

# **SAND KEY BEACH RENOURISHMENT PROJECT: FUNCTIONALITY OF MITIGATIVE ARTIFICIAL REEFS AND IMPLICATIONS FOR FUTURE PROJECTS**

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## **ABSTRACT**

To meet state permit requirements for mitigation of impacts associated with beach renourishment activities on Sand Key, Pinellas County constructed a total of 16 artificial reefs between 1997 and 2006. Biological monitoring was conducted on three of these reefs to determine at what age mitigative artificial reefs within the study area become biologically equivalent with the surrounding natural hardbottom. The three installations were compared to two natural hardbottom sites. Each of the five sampling units consisted of six temporary transects, 10 meters in length, established at the time of data collection. A point-intercept method of assessment was conducted every 0.5 meters.

Sand and other sediment types had the highest percent cover at all sites, both natural and artificial, followed by turf algae. Excluding turf, the dominant functional groups across all sites were macroalgae, sponge, tunicate, octocoral and hydroid. Dominant species included the octocoral *Leptogorgia virgulata*, at both natural and artificial reef sites, and the sponge species *Cliona celata* at natural hardbottom sites. Multivariate analyses using PRIMER<sup>®</sup> v6 indicated that the benthic habitat on nearshore artificial reefs within the study area become biologically similar to the surrounding natural hardbottom between two and five years after installation, and by 10 years post-installation the artificial reefs reach a benthic community complexity which supersedes that of the natural hardbottom. This study provides a timeframe for functional equivalency implications for permit conditions and management of future nearshore artificial reef projects in the area.

**KEY WORDS** – Mitigation, artificial reefs, benthic community

## INTRODUCTION

With increasing coastal development and impacts to nearshore benthic resources, artificial reefs are becoming widely used as a means of mitigating these impacts. Although Florida waters support over half of the nation's artificial reefs (Seaman, 2004; Bortone and Van Orman, 1985) there is still a need for accurate data in order to make decisions regarding construction materials, optimal siting and functionality of the installations (Seaman, 2004; Baynes and Szmant, 1989; Heukel et al., 1989; Bohnsack and Sutherland, 1985). Increasing demands are being placed on artificial reef programs to satisfactorily prove that the installations are performing as expected (FDNR, 1992); that is, they must reach functional equivalency with the natural reef environment being replaced, often within a designated amount of time.

The greatest challenge in damage and/or mitigation assessments involves determining how to best characterize the health and level of services provided by the damaged site and then assessing the scale of damage. Further, one must determine the rate of progression of natural recovery or succession of the mitigation site to conditions that would prevail had the damage or injury not occurred (Peterson, et al., 2003). As recovery rates are often dependent on environmental conditions and geographic location, specific data for ecosystem recovery and succession/colonization at mitigation sites for different regions of coastal Florida are needed to accurately determine permit conditions and mitigation requirements.

Sand Key is located on the west-central coast of Florida in Pinellas County. A total of 16 artificial reefs were constructed between 1997 and 2006 in order to meet state permit requirements for mitigation of impacts associated with beach renourishment activities (Figure 1). The reefs were constructed with concrete construction materials, such as culverts, telephone poles, etc. In order to determine if and at what age the artificial reefs off Sand Key successfully mitigate for loss of services provided by natural hardbottom impacted by project activities, three artificial reefs were sampled and compared to two natural hardbottom sites. It is the intent of this report to provide a rate at which nearshore mitigation sites reach similar functionality with adjacent natural hardbottom areas, with management applications for future projects in the central Florida gulf coast region.

