Baseline Biological Monitoring of Miami-Dade Limerock Boulder Reefs
2007

FINAL REPORT

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By:
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ABSTRACT

During the last 15 years, limerock boulder artificial reefs have been deployed offshore of Miami-Dade County for a variety of purposes including mitigation and fisheries enhancement. This study sought to examine the previously undocumented fish and benthic assemblages utilizing five of the limerock boulder reefs in Miami-Dade County. The five boulder reefs evaluated included the Golden Beach Boulder Reefs, Arcos Boulder Reef, Anchorage Boulder Reef, Port of Miami Boulder Rows, and Port of Miami Boulder Piles. The 'age' (time since deployment) of the reefs ranged between 2 years (Golden Bach Boulder Reef) and 11.5 years (Anchorage Boulder Reef). This baseline study demonstrated that all five boulder reefs provide habitat that has supported abundant and diverse biological assemblages. The benthic assemblages were dominated by turf algae coverage followed by sponge (Porifera) species and to a lesser extent soft coral (Octocorallia) and stony coral (Scleractinia) species. The fish assemblages on the boulder reefs were often composed of large schools of grunts (Haemulidae) and gobies (Gobiidae). Other common reef fish families were also observed including snappers (Lutjanidae), wrasses (Labridae), damselfish (Pomacentridae), and parrot fish (Scaridae). This study has provided baseline information for evaluating the effectiveness of these reefs in meeting the objectives for which they were constructed such as fisheries enhancement or habitat mitigation and will assist in future artificial reef planning.

INTRODUCTION

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

Over the last 15 years, numerous artificial reefs constructed from limerock boulders have been deployed for a variety of purposes in Miami-Dade County including mitigation and fisheries enhancement. However, the benthic and fish assemblages utilizing these limerock boulder artificial reefs have not been well described. This project documented and quantified the biological assemblages on five different limerock boulder reefs offshore Miami-Dade County (Figure 1). Due to time and funding limitations, a 'seasonal' assessment could not be conducted. Rather replicate surveys (three per site) were conducted on each of the five sites to provide baseline information for description of the associated communities. This information will assist in evaluation the effectiveness of these reefs in meeting the objectives for which they were constructed such as fisheries enhancement or habitat mitigation.

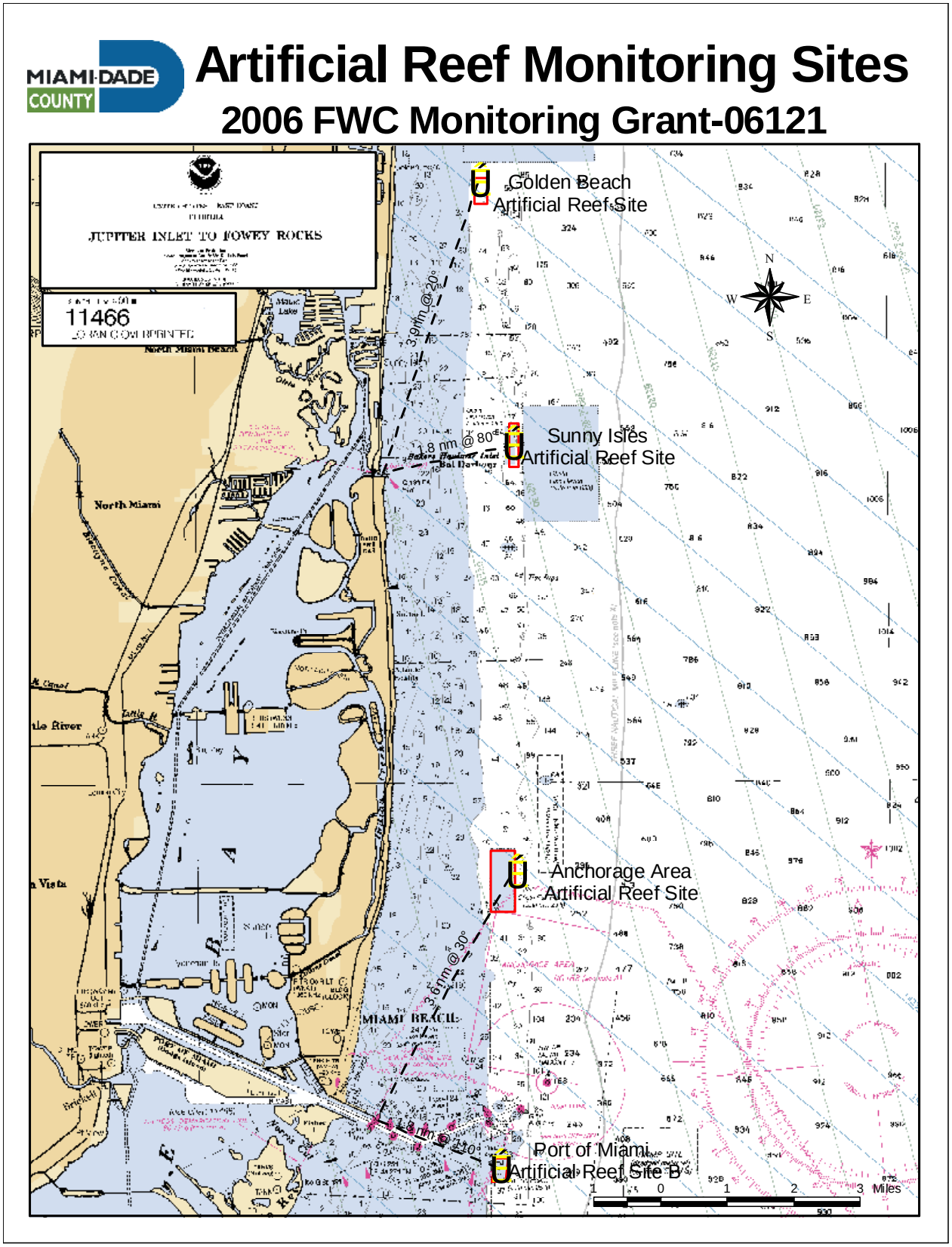

Figure 1. Location of the boulder reefs and respective artificial reef sites evaluated through FWC Grant 06121.

SITE LOCATION AND DESCRIPTION

Five different limerock boulder reefs were evaluated across Miami-Dade County from the northern county boundary to just south of Government Cut (Figure 1). These reefs have varying characteristics as described below and shown in Figure 2, however, all were constructed with quarried limerock boulder, that ranged between 3ft and 6 ft diameter, placed in a 'multi-layered' arrangement. These specifications were selected following analysis of the material for stability in storm events. Miami-Dade County stability analysis assesses the material's resistance to overturning and horizontal movement (sliding), utilizing characteristics of a 25-year return storm event, in consideration of the depth and bottom slope of the deployment location.

Golden Beach Boulders: The Golden Beach Boulder Reef was the youngest (i.e., most recent deployment; see Figure 2) reef evaluated. This artificial reef area is composed of 3 multi-layered boulder piles ranging in length from 14 to 20m (45-65ft) with 29 Reef Balls® in between the piles. No other artificial reef material is in the area. The closest natural hard bottom is approximately 49m (160ft) to the west.

Arcos Boulder Reef: The Arcos Boulder Reef was deployed in August of 2001 and consists of a single multi-layered pile with a diameter of approximately 14m (45ft). Approximately 12m (40ft) north of the boulder pile is the southern extent of a group of 64 prefabricated "DERM" modules. The modules have approximately four feet of relief and are spaced roughly 9m (30ft) apart. Other than the modules, no other artificial reef material is found with in the vicinity. The closest natural hard bottom is 79m (260ft) to the west.

Anchorage Boulder Reef: Deployed in 1995, the Anchorage Boulder Reef is the oldest boulder reef evaluated. This reef consists of one row of multi-layered boulders approximately 40m x15m (130ft x 50ft). Approximately 14m (45ft) to the northeast of the Anchorage Boulder Reef lies the Patricia, a 20m (65ft) steel tug with 5m (15ft) of relief. Miss Karline, a 26m (85ft) steel hull with 5m (15ft) relief, lies approximately 21m (70ft) to the southeast of the boulder reef. Natural hard bottom is approximately 183m (600ft) to the north-north west of the Anchorage Boulder Reef.

Port of Miami Row and Pile Boulder Reefs: As the largest site evaluated, the Port of Miami (POM) Site B is comprised of multi-layered boulder rows and piles stretched across an area 500m x 460m area (1600ft x 1500ft). The 11 POM Rows are each approximately 152m x 15m (500ft x 50ft) and the 35 POM Piles are each approximately 27m x 15m (90ft x 50ft). Other than the boulder piles and rows no other artificial reef material is found nearby. Spoil material from old Government Cut dredging projects is located approximately 61m (200ft) to the north and the closest natural hard bottom area is 122m (400ft) to the west.

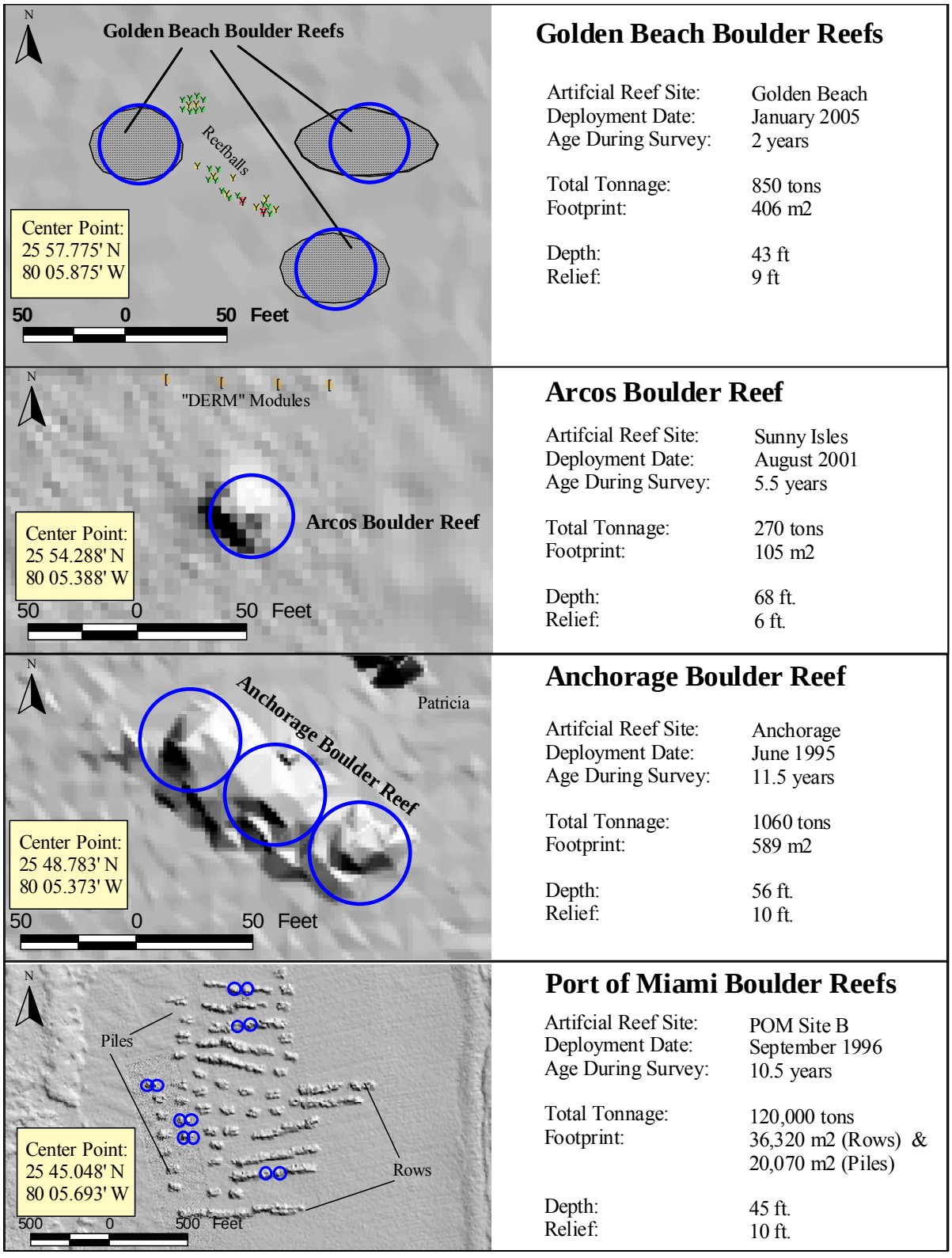

Figure 2. Boulder reef locations. Note circles indicate approximate locations of fish surveys. Gray-scaled bottom topography is from a survey using Laser Airborne Depth Sounder or LADS (Coastal Planning and Engineering, Inc., 2003).

