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Running Head: Foram Assemblages from Three Substrata Comparison of Foraminiferal Assemblages from Three Kinds of Substrata, Durney Key, West-Central Florida, USA

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Abstract: As part of a project that assessed a proposed artificial reef site, this study compared benthic foraminiferal assemblages from three substrata: sediment, natural lime rock and recruitment tiles. The assemblage from sediment samples included 21 foraminiferal species representing 12 genera and was dominated by stress-tolerant taxa, especially *Ammonia* and *Elphidium*. Natural lime rock and recruitment tiles yielded 21 foraminiferal species representing 11 genera, which were dominated by miliolids. Intersample variability was characterized by "pulsating patches" as has been previously described for Florida estuaries. The predominance of stress-tolerant taxa in sediments was consistent with other observations from the site, which indicated that proposed artificial reef structures were not likely to recruit significant coral-reef biota.

Key words: Durney Key, recruitment plates, foraminifera, artificial reef pre-emplacement assessment.

1. Introduction

Durney Key, a dredge-spoil island in the Gulf of Mexico (28º16'59.12"N and 82º45'7.10"W) off Pasco County, Florida, USA (Fig. 1), and immediately adjacent waters were under consideration in 2006-2007 as a site for a coastal park. Our study was part of a preliminary assessment of the potential at that location for recruiting coral-reef biota to proposed artificial reef structures [1]. The island and nearby shoals were created by channel dredging to provide access for recreational boaters to open waters of the Gulf of Mexico. The island is approximately 65 m wide and 177 m long, located about 1.1 km from the nearest coastline and 2.6 km west of the mouth of the Pithlachascotee River. Shallow (~1-3 m) grass flats surround Durney Key. Average summer water temperature for 2007 was 30.6 ºC with an average salinity of 23.7 ppt and average pH of 8.3. Averages for winter 2008 were 20.8 ºC, 28.2 ppt salinity and pH of 7.8 at 0.1 m depth [1]. The expanse of shallow water combined with fluvial influence from the Pithlachascotee River contributed to the substantial temperature (17.4-33 ºC) and salinity (22.3-32.8 ppt) fluctuations at this site.

Benthic foraminifers can be important bioindicators in many habitats [2, 3]. Live assemblages are commonly studied from sediments, phytal or other natural substrata [4-8]. Because many foraminiferal taxa reproduce sexually by gamete broadcasting and asexually by multiple fission, densities of individual

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Fig. 1 Coastal Pasco County, Florida, with Durney Key indicated; inset shows location in Florida, USA (adapted from Florida Fish and Wildlife Research Institute).

taxa can vary dramatically between samples and over time, as demonstrated by Buzas et al. [9]. While several authors have argued against analyses based on total assemblages [4-7], others have argued that total assemblages in sediment samples can be used to interpret conditions integrated over time [10].

Because we were tasked to assess temporal variability, general environmental conditions, and the likelihood of recruitment of coral-reef biota to the proposed artificial reef structures around Durney Key, we examined foraminiferal assemblages using three approaches. We collected sediment cores to determine total assemblages. We collected algal-covered lime rock to provide a snapshot of what foraminifers were living on firm substrates, and we assessed the foraminifers that had recruited onto introduced artificial substrates emplaced on a known date. The purpose of this note is to compare the results of these three quite different methods.

2. Methods

Short sediment cores were collected from the sand flat south of Durney Key (Fig. 1) in July 2007. Three cores (1, 2, 3), 10 cm in length and 7 cm in diameter, were taken in 0.5, 1 and 1.5 m water depths at distances of 10, 20 and 30 m south of Durney Key, respectively. Standard grain-size analyses [11] were performed to determine % mud and median Phi for each sample, as indicators of sediment texture. Foraminiferal assemblages in the sand fractions (> 0.063 mm) of the top half of each core were assessed. Sediment examined was weighed to the nearest milligram, distributed onto a gridded tray and examined under a stereomicroscope. Intact foraminifer shells were removed from the sample, placed on a micropaleontological slide, and identified.

Six pieces of unattached lime rock were collected from 1-2 m water depth south of Durney Key in February 2008. The rocks were placed in sealable plastic bags with seawater. Each bag was emptied into a small bucket where the entire rock surface was scrubbed with a soft bristled brush. The rock was removed and the resulting slurry was allowed to settle overnight, after which excess water was siphoned off. Five subsamples of 0.2 g were determined to be sufficient to survey the majority of species present by creating rarefaction curves for each piece of lime rock. Each subsample was scattered in a gridded tray and foraminiferal shells removed, identified and counted.

Porcelain recruitment tiles deployed were 10.2 cm^2 in area and 1 cm thick. Tiles were attached to PVC rods with two pairs of tiles per rod, separated by 30 cm. Rods were placed vertically in the water column on June 22, 2007, at 1.5 m depth south of Durney Key. Tiles were collected on November 25, 2007, and frozen until analyzed. To subsample the foraminiferal assemblages on tiles, a 100 cm^2 grid was used to identify subsamples of each 10 × 10 cm^2 tile. Ten random numbers were generated using the random-numbers generator in Microsoft Excel 2004 for each tile and these ten 1 cm squares in the grid were outlined on each tile. Foraminifers within each square were identified and counted.

