Martin County Artificial Reef Program
2015 Monitoring Report

Report Date: September 2016

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1.0 INTRODUCTION

The Martin County Artificial Reef Program has actively developed and managed the deployment of over 70 artificial reef structures since program establishment in 1972. There are currently four permitted offshore artificial reef areas (Donaldson, Sirotkin, Ernst, and South County) located within water depths of 50 to 200 ft (15 to 60 m). Each permitted artificial reef area contains multiple deployments of materials including bridge rubble, steel barges, prefabricated reef modules, concrete railroad ties, and large steel vessels such as the U.S.S. Rankin. In addition, nearshore and estuarine reefs have been deployed. The goals of the program are outlined in the 2013 Martin County Artificial Reef Management Plan developed in accordance with the guidelines presented in the State of Florida Artificial Reef Strategic Plan (FFWCC, 2003).

This report presents the results of the 2015 annual monitoring of the offshore artificial reef structures deployed under the Martin County Artificial Reef Program in 2013 (second year monitoring) and 2014 (first year monitoring). During the spring and summer of 2013, five artificial reefs, consisting primarily of concrete scrap materials, were deployed within the Donaldson artificial reef area. The Donaldson Reef contains numerous previous deployments and supports easily accessible dive sites and popular bottom fishing locations. In July and August 2014, six artificial reef structures were deployed within the South County artificial reef area. The South County artificial reef is located to enhance demersal fish populations offshore of Martin County; these reefs are not as easily accessible to anglers as the other three artificial reef areas in the county. The locations of the Donaldson and South County artificial reef sites and deployments surveyed in 2015 are shown in **Figure 1.**

The fish survey methodology presented in this report differs from that previously used on Martin County artificial reefs. Previously, a roving diver census was used following the methods outlined by the Reef Environmental Education Foundation (REEF). In order to obtain more quantifiable data on fish abundance, a modified point count method (Bohnsack and Bannerot 1986, Brandt et al. 2009) similar to that used by the regional multi-agency Reef Visual Census (RVC) was conducted. By using comparable survey methods, artificial reef data can be quantitatively compared to data collected annually by the RVC southeast Florida fisheries-independent monitoring program. Benthic data collected on the artificial reefs have previously been qualitative with presence/absence of certain organisms noted. During the current study, a quantitative method was used to estimate percent cover of benthic functional groups.

In addition to the permit-required monitoring conducted on artificial reefs deployed within the past two years, additional surveys were completed on older artificial reef deployments and on natural reef habitat located within the South County area in order to provide comparisons between density and diversity of reef fish and benthic community based on reef age and distance to natural hardbottom. The results of this study will begin to address whether the artificial reef deployments in Martin County are achieving their goal of fishery enhancement and/or increased recruitment. The location of the South County artificial reef deployments within the limits of recreational diving and in close proximity to natural reef habitat (**Figure 1**) presents a unique opportunity to monitor the development of the fish and benthic community at both the artificial reef deployments and the nearby natural reef. Due to the numerous differences between the Donaldson and South County reef sites (different water depths, deployment ages, distance to natural reefs, number of adjacent artificial reefs, and fishing pressure), the 2015 survey results at the two areas are not directly compared in this report.

The objectives of the 2015 surveys were to determine if differences in the fish and benthic community exist between the following groups:

1. Old and new artificial reef deployments within the Donaldson and South County artificial reef area.
2. Natural and artificial reefs within the South County artificial reef area.

2.0 METHODS

2.1 Survey Locations

Locations of sites surveyed in 2015 are shown in **Figure 1**. Surveys focused on the 2006 and 2013 Donaldson area deployments and the 2008 and 2014 South County area deployments.

2.1.1 Donaldson Artificial Reef Area

The Donaldson Reef Site is located about 3.2 nmi (6 km) northeast of the St. Lucie Inlet and lies partially within state waters. The site is approximately 4 mi^2 (10 km^2) in area and has a depth range of 40 to 70 ft (12 to 21 m). Materials were first deployed at this site in the early 1970s. The PCL Shallow Reef was deployed in the northeast corner of the Donaldson Reef area in the winter of 2006 at 62 ft (19 m) depth. The footprint of the site is larger than other deployments in this study, covering over one acre of seafloor (approximately 48,000 ft^2 or 4,459 m^2). Materials at this site consist of approximately 2,800 tons of concrete and steel bridge scrap.

The five artificial reef structures deployed in 2013 within the Donaldson site are located in federal waters along the eastern portion of the area in depths ranging from 55 to 60 ft. Each structure consists of between 493 and 700 tons of concrete rubble including culverts, boxes, columns, bridge pilings, and other concrete bridge scrap. Due to the much lower amount of material used in construction, the 2013 Donaldson deployments do not occupy as large of an area as the PCL Shallow site. The relative locations of the sites within the Donaldson area are shown in **Figure 2**.

2.1.2 South County Artificial and Natural Reef Area

The South County site is close to the southern boundary of Martin County and is 4 mi^2 (10 km^2) in area; depths range from 55 to 120 feet (17 to 37 m). This site is located approximately 7.5 nmi (14 km) southwest of the St. Lucie Inlet and is half way between the St. Lucie and Jupiter Inlets. This site was developed as a fisheries enhancement site for Martin County reef fish populations, specifically for demersal reef fish species that are obligate hardbottom larval settlers (Hesperides Group, 2013). According to the Martin County Artificial Reef Plan, the goal of this site is to recruit larval and juvenile demersal fishes such as grouper and snapper. Numerous patch reefs are to be deployed in this reef area, spaced at a minimum of 738 feet (225 m) apart. This distance is based on previous studies that have shown that a larger isolation distance diminishes competition between resident reef fish that shelter in the artificial structure but forage in nearby sand flats (Frazer and Lindberg 1994, Lindberg 1996). The location of the artificial reef deployments within the South County area and proximity to the natural hardbottom are shown in **Figure 3**.