METHODOLOGY

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

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

The assessment procedures had to be tailored to the specific reef sites due to the size of the reefs, as insufficient room was available to allow for independent, non-overlapping surveys. The larger reefs (Port of Miami-Row, and Port of Miami-Pile) each had six (6) non-overlapping fish surveys per round, while the Anchorage and Golden Beach sites each had three (3) non-overlapping fish surveys per round. Due to the smaller size, the ARCOS boulder site only had one (1) fish assessment per replicate survey.

Benthic assemblages were assessed using a quadrat photo method. In the quadrat photo method, digital pictures were taken of a quadrat at a fixed distance. Each quadrat was 40cm x 50cm. The number of quadrat photographs taken and analyzed depended on the size of the limerock boulder reef. The small Arcos Boulder Reef only had 54 photographs taken yielding a surveyed benthic area of $10.8m^2$. The other four sites, POM Pile, POM Row, Anchorage, and Golden Beach, each had approximately 150 photographs taken. However, several pictures were discarded due to poor quality. Therefore, a total of 144 photographs were analyzed for POM Pile, POM Row, Anchorage, and Golden Beach yielding a total benthic survey area of $28.8m^2$. Coral Point Count Software developed by National Coral Reef Institute and Nova Southeastern University (Kohler and Gill 2006) was then used to overlay 20 random points on top of each

image. The benthic organisms or substrate under each point were identified providing an estimate of relative percent cover of each benthic taxa or substrate. All hard coral colonies in the images were also measured with the Coral Point Count program. The image was first calibrated with a known dimension (the size of the quadrat) and the number of pixels per centimeter was estimated. Then each hard coral was outlined and the internal area was calculated based on the number of pixels/cm.

Statistical analysis. As the focus of the monitoring for this project was to provide baseline information on the benthic and fish assemblages on several boulder reefs throughout Miami-Dade County, basic descriptive statistics, similarity indices and non-parametric multi-parameter scaling was deemed appropriate for this evaluation. The information provided in the report will hopefully serve as foundation for more rigorous scientific evaluations in the future including parametric evaluations (i.e., ANOVA).

Multiple software applications were used to summarize and analyze the benthic and fish population data. Microsoft Excel was used to calculate descriptive statistics and graph results of the data and indices. "Primer-5 for Windows®" (Primer-E, 2002) multivariate statistical software was used to calculate and display Bray-Curtis similarity indices (Bray and Curtis, 1957), similarity and evenness indices, well as ordination clustering of the data using non-metric multidimensional scaling (MDS) procedures.

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

Prior to the calculation of the Bray-Curtis indices, the data was fourth-root transformed in order to reduce the weight of the common species and incorporate the importance of both the intermediate and rare species (Field et. al 1982; Clark and Warwick 1994). The non-metric MDS analysis (Kruskal and Wish, 1978) generated a graph based on the calculated Bray-Curtis indices. The MDS analysis generates a "stress value" for each plot, which indicates the level of difficulty in representing the similarity relationships for all samples into a two-dimensional space. Clarke and Warwick (1994) state that a stress value ≤ 0.05 indicates a plot with excellent representation and minimal chance of misinterpretation, values from 0.05 to 0.10 correspond to a good ordination with slight chance of misinterpretation, values from 0.10 to 0.20 indicate a potentially useful plot, but have a greater chance of misinterpretation, and values between 0.20 and 0.30 are considered acceptable although conclusions should be crosschecked with other statistical measures. Plots associated with stress levels ≥ 0.30 represent a more or less arbitrary arrangement.

RESULTS

Fish Assemblages

To account for variability in fish assemblages that may occur in one survey area from day to day, three replicate survey rounds were conducted at all five sites as seen in Table 1.

Table 1. Survey dates for each replicate round of fish surveys at each site.

	Round 1	Round 2	Round 3
Golden Beach	10/19/06	12/19/06	1/30/07
Arcos	10/19/06	1/5/07 – 1/16/07	1/30/07
Anchorage	10/20/06	1/3/07	1/16/07
POM Piles	11/29/06 – 12/14/06	1/3/07	2/9/07
POM Rows	11/2/06 – 12/14/06	1/5/07	2/12/07 – 2/13/07

Species Richness. Figure 3 shows the total number fish species observed across all replicate rounds on the five boulder reefs. Refer to Appendix 1 for a complete species listing per round. The highest number of species observed occurred at the two Port of Miami (POM) boulder reefs, POM Pile and POM Row, with 67 and 66 respectively. The POM sites were followed closely by the much younger Golden Beach site with 62 different species observed. The smallest boulder reef and the site with the fewest surveys, Arcos, also had the fewest fish species with 38. Although some differences were observed in the total number of species at the five sites, all sites had relatively similar average number of total species per survey ranging from 20.56 to 24.33.

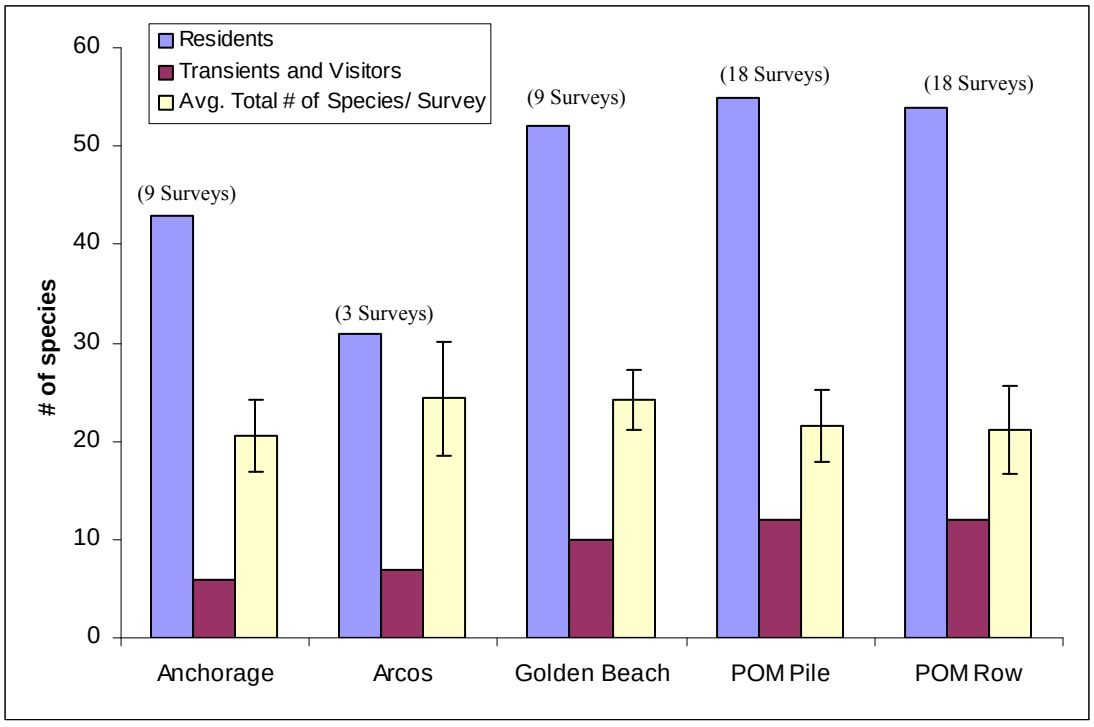

Figure 3. Total resident and transient and visitor fish species observed across all three rounds and the average total number of fish species per survey with standard deviation bars plotted. Note that due to the sizes of each reef, the number of surveys varied between sites. Note: Survey Area = 176 m^2.

Diversity. The Shannon Diversity Index (H') and Pielou's Evenness measure (J') were calculated for the resident fish assemblages at each boulder reef. Figure 4 shows the mean H' and J' values at each site averaged from Rounds 1-3. The two Port of Miami sites had the highest H' values (POM Pile: 3.00 and POM Row: 2.88) as well as the highest J' value (POM Pile: 0.88 and POM Row: 0.77) of the five boulder reefs indicating a diverse fish assemblage with the individuals distributed more evenly between the species. The smaller Arcos reef showed the lowest diversity (1.26) and evenness measure (0.42). As indicated in Figure 3, the Arcos reef had fewer species than the other sites and the majority of the individuals (approximately 69%) were *Haemulon aurolineatum* (Tomtate) accounting for the low evenness measure.

