SPATIAL ARRAY AND DEPTH STUDY OF MIAMI-DADE ARTIFICIAL REEF MODULES
2009

FINAL REPORT

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ABSTRACT

During the last 15 years, modular artificial reefs have been deployed offshore of Miami-Dade County for a variety of purposes including mitigation and fisheries enhancement. This study sought to evaluate two relationships: 1. Influence of proximity of artificial reef modules (ARMs) on fish assemblages and 2. Depth of ARMs on both fish and benthic assemblages. The modules evaluated in this study are located in the Port of Miami Artificial Reef Site A (POM A) and Sunny Isles Artificial Reef Site (specifically the Bal Harbour Mitigation Site [BHM]). The POM A modules were deployed in July and August 1996 and the BHM modules were deployed in May 1999. This study demonstrated that varying spatial arrays (less than 10' centers, 25' centers, 50' centers, and 100' centers) and depths (25' and 68') of modules provide habitat that has supported abundant and diverse biological assemblages. The benthic assemblages on all spatial arrays at POM A and BHM were dominated by turf algae followed by sponge (Porifera) species and to a much lesser extent soft corals (Octocorallia) and stony corals (Scleractinia). The BHM modules had slightly more soft corals while POM A modules had more stony corals, mostly of the species *Oculina diffusa*. The fish assemblages on all POM A spatial arrays were dominated by the family Haemulidae (Grunts) and Labridae (Wrasse) most commonly of the species *Thalassoma bifasciatum* (blueheaded wrasse). The family Gobiidae (Gobies) was most abundant on the BHM modules, with *Coryphopterus personatus* (Masked Goby) being most common. Other common reef fish families observed include Acanthuridea (butterfly fish), Pomacentridae (damselfish), and Tertadontidea (puffer fish). This study has provided information for evaluating the effectiveness of these reefs in meeting the objectives for which they were constructed (habitat mitigation) and will assist in future artificial reef planning.

INTRODUCTION

Artificial reefs are best known as a tool for fishery enhancement (Bohnsack and Sutherland 1985, Palmer-Zwahlen and Aseltine 1994, Pickering et al. 1998, Seaman 2000). However, during the last few decades, the uses of artificial reefs have expanded to include mitigation, habitat rehabilitation, habitat restoration, and habitat protection (Pickering et al. 1998). Seaman (2000) defined artificial reefs as objects, natural or human made, deployed purposefully on the seafloor to influence physical, biological, or socioeconomic processes related to living marine resources. Seaman's definition has incorporated all such uses.

Over the last 15 years, numerous artificial reefs constructed from pre-fabricated concrete modules have been deployed for a variety of purposes in Miami-Dade County including mitigation and fisheries enhancement. However, the benthic and fish assemblages utilizing these artificial reefs have not been well described. This project documented and quantified the biological assemblages on four different module spatial arrays and two different module depths. The four module arrays were set on varying different distances (centers) from each other: less than 10 ft. centers, 25 ft. centers, 50 ft. centers, and 100 ft. centers. The depth study involved modules on 25 ft. centers at 25 ft. and 68 ft. deep. Due to time and funding limitations, a 'seasonal' assessment could not be conducted. This information will assist in evaluation the effectiveness of these reefs in meeting the objectives for which they were constructed such as fisheries enhancement or habitat mitigation.

SITE LOCATION AND DESCRIPTION

The Port of Miami Mitigation A (POM A) and the Bal Harbour Mitigation (BHM) modules were utilized for this study (Figures 1, 2, and 3). The BHM Modules are located in the Sunny Isles Artificial Reef Site. This site is composed of 264 modules set on 25 ft. centers around a 5,000 ton pile of limestone boulders (Figure 2). The POM A site is composed of 645 modules in four different spatial arrays: 50 modules set on <10 ft. centers, 495 modules on 25 ft. centers, 50 modules on 50 ft. centers and 50 modules on 100 ft. centers (Figure 3).

All modules are pre-fabricated and constructed of concrete and limerock. Miami-Dade County stability analysis assessed the material's resistance to overturning and horizontal movement, utilizing characteristics of a 25-year return storm event, in consideration of the depth and bottom slope of the deployment location. Both modules were constructed with a concrete slab base approximately 6' wide x 9' long x 1' thick (1.8m x 2.7m x 0.4m) with four corner concrete pedestal feet approximately 1' high (0.4m). The BHM module design consisted of five 12" diameter culvert pipes in a "2-on-3" configuration (Figure 4). The POM A module design, on the other hand, consisted of three 12" or 18" diameter concrete culvert pipes in a "1-on-2" configuration secured to the concrete based (Figure 5). In both designs, small limerock pieces (6"-9") were grouted onto the exterior of the pipes to provide a natural, rough surface to facilitate benthic recruitment. Overall 'as-built' height of the two module types was approximately 5' (1.5 m), however, final in situ relief was between 3' – 4' (0.9 m – 1.2 m) due to subsidence in sand.

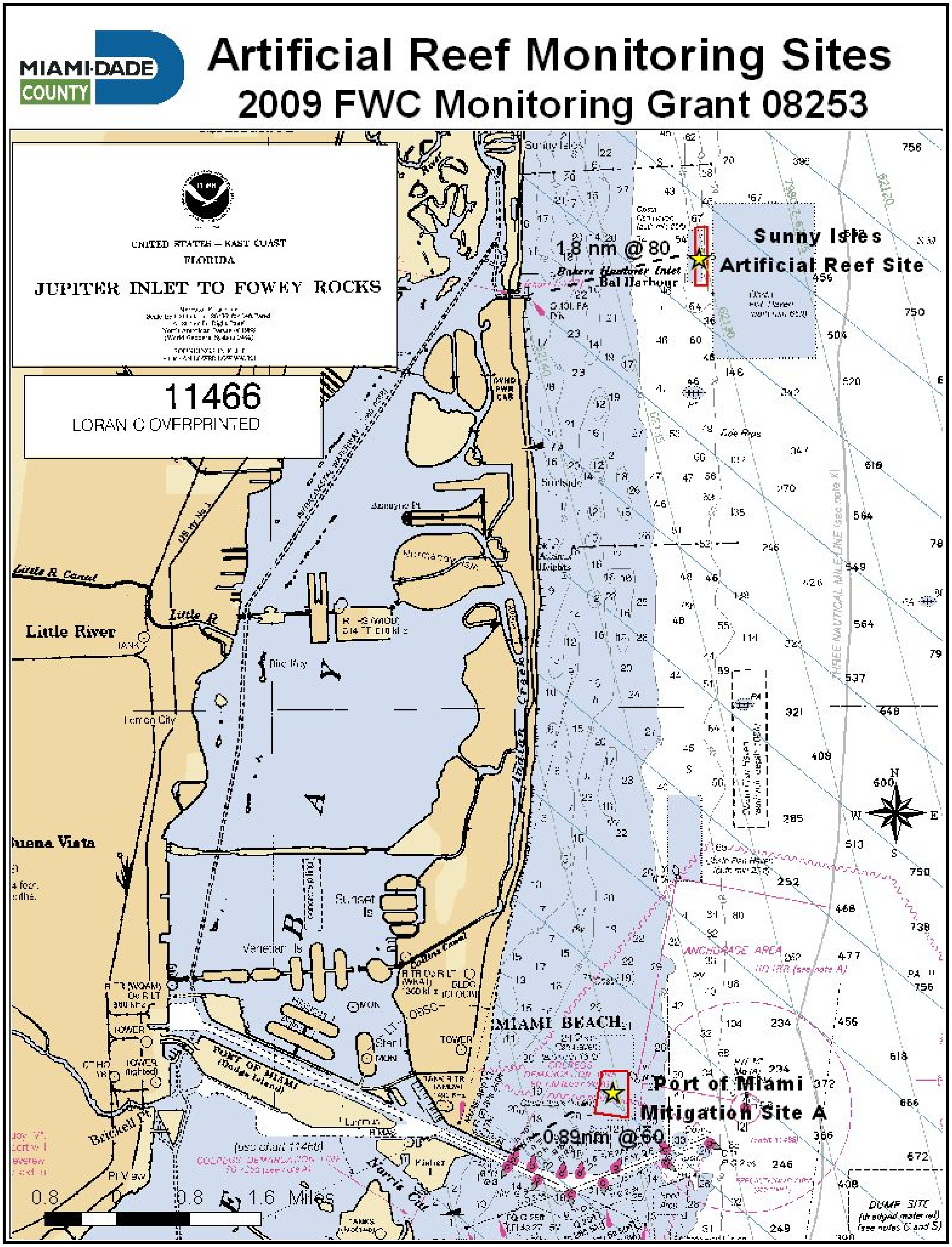

Figure 1. Location of the Sunny Isles Artificial Reef Site and Port of Miami Mitigation Site A and the respective artificial reefs evaluated through FWC Grant 08253.

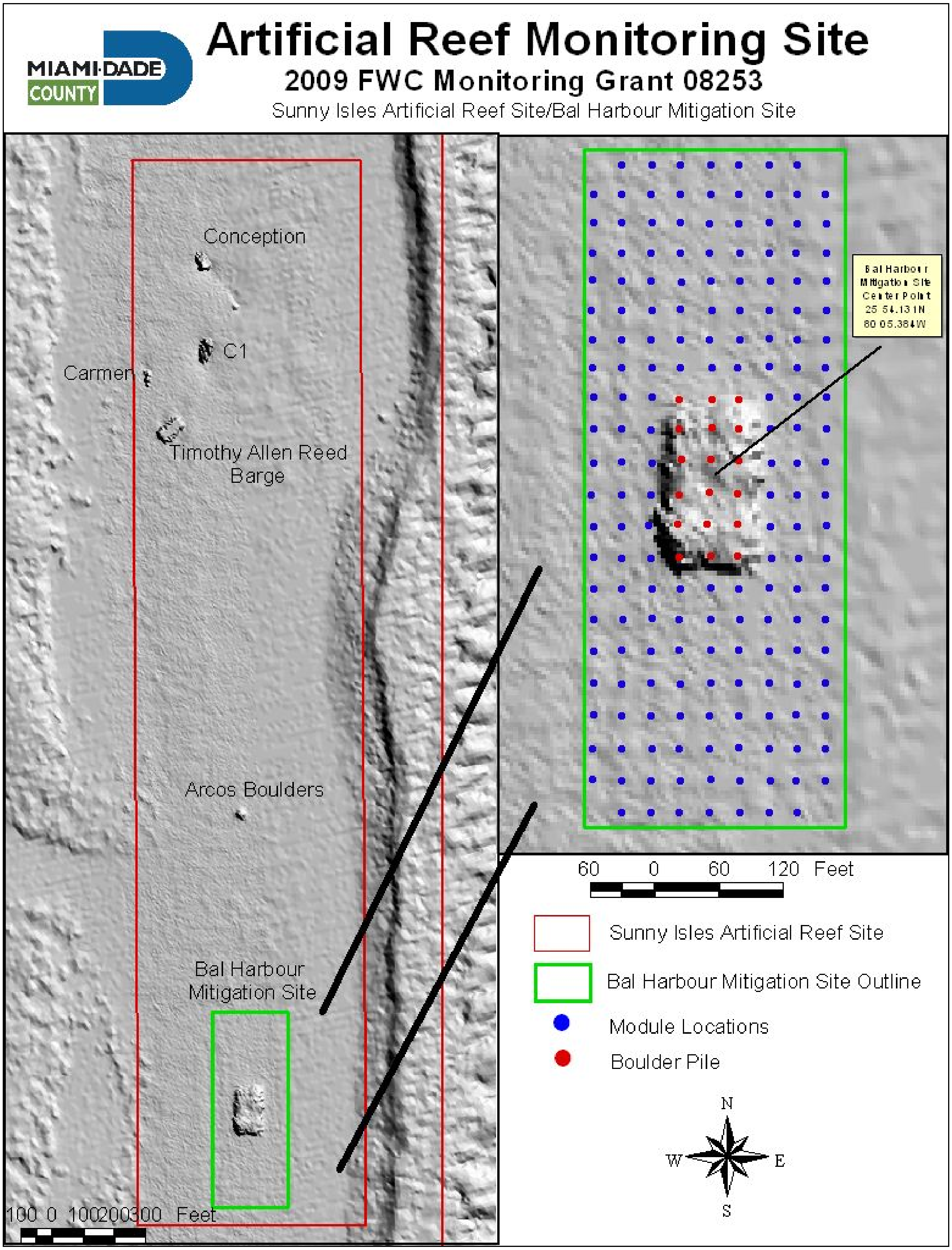

Figure 2. Sunny Isles Artificial Reef site and Bal Harbour Mitigation study site map. Gray-scaled bottom topography is from a survey using Laser Airborne Depth Sounder or LADS (Coastal Planning and Engineering, Inc., 2003).

