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Comparing Reef Bioindicators on Benthic Environments off Southeast Florida

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by

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DEDICATION

I dedicate this thesis to my family, especially my mother, for her continuous support and effortless love throughout my graduate school career.

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ABSTRACT

A goal of the U.S. Environmental Protection Agency is to develop protocols applicable to coral reefs to distinguish between the effects of local water quality and those associated with regional to global environmental change. One test case is the current-dominated southeast coast of Florida where the Delray Outfall delivers 30 million gallons/day (114,000 cubic meters/day) of secondary-treated sewage into the ocean. Five study sites were established at depths between 15 and 18 m, and at distances between 1 and 18 km distance from the outfall, where the Stony Coral Rapid Bioassessment Protocol (RBP) was conducted to determine coral cover and selected other parameters. During sampling, 29 surface sediment samples were collected that I analyzed with respect to sediment texture, foraminiferal assemblages, and sediment constituents.

Most samples were characterized by fine sands with <2% mud. A total of 77 genera of foraminifers were identified, averaging 28 genera per sample. Abundances of foraminiferal shells varied among samples by more than an order of magnitude (83 to 1010 shells/g sediment). The Foraminifera in Reef Assessment and Monitoring (FORAM) Index was calculated from the foraminiferal data, yielding values of 3 or more

for all sites, with 26 of the 29 test sites yielding values >4, indicating that water quality should support coral growth.

Sediment constituent analyses revealed that the sediments were overwhelmingly dominated by unidentifiable fragments (60%), with molluscan debris second (20%), and calcareous algae third (4.5%); larger foraminiferal shells and coral fragments together made up <5.5%. The resulting sediment constituent (SEDCON) Index was consistently <2, indicating that erosional processes dominate over sediment production along the sampled shelf area.

Results provided by the FORAM and SEDCON indices are consistent with results for stony coral based on the RBP. Stony coral cover was low at all sites, <2%, indicating that coral occurs in the area but neither dominates the benthos nor builds reefs. No relationship was observed between any parameter and distance from the Delray Outfall. However, both the RBP and FORAM Index indicated poorest conditions at the Horseshoe site, suggesting unidentified stressors in that vicinity.

INTRODUCTION

State of Coral Reefs

The activities of humans are having dire effects on coral reef ecosystems worldwide (Hallock, 2005; Hoegh-Guldberg et al., 2007; many others). Biologically available nitrogen has doubled annually due to human activities and is washed in aquatic ecosystems directly through rainfall and indirectly by river runoff (Vitousek et al., 1997). With the ocean surface taking up 30% of the atmospheric carbon dioxide associated with fossil-fuel burning, deforestation, and other human activities, climates are changing while carbonate saturation in the oceans is decreasing, likely affecting rates calcification of reef building corals and other organisms that produce $CaCO_3$ shells or skeletons (Kleypas and Langdon, 2006). Due to the depletion of the stratospheric ozone layer, ultraviolet radiation (UV_b) has increased such that the intensity reaching the sea surface at Florida latitudes between April and August is comparable to that only seen around the summer solstice in the 1960s (Galloway et al., 1996). The input of additional terrestrial sediments associated with land-use, the outbreak of diseases, polluted groundwater and nutrient-rich runoff, damaging fishing practices, overfishing, heating of tropical water, and disturbance of important echinoderm species has all contributed to coral decline (Sammarco et al., 2007). With these threats increasing globally every year, the very future of coral reefs is in question (Jackson, 2008).

Introduction to Bioindicators

As defined by Jackson and others (2000), an ecological indicator is "a measure, an index of measures, or a model that characterizes an ecosystem or one of its critical components" and could be biological, chemical, or physical. A bioindicator has to be measureable and connected to a disturbance at one of the levels of organization in that ecosystem (Sammarco et al., 2007). Coral reefs have been studied for decades, but few measurements have related the condition of a coral reef to the potential of the benthic community to construct reefs (Sammarco et al., 2007). For example, high percent cover by mature colonies does not necessarily mean that juvenile corals are able to recruit (Hallock et al., 2004). Thus, after a hurricane or ship grounding, the loss of mature colonies does not predict whether juveniles will recruit and the reef will recover. Jameson (2001) reviewed parameters that have been proposed and discussed their potential for use as bioindicators of reef condition. A bioindicator for coral reefs, as for all ecosystems, has to be quantifiable and linked to a level of organization in the ecosystem (Sammarco et al., 2007). An ideal bioindicator could be used by regulatory agencies, like the U.S. Environmental Protection Agency (EPA), to create limits that could hold violators accountable (Sammarco et al., 2007).

Violaters can be held responsible with the aid of the Federal Water Pollution Control Act of 1987, also known as Clean Water Act (CWA). The aim is to, "to restore and maintain the chemical, physical, and biological integrity of the nation's waters by preventing point and nonpoint pollution sources, providing assistance to publicly owned treatment works for the improvement of wastewater treatment, and maintaining the integrity of wetlands" (CWA, 1987). One goal of the EPA's Stoney Coral Rapid

Bioassessment Protocol (RBP) is to provide biocriteria to allow states to establish thresholds for aquatic resources for certain bodies of water and subsequently monitor those areas (Sammarco et al., 2007; Fisher, 2007). If the area is considered "impaired" or the environment is not being able to sustain itself similar to surrounding waters, action should be taken.

Numerous researchers have proposed that foraminifers can be useful as bioindicators (e.g., Alve, 1995; Yanko et al., 1999; Schafer et al., 2000). Hallock et al. (2003) proposed characterizing low latitude, shallow-water benthic foraminiferal taxa into functional groups that reflect benthic community structure, including symbiont-bearing, stress-tolerant, and other small heterotrophic taxa (modified by Carnahan et al., 2009) (Table 1). Larger benthic foraminifers that host algal symbionts have similar environmental requirements as reef-building corals, and they respond to similar stresses (Hallock et al., 2003). Their shorter life cycle, as compared to that of reef-building corals, can indicate if changes in water quality might impact coral recruitment, thereby limiting the potential for coral communities to recover from a short-term mortality event. Hallock and others (2003) proposed that foraminifers, especially the larger foraminifers that are prevalent on healthy coral reefs, provide a relatively inexpensive and statistically favorable (in terms of sample size) bioindicator for coral reefs.

Table 1. Functional groups of Foraminifera used in coral reef assessments (Hallock et al., 2003, modified according to Carnahan et al., 2009).

Functional Group	*Order*	*Family*	*Genus*	*Distribution*
Symbiont-Bearing	Rotaliida	Amphisteginidae	*Amphistegina*	Circumtropical
		Calcarinidae	5 genera	Indo-Pacific
		Nummulitidae	*Heterostegina*	Circumtropical
			3 other genera	Indo-Pacific
	Miliolida	Alveolinidae	*Alveolinella*	Indo-Pacific
			Borelis	Circumtropical
		Peneroplidae	Several genera	Circumtropical
		Soritidae	*Sorites*	Circumtropical
			Amphisorus	Circumtropical
			3 genera	Caribbean
			Marginopora	Indo-Pacific
Opportunistic*	Trochamminida	Trochamminidae	Several genera	Cosmopolitan
	Textulariida	Lituolidae	Several genera	Cosmopolitan
	Buliminida	Bolivinidae	Several genera	Cosmopolitan
		Buliminidae	Several genera	Cosmopolitan
	Rotaliida	Rotaliidae	*Ammonia*	Cosmopolitan
		Elphidiidae	*Elphidium*	Cosmopolitan
Other Small Taxa	Miliolida	Most except larger taxa noted above		Cosmopolitan
	Rotaliida	Most except those noted above		Cosmopolitan
	Textulariida	Most		Cosmopolitan
	Other	Most		Cosmopolitan

(*Opportunistic is considered stress-tolerant in this project)

Characteristics of the Class Foraminifera

The Foraminifera are a class of amoeboid protists in the Phylum Granuloreticulosea, which are characterized by granular reticulopodia (a specific kind of pseudopodia) (Sen Gupta, 1999). The Foraminifera are characterized by an organic, agglutinated or calcareous test (i.e., shell), which may be a single chamber or multiple chambers. Though unicellular, the cytoplasm has two distinct components with relatively different functions. The endoplasm, which is contained within the shell, contains the nucleus (or many nuclei) and functions to accumulate the organic matter required for reproduction. The microtubule-rich ectoplasm is found in the outermost portion of the shell where it produces reticulopodia, enabling foraminifers to feed, move, and grow new chambers (Hallock, 1999).

Benthic foraminifers have been recorded in the geologic record back to the Cambrian Period (e.g., Sen Gupta, 1999). These protists can be epibenthic, epiphytic, infaunal, or planktic. The estimate of 16 orders and 10,000 species ranks them among the most diverse protists in the ocean. Foraminifers are identified by shell characteristics, including mineralogy, chamber arrangement, and ornamentation. These protists range in size from less than 0.05 mm to >5 cm in diameter. Only a small percentage, 40 to 50 species, are planktonic (Sen Gupta, 1999). Approximately 10% of the 150 families of Foraminifera include members that host algal endosymbionts (Lee and Anderson, 1991). Most, but not all benthic symbiont-bearing foraminifers tend to grow to larger sizes than most other benthic foraminifers and as a consequence, are generally known as the "larger benthic foraminifers" (Hallock, 1999).

There are both advantages and disadvantages to symbioses with algae (e.g. Hallock, 2000; Wooldridge, 2009). The major advantage is that the algae photosynthesize and provide the host with sugars or lipids when the host lives in shallow, clear waters where there is plenty of sunlight. But there are several disadvantages as well. If food is plentiful, faster growing smaller foraminifers can dominate the assemblage. If dissolved nutrients (DIN, DIP) are plentiful, the symbionts will use the products of photosynthesis to grow and reproduce, instead of providing photosynthate to the host. Algal symbiosis packs many active cells into a very small space. As a consequence, the host-symbiont unit, known as a holobiont, may be particularly sensitive to oxygen depletion at night when both the host and the algae are using oxygen for respiration. During the day, if the algae are exposed to too much sunlight, they may produce toxic levels of oxygen radicals within the host, causing photo-oxidative stress. Thus, environments containing excess organic carbon, excess nitrogen or excess sunlight can cause physiological stress to the host (Hallock, 1999; Hallock and others, 2006a,b; Wooldridge, 2009).

FORAM Index

The Foraminifera in Reef Assessment and Monitoring (FORAM) Index utilizes benthic foraminiferal assemblages from surface sediments (Table 1) (Carnahan et al., 2009).

Table 2. FI equation.

FI = (10 x P_s) + (P_o) + (2 x 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

This index is based upon three ecological groupings of foraminifers: a) the larger foraminifers that host algal symbionts, b) smaller foraminifers which bloom when food resources are fairly abundant but organic matter does not exceed availability of oxygen, and c) stress-tolerant foraminifers that prevail in euryhaline environments, where oxygen becomes limiting or where chemical pollutants are prevalent (Hallock et al., 2003, modified by Carnahan et al., 2009). Foraminiferal assemblages can indicate whether water quality can support healthy coral reefs and allow them to recover after a mortality event. For example, because foraminifers have shorter life spans than corals, the slow decline of water quality, which adult corals can survive, but that limits coral recruitment, can be detected using foraminifers (Hallock et al., 2004).

The FORAM Index (FI) is based upon observations that larger foraminifers are prevalent on healthy coral reefs, but smaller taxa overwhelm the larger ones when nutrification occurs (Hallock et al., 2003). With an indicator of suitable water quality, resource managers can predict if the coral reef can recover after a mass bleaching, ship grounding, or disease event. The FI would be able to detect, over time, decline in local water quality as compared to regional to global changes that are affecting benthic communities, including coral reefs (Hallock et al., 2003, 2006).

Carnahan and others (2009) explained that the FI has a reference point of 2 (Table 2), representing 100% smaller taxa. To have an FI>2, there must be some symbiont-bearing taxa, and for FI>4, symbiont-bearing taxa must make up at least 25% of the assemblage. The latter can occur either under limited supply of organic matter or physical conditions that limit the abundance of the shells of smaller foraminifers in the sediments. On the other hand, if stress-tolerant taxa are present and symbiont-bearing taxa are sparse or absent, the FI <2. Stress-tolerant foraminifers predominate under hyposaline environments, where excess organic matter results in high biological oxygen demand, or where other chemical stresses would preclude reef growth.

SEDCON Index

The SEDCON index, which utilizes sediment constituents, was proposed to indicate combined effects of water quality, benthic community structure, and bioerosion (Table 3) (Daniels, 2005). The basic premise is similar to that for the FI, i.e., sediment constituents will be dominated by remains of the dominant producers. So on a healthy accreting coral reef, sediments should be dominated by recognizable fragments of stony coral and the shells of larger benthic foraminifers, resulting in a SEDCON value greater than four (Table 3) (Daniels, 2005). On a nutrified reef, remains of calcareous green algae and grazing gastropods should dominate, generally with shells of smaller foraminifers and some unrecognizable fragments originating from bioerosion of the reef substrate. As nutrification increases, the proportion of bioeroded material should theoretically increase (Hallock, 1988).

Table 3. Examples of what the range of SEDCON Index values can represent.

SEDCON INDEX	Sediment Constituent Example
10	100% coral fragments
9	50% coral fragments, 50% LBF
8	100% symbiont-bearing foraminiferal shells
6	50% coral fragments and 50% algal or non-symbiotic skeletal grains
4	25% coral fragments and 75% algal or non-symbiotic skeletal grains
2	100% algal or non-symbiotic skeletal grains
1.05	50% algal or non-symbiont skeletal grains and 50% unidentifiable fragments
0.1	100% unidentifiable fragments

Southeast Florida Bioindicators Project

The EPA's Global Change Research Team (with principal investigator William Fisher) are developing protocols applicable to coral reefs to distinguish between the effects of local water quality and those of regional to global environmental change. One test case consists of 5 stations off the southeast of Florida at depths of ~15-17 m (Fig. 1), in the general vicinity of the Delray Outfall, which delivers 30 million gallon/day (~114,000 cubic meters) through a 0.76m port of secondarily treated sewage into the ocean in the Atlantic at a depth of 29m (Hazen and Sawyer, 1994). The discharge is approximately 609m away from shore. A collaborating team (Region IV, Georgia Institute of Technology) observed that *Lyngbya*, an opportunistic cyanobacterium, was prevalent on soft coral near the outfall and declined in abundance with increasing distance from the outfall (Fisher, unpublished 2007a).

