SUNNY ISLES REEF RESTORATION ONSITE MITIGATION MONITORING RESTUDY PROJECT 2003

INTERIM FINAL REPORT
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By:
Miami-Dade County
Department of Environmental Resources Management

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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's (2000) definition of an artificial reef as "one or more objects of natural or human origin deployed purposefully on the seafloor to influence physical, biological, or socioeconomic processes related to living marine resources" has since incorporated all the uses of an artificial reefs. Several studies have examined artificial reefs for purposes other than a fishery enhancement tool. Clark and Edwards (1994) monitored the progress of artificial reef structures in the rehabilitation of reef flats degraded by coral mining in the Maldives. Palmer-Zwahlen and Aseltine (1994) conducted a long-term investigation on Pendleton Artificial Reef off California to determine the potential of quarry rock artificial reefs as mitigation for damage to near-shore habitats. Relini et. al (1994) observed community development on an artificial reef structure built to restore and mitigate for damage caused by illegal trawling. More recently, Miller and Barimo (2001) described juvenile coral populations at two sites in the Florida Keys where artificial reef material was used to restore the reef following damage by ship groundings.

The Sunny Isles Reef Restoration (SIRR), an artificial reef pilot project, began as required mitigation for impacts to a natural coral reef off Sunny Isles (Miami-Dade County), Florida sustained during the dredging phase of a beach renourishment project in 1988. The subsequent restoration included a four year, post-construction monitoring project. The modules were monitored for the initial four years post-deployment and had not been quantitatively evaluated again until this restudy. The objectives of this study were to compare the final analysis from the initial four-year study to the present to evaluate the changes in species diversity and dominance, and the measurements of habitat complexity among modules and in comparison with the natural reef. To that end, efforts were made use the same methodologies, to sample the same modules, and apply similar statistical analyses to data collected under the original monitoring program (G.M. Selby and Associates 1992) to allow as direct as possible "point in time" comparison.

Project Background:

In 1988, the Army Corps of Engineers and the Miami-Dade County Department of Environmental Resources Management restored a 2.5 mile segment of Sunny Isles Beach. An offshore borrow area located between the second and third reef tracks was utilized as a source of sand. During construction, the dredging contractor went outside of the permitted borrow area, damaging the adjacent hard bottom by reducing the physical relief and complexity of the reef. Blair and Flynn (1988) described the damage in detail. The impacted habitat was a relatively low-relief reef dominated by sponges and soft coral (Blair and Flynn, 1988).

Miami-Dade County established an advisory committee of artificial and natural reef experts, marine resource analysts, and resource managers to develop criteria for and selection of the artificial reef units to be used in the mitigation. After issuance of a "Request for proposals, " the advisory committee reviewed the designs and selected three module designs described below. It should be noted that the advisory committee recognized the "enhancement" potential of the "M" module and felt that utilization of that design would provide a point of comparison for the level of enhancement effect that might occur on the other designs.

As required mitigation, the Sunny Isles Reef Restoration (SIRR) project consisted of a total of 80 artificial reef modules of three different designs deployed in August 1991. The modules were placed in the impacted area on the eastern edge of the "second reef" at a depth of approximately 60 feet or 18 meters (Figure 1). The project consisted of 50 Dome Modules (D), 20 Reef Replacement Modules (R), and 10 CSA2 Module Designs (M). The D modules were basically hemispheres constructed to mimic a large coral head. The R modules were constructed of natural limestone rock cemented into a rectangular structure. The M modules were constructed from pre-cast concrete with higher relief than the R modules. A detailed description of each module will be discussed in the next section. The original study also included the evaluation of ten 2.25m^2 biological control areas that were scraped clean of all benthic organisms.

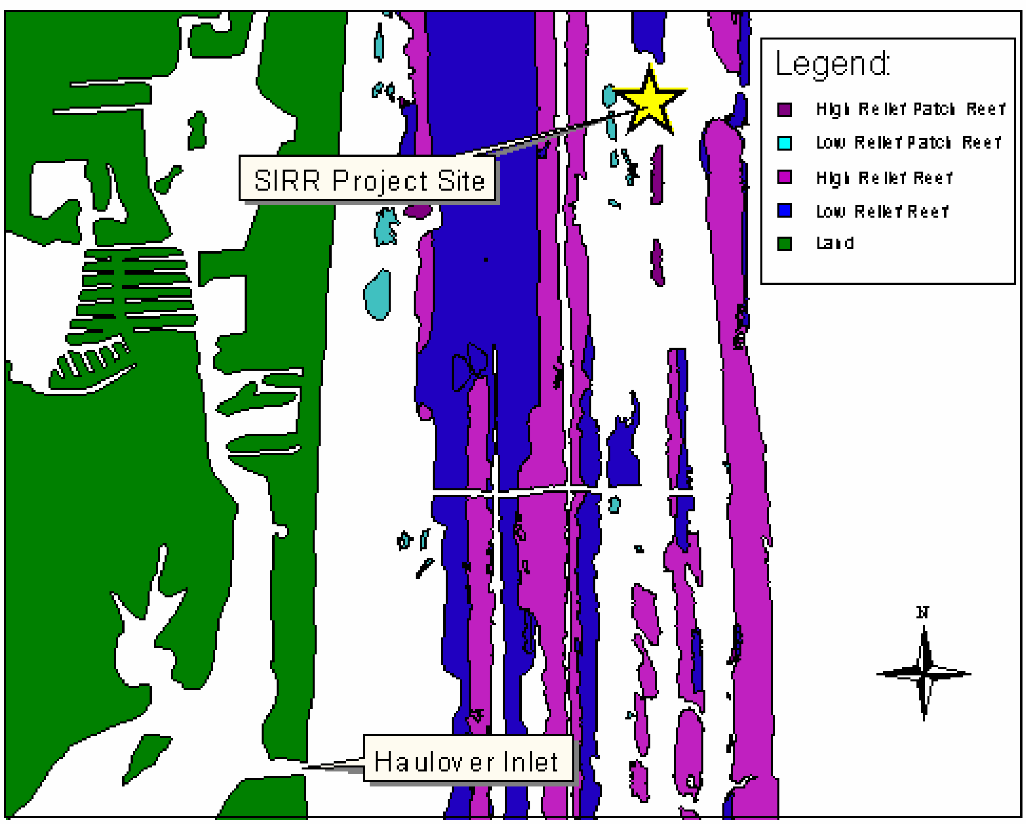


Figure 1: SIRR Project Site Location Map. Reef coverages are from the Army Corps of Engineers, 1996.

According to Blair (1989), the goal of this restoration effort was to deploy modules that would: 1) mimic the physical characteristics of the reef (i.e., provide a variety of surfaces and habitat types such as exposed, cryptic and intermediate), 2) be constructed of carbonate-based material, 3) utilize forms with a high surface area to footprint ratio, and 4) provide a basis for the biological recovery of the impacted hard bottom while minimizing the enhancement effects (i.e., avoiding over-representation of any specific community component) of the modules.

The three artificial reef module designs (as well as a ‘modification’ of one module) represented a range of the desired characteristics and were monitored for four years following deployment. In addition to the modules being monitored, the original study consisted of ten $2.25m^2$ areas that were scraped clean of all benthic organisms. The modules and control sites were examined for the purpose of monitoring the colonization and community development of invertebrates, plants and fish fauna relative to the natural substrate, as well as evaluating the effectiveness of the module design in restoring the reef habitat. The different module types varied in their structural design and thus their ability to attract numbers of individuals and numbers of species of fish and invertebrates.

Module Descriptions:

The three module types examined in this study are the Module Design (M), the Reef Replacement Module (R), and the Dome Module (D) (see Figure 2 below). Appendix B.1 contains images of the modules prior to deployment.

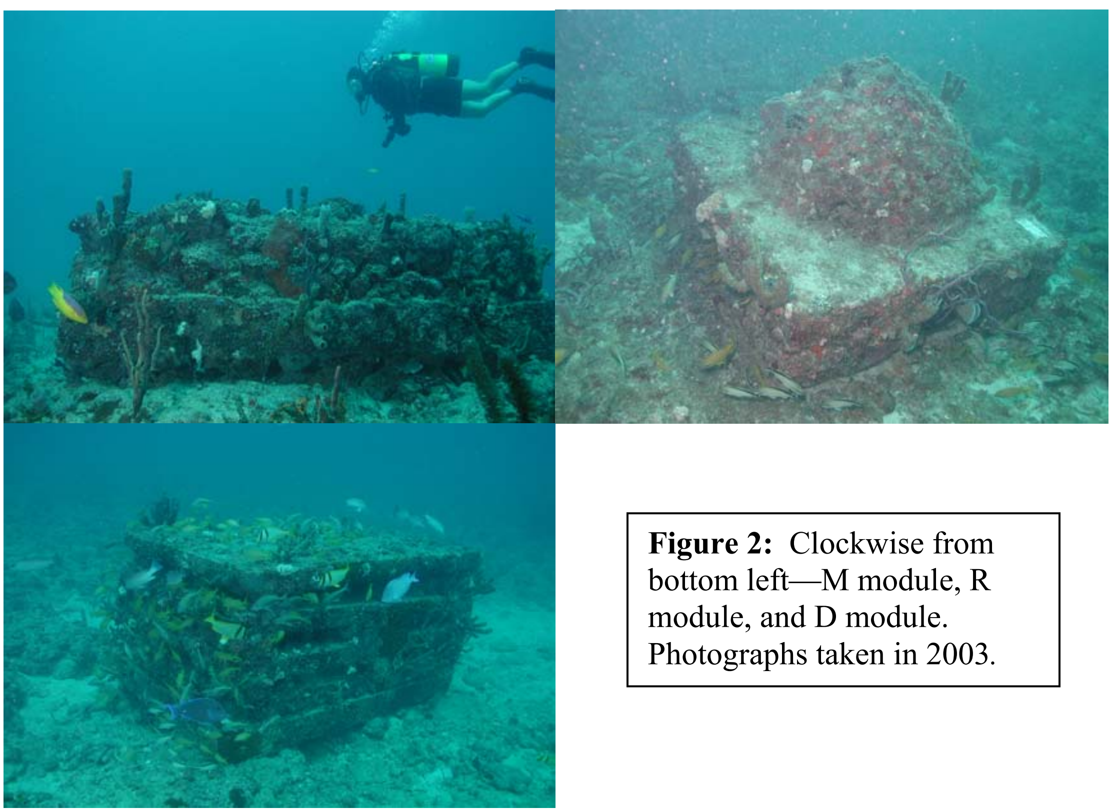


Figure 2: Clockwise from bottom left—M module, R module, and D module. Photographs taken in 2003.

The M design is the largest structure with a height of 3’6” (1.1 m) on one end and 4’6” (1.4 m) on the other. M modules were made from pre-cast concrete components and had the highest volume of internal void space with numerous access openings to the interior of the module (Figure 3). For a summary of the surficial and volumetric dimensions of the various module designs, please refer to Table 1.

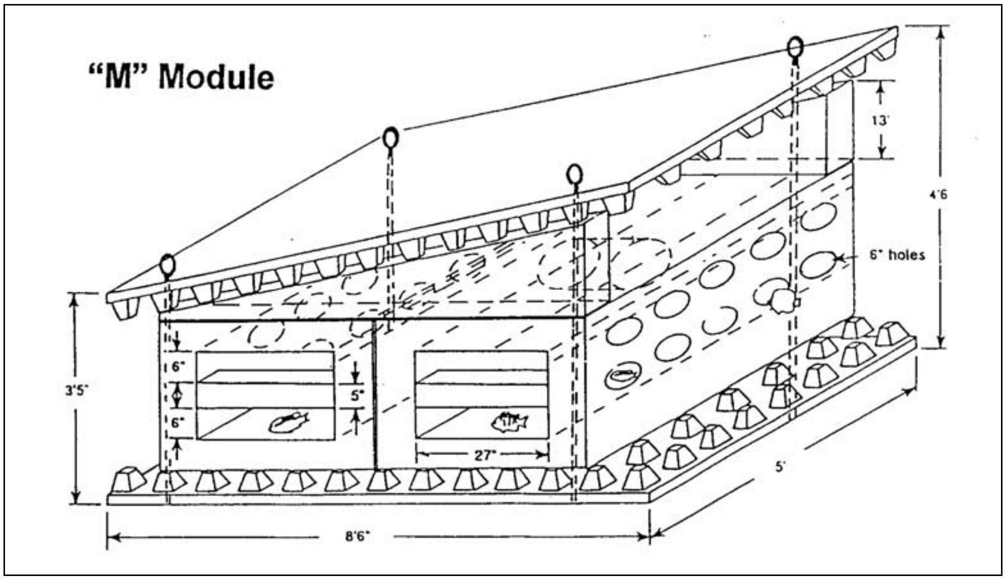


Figure 3. Module Design (M) diagram (Selby and Associates, Sunny Isles Artificial Reef Monitoring Program: 8th Quarterly Report, 1994).

The R module design was formed with natural limestone rock cemented onto the surface which created a rectangular structure with a highly irregular surface area (Figure 4). This module had openings on both ends and a central cavity that ran the length of the module.

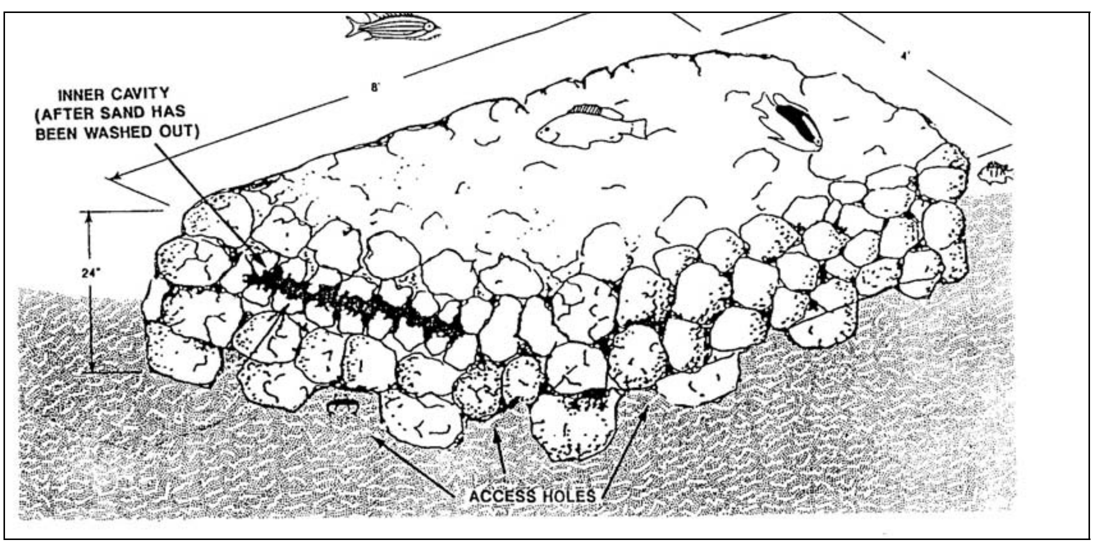


Figure 4: Reef Replacement Module (R) diagram(Selby and Associates, Sunny Isles Artificial Reef Monitoring Program: 8th Quarterly Report, 1994).

The D modules were the smallest, structures with the lowest relief (approximately 3'). Dome modules have access at the base of the 'dome' and from the central base of the entire unit (Figure 5). Two types of domes were constructed: smooth domes, with a surface of concrete only, and rough domes (D-alt in Figure 5), which was covered with 3 to 6 in. (7.6 to 15.2 cm), limerock cobble grouted to the exterior to create increased surface complexity. Both types of domes were secured to a 4' by 4' (1.2 m x 1.2 m) concrete base, and had 3 to 6 in. (7.6 to 15.2 cm) limerock cobble cemented to the interior of the dome. For the original study and this study only the rough domes were monitored.

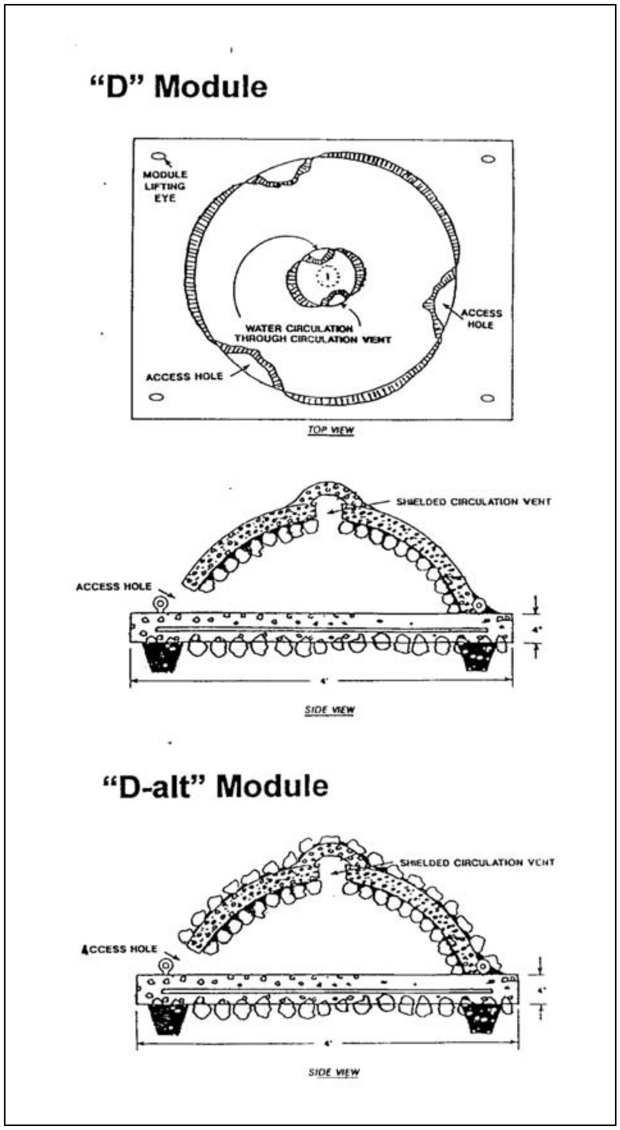


Figure 5: Dome Module (D) diagram (Selby and Associates, Sunny Isles Artificial Reef Monitoring Program: 8th Quarterly Report, 1994). The "D" module, or the smooth dome, lacks the cobbled, exterior surface. The "D-alt" module, or the rough dome, has the cobbled, exterior surface.

Table 1 below summarizes the surficial and volumetric dimensions of the three different module designs and the area surveyed on each module and station type.

Table1. Module dimensions, surface area, and void space by type.

Module/ Station Type	***Module/ Station Dimensions (LxWxH)*** ft.	m.	**Total Exposed Surface Area** ft^2	m^2	**Internal Void Space** ft^3	m^3	**Benthic Area Surveyed** ft^2	m^2
D	4 x 4 x 3	1.2 x 1.2 x 0.9	28	2.60	7	0.20	20.45	1.90
M	8.5 x 5 x 4.5	2.6 x 1.5 x 1.4	130	12.08	71	2.01	40.90	3.80
R	5 x 4 x 2	2.4 x 1.2 x 1.1	160	14.86	12	0.34	28.63	2.66
NR	2.5 x 6.6	0.76 x 2.0	16.36	1.52	NA	NA	16.36	1.52

Site Selection:

<u>Modules:</u>

This study intended to replicate the original assessment and evaluation conducted by Selby and Associates (with the exception of four that were removed from analysis for reasons described below). This study evaluated 27 modules of three different design types. See Table 2 for a listing of monitored modules. In the original monitoring program, 11 of the 50 D modules, and 11 of the 20 R modules were haphazardly selected for sampling. Of the modules in the initial study, M-6 was destroyed in 1992 by Hurricane Andrew; D-49 slid into a 'valley'; R-5 was repeatedly difficult to locate; both of the latter were not consistently monitored in the original study and were omitted from the current project. Because the loss of M-6 reduced the total number of M modules to nine, D-20 and R-17 were arbitrarily excluded from the current study to maintain an equal sample size (9) among all the modules.

Table 2. Summary of modules monitored during the original 1995 study and the 2003 Restudy.

Module Type	**D**		**M**		**R**	
Study	**1995**	**2003**	**1995**	**2003**	**1995**	**2003**
Modules Sampled	D18	D18	M1	M1	R2	R2
	D19	D19	M2	M2	R4	R4
	D20	X	M3	M3	R5	X
	D21	D21	M4	M4	R7	R7
	D22	D22	M5	M5	R14	R14
	D25	D25	M6	X	R15	R15
	D30	D30	M7	M7	R16	R16
	D34	D34	M8	M8	R17	X
	D43	D43	M9	M9	R21	R21
	D49	X	M10	M10	R22	R22
	D50	D50			R23	R23
Total	**11**	**9**	**10**	**9**	**11**	**9**

Natural Reef Areas:

During the original assessment of the SIRR project, nine 2.25 m^2 natural reef areas were scraped clean of all benthic organisms. These sites were monitored to compare colonization of bare, natural substrate areas with artificial modules. Despite efforts to relocate these "Barren Control" sites, these areas could not be re-located for this study.

In the absence of the "Barren Control" sites, it was determined that for the purpose of conducting the Restudy, a separate, "new" suite of nine natural reef (NR) control sites would be randomly established on the adjacent natural reef and evaluated for comparison with the modules. Each NR station consisted of a 1.52 m^2 area comprised of four contiguous 50 cm by 76 cm quadrats. The locations of the NR stations were established using the northwest corners of nine randomly selected study modules as reference points. Rebars marking the sites were driven into the substrate at random compass headings (limited to bearings between 200° and 340° to ensure that none of the sites would be located in the sand plain to the east of the project area) and random distances (10 m to 50 m) from each reference module. The random degree headings and distances were obtained from the random number generator function in Microsoft Excel..

Site Reconnaissance:

The first field task of the Restudy consisted of an effort to relocate all the modules and control sites established and evaluated during the original SIRR project. At the time of construction, each module was identified with a unique alphanumeric sequence embossed onto an aluminum plate with a welded "bead". The ID plate was permanently secured to a flat surface on the module. Over time, encrusting organisms had fouled the plates and had to be removed by chipping, scraping, or wire-brushing for the plate to be legible and positive module identification to be made.

Although generalized GPS coordinates for the overall SIRR site were available from the previous study, individual module positions had never been "fixed". Original as-built module mapping consisted of E/W distance measures off an established N/S baseline. Using the as-built map as an indication of relative module orientation, divers began the reconnaissance phase of the restudy by locating the southernmost module in the array and working their way north with the prevailing current confirming the identification and collecting a GPS fix for each module. Module relocation was largely uncomplicated due to the availability of the as-built map, the relatively close proximity of the modules to each other and the moderate water clarity. The Figure 6 depicts the positions of all monitored modules and the natural reef stations along the reef edge.

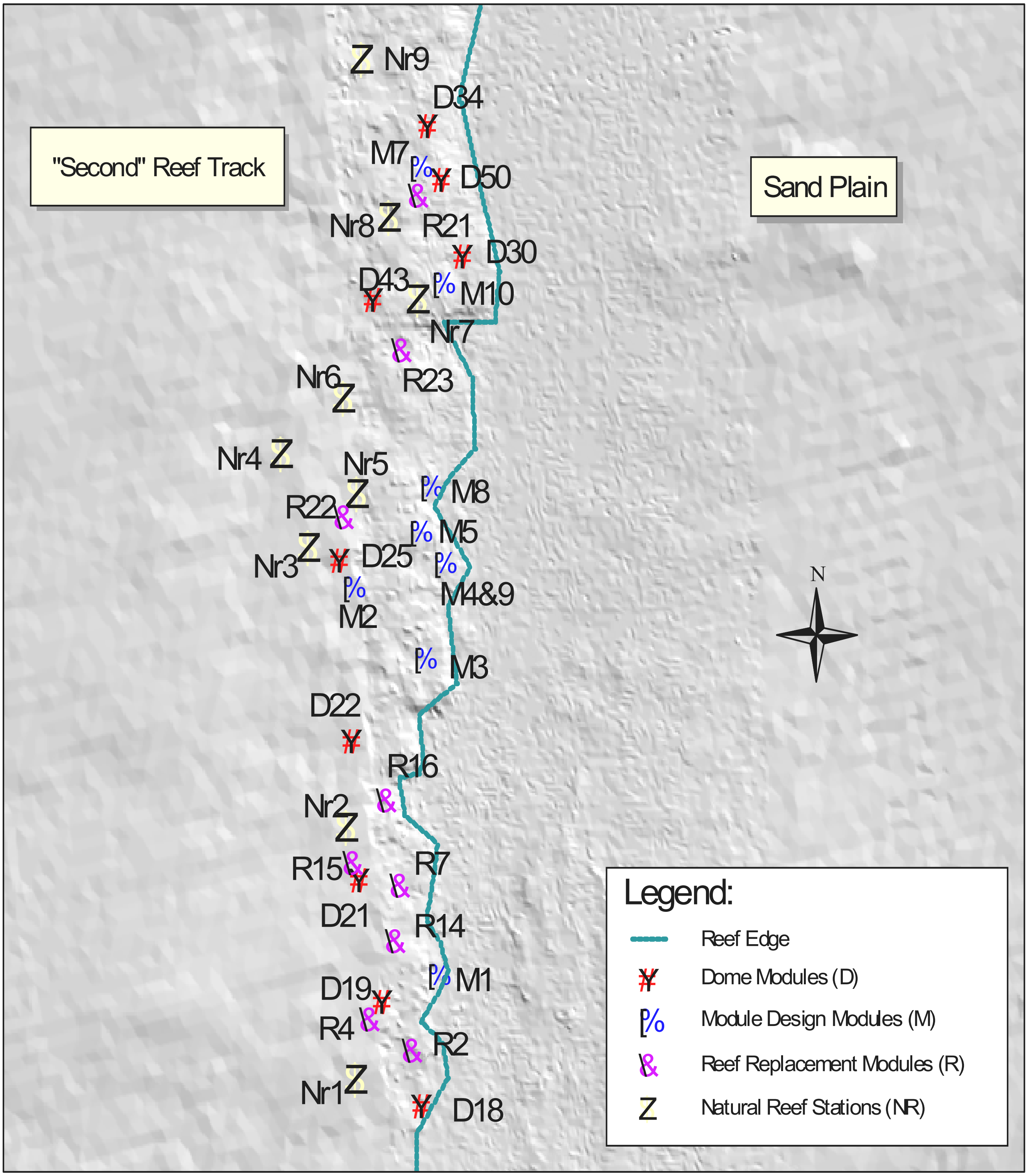


Figure 6: 2003 Station Location Map. Grayscale imagery is from Laser Airborne Depth Sounder or LADS Survey (Coastal Planning and Engineering, Inc 2003).