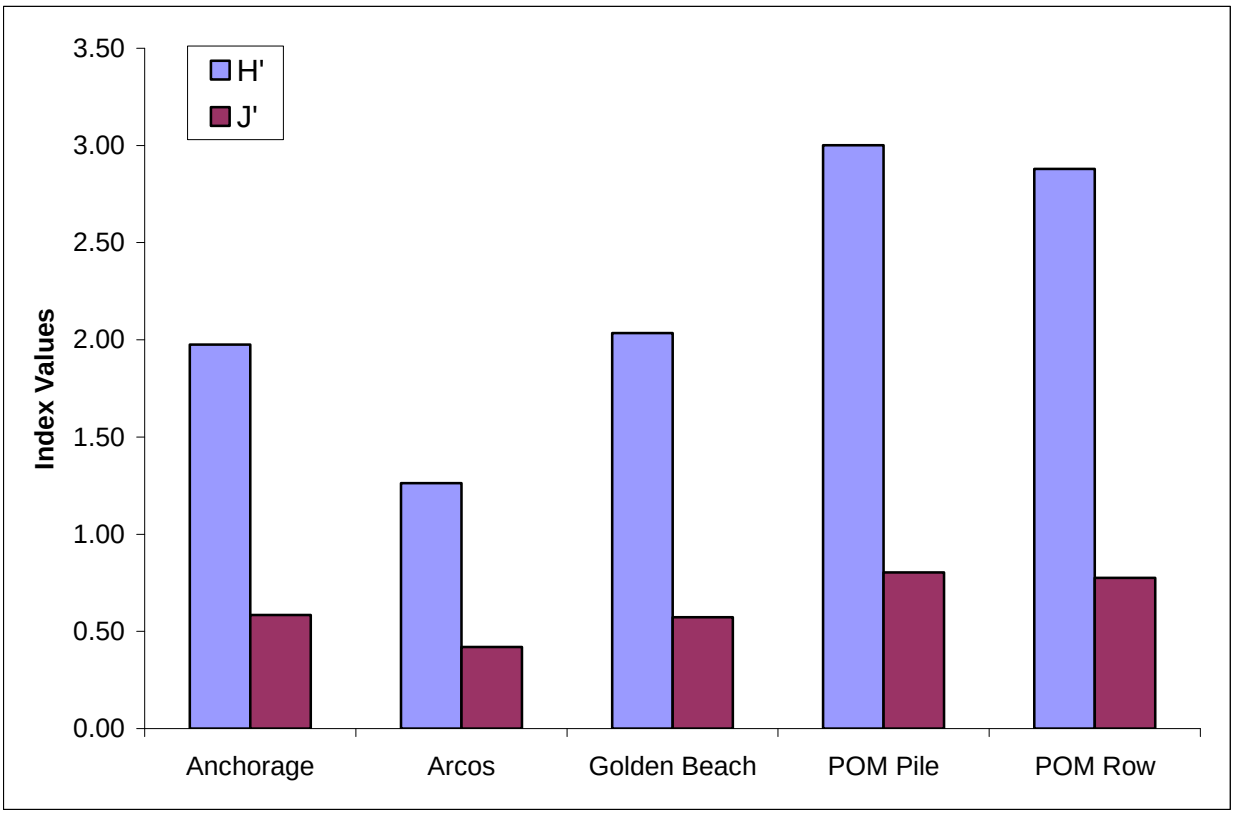

Figure 4. Mean Shannon Diversity Index (H'; range= 0.00-+3.00) and Pielou's Evenness measure (J'; range= 0.00-1.00) per replicate round for the resident fish assemblages on each boulder reef. Note that due to the sizes of each reef, the area (number of surveys) per round varied between sites: 1060m^2 (6 surveys) on POM Pile and POM Row, 530m^2 (3 surveys) for Anchorage and Golden Beach, and 176m^2 (1 survey) for Arcos.

Density. Figure 5 shows the mean density (individuals/m^2) per replicate at the boulder reefs. Although the Port of Miami sites showed the highest species richness and diversity, they exhibited the lowest density with an average of 1.53 individuals/m^2 across all surveys at POM Pile and 1.79 individuals/m^2 at POM Row. The other three sites had approximately twice the density seen at the POM sites. Anchorage, Arcos, and Golden Beach had relatively similar density levels with occasional spikes; as seen in Replicate 1 at Anchorage and Arcos and Replicate 3 at Golden Beach. During those surveys, very large schools (>1000 individuals) of *Haemulon aurolineatum* (Tomtate) were observed.

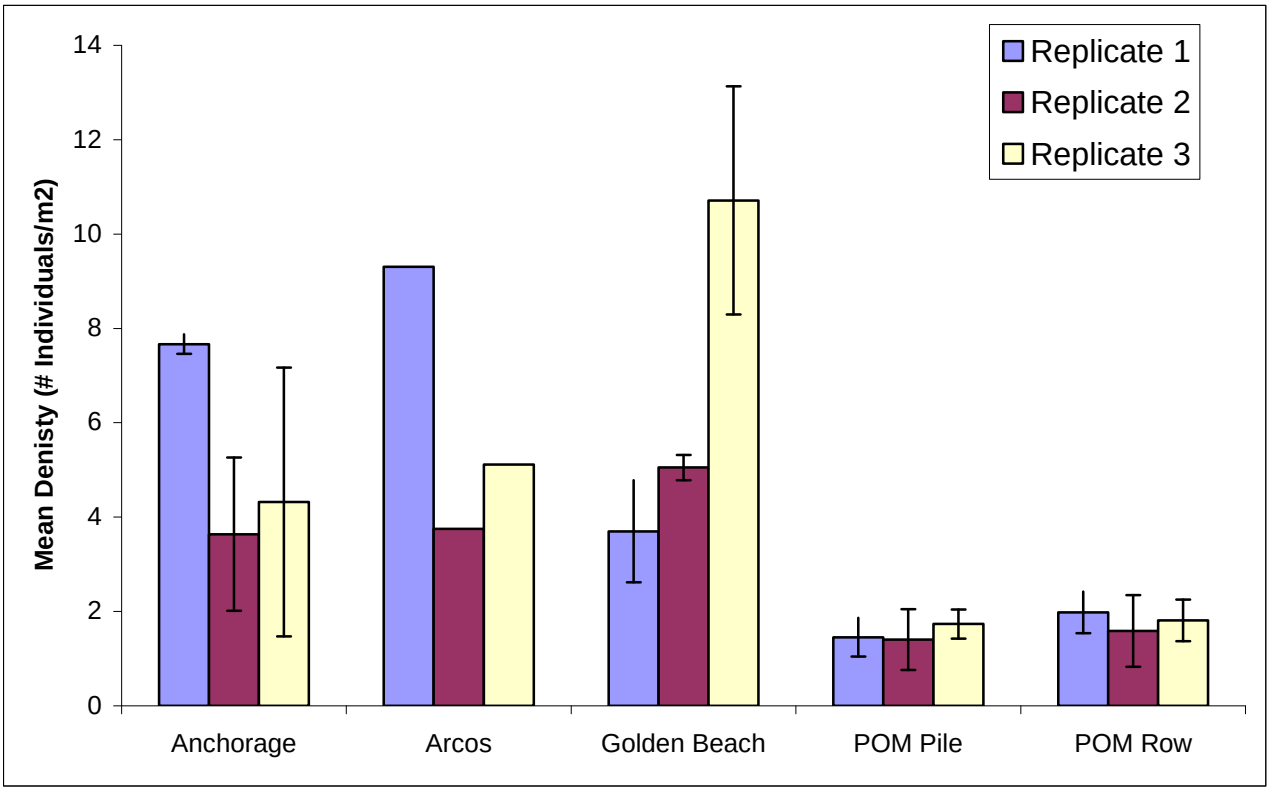

Figure 5. Mean resident fish density (individuals/m^2) for each replicate round at the five boulder reefs. Standard deviation bars plotted for all sites except Arcos which only had one survey per replicate. Note that due to the sizes of each reef, the area (number of surveys) per replicate round varied between sites: $1060m^2$ (6 surveys) on POM Pile and POM Row, $530m^2$ (3 surveys) for Anchorage and Golden Beach, and $176m^2$ (1 survey) for Arcos.

Family Composition. On all five boulder reefs, a large percentage of the resident fish belonged to either the Haemulidae (grunts) and Gobiidae (gobies) families (Figure 6). The large percent composition by the Haemulidae family was primarily due to the large schools of *Haemulon aurolineatum* (Tomtate) present particularly at the Anchorage, Arcos, and Golden Beach sites. The large percent composition by the Gobiidae family was due to the presence of large numbers of *Coryphopterus personatus* (Masked goby) that hovered in the crevices between boulders. Lutjanidae was also a major family on the Anchorage, Arcos, and Golden Beach sites. Labridae, Pomacentridae, Scaridae, and Tetraodontidae were also relatively abundant at all the sites, but on the Anchorage, Arcos, and Golden Beach sites the percent composition was diminished by the total sample size and large number of Haemulidae and Gobiidae individuals.

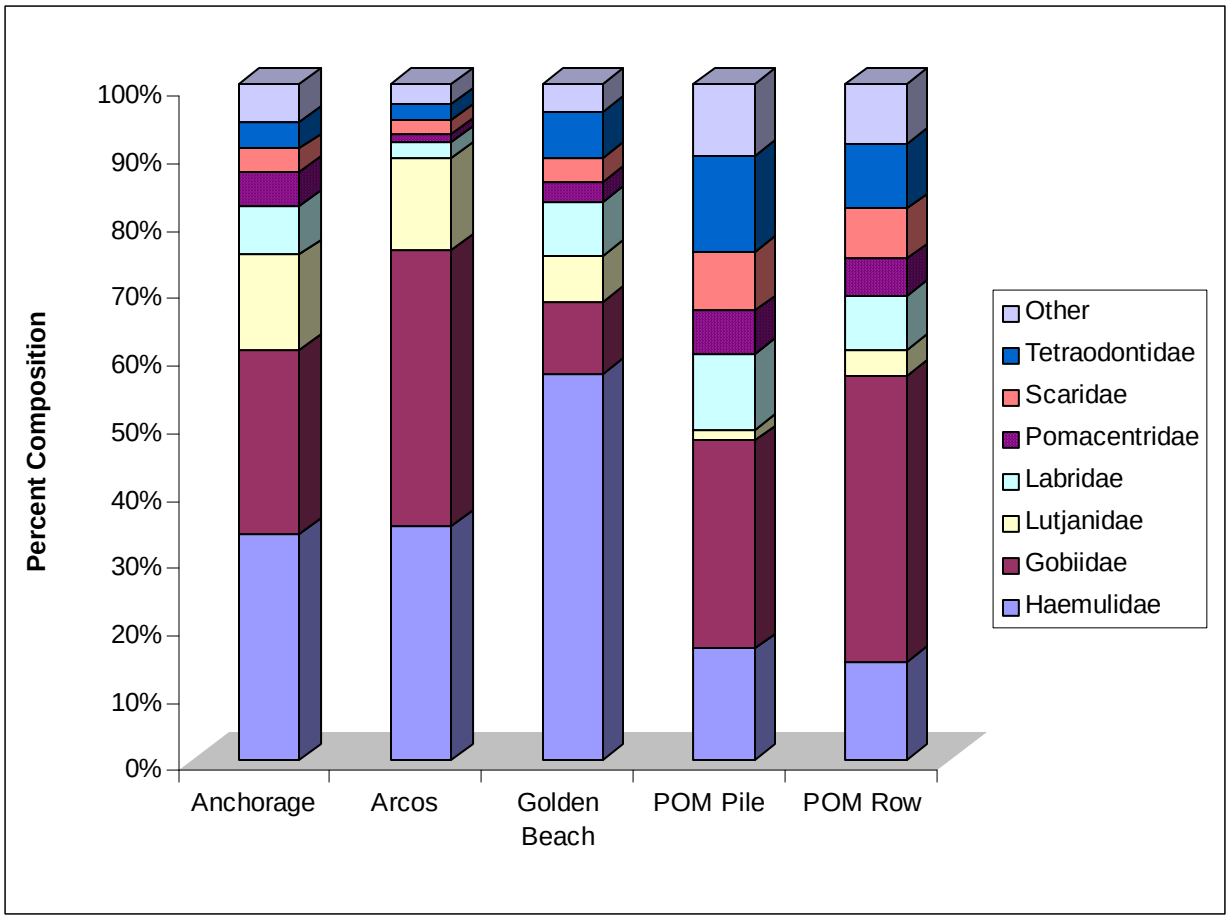

Figure 6. Mean percent composition (%) of resident individuals per survey across all rounds by major family constituents

In addition to *Haemulon aurolineatum* and *Coryphopterus personatus*, several other species were common across all sites as indicated in Table 2. *Haemulon sciurus* (Blue-stripped grunt) and *H. flavolineatum* (French grunt) of the Haemulidae family were observed at all sites. Lutjanus synagris (Lane snapper) from the Lutjanidae family was a found at all five bolder reefs but most abundant at the Anchorage and Arcos sites. Common Labridae and Pomacentridae species included *Thalassoma bifasciatum* (Blue-head wrasse), *Halichoeres garnoti* (Yellow-head wrasse), and *Pomacentrus partitus* (Bicolor damsel). Several Scaridae species were also consistently abundant across all sites including *Sparisoma aurofrenatum* (Redband parrotfish), *Scarus taeniopterus* (Princess parrotfish), and *Scarus iserti* (Stripped parrotfish).