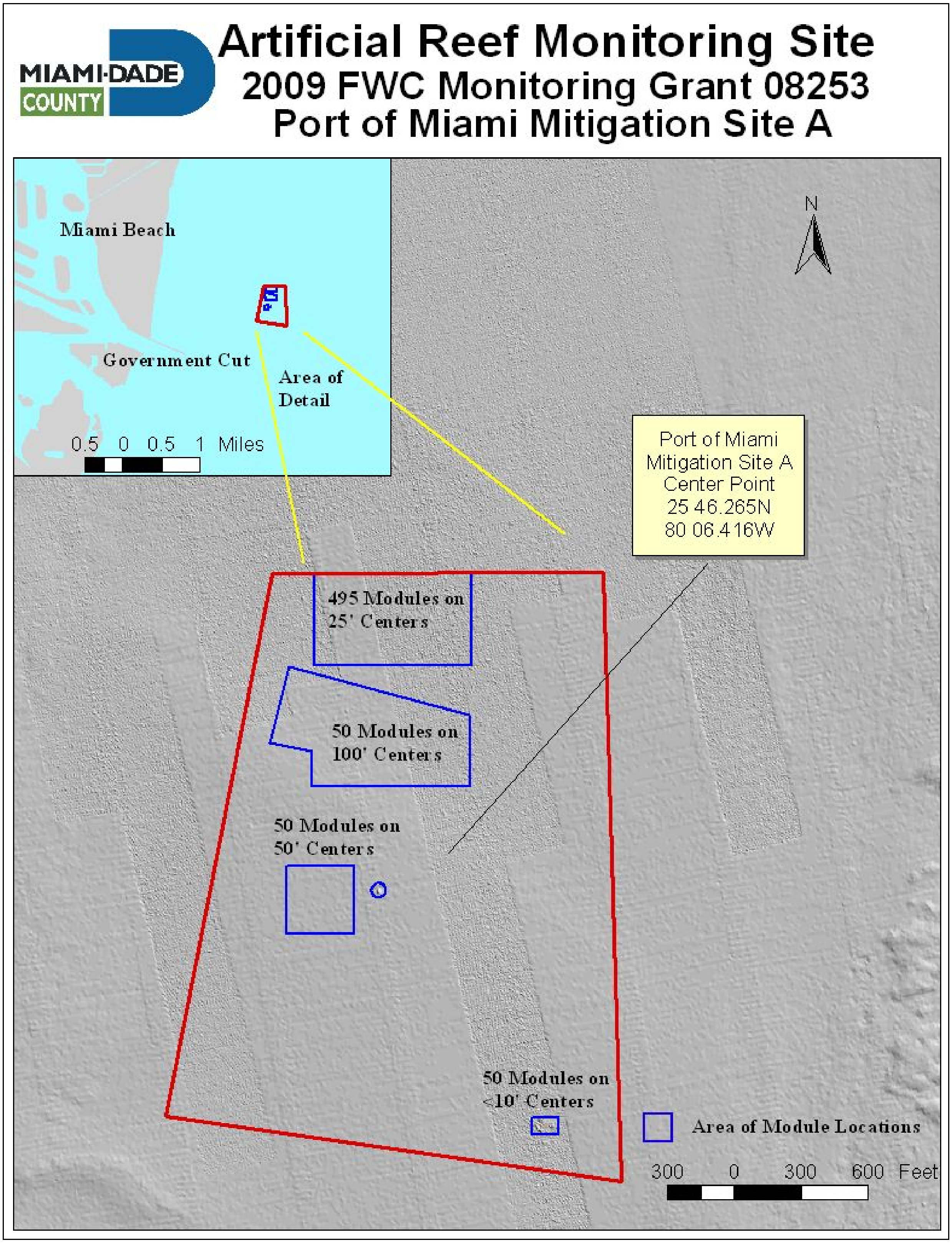

Figure 3. Port of Miami Mitigation Site A and study site map. Gray-scaled bottom topography is from a survey using Laser Airborne Depth Sounder or LADS (Coastal Planning and Engineering, Inc., 2003).

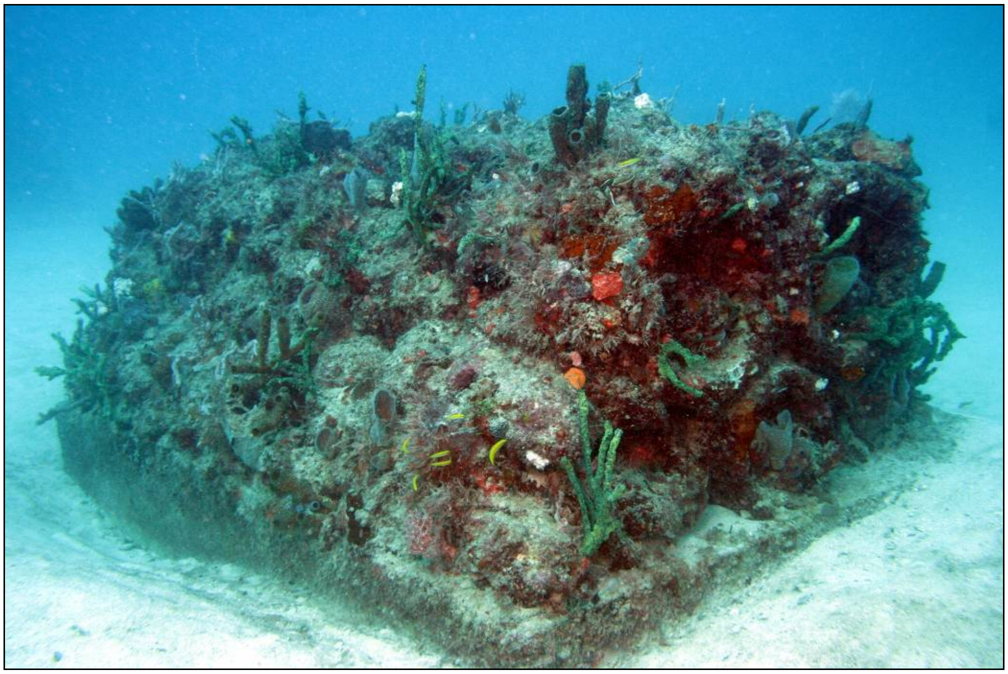

Figure 4. Photograph of Bal Harbour Mitigation Module (September 2009).

Figure 5. Photograph of a POM A Module (100’ Center) (May 2009).

METHODOLOGY

Fish surveys conducted utilized the Bohnsack-Banerot (quick visual assessment) method (1986) with one modification. With the Bohnsack-Banerot method, each fish census is made within an imaginary vertical cylinder in the water column. The diameter of the cylinder is 15m, and the height of the cylinder extends from the reef substrate up to the surface (to the limits of visibility). For the standard Bohnsack-Banerot (1986) method, the survey is conducted from a stationary position in the center of the cylinder. For this study, the method was modified in that the surveyor did not remain stationary during the survey. The modified Bohnsack-Banerot method consisted primarily of a comprehensive listing of all fish species observed within the first five minutes of the survey by generally swimming around the perimeter of the cylinder and, then a second smaller circle closer to the center of the cylinder. This modified method allows for a closer observation of smaller and cryptic species and more accurate species listing in lower visibility situations. Following the first five minutes, a count was made of the number of individuals of each previously noted species. Each listed species was counted separately (diver swims one entire rotation around the cylinder for each count). In addition to the number of individuals seen, the size range (min, mean, and max overall length) of each species was recorded. All species observed after the first five minutes of a survey were listed, counted, and measured, but not evaluated in analysis.

Although the comprehensive fish survey datasets included all species observed and recorded, fish assemblage analyses for this report were limited to those species characterized as the "resident" species or guild (Bohnsack et al. 1994). Resident species tend to remain at one site and are often observed on one or more consecutive surveys (Bohnsack et al. 1994). Other classifications such as "visitors" (only use the habitat for temporary shelter or feeding) and "transient" (roam over a wide area and appear not to react to the reef presence) were omitted from analysis unless otherwise noted in order to reduce the variability added by the inclusion of these classifications.

Twelve (12) fish surveys (non-overlapping) were completed on each of the four module spatial array at POM A (25 ft. deep).. Twelve (12) surveys (non-overlapping) were also completed on the BHM modules (25 ft. apart) at a depth of 68 feet.

Benthic assemblages were assessed using a photogrametetric method (POM A) and video transect methodology (BHM). For the POM A, the photogrametetric method involved taking digital pictures of a quadrat at a fixed distance. Each quadrat was 40cm x 50cm or 0.20 m^2. Over 500 images were taken on the POM A 25 ft. spatial array from June 3, 2009 to July 14, 2009. Poor quality (blurry/ out of focus) images were discarded yielding a total of 511 images or a survey area of 102 m^2.

The benthic data for the BHM modules was obtained from an existing annual monitoring program (Bal Harbour Mitigation Monitoring Program). The methodology for this program uses a video transect methodology (instead of a quadrat photo method) The video methodology involves filming three stations, each comprised of three transects over eight modules. Two of the transects are on the sides of the module and one runs down the middle. Each transect runs the length of all eight modules omitting the sand in between. The transects were filmed from July

17th to 21st, 2009. Once the filming was complete, abutting still images were retrieved (frame grabbed) using video editing software (Pinnacle v12). The three video transects yielded over 1100 still images. Each image has a survey area of approximately 30cm by 40cm (0.12 m^2). To match the survey area on the POM A modules, 850 BHM images were used for an equivalent survey area of 102 m^2.

Coral Point Count Software developed by National Coral Reef Institute and Nova Southeastern University (Kohler and Gill 2006) was then used on both sets of images to overlay random points on top of each image. Due to different image sizes (POM A = 0.20 m^2; BHM = 0.12 m^2) and image quantities (POM A = 511; BHM = 811) between the methods, the number of random points overlaid on each image differed in order to maintain a similar sampling effort. Twenty (20) points were overlaid on each POM A image and 12 points were overlaid on each BHM image for a total of 10,200 analyzed points at each site. For both POM A and BHM images, the benthic organism or substrate under each point was identified to the lowest possible taxa or substrate category providing an estimate of relative percent cover of each benthic taxa or substrate.

Statistical analysis. One focus of this monitoring project was to provide information on the fish assemblages on the various module spatial arrays as well as benthic and fish assemblages at the two different module depths. Basic descriptive statistics, similarity indices and non-parametric multi-parameter scaling was deemed appropriate for these evaluations. The information provided in the report will hopefully serve as foundation for more rigorous scientific evaluations in the future including parametric evaluations (i.e., ANOVA).

Multiple software applications were used to summarize and analyze the benthic and fish population data. Microsoft Excel was used to calculate descriptive statistics and graph results of the data and indices. "Primer-5 for Windows®" (Primer-E, 2002) multivariate statistical software was used to calculate and display Bray-Curtis similarity indices (Bray and Curtis, 1957), similarity and evenness indices, ordination clustering of the data using non-metric multidimensional scaling (MDS) procedures, analysis of similarities (ANOSIM), and similarity percentage breakdowns (SIMPER). SAS® (SAS Institute, Inc.) was used to compare fish size class data.

Summary statistics included total abundance, relative percent cover, number of species, and diversity. The Shannon Diversity Index (H') is the most commonly used diversity measure (Clarke and Warwick 1994). The value of the Shannon Index lies in its incorporation of species richness (S), or the total number of species, as well as the relative abundances of species. H' falls to zero when all the individuals in a population sample belong to the same species and increases as the number of species increases. Relative numbers of individuals of each species also affects the value of H'. If only a small portion of species in the sample account for most of the individuals, the value of H' will be lower than if all the individuals were distributed evenly among all the species. Pielou's Evenness measure (J) was also calculated because it expresses how evenly the individuals are distributed among the different species. Higher values of J indicate the more evenly the number of individuals are spread among the different species.