A set of six artificial reef structures were deployed in the South County area in June 2008 in 68 to 70 ft (20 to 21 m) water depth in the southwestern corner of the South County artificial reef area. The 2008 deployments were the first set of deployments within this area. The primary building material used at these sites was concrete culvert pieces, deck sections, and concrete slabs. Each reef consists of between 240 and 272 tons of material and covers approximately 0.4

acres (17,500 ft^2 or 1600 m^2) of seafloor. Each of the six reefs was named in honor of the primary donor. The closest natural hardbottom habitat is a narrow ridge that lies approximately 1,260 ft (385 m) to the west of the artificial reef deployments (**Figure 3**)

An additional group of six artificial reef structures was deployed in July and August of 2014 to the east (3 sites) and west (3 sites) of the natural hardbottom ridge that runs through the central portion of the South County area. Water depth in the area during deployment was measured as 72 ft (22 m); however, diver observations during the 2015 study recorded depths of 88 ft (27 m) on the eastern side of the deployments. The primary building material consisted of concrete culverts, slabs, and cylinders. The natural hardbottom ridge that runs from north to south through the deployment area is classified as “Natural Ridge – Deep” habitat according to the Florida Fish and Wildlife Conservation Commission (FFWCC) Unified Reef Tract Map. The ridge is located 650 ft (200 m) to the east of Sites 8 and 9, and 590 ft (180 m) west of Sites 10 and 12 (**Figure 3**). Site 11 was misplaced during deployment and is located approximately 1,968 ft (600 m) to the east of the natural reef.

2.2 Experimental Design

A stratified sampling design was used to sample the fish and benthic community at 20 locations within the Donaldson and South County artificial reef sites. Treatment groups were assigned based on reef type (artificial or natural) and age of the structure. The “New” age class was assigned to recent deployments from 2013 and 2014. The “Old” age class was assigned to deployments from 2006 and 2008. The sampling structure within each treatment group, the location of each site, and the sample date are shown in **Table 1**. The intended sampling strategy was to conduct 6 fish surveys and sample a minimum of 20 quadrats within each Type-Age treatment group; however, sea conditions and visibility restricted sampling within the Artificial-Old treatment group at the Donaldson site and the Natural-Natural group at the South County site. Overall, a total of 25 point count fish surveys were completed and 88 benthic quadrats (0.5 m^2) were sampled. In order to achieve the proper number of replicates for fish surveys, several locations were sampled multiple times if the area was large enough to avoid sample overlap. These locations are indicated in **Table 1** by a value in parenthesis, indicating the number of fish surveys completed at the location.

Table 1. Survey locations, sample date, bottom temperature, and designated Type-Age treatment group.

SITE	Type - Age (Treatment)	Fish Survey N	Benthic Quadrat N	Patch Name	Latitude (DD)	Longitude (DD)	Sample Date	Bottom Temp (°F)
Donaldson	Artificial - New	6	22	Donaldson North	27.20934	-80.09234	7/23/15	72
				Donaldson East	27.20877	-80.09127	8/11/15	74
				Donaldson South	27.20793	-80.09255	8/11/15	76
				Donaldson West (2x)	27.20858	-80.09337	8/11/15	76
				BJM13	27.20735	-80.09379	11/8/2015	80
	Old	3	10	PCL Shallow (3x)	27.21744	-80.09572	7/22 & 7/23/15	68
South County	Artificial - New	6	22	Site 7	27.08650	-80.03397	8/10/2015	76
				Site 8	27.08860	-80.03447	8/10/2015	75
				Site 9	27.09095	-80.03473	8/10/2015	76
				Site 10	27.08654	-80.02845	8/10/2015	76
				Site 11	27.08661	-80.02398	8/10/2015	77
				Site 12	27.08868	-80.02900	8/10/2015	74
	Artificial - Old	6	21	The Heap	27.08144	-80.04050	11/8/2015	80
				Jack MacDonald	27.08140	-80.03855	8/10/2015	75
				Lentine	27.07946	-80.04041	11/8/2015	80
				Fogel Capital	27.07954	-80.03829	11/8/2015	80
				Shirley Reef	27.07770	-80.04067	11/8/2015	81
				Ann Marie	27.07761	-80.03832	11/8/2015	82
	Natural - Natural	4	13	Natural Center (2x)	27.08832	-80.03149	11/8/2015	80
				Natural North (2x)	27.09346	-80.03299	11/8/2015	81

The July 2015 surveys were conducted during a period of upwelling that created bottom temperatures that were colder than expected (**Table 1**). Bottom temperatures at the PCL Shallow site were 68°F (20°C), and bottom temperature at Donaldson North was 72°F (22°C) while surface temperatures were 85°F (29°C) at both sites. Numerous Atlantic black sea hares (*Aplysia morio*) were sighted during the July 2015 surveys. Many sea hares were dying and also observed washing up on Martin County shorelines during this time. The upwelling seemed to decrease in intensity by the time of the August surveys; mean bottom temperature recorded during August was 75°F (24°C). Bottom temperatures during the final survey on November 8 had increased to a mean of 80°F (27°C).