Five study sites were established between 1 and 18 km distance from the outfall (Fig. 1, Table 4), where the Stony Coral Rapid Bioassessment Protocol (RBP) was conducted to determine coral cover and selected other parameters (Table 5). To make the observations, a radial belt transect method was used. In an area suitable for coral growth, a 10 m line was extended from a tripod. A 2 m wide swath was then surveyed along an 180^{o} arc, maintaining a distance of 10 m from the tripod, resulting in an assessment area of 56.6 m^2. The EPA field team also videotaped benthic communities along transects at Southeast Florida Coral Reef Evaluation and Monitoring Project (SECREMP) locations. Video transect stations at each site are 2x22 m and are 10 m apart. Sediment samples collected from the Delray sites and one SECREMP reference site were made available for my study.

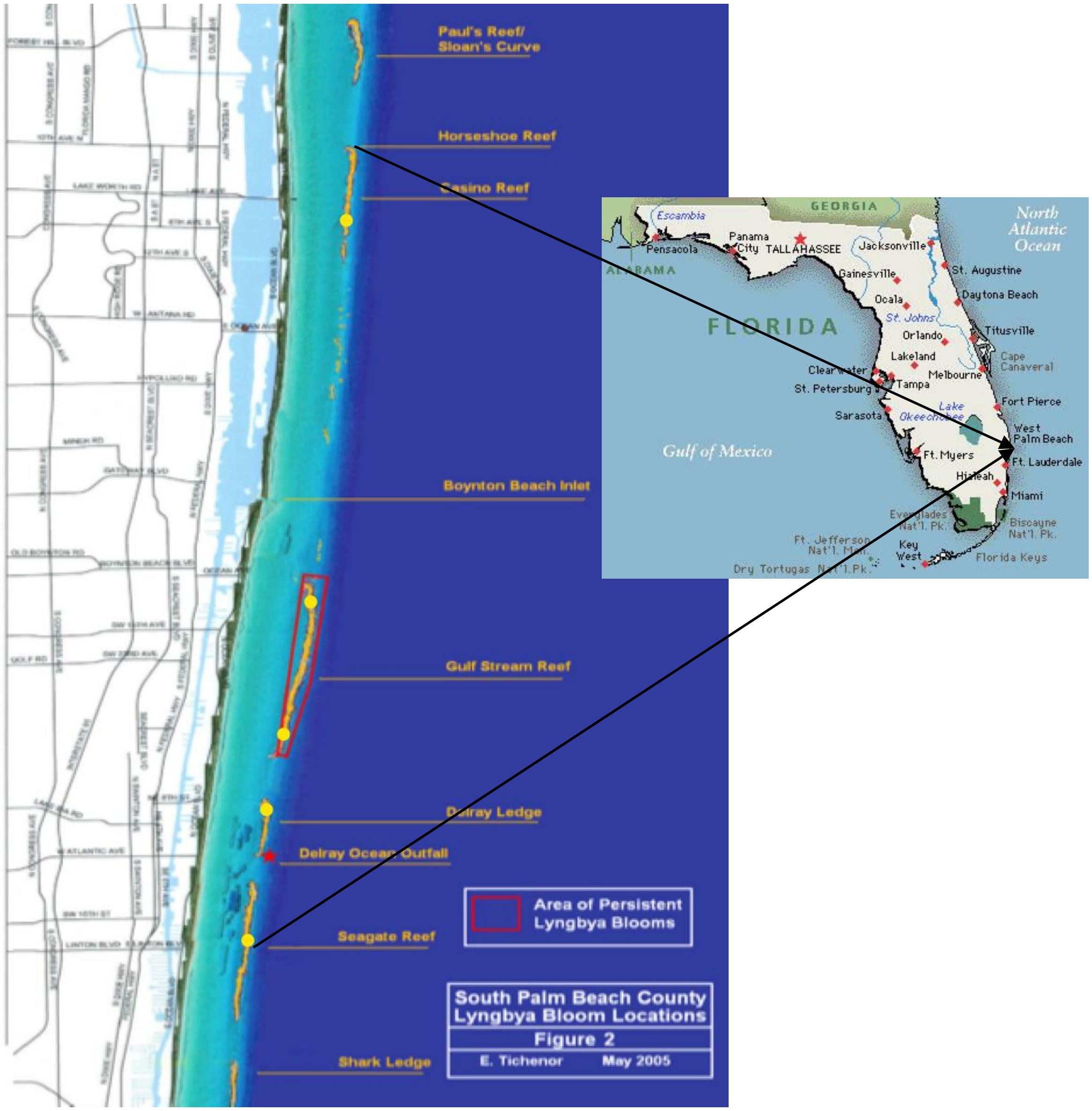

Figure 1. Sites sampled for this study, indicating locations along the southeast shelf of Florida (Fisher, unpublished 2007b) (image of Florida found at http://www.doh.state.fl.us/disease_ctrl/refugee/Overview/mission.html.)

Table 4. Site information: distance represents distance from Delray Outfall off southeast Florida. + indicates distance down current, - indicates up current

Site	Depth (m)	Distance (km)	Latitude	Longitude
Horseshoe Reef	17.4	+18.3	26° 37.561’	80° 01.410’
Gulf Stream N	15.2	+6.6	26° 31.240’	80° 01.935’
Gulf Stream S	15.8	+2.9	26° 29.272’	80° 02.350’
Delray Ledge	16.2	+1.0	26° 28.238’	80° 02.566’
Seagate Reef	16.5	-1.0	26° 26.587’	80° 02.848’
SECREMP	7.6	NA	26° 08.872’	80° 05.758’

Table 5. Rapid Bioassessment Protocol (RBP) coral condition indicators.

RBP CORAL CONDITION INDICATORS
<u>Abundance and Composition</u>
Abundance: number of colonies
Density: number of colonies per m^2 sea floor
Relative species abundance: abundance of a selected species per total abundance
Species (tax) richness: number of species occurring in a reef or region
Protected species: richness and abundance of protected coral species
Community composition: relative richness or abundance of a species or group of species with some discretionary biological or physical attributes (e.g, tolerance)
<u>Physical Status</u>
Total surface area (TSA): skeletal (living and dead) surface area of a whole colony (m^2)
3D total coral cover (3DTC): TSA per m^2 seafloor
Average colony surface area (AvCSA): TSA per total abundance (m^2)
Relative species total surface area: TSA of a selected species per TSA for the entire station
Population structure: colony size distribution for a species compared to colony number or other attribute
Community structure: colony size distribution for all species compared to colony number or other attribute
<u>Biological Condition</u>
Percent live tissue (%LT): proportion of live coral tissue on each colony
Live surface area (LSA): live 3D surface are (m^2)=TSA*[%LT/100]
Relative species live surface area: LSA of a selected species per LSA for the entire station
Vitality Index (VI): comparative index of live and total surface area ([LSA/TSA]*100)

PROJECT OBJECTIVES

The primary goal of my project was to apply the FORAM and SEDCON indices at sites off southeast Florida in conjunction with RBP bioindicator data collected by Region 4 personnel of the U.S. EPA Global Change Research Team. In doing so, I collected and analyzed foraminiferal assemblage and sediment constituent data. My results are then compared to the results from the EPA-conducted RBP.

METHODS

The 29 surface sediment samples assessed for this study were collected by the EPA Global Change Research Team on September 24-October 3, 2007 (Fisher, unpublished 2007b). Samples were kept frozen until processed. The samples were sent to me identified only by numbers so I had no knowledge of which samples represented replicates.

Sediment Texture and Constituents

Each sediment sample was washed over a 0.063 mm sieve to remove and collect most of the mud fraction. The suspended mud fraction was placed in a beaker and allowed to settle overnight, then as much water as possible was extracted from the beaker using a pipette without disturbing the settled mud. The remaining mud sample was placed into a smaller beaker and allowed to settle overnight, after which additional water was removed. Then the sample was dried in an oven at 60^{o}C and then weighed.

The sand-sized sediments (>0.063 mm) were washed into a small beaker and water was extracted using a pipette. The sample was then dried and weighed. The dry sand-sized fraction was divided using a sample splitter. One half of the sand-sized fraction was sub-sampled to assess the foraminiferal assemblages. The other half was used for grain-size analysis and assessment of the sediment constituents.

To determine grain-size distribution, the subsample was weighed, then placed in a tower of sieves (0.063-2mm) and shaken for 10 minutes. Each fraction was weighed and recorded, including any sediment that passed through the 0.063 mm sieve. The weight-percent of each size fraction was then calculated and the median phi size was determined.

For sediment constituent analysis, the medium and coarse sand fractions captured on the 0.5 mm and 1.0 mm sieves were thoroughly mixed. Approximately 1 g of sediment was sprinkled over a gridded tray and 300 pieces that fell on the grid lines were picked to a micropaleontological slide for further identification (Daniels, 2005). The 300 pieces are identified into the categories shown in Table 6. The SEDCON Index was calculated using the formula developed by Daniels (2005) (Table 7).

Table 6. Sediment constituent categories (Daniels, 2005).

SI functional group	Sediment grain	Community Role/ Feeding mode	Interpretation
c	Scleractinian coral	Primary reef builder, mixotrophic	Area suitable for calcification by algal symbiosis
f	Larger, symbiont-bearing foraminifers	Sediment producer, mixotrophic	Area suitable for calcification by algal symbiosis
ah	Coralline algae	Framework builder, autotrophic	Varies with other components
	Calcareous algae	Sediment producers, autotrophic	Nutrient signal, high $CaCo_3$ saturation
	Mollusks	Grazers/predators, heterotrophic	Food resources plentiful, nutrient signal
	Echinoid spines	Bioeroders/grazers, heterotrophic	Bioerosion, nutrient signal
	Worm tubes	Heterotrophic	Abundant food resources
	Other (smaller foraminifers, bryozoans, fecal pellets, etc)	Sediment producers, heterotrophic	Abundant food resources
u	Unidentifiable	Bioerosion proxy	Bioerosion proxy

Table 7. SEDCON Index equation (Daniels, 2005; Ramirez, 2008).

SI= $(10*P_c)+(8*P_f)+(2*P_{ah})+(0.1*P_u)$	
Where,	$P_c = N_c/T$ $P_f = N_f/T$ $P_{ah} = N_{ah}/T$ $P_u = N_u/T$
And,	**T**= total number of grains counted (300)
	N_c =number of coral fragments
	N_f =number of symbiont-bearing foraminifera/shells
	N_{ah} =number of coralline algae, calcareous algae, and heterotrophic skeletal grains
	N_u =number of unidentifiable grains

Foraminiferal Assemblages

The unsieved half of the sediment sample was thoroughly mixed, then a subsample was weighed, sprinkled over a gridded tray, and examined under a stereomicroscope (Hallock et al., 2003). All foraminiferal specimens were picked onto a micropaleontological faunal slide coated with water-soluble glue (Ramirez 2008). If 150-200 foraminifers were not obtained in the first portion, the procedure was repeated with subsequent weighed subsamples until 150-200 specimens were isolated or until 1 g of sediment was examined (Hallock et al., 2003). The foraminifers were then sorted and identified to genus and the genera were sorted into functional groups (Table 1). From the foraminiferal assemblages the FI was calculated using the formula described in Table 2.

After evaluating the foraminiferal assemblages and calculating the FORAM and SEDCON indices, those data were sent to the EPA Global Change Research Team for comparison with their data set. I then received the sample locations and depths from the EPA team, along with a summary of their coral assessment data (RBP) and the distances of the sites from the Delray Outfall. The null hypotheses are that sites do not differ significantly with respect to sample median phi size, percent mud, SEDCON index, foraminiferal shell abundances (#/gram of sediment), number of genera, and FI. The alternative hypotheses are that the samples will differ in one or more of the parameters.

Data Analysis

Data analysis procedures primarily used non-parametric techniques conducted using the PRIMER software (Clarke and Gorley, 2006). Bray-Curtis Cluster Analyses and Multi-Dimensional Scaling (Q-mode) were used to identify clusters of similar samples (Fig. 2) based on sediment constituents, foraminiferal assemblages, or both. The same techniques in r-mode attempted to identify foraminiferal taxa that tended to occur together. The raw data were transformed by finding the fourth roots to minimize the effect of larger sample sizes from dominating the analysis. Scatter plots and regression analysis were used to compare the indices, median phi, total genera, percent mud, and density. The ANOSIM analysis was used as an analysis of similarities, between the foraminifer abundance and distance, median phi and foraminifer abundance, SEDCON Index and foraminifer abundance, and distance and the FORAM Index.

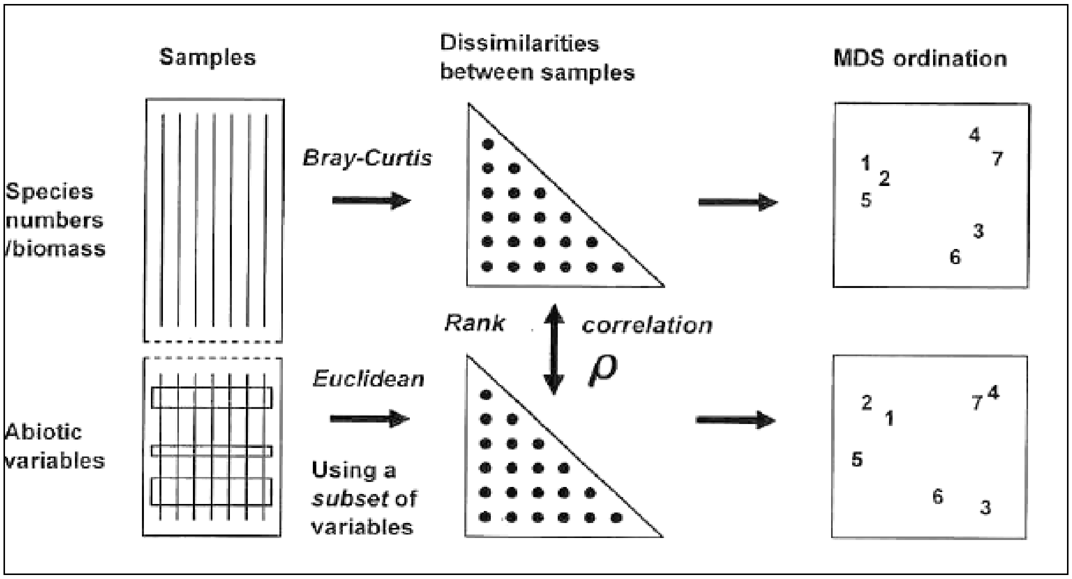

Figure 2.Schematic diagram of the Bray-Curtis and MDS plot output of data. (Clarke and Warwick, 2001).

