

Patterns in southeast Florida coral reef community composition

M.P. Sathe¹, D.S. Gilliam¹, R.E. Dodge¹, and L.E. Fisher²

1) Nova Southeastern University Oceanographic Center, Dania Beach, FL, 33004 U.S.A.

2) Broward County Environmental Protection and Growth Management Department, Ft. Lauderdale, FL 33301, U.S.A.

Abstract. The Southeast (SE) Florida coral reef system is the northern extension of the Florida reef tract. This high latitude system lies offshore a heavily populated and urbanized coast and therefore is affected by numerous environmental and anthropogenic stressors. Using annual monitoring data collected in 2004, the southeast Florida reef community was analyzed to investigate patterns in community composition in various habitat types. Data was collected by SCUBA divers who conducted a 30m² belt transect survey at 24 sample sites offshore Broward County (SE), Florida. Sites ranged in depth range from six to 18 meters. The 24 sites occurred on five different reef habitat categories: ridge-shallow, colonized pavement-shallow, linear inner reef, linear middle reef, and linear outer reef. These sites were established for the Broward County Board of County Commissioners and Environmental Protection and Growth Management Department, Biological Resources Division, in order to monitor Broward County coral communities and sedimentation rates in relation to possible effects from a beach renourishment project. The assessment took place prior to the renourishment project.

Key words: SE Florida, community composition, reef habitats

Introduction

Southeast Florida is comprised of Martin, Palm Beach, Broward, and Miami-Dade Counties. The reefs offshore southeast Florida are the northern portion of the Florida reef tract which ranges from the Dry Tortugas in the south to the St. Lucie Inlet in Martin County to the north. Early studies classified the system into three terraces running parallel to shore (first, second, and third reefs), each separated by sloping sand (Goldberg 1973). Recently, the SE Florida reef system habitats have been characterized in more detail (Moyer et al. 2003; Banks et al. 2007; Walker et al. 2008). From nearshore to offshore, reef habitats include: colonized pavement-shallow, ridge shallow, linear inner reef, linear middle reef, and linear outer reef. These habitats are generally deeper offshore with the colonized pavement-shallow and ridge shallow habitats ranging in depth from approximately 3m to 5m; linear inner reef ranging from approximately 6m to 8m; linear middle reef 12m to 15m; and the linear outer reef 15m to 20m.

Temporal and spatial variations exist in coral reef communities. In Florida Keys National Marine Sanctuary, the Coral Reef Monitoring Project (CREMP) documented stony coral cover declines between 1996-2000 (Callahan et al. 2007). Stony coral species richness was found to be greater on offshore patch reefs (Miller et al. 2002). For southeast

Florida, offshore Broward County, species richness and evenness has been shown to increase on a north to south gradient, and *Montastraea cavernosa* was demonstrated to be the dominant scleractinian coral (Moyer et al. 2003). In 1973, Goldberg noted that the second reef (now classified as the linear middle reef) exhibited a greater abundance of gorgonians and stony corals such as *M. cavernosa* and *Dichocoenia stokesii* while the third reef (linear outer reef) had greater abundance and larger colonies of *Meandrina meandrites* and *Agaricia agaricites*. The processes and mechanisms that drive potential differences in community composition throughout the southeast Florida reef system remain unclear (Moyer et al. 2003).

The southeast Florida reef system exists within 3km of the coast offshore a highly urbanized area influenced by numerous impacts from commercial and recreational fishing and diving, major shipping ports, sewer outfalls, canal discharges, ship groundings, and marine construction activities. These reefs are important economic assets with an annual economic input for southeast Florida at over 5.7 billion dollars (Johns et al. 2003, 2004). The uniqueness, proximity, and value require characterization of the community, sustained monitoring, and increased investigations into limiting environmental/ecological processes.

Material and Methods

Data collected in 2004 from 24 sites was analyzed for this study. This year was selected for analysis because this was a period prior to planned beach renourishment dredging and construction activities. These sites were established for the Broward County Board of County Commissioners and the Environmental Protection and Growth Management Department, Biological Resources Division in order to monitor Broward County, Florida (southeast Florida) coral communities and sedimentation rates in relation to possible effects from the beach renourishment (restoration) project (Gilliam et al. 2005).