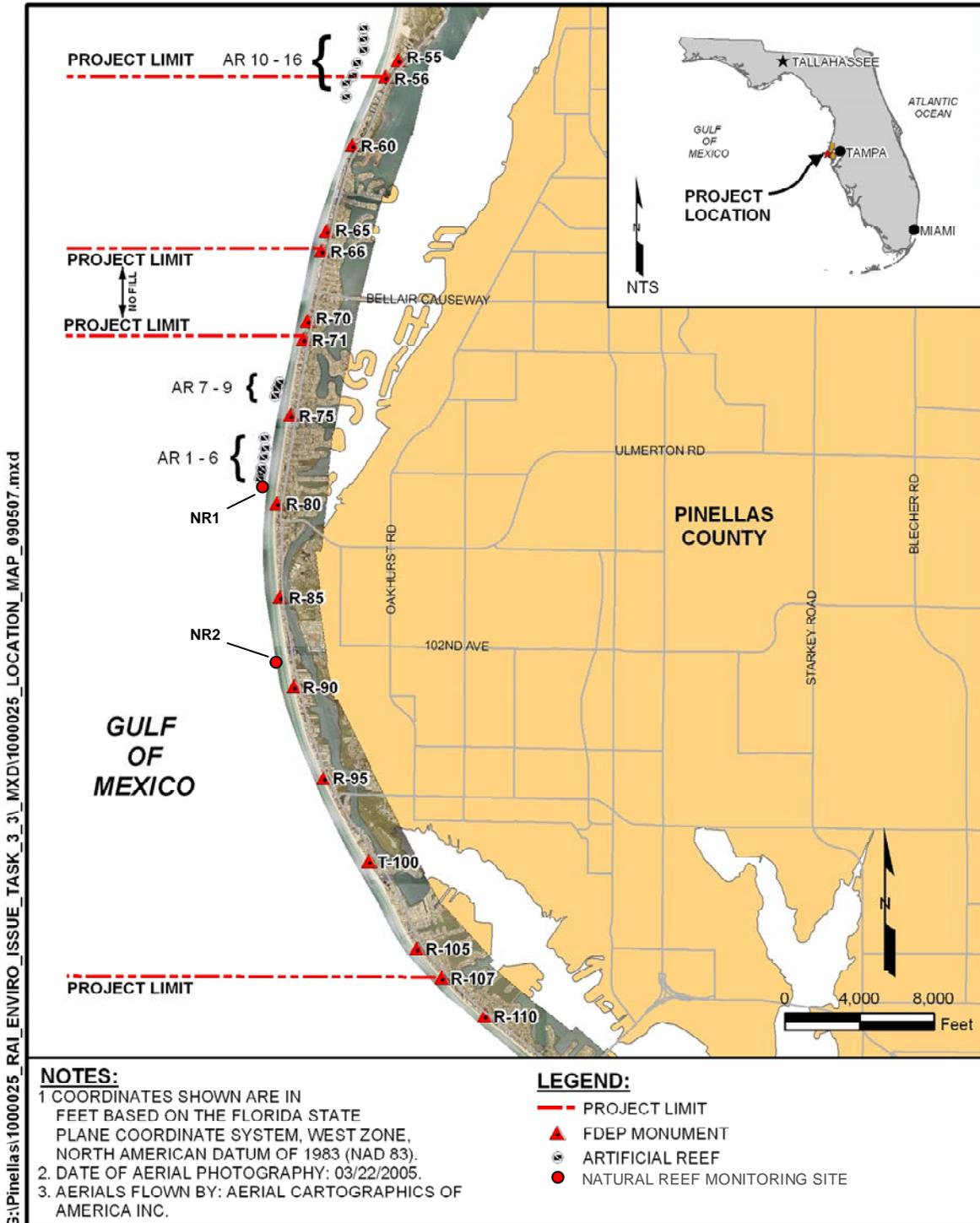


Figure 1. Project location map.

## METHODS

Mitigative artificial reefs and natural hardbottom sites were chosen based on construction dates for the artificial reefs and proximity to potential impact sites. Nearshore Artificial Reefs (AR) 1, 5 and 13 were chosen in order to sample across an even distribution of age. The installations were 2, 5 and 10 years old, respectively, at the time of sampling. Areas with contiguous hardbottom of relatively high quality (determined qualitatively from reconnaissance dives) suitable for the sampling methods described here were chosen for the natural hardbottom monitoring sites: Natural Reef 1 (NR1) and Natural Reef 2 (NR2) (Figure 1).