Results

Sediment Texture and Constituents

Grain-size analysis of the 29 samples revealed that most contained less than 2% mud (Appendix I). The median phi ranged from -1 (coarse) to 3 (fine), with the finer sands predominating (Appendix II).

The dominant medium and coarse sand-sized sediment constituents in all samples were unidentifiable grains, with percentages ranging from 50% to 69%. Molluscan shell fragments were the most common identifiable constituent, ranging from 11% to 30%. Coral fragments and shells of symbiont-bearing foraminifers together never made up more than 13% of this size fraction (Fig. 3, Appendix III). Multidimensional scaling (MDS) plots of sample sites based on Bray-Curtis similarity analysis for the sediment constituents did not show any grouping by sample sites (Fig. 4). The MDS plot had a 2-D stress of 0.18, indicating a useful representation of the data set.

As a result of the predominance of unidentifiable grains, all of the SEDCON indices were similar and very low, ranging from 0.92 to 1.50 (Table 8). The lowest average SEDCON value was from the Horseshoe Reef, 1.13, while the highest average SEDCON value was from Gulf Stream South, 1.28.

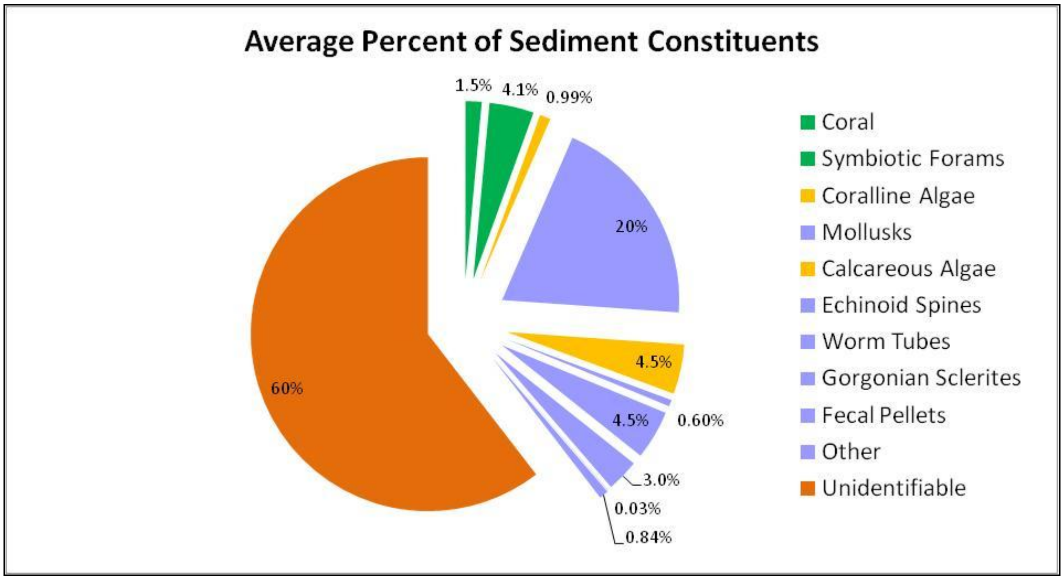

Figure 3. Average percent occurrence of sediment constituents in samples.

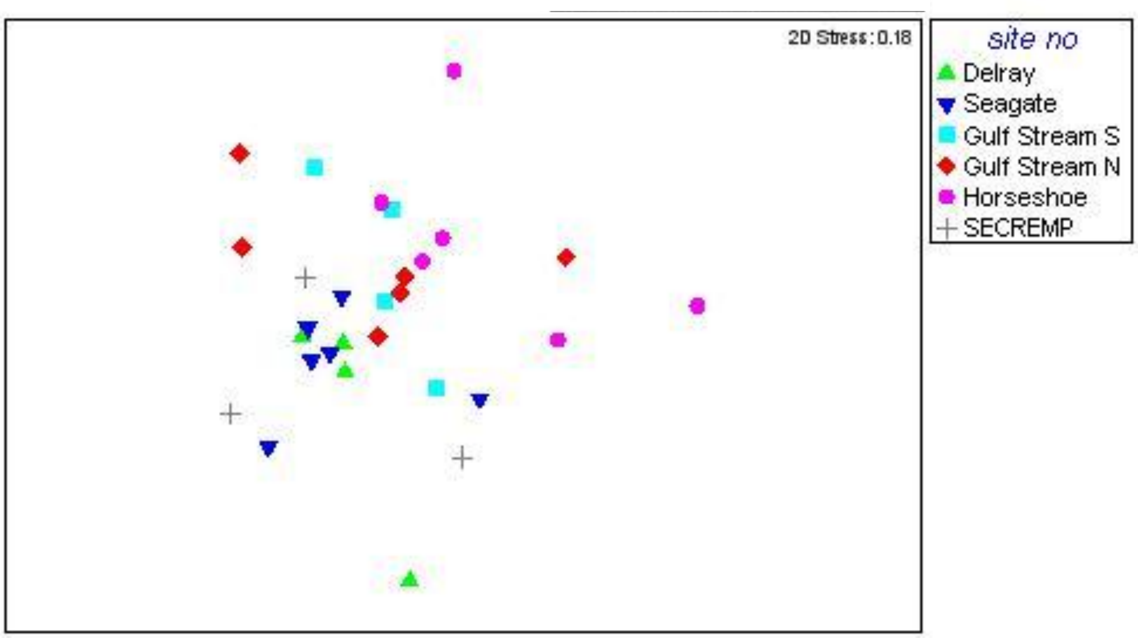

Figure 4. Bray-Curtis MDS plots for sediment constituents.

Foraminiferal Assemblages

In the 29 samples examined, a total of 77 genera were identified (Appendix IV). The dominant genus was *Amphistegina*, representing 24% of foraminiferal shells identified, followed by *Quinqueloculina*, 8.4%, *Laevipeneroplis*, 8.2%, *Ammonia*, 7.9% and *Haynesia*, 6.4%. Symbiont-bearing foraminifers dominated in 21 of the 29 samples and 4 were dominated by the other small foraminifera. The Horseshoe Reef foraminiferal assemblage was dominated by stress-tolerant taxa. The number of genera per sample ranged from 17 to 38. All of the samples yielded more than 50 shells per gram of sediment, so all samples were included in subsequent analyses. Seventeen out of the 29 samples did not have 150 foraminifers per one gram, but five of those reached at least 140 foraminifers. Shell abundance was quite variable, ranging from 84 to more than 1010 foraminiferal shells per gram.

Bray-Curtis similarity analysis for foraminiferal assemblages revealed that all samples examined were more than 50% similar (Fig. 5) and that 27 of the 29 samples analyzed were more than 60% similar. The three SECREMP samples, which were the most similar set of samples, were only 70-75% similar. The MDS plot produced by this analysis did not produce a meaningful representation, as the stress value exceeded 0.20 (see criteria of Clarke and Warwick, 2001).

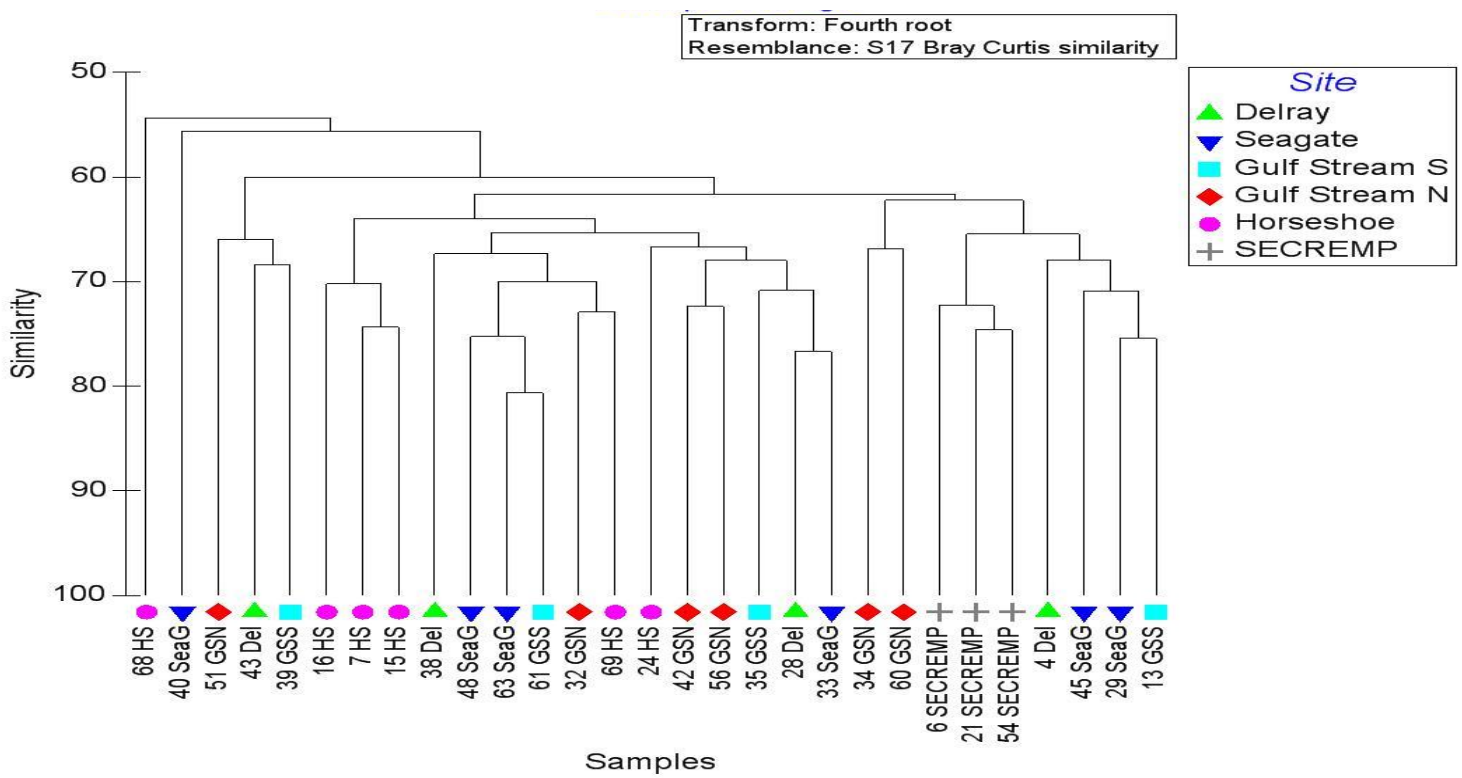

Figure 5. Cluster analysis of foraminiferal data showing similarity among sites.

Bray-Curits similarity analysis was also used for the generic-level data. Only 56 genera that occurred in at least 3 samples were included in the analyses (Fig. 7). The resulting cluster diagram revealed that 35 genera were very loosely related to the overall assemblage, while a core group of 21 genera tended to occur with >50% similarity. Those taxa tended to be the most common ones (Fig. 6), so an MDS plot was constructed that included only the 21 genera that made up at least 1% of the assemblage. That group included the symbiont-bearing, *Amphistegina, Borelis, Cyclorbiculina, Laevipenoroplis,* and *Asterigerina*, along with two ubiquitous smaller miliolids, *Quinqueloculina* and *Triloculina*, and the common agglutinate, *Textularia*, which occurred together 80% of the time. The two stress-tolerant genera, *Ammonia* and *Haynesia*, occurred together with more than 85% similarity.

All samples yielded a FI of at least 3, and 26 of 29 yielded FI values greater than 4. The three samples with FIs <4 were from fine sandy sediments (median phi=3).

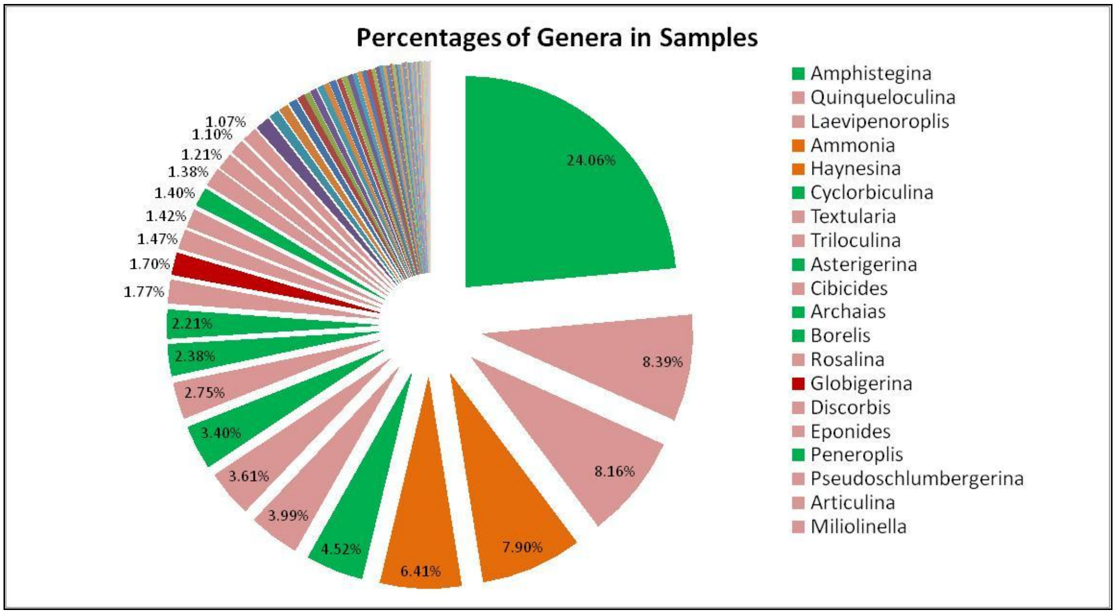

Figure 6. Percentages of genera in the samples from the southeast Florida coast.