SECTION I - BENTHIC COMMUNITY ASSESSMENT

Monitoring Methodology:

Each of the selected identified modules and natural reef sites were photographed and examined for benthic community structure with the same basic methodology as in the previous studies. The ground-truthing "belt" transects were made over each module by successive, contiguous quadrat placement, always beginning at the south end of the module and continuing along the long axis to the opposite end. Each quadrat was 76 cm by 50 cm (0.38 m^2). To conduct the "belt" transect monitoring more easily, a ladder-like arrangement was constructed (Figure 7). The "rung" of the ladder was comprised of a 76 cm long PVC pipe, the long side of a quadrat. The distance between each "rung" was 50 cm, the short side of the quadrat. The sides were made from a light-weight chain to fit the different contours of each module. This arrangement allowed for two or more divers to work simultaneous on one module without the difficulty lining up each successive quadrat. The arrangement also allowed for the ladder, and consequently each quadrat, to be left in place if the monitoring could not be completed in one dive. Monitoring errors associated with the successive quadrat placement were reduced using the ladder arrangement.

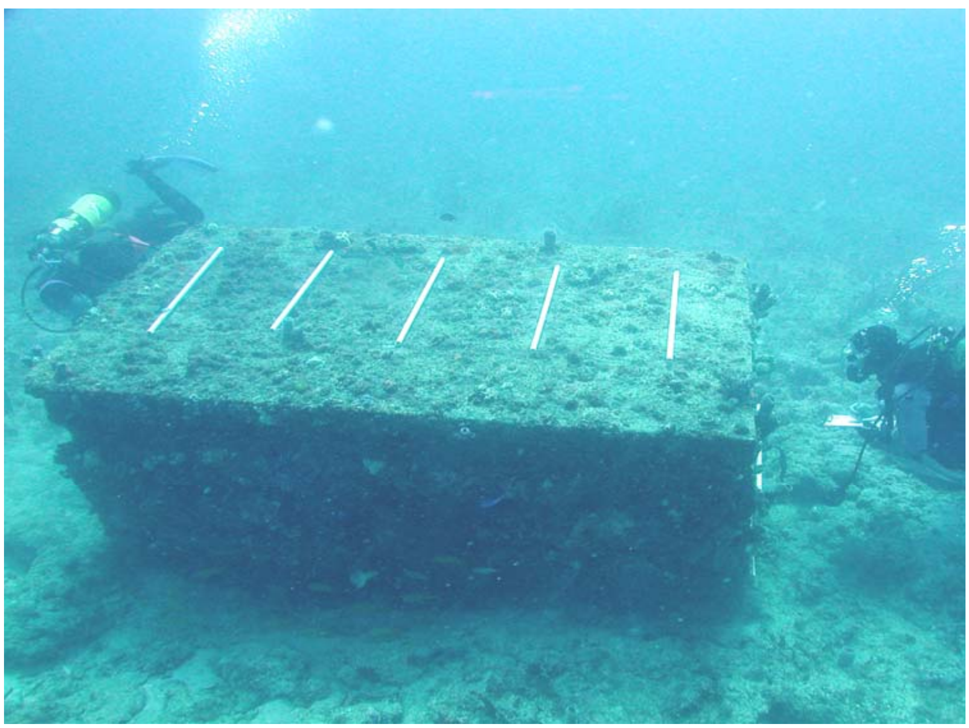


Figure 7: Photo of belt methodology using the ladder arrangement.

The number of quadrat frames required to complete the belt transect on each module varied with the type of each module. The M modules required ten quadrats, the R modules seven, and the D modules five. The orientation of each quadrat was recorded and categorized as the following: Vertical (V), Horizontal (H), Both (B) where the quadrat fell on a corner and was not at least 75% horizontal or at least 75% vertical, or

Angle (A) where the quadrat fell on the side of the rounded dome portion of the D module. Ground-truthing surveys consisted of field identifying and enumerating all macroinvertebrate species with in each quadrat. Soft coral and sponges were identified to at least the genus level and enumerated. All hard corals were identified minimally to genus, enumerated, and each colony was field-measured along its major and minor axes for the calculation of area covered. Because it was difficult to count some of the colonial tunicates, hydroids, and algae, those taxa were only recorded as present. Each station was photographed and ground-truthed concurrently. A digital Nikon camera (in underwater housing) was mounted on a fixed PVC biped and attached to a 50 cm by 76 cm quadrat frame. The camera with fixed quadrat frame was used to photograph each quadrat section of the ladder arrangement. Digital photographs were used to confirm taxonomic identification and measurements made in the field (see Appendix B.2 for example photographs).

Statistical Analyses:

Diversity indices were calculated and used as a general comparison between the data collected in 1995 and in 2003 to evaluate the changes in diversity. The Shannon Wiener Diversity Index (H') is the most commonly used diversity measure (Clarke and Warwick 1994). The value of the Shannon Index is that the species richness (S), or the total number of species, is incorporated as well as the abundance of the individual. H' was calculated in the previous studies (G.M. Selby and Associates 1994 a, b and 1995 a, b, c); and therefore, it was calculated again for the 2003 study as follows:

$$\mathbf{H' = - \Sigma\ (p_i ln p_i)}$$

Where $p_i = n_i / N$ and n_i = number of individuals of the i-th species. H' falls to zero when all the individuals in a population 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 few species 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 Eveness measure (J) was also calculated because it expresses how evenly the individuals are distributed between the different species. The calculation for J is as follows:

$$\mathbf{J = H'/lnS}$$

Where H'=Shannon Weiner Index and S=the total number of species. The value of J represents the percentage of the maximum theoretical diversity a sample has based on the number of species present. The higher the value of J the more even the number of individuals are spread between the different species.

While Shannon's Index and Pielou's Eveness Measure describe the general diversity for a particular station type, they do not describe the similarity in the species composition from one station type to another. Therefore, two similarity indices were calculated. The first index calculated was Jaccard's Similarity Coefficient (JC). The second index is the Bray Curtis Similarity Index.

The JC is a simple similarity measure based on the number of species shared by each station type. JC was calculated for the previous studies (G. M. Selby and Associates 1994 a, b and 1995 a, b, c) and was again calculated in 2003 data based on the following formula (G.M Selby and Associates 1994 a):

$$\mathbf{JC = a / (a + b + c)}$$

Where a = number of species present at both station types, b = number of species at first station type only, c = number of species at second station type only. This index produces values from 0 to 1, with values closer to 1 having higher similarity. A value of one is rare in most samples drawn from ecological populations; therefore, a JC value of 0.5 or greater indicates a high level of similarity.

The Shannon Weiner Diversity Index (H'), Pielou's Eveness Measure (J), and Jaccard's Similarity Coefficient (JC) were all calculated based on pooled data for each station type (D, M, R, and NR). The pooled data consisted of the summation of the number of different species found on each station type and the total number of individuals of each of those species.

The second type of similarity index calculated was the Bray-Curtis Similarity Index. The Bray-Curtis values, which include species composition and abundance as factors, were plottedusing Multi-Dimensional Scaling (MDS) to demonstrate non-metric associations between samples. All calculations for this analysis were conducted using Primer v5 Statistical Software (Primer-E Ltd. Plymouth, UK). This similarity index was first calculated using the standardized density of the number of individuals of each species per meter squared per sample. In the comparisons between the 1995 and the 2003 data, the samples were the station type (D, M, R or NR). The individual stations (9 of the D module, 9 of the M module, 9 of the R, and 9 of the NR stations) were the samples for the comparisons with the 2003 data only.

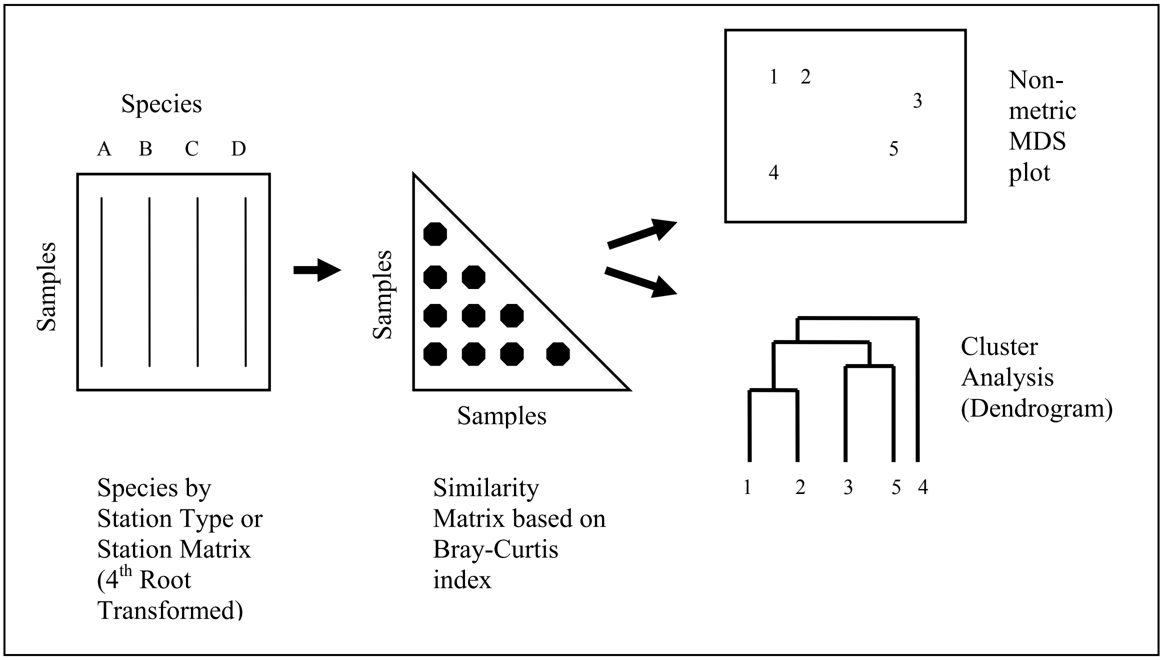


Figure 8: The path of data manipulation for statistical analysis with Primer 5. Figure from Clarke and Warwick 1994.

Using a spreadsheet, the data was first formatted into a square matrix with the number of individuals of each species for each sample as a separate entry (Figure 8). Before the Bray Curtis Similarity Index was calculated a fourth root transformation was used. A fourth root transformation (Field et. al 1982, Clark & Warwick 1994) was chosen to reduce the weight of the common species and incorporate the importance of both the intermediate and rare species.

The transformed data, species abundance by sample, was subsequently converted into a sample by sample similarity matrix by calculating the Bray-Curtis Similarity Index. This index (Bray and Curtis 1957) was calculated between all samples as:

$$S = 100 * \left\{ 1 - \frac{\sum \left| y_{ij} - k_{ij} \right|}{\sum \left(y_{ij} + k_{ij} \right)} \right\}$$

where y_{ij} = the entry in the i-th row and the j-th column, i.e., the abundance of the i-th species in the j-th sample, and k_{ij} = the entry in the i-th row and the k-th column, i.e., the abundance of the i-th species in the k-th sample. Values for S range from 0% if 2 samples are totally similar, to 100% if 2 samples are totally dissimilar.

The final steps can include a cluster analysis or a non-metric MDS analysis based on the Bray-Curtis sample by sample similarity matrix. The cluster analysis creates a dendrogram based on the level of similarity between the samples. The non-metric MDS analysis is the based on the theory of Kruskal and Wish (1978). The MDS analysis results in a graph, or a Shepard diagram, in which samples that are more similar appear closer together. Although the MDS plot can be made in two or more dimensions, the two-dimensional graphs were used in this study because they were easier to interpret. In the upper right hand corner of the graph, a stress level indicates how difficult it was to translate the similarity indices for all the quadrats into a two-dimensional space and is calculated by the following formula (Clarke and Warwick 1994):

$$Stress = \frac{\sum_j \sum_k \left(d_{jk} - \hat{d}_{jk}\right)^2}{\sum_j \sum_k d_{jk}^{\,2}}$$

Where d_{jk} = the distance between the jth and kth sample on the ordination plot and $\hat{d}_{jk}$ = the distance predicted from the fitted regression line corresponding to Bray Curtis Similarity Index.

Clarke and Warwick (1994) provide guidelines for interpreting the stress levels: Stress levels less than 0.05 indicate a plot with excellent representation and no chance of misinterpretation. Stress levels less from 0.05 to 0.10 correspond to a good ordination with little chance of misinterpretation. Stress levels from 0.10 than 0.20 indicate of a potentially useful plot, but have a greater chance of misinterpretation. Stress values between 0.20 and 0.30 are considered acceptable but any conclusions should be cross-checked with other statistical measures. When stress levels are greater than 0.30, the plot represents more or less by an arbitrary arrangement. One statistical measure that can be performed to cross-check and confirm the results of the MDS plot is a one-way pair-wise analyses of similarity, or ANOSIM (Clarke and Warwick 1994). ANOSIM determines if any statistically significant differences exist in the similarity between the stations. The ANOSIM calculations produce an R test statistic based on the following:

$$R = \frac{\overline{r}_B - \overline{r}_W}{\left(M \;/\; 2\right)}$$

Where $\overline{r}_B$ = average rank similarities arising from all pairs of replicates between different sites; $\overline{r}_W$ = average of all the rank similarities among replicates within sites; M = n(n-1); and n = total number of samples under consideration. An R value close to zero fails to reject the null hypothesis and no significant differences exist between the quadrats.

If differences were observed, a non-parametric similarity of percentages analysis or SIMPER was calculated (Clarke and Warwick 1994). This analysis shows which species contributed the most to the similarity within samples types or the dissimilarity between each sample types.

In addition to the diversity indices, Jaccard's Coefficient of Similarity, and Bray Curtis Similarity Index with MDS, some of the data collected in 2003 was also analyzed with Analysis of Variance (ANOVA) followed by the Student Newman Kuels (SNK) post hoc test using Statistica software. The ANOVA with post hoc test indicated whether significant differences were found between the samples tested. ANOVA with the post hoc test was performed on the overall density (individuals per square meter) for the individual stations in 2003. ANOVA with the post hoc test was also performed on the relative percentage of sponge individuals and relative percentage of hard coral in 2003 based on station type after arc sine transformations were applied. The arc sine transformation was applied because it improved the normality of the percentage data in order to comply with the assumptions of the ANOVA test.

Summary of Results:

1995 Summary:

In the last survey G. M. Selby and Associates (1995c) found a total of 36 different invertebrate and algal species and 1154 individuals on the 27 different modules that were monitored in 2003. Sponges, especially *Holopsamma helwigi,* dominated all surveys. Fire coral, *Millepora alcicornis,* was the next most common invertebrate. Overall, 13 species of sponges and 15 species of soft and stony corals were recorded during the last survey. The remaining 8 species were comprised of algae, bivalves, polychaetes, bryozoans, and hydrocoral. G.M. Selby and Associates (1995c) noted that both the number of invertebrate species and the number of invertebrate individuals had not clearly leveled off by the end of the four years of monitoring and populations were still changing.

Overall, in the first four years, the R modules supported the highest density and diversity of invertebrates followed by the M modules. The D modules showed the least dense and diverse invertebrate populations; however, they had the closest similarity to the natural reef areas that had been scraped clean for comparison of colonization. The greater density and diversity of benthos on the R and M modules were attributed to enhancement characteristics such as relief and more complex internal void and cryptic spaces not observed on adjacent reef areas (Blair, 1998). Therefore, in 1995 the D modules came the closest to meeting the original project goal of restoring a habitat complexity similar to that of the surrounding natural reef areas with minimum enhancement.

1995 vs. 2003 Comparisons.

Table 3 provides an overall summary of the number of species and individuals recorded and the range of each per station as well as identifies the most common species. Appendix B.3 lists the number of individuals of each species by station type for both 1995 and 2003 while Appendix B.4 lists the number of individuals of each species by individual station for 2003. Table 3 and the appendices clearly demonstrate that numbers of species and individuals on the modules increased considerably between 1995 and 2003. The modules supported 1015 individuals belonging to 35 different species in 1995 and 7987 individuals of 118 species in 2003.

The most common species changed on all three module sites. *Holopsamma helwigi* was the most abundant species on all module types from the second to the fourth year following deployment (G.M. Selby and Associates 1994 a, b, 1995 a, b, c) but is now absent or only present in low numbers (a total of 34 individuals on 11 of the 36 monitored stations). In addition to *H. helwigi*, sponge species *Callyspongia vaginalis*, *Dysidea* species, and *Iotrochota birotulata* were also commonly found in 1995. The algae *Dictyota* species and hydrocoral *Millepora alcicornis* were also abundant on the modules in 1995. In 2003, however, *Monanchora barbadensis* is the most commonly found organism on the three module types and is also the most common sponge species on the natural reef sites. Other abundant species on the modules in 2003 include the sponge species *Dictyonella ruetzleri*, second in abundance on all three modules. As in 1995*, Iotrochota birotulata* is still the one of the more abundant species on the three of the modules and *Dysidea* species is still abundant on the M modules. *Strongylacidon* species are also common on the D and R modules. The natural reef stations are dominated by the encrusting soft coral *Briareum asbestinum* which is five times less abundant on the modules. Although algae and colonial tunicates were not enumerated in 2003, the algae *Dictyota bartayresii* and Crustose Coralline algae as well as the tunicate *Stolonicus sabulosa* were present on all the 36 of the stations in 2003. Algae species *Martensia pavonia* and *Peyssonnelia* species were also found on a large majority of the stations in 2003. Only further monitoring would indicate whether the current populations found on the modules will continue to change or have leveled off.

Table 3: 1995 vs. 2003 Comparison Summary (Italized numbers are values including algae, colonial tunicates, and hydroids).

Site	Surveyed Area (m2)	Total # ind. 1995	Total # ind. 2003	Range of # Ind. per module 1995	Range of # Ind. per module 2003	Total Species 1995	Total Species 2003	Range of Tot. Spp. per module 1995	Range of Tot. Spp. per module 2003	Most Common Species 1995	Most Common Species 2003
D	17.1	289	1889	23-35	149-238	24	69	5-12	23-40	*Holopsomma helwigi* (142)	*Monanchora barbadensis* (534)
		334		*23-55*		*26*	*81*	*5-13*	*28-48*	*Dictyota* species *(40)*	*Dictyonella ruetzleri* (136)
	(1.90 per									*Millepora alcicornis* (35)	*Strongylacidon* species (123)
	module)									*Dysidea* species (28)	*Iotrochota birotulata* (100)
M	34.2	352	3358	22-44	289-446	17	73	6-10	33-44	*Holopsomma helwigi* (151)	*Monanchora barbadensis* (842)
		372		*22-64*		*18*	*89*	*6-10*	*42-53*	*Callyspongia vaginalis* (54)	*Dictyonella ruetzleri* (364)
	(3.80 per									*Iotrochota birotulata* (49)	*Iotrochota birotulata* (222)
	module)									*Dysidea* species (26)	*Dysidea* species (215)
R	23.94	307	2740	16-47	255-369	24	84	7-12	36-51	*Holopsomma helwigi* (103)	*Monanchora barbadensis* (588)
		309		*16-47*		*26*	*101*	*7-13*	*43-59*	*Callyspongia vaginalis* (37)	*Dictyonella ruetzleri* (287)
	(2.66 per									*Dysidea* species (33)	*Iotrochota birotulata* (167)
	module)									*Millepora alcicornis* (30)	*Strongylacidon* species (138)
NR	13.68		1027		70-170		71		23-40		*Briareum asbestinum* (158)
							87		*28-48*		*Monanchora barbadensis* (96)
	(1.52 per										*Aplysina cauliformis* (70)
	module)										*Niphates erecta* (68)

Table 4 shows that diversity and evenness has also increased since 1995 and summarizes the increase in species richness as well. Algae, colonial tunicate, and hydroid species were omitted from the 2003 data calculations due to the difficulty of enumerating individuals.

Table 4: Diversity Indices for 1995 and 2003. S = species richness; H' = Shannon Wiener Diversity Index; and J = Pielou's Evenness measure for H'. Italized numbers are values including algae, colonial tunicate, and hydroid species.

Module/ Station Type	***S***		***H'***		***J***	
	1995	***2003***	***1995***	***2003***	***1995***	***2003***
D	26	81	1.916 *2.100*	3.033	0.603 *0.645*	0.716
M	18	89	1.862 *1.971*	2.973	0.657 *0.682*	0.693
R	26	101	2.311 *2.335*	3.250	0.727 *0.717*	0.734
NR		87		3.313		0.777

In 2003, the NR stations had the highest diversity followed closely by the R, D, and M modules respectively. The natural reef stations also had the highest measure of evenness (J), 77.7% of the maximum theoretical diversity, indicating that the number of individuals was spread out more evenly between species than on the modules. The M modules had the lowest H' and J indicating a less diverse benthic population. The D modules had the least species richness increase and the greatest J increase. Although the R modules experienced the greatest increase in species richness, they showed the least increase in H'. The R modules also had the closest value of H' and J to the natural reef station in 2003.

Jaccard's Similarity Coefficient was used to test how similar each module type was to one another in 1995. Therefore, it was again calculated with the 2003 data. Table 5 indicates the substantial increase in similarity among the modules types from 1995 to 2003. The pair of module types shared 13 to 18 species in 1995 and 71-76 species in 2003. Jaccard's Coefficient was greater for all module pairs in 2003, although this is at least partly due to an increased cumulative numbers of species (29 to 34 in 1995 and 99-114 in 2003). All module pairs fall above the 0.5 threshold in 2003 and are thus all similar, with the R and M modules being the most similar.

Table 5: Jaccard's Similarity Coefficient for the three different module types in 1995 and 2003.

	D vs. R		*R vs. M*		*D vs. M*	
	1995	*2003*	*1995*	*2003*	*1995*	*2003*
No. of species present on both types of modules **(a)**	18	72	13	71	13	76
No. of species present on the 1st module type only **(b)**	8	9	12	10	13	25
No. of species present on the 2nd module type only **(c)**	8	29	4	18	5	13
Cumulative No. of Species **(a+b+c)**	34	110	29	99	31	114
Jaccard's Coefficient [a/(a+b+c)]	0.53	0.65	0.45	0.72	0.42	0.67

The 2003 data also shows virtually no differences in Jaccard's Coefficients when comparing the different module types to the natural reef. The R modules, sharing more species in common with the natural reef stations, are slightly closer in similarity to the natural reef than the other modules (Table 6).

Table 6: Jaccard's Coefficient of Similarity for the 2003 modules and natural reef stations.

	D vs. NR	*M vs. NR*	*R vs. NR*
No. of species present on both stations **(a)**	60	63	70
No. of species present on the 1st station type only **(b)**	21	26	31
No. species present on the 2nd station type only **(c)**	27	24	17
Cumulative No. of Species **(a+b+c)**	108	113	118
Jaccard's Coefficient [a/(a+b+c)]	0.56	0.56	0.59

In addition to Jaccard's Coefficient of Similarity, comparisons with the Bray-Curtis Similarity Index (BC) were also made. Algae, colonial tunicate, and hydroid species were omitted from all Bray-Curtis Similarity Index calculations for both 1995 and 2003 due to the difficulty in accurately counting the number of individuals of these organisms. Figure 9 shows the MDS plot based on the BC Index for the standardized density of the individuals of each species on the D, M, and R module types in 1995 and 2003 as well as NR station types in 2003.

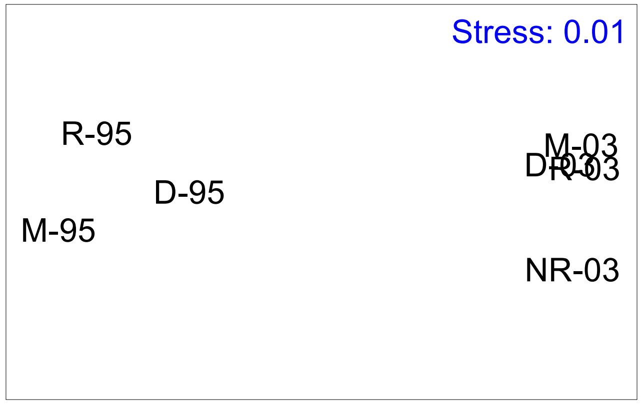


Figure 9. MDS plot comparing the standardized density of the benthic individuals on the 1995 station types and the 2003 station types. D = Dome modules; M = Module design; NR = Natural Reef stations; and R = Reef Replacement modules. The numbers following the station type are the year in which the station was monitored, 95 = 1995 and 03 = 2003.

The MDS plot visibly shows the large distance between the similarity of the 1995 stations and 2003 stations. The low stress level, 0.01, and high R statistic values, 1.0, for the 1995 versus 2003 comparisons of the M, D, and R modules further conclude that a distinct difference is present between the station types in 1995 and 2003. The module station types in 2003 also demonstrate an increase in similarity (smaller cluster grouping) to one another compared to the module station types in 1995. The station types in 1995 and in 2003 are only approximately 30% similar (Figure 10).