Each of the five sampling units consisted of six temporary transects established at the time of data collection. A baseline was first established in a north-south direction along the eastern interface of natural hardbottom and sand or artificial reef boundaries. Beginning at the eastern sand/reef interface, each monitoring transect was extended to the west, perpendicular to the baseline every three to five meters, depending on the size of the area being sampled. Each transect was 10 m in length and was sampled using a point-intercept method of benthic data collection every 0.5 m, starting at 0.5 m and ending at 10 m. The point-intercept method was chosen due to the poor visibility often experienced in the study area. At each point, a marine biologist documented attached benthic flora and fauna contacting or under the right and left sides of the 0.5-m marks to the lowest taxon possible, for a total of 60 points per transect. Typically, the only organisms identifiable to species were octocorals. Stony coral colonies were also identified to species when they were observed, although stony coral was rare at all sites. The height of any coral colony encountered, either stony or octocoral, was then measured to the nearest centimeter.

Data were summarized and tabulated, and community differences between artificial and natural reef sampling units were compared using the Plymouth Routines in Multivariate Ecological Research (PRIMER<sup>®</sup> v6) 2006 software.

## RESULTS

### **Artificial vs. Natural Reef Site Functional Groups**

A summary of monitoring results is provided in Table 1. Because only corals were identified to species, functional groups were used to describe and compare overall benthic communities. Sand, rubble/shell hash and sediment were most abundant across all sites, followed by turf algae. After turf algae, the most dominant biotic functional groups across all sites were macroalgae, tunicate, sponge, hydroid and octocoral, with the order of abundance varying at each site.

Table 1. Summary of functional group raw abundance per sampling unit.

Functional Group	Total points				
	AR1	AR5	AR13	NR1	NR2
sand/shell/sed	162	158	208	126	156
turf	151	86	61	152	109
macroalgae	7	16	33	45	32
tunicate	6	22	21	3	31
sponge	0	21	5	22	27
octocoral	18	29	29	8	2
hydroid	12	26	0	1	0
stony coral	4	0	2	0	1
zoanthid	0	0	0	1	1
bryozoan	0	0	0	0	1
worm	0	1	1	2	0
bivalve	0	1	0	0	0

Community differences between artificial and natural reef sampling units were compared using the Plymouth Routines in Multivariate Ecological Research 2006 (PRIMER<sup>®</sup> v6) software. Functional group abundance data were transformed using fourth root transformation. Since NR1 and NR2 sampling units are essentially replicates, abundance data from these sites were averaged into a single sampling unit representing natural hardbottom prior to analysis. A Bray-Curtis similarity matrix was used to create a non-metric multidimensional scaling (MDS) ordination plot (Figure 2).