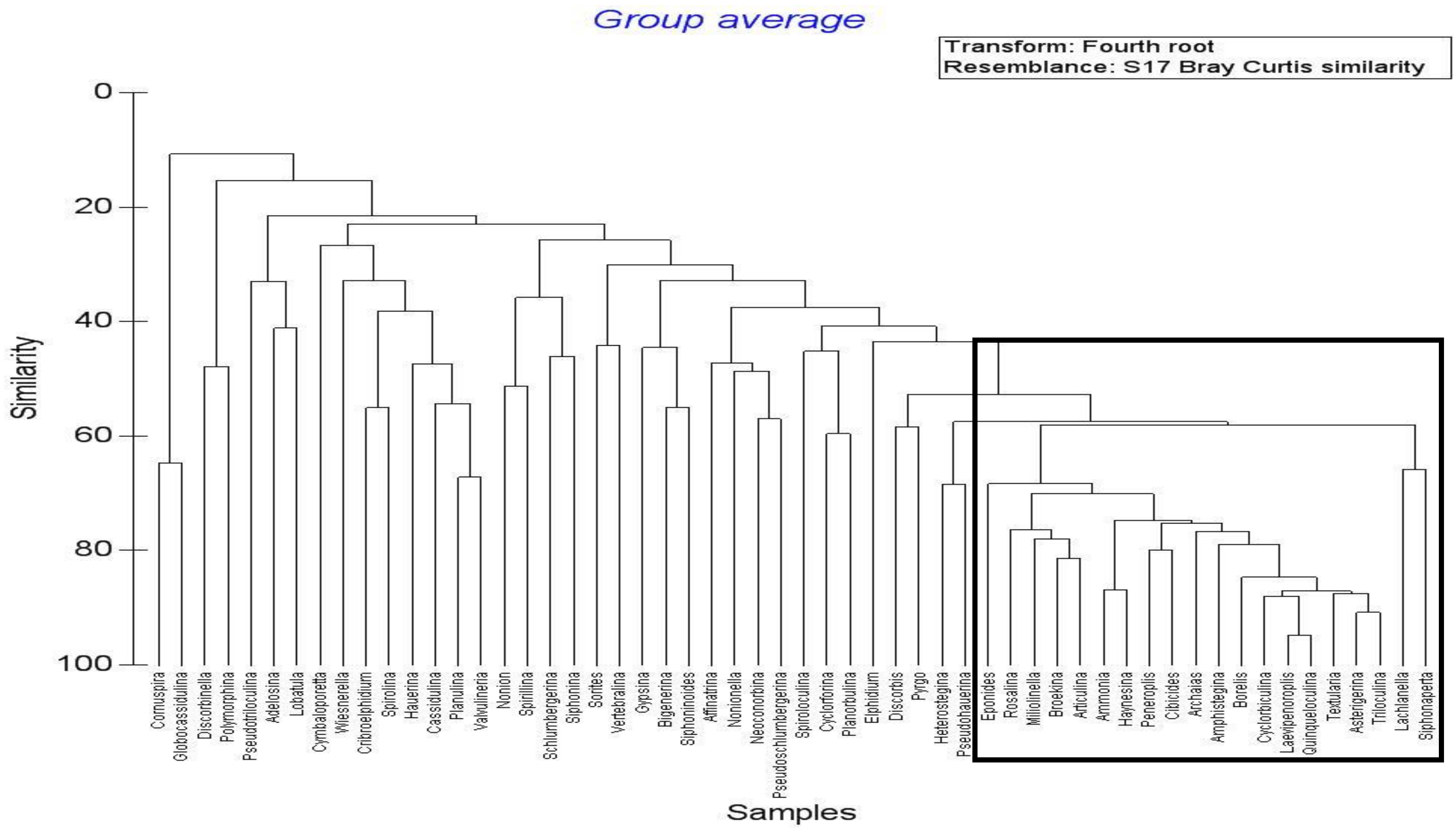

Figure 7. Cluster diagram of genera that occurred in at least three samples. The core group of 21 genera are in the black box.

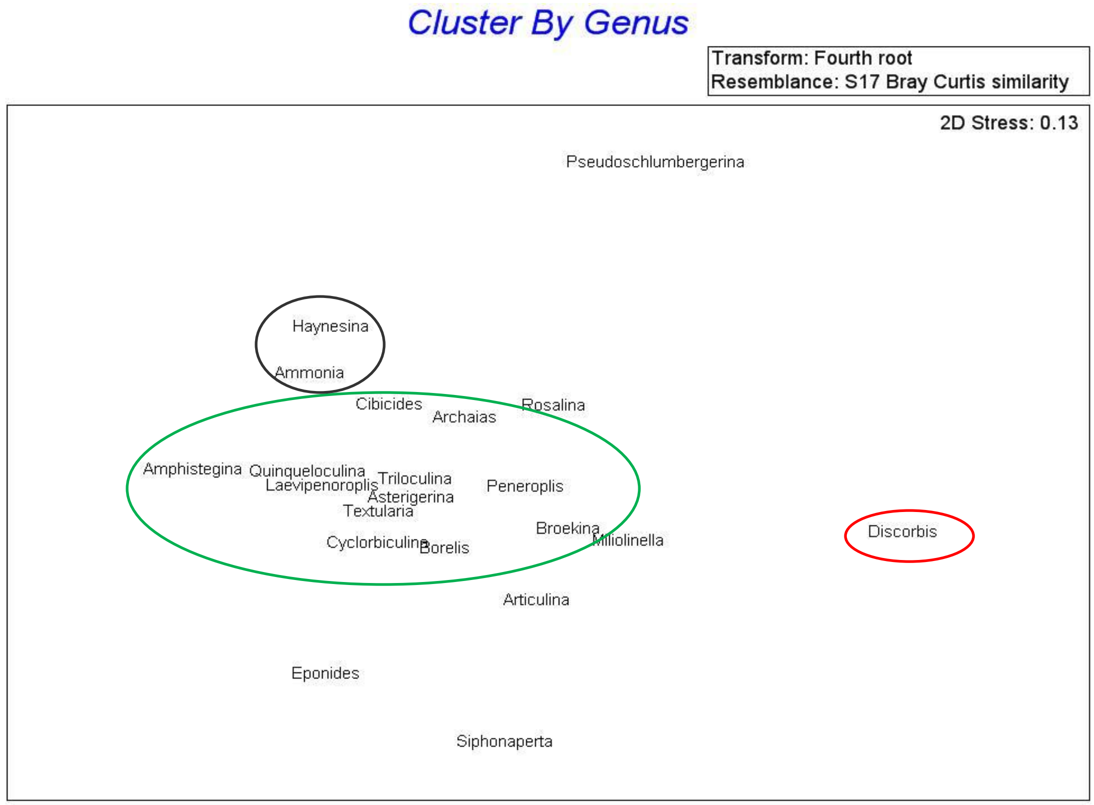

Figure 8. Bray-Curtis MDS plot of the genera that made up at least 1% of the specimens from the combined data (Fig. 6). The green ellipse indicates most of the symbiont-bearing foraminifers, red indicates the high energy tolerant *Discorbis*, and brown indicates the stress-tolerant genera.

Table 8. Summary of data from all sites: % mud, median phi, abundance (# shells/g sediment), number of genera, percentages of symbiont-bearing (SB), stress-tolerant (ST), and other small foraminifers (OS), as well as FORAM Index (FI) and SEDCON Index (SI).

Location	Site ID	% Mud	Median phi	Abundance	# Genera	% SB	% ST	% OS	FI	SI
Delray Ledge	4	0.35%	1	86	24	62.5%	4.5%	33.0%	6.95	1.19
	38	0.94%	1	117	27	69.7%	1.7%	28.6%	7.56	1.45
	43	0.43%	1	231	28	58.9%	10.3%	30.8%	6.61	0.98
	28	0.59%	-1	423	32	42.1%	23.6%	34.4%	5.13	1.41
Seagate	29	1.23%	2	181	27	64.8%	1.6%	35.5%	7.17	1.15
	33	0.89%	1	665	38	31.2%	13.8%	55.0%	4.36	1.14
	40	0.42%	1	101	19	71.3%	1.0%	27.7%	7.69	1.14
	45	0.59%	1	147	23	72.4%	0.7%	26.9%	7.78	1.50
	48	1.64%	2	191	26	64.3%	2.8%	32.9%	7.12	1.10
	63	0.72%	3	671	30	36.3%	21.1%	42.6%	4.69	1.40
Gulf Stream S	13	0.59%	2	188	27	57.4%	2.0%	40.5%	6.57	1.30
	35	0.67%	2	299	33	50.0%	16.4%	33.6%	5.84	1.18
	39	0.62%	2	1010	27	31.4%	24.5%	44.1%	4.26	1.50
	61	0.22%	1	214	27	52.4%	17.0%	30.6%	6.02	1.14
Gulf Stream N	32	0.60%	3	106	20	69.5%	6.7%	23.8%	7.50	1.16
	42	0.86%	3	237	34	52.4%	15.9%	31.7%	6.03	1.28
	51	0.29%	1	400	31	39.2%	23.5%	37.3%	4.90	1.01
	34	0.57%	2	166	28	65.7%	6.3%	28.0%	7.20	1.12
	56	0.70%	3	414	30	48.4%	9.7%	41.9%	5.77	1.50
	60	0.61%	3	366	23	47.0%	14.8%	38.3%	5.61	1.18
Horseshoe	24	1.53%	3	296	35	29.5%	42.1%	28.4%	3.94	1.18
	16	0.87%	3	465	28	31.4%	43.4%	25.1%	4.08	1.27
	69	0.53%	3	84	24	53.0%	19.3%	27.7%	6.05	0.92
	7	0.80%	3	355	30	30.5%	49.9%	24.6%	3.99	1.40
	15	1.10%	3	801	25	32.7%	41.8%	25.5%	4.20	0.95
	68	0.91%	3	510	17	22.5%	43.1%	34.3%	3.37	1.04
SECREMP	6	4.40%	2	467	33	53.9%	2.1%	44.0%	6.29	1.03
	21	4.20%	1	281	32	48.5%	0.7%	50.7%	5.87	1.19
	54	7.14%	1	291	24	53.8%	1.4%	44.8%	6.29	1.34

Comparisons

Comparing the FI to median phi (Fig. 9) shows that all FIs less than 4 were found in fine sands (phi 3). Otherwise no trend is evident between sediment texture and the FI.

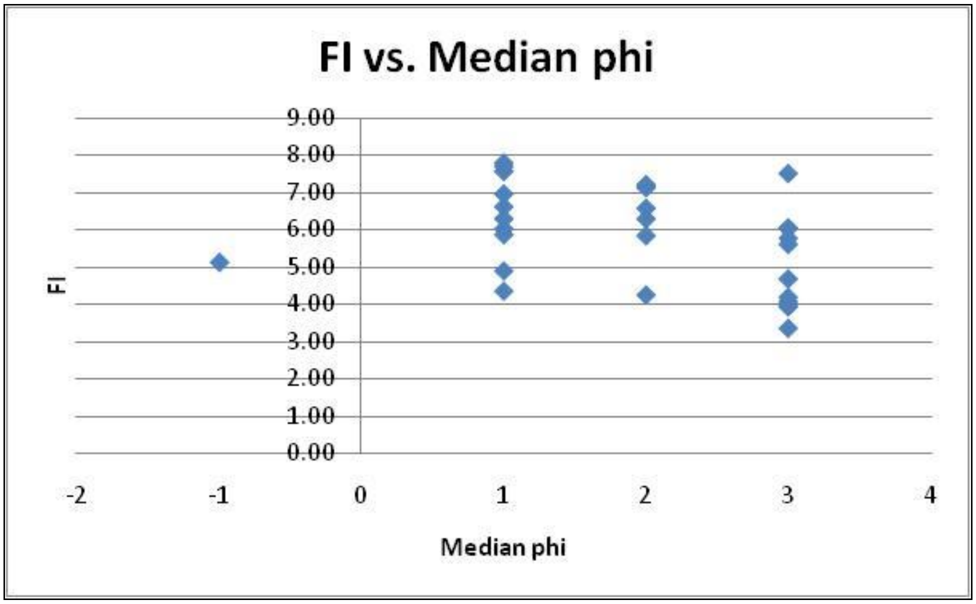

Figure 9. Comparison of FI with median phi.

There was no significant relationship with FI and the number of genera. In samples with an FI of 6 or more, between 19 and 34 genera were found (Fig. 10). Interestingly, number of genera per sample was not related to shell abundance (Fig.11; Appendix IV). In the sample with the highest shell abundance, 1010/g, 27 genera were identified. In the sample with the fewest shells, 84/g, 24 genera were found.

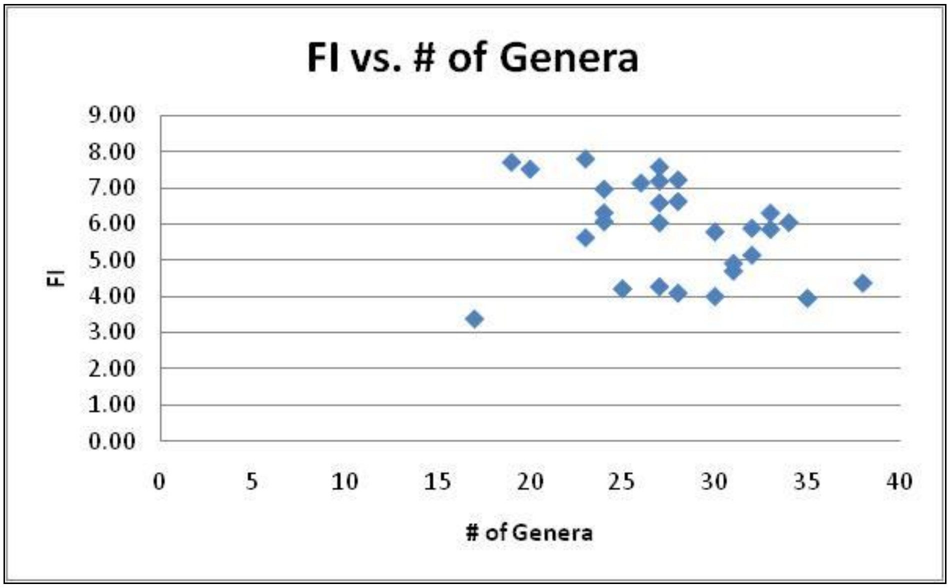

Figure 10: Comparison of the FI to the number of genera identified.