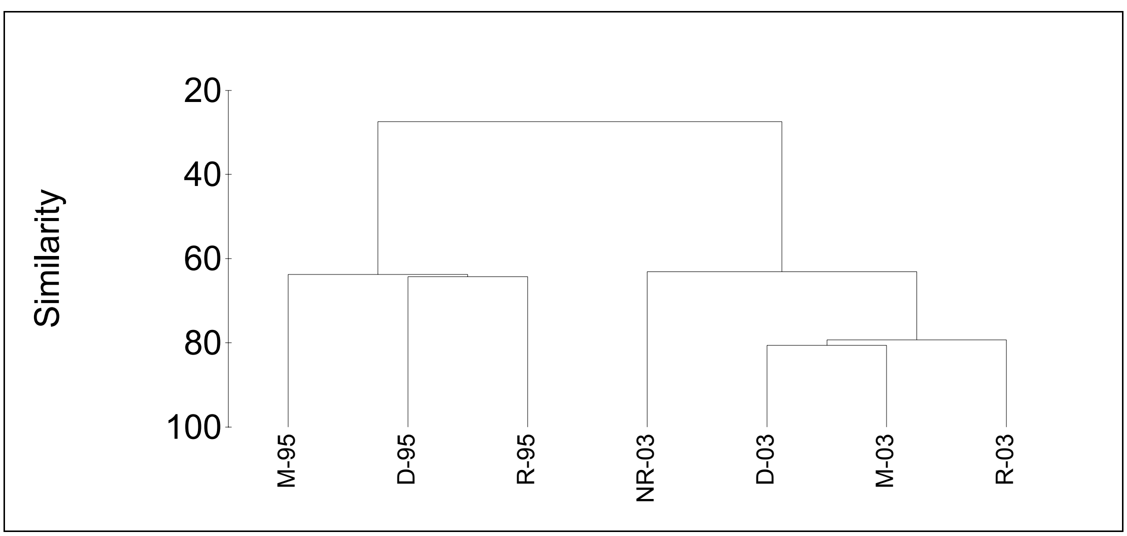


Figure 10. Dendrogram comparing the level of similarity between the 1995 and 2003 station types.

The different module types in 1995 are approximately 64% similar to each other while the module types in 2003 are 80% similar. The 2003 module types are 60-65%

similar to the natural reef station types in 2003. The dendrogram based on the BC Index indicates that the module types are more similar to the natural reef station types than indicated by Jaccard's Similarity Coefficient. The R module type is still slightly more similar to the natural reef based on both indices.

<u>2003 Overall Comparisons</u>.

The overall density or the number of individuals per square meter was analyzed to evaluate the differences between the four different station types—D modules, M modules, R modules, and NR stations. The density differed significantly between the different station types (ANOVA, $p < 0.00$, Figure 11).

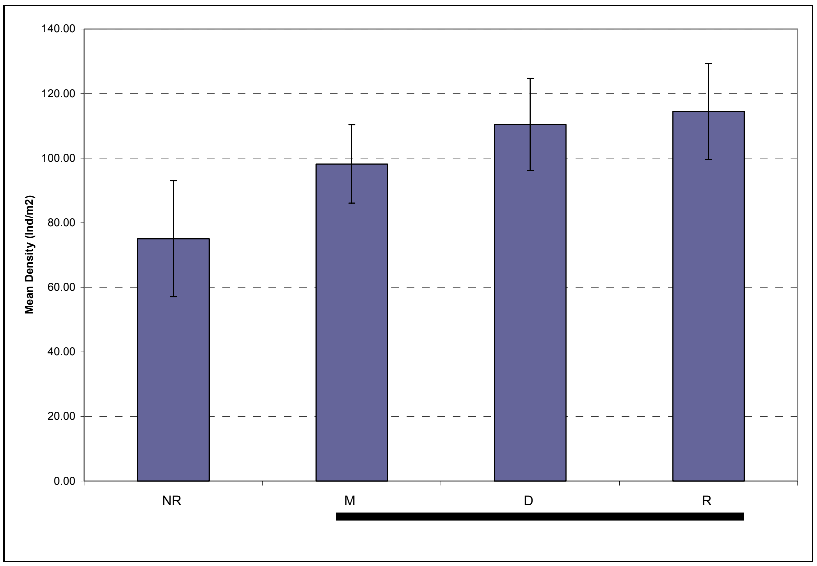


Figure 11: Number of individuals per square meter based on station type. Underlined columns are not significantly different based on the SNK post hoc ANOVA test.

The SNK post hoc test indicated that the Natural Reef stations have a lower density, 75.07 individuals per m^2, and are significantly different from all three module types. The M, D, and R modules have 98.19, 110.47, and 114.45 individuals per m^2 respectively.

The overall density analysis only takes into account the number of individuals per meter squared unlike the BC index which takes into account the number of individuals of each species per meter squared. Therefore, the Bray-Curtis Similarity Index was also calculated to compare the module and natural reef stations in 2003 in more detail. Figure 12 shows the MDS plot based on the BC index for the standardized density of individuals of each species per meter squared for each of the nine D modules, M modules, R modules, and Natural Reef stations.

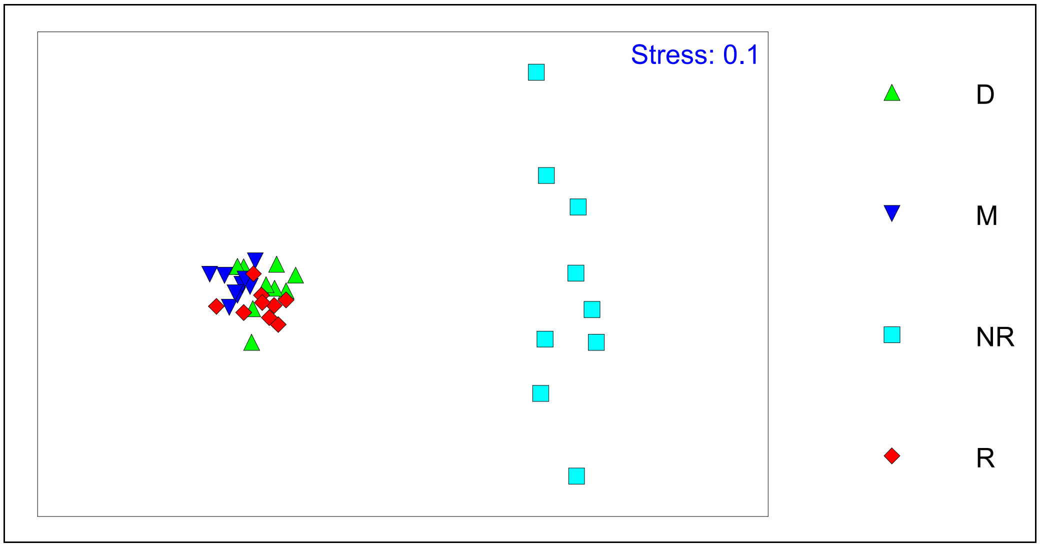


Figure 12. MDS plot based on the Bray-Curtis Similarity Index comparing the standardized density of the benthic individuals on the 2003 module and natural reef stations. D = Dome modules; M = Module design; NR = Natural Reef stations; and R = Reef Replacement modules.

The separation of the natural reef stations off to the right is apparent and indicative of lower similarity between the module stations and the natural reef stations. The low stress value (0.1) and the R statistic values confirm that the natural reef stations and the modules are significantly different (Table 7).

Table 7. R statistic results for the ANOSIM analysis comparing the standardized density of the benthic individuals on the D, M, and R modules and the NR stations.

Groups	***R statistic***	***Significance Level (%)***
D vs. M	0.403	0.1
D vs. NR	0.926	0.1
D vs. R	0.211	0.8
M vs. NR	0.988	0.1
M vs. R	0.440	0.1
NR vs. R	0.939	0.1

The R statistic values above indicate the D and R modules are the only pair of modules not significantly different from one another. The overlapping of the D and R modules can be seen more clearly in the MDS plot in Figure 13 when the NR stations are removed.

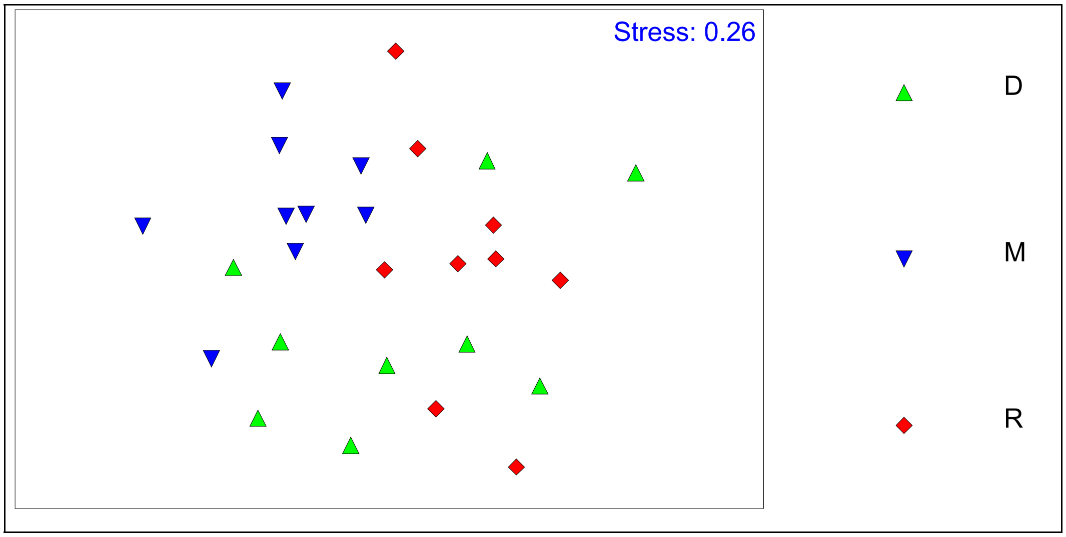
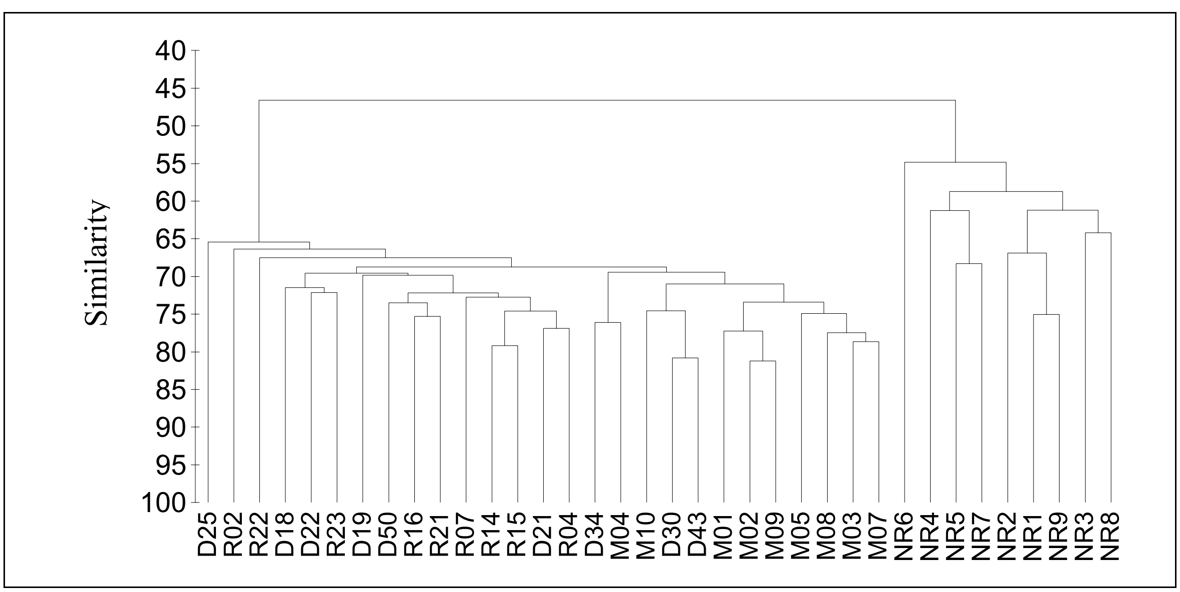


Figure 13. MDS plot based on the Bray-Curtis Similarity Index comparing the standardized density of the benthic individuals on the 2003 modules only. D = Dome modules; M = Module design; and R = Reef Replacement modules.

The level of similarity between all the 2003 stations based on the Bray-Curtis Index is shown in the dendrogram in Figure 14. The natural reef stations are only about 55% similar to one another while all the modules are at least approximately 65% similar to each other. The NR stations and the modules are roughly 47% similar.

Figure 14. Dendrogram based on the Bray-Curtis Similarity Index comparing the levels of similarity between the benthic communities on the module and natural reef stations in 2003.



To investigate the similarities and differences between the 2003 stations more fully the composition of the individuals per station type was examined (Figure 15).

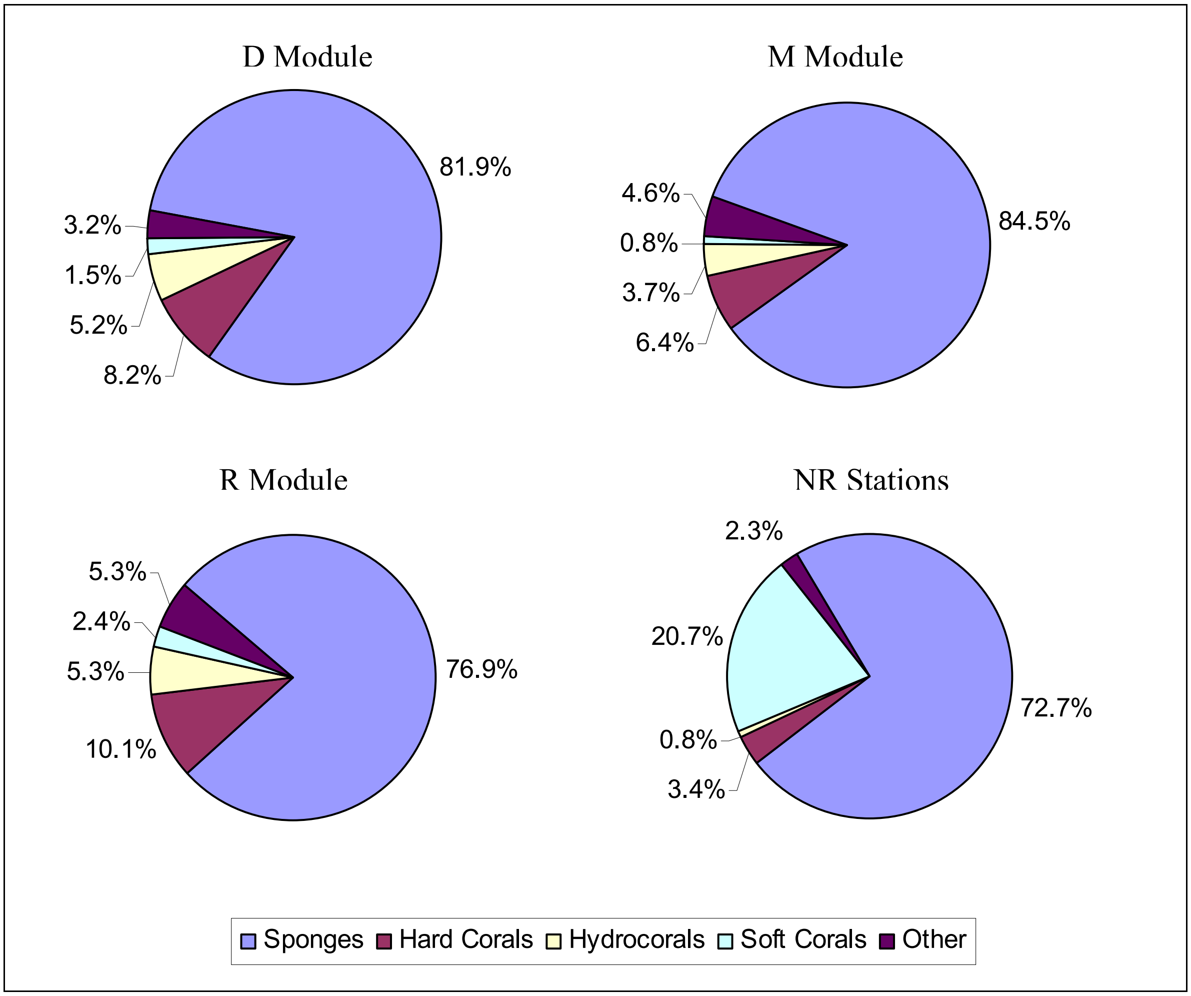


Figure 15. Relative percent composition of individuals on the Dome module (D), Module Design (M), Reef Replacement module (R), and the Natural Reef Station (NR). The "Other" taxonomic group included Anemones, Bivalves, Bryozoans, Crustaceans, Echinoderms, Polychaetes, and Tunicates.

Sponges made up the largest percentage of individuals on each station type. On the module stations, hard corals were the next largest taxonomic group. Hard coral individuals comprised of the third largest group on the NR stations. Soft coral individuals made up the second largest taxonomic group on the NR stations. The large difference in the relative percent of soft coral individuals between the module stations and the NR stations is due to the abundance of soft coral species *Briareum asbestinum*. The density of *B. asbestinum* was at least five times greater on the natural reef stations than on the module stations. ANOVA with the SNK post hoc test was used to determine if significant differences were found between the stations based on the percent composition of the two largest groups, sponges and hard corals.

The total count of sponge individuals makes up 81.9% of individuals on the D modules, 84.5% on the M modules, 76.9% on the R modules, and 72.7% on the NR stations. The relative percent of sponge individuals on each of the 36 stations (9 D modules, 9 M modules, 9 R modules, and 9 NR stations) was arc sine transformed to better meet normality constraints of an ANOVA test. An ANOVA with SNK post hoc test was then performed indicating significant differences between the station types (ANOVA, $p = 0.001$, Figure 16).

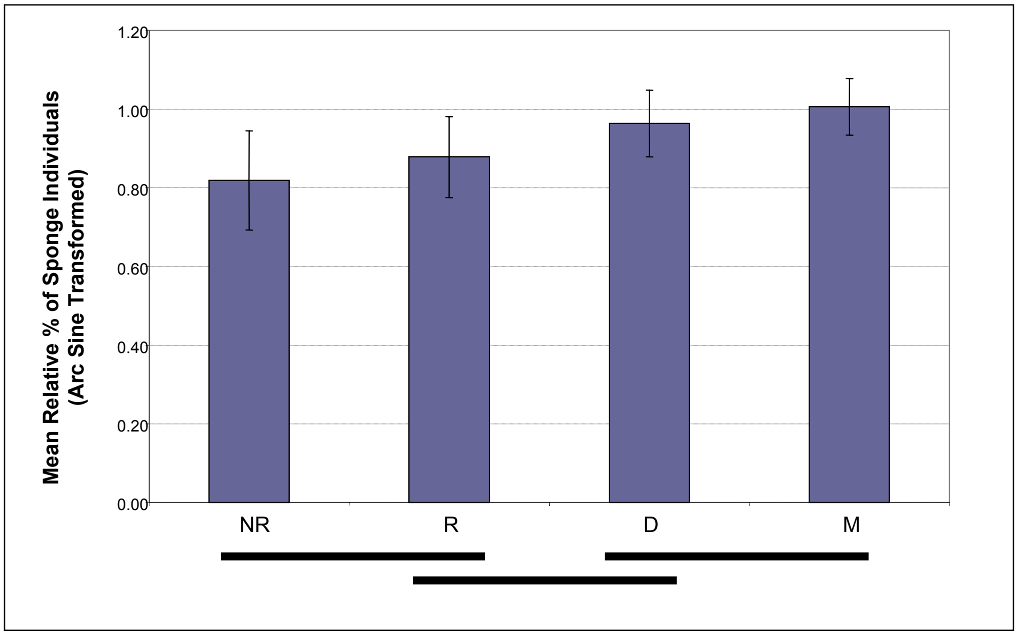


Figure 16: Relative percent of sponge individuals, arc sine transformed, based on station type. Underlined columns are not significantly different based on the SNK post hoc ANOVA test.

The SNK test indicated that the NR stations were significantly lower in the percentage of individuals that were sponges than the D and M modules but not the R modules. The R modules were significantly lower than M modules but not the D modules.

Hard coral colonies, the next largest taxonomic group on the modules, had 6.4%, 8.2%, and 10.2% on the M, D, and R modules respectively. On the natural reef habitats, however, hard coral colonies only made up 3.4% of the total number of individuals while soft coral was the next most abundant group making up 20.7% of the individuals. Again, the relative percent of hard coral individuals on each of the 36 stations was arc sine transformed to better met normality constraints. An ANOVA with the SNK post hoc test was then performed indicating a significant difference between the different station types (ANOVA, $p < 0.00$, Figure 17).

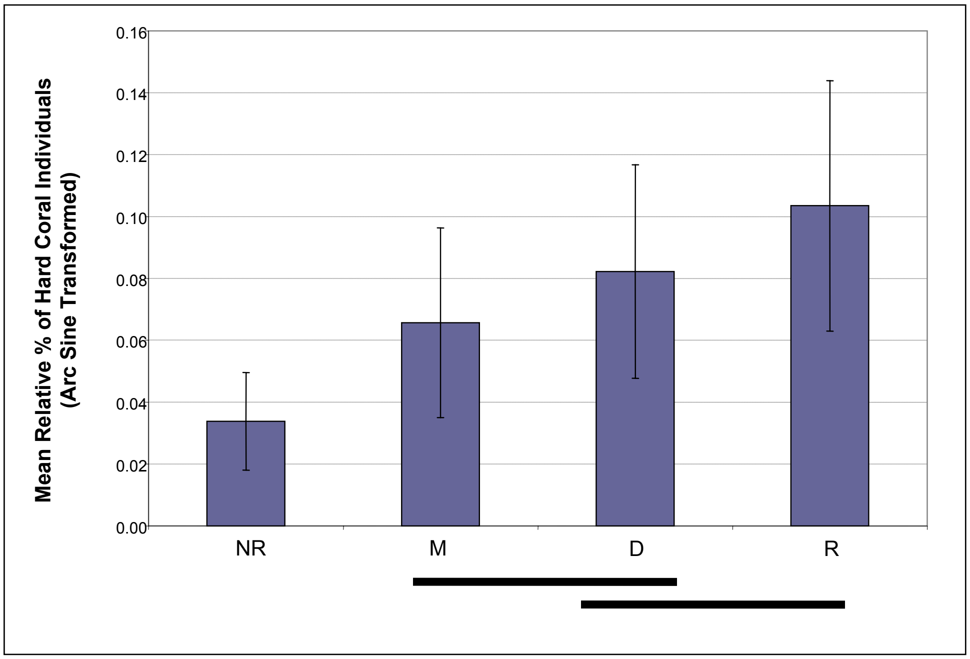


Figure 17. Relative percent of hard coral individuals, arc sine transformed, based on the station type. Underlined columns are not significantly different based on the SNK post hoc ANOVA test.

The SNK post hoc tests indicated that the NR stations were significantly lower in the percentage of individuals that were hard corals than the M, D and R modules. This test also indicated that the R modules were significantly higher than the M modules, but not the D modules.

To get a better understanding of what specific species abundance factored into the similarity and differences between station types a similarity of percentages analysis (SIMPER) was performed based on the Bray-Curtis Similarity Index. The species that accounted for the first 50% of the similarity among stations and the first 30% of the dissimilarity between the stations were included in the SIMPER analysis. Table 8 shows the species contributing to the similarity within the station types while Table 9 shows the species contributing to the dissimilarity between station types. *Monanchora barbadensis,* the most common species on the modules, contributed the most to the similarity within each module groups. Sponge species *Strongylacidon* species, *Dictyonella ruetzleri,* and *Iotrochota birotulata* are the next three species that contributed the most to the similarity within each module group. The D, M, and R modules also had higher average similarities with in their respective types than the natural reef stations. On the natural reef stations, soft coral species *Briareum asbestinum* played the largest role in the similarity among the NR stations. As with the module stations, the sponge species *Monanchora barbadensis* contributed to the similarity of the NR stations with the second largest role. *Niphates erecta* and *Monanchora* species were the third and fourth contributors respectively to the similarity between the natural reef stations.

Table 8. Species causing similarity within the station types (D, M, and R modules and NR stations) based on the Bray-Curtis index. Species are listed in ascending order according the percent contribution to similarity.