Prior to the calculation of the Bray-Curtis indices, the data was fourth-root transformed in order to reduce the weight of the common species and incorporate the importance of both the intermediate and rare species (Field et. al 1982; Clark and Warwick 1994). The non-metric MDS analysis (Kruskal and Wish, 1978) generated a graph based on the calculated Bray-Curtis indices. The MDS analysis generates a "stress value" for each plot, which indicates the level of difficulty in representing the similarity relationships for all samples into a two-dimensional space. Clarke and Warwick (1994) state that a stress value ≤ 0.05 indicates a plot with excellent representation and minimal chance of misinterpretation, values from 0.05 to 0.10 correspond to a good ordination with slight chance of misinterpretation, values from 0.10 to 0.20 indicate a potentially useful plot, but have a greater chance of misinterpretation, and values between 0.20 and 0.30 are considered acceptable although conclusions should be crosschecked with other statistical measures. Plots associated with stress levels ≥0.30 represent a more or less arbitrary arrangement. SIMPER analysis produces an average dissimilarity between samples and gives each species' percent contribution to this dissimilarity. ANOSIM is an analysis of similarities. ANOSIM produces an R statistic which correlates to how similar the samples are. This analysis produces global (over all samples) and pairwise (between each combination of two samples) R statistics and p values. An R statistic of 1.00 indicates that samples are completely different while an R statistic of zero indicates samples are identical (Clarke and Warwick, 1994). R statistics are only interpreted here where p values are <0.05.

Count data are best modeled with Poisson distributions, but can be over-dispersed (aggregated) in either space or time (McCullagh and Nelder, 1989). Overdispersion is characterized by a high incidence of low values (counts). In cases of over dispersion the negative binomial distribution, which can be derived from the poisson, best fits the data as it naturally accounts for over dispersion. Furthermore, the model can be corrected for over dispersion (Cox, 1983; Pedan, 2001). To evaluate the differences in total abundance and individual size class abundance between spatial arrays and depths the GENMOD procedure in SAS/STAT® was used to analyze the count data. This method uses maximum likelihood to derive the parameter estimates and compares to its expected value based on the chi square distribution. Mean fish size for each species was divided into 5 classes: 0-2 cm, 2-5 cm, 5-10 cm, 10-20 cm, and >20 cm. Fish abundance in each size class as well as overall fish abundance was compared throughout the module spatial arrays and depths. P values less than 0.05 were considered significant.

Results

Fish Assemblages at the POM A Module Spatial Arrays

The fish surveys were conducted in May, June, and July 2009.

*Species Richness***.** Figure 6 shows the total number of fish species observed at each module spatial array on the POM A site. Refer to Appendix 1 for a complete species listing per array. The highest number of resident species observed on all surveys occurred where the modules were placed on <10 ft. centers with 50 species. The lowest number occurred where the modules were placed on 25 ft. centers with 37 species.

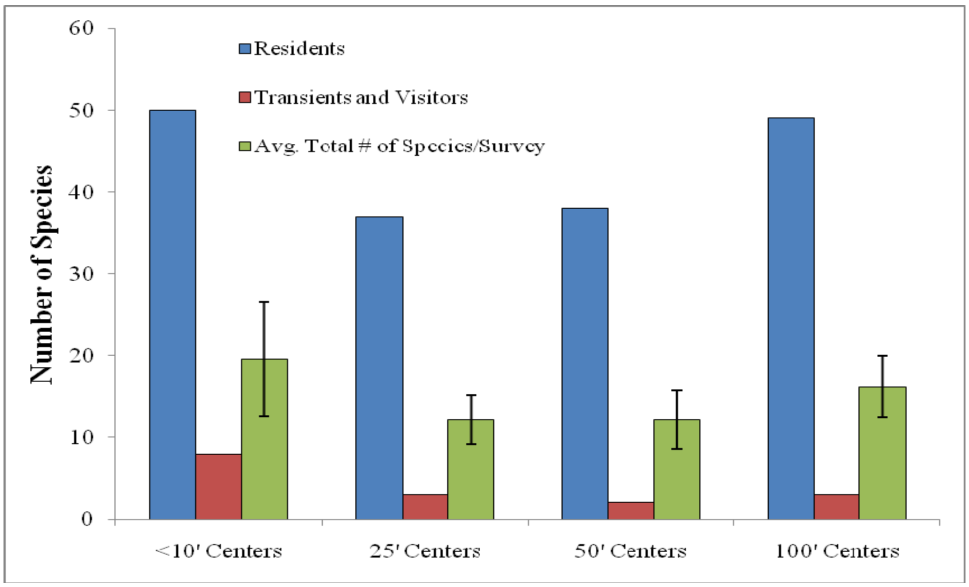

Figure 6. Total number of fish species observed at each module spatial array at the POM A Artificial Reef Site. NOTE: Area of each survey = 176 m^2.

Diversity. The Shannon Diversity Index (H') and Pielou's Evenness measure (J') were calculated for the resident fish assemblages at each module spatial array. Figure 7 shows the mean H' and J' values at each site. The J' values were low across all sites. The modules on 25 ft. centers had the highest H' value, 3.25, as well as the highest J' value, 0.09 (Figure 7). The lowest H' (2.37) and J' (0.05) value occurred where the modules were set on <10 ft. centers.

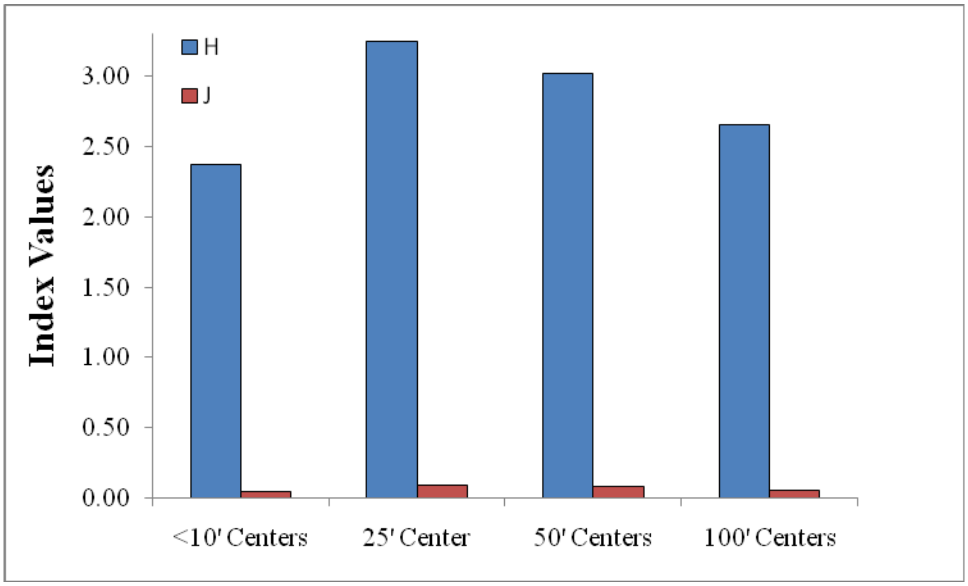

Figure 7. Mean Shannon Diversity Index (H'; range= 0.00-+3.00) and Pielou's Evenness measure (J'; range= 0.00-1.00) for the resident fish assemblages on each module spatial array at the POM A Artificial Reef Site. NOTE: Area of each survey = 176 m^2.

Abundance. Figure 8 shows the mean abundance (number of individuals) per survey at each module spatial array. The modules on < 10 ft. centers not only had the greatest species richness but also the highest abundance with an average of 241.67 individuals across all surveys. The modules on 25 ft. centers showed the lowest mean abundance with 44 individuals across all surveys. Significant differences (Chi-Square, $p<0.05$) occurred between all spatial arrays except <10' centers vs. 100' centers and 25' centers vs. 50' centers.

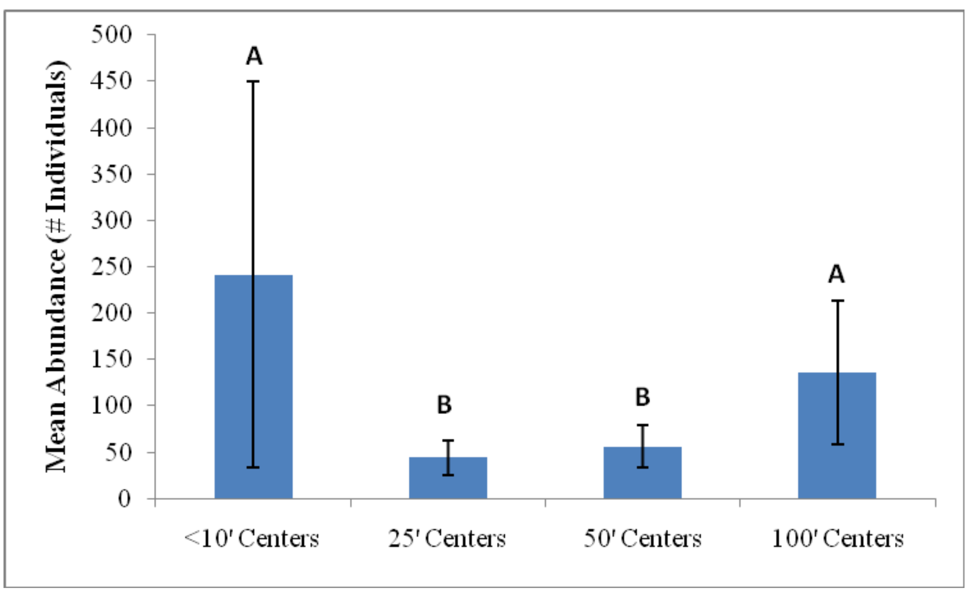

Figure 8. Mean resident fish abundance for each module spatial array at the POM A Artificial Reef Site. Differing letters indicate a significant difference. Standard deviation bars plotted for all sites.

Family Composition and Abundant Species. On all spatial arrays, a large percentage of the resident fish belonged to either Labridae (Wrasses), Haemulidae (Grunts), or Pomacentridae (Damsels) families (Figure 9). The modules on 100 ft. centers had the highest percentage of the family Haemulidae. The modules on 25 ft. centers had the highest percentage of the family Labridae and Pomacentridae. The most abundant Labridae species across all reefs was *Thalassoma bifasciatum* (Bluehead Wrasse) while *Haemulon aurolineatum* (Tomtate) was the most abundant species of the family Haemulidae.

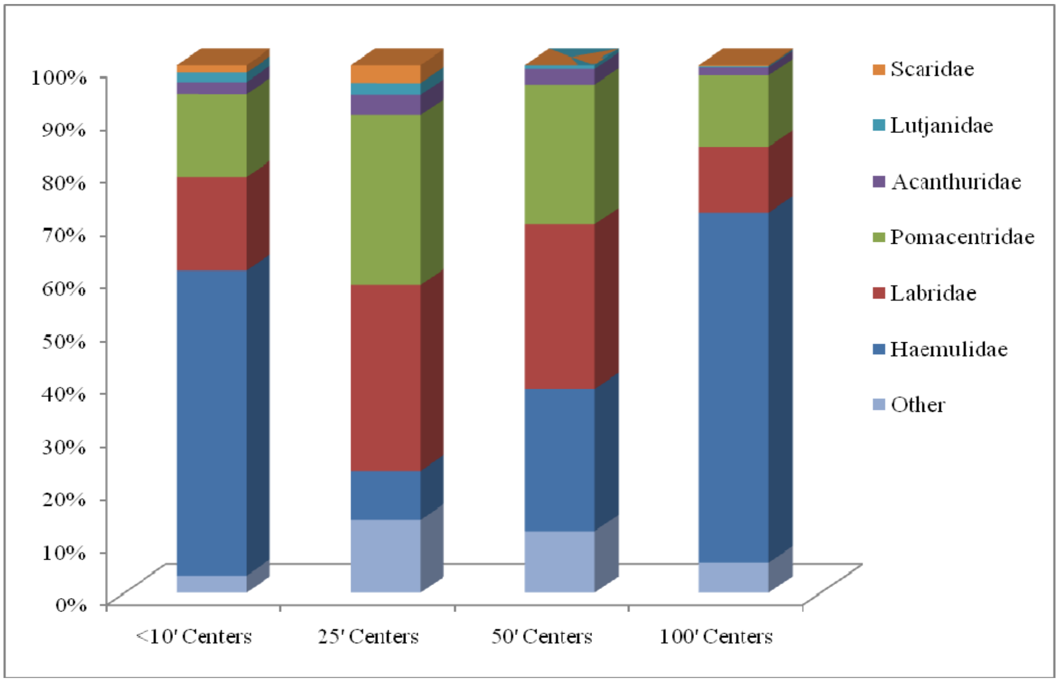

Figure 9. Mean percent composition (%) of resident individuals per survey by major family constituents for each module spatial at the POM A Artificial Reef Site.