Comparing FI with the abundances of foraminiferal shells per gram of sediment revealed a significant (R^2=0.52, p <0.01) negative correlation (Fig. 11). The number of genera is not significantly correlated (R^2=0.07) with shell abundance (Fig. 12).

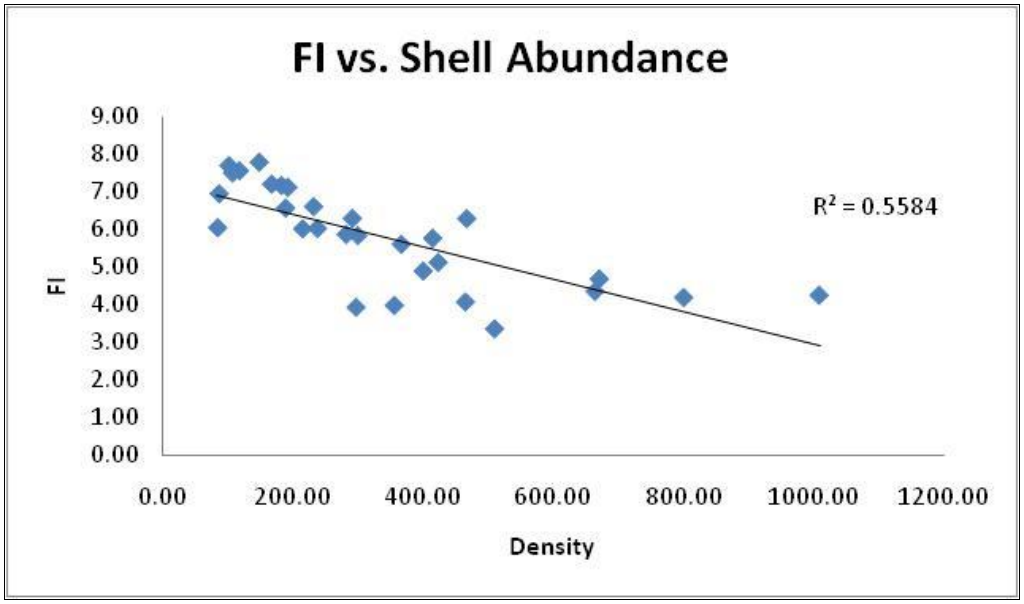

Figure 11. Comparison of FI with shell abundance (#/g) in the sediment samples ($p<0.01$).

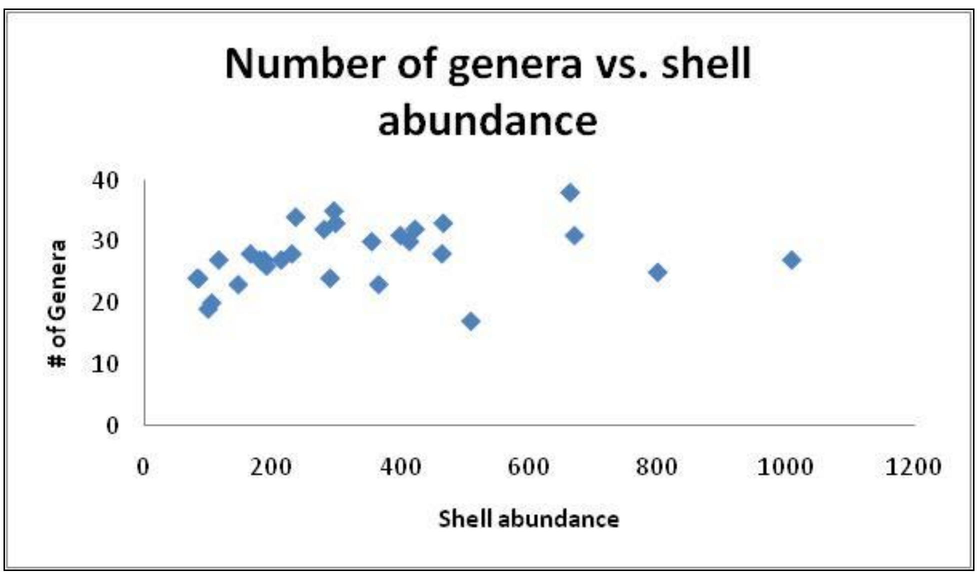

Figure 12. Comparison of the number of genera with shell abundance in samples.

Data from my analyses are summarized by sites in Table 8. Seagate had the highest median FI (7.2) and highest median percentage of SBF (65%), followed by Delray Ledge (median FI= 6.8, medium SBF= 61%). Those sites had relatively coarse sediments with the predominant median phi of 1. Gulfstream North and South Sites were relatively similar with median FI ~6 and median % SBF ~50% . The predominant median phi for those sites was 3. The highest shell abundance (1010/g) was recorded at the Gulfstream South site. The three samples from the SECREMP site were the most homogenous of the replicates, median SBF= 54%, FI= 6.2, and median phi= 1. The lowest overall percentage of symbiont-bearing foraminifers came from the Horseshoe Reef (median 31%), which also has the lowest FI values (median 4.0) and by far the highest percentages of the stress-tolerant taxa (median 43%). The ANOSIM analyses between median phi and the foraminifer abundance, distance from the outfall and foraminifer abundance, and distance from the outfall and the FI value (Fig. 13) revealed that Horseshoe Reef was the most significantly different compared to other sites, with r-values equaling, 3%, 1%, and 1.5%, respectively.

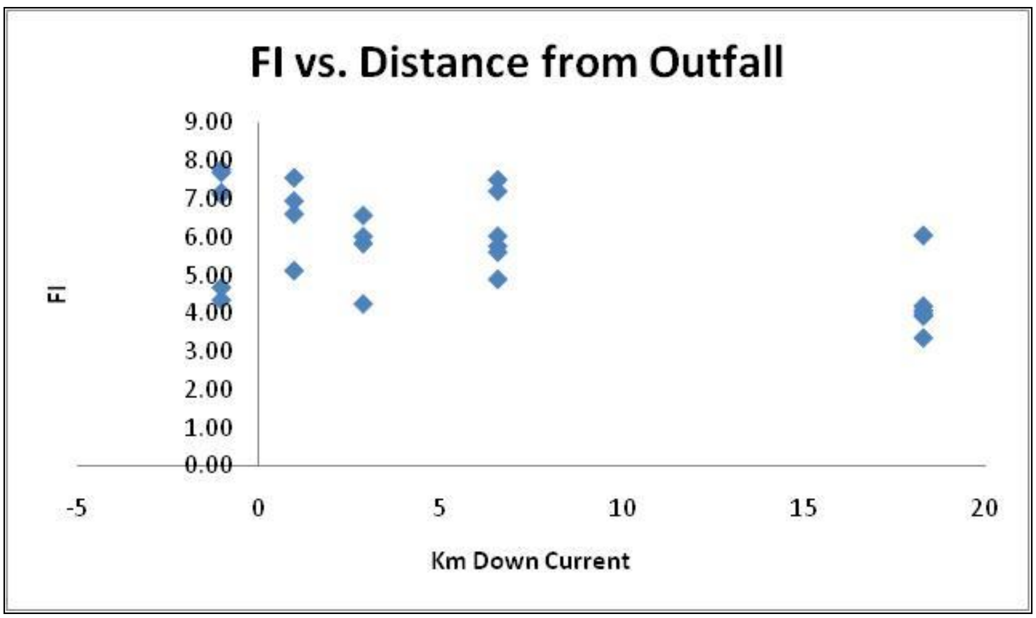

Figure 13. Comparison of FI with site –distance from the Delray Outfall. The negative distances reflect an upcurrent site.

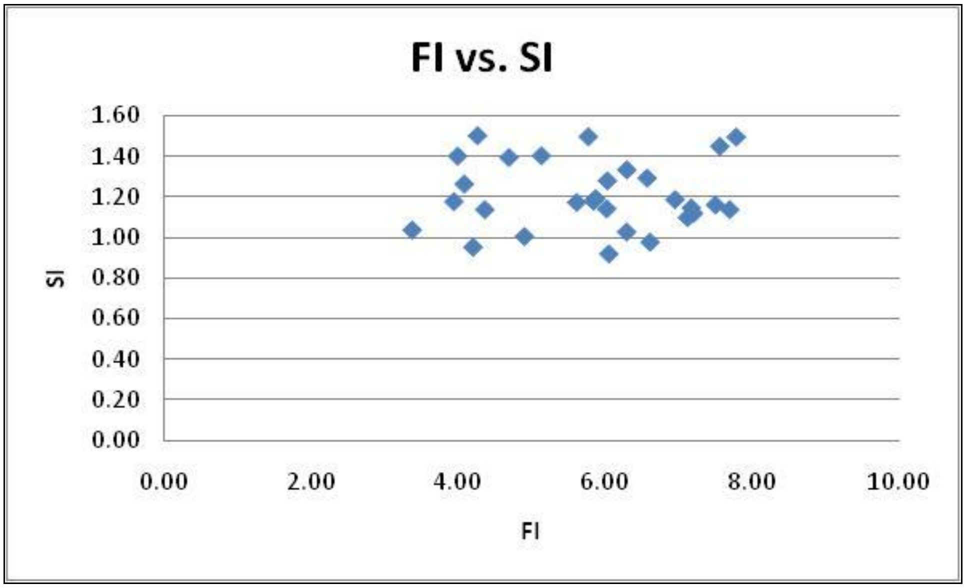

Figure 14. Comparison of FI with SEDCON Index.

The SEDCON indices were quite homogenous, varying less than 0.8 units over all 29 samples. Thus, comparisons of the SEDCON Index with other parameters (Fig. 14 and 15) yielded few insights. SEDCON Index values show no change with sediment texture, falling almost evenly into the three median phi groups, indicating that overall sediment texture did not influence composition of the medium and coarse fractions (Fig. 15; Table 8).

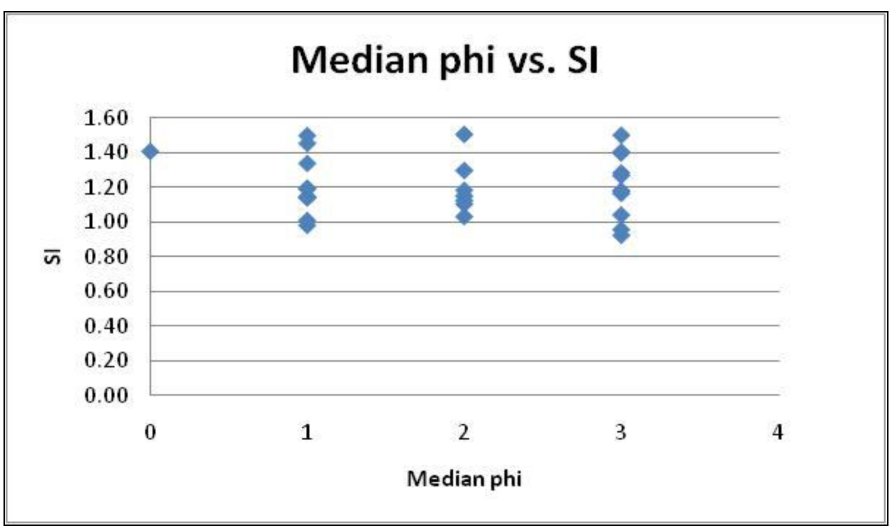

Figure 15. Comparison of median phi with the SEDCON Index.

DISCUSSION

Analyses of the sediment samples from the Delray Outfall vicinity revealed that the foraminiferal assemblages have a relatively high proportion of symbiont-bearing taxa, while the sediment constituents indicate predominance of erosion rather than reef accretion. Thus, my data indicate that the water quality at the sites is suitable at least for symbiont-bearing foraminifers and that other processes must be promoting erosion over carbonate accretion. Comparison of my data with the data collected by the EPA using the RBP methods may help illuminate what is limiting coral production.

Rapid Bioassessment Protocol Data

Fisher (2007) and personal communication (2009) described the results of Stony Coral Rapid Bioassessment Protocol (RBP) at the five Delray Outfall sites (Table 5). The goal for the RBP is use as a means to regulate human-induced stressors under the Clean Water Act (CWA). The RBP provided data on abundance, composition, size, presence of bleaching or disease in the corals, as well as, presence of boring sponges (*Cliona*), sea fans (*Gorgonia*), and sea urchins (*Diadema*) (Table 9). Coral species richness was determined for each station to compare with regional values.

Table 9. Parameters calculated for the RBP. (Fisher, personal communication 2009)

Colony density	= # of colonies/ 56.5m^2
Average % live tissue	= Σ% LT (live tissue) / # of colonies
Sum of Colony Surface Area	=total surface area (TSA)
Average Colony Surface Area (AVCSA)	= TSA/ # of colonies in transect area
Live Surface Area (LSA)	= colony surface area x decimal percent live tissue (eg. 87.5%= 0.875)
Vitality Index	= (LSA/TSA) *100
3D Total Coral Cover (3DTC)	=TSA normalized by transect area (m^2)
3D Live Coral Cover (3DLC)	=LSA normalized by transect area (m^2)

Table 10. Results of Stony Coral Rapid Bioassessment Protocol: colony density (Col Dens), average % live tissue (Avg %LT), % live cover (%LC), total surface area (TSA), live surface area (LSA), average coral surface area (Avg CSA), and vitality index (VI) (Fisher, personal communication, 2009).