Each monitored site consisted of a permanent belt quadrat transect. Each transect was 20m long and 1.5m in width for a sample area of 30m². The transects were marked with 21, 45.7cm long and 1.3 cm diameter stainless steel pins fixed in the bottom with marine, two part epoxy or Portland Cement, one meter apart (± 1.0 cm) in a straight line. The transects were placed in a generally north/south direction. The 30m² transects were assessed by sequentially sampling 0.75 m² quadrats along both sides of the transect.

Each stony coral colony (scleractinian and hydrozoan, *Millepora alcicornis*) greater than 2cm diameter in the belt transect was identified (genus and species) and measured (± 1.0 cm). Two measurements were collected: live tissue length and width and whole colony length and width (which included dead portions and parts of the colony outside of the 30m² belt transect). The number of branching octocorals (excluding *Briareum asbestinum* and *Erythropodium caribaeorum*) and fleshy sponges greater than approximately 2cm in width or height were counted. Community data calculations were: stony coral species density (colonies/m²), stony coral percent live cover, stony coral whole colony size (cm²), sponge density (colonies/m²), and octocoral density (colonies/m²).

Stony coral, octocoral, and sponge densities were determined by dividing the number of colonies in each transect by 30m². Live tissue area of each stony coral species was determined by applying live tissue length and width measurements to the equation $A = L \times W$ (if $L \neq W$) or $A = \pi(L/2)^2$ (if $L = W$). The sum of all colony surface area values was divided by the entire transect surface area (30m²) to calculate percent live stony coral cover.

Possible relationships among community data and habitat types (treatments) were investigated using multivariate (PrimerE, Clarke and Warwick 2001) and univariate (Statistica 6.0 (Statsoft)) statistical analyses. The sites occurred within five southeast Florida reef system habitat categories: colonized

pavement – shallow (n=7 sites), ridge-shallow (n=4 sites), the linear inner reef (n=1 sites), the linear middle reef (n=6 sites) and the linear outer reef (n=6 sites) (Walker et al. 2008).

Community density parameters (three functional groups: stony coral, octocoral, and sponge), stony coral species density, stony coral percent live cover, and stony coral whole colony size (cm²) data were analyzed. Multivariate analyses were completed on stony coral, octocoral and sponge density as a group along with stony coral species density and percent live cover data to examine differences across habitat categories. Site community data was square root transformed prior to the multivariate analysis and pooled into the five habitat categories (colonized pavement – shallow, ridge-shallow, linear inner reef, linear middle reef, and linear outer reef). Multidimensional scaling plots (MDS) (Clarke and Warwick 2001) were created using a Bray-Curtis Similarity matrix. MDS plots provide a visual representation (a “map”) of the similarity (or dissimilarity) between sites such that the distance between sites in these plots is a measure of the relative dissimilarity in community composition. ANOSIM (analysis of similarities) (Clarke and Warwick 2001) tests were used to examine differences in stony coral species and community composition by habitat category. Sample site comparisons with R values of 1.00 indicated that the treatments were completely dissimilar while site comparisons with R values of 0.00 indicated that the treatments were completely similar. SIMPER (similarity percentage breakdown) (Clarke and Warwick 2001) analysis was used to determine which stony coral species or functional group (stony coral, sponge, or octocoral density) was responsible for driving the differences between treatments (habitat categories).

Univariate statistics were performed on the mean whole colony size (cm²) of three important stony coral species in the system: *M. cavernosa*, *Stephanocoenia intersepta*, and *Siderastrea siderea*. Parametric analysis of variance techniques between habitat categories (ANOVA) and the Student-Newman-Keuls Post Hoc test between means (SNK) were completed after data was log transformed ($\log_{10}[x+1]$). Results were considered significantly different for values of $P < 0.05$.