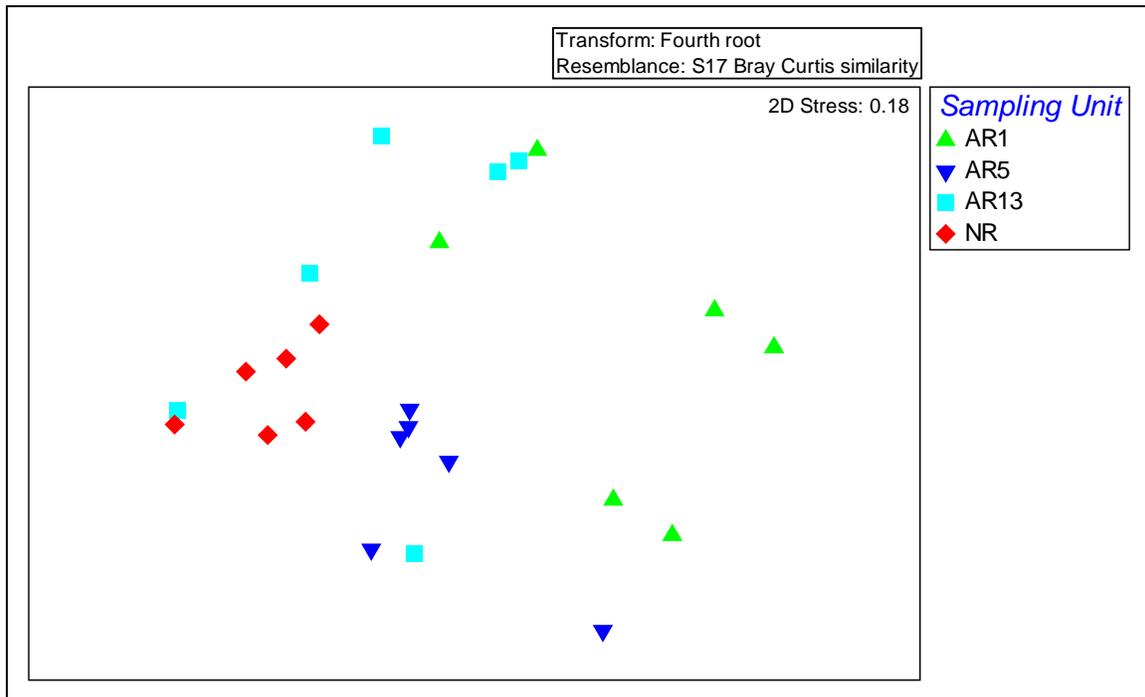


Figure 2. MDS plot illustrating similarity of transects between NR and AR sampling units.

On the MDS orientation plot, points that fall close together represent similar communities, whereas points that fall farther apart are less similar. The natural

hardbottom sampled (shown in red) is more similar to AR5 and AR13 than to AR1 (Figure 2).

A Similarity of Percent analysis (SIMPER) was used to identify the discriminating taxa between NR and AR sampling units (Table 2). Taxa were listed in decreasing order by their average contribution to the total average dissimilarity ( $\delta$ ) between groups, with a cutoff at 90%. Analysis of Similarity (ANOSIM) was conducted post-hoc (Table 3) to assess the significance of differences in community composition between NR and AR sampling units. The null hypothesis was that there were no differences between sampled groups of transects.

Table 2. Order of functional groups comprising 90% of each sampling unit based on average abundance calculated by SIMPER analysis.

Functional Group	Rank			
	NR	AR1	AR5	AR13
sand/shell/sediment	1	1	1	1
turf	2	2	2	2
macroalgae	3	5	--	4
sponge	4	--	6	--
tunicate	5	--	4	5
hydroid	--	3	5	--
octocoral	--	4	3	3

Table 3. ANOSIM and SIMPER pairwise comparisons of NR and AR sampling units.

Groups (Pairwise Tests)	R Statistic	P value ( $\alpha=0.05$ )	SIMPER $\delta$ (%)
AR5, NR	0.406	0.002	23.08
AR13, NR	0.402	0.009	25.75
AR1, NR	0.757	0.002	34.12

The *Global R* statistic for the data was 0.446. Since none of the computed permutations were larger than *Global R*, the null hypothesis that there are no differences between sampled groups of transects was rejected ( $p < 0.1\%$ ). In order to determine where differences lie, it is necessary to examine the value of R for each pair-wise comparison. A low R statistic indicates that the groups of data are not *exactly* the same but do overlap (a value of zero would indicate no differences; Clarke and Gorley, 2006). The largest R statistic obtainable is 1.0, and the larger the R statistic the greater the difference between groups. The ANOSIM results show that the natural hardbottom communities (NR) sampled are most different from the data set sampled at AR1 ( $R=0.757$ ), the youngest of the artificial reef installations. The average dissimilarity ( $\delta$ ) calculated by the SIMPER tests support the ANOSIM results, with the greatest average dissimilarity occurring between the natural reef and AR1 ( $\delta=34.12\%$ ).