Figure 1
Martin County Artificial Reef
2015 Survey Locations

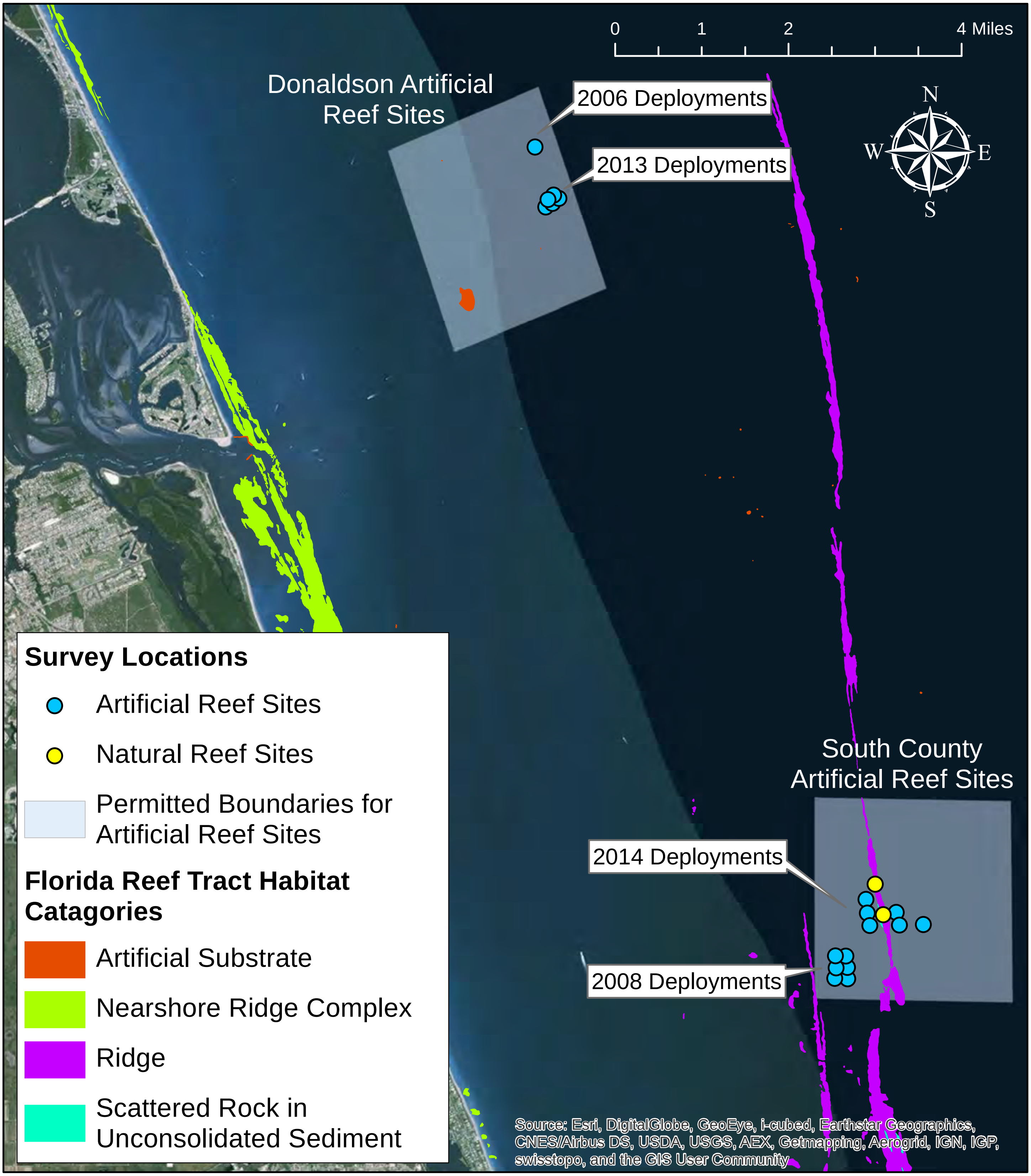

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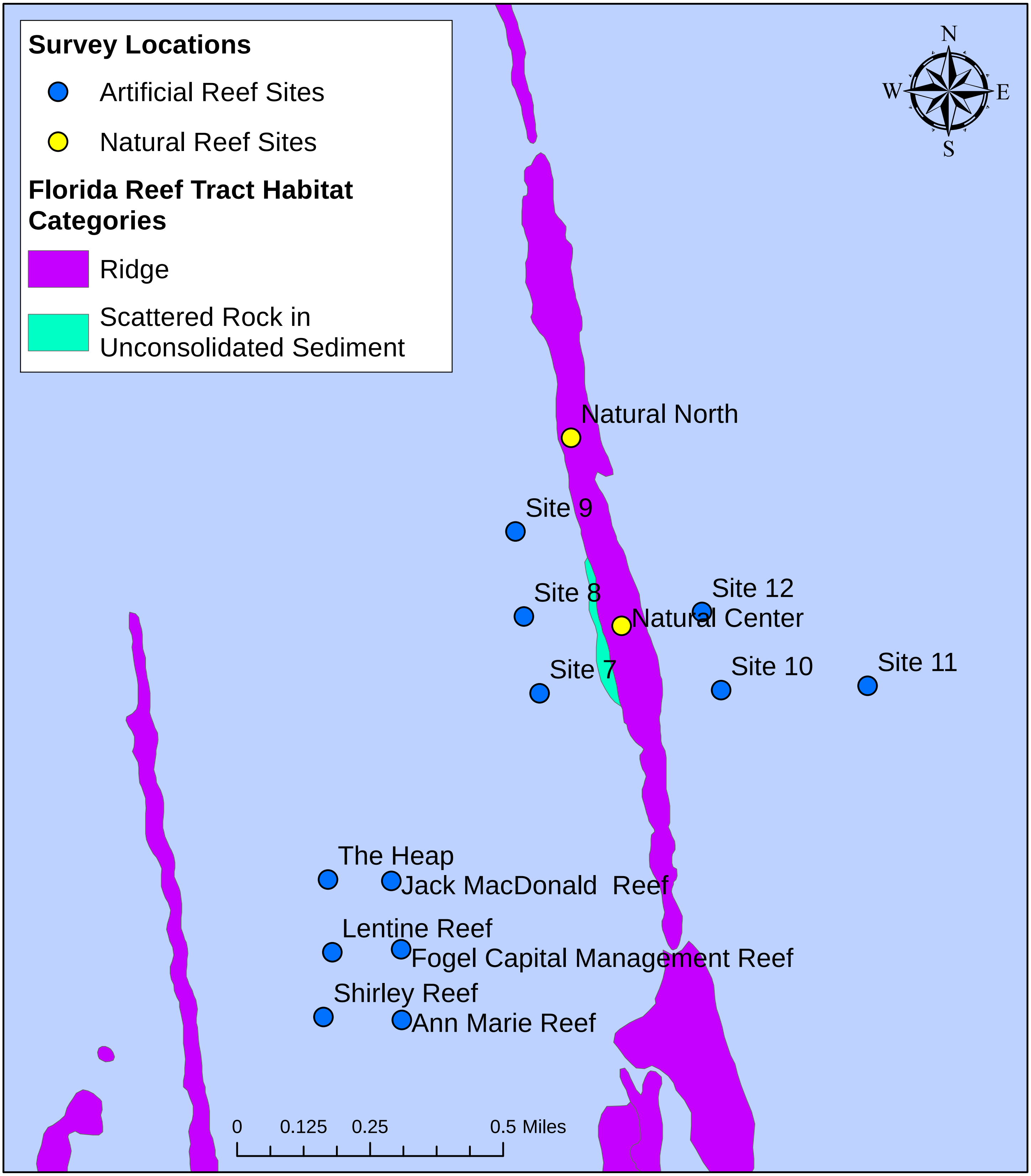
Figure 2
Donaldson Artificial Reef Site
2015 Survey Locations