	Col Dens	Avg %LT	%LC (2D)	TSA (3D)	LSA (3D)	%LC (3D)	Avg CSA	VI
Seagate	0.73	89.76	1.34	1.77	1.48	3.13	0.04	83.77
Delray	0.58	84.55	1.78	2.52	2.14	4.46	0.08	84.88
Gulf Stream S	0.51	82.76	1.91	3.15	2.22	5.57	0.11	70.60
Gulf Stream N	0.66	83.51	1.96	3.40	2.38	6.02	0.09	70.07
Horseshoe	0.23	90.00	0.74	0.95	0.83	1.67	0.07	87.66

The RBP assessment found 12 coral species and 153 colonies. The dominate coral was *Montastraea cavernosa* (60%), followed by *Porites astreoides*, *Meandrina meandrites*, and *Dichocoenia stokesii.* The relative abundance of *M. cavernosa* varied from 46% at Horseshoe Reef to 66% at Seagate Reef. The RBP data are summarized in Table 10.

There are no apparent trends in any parameter with distance from the Delray Outfall. Horseshoe Reef, which was the furthest downstream and Seagate Reef, which was the only upstream site, were least likely to be affected by the secondary-treated sewage treatment water. Seagate Reef had the highest colony density, but the smallest colonies overall. Horseshoe Reef had the lowest colony density and lowest coral cover, but the highest average percent live tissue on individual corals counted. The sites, which likely received the most nutrients from the treated sewage, were the Delray Ledge and Gulf Stream; these sites had higher total and live surface areas and higher percent live cover (both 2 and 3 dimensional estimates) than the other sites (Table 11). Fisher (personal communication, 2009) recommended repeat sampling with higher number of samples to better define variability among stations and detect potential differences in responses.

Live coral cover data collected by SECREMP from Palm Beach County stations in 2003-2005 (FWC-RI, 2005) were similar to those collected by Fisher using RBP (Fisher, personal communication, 2009). At three SECREMP sites, coral cover ranged from 0.90-1.26% and *M. cavernosa* was dominate. Fisher (personal communication, 2009) concluded that the two methods, SECREMP's videographic method and RBP provide similar estimates for live coral cover.

Table 11. Summary of RBP observations.

Site Name	**Observations**
Horseshoe Reef	• Lowest colony density • Lowest coral cover
Seagate Reef	• Highest density • Smallest colonies • Highest abundance of *Montastraea cavernosa*
Gulf Stream (N and S)	• Highest total and live coral cover • Largest colonies of *M. cavernosa* • Lowest vitality index (live surface area to total surface area)
Delray Ledge	• Infested by a boring sponge, *Cliona*

Comparisons of Sediment Samples with RBP Results

The EPA data for coral cover and average sizes are consistent with the data resulting from the FORAM and SEDCON Indices. The foraminiferal assemblages are dominated by *Amphistegina*, a symbiont-bearing genus, as is reflected in FI values ≥3 in all cases and >4 in 26 of 29 samples. According to Hallock and others (2003), in areas having an FI ≥4, water quality should be suitable for zooxanthellate corals. However, the SEDCON Indices for all sites indicate that erosion is the dominant process, which is consistent with the generally small coral size and low percent coral cover.

Interestingly, at Horseshoe Reef, which was 18.3 km from the Delray Outfall and the deepest of all the sites, 17.4 m, FI values were the lowest, as were both coral colony density and live coral cover. The stress-tolerant foraminiferal genera were dominant in most samples at this site. Thus, the various bioindicators suggest that other factors are likely affecting water quality at the Horseshoe Reef site.

Temperature may be limiting coral growth and accretion more than it is limiting the occurrence of symbiont-bearing foraminifers. This study represents the northern-most application of these bioindicators and previous studies have shown that the symbiont-bearing foraminifers have wider temperature ranges, thriving as low 15^{o}C (Culver and Buzas, 1981; Langer and Hottinger, 2000), than reef accretion (e.g., Grigg, 1982). According to Veron (2000), coral reef development occurs where temperatures lower than 18^{o}C and higher than about 32 ^{o}C not occur for extended periods of time. Many zooxanthellate coral taxa, like symbiont-bearing foraminifera, can occur over wider temperature ranges.

The southeast coastline of Florida has a narrow continental shelf that is exposed to the northward flowing Florida Current (Beal et. al., 2008). The narrow shelf is also exposed to high wave energy, at least during winter storms and summer tropical storm activity (Hartog et al., 2008). Strong mixing of sediments likely accounts for general similarity among sediment constituents and foraminiferal assemblages. The SEDCON values were extremely consistent and ranged from 0.92 to1.50 (Fig. 14). Ramirez (2008) found similar SEDCON values on the most exposed reefs in Biscayne National Park.

While the FI was not as consistent as the SEDCON Index, the similarity of foraminiferal assemblages among samples always exceeded 50%, but never exceeded 80% (Fig. 5). Moreover the assemblages in the three SECREMP samples, which were the most similar set of replicates, again, were only 70-75% similar to each other and fell within the overall group of samples. Likewise, a core group of 21 genera occurred in most of the samples (Fig. 8). Again, Ramirez (2008) reported similar foraminiferal assemblages and FI values on the most exposed reefs in Biscayne National Park.

CONCLUSIONS

1. The Delray Outfall did not appear to influence foraminiferal assemblages at the sampled sites.

2. The water quality at the southeast Florida study sites is sufficiently high that both zooxanthellate corals and algal symbiont-bearing larger foraminifers are common in the benthic communities, but are not major constituents in the sediments.

3. Unidentifiable carbonate fragments are the overwhelmingly dominant medium to coarse sand-size sediment constituents, while coral fragments and shells of larger foraminifers accounted for an average of less than 6% of the sediment constituents, indicating that erosion exceeds carbonate accretion in the study area.

4. The foraminifers found in the sediments represent a relatively well-mixed assemblage of the most common taxa along the southeast Florida shelf: *Amphistegina* was the single most abundant genus seen, followed by *Quinqueloculina* and *Laevipeneroplis.*

5. Shells of *Ammonia* and *Haynesia*, both characteristically stress-tolerant genera, were surprisingly abundant, making up approximately 15% of the total assemblage. Their abundance may reflect the prevalence of *Lyngbya* blooms observed in the study area.

6. Along the relatively narrow, high wave and current energy coastline of southeast Florida, regional processes are at least as important as local factors in limiting coral growth and reef accretion.

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APPENDICES

Appendix I. Percent mud and the corrected sediment mass examined for analysis of the foraminiferal assemblage.

Delray Ledge		
Site ID	**% Mud**	**Corrected mass (g)**
4	0.35%	1.031
28	0.59%	0.438
38	0.94%	1.027
43	0.43%	0.465
Seagate		
Site ID	**% Mud**	**Corrected mass (g)**
29	1.23%	1.015
33	0.89%	0.331
40	0.42%	1.007
45	0.59%	0.914
48	1.64%	0.759
63	0.72%	0.285
Gulf Stream S		
Site ID	**% Mud**	**Corrected mass (g)**
13	0.59%	0.979
35	0.67%	0.511
39	0.62%	0.102
61	0.22%	0.688
Gulf Stream N		
Site ID	**% Mud**	**Corrected mass (g)**
32	0.60%	0.995
34	0.57%	0.864
42	0.86%	0.617
51	0.29%	0.256
56	0.70%	0.377
60	0.61%	0.316
Horseshoe		
Site ID	**% Mud**	**Corrected mass (g)**
7	0.80%	0.457
15	1.10%	0.168
16	0.87%	0.317
24	1.53%	0.541
68	0.91%	0.202
69	0.53%	0.999
SECREMP		
Site ID	**% Mud**	**Corrected mass (g)**
6	4.40%	0.381
21	4.20%	0.976
54	7.14%	0.530

Appendix II. Sediment textures: weight percent by phi size.

				Phi Sizes			
Site ID	-1	0	1	2	3	4	>4
Delray Ledge	>2mm	>1mm	>0.5mm	>0.25mm	>0.125mm	>0.063mm	<0.063mm
4	27.2%	12.1%	29.6%	14.9%	10.3%	5.5%	0.4%
28	47.9%	8.3%	16.8%	9.1%	10.4%	6.9%	0.6%
38	9.9%	16.2%	33.7%	16.0%	14.2%	9.0%	0.9%
43	7.9%	24.2%	37.1%	13.9%	10.2%	6.4%	0.4%
				Phi Sizes			
Site ID	-1	0	1	2	3	4	>4
Seagate	>2mm	>1mm	>0.5mm	>0.25mm	>0.125mm	>0.063mm	<0.063mm
29	4.5%	9.6%	24.4%	20.6%	25.5%	14.1%	1.2%
33	10.2%	12.8%	32.7%	17.8%	15.7%	10.0%	0.9%
40	8.8%	16.3%	31.4%	26.7%	10.9%	5.5%	0.4%
45	7.5%	11.8%	32.4%	20.6%	18.0%	9.1%	0.6%
48	3.8%	8.5%	23.4%	17.7%	29.1%	15.9%	1.6%
63	6.1%	4.9%	14.3%	19.0%	35.4%	19.8%	0.7%
				Phi Sizes			
Site ID	-1	0	1	2	3	4	>4
Gulf stream S	>2mm	>1mm	>0.5mm	>0.25mm	>0.125mm	>0.063mm	<0.063mm
13	3.6%	11.1%	33.8%	20.0%	22.2%	8.7%	0.6%
35	4.0%	9.0%	25.0%	17.1%	30.3%	14.0%	0.7%
39	5.2%	7.0%	25.6%	17.4%	30.1%	14.0%	0.6%
61	10.9%	14.3%	32.3%	14.6%	21.4%	6.3%	0.2%
				Phi Sizes			
Site ID	-1	0	1	2	3	4	>4
Gulf Stream N	>2mm	>1mm	>0.5mm	>0.25mm	>0.125mm	>0.063mm	<0.063mm
32	1.9%	2.4%	7.9%	9.0%	30.7%	47.5%	0.6%
34	3.8%	9.9%	27.0%	20.1%	30.4%	8.2%	0.6%
42	1.4%	7.8%	20.7%	17.1%	40.3%	12.0%	0.9%
51	4.4%	16.6%	32.9%	15.5%	23.0%	7.3%	0.3%
56	11.8%	3.4%	6.5%	10.2%	52.8%	14.6%	0.7%
60	4.7%	6.4%	17.5%	19.0%	42.3%	9.5%	0.6%
				Phi Sizes			
Site ID	-1	0	1	2	3	4	>4
Horseshoe	>2mm	>1mm	>0.5mm	>0.25mm	>0.125mm	>0.063mm	<0.063mm
7	3.8%	6.6%	18.1%	10.7%	31.0%	28.9%	0.8%
15	4.3%	4.8%	10.3%	9.4%	30.4%	39.8%	1.1%
16	6.5%	2.4%	5.9%	6.2%	29.5%	48.8%	0.9%
24	1.8%	2.4%	7.8%	8.9%	30.4%	47.1%	1.5%
68	4.8%	9.2%	20.3%	9.7%	23.4%	31.7%	0.9%
69	21.3%	10.0%	9.7%	0.7%	16.8%	40.9%	0.5%
				Phi Sizes			
Site ID	-1	0	1	2	3	4	>4
SECREMP	>2mm	>1mm	>0.5mm	>0.25mm	>0.125mm	>0.063mm	<0.063mm
6	3.8%	10.2%	26.9%	29.3%	22.0%	3.3%	4.4%
21	8.0%	15.7%	26.7%	21.9%	19.5%	4.0%	4.2%
54	45.0%	3.4%	7.6%	18.0%	16.0%	3.0%	7.1%

Appendix III. Raw data for the sediment constituents and SEDCON Index.

	Sample IDs			
	Delray Ledge			
Constituent Counts	4	38	28	43
Coral (Pc)	7	8	6	3
Symbiotic Forams (Pf)	9	11	18	7
Coralline Algae (Pah)	4	0	5	1
Molluscs (Pah)	54	62	34	54
Calcareous Algae (Pah)	23	43	33	24
Echinoid Spines (Pah)	2	0	4	2
Worm Tubes (Pah)	7	11	15	6
Gorgonian Sclerites (Pah)	6	10	8	4
Fecal Pellets (Pah)	0	0	0	0
Other (Pah)	2	0	1	3
Unidentifiable (Pu)	186	155	176	196
Percentages				
Coral	2.33%	2.67%	2.00%	1.00%
Symbiotic Forams	3.00%	3.67%	6.00%	2.33%
Coralline Algae	1.33%	0.00%	1.67%	0.33%
Molluscs	18.00%	20.67%	11.33%	18.00%
Calcareous Algae	7.67%	14.33%	11.00%	8.00%
Echinoid Spines	0.67%	0.00%	1.33%	0.67%
Worm Tubes	2.33%	3.67%	5.00%	2.00%
Gorgonian Sclerites	2.00%	3.33%	2.67%	1.33%
Fecal Pellets	0.00%	0.00%	0.00%	0.00%
Other	0.67%	0.00%	0.33%	1.00%
Unidentifiable	62.00%	51.67%	58.67%	65.33%
SEDCON INDEX VALUE	1.189	1.452	1.405	0.979

Appendix III. (Continued)

	Samples IDs					
	Seagate					
Constituent Counts	29	33	40	45	48	63
Coral (Pc)	3	3	5	13	2	11
Symbiotic Forams (Pf)	12	9	7	12	10	9
Coralline Algae (Pah)	3	1	4	0	2	4
Molluscs (Pah)	54	63	51	53	55	54
Calcareous Algae (Pah)	21	23	27	19	14	28
Echinoid Spines (Pah)	0	3	2	4	1	1
Worm Tubes (Pah)	15	12	20	21	19	15
Gorgonian Sclerites (Pah)	7	4	3	5	9	3
Fecal Pellets (Pah)	0	0	0	0	0	0
Other (Pah)	0	5	2	1	6	5
Unidentifiable (Pu)	185	177	179	172	182	170
Percentages						
Coral	1.00%	1.00%	1.67%	4.33%	0.67%	3.67%
Symbiotic Forams	4.00%	3.00%	2.33%	4.00%	3.33%	3.00%
Coralline Algae	1.00%	0.33%	1.33%	0.00%	0.67%	1.33%
Molluscs	18.00%	21.00%	17.00%	17.67%	18.33%	18.00%
Calcareous Algae	7.00%	7.67%	9.00%	6.33%	4.67%	9.33%
Echinoid Spines	0.00%	1.00%	0.67%	1.33%	0.33%	0.33%
Worm Tubes	5.00%	4.00%	6.67%	7.00%	6.33%	5.00%
Gorgonian Sclerites	2.33%	1.33%	1.00%	1.67%	3.00%	1.00%
Fecal Pellets	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Other	0.00%	1.67%	0.67%	0.33%	2.00%	1.67%
Unidentifiable	61.67%	59.00%	59.67%	57.33%	60.67%	56.67%
SEDCON INDEX VALUE	1.148	1.139	1.140	1.497	1.101	1.397

