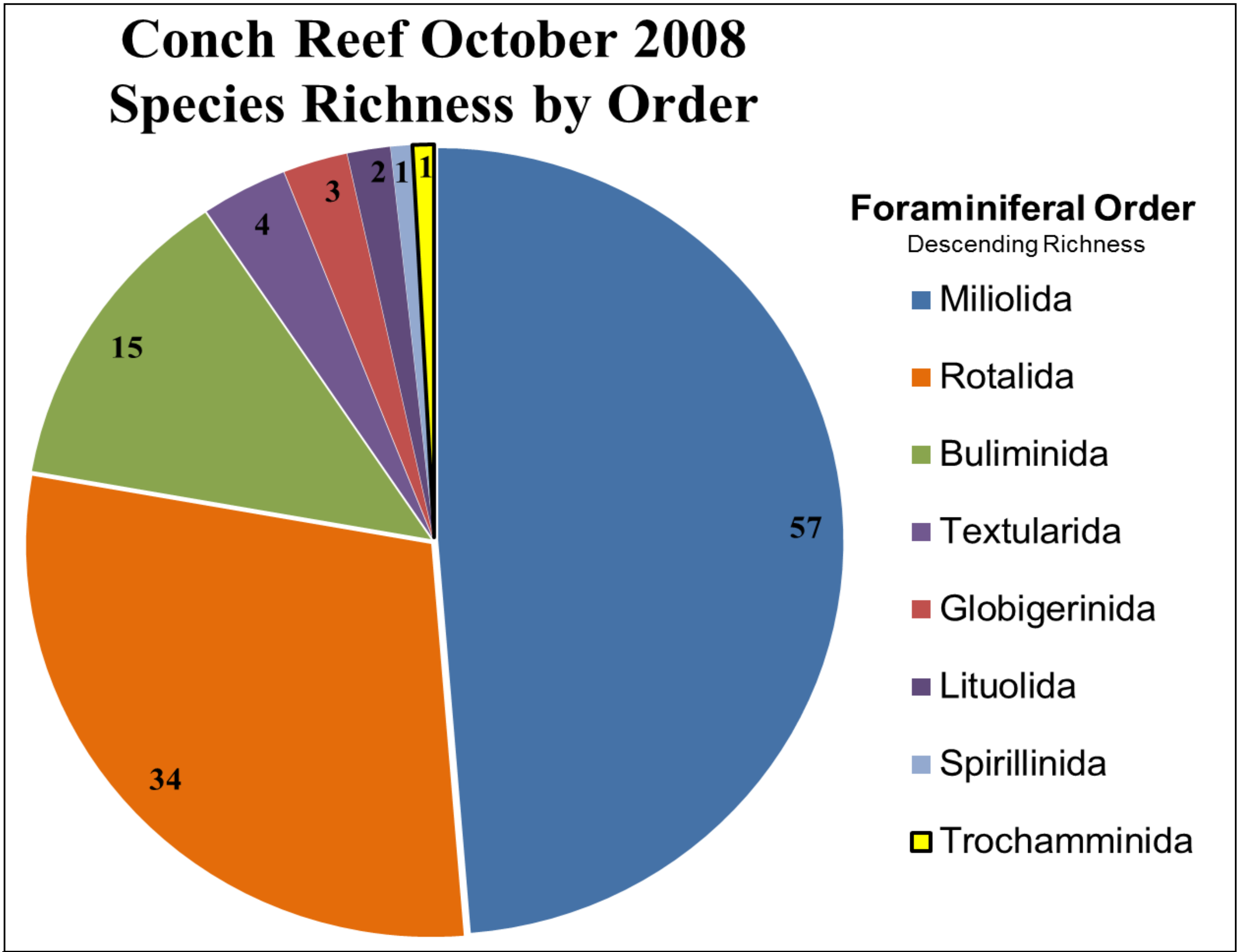


Figure 19. Species richness by foraminiferal order of samples collected at Conch Reef, October 2008.

Sample distribution

The normalized data for the sediment and rubble samples were analyzed in PRIMER as with the other data. After combining the sediment and rubble samples, genera present in less than 5% of the samples were not included in statistical analyses (Clark and Warwick 2001; Parker and Arnold 2002). Those genera were *Bolivinellina, Cibicoides, Glabratella, Parahauerina, Reophax, Reussella, Trochammina,* and *Valvulina.*

Cluster analysis (q-mode) comparing the sediment and rubble samples by sample type showed three major clusters (**Figure 19**). The MDS plot of the same data had a stress value of 0.11, indicating a good representation of the data (**Figure 20**).

ANOSIM and SIMPER analyses via Bray-Curtis similarity (**Appendix F**) were run using a one-way analysis using comparison of sediment to rubble samples, with clusters utilized as the factor of comparison (**Table 11**). The ANOSIM analysis resulted in a Global R of 0.909 and a confidence (p) value of 0.1%, which, along with the pairwise comparison statistics confirms that differences between clusters are significant.

Table 11. ANOSIM and SIMPER pairwise tests by cluster groups on the foraminiferal clusters.

Combined Sediment and Rubble Samples					
ANOSIM			**SIMPER**		
Cluster Comparison (within or between)	**R Statistic**	**Significance Level %**	**Similarity**	**Dissimilarity**	**# genera = 90%**
Cluster 1 (within)	Global R: 0.909	0.1	75.7	---	35
Cluster 2 (within)			71.1	---	28
Cluster 3 (within)			62.8	---	14
Clusters 1 & 2 (between)	0.903	0.1	---	36.0	49
Clusters 3 & 2 (between)	0.807	0.2	---	41.1	39
Clusters 1 & 3 (between)	0.998	0.1	---	54.5	45

Cluster 1 consisted of all 21 rubble samples, with *Rosalina, Quinqueloculina,* and *Planorbulina* as the top three contributors to the average similarity of 76%. Cluster 1 contained 3 outliers, one of which was station 11_2 with the highest foraminifers/gram and the lowest FI of the rubble samples. The other two outliers had the fewest foraminifers per gram, the highest FI, the fewest stress-tolerant specimens, and contained more *Archaias* than any other rubble samples. Cluster 1 contained 9 symbiont-bearing, 3 stress-tolerant, 1 agglutinated taxon, and numerous other smaller taxa found more consistently in rubble samples. Cluster 2 consisted of 12 sediment samples, with *Laevipeneroplis, Quinqueloculina,* and *Asterigerina* being the top three contributors to the average similarity of 71%. Cluster 2 includes two outliers; both of which contain more taxa abundant in rubble samples (examples *Rosalina, Discorbis rosea*, and *Milionella)* than other sediment samples; all samples have more other smaller foraminifers than symbiont-bearing taxa. Cluster 2 included 8 symbiont-bearing, 1 stress-tolerant, 2 agglutinated genera, and numerous other smaller taxa. Cluster 3 consisted of the remaining 5 sediment samples with *Amphistegina*, *Laevipeneroplis,* and *Archaias* being the top three foraminifers contributing to the average similarity of 63%. Cluster 3 contained more symbiont-bearing foraminifers than other smaller taxa, as well as four of which contain the lowest density sediment samples. Cluster 3 included 6 symbiont-bearing genera, no stress-tolerant, 1 agglutinated and the rest other smaller taxa. The dissimilarity between Clusters 1 and 2 is 36 % with *Planorbulina, Bolivina,* and *Asterigerina* contributing most to the dissimilarity. The dissimilarity between clusters 1 and 3 is 54 % with *Miliolinella, Rosalina*, and *Cyclorbiculina* contributing most to the dissimilarity. The dissimilarity between clusters 3 and 2 is 41% with *Rosalina, Miliolinella,* and *Textularia* contributing the most to the dissimilarity (**Table 11**).

ANOSIM analysis was made on the combined data set with the factor of comparison changed to sample type. Results produced a Global R of 0.732 with a significance level of 0.1%. This indicates a significant difference between the sample types. SIMPER analysis via Bray-Curtis similarity (**Appendix G**) comparison of sediment and rubble samples revealed that sediment samples grouped at 65% similarity with *Laevipeneroplis*, *Amphistegina, Quinqueloculina,* and *Asterigerina* as the top four foraminifers contributing to the similarity. Rubble samples group together at 76% similarity with *Rosalina, Quinqueloculina, Planorbulina,* and *Laevipeneroplis* as the top four contributors to the similarity. Sediment and rubble samples were 41% dissimilar with *Planorbulina, Bolivina*, *Asterigerina,* and *Rosalina* contributing most to the dissimilarity (**Table 12**).

Table 12. Summary of ANOSIM and SIMPER results of foraminiferal assemblages by sample type.

Sample Type Comparison (within or between)	**ANOSIM** (within)		**SIMPER** (between)		
	Global R:	**Significance Level %**	**Similarity**	**Dissimilarity**	**# genera = 90%**
Sediment	0.732	0.1	65.1	---	26
Rubble			75.7	---	35
Sediment & Rubble			---	41.5	48

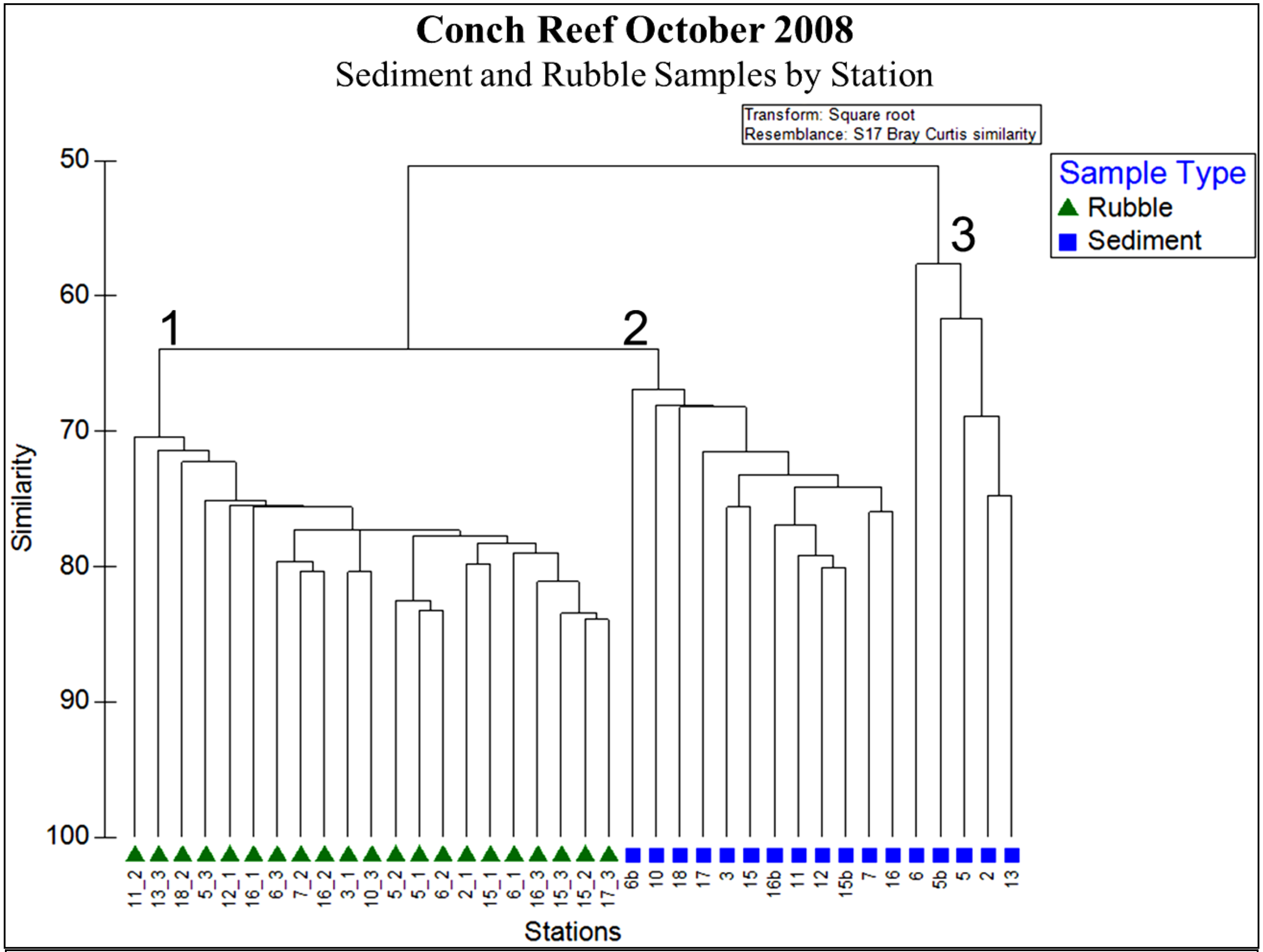


Figure 20. Cluster analysis of the combined data set (sediment and rubble samples) noting sample types at Conch Reef, October 2008.

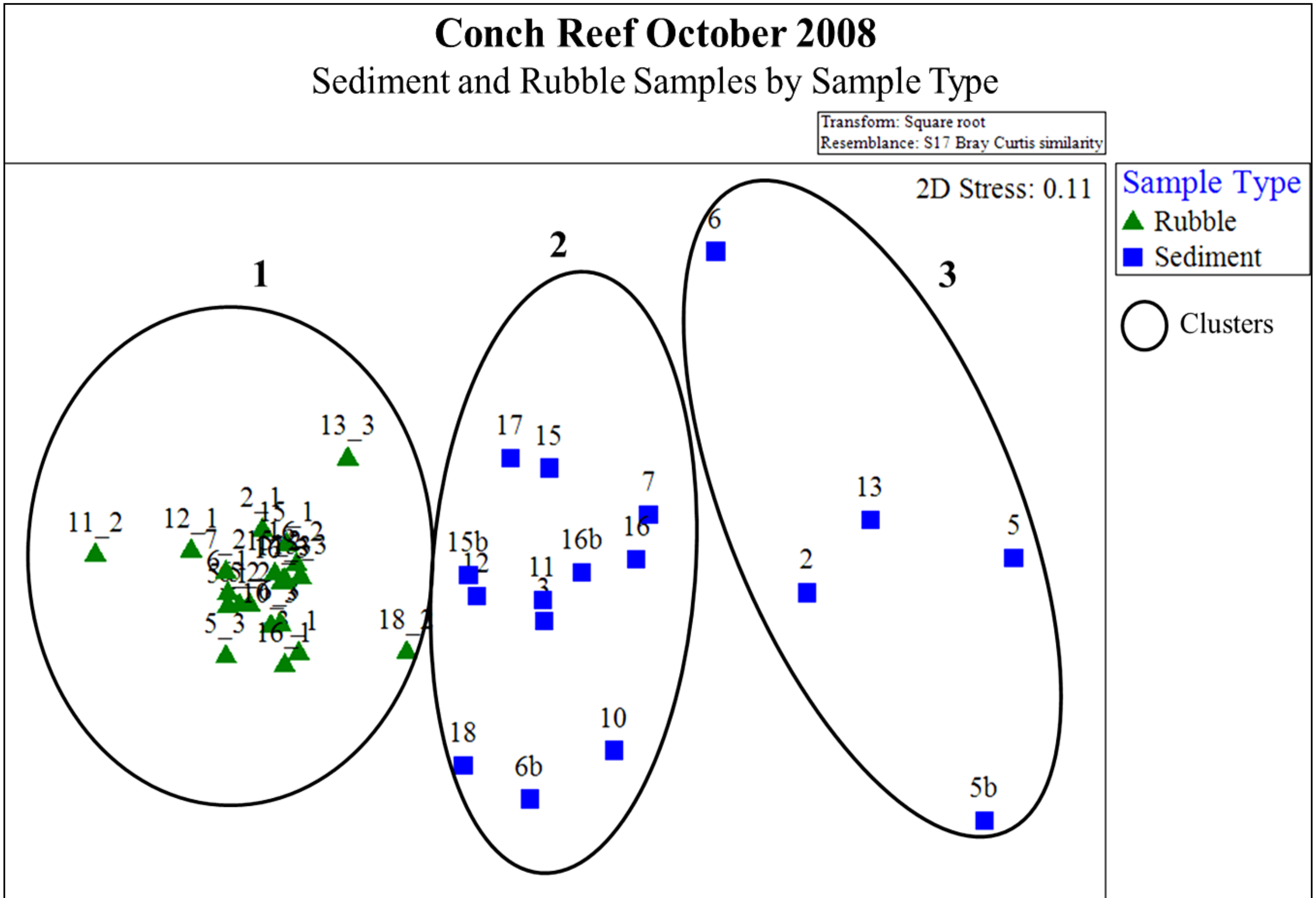


Figure 21. Bray- Curtis MDS plot of all samples, based on relative abundances of foraminifers.

Cluster analysis (r-mode) (**Figure 21**) based on foraminiferal genera in the combined data set exhibited an MDS stress value of 0.15, which is a good representation of the data. A one-way ANOSIM assessed FI groupings, which resulted in a Global R: 0.119 and significance level (p) of 7.8%, indicating that the assemblage is relatively homogeneous as a whole, comparing sediment and rubble samples. However, the pairwise test comparing the FI groups revealed significant differences between symbiont-bearing and stress-tolerant taxa and between stress-tolerant and other foraminifers (**Table 13**), as in previous anlayses.

Table 13. ANOSIM pairwise test of the combined data set (sediment and rubble) to FI groupings.

Combined Samples - ANOSIM	**Global R: 0.119**	**Significance: 7.8%**
FI Groups	**R Statistic**	**Significance Level %**
Symbiont-bearing vs. Stress-tolerant	0.152	1.5
Symbiont-bearing vs. Other	-0.03	58.3
Stress-tolerant vs. Other	0.248	2

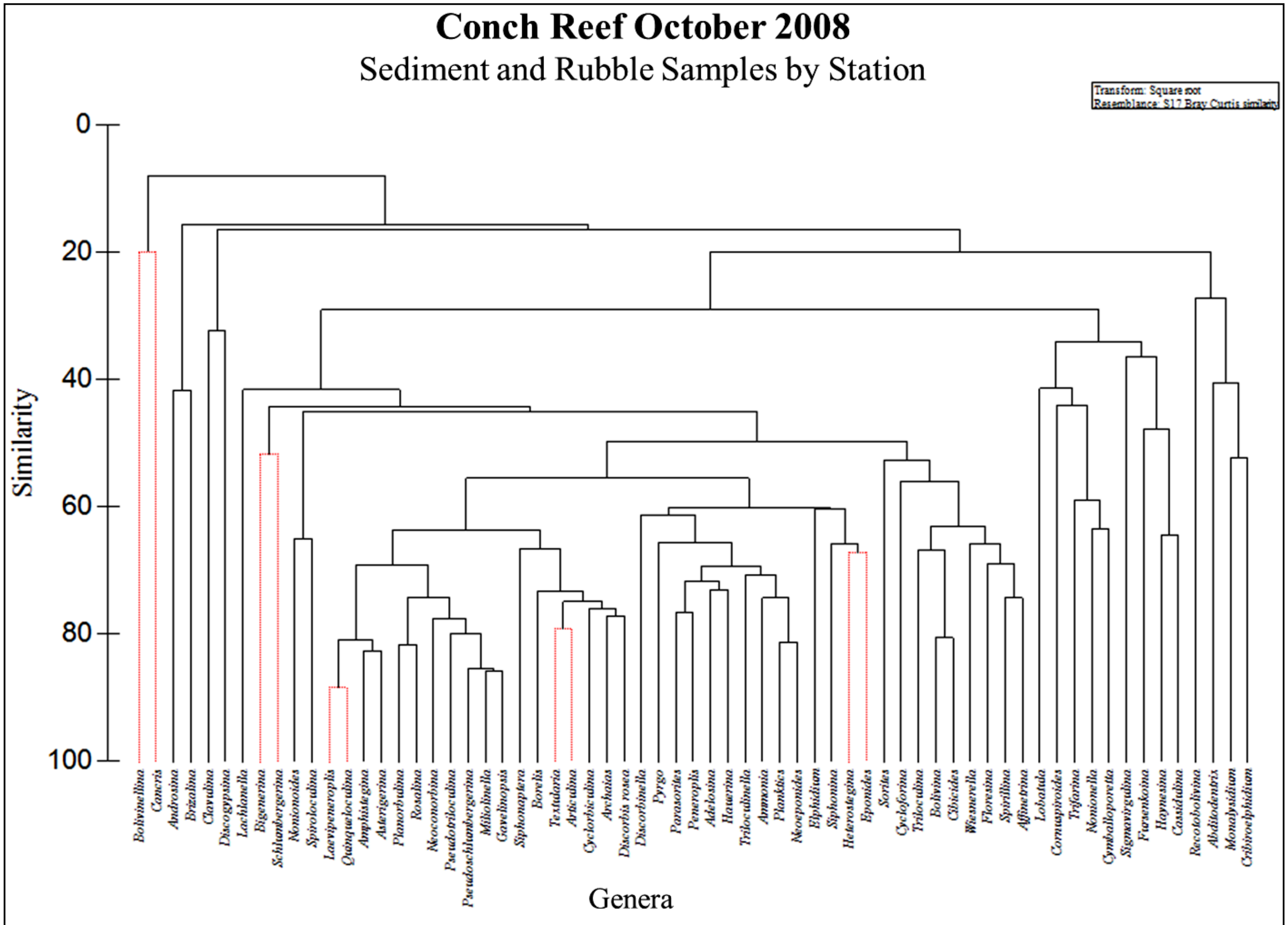


Figure 22. Cluster analysis of foraminiferal genera using the combined (sediment and rubble) data set.