Figure 3
South County Artificial Reef Site
2015 Survey Locations



2.3 Fish Surveys

2.3.1 Field Methods

Fish survey methods were based on the stationary point count method outlined in Bohnsack and Bannerot (1986) and Brandt et al. (2009). Modifications to these methods were made in order to account for the complexity of the artificial reef habitat and lowered visibility on some field days. The method and modifications are summarized here.

During the fish surveys, an imaginary cylinder extending from the seafloor to the vertical limit of visibility with a diameter of 15 m was assessed by the diver. In the standard Bohnsack-Bannerot (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 entirely stationary during the survey. Divers recorded the start time of the sample on the datasheet, and proceeded to record all species observed within the first five minutes while rotating their position. Due to the complex nature of the habitat, divers were allowed to move slowly around the cylinder in order to view obstructed areas of the cylinder. Extensive searching of cavities or overhangs was not done during this period.

After five minutes had elapsed, abundance of each species was recorded along with the mean, minimum and maximum fork lengths ("Avg", "Min" and "Max"). Concurrent with the species enumeration and length estimation, new species that were observed after the initial five-minute observation period and until completion of all data collection were also recorded, along with estimates of their abundance and minimum, mean, and maximum lengths. These species are noted as having been observed "Between 5 and 10 minutes" or "After 10 minutes", depending on the time elapsed at time of observation. During the survey, the final five minutes was used to search for new cryptic species located under overhangs or within cavities in the reef structure. Divers were equipped with 1 m measuring sticks fitted with a 40 cm cross piece at one end, demarcated in 10-cm increments, to aid in both distance and fish size estimations.

2.3.2 Data Analysis

Due to the high density of species such as juvenile *Haemulon* sp. and small *Stegastes* sp. at some sites, frequently numbering in the hundreds or thousands per survey, accurate identification of every individual was not practical or time-effective considering the dive depth and limited bottom time at most locations. Although individuals were recorded to the species level wherever possible, multivariate analyses were conducted on combined genus data rather than individual species during data processing in order to account for possible misidentified abundant groups and to minimize surveyor bias. Individual species within the same genus often play a similar ecological role.

Taxonomic richness values were calculated at the species level with a few exceptions. Juvenile grunts (*Haemulon* sp.) were not considered a separate species if adult *Haemulon* sp. were recorded at the same site. Species lists were carefully reviewed by the surveyors in order to provide quality control for differences in identification between the two surveyors. As a result, abundance of several species was combined under a genus designation in order to account for possible surveyor differences and uncertainty in identification of highly similar species. The pygmy and planehead filefish, *Stephanolepis setifer* and *S. hispidus,* were combined into *Stephanolepis* sp*.* The mackerel and round scad (*Decapterus macarellus* and *D. punctatus*) were combined into *Decapterus* sp. Saucereye and sheepshead porgy (*Calamus calamus* and *C. penna*) were combined into *Calamus* sp. The surveyors believe that no other species within the above genera were observed; however, surveyors could not guarantee accuracy to the species level within these genera, especially under turbid conditions. Each of these genera is considered only once in species richness calculations.

The feeding guild of each species was determined based on the majority diet of the adult size class of each species through information available in published articles and on Fishbase (Froese and Pauly 2016). “Invertivores” were defined as those that fed primarily on benthic invertebrates whereas “Planktivore” was defined as those that fed primarily on planktonic invertebrates and eggs. “Piscivore” was defined as a species that preys primarily on finfish and “Herbivore” was defined as those that prey primarily on benthic algae.

The abundance of each genus was first square root transformed to reduce the influence of common genera. Transformed abundance values were then converted into resemblance matrices using Bray-Curtis similarity and visually examined as non-metric multi-dimensional scaling (nMDS) plots using PRIMER-e (Clarke & Warwick 2001, Clarke & Gorley 2006). The similarity profile (SIMPROF) procedure was used to determine if there was significant structure within the data potentially caused by factors other than the pre-determined treatment groups. The contribution of individual genera to the separation of clusters established using SIMPROF were determined using the similarity percentages (SIMPER) routine. This routine indicates which species were principally responsible for the groupings. The categorical variable of reef age (new, old, natural) was examined using analysis of similarities (ANOSIM).

2.4 Benthic Quadrat Assessments

2.4.1 Field Methods

Benthic community monitoring was conducted using the Benthic Ecological Assessment for Marginal Reefs (BEAMR) method (Makowski et al. 2009). The BEAMR protocol evaluates physical habitat characteristics, percent cover of benthic functional groups, and stony coral and octocoral density. Visual estimates of planar percent cover are determined for 18 functional groups including sediment, bare hard substrate, macroalgae, turf algae, cyanobacteria, encrusting red algae, sponge, hydroid, octocoral, stony corals, tunicates, anemone, *Millepora* sp., sessile worm, worm rock, bivalve, bryozoan, zoanthid, and seagrass. Each functional group is assigned a percent cover ranging from 0% to 100%, and total functional group cover must equal 100%. If a functional group is present within a quadrat, it is assigned a minimum value of 1% cover. A 0.5 m^2 (0.7 m x 0.7 m) quadrat was used.