Results

In 2004, within the 24 sample sites, 31 stony coral species were identified. Overall, the average site stony coral percent live cover was $2.1\% \pm 3.4\%$ (mean \pm SD) and average stony coral density was 2.6 ± 1.2 colonies/m². Stony coral cover was particularly high on two sample sites on the colonized pavement-

shallow habitat, FTL4 (16.9%) and FTL5 (14.2%). Octocoral density was 8.9 ± 13.9 colonies/m² and sponge density was 12.9 ± 9.4 colonies/m². Two of the most common stony coral species were *M. cavernosa* and *S. siderea*. *M. cavernosa* contributed most to overall stony coral cover (Table 1) while *S. siderea* had the greatest density. Table 1 shows *M. cavernosa*, *Porites astreoides*, *S. siderea*, and *S. intersepta* (common species in the area) mean site percent cover and percent of total stony coral cover.

	Mean Site % Cover	SD	% of Total Stony Coral Cover
<i>M. cavernosa</i>	1.7	4.2	53.3
<i>P. astreoides</i>	0.2	0.4	7.4
<i>S. siderea</i>	0.1	0.1	5.1
<i>S. intersepta</i>	0.1	0.1	2.8
Other	0.1	0.4	31.4

Table 1: Mean percent live cover, standard deviation (SD), and percent of total stony coral cover for *M. cavernosa*, *P. astreoides*, *S. siderea*, and *S. intersepta*. Other species include: *A. cervicornis*, *A. agaricities*, *Agaricia* spp., *C. natans*, *D. stokesii*, *D. clivosa*, *D. labyrinthiformis*, *D. strigosa*, *E. fastigiata*, *M. decactis*, *M. meandrites*, *M. alcornis*, *M. faveolata*, *Mycetophyllia* spp., *O. diffusa*, *P. americana*, *P. porites*, *Scolymia* spp., *S. radians*, and *S. bournoni*.

Fig. 1 shows the MDS plot of community density (the three functional groups: octocoral, sponge, and stony coral) by habitat category. The ridge-shallow habitat was separated from all other habitat categories. This indicated that the ridge-shallow had a dissimilar community composition than the other habitat categories. Bray-Curtis similarity values showed that all sites were 60% similar and the ridge-shallow separated at the 80% level indicating that the ridge-shallow sample sites had more similarities with each other than the other habitat categories.

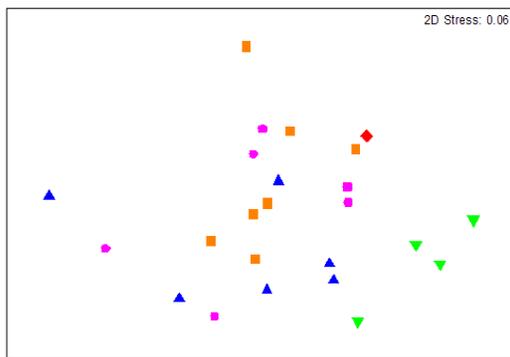


Figure 1: MDS plot of community density by habitat category. Each shape represents community density at one sample site.

ANOSIM results showed that the ridge-shallow community was clearly different but did overlap with

the colonized pavement-shallow ($R=0.405$, $p=0.029$) and the linear outer reef ($R=0.472$, $p=0.010$) communities. The ridge-shallow reef community was well separated from the linear middle reef community ($R=0.799$, $p=0.003$). SIMPER results showed that sponge density was the functional group driving the differences (vs. octocoral and stony coral density) between the ridge-shallow and the other habitat categories with lower densities on the ridge-shallow sites (Fig. 2).

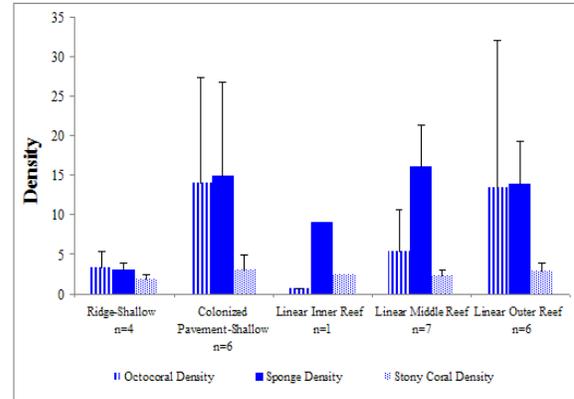


Figure 2: Octocoral, sponge and stony coral density by habitat category. Error bars represent +1 SD (n= the number of sites in each habitat category).