Concentration ratio

A concentration ratio was calculated by comparing the relative abundances of 20 genera that were most common in both sample sets (**Table 14**). The sediment abundances (S) were divided by the rubble abundances (R) to establish a ratio (S/R). The five symbiont-bearing taxa, along with one agglutinated textularid (**Textularia*) and one agglutinated miliolid (***Siphonaptera*), were 2.5 - 5.5 times more abundant in sediments than in the rubble samples. In contrast, the smaller, more fragile taxa were under represented by at least half in most cases (**Figure 22**).

Table 14. Relative abundances of the 20 most common genera used to calculate a Concentration Ratio (S/R) for each genus.

Genera	Sediment	Rubble	S/R
Amphistegina	9.37	3.76	2.50
Archaias	5.45	1.97	2.77
Articulina	2.68	2.23	1.21
Asterigerina	8.34	2.85	2.92
Bolivina	0.21	3.10	0.07
Borelis	2.50	0.91	2.73
Cibicides	0.41	2.48	0.16
Cyclorbiculina	3.96	0.71	5.55
Discorbis	3.70	1.95	1.90
Gavelinopsis	1.68	4.66	0.36
Laevipeneroplis	11.41	7.14	1.60
Miliolinella	1.87	5.25	0.36
Neoconorbina	0.80	3.24	0.25
Planorbulina	1.79	8.10	0.22
Pseudoschlumbergerina	2.01	4.02	0.50
Pseudotriloculina	1.35	3.04	0.44
Quinqueloculina	8.09	8.17	0.99
Rosalina	5.11	8.85	0.58
***Siphonaptera*	2.83	0.57	5.01
**Textularia*	5.43	2.11	2.57
(****** agglutinated miliolid)	(*****agglutinated textularid)		

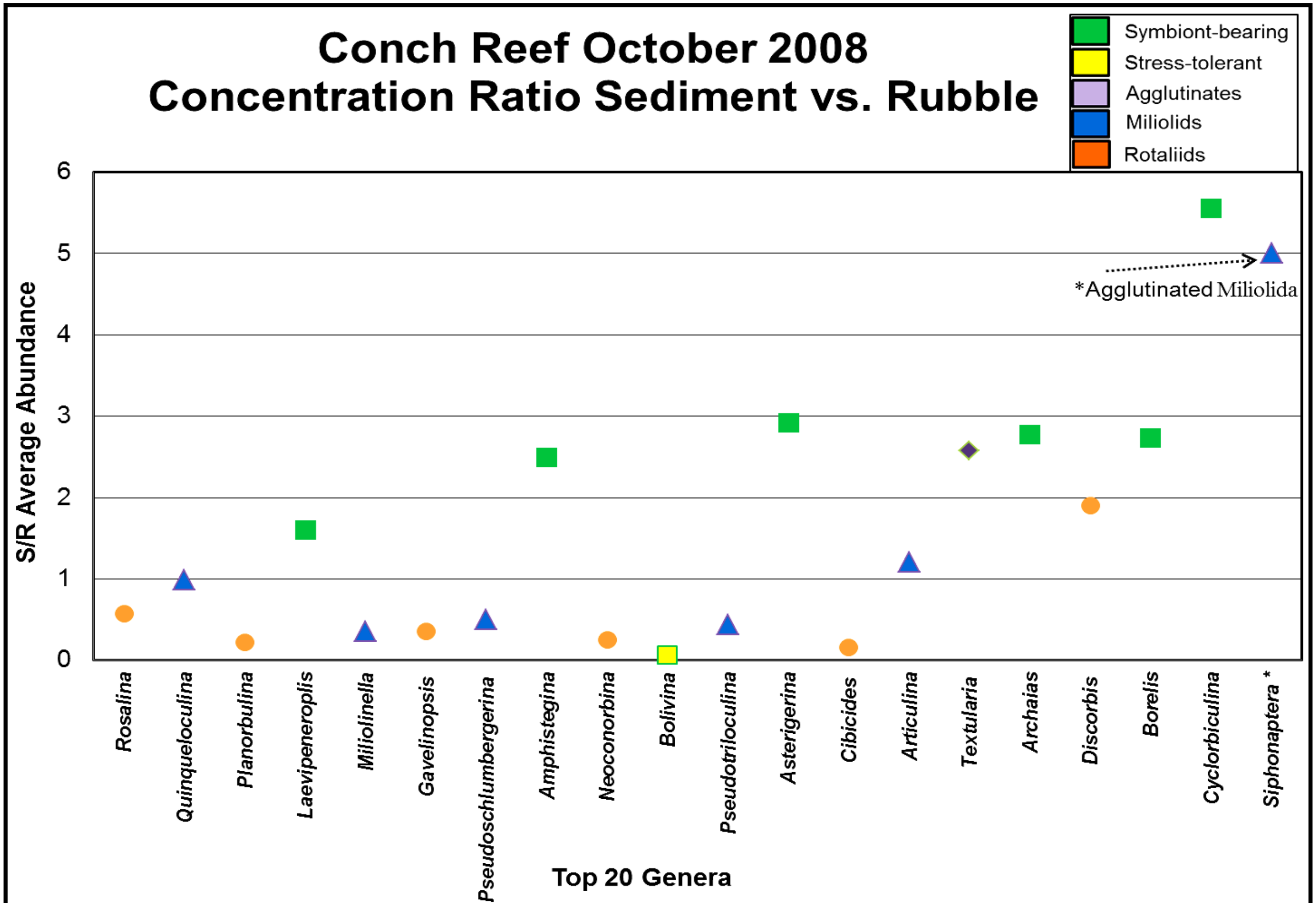


Figure 23. Concentration ratio of the 20 most common genera, calculated by dividing the average relative abundance of each genus in the sediment by its average relative abundance in the rubble.

Comparison of live versus dead foraminiferal assemblages

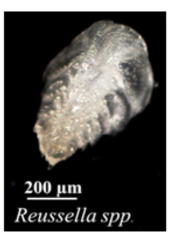
Although samples were not stained, the specimens of some species collected live can be distinguished when the protoplasm has distinctive color, as previously noted for those taxa that host algal endosymbionts (Hallock *et al.* 1986b; Goldstein and Corliss 1994; Bernhard 2000). In the sediment, ten genera were readily distinguishable as being alive or dead at the time of collection. Four of the genera were symbiont-bearing foraminifers, *Amphistegina, Asterigerina, Laevipeneroplis,* and *Peneroplis;* the remaining were other smaller rotalida taxa. In the rubble, 28 genera were readily distinguishable as alive or dead at the time of collection. Nine of the genera were symbiont-bearing foraminifers, *Amphistegina*, *Archaias, Asterigerina, Cyclorbiculina, Heterostegina, Laevipeneroplis, Parasorites, Peneroplis* and *Sorites*, 4 were stress tolerant, 4 small other taxa, and the remaining 11 were smaller Rotalida taxa (**Table 15**). *Discorbis rosea* was the only taxon for which the proportion of specimens collected live in sediments exceeded that of the rubble samples.

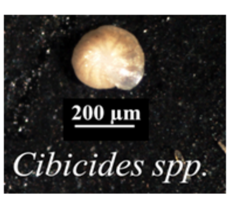
Langer Morphotype

The Langer (1993) Morphotype categories (**Figure 3**) were incorporated into the comparison of live to dead foraminifers (**Table 15)** and in comparing the relative abundances of foraminifers in sediment and rubble samples **(Table 16, 17**). The relative abundances of foraminifers in each sample type were distinguished by the Langer Morphotype are shown in **Table 17**. The total abundances of each Morphotype were divided by the total abundance for that sample type to calculate the abundance of foraminifers for each Morphotype. The calculations of the foraminiferal abundances by

Langer Morphotype (**Table 16**) show that the sediment and rubble were essentially the same. Only three genera from my samples were included in that category (*Heterostegina, Cribroelphidium, and Elphidium*), which were more abundant in the sediments.

Table 15. Percentage of live foraminifers found in sediment and rubble with Langer Morphotype and colored according to functional categories





Functional Categories (and examples)	Genera	Langer Morphotype	Sediment % Alive	Rubble % Alive
Symbiont-bearing	*Amphistegina*	B	5	52
	Archaias	D	0	12
	Asterigerina	B	6	9
	Cyclorbiculina	D	0	25
	Heterostegina	C	0	60
	Laevipeneroplis	D	6	14
	Parasorites	B	0	24
	Peneroplis	D	4	4
	Sorites	A	0	22
Stress-tolerant	*Ammonia*	B	0	22
	Bolivina	D	0	49
	Elphidium	C	0	2
	Nonionoides	B	0	28
Other-smaller taxa	*Floresina*	D	0	58
	Reussella	D	0	33
	Spirillina	B	0	5
	Trifarina	D	0	36
Other-Rotaliida	*Cibicides*	B	0	75
	Discogypsina	B	0	60
	Discorbinella	B	0	5
	Discorbis	B	81	73
	Eponides	B	13	42
	Gavelinopsis	B	17	44
	Neoconorbina	B	0	44
	Neoeponides	B	17	57
	Planorbulina	A	7	73
	Rosalina	B	22	73
	Siphonina	D	0	33

Table 16. Langer Morphotype comparison of foraminiferal relative abundances in sediment and rubble samples from Conch Reef, October 2008.

Morphotypes	Sediment Abundance	# Genera in Sediment	Rubble Abundance	# Genera in Rubble
A- Attached	**1.84**	**2**	**1.57**	**2**
B- Temporarily motile	**35.74**	**21**	**36.12**	**23**
C- Motile (filter feeders)	**2.11**	**2**	**1.28**	**3**
D- Permanently motile	**60.32**	**39**	**61.03**	**42**

Table 17. Relative abundances and Langer Morphotype of foraminiferal genera by order in sediment and rubble samples from Conch Reef, October 2008.

Order	*Genera*	Morphotypes	Sediment Abundance	Rubble Abundance
Buliminida	*Abditodentrix*	D	0.04	0.16
Buliminida	*Bolivina*	D	0.21	3.10
Buliminida	*Bolivinellina*	D	0.00	0.02
Buliminida	*Brizalina*	D	0.09	0.09
Buliminida	*Cassidulina*	B	0.00	0.17
Buliminida	*Floresina*	D	0.00	1.07
Buliminida	*Fursenkonia*	D	0.04	0.13
Buliminida	*Rectobolivina*	D	0.05	0.03
Buliminida	*Reussella*	D	0.00	0.05
Buliminida	*Sigmavirgulina*	D	0.00	0.11
Buliminida	*Trifarina*	D	0.10	0.27
Lituolida	*Reophax*	D	0.07	0.00
Lituolida	*Valvulina*	D	0.00	0.01
Miliolida	*Adelosina*	D	0.44	1.17
Miliolida	*Affinetrina*	D	0.14	1.03
Miliolida	*Androsina*	D	0.14	0.03
Miliolida	*Archaias*	D	5.45	1.97
Miliolida	*Articulina*	D	2.68	2.23
Miliolida	*Borelis*	D	2.50	0.91
Miliolida	*Cornuspiroides*	D	0.11	0.32
Miliolida	*Cycloforina*	D	0.29	0.67
Miliolida	*Cyclorbiculina*	D	3.96	0.71
Miliolida	*Hauerina*	D	0.50	0.86
Miliolida	*Lachlanella*	D	0.71	0.28
Miliolida	*Laevipeneroplis*	D	11.41	7.14
Miliolida	*Miliolinella*	D	1.87	5.25
Miliolida	*Monalysidium*	D	0.03	0.13
Miliolida	*Parahauerina*	D	0.00	0.75
Miliolida	*Parasorites*	B	1.60	1.12
Miliolida	*Peneroplis*	D	0.92	1.22
Miliolida	*Pseudohauerina*	D	1.79	8.08
Miliolida	*Pseudoschlumbergerina*	D	2.01	4.02
Miliolida	*Pseudotriloculina*	D	1.35	3.04
Miliolida	*Pyrgo*	D	1.10	0.49
Miliolida	*Quinqueloculina*	D	8.09	8.17
Miliolida	*Schlumbergerina*	D	1.11	0.28

Table 17. Continued				
Order	***Genera***	**Morphotypes**	**Sediment Abundance**	**Rubble Abundance**
Miliolida	*Siphonaptera*	D	2.83	0.57
Miliolida	*Sorites*	A	0.21	0.42
Miliolida	*Spirillina*	B	0.11	1.12
Miliolida	*Spiroloculina*	D	0.38	0.35
Miliolida	*Triloculina*	D	0.21	1.45
Miliolida	*Triloculinella*	D	1.77	1.63
Miliolida	*Wiesnerella*	D	0.07	0.60
Rotalida	*Ammonia*	B	0.62	1.03
Rotalida	*Amphistegina*	B	9.37	3.76
Rotalida	*Asterigerina*	B	8.34	2.85
Rotalida	*Cancris*	B	0.04	0.05
Rotalida	*Cibicides*	B	0.41	2.48
Rotalida	*Cibicoides*	B	0.03	0.00
Rotalida	*Cribroelphidium*	C	0.10	0.19
Rotalida	*Cymballoporetta*	B	0.19	0.26
Rotalida	*Discogypsina*	B	0.07	0.03
Rotalida	*Discorbinella*	B	0.53	0.62
Rotalida	*Discorbis*	B	3.70	1.95
Rotalida	*Elphidium*	C	1.06	0.58
Rotalida	*Eponides*	B	1.43	0.57
Rotalida	*Gavelinopsis*	B	1.68	4.66
Rotalida	*Glabratella*	B	0.00	0.04
Rotalida	*Haynesina*	B	0.00	0.50
Rotalida	*Heterostegina*	C	0.95	0.51
Rotalida	*Lobatula*	B	0.04	0.26
Rotalida	*Neoconorbina*	B	0.80	3.24
Rotalida	*Neoeponides*	B	1.24	1.68
Rotalida	*Nonionella*	B	0.10	0.38
Rotalida	*Nonionoides*	B	0.33	0.47
Rotalida	*Planorbulina*	A	1.62	1.15
Rotalida	*Rosalina*	B	5.11	8.85
Rotalida	*Siphonina*	D	1.10	0.27
Textularida	*Bigenerina*	D	1.01	0.22
Textularida	*Clavulina*	D	0.29	0.05
Textularida	*Textularia*	D	5.43	2.11
Trochamminida	*Trochammina*	B	0.00	0.02

DISCUSSION

History of previous studies

Classic systematic paleontological studies of Caribbean benthic foraminiferal assemblages include those of d'Orbigny (1839), Cushman (1922, 1930), and Bock (1971). The modern foraminiferal assemblages of the Florida reef tract are well known (e.g, Bock 1971; Culver and Buzas 1982; Martin 1986; Cockey *et al.* 1996). The primary differences in the assemblages between the species list presented in this study and previous studies are in the more recent generic distinctions (Loeblich and Tappan 1987). This list includes, for example, *Abditodentrix, Triloculinella,* and *Pseudotriloculina,* which were previously classified as *Triloculina* or *Quinqueloculina.*

Lidz and Rose (1989) reported approximately 50 foraminiferal species common in Florida reef sediments representing 32 genera and 20 families. Wright and Hay (1971) found 117 species representing 60 genera from the Florida reef tract. Both of those data sets included a greater range of environments than this data set from a single shelf-margin reef. Nevertheless, the results of this study document that the taxonomy of the benthic foraminiferal assemblages on the Florida reef tract is well known and are well represented at any reef location.

Sample homogeneity and distribution

My samples overall are very homogenous. Hydrodynamics, and sediment movement and transport, especially of shells of smaller foraminifers, may account for the relatively homogeneity of the suites of samples within a sampled area. Sixty genera were identified from the sediment samples and 70 genera in the rubble samples. The primary differences between sample types are in the relative abundances of smaller foraminifers. In both, more than 70% of the genera occur at 1% abundance or less. The 12 genera not found in both sample types were uncommon, typically occurring in only one or two samples overall. Thus, the sediment assemblages, which were mostly dead shells, well represented taxa living primarily on solid and phytal substrates in the area.

Despite the taxonomic similarity between rubble and sediment samples, the relative abundances of the most common taxa found in the sediment samples differed from those found on the rubble. Sonication of the rubble material may have contributed to the presence of the specimens attached to substrates like algal mats, where the foraminifera were living. Taphonomic destruction and sediment sorting reduced the relative abundances of smaller taxa (**Table 17**). Nevertheless, about 70% of the sediment samples clustered with the rubble samples at greater than 60% similarity.

Comparing the relative abundances of the 20 most common taxa between the two sample sets (**Table 14**) indicates that the smaller taxa are under-represented in the sediments compared to genera with larger or more robust shells. In sediment samples, six of the top 20 taxa are symbiont-bearing genera, three of which are the most abundant overall. In the rubble samples, the three most abundant genera are other smaller foraminifers, and only three symbiont-bearing genera are among the top 20.

The distributions of *Asterigerina carinata* (only one species of this genus occurs in Florida) were notable in my study, as in previous studies. These foraminifers have intermediate-sized shells, are thick-walled and biconvex in shape, and host algal symbionts. The shells and even living specimens of this species are commonly found abundantly in both sediment and rubble samples. Previous studies have noted the abundance of this species in higher energy environments (Crevison *et al*. 2006; Ramirez 2008; Baker *et al*. 2009). Similarly, the robust, asymbiotic *Discorbis rosea* was also very common, both as dead shells and specimens collected live in sediments, consistent with those previous studies. The abundance of *Discorbis rosea* indicates moderate to high energy environments (Triffleman *et al*.1991; Peebles *et al*.1997). Robust-shelled foraminifers are resistant to breakage and, depending upon shape, less susceptible to transport. Individual foraminiferal species from high-energy environments with coarse-sediment substrates have stronger shells than similar-sized individuals from low-energy habitats (Wetmore 1987).

Concentration ratio

The concentration ratios (**Figure 22**) revealed the tendency for the larger and more robust taxa to be concentrated in the sediments compared to smaller and more delicate taxa. *Amphistegina, Archaias, Asterigerina, Borelis,* and *Laevipeneroplis* all exhibited concentrations ratios between approximately 1.5 and 3. *Cyclorbiculina* had the highest concentration ratio of the symbiont-bearing taxa. This might be an artifact of its larger, wing-shaped structure, which may enhance transport of the shells from shallower environments (Hohenegger *et al.* 1999). *Archaias*, a symbiont-bearing Miliolida, has robust shells that are thick and reinforced by pillars, which form the chamberlets for algal symbionts. This test shape and thickness enables *Archaias* shells to be resistant to abrasion and winnowing and therefore to accumulate in carbonate sediments (Martin 1986).

In addition to *Discorbis*, two other smaller genera were found more than twice as commonly in sediment as on rubble (**Figure 22**). *Siphonaptera*, an agglutinated miliolid, was approximately five times more common, while *Textularia*, which belongs to the agglutinate Order Textularida, was about 2.5 times more common in sediment. Whether that difference indicates that these taxa live in sediments or are simply more resistant to destruction is not known, but one can speculate on both possibilities. In the first possibility, sediment particles with which to build an agglutinated shell are more readily available to foraminifers living in the sediments. Moreover, living in sediments likely necessitates a stronger shell. *Siphonatera* was previously reported (Hallock *et al.* 2003; Carnahan *et al.* 2009) as clustering with symbiont-bearing foraminifers.

Two other smaller miliolid genera, *Articulina* and *Quinqueloculina*, were found equally commonly in sediment and rubble samples (**Figure 22**). Both genera are relatively diverse and some species in both genera have intermediate-sized and relatively thick shells. Again, members of these genera may be living in the sediment as commonly as on rubble, and those with relatively thick shells would have higher preservation potential.

Wetmore (1987) reported that test strength increases with size and with increasing physical energy in the environment. Species living in coarse sediments have stronger shells relative to their size than species living in fine sediments or on algae. Overall shape, chamber size and arrangement, wall thickness, test composition, and strength of connections between chambers would all be expected to affect the test strength (Boltovskoy and Wright 1976; Wetmore 1987). Sample assemblages revealed no relationship to sediment texture, which varied little across the study area (**Table 2**). The sediment samples with the fewest shells per gram that differed most from the other sediment samples, and from the rubble samples, were either from shallower depths or from the immediate vicinity of the underwater habitat, either of which could have resulted in disturbance that resulted in additional removal of smaller shells.

Martin (1986) did not report *Planorbulina* and *Rosalina* in his sediment samples from near Mosquito Bank in the Florida Keys. While these two species are either permanently attached (*Planorbulina*) or temporarily attached (*Rosalina*), they were both found alive in low percentages in sediment samples. Langer (1993) states that, while *Rosalina* and other species with similar test shapes are primarily attached, they do have the capability to detach themselves in response to unfavorable environmental conditions or competition for space.

No significant depth trends were found, which is not surprising given the limited range of depths sampled (13-26m). However, there were a few subtle differences in individual genera and average abundances of foraminifers related to depth. In both the sediment and rubble samples, the deeper stations had higher absolute abundances of foraminifers. Baker *et al.* (2009) reported that live larger foraminifers at Conch Reef increased in abundance with depth over approximately the same depth range. In the sediment samples *Quinqueloculina, Laevipeneroplis,* and *Asterigerina* were more abundant at the deeper depths. In the rubble samples, *Quinqueloculina, Amphistegina,* and *Asterigerina* were more abundant in the deeper samples.

Faunal assemblages

Faunal assemblages rather than individual species of foraminifers tend to be diagnostic as environmental indicators (Lidz and Rose 1989). The composition of benthic foraminiferal assemblages is influenced by test production, taphonomic destruction, vertical mixing, and horizontal transport (Loubere *et al.* 1993; Walker and Goldstein 1999). The most important taphonomic processes affecting the assemblage of benthic foraminifers are transport and destruction of shells. Interpretation of the data from this study shows the sediment assemblages are dominated by foraminifers that are more robust. Previous studies found that shells of calcareous species (*Cibicides lobatulus*) remained intact longer than shells of an agglutinated species (*Reophax atlantica*), and the relative survival time of the shells of those two species appeared to correspond to the increased energy of the microhabitat in which they lived (Miller and Ellison 1982; Wetmore 1987).