Under standard BEAMR protocol, maximum relief and maximum sediment depth measurements (to the nearest centimeter) are recorded within each quadrat. On the artificial reefs, sediment depth was generally zero, and vertical relief from the bottom (position of the quadrat to the sand) was recorded. All quadrats were sampled on horizontal or angular faces with upward exposure, avoiding overhangs and downward facing surfaces in order to sample a consistent habitat.

Common macroalgae were identified to genus level if present at 1% cover or greater within an individual quadrat, and assigned an individual percent cover. Octocorals and stony corals within quadrats were measured for a maximum height or diameter to the nearest centimeter. Octocorals were identified to genus level, and stony corals were identified to species level. Stony corals measuring less than 1 cm in diameter were recorded as 1 cm.

2.4.2 Data Analysis

Percent cover data were first tested for normality using Shapiro-Wilk tests. Group variances were then tested using a Brown-Forsythe test. Comparisons of the percent cover of each functional group between two treatments were conducted using t-tests for independent samples on normally distributed data; the Welch's t-test was used for groups with unequal variance. If data was not normally distributed, both the parametric t-tests and non-parametric Mann-Whitney U test were performed. In all cases, non-parametric results matched the parametric values, and the assumption violation was deemed to be non-significant; parametric results are reported as stated above.

3.0 RESULTS

3.1 Donaldson Artificial Reef Area

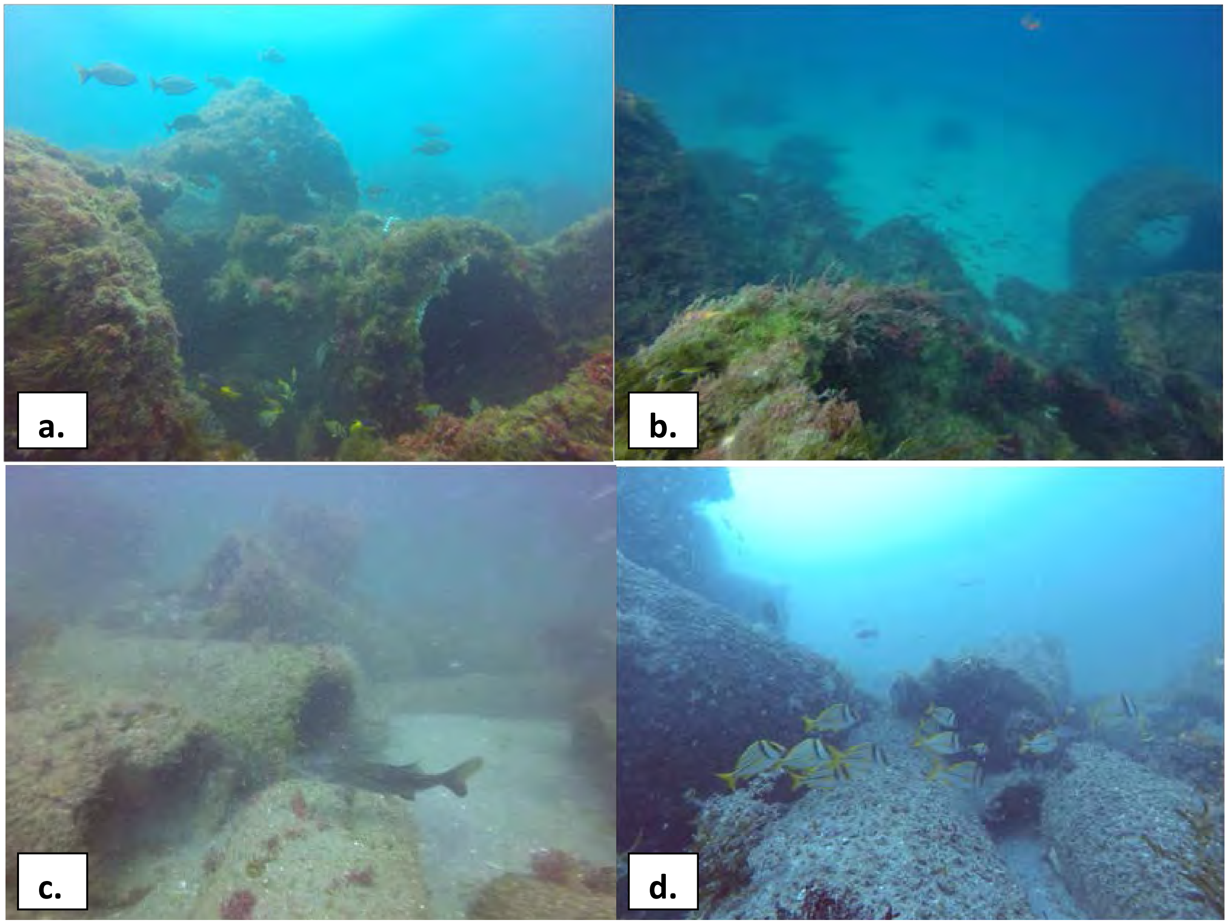
3.1.1 Structural Summary

The minimum depth (top of reef), maximum depth (to the sand), and maximum structural relief recorded at each Donaldson artificial reef site immediately after deployment and during the 2015 surveys is shown in **Table 2**. The artificial reefs deployed in 2013 consist of varying quantities of concrete culverts, boxes, columns, slabs, bridge pilings and railings. A selection of images of the 2013 Donaldson area deployments taken in 2015 are shown in **Photos 1a through 1d** and **Appendix B**. The material is generally consolidated in several layers in the central portion of the structure with lower relief, single-layer material along the perimeter and individual pieces of scattered material on the surrounding seafloor. The maximum relief of the central portion ranges from 11 to 16 feet with numerous crevices, caves and other areas for sheltering. Several culvert pieces were observed to be standing upright and may possibly settle or fall over time.