In addition to *T. bifasciatum* and *H. aurolineatum*, several other species were common across all sites as indicated in Table 1. *Acanthurus bahianus* (Ocean Surgeonfish) of the family Acanthuridae was abundant on all spatial arrays Other Labridae species including *Halichores bivittatus* (Slippery Dick) and *Halichoeres maculipinna* (Clown Wrasse) were observed at all sites. The Lutjanidae family was also represented on all sites with the species *Lutjanus griseus* (Gray Snapper). Five species of the family Pomacentridae were abundant across all spatial arrays.

Table 1. Average number of individuals per survey for the most abundant species.

		< 10' Centers	25' Centers	50' Centers	100' Centers
Acanthuridae	*Acanthurus bahianus*	4.92	0.42	0.92	1.67
Balistidae	*Balistes capriscus*	0.08	1.75	0.75	0.17
Blennidae	*Parablennius marmoreus*	0.75	0.08	1.25	1.58
Gobiidae	*Gobiosoma oceanops*	1.00	0.17	0.25	1.08
Haemulidae	*Haemulon aurolineatum*	104.08	3.75	9.92	78.00
	Haemulon plumieri	9.00			
	Haemulon sciurus	2.00		0.08	0.08
	Haemulon species (unid juv.)	23.33		5.00	10.83
Kyphosidae	*Kyphosus sectarix*	0.58	1.92		
Labridae	*Halichoeres bivittatus*	3.75	0.83	0.58	1.08
	Halichoeres maculipinna	1.08	0.33	1.33	0.67
	Thalassoma bifasciatum	36.75	13.25	14.33	14.67
Labrisomidea	*Malacoctenus triangulatus*	1.92	0.25	1.17	0.83
Lutjanidae	*Lutjanus griseus*	3.33	0.92	0.42	0.25
Pomacentridae	*Abudefduf saxatilis*	6.00	1.33	1.58	0.67
	Chromis multilineatus	3.00	1.00	0.75	2.42
	Stegastes adustus	4.00	1.50	1.83	2.33
	Stegastes leucostictus	3.75	1.08	0.42	0.67
	Stegastes partitus	20.42	9.00	10.00	11.42
Scaridae	*Sparisoma aurofrenatum*	2.17	0.58		0.08
Tetraodontidae	*Canthigaster rostrata*	0.83	1.00	0.33	0.58

Similarity. Figure 10 shows the MDS plot graphically depicting the Bray-Curtis similarity values for the abundance of each resident fish species for each survey. The stress value is moderately low indicating an accurate representation of the plot. The purpose of this assessment is to provide an indication of the consistency of the resident fish population on each of the spatial arrays, through comparison of the similarity (and thereby the composition and abundance) between the rounds of samples.

No strong groupings were observed; however, each spatial array appears to aggregate to a similar area on the plot (Figure 10). ANOSIM results of fish abundance per survey showed a significant difference between the various spatial arrays. The 100’ centers and the 25’ centers were the most dissimilar (R=0.490) while the 25’ centers and the 50’ centers were the most similar (R=0.174) (Table 2). SIMPER analysis showed that the species responsible for the difference between all spatial arrays was *H. aurolineatum* (Tomtate) (Table 3). *Haemulon aurolineatum* (Tomtate) was most abundant on the modules set on <10 ft. centers followed by modules set on 100 ft. centers, 50 ft. centers, and 25’ centers respectively.

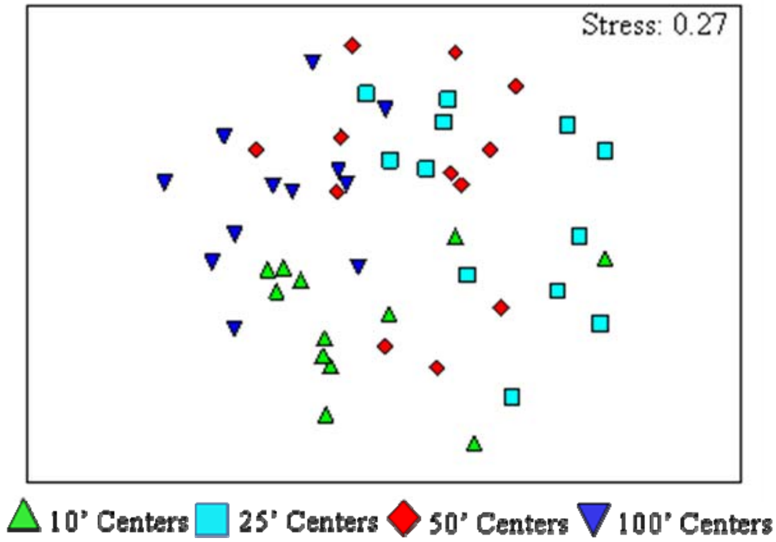

Figure 10. Multi-dimensional scaling (MDS) plot based on the Bray-Curtis Similarity values for the resident fish species abundance for each survey at POM A.

Table 2. ANOSIM results for resident fish abundance for each survey at POM A. An R statistic of 1.00 indicates the samples are completely different, 0.0 indicates samples are identical. R statistics with P values of <0.05 are considered significant.

	R Statistic	P Value
Global (Overall)	0.322	0.001
<10' Centers vs. 100' Centers	0.311	0.001
<10' Centers vs. 25' Centers	0.383	0.002
<10' Centers vs. 50' Centers	0.356	0.002
100' Centers vs. 25' Centers	0.490	0.001
100' Centers vs. 50' Centers	0.191	0.008
25' Centers vs. 50' Centers	0.174	0.006

Table 3. SIMPER results for resident fish abundance for each survey showing the average dissimilarity between spatial arrays at POM A, the species responsible for the dissimilarity and the percent contribution of that species to the dissimilarity.

	Average Dissimilarity	Species	% Contribution
<10' Centers vs. 100' Centers	66.65	*H. aurolineatum*	42.62
<10' Centers vs. 25' Centers	73.26	*H. aurolineatum*	32.18
<10' Centers vs. 50' Centers	70.53	*H. aurolineatum*	32.99
100' Centers vs. 25' Centers	68.19	*H. aurolineatum*	48.41
100' Centers vs. 50' Centers	61.65	*H. aurolineatum*	50.30
25' Centers vs. 50' Centers	54.65	*H. aurolineatum*	18.55

Size Class. Mean abundance in each size class is shown in Table 4 and the p values for each comparison are shown in Table 5. Small fish (0-2 cm) were more abundant on modules set on 100' centers, while large fish (> 20 cm) were more abundant on modules set on <10' centers. Many significant differences occurred between module spatial arrays in the various size classes. The significantly largest amount of fish were of the size class 10-20 cm at the modules set on <10' centers.

Table 4. Mean abundance, median abundance, and standard error for each module spatial array in each size class.

	10' Centers			25' Centers			50' Centers			100' Centers		
Size Class	**Mean Abun.**	**Median**	**SE**	**Mean Abun.**	**Median**	**SE**	**Mean Abun.**	**Median**	**SE**	**Mean Abun.**	**Median**	**SE**
0-2 cm	1.5	1	0.27	1	1	1.76	7.33	1	10.02	2.37	1	5.06
2-5 cm	15.47	3	0.59	7.16	5	3.36	6.87	5	6.84	12.02	2	0.61
5-10 cm	10.24	4	7.37	3.18	2	0	3.97	2	1.09	11.93	3	0.22
10-20 cm	22.05	2	0.68	2.64	2	0.48	1.85	1.5	3.3	10.3	2	0.45
>20 cm	2.93	2	0.92	1.96	1	0.23	1.41	1	0.12	1.54	1	0.96

Table 5. Negative Binomial regression p values for each size class comparing the four module spatial arrays. Highlighted values are not significant (Chi-Square, p>0.05).

	0-2 cm	**2-5 cm**	**5-10 cm**	**10-20 cm**	**>20 cm**
10' vs. 25' Centers	0.6068	0.0116	0.0002	<0.0001	0.0487
10' vs. 50' Centers	0.0028	0.0032	0.0013	<0.0001	0.0029
10' vs. 100' Centers	0.3622	0.3013	0.5786	0.0525	0.0147
25' vs. 50' Centers	0.0084	0.8873	0.5155	0.3651	0.2151
25' vs. 100' Centers	0.2297	0.0585	0.0002	0.0004	0.3932
50' vs. 100 ' Centers	0.0023	0.021	0.0011	0.0002	0.7864

Fish Assemblage Comparison on Modules Deployed at 25 ft. (POM A 25' centers) versus 68 ft. (Bal Harbour Mitigation)

Species Richness. The number of average total number of fish species at each depth was very similar, with 12.16 per survey on POMA and 13.25 on BHMM. The BHM modules had more total resident fish species (45) than the POM A modules (37) (Figure 11).

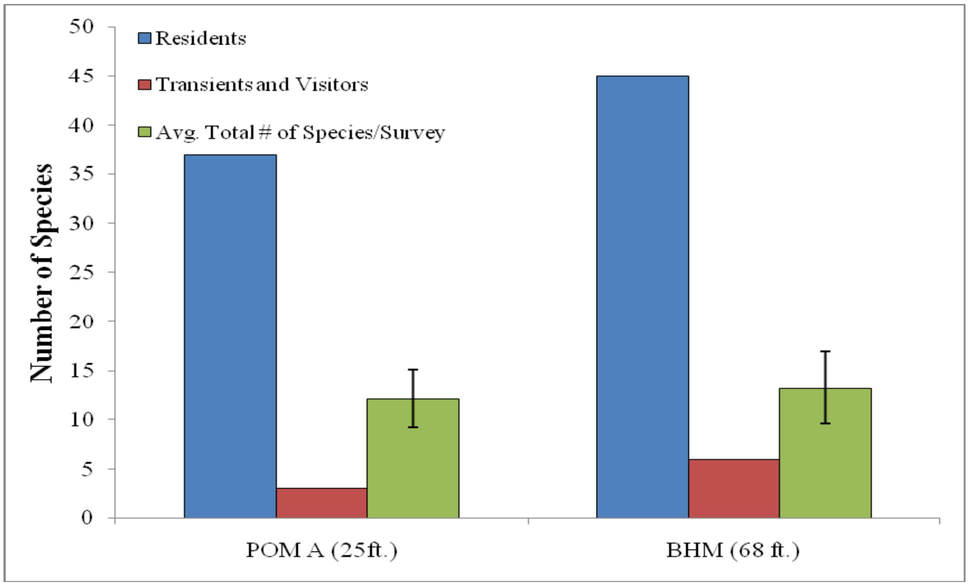

Figure 11. Total number of fish species observed at the POM A and BHM modules surveyed. NOTE: Area of each survey = 176 m^2.

Diversity. Diversity was higher on the POM A modules compared to the BHM modules (Figure 12). The POM A modules had an H' value of 3.25 while the BHM modules had an H' value of 2.49. Both had low J' or evenness values of less than 0.10.