Foraminifers were identified to species where possible using a stereomicroscope; counted; tallied as Order Miliolida, Order Rotalida, or other; and also categorized as “stress-tolerant”, “symbiont-bearing”, or “other smaller” foraminifers. The latter categories were used to calculate the Foraminifera in Reef Assessment and Monitoring (FORAM) Index as described by SenGupta [3] and refined by Carnahan and others [11]. The FORAM Index (FI) is a procedure for determining the suitability of benthic environments for communities dominated by algal symbiotic organisms. The FI 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 [2].

3. Results

Sediments at Durney Key are predominantly fine to very fine quartz sands (median Phi 2-3), with less than 1% mud. In the three 1-g sediment subsamples examined (SC-1, SC2, SC-3 in Table 1), shells of 21 foraminiferal species representing 12 genera were identified. FORAM Index values calculated for each of these subsamples ranged from 1.2-1.4, reflecting dominance of the total assemblage by stress-tolerant rotaliid taxa, notably *Elphidium* and *Ammonia*. Miliolids were common but not abundant, making up less than 30% of the assemblage (Fig. 2). Of the nearly 500 foraminiferal shells counted, only three were from symbiont-bearing taxa.

The lime rock-derived samples yielded 21 foraminiferal species representing 11 genera (Table 1). FORAM Index values calculated for each of these

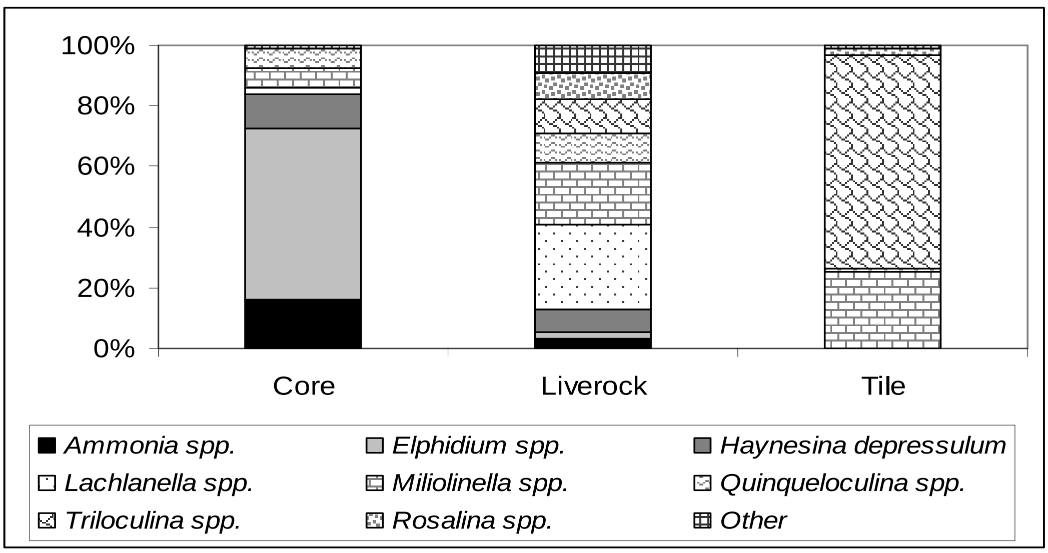

Fig. 2 Relative abundances of most common taxa on the three substrata: solid fill represents stress-tolerant taxa, textured fill represents other smaller taxa.

Table 1 Foraminiferal assemblages on three different substrates.

Taxa	Group*	Sediment cores			Lime rock samples						Porcelain tiles	
	(**)	SC-1	SC-2	SC-3	LR-1	LR-2	LR-3	LR-4	LR-5	LR-6	PT-1	PT-2
Ammonia spp.	ST(R)	15	50	63	1	3	0	41	18	14	5	0
Elphidium spp.	ST(R)	52	86	54	6	19	13	2	4	7	0	0
Haynesina depressulum	ST(R)	10	19	10	14	20	33	64	26	14	0	0
Cyclorbiculina compressus	SB(M)	0	`	1	0	0	0	0	0	0	0	0
Amphistegina gibbosa	SB(R)	0	0	2	0	0	0	0	0	0	0	0
Cycloforina subpoeyana	OT(M)	0	8	52	8	22	28	22	17	15	0	0
Lachlanella spp.	OT(M)	2	1	0	260	70	91	64	71	105	5	0
Miliolinella spp.	OT(M)	6	9	0	40	30	26	131	70	194	348	22
Quinqueloculina spp.	OT(M)	6	23	0	78	68	60	0	2	19	4	1
Pseudotriloculina spp.	OT(M)	0	3	0	13	19	6	6	34	23	1	1
Pyrgo spp.	OT(M)	1	0	0	0	0	0	0	0	0	0	0
Triloculina spp.	OT(M)	0	1	0	7	85	12	58	70	33	85	61
Rosalina spp.	OT(R)	0	0	0	99	17	18	19	22	29	24	2
Planorbulina sp.	OT(R)	0	0	0	0	0	0	0	0	0	1	
Spirillina vivipara	OT(OT)	0	0	0	0	1	0	2	0	0	0	0
Total counted	All	92	200	182	526	354	287	409	334	453	473	87
# genera	***	7	9	6	10	11	9	9	10	9	8	5
# species	***	12	17	10	18	18	15	9	14	18	13	7
Median Phi (sediment)	***	2	3	3	**	**	**	**	**	**	**	**
FORAM Index	***	1.16	1.23	1.43	1.96	1.88	1.84	1.74	1.86	1.92	1.99	2.00
% rotaliids	***	84%	78%	71%	23%	17%	22%	31%	21%	14%	6%	2%
% miliolids	***	16%	23%	29%	77%	83%	78%	69%	79%	86%	94%	98%