When analyzing each stony coral species percent cover and density in a multivariate manner, the ridge-shallow also had a dissimilar community composition compared to the linear middle and outer reefs. For stony coral percent cover, the ridge-shallow community was clearly different but did overlap with the linear middle reef ($R=0.508$, $p=0.009$) and the linear outer reef ($R=0.528$, $p=0.005$). SIMPER results showed that *M. cavernosa* was the discriminating species between the ridge-shallow and the linear middle and outer reefs. *M. cavernosa* had more cover on the linear middle and outer reefs compared to the ridge-shallow. *M. cavernosa* also had higher cover on the colonized pavement-shallow due to the two sample sites FTL4 and FTL5, but ANOSIM results did not indicate strong differences with the communities on the other habitat categories (Fig. 3).

For stony coral density, the ridge-shallow community was also clearly different but did overlap with the linear middle ($R=0.664$, $p=0.003$) and outer reef ($R=0.687$, $p=0.005$) communities. SIMPER analysis showed that the discriminating species in this case was *S. intersepta* because this species was absent on the ridge-shallow sites (Fig. 4). *M. cavernosa* had more colonies on the colonized pavement-shallow due to sample sites FTL4 and FTL5, but ANOSIM results did not indicate strong differences among the communities in the other habitat categories (Fig. 5).

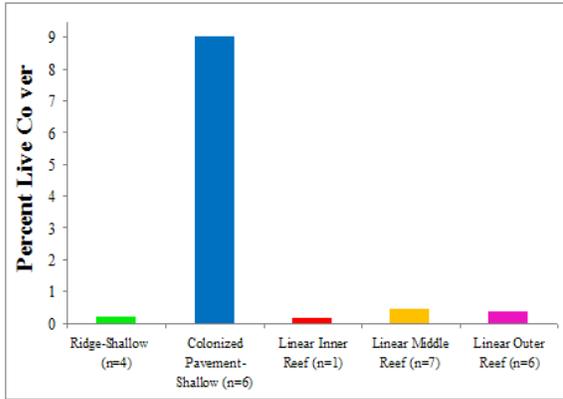


Figure 3: *M. cavernosa* mean percent live cover on all habitat categories. (SDs not shown are: Ridge-Shallow = 0.30, Colonized Pavement-Shallow = 8.02, Linear Middle Reef = 0.70, Linear Outer Reef = 0.23) (n= the number of sites in each habitat category).

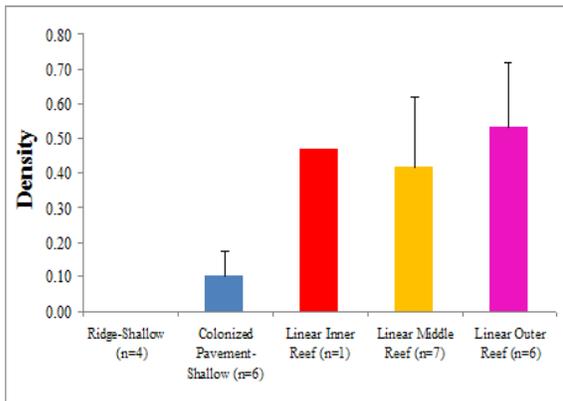


Figure 4: *S. intersepta* mean density for all habitat categories. Error bars represent + 1 SD (n= the number of sites in each habitat category).

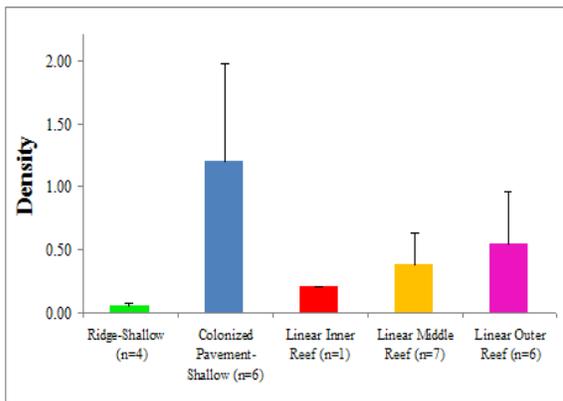


Figure 5: *M. cavernosa* mean density for all habitat categories. Error bars represent + 1 SD (n= the number of sites in each habitat category).