Figure 3 uses the abundance data summed for each sampling unit to illustrate overall similarity of sites, and to illustrate the trajectory of benthic communities on the artificial reefs with age. According to this MDS plot, the natural reef is most similar in

community composition to AR13 (81%) and AR5 (80%). AR5 and AR13 are also more similar to each other than either reef is to AR1.

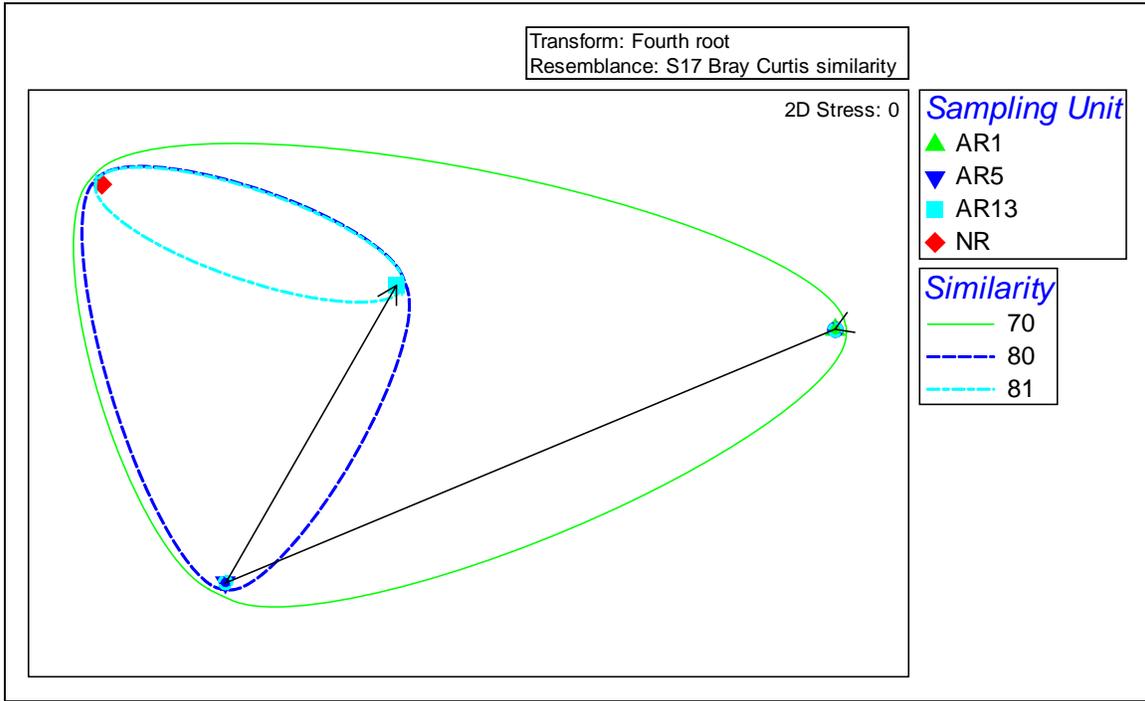


Figure 3. MDS plot illustrating similarity of AR and NR benthic communities.

## Benthic Species

The only organisms identified to species were stony corals and octocorals, with the exception of one common sponge species. Macroalgae were identified to genus. In the case of corals, very few stony corals were found at any of the sampling units, and only two species of octocorals were observed during these investigations. Table 4 lists the abundance of genera and/or species.

Table 4. Abundance of genera/species within the functional groups octocoral, stony coral, macroalgae and sponge.