*FORAM Index: ST-stress-tolerant; SB-algal symbiont-bearing; OT-other; ** Order: M-miliolida; R-rotaliida; OT-other; ***Not applicable.

subsamples ranged from 1.7-2.0, reflecting dominance of the assemblage by smaller miliolid taxa, notably *Lachlanella bermudezi* and *Miliolinella* spp. In contrast with the sediment samples, miliolids were more than two thirds of the assemblage (Fig. 2). No symbiont-bearing taxa were found in these samples

Only two tiles were recovered and analyzed for foraminiferal assemblages (others were lost to vandalism). One tile (PT-1 in Table 1) was dominated by *Miliolinella*, of which approximately 60% appeared to be deformed. The other tile (PT-2) had far fewer foraminifers and was dominated by *Triloculina*.

4. Discussion

The taxa of foraminiferal shells found in the sediment were essentially the same as those found living on the lime rock, with fewer taxa found on the recruitment tiles (Table 1). The term "pulsating patches", as reported by Buzas et al. [9], effectively described what we found for all three substrata, with a single taxon accounting for more than 40% of the shells found in 6 of the 11 samples. For example, *Elphidium* made up 57% of the shells identified from SC-1, *Lachlanella* 49% from LR-1, and *Miliolinella* 74% from PT-1.

Notable differences in assemblage makeup were observed among the different substrates, probably a consequence of preservation potential. The recruitment tiles had been colonized predominantly by miliolids, many of which were so fragile that they were broken by efforts to remove them. Many similar specimens likely did not survive the process of removal from the lime rock. Certainly such specimens would not survive any length of time in quartz sand, even on this relatively low energy coastline. Also, since miliolid shells are Mg-calcite, they are therefore less likely than the *Ammonia* and *Elphidium* shells to be preserved in either organic-rich sediments or when exposed to hyposaline waters.

Water quality characteristics, specifically wide variation in temperature and salinity ranges, do not appear to be conducive to the presence of holobionts. This is supported by the lack of coral, very low presence of symbiont-bearing foraminifers-only 3 out of 3,397 foraminifers identified were symbiont-bearing, and strong presence of stress-tolerant foraminifers. Furthermore, the FI score of less than two for all substrates corroborates that these environmental conditions are not conducive to the presence of holobionts. These conditions preclude many coral-reef biota, thus making the use of artificial reef structures a fruitless pursuit.

Within the FI, proportions of each functional class are determined and weighted to calculate the FI value, where a FI value > 4 indicates environment conducive to reef growth, 2 < FI value < 4 indicates environment marginal for reef growth and unsuitable for recovery, and a FI value < 2 indicates stressed conditions unsuitable for reef growth [2].

The recruitment tiles indicate what recruited during the deployment time, which was predominantly *Miliolinella*. This too supports the basic interpretation from the lime rock assemblage. However, the presence of so many deformed specimens is problematic; the best-case scenario is that the malformations result from salinity and pH variability, worst-case scenario is they deformities are the result of toxic contaminants in the environment.

5. Conclusion

Use of recruitment tiles or other artificial substrata offers a simple method of determining recruitment, identifying early colonizers vs. late settlers, determining actively recruiting species at specific times, and can more effectively sample fragile species. Especially in a predominantly soft-bottom environment, providing recruitment substratum at the assessment site can provide a strategy to conveniently determine what foraminiferal taxa that require firm substrata can live in an environment, even when their shells have little preservation potential.

The combination of strategies enabled us to determine which taxa were underrepresented in the sediment. As for the differences among the substrata reflected in the FI, we should note that this index was originally designed for reef environments, where sediments are typically dominated by carbonate rather than by quartz sand, and therefore the preservation potential of miliolids is higher. Nevertheless, the predominance of stress-tolerant taxa in the sediments and consequent FI were consistent with other observations from the site which indicated that proposed artificial reef structures were not likely to recruit significant coral-reef biota.

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