Crevison *et al.*(2006) analyzed cores taken along the Florida reef track and found strong evidence for vertical mixing, as individual cores were very homogeneous and did not stratigraphically reveal the decadal changes found in surface sediments reported by Cockey *et al.*(1996) and, Lidz and Hallock (2000). Crevison *et al.* (2006) also noted strong differences in sorting and taphonomic destruction between cores from the middle keys region, which were well sorted and exhibited a more even distribution of functional groups, than cores from the upper and lower keys, which contained a more diverse assemblage of shells of smaller taxa.

Total assemblage controversy

Basing analyses on total assemblages in sediment samples is controversial among some foraminiferal researchers. Shefflett (1961), Murray and Alve (1999a-b), Patterson *et al.* (1999), Murray and Pudsey (2004) and others contended that this method misses many specimens due to taphonomic loss. Particularly in higher latitudes, hyposaline (estuarine), and deep-sea environments, dissolution often precludes preservation of calcareous shells (Aller 1982; Murray and Alve1999a-b; Patterson et *al.* 1999; Murray and Pudsey 2004). In environments with significant terrigenous input, the taphonomic loss can be attributed to shells breaking against much harder quartz sands. However, in tropical estuaries and coastal regions where salinity is near normal, the majority of the taxa live on phytal or hard substrates (Cockey *et al.*1996; Peebles *et al.*1997), live individuals are lost due to sorting and not to dissolution, and breakage can occur but is less frequent when sediment have similar hardness. When working in areas where taphonomic loss or environmental changes have occurred in the area sampled within the last few years, the total assemblages should be interpreted cautiously (Martinez-Colon *et al.* 2009). When analyzing the data from this study, it shows that the total foraminiferal assemblage in the sediments is a good representation of what taxa had been living in the area of study.

Comparison of live versus dead foraminiferal assemblages

Previous studies on live versus dead assemblages in the Baltic Sea by Alve (1999) reported that living foraminifers typically were not abundant in sediment samples. The dead assemblage observed had a much higher diversity. Living populations in the North Atlantic have been observed in both percentages and total numbers, to fluctuate greatly while corresponding total populations fluctuate only in total numbers (Scott and Medioli 1980). According to Murray and Alve (1999a), the dead assemblages represent the time-averaged contribution of empty shells from the production of successive living assemblages and subsequent modification due to postmortem processes. Buzas et al (2002) reported that dead assemblages depicted modern environments, while the live assemblage in any given sample is a representation of a "pulsating patch." When the dead assemblage and the live assemblage differ substantially, it could be representative of a local bloom. Murray and Alve (2000) took replicate samples adjacent to each other and found substantial spatial variation may occur within a centimeter.

Studies that compared live and dead assemblages in reef-sediment samples (*e.g.*, Cockey *et al.* 1996; Peebles *et al.* 1997) reported that foraminifers collected alive typically made up less than 10% of the foraminiferal shells identified and therefore, differences between dead and total assemblages were insufficient to justify the greater expenditure of effort to distinguish between them.

Comparing live versus dead assemblages was not a primary goal of this study; hence, the samples evaluated were not preserved and stained. Nevertheless, the protoplasm color is readily preserved in some genera, so specimens collected live are easily distinguished from dead shells. In the sediment samples, 10 genera were identified that included live specimens. In the rubble samples, 28 genera were identified that included specimens collected alive (**Table 14**). Of the genera for which individuals collected live were identifiable, about 15% of the specimens in the sediments and about 85% of those in the rubble were collected alive. Thus, future studies in this area should consider doing a live vs. dead comparison including all available substrates.

Abundances of larger foraminifers collected live from Conch Reef and other Florida reef-tract sites by Baker *et al.* (2009) show numbers that varied with season and depth. Over a five-year period, Buzas *et al.* (2002) observed no overall increase or decrease in densities of foraminifers in his study. However, individual species densities often exhibited maximum densities at particular times of the year. Substrate, currents, wave intensity, and wave direction affect local distributions of foraminiferal assemblages but do not alter regional patterns (Lidz and Rose 1989). In some areas of the Indian River, there was a seasonal cycle, while other areas and species exhibited patchiness, even between sites within a few meters of each other (Buzas 1968, 1970). The distribution of live benthic foraminifers can change substantially in a short distance, even in areas that have the similar physical and chemical characteristics (Peebles *et al.* 1997).

Most reef-dwelling taxa tend to live on phytal or hard substrates rather than directly on the sediments. Martin (1986) found that, in the northern Florida Keys, *Archaias* lived primarily on vegetation. He found virtually no living *Archaias* in the sediment samples. Similarly, I found neither live *Archaias* nor *Cyclorbiculina* in the sediment, though many dead shells. *Archaias* in Florida Bay near Long Key are abundant on epiphytes or macroalgae (Fujita and Hallock 1999). Because these taxa have relatively large shells that are resistant to destruction, their dead shells are widespread in the shelf sediments of the tropical western Atlantic and Caribbean (Martin 1986; Triffleman *et al.*1991; Peebles *et al.*1997).

Within sample versus within site variability

Samples in this study were evaluated to see if there was a difference in the total assemblages between samples and sample type. Four sediment samples (5, 6, 15, and 16) were evaluated with two subsamples each, to determine within sample variability. Sediment subsamples 5 and 5b were not significantly different from each other, nor from sample 13, which clustered together (**Figure 8**). These samples had the least amount of total foraminifers yet the highest FI values of 6.3-7.4, as well as the most abundant symbiont-bearing taxa compared to other foraminiferal taxa.

Sediment subsamples 6 and 6b were significantly different. The subsamples were nearly identical with respect to symbiont-bearing taxa; the differences between the two subsamples were more abundant other smaller taxa. Between the two subsamples, there was a difference of 10 genera as well. Both differences could be accounted for by one subsample containing finer material.

Intra-site variability was also evaluated for the rubble samples. Three samples each were examined from stations 5, 6, 15 and 16. Again samples from the same site could be very similar (16_1, 2, 3) or as different as between sites (*e.g.,* 5_1 versus 5_2 and 5_3).

Indices

The Foram Index was developed to relate the response of the calcifying benthic community to the status and suitability of the environment for future reef growth (Hallock *et al.* 2003). The mean FI of the sediment samples was 5.6 $\pm$ 0.8, indicating that the water quality at Conch Reef is suitable for reef growth. The FI was developed using sediment samples, because their collection adds minimal time or effort to a field sampling effort. Moreover, collection of sediment samples for analysis of total assemblages does not require transport of preservatives, minimizing costs of collection and transport to the laboratory (Hallock *et al.* 2003).

Although the FI design was to be applied to sediment samples, some researchers have applied it to live assemblages (P. Hallock, personal communication 03/2011). My study provided the opportunity to compare the FI values from rubble substrate, which predominantly represented the live assemblage, and from the total assemblage from sediments. The mean FI for the live assemblages was lower, 3.6 $\pm$ 0.4; but still indicates a significant contribution by symbiont-bearing foraminifers, thereby supporting the assessment that water quality at Conch Reef is suitable for calcifying symbioses.

There were no significant differences seen in the means of the other indices calculated (Shannon Diversity, Simpson's Diversity Index, and Evenness) between sediment and rubble samples, other than FI and the number of genera found in the samples. Although Hayek and Buzas (2010) recommend the use of these indices for assessing biodiversity, those indices did not reveal any significant differences in my samples. Researchers have used these indices, because the absolute number of taxa identified is to some degree a function of the number of individuals found in a sample.

Foraminiferal genera were more abundant in the rubble samples (49) than in the sediment samples (34). However when standardized for the number of individuals counted per samples, the Fishers [α] diversity index indicates there is no significant difference in diversities between the sample type. Thus, the FI in this case was the only index that showed a difference in the sample sets.

The sediment reveals what taxa have been living in that area in the past or that are present at the time of sampling. The underlying observation for the FI is that sediments on healthy reefs have a larger proportion of shells of symbiont-bearing foraminifers compared to other smaller foraminifers and stress-tolerant foraminifers (Hallock 1988; Hallock *et al.* 2003). Foraminifers found in the sediments are represented primarily by empty shells, while live specimens can be found living on a variety of substrates. According to Engle (2000 p. 3-1) " an ideal indicator of the response of benthic organisms to perturbations in the environment would not only quantify their present condition in the ecosystems, but would also integrate the effects of anthropogenic and natural stressors on the organisms over time (Boesch and Rosenberg 1981; Messer *et al.* 1991). This information is precisely what foraminiferal shells in the sediments can provide (Hallock *et al.* 2003).

CONCLUSIONS

Overall, the foraminiferal assemblage at Conch Reef was extremely homogenous taxonomically. In October 2008, 117 foraminiferal species, representing 72 genera, 37 families, and 8 orders were identified in 17 sediment samples and 21 rubble samples collected from a depth range of 13 to 26 m.

Foraminiferal assemblages in the sediment samples were more variable than in the rubble samples. Sixty-two genera in total were found in the sediment samples, while 70 genera in total were found in the rubble samples. Two rare genera occurred only in sediment samples, while 10 genera were found only in the rubble. The sonication of rubble material is important to describe the species living on the rubble. Without sonication, those foraminifera living in the substrate, on the rubble (*e.g.*, algal mats) could have been missed.

Overall, the differences between the foraminiferal assemblages found in the rubble and sediment were primarily the differences in relative abundances of the taxa. Depth and sediment texture were not significant factors influencing, the foraminiferal assemblages over the depth range sampled.

Sediment samples included 12 symbiont-bearing foraminiferal genera representing 41% of the total assemblage, 10 stress-tolerant genera representing 3%, planktic taxa representing 2% of the assemblage, and 40 other smaller foraminiferal genera representing 54% of the total. Ten samples were sufficient to encounter 90% of the genera found. Sediments reflect the taphonomic assemblage in the area.

In the rubble samples, 12 symbiont-bearing foraminiferal genera represented 20% of the total assemblage, 12 stress-tolerant genera represented 6%, planktic foraminifers represented 1%, and 46 other smaller foraminiferal genera represented 73% of the total foraminiferal assemblage. Seven samples were sufficient to encounter 90% of the genera found on reef rubble.

A concentration ratio comparing relative abundances in rubble vs. sediment revealed that smaller taxa were more abundant in the rubble, while shells of larger, symbiont-bearing taxa were about 2.5-5.5 times more concentrated in the sediment, indicating winnowing of smaller taxa. Shells of *Siphonatera*, an agglutinated miliolid, and *Textularia*, an agglutinated textularid, were more abundant in sediments as compared to rubble, indicating their high preservation potential. The concentration ratio provides a loss index that reflects the size and durability of foraminiferal taxa.

Fishers α diversities were slightly lower in assemblages from sediments (11.4 ± 2.3) compared to rubble samples (12.9 ± 1.4). This alpha index measures the diversity within an area or community. In this set of samples, the diversity in the rubble is slightly higher than those in the sediment, due to foraminifers living on the rubble rather than in the sediment. Mean Shannon Diversity [H], Simpson's Diversity Index [D], and Evenness [E] were similar between sample types. In contrast, the FORAM Index was higher in assemblages from sediment samples (5.6 ± 0.8) compared with rubble samples (3.6 ± 0.4). The mean FORAM Index [FI] for the sediment samples (5.6 ± 0.8) indicates that water quality at Conch Reef is suitable for calcifying symbioses. The most abundant symbiont-bearing genera were *Amphistegina, Laevipeneroplis, Asterigerina*, and *Archaias.*

There are inter-site differences in the foraminiferal assemblages on both reef rubble and sediment samples from Conch Reef. The driving difference among the rubble stations was the quantity of stress-tolerant foraminifers and the relative abundance of other-smaller taxa. The rubble samples exhibited $\geq$ 70 % similarity among the stations.

Sediment samples differed among the stations, with the difference being the sites that contained an assemblage that was similar to a rubble sample with greater abundances of stress-tolerant foraminifers and of other-smaller taxa. The other major differences in the sediment samples were in the shells/gram and the presence of symbiont-bearing foraminifers.

One set of replicate rubble samples from the same station clustered together. However another set of rubble samples replicates did not cluster together, demonstrating the intra-site differences could be as great as inter-site.

The foraminiferal assemblages from rubble samples differed from the assemblages in the sediment sample, primarily in relative abundances. The taxonomic differences were in minimal and were mainly in occurrences of rare taxa. Thus, sediment samples appear to adequately represent the local populations for foraminiferal assemblages in a reef ecosystem.

REFERENCES

Aller, R.C., 1982, Carbonate Dissolution in Nearshore Terrigenous Muds: the Role of Physical and Biological Reworking: *Journal of Geology*, v.90, p.79-95.

Alve, E., 1999, Colonization of New Habitats by Benthic Foraminifera: a Review: *Earth Science Reviews*, v.46, p.167-185.

Baker, R.D., Hallock, P., Moses, E.F., Williams, D.E., and Ramirez, A., 2009, Larger Foraminifers of the Florida Reef Tract, USA: Distribution Patterns on Reef-Rubble Habitats: *Journal of Foraminiferal Research*, v.39, p.267-277.

Bernhard, J. M., 2000, Distinguishing Live from Dead Foraminifera: Methods Review and Proper Applications: *Micropaleontology*, v.46, p.37-46.

Blatt, H., Middleton, G. V., and Murray, R. C., 1972, *Origin of sedimentary rocks*: Prentice –Hall, N.J, 782 pp.

Bock, W.D., 1971, A Handbook of Benthic Foraminifera of Florida Bay and Adjacent Waters, In: Jones, J.I., and Bock, W.D., (Eds.), A Symposium of Recent South Florida Foraminifera: *Miami Geological Society Memoir*, v.1, p.1-72.

Boesch, D.F., and Rosenberg, R., 1981, Response to Stress in Marine Benthic Communities, In: Barrett, W.G., and Rosenberg, R., (Eds.), *Stress effects on Natural Ecosystems,* Wiley- Interscience, New York, pp.179-200.

Boltovskoy, E., and Wright, R., 1976, *Recent Foraminifera:* Junk, The Hague, 515pp.

Buzas, M.A., 1968, On the Spatial Distribution of Foraminiferal: *Contributions from the Cushman Foundation for Foraminiferal Research*, v.19, p.1-11.

Buzas, M.A., 1970, Spatial Homogeneity: Statistical Analysis of Unispecies and Multispecies Population of Modern Foraminifera: *Ecology*, v.57, p.874-879.

Buzas, M.A., Hayek, L.C., Reed, S.A., and Jett, J.A., 2002, Foraminiferal Densities over Five Years in the Indian River Lagoon, Florida: A Model of Pulsating Patches: *Journal of Foraminiferal Research*, v.32, p.68-93.

Carnahan, E.A., 2005, Foraminiferal Assemblages as Bioindicators of Potentially Toxic Elements in Biscayne Bay, Florida. Tampa, Florida: University of South Florida, Master's Thesis, 228p.

Carnahan, E.A., Hoare, A.M., Hallock, P., Lidz, B.H., and Reich, C.D., 2008, Distribution of Heavy Metals and Foraminiferal Assemblages in Sediments of Biscayne Bay, Florida, USA: *Journal of Coastal Research*, v.24, p.159-169.

Carnahan, E.A., Hoare, A.M., Hallock, P., Lidz, B.H., and Reich, C.D., 2009, Foraminiferal Assemblages in Biscayne Bay, Florida, USA: Responses to Urban and Agricultural Influence in a Subtropical Estuary: *Marine Pollution Bulletin,* v.59, p.221-233

Crevison, H., Hallock, P., and McRae, G., 2006, Sediment Cores from the Florida Keys Reef Tract (USA): Is Resolution Suffient for Environmental Applications?: *JEMMM*, v.3, p.61-82.

Cimerman, F., and Langer, M., 1991, *Mediterranean Foraminifera*: Slovenska Akaademija Znanosti in Umetnosti, Ljubljana, 118 pp.

Clarke, K.R., and Gorley, R.N., 2006, *PRIMER v6*. *User Manual Tutorial*: PRIMER-E Ltd. UK. Plymouth Marine Laboratory.

Clarke, K. R., and Warwick, R. M., 2001, *Changes in Marine Communities: An Approach to Statistical Analysis and Interpretations*: PRIMER-E Ltd. UK. Plymouth Marine Laboratory. www.PRIMER-e.com.

Cockey, E., Hallock, P., and Lidz, B.H., 1996, Decadal Scale Changes in Benthic Foraminiferal Assemblages off Key Largo, Florida: *Coral Reefs*, v.15, p.237-248.

Crevison, H., Hallock, P., and McRae, G., 2006, Sediment Cores from the Florida Keys Reef Tract (USA): Is Resolution Suffient for Environmental Applications?: *JEMMM*, v.3, p.61-82.

Culver, S.J., and Buzas, M.A., 1982, Distribution of Recent Benthic Foraminifera in the Caribbean Region: *Smithsonian Contributions to the Marine Sciences*, v.14, p.1-382.

Cushman, J.A., 1922, Shallow-Water Foraminifera of the Tortugas Region: *Papers from the Department of Marine Biology of the Carnegie Institution of Washington*, Publication 31, v.17, p.1-85.

Cushman, J. A., 1930, The Foraminiferida of the Atlantic Ocean, Part 7. Nonionidae, Camerinidae, Peneroplidae, and Alveolinellidae: *U.S. National Museum Bulletin*, v.104, 79pp.

Done, T.J., 1992, Phase Shifts in Coral Reef Communities and Their Ecological Significance: *Hydrobiologia*, v.247, p.121-132.

Engle, V. D., 2000, Application of the Indicator Evaluation Guidelines to an Index of Benthic Condition for Gulf of Mexico Estuaries, In: Jackson, L. E., Kurtz, J. C., and Fisher, W. S., (Eds.): *Evaluation Guidelines for Ecological Indicators*. EPA/620/R-99/005: U.S. Environmental Protection Agency, Research Triangle Park NC, p.3-1 to 3-29.

Fujita, K., and Hallock, P., 1999, A Comparison of Phytal Substrate Preferences of *Archaias angulatus* and *Sorites orbiculus* in Mixed Macroalgal-Seagrass Beds in Florida Bay: *Journal of Foraminiferal Research*, v.29, p.143-151.

Galloway, J. J., and Hemingway, C.H., 1971, *The Tertiary Foraminifera of Porto Rico*: Antiquariaat Junk, The Hague, 491pp.

Goldstein, S.T., 1999, Foraminifera: A Biological Review, In: Sen Gupta, B.K., (Ed.), *Modern Foraminifera*: Kluwer Academic Publishers, Boston, pp.37-55.

Goldstein, S.T., and Corliss, B.H., 1994, Deposit Feeding in the Selected Deep- Sea and Shallow-Water Benthic Foraminifera: *Deep Sea Research*, v.41, p.229-241.

Greenstein, B.J., and Pandolfi, J.M., 2003, Taphonomic Alteration of Reef Corals: Effects of Reef Environment and Coral Growth from II: The Florida Keys: *Palaios,* v.18, p.495-509.

Hallock, P., 1988, The Role of Nutrient Availability in Bioerosion: Consequences to Carbonate Buildups: *Palaeogeography, Paleoclimatology, Paleoecology,* v.63, p.275-291.

Hallock, P., 1999, Chapter 8: Symbiont-bearing Foraminifera, In: Sen Gupta, B.K., (Ed.), *Modern Foraminifera,* Kluwer Academic Publisher, Dordrecht, pp.123-139.

Hallock, P., 2000a, Symbiont-bearing Foraminifera: Harbingers of Global Change? : *Micropaleontology*, v.46, p.95-104.

Hallock, P., 2000b, Larger Foraminifera as Indicators of Coral-Reef Vitality, In: Martin R. E., (Ed), *Environmental Micropaleontology*, Kluwer Academic/Plenum Publishers, New York, pp.121-150.

Hallock, P., and Glenn, E.C., 1986, Larger Foraminifera: A Tool for Paleoenvironmental Analysis of Cenozoic Carbonate Depositional Facies: *Palaios*, v.1, p.55-64.

Hallock, P., and Peebles, M.W., 1993, Foraminifera with Chlorophyte Endosymbionts: Habitats of Six Species in the Florida Keys: *Marine Micropaleontology*, v.20, p.277-292.

Hallock, P., and Talge, H.K., 1993, Symbiont Loss ("Bleaching") in the Reef Dwelling Benthic Foraminifer *Amphistegina gibbosa* in the Florida Keys in 1991-92: *Proceedings of the Colloquium on Global Aspects of Coral Reefs: Health, Hazards, and History*, Miami, Florida, June 10-11, p.94-100.

Hallock, P., and Talge, H.K., 1994, A Predatory Foraminifer, *Floresina amphiphaga*, n. sp., from the Florida Keys: *Journal of Foraminiferal Research*, v.24, p.210-213.

Hallock, P., Cottey, T.L., Forward, L.B., and Halas, J., 1986, Population Biology and Sediment Production of *Archaias angulatus* (Foraminiferida) in Largo Sound, Florida: *Journal of Foraminiferal Research*, v.16 p.1-8.

Hallock, P., Lidz, B.H., Cockey-Burkhard, E.M., and Donnelly, K.B., 2003, Foraminifera as Bioindicators in Coral Reef Assessment and Monitoring: The FORAM Index: *Environmental Monitoring and Assessment*, v.81, p.221-238.

Hallock, P., Talge, H.K., Cockey, E.M., and Muller, R.G., 1995, A New Disease in Reef-Dwelling Foraminifera; Implications for Coastal Sedimentation: *Journal of Foraminiferal Research*, v.25, p.280-286.

Hallock, P., Williams, D.E., Fisher, E.M., and Toler, S.K., 2006a, Bleaching in Foraminifera with Algal Symbionts: Implications for Reef Monitoring and Risk Assessment: *Anuario de Instituto de Geociencias- UFRJ*, v.29, p.108-128.