Both the Donaldson East and BJM13 site consist primarily of material other than culverts; therefore, these two sites have a somewhat different visual appearance. BJM13 was constructed with bridge pilings, railings, piling footers, and deck sections as the primary building material (versus culverts and boxes). Many of the materials at the BJM13 site are elongated and have landed parallel to one another, giving the uppermost surface of the artificial reef a relatively flat horizontal structure with numerous crevices and horizontal overhangs (**Photo 2**). In contrast, the concrete columns that were the primary building material at Donaldson East have mostly landed at angles to one another (**Photo 3**). Additional photographs from each of the sites are presented in **Appendix B.**

Table 2. Minimum depth, maximum depth, and maximum relief of the Donaldson deployments immediately after deployment and during the 2015 surveys.

Area	Deploy Year	Name	2015 Min Depth	2015 Max Depth	2015 Max Relief	Deploy Min Depth	Deploy Max Depth	Deploy Max Relief	Other Relief Measures
Donaldson	2013	Donaldson North	45	56	11	40	53	13	
		Donaldson East	41	55	14	42	53	11	
		Donaldson South	41	57	16	43	50	7	
		Donaldson West	43	58	15	44	53	9	
		BJM13	44	58	14	43	61	18	
	2006	PCL Shallow	45	59	14	43	62	19	18 ft (2009)



Photos 1a-d. Photographs of the overall structure of the 2013 Donaldson area deployments. a & b.) Donaldson North, taken July 23, 2015; c.) Donaldson West, taken August 11, 2015; d.) Donaldson South, taken August 11, 2015.

Photo 2. Uppermost surface at the BJM13 site (2013 Donaldson deployment) showing general horizontal structure (top) and parallel materials forming overhangs (bottom). Photo taken November 20, 2015.

Photo 3. Concrete columns at the Donaldson East site (2013 deployment) that settled in a cross-wise fashion. Photo taken August 11, 2015.

3.1.2 Fish

A total of 84 fish species from 30 different families were recorded during 9 fish surveys in the Donaldson artificial reef area. The mean and relative abundance of each species observed on the new (2013) and old (2006) Donaldson deployments are shown in **Table 3** along with the overall mean abundance in each artificial reef age class (old and new). The new Donaldson deployments had greater mean abundance (# of fish per survey) and overall species richness than the old deployment (PCL Shallow). The difference in abundance was largely attributed to the very high density of juvenile grunts observed at the new Donaldson deployments. The majority of grunts observed at the site were juvenile tomtate (*Haemulon aurolineatum*). It is important to note that during the survey of site BJM13, conducted in November, no juvenile grunts were recorded, and all grunts had reached a larger size class and were found in lower abundance. This indicates that the summer surveys likely captured a large recruitment event to the artificial reefs. Abundance of fish species at each survey location is provided in **Appendix A**.

Other than *Haemulon* sp., the most abundant fish at the Donaldson sites were small reef-associated species including beaugregory and cocoa damselfish (*Stegastes leucostictus* and *S. variabilis*), bluehead wrasse (*Thalassoma bifasciatum*), seaweed blenny, saddled blenny, and yellowtail reeffish. The number of species recorded, abundance, and Shannon diversity index for each survey are shown in **Table 4**. Mean species richness at the new deployments was 38 species (± 2 SE), and mean species richness at the old deployment was 30 species (± 3 SE). This difference was not significant (*t*-test, p=0.111). The Shannon diversity index provides a measure of the diversity of the community accounting for both the number of species observed and the abundance of each species. Diversity indices at the old deployment were generally higher than those at the new deployments. The site with the greatest species richness (Donaldson North, 45 species) had the lowest diversity index of 0.57. This results from the overwhelming abundance of *Haemulon* sp. at the new deployments, resulting in a high overall abundance but lower community diversity. Juvenile *Haemulon* sp. made up 77.6% of the population at the new deployments, but only 36.4% of the community at the old deployment.

A total of 25 managed species were observed on the Donaldson artificial reef sites; 24 species on the new deployments and 12 species on the old deployment (**Table 5**). It is expected that fewer species would be found on the older deployment due to half the number of surveys being conducted (6 on the new deployments versus 3 on the old deployment). However, species that were observed on 50% or more of the surveys at the new deployments that were not observed on the older deployment were snook (*Centropomus undecimalis*), lane snapper (*Lutjanus synagris*), vermillion snapper (*Rhomboplites aurorubens*), and scamp (*Mycteroperca phenax*), suggesting that these species may have been more common on the new deployments. The managed species found in the highest frequency were tomtate (*H. aurolineatum*), almaco jack (*Seriola rivoliana*), sheepshead (*Archosargus probatocephalus*), greater amberjack (*Seriola dumerili*), blue runner (*Caranx crysos*), and gray snapper (*Lutjanus griseus*). A total of 20 species in the Snapper Grouper Complex, managed by the South Atlantic Fisheries Management Council (SAFMC), were found in surveys at the Donaldson sites. The goliath grouper (*Epinephelus itajara*) was found in similar abundance (**Table 3**) and the same frequency of occurrence (**Table 5**) on old and new deployments.

Table 3. Mean (± SE) and relative abundance of fish species observed on the old and new artificial reef deployments within the Donaldson artificial reef area. RA= Relative abundance.