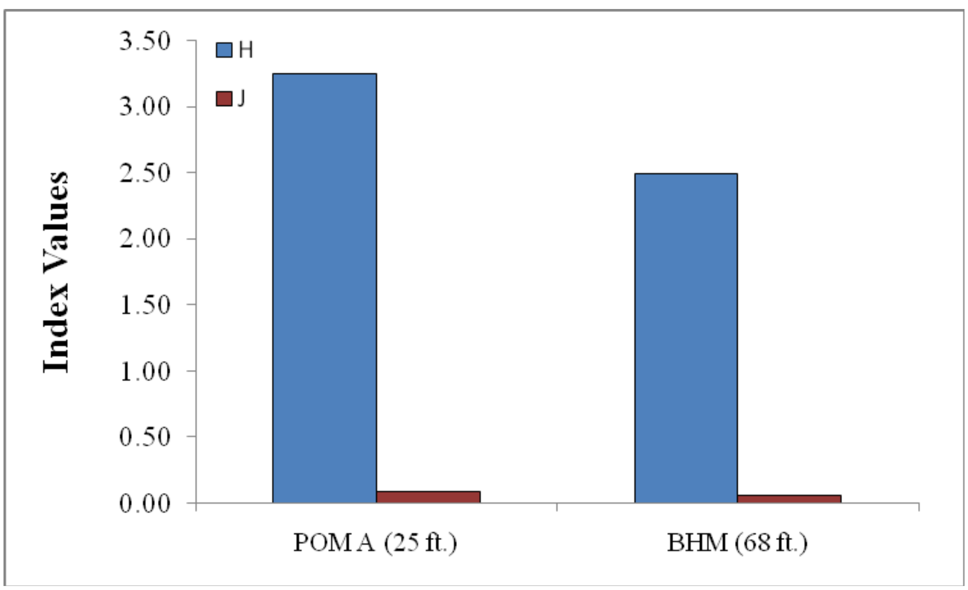

Figure 12. Mean Shannon Diversity Index (H'; range= 0.00-+3.00) and Pielou's Evenness measure (J'; range= 0.00-1.00) for the resident fish assemblages at the POM A and BHM modules.

Abundance. Overall fish abundance was significantly lower at the POM A compared to the BHM modules (Chi-Square, p<0.001).

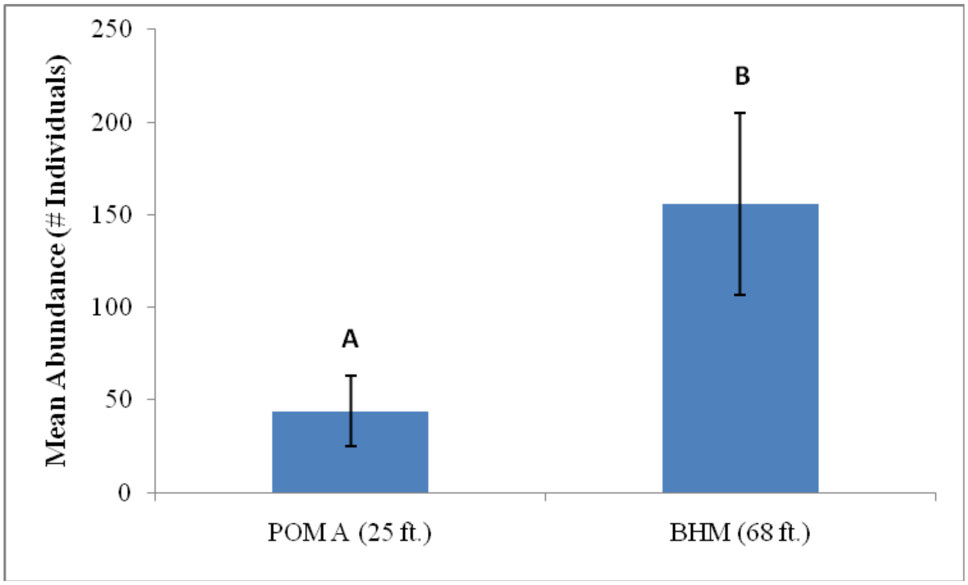

Figure 13. Mean resident fish abundance for each survey at the POM A and BHM modules. Differing letters indicate a significant difference. Standard deviation bars plotted for both sites.

Family Composition and Abundant Species. The largest percent composition of individuals for BHM modules came from the family Gobiidae (47 %) while the Labridae (35%) and Pomacentridae (32%) were the largest families represented at the POM A modules (Figure 14). More Haemulidae individuals were also represented on POM A (9%) than BHM (2%).

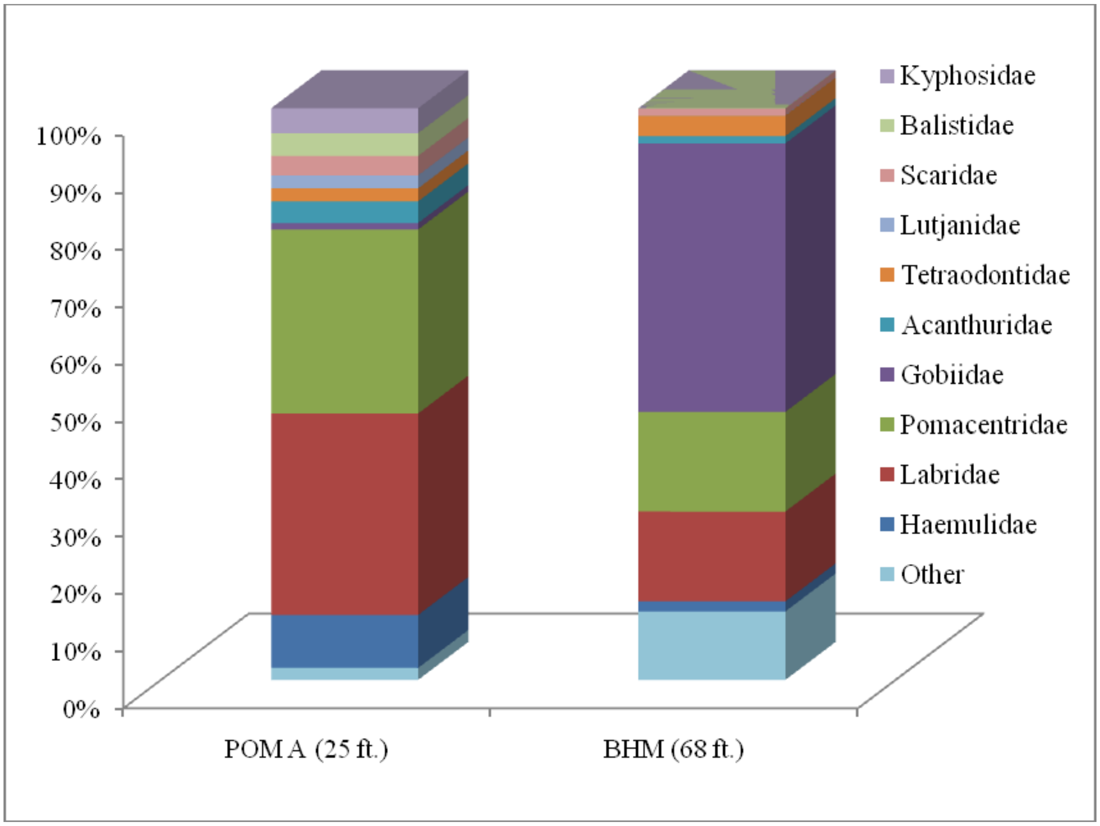

Figure 14. Mean percent composition (%) of resident individuals per survey at the POM A and BHM modules by major family constituents.

Several species of the family Acanthuridae, Gobiidae, Haemulidae, Labridae, Pomacentridae, and Tetradontidae were found on both depths of module reefs (Table 6). *Thalassoma bifasciatum* (Bluehead Wrasse) was the most abundant fish of the Labridae family on both the POM A and BHM modules. *Stegastes partitus* was the most abundant species from the Pomacentridae family at both sites. The BHM modules had a much higher presence of the family Gobiidae due to one species in particular the *Coryphopterus personatus* (Masked Goby). In addition to *C. personatus*, *Pterelotirs calliurs* (Blue Goby), *Halichoeres garnoti* (Yellowhead Wrasse), and *Chromis scotti* (Purple Reeffish) were also abundant on the deeper BHM modules, but absent from the shallower POM A modules. Several abundant species on the POM A modules absent from BHM modules included *Balistes capriscus* (Gray Triggerfish), *Kyphosus sectarix* (Bermuda Chub), and *Stegastes leucostictus* (Beaugregory). The POM A modules had a higher abundance of *H. aurolinateum* and unidentified juvenile *Haemulon* species which accounted for the higher percent composition of the Haemulidae family.

Table 6. Average number of individuals per survey for the most abundant species.

		POM A (25 ft.)	BHM (68 ft.)
Acanthuridae	*Acanthurus bahianus*	0.42	1.58
	Acanthurus chirugus	0.92	0.25
Balistidae	*Balistes capriscus*	1.75	
Gobiidae	*Coryphopterus glaucofraenum*	0.17	16.50
	Coryphopterus personatus		52.92
	Ptereleotris calliurus		2.25
Haemulidae	*Haemulon aurolineatum*	3.75	0.08
	Haemulon species (unid juv.)	5.00	1.83
Kyphosidae	*Kyphosus sectarix*	1.92	
Labridae	*Halichoeres garnoti*		1.67
	Thalassoma bifasciatum	13.25	22.58
Lutjanidae	*Lutjanus griseus*	0.92	
Pomacentridae	*Abudefduf saxatilis*	1.33	0.33
	Chromis multilineatus	1.00	
	Chromis scotti		1.17
	Stegastes adustus	1.50	0.08
	Stegastes leucostictus	1.08	
	Stegastes partitus	9.00	25.33
Tetraodontidae	*Canthigaster rostrata*	1.00	5.58

Similarity. An MDS plot comparing fish abundance for each survey of the POM A and BHM modules shows that the 68 ft. deep (BHM) modules are well separated from the 25 ft. modules (POM A) (Figure 15). The POM A modules also show greater variation between surveys. The average dissimilarity between the depths was 75.83%. ANOSIM results indicate the dissimilarity was significantly different between the modules at 25 ft. deep and 68 ft. deep ($R=0.894$, $p=0.001$). SIMPER analysis further shows that the species driving the difference between module depths is *C. personatus* (Masked Goby) contributing 34.99% to the dissimilarity between samples. *Coryphopterus personatus* had a higher density on the BHM modules.

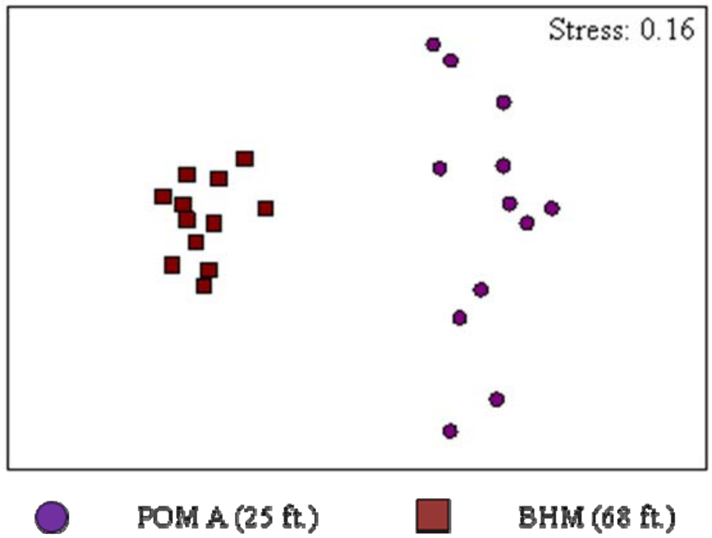

Figure 15. Multi-dimensional scaling (MDS) plot based on the Bray-Curtis Similarity values for the abundance of each resident fish species for each survey on the POM A and BHM modules.

Size Class. All size classes showed significant differences between depths except fish greater than 20 cm (Table 7). The deeper (BHM) modules had a significantly higher fish abundance in most categories except for 10-20 cm where the shallower (POM A) modules had significantly more fish. The most significant difference occurred with small fish (0-2 cm). The BHM modules had significantly more fish in the smallest size class compared to POM A (Figure 16).

Table 7. Mean abundance, median, standard error and associated p value of fish in each size class for POM A (25 ft.) and BHM (68) ft. Highlighted values are not significant.