Hallock, P., Williams, D.E., Toler, S.K., Fisher, E.M., and Talge, H.K., 2006b, Bleaching in Reef-Dwelling Foraminifers: Implications for Reef Decline: *Proceedings of the 10th International Coral Reef Symposium*, Okinawa, Japan, June 2004, p.729-737.

Hayek, L. C., and Buzas, M. A., 1997, *Surveying Natural Populations*: Columbia University Press, New York, 563pp.

Hayek, L. C., and Buzas, M. A., 2010, *Surveying Natural Populations: Quantitative Tools for Assessing Biodiversity*: Columbia University Press, New York, 616pp.

Hohenegger, J., Yordanova, E., Nakano, Y., and Tatazreiter, F., 1999, Habitats of Larger Foraminifera on the Upper Reef Slope of Sesoko Island, Okinawa Japan: *Marine Micropaleontology*, v.36, p.109-168.

Hottinger, L., Halicz, E., and Reiss, Z., 1993, *Recent Foraminifera from the Gulf of Aqaba, Red Sea*: Slovenska Akaademija Znanosti in Umetnosti, Ljubljana, Slovakia, 230pp.

Jones, R. W., 1994, *The Challenger Foraminifera*: Oxford University Press, London, England, 300pp.

Langer, M.R., 1993, Epiphytic Foraminifera: *Marine Micropaleontology*, v.20, p.235-265.

Lee, J.J., and Anderson, O.R., 1991, Symbiosis in Foraminifera, In: J.J. Lee and O.R. Anderson (Eds), *Biology of Foraminifera*, Academic Press, London, pp.157-220.

Lee, J.J., Muller, W.A., Stone, R.J., McEnery, M. W., and Zucker, W., 1969, Standing Crop of Foraminifera in Sublittoral Epiphytic Communities of a Long Island Salt Marsh: *Marine Biology*, v.4, p.44-61.

Lidz, B.H., and Hallock, P., 2000, Sedimentary Petrology of a Declining Reef Ecosystem, Florida Reef Tract (U.S.A): *Journal of Coastal Research*, v.16, p.675-697.

Lidz, B. H., and Rose, P. R., 1989, Diagnostic Foraminiferal Assemblages of Florida Bay and Adjacent Shallow Waters: A Comparison: *Bulletin of Marine Science*, v.44, p.399-418.

Loeblich, A.R. Jr., and Tappan, H., 1987, *Foraminiferal Genera and their Classification*: Van Nostrand Reinhold, New York, 970pp.

Loubere, P., Gary, A., and Lagoe, M., 1993, Generation of the Benthic Foraminiferal Assemblage: Theory and Preliminary Data: *Marine Micropaleontology*, v.20, p.165-181.

Lynts, G.W., 1966, Variation of Foraminiferal Standing Crop over Short Distances in Buttonwood Sound, Florida Bay: *Limnology and Oceanography*, v.11, p.562-566.

Martin, R.E., 1986, Habitat and Distribution of the Foraminifer *Archaias Angulatus* (Fitchel and Moll) (Miliolida, Soritidae) Northern Florida Keys: *Journal of Foraminiferal Research,* v.16, p.201-206.

Martin, R.E., and Wright, R.C., 1988, Information Loss in the Transition from Life to Death Assemblages of Foraminifera in Back Reef Environments, Key Largo, Florida: *Journal of Paleontology*, v.62, p.399-410.

Martinez-Colon, M., Hallock, P., and Green-Ruiz, C., 2009, Strategies for Using Shallow-Water Benthic Foraminifers as Bioindicators of Potentially Toxic Elements: A Review: *Journal of Foraminiferal Research,* v.39, p.278-299.

McManus, J.W., and Polsenberg, J.F., 2004, Coral-Algal Phase Shifts on Coral Reefs: Ecological and Environmental Aspects: *Progress in Oceanography*, v.60, p.263-279.

Messer, J.J., Linthurst, R.A., and Overton, W.S., 1991, An EPA Program for Monitoring Ecological Status and Trends: *Environmental Monitoring and Assessment*, v.17, p.67-78.

Miller, D.S., and Ellison, R.L., 1982, The Relationship of Foraminifera and Submarine Topography on New Jersey-Delaware Continental Shelf: *Bulletin of the Geological Society of America,* v.93, p.239-245.

Murray, J. W., 1983, Population Dynamics of Benthic Foraminifera: Results from the Exe Estuary, England: *Journal of Foraminiferal Research,* v.13, p.1–12.

Murray, J.W., 2001, The Niche of Benthic Foraminifera, Critical Thresholds, and Proxies: *Marine Micropaleontology*, v.41, p.1-7.

Murray, J., 2006, *Ecology and Applications of Benthic Foraminifera*: Cambridge University Press, New York, 440pp.

Murray, J.W., and Alve, E., 1999a, Taphonomic Experiments on Marginal Marine Foraminiferal Assemblages: How Much ecological Information is Preserved?:*Paleogeography, Paleoclimatology, Paleoecology*, v.149, p.183-197.

Murray, J.W., and Alve, E., 1999b, Natural Dissolution of Modern Shallow Water Benthic Foraminifera: Taphonomic Effect on the Paleoecological record: *Paleogeography, Paleoclimatology, Paleoecology*, v.146, p.195-209.

Murray, J.W., and Alve, E., 2000, Major Aspects of Foraminiferal Variability (Standing Crop and Biomass) on A Monthly Scale in an Intertidal Zone: *Journal of Foraminiferal Research*, v.30, p.177-191.

Murray, J.W., and Pudsey, C.J., 2004, Living (Stained) and Dead Foraminifera from the Newly Ice-Free Larsen Ice Shelf, Weddel Sea Antarctica: Ecology and Taphonomy: *Marine Micropaleontology*, v.53, p.67-81.

Murray, J.W., Sturrock, S., and Weston, J., 1982, Suspended Load Transport of Foraminiferal Tests in a Tide and Wave Swept Sea: *Journal of Foraminiferal Research*, v.12, p.51-65.

Orbingy, A. d'. 1839, *Foraminifères*, In: Ramon de la Sagra, Histoire physique, politique et anturelle de l'Ile de Cuba. Paris: Arthus Bertrand, 124pp.

Palandro, D.A., Andrefouet, S., Chuanmin, H., Hallock, P., Muller-Karger, F.E., Dustan, P., Callahan, M.K., Kranenburg, C., and Beaver, C.R., 2008, Quantification of Two Decades of Shallow- Water Coral Reef Habitat Decline in the Florida Keys National Marine Sanctuary using Landsat Data (1984-2002): *Remote Sensing of Environment*, v.112, p. 3388-3399.

Parker, W.C., and Arnold, A.J., 2002, Quantitative Methods in Data Analysis in Foraminiferal Ecology, In: Sen Gupta, B(Ed), *Modern Foraminifera,* Kluwer Academic Publisher, Dordrecht, pp.71-89.

Patterson, R.T., Guilbault, J.P., and Claugue, J.J., 1999, Taphonomy of Tidal Marsh Foraminifera: Implications of Surface Sample Thickness for High Resolution Sea-Level studies: *Palaeogeography, Palaeoclimatology, Palaeoecology*, v.149, p.199-211.

Peebles, M. W., Hallock, P., and Hine, A.C., 1997, Benthic Foraminiferal Assemblages from Current- Swept Carbonate Platforms of the Northern Nicaraguan Rise, Caribbean Sea: *Journal of Foraminiferal Research,* v.27, p.42-50.

Phleger, F. B., and Parker, F. L., 1951, Ecology of Foraminifera, Northwest Gulf of Mexico: Part I. Foraminifera Distribution; Part II, Foraminiferal Species: *Geological Society of America Memoir*, 166pp.

Poag, W.C., 1981, *Ecologic Atlas of Benthic Foraminifera of the Gulf of Mexico*: Van Nostrand Reinhold, Woods Hole, Mass., 174pp.

Ramirez, A., 2008, Patch Reef Health in Biscayne National Park: A Comparison of Three Foraminiferal Indices: MS Thesis (unpublished), University of South Florida. Tampa, FL.

Richardson, S.L., 2006, Endosymbiont-Bleaching in Epiphytic Populations of *Sorites dominicensis*: *Symbiosis*, v.42, p.103-117.

Rose, P.R., and Lidz, B.H., 1977, Diagnostic Foraminiferal Assemblages of Shallow-Water Modern Environments: South Florida and the Bahamas: *Sedimentia*, v.1, p.1-56.

Scott, D.B., and Medioli, F.S., 1980, Total Foraminiferal Populations: Their Relative Usefulness in Paleoecology: *Journal of Paleontology*, v.54, p.814-831.

Schafer, C. T., 2000, Monitoring Nearshore Marine Environments Using Benthic Foraminifera: Some Protocols and Pitfalls: *Micropaleontology*, v.46, p.161-169.

Sen Gupta, B., (Ed.), 1999, *Modern Foraminifera*: Kluwer Academic Publisher, Dordrecht, 371pp.

Severin, K.P., 1983, Test Morphology of Benthic Foraminifera as a Discriminator of Biofaces: *Marine Micropaleontology*, v.8 p.65-76.

Shifflett, E., 1961, Living Dead and Total Foraminiferal Faunas, Heald Bank, Gulf of Mexico: *Micropaleontology*, v.7, p.45-54.

Triffleman, N.J., Hallock, P., Hine, A.C., and Peebles, M., 1991, Distribution of Foraminiferal Tests in Sediments of Serranilla Bank Site, Nicaraguan Rise, Southwestern Caribbean: *Journal of Foraminiferal Research*, v.21, p.39-47.

Walker, S.E., and Goldstein, S.T., 1999, Taphonomic Tiering: Experimental Field Taphonomy of Mollusks and Foraminifera Above and Below the Sediment-Water Interface: *Palaeogeography, Palaeoclimatology, Palaeoecology*, v.149, p.227-244.

Wentworth, C. K., 1922, A Scale of Grade and Class Terms for Clastic Sediments: *Journal of Geology*, v.30, p.377-392.

Wetmore, K.L., 1987, Correlations between Test Strength, Morphology, and Habitat in Some Benthic Foraminifera from the Coast of Washington: *Journal of Foraminiferal Research*, v.17, p.1-13.

Wooldridge, S.A., 2009, A New Conceptual Model for the Warm-Water Breakdown of the Coral-Algae Endosymbiosis: *Marine and Freshwater Research*, v.60, p.483-496.

Wright, R.C., and Hay, W.W., 1971, The Abundance and Distribution of Foraminifers in a Back-Reef Environment, Molasses Reef, Florida, In: Jones, J.I., and Bock, W.D., (Eds.), A Symposium of Recent South Florida Foraminifera: *Miami Geological Society Memoir*, v. 1, p.121-174.

Zeiss, C., 2002, *AxioVison v4.4*, Digital Imagine Processing Software, Carl Zeiss Microimaging, Germany.

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www.floridakeys.noaa.gov.com

APPENDICES

Appendix A. Raw data from sediment samples

Table A1. Foraminiferal abundances (#/gm) in sediment samples collected in October 2008 at Conch Reef, Florida

Conch Reef 101808 Sediment Abundance (#/gm)																	
Sample Number	**2**	**3**	**5**	**5b**	**6**	**6b**	**7**	**10**	**11**	**12**	**13**	**15**	**15b**	**16**	**16b**	**17**	**18**
Symbiont-bearing																	
Amphistegina	21.9	35.8	7.0	4.0	12.0	5.0	15.2	22.6	25.5	8.5	7.4	23.3	24.6	35.4	18.9	36.5	31.6
Androsina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	7.0
Archaias	20.9	33.4	5.0	3.0	5.0	3.0	7.6	18.8	16.2	21.3	5.2	3.6	12.3	3.1	17.2	0.0	24.6
Asterigerina	10.0	33.4	5.0	5.9	0.0	4.0	19.8	32.0	41.8	42.7	2.9	41.3	26.7	18.5	34.4	16.4	56.2
Borelis	4.0	9.5	1.0	0.0	2.0	4.0	7.6	7.5	7.0	12.8	1.0	7.2	2.1	4.6	10.3	11.0	31.6
Cyclorbiculina	11.0	2.4	2.0	4.9	5.0	3.0	7.6	15.1	11.6	4.3	4.2	10.8	2.1	6.2	8.6	9.1	7.0
Heterostegina	0.0	2.4	0.0	1.0	0.0	5.0	1.5	3.8	0.0	8.5	0.6	0.0	2.1	1.5	3.4	5.5	0.0
Laevipeneroplis	23.9	54.9	6.0	4.9	5.0	11.0	35.0	22.6	65.0	68.2	5.8	19.7	39.0	26.2	37.8	31.0	66.8
Monalysidium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0
Parasorites	0.0	19.1	0.0	1.0	1.0	0.0	4.6	1.9	7.0	8.5	0.0	10.8	12.3	1.5	5.2	7.3	10.5
Peneroplis	0.0	4.8	0.0	0.0	1.0	0.0	6.1	1.9	7.0	12.8	0.3	1.8	4.1	0.0	3.4	3.7	10.5
Sorites	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	4.3	0.0	0.0	2.1	0.0	0.0	1.8	0.0
Stress-tolerant																	
Abditodentrix	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ammonia	2.0	2.4	0.0	0.0	0.0	1.0	1.5	0.0	2.3	4.3	0.0	7.2	4.1	1.5	1.7	3.7	0.0
Bolivina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	1.8	0.0	1.5	1.7	3.7	0.0
Bolivinellina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brizalina	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cribroelphidium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0
Elphidium	3.0	9.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5	1.9	9.0	2.1	1.5	1.7	0.0	7.0
Haynesina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nonionella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	3.5
Nonionoides	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	4.3	0.0	1.8	4.1	1.5	6.9	0.0	0.0
Rectobolivina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0
Reophax	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0
Trochammina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix A (Continued)

Table A1. Continued

Conch Reef 101808 Sediment Abundance (#/gm)																	
Sample Number	**2**	**3**	**5**	**5b**	**6**	**6b**	**7**	**10**	**11**	**12**	**13**	**15**	**15b**	**16**	**16b**	**17**	**18**
Planktics	2.0	4.8	0.0	0.0	1.0	2.0	4.6	3.8	4.6	34.1	0.0	7.2	10.3	6.2	8.6	7.3	0.0
Other smaller taxa																	
Fursenkoina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0
Spirillina	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	3.5
Trifarina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	3.5
Other Agglutinates																	
Bigenerina	6.0	2.4	0.0	0.0	1.0	2.0	3.0	1.9	2.3	4.3	0.6	5.4	0.0	4.6	3.4	0.0	3.5
Clavulina	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	2.3	0.0	0.6	0.0	2.1	3.1	0.0	0.0	0.0
Textularia	9.0	11.9	0.0	0.0	4.0	2.0	44.2	7.5	18.6	68.2	3.9	28.7	18.5	18.5	17.2	11.0	14.1
Other Miliolida																	
Adelosina	0.0	0.0	0.0	0.0	0.0	2.0	0.0	1.9	7.0	8.5	0.0	0.0	4.1	0.0	1.7	0.0	3.5
Affinetrina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0	3.6	0.0	0.0	0.0	0.0	3.5
Articulina	3.0	14.3	2.0	1.0	3.0	2.0	6.1	1.9	13.9	21.3	1.3	10.8	16.4	3.1	6.9	5.5	10.5
Cornuspiroides	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cycloforina	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	0.0	1.5	1.7	1.8	3.5
Hauerina	0.0	2.4	0.0	0.0	0.0	0.0	1.5	0.0	7.0	12.8	0.0	1.8	8.2	0.0	1.7	1.8	0.0
Lachlanella	0.0	4.8	0.0	0.0	1.0	0.0	0.0	3.8	0.0	12.8	0.6	7.2	0.0	0.0	1.7	1.8	0.0
Miliolinella	0.0	16.7	0.0	0.0	0.0	3.0	1.5	17.0	9.3	17.1	0.0	5.4	16.4	1.5	8.6	5.5	14.1
Pseudohauerina	1.0	7.2	0.0	1.0	0.0	1.0	0.0	0.0	0.0	12.8	0.0	1.8	6.2	1.5	5.2	1.8	3.5
Pseudoschlumbergerina	0.0	21.5	0.0	0.0	1.0	4.0	1.5	9.4	11.6	17.1	0.0	7.2	6.2	0.0	1.7	18.3	21.1
Pseudotriloculina	2.0	4.8	0.0	0.0	0.0	0.0	0.0	5.7	16.2	21.3	0.6	1.8	6.2	0.0	1.7	7.3	28.1
Pyrgo	0.0	0.0	0.0	0.0	1.0	0.0	1.5	0.0	4.6	12.8	0.3	3.6	8.2	9.2	5.2	0.0	3.5
Quinqueloculina	11.0	40.6	2.0	1.0	2.0	10.0	27.4	54.6	30.2	68.2	2.6	25.1	39.0	18.5	20.6	11.0	70.3
Schlumbergerina	4.0	0.0	0.0	2.0	0.0	3.0	0.0	1.9	2.3	17.1	0.0	0.0	6.2	4.6	3.4	1.8	0.0
Siphonaptera	5.0	4.8	3.0	2.0	0.0	2.0	4.6	3.8	25.5	0.0	2.6	5.4	4.1	9.2	13.7	11.0	0.0
Spiroloculina	0.0	0.0	0.0	0.0	1.0	0.0	3.0	0.0	0.0	0.0	0.0	3.6	4.1	1.5	1.7	1.8	0.0
Triloculina	1.0	0.0	1.0	0.0	1.0	2.0	3.0	0.0	7.0	8.5	1.0	5.4	20.5	4.6	12.0	11.0	7.0
Triloculinella	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wiesnerella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0

Appendix A (Continued)

Table A1. Continued

Conch Reef 101808 Sediment Abundance (#/gm)

Sample Number	**2**	**3**	**5**	**5b**	**6**	**6b**	**7**	**10**	**11**	**12**	**13**	**15**	**15b**	**16**	**16b**	**17**	**18**
Other Rotaliida																	
Cancris	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5
Cibicides	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	1.5	0.0	3.7	0.0
Cibicoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0
Cymballoporetta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	6.9	0.0	3.5
Discogypsina	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0
Discorbinella	0.0	2.4	0.0	0.0	0.0	3.0	0.0	1.9	2.3	8.5	0.0	0.0	4.1	1.5	3.4	0.0	3.5
Discorbis	1.0	4.8	1.0	3.0	6.0	13.9	3.0	11.3	18.6	17.1	1.6	3.6	6.2	9.2	8.6	7.3	24.6
Eponides	3.0	4.8	0.0	3.0	1.0	0.0	1.5	1.9	7.0	4.3	1.6	0.0	8.2	1.5	6.9	3.7	0.0
Gavelinopsis	1.0	14.3	1.0	0.0	0.0	4.0	1.5	0.0	16.2	21.3	0.0	7.2	4.1	1.5	0.0	5.5	24.6
Lobatula	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5
Neoconorbina	1.0	2.4	0.0	0.0	0.0	1.0	4.6	5.7	4.6	4.3	0.0	0.0	6.2	6.2	1.7	0.0	7.0
Neoeponides	1.0	4.8	0.0	0.0	0.0	2.0	1.5	3.8	7.0	12.8	0.0	3.6	14.4	4.6	6.9	1.8	14.1
Planorbulina	0.0	4.8	1.0	0.0	3.0	2.0	0.0	0.0	4.6	34.1	0.3	7.2	10.3	6.2	3.4	14.6	3.5
Rosalina	3.0	11.9	0.0	3.0	27.9	10.0	7.6	13.2	7.0	21.3	0.3	9.0	20.5	9.2	8.6	3.7	21.1
Siphonina	1.0	2.4	0.0	0.0	0.0	0.0	3.0	1.9	7.0	8.5	2.9	0.0	4.1	3.1	1.7	1.8	0.0

Appendix A (Continued)

Table A2. Summary of sediment foraminiferal data of samples collected in October 2008 at Conch Reef, Florida from the table above.																	
Conch Reef 101808 Sediment Abundance (#/gm)																	
Sample Number	**2**	**3**	**5**	**5b**	**6**	**6b**	**7**	**10**	**11**	**12**	**13**	**15**	**15b**	**16**	**16b**	**17**	**18**
Total Foraminifers	157	168	38	42	85	111	155	154	183	160	156	167	196	154	191	150	158
Total Genera	30	35	14	16	21	31	35	35	36	45	24	38	46	40	50	39	36
Corrected mass picked	1.003	0.419	1.004	1.013	1.004	1.005	0.656	0.531	0.431	0.234	3.087	0.557	0.488	0.649	0.582	0.548	0.285
Foraminifers/Gram Sediment	157	401	38	41	85	110	236	286	425	678	51	301	402	239	326	274	555
Symbiont-bearing	94	82	26	25	31	35	69	68	79	45	85	66	63	63	82	67	70
Stress-tolerant	5	5	1	0	0	2	3	3	2	4	6	11	5	4	11	5	3
Other	58	81	11	17	54	74	83	83	102	111	65	90	128	87	98	78	85
FORAM Index	6.8	5.9	7.4	6.8	4.9	4.5	5.5	5.5	5.4	4.2	6.3	5.1	4.5	5.2	5.4	5.5	5.5