Family	Latin Name	Common Name	Feeding Guild	NEW (2013)		OLD (2006)	
				Abundance (Mean ± SE)	RA (%)	Abundance (Mean ± SE)	RA (%)
Acanthuridae	*Acanthurus bahianus*	Ocean surgeon	Herbivore	0.5 ± 0.5	0.01	1.7 ± 1.7	0.10
	Acanthurus chirurgus	Doctorfish	Herbivore	7.0 ± 3.1	0.18	4.3 ± 3.8	0.26
	Acanthurus coeruleus	Blue tang	Herbivore	0.5 ± 0.5	0.01		
Apogonidae	*Apogon pseudomaculatus*	Twospot cardinalfish	Invertivore	0.8 ± 0.8	0.02	17.7 ± 7.4	1.06
Balistidae	*Balistes capriscus*	Gray triggerfish	Invertivore	0.5 ± 0.5	0.01		
Blenniidae	*Parablennius marmoreus*	Seaweed blenny	Herbivore	150.2 ± 74.1	3.89	28.3 ± 15.9	1.70
Carangidae	*Carangoides ruber*	Bar jack	Piscivore	1.0 ± 1.0	0.03		
	Caranx crysos	Blue Runner	Piscivore	27.0 ± 8.2	0.70	15.3 ± 14.8	0.92
	Decapterus sp.	Mackerel/Round scad	Planktivore	12.5 ± 12.5	0.32		
	Seriola dumerili	Greater amberjack	Piscivore	1.3 ± 0.9	0.03	6.7 ± 2.7	0.40
	Seriola rivoliana	Almaco Jack	Piscivore	6.3 ± 1.9	0.16	4.3 ± 1.5	0.26
Centropomidae	*Centropomus undecimalis*	Common snook	Piscivore	5.8 ± 1.2	0.15		
Chaetodontidae	*Chaetodon ocellatus*	Spotfin butterflyfish	Invertivore	0.7 ± 0.4	0.02	0.7 ± 0.7	0.04
	Chaetodon sedentarius	Reef butterflyfish	Invertivore	1.7 ± 0.4	0.04	1.3 ± 0.7	0.08
Dasyatidae	*Dasyatis centroura*	Roughtail stingray	Invertivore	0.2 ± 0.2	<0.01		
Ephippidae	*Chaetodipterus faber*	Atlantic spadefish	Invertivore	0.5 ± 0.3	0.01	3.3 ± 3.3	0.20
Ginglymostomatidae	*Ginglymostoma cirratum*	Nurse shark	Invertivore	0.2 ± 0.2	<0.01		
Gobiidae	*Coryphopterus dicrus*	Colon goby	Herbivore	0.2 ± 0.2	<0.01	0.7 ± 0.7	0.04
	Coryphopterus glaucofraenum	Bridled goby	Herbivore	1.8 ± 1.3	0.05	3.3 ± 3.3	0.20
	Gnatholepis thompsoni	Goldspot goby	Invertivore			1.0 ± 1.0	0.06
Haemulidae	*Anisotremus surinamensis*	Black margate	Invertivore	0.8 ± 0.3	0.02	0.7 ± 0.7	0.04
	Anisotremus virginicus	Porkfish	Invertivore	17.8 ± 2.7	0.46	5.3 ± 2.4	0.32
	Haemulon aurolineatum	Tomtate	Invertivore	168.3 ± 26.6	4.36	158.3 ± 43.2	9.48
	Haemulon flavolineatum	French grunt	Invertivore	0.2 ± 0.2	<0.01		
	Haemulon macrostomum	Spanish grunt	Invertivore	0.2 ± 0.2	<0.01	8.3 ± 8.3	0.50
	Haemulon parra	Sailor's choice	Invertivore	0.2 ± 0.2	<0.01		
	Haemulon plumierii	White grunt	Invertivore	2.7 ± 0.6	0.07	4.0 ± 4.0	0.24
	Haemulon spp.	Juvenile grunts	Invertivore	3000.0 ± 930.9	77.63	608.3 ± 260.8	36.42
Kyphosidae	*Kyphosus sectatrix*	Chub	Herbivore	4.0 ± 3.0	0.10		

Table 3. continued. Mean (± SE) and relative abundance of fish species observed on the old and new artificial reef deployments within the Donaldson artificial reef area. RA= Relative abundance.

				NEW (2013)		OLD (2006)	
Family	**Latin Name**	**Common Name**	**Feeding Guild**	**Abundance (Mean ± SE)**	**RA (%)**	**Abundance (Mean ± SE)**	**RA (%)**
Labridae	*Bodianus rufus*	Spanish hogfish	Invertivore	1.8 ± 0.5	0.05	5.3 ± 3.5	0.32
	Halichoeres bivittatus	Slippery dick	Invertivore	32.5 ± 18.0	0.84	25.0 ± 12.6	1.50
	Halichoeres garnoti	Yellowhead wrasse	Invertivore	3.0 ± 2.0	0.08	14.0 ± 6.0	0.84
	Halichoeres maculipinna	Clown wrasse	Invertivore	0.3 ± 0.3	0.01	16.7 ± 12.0	1.00
	Halichoeres radiatus	Puddingwife	Invertivore	0.5 ± 0.2	0.01	0.3 ± 0.3	0.02
	Thalassoma bifasciatum	Bluehead wrasse	Invertivore	47.8 ± 14.3	1.24	104.0 ± 73.8	6.23
Labrisomidae	*Labrisomus nuchipinnis*	Hairy blenny	Invertivore	0.8 ± 0.8	0.02	50.0 ± 50.0	2.99
	Malacoctenus triangulatus	Saddled blenny	Invertivore	99.7 ± 58.8	2.58	35.7 ± 23.1	2.14
Lutjanidae	*Lutjanus buccanella*	Blackfin snapper	Piscivore	0.3 ± 0.3	0.01		
	Lutjanus griseus	Gray snapper	Piscivore	12.3 ± 3.5	0.32	2.7 ± 1.3	0.16
	Lutjanus jocu	Dog snapper	Piscivore			0.3 ± 0.3	0.02
	Lutjanus synagris	Lane snapper	Piscivore	3.7 ± 2.0	0.09		
	Ocyurus chrysurus	Yellowtail snapper	Piscivore	0.5 ± 0.3	0.01		
	Rhomboplites aurorubens	Vermillion Snapper	Piscivore	0.7 ± 0.3	0.02		
Monacanthidae	*Cantherhines macrocerus*	Whitespotted filefish	Invertivore	2.5 ± 2.5	0.06		
	Cantherhines pullus	Orangespotted filefish	Invertivore	0.7 ± 0.4	0.02		
	Stephanolepis sp.	Planehead/Pygmy filefish	Invertivore	0.3 ± 0.2	0.01		
Muraenidae	*Gymnothorax moringa*	Spotted moray	Piscivore			0.3 ± 0.3	0.02
Ogocephalidae	*Ogcocephalus nasutus*	Shortnose Batfish	Invertivore	0.2 ± 0.2	<0.01		
Pomacanthidae	*Holacanthus bermudensis*	Blue angelfish	Invertivore	0.7 ± 0.2	0.02		
	Holacanthus ciliaris	Queen angelfish	Invertivore	0.2 ± 0.2	<0.01		
	Holacanthus tricolor	Rock beauty	Invertivore	0.2 ± 0.2	<0.01		
	Abudefduf saxatilis	Sergeant major	Herbivore	2.7 ± 1.1	0.07	1.0 ± 0.6	0.06
Pomacentridae	*Chromis enchrysura*	Yellowtail reeffish	Planktivore	58.3 ± 32.7	1.51	190.0 ± 117.9	11.37
	Chromis insolata	Sunshinefish	Planktivore	0.3 ± 0.3	0.01		
	Chromis scotti	Purple reeffish	Planktivore	11.7 ± 7.5	0.30		
	Stegastes diencaeus	Longfin damselfish	Herbivore	0.5 ± 0.5	0.01	33.7 ± 33.2	2.02
	Stegastes leucostictus	Beaugregory	Herbivore	49.2 ± 27.0	1.27	146.7 ± 127.2	8.78
	Stegastes partitus	Bicolor damselfish	Herbivore	22.5 ± 15.9	0.58		
	Stegastes variabilis	Cocoa damslefish	Herbivore	24.8 ± 15.6	0.64	138.0 ± 131.0	8.26