	Species	Cont. %	Cum. %
D Modules	*Monanchora barbadensis*	8.17	8.17
Avg. Similarity = 68.89	*Strongylacidon* species	5.68	13.84
	Dictyonella ruetzleri	5.60	19.45
	Iotrochota birotulata	5.51	24.96
	Millepora species	4.95	29.91
	Diplastrella species	4.91	34.82
	Dysidea species	4.87	39.69
	Niphates amorpha	4.30	43.98
	Haliscara species	4.24	48.22
	Siderastrea species	4.04	52.27
M Modules	*Monanchora barbadensis*	7.01	7.01
Avg. Similarity = 73.47	*Dictyonella ruetzleri*	5.11	12.11
	Iotrochota birotulata	4.84	16.95
	Strongylacidon species	4.82	21.77
	Dysidea species	4.54	26.31
	Diplastrella species	4.16	30.48
	Diplastrella megastella	4.16	34.64
	Cliona species	4.01	38.64
	Haliscara species	3.78	42.42
	Millepora species	3.77	46.19
	Monanchora unguifera	3.57	49.76
	Madracis decactis	3.47	53.24
R Modules	*Monanchora barbadensis*	6.03	6.03
Avg. Similarity = 70.88	*Dictyonella ruetzleri*	4.97	11.00
	Strongylacidon species	4.18	15.17
	Iotrochota birotulata	4.13	19.30
	Millepora species	4.06	23.37
	Dysidea species	3.70	27.07
	Diplastrella species	3.67	30.74
	Diplastrella megastella	3.57	34.31
	Niphates amorpha	3.27	37.59
	Siderastrea species	3.10	40.69
	Monanchora unguifera	3.08	43.77
	Cliona species	3.00	46.77
	Ircinia felix	2.93	49.70
	Ircinia strobilina	2.88	52.59
NR Stations	*Briareum asbestinum*	7.71	7.71
Avg. Similarity = 59.73	*Monanchora barbadensis*	7.13	14.84
	Niphates erecta	6.71	21.55
	Monanchora species	6.31	27.87
	Ptilocaulis species	6.07	33.94
	Niphates amorpha	5.94	39.88
	Dictyonella ruetzleri	5.92	45.79
	Amphemedon compressa	5.43	51.22

The D modules had the lowest average dissimilarity percentage between the natural reef stations followed by the R and M modules. *Millepora* species was more abundant on all of the modules than the natural reef stations and attributed greatly to dissimilarity between the modules and the natural reef. For the D and R modules, *Millepora* species was the largest contributor to the dissimilarity between the NR stations while it was the third for the M modules. *Briareum asbestinum* was the largest contributor to the dissimilarity between the M modules and the NR stations, fourth on the R modules, and fifth on the D modules. This soft coral species was at least five times more prevalent on the natural reef stations than on the modules. Sponge species *Monanchora* species played the second largest role in the dissimilarity between the NR stations and the D and M modules and sixth for the R modules. *Monanchora* species, like *Briareum asbestinum*, was at least five times more abundant on the natural reef stations than on the modules. *Ircinia strobilina* and *Diplastrella megastella,* more numerous on the modules than the natural reef station, also contributed significantly to the dissimilarity between the NR stations and the modules.

Table 9. Species causing dissimilarity between the different groups (D, M, and R modules and NR stations) based on the Bray-Curtis indices. Species are listed in ascending order according the percent contribution to the dissimilarity.

Species	Cont. %	Cum. %
D vs. NR		
Avg. Dissimilarity = 51.38		
Millepora species	3.64	3.64
Monanchora species	3.16	6.80
Ircinia strobilina	2.60	9.41
Ptilocaulis species	2.41	11.82
Briareum asbestinum	2.38	14.20
Haliscara species	2.27	16.47
Diplastrella megastella	2.24	18.70
Aplysina cauliformis	2.13	20.83
Madracis decactis	2.09	22.92
Callyspongia vaginalis	2.08	25.01
Aplysina fistularis	2.06	27.06
Ircinia felix	2.04	29.11
Strongylacidon species	2.00	31.10
R vs. NR		
Avg. Dissimilarity = 52.2		
Millepora species	3.21	3.21
Ircinia strobilina	2.28	5.49
Diplastrella megastella	2.22	7.71
Briareum asbestinum	2.19	9.90
Ircinia felix	2.14	12.04
Monanchora species	2.14	14.18
Ptilocaulis species	2.10	16.29
Ircinia strobilina	2.05	18.34
Madracis decactis	1.96	20.29
Aplysina cauliformis	1.91	22.21
Porites astreoides	1.91	24.12
Haliscara species	1.86	25.98
Callyspongia vaginalis	1.83	27.81
Porites species	1.81	29.61
Amphemedon compressa	1.80	31.41
M vs. NR		
Avg. Dissimilarity = 56.65		
Briareum asbestinum	3.42	3.42
Monanchora species	3.21	6.62
Millepora species	2.79	9.42
Madracis decactis	2.70	12.11
Amphemedon compressa	2.68	14.80
Spondylus americanus	2.68	17.47
Aplysina cauliformis	2.64	20.11
Ircinia strobilina	2.38	22.49
Haliscara species	2.15	24.64
Ptilocaulis species	2.13	26.77
Diplastrella megastella	2.11	28.88
Ircinia felix	2.09	30.96
M vs. R		
Avg. Dissimilarity = 31.08		
Briareum asbestinum	2.67	2.67
Siderastrea species	2.58	5.26
Siderastrea siderea	2.14	7.39
Holopsamma helwigi	2.03	9.43
Cliona delitrix	1.97	11.40
Aplysina cauliformis	1.97	13.36
Millepora alcicornis	1.94	15.31
Porites species	1.92	17.22
Pseudoceratina crassa	1.91	19.14
Stephanocoenia michelinii	1.77	20.91
Agaricia species	1.77	22.68
Unidentified Bivalve species	1.75	24.43
Niphates erecta	1.75	26.18
Unidentified Sponge species	1.69	27.87
Meandrina meandrites	1.67	29.54
Sabellidae species	1.67	31.21
D vs. R		
Avg. Dissimilarity = 31.37		
Briareum asbestinum	2.28	2.28
Polycarpa spongiablilis	2.19	4.48
Siderastrea species	2.18	6.66
Aplysina cauliformis	2.17	8.83
Sabellidae species	2.16	10.98
Porites species	2.14	13.13
Unidentified Sponge species	2.11	15.24
Millepora alcicornis	1.98	17.22
Pseudoceratina crassa	1.94	19.17
Spondylus americanus	1.90	21.07
Agaricia species	1.86	22.93
Monanchora unguifera	1.86	24.79
Siderastrea radians	1.83	26.62
Amphemedon compressa	1.82	28.44
Ircinia species	1.81	30.25
D vs. M		
Avg. Dissimilarity = 31.83		
Briareum asbestinum	2.84	2.84
Unidentified Sponge Species	2.64	5.48
Spondylus americanus	2.49	7.97
Aplysina cauliformis	2.46	10.43
Unidentified Bivalve species	2.33	12.76
Siderastrea species	2.22	14.98
Cliona delitrix	2.20	17.17
Holopsamma helwigi	2.18	19.36
Ircinia species	2.16	21.52
Polycarpa spongiablilis	2.14	23.66
Niphates erecta	2.14	25.80
Amphemedon compressa	2.03	27.83

	Oceanapia bartschi	2.00	29.83
	Millepora alcicornis	1.97	31.81

The comparisons between the modules were relatively close with the average dissimilarities percentages ranging from 31.08% to 31.83%. The M and R modules had the lowest average dissimilarity percentage followed by the D and R and D and M comparisons. The abundance of *Briareum asbestinum* was the largest contributor to the dissimilarity between the all three of the module comparisons. The R modules had a greater abundance of *Briareum asbestinum* than the D modules and almost seven times the amount as the M modules. With the comparison between the M and R modules, *Siderastrea* species and *Siderastrea siderea* were more abundant on the R modules and were the second and third major contributors to the dissimilarity between the two. *Polycarpa spongiablilis* and *Siderastrea* species were the second and third major contributors for the dissimilarity between the D and R module due to the higher abundance on the R modules. Between the D and M modules, an unidentified sponge species and *Spondylus americanus* were the second and third largest factors in the dissimilarity between these two modules. Both the unidentified sponge species and *Spondylus americanus* were more common on the M modules.

2003 Horizontal Module Surfaces and Natural Reef Stations.

Due to the fact that the natural reef stations lacked vertically oriented surfaces, the benthic data collected in the vertical quadrats on the modules were removed to determine if the natural reef stations were any more similar to the non-vertical surfaces of the modules than they were to the entire module. The Bray-Cutis Similarity Index was calculated and a MDS plot was created (Figure 18) with the non-vertical surfaces of the modules and the natural reef stations.

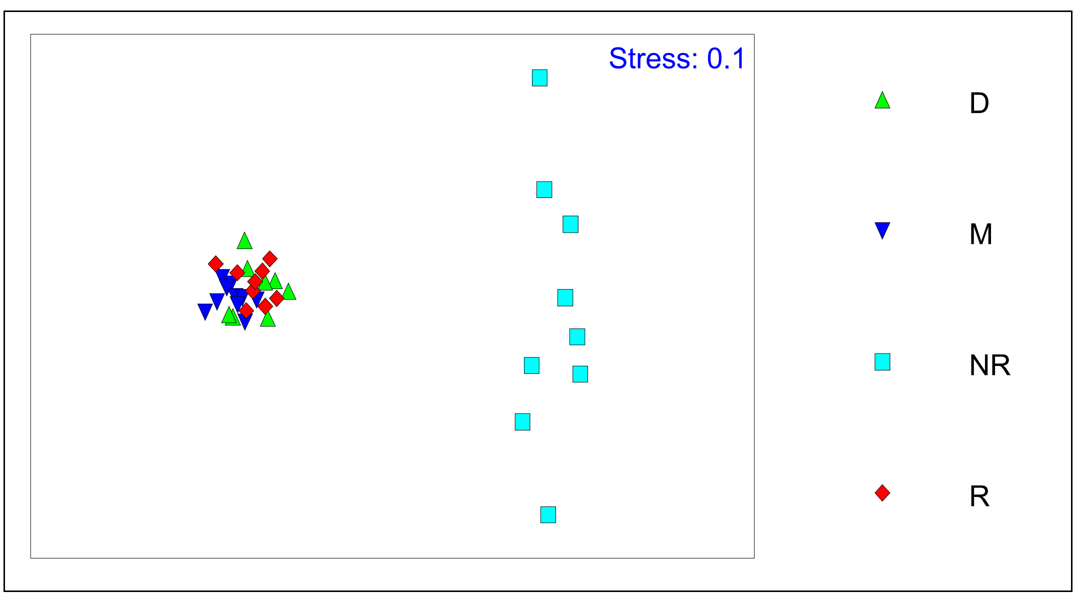


Figure 18. MDS plot based on the Bray-Curtis Similarity Index comparing the standardized density of the benthic individuals on the non-vertical surfaces of the 2003 module and natural reef stations. D = Dome modules; M = Module design; NR = Natural Reef stations; and R = Reef Replacement modules.

The MDS plot in Figure 18 appears very similar to the MDS plot in Figure 12 which included the vertically oriented surfaces. The R statistic values (Table 10) are also similar with two exceptions. With the vertical surfaces of the modules removed, the D and R modules are not the only pair of modules similar to one another based on the BC index. The D and M modules and the M and R modules are also similar and not significantly different from one another. The exclusion of the vertical surfaces did not change the fact that all the module stations are significantly different from NR stations.

Table 10. R statistic results for the ANOSIM analysis comparing the standardized density of the benthic individuals on the non-vertical surfaces of the D, M, and R modules and the NR stations.

Groups	***R statistic***	***Significance Level (%)***
D vs. M	**0.225**	**1.0**
D vs. NR	0.996	0.1
D vs. R	**0.211**	**10.6**
M vs. NR	1.000	0.1
M vs. R	**0.120**	**5.0**
NR vs. R	0.997	0.1

2003 Vertical vs. Horizontal Comparisons.

Comparisons were also made to determine if any significant differences were found between the horizontal and vertical surfaces on the modules. The Bray-Curtis Similarity Index was calculated based on the standardized density of individuals of each species for the vertical and horizontal surfaces of each module. An MDS plot was created base on this index (Figure 19).

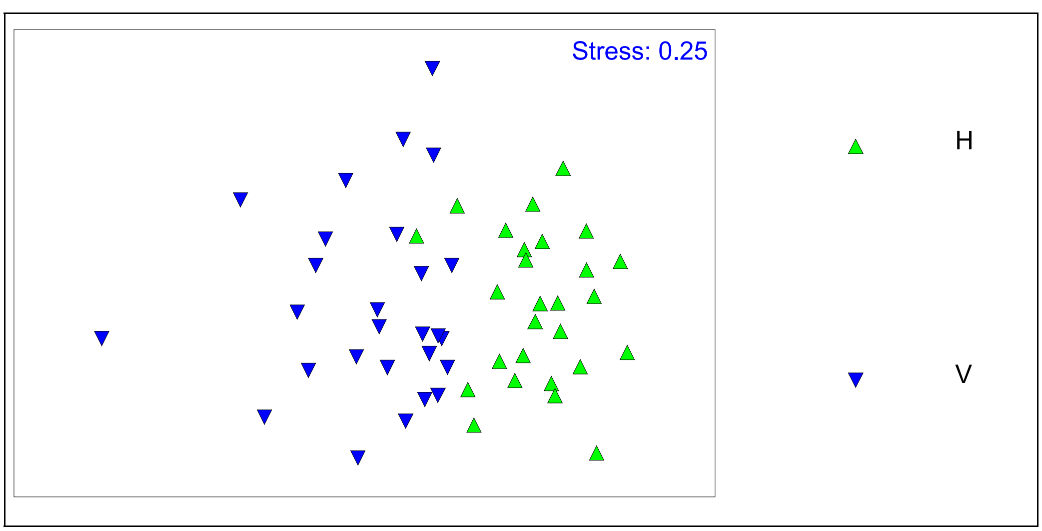


Figure 19. MDS plot based on the Bray-Curtis Similarity Index comparing the standardized density of the benthic individuals on the vertical and horizontal surfaces of the modules. H = Horizontal surfaces and V = Vertical surfaces.

In the MDS plot, the horizontal and vertical surfaces separate out into two groupings with vertical surfaces on the right and horizontal on the left. The R statistic value and significance level, 0.377 and 0.1 % respectively, confirmed the separation of the standardized density of the individuals on the horizontal and vertical surfaces. The dendrogram in Figure 20 shows the level of similarity between the vertical and horizontal surfaces.

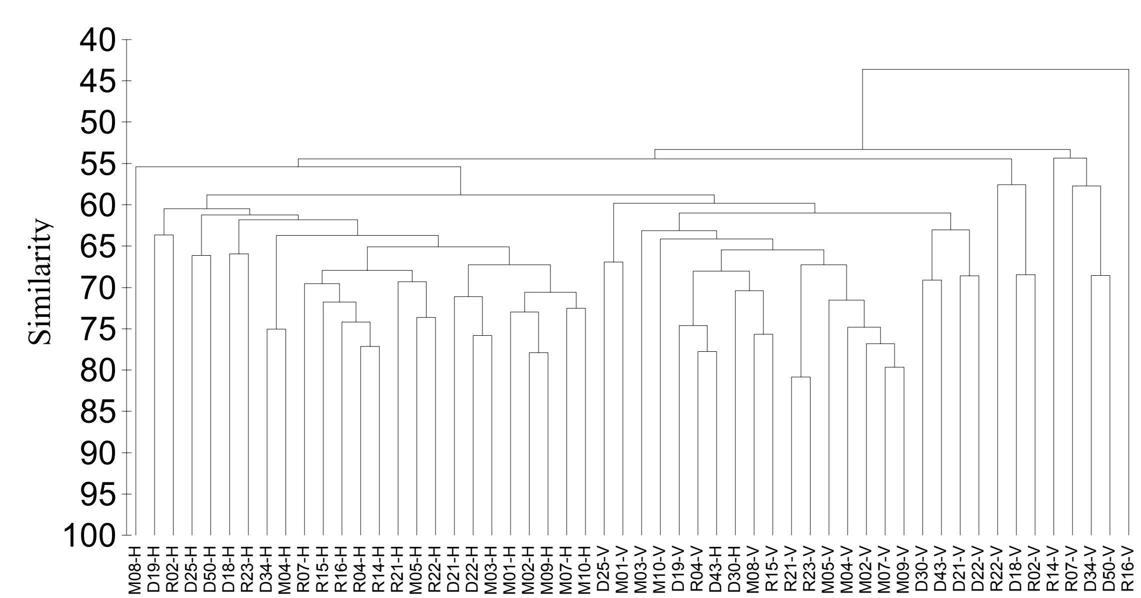


Figure 20. Dendrogram based on the Bray-Curtis Similarity Index comparing the levels of similarity between the standardized densities of the benthic individuals on the module stations. The sample names are given based on the module number and the surface orientation (i.e.; D18-V represents the vertical surfaces of D18 and D18-H represents the horizontal surfaces of D18).

All horizontal surfaces of the modules are approximately similar at 55% while the vertical surfaces are only approximately 43% similar. However, the average similarity within the horizontal and vertical groups is higher at 63.18% and 59.25% respectively.

A SIMPER analysis was performed to determine what species contributed the most to the similarities within the groups and the dissimilarity between the groups (Table 11). The higher-contributing species that accounted for the first 50% of the similarity among stations and the first 30% of the dissimilarity between the stations were included in the SIMPER analysis.

Table 11. Species causing the similarity within the groups and dissimilarity between the groups based on the Bray-Curtis Index. Species are listed in ascending order according the percent contribution to the similarity or dissimilarity.

	Species	Cont. %	Cum. %
Horizontal Surfaces	*Monanchora barbadensis*	9.01	9.01
Average Similarity = 63.18	*Dictyonella ruetzleri*	6.67	15.68
	Strongylacidon species	5.92	21.60
	Millepora species	5.65	27.65
	Dysidea species	4.92	32.17
	Iotrochota birotulata	4.81	36.98
	Diplastrella species	4.74	41.72
	Haliscara species	4.68	46.40
	Cliona species	4.66	51.06
Vertical Surfaces	*Monanchora barbadensis*	11.31	11.31
Average Similarity = 59.25	*Iotrochota birotulata*	9.13	20.44
	Dictyonella ruetzleri	7.30	27.75
	Strongylacidon species	6.34	34.09
	Dysidea species	5.78	39.87
	Diplastrella species	5.70	45.56
	Niphates amorpha	5.68	51.25
Horizontal vs. Vertical	*Niphates erecta*	2.77	2.77
Average Dissimilarity = 43.64	*Madracis decactis*	2.75	5.52
	Cliona species	2.55	8.07
	Siderastrea siderea	2.49	10.57
	Porites astreoides	2.49	13.05
	Stephanocoenia michelinii	2.35	15.40
	Briareum asbestinum	2.33	17.73
	Haliscara species	2.33	20.06
	Unidentified Sponge species	2.30	22.36
	Ircinia species	2.15	24.51
	Niphates digitalis	2.14	26.64
	Ircinia felix	2.12	28.76
	Hippopodina feegeensis	2.09	30.85

The most common sponge found on the modules, *Monanchora barbadensis,* again contributes the most to the similarity within the vertical and within the horizontal surfaces. *Dictyonella ruetzleri, Strongylacidon* species, and *Iotrochota birotulata* are other sponge species contributing to the similarity within the two groups. *Niphates erecta* and *Madracis decactis* were more abundant on the vertical surfaces and played the largest role in the dissimilarity between the vertical and horizontal surfaces. Sponge species *Cliona* species, hard coral species *Siderastrea siderea*, *Porites astreoides*, and *Stephanocoenia michelinii* as well as the soft coral species *Briareum asbestinum* were more abundant on the horizontal surfaces than the vertical surfaces thereby also contributing to the dissimilarity between the two groups.

Section Discussion:

Changes from 1995 to 2000. Considerable changes occurred on the SIRR modules from 1995 to 2003. One of the most noticeable was the decrease of the main "pioneering" species, *Holopsamma helwigi*, giving rise to a more diverse population. The modules now have 83 more species than were present in 1995. Similar dominance by *H. helwigi* in the early stages of benthic community development on artificial reefs has been observed in Miami-Dade County's Bal Harbor Mitigation Project (DERM 2002, 2003). This mitigation project, deployed approximately 5 years ago, is located in the sand plain between the 2nd and 3rd reef tracks off of Haulover Beach in a comparable depth. The limerock boulders and prefabricated modules are following a similar progression to the SIRR modules and the trend is expected to continue.

The increase in the number of species and the number of individuals on the SIRR modules has lead to the considerable increase in the diversity (H') as well. The R modules were the most diverse module type in 1995 and in 2003. Based on the H' value, the R modules are also slightly more representative of the diversity of the natural reef in 2003. The lowest value of H' and J was found on the M modules both in 1995 and 2003. In addition to the diversity, the similarity between the different module types also increased from 1995 to 2003 based on both Jaccard's Coefficient of Similarity and the Bray-Curtis Similarity Index.

2003 Comparisons. Most of the analysis with the 2003 data indicated that the module stations were significantly different from the natural reef stations. The NR stations had a lower overall density than the module stations. When examining the density of each species per module with the Bray-Curtis Similarity Index, the modules were more similar to one another than to the NR stations. The NR stations were only similar to the R module stations with respect to the percentage of individuals that were sponges. Both the D and M module stations had more sponge individuals than the natural reef. The abundance of sponge species, *Monanchora barbadensis*, was responsible for a large portion of the similarity within and between the modules. The soft coral species, *Briareum asbestinum*, accounted for most of the similarity between the NR stations and the dissimilarity between the NR stations and the module stations.

The module stations could only be expected to be as similar to the NR stations as the NR stations are themselves. The NR stations had an average similarity of roughly 60% with a range of 48% to 75%. The D module stations and the NR stations were, on average, approximately 49% similar. The R module stations and the NR station were slightly less similar with an average of about 48% similarity. The M module stations were the least similar to the NR stations with an average 43% similarity.

The artificial reef modules will most likely never reach the same similarity percentage that exists within the natural reef stations due to several factors that set them apart from the natural reef. These factors include higher relief with less sedimentation, vertical surfaces, and composition of the substrate. The modules had structural relief from 3 to 4.5 feet (0.9 to 1.4 meters) while the relief on the NR stations was much lower, around 1 foot (0.3 meters). The NR stations had depressed hard-bottom areas covered with a layer of sand (Figure 21).

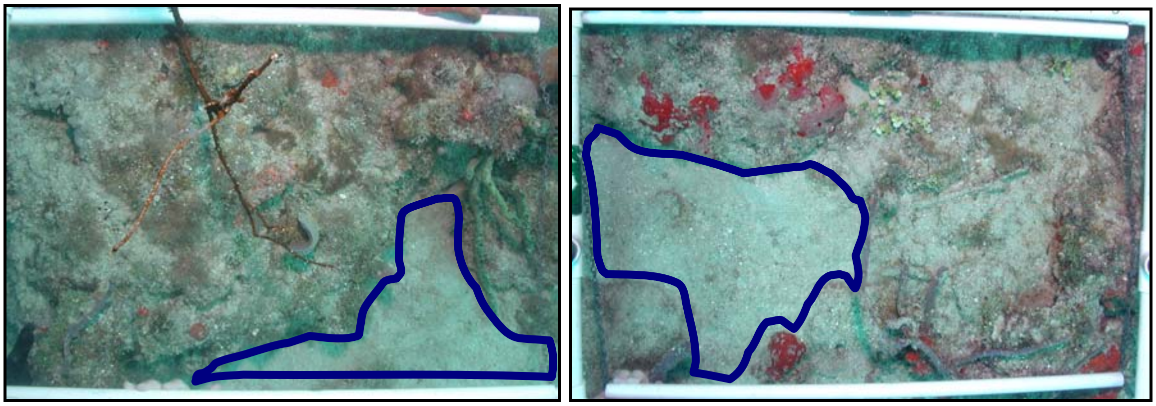


Figure 21. Two quadrats on natural reef stations. The sand covered areas are outlined in blue.

These sandy areas were absent from the surfaces of the module stations allowing for increased surface area that was suitable for settlement and growth of benthic organisms. The modules also had vertical surfaces that were absent on the natural reef stations monitored. The vertical surfaces provided additional specific habitats for species such as *Madracis decactis* that are not commonly found on the horizontal natural reef surfaces. The modules are also composed of different materials from limestone rock for the R modules and the exterior of the D modules and pre-cast cement for the M modules. With these differences between the natural reef and the modules, the modules and natural reefs may never reach the similarity level that is found within the natural reef stations.

To determine if the horizontal module surfaces were more similar to the NR stations than the entire modules, the vertical module surfaces were removed for the comparison of the NR stations and the horizontal module surfaces. The removal of the vertical surfaces of the modules did not increase the similarity between the modules and the natural reef stations. It did, however, increase the similarity between the different modules types. The horizontal surfaces of the modules maintained the same level of similarity with the NR stations as the entire module. The differences in the horizontal module surfaces and the NR stations were still caused predominantly by *Millepora* species which was more abundant on the modules and *Monanchora* species and *Briareum asbestinum* which were more abundant on the NR stations.

The modules were also analyzed separately to compare the vertical and horizontal surfaces. The average similarity between the vertical and horizontal surfaces was only roughly 56% while the vertical surfaces were 59% similar and the horizontal surfaces were 63% similar. *Monanchora barbadensis* was again the species most responsible for the similarity within the horizontal surfaces and within the vertical surfaces. The differences were caused by *Niphates erecta* and *Madracis decactis* which were more abundant on the vertical surfaces, and *Cliona* species, *Porites astreoides*, and *Siderastrea siderea* which were more abundant on the horizontal surfaces.

SECTION II - FISH POPULATION ASSESSMENT

Monitoring Methodology:

As during the initial SIRR monitoring, fish surveys were conducted on each module and natural reef control station by utilizing a rapid visual total count census technique. Consistent with the Bonsack-Bannerot (1986) technique, the fish population within an imaginary cylinder of water surrounding each sample site was assessed. Surveys were centered on each module with a survey area extending out in a 3m radius over the adjacent reef creating a 6m diameter cylinder. Modification to the Bonsack-Bannerot census technique included a reduction in the diameter of each survey area from 15m to 6m to minimize the effects of external influences, such as other nearby modules. Additionally, instead of remaining stationary at the center of the cylinder, the surveying diver swam two slow circumferences around the module or station during the first five minutes of each survey, recording all species present within the imaginary cylinder. The first revolution was made at the perimeter of the imaginary cylinder (3m from the center of the module or NR station) to minimize disturbance of the resident species. The observer then swam a second, tighter circle to locate and identify smaller, cryptic species that might otherwise be missed from the 3m range. For the remainder of the survey, divers continued swimming this circular pattern (one full revolution for each species observed and recorded during the first five minutes of the survey), enumerating individuals and estimating the size range (cm) of that species (Although estimates of minimum, maximum, and mean overall fish lengths are standard observations, those data were not recorded or evaluated in the original monitoring project. Analyses of 2003 data for inter-modular biomass trends would be a valuable future exercise.). Minimal disturbance of the fish (i.e., flight or 'startled' response) was noted by the surveyors when moving slowly and regularly within the cylinder. New species encountered after five minutes were noted on the survey sheet, but their numbers were not counted, nor size estimated. Additionally, habitat features and sampling conditions were also noted on the survey sheet.