Table 2. Average number of individuals per survey across all replicates for the most abundant species of the dominant families. Note that due to the sizes of each reef, the area (number of surveys) per round varied between sites: 1060m^2 (6 surveys) on POM Pile and POM Row, 530m^2 (3 surveys) for Anchorage and Golden Beach, and 176m^2 (1 survey) for Arcos.

		Anch.	Arcos	Golden Beach	POM Pile	POM Row
Gobiidae	*Coryphopterus personatus*	55.67	66.67	213.89	39.56	50.17
Haemulidae	*Haemulon aurolineatum*	532.22	741.67	737.22	61.89	79.06
	Haemulon sciurus	41.11	29.67	56.33	2.28	19.11
	Haemulon flavolineatum	38.44	61.33	39.78	2.06	5.28
Lutjanidae	*Lutjanus synagris*	28.56	44.33	5.00	0.44	0.44
	Lutjanus griseus			24.89	0.11	4.89
Labridae	*Thalassoma bifasciatum*	57.78	28.33	71.56	36.06	25.67
	Halichoeres garnoti	9.78	1.33	29.11	10.61	7.61
Pomacentridae	*Pomacentrus partitus*	31.89	5.00	28.22	23.67	24.00
	Abudefduf saxatilis	31.00		5.00	2.67	7.00
Scaridae	*Sparisoma aurofrenatum*	13.44	11.67	13.33	11.22	15.72
	Scarus taeniopterus	10.78	14.00	7.11	10.61	12.00
	Scarus iserti	4.33	2.33	5.44	8.72	6.78
Tetraodontidae	*Canthigaster rostrata*	18.67	11.00	24.78	19.56	20.33

Similarity. Figure 7 shows the MDS plot graphically depicting the Bray-Curtis similarity values for the average density of resident fish species for each round. Although the stress value is moderate (indicating an possible misinterpretation) across the samples plotted, the purpose of this assessment is to provide an indication of the consistency of the resident fish population on each of the reefs, through comparison of the similarity (and thereby the composition and abundance) between the replicate samples. However, where the level of assessment (e.g., number of surveys) were equivalent, comparisons between reefs would be possible.

The two POM sites showed the greatest similarity (69.1%) as indicated by the tighter clustering of the two reefs. The two boulder reefs at POM still formed two distinct groups indicating a difference between fish assemblages on the piles compared to the rows. As indicated in Figure 7, the other reef sites showed more variability within the site (increased spread of replicates for the site). This is most likely a combination of the size of the site, as well as the fact that there were fewer surveys on these sites, however, we are not able to partition the relative contribution of those affecters. The Golden Beach, Arcos, and Anchorage sites also had a lower similarity value between assessments.

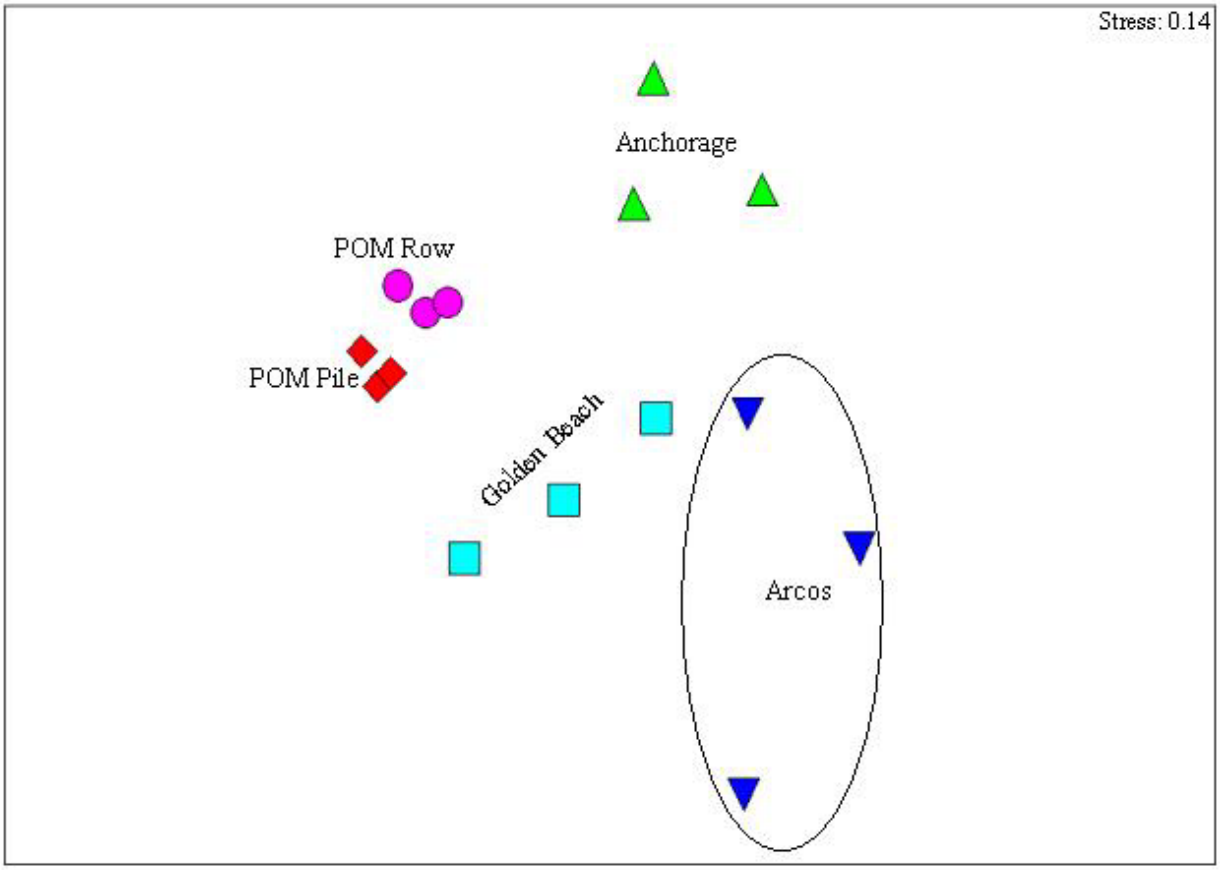

Figure 7. Multi-dimensional scaling (MDS) plot based on the Bray-Curtis Similarity values for the mean density of each resident fish species for each round.

Sportfish Abundance and Size. Several sport fish were observed on the boulder reefs including jacks, groupers, snappers, and hogfish. Table 3 shows the abundance, mean size, and range of sport fish across all surveys and round for the boulder reefs. A few large jacks (i.e., *Seriola dumerii;* Greater Amberjack) were observed at the two POM sites, but all were smaller than the minimum size limit of approximately 71cm. Occasionally other smaller jacks (e.g., *Caranx ruber*, the Bar Jack) were also noted. From the grouper family, *Cephalopholis cruentatus* (e.g., Grasby) was also observed on all of the boulder reefs. Observations of large grouper individuals was unique to the Golden Beach Boulder Reef. During Round 3, a large Black Grouper, *Mycteroperca bonaci*, and a protected Goliath Grouper, *Epinephelus itajara*, were observed. Unlike the Black Grouper, the Goliath Grouper was not observed prior to this study on any of the reef evaluated, and was not observed at subsequent visits conducted February through August 2007. Observations of Gag Grouper (*Mycteroperca microlepis*) were also unique to the Golden Beach Boulder Reef site. From the snapper family, *Lutjanus synagris*, the Lane Snapper, was observed across all boulder reef sites. Large Lane Snapper schools were often recorded on or immediately adjacent to boulder reefs at all sites except for the POM piles and rows. At the Golden Beach site, the Gray Snapper, *Lutjanus griseus*, was also common with observations on eight of nine surveys. Although not seen in abundance, the Hogfish, *Lachnolaimus maximus*, was observed at all of the boulder reefs. At both of the POM sites, at least one Hogfish individual was observed on 13 of 18 surveys.

Table 3. Abundance, mean size, and range of sport or regulated fish observed across all surveys and all rounds at the boulder reefs. The values below include species observed in the initial five minutes of the surveys as well as after. Note that due to the sizes of each reef, number of surveys varied between sites.

	Anchorage (9 Surveys)			**Arcos** (3 Surveys)			**Golden Beach** (9 Surveys)			**POM Pile** (18 Surveys)			**POM Row** (18 Surveys)		
	No.	Mean (cm)	Range (cm)	No.	Mean (cm)	Range (cm)	No.	Mean (cm)	Range (cm)	No.	Mean (cm)	Range (cm)	No.	Mean (cm)	Range (cm)
Jacks:															
Caranx bartholomaei (Yellow)							5	28	25-30						
Caranx crysos (Blue runner)	21	15.2	15-20							1	12				
Caranx hippos (Crevalle)							3	6					5	40	30 - 45
Caranx ruber (Bar)	83	16.8	10-30	1	30		8	21.5	8-40	21	14.1	5-60	106	13.6	8 - 40
Caranx species (unidentified)							30	8	7-10	1	60		12	50	35 - 45
Seriola dumerili (Amberjack)										3	50		8	50	50 - 55
Seriola rivoliana (Almaco)							8	38	25-50						
Groupers:															
Cephalopholis cruentatus (Graysby)	9	15.3	10-20	6	14.2	10-22	3	18.7	16-20	14	18.1	10-25	14	17.7	15 - 25
Epinephelus guttatus (Red hind)	1	12													
Epinephelus itajara (Goliath)							1	175							
Mycteroperca bonaci (Black)							1	100							
Mycteroperca microlepis (Gag)							6	18.5	7-28						
Mycteroperca phenax (Scamp)							7	20.6	8-30	1	12		7	17	16 - 26
Snappers:															
Lutjanus apodus (Schoolmaster)										10	19	13-28	18	20.9	17 - 30
Lutjanus campechanus (Red)							26	19	15-22						
Lutjanus griseus (Gray)	67	20.6	10-40				224	20.2	8-30	3	20		89	20	13 - 30
Lutjanus jocu (Dog)							2	40					1	35	
Lutjanus mahogoni (Mahogany)										3	12	12-13			
Lutjanus synagris (Lane)	261	17.1	10-30	134	19.9	12-23	82	12.8	10-25	11	14.5	12-20	15	15.2	8 - 25
Ocyurus chrysurus (Yellowtail)				2	23	15-35	1	19		15	19.1	12-27	20	17.3	12 - 27
Hogfish:															
Lachnolaimus maximus (Hogfish)	2	30		3	28.6	20-40	8	24.8	15-40	27	16.3	10-32	17	17.3	10 - 40

Benthic Assemblages

The benthic assemblages were quantified through photogrametric evaluation using Coral Point Count software (Kohler and Gill, 2006) from digital photography taken February through April 2007.

Relative Percent Cover. Table 4 shows the relative percent cover of the major benthic categories for the five boulder reefs studied. Refer to Appendix 2 for a complete listing of the relative percent cover by species (or lowest possible discernable taxonomic group). All sites were dominated by algae cover. Porifera were the second highest percent cover on all sites except POM Row. On POM Row, Octocorallia had the second highest percent cover followed by Porifera. Octocoralia were relatively abundant at the POM Pile and POM Row sites, but non-existent or sparse at the Anchorage, Arcos, and Golden Beach sites. The two POM sites had the highest percent cover of scleractinians followed by Arcos and Anchorage respectively. The youngest site, Golden Beach, had the lowest percent cover of scleractinians, and the highest ascidarian coverage (3.38%).