	AR1	AR5	AR13	NR1	NR2	Total Points	Percent of Functional Group
<b>OCTOCORAL</b>							
<i>Leptogorgia virgulata</i>	18	28	25	8	2	81	94.2%
<i>Leptogorgia hebes</i>	0	1	4	0	0	5	5.8%
<b>Total Points</b>	<b>18</b>	<b>29</b>	<b>29</b>	<b>8</b>	<b>2</b>	<b>86</b>	
<b>STONY CORAL</b>							
<i>Occulina diffusa</i>	4	0	0	0	0	4	57.1%
<i>Phyllangia americana</i>	0	0	2	0	0	2	28.6%
<i>Solenastrea bournoni</i>	0	0	0	0	1	1	14.3%
<b>Total Points</b>	<b>4</b>	<b>0</b>	<b>2</b>	<b>0</b>	<b>1</b>	<b>7</b>	
<b>MACROALGAE</b>							
<i>Codium</i>	3	0	11	0	0	14	10.5%
<i>Dictyota</i>	3	4	0	0	0	7	5.3%
<i>Hypnea</i>	1	12	9	39	23	84	63.2%
<i>Dasya</i>	0	0	7	0	0	7	5.3%
<i>Sargassum</i>	0	0	3	0	0	3	2.3%
<i>Halymenia</i>	0	0	3	0	0	3	2.3%
<i>Gracilaria</i>	0	0	0	1	1	2	1.5%
<i>Ceramium</i>	0	0	0	1	8	9	6.8%
<i>Spyridia</i>	0	0	0	1	0	1	0.8%
<i>Caulerpa</i>	0	0	0	1	0	1	0.8%
<i>Chondria</i>	0	0	0	1	0	1	0.8%
<i>Laurencia</i>	0	0	0	1	0	1	0.8%
<b>Total Points</b>	<b>7</b>	<b>16</b>	<b>33</b>	<b>45</b>	<b>32</b>	<b>133</b>	
<b>SPONGE</b>							
<i>Cliona cellata</i>	0	0	0	9	18	27	36.0%
<i>Cinachyra sp.</i>	0	0	0	1	0	1	1.3%
unknown spp.	0	21	5	12	9	47	62.7%
<b>Total Points</b>	<b>0</b>	<b>21</b>	<b>5</b>	<b>22</b>	<b>27</b>	<b>75</b>	

Of the two species of octocorals observed, *L. virgulata* was by far the more common species, accounting for 94.2% of total octocoral abundance (Table 4). *L. virgulata* was documented at every sampling unit. *L. hebes* accounted for only 5.8% of total octocoral abundance and occurred only at AR5 and AR13. Octocorals in general were considerably more abundant on the artificial reefs than on the natural hardbottom (88.4% and 11.6%, respectively) (Photographs 1-2).



Photographs 1-2. Comparison of *L. virgulata* on artificial versus natural reef.

Macroalgae abundance increased on the artificial reefs with increasing age of the installations, with AR13 supporting the highest abundance of macroalgae (9.2%). AR13 was also closest to the natural reef sites in macroalgae abundance, which had an average of 10.7% abundance; however, all 12 observed macroalgae genera occurred on the natural hardbottom, and only six of the 12 observed genera occurred on the artificial reefs.

Sponge abundance was higher on the natural reefs than on the artificial reefs (Tables 1 and 4). Natural reefs accounted for 65.3% (n=2) of total sponge abundance, while artificial reefs accounted for only 34.6% (n=3). No sponges were recorded along AR1 transects. The only sponge identified to the species level was *Cliona celata*. All other sponges observed were placed into the unknown category with the exception of two specimens of *Cinchyrella* sp. (*Cinachyrella*, as well as many other sponges, are only identifiable to species through microscopic examination of spicules). *C. celata* was the dominant sponge on the natural reefs, accounting for over half (55.1%) of the sponge abundance there (Photograph 3). It is a large species of sponge and is one of the dominant species found on the natural hardbottom within the study area. *C. celata* was not recorded on any of the artificial reef transects although it was qualitatively observed on AR13.



Photograph 3. *Cliona celata* growing on the natural hardbottom.