A steel reinforcement rod or “rebar” was driven into the reef to mark the origin of each natural reef control site. Those rebar served as the center points of the 3m diameter imaginary cylinders, the circumference of which the observer swam to conduct the NR fish surveys. With that exception, the survey technique for NR stations was identical to that for the modules.

To increase the sample size, fish population sampling was conducted in three phases during this Restudy. The three subsets, or rounds of surveys, were collected over a period of seven months from February to August, 2003, potentially reducing seasonal influences that might skew isolated data points. The initial sampling period (S-1) was conducted immediately following the Site Reconnaissance period and prior to the initiation of the Benthic Assessment, a process in which belt transects were photogrammetrically sampled on each monitored module. The second "round" of Fish Surveys (S-2) was conducted on the same suite of modules at the approximate midpoint of the Benthic Assessment period. Fish populations on the complete set of modules and natural reef site stations were sampled one final time (S-3) after completion of the

Benthic Assessment. Data were combined and summarized by module type/station for comparison with previously collected data, data from other module types, and data from the adjacent natural reef controls. Although conditions were never poor enough to require implementation, a quality control restriction was established during the planning phase of the project whereby no fish census would be performed and surveys would be conducted at a later date if horizontal visibility was judged to be less than 7.5m on station.

Statistical Analyses:

The "Section I - Benthic Community Assessment" narrative contains full descriptions of the types of statistical analyses applied. Calculations included density (number of individuals per survey or area), Relative Abundance, Shannon-Wiener Diversity, Pielou's Evenness Measure, Jaccard's Similarity Coefficient and Bray-Curtis Similarity Index. Data from the final post-construction survey in 1995 and the 2003 ReStudy were evaluated on the bases of module type, species and family. Analysis included comparisons of similarity and differences in patterns of recruitment and colonization, changes in species diversity and dominance (density), and measurements of habitat complexity for the following:

- Each module type (D, M, R) compared over time (1995 vs. 2003);
- Each module type vs. the other types (2003 vs. 2003; also referred to as "mods vs mods"); and
- Each module type vs. adjacent natural reef (2003 vs. 2003; also referred to as mods vs control)

Summary of Results:

During the final sampling of the original assessment (September of 1995), G. M. Selby and Associates (1995c) documented 4426 individuals comprising 56 different species of fish. Grunts (*Haemulon sp.*) were the dominant species in the final survey of the study as well as in the previous surveys. The highest fish population density values from the original monitoring were consistently found on the M modules. The D modules showed the least dense populations; however, they had the closest similarity to the natural reef areas that were scraped clean for comparison of colonization. The R and M modules had enhancement characteristics such as relief and more complex void spaces (i.e., cryptic spaces) not observed on adjacent reef areas that attributed to the higher densities and diversities (Blair, 1998). Therefore, the D modules came the closest to meeting the original project goals restoring the habitat complexity similar to that of the surrounding natural reef areas with minimum enhancement. G.M. Selby and Associates (1995c) noted that the number of invertebrate taxa had not clearly leveled off by the end of the four years of monitoring and populations were still changing.

For a comprehensive species list and a reference table of the scientific and common names corresponding to the species code abbreviations, see Appendix F.1. Appendix F.2 provides data from the final sampling in 1995 and the 2003 Restudy by module/station type and totals. Data in the “2003” columns are averages of the cumulative number of individuals observed on each module type and natural reef control stations during all three “rounds” of surveys.

Density:

<u>1995 vs. 2003 Comparisons:</u>

Consistent with the results of the Benthic community data evaluation presented in Section I, Appendix F2 and Table 12 demonstrate that the number of individual fishes, as well as fish species observed on the modules during the 2003 Restudy increased considerably over 1995. Table 12 provides an overall summary of the number surveys per module type/station, total number of individuals per species (2003 data shown are averages from three rounds of surveys), total number of species recorded per station, as well as identifies the most common species found at module type/station. During the final sampling of the Sunny Isles Artificial Reef Monitoring Project in 1995, 51 different species and 4427 individuals were recorded overall. In 2003, the numbers increased to 21,388 individuals representing 100 different species. Although the number of surveys conducted on each module type increased from 10 – 11 in 1995 to 27 in 2003, the average number of individuals observed on each module type was notably greater (more than 25% higher on M modules, and in all other cases higher than 100%) in 2003.

Table 12: 1995 vs. 2003 Fish data comparison summary

	Number of Surveys		Total Number of Individuals/Module Type		Number of Individuals/survey		Total Number of Species		Most Common Species			
									1995		2003	
Site	1995	2003	1995	2003	1995	2003	1995	2003	Species	n =	Species	n =
D	11	27	538	3059	48.8	113.3	35	52	*Haemulon sp*	278	*Haemulon melanurum*	822
									Thalassoma bifasciatum	109	*Coryphopterus personatus*	565
									Acanthurus bahianus	14	*Haemulon flavolineatum*	500
									Equetus acuminatus	14	*Haemulon plumieri*	297
											Thalassoma bifasciatum	189
M	10	27	2873	9724	287.2	360.1	39	66	*Haemulon sp*	2103	*Coryphopterus personatus*	2572
									Lutjanus synagris	600	*Haemulon flavolineatum*	1795
									Lutjanus griseus	112	*Haemulon chrysargyreum*	1389
									Thalassoma bifasciatum	90	*Haemulon melanurum*	837
											Thalassoma bifasciatum	647
R	10	27	1021	6478	101.8	239.9	42	64	*Haemulon sp*	644	*Haemulon melanurum*	1530
									Thalassoma bifasciatum	120	*Coryphopterus personatus*	1515
									Lutjanus griseus	25	*Haemulon flavolineatum*	1368
									Chromis scotti	24	*Haemulon sp*	308
											Thalassoma bifasciatum	298
NR		27		2127		78.8		54			*Decapturus sp.*	1025
											Pomacentrus partitus	364
											Thalassoma bifasciatum	162
											Halichoeres garnoti	90
											Sparisoma aurofrenatum	87
Total	31	108	4432	21388	143.0	198.0	51	100	*Haemulon sciurus*	1126	*Coryphopterus personatus*	4662
									Haemulon plumieri	951	*Haemulon flavolineatum*	3663
									Lutjanus synagris	600	*Haemulon melanurum*	3189
									Haemulon flavolineatum	570	*Haemulon chrysargyreum*	1417
									Thalassoma bifasciatum	319	*Thalassoma bifasciatum*	1296

2003 Modules vs. Modules:

Figure F.1 shows that the distribution of the number of individuals between module types followed strikingly parallel patterns in 95 and 03. The M modules, not coincidentally the largest structures, consistently yielded the highest total number of individuals and number of individuals per survey (9724 and 360.1 respectively in 03).

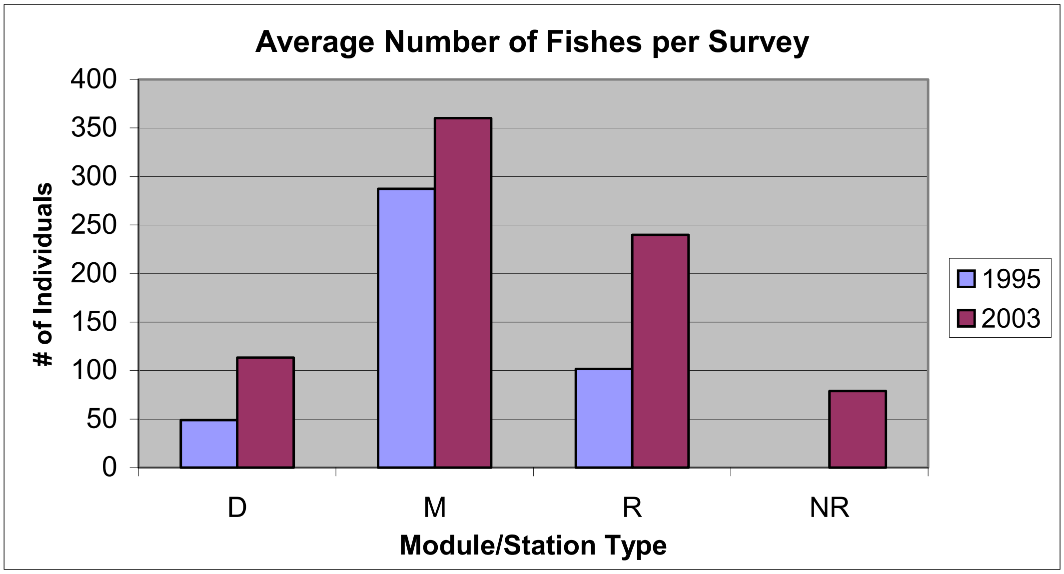


Figure 22: Average number of fishes per survey by module type, 1995 and 2003.

Although the numbers of individuals seen on R modules was lower than those on the M modules in both years, the average number of individuals per survey was consistently at least two times greater than the number seen on the D modules in either study.

The M modules categorically dominate the other module types in total numbers of individuals and density calculations until adjustments are made to factor in the area and volume of the structure types. As discussed in the previous monitoring project's reports (see G.M. Selby and Associates' 16th Quarterly Report), the external, exposed, 'sample-able' surface area dimensions of the various module types are considerably different. See Table 1 for a summary of design dimensions. The average numbers of individuals per surveys were divided by the areal dimensions (or multiplied by the coefficients) to obtain adjusted values of the average number of individuals per square meter of module surface area (see Figure 23). Adjusted M module density values were still higher than the other types in 1995, but by a much-reduced margin. The D modules showed substantially higher density of fish per unit area of module in 2003.

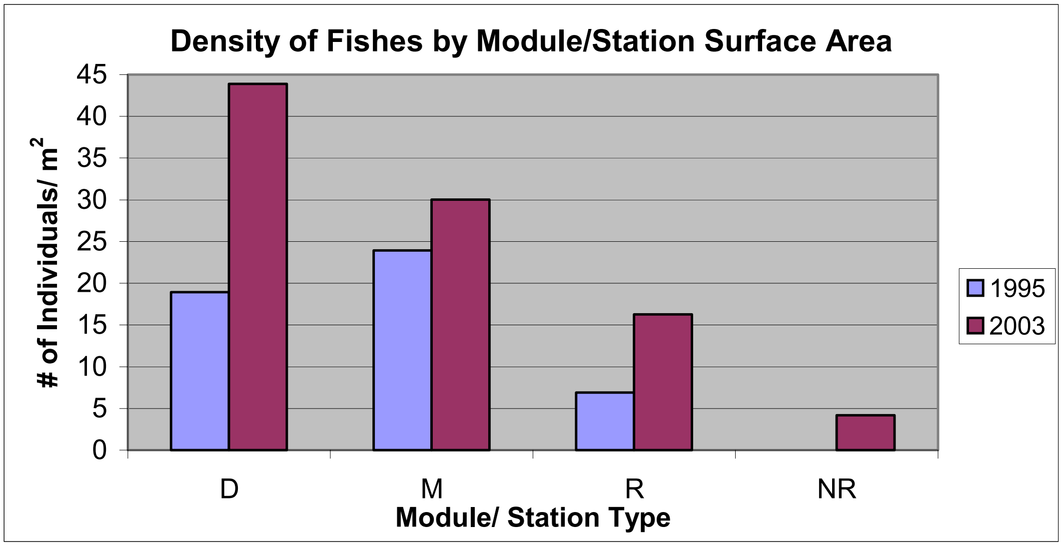


Figure 23: Average number of fishes per square meter of module surface area by module type and year.

<u>2003 Modules vs. Natural Reef Control:</u>

The density values found at the natural reef control sites are consistently below those of any of the types of artificial reef modules. This observation led to the assumption that there may be a direct correlation between the size of fish populations and the height of the structure with which that population is associated, . An experimental effort was made to normalize the observed populations by dividing the average number of individuals per survey by the total vertical relief of each module type. As before, the dimension of each module type was applied as a coefficient. In this case, the overall height in feet (including the base or feet) of each module type is as follows: M = 6'; R = 4'; D= 2'. It was found that even the populations on the surrounding natural reefs can be brought into range by applying the average relief of the surrounding reef (approximately 1.5') as a coefficient (See Figure 24). Although both 95 and 03 data sets were normalized, only the 2003 data showed

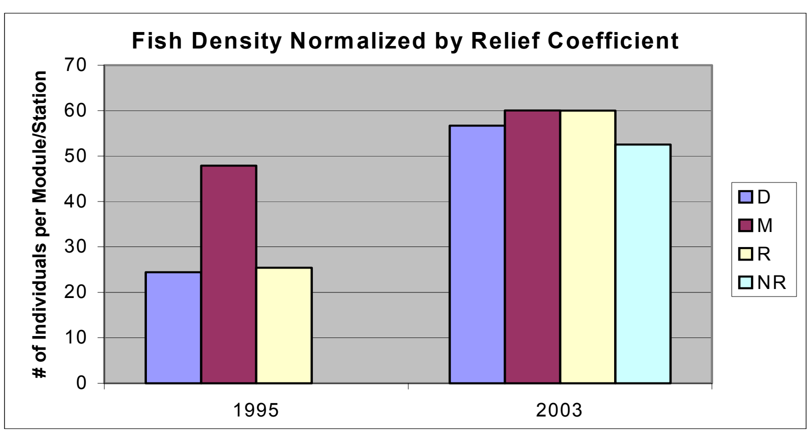


Figure 24: Average number of fishes per module with relief coefficient adjustment by module type and year.

a notable smoothing effect, while the 1995 data retained the typical M spike and low control value. This response, or lack thereof, echoes the result of the previous manipulation, which also failed to diminish, and rather, underscored the substantial size of the M module population in the 1995 data.

Relative Abundance:
<u>1995 vs. 2003 Comparisons:</u>

As indicated in Table F.2, 2003 species richness values, or the number of species observed on each module type increased by at least 50% over 95 results (See Figure 25). It is clear that the populations at the site have continued to develop over the years. It has been suggested that increases in numbers of individuals and species observed could be attributable to improved sampling methodology and skill. This hypothesis is not testable since the two monitoring events were conducted by completely independent parties. It should be noted, however, that the original study was conducted by highly credentialed professional consultants, while the Restudy sampling was performed by experienced field biologists.

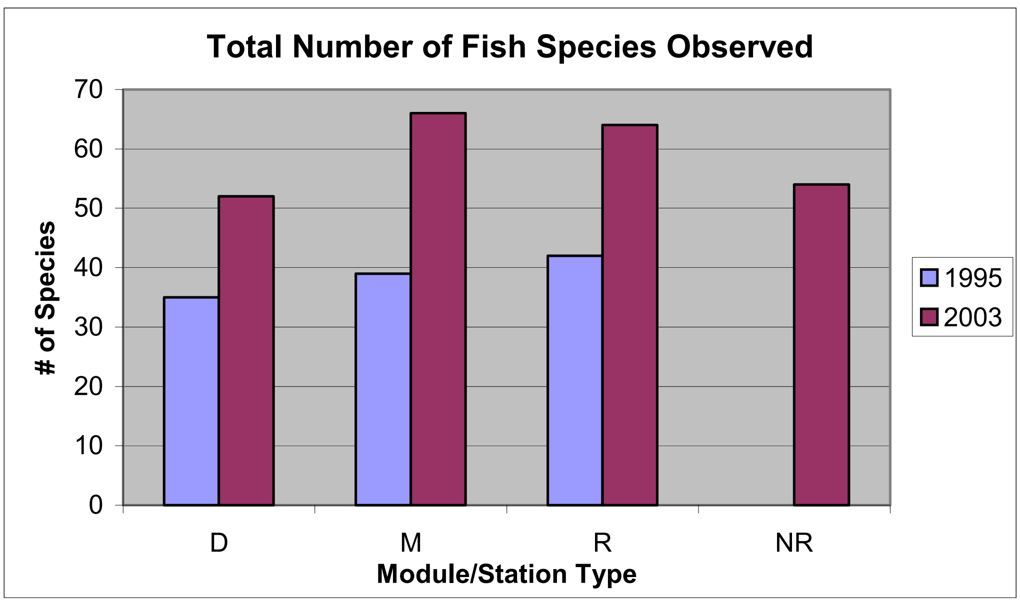


Figure 25: Average number of species per module/station type.

Not only have the numbers of species increased, but also the proportions of individuals representing those species have shifted. Unequivocally, the dominant species, or the species with the highest number of individuals, at all three module sites in 1995 was *Haemulon sp*. (See Figure 26). Populations on D, M, and R modules were comprised of staggering numbers of Haemulidae (Grunts) species, occupying 53%, 64%, and 64% of the respective populations. Lutjanidae (Snappers), a closely related family, represented 25% of the population on the M modules in 1995.

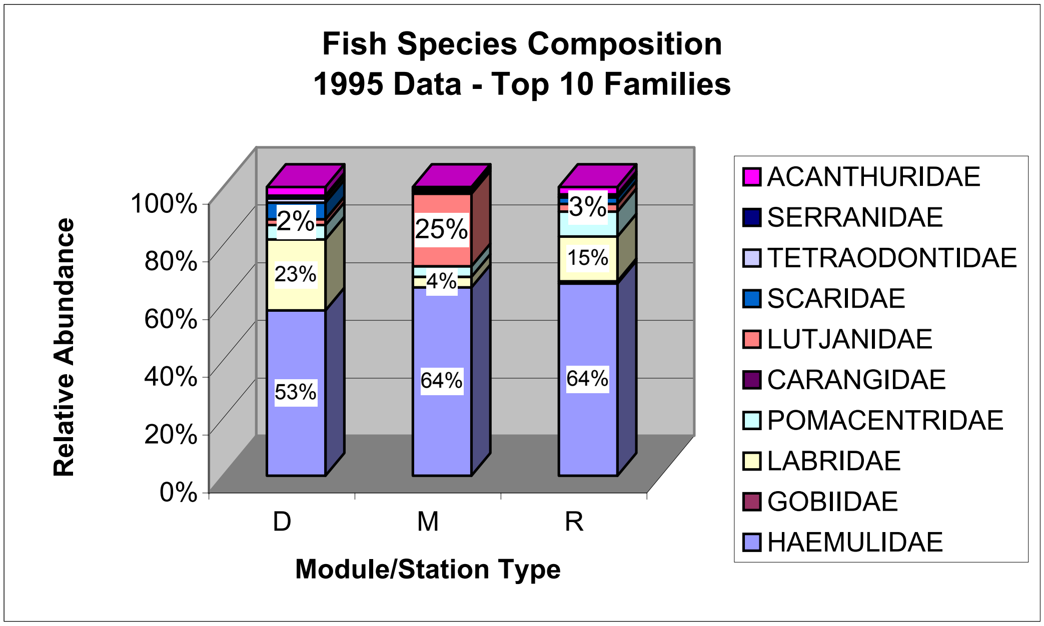


Figure 26: Relative abundance of top 10 families by module type in 1995.

Interestingly, the Lutjanidae species were not present in such numbers on either of the other modules in 1995 and did not even register in the top five species of any module type in 2003 (See Figure 27). The Labridae (wrasse) species, namely *Thallassoma bifasciatum*, represented the second major constituent on the D and R modules in 1995. In 2003, Haemulidae

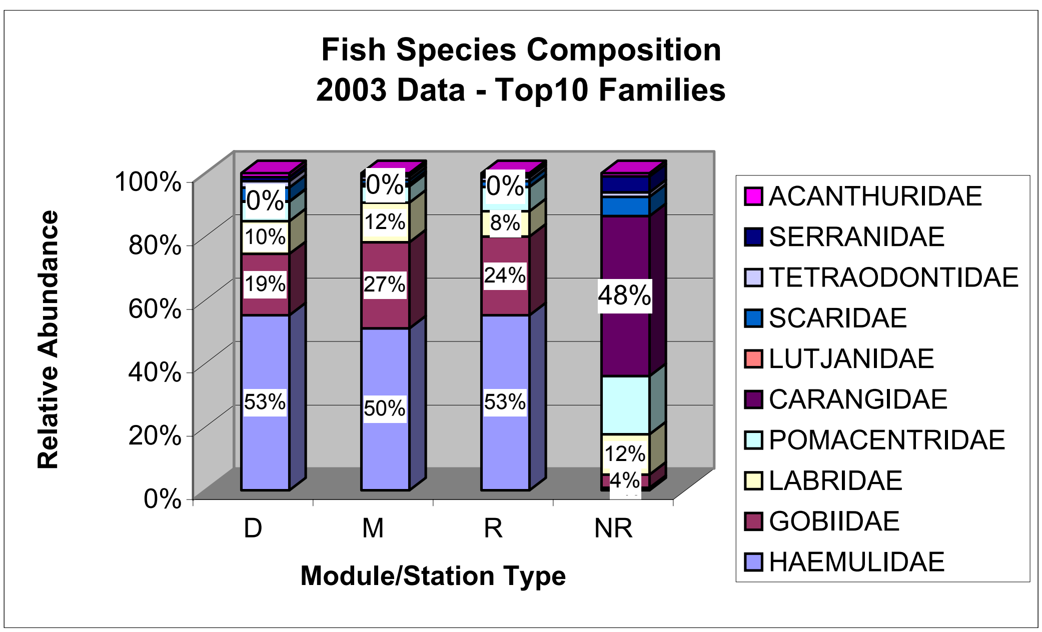


Figure 27: Relative abundance of top 10 families by module type in 2003.

species still dominated with similar percentages (although lower than 1995 on M and R modules). The most notable differences in the 2003 data included the appearance of large numbers of *Coryphopterus personatus* (masked gobies constituted 19 – 27% of the populations on all module types), and *Thallassoma bifasciatum* (bluehead wrasses comprised 8- 12% of the module populations. Figure F.6 also demonstrates that there no notable differences were seen between major population constituents of the different module types in 2003.

<u>2003 Modules vs. Natural Reef Control:</u>

As distinctly similar as the species (family) compositions of the module types are to each other, they are all as distinctly different than the Natural Reef Controls. The only major commonality is the presence of the Labridae family that makes up a similar percentage (12%) of the natural reef population. The dominant statistical component of the NR population is the Carangidae family. This is actually an artifact of a one-time observation of a very large school of pelagics that swam through the biologist's imaginary cylinder during the first minutes of the survey. If that single outlying data point was excluded, and only resident species were evaluated, the NR species composition would be 34% Pomacentridae and 25% Labridae.

Diversity:

<u>1995 vs. 2003 Comparisons:</u>

Shannon Weiner Diversity Indices (H') and Pielou's Evenness Measures (J) calculated from the 95 and 03 data show several interesting patterns. The D modules showed a slight decrease in diversity that could be attributable to a corresponding decrease in evenness from 95 to 03. The M modules showed an increase in both diversity and evenness. While the calculated diversity of the R modules in 03 was identical to that in 95, evenness measures decreased slightly. The diversity and eveness of the communities found on the modules has also increased since 1995 (Table 13).

Table 13: Diversity indices and evenness measures for 1995 and 2003 data.

Station Type	Shannon-Weiner Diversity Index (H') 1995	Shannon-Weiner Diversity Index (H') 2003	Pielou's Evenness Measure for H' (J) 1995	Pielou's Evenness Measure for H' (J) 2003
D	2.54	2.42	0.71	0.61
M	1.98	2.44	0.54	0.58
R	2.36	2.36	0.63	0.57
NR		2.01	0.53	0.50

2003 Modules vs. Modules:

As Figure 28 demonstrates, no notable differences were seen between diversity indices of the module populations in 2003.

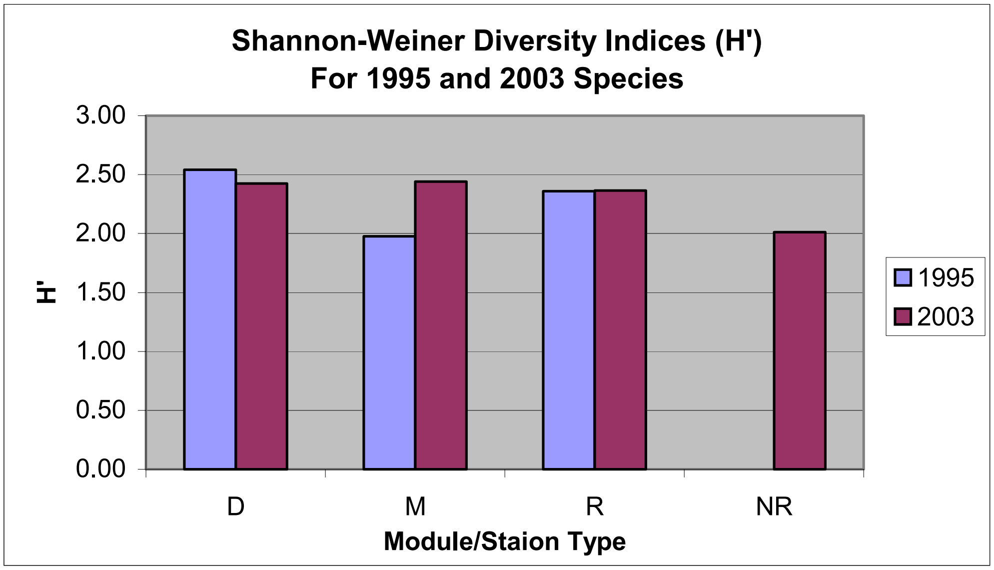


Figure 28: Shannon-Weiner diversity indices by module type and year.