Table 3. continued. Mean (± SE) and relative abundance of fish species observed on the old and new artificial reef deployments within the Donaldson artificial reef area. RA= Relative abundance.

Family	Latin Name	Common Name	Feeding Guild	NEW (2013)		OLD (2006)	
				Abundance (Mean ± SE)	RA (%)	Abundance (Mean ± SE)	RA (%)
Priacanthidae	*Heteropriacanthus cruentatus*	Glasseye	Invertivore	0.5 ± 0.2	0.01		
Rachycentridae	*Rachycentron canadum*	Cobia	Invertivore	0.2 ± 0.2	<0.01	0.3 ± 0.3	0.02
Scaridae	*Cryptotomus roseus*	Bluelip parrotfish	Herbivore	6.7 ± 3.3	0.17	7.3 ± 2.3	0.44
	Sparisoma atomarium	Greenblotch parrotfish	Herbivore	14.5 ± 4.6	0.38	1.7 ± 1.7	0.10
	Sparisoma aurofrenatum	Redband parrotfish	Herbivore	0.7 ± 0.3	0.02	0.7 ± 0.3	0.04
Sciaenidae	*Pareques acuminatus*	Highhat	Invertivore			0.7 ± 0.7	0.04
	Pareques umbrosus	Cubbyu	Invertivore	4.0 ± 2.1	0.10		
Scorpaenidae	*Pterois* spp.	Lionfish species	Piscivore	2.2 ± 0.7	0.06		
	Scorpaena plumieri	Spotted scorpionfish	Invertivore	0.3 ± 0.2	0.01	0.7 ± 0.3	0.04
Serranidae	*Centropristis striata*	Black Sea Bass	Invertivore	0.8 ± 0.5	0.02		
	Cephalopholis cruentata	Graysby	Piscivore	0.2 ± 0.2	<0.01		
	Epinephelus itajara	Goliath grouper	Invertivore	1.0 ± 0.4	0.03	0.7 ± 0.3	0.04
	Epinephelus morio	Red Grouper	Piscivore	0.2 ± 0.2	<0.01		
	Hypoplectrus spp.	Hamlet juvenile	Invertivore	0.2 ± 0.2	<0.01		
	Mycteroperca phenax	Scamp	Piscivore	1.2 ± 0.5	0.03		
	Serranus baldwini	Lantern bass	Invertivore	0.3 ± 0.3	0.01		
	Serranus phoebe	Tattler bass	Invertivore	0.2 ± 0.2	<0.01		
	Serranus subligarius	Belted sandfish	Invertivore	7.2 ± 3.6	0.19	10.7 ± 7.2	0.64
	Serranus tortugarum	Chalk bass	Planktivore	0.3 ± 0.3	0.01		
Sparidae	*Archosargus probatocephalus*	Sheepshead	Invertivore	4.7 ± 1.3	0.12	1.3 ± 0.9	0.08
	Calamus spp.	Saucereye/Sheepshead porgy	Invertivore	3.3 ± 1.4	0.09	3.3 ± 2.3	0.20
Synodontidae	Synodus intermedius	Sand diver	Piscivore	0.2 ± 0.2	<0.01		
Tetraodontidae	*Canthigaster rostrata*	Sharpnose puffer	Invertivore	17.2 ± 9.4	0.44	5.7 ± 2.9	0.34
	Sphoeroides spengleri	Bandtail puffer	Invertivore	7.2 ± 4.6	0.19		
	Sphoeroides testudineus	Checkered puffer	Invertivore	0.2 ± 0.2	<0.01		
MEAN ABUNDANCE (± SE)				**3864.7 ± 1078.6**		**1670.3 ± 746.8**	
OVERALL SPECIES RICHNESS				**80**		**45**	

Table 4. Species richness, abundance, and Shannon diversity index at each site within the Donaldson artificial reef area.

AGE CLASS	SITE NAME	Species Richness (S)	Abundance (N)	Shannon Diversity (H')
New (2013)	Donaldson East	43	6183	0.95
	Donaldson North	46	5845	0.74
	Donaldson South	43	6528	1.10
	Donaldson West	35	2646	1.15
	Donaldson West (2)	39	1511	1.63
	BJM13*	29	475	2.09
Old (2006)	PCL Shallow	30	2985	2.37
	PCL Shallow (2)	25	399	2.25
	PCL Shallow (3)	37	1627	1.60

Table 5. Frequency of occurrence (% of surveys in which species occurred) of each managed fish species within the Donaldson artificial reef area.

Family	Latin Name	Common Name	Frequency of Occurrence	
			NEW	OLD
Balistidae	*Balistes capriscus*	Gray triggerfish	16.7	-
Carangidae	*Carangoides ruber*	