	POM A (25 ft.)			BHM (68 ft.)			
Size Class	**Mean Abundance**	**Median**	**Standard Error**	**Mean Abundance**	**Median**	**Standard Error**	Chi-Square, **p Value**
0-2 cm	1	1	0	32.97	21	6.48	0.0013
2-5 cm	7.16	5	1.09	11.79	7	1.6	0.0284
5-10 cm	3.18	2	0.68	8.14	3	1.87	0.0018
10-20 cm	2.64	2	0.45	1.43	1	0.12	0.0015
>20 cm	1.96	1	0.48	1.92	1	0.76	0.0951

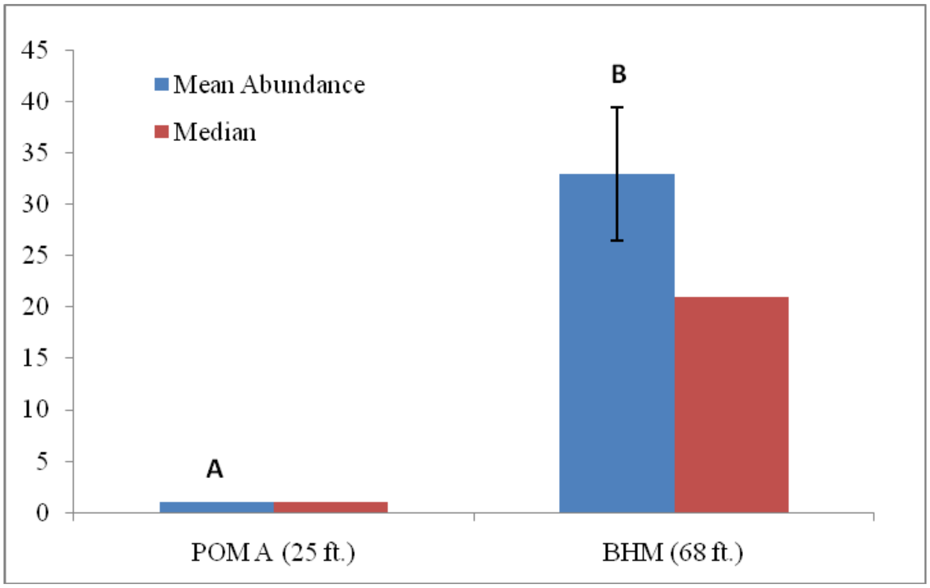

Figure 16. Mean abundance and median values for fish in the size class 0-2 cm for POM A (25 ft.) and BHM (68 ft.) modules. Different letters indicate a significant difference.

Sportfish Abundance and Size

Several sport fish were observed on the module reefs including jacks, groupers, snappers, triggerfish and hogfish. Table 8 shows the abundance, mean size, and range of sport fish across all surveys for each module reef. A few large jacks (i.e., *Seriola dumerii;* Greater Amberjack) were observed at the BHM and POM A modules on <10 ft. centers, but all were smaller than the minimum size limit of approximately 71cm. Occasionally, other smaller jacks (e.g., *Caranx ruber*, the Bar Jack) were also noted. From the grouper family, *Cephalopholis cruentatus* (e.g., Grasby) was observed on all of the module reefs. One Gag Grouper (*Mycteroperca microlepis*) was observed at POM A 25 ft. centers site. A juvenile Yellowmouth Grouper (*Mycteroperca interstitialis)* was observed at POM A 100 ft. centers. From the snapper family, *L. griseus*, the Gray Snapper, was observed across all POM A spatial arrays. Large Mutton Snapper, *L. analis*, were observed at BHM modules. The Hogfish, *Lachnolaimus maximus*, was observed at all module reefs.

Table 8. Abundance, mean size, and range of sport or regulated fish observed across all surveys at all module spatial arrays and depths. The values below include species observed in the initial five minutes of the surveys as well as after.

	BHM			POM A 10			POM A 25			POM A 50			POM A 100		
	No.	Mean (cm)	Range (cm)	No.	Mean (cm)	Range (cm)	No.	Mean (cm)	Range (cm)	No.	Mean (cm)	Range (cm)	No.	Mean (cm)	Range (cm)
Jacks:															
Caranx bartholomaei (Yellow)	8	60													
Caranx crysos (Blue Runner)							2	14	13-15	4	21.7	17-25	3	22	20-25
Caranx ruber (Bar)				5	19.5	4-30	1	27		1	18		1	16	
Seriola rivoliana (Almaco)				3	30	30-31									
Groupers:															
Cephalopholis cruentatus (Graysby)	4	16	15-17	2	22		1	17		2	12.5	10-15	3	16	12-23
Epinephelus morio (Red)				1	27		3	23.7	21-27	8	27.3	22-40	1	60	
Mycteroperca interstitialis (Yellowmouth)													1	6	
Mycteroperca microlepis (Gag)							1	22							
Snappers:															
Lutjanus analis (Mutton)	2	24.5	23-26							1	24				
Lutjanus campechanus (Red)							3	21.5	15-28				1	15	
Lutjanus griseus (Gray)				41	21	16-27	13	18.2	10-23	6	21	15-26	3	15	13-25
Lutjanus synagris (Lane)	2	12	12-13	22	17.8	15-20									
Ocyurus chrysurus (Yellowtail)				7	27.8	18-34	6	21.5	14-30	2	21	20-22	9	24	20-28
Hogfish:															
Lachnolaimus maximus (Hogfish)	5	21.3	16-25	8	21.4	14-34	6	20.3	16-27	7	21.8	13-30	9	21.7	15-32
Triggerfish:															
Balistes capriscus (Gray)				3	17	15-20	23	20.4	15-25	9	17.2	14-21	2	18	15-20

Benthic Assemblages at the POM A (25 ft.) and Bal Harbour Mitigation (68 ft.) Modules

The benthic assemblages were quantified through photogrametric evaluation using Coral Point Count software (Kohler and Gill, 2006) from digital (Figure 17) and video (Figure 18) photography taken June and July 2009.

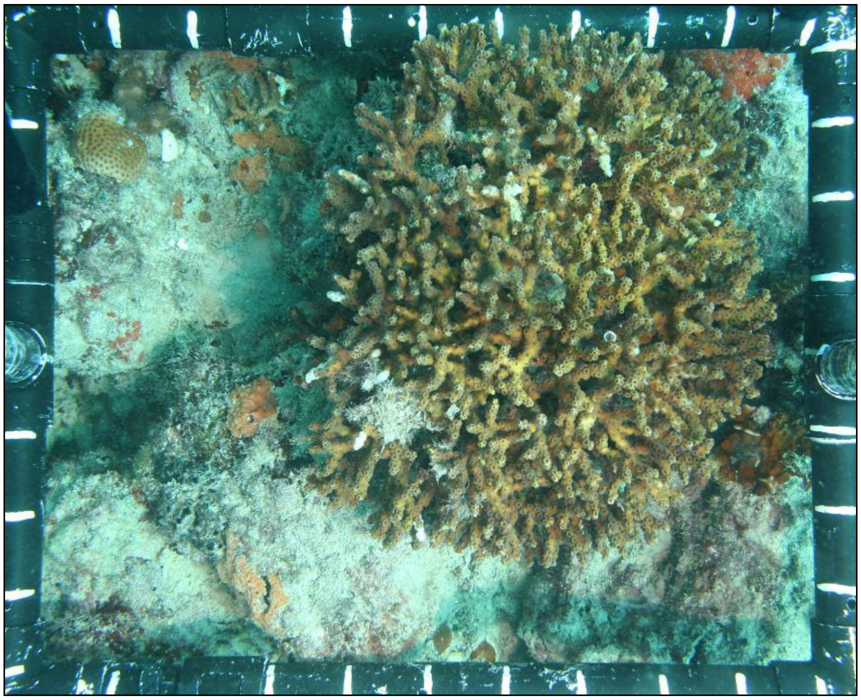

Figure 17. Digital image of benthic biota on POM A modules (25 ft.).

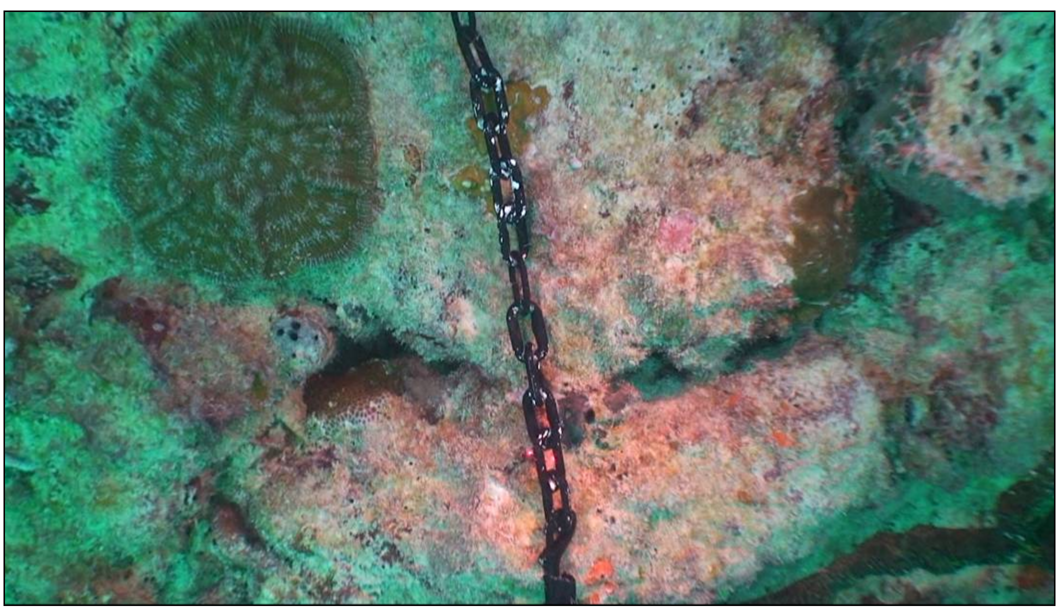

Figure 18. Video image of benthic biota on the BHM modules (68 ft.).

Relative Percent Cover. Table 9 shows the relative percent cover of the major benthic categories for the POM A and BHM modules studied. Refer to Appendix 2 for a complete listing of the relative percent cover by species (or lowest possible discernable taxonomic group). Both sites were dominated by algae cover. Porifera (sponges) had the second highest percent cover on all sites. Octocorallia (soft corals) were slightly more abundant at the BHM modules than the POM A modules while scleractinians (hard corals) were more abundant on POM A than the BHM.

Table 9. Relative percent (%) cover of major benthic categories.

	POM A (25 ft.)	**BHM (68 ft.)**
Algae	74.75	70.34
Porifera	18.01	25.82
Octocorallia	0.04	0.07
Scleractinia	4.57	1.96
Milleporidae	0.8	0.67
Zoanthidae	0.09	0.01
Ascidaria	0.37	0.08
Other Live	0.44	0.55
Substrate (sand or bare)	0.28	0.46

As indicated in Table 10, turf algae dominated the algae percent cover component as well as all biotic components. High algal coverage is common at other artificial and natural reef sites in Miami-Dade County (DERM, unpublished). *Peyssonnelia* species were much more common on the BHM compared to the POM A modules while blue-green algae was more common on POM A. *Iciligorgia* species was the most common octocoral on the BHM modules. *Eunicea* species was the most common octocoral on the POM A modules. *Iotrochota birotulata* was the most common poriferan species at both the BHM and POM A modules. *Porites astreoides* was the most abundant scleractinian on the BHM modules and *Oculina diffusa* was the most common on the POM A modules.

Table 10. Relative percent (%) cover for the highest contributors.

		POM A (25 ft.)	**BHM (68 ft.)**
Algae	Turf	68.18	62.69
	Peyssonnelia species	2.32	6.40
	Blue Green Algae	2.02	0.62
Octocorallia	*Iciligorgia* species	0.00	0.04
	Eunicea species	0.03	0.00
	Gorgonian species	0.00	0.01
	Gorgonia ventalina	0.00	0.01
	Pseudoplexaura species	0.01	0.00
Porifera	*Iotrochota birotulata*	3.49	6.65
	Porifera *species*	2.41	3.71
	Holopsamma helwigi	1.59	3.27
	Ircinia felix	1.98	1.18
	Artemisina melana	1.76	1.43
	Niphates digitalis	0.10	1.32
Scleractinia	*Oculina diffusa*	2.90	0.00
	Porites astreoides	0.10	0.95
	Porites porites	0.24	0.01
	Siderastrea siderea	0.13	0.17

Diversity. The Shannon Diversity Index (H') and Pielou's Evenness measure (J') were evaluated for the benthic assemblages at both module reefs (Figure 19). The H' value was equivalent for both sites (H' was 1.74 and 1.64 for the BHM and POM A modules, respectively). Both modules showed low J' values with respect to their benthic assemblages due to the overwhelming coverage of turf algae (Table 10) that reduced the even distribution of individuals among the benthic species.