2003 Modules vs. Natural Reef Control:

Although all of the stations had similar values for the Shannon-Wiener Diversity Index, the NR stations had lower diversity than the modules. The natural reef stations also had the lowest measure of evenness (J), 50% of the maximum theoretical diversity, indicating that the number of individuals was spread out less evenly between species on the natural reef than on the modules.

Similarity

Jaccard's Coefficient of Similarity

1995 vs. 2003 Comparisons:

Jaccard's Similarity Coefficient was used to test how similar the species composition on each module type in 2003 was to the same module type in 1995 (Table 14).

Table 14: Jaccard's Similarity Coefficient among each module type between 1995 and 2003.

	D vs D	*R vs. R*	*M vs M*
# spp present both studies(a)	59	73	73
# spp present 1995 only (b)	35	42	39
# spp present 2003 only (c)	52	64	66
Cummulative Number of Spp (a+b+c)	146	179	178
Jaccard's Coefficient [a/(a+b+c)]	**0.40**	**0.41**	**0.41**

2003 Modules vs. Modules:

Jaccard's Similarity Coefficient was again calculated between module/station types (Table 15). The 0.39 coefficient indicates that the similarity between the different module types in 2003 is greater than the coefficient between the module types and the natural reef stations.

Table 15: Jaccard's Coefficient of similarity between the various module types.

	D vs R		*R vs M*		*D vs M*	
	1995	*2003*	*1995*	*2003*	*1995*	*2003*
# spp present on both module types (a)	47	75	49	80	46	75
# spp present on first module type only (b)	35	52	42	64	35	52
# spp present on second module type only (c)	42	64	39	66	39	66
Cummulative Number of Spp (a+b+c)	124	191	130	210	120	193
Jaccard's Coefficient [a/(a+b+c)]	**0.38**	**0.39**	**0.38**	**0.38**	**0.38**	**0.39**

2003 Modules vs. Natural Reef Control:

Finally, Jaccard's Coefficient was calculated independently between all 2003 module types and the natural reef controls (Table 16). According to these results, the 2003 module and natural reef populations are no more similar to each other than the 2003 modules are to the same modules in 1995.

Table 16: Jaccard's Coefficient of Similarity for the 2003 modules and natural reef stations.

	D vs NR	*M vs NR*	*R vs NR*
# spp present on both modules and NR (a)	76	87	85
# spp present on mod type only (b)	52	66	64
# spp present at NR stations only (c)	54	54	54
Cummulative Number of Spp (a+b+c)	182	207	203
Jaccard's Coefficient [a/(a+b+c)]	**0.42**	**0.42**	**0.42**

Bray-Curtis Similarity Index

1995 vs. 2003 Comparisons:

Bray-Curtis Similarity Indices were calculated and plotted in a graph between the number of individuals of each species for each of the three module types and the natural reef sites. Figure 29 shows that all the comparisons were rather dissimilar, and the M modules were least similar with a coefficient of 0.85 (where 0 = identical and 1.0 = completely dissimilar).

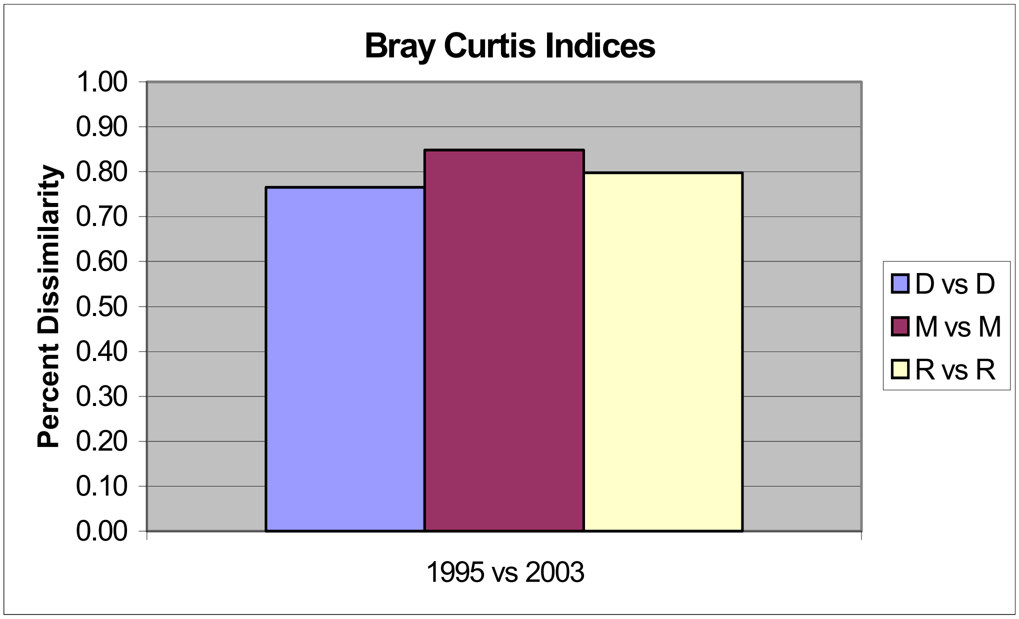


Figure 29: Bray-Curtis Similarity Indices by species between like module types; 1995 vs. 2003.

<u>2003 Modules vs. Modules:</u>

Bray-Curtis Similarity was also calculated between species from different module types in 2003. Figure 30 shows that R and M modules were most similar to each other with a coefficient of 0.32, followed by D and R modules at 0.40. D and M modules were least similar at 0.55.

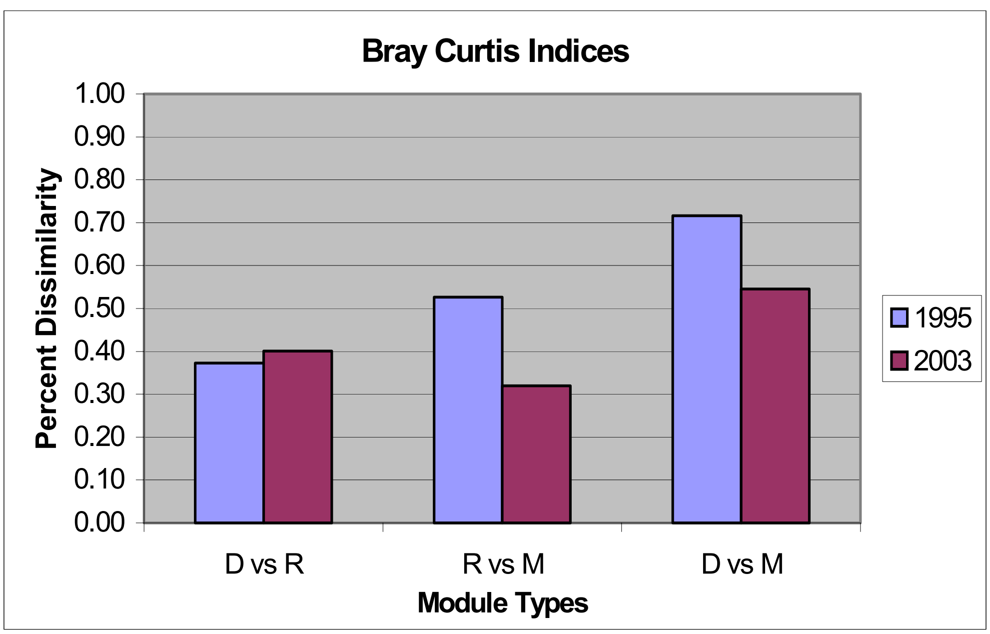


Figure 30: Bray-Curtis Similarity Indices by species between different module types; 2003.

2003 Modules vs. Natural Reef Control:

Similarities were also calculated between species found on all module types vs. the natural reef controls (see Figure 31). The coefficients were all high (low similarity). The M modules were the most dissimilar with a coefficient of 0.91.

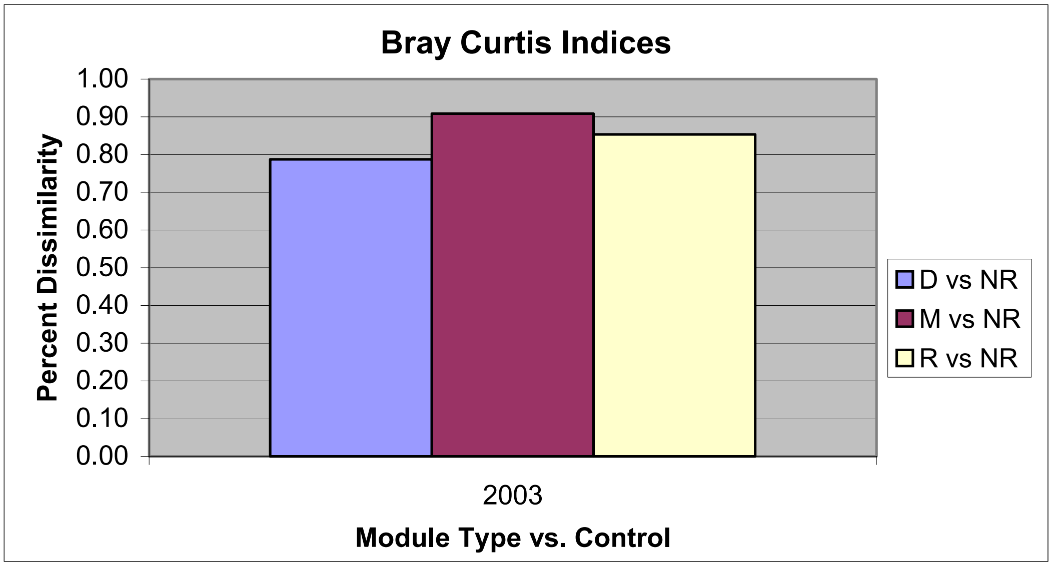


Figure 31: Bray-Curtis similarity indices by species between all module types and the natural reef control; 2003.

Using PRIMER-E ® Software, dendograms and MDS cluster plots were generated from all modules/station species data (1995 and 2003) to show the Bray-Curtis Similarities as they relate to each other. Figure 32 demonstrates that the species similarity between the natural reef stations and the modules was very low (less than 20%). Interestingly, comparison of 95 vs. 03 stations overall showed only about 20% similarity. 2003 M and R modules are most similar at almost 70%, followed by 1995 D and R modules at about 60% similarity. Findings of similar statistical analyses from the Bal Harbor Mitigation Monitoring Project indicated that 70 – 75% similarity is very high and rarely exceeded, even with intra-station comparisons.

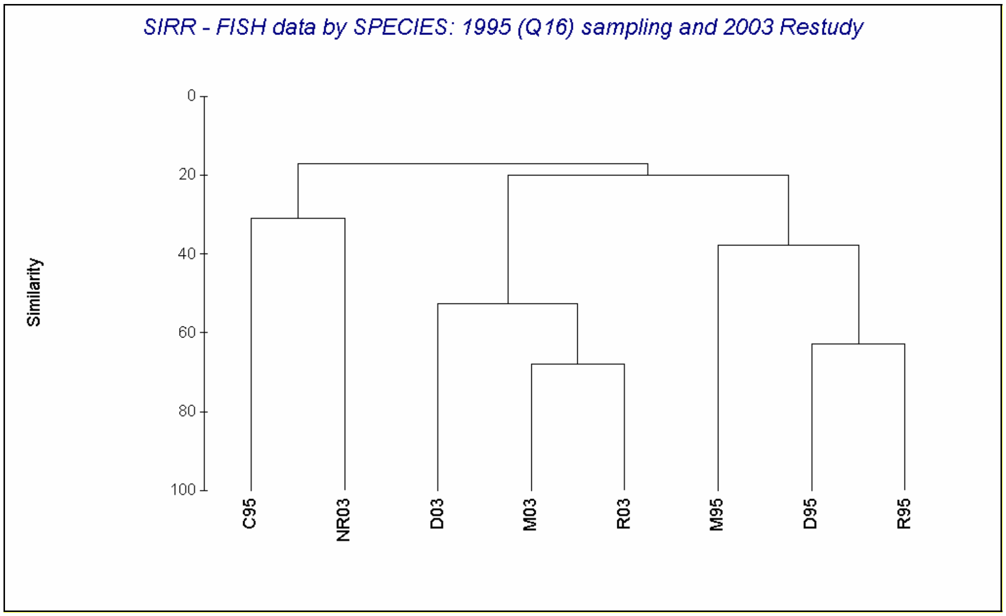


Figure 32: Bray-Curtis Similarity dendogram showing species comparisons between all module/ station types; 1995 and 2003.

In a corresponding MDS non-scalar cluster plot (Figure 33) the natural reef stations clearly separated out to the upper left of the module quadrats. D95 and R95 were relatively close, but the tightest relationship, supporting the depictions of the previous dendogram, was between R03 and M03.

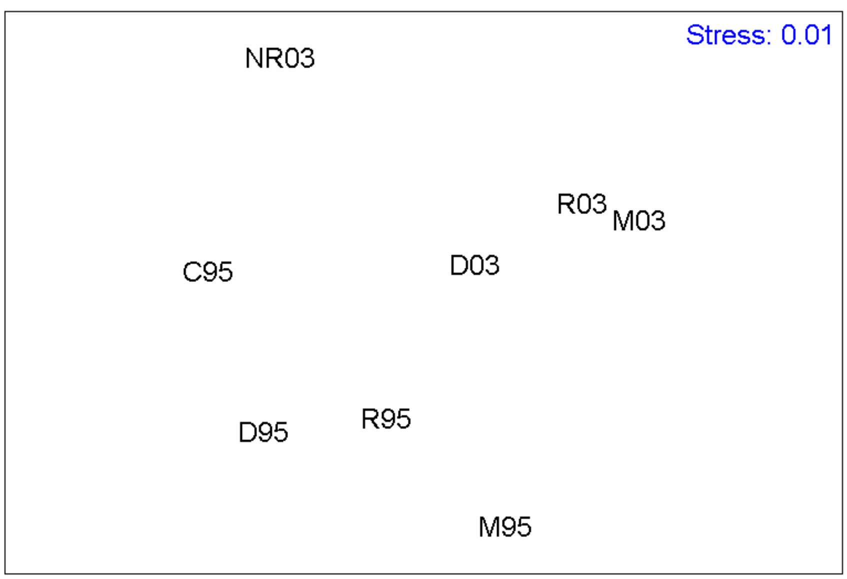


Figure 33: Bray-Curtis Similarity MDS cluster showing species comparisons between all module/ station types; 1995 and 2003.

Dendograms and MDS Cluster plots were also generated using all modules/station fish data categorized by Family (1995 and 2003) to show the relative Bray-Curtis

Similarities. Figure 34 demonstrates that the species similarity between the 2003 natural reef station and all other stations was very low (about 25%). Interestingly, comparison of 95 vs. 03 stations overall showed only about 25 – 30% similarity. 2003 M and R modules are most similar at almost 80%, followed by 1995 D and R modules at about 65% similarity. M95 and D03 are also notably similar.

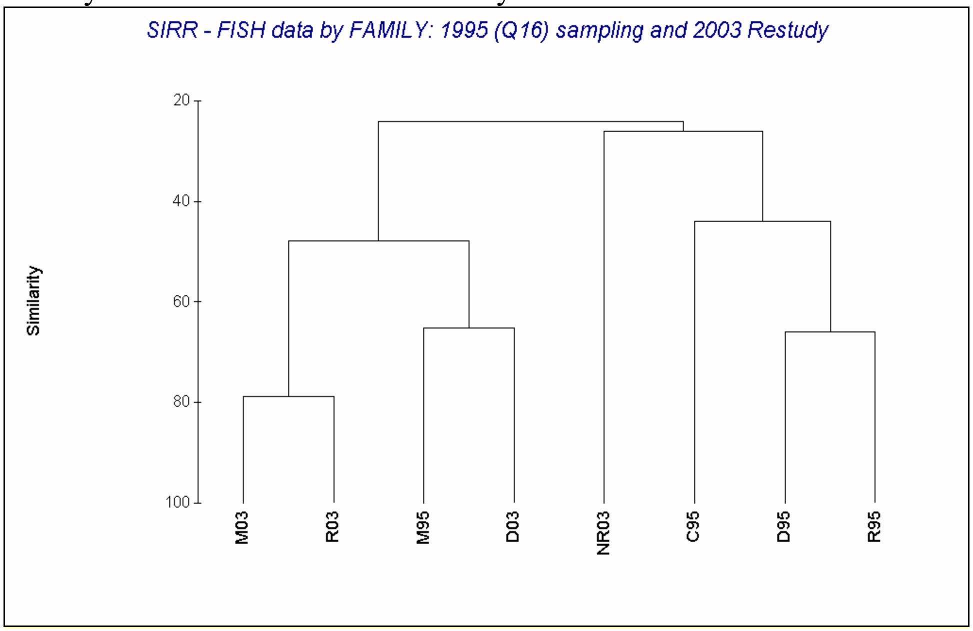


Figure 34: Bray-Curtis Similarity dendogram showing Family comparisons between all module/ station types; 1995 and 2003.

In a corresponding MDS non-scalar cluster plot (Figure 35) the natural reef stations clearly separated out to the lower right of the module quadrats. D95 and R95 were relatively close, but the tightest relationship, supporting the depictions of the previous dendogram, was between R03 and M03.

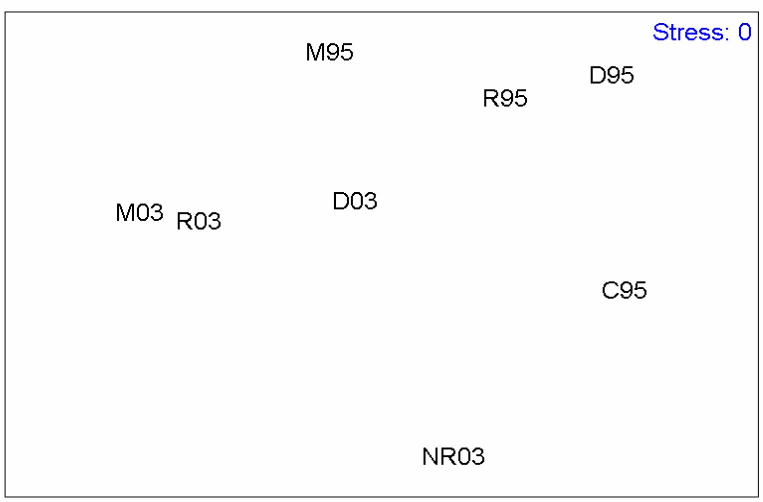


Figure 35: Bray-Curtis Similarity MDS cluster showing family comparisons between all module/ station types; 1995 and 2003.

Section Discussion:

The original goal of the SIRR project was to deploy modules that provided a basis for the biological recovery of the impacted hard bottom while minimizing the enhancement effects (over representation of a specific community component) of the modules. Unlike the results of the benthic community assessment which shows that, nearly 12 years post deployment, this goal appears to be met for each type of module, the fish populations on all the modules exhibited some "enhancement" characteristics.

The fish populations appear to be largely influenced by structure and relief. Void space and surface area are also considerable influences. The M modules, which are characterized by the greatest relief and volume of void space exhibit the strongest enhancement effects. Although the various module designs implemented in this project were creative, innovative, and attempted to minimize those influencing factors, it may not be possible to simply restore (and not enhance) the original fish populations using artificial means unless the structures physically replicate the ambient relief and structure.

CONCLUSIONS

The original goal of the SIRR project was to deploy modules that provided a basis for the biological recovery of the impacted hard bottom while minimizing the enhancement effects (over representation of a specific community component) of the modules. Nearly 12 years post deployment, this goal appears to be met from the benthic community viewpoint for each type of module. All the modules exhibited some "enhancement" characteristics based on different aspects such as a greater density of individuals or a higher relative percentage of hard coral individuals, but these characteristics were minimized. Each module type also exhibited some level of similarity to the natural reef. The goal of benthic communities found on artificial reef modules designed for mitigation or restoration purposes should be to reach a level of similarity as close as possible to that found within the surrounding natural reef habitats. The CSA2 Module design modules' large size attracted a large number of fish (unpublished data, DERM); however, their level of benthic similarity to the natural reef was lower than the other two module types. Based on the slightly more similar structure to the natural reef (lower relief) and lime rock exterior, the Dome and Reef Replacement modules would be more suitable for the mitigation of the benthic habitat.

The similarity between the modules may increase over time as the benthic and fish communities continue to develop and change. For example, if the abundance of the dominant species on the natural reef stations, *Briareum asbestinum*, increases on the modules the similarity between the modules and natural reef would most likely increase as well. Changes in the monitoring methodology such as only including exposed hard-bottom areas and eliminating the sand covered areas from natural reef stations could also influence the level of similarity. Determining if the similarity between the benthos on the modules and natural reef has leveled off or if an increased level of similarity is still attainable necessitates future research and monitoring efforts.

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APPENDICES

Appendix B.1: Photographs of the Modules Prior to Deployment

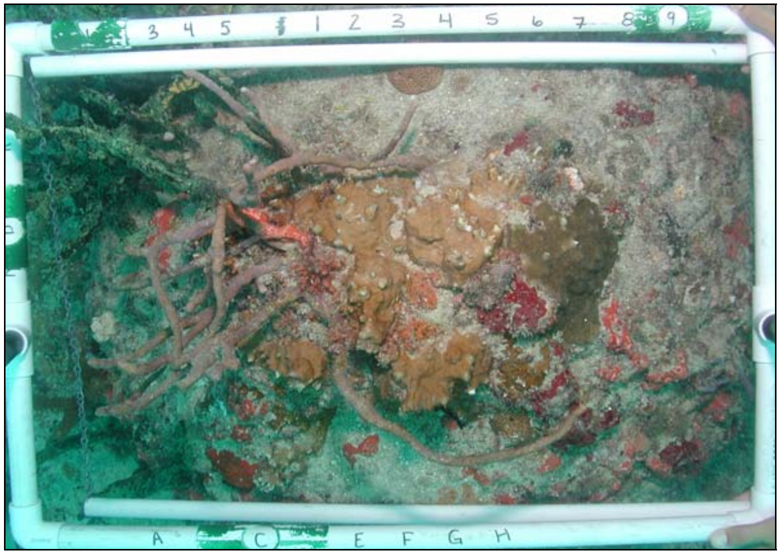
“Rough” Dome Module (D) with “Smooth” domes in the background.

Assembly of CSA2 Module Design Module (M)


Reef Replacement Modules (R) staged for transport.