Appendix B. Raw SIMPER results from sediment samples

Table B1. SIMPER similarity results on sediment samples by Cluster 1

SIMPER--- Sediment Samples by Clusters					
Cluster 1	**Average Similarity: 69.54**			**# genera = 90% is 29**	
Genera	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Laevipeneroplis	6.37	5.43	6.93	7.81	7.81
Asterigerina	5.65	4.92	7.2	7.07	14.88
Quinqueloculina	5.87	4.79	4.86	6.89	21.78
Amphistegina	4.94	4.39	3.88	6.32	28.09
Textularia	4.6	3.68	4.49	5.29	33.38
Rosalina	3.37	2.8	5.11	4.02	37.41
Borelis	3.02	2.45	3.85	3.53	40.93
Discorbis	3.07	2.4	4.38	3.45	44.38
Archaias	3.44	2.35	1.71	3.37	47.75
Articulina	3.02	2.35	3.85	3.37	51.13
Miliolinella	3.02	2.27	2.79	3.27	54.4
Cyclorbiculina	2.68	2.25	2.81	3.23	57.63
Parasorites	2.7	2.09	3.51	3	60.63
Pseudoschlumbergerina	2.89	1.89	1.53	2.72	63.35
Planktics	2.57	1.88	2	2.71	66.06
Neoeponides	2.47	1.86	4.34	2.68	68.74
Siphonaptera	2.34	1.58	1.29	2.27	71.01
Triloculina	2.34	1.49	1.31	2.14	73.16
Peneroplis	2.06	1.43	1.87	2.06	75.22
Planorbulina	2.37	1.37	1.27	1.96	77.18
Gavelinopsis	2.45	1.32	1.16	1.89	79.07
Pseudotriloculina	2.4	1.26	1.18	1.81	80.89
Neoconorbina	1.75	1.19	1.24	1.72	82.6
Bigenerina	1.5	1.06	1.31	1.53	84.13
Eponides	1.65	1.05	1.28	1.51	85.65
Siphonina	1.52	0.99	1.31	1.43	87.08
Ammonia	1.41	0.93	1.32	1.34	88.42
Pyrgo	1.72	0.91	0.96	1.31	89.73
Pseudohauerina	1.53	0.76	0.96	1.1	90.83

Appendix B (Continued)

Table B2. SIMPER similarity results on sediment samples by Cluster 2

SIMPER--- Sediment Samples by Clusters					
Cluster 2	**Average Similarity: 62.83**			**# genera = 90% is 19**	
Genera	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Laevipeneroplis	4.1	6	6.44	9.55	9.55
Quinqueloculina	3.23	5.72	4.36	9.11	18.66
Amphistegina	3.46	4.05	2.08	6.44	25.1
Asterigerina	2.58	3.62	1.34	5.76	30.86
Borelis	2	3.62	1.27	5.76	36.62
Rosalina	2.44	3.14	1.23	4.99	41.62
Archaias	3.15	3.13	1.2	4.99	46.6
Cyclorbiculina	2.52	3.13	1.19	4.99	51.59
Schlumbergerina	1.86	3.13	1.1	4.99	56.58
Planktics	1.41	2.56	1.08	4.07	60.66
Bigenerina	1.93	2.56	1.07	4.07	64.73
Textularia	2.2	2.56	0.95	4.07	68.8
Articulina	1.57	2.56	0.92	4.07	72.88
Siphonaptera	1.82	2.56	0.89	4.07	76.95
Triloculina	1.2	1.81	0.83	2.88	79.83
Discorbis	2.37	1.81	0.81	2.88	82.71
Gavelinopsis	1.5	1.81	0.81	2.88	85.6
Neoeponides	1.2	1.81	0.8	2.88	88.48
Ammonia	1.2	1.81	0.78	2.88	91.36

Appendix B (Continued)

Table B3. SIMPER similarity results on sediment samples by Cluster 3					
SIMPER--- Sediment Samples by Clusters					
Cluster 3	**Average Similarity:60.50**			**# genera = 90% is 13**	
Genera	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Amphistegina	2.7	8.25	6.45	13.64	13.64
Laevipeneroplis	2.33	8.07	7.11	13.33	26.97
Archaias	2.12	7.02	6.71	11.6	38.57
Cyclorbiculina	1.98	6.18	6.17	10.22	48.79
Discorbis	1.61	4.26	5.32	7.04	55.83
Quinqueloculina	1.36	4.26	5.46	7.04	62.87
Articulina	1.32	3.95	6.09	6.53	69.41
Asterigerina	1.59	3.71	0.87	6.13	75.54
Siphonaptera	1.19	2.87	0.91	4.74	80.28
Eponides	1	1.8	0.88	2.97	83.25
Borelis	0.85	1.68	0.9	2.78	86.04
Triloculina	0.75	1.68	0.9	2.78	88.82
Rosalina	1.89	1.57	0.71	2.59	91.41

Appendix B (Continued)

Table B4. SIMPER dissimilarity results on sediment samples comparing Clusters 1 & 2						
SIMPER--- Sediment Samples by Clusters						
Clusters 1 & 2	**Average Dissimilarity: 41.76**			**# genera = 90% is 40**		
Genera	**Cluster 1 Av.Abund**	**Cluster 2 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Asterigerina	5.65	2.58	1.93	2.82	4.63	4.63
Parasorites	2.7	0	1.7	3.25	4.08	8.71
Quinqueloculina	5.87	3.23	1.62	1.81	3.89	12.6
Textularia	4.6	2.2	1.54	1.43	3.68	16.28
Laevipeneroplis	6.37	4.1	1.43	1.68	3.42	19.7
Miliolinella	3.02	0.86	1.39	1.92	3.32	23.03
Pseudoschlumbergerina	2.89	1	1.38	1.66	3.29	26.32
Peneroplis	2.06	0	1.28	2.4	3.05	29.38
Pseudotriloculina	2.4	0.71	1.19	1.4	2.85	32.23
Planorbulina	2.37	0.71	1.18	1.5	2.82	35.05
Amphistegina	4.94	3.46	1.15	1.33	2.74	37.8
Archaias	3.44	3.15	1.12	1.28	2.68	40.48
Pyrgo	1.72	0	1.06	1.42	2.54	43.01
Gavelinopsis	2.45	1.5	0.99	1.6	2.37	45.39
Discorbis	3.07	2.37	0.99	1.78	2.37	47.75
Triloculina	2.34	1.2	0.98	2.23	2.35	50.1
Articulina	3.02	1.57	0.9	1.78	2.16	52.26
Hauerina	1.44	0	0.87	1.37	2.09	54.36
Planktics	2.57	1.41	0.85	1.77	2.04	56.4
Elphidium	1.42	0.86	0.81	1.3	1.95	58.35
Eponides	1.65	0.86	0.78	1.4	1.86	60.21
Siphonaptera	2.34	1.82	0.77	1.32	1.84	62.05
Neoeponides	2.47	1.2	0.77	1.67	1.83	63.88
Siphonina	1.52	0.5	0.76	1.59	1.81	65.69
Heterostegina	1.32	1.12	0.76	1.4	1.81	67.5
Lachlanella	1.19	0	0.74	0.99	1.76	69.26
Neoconorbina	1.75	1	0.72	2.66	1.72	70.98
Rosalina	3.37	2.44	0.71	1.49	1.71	72.69
Schlumbergerina	1.35	1.86	0.69	1.37	1.66	74.35
Borelis	3.02	2	0.69	1.41	1.65	76
Pseudohauerina	1.53	1	0.66	1.92	1.57	77.57
Adelosina	1.1	0.71	0.65	1.24	1.55	79.12
Discorbinella	1.31	0.86	0.64	1.23	1.53	80.65
Nonionoides	0.96	0	0.6	1.01	1.43	82.09
Cibicides	0.47	1	0.59	3.86	1.41	83.5
Spiroloculina	0.87	0	0.59	1.03	1.41	84.91
Cyclorbiculina	2.68	2.52	0.58	1.39	1.39	86.3
Cycloforina	0.88	0	0.57	1.01	1.36	87.66
Bigenerina	1.5	1.93	0.5	1.17	1.19	88.85
Sorites	0.58	0.71	0.49	1.04	1.17	90.02

Appendix B (Continued)

Table B5. SIMPER dissimilarity results on sediment samples comparing Clusters 2 & 3						
SIMPER--- Sediment Samples by Clusters						
Clusters 2 & 3	**Average Dissimilarity:46.56**			**# genera = 90% is 32**		
Genera	**Cluster 2 Av.Abund**	**Cluster 3 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Rosalina	2.44	1.89	2.36	1.72	5.08	5.08
Quinqueloculina	3.23	1.36	2.26	5.78	4.86	9.94
Laevipeneroplis	4.1	2.33	2.1	2.2	4.5	14.44
Textularia	2.2	0.99	1.83	1.48	3.94	18.38
Schlumbergerina	1.86	0.35	1.8	2.3	3.86	22.24
Bigenerina	1.93	0.45	1.79	1.94	3.85	26.09
Discorbis	2.37	1.61	1.68	1.28	3.61	29.7
Archaias	3.15	2.12	1.67	1.26	3.59	33.29
Amphistegina	3.46	2.7	1.52	1.44	3.27	36.56
Gavelinopsis	1.5	0.25	1.5	1.72	3.22	39.78
Neoeponides	1.2	0	1.46	4.29	3.14	42.91
Ammonia	1.2	0	1.44	6.13	3.1	46.01
Planktics	1.41	0.25	1.43	2.34	3.06	49.07
Borelis	2	0.85	1.41	1.92	3.02	52.09
Heterostegina	1.12	0.45	1.37	1.26	2.95	55.04
Asterigerina	2.58	1.59	1.31	1.24	2.82	57.86
Pseudoschlumbergerina	1	0.25	1.24	1.03	2.66	60.51
Neoconorbina	1	0	1.2	12.07	2.58	63.1
Miliolinella	0.86	0	1.08	0.93	2.32	65.41
Discorbinella	0.86	0	1.08	0.93	2.32	67.73
Eponides	0.86	1	1.05	1.18	2.25	69.97
Cyclorbiculina	2.52	1.98	1.04	1.53	2.22	72.2
Elphidium	0.86	0.6	1.03	1.24	2.21	74.41
Planorbulina	0.71	0.82	0.94	1.39	2.01	76.42
Pseudohauerina	1	0.25	0.89	1.61	1.91	78.33
Cibicides	1	0.25	0.89	1.61	1.91	80.24
Adelosina	0.71	0	0.88	0.93	1.89	82.14
Siphonaptera	1.82	1.19	0.87	1.12	1.87	84.01
Pseudotriloculina	0.71	0.2	0.83	1.07	1.78	85.78
Sorites	0.71	0	0.82	0.93	1.76	87.54
Siphonina	0.5	0.43	0.79	1.06	1.71	89.25
Brizalina	0.5	0	0.62	0.93	1.34	90.59

Appendix B (Continued)

Table B6. SIMPER dissimilarity results on sediment samples by Clusters 1 & 3						
SIMPER--- Sediment Samples by Clusters						
Sediment - Clusters 1 & 3	**Average Dissimilarity: 60.96**			**# genera = 90% is 37**		
Genera	**Cluster 1 Av.Abund**	**Cluster 3 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Quinqueloculina	5.87	1.36	3.43	3.27	5.63	5.63
Asterigerina	5.65	1.59	3.07	3.54	5.03	10.66
Laevipeneroplis	6.37	2.33	3.05	4.05	5	15.66
Textularia	4.6	0.99	2.82	1.88	4.62	20.28
Miliolinella	3.02	0	2.28	3.13	3.73	24.01
Pseudoschlumbergerina	2.89	0.25	2.03	1.86	3.32	27.34
Rosalina	3.37	1.89	1.88	2.31	3.08	30.42
Neoeponides	2.47	0	1.84	4.19	3.02	33.44
Amphistegina	4.94	2.7	1.81	2.03	2.97	36.41
Planktics	2.57	0.25	1.8	2.24	2.96	39.38
Parasorites	2.7	0.5	1.67	2.19	2.75	42.12
Borelis	3.02	0.85	1.67	2.1	2.74	44.86
Gavelinopsis	2.45	0.25	1.66	1.59	2.72	47.58
Pseudotriloculina	2.4	0.2	1.63	1.56	2.68	50.26
Triloculina	2.34	0.75	1.41	1.98	2.31	52.58
Planorbulina	2.37	0.82	1.38	1.54	2.26	54.84
Archaias	3.44	2.12	1.36	1.77	2.24	57.08
Neoconorbina	1.75	0	1.35	1.77	2.21	59.29
Peneroplis	2.06	0.39	1.31	2.05	2.15	61.43
Articulina	3.02	1.32	1.27	2.02	2.08	63.51
Siphonaptera	2.34	1.19	1.22	1.44	1.99	65.5
Pyrgo	1.72	0.39	1.15	1.51	1.89	67.4
Discorbis rosea	3.07	1.61	1.14	1.58	1.88	69.27
Ammonia	1.41	0	1.09	1.77	1.79	71.06
Hauerina	1.44	0	1.05	1.41	1.72	72.79
Pseudohauerina	1.53	0.25	1.02	1.48	1.67	74.46
Siphonina	1.52	0.43	1	1.51	1.64	76.1
Bigenerina	1.5	0.45	0.96	1.68	1.57	77.66
Elphidium	1.42	0.6	0.95	1.29	1.55	79.22
Discorbinella	1.31	0	0.94	1.56	1.54	80.75
Schlumbergerina	1.35	0.35	0.92	1.19	1.51	82.26
Lachlanella	1.19	0.45	0.86	1.22	1.41	83.68
Heterostegina	1.32	0.45	0.85	1.5	1.4	85.08
Eponides	1.65	1	0.82	1.43	1.34	86.42
Adelosina	1.1	0	0.76	1.03	1.25	87.67
Cyclorbiculina	2.68	1.98	0.73	1.42	1.2	88.87
Nonionoides	0.96	0	0.72	1.03	1.19	90.06

Appendix C: Raw data from rubble samples

Table C1. Foraminiferal abundance (#/100cm^2) in rubble samples collected in October 2008 at Conch Reef, Florida

Conch Reef 101808 Rubble Abundance (#/100cm^2)

Sample Number	**2_1**	**3_1**	**5_1**	**5_2**	**5_3**	**6_1**	**6_2**	**6_3**	**7_2**	**10_3**	**11_2**	**12_1**	**13_3**	**15_1**	**15_2**	**15_3**	**16_1**	**16_2**	**16_3**	**17_3**	**18_2**
Symbiont-bearing																					
Amphistegina	704	714	771	810	437	843	1430	597	276	311	366	605	145	5749	2013	3336	11921	9949	5952	3153	644
Androsina	21	0	0	0	0	0	0	0	0	0	278	0	0	0	0	0	0	0	0	0	0
Archaias	283	115	1410	784	538	310	541	387	216	88	331	108	575	2114	692	999	409	3027	485	457	1331
Asterigerina	1636	990	967	316	618	1171	327	371	359	118	366	343	48	5130	3675	4005	3185	1490	632	1374	1447
Borelis	133	373	771	474	394	173	0	581	126	48	9	0	36	1804	70	221	865	1129	316	0	494
Cyclorbiculina	128	23	391	171	21	0	327	226	60	44	53	514	89	507	70	891	1706	1082	801	405	276
Heterostegina	43	74	288	13	186	87	152	250	30	44	9	81	0	197	762	1112	613	1442	316	356	117
Laevipeneroplis	1892	1202	5289	1812	2328	1749	1960	1315	1509	692	3463	1976	503	5327	2768	7336	4639	7473	4635	4067	2895
Monalysidium	0	0	0	0	144	0	0	0	0	0	0	153	0	0	278	556	204	0	0	356	0
Parasorites	464	244	535	13	0	310	225	234	214	48	600	793	24	1099	207	1668	637	2595	1938	1018	268
Peneroplis	1375	88	1214	336	165	310	388	387	30	78	1670	289	40	2424	485	891	637	361	643	356	134
Sorites	21	0	0	171	43	87	265	48	30	39	287	361	32	592	70	221	637	0	1454	101	117
Stress-tolerant																					
Abditodentrix	0	0	0	0	0	0	0	0	0	0	0	306	32	0	0	335	0	0	0	509	117
Ammonia	21	235	0	171	597	291	51	290	126	35	305	766	76	987	833	2553	204	1514	1127	1067	0
Bolivina	773	373	2509	1665	1380	638	1441	734	628	104	3896	1253	193	2931	626	556	1911	3748	3044	712	243
Bolivinellina	0	0	0	0	0	0	0	0	63	0	0	0	0	0	0	0	0	0	0	0	0
Brizalina	133	5	196	0	0	0	0	0	0	0	278	0	0	0	0	556	0	0	158	0	0
Cribroelphidium	0	0	0	0	144	87	0	0	0	0	557	334	0	0	0	221	433	0	485	0	0
Elphidium	21	221	535	0	21	223	51	89	63	108	26	81	12	507	485	1107	1706	745	485	255	117
Haynesina	0	0	196	0	0	87	113	266	126	0	1948	460	0	0	207	0	204	1537	474	0	0
Nonionella	0	74	144	13	21	0	113	379	0	74	18	27	0	1409	70	0	433	745	969	356	0
Nonionoides	21	74	196	0	0	87	113	177	344	39	278	0	32	1409	0	664	0	384	485	509	0
Rectobolivina	0	0	0	0	0	0	0	0	0	0	0	153	0	0	0	0	204	0	0	0	0
Reophax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trochammina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	384	158	0	0

Appendix C (Continued)

Table C1. Continued

Conch Reef 101808 Rubble Abundance (#/100cm^2)

Sample Number	**2_1**	**3_1**	**5_1**	**5_2**	**5_3**	**6_1**	**6_2**	**6_3**	**7_2**	**10_3**	**11_2**	**12_1**	**13_3**	**15_1**	**15_2**	**15_3**	**16_1**	**16_2**	**16_3**	**17_3**	**18_2**
Planktics	309	295	432	461	432	310	102	89	78	39	9	334	64	790	762	1781	3185	1874	2581	966	8
Other smaller taxa																					
Cassidulina	21	0	0	0	0	87	0	0	63	0	278	207	4	0	70	0	433	721	485	0	0
Floresina	21	147	1214	474	575	328	501	0	188	69	1679	153	129	902	414	777	0	745	474	405	234
Fursenkonia	0	74	0	0	0	137	0	24	0	0	0	306	0	0	0	0	204	361	158	0	0
Reussella	133	0	0	0	0	0	0	0	63	0	0	0	0	0	0	0	0	0	0	101	0
Sigmavirgulina	0	5	196	0	43	68	51	0	0	5	557	0	0	0	70	0	0	0	158	0	0
Spirillina	330	78	288	165	352	619	327	532	188	78	278	361	8	0	970	2337	1502	1490	1127	813	117
Trifarina	0	78	0	151	0	0	113	89	0	35	278	153	68	0	0	0	433	384	0	255	0
Other Agglutinates																					
Bigenerina	0	0	0	0	0	68	0	0	0	39	287	180	64	0	0	335	637	721	0	101	17
Clavulina	0	0	0	0	144	0	0	0	0	0	0	0	0	0	0	0	0	721	0	0	0
Textularia	794	313	679	468	272	223	570	250	153	221	331	469	386	902	1106	2780	1502	3748	4034	1730	636
Valvulina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	101	0
Other Miliolida																					
Adelosina	485	14	483	151	144	415	276	710	188	35	835	306	0	2114	829	1339	817	1537	474	1678	234
Affinetrina	400	0	1410	158	330	756	102	266	188	69	835	919	64	0	626	556	204	361	474	255	234
Articulina	816	152	1214	942	458	669	388	137	374	78	2836	749	109	987	1521	1441	2115	4109	1601	2490	611
Cornuspiroides	0	0	915	151	0	68	113	89	63	39	0	0	36	0	211	335	637	769	0	202	8
Cycloforina	533	0	288	7	288	137	102	0	126	9	0	388	32	2424	1451	335	0	384	801	509	0
Hauerina	0	152	1162	171	165	341	563	48	45	23	305	415	0	1522	414	891	1070	1129	1117	1221	117
Parahauerina	0	0	391	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lachlanella	0	5	0	151	415	0	102	89	15	0	0	306	32	0	0	335	0	0	158	509	0
Miliolinella	2617	682	3580	1429	1614	1362	1121	1210	482	392	2124	1001	109	9160	3749	4561	7667	4830	7405	4880	0
Pseudohauerina	155	299	771	316	453	546	51	177	63	9	844	27	36	197	278	0	841	1153	158	356	0
Pseudoschlumbergerina	1706	769	3067	2173	703	1881	980	581	452	221	1148	1974	334	4595	1666	4221	1730	4517	4172	2592	352
Pseudotriloculina	1690	686	2129	639	1076	1417	592	403	234	378	2045	388	193	5045	1400	4788	637	3293	2423	2340	0
Pyrgo	0	9	587	20	165	137	152	194	60	0	305	207	0	0	555	1555	1070	721	1127	202	17
Quinqueloculina	2052	1253	5628	1672	826	1512	1357	1509	1391	777	4942	2273	282	10654	4719	11444	9193	15762	14631	6251	1439
Schlumbergerina	0	74	0	158	144	137	0	89	0	0	835	0	0	0	0	0	409	384	485	101	126
Siphonaptera	0	5	391	158	21	0	225	0	0	35	9	54	113	1297	762	443	0	0	643	356	636
Spiroloculina	64	0	0	0	0	0	0	113	15	0	287	0	64	1522	278	1004	433	1082	485	202	0
Triloculinella	1066	0	1410	606	0	68	563	290	153	0	278	316	129	2226	1662	3444	1863	1898	4677	1371	0
Triloculina	421	9	1934	810	43	1039	1154	73	30	23	879	163	12	3298	696	3449	637	2643	632	1119	25
Wiesnerella	85	299	340	7	64	223	51	89	78	69	852	460	0	197	207	1004	433	1105	158	101	117

Appendix C (Continued)

Table C1. Continued

Conch Reef 101808 Rubble Abundance (#/100cm^2)

Sample Number	**2_1**	**3_1**	**5_1**	**5_2**	**5_3**	**6_1**	**6_2**	**6_3**	**7_2**	**10_3**	**11_2**	**12_1**	**13_3**	**15_1**	**15_2**	**15_3**	**16_1**	**16_2**	**16_3**	**17_3**	**18_2**
Other Rotaliida																					
Cancris	0	74	0	0	0	0	0	0	15	5	0	0	0	0	0	0	433	0	0	0	0
Cibicides	661	387	2509	764	804	1307	817	444	203	175	557	848	217	2903	696	3109	3437	1874	3213	764	352
Cibicoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymballoporetta	0	152	0	165	0	0	113	24	0	0	0	153	0	705	141	0	433	0	485	356	126
Discogypsina	0	0	0	0	21	0	0	48	0	0	0	27	0	0	0	0	0	361	0	0	0
Discorbinella	309	221	0	303	21	155	225	113	0	0	9	153	64	1607	899	2116	433	0	643	0	0
Discorbis	464	387	771	309	1033	843	1470	1678	15	92	305	190	169	197	278	891	841	745	2075	304	820
Eponides	85	28	0	0	165	241	102	89	63	35	574	262	68	507	0	1333	204	2956	969	101	17
Gavelinopsis	1242	608	3487	1541	1156	2155	1582	758	595	387	3096	1794	80	3608	3687	7012	1502	3772	5151	3254	1055
Glabratella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	158	0	0
Lobatula	64	0	0	0	0	0	0	0	63	69	557	153	52	0	207	0	0	0	158	558	0
Neoconorbina	1503	677	2141	1376	1007	137	316	984	563	251	2522	793	68	3918	762	3671	4458	8313	2075	1221	352
Neoeponides	400	166	1945	790	453	651	377	323	419	161	26	388	8	1014	833	777	3846	721	2897	1119	368
Planorbulina	1242	1220	6170	1910	2487	3102	5244	1379	969	867	2549	1542	414	10512	3706	4335	8989	10960	8838	5933	1614
Rosalina	1636	1465	6411	3101	3686	2373	2816	1049	1439	809	7098	2615	732	6567	4253	8113	12762	7857	7395	4220	1172
Siphonina	21	0	0	0	186	155	0	0	0	35	0	27	32	0	207	891	409	384	158	356	126

Appendix C (Continued)

Table C2. Summary of rubble foraminiferal data of samples collected in October 2008 at Conch Reef, Florida from the table above.