Appendix III. (Continued)

	Sample IDs			
	Gulf Stream S			
Constituent Counts	13	35	39	61
Coral (Pc)	5	2	1	5
Symbiotic Forams (Pf)	17	15	22	11
Coralline Algae (Pah)	4	6	1	3
Molluscs (Pah)	57	39	84	48
Calcareous Algae (Pah)	3	24	13	4
Echinoid Spines (Pah)	0	4	0	1
Worm Tubes (Pah)	14	13	9	25
Gorgonian Sclerites (Pah)	7	12	17	9
Fecal Pellets (Pah)	0	0	0	0
Other (Pah)	7	0	1	3
Unidentifiable (Pu)	186	185	152	191
Percentages				
Coral	1.67%	0.67%	0.33%	1.67%
Symbiotic Forams	5.67%	5.00%	7.33%	3.67%
Coralline Algae	1.33%	2.00%	0.33%	1.00%
Molluscs	19.00%	13.00%	28.00%	16.00%
Calcareous Algae	1.00%	8.00%	4.33%	1.33%
Echinoid Spines	0.00%	1.33%	0.00%	0.33%
Worm Tubes	4.67%	4.33%	3.00%	8.33%
Gorgonian Sclerites	2.33%	4.00%	5.67%	3.00%
Fecal Pellets	0.00%	0.00%	0.00%	0.00%
Other	2.33%	0.00%	0.33%	1.00%
Unidentifiable	62.00%	61.67%	50.67%	63.67%
SEDCON INDEX VALUE	1.295	1.182	1.504	1.144

Appendix III. (Continued)

	Sample IDs					
	Gulf Stream N					
Constituent Counts	32	42	51	34	56	60
Coral (Pc)	2	7	3	2	0	0
Symbiotic Forams (Pf)	15	13	10	12	25	11
Coralline Algae (Pah)	4	9	4	4	4	1
Molluscs (Pah)	65	44	50	68	71	76
Calcareous Algae (Pah)	1	10	3	3	20	19
Echinoid Spines (Pah)	0	3	2	4	0	2
Worm Tubes (Pah)	8	14	13	8	11	11
Gorgonian Sclerites (Pah)	17	14	12	12	7	12
Fecal Pellets (Pah)	0	0	0	0	0	0
Other (Pah)	0	2	2	2	4	3
Unidentifiable (Pu)	188	184	201	185	158	165
Percentages						
Coral	0.67%	2.33%	1.00%	0.67%	0.00%	0.00%
Symbiotic Forams	5.00%	4.33%	3.33%	4.00%	8.33%	3.67%
Coralline Algae	1.33%	3.00%	1.33%	1.33%	1.33%	0.33%
Molluscs	21.67%	14.67%	16.67%	22.67%	23.67%	25.33%
Calcareous Algae	0.33%	3.33%	1.00%	1.00%	6.67%	6.33%
Echinoid Spines	0.00%	1.00%	0.67%	1.33%	0.00%	0.67%
Worm Tubes	2.67%	4.67%	4.33%	2.67%	3.67%	3.67%
Gorgonian Sclerites	5.67%	4.67%	4.00%	4.00%	2.33%	4.00%
Fecal Pellets	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Other	0.00%	0.67%	0.67%	0.67%	1.33%	1.00%
Unidentifiable	62.67%	61.33%	67.00%	61.67%	52.67%	55.00%
SEDCON INDEX VALUE	1.163	1.281	1.007	1.122	1.499	1.175

Appendix III. (Continued)

	Sample IDs Horseshoe					
Constituent Counts	24	16	69	7	15	68
Coral (Pc)	0	2	1	5	2	4
Symbiotic Forams (Pf)	15	17	9	11	3	9
Coralline Algae (Pah)	3	2	2	5	3	3
Molluscs (Pah)	83	69	55	91	70	57
Calcareous Algae (Pah)	0	3	1	0	1	2
Echinoid Spines (Pah)	2	0	2	1	4	1
Worm Tubes (Pah)	11	18	12	16	17	12
Gorgonian Sclerites (Pah)	8	8	13	19	10	14
Fecal Pellets (Pah)	0	0	0	2	0	1
Other (Pah)	1	3	2	0	7	0
Unidentifiable (Pu)	177	178	203	150	183	197
Percentages						
Coral	0.00%	0.67%	0.33%	1.67%	0.67%	1.33%
Symbiotic Forams	5.00%	5.67%	3.00%	3.67%	1.00%	3.00%
Coralline Algae	1.00%	0.67%	0.67%	1.67%	1.00%	1.00%
Molluscs	27.67%	23.00%	18.33%	30.33%	23.33%	19.00%
Calcareous Algae	0.00%	1.00%	0.33%	0.00%	0.33%	0.67%
Echinoid Spines	0.67%	0.00%	0.67%	0.33%	1.33%	0.33%
Worm Tubes	3.67%	6.00%	4.00%	5.33%	5.67%	4.00%
Gorgonian Sclerites	2.67%	2.67%	4.33%	6.33%	3.33%	4.67%
Fecal Pellets	0.00%	0.00%	0.00%	0.67%	0.00%	0.33%
Other	0.33%	1.00%	0.67%	0.00%	2.33%	0.00%
Unidentifiable	59.00%	59.33%	67.67%	50.00%	61.00%	65.67%
SEDCON INDEX VALUE	1.179	1.266	0.921	1.403	0.954	1.039

Appendix III. (Continued)

	Sample IDs		
	SECREMP		
Constituent Counts	**6**	**21**	**54**
Coral (Pc)	1	14	10
Symbiotic Forams (Pf)	16	5	13
Coralline Algae (Pah)	3	1	0
Molluscs (Pah)	39	59	47
Calcareous Algae (Pah)	8	4	20
Echinoid Spines (Pah)	3	1	3
Worm Tubes (Pah)	15	11	11
Gorgonian Sclerites (Pah)	2	3	2
Fecal Pellets (Pah)	0	0	0
Other (Pah)	5	0	6
Unidentifiable (Pu)	208	202	188
Percentages			
Coral	0.33%	4.67%	3.33%
Symbiotic Forams	5.33%	1.67%	4.33%
Coralline Algae	1.00%	0.33%	0.00%
Molluscs	13.00%	19.67%	15.67%
Calcareous Algae	2.67%	1.33%	6.67%
Echinoid Spines	1.00%	0.33%	1.00%
Worm Tubes	5.00%	3.67%	3.67%
Gorgonian Sclerites	0.67%	1.00%	0.67%
Fecal Pellets	0.00%	0.00%	0.00%
Other	1.67%	0.00%	2.00%
Unidentifiable	69.33%	67.33%	62.67%
SEDCON INDEX VALUE	1.029	1.194	1.336

Appendix IV. Raw data of all the foraminifera counted in the 29 samples.

Site ID				
SEFL 2007	Delray Ledge			
Genus	4	38	43	28
Amphistegina	35	52	35	24
Archaias	2	3	2	2
Asterigerina	2	2	3	5
Borelis	3	3	2	3
Broekina	1	2	0	3
Cyclorbiculina	3	6	8	5
Gypsina	0	1	3	0
Heterostegina	2	4	1	0
Laevipenoroplis	5	9	8	23
Peneroplis	2	1	0	6
Sorites	0	0	1	0
Ammonia	1	0	5	26
Bolivina	0	0	0	0
Cribroelphidium	0	0	0	0
Elphidium	0	0	0	0
Haynesina	2	2	5	18
Nonion	0	0	1	1
Nonionella	0	0	0	1
Nonionidae	0	0	0	0
Nonionoides	1	0	0	0
Adelosina	0	0	0	0
Affinatrina	0	0	0	0
Articulina	0	0	0	1
Bigenerina	0	1	1	1
Cassidulina	0	0	0	1
Cibicidella	0	0	0	0
Cibicides	4	1	2	8
Cibicidoides	0	0	0	0
Clavulina	0	0	0	0
Cornuspira	0	0	0	0
Cyclorforina	0	1	0	0
Cymbaloporetta	0	0	0	0
Dentostomina	0	1	0	0
Discorbinella	2	0	1	0
Discorbis	0	1	0	2
Eponides	3	2	1	0
Fursenkoina	0	0	0	0
Globocassidulina	0	0	1	0
Guttulina	0	0	0	0
Hauerina	0	0	1	0
Lachlanella	1	2	0	0
Lobatula	0	0	0	0
Miliolinella	1	3	0	2
Neoconorbina	0	0	0	0
Nonionellina	0	0	0	0
Nummulopyrgo	0	0	0	0
Parahaurina	0	0	0	0
Patellina	0	0	0	0
Planorbulina	0	1	1	0
Planulina	0	0	0	1
Polymorphina	1	0	0	0
Pseudohauerina	1	0	2	0
Pseudoschlumbergerina	0	0	0	9
Pseudotriloculina	0	0	0	1
Pyrgo	0	1	0	3
Quinqueloculina	5	13	10	12
Rosalina	0	1	0	3
Schlumbergerina	0	0	0	1
Sigmoihauerina	0	0	0	0
Sigmoilina	0	0	1	0
Sigmoilinita	0	0	0	0
Siphonaperta	0	2	2	1
Siphonina	0	2	2	2
Siphoninoides	1	0	1	1
Spirilina	0	0	0	1
Spirolina	0	0	0	0
Spiroloculina	0	1	0	1
Textularia	4	0	3	12
Triloculina	5	1	3	4
Triloculinoides	0	0	0	0
Trochammina	0	0	0	0
Unidentified Miliolid	0	0	0	0
Unidentified Rotallid	0	0	1	0
Valvulineria	0	0	0	0
Vertebralina	1	0	0	0
Wiesnerella	0	0	0	0
Globigerina	0	0	2	7
Globigernoides	0	2	1	0
Globorotalia	0	0	0	1
Total Forams*	88	119	107	184
Sample Weight (g)	1.03	1.02	0.463	0.44
* Not counting planktonics				

Appendix IV. (Continued)

Site ID						
SEFL 2007	Seagate					
Genus	29	33	40	45	48	63
Amphistegina	54	23	49	67	54	23
Archaias	2	4	1	0	3	2
Asterigerina	4	3	2	4	2	6
Borelis	6	4	1	5	8	5
Broekina	2	1	0	0	1	2
Cyclorbiculina	20	4	11	9	9	12
Gypsina	0	0	2	0	0	0
Heterostegina	3	4	2	1	0	0
Laevipenoroplis	20	20	3	9	12	17
Peneroplis	7	5	0	1	3	2
Sorites	0	0	1	1	0	0
Ammonia	0	19	1	0	2	22
Bolivina	0	0	0	0	0	0
Cribroelphidium	0	0	0	0	0	1
Elphidium	1	0	0	1	0	0
Haynesina	2	10	0	0	2	15
Nonion	0	0	0	0	0	0
Nonionella	0	1	0	0	0	2
Nonionidae	0	0	0	0	0	0
Nonionoides	0	0	0	0	0	0
Adelosina	0	1	0	0	0	0
Affinatrina	0	1	0	1	0	0
Articulina	3	2	2	3	2	2
Bigenerina	0	1	1	0	0	0
Cassidulina	0	1	1	0	0	0
Cibicidella	0	0	0	0	0	0
Cibicides	2	6	0	1	3	13
Cibicidoides	0	0	0	0	0	0
Clavulina	0	0	0	0	0	1
Cornuspira	0	0	0	0	0	0
Cyclorforina	1	3	0	0	1	1
Cymbaloporetta	1	0	0	0	0	0
Dentostomina	0	0	0	0	0	0
Discorbinella	0	0	0	0	0	0
Discorbis	0	2	0	0	0	0
Eponides	4	0	6	6	1	1
Fursenkoina	0	0	0	0	0	0
Globocassidulina	0	0	0	0	0	0
Guttulina	0	0	0	0	0	0
Hauerina	5	2	0	0	0	0
Lachlanella	0	1	0	0	2	1
Lobatula	0	1	0	0	1	1
Miliolinella	1	3	0	1	2	9
Neoconorbina	0	4	0	0	0	2
Nonionellina	0	0	0	0	0	0
Nummulopyrgo	0	0	0	0	1	0
Parahaurina	0	0	0	0	0	0
Patellina	0	0	0	0	0	0
Planorbulina	1	4	3	0	1	1
Planulina	0	1	0	1	0	0
Polymorphina	0	0	0	0	0	0
Pseudohauerina	1	2	0	1	1	1
Pseudoschlumbergerina	0	14	0	0	0	4
Pseudotriloculina	0	0	0	0	0	0
Pyrgo	0	2	0	1	3	0
Quinqueloculina	18	31	10	10	12	19
Rosalina	4	14	1	0	0	2
Schlumbergerina	0	0	0	0	0	0
Sigmoihauerina	0	0	0	0	0	0
Sigmoilina	0	0	0	0	0	0
Sigmoilinita	0	0	0	0	0	0
Siphonaperta	1	1	2	3	4	2
Siphonina	0	0	0	0	0	3
Siphoninoides	1	1	0	0	0	0
Spirilina	0	3	0	0	0	0
Spirolina	0	0	0	0	0	0
Spiroloculina	1	0	0	1	0	0
Textularia	11	7	2	5	5	13
Triloculina	6	11	0	1	7	5
Triloculinoides	0	0	0	0	0	0
Trochammina	0	0	0	0	0	0
Unidentified Miliolid	0	0	0	0	1	0
Unidentified Rotallid	0	0	0	0	0	0
Valvulineria	0	0	0	0	0	0
Vertebralina		0	0	1	0	0
Wiesnerella	0	1	0	0	0	0
Globigerina	0	7	0	0	4	7
Globigernoides	1	0	0	0	0	0
Globorotalia	0	1	0	0	0	0
Total Forams*	182	218	101	134	143	190
Sample Weight (g)	1.00	0.33	1.003	0.909	0.747	0.283
* Not counting planktonics						