Appendix B.2

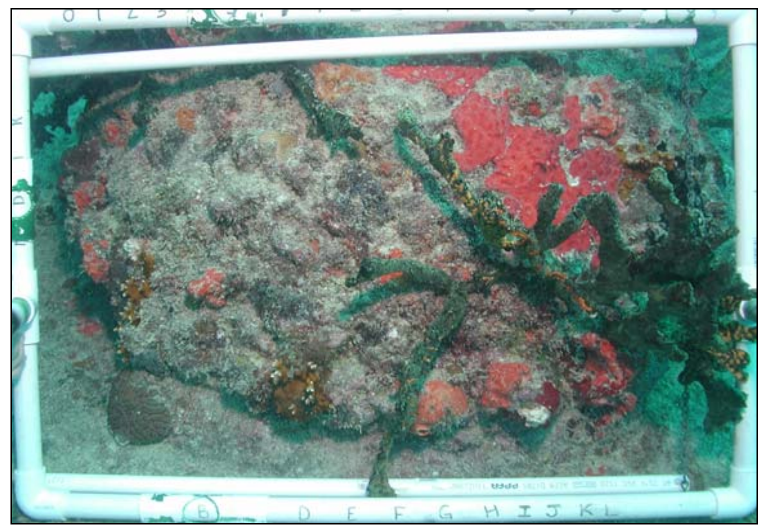
Dome Module (D) Quadrats



Top of Dome (Quadrat D19c)

Vertical, South Side of Dome (Quadrat D50a)

North Sloping Side of Dome (Quadrat D30d)

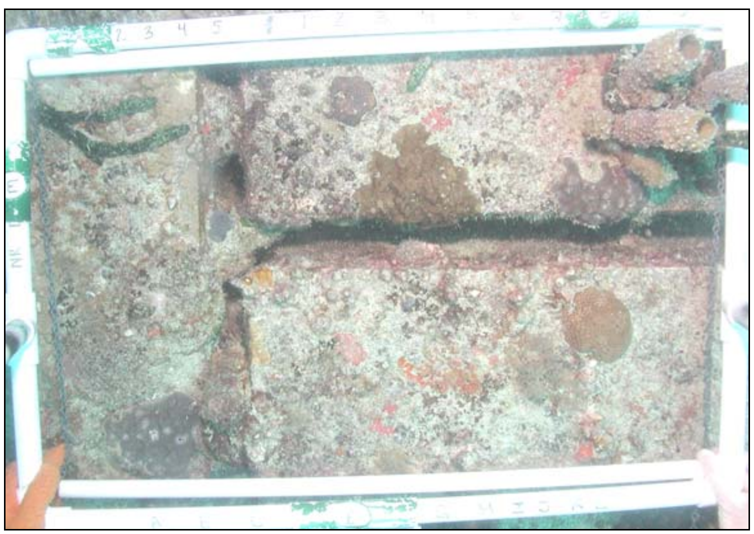


South Sloping Side of Dome (D50b)

CSA2 Module Design (M) Quadrats

Top of M Module (Quadrat M05f)

Top of M Module (Quadrat M05d)



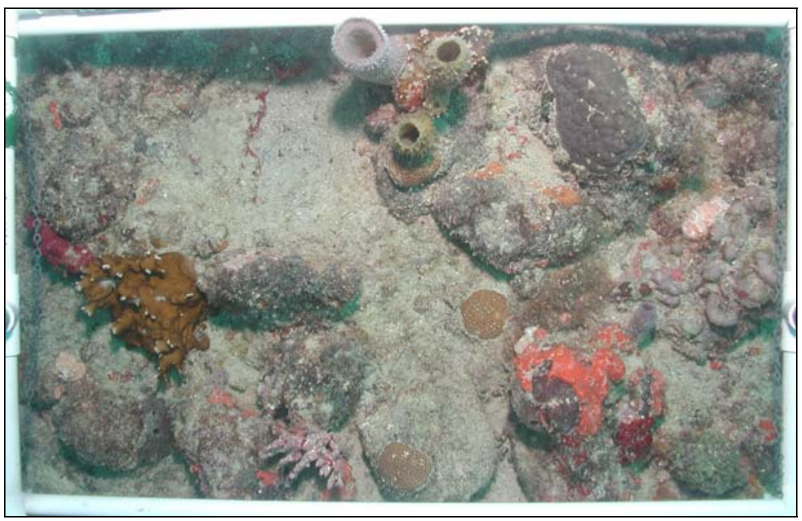
Top of M Module (Quadrat M08e)

North Side of M Module (Quadrat M07j)

Reef Replacement Module (R) Quadrats

Top of R module (Quadrat R15c)

Top of R module (Quadrat R 21b)



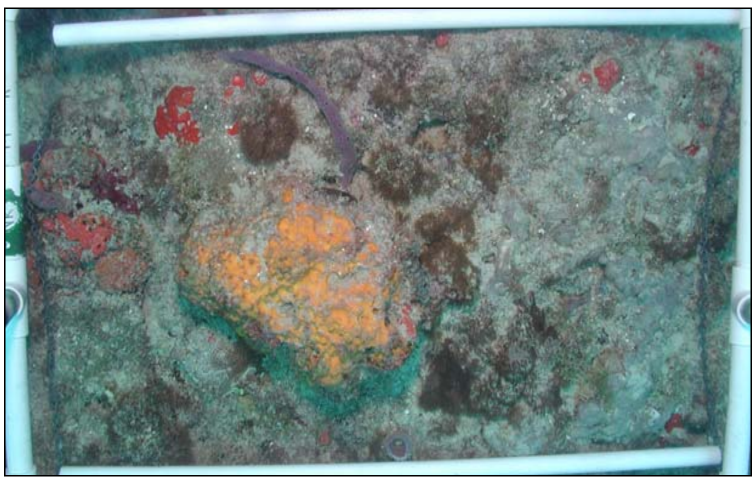
Top of R module (Quadrat R23d)

Side of R module (Quadrat R23a)

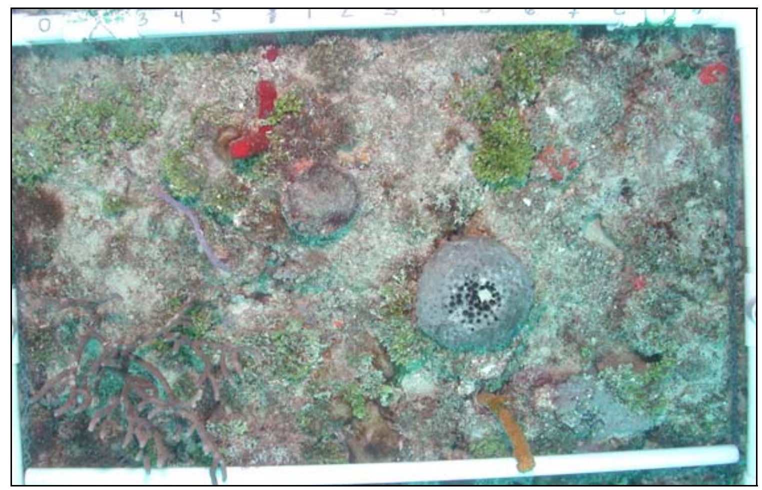
Natural Reef Station (NR) Quadrats

Natural Reef (Quadrat NR3b)

Natural Reef (Quadrat NR7a)



Natural Reef (Quadrat NR8d)



Natural Reef (Quadrat NR9d)

Appendix B.3: Number of individuals of each species recorded on the modules and natural reef stations for 1995 and 2003. A letter P represents presence without enumeration of individuals.

			D		M		R		NR	
Phylum	**Species**	**Species Code**	**1995**	**2003**	**1995**	**2003**	**1995**	**2003**	**1995**	**2003**
Phaeophyta	*Dictyota* species/ *Dictyota bartayresii*	DIC BART	40	P	20	P	1	P		P
	Martensia pavonia	MAR PAVO		P		P		P		P
Chlorophyta	Green Filamentous Algae	GFA SPEC				P		P		P
	Halimeda species	HAL SPEC				P		P		P
	Halimeda opuntia	HAL OPUN						P		P
	Udotea species	UDO SPEC								P
Rhodophyta	*Amphiroa* species	APH SPEC						P		
	Crustose Coralline Algae	CCA SPEC		P		P		P		P
	Peyssonnelia species	PEY SPEC		P		P		P		P
	Galaxaura species	GAL SPEC								P
	Red Filamentous Algae	RFA SPEC		P		P		P		P
	Wrangelia argus	WRA ARGU		P		P		P		
Cyanophyta	Blue-Green Algae	BGA SPEC				P		P		P
Porifera	**Class Demospongiae**									
	Agelas clathrodes	AGE CLAT				1		1		5
	Agelas conifera	AGE CONI								2
	Agelas species	AGE SPEC						1		
	Agelas wiedenmyeri	AGE WIED								9
	Amphemedon compressa	AMP COMP		11		2		7		42
	Amphemedon species	AMP SPEC				5		5		3
	Anthosigmella varians	ANT VARI								2
	Aplysina cauliformis	APL CAUL		21		3		15		70
	Aplysina fistularis	APL FIST				2		3		22
	Aplysina lacunosa	APL LACU		1						1
	Aplysina species	APL SPEC						2		
	Callyspongia fallax	CAL FALL	6		6		8			
	Callyspongia plicifera	CAL PLIC		2	1	1	5	6		4
	Callyspongia vaginalis	CAL VAGI	23	30	54	27	37	39		4
	Cinachyra kuekenthali	CIN KUEK				1				2
	Clathria species	CLA SPEC	1				5	1		1
	Cliona delitrix	CLI DELI	6	11		7	5	12		2
	Cliona species	CLI SPEC		41		104		48		11
	Dictyonella ruetzleri	DIC RUET	4	136	6	364	6	287		46
	Diplastrella megastellata	DIP MEGA		59		125		115		8
	Diplastrella species	DIP SPEC		87		155		97		18
	Dysidea species	DYS SPEC	28	91	26	215	33	118		40
	Ectyoplasia ferox	ECT FERO				3		2		
	Haliscara species	HAL SPEC		50		133		61		6
	Holopsammia helwigi	HOL HELW	142	2	151	26	103	5		1
	Iotrochota birotulata	IOT BIRO	8	100	49	222	26	167		30
	Ircinia campana	IRC CAMP				7		7		1
	Ircinia felix	IRC FELI		24		52		42		2
	Ircinia species	IRC SPEC		24		26		37		2

	Ircinia strobilina	IRC STRO		34		66		40		1
	Monanchora barbadensis	MON BARB		534		842		588		96
	Monanchora species	MON SPEC		2				18		53
	Monanchora unguifera	MON UNGU		20		62		51		11
	Mycale laevis	MYC LAEV		9		13		11		13
	Mycale species	MYC SPEC		2		4				
	Niphates amorpha	NIP AMOR		43		39		69		58
	Niphates digitalis	NIP DIGI	1	22	3	28	1	28		12
	Niphates erecta	NIP EREC		42		27		40		68
	Niphates species	NIP SPEC	1		9		11			2
	Oceanapia bartschi	OCE BART		2		10		4		2
	Pseudoceratina crassa	PSE CRAS		2		3		12		7
	Ptilocaulis species	PTI SPEC		6		6		9		44
	Unidentified encrusting sponge species	SPO SPEC		11		49		19		2
	Unidentified sponge species	SPO UNID	1	4	1			2		
	Strongylacidon species	STR SPEC		123		208		138		22
	Xestospongia muta	XES MUTA		1			1			20
Cnidaria	**Class Hydrozoa, Order Hydroida**									
	Thyroscyphus ramosus	THY RAMO		P		P		P		P
	Class Hydrozoa, Order Milliporina									
	Millepora alcicornis	MIL ALCI	35	11	25	12	30	24		7
	Millepora species	MIL SPEC		88		111		122		1
	Class Anthozoa, Order Actiniara									
	Bartholomea annulata	BAR ANNU		1				1		1
	Class Anthozoa, Order Zoanthidea									
	Palythoa caribaeorum	PAL CARI						1		2
	Palythoa species	PAL SPEC				4				
	Zoanthid species	ZOA SPEC				10				
	Class Anthozoa, Subclass Octocorallia									
	Briareum asbestinum	BRI ASBE		27	3	11	1	53		158
	Carijoa riisei	CAR RIIS			11	13		1		
	Eunicea calyculata	EUN CALY								4
	Eunicea palmeri	EUN PALM								24
	Eunicea species	EUN SPEC				1	2	3		10
	Eunicea succinea	EUN SUCC						4		5
	Gorgonia ventalina	GOR VENT		1						
	Muricea species	MUR SPEC								1
	Plexaura flexuosa	PLE FLEX	1							1
	Pseudopterogorgia acerosa	PSE ACER		1		2				1
	Pseudopterogorgia americana	PSE AMER						1		5
	Pseudoplexaura species	PSE PLEX	1				2	3		4
	Class Anthozoa, Subclass Hexacorallia, Order Scleractinia									
	Agaricia fragilis	AGA FRAG		2		2		8		
	Agaricia species	AGA SPEC		7	1	6		10		1
	Colpophyllia natans	COL NATA						2		
	Dichocoenia species	DIC SPEC						1		
	Dichocoenia stokesii	DIC STOK	1	1		1	1	2		3
	Diploria clivosa	DIP CLIV						2		
	Diploria labyrinthiformis	DIP LABR		4		6		5		
	Diploria strigosa	DIP STRI		3		1				

	Diploria species	DPL SPEC	1	3		3		1		
	Eusmilia fastigiata	EUS FAST		1		4		3		
	Eusmilia species	EUS SPEC						1		
	Hard Coral Species (Unidentified)	HCO UNID	1					2		
	Madracis decactis	MAD DECA		11		69		33		
	Meandrina meandrites	MEA MEAN	3	3		9	1	5		
	Montastrea annularis	MON ANNU	1	1	1	2		5		
	Montastrea cavernosa	MON CAVE		1		9		6		1
	Oculina species	OCU SPEC				1		1		
	Phyllangia americana	PHY AMER				4				
	Porites astreoides	POR ASTR		15		27		34		2
	Porites porites	POR PORI		6				2		
	Porites species	POR SPEC	3	4	1	4	4	14		
	Scolymia species	SCO SPEC		1		1		2		1
	Siderastrea radians	SID RADI		9		5		17		1
	Siderastrea siderea	SID SIDE	11	39		39		60		7
	Siderastrea species	SID SPEC	4	15		5		31		6
	Solenastrea bournoni	SOL BOUR				1				1
	Solenastrea species	SOL SPEC						1		
	Stephanocoenia michelini	STE MICH	5	28		15	2	29		12
Anneida	**Class Polychaeta**									
	Melanostigmata nigromaculata	MEL NIGR					3			
	Pomatostegus stellatus	POM STEL		1				5		
	Sabellidae species	SAB SPEC		9		19		33		11
	Spirobranchus giganteus	SPI GIGA						13		
Arthropoda	**Class Crustacea, Order Decapoda**									
	Stenopus hispidus	STE HISP		1		4				2
	Stenorhynchus seticornis	STE SETI		1		4				
Ectoprocta	*Canda simplex*	CAN SIMP		1				4		1
(Bryozoans)	*Hippopodina feegeensis*	HIP FEEG		17		18		31		3
	Trematooecia aviculifera	TRE AVIC		1		5	1			
	Watersiporia species	WAT SPEC	1		4					
Mollusca	**Class Bivalvia**									
	Bivalve species	BIV SPEC		16		10		7		
	Lima lima	LIM LIMA					15			1
	Lima scabra	LIM SCAB						1		
	Lima species	LIM SPEC		1		4		6		
	Spondylus americanus	SPON AMER		8		67	4	21		
Echinodermata	**Class Echinoidea**									
	Diadema antillarum	DIA ANTI				1				
	Eucidaris tribuloides	EUC TRIB						6		
Chordata	**Class Ascidiacea**									
	Didemnum species	DID SPEC		P		P		P		P
	Ascidia nigra	ASC NIGR		1				1		1
	Botrylloides species	BOT SPEC		P		P		P		
	Clavelina species	CLV SPEC		P		P		P		P
	Eudistoma species	EUD SPEC				P				
	Polycarpa spongiabilis	POL SPON		2		10		15		2
	Stolonicus sabulosa	STO SABU	5	P		P	1	P		P
	Tunicate (unidentified)	TUN SPEC		P		P		P		P

Appendix B.4: Raw Benthic Data

Species Code	D18	D19	D21	D22	D25	D30	D34	D43	D50
AGA FRAG									2
AGA SPEC	1		1						5
AGE CLAT									
AGE CONI									
AGE SPEC									
AGE WIED									
AMP COMP	5		1	1	1		3		
AMP SPEC									
ANT VARI									
APH SPEC									
APL CAUL	6	5	5			1		4	
APL FIST									
APL LAUC				1					
APL SPEC									
ASC NIGR		1							
BAR ANNU				1					
BGA SPEC									
BIV SPEC				6	10				
BOT SPEC			P						P
BRI ASBE	3	4	1	2	2		8		7
CAL PLIC						1		1	
CAL VAGI	3		8	4	3	3	3	5	1
CAN SIMP			1						
CAR RIIS									
CCA SPEC	P	P	P	P	P	P	P	P	P
CIN KUEK									
CLA SPEC									
CLI DELI				1	1	1	3	3	2
CLI SPEC		6	8	8	3	6	4	2	4
CLV SPEC	P		P						
COL NATA									
DIA ANTI									
DIC BART	P	P	P	P	P	P	P	P	P
DIC RUET	7	16	14	27	6	18	18	20	10
DIC SPEC									
DIC STOK					1				
DID SPEC									P
DIP CLIV									
DIP LABR			1			1		1	1
DIP MEGA	8	20	9	3		6	3	9	1
DIP SPEC	10	7	2	9	21	12	6	9	11
DIP STRI		1	1		1				
DPL SPEC				2			1		
DYS SPEC	18	9	4	12	20	5	9	11	3
ECT FERO									
EUC TRIB									
EUD SPEC									

Species Code	D18	D19	D21	D22	D25	D30	D34	D43	D50
EUN CALY									
EUN PALM									
EUN SPEC									
EUN SUCC									
EUS FAST				1					
EUS SPEC									
GAL SPEC									
GFA SPEC									
GOR VENT	1								
HAL MEDA									
HAL OPUN									
HAL SPEC	6	2	8	7	10	7	5	2	3
HCO SPEC									
HIP FEEG	1	2	1			1	6	1	5
HOL HELW					1				1
IOT BIRO	10	11	14	12	8	11	12	9	13
IRC CAMP									
IRC FELI	3		2		3	4	1	6	5
IRC SPEC	2	5	7	3	2				5
IRC STRO	3	3	5	4		4	6	7	2
LIM SCAB									
LIM SPEC									1
MAD DECA	1	1	1	4	1	1		1	1
MAR PAVO				P	P	P	P	P	P
MEA MEAN	1			1				1	
MIL ALCI	1	2	6	1					1
MIL SPEC	6	11	3	7	12	6	10	21	12
MON ANNU					1				
MON BARB	68	55	66	63	70	22	54	80	56
MON CAVE			1						
MON SPEC			1		1				
MON UNGU	5		3	6		3	1	2	
MUR SPEC									
MYC LAEV	2	1			1	2			3
MYC SPEC	1					1			
NIP AMOR	5	5	3	8	6	4	2	5	5
NIP DIGI	1	2	3	2	2		2	8	2
NIP EREC	11	9		4	4	1	1	3	9
NIP SPEC									
OCE BART							2		
OCU SPEC									
PAL CARI									
PAL SPEC									
PEY SPEC	P	P	P	P	P	P	P	P	P
PHY AMER									
PLE FLEX									
POL SPON		1				1			
POM STEL			1						
POR ASTR		1	1	4	3	1	2	1	2

Species Code	D18	D19	D21	D22	D25	D30	D34	D43	D50
POR PORI					6				
POR SPEC	2		1		1				
PSE ACER	1								
PSE AMER									
PSE CRAS			1		1				
PSE PLEX									
PTI SPEC		3	1				1		1
RFA SPEC						P	P		P
SAB SPEC	3	1	2	1			2		
SCO SPEC							1		
SID RADI	2		1	1	3				2
SID SIDE	2	5	4	8	2	7	5	2	4
SID SPEC				1	1	2	5		6
SOL BOUR									
SOL SPEC									
SPI GIGA									
SPO AMER			1	1	2	3		1	
SPO SPEC					1		6	1	3
SPO UNID	3					1			
STE HISP							1		
STE MICH	7	1	1	5	3	1	6		4
STE SETI									1
STO SABU	P	P	P	P	P	P	P	P	P
STR SPEC	10	13	15	14	18	12	10	22	9
THY RAMO					P				
TRE AVIC							1		
TUN SPEC						P			P
UDO SPEC									
WRA ARGU					P				
XES MUTA			1						
ZOA SPEC									
Number of Individuals*:	219	203	210	235	232	149	200	238	203
Number of Species:	43	36	49	43	46	41	42	36	48
Individuals per m^2:	115.3	106.8	110.5	123.7	122.1	78.4	105.3	125.3	106.8

Species Code	M01	M02	M03	M04	M05	M07	M08	M09	M10
AGA FRAG					2				
AGA SPEC							5		1
AGE CLAT		1							
AGE CONI									
AGE SPEC									
AGE WIED									
AMP COMP				2					
AMP SPEC					2			1	2
ANT VARI									
APH SPEC									
APL CAUL			1			1	1		
APL FIST					1	1			
APL LAUC									
APL SPEC									
ASC NIGR									
BAR ANNU									
BGA SPEC		P				P			P
BIV SPEC	2	2	2		1		2	1	
BOT SPEC	P		P	P	P	P		P	P
BRI ASBE			8	1	2				
CAL PLIC					1				
CAL VAGI	1	3	2	2	4	4	5	5	1
CAN SIMP									
CAR RIIS	8	4		1					
CCA SPEC	P	P	P	P	P	P	P	P	P
CIN KUEK	1								
CLA SPEC									
CLI DELI					1	5			1
CLI SPEC	12	11	5	10	19	13	8	16	10
CLV SPEC	P	P	P		P				
COL NATA									
DIA ANTI									1
DIC BART	P	P	P	P	P	P	P	P	P
DIC RUET	56	49	48	71	25	30	3	47	35
DIC SPEC									
DIC STOK	1								
DID SPEC	P			P				P	
DIP CLIV									
DIP LABR			1		2	1	2		
DIP MEGA	19	15	17	17	4	17	10	17	9
DIP SPEC	21	17	12	16	37	10	4	28	10
DIP STRI							1		
DPL SPEC		2				1			
DYS SPEC	15	58	33	24	12	27	14	24	8
ECT FERO					3				
EUC TRIB									
EUD SPEC				P					

Species Code	M01	M02	M03	M04	M05	M07	M08	M09	M10
EUN CALY									
EUN PALM									
EUN SPEC								1	
EUN SUCC									
EUS FAST	2		2						
EUS SPEC									
GAL SPEC									
GFA SPEC		P	P	P	P			P	
GOR VENT									
HAL MEDA	P		P				P		
HAL OPUN									
HAL SPEC	26	5	20	9	15	6	26	24	2
HCO SPEC									
HIP FEEG	1		5	3	1	6		1	1
HOL HELW		16	6		1	1		1	1
IOT BIRO	17	20	22	20	23	29	55	21	15
IRC CAMP	1	2						2	2
IRC FELI	10	3	6	2	5	8	4	7	7
IRC SPEC	2	3	3		5	2	2	9	
IRC STRO	2	1	7	10	11	6	8	7	14
LIM SCAB									
LIM SPEC	2		1				1		
MAD DECA	10	5	2	7	10	4	14	10	7
MAR SPEC		P	P	P	P	P	P	P	P
MEA MEAN	1		3			1	1	1	2
MIL ALCI	6	1	2	1				2	
MIL SPEC	9	22	15	2	7	18	21	6	11
MON ANNU	1						1		
MON BARB	96	125	64	79	110	91	79	102	96
MON CAVE	1		3		3	1			1
MON SPEC									
MON UNGU	6	7	4	8	5	6	9	11	6
MUR SPEC									
MYC LAEV		4	3	1		2		2	1
MYC SPEC			1	1	1		1		
NIP AMOR	8	4	2		8	4	3	6	4
NIP DIGI	1	6	2	1	7	4	4	3	
NIP EREC	1	8		1	6	3	4	4	
NIP SPEC									
OCE BART		4	2	1		1	1	1	
OCU SPEC									1
PAL CARI									
PAL SPEC	1			1				2	
PEY SPEC	P	P	P	P	P	P	P	P	P
PHY AMER			1				3		
PLE FLEX									
POL SPON	1	1		1	2	1	1	1	2
POM STEL									
POR ASTR	1	2	2	3	4	2	9	3	1

Species Code	M01	M02	M03	M04	M05	M07	M08	M09	M10
POR PORI									
POR SPEC			1		1		1	1	
PSE ACER	1							1	
PSE AMER									
PSE CRAS	1		2						
PSE PLEX									
PTI SPEC			1	1	2	1	1		
RFA SPEC			P		P	P			P
SAB SPEC	1	2	2	5	3	3	2	1	
SCO SPEC	1								
SID RADI	1	3			1				
SID SIDE	4	1	1	2	4	4	7	5	11
SID SPEC	1			4					
SOL BOUR							1		
SOL SPEC									
SPI GIGA									
SPO AMER	5	6	6	13	8	2	9	13	5
SPO SPEC	1	5	9	9	5	2	5	9	4
SPO UNID									
STE HISP			1			1	2		
STE MICH	1	1	5	3	2		1		2
STE SETI						2	2		
STO SABU	P	P	P	P	P	P	P	P	P
STR SPEC	20	27	16	21	27	37	16	29	15
THY RAMO				P		P		P	
TRE AVIC				3	2				
TUN SPEC		P		P				P	P
UDO SPEC									
WRA ARGU	P					P			
XES MUTA									
ZOA SPEC				10					
Number of Individuals*:	379	446	351	366	395	358	349	425	289
Number of Species:	56	48	56	51	55	52	51	51	45
Individuals per m^2:	99.7	117.4	92.4	96.3	103.9	94.2	91.8	111.8	76.1

Species Code	R02	R04	R07	R14	R15	R16	R21	R22	R23
AGA FRAG	2		1	1		1	3		
AGA SPEC	1		4				1	3	1
AGE CLAT	1								
AGE CONI									
AGE SPEC			1						
AGE WIED									
AMP COMP	2	1	1	2				1	
AMP SPEC							2	3	
ANT VARI									
APH SPEC					P				
APL CAUL			4	2	2	2	4	1	
APL FIST						3			
APL LAUC									
APL SPEC			1				1		
ASC NIGR			1						
BAR ANNU	1								
BGA SPEC									P
BIV SPEC				3	2			2	
BOT SPEC	P	P	P	P	P				P
BRI ASBE			2	21	5	10	8		7
CAL PLIC				2	3	1			
CAL VAGI	1	8	5	2	1	4	11	4	3
CAN SIMP			1			2		1	
CAR RIIS			1						
CCA SPEC	P	P	P	P	P	P	P	P	P
CIN KUEK									
CLA SPEC					1				
CLI DELI	1		1		1	3	1	2	3
CLI SPEC	3	4	6	3	8	1	10	7	6
CLV SPEC	P	P	P		P				
COL NATA	1				1				
DIA ANTI									
DIC BART	P	P	P	P	P	P	P	P	P
DIC RUET	29	55	21	20	39	38	23	42	20
DIC SPEC					1				
DIC STOK			1	1					
DID SPEC							P	P	
DIP CLIV								2	
DIP LABR		1		2	1	1			
DIP MEGA	22	26	6	17	16	14	2	7	5
DIP SPEC	13	24	11	8	5	6	6	15	9
DIP STRI									
DPL SPEC						1			
DYS SPEC	16	20	21	4	17	10	2	10	18
ECT FERO			1		1				
EUC TRIB	1			3	2				
EUD SPEC									