M. cavernosa had significantly larger mean whole colony sizes on the colonized-pavement shallow (Fig. 6). The largest colony in terms of diameter was a *M.*

cavernosa colony (150cm) at sample site FTL4. *S. siderea* had significantly larger mean whole colony sizes on the linear inner, middle, and outer reefs and significantly smaller sizes on the ridge-shallow (Fig. 7). *S. intersepta* had significantly larger mean whole colony sizes on the colonized pavement-shallow and the linear outer reef compared to the linear inner and middle reefs (Fig. 8).

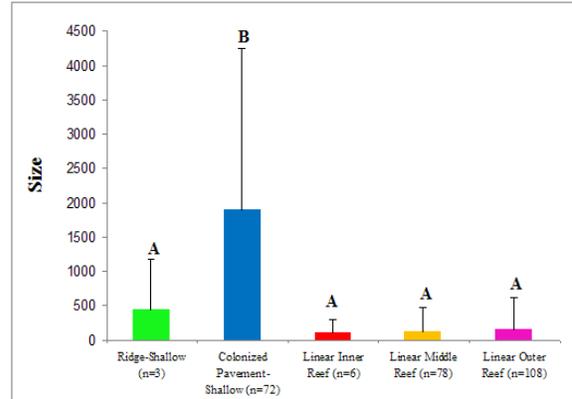


Figure 6: Mean *M. cavernosa* whole colony size (cm²) for all habitat categories. Error bars represent + 1 SD (n= the number of colonies in each habitat category) (Differing letters indicate a significant difference between habitat categories).

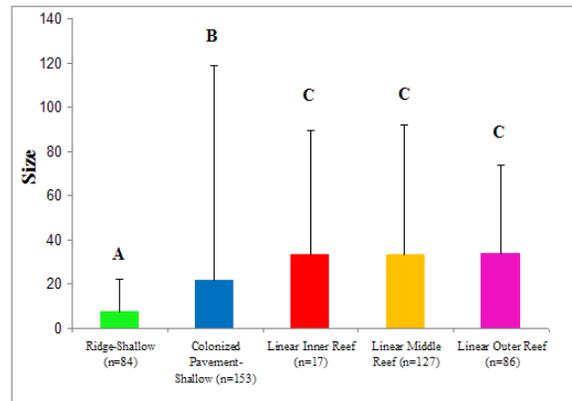


Figure 7: *S. siderea* mean whole colony size (cm²) for all habitat categories. Error bars represent + 1 SD (n= the number of colonies in each habitat category) (Differing letters indicate a significant difference between habitat categories).

Discussion

The reef system offshore southeast Florida has greater octocoral and sponge densities than stony corals. Stony coral cover is generally less than 3%; however, there are exceptions with several colonized pavement-shallow sites (FTL4 and FTL5) having especially high cover (approximately 15%). The southeast Florida reef community varies by habitat category. With lower sponge densities and stony coral cover, the ridge-shallow has a dissimilar community compared to the linear middle and outer reefs. Three stony coral species (*M. cavernosa*, *S. siderea*, and *S.*

intersepta) are very common and important components of the system. *M. cavernosa* and *S. intersepta* have larger colonies on the colonized pavement-shallow. *S. siderea* have larger colonies on the linear inner, middle, and outer reefs.