Conch Reef 101808 Rubble Abundance (Foraminifers/100cm2)

Sample Number	**2_1**	**3_1**	**5_1**	**5_2**	**5_3**	**6_1**	**6_2**	**6_3**	**7_2**	**10_3**	**11_2**	**12_1**	**13_3**	**15_1**	**15_2**	**15_3**	**16_1**	**16_2**	**16_3**	**17_3**	**18_2**
Total Foraminifers/100cm^2	28996	15586	67355	28451	26783	30117	30106	20272	13234	7402	55084	29659	6014	111559	53398	108628	105946	131990	109405	64443	19849
Total Genera	47	48	45	45	49	49	49	49	50	48	54	55	45	43	51	50	54	53	57	54	42
Total Foraminifers/gram	1503	1923	1030	2148	1111	1101	1746	1225	1899	1450	2790	1649	578	2540	2318	2134	1316	1331	1711	1303	594
Seafloor area (cm2)	99.86	107.8	44.6	76.04	53.24	20.06	46.74	118.2	82.62	94.64	104.23	91.31	52.85	42.28	31.16	57.93	44.47	50.19	40.22	45.19	37.37
Symbiont-bearing / 100cm^2	6700	3824	11636	4902	4874	5037	5614	4397	2850	1510	7431	5223	1493	24944	11092	21235	25453	28548	17171	11642	7723
Stress-tolerant/ 100cm^2	970	981	3775	1850	2163	1412	1880	1936	1348	360	7306	3381	346	7244	2221	5992	5095	9058	7384	3407	477
Other/ 100cm^2	21326	10782	51943	21698	19746	23667	22612	13939	9035	5532	40347	21056	4175	79371	40086	81401	75397	94385	84850	49393	11649
FORAM Index	3.8	3.9	3.3	3.3	3.4	3.3	3.4	3.6	3.6	3.6	2.9	3.3	3.9	3.7	3.6	3.5	3.9	3.7	3.2	3.4	5.1

Appendix D: Raw SIMPER results from rubble samples

Table D1. SIMPER similarity results on rubble samples for Cluster 1

SIMPER--- Rubble Samples by Clusters					
Cluster 1	**Average Similarity: 74.63**			**# genera = 90% is 31**	
Genera	**Av. Abund**	**Av. Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Rosalina	27.75	5.71	9.06	7.66	7.66
Laevipeneroplis	24.36	4.73	6.59	6.34	14
Planorbulina	24.9	4.3	7.69	5.76	19.76
Quinqueloculina	22.33	3.54	5.4	4.75	24.51
Textularia	17.27	3.14	9.3	4.21	28.72
Pseudoschlumbergerina	16.57	3.14	6.4	4.21	32.93
Pseudotriloculina	16.67	2.93	4.7	3.93	36.86
Cibicides	13.99	2.79	4.58	3.74	40.6
Amphistegina	14.84	2.54	6.47	3.4	44.01
Miliolinella	15.11	2.2	3.01	2.95	46.96
Bolivina	12.04	2.15	3.41	2.88	49.84
Discorbis	11.3	2.03	6.42	2.72	52.56
Archaias	16.67	1.98	3.72	2.65	55.2
Gavelinopsis	14.33	1.89	6.53	2.54	57.74
Articulina	9.64	1.87	1.96	2.51	60.25
Floresina	9.83	1.76	1.77	2.35	62.6
Neoconorbina	12.06	1.75	5.07	2.34	64.94
Affinetrina	8.17	1.69	3.26	2.27	67.21
Lobatula	7.78	1.53	4.38	2.05	69.26
Asterigerina	8.9	1.47	2.6	1.97	71.23
Cyclorbiculina	8.01	1.4	3.09	1.87	73.1
Peneroplis	7.6	1.34	1.76	1.79	74.89
Planktics	7.14	1.32	2.09	1.77	76.67
Bigenerina	7.14	1.32	1.47	1.77	78.44
Borelis	6.49	1.27	1.48	1.7	80.14
Cornuspiroides	6.14	1.27	1.14	1.7	81.84
Ammonia	7.31	1.24	1.4	1.66	83.51
Trifarina	7.08	1.24	1.67	1.66	85.17
Siphonaptera	8.25	1.24	2.73	1.66	86.84
Eponides	7.08	1.24	1.4	1.66	88.5
Sorites	5.97	1.2	0.56	1.6	90.1

Appendix D (Continued)

Table D2. SIMPER similarity results on rubble samples by Cluster 2					
SIMPER--- Rubble Samples by Clusters					
Cluster 2	**Average Similarity: 73.17**			**# genera = 90% is 34**	
Genera	**Av. Abund**	**Av. Sim**	**Sim/SD**	**Contrib.%**	**Cum.%**
Laevipeneroplis	42.85	4.36	10.03	5.96	5.96
Rosalina	45.26	4.32	7.35	5.9	11.86
Planorbulina	43.96	4.08	8.92	5.58	17.44
Quinqueloculina	38.78	3.96	6.9	5.42	22.85
Gavelinopsis	34.61	3.28	8.62	4.49	27.34
Miliolinella	34.05	3.19	7.9	4.36	31.7
Pseudoschlumbergerina	32.54	2.86	4.7	3.91	35.61
Bolivina	29.14	2.63	4.58	3.59	39.2
Amphistegina	26.05	2.52	6.47	3.45	42.65
Neoconorbina	26.51	2.36	3.01	3.23	45.88
Asterigerina	26.16	2.33	3.41	3.19	49.07
Cibicides	24.93	2.3	6.42	3.14	52.21
Articulina	22.17	2	3.72	2.73	54.94
Neoeponides	20.45	2	6.53	2.73	57.67
Discorbis rosea	24.56	1.92	1.96	2.63	60.3
Pseudotriloculina	24.24	1.88	1.77	2.57	62.87
Textularia	19.79	1.84	5.07	2.51	65.38
Archaias	20.09	1.7	3.26	2.33	67.7
Spirillina	16.82	1.49	4.38	2.04	69.74
Adelosina	16.02	1.34	2.6	1.83	71.57
Peneroplis	16.87	1.31	3.09	1.8	73.37
Affinetrina	16.4	1.23	1.76	1.68	75.05
Planktics	14.41	1.17	2.09	1.6	76.65
Parasorites	14.79	1.16	1.47	1.58	78.23
Floresina	14.44	1.09	1.48	1.49	79.73
Borelis	14.32	1.07	1.14	1.46	81.19
Ammonia	13.76	0.94	1.4	1.29	82.47
Hauerina	12.53	0.91	1.67	1.25	83.72
Triloculina	15.65	0.91	1.31	1.24	84.97
Pseudohauerina	12.57	0.88	1.38	1.21	86.17
Wiesnerella	10.97	0.87	2.27	1.19	87.36
Heterostegina	9.52	0.8	2.73	1.09	88.46
Cyclorbiculina	11.4	0.79	1.4	1.08	89.54
Triloculinella	13.64	0.71	0.84	0.97	90.51

Appendix D (Continued)

Table D3. SIMPER similarity results on rubble samples by Cluster 3					
SIMPER--- Rubble Samples by Clusters					
Cluster 3	**Average Similarity: 73.86**			**# genera = 90% is 37**	
Genera	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Quinqueloculina	93.96	4.48	10.06	6.06	6.06
Rosalina	83.69	4.22	8.78	5.71	11.78
Planorbulina	80.98	3.84	5.89	5.2	16.98
Laevipeneroplis	69.91	3.52	10.3	4.77	21.75
Miliolinella	71.48	3.45	7.2	4.67	26.43
Gavelinopsis	60.91	3.05	4.98	4.14	30.56
Pseudoschlumbergerina	54.13	2.57	5.59	3.48	34.04
Amphistegina	63.06	2.41	2.45	3.27	37.31
Neoconorbina	53.97	2.37	4.47	3.2	40.51
Pseudotriloculina	49.91	2.32	3.93	3.14	43.65
Articulina	44.05	2.14	5.22	2.9	46.55
Bolivina	44.67	1.98	2.75	2.68	49.22
Cibicides	43.99	1.96	3.46	2.65	51.87
Triloculinella	43.67	1.95	3.66	2.64	54.52
Asterigerina	44.78	1.87	2.58	2.53	57.04
Triloculina	39.05	1.72	3.88	2.33	59.37
Textularia	40.6	1.71	3.73	2.31	61.68
Adelosina	32.53	1.54	4.67	2.08	63.76
Hauerina	30.6	1.48	4.47	2	65.76
Neoeponides	34.89	1.39	2.06	1.88	67.65
Parasorites	32.02	1.38	4.07	1.86	69.51
Peneroplis	29.47	1.32	3.53	1.79	71.3
Archaias	30.92	1.31	3.98	1.77	73.07
Planktics	33.7	1.29	1.93	1.75	74.82
Discorbis rosea	25.01	1.08	4.12	1.46	76.28
Spirillina	28.06	1.08	1.62	1.46	77.74
Floresina	24.81	1.04	1.68	1.41	79.15
Ammonia	27.52	1.03	1.53	1.39	80.54
Elphidium	23.63	0.97	2.47	1.32	81.86
Pyrgo	23.56	0.93	1.67	1.25	83.12
Cyclorbiculina	23.38	0.9	2.36	1.22	84.34
Wiesnerella	20.49	0.85	2.9	1.16	85.49
Affinetrina	20.67	0.84	1.56	1.14	86.63
Heterostegina	21.59	0.84	1.99	1.13	87.76
Pseudohauerina	20.21	0.8	1.48	1.08	88.85
Spiroloculina	21.58	0.79	1.7	1.07	89.92
Cycloforina	21.45	0.67	1.07	0.9	90.82

Appendix D (Continued)

Table D4. SIMPER dissimilarity results on rubble samples by Clusters 2 & 1

SIMPER--- Rubble Samples by Clusters						
Clusters 2 & 1	**Average Dissimilarity: 40.19**			**# genera = 90% is 48**		
Genera	**Cluster 2 Av.Abund**	**Cluster 1 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Gavelinopsis	34.61	14.33	1.44	2.45	3.57	3.57
Miliolinella	34.05	15.11	1.35	2.11	3.35	6.92
Planorbulina	43.96	24.9	1.34	1.57	3.34	10.26
Laevipeneroplis	42.85	24.36	1.34	2.97	3.33	13.6
Asterigerina	26.16	8.9	1.27	1.84	3.16	16.75
Rosalina	45.26	27.75	1.23	1.98	3.06	19.82
Bolivina	29.14	12.04	1.2	2.23	2.99	22.81
Quinqueloculina	38.78	22.33	1.19	2.21	2.96	25.77
Pseudoschlumbergerina	32.54	16.57	1.1	1.67	2.75	28.52
Neoconorbina	26.51	12.06	1.08	1.77	2.68	31.2
Discorbis rosea	24.56	11.3	1.07	1.67	2.65	33.85
Adelosina	16.02	2.94	0.95	2.09	2.37	36.23
Neoeponides	20.45	7.77	0.92	1.96	2.28	38.5
Articulina	22.17	9.64	0.89	2.07	2.21	40.71
Triloculinella	13.64	5.67	0.83	1.32	2.05	42.77
Pseudotriloculina	24.24	16.67	0.81	1.44	2.03	44.79
Amphistegina	26.05	14.84	0.81	1.99	2.01	46.8
Triloculina	15.65	4.14	0.8	1.03	1.99	48.79
Spirillina	16.82	5.85	0.78	1.94	1.93	50.73
Borelis	14.32	6.49	0.77	1.99	1.91	52.64
Cibicides	24.93	13.99	0.76	1.95	1.89	54.52
Parasorites	14.79	5.94	0.75	2.22	1.87	56.39
Hauerina	12.53	2.4	0.75	1.77	1.87	58.26
Affinetrina	16.4	8.17	0.69	1.83	1.73	59.99
Peneroplis	16.87	7.6	0.68	1.25	1.68	61.67

Appendix D (Continued)

Table D4. Continued

SIMPER--- Rubble Samples by Clusters						
Clusters 2 & 1	**Average Dissimilarity: 40.19**			**# genera = 90% is 48**		
Genera	**Cluster 2 Av.Abund**	**Cluster 1 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Archaias	20.09	16.67	0.66	1.29	1.64	63.31
Pseudohauerina	12.57	4.52	0.65	1.53	1.62	64.93
Ammonia	13.76	7.31	0.61	1.56	1.52	66.45
Discorbinella	10.49	4.01	0.6	1.6	1.5	67.95
Pyrgo	8.46	0	0.6	1.77	1.49	69.44
Cycloforina	9.53	4.35	0.58	1.59	1.43	70.88
Planktics	14.41	7.14	0.57	1.75	1.43	72.3
Siphonaptera	6.69	8.25	0.55	1.48	1.36	73.67
Wiesnerella	10.97	4.16	0.55	1.27	1.36	75.03
Floresina	14.44	9.83	0.54	1.78	1.35	76.38
Lachlanella	7.98	2.84	0.49	1.27	1.21	77.58
Haynesina	6.89	0	0.48	0.9	1.21	78.79
Heterostegina	9.52	3.31	0.48	1.49	1.2	79.99
Schlumbergerina	6.55	0	0.48	1.18	1.19	81.18
Cymballoporetta	6.43	0	0.47	1.1	1.16	82.35
Cyclorbiculina	11.4	8.01	0.45	1.71	1.13	83.48
Bigenerina	2.58	7.14	0.44	2.49	1.1	84.58
Lobatula	2.83	7.78	0.43	1.94	1.08	85.66
Nonionoides	6.5	5.97	0.42	1.55	1.04	86.7
Nonionella	5.21	4.3	0.41	1.08	1.01	87.71
Trifarina	5.36	7.08	0.39	2.09	0.97	88.68
Siphonina	4.71	5.78	0.37	2.21	0.93	89.61
Textularia	19.79	17.27	0.35	1.4	0.88	90.49

Appendix D (Continued)

Table D5. SIMPER dissimilarity results on rubble samples by Clusters 2 & 3

SIMPER--- Rubble Samples by Clusters						
Clusters 2 & 3	**Average Dissimilarity: 39.77**			**# genera = 90% is 50**		
Genera	**Cluster 2 Av.Abund**	**Cluster 3 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Quinqueloculina	38.78	93.96	1.98	3.38	4.99	4.99
Rosalina	45.26	83.69	1.42	2.38	3.56	8.55
Planorbulina	43.96	80.98	1.38	2.04	3.47	12.02
Miliolinella	34.05	71.48	1.37	2.36	3.45	15.47
Amphistegina	26.05	63.06	1.37	1.55	3.43	18.91
Triloculinella	13.64	43.67	1.12	1.97	2.82	21.73
Neoconorbina	26.51	53.97	1	1.7	2.52	24.25
Gavelinopsis	34.61	60.91	0.99	2.08	2.5	26.75
Laevipeneroplis	42.85	69.91	0.98	2.54	2.47	29.22
Pseudotriloculina	24.24	49.91	0.98	1.65	2.46	31.68
Triloculina	15.65	39.05	0.92	1.62	2.3	33.98
Pseudoschlumbergerina	32.54	54.13	0.84	1.73	2.11	36.09
Articulina	22.17	44.05	0.82	1.87	2.06	38.15
Asterigerina	26.16	44.78	0.8	1.37	2.01	40.17
Planktics	14.41	33.7	0.78	1.78	1.97	42.14
Textularia	19.79	40.6	0.76	1.6	1.91	44.05
Cibicides	24.93	43.99	0.74	1.59	1.86	45.91
Bolivina	29.14	44.67	0.72	1.47	1.81	47.72
Spiroloculina	2.25	21.58	0.71	2	1.78	49.51
Hauerina	12.53	30.6	0.68	2.04	1.7	51.21
Neoeponides	20.45	34.89	0.66	1.51	1.67	52.88
Ammonia	13.76	27.52	0.65	1.61	1.64	54.52
Parasorites	14.79	32.02	0.64	1.65	1.62	56.14
Cycloforina	9.53	21.45	0.63	1.26	1.57	57.71
Adelosina	16.02	32.53	0.62	1.71	1.56	59.27

Appendix D (Continued)

Table D5. Continued

SIMPER--- Rubble Samples by Clusters						
Clusters 2 & 3	**Average Dissimilarity: 39.77**			**# genera = 90% is 40**		
Genera	**Cluster 2 Av.Abund**	**Cluster 3 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Pyrgo	8.46	23.56	0.62	1.89	1.56	60.83
Discorbinella	10.49	18.35	0.61	1.53	1.54	62.36
Eponides	9.06	21.43	0.59	1.41	1.49	63.86
Elphidium	8.34	23.63	0.58	1.88	1.46	65.32
Spirillina	16.82	28.06	0.57	1.78	1.44	66.76
Peneroplis	16.87	29.47	0.56	1.31	1.4	68.16
Haynesina	6.89	16.42	0.55	1.07	1.39	69.55
Siphonaptera	6.69	16.85	0.55	1.4	1.38	70.93
Floresina	14.44	24.81	0.53	1.39	1.34	72.27
Nonionella	5.21	17.8	0.53	1.44	1.33	73.6
Borelis	14.32	19.7	0.52	1.54	1.3	74.9
Nonionoides	6.5	17.57	0.51	1.53	1.29	76.19
Cyclorbiculina	11.4	23.38	0.51	1.58	1.29	77.48
Archaias	20.09	30.92	0.5	1.29	1.25	78.73
Heterostegina	9.52	21.59	0.49	1.69	1.24	79.97
Cornuspiroides	5.14	14.47	0.47	1.42	1.19	81.16
Pseudohauerina	12.57	20.21	0.45	1.46	1.13	82.28
Discorbis rosea	24.56	25.01	0.43	1.33	1.08	83.36
Affinetrina	16.4	20.67	0.42	1.22	1.05	84.41
Sorites	9.21	15.33	0.41	1.36	1.04	85.44
Siphonina	4.71	12.83	0.41	1.36	1.03	86.47
Wiesnerella	10.97	20.49	0.4	1.39	1.01	87.48
Schlumbergerina	6.55	11.2	0.4	1.3	1	88.48
Cymballoporetta	6.43	11.12	0.38	1.41	0.96	89.44
Bigenerina	2.58	10.82	0.38	1.15	0.96	90.4

Appendix D (Continued)

Table D6. SIMPER dissimilarity results on rubble samples by Clusters 3 & 1						
SIMPER--- Rubble Samples by Clusters						
Clusters 3 & 1	**Average Dissimilarity: 61.18**			**# genera = 90% is 46**		
Genera	**Group 3 Av.Abund**	**Group 1 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Quinqueloculina	93.96	22.33	3.09	5.33	5.05	5.05
Miliolinella	71.48	15.11	2.46	4.32	4.03	9.08
Rosalina	83.69	27.75	2.46	4.82	4.02	13.09
Planorbulina	80.98	24.9	2.43	3.65	3.97	17.06
Gavelinopsis	60.91	14.33	2.07	3.74	3.38	20.44
Amphistegina	63.06	14.84	2.01	1.81	3.29	23.73
Laevipeneroplis	69.91	24.36	1.99	5.95	3.25	26.99
Neoconorbina	53.97	12.06	1.8	2.81	2.93	29.92
Triloculinella	43.67	5.67	1.64	2.92	2.68	32.6
Pseudoschlumbergerina	54.13	16.57	1.62	3.77	2.66	35.26
Asterigerina	44.78	8.9	1.58	1.98	2.58	37.83
Articulina	44.05	9.64	1.53	3.37	2.5	40.34
Triloculina	39.05	4.14	1.53	2.97	2.5	42.84
Pseudotriloculina	49.91	16.67	1.46	2.64	2.38	45.22
Bolivina	44.67	12.04	1.44	2.05	2.36	47.58
Adelosina	32.53	2.94	1.31	3.45	2.14	49.72
Cibicides	43.99	13.99	1.28	2.39	2.09	51.81
Hauerina	30.6	2.4	1.24	4.12	2.02	53.84
Neoeponides	34.89	7.77	1.22	1.88	2	55.83
Planktics	33.7	7.14	1.16	2.23	1.9	57.73
Parasorites	32.02	5.94	1.11	3.01	1.82	59.55

Appendix D (Continued)

Table D6. Continued						
SIMPER--- Rubble Samples by Clusters						
Clusters 3 & 1	**Average Dissimilarity: 61.18**			**# genera = 90% is 46**		
Genera	**Group 3 Av.Abund**	**Group 1 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Pyrgo	23.56	0	1.03	2.29	1.69	61.24
Spirillina	28.06	5.85	1.01	2.16	1.66	62.89
Peneroplis	29.47	7.6	0.99	1.99	1.62	64.51
Textularia	40.6	17.27	0.98	1.77	1.6	66.11
Ammonia	27.52	7.31	0.94	2.1	1.54	67.65
Cycloforina	21.45	4.35	0.85	1.43	1.39	69.03
Heterostegina	21.59	3.31	0.81	2.01	1.32	70.35
Spiroloculina	21.58	4.01	0.78	1.96	1.28	71.63
Floresina	24.81	9.83	0.78	1.9	1.28	72.91
Discorbinella	18.35	4.01	0.76	1.22	1.24	74.15
Pseudohauerina	20.21	4.52	0.75	1.89	1.23	75.38
Haynesina	16.42	0	0.74	0.99	1.21	76.59
Elphidium	23.63	6.95	0.74	1.99	1.21	77.8
Eponides	21.43	7.08	0.73	1.47	1.19	78.99
Wiesnerella	20.49	4.16	0.72	1.75	1.17	80.17
Archaias	30.92	16.67	0.68	1.36	1.1	81.27
Affinetrina	20.67	8.17	0.67	1.65	1.09	82.36
Borelis	19.7	6.49	0.65	1.39	1.07	83.43
Cyclorbiculina	23.38	8.01	0.65	1.65	1.06	84.49
Nonionella	17.8	4.3	0.63	1.42	1.03	85.52
Nonionoides	17.57	5.97	0.62	1.96	1.01	86.53
Siphonaptera	16.85	8.25	0.6	1.87	0.98	87.51
Discorbis rosea	25.01	11.3	0.58	1.55	0.95	88.46
Cornuspiroides	14.47	6.14	0.55	1.75	0.89	89.35
Sorites	15.33	5.97	0.51	1.41	0.84	90.19

Appendix E: Foraminiferal Species list for Conch Reef, Florida

Table E1. Foraminiferal species identified in samples collected at Conch Reef in October 2008.