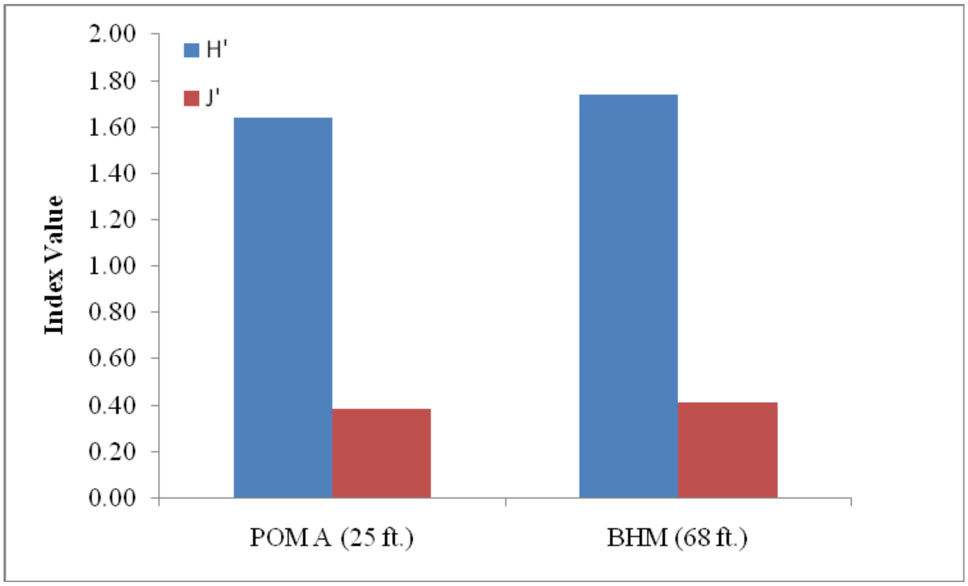

Figure 19. Mean Shannon Diversity Index (H'; range= 0.00-+3.00) and Pielou's Evenness measure (J'; range= 0.00-1.00) for the BHM and POM A modules.

Similarity. The two module sites had a Bray-Curtis similarity percentage of 68.9. The study design did not allow in depth investigations using Primer-E (v.5). Only one replicate (one round of images) from each site was investigated. Therefore, a large enough sample size was not available to produce a Bray-Curtis similarity matrix to draw further conclusions on the differences or similarities in benthic community composition.

DISCUSSION

Fish Assemblages.

Spatial Array Comparison. The fish surveys at the various spatial arrays at POM A showed that all the differing array structures supported a wide variety of fish species and numerous individuals (Figures 6-9 and Appendix 1). Some of the most abundant families on the POM A modules included Labridae, Pomacentridae, Acanthuidae, Haemulidae, Lutjanidae, and Scaridae (Figure 9 and Table 1). The modules on 25 ft. centers contained more diverse and evenly distributed fish assemblages compared to all module spatial arrays (Figure 7). However, the modules on 25 ft. centers also had the lowest resident fish abundance (Figure 8). The modules on 10 ft. and 100 ft. centers had the highest resident fish abundance of the module spatial arrays (Figure 8). A study in Broward County in a similar depth (8m) also evaluated spatial arrays (0.33m, 5m, 15m, and 25 m in triangular arrays) and showed that 'varying reef module isolation' (spacing) does alter fish assemblage structure. The Broward study showed a similar pattern to this study in that the modules closest together and furthest apart had the highest fish abundances (Jordan et al, 2005). The modules on 50' centers had the highest amount of small fish (0-2 cm), while the modules on <10' centers had the highest amount of large fish (>20 cm). The most abundant size class of fish occurred in the 10-20 cm class on the modules set on <10 ft. centers. Overall, based on the similarity in species richness, diversity measures, family composition, abundant species, and overall species abundance, the 25' and 50' centers showed the most similarity to one another.

Depth Comparison. The fish surveys at both the POM A and BHM modules showed that modules at both depths support a wide variety of fish species and numerous individuals (Figures 11-14, and Appendix 1). The POM A modules at 25 ft depth contained slightly more diverse and evenly distributed fish assemblages compared to the modules at 68 ft. at BHM (Figure 12). Pomacentridae, Labridae, and Haemulidae had the most abundant representation on the POM A modules (Figure 14). The deeper modules at BHM showed a higher mean abundance (Figure 13). The fish population was dominated by the Gobiidae family (Figure 14), mainly *C. personatus* (Masked Goby) (Table 6), the abundance of which reduced the diversity value. The POM A modules at 25 ft. also had significantly lower resident fish abundance (Figure 13) due reduced representation of most groups (families) of fish on those modules (Table 6). Significant differences were noted in all size classes between the two depths, except fish >20 cm. The deeper modules had a greater abundance of smaller fish (0-2 cm, 2-5 cm, and 5-10 cm classes). The largest difference occurred between the smallest size class (0-2 cm) (Figure 16). This difference is primarily due to the abundance of *C. personatus* (Masked Goby). The only size class that was significantly larger on the shallower modules (POM A) was 10-20 cm. The shallower modules had more species of the families Pomacentridae, Labridae, and Haemulidae.

Gamefish. Numerous game fish species were observed at both study sites. The most common were *Caranx crysos* (Blue Runner), *Caranx ruber* (Bar Jack), *Cephalopholis cruentatus* (Graysby), *Epinephelus morio* (Red Grouper), *Lutjanus griseus* (Gray Snapper), *Ocyurus chrysurus* (Yellowtail Snapper), *Balistes capriscus* (Gray Triggerfish), and *Lachnolaimus maximus* (Hogfish) (Table 5, Appendix 1). While conducting the fish surveys, no recreational fishing or scuba diving activities were observed. Monofilament fishing line, anchor line, and anchors were found at both the POM A and BHM sites.

Benthic Assemblages.

The evaluation of the benthic assemblages showed that both depth profiles at the POM A and BHM modules supported a variety of benthic taxa and species (see Appendix 2). Both sites were dominated by algae, in particular turf algae (Table 6 and 7). The POM A and BHM modules had comparable turf algae cover. It should be noted that while a large percentage of the bottom has 'turf algae', the 'turf' is composed of fine filamentous red and occasionally green algae. The 'tuft' most often does not cover 100% of the bottom, rather is a more open matrix of filaments. The actual 'cover' within a turf community can range from 30 to 80% percent.

The second most abundant benthic component on both the POM A and BHM modules was porifera. Scleractinians were the third most abundant benthic component. The POM A modules had more scleractinian coverage than the BHM modules in large part due to the presence of numerous *Oculina diffusa* colonies which were not present at the BHM modules. Octocorallia had very low abundance. Although only five species were recorded during these surveys (two species on the shallow and three on the deep modules), none of the species were common to both sites (Table 10). On both sets of modules, octocoral cover was low, with each species having a cover of less than 0.1%. Another study conducted on the BHM modules also showed low octocoral coverage especially when compared to the surrounding natural reefs (Thanner et al, 2006). Encrusting species such as *Briarium asbestinum* and *Erythropodium caribaeorum* are not well represented on the modules. The POM A modules had larger coverage of ascidian species than the BHM modules (Table 6, Table 7, Appendix 2). Overall, the BHM modules had slightly higher diversity (H') as indicated in Figure 16. Both the POM A and BHM modules had a low evenness measure (J') though due to the overwhelming abundance of turf algal cover.

Both the POM A and BHM modules were constructed for the purpose of mitigation for damages to the natural generally low-relief (<1.5m) hardgound reef resources and not specifically designed for fisheries enhancement. Data from this study provide information regarding the effectiveness of these reefs in meeting the objectives for which they were constructed. To that end, the desired communities for the reefs would reflect adjacent natural reef systems, with have diverse and abundant benthic communities with a significant resident fish population. Previous evaluations of artificial reef materials with surrounding areas have demonstrated that, while not being equivalent, these modular artificial reef biotic communities have a high degree of similarity to adjacent natural reefs ((Thanner et al, 2006).

It is also important to note that this study is a snap shot of the existing biological community, to truly understand these sites and draw concrete conclusions further monitoring effort is needed to capture seasonal and temporal (long-term) changes. The higher abundance of resident fish species on the modules (relative to transient or visitor species), is a desired affect, and generally supports the intended purpose of the artificial reef placement. However, to correctly identify the extent to which the site has fulfilled this purpose, comparative evaluations of adjacent natural reefs would need to be conducted.

CONCLUSION

Documenting and quantifying the differences in biological assemblages on the various module spatial arrays and depths is an important step in understanding the role these reefs play in natural resource management. This 'single assessment' study did demonstrate that modules in all spatial arrays, as well as shallow and moderately deep sites, provide complex habitat that support abundant and diverse benthic and fish assemblages. However, each module reef type evaluated exhibited some unique characteristics as summarized below.

Fish Assemblages. For the spatial arrays, unique fish assemblage characteristics included higher fish abundance on modules set on 10 ft. and 100 ft. centers; the modules with the smallest and largest amount of spacing. A similar pattern was also found by (Jordan et al. (2005) in a study of Broward County artificial reefs. The fish population documented on the reefs had a strong representation by resident species. Additionally, minimal differences were observed between module spatial arrays (10 ft. centers, 25 ft. centers, 50 ft. centers, and 100 ft. centers) for fish community structure (e.g., species composition), indicating that the species composition is not heavily influenced by module spacing at this artificial reef site. Relative to the depth comparisons a distinct difference was observed in the fish community between the sites. While the average number of species noted and diversity were comparable between the two locations, the shallow modules had significantly lower abundance. The difference in abundance was especially seen in the 0-2 cm size class, which was caused by the high density of small masked gobies on the deeper modules. The differences in the community structure (overall abundance and size class representation) indicate that depth may determine the type of fish assemblages that will eventually settle. Smaller size classes of fish (i.e. Gobiidae family) seem to inhabit the deeper modules more so than the shallow modules.

Benthic Assemblages. Unique benthic characteristics included higher percent cover of scleractinians at the shallower modules compared to the deeper modules, primarily due to the large cover of *O. diffusa* on the shallower modules at POM A. The deeper modules had a different octocoral community compared to the shallow modules. *Iciligorgia* species were not present on the shallower modules and *Eunicea* species were more abundant on the shallower modules. Both module depths had low cover of octocorals. It is speculated that low octocoral cover may be due to the physical characteristics of the modules such as higher relief when compared to the natural reefs. The porifera community is more diverse with a higher percent cover on the deeper modules possibly to a point that may limit scleractinian settlement and growth. Overall, depth does have an influence on the benthic community on ARMs and should be heavily considered in project planning.

While this study provides a snap shot of the existing biological community, the higher abundance of resident fish species on the modules (relative to transient or visitor species), is a desired affect, and generally supports the intended purpose of the artificial reef placement. However, to truly understand the stability and complexity of these communities, further monitoring effort is needed to capture seasonal and temporal (long-term) changes. Additionally, comparative evaluations of adjacent natural reefs would need to be conducted to truly understand the relative similarity and contribution these modular units to our coastal marine resources.

Reports and studies similar to this one are essential in providing information on the status of the biological assemblages on existing module reefs to evaluate the success of current projects, planning future projects, and determining where further research and monitoring efforts are needed.

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APPENDICES

Appendix 1: All fish species observed per round at each of the five boulder reefs studied. The numbers listed in the table are the number of surveys in which the species was present and recorded in the first five minutes. The numbers in parenthesis refer to number of surveys in which the species was observed after the initial five minutes. Species are listed based on Resident, Transient, and Visitor categories (Bohnsack et al. 1994).