Appendix IV. (Continued)

Site ID				
SEFL 2007	Gulf Stream S			
Genus	13	35	39	61
Amphistegina	70	50	12	41
Archaias	0	2	2	3
Asterigerina	5	2	3	11
Borelis	4	1	1	1
Broekina	3	2	0	3
Cyclorbiculina	16	9	6	2
Gypsina	2	0	0	1
Heterostegina	2	1	0	0
Laevipenoroplis	16	7	6	12
Peneroplis	2	2	2	3
Sorites	0	0	0	0
Ammonia	1	12	8	9
Bolivina	0	0	0	0
Cribroelphidium	0	0	0	1
Elphidium	2	1	0	0
Haynesina	0	11	8	13
Nonion	0	1	6	0
Nonionella	0	0	3	2
Nonionidae	0	0	0	0
Nonionoides	0	0	0	0
Adelosina	0	1	0	0
Affinatrina	0	0	0	1
Articulina	3	1	1	2
Bigenerina	1	0	2	0
Cassidulina	0	0	0	0
Cibicidella	0	0	0	0
Cibicides	1	0	3	7
Cibicidoides	0	0	0	0
Clavulina	0	0	0	0
Cornuspira	0	0	0	0
Cyclorforina	0	1	0	1
Cymbaloporetta	0	0	0	0
Dentostomina	0	0	0	0
Discorbinella	0	0	1	0
Discorbis	0	0	0	0
Eponides	6	2	2	0
Fursenkoina	0	0	0	0
Globocassidulina	0	0	0	0
Guttulina	0	0	0	0
Hauerina	0	2	4	0
Lachlanella	2	1	0	2
Lobatula	0	0	0	0
Miliolinella	1	2	0	1
Neoconorbina	0	0	0	0
Nonionellina	0	0	0	0
Nummulopyrgo	0	0	0	0
Parahaurina	0	1	0	0
Patellina	0	0	0	0
Planorbulina	0	0	0	0
Planulina	0	1	0	0
Polymorphina	1	1	0	0
Pseudohauerina	2	1	2	1
Pseudoschlumbergerina	0	3	0	3
Pseudotriloculina	0	0	0	0
Pyrgo	0	6	1	0
Quinqueloculina	15	14	8	10
Rosalina	3	3	5	3
Schlumbergerina	0	0	3	0
Sigmoihauerina	0	0	0	0
Sigmoilina	4	0	0	0
Sigmoilinita	0	0	0	0
Siphonaperta	4	1	0	2
Siphonina	1	0	1	0
Siphoninoides	1	0	0	0
Spirilina	0	1	2	0
Spirolina	0	0	0	0
Spiroloculina	0	0	0	1
Textularia	11	5	6	4
Triloculina	4	3	3	7
Triloculinoides	0	0	0	0
Trochammina	0	0	0	0
Unidentified Miliolid	0	0	1	0
Unidentified Rotallid	0	0	0	0
Valvulineria	0	1	0	0
Vertebralina	0	0	0	0
Wiesnerella	0	0	0	0
Globigerina	0	6	0	6
Globigernoides	2	0	4	0
Globorotalia	0	0	0	0
Total Forams*	183	152	102	147
Sample Weight (g)	0.97	0.51	0.10	0.686
* Not counting planktonics				

Appendix IV. (Continued)

Site ID						
SEFL 2007	Gulf Stream N					
Genus	32	42	51	34	56	60
Amphistegina	50	34	27	53	32	29
Archaias	2	1	0	3	0	0
Asterigerina	5	8	2	9	6	5
Borelis	4	2	3	7	5	3
Broekina	0	2	1	1	4	2
Cyclorbiculina	0	4	1	7	8	2
Gypsina	0	1	1	0	0	0
Heterostegina	0	4	1	2	1	0
Laevipenoroplis	10	16	3	11	18	10
Peneroplis	2	3	1	0	1	3
Sorites	0	1	0	1	0	0
Ammonia	1	7	8	7	5	4
Bolivina	0	0	0	0	0	0
Cribroelphidium	0	1	1	0	1	0
Elphidium	0	0	6	1	2	0
Haynesina	6	15	5	1	7	12
Nonion	0	0	2	0	0	0
Nonionella	0	0	1	0	0	0
Nonionidae	0	0	0	0	0	1
Nonionoides	0	0	1	0	0	0
Adelosina	0	0	0	0	0	0
Affinatrina	0	0	0	0	0	0
Articulina	0	1	3	2	1	1
Bigenerina	0	0	1	0	0	0
Cassidulina	0	1	0	0	0	0
Cibicidella	0	0	1	0	0	0
Cibicides	2	5	6	2	2	7
Cibicidoides	0	0	0	1	0	0
Clavulina	0	0	0	0	0	0
Cornuspira	0	0	1	1	0	1
Cyclorforina	0	0	0	0	0	0
Cymbaloporetta	1	1	0	0	0	0
Dentostomina	0	0	0	0	0	0
Discorbinella	0	0	0	0	0	0
Discorbis	1	2	0	1	1	1
Eponides	1	2	1	6	1	4
Fursenkoina	0	0	0	1	0	0
Globocassidulina	0	0	2	0	0	1
Guttulina	0	0	0	0	0	0
Hauerina	0	1	0	0	0	0
Lachlanella	1	0	0	1	0	0
Lobatula	0	0	0	0	1	0
Miliolinella	1	0	1	0	3	0
Neoconorbina	0	1	0	0	0	0
Nonionellina	0	0	0	1	0	0
Nummulopyrgo	0	0	0	0	0	0
Parahaurina	0	0	0	1	0	0
Patellina	0	0	0	1	0	0
Planorbulina	0	0	0	0	1	0
Planulina	0	1	0	0	0	0
Polymorphina	0	0	0	0	0	0
Pseudohauerina	0	3	2	0	4	0
Pseudoschlumbergerina	4	4	0	2	5	0
Pseudotriloculina	0	0	0	0	0	0
Pyrgo	0	1	1	0	0	0
Quinqueloculina	4	10	10	5	15	14
Rosalina	1	2	1	0	2	0
Schlumbergerina	0	0	0	0	1	2
Sigmoihauerina	0	0	0	0	0	0
Sigmoilina	0	0	0	0	0	0
Sigmoilinita	0	0	0	0	0	0
Siphonaperta	2	0	0	4	0	3
Siphonina	0	0	0	0	1	1
Siphoninoides	0	0	1	0	0	0
Spirilina	0	0	0	0	0	0
Spirolina	0	1	0	0	1	0
Spiroloculina	0	1	0	0	3	0
Textularia	6	6	5	7	14	6
Triloculina	1	1	2	4	8	2
Triloculinoides	0	0	0	0	0	0
Trochammina	0	0	0	0	1	0
Unidentified Miliolid	0	0	0	0	0	0
Unidentified Rotallid	0	0	0	0	0	0
Valvulineria	0	1	0	0	0	0
Vertebralina	0	0	0	0	0	1
Wiesnerella	0	1	0	0	0	0
Globigerina	0	0	0	2	9	0
Globigernoides	0	0	5	0	0	3
Globorotalia	1	0	0	0	0	0
Total Forams*	105	145	102	143	155	115
Sample Weight (g)	0.99	0.612	0.255	0.86	0.374	0.314
* Not counting planktonics						

Appendix IV. (Continued)

Site ID						
SEFL 2007	Horseshoe					
Genus	24	16	69	7	15	68
Amphistegina	10	6	17	9	3	5
Archaias	2	4	10	3	5	5
Asterigerina	3	5	3	4	6	3
Borelis	1	0	2	4	1	0
Broekina	3	1	1	1	1	0
Cyclorbiculina	3	3	5	2	1	0
Gypsina	0	0	1	0	0	0
Heterostegina	0	0	0	1	0	0
Laevipenoroplis	7	4	3	4	4	7
Peneroplis	0	3	1	2	0	3
Sorites	0	0	1	1	1	0
Ammonia	38	38	10	42	42	27
Bolivina	0	1	0	1	0	0
Cribroelphidium	4	0	0	5	0	0
Elphidium	2	2	0	0	0	0
Haynesina	33	30	6	29	26	16
Nonion	0	2	0	0	0	1
Nonionella	0	3	0	7	1	0
Nonionidae	0	0	0	0	0	0
Nonionoides	0	0	0	0	0	0
Adelosina	0	0	0	0	0	0
Affinatrina	1	0	0	1	1	0
Articulina	4	2	0	1	1	0
Bigenerina	1	0	0	0	0	0
Cassidulina	1	1	0	0	0	0
Cibicidella	0	0	0	0	0	0
Cibicides	0	5	2	11	10	11
Cibicidoides	0	0	0	0	0	0
Clavulina	0	0	0	0	0	0
Cornuspira	0	0	0	0	0	0
Cyclorforina	1	0	0	0	0	0
Cymbaloporetta	0	0	0	0	0	0
Dentostomina	0	0	0	0	0	0
Discorbinella	0	0	0	0	0	0
Discorbis	1	0	1	1	0	0
Eponides	2	1	1	0	1	3
Fursenkoina	0	0	0	1	0	0
Globocassidulina	0	0	0	0	0	0
Guttulina	0	0	0	0	0	1
Hauerina	1	1	0	0	0	0
Lachlanella	2	0	1	0	0	0
Lobatula	0	0	0	4	0	0
Miliolinella	1	2	0	1	1	0
Neoconorbina	1	0	1	2	2	0
Nonionellina	4	0	0	0	0	0
Nummulopyrgo	0	0	0	0	0	0
Parahaurina	0	0	0	0	0	0
Patellina	0	0	0	0	0	0
Planorbulina	2	0	0	0	1	0
Planulina	3	0	0	0	0	0
Polymorphina	0	0	0	0	0	0
Pseudohauerina	0	0	1	0	0	0
Pseudoschlumbergerina	1	1	1	4	4	0
Pseudotriloculina	0	1	0	1	0	0
Pyrgo	1	0	1	0	1	0
Quinqueloculina	6	8	6	8	12	8
Rosalina	5	5	0	3	3	3
Schlumbergerina	0	0	0	0	0	0
Sigmoihauerina	0	0	0	0	0	0
Sigmoilina	0	0	0	0	0	0
Sigmoilinita	1	0	0	0	0	0
Siphonaperta	0	1	1	0	0	0
Siphonina	0	0	0	0	0	1
Siphoninoides	0	1	0	0	0	0
Spirilina	0	0	0	0	0	0
Spirolina	1	0	0	0	0	0
Spiroloculina	1	1	0	0	1	0
Textularia	1	1	2	1	0	2
Triloculina	8	13	5	6	3	5
Triloculinoides	0	0	0	0	0	0
Trochammina	0	0	0	0	0	0
Unidentified Miliolid	0	0	0	0	0	0
Unidentified Rotallid	0	0	0	0	1	0
Valvulineria	2	0	0	0	0	0
Vertebralina	0	0	0	0	0	0
Wiesnerella	0	0	0	1	0	1
Globigerina	4	7	0	6	3	2
Globigernoides	0	0	0	0	0	0
Globorotalia	0	0	0	0	0	0
Total Forams*	158	146	83	161	133	102
Sample Weight (g)	0.53	0.31	0.994	0.45	0.17	0.2
* Not counting planktonics						

Appendix IV. (Continued)

Site ID			
SEFL 2007	SECREMP		
Genus	6	21	54
Amphistegina	12	30	10
Archaias	10	18	11
Asterigerina	6	13	14
Borelis	5	8	3
Broekina	1	5	2
Cyclorbiculina	12	12	14
Gypsina	0	0	0
Heterostegina	2	1	0
Laevipenoroplis	32	34	20
Peneroplis	0	3	2
Sorites	1	1	1
Ammonia	2	1	1
Bolivina	0	0	0
Cribroelphidium	0	0	0
Elphidium	1	0	1
Haynesina	1	0	0
Nonion	0	0	0
Nonionella	0	0	0
Nonionidae	0	0	0
Nonionoides	0	1	0
Adelosina	3	0	0
Affinatrina	0	0	0
Articulina	3	6	5
Bigenerina	1	0	0
Cassidulina	0	0	0
Cibicidella	0	0	0
Cibicides	2	2	0
Cibicidoides	0	0	0
Clavulina	0	0	0
Cornuspira	0	0	0
Cyclorforina	0	0	0
Cymbaloporetta	0	0	0
Dentostomina	0	0	0
Discorbinella	0	2	0
Discorbis	12	31	6
Eponides	4	0	0
Fursenkoina	0	0	0
Globocassidulina	0	0	0
Guttulina	0	0	0
Hauerina	0	0	1
Lachlanella	1	2	0
Lobatula	1	0	0
Miliolinella	6	4	1
Neoconorbina	1	0	0
Nonionellina	0	0	0
Nummulopyrgo	1	0	0
Parahaurina	0	0	0
Patellina	0	0	0
Planorbulina	0	1	1
Planulina	0	0	0
Polymorphina	0	1	0
Pseudohauerina	1	1	0
Pseudoschlumbergerina	0	0	0
Pseudotriloculina	1	0	0
Pyrgo	3	1	3
Quinqueloculina	16	38	13
Rosalina	5	4	3
Schlumbergerina	1	0	0
Sigmoihauerina	0	2	0
Sigmoilina	0	0	0
Sigmoilinita	0	0	0
Siphonaperta	1	1	8
Siphonina	0	1	1
Siphoninoides	0	0	0
Spirilina	0	0	0
Spirolina	0	0	0
Spiroloculina	0	1	0
Textularia	9	13	10
Triloculina	10	17	10
Triloculinoides	0	1	0
Trochammina	0	0	0
Unidentified Miliolid	0	0	0
Unidentified Rotallid	0	0	0
Valvulineria	0	0	0
Vertebralina	3	7	2
Wiesnerella	0	0	0
Globigerina	1	0	0
Globigernoides	0	0	0
Globorotalia	0	1	0
Total Forams*	170	263	143
Sample Weight (g)	0.36	0.94	0.492
* Not counting planktonics			