Table 4. Relative percent (%) cover of major benthic categories. Note that 28.8m^2 was surveyed at each site except Arcos. Due to the small reef size at Arcos, only 10.8m^2 was surveyed. (Anchorage = Anch.).

Major Category	Anch.	Arcos	Golden Beach	POM Pile	POM Row
Algae	84.67	82.57	84.14	79.90	76.54
Porifera	12.43	14.03	10.68	10.49	5.14
Octocorallia	0.00	0.21	0.00	4.83	11.73
Scleractinia	1.14	1.28	0.04	3.57	4.04
Milleporidae	0.15	1.17	0.24	0.42	0.38
Zoanthidae	0.00	0.00	0.00	0.04	0.04
Ascidaria	0.00	0.21	3.38	0.00	0.11
Other Live	0.63	0.53	0.08	0.49	0.23
Substrate (sand or bare)	0.99	0.00	1.45	0.27	1.79

As indicated in Table 5, turf algae dominated the algae percent cover component as well as all biotic components. High algal coverage is common at other boulder and natural reef sites in Miami-Dade County (DERM, unpublished). At the Golden Beach site, a large percent cover of the algae component was *Wrangelia argus* which was not common at the other sites. *Pseudopterogorgia* sp. had the highest percent cover for octocorals at the POM Pile and Row sites and the only type of octocoral recorded at the ARCOS site. The poriferan species with the largest percent cover were *Holopsamma helwigi* and *Diplastrella* sp.. *Porites astreoides* was the most abundant scleractinian on four of the five sites. Other (3.38%) Scleractinia included *Siderastrea siderea* and *Stephanocoenia intersepts*.

Table 5. Relative percent (%) cover for the highest contributors. Note that 28.8m^2 was surveyed at each site except Arcos. Due to the small reef size at Arcos, only 10.8m^2 was surveyed. (Anchorage = Anch.).

		Anch.	Arcos	Golden Beach	POM Pile	POM Row
Algae	Turf	83.68	77.79	59.25	74.73	74.10
	Peysonnelia species	0.66	2.76	2.24	2.93	3.73
	Wrangelia argus			22.30	0.04	0.04
Octocorallia	*Pseudopterogorgia* species		0.21		2.89	9.25
	Pseudoplexuara species				0.53	0.73
	Eunicea species				0.30	0.34
Porifera	*Holopsamma helwigi*	3.13	4.46	5.14	2.47	0.80
	Diplastrella species	1.14	1.06	0.71	1.25	0.27
	Diplastrella megastellata	0.15	2.87	2.20	0.19	0.15
	Iotrochota birotulata	2.35		0.04	2.01	0.27
	Monanchora barbadensis	0.33	0.96	0.12	0.30	0.38
	Cliona species	0.44	0.11	0.43	0.15	0.19
Scleractinia	*Porites astreoides*	0.63	0.11	0.04	2.62	2.89
	Siderastrea siderea	0.15	0.64		0.23	0.15
	Stephanocoenia intersepts	0.11	0.11		0.30	0.27

Diversity. The Shannon Diversity Index (H') and Pielou's Evenness measure (J') were evaluated for the benthic assemblages at each boulder reef (Figure 8). The POM Pile site had the highest H' value (1.35) followed closely by the Golden Beach and POM Row sites with an H' value of 1.34 and 1.31 respectively. The lowest diversity (H' = 0.88) and evenness measure (J'= 0.24) of all five boulder reefs was exhibited at the Anchorage site. All sites showed low J' values with respect to their benthic assemblages due to the overwhelming coverage of turf algae ranging from 59.25 to 83.68 percent cover (Table 4) that reduced the even distribution the benthic coverage.

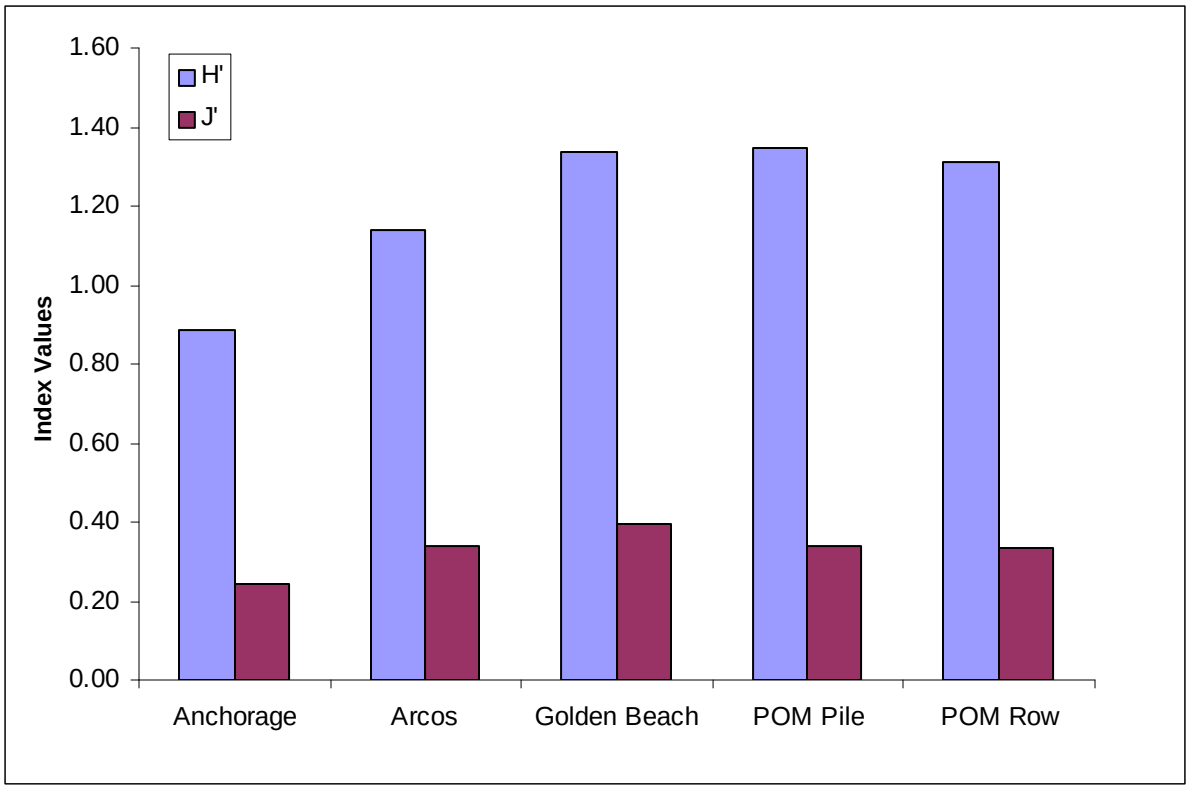

Figure 8. Mean Shannon Diversity Index (H'; range= 0.00-+3.00) and Pielou's Evenness measure (J'; range= 0.00-1.00) for each boulder reef. Note that 28.8m^2 was surveyed at each site except Arcos. Due to the small reef size at Arcos, only 10.8m^2 was surveyed.

Scleractinian Measurements. In addition to estimating the scleractinian relative percent cover through the random point overlay method, scleractinian coverage was also estimated by tracing and calculating the area of each scleractinian colony in each photograph as seen in Figure 9.

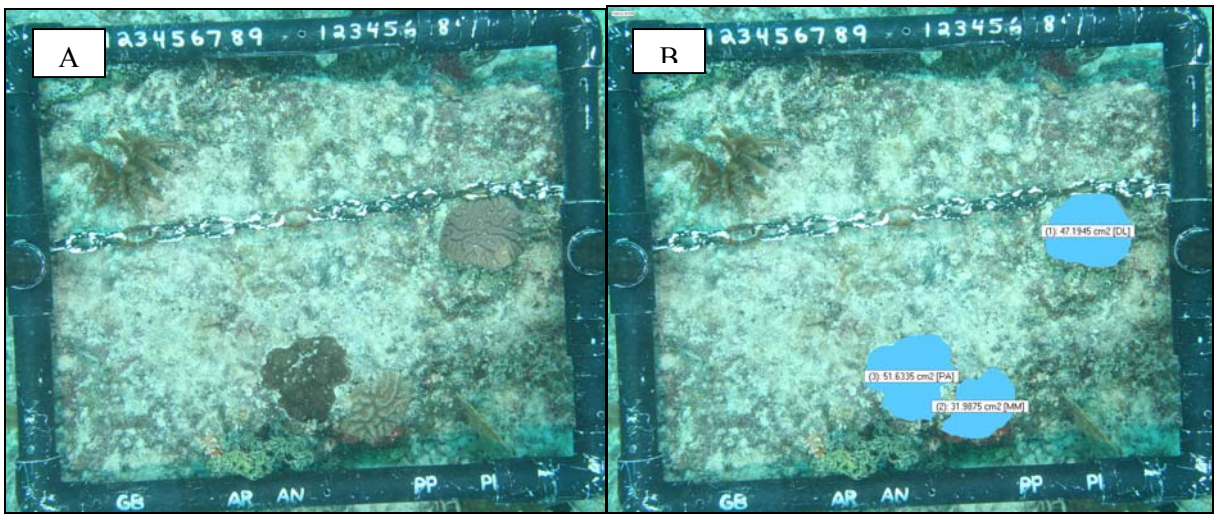

Figure 9. A) Raw quadrat image; B) Quadrat image after scleractinian colonies have been traced.

Slight differences were noted between the two different methodologies as seen in Table 6. The 'tracing' method consistently identified more species, however, there was'n a consistent difference in the estimated % cover.

With both methodologies POM Row and POM Pile had the highest number of scleractinian species and highest percent scleractinian coverage and the youngest site, Golden Beach, had the lowest. Through the tracing methodology *Porites astreoides* was still the most abundant scleractinian on four of the five sites with *Siderastrea siderea* the most abundant on Arcos. *Stephanocoenia intersepts* was also abundant at the Anchorage, Arcos, POM Pile, and POM Row sites. On Anchorage and the two POM sites *Meandrina meandrites and Madracis decactis* (on vertical services) were also common. Three small colonies of an uncommon species, *Tubastrea coccinea*, were observed on vertical surfaces of the POM Pile boulders yielding a total area of 33.11cm^2.

Table 6. Percent (%) cover and number of species of scleractinians. Note that 28.8m^2 was surveyed at each site except Arcos. Due to the small reef size at Arcos, only 10.8m^2 was surveyed. (Anchorage = Anch.).

		Anch.	Arcos	Golden Beach	POM Pile	POM Row
Point Overlay	Number of species	6	5	1	10	13
	Relative %	1.14	1.28	0.04	3.57	4.04
Colony Trace	Number of species	13	9	5	18	18
	Actual %	1.19	0.56	0.03	2.74	3.85

Similarity. Figure 10 shows the MDS plot graphically depicting the Bray-Curtis similarity values between sites for the relative percent composition of benthic species, substrate, and sand. The Golden Beach site showed the greatest separation from the other four sites indicating a lower similarity level with those sites. This decreased similarity is expected as the Golden Beach site is four to ten years younger than the other sites (see Table 1) with benthic components more characteristic of ephemeral and 'pioneering' species of sponge and algae, and lack of octocorals and scleractinians. The POM Pile and POM Row sites showed the greatest similarity (79.99%).