## Artificial Reef Colonization and Succession

Abundance data were used to compare individual functional groups across artificial reef sites to identify successional patterns with age of the installations. For example, Table 1 shows hydroids are present on AR1 and AR5, but not on AR13, and only a single point identified hydroid on any of the natural reef transects. This may indicate hydroids are fouling organisms that become out-competed on older, more established reefs. This has been found to occur with the white telesto *Carijoa riisei* on artificial reefs on the east coast of Florida (CPE, 2005). Tunicates appear to increase with increasing age of the reef, and then reach a maximum abundance after five years. Macroalgae appear to increase almost linearly with increasing age of the reef.

In general, a decreasing trend in turf algae is apparent with increasing age of the artificial reefs, most likely due to the increasing abundance over time of encrusting organisms, such as tunicates (Photographs 4 and 5). Most biotic groups, with the exception of macroalgae, which appear to increase almost linearly with time, appear to reach a plateau approximately five years post-construction. Differences in biotic cover can be seen in Photographs 6 through 8. AR1 is covered primarily in turf algae with some octocorals, while the older reefs (AR5 and AR13) are encrusted with tunicates, macroalgae, sponges, and dense octocoral growth.



Photograph 4. Encrusting tunicates on AR13. Photograph 5. Encrusting growth on AR5.



Photographs 6-8. Comparing benthic growth between AR1, AR5, and AR13.

*Leptogorgia virgulata* colony heights were also compared between reef units. AR13 had the highest average *L. virgulata* height as well as the tallest single colony of all sites (Table 5). The groups of heights were tested for significant differences between

sampling units using two-sample t-tests assuming unequal variances. The only significant difference was found between AR1 and AR13 ( $p=0.047$ ). This indicates that the natural hardbottom exhibits a range of *L. virgulata* heights typical of a natural environment, but that colonies on artificial reefs can be grouped into size classes based on length of time since placement of the artificial reef.

Table 5. *Leptogorgia virgulata* heights across sampling units.

	AR1	AR5	AR13	NR
Average (cm)	21.1	26.2	30.5	16.3
Max Ht (cm)	28	35	57	47
St. Dev	6.0	9.0	15.2	18.6
n	9	18	15	10

## DISCUSSION

Test results show that the natural hardbottom is more similar in benthic community composition to AR5 (5 years old) and AR13 (10 years old) than to AR1, the youngest of the artificial reefs assessed (2 years old). This suggests that the nearshore artificial reefs installed within the study area reach habitat equivalency with nearby natural hardbottom between two and five years post-installation.

Results also indicate that AR5 and AR13 are more similar in their community composition to each other than either reef is to AR1. In addition, the artificial reefs show trends in biotic cover that indicate AR1 and AR5 are still in earlier successional stages compared to AR13. Hydroids were identified along transects at both AR1 and AR5, but absent from AR13. This may indicate hydroids are fouling organisms that become out-competed on older, more established reefs, similar to the white telesto (*Carijoa riisei*) on artificial reefs on the east coast of Florida (CPE, 2005). Tunicate percent cover appears to increase with increasing age of the reef, and then reach a maximum abundance after five years, while macroalgae appear to increase continually with increasing age of the reef.

## CONCLUSION

Sand and other sediment types had the highest percent cover at all sites, both natural and artificial, followed by turf algae. Excluding turf, the dominant functional groups across all sites were macroalgae, sponge, tunicate, octocoral and hydroid. Dominant species included the octocoral *Leptogorgia virgulata*, at both natural and artificial reef sites, and the sponge species *Cliona celata* at natural hardbottom sites.

The overall benthic community cover and composition of the artificial reefs appear to reach functional equivalency with the natural hardbottom between two and five years post-construction, and by 10 years post-construction, the artificial reef installations reach a community complexity which exceeds that of the natural hardbottom. This timeframe for functional equivalency may provide a guideline for developing requirements and timelines for compliance in future coastal development projects on the west-central Florida coast that require mitigation reef installations or for other artificial reef studies.

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