Order	*Genus Species*	Species Author	Reference with Illustrations
Buliminida	*Abditodentrix rhoimboidalis*	(Millett)	Cimerman and Langer, 1991 Plate 61 Figures 4-6
Buliminida	*Bolivina lowmani*	Phleger and Parker	Bock, 1971 Plate 16 Figure 14
Buliminida	*Bolivina pulchella*	Cushman	Bock, 1971 Plate 17 Figure 1
Buliminida	*Bolivina striatula*	Cushman	Bock, 1971 Plate 17 Figure 2
Buliminida	*Bolivinellina lanceolata*	(Parker)	Bock, 1971 Plate 16 Figure 13
Buliminida	*Brizalina goesit*	Cushman	Bock, 1971 Plate 16 Figure 11
Buliminida	*Brizalina mexicana*	Cushman	Galloway and Hemingway, 1971 Plate 17 Figure 3
Buliminida	*Rectobolivina advena*	(Cushman)	Bock, 1971 Plate17 Figure 5
Buliminida	*Cassidulina laevigata*	d'Orbigny	Phleger and Parker, 1951 Plate 14 Figures 6a-6b
Buliminida	*Cassidulina subglobosa*	Brady	Bock, 1971 Plate 23 Figure 12
Buliminida	*Floresina amphiphaga*	Hallock and Talge	Hallock and Talge, 1994 Plate 1 Figures 1-4
Buliminida	*Fursenkoina compressa*	(Bailey)	Bock, 1971 Plate 23 Figure 7
Buliminida	*Reussella atlantica*	Cushman	Loeblich and Tappan, 1987 Plate 575 Figures 9-12
Buliminida	*Sigmavirgulina tortuosa*	(Brady)	Loeblich and Tappan, 1987 Plate 579 Figures 1-5
Buliminida	*Trifarina bella*	(Phleger and Parker)	Bock, 1971 Plate 17 Figure 13
Globigerinida	*Globigerinella siphonifera*	(d'Orbigny)	Bock, 1971 Plate 25 Figures 1-2
Globigerinida	*Globigerinoides ruber*	d'Orbigny	Loeblich and Tappan, 1987 Plate 536 Figures 1-6
Globigerinida	*Globorotalia tumida*	(d'Orbigny)	Loeblich and Tappan, 1987 Plate 515 Figures 4-6
Lituolida	*Reophax difflugiformis*	Brady	Bock, 1971 Plate 1 Figure 8
Lituolida	*Valvulina oviedoiana*	d'Orbigny	Bock, 1971 Plate 2 Figure 11
Miliolida	*Androsina lucasi*	Levy	Loeblich and Tappan, 1987 Plate 410 Figures 6-10
Miliolida	*Archaias angulatus*	(Fichtel and Moll)	Bock, 1971 Plate 14 Figures 1-3

Appendix E (Continued)

Table E1. Continued

Order	*Genus Species*	Species Author	Reference with Illustrations
Miliolida	*Borelis pulchra*	(d'Orbigny)	Bock, 1971 Plate 14 Figure 7
Miliolida	*Cyclorbiculina compressa*	(d'Orbigny)	Loeblich and Tappan, 1987 Plate 412 Figures 1-6
Miliolida	*Laevipeneroplis bradyi*	Cushman	Bock, 1971 Plate 2 Figure 8
Miliolida	*Laevipeneroplis carinatus*	d'Orbigny	Bock, 1971 Plate 13 Figure 9
Miliolida	*Laevipeneroplis proteus*	d'Orbigny	Bock, 1971 Plate 13 Figure 11
Miliolida	*Monalysidium politum*	Chapman	Bock, 1971 Plate 13 Figure 12
Miliolida	*Parasorites orbitolitoides*	(Hofker)	Bock, 1971 Plate 13 Figure 15
Miliolida	*Peneroplis pertusus*	(Forskal)	Bock, 1971 Plate 13 Figure 10
Miliolida	*Sorites dominicensis*	Ehrenberg	Richardson, 2006 Figures 1-2
Miliolida	*Adelosina fitterei*	Acosta	Bock, 1971 Plate 10 Figures 5-7
Miliolida	*Affinetrina bermudzi*	(Acosta)	Bock, 1971 Plate 9 Figures 9-11
Miliolida	*Affinetrina oblonga*	(Montague)	Bock, 1971 Plate 11 Figures 2-4
Miliolida	*Articulina antillarum*	Cushman	Bock, 1971 Plate 12 Figure 13
Miliolida	*Articulina mexicana*	Cushman	Bock, 1971 Plate 13 Figure 3
Miliolida	*Articulina mucronata*	(d'Orbigny)	Bock, 1971 Plate 13 Figure 4
Miliolida	*Articulina sagra*	Brady	Bock, 1971 Plate 13 Figure 7
Miliolida	*Cornuspiroides foliacea*	(Phillipi)	Bock, 1971 Plate 3 Figure 4
Miliolida	*Cycloforina subpoeyana*	(Cushman)	Bock, 1971 Plate 7 Figures 10-12
Miliolida	*Cylcoforina arenata*	(Cushman)	Bock, 1971 Plate 3 Figure 8
Miliolida	*Hauerina bradyi*	Cushman	Bock, 1971 Plate 12 Figure 9
Miliolida	*Lachlanella bicarinata*	(d'Orbigny)	Bock, 1971 Plate 9 Figures 12-13
Miliolida	*Lachlanella polygona*	(d'Orbigny)	Bock, 1971 Plate 7 Figures 1-3
Miliolida	*Miliolinella circularis*	(Bornemann)	Bock, 1971 Plate 12 Figure 5

Appendix E (Continued)

Table E1. Continued

Order	***Genus Species***	**Species Author**	**Reference with Illustrations**
Miliolida	*Miliolinella fichteliana*	(d'Orbigny)	Bock, 1971 Plate 12 Figure 6
Miliolida	*Miliolinella labiosa*	(d'Orbigny)	Bock, 1971 Plate 12 Figure 7
Miliolida	*Pseudohauerina speciosa*	(Karrer)	Bock, 1971 Plate 12 Figures 10-11
Miliolida	*Pseudoschlumbergerina ovata*	(Sidebottom)	Hottinger, *et al.*1993 Plate 46 Figures 1-6
Miliolida	*Pseudoschlumbergerina spp.*		Loeblich and Tappan, 1987
Miliolida	*Pseudotriloculina bosciana*	(d'Orbigny)	Bock, 1971 Plate 5 Figures 3-5
Miliolida	*Pseudotriloculina laevigata*	d'Orbigny	Bock, 1971 Plate 6 Figures 4-6
Miliolida	*Pyrgo denticulata*	(Brady)	Bock, 1971 Plate 8 Figure 11
Miliolida	*Pyrgo elongata*	(d'Orbigny)	Bock, 1971 Plate 8 Figure 12
Miliolida	*Pyrgo fornasinii*	Chapman and Parr.	Bock, 1971 Plate 8 Figure 13
Miliolida	*Quinqueloculina bicostata*	d'Orbigny	Bock, 1971 Plate 4 Figures 9-11
Miliolida	*Quinqueloculina bicarinata*	d'Orbigny	Bock, 1971 Plate 4 Figures 6-8
Miliolida	*Quinqueloculina candeina*	d'Orbigny	Poag, 1981 Plate 55 and 56 Figures 4-4a
Miliolida	*Quinqueloculina collumnosa*	Cushman	Bock, 1971 Plate 5 Figures 9-11
Miliolida	*Quinqueloculina lamarckiana*	d'Orbigny	Bock, 1971 Plate 6 Figures 7-9
Miliolida	*Quinqueloculina parkeri*	Cushman	Bock, 1971 Plate 6 Figures 10-12
Miliolida	*Quinqueloculina seminulum*	(Linnaeus)	Bock, 1971 Plate 7 Figures 7-9
Miliolida	*Quinqueloculina tricarinata*	d'Orbigny	Bock, 1971 Plate 8 Figures 1-2
Miliolida	*Schlumbergerina alveoliniformis*	Cushman	Bock, 1971 Plate 12 Figure 12
Miliolida	*Siphonaptera agglutinans*	(d'Orbigny)	Bock, 1971 Plate 4 Figures 3-5
Miliolida	*Siphonaptera bidentata*	d'Orbigny	Bock, 1971 Plate 5 Figures 1-2
Miliolida	*Siphonaptera horrida*	(Cushman)	Bock, 1971 Plate 6 Figures 1-3

Appendix E (Continued)

Table E1. Continued

Order	*Genus Species*	Species Author	Reference with Illustrations
Miliolida	*Spirolina arietinus*	(Batsch)	Bock, 1971 Plate 13 Figure 14
Miliolida	*Spiroloculina antillarum*	d'Orbigny	Bock, 1971 Plate 3 Figure 7
Miliolida	*Spiroloculina communis*	Cushman	Bock, 1971 Plate 3 Figure 10
Miliolida	*Triloculina linneiana*	Bandy	Bock, 1971 Plate 10 Figures 11-12
Miliolida	*Triloculina triangularis*	(d'Orbigny)	Bock, 1971 Plate 8 Figures 6-7
Miliolida	*Triloculina tricarinata*	d'Orbigny	Bock, 1971 Plate 12 Figures 1-2
Miliolida	*Triloculina trigonula*	(Lamarck)	Bock, 1971 Plate 12 Figures 3-4
Miliolida	*Triloculinella spp.*		Cimerman and Langer, 1991 Plate 44 Figure 5
Miliolida	*Wiesnerella auriculata*	(Egger)	Loeblich and Tappan, 1987 Plate 330 Figures 11-13
Rotalida	*Amphistegina gibbosa*	d'Orbigny	Hallock and others, 1995 Plate 1
Rotalida	*Asterigerina carinata*	d'Orbigny	Bock, 1971 Plate 19 Figure 12
Rotalida	*Heterostegina depressa*	d'Orbigny	Bock, 1971 Plate 21 Figure 3
Rotalida	*Ammonia parkinsoniana*	(d'Orbigny)	Bock, 1971 Plate 20 Figures 5-6
Rotalida	*Cribroelphidium poeyanum*	Cushman and Bronnimann	Bock, 1971 Plate 21 Figures 1-2
Rotalida	*Elphidium advenum*	(Cushman)	Bock, 1971 Plate 20 Figures 7-8
Rotalida	*Elphidium discoidale*	(d'Orbigny)	Bock, 1971 Plate 20 Figures 9-10
Rotalida	*Elphidium sagrum*	(d'Orbigny)	Bock, 1971 Plate 20 Figures 11-12
Rotalida	*Haynesina despresula*	(Kornfeld)	Bock, 1971 Plate 23 Figure 14
Rotalida	*Nonionella spp.*		Loeblich and Tappan, 1987
Rotalida	*Nonionoides grateloupi*	(d'Orbigny)	Bock, 1971 Plate 23 Figure 15
Rotalida	*Cancris sagra*	(d'Orbigny)	Bock, 1971 Plate 19 Figures 6-7
Rotalida	*Cibicides robustus*	(Flint)	Bock, 1971 Plate 22 Figures 5-6

Appendix E (Continued)

Table E1. Continued

Order	***Genus Species***	**Species Author**	**Reference with Illustrations**
Rotalida	*Cibicoides spp.*		Loeblich and Tappan, 1987
Rotalida	*Cymballoporetta squammosa*	(d'Orbigny)	Bock, 1971 Plate 23 Figures 1-2
Rotalida	*Discogypsina vesicularis*	Silvestri	Loeblich and Tappan, 1987 Plate 661 Figures 11-13
Rotalida	*Discorbinella bertheloti*	(d'Orbigny)	Loeblich and Tappan, 1987 Plate 630 Figures 1-4
Rotalida	*Discorbis rosea*	(d'Orbigny)	Bock, 1971 Plate 17 Figures 15-16
Rotalida	*Eponides antillarum*	d'Orbigny	Bock, 1971 Plate 21 Figures 4-5
Rotalida	*Eponides repandus*	(Fichtel and Moll)	Bock, 1971 Plate 21 Figures 6-7
Rotalida	*Gavelinopsis praegeri*	(Heron-Allen and Earland)	Loeblich and Tappan, 1987 Plate 608 Figures 6-12
Rotalida	*Glabratella pulvinata*	(Brady)	Jones *et al.* 1994 Plate 88 Figure 10
Rotalida	*Lobatula lobatula*	(Walker and Jacob)	Loeblich and Tappan, 1987 Plate 637 Figures 10-13
Rotalida	*Neoconorbina orbicularis*	(Terquem)	Bock, 1971 Plate 18 Figures 7-8
Rotalida	*Neoeponides mira*	(Cushman)	Bock, 1971 Plate 18 Figures 3-4
Rotalida	*Planorbulina acervalis*	Brady	Bock, 1971 Plate 22 Figures 9-10
Rotalida	*Planorbulina mediterranasis*	d'Orbigny	Bock, 1971 Plate 22 Figures 11-12
Rotalida	*Rosalina bahameaensis*	Todd and Low	Poag, 1981 Plate 41-42 Figure 3
Rotalida	*Rosalina bradyi*	Cushman	Cimerman and Langer , 1991 Plate 71 Figures 1- 5
Rotalida	*Rosalina concinna*	(Brady)	Poag, 1981 Plate 41-42 Figure 4
Rotalida	*Rosalina floridana*	(Cushman)	Bock, 1971 Plate 18 Figures 9-10
Rotalida	*Rosalina floridensis*	(Cushman)	Poag, 1981 Plate 41-42 Figure 2
Rotalida	*Rosalina subaraucana*	(Cushman)	Poag, 1981 Plate 41-42 Figure 1
Rotalida	*Siphonina pulchra*	Cushman	Bock, 1971 Plate 19 Figures 10-11
Spirillinida	*Spirillina vivipara*	Ehrenberg	Bock, 1971 Plate 20 Figure 4

Appendix E (Continued)

Table E1. Continued

Order	***Genus Species***	Species Author	Reference with Illustrations
Textularida	*Bigenerina nosdosaria*	d'Orbigny	Bock, 1971 Plate 2 Figure 6
Textularida	*Clavulina tricarinata*	d'Orbigny	Bock, 1971 Plate 2 Figure 14
Textularida	*Textularia agglutinans*	d'Orbigny	Bock, 1971 Plate 2 Figure 1
Textularida	*Textularia conica*	d'Orbigny	Bock, 1971 Plate 2 Figure 3
Trochamminida	*Trochammina japonica*	Ishiwada	Bock, 1971 Plate 2 Figures 8-9

Appendix F: Raw SIMPER results on the combined data set by Clusters

Table F1. SIMPER similarity results on the comparison of sediment and rubble samples by Cluster 1

SIMPER--Combinded Sediment and Rubble					
Cluster 1	**Average similarity: 75.66**			**# genera = 90% is 35**	
Genera	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Rosalina	2.94	4.57	7.53	6.04	6.04
Quinqueloculina	2.82	4.33	6.28	5.73	11.76
Planorbulina	2.81	4.33	6.83	5.72	17.48
Laevipeneroplis	2.64	4.11	8.66	5.44	22.92
Miliolinella	2.25	3.43	6.19	4.54	27.45
Gavelinopsis	2.12	3.24	4.72	4.28	31.73
Pseudoschlumbergerina	1.97	2.94	5.82	3.89	35.63
Amphistegina	1.86	2.62	3.99	3.46	39.08
Neoconorbina	1.74	2.48	3.27	3.28	42.37
Bolivina	1.69	2.38	3.49	3.14	45.51
Cibicides	1.55	2.35	5.45	3.11	48.62
Pseudotriloculina	1.66	2.31	2.38	3.05	51.67
Articulina	1.45	2.09	4.39	2.77	54.43
Asterigerina	1.58	2.08	2.92	2.75	57.18
Textularia	1.39	1.96	4.14	2.59	59.77
Neoeponides	1.22	1.67	2.43	2.2	61.98
Archaias	1.27	1.63	3.04	2.16	64.13
Discorbis rosea	1.24	1.5	2.18	1.98	66.12
Peneroplis	1.03	1.39	3.61	1.83	67.95
Spirillina	0.99	1.32	2.26	1.75	69.7
Parasorites	0.99	1.31	2.07	1.73	71.43
Adelosina	1	1.31	2.16	1.73	73.16
Planktics	1	1.3	2.19	1.72	74.88
Triloculina	1.07	1.24	1.71	1.64	76.52
Triloculinella	1.1	1.23	1.2	1.63	78.15
Floresina	0.94	1.16	1.65	1.54	79.69
Affinetrina	0.91	1.1	1.63	1.45	81.14
Hauerina	0.85	1.09	1.81	1.43	82.58
Ammonia	0.91	1.07	1.53	1.42	84
Cyclorbiculina	0.77	0.96	1.88	1.27	85.27
Borelis	0.81	0.86	1.18	1.14	86.41
Wiesnerella	0.69	0.83	1.84	1.09	87.5
Elphidium	0.68	0.83	1.79	1.09	88.59
Heterostegina	0.64	0.78	1.79	1.04	89.63
Eponides	0.65	0.72	1.37	0.95	90.58

Appendix F (Continued)

Table F2. SIMPER similarity results on the comparison of sediment and rubble samples by Cluster 2					
SIMPER--Combinded Sediment and Rubble					
Cluster 2	**Average similarity: 71.13**			**# genera = 90% is 28**	
Genera	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Laevipeneroplis	3.32	5.86	8.76	8.23	8.23
Quinqueloculina	3.05	5.18	5.99	7.29	15.52
Asterigerina	2.88	4.94	6.35	6.94	22.46
Amphistegina	2.63	4.27	3.85	6	28.46
Textularia	2.35	3.53	4.18	4.97	33.42
Rosalina	1.87	3.05	5.13	4.28	37.71
Discorbis rosea	1.76	2.65	4.1	3.72	41.43
Borelis	1.61	2.62	3.76	3.68	45.11
Articulina	1.54	2.53	4.38	3.56	48.67
Archaias	1.75	2.52	1.9	3.54	52.21
Miliolinella	1.56	2.45	3.62	3.45	55.66
Cyclorbiculina	1.48	2.27	2.64	3.18	58.84
Pseudoschlumbergerina	1.51	2.08	1.68	2.92	61.77
Neoeponides	1.27	2.07	5.25	2.91	64.67
Planktics	1.35	2.03	2.08	2.86	67.53
Parasorites	1.29	1.81	1.87	2.55	70.08
Siphonaptera	1.32	1.67	1.35	2.35	72.44
Triloculinella	1.24	1.61	1.41	2.27	74.7
Gavelinopsis	1.27	1.6	1.24	2.25	76.96
Planorbulina	1.22	1.48	1.32	2.08	79.04
Peneroplis	0.96	1.28	1.37	1.8	80.84
Neoconorbina	0.92	1.2	1.34	1.69	82.52
Pseudotriloculina	1.07	1.13	0.97	1.59	84.11
Bigenerina	0.84	1.13	1.36	1.58	85.7
Ammonia	0.77	1.03	1.42	1.44	87.14
Eponides	0.8	0.93	1.05	1.31	88.44
Heterostegina	0.83	0.9	1.04	1.26	89.7
Siphonina	0.73	0.88	1.05	1.24	90.95