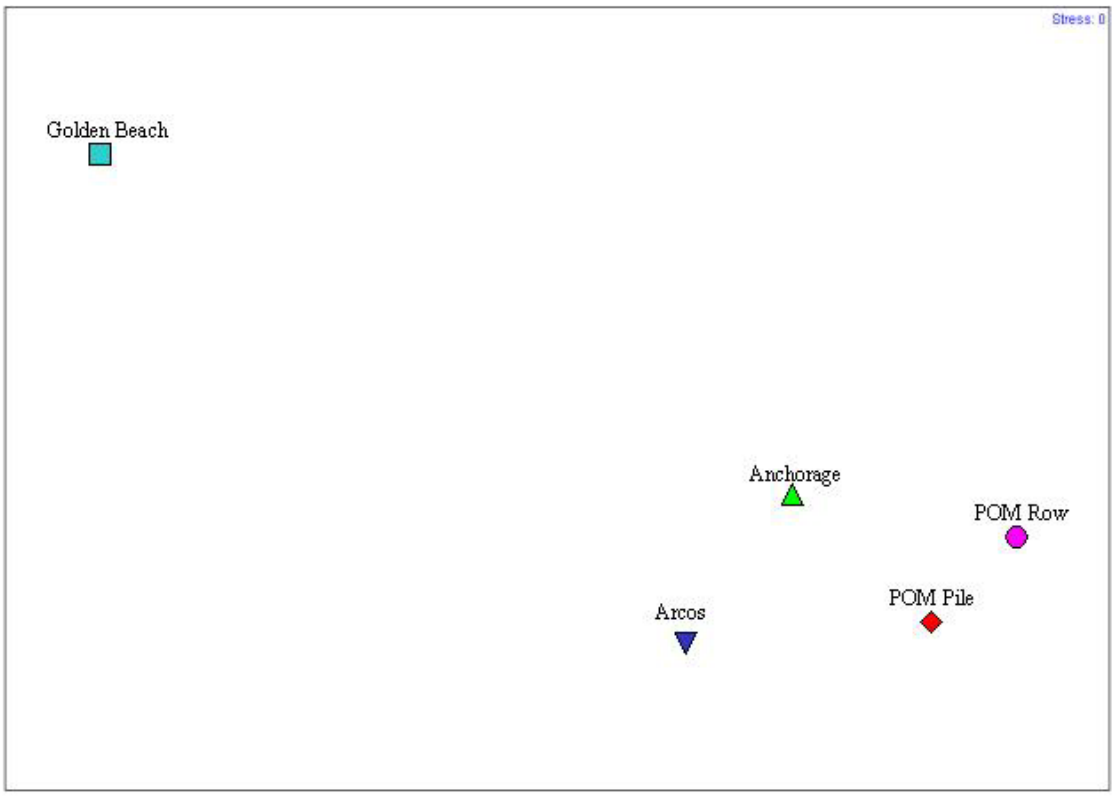

Figure 10. Multi-dimensional scaling (MDS) plot based on the Bray-Curtis Similarity values for the relative percent composition of benthic species, substrate, and sand. Note that 28.8m^2 was surveyed at each site except Arcos. Due to the small reef size at Arcos, only 10.8m^2 was surveyed.

DISCUSSION

Fish Assemblages. The baseline fish surveys showed that the five boulder reefs support a wide variety of fish species and numerous individuals (Figures 3-5 and Appendix 1). The most diverse and evenly distributed fish assemblages on the boulder reefs were found on the row and pile boulder reefs at the Port of Miami site (Figure 4). This site is one of the older boulder reefs studied and is considerably larger than the other four sites. The lower resident fish density at the POM Pile and Row sites (Figure 5) is most likely directly related to the larger size of the site yielding more habitat for the fish to be dispersed across. The three other smaller sites, Anchorage, Arcos, and Golden Beach supported twice the density of resident fish than the POM sites (Figure 5). At these sites, substantial portions of the fish were attributed to large schools of *H. aurolineatum* (Tomtate) as seen in Figure 11 as well as Figure 6 and Table 2. All of the boulder reefs supported fish from numerous other families besides Haemulidae. Some of the most abundant families included Gobiidae, Lutjanidae, Labridae, Pomacentridae, Scaridae, and Tetraodontidae (Figure 6 and Table 2).

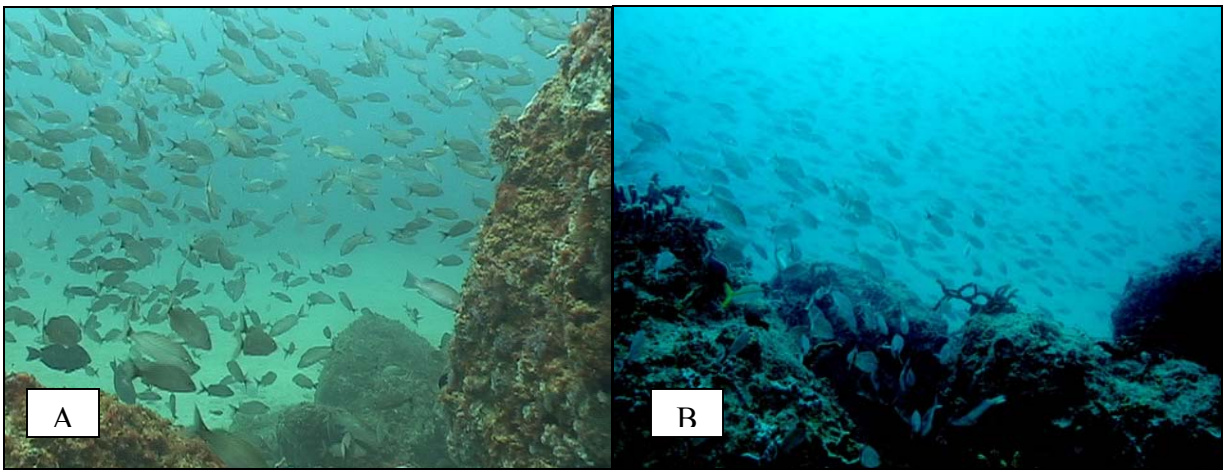

Figure 11. Large school of *Haemulon aurolineatum* (Tomtate) on the (A) Golden Beach and (B) Anchorage boulders.

Several game fish species including jacks, groupers, snappers, and hogfish were observed on the boulder reefs (Table 3). Non regulated jack species including the bar jack were common at the boulder reefs. The Greater Amberjack, *S. dumerili,* (a regulated species), was observed at the POM sites, however, they were below the minimum 'take' size limits. Of the larger groupers, only one Black Grouper (*M. bonaci*) observed on the Golden Beach Boulders was above the legal harvest size. All the Gag Grouper (*M. microlepis*) and Scamps (*M. phenax*) were below the minimum size limits. Within the snapper aggregate, only a few individual Lane Snapper (*L. synagris*), Gray Snapper (*L. griseus*), and Schoolmaster (*L. apodus*) were observed at the upper size range and were above the legal harvest size. Only a solitary individual Yellowtail Snapper (*Ocyurus chrysurus*) was observed at a legal harvest size on the Arcos boulders. For these snapper species (gray, lane, schoolmaster, and yellowtail), the majority of individuals observed were below the minimum size limit. A similar scenario was observed with the Hogfish (*L. maximus*)—only a few individuals were above the minimum size limit with the mean size falling below the legal harvest limits.

While conducting the fish surveys, no recreational fishing or scuba diving activities were observed. However, recreational and commercial fishing vessels have been observed at all five sites in the past as well as during this study period. Monofilament fishing line, anchor line, and anchors are frequently found at these sites. Mesh chum bags have also been found at the Golden Beach Site. At the Anchorage Boulder Reef and adjacent vessel artificial reefs, commercial charter boats have been observed trawling with outriggers. Commercial lobster traps and lines have also been found on and near the Port of Miami Boulders. Scuba diving activities have been reported on the Anchorage Boulder Reef and the Golden Beach Boulders. Free diving and spear fishing has also been reported on the Golden Beach Boulders. The extent of diving activities at the Arcos Boulders and the Port of Miami Boulder Piles and Rows is unknown. These fishing and diving activities may have influenced the size and quantity of the observed fish assemblages especially the game fish.

Benthic Assemblages. The baseline evaluation of the benthic assemblages showed that the boulder reefs supported a variety of benthic taxa and species (see Appendix 2). All sites were dominated by algae, in particular turf algae (Table 3 and 4). It should be noted that while a large percentage of the bottom has 'turf algae', the 'turf' is composed of fine filamentous red and occasionally green algae. The 'tuft' most often does not cover 100% of the bottom, rather is a more open matrix of filaments. The actual 'cover' within a turf community can range from 30 to 80% percent.

The second most abundant benthic component on four out of five boulder reefs was porifera. On POM Row, octocorallia was the second most abundant component as seen in Figure 12A. Scleractinian species were observed on all sites with the highest coverage on the two POM boulder reefs and the lowest coverage on the 2-year old Golden Beach site (Table 3 and Table 5). The Golden Beach site was unique in that it had 3.38% Ascidaria coverage which was not found at the other four sites (Figure 12B and Table 3). Overall, the POM Pile, POM Row, and the Golden Beach site had the highest diversity (H') as indicated in Figure 8. All sites had a low evenness measure (J') though due to the overwhelming abundance of turf algal cover.

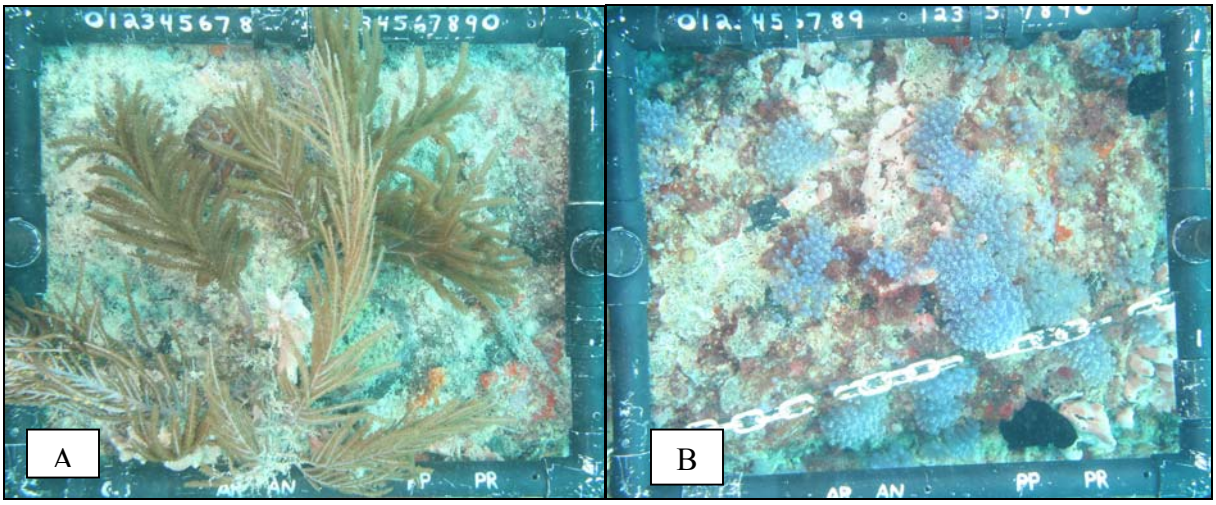

Figure 12. A) Quadrat photograph at POM Row showing the abundance of octocorallia (*Pseudopterogorgia* spp.); B) Quadrat photograph on the Golden Beach boulders showing the abundance of Ascidaria (*Clavelina* spp. and *Ascidia nigra*).