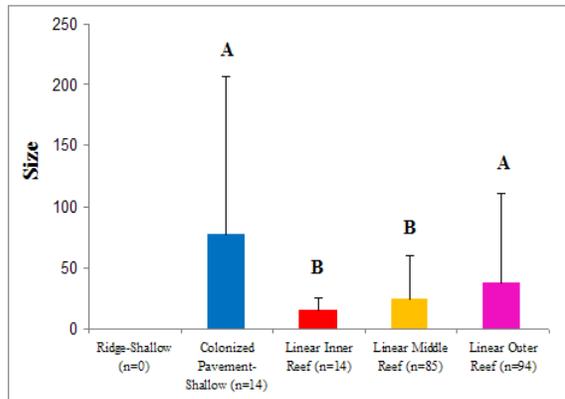


Figure 8: *S. intersepta* mean whole colony size (cm²) for all habitat categories. Error bars represent + 1 SD (n= the number of colonies in each habitat category) (Differing letters indicate a significant difference between habitat categories).

The ridge-shallow and the colonized pavement-shallow habitats are part of a Ridge Complex that extends from Hillsboro Inlet (Broward County) south to Miami-Dade County (Banks et al. 2007). This complex is made up of sediments from cemented beaches and nearshore deposits (Banks et al. 2007). The linear reefs are made up of a Holocene *Acropora* framework (Lighty 1977; Lighty et al. 1978). According to this study, the inshore (ridge-shallow and colonized pavement-shallow) communities occurring on the cemented beach sand communities are dissimilar to those reef communities occurring on the Holocene *Acropora* framework (linear inner, middle, and outer reefs). The inshore communities are also more likely to be subjected to stress from re-suspension of beach sediments due to wave energy. It is unclear why the two sample sites on the colonized pavement-shallow, FTL4 and FTL5, have such high stony coral cover. Perhaps as Moyer et al. (2003)

hypothesized, underlying substrate influences reef community composition. A complete understanding of the reef resources in SE Florida and what influences these vital communities is important for optimal management of a system that is subjected to so many stressors.

Acknowledgements

This work was supported by the Broward County (BC) Board of County Commissioners and the BC Environmental Protection and Growth Management Department (RLI# 050797-RB). We thank K. Banks, J. Ligas, and D. Stout of BC and B. Ettinger, D. Fahy, S. Gill, L. Jordan, L. Klink, J. Monty, N. Stephens, J. Walczak, and B. Walker of NSUOC for field work and data management assistance.

References

- Banks KW, Riegl BM, Shinn EA, Piller WE, Dodge RE (2007) Geomorphology of the southeast Florida continental reef tract (Miami-Dade, Broward, and Palm Beach Counties, USA). *Coral Reefs* 26:617-633
- Callahan M, Wheaton J, Beaver C, Brooke S, Johnson D, Kidney J, Kupfner S, Porter JW, Meyers M, Wade S, Colella M, Bertin M (2007) Coral Reef Evaluation and Monitoring Project 2006: Executive Summary.
- Gilliam DS, Dodge RE, Spieler RE, Jordan LKB, Monty JM (2005) Marine Biological Monitoring in Broward County, Florida: Year 4 Annual Report. Technical report 05-01.
- Goldberg WM (1973) The Ecology of the Coral-Octocoral Communities off the Southeast Florida Coast: Geomorphology, Species Composition, and Zonation. *Bull Mar Sci* 23:465-488
- Johns GM, Leeworthy VR, Bell FW, Bonn MA (2003) Socioeconomic study of reefs in southeast Florida October 19, 2001 as revised April 18, 2003. Silver Spring MD: Special Projects NOS.
- Lighty RG (1977) Relict shelf edge Holocene coral reef: Southeast coast of Florida. *Proc 3rd Int Coral Reef Symp* 2:215-221
- Lighty RG, Macintyre IG, Stuckenrath R (1978) Submerged early Holocene barrier reef south-east Florida shelf. *Nature* 275:59-60
- Miller SL, Swanson DW, Chiappone M (2002) Multiple spatial scale assessment of coral reef and hardbottom community structure in the Florida Keys National Marine Sanctuary. *Proc 9th Int Coral Reef Symp* 1:69-74
- Moyer RP, Riegl B, Banks K, Dodge RE (2003) Spatial patterns and ecology of benthic communities on a high-latitude South Florida (Broward County, USA) reef system. *Coral Reefs* 22:447-464
- Walker BK, Riegl B, Dodge RE (2008) Mapping coral reef habitats in southeast Florida using a combined technique approach. *J Coast Res* 24:1138-1150