Appendix F (Continued)

Table F3. SIMPER similarity results on the comparison of sediment and rubble samples by Cluster 3

SIMPER--Combinded Sediment and Rubble					
Cluster 3	**Average similarity: 62.82**			**# genera = 90% is 14**	
Genera	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Amphistegina	3.74	8.72	10.28	13.88	13.88
Laevipeneroplis	3.43	7.68	5.13	12.22	26.1
Archaias	3.12	6.93	6.77	11.03	37.12
Cyclorbiculina	2.74	6.15	13.27	9.79	46.91
Quinqueloculina	2.06	4.38	5.4	6.97	53.88
Asterigerina	2.47	3.99	1.09	6.35	60.23
Articulina	1.74	3.83	6.48	6.09	66.33
Discorbis rosea	1.91	3.63	2.13	5.78	72.11
Siphonaptera	1.81	3	1.13	4.77	76.88
Borelis	1.23	2.16	1.15	3.44	80.32
Rosalina	2.12	1.94	0.87	3.08	83.4
Eponides	1.39	1.89	1.11	3.01	86.41
Textularia	1.47	1.56	0.62	2.49	88.89
Triloculinella	0.98	1.47	1.08	2.33	91.23

Appendix F (Continued)

Table F4. SIMPER dissimilarity results on the comparison of sediment and rubble samples by Clusters 1 & 2

SIMPER---Combined Sediment and Rubble Samples						
Clusters 1 & 2	**Average Dissimilarity= 36.03**			**# genera = 90% is 49**		
Genera	**Cluster 1 Av.Abund**	**Cluster 2 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Planorbulina	2.81	1.22	1.45	1.87	4.02	4.02
Bolivina	1.69	0.35	1.21	2.08	3.37	7.38
Asterigerina	1.58	2.88	1.19	1.91	3.31	10.7
Cibicides	1.55	0.33	1.1	2.23	3.06	13.76
Rosalina	2.94	1.87	1	1.97	2.78	16.53
Textularia	1.39	2.35	0.93	1.22	2.59	19.12
Triloculina	1.07	0.07	0.91	1.81	2.53	21.65
Siphonaptera	0.55	1.32	0.88	1.56	2.44	24.1
Amphistegina	1.86	2.63	0.88	1.53	2.44	26.54
Floresina	0.94	0	0.84	2.08	2.34	28.88
Gavelinopsis	2.12	1.27	0.84	1.34	2.34	31.22
Archaias	1.27	1.75	0.8	1.61	2.23	33.45
Pseudotriloculina	1.66	1.07	0.8	1.32	2.21	35.66
Neoconorbina	1.74	0.92	0.8	1.53	2.21	37.88
Borelis	0.81	1.61	0.78	1.56	2.15	40.03
Spirillina	0.99	0.2	0.74	1.91	2.06	42.08
Discorbis rosea	1.24	1.76	0.73	1.23	2.03	44.12
Cyclorbiculina	0.77	1.48	0.7	1.56	1.96	46.07
Affinetrina	0.91	0.22	0.7	1.64	1.94	48.01
Miliolinella	2.25	1.56	0.69	1.51	1.92	49.93
Laevipeneroplis	2.64	3.32	0.68	1.72	1.89	51.82
Triloculinella	1.1	1.24	0.65	1.22	1.8	53.62
Pseudoschlumbergerina	1.97	1.51	0.63	1.2	1.76	55.37
Schlumbergerina	0.37	0.77	0.59	1.34	1.64	57.01
Bigenerina	0.31	0.84	0.59	1.48	1.63	58.64

Appendix F (Continued)

Table F4. Continued

SIMPER---Combined Sediment and Rubble Samples						
Clusters 1 & 2	**Average Dissimilarity= 36.03**			**# genera = 90% is 49**		
Genera	**Cluster 1 Av.Abund**	**Cluster 2 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Pyrgo	0.6	0.81	0.57	1.41	1.58	60.22
Adelosina	1	0.59	0.57	1.34	1.58	61.8
Wiesnerella	0.69	0.13	0.56	1.74	1.55	63.35
Elphidium	0.68	0.65	0.53	1.53	1.48	64.83
Planktics	1	1.35	0.53	1.35	1.47	66.3
Quinqueloculina	2.82	3.05	0.53	1.19	1.46	67.76
Parasorites	0.99	1.29	0.53	1.28	1.46	69.23
Lachlanella	0.36	0.56	0.51	1.24	1.43	70.65
Cycloforina	0.65	0.44	0.51	1.29	1.41	72.06
Heterostegina	0.64	0.83	0.5	1.27	1.38	73.44
Discorbinella	0.62	0.73	0.49	1.28	1.37	74.81
Siphonina	0.39	0.73	0.49	1.43	1.36	76.17
Eponides	0.65	0.8	0.49	1.47	1.35	77.52
Hauerina	0.85	0.66	0.48	1.34	1.34	78.85
Nonionoides	0.54	0.47	0.47	1.28	1.29	80.15
Ammonia	0.91	0.77	0.45	1.32	1.25	81.4
Peneroplis	1.03	0.96	0.45	1.23	1.24	82.63
Spiroloculina	0.43	0.47	0.44	1.23	1.22	83.85
Cornuspiroides	0.44	0.11	0.43	1.27	1.2	85.06
Sorites	0.56	0.26	0.43	1.46	1.18	86.24
Haynesina	0.46	0	0.41	0.87	1.14	87.38
Nonionella	0.46	0.13	0.41	1.17	1.13	88.51
Cymballoporetta	0.36	0.25	0.39	1.06	1.07	89.58
Articulina	1.45	1.54	0.37	1.4	1.03	90.61

Appendix F (Continued)

Table F5. SIMPER dissimilarity results on the comparison of sediment and rubble samples by Clusters 3 & 2

SIMPER---Combined Sediment and Rubble Samples						
Clusters 3 & 2	**Average Dissimilarity= 41.11**			**# genera = 90% is 39**		
Genera	**Cluster 3 Av.Abund**	**Cluster 2 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Rosalina	2.12	1.87	1.79	1.27	4.36	4.36
Miliolinella	0	1.56	1.69	3.38	4.1	8.46
Textularia	1.47	2.35	1.51	1.25	3.68	12.14
Archaias	3.12	1.75	1.5	1.67	3.65	15.78
Pseudoschlumbergerina	0.22	1.51	1.46	1.84	3.55	19.33
Cyclorbiculina	2.74	1.48	1.36	1.96	3.31	22.64
Amphistegina	3.74	2.63	1.26	1.66	3.06	25.7
Asterigerina	2.47	2.88	1.22	1.12	2.96	28.66
Neoeponides	0.16	1.27	1.2	2.54	2.93	31.59
Siphonaptera	1.81	1.32	1.18	1.45	2.86	34.45
Quinqueloculina	2.06	3.05	1.14	1.54	2.77	37.22
Gavelinopsis	0.48	1.27	1.11	1.47	2.7	39.92
Planktics	0.44	1.35	1.07	1.53	2.61	42.54
Parasorites	0.53	1.29	1.03	1.52	2.51	45.05
Eponides	1.39	0.8	1.03	1.3	2.5	47.55
Schlumbergerina	0.76	0.77	0.99	1.34	2.4	49.95
Planorbulina	0.86	1.22	0.98	1.39	2.37	52.32
Pseudotriloculina	0.45	1.07	0.97	1.29	2.37	54.69
Elphidium	0.99	0.65	0.95	1.35	2.32	57.01
Siphonina	0.64	0.73	0.91	1.39	2.21	59.21
Neoconorbina	0.16	0.92	0.89	1.58	2.17	61.39
Discorbis rosea	1.91	1.76	0.87	1.45	2.12	63.51
Heterostegina	0.54	0.83	0.83	1.34	2.01	65.52
Peneroplis	0.38	0.96	0.79	1.39	1.93	67.46
Discorbinella	0	0.73	0.78	1.48	1.9	69.35
Bigenerina	0.83	0.84	0.77	1.45	1.88	71.24
Triloculinella	0.98	1.24	0.77	1.23	1.87	73.11
Ammonia	0.23	0.77	0.76	1.64	1.86	74.97
Pyrgo	0.38	0.81	0.76	1.22	1.85	76.82
Hauerina	0	0.66	0.71	1.27	1.72	78.54
Lachlanella	0.44	0.56	0.65	1.09	1.58	80.12
Adelosina	0	0.59	0.63	1.1	1.54	81.66
Borelis	1.23	1.61	0.63	0.92	1.53	83.19
Cibicides	0.47	0.33	0.61	0.97	1.47	84.66
Laevipeneroplis	3.43	3.32	0.6	1.35	1.46	86.12
Spiroloculina	0.22	0.47	0.54	1.02	1.31	87.43
Nonionoides	0	0.47	0.5	0.94	1.21	88.64
Clavulina	0.39	0.28	0.48	0.98	1.17	89.81
Cycloforina	0	0.44	0.47	0.94	1.14	90.95

Appendix F (Continued)

Table F6. SIMPER dissimilarity results on the comparison of sediment and rubble samples comparing Clusters 1 & 3

SIMPER---Combined Sediment and Rubble Samples						
Clusters 1 & 3	**Average Dissimilarity= 54.45**			**# genera = 90% is 45**		
Genera	**Cluster 1 Av.Abund**	**Cluster 3 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Miliolinella	2.25	0	2.28	5.36	4.19	4.19
Rosalina	2.94	2.12	2	1.89	3.68	7.87
Cyclorbiculina	0.77	2.74	2	3.51	3.67	11.54
Planorbulina	2.81	0.86	1.96	2.12	3.6	15.14
Amphistegina	1.86	3.74	1.92	2.75	3.52	18.67
Archaias	1.27	3.12	1.88	2.65	3.46	22.13
Pseudoschlumbergerina	1.97	0.22	1.77	2.94	3.25	25.38
Bolivina	1.69	0	1.71	3.33	3.15	28.52
Gavelinopsis	2.12	0.48	1.67	2.29	3.06	31.59
Neoconorbina	1.74	0.16	1.61	2.68	2.96	34.55
Asterigerina	1.58	2.47	1.58	1.86	2.9	37.44
Siphonaptera	0.55	1.81	1.5	1.87	2.76	40.2
Pseudotriloculina	1.66	0.45	1.3	1.77	2.39	42.59
Textularia	1.39	1.47	1.22	2.51	2.24	44.82
Cibicides	1.55	0.47	1.14	1.82	2.09	46.92
Neoeponides	1.22	0.16	1.11	2.15	2.03	48.95
Triloculina	1.07	0	1.08	1.89	1.98	50.93
Eponides	0.65	1.39	1.03	1.46	1.89	52.82
Adelosina	1	0	1.01	2.48	1.86	54.68
Spirillina	0.99	0	1	2.73	1.83	56.51
Discorbis	1.24	1.91	0.98	1.48	1.79	58.31
Floresina	0.94	0	0.95	2.06	1.75	60.06
Laevipeneroplis	2.64	3.43	0.92	1.77	1.69	61.75

Appendix F (Continued)

Table F6. Continued						
SIMPER---Combined Sediment and Rubble Samples						
Clusters 1 & 3	**Average Dissimilarity= 54.45**			**# genera = 90% is 45**		
Genera	**Cluster 1 Av.Abund**	**Cluster 3 Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Affinetrina	0.91	0	0.92	2.02	1.69	63.44
Elphidium	0.68	0.99	0.87	2.11	1.59	65.03
Hauerina	0.85	0	0.86	2.3	1.58	66.61
Quinqueloculina	2.82	2.06	0.86	1.57	1.58	68.19
Schlumbergerina	0.37	0.76	0.84	1.16	1.55	69.73
Ammonia	0.91	0.23	0.81	1.66	1.49	71.22
Borelis	0.81	1.23	0.77	1.55	1.41	72.64
Parasorites	0.99	0.53	0.77	1.68	1.41	74.05
Bigenerina	0.31	0.83	0.76	1.3	1.4	75.45
Peneroplis	1.03	0.38	0.76	1.44	1.4	76.85
Planktics	1	0.44	0.74	1.48	1.35	78.2
Siphonina	0.39	0.64	0.72	1	1.31	79.52
Wiesnerella	0.69	0	0.7	1.99	1.28	80.8
Triloculinella	1.1	0.98	0.69	1.24	1.28	82.08
Heterostegina	0.64	0.54	0.68	1.97	1.24	83.32
Cycloforina	0.65	0	0.65	1.28	1.2	84.52
Discorbinella	0.62	0	0.63	1.26	1.15	85.67
Sorites	0.56	0.23	0.57	1.76	1.05	86.72
Nonionoides	0.54	0	0.55	1.26	1.01	87.72
Pyrgo	0.6	0.38	0.53	1.39	0.98	88.7
Lachlanella	0.36	0.44	0.52	1.22	0.96	89.66
Spiroloculina	0.43	0.22	0.48	1.13	0.88	90.54

Appendix G: Raw SIMPER results on the combined data set to sample type

Table G1. SIMPER similarity results for sediment samples using combined data set.

Combined-- Sediment	**Average similarity:65.12**		**# genera = 90% is 26**		
Genera	**Av. Abund**	**Av. Sim**	**Sim/SD**	**Contrib. %**	**Cum.%**
Laevipeneroplis	3.35	6.36	5.9	9.76	9.76
Amphistegina	2.96	5.2	3.02	7.98	17.74
Quinqueloculina	2.76	4.77	5.03	7.32	25.06
Asterigerina	2.76	4.71	2.35	7.23	32.3
Archaias	2.15	3.39	1.85	5.2	37.5
Cyclorbiculina	1.85	2.96	2.14	4.55	42.05
Textularia	2.09	2.96	1.64	4.54	46.59
Discorbis	1.8	2.92	2.9	4.49	51.08
Articulina	1.6	2.88	4.01	4.43	55.51
Rosalina	1.94	2.73	2	4.2	59.71
Borelis	1.5	2.5	2.23	3.84	63.55
Siphonaptera	1.46	2.01	1.23	3.08	66.63
Triloculinella	1.16	1.6	1.34	2.46	69.09
Planktics	1.09	1.38	1.13	2.12	71.21
Planorbulina	1.11	1.34	1.04	2.06	73.27
Parasorites	1.07	1.32	1.08	2.02	75.29
Miliolinella	1.1	1.19	0.9	1.83	77.12
Pseudoschlumbergerina	1.13	1.19	0.88	1.83	78.94
Eponides	0.97	1.17	1.06	1.8	80.74
Neoeponides	0.94	1.15	1.11	1.76	82.5
Gavelinopsis	1.04	1.14	0.87	1.75	84.25
Bigenerina	0.84	1.05	1.09	1.61	85.86
Peneroplis	0.79	0.92	0.94	1.41	87.27
Pseudotriloculina	0.89	0.85	0.77	1.3	88.57
Heterostegina	0.74	0.74	0.77	1.14	89.71
Neoconorbina	0.7	0.7	0.79	1.08	90.78

Appendix G (Continued)

Table G2. SIMPER similarity results for rubble samples using combined data set.					
Combined-- Rubble	**Average Similarity: 75.66**		**# genera = 90% is 35**		
Genera	**Av. Abund**	**Av. Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Rosalina	2.94	4.57	7.53	6.04	6.04
Quinqueloculina	2.82	4.33	6.28	5.73	11.76
Planorbulina	2.81	4.33	6.83	5.72	17.48
Laevipeneroplis	2.64	4.11	8.66	5.44	22.92
Miliolinella	2.25	3.43	6.19	4.54	27.45
Gavelinopsis	2.12	3.24	4.72	4.28	31.73
Pseudoschlumbergerina	1.97	2.94	5.82	3.89	35.63
Amphistegina	1.86	2.62	3.99	3.46	39.08
Neoconorbina	1.74	2.48	3.27	3.28	42.37
Bolivina	1.69	2.38	3.49	3.14	45.51
Cibicides	1.55	2.35	5.45	3.11	48.62
Pseudotriloculina	1.66	2.31	2.38	3.05	51.67
Articulina	1.45	2.09	4.39	2.77	54.43
Asterigerina	1.58	2.08	2.92	2.75	57.18
Textularia	1.39	1.96	4.14	2.59	59.77
Neoeponides	1.22	1.67	2.43	2.2	61.98
Archaias	1.27	1.63	3.04	2.16	64.13
Discorbis	1.24	1.5	2.18	1.98	66.12
Peneroplis	1.03	1.39	3.61	1.83	67.95
Spirillina	0.99	1.32	2.26	1.75	69.7
Parasorites	0.99	1.31	2.07	1.73	71.43
Adelosina	1	1.31	2.16	1.73	73.16
Planktics	1	1.3	2.19	1.72	74.88
Triloculina	1.07	1.24	1.71	1.64	76.52
Triloculinella	1.1	1.23	1.2	1.63	78.15
Floresina	0.94	1.16	1.65	1.54	79.69
Affinetrina	0.91	1.1	1.63	1.45	81.14
Hauerina	0.85	1.09	1.81	1.43	82.58
Ammonia	0.91	1.07	1.53	1.42	84
Cyclorbiculina	0.77	0.96	1.88	1.27	85.27
Borelis	0.81	0.86	1.18	1.14	86.41
Wiesnerella	0.69	0.83	1.84	1.09	87.5
Elphidium	0.68	0.83	1.79	1.09	88.59
Heterostegina	0.64	0.78	1.79	1.04	89.63
Eponides	0.65	0.72	1.37	0.95	90.58

Appendix G (Continued)

Table G3. SIMPER dissimilarity results on the comparison of sediment and rubble samples using the combined data set.

Sediment vs. Rubble	**Average Dissimilarity= 41.45**			**# genera = 90% is 48**		
Genera	**Rubble Av. Abund**	**Sediment Av. Abund**	**Av. Diss**	**Diss/SD**	**Contrib. %**	**Cum.%**
Planorbulina	2.81	1.11	1.6	1.87	3.86	3.86
Bolivina	1.69	0.25	1.36	2.24	3.28	7.14
Asterigerina	1.58	2.76	1.31	1.82	3.15	10.29
Rosalina	2.94	1.94	1.3	1.53	3.13	13.42
Amphistegina	1.86	2.96	1.19	1.53	2.86	16.28
Miliolinella	2.25	1.1	1.16	1.36	2.8	19.08
Archaias	1.27	2.15	1.12	1.49	2.7	21.78
Cibicides	1.55	0.37	1.11	2.08	2.69	24.47
Gavelinopsis	2.12	1.04	1.09	1.43	2.62	27.09
Cyclorbiculina	0.77	1.85	1.08	1.42	2.62	29.7
Siphonaptera	0.55	1.46	1.06	1.52	2.56	32.27
Neoconorbina	1.74	0.7	1.04	1.57	2.5	34.77
Textularia	1.39	2.09	1.02	1.44	2.45	37.22
Pseudoschlumbergerina	1.97	1.13	0.97	1.28	2.33	39.55
Triloculina	1.07	0.05	0.96	1.82	2.32	41.87
Pseudotriloculina	1.66	0.89	0.95	1.38	2.28	44.16
Floresina	0.94	0	0.88	2.06	2.11	46.27
Spirillina	0.99	0.14	0.82	2.05	1.97	48.24
Discorbis	1.24	1.8	0.8	1.29	1.94	50.18
Borelis	0.81	1.5	0.77	1.56	1.87	52.05
Affinetrina	0.91	0.16	0.76	1.71	1.84	53.89
Laevipeneroplis	2.64	3.35	0.75	1.67	1.81	55.7

Appendix G (Continued)

Table G3. Continued						
Sediment vs. Rubble	**Average Dissimilarity= 41.45**			**# genera = 90% is 48**		
Genera	**Rubble Av. Abund**	**Sediment Av. Abund**	**Av. Diss**	**Diss/SD**	**Contrib. %**	**Cum.%**
Adelosina	1	0.42	0.7	1.5	1.69	57.39
Schlumbergerina	0.37	0.77	0.66	1.2	1.6	58.99
Triloculinella	1.1	1.16	0.66	1.22	1.6	60.58
Eponides	0.65	0.97	0.65	1.22	1.56	62.14
Bigenerina	0.31	0.84	0.64	1.37	1.54	63.68
Elphidium	0.68	0.75	0.63	1.59	1.52	65.2
Quinqueloculina	2.82	2.76	0.63	1.25	1.51	66.71
Wiesnerella	0.69	0.09	0.6	1.79	1.45	68.16
Parasorites	0.99	1.07	0.6	1.36	1.44	69.6
Hauerina	0.85	0.47	0.59	1.47	1.43	71.03
Planktics	1	1.09	0.59	1.36	1.43	72.46
Neoeponides	1.22	0.94	0.58	1.17	1.41	73.87
Pyrgo	0.6	0.69	0.56	1.4	1.35	75.22
Ammonia	0.91	0.61	0.56	1.31	1.34	76.56
Siphonina	0.39	0.71	0.56	1.13	1.34	77.91
Cycloforina	0.65	0.31	0.55	1.27	1.33	79.23
Heterostegina	0.64	0.74	0.55	1.42	1.33	80.56
Peneroplis	1.03	0.79	0.54	1.22	1.3	81.86
Discorbinella	0.62	0.51	0.53	1.25	1.28	83.14
Lachlanella	0.36	0.52	0.52	1.23	1.25	84.39
Nonionoides	0.54	0.33	0.49	1.27	1.18	85.57
Sorites	0.56	0.25	0.47	1.52	1.13	86.7
Spiroloculina	0.43	0.39	0.45	1.19	1.09	87.79
Cornuspiroides	0.44	0.08	0.44	1.26	1.06	88.84
Haynesina	0.46	0	0.43	0.86	1.03	89.87
Nonionella	0.46	0.09	0.42	1.15	1.02	90.9