CONCLUSION

Documenting and quantifying the biological assemblages on limerock boulder reefs is an important step in understanding the role boulder reefs play in artificial reef management. This baseline study demonstrated that all five boulder reefs provide habitat that has supported abundant and diverse benthic and fish assemblages. However, each reef has varying characteristics from age, depth, relief, and location (Figure 1-2) and each reef exhibited some unique characteristics. Unique characteristics included the higher percent cover of octocorallia on the POM pile boulder reef than any of the other four sites and the lower fish diversity but high density of resident fish on the single Arcos boulder pile. The Golden Beach boulder reef also exhibited unique characteristics in its benthic assemblages as it continues to develop two years

after deployment. The oldest boulder reef, Anchorage, was unique in that it lacked significant octocorallia development. Although this study is not able to identify factors that may affect the erect octocoral presences, similar observations have been noted on artificial reef materials within the County. One common element with the sites is the lack of horizontal surfaces associated with the boulders, however, no detailed documentation or assessment of this or other potential factors has been conducted to date.

This report has provided a starting point for evaluating the effectiveness of these reefs in meeting the objectives for which they were constructed such as fisheries enhancement or habitat mitigation. For example, the POM pile and row boulders and the Arcos boulder site were constructed for the purpose of mitigation. To truly understand the extent to which the POM site has fulfilled this purpose, comparative evaluations of adjacent natural reefs would need to be conducted. The Golden Beach and the Anchorage boulder reefs were deployed to provide new habitat for the purpose of diving and recreational fishing. Continuing to monitor the development of the benthic assemblages and any subsequent changes in the fish assemblages would be beneficial in managing this site and planning for future sites. Reports providing information on the status of the biological assemblages on existing limerock boulder reefs is essential in evaluating the success of current projects, planning future projects, and determining where further research and monitoring efforts are needed.

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

		Anchorage 3 surveys/round			Arcos 1 survey/round			Golden Beach 3 surveys/round			POM Piles 6 surveys/round			POM Rows 6 surveys/round		
Resident Species	**Common Name**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Abudefduf saxatilis	Sergeant major	3	3	3				2 (1)	2 (1)	3	5 (1)	4 (1)	5 (1)	5	5 (1)	5 (1)
Acanthemblemaria aspera	Roughhead blenny										1					
Acanthostracion polygonia	Honeycomb cowfish										1 (1)					
Acanthostracion quadricornis	Scrawled cowfish			1					(1)		1 (1)	3 (2)	2 (2)	(2)	(1)	2 (1)
Acanthurus bahianus	Ocean surgeon	2	1 (1)	3	1	(1)	1	3	3	3	3 (1)	6	6	6	4 (1)	5 (1)
Acanthurus chirurgus	Doctorfish	(1)	1 (1)			1	1	1		(1)	5 (1)	5 (1)	3 (2)	3 (1)	3 (3)	2 (2)
Acanthurus coeruleus	Blue tang	2 (1)	2 (1)	2 (1)	(1)	1	1	1	3	3	4 (1)	3 (2)	6	4 (1)	6	6
Aluterus scriptus	Scrawled filefish	1 (1)				(1)		1			(1)	1 (1)	1 (2)	(1)	(1)	
Anisotremus surinamensis	Black margate									(1)			1	1		
Anisotremus virginicus	Porkfish	(3)	1 (1)	(2)	1	1	1	2 (1)	1	1 (1)	1 (1)	1 (2)	2	5 (1)	3 (2)	4 (1)
Apogon binotatus	Barred cardinalfish						(1)									
Aulostomus maculatus	Trumpetfish	1 (2)	1	1 (1)							3 (2)	1 (4)	2 (3)	3 (1)	2 (2)	1 (5)
Blenny species	Unidentified blenny											(1)				
Bodianus pulchellus	Spotfin hogfish				1					(1)			1 (1)			
Bodianus rufus	Spanish hogfish	1 (2)	3	1 (2)	1	1	1	3	3	2 (1)	2 (2)	2 (3)	3 (2)	4 (1)	(2)	2
Cantherhines pullus	Orangespotted filefish													(1)	1	(1)
Canthidermis sufflamen	Ocean trigger	(1)			(1)	(1)							(2)	(1)		
Canthigaster rostrata	Sharpnose puffer	3	3	3	1	1	1	3	3	2 (1)	5 (1)	5 (1)	6	6	6	5 (1)
Chaetodon capistratus	Foureye butterflyfish													1 (2)		1
Chaetodon ocellatus	Spotfin butterflyfish	(2)	2	1							2 (3)	3 (1)	2 (2)	1 (2)	1 (4)	2 (2)
Chaetodon sedentarius	Reef butterflyfish	1 (1)	1	1	(1)	(1)	(1)				1 (1)			3 (2)	(1)	(3)
Chaetodon striatus	Banded butterflyfish	1														
Chromis cyaneus	Blue chromis	1												1 (1)	1	
Chromis insolatus	Sunshinefish	(1)	2	(1)				1 (1)	1 (1)		(2)	(1)	(1)	1		(2)
Chromis multilineatus	Brown chromis	2 (1)	2	(1)	1	(1)		2	(3)	1	(2)	1	1 (1)	1 (1)		1 (1)
Chromis scotti	Purple reeffish	(1)	(1)	(1)	1	1	1	2	3	1 (1)	3	1 (3)	2 (1)	2	1	2
Coryphopterus glaucofraenum	Bridled goby							(1)		(1)		1 (2)		1		
Coryphopterus personatus	Masked goby	3	1 (1)	(1)	1	(1)	(1)	2 (1)	1 (1)	1 (1)	3 (2)	4 (2)	6	4 (1)	4 (2)	1
Cryptotomus roseus	Bluelip parrotfish				(1)											
Diodon holocanthus	Balloonfish			(1)					1							
Diodon hystrix	Porcupinefish														(1)	(1)

Appendix 1 (continued)

		Anchorage			Arcos			Golden Beach			POM Piles			POM Rows		
		3 surveys/round			1 survey/round			3 surveys/round			6 surveys/round			6 surveys/round		
Resident Species	**Common name**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Cephalopholis cruentatus	Graysby	1 (2)	1 (1)	1 (1)	1	(1)	(1)	1	(1)	(1)	1 (3)	(3)	3 (1)	2 (2)	1 (1)	1 (1)
Epinephelus guttatus	Red Hind		(1)										(1)			
Epinephelus itajara	Goliath Grouper									1						
Equetus acuminatus	Highhat	1	1												1	
Equetus lanceolatus	Jacknife-fish														1	
Gobiosoma oceanops	Neon goby							1 (1)		(2)			1			
Gymnothorax funebris	Green moray	1 (1)			1											
Gymnothorax miliaris	Goldentail moray								(1)							
Haemulon album	White Margate		1	1		(1)						(1)	(1)		1 (1)	1 (2)
Haemulon aurolineatum	Tomtate	3	3	3	1	1	1	3	3	3	6	6	5 (1)	6	6	6
Haemulon carbonarium	Caesar grunt		1 (1)						(1)			1	1 (1)			
Haemulon chrysargyreum	Smallmouth grunt	1	1	1	1		1			1						
Haemulon flavolineatum	French grunt	2	1	3	1		1	1 (1)	2	3	2 (3)	3 (2)	3	4 (2)	3 (2)	2
Haemulon parra	Sailor's Choice	1	1	2			(1)				(1)					
Haemulon plumieri	White grunt		(1)	2 (1)	1		1	1	1 (1)	2 (1)	2 (1)	3 (2)	2 (1)	3	2 (1)	1 (2)
Haemulon sciurus	Bluestriped grunt	3	3	3	1	1	1	3	3	3	3	4 (1)	3 (1)	5	5 (1)	6
Halichoeres bivittatus	Slippery dick		1			(1)		1		1 (1)	2 (1)	4 (1)	2 (1)	(2)	(1)	
Halichoeres garnoti	Yellowhead wrasse	2	1 (2)	1 (1)	1	(1)	(1)	3	3	2 (1)	4 (1)	4 (2)	5	4 (2)	4 (2)	3 (3)
Halichoeres maculipinna	Clown wrasse					(1)			3		3 (1)	1 (2)	1	(1)	(1)	(1)
Holacanthus bermudensis	Blue angelfish		(1)		(1)	(1)						1	(1)	1 (2)	1 (2)	1 (2)
Holacanthus ciliaris	Queen anglefish	(1)				1	1	1 (1)	2	2 (1)	1	1 (2)	1	2 (3)	1 (2)	4 (1)
Holacanthus tricolor	Rock beauty		(1)		1				(1)	1 (1)				(1)		(2)
Holocentrus adscensionis	Squirrelfish				1	1	(1)	1	(1)	1	(1)					(1)
Holocentrus rufus	Longspine squirrelfish						(1)								(1)	
Hypoplectrus cholorurus	Yellowtail hamlet								(1)							
Hypoplectrus gemma #	Blue hamlet							1	1		3	(1)	1 (1)	1 (3)	(2)	
Hypoplectrus nigrricans	Black hamlet							1	1		1 (1)	(1)	(1)			
Hypoplectrus puella #	Barred hamlet				(1)						1			(1)		
Hypoplectrus species	Unidentified hamlet														(1)	
Hypoplectrus species (Tan)	Unidentified hamlet (Tan)										(1)				(1)	
Hypoplectrus unicolor	Butter hamlet	3	2 (1)	(3)	1	1	(1)	3	3	(2)	5 (1)	3 (3)	4 (2)	5 (1)	2 (1)	2 (3)
Kyphosus sectarix	Bermuda chub		1 (1)	(2)									(1)	(1)	(1)	1 (1)
Labrisomus gobio	Palehead blenny									(1)						
Lachnolaimus maximus	Hogfish	(1)			(1)	1			2 (1)	1 (1)	3 (3)	1 (2)	1 (3)	3 (2)	(5)	3

Appendix 1 (continued)