Resident Species	**Common Name**	**BHM**	**POMA 10**	**POM A 25**	**POMA 50**	**POMA 100**
Abudefduf saxatilis	Sergeant major	2	11	9	8 (1)	5
Acanthemblemaria aspera	Roughhead blenny		3		2	7
Acanthurus bahianus	Ocean surgeon	6 (1)	12	4	7	8
Acanthurus chirurgus	Doctorfish	1 (1)	1	5	1	2
Acanthurus coeruleus	Blue tang	1 (1)	4	3	3	1
Aluterus scriptus	Scrawled filefish	2	(1)			
Anisotremus surinamensis	Black margate					2
Anisotremus virginicus	Porkfish	3 (2)	5 (1)	4 (1)	1	5
Apogon maculatus	Flamefish				1	
Apogon pseudomaculatus	Twospot cardinalfish	1			1 (1)	2 (1)
Archosargus probatocephalus	Sheepshead				(1)	1
Balistes capriscus	Gray triggerfish		1 (2)	8 (2)	5	1
Unidentified Blenny	Unidentified Blenny		1			1
Bodianus pulchellus	Spotfin hogfish		3			
Bodianus rufus	Spanish hogfish	1			1	
Cantherhines macrocerus	Whitespotted filefish	1				
Chaetodon ocellatus	Spotfin butterflyfish	2				
Chaetodon sedentarius	Reef butterflyfish	3 (1)				1
Chromis cyaneus	Blue chromis	1				
Chromis insolatus	Sunshinefish				1	2
Chromis multilineatus	Brown chromis		7	3	4	8
Chromis scotti	Purple reeffish	6	1			
Coryphopterus dicrus	Colon goby			1		
Coryphopterus glaucofraenum	Bridled goby	12	1	2	3	
Coryphopterus personatus	Masked goby	12				2

Coryphopterus species	Unidentified goby	1				
Diodon holocanthus	Balloonfish		2 (1)		2	
Diplectrum formosum	Sand Perch			1		
Epinephelus/Cephalopholis cruentatus	Graysby	2 (2)	2	1	2	1 (2)
Epinephelus morio	Red grouper		(1)	2 (1)	5 (2)	1
Equetus acuminatus	Highhat		(1)		1	1
Equetus punctatus	Spotted Drum		1			2
Gerres cinereus	Yellowfin Mojarra				(1)	
Ginsburgellus novemlineatus	Nineline goby				(1)	
Gnatholepis thompsoni	Goldspot goby	2	1	1		
Gobiosoma macrodon	Tiger Goby					1
Gobiosoma oceanops	Neon goby	5	4	2	3	5
Gymnothorax moringa	Spotted Moray	1				
Gymnothorax vicinus	Purplemouth moray	1	1			
Haemulon aurolineatum	Tomtate	1	9	6	5 (1)	12
Haemulon carbonarium	Caesar grunt	1				1 (1)
Haemulon flavolineatum	French grunt	4 (1)	3			1
Haemulon parra	Sailor's Choice	(1)		(1)		(1)
Haemulon plumieri	White grunt		8 (1)			(2)
Haemulon sciurus	Bluestriped grunt	1	5 (1)		1	1 (2)
Haemulon sp.	Unidentified grunt	2	2 (1)		4	4
Haemulon striatum	Striped grunt	(1)				
Halichoeres bivittatus	Slippery dick	(1)	10 (1)	5 (1)	3 (1)	4
Halichoeres cyanocephalus	Yellowcheek wrasse	1 (1)				
Halichoeres garnoti	Yellowhead wrasse	9				
Halichoeres maculipinna	Clown wrasse		4	2	5 (1)	4 (2)
Halichoeres radiatus	Puddingwife		4	4 (1)	6 (1)	1 (1)
Holocentrus adscensionis	Squirrelfish	1				
Holacanthus bermudensis	Blue angelfish	1	1 (3)			
Holacanthus ciliaris	Queen anglefish		4 (1)	(1)	2	6
Hypoplectrus unicolor	Butter hamlet	1	1 (2)			
Ioglossus calliurus	Blue goby	2	2			

Kyphosus sectarix	Bermuda chub		3 (2)	7 (1)		(1)
Lactophrys bicaudalis	Spotted trunkfish		(1)			
Lachnolaimus maximus	Hogfish	1 (2)	5 (2)	3 (1)	4 (1)	4 (4)
Lutjanus analis	Mutton snapper	1 (1)			(1)	
Lutjanus campechanus	Red snapper			1 (1)		1
Lutjanus griseus	Gray snapper		5 (1)	4 (2)	3 (1)	1
Lutjanus synagris	Lane snapper	(1)	5 (1)			
Malacoctenus macropus	Rosy blenny	1	3		1	1
Malacoctenus triangulatus	Saddled Bleeny		8	2	8	4
Microspathodon chrysurus	Yellowtail damsel		(2)			
Mycteroperca interstitialis	Yellowmouth grouper					(1)
Mycteroperca microlepis	Gag			(1)		
Ptereleotris calliurus	Blue Goby	1				1
Pomacanthus arcuatus	Gray angelfish	(1)		3	3 (1)	1
Scartella cristata	Molly Miller					1
Scarus croicensis	Striped parrotfish	1	2 (2)	2		
Scarus iserti	Striped parrotfish		1 (1)	1		
Scarus taeniopterus	Princess parrotfish		1	1 (1)		
Serranus tabacarius	Tobaccofish	(2)				
Serranus tigrinus	Harlequin bass	1 (1)	1 (1)			
Sparisoma atomarium	Greenblotch parrotfish	6 (1)	4 (1)	4 (1)		1
Sparisoma aurofrenatum	Redband parrotfish	4 (2)	8 (1)	5		1 (1)
Sparisoma chrysopterum	Redtail parrotfish			1		1
Stegastes adustus	Dusky damselfish	1	5	5	8	9
Stegastes diencaeus	Longfin damselfish		2 (1)			
Stegastes leucostictus	Beaugregory		7	6	4 (2)	4
Stegastes partitus	Bicolor damselfish	12	12	12	12	11
Stegastes variabilis	Cocoa damselfish		6	2	2	5 (1)
Thalassoma bifasciatum	Bluehead	12	12	12	12	12
Unidentified fish	Unidentified fish	2				
Scartella cristata	Molly Miller	(1)			1	1
Parablennius marmoreus	Seaweed blenny		5	1	5	8

Transient Species	**Common Name**					
Pseudupeneus maculatus	Spotted goatfish	2	8 (2)	2		2
Serranus baldwini	Lanternfish	1 (3)				
Seriola rivoliana	Almaco Jack		2			
Urolophus jamaicensis	Yellow Stingray		1 (1)			
Visitor Species	**Common Name**					
Calamus calamus	Saucereye porgy	5	3 (1)		(1)	
Calamus penna	Sheepshead porgy	1 (3)				
Calamus species	Unidentified porgy			1		
Canthigaster rostrata	Sharpnose puffer	11 (1)	5 (5)	3	3	5
Caranx bartholomaei	Yellow jack	(1)				
Caranx crysos	Blue runner			(2)	2 (1)	(2)
Caranx ruber	Bar jack		1 (3)	(1)	(1)	(1)
Lactophrys triqueter	Smooth trunkfish	1	1			
Ocyurus chrysurus	Yellowtail snapper		(4)	5 (1)	1	1
Opistognathus aurifrons	Yellowhead jawfish	(1)				
Scarus coelestinus	Midnight parrotfish		3			
Sparisoma viride	Stoplight parrotfish	4	2 (2)	(1)		2
Synodus intermedius	Sand diver	1				

Appendix 2. Relative percent (%) cover of benthic subcategories (species or lowest possible taxonomic group).

	POM A (25 ft.)	BHM (68 ft.)
Scleractinia (stony coral)		
Agaricia agaricites	0.0560	0.0523
Agaricia fragilis	0.0000	0.0392
Agaricia species	0.0000	0.0523
Colpophyllia natans	0.0224	0.0000
Scleractinia species	0.0000	0.0130
Dichocoenia stokesi	0.0112	0.0000
Diploria labyrinthiformis	0.0112	0.0092
Diploria strigosa	0.1009	0.0262
Eusmilia fastigiata	0.0000	0.0523
Madracis decactis	0.0112	0.1964
Meandrina meandrites	0.0336	0.0655
Montastraea annularis	0.0224	0.0131
Montastraea cavernosa	0.0112	0.0655
Mycetophyllia aliciae	0.0000	0.0393
Mycetophyllia species		0.0131
Oculina diffusa	2.9029	0.0000
Porites astreoides	0.9751	0.9560
Porites porites	0.2354	0.0131
Scolymia species	0.0000	0.0262
Siderastrea radians	0.0336	0.0131
Siderastrea siderea	0.1345	0.2095
Stephanocoenia intersepta	0.0112	0.1048
Tubastraea coccinea	0.0000	0.0131
Dead coral with algae	0.4820	0.0262
Old dead coral	0.0672	0.0000
Recently dead coral	0.0897	0.0262
Octocorallia (soft coral)		
Eunicea species	0.0336	0.0000
Gorgonia ventalina	0.0000	0.0092
Gorgonian (unidentified)	0.0000	0.0131
Iciligorgia schrammi	0.0000	0.0393
Pseudoplexuara species	0.0112	0.0000
Porifera (sponges)		
Amphimedon compressa	0.0897	0.0000
Aplysina cauliformis	0.0336	0.1572
Aplysina fistularis	0.1009	0.0000
Aplysina fulva	0.0336	0.0262
Artemisina melana	1.7597	1.4274

Callyspongia plicifera	0.0000	0.1179
Callyspongia vaginallis	0.0224	0.8381
Cliona delitrix	0.3475	0.0000
Cliona species	1.4571	0.1833
Dictyonella ruetzleri	0.2017	0.1310
Diplastrella megastellata	0.0560	1.0608
Dysidea species	0.1681	0.0131
Dysidea species-tube growth	0.0112	0.0131
Ectoplasia ferox	0.0785	0.0000
Haliscara species	0.0112	0.1441
Holopsamma helwigi	1.5916	3.2740
Iotrochota birotulata	3.4858	6.6527
Ircinia species	0.1121	0.3798
Ircinia campana	1.1208	0.9298
Ircinia felix	1.9839	1.1786
Ircinia strobilina	0.9639	1.0215
Monanchora barbadensis	0.2802	1.0215
Monanchora unguifera	0.0560	0.3668
Mycale laevis	0.0224	0.0000
Niphates amorpha	0.1009	0.1179
Niphates digitalis	0.1009	1.3227
Niphates erecta	0.1569	0.4322
Oceanapia bartshi	0.0000	0.0131
Pseudoceratina crassa	0.0000	0.0262
Red *Monanchora unguifera*	0.0000	0.0262
Spheciospongia vesparium	0.8855	0.0000
Sponge (unidentified)	2.4098	3.7061
Strongylacidon species	0.2017	0.5631
Millepioridae (firecoral)		
Millipora alcicornis	0.7958	0.6679
Zoanthidae (zoanthids)		
Unidentified zooanthid	0.0897	0.0131
Ascidarian (tunicates)		
Ascidian	0.0897	0.0000
Ascidia nigra	0.0224	0.0000
Didemnum species	0.0000	0.0276
Eudistoma species	0.2578	0.0092
Stolonicus sabulosa	0.0000	0.0552
Other Live		
Unidentified Bryozoan	0.0112	0.0000
Unidentified Bryozoan-encrusting	0.0785	0.0786
Diadema antillarium	0.0112	0.0000
Eucidaris tribuloides	0.0000	0.0131

	Filograna huxleyi	0.0000	0.0131
	Hydroid species	0.2466	0.3274
	Lima species	0.0448	0.0262
	Spondylus americana	0.0336	0.0000
	Unidentified bivalve	0.0112	0.0786
	Other	0.0000	0.0131
Algae			
	Amphiroa	0.0112	0.0000
	Blue-green algae	2.0175	0.6155
	Coralline algae	1.3002	0.6417
	Lyngbya species	0.0672	0.0000
	Peysonnelia species	2.3201	6.4039
	Turf	68.1798	62.6900
	Wranelia argus	0.0336	0.0000
Substrate			
	Sediment covered substrate	0.2802	0.4584