Species Code	R02	R04	R07	R14	R15	R16	R21	R22	R23
EUN CALY									
EUN PALM									
EUN SPEC	1		1						1
EUN SUCC									4
EUS FAST			1			2			
EUS SPEC	1								
GAL SPEC									
GFA SPEC	P			P	P		P		
GOR VENT									
HAL MEDA	P						1		
HAL OPUN							P		
HAL SPEC	14	11	5	8	5	7	2	9	
HCO SPEC									2
HIP FEEG	3	2	2	3	2	9	4	4	2
HOL HELW							4	1	
IOT BIRO	14	19	10	24	15	21	44	5	15
IRC CAMP		1		3	1	1			1
IRC FELI	3	9	3	6	6	6	4	1	4
IRC SPEC	3	7	7	5	1	2	6	5	1
IRC STRO	4	4	3	1	5	3	10	3	7
LIM SCAB	1								
LIM SPEC			3	2	1				
MAD DECA	5		4	3	4	8	5		4
MAR SPEC			P		P	P	P	P	P
MEA MEAN				1		3			1
MIL ALCI	2	3	6	6	3		2	1	1
MIL SPEC	8	16	6	16	14	17	17	12	16
MON ANNU	1						1	2	1
MON BARB	34	95	52	64	77	86	50	75	55
MON CAVE	2	1		1	1			1	
MON SPEC	3			2		11	2		
MON UNGU	7	4	4	2	9	2	11	6	6
MUR SPEC									
MYC LAEV	2	1		1	1	2	1		3
MYC SPEC									
NIP AMOR	4	7	11	11	4	11	14	2	5
NIP DIGI	1	2	2	4	8	3	2	3	3
NIP EREC	5	6	7	1	1	7	11		2
NIP SPEC									
OCE BART				2	1		1		
OCU SPEC									1
PAL CARI	1								
PAL SPEC									
PEY SPEC	P	P	P	P	P	P	P	P	P
PHY AMER									
PLE FLEX									
POL SPON	4	2	1	4		1	2		1
POM STEL			2		2			1	
POR ASTR	1	1	3	4	9	3	5	2	6

Species Code	R02	R04	R07	R14	R15	R16	R21	R22	R23
POR PORI				1	1				
POR SPEC	1	1	1	2		1	2	2	4
PSE ACER									
PSE AMER	1								
PSE CRAS		1	2	1	1	4	3		
PSE PLEX	1					2			
PTI SPEC		3	1	1	4				
RFA SPEC			P				P	P	
SAB SPEC	6		7	4	8	1	2	5	
SCO SPEC			1					1	
SID RADI		2	2	4	1	3	3		2
SID SIDE	5	4	2	3	7	4	5	8	22
SID SPEC	10	3	3	4		9	1		1
SOL BOUR									
SOL SPEC							1		
SPI GIGA					3	6		2	2
SPO AMER		1	4		6	3	3	3	1
SPO SPEC		2		1	5	6	2	3	
SPO UNID			1						1
STE HISP									
STE MICH	5	4	7	6	1	2			4
STE SETI									
STO SABU	P	P	P	P	P	P	P	P	P
STR SPEC	8	18	17	18	13	11	11	25	17
THY RAMO						P			
TRE AVIC									
TUN SPEC		P			P		P	P	P
UDO SPEC									
WRA ARGU								P	
XES MUTA									
ZOA SPEC									
Number of Individuals*:	255	369	271	310	326	354	306	282	268
Number of Species:	57	46	62	58	62	56	58	51	52
Individuals per m^2:	95.9	138.7	101.9	116.5	122.6	133.1	115.0	106.0	100.8

Species Code	NR1	NR2	NR3	NR4	NR5	NR6	NR7	NR8	NR9
AGA FRAG									
AGA SPEC					1				
AGE CLAT			1		2		1	1	
AGE CONI				1	1				
AGE SPEC									
AGE WIED	1	1	4		1			1	1
AMP COMP	10	5	5	4	2	1	2	3	10
AMP SPEC				2				1	
ANT VARI		2							
APH SPEC									
APL CAUL	23	6	10	10	4	7	3		7
APL FIST	3	2	4	8	2				3
APL LAUC			1						
APL SPEC									
ASC NIGR	1								
BAR ANNU					1				
BGA SPEC								P	P
BIV SPEC									
BOT SPEC									
BRI ASBE	14	21	7	4	9	12	39	35	17
CAL PLIC			2			1		1	
CAL VAGI	1	2							1
CAN SIMP							1		
CAR RIIS									
CCA SPEC	P	P	P	P	P	P	P	P	P
CIN KUEK			1			1		1	1
CLA SPEC							1		
CLI DELI				1	1				
CLI SPEC		2	1			4	1	3	
CLV SPEC					P				
COL NATA									
DIA ANTI									
DIC BART	P	P	P	P	P	P	P	P	P
DIC RUET	5	2	4	8	10	2	4	6	5
DIC SPEC									
DIC STOK	2								1
DID SPEC							P		
DIP CLIV									
DIP LABR									
DIP MEGA	2	3	2			1			
DIP SPEC	5		3		4		1	2	3
DIP STRI									
DPL SPEC									
DYS SPEC	12		2	9	2	1	3	8	3
ECT FERO									
EUC TRIB									
EUD SPEC									

Species Code	NR1	NR2	NR3	NR4	NR5	NR6	NR7	NR8	NR9
EUN CALY		2	1						1
EUN PALM	6	6	1	1					10
EUN SPEC	3	2		5					
EUN SUCC		4	1						
EUS FAST									
EUS SPEC									
GAL SPEC							P		
GFA SPEC	P						P	P	P
GOR VENT									
HAL MEDA		P	P	P	P	P		P	P
HAL OPUN			1				P	P	P
HAL SPEC	2		1	2					1
HCO SPEC									
HIP FEEG			1	1	1				
HOL HELW							1		
IOT BIRO	4	4	2		4	2	6		8
IRC CAMP						1			
IRC FELI			1					1	
IRC SPEC			1		1				
IRC STRO						1			
LIM SCAB									
LIM SPEC				1					
MAD DECA									
MAR SPEC			P	P	P		P		P
MEA MEAN									
MIL ALCI			1	1	2			1	2
MIL SPEC	1								
MON ANNU									
MON BARB	14	9	2	14	9	6	18	15	9
MON CAVE			1						
MON SPEC	2	8	10	6	4	7	5	7	4
MON UNGU	1		3	1	2		1	2	1
MUR SPEC	1								
MYC LAEV	3	3			1		1		5
MYC SPEC									
NIP AMOR	10	6	12	9	2	1	8	6	4
NIP DIGI	1			2	2	1	3	2	1
NIP EREC	12	6	12	9	4	8	4	8	5
NIP SPEC				1					1
OCE BART			1				1		
OCU SPEC									
PAL CARI						1		1	
PAL SPEC									
PEY SPEC	P		P		P		P	P	
PHY AMER									
PLE FLEX									1
POL SPON			1	1					
POM STEL									
POR ASTR					1		1		

Species Code	NR1	NR2	NR3	NR4	NR5	NR6	NR7	NR8	NR9
POR PORI									
POR SPEC									
PSE ACER							1		
PSE AMER	1					2		1	1
PSE CRAS	3	3						1	
PSE PLEX	1	1	1					1	
PTI SPEC	5	3	2	6	6	6	5	3	8
RFA SPEC				P			P		
SAB SPEC			3	1	2	2	2		1
SCO SPEC		1							
SID RADI			1						
SID SIDE	1		1			1		3	1
SID SPEC	1	2	1			1		1	
SOL BOUR			1						
SOL SPEC									
SPI GIGA									
SPO AMER									
SPO SPEC	1			1					
SPO UNID									
STE HISP					2				
STE MICH	3	1	2	1	2		2	1	
STE SETI									
STO SABU	P	P	P	P	P	P	P	P	P
STR SPEC	8	2	5	2			2	2	1
THY RAMO									P
TRE AVIC									
TUN SPEC		P				P		P	
UDO SPEC	P		P	P	P		P	P	P
WRA ARGU									
XES MUTA	7	2		1	2			3	5
ZOA SPEC									
Number of Individuals*:	170	111	117	113	87	70	117	121	122
Number of Species:	44	36	51	39	41	31	40	42	44
Individuals per m^2:	111.8	73.0	77.0	74.3	57.2	46.1	77.0	79.6	80.3

APPENDIX F.1
SIRR - FISH data: 1995 (Q16) sampling and 2003 Restudy

SPECIES CODE	*SCIENTIFIC NAME*	COMMON NAME	FAMILY NAME	COMMON FAMILY NAME
ABU SAXA	*Abudefduf saxatilis*	Sergeant major	POMACENTRIDAE	Damselfishes
ACA BAHI	*Acanthurus bahianus*	Ocean surgeon	ACANTHURIDAE	Surgeonfishes
ACA CHIR	*Acanthurus chirurgus*	Doctorfish	ACANTHURIDAE	Surgeonfishes
ACA COER	*Acanthurus coeruleus*	Blue tang	ACANTHURIDAE	Surgeonfishes
AET NARI	*Aetobatus narinari*	Spotted eagle ray	MYLIOBATIDAE	Eagle rays
AMB PINO	*Amblycirrhitus pinos*	Redspotted hawkfish	CIRRHITIDAE	Hawkfishes
ANI SURI	*Anisotremus surinamensis*	Black margate	HAEMULIDAE	Grunts
ANI VIRG	*Anisotremus virginicus*	Porkfish	HAEMULIDAE	Grunts
APO BINO	*Apogon binotatus*	Barred cardinalfish	APOGONIDAE	Cardinalfishes
APO MACU	*Apogon maculatus*	Flamefish	APOGONIDAE	Cardinalfishes
APO PSEU	*Apogon pseudomaculatus*	Twospot cardinalfish	APOGONIDAE	Cardinalfishes
APO SPE.	*Apogon sp.*	Unidentified cardialfish	APOGONIDAE	Cardinalfishes
APO TOWN	*Apogonidae townsendi*	Belted cardinalfish	APOGONIDAE	Cardinalfishes
AUL MACU	*Aulostomus maculatus*	Trumpetfish	AULOSTOMIDAE	Trumpetfishes
BOD PULC	*Bodianus pulchellus*	Spotfin hogfish	LABRIDAE	Wrasses
BOD RUFU	*Bodianus rufus*	Spanish hogfish	LABRIDAE	Wrasses
CAN MACR	*Cantherhines macrocerus*	Whitespotted filefish	BALISTIDAE	Leatherjackets
CAN PULL	*Cantherhines pullus*	Orangespotted filefish	BALISTIDAE	Leatherjackets
CAN ROST	*Canthigaster rostrata*	Sharpnose puffer	TETRAODONTIDAE	Puffers
CAR CRYS	*Caranx crysos*	Blue runner	CARANGIDAE	Jacks
CAR RUBE	*Caranx ruber*	Bar jack	CARANGIDAE	Jacks
CHA CAPI	*Chaetodon capistratus*	Foureye butterflyfish	CHAETODONTIDAE	Butterflyfishes
CHA FABE	*Chaetodiperus faber*	Atlantic spadefish	EPHIPPIDAE	Spadefishes
CHA OCEL	*Chaetodon ocellatus*	Spotfin butterflyfish	CHAETODONTIDAE	Butterflyfishes
CHA SEDE	*Chaetodon sedentarius*	Reef butterflyfish	CHAETODONTIDAE	Butterflyfishes
CHR SCOT	*Chromis scotti*	Purple reeffish	POMACENTRIDAE	Damselfishes
CHR CYAN	*Chromis cyaneus*	Blue chromis	POMACENTRIDAE	Damselfishes
CHR ENCH	*Chromis enchrysurus*	Yellowtail reeffish	POMACENTRIDAE	Damselfishes
CHR INSO	*Chromis insolatus*	Sunshinefish	POMACENTRIDAE	Damselfishes
CHR MULT	*Chromis multilineatus*	Brown chromis	POMACENTRIDAE	Damselfishes
CLE PARR	*Clepticus parrai*	Creole wrasse	LABRIDAE	Wrasses
COR GLAU	*Coryphopterus glaucofraenum*	Bridled goby	GOBIIDAE	Gobies
COR PERS	*Coryphopterus personatus*	Masked goby	GOBIIDAE	Gobies
CRY ROSE	*Cryptotomus roseus*	Bluelip parrotfish	SCARIDAE	Parrotfishes
DEC SPE.	*Decapturus sp.*	Unidentified scad	CARANGIDAE	Jacks
DIO HOLO	*Diodon holocanthus*	Balloonfish	DIODONTIDAE	Porcupinefishes
EPI ADSC	*Epinephelus adscensionis*	Rock hind	SERRANIDAE	Sea basses
EPI CRUE	*Epinephelus cruentatus*	Graysby	SERRANIDAE	Sea basses
EPI FULV	*Epinephelus fulvus*	Coney	SERRANIDAE	Sea basses
EPI GUTT	*Epinephelus guttatus*	Red hind	SERRANIDAE	Sea basses
EQU ACUM	*Equetus acuminatus*	High-hat	SCIAENIDAE	Drums
EQU LANC	*Equetus lanceolatus*	Jacknife-fish	SCIAENIDAE	Drums
EQU PUNC	*Equetus punctatus*	Spotted drum	SCIAENIDAE	Drums
EQU UMBR	*Equetus umbrosus*	Cubbyu	SCIAENIDAE	Drums
GIN CIRR	*Ginglymostoma cirratum*	Nurse shark	ORECTOLOBIDAE	Carpet sharks
GNA THOM	*Gnatholepis thompsoni*	Goldspot goby	GOBIIDAE	Gobies
GOB OCEA	*Gobiosoma oceanops*	Neon goby	GOBIIDAE	Gobies
GYM MORI	*Gymnothorax moringa*	Spotted moray	MURAENIDAE	Morays
HAE AURO	*Haemulon aurolineatum*	Tomtate	HAEMULIDAE	Grunts
HAE CHRY	*Haemulon chrysargyreum*	Smallmouth grunt	HAEMULIDAE	Grunts
HAE FLAV	*Haemulon flavolineatum*	French grunt	HAEMULIDAE	Grunts
HAE MELA	*Haemulon melanurum*	Cottonwick	HAEMULIDAE	Grunts

SPECIES CODE	SCIENTIFIC NAME	COMMON NAME	FAMILY NAME	COMMON FAMILY NAME
HAE PLUM	*Haemulon plumieri*	White grunt	HAEMULIDAE	Grunts
HAE SCIU	*Haemulon sciurus*	Bluestriped grunt	HAEMULIDAE	Grunts
HAE SPE.	*Haemulon sp.*	Unidentified grunt	HAEMULIDAE	Grunts
HAL BIVI	*Halichoeres bivittatus*	Slippery dick	LABRIDAE	Wrasses
HAL GARN	*Halichoeres garnoti*	Yellowhead wrasse	LABRIDAE	Wrasses
HOL BERM	*Holacanthus bermudensis*	Blue angelfish	POMACANTHIDAE	Angelfishes
HOL CILI	*Holacanthus ciliaris*	Queen anglefish	POMACANTHIDAE	Angelfishes
HOL RUFU	*Holocentrus rufus*	Longspine squirrelfish	HOLOCENTRIDAE	Squirrelfishes
HOL TRIC	*Holacanthus tricolor*	Rock beauty	POMACANTHIDAE	Angelfishes
HYP GEMM	*Hypoplectrus gemma #*	Blue hamlet	SERRANIDAE	Sea basses
HYP PUEL	*Hypoplectrus puella #*	Barred hamlet	SERRANIDAE	Sea basses
HYP SPE.	*Hypoplectrus sp.*	Unidentified hamlet	SERRANIDAE	Sea basses
HYP UNIC	*Hypoplectrus unicolor*	Butter hamlet	SERRANIDAE	Sea basses
LAC MAXI	*Lachnolaimus maximus*	Hogfish	LABRIDAE	Wrasses
LAC QUAD	*Lactophrys quadricornis*	Scrawled cowfish	OSTRACIIDAE	Boxfishes
LAC TRIQ	*Lactophrys triqueter*	Smooth trunkfish	OSTRACIIDAE	Boxfishes
LUT ANAL	*Lutjanus analis*	Mutton snapper	LUTJANIDAE	Snappers
LUT BUCC	*Lutjanus buccanella*	Blackfin snapper	LUTJANIDAE	Snappers
LUT GRIS	*Lutjanus griseus*	Gray snapper	LUTJANIDAE	Snappers
LUT SYNA	*Lutjanus synagris*	Lane snapper	LUTJANIDAE	Snappers
MAL PLUM	*Malacanthus plumieri*	Sand tilefish	MALACANTHIDAE	Tilefishes
MAL TRIA	*Malacoctenus triangulatus*	Saddled blenny	CLINIDAE	Clinids
MON TUCK	*Monacanthus tuckeri*	Slender filefish	BALISTIDAE	Leatherjackets
MUR MILI	*Muraena miliaris*	Goldentail moray	MURAENIDAE	Morays
MYC INTE	*Mycteroperca interstitialis*	Yellowmouth grouper	SERRANIDAE	Sea basses
MYC MICR	*Mycteroperca microlepis*	Gag	SERRANIDAE	Sea basses
OCY CHRY	*Ocyurus chrysurus*	Yellowtail snapper	LUTJANIDAE	Snappers
OPI AURI	*Opistognathus aurifrons*	Yellowhead jawfish	OPISTOGNATHIDAE	Jawfishes
PAR MARM	*Paraclinus marmolatus*	Marbled goby	CLINIDAE	Clinids
POM ARCU	*Pomacanthus arcuatus*	Gray angelfish	POMACANTHIDAE	Angelfishes
POM FUSC	*Pomacentrus fuscus*	Dusky damselfish	POMACENTRIDAE	Damselfishes
POM LEUC	*Pomacentrus leucostictus*	Beaugregory	POMACENTRIDAE	Damselfishes
POM PART	*Pomacentrus partitus*	Bicolor damselfish	POMACENTRIDAE	Damselfishes
POM PARU	*Pomacanthus paru*	French angelfish	POMACANTHIDAE	Angelfishes
POM PLAN	*Pomacentrus planifrons*	Three spot damselfish	POMACENTRIDAE	Damselfishes
POM VARI	*Pomacentrus variabilis*	Cocoa damselfish	POMACENTRIDAE	Damselfishes
PSE MACU	*Pseudupeneus maculatus*	Spotted goatfish	MULLIDAE	Goatfishes
SCA CROI	*Scarus croicensis*	Striped parrotfish	SCARIDAE	Parrotfishes
SCA GUAC	*Scarus guacamaia*	Rainbow parrotfish	SCARIDAE	Parrotfishes
SCA TAEN	*Scarus taeniopterus*	Princess parrotfish	SCARIDAE	Parrotfishes
SCO PLUM	*Scorpaena plumieri*	Scorpion fish	SCORPAENIDAE	Scorpionfishes
SCO REGA	*Scomberomorus regalis*	Cero mackerel	SCOMBRIDAE	Mackerels/Tunas
SER BALD	*Serranus baldwini*	Lanternfish	SERRANIDAE	Sea basses
SER TABA	*Serranus tabacarius*	Tobaccofish	SERRANIDAE	Sea basses
SER TIGR	*Serranus tigrinus*	Harlequin bass	SERRANIDAE	Sea basses
SPA ATOM	*Sparisoma atomarium*	Greenblotch parrotfish	SCARIDAE	Parrotfishes
SPA AURO	*Sparisoma aurofrenatum*	Redband parrotfish	SCARIDAE	Parrotfishes
SPA CHRY	*Sparisoma chrysopterum*	Redtail parrotfish	SCARIDAE	Parrotfishes
SPA RUBR	*Sparisoma rubripinne*	Yellowtail parrotfish	SCARIDAE	Parrotfishes
SPA VIRI	*Sparisoma viride*	Stoplight parrotfish	SCARIDAE	Parrotfishes
THA BIFA	*Thalassoma bifasciatum*	Bluehead wrasse	LABRIDAE	Wrasses
URO JAMA	*Urolophus jamaicensis*	Yellow stingray	DASYATIDAE	Stingrays

APPENDIX F.2 (2003 columns show averages of three rounds of sampling)

Fish Species Data Summarized by Module/Station Type

	D		M		R		Control	Totals	
Species Code	1995	2003	1995	2003	1995	2003	NR03	1995	2003
ABU SAXA	3	6.0	34	18.0	17	13.0		54	37.0
ACA BAHI	14	4.7	19	5.3	23	4.7	5.3	78	20.0
ACA CHIR		4.0	1	0.7	1	2.7	0.3	2	7.7
ACA COER	1	3.3	2	7.0	1	5.3	1.3	5	17.0
AET NARI								1	0.0
AMB PINO				2.0		0.7			2.7
ANI SURI			6	2.7				6	2.7
ANI VIRG	9	2.3	15	3.7	7	11.0		33	44.0
APO BINO				4.0		4.7			8.7
APO MACU				3.3		0.3			3.7
APO PSEU						4.7			4.7
APO SPE.	1		1			1.0		2	1.0
APO TOWN				5.7		5.0	0.3		11.0
AUL MACU		2.7				2.3			5.0
BOD PULC				0.3					0.3
BOD RUFU	8	6.0	14	36.3	18	7.7	1.0	42	51.0
CAN MACR				0.3					0.3
CAN PULL			4	0.7	1		1.3	7	2.0
CAN ROST	7	19.3	10	33.3	4	25.7	1.0	29	88.3
CAR CRYS		0.3							0.3
CAR RUBE				15.0			0.7		15.7
CHA CAPI	2	0.7		4.7			0.3	2	5.7
CHA FABE			1		9	15.0		10	15.0
CHA OCEL	2	3.0		3.0	2	2.7		8	8.7
CHA SEDE	4	6.3	9	3.0	8	1.7	8.0	30	19.0
CHO SCOT	3	6.3	23	71.7	24	45.0	1.0	51	124.0
CHR CYNA	10	6.0	31	16.0	20	15.3	1.0	61	38.3
CHR ENCH						1.0			1.0
CHR INSO			1	8.0	5	4.0		11	12.0
CHR MULT	1	7.0	6	25.7	3	28.3	0.3	10	61.3
CLE PARR		11.0		122.3	10	29.3		10	162.7
COR GLAU		2.0		1.3		7.7	19.7		30.7
COR PERS		188.3		857.3		55.0	3.3		1554.0
CRY ROSE		15.7				4.3	5.7		25.7
DEC SPE.							341.7		341.7
DIO HOLO						0.3	1.0	3	1.3
EPI ADSC						0.3			0.3
EPI CRUE	2	2.0	6	8.3	3	6.0	0.3	11	16.7
EPI FULV				0.7			0.7		1.3
EPI GUTT							0.3		0.3
EQU ACUM	14	8.3	4	4.3	5	13.3		23	26.0
EQU LANC	1	0.3			3			4	0.3
EQU PUNC			3		1			4	0.0
EQU UMBR	1	0.3	1					2	0.3
GIN CIRR	1	0.3	2	0.3	1			4	0.7
GNA THOM						0.3	5.3		5.7
GOB OCEA				6.7	8	6.0		8	12.7
GYM MORI				0.3		0.3			0.7
HAE AURO	33		35		32		2.0	100	2.0
HAE CHRY		1.3		463.0		8.0			472.3
HAE FLAV	80	166.7	260	598.3	230	456.0		570	1221.0
HAE MELA		274.0		279.0	1	51.0		1	1063.0
HAE PLUM	101	99.0	525	119.0	325	67.0	3.0	986	288.0

Species Code	D		M		R		Control	Totals	
	1995	2003	1995	2003	1995	2003	NR03	1995	2003
HAE SCIU	64		1005	1.3	57			1131	1.3
HAE SPE.				131.3		12.7			234.0
HAL BIVI		0.7					1.3		2.0
HAL GARN	5	2.0		24.7	1	29.0	3.0	9	103.7
HOL BERM	2		4	1.0		0.3	0.3	7	1.7
HOL CILI			1	4.7		2.7		2	7.3
HOL RUFU			2		1			5	0.0
HOL TRIC	6	2.3	8	6.0	3	5.0	2.0	22	15.3
HYP GEMM		2.0					1.3		3.3
HYP PUEL		0.3		0.7					1.0
HYP SPE.		0.3		0.3					0.7
HYP UNIC	3	2.0	5	5.0	4	2.7	0.7	14	10.3
LAC MAXI	1	1.0		1.0	3	0.3		8	2.3
LAC QUAD			1				1.0	1	1.0
LAC TRIQ							0.3		0.3
LUT ANAL					1			1	0.0
LUT BUCC				3.0					3.0
LUT GRIS	10		112	0.3	25			147	0.3
LUT SYNA		0.3	600	5.0				600	5.3
MAL PLUM							0.3		0.3
MAL TRIA		0.7				1.7			2.3
MON TUCK							0.7		0.7
MUR MILI				0.3					0.3
MYC INTE		1.3		0.3		0.3			2.0
MYC MICR						0.3			0.3
OCY CHRY		0.3				0.3			0.7
OPI AURI							0.7		0.7
PAR MARM						1.0			1.0
POM ARCU		0.7		0.7	1	0.3	1.0	1	2.7
POM FUSC		0.7		1.0		0.3	0.7		2.7
POM LEUC		6.0		1.3		4.0			11.3
POM PART		26.0	2	18.3	10	46.7	121.3	178	212.3
POM PARU	1						0.3	2	0.3
POM PLAN		0.3		0.7					1.0
POM VARI	8	2.3	6	4.3	6	2.0	0.7	24	9.3
PSE MACU	1	9.7		11.0	3	5.7	11.7	6	38.0
SCA CROI	17	6.0	14	4.0	8	4.7	0.3	41	15.0
SCA GUAC				0.7		1.3			2.0
SCA TAEN		1.7		8.0		4.0	1.7		15.3
SCO PLUM				0.3		0.3			0.7
SCO REGA							0.7		0.7
SER BALD							2.7		2.7
SER TABA							14.7	1	14.7
SER TIGR		5.0		3.7		4.7	13.0	12	26.3
SPA ATOM							1.7		1.7
SPA AURO	11	19.7	5	27.0	9	22.3	29.0	31	98.0
SPA CHRY							1.7		1.7
SPA RUBR						0.7	0.3		1.0
SPA VIRI	1		4	1.3	4	1.0	0.7	12	3.0
THA BIFA	109	63.0	90	215.7	120	99.3	54.0	562	432.0
URO JAMA							0.3		0.3
Total # Spp.	35	52	39	66	42	64	54	55	104
Total # Ind.	537	1001.7	2872	3214.3	1018	1160.3	673	4985	7129.33