		Anchorage 3 surveys/round			Arcos 1 survey/round			Golden Beach 3 surveys/round			POM Piles 6 surveys/round			POM Rows 6 surveys/round		
Resident Species	**Common name**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Lutjanus campechanus	Red snapper								1							
Lutjanus griseus	Gray snapper	(2)	(2)					2	3	3		(1)	1	2	3 (1)	3
Lutjanus jocu	Dog snapper								1						1	
Lutjanus mahogoni	Mahogany snapper											1				
Lutjanus synagris	Lane snapper	3	1	(1)	1	1	(1)	1 (1)			1	1	1 (2)	2 (1)	1 (2)	(1)
Malacoctenus triangulatus	Saddled blenny								(1)					(1)		
Microspathodon chrysurus	Yellowtail damsel							1		(1)						
Mycteroperca bonaci	Black grouper									1						
Mycteroperca microlepis	Gag							(1)	1 (1)	(1)						
Mycteroperca phenax	Scamp							(1)		1 (2)		1		1 (1)	2	1 (1)
Parablennius marmoreus	Seaweed blenny							1 (2)		1 (1)			(1)			
Pareques umbrosus	Cubbyu								(1)							
Pempheris schomburgki	Glassy sweeper														(1)	
Pomacanthus arcuatus	Gray angelfish	(2)	(1)	(2)				(1)	1	1 (1)	1 (2)	2 (2)	1 (1)	1 (3)	2 (1)	(3)
Pomacanthus paru	French angelfish	1 (1)		(1)			(1)	2		1	(1)	(2)	(3)	1 (4)	(2)	2 (1)
Pomacanthus planifrons	Threespot damselfish	(2)	(1)	(1)				(1)	(1)		1 (2)		1	1	1	1 (1)
Pomacentrus fuscus	Dusky damselfish		(1)	(1)					2 (1)		1 (2)	1 (3)	1 (2)	(1)	1 (2)	2 (3)
Pomacentrus leucostictus	Beaugregory	1	1 (2)		1	1		2	3	3	5	4 (1)	4 (2)	4 (2)	2	4 (2)
Pomacentrus partitus	Bicolor damselfish	3	3	3	1	(1)	1	3	3	3	6	6	5	6	6	5 (1)
Pomacentrus variabilis	Cocoa damselfish	(1)	(1)	(2)	1		1	1	(2)	2	1	2 (1)	2	1 (1)	2 (1)	(1)
Scarus guacamai	Rainbow Parrotfish										(2)	1	(2)	2	1	1
Scarus iserti	Striped parrotfish	(1)	1	3	1		1	(1)	2	2 (1)	5 (1)	4 (1)	4 (1)	4	2 (1)	3 (3)
Scarus taeniopterus	Princess parrotfish	1 (2)	1 (2)	2 (1)	1	1	1	2	1 (1)	1	4 (1)	5 (1)	3 (1)	5	3 (3)	4 (2)
Scorpaena plumieri	Scorpion fish	1						(1)	(1)	2		(1)		1		
Serranus baldwini	Lanternfish									1			1			
Serranus tigrinus	Harlequin bass							(1)								(1)
Sparisoma atomarium	Greenblotch parrotfish	1 (1)						(1)			1					
Sparisoma aurofrenatum	Redband parrotfish	2 (1)	3	3	1	1	1	2	3	3	4 (1)	5 (1)	5	6	5	5 (1)
Sparisoma chrysopterum	Redtail parrotfish	(1)		1								2	2 (1)	(1)	1 (2)	3 (2)
Sphoeroides spengleri	Bandtail puffer													1 (1)		(1)
Thalassoma bifasciatum	Bluehead	3	3	3	1	1	1	2 (1)	3	3	6	6	6	4	6	4 (2)

Appendix 1 (continued)

		Anchorage 3 surveys/round			Arcos 1 survey/round			Golden Beach 3 surveys/round			POM Piles 6 surveys/round			POM Rows 6 surveys/round		
Transient Species	**Common Name**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Dasyatis americana	Southern stingray													(1)		
Decapterus punctatus	Round scad	(1)						1 (1)								
Echeneis naucrates	Sharksucker								(1)							(1)
Mulloidichthys martinicus	Yellow goatfish	3	3	2 (1)		1	1	1	2 (1)	3	1 (1)	2 (1)	2	3 (1)	(2)	1 (2)
Pseudupeneus maculatus	Spotted goatfish	3	2	3	1	1	(1)	1	(3)	1 (2)	2 (1)	1 (3)	2 (4)	1 (2)	1 (2)	1 (3)
Seriola dumerili	Amberjack												(1)		1	
Seriola rivoliana	Almaco Jack							1								
Visitor Species																
Calamus bajonado	Jolthead Porgy											1				
Calamus calamus	Saucereye porgy													(1)		
Calamus species	Unidentified porgy															(1)
Caranx bartholomaei	Yellow jack									1						
Caranx crysos	Blue runner		(1)	(1)							1					
Caranx ruber	Bar jack	(1)	3	(1)	(1)			(1)	1 (1)		(3)	1 (2)	(2)	1 (3)	1 (2)	1
Caranx species	Unidentified jack							(1)				(1)		(1)		
Caranz hippos	Crevalle jack								(1)						(1)	
Clepticus parrai	Creole wrasse		1 (1)		1	(1)	1	(1)			1	1	1		1 (1)	2
Ginglymonstoma cirratum	Nurse Shark					1		1								
Lactophrys bicaudalis	Spotted trunkfish											(1)	1 (1)			
Lactophrys trigonus	Trunkfish											1 (1)	1		(1)	
Lactophrys triqueter	Smooth trunkfish			(1)				(1)	1		(1)				1	(2)
Lutjanus apodus	Schoolmaster											1 (2)	2 (2)	1	3	(2)
Ocyurus chrysurus	Yellowtail snapper				1					1	1 (2)	1 (1)		3 (2)	1 (1)	(2)
Rhinobatos lentiginosus	Atlantic guitarfish	(1)												(1)		
Scarus coelestinus	Midnight parrotfish			(1)										1		
Sparisoma rubripinne	Yellowtail parrotfish														1	
Sparisoma viride	Stoplight parrotfish	1	2 (1)	(1)	(1)	1		3	2	(2)	6	4 (2)	4 (1)	5 (1)	3 (2)	5 (1)
Synodus intermedius	Sand diver	2	1	2 (1)	1						(1)	1 (1)	2 (1)	1 (2)	(4)	(1)

Appendix 2. Relative percent (%) cover of benthic subcategories (species or lowest possible taxonomic group). Note that 28.8m^2 was surveyed at each site except Arcos. Due to the small reef size at Arcos, only 10.8m^2 was surveyed.

	Anchorage	Arcos	Golden Beach	POM Pile	POM Row
Scleractinia (stony coral)					
Agaricia agaricites	0.000	0.000	0.000	0.000	0.076
Agaricia species	0.037	0.213	0.000	0.000	0.000
Colpophyllia natans	0.000	0.000	0.000	0.114	0.038
Diploria labyrinthiformis	0.000	0.000	0.000	0.076	0.152
Diploria strigosa	0.000	0.000	0.000	0.038	0.114
Eusmilia fastigiata	0.000	0.213	0.000	0.038	0.038
Favia fragum	0.000	0.000	0.000	0.076	0.000
Madracis decactis	0.184	0.000	0.000	0.000	0.038
Meandrina meandrites	0.037	0.000	0.000	0.000	0.114
Montastraea annularis	0.000	0.000	0.000	0.038	0.000
Montastraea cavernosa	0.000	0.000	0.000	0.000	0.076
Mycetophyllia aliciae	0.000	0.000	0.000	0.000	0.038
Porites astreoides	0.625	0.106	0.039	2.622	2.894
Porites porites	0.000	0.000	0.000	0.038	0.038
Siderastrea siderea	0.147	0.638	0.000	0.228	0.152
Stephanocoenia michelinii	0.110	0.106	0.000	0.304	0.267
Octocorallia (soft coral)					
Briareum asbestinum	0.000	0.000	0.000	0.000	0.038
Eunicea species	0.000	0.000	0.000	0.304	0.343
Gorgonia ventalina	0.000	0.000	0.000	0.532	0.038
Gorgonian (unidentified)	0.000	0.000	0.000	0.342	1.333
Muricea species	0.000	0.000	0.000	0.038	0.000
Plexaura flexuosa	0.000	0.000	0.000	0.152	0.000
Pseudoplexuara species	0.000	0.000	0.000	0.532	0.724
Pseudopterogorgia species	0.000	0.213	0.000	2.888	9.254
Pterogorgia guadalupensis	0.000	0.000	0.000	0.038	0.000
Porifera (sponges)					
Agelas conifera	0.037	0.000	0.000	0.000	0.000
Amphimedon compressa	0.000	0.000	0.000	0.038	0.000
Anthosigmella varians	0.037	0.000	0.000	0.000	0.000
Aplysina cauliformis	0.184	0.000	0.000	0.038	0.000
Aplysina fistularis	0.074	0.000	0.000	0.038	0.076
Callyspongia plicifera	0.147	0.106	0.000	0.114	0.000
Callyspongia vaginallis	0.515	0.106	0.000	0.000	0.114
Clathria species	0.000	0.213	0.039	0.000	0.000
Cliona delitrix	0.588	0.000	0.000	0.380	0.152
Cliona species	0.441	0.106	0.432	0.152	0.190
Dictyonella ruetzleri	0.147	0.531	0.039	0.038	0.038
Diplastrella megastllata	0.147	2.869	2.199	0.190	0.152
Diplastrella species	1.140	1.063	0.707	1.254	0.267
Dysidea species	0.000	0.000	0.236	0.038	0.000
Dysidea species-tube growth	0.000	0.000	0.118	0.076	0.000
Haliscara speices	0.147	0.319	0.079	0.038	0.114
Holopsamma helwigi	3.125	4.463	5.143	2.470	0.800

Appendix 2 (continued)

	Anchorage	Arcos	Golden Beach	POM Pile	POM Row
Porifera (sponges) continued					
Iotrochota birotulata	2.353	0.000	0.039	2.014	0.267
Ircinia species	0.074	0.000	0.000	0.494	0.381
Ircinia campana	0.551	0.000	0.000	0.456	0.114
Ircinia felix	0.221	0.106	0.000	0.494	0.228
Ircinia strobilina	0.257	0.000	0.000	0.228	0.152
Monanchora barbadensis	0.331	0.956	0.118	0.304	0.381
Monanchora unguifera	0.221	0.638	0.118	0.076	0.000
Mycale laevis	0.037	0.000	0.039	0.190	0.152
Niphates amorpha	0.110	0.000	0.000	0.000	0.000
Niphates digitalis	0.221	0.425	0.000	0.152	0.114
Niphates erecta	0.404	0.000	0.000	0.076	0.038
Sponge (unidentified)	0.882	1.382	1.296	0.950	1.295
Strongylacidon species	0.037	0.744	0.079	0.190	0.114
Millepioridae (firecoral)					
Millipora alcicornis	0.147	1.169	0.236	0.380	0.381
Millipora species	0.000	0.000	0.000	0.038	0.000
Zoanthidae (zoanthids)					
Zoantus pulchellus	0.000	0.000	0.000	0.038	0.038
Ascidarian (tunicates)					
Ascidia nigra	0.000	0.000	0.314	0.000	0.038
Ascidian (unidentifed)	0.000	0.000	0.510	0.000	0.000
Clavelina species	0.000	0.000	2.473	0.000	0.000
Didemnum species	0.000	0.000	0.079	0.000	0.000
Polycarpa spongiabilis	0.000	0.000	0.000	0.000	0.076
Stolonicus sabulosa	0.000	0.213	0.000	0.000	0.000
Other Live					
Bryozoan (encrusting species)	0.000	0.000	0.039	0.000	0.000
Hydroid species	0.625	0.531	0.039	0.494	0.228
Algae					
Blue-green algae	0.000	0.531	0.039	1.292	0.647
Coralline algae	0.331	1.488	0.000	0.798	0.724
Dictyota species	0.000	0.000	0.039	0.038	0.038
Macroalgae (unidentifed spp.)	0.000	0.000	0.000	0.076	0.267
Peysonnelia species	0.662	2.763	2.238	2.926	3.732
Red filamentous algae	0.000	0.000	0.118	0.000	0.000
Turf (unidentified spp.)	83.676	77.790	59.246	74.734	71.097
Udotea species	0.000	0.000	0.157	0.000	0.000
Wranelia argus	0.000	0.000	22.301	0.038	0.038
Substrate					
Sediment covered substrate	0.993	0.000	1.453	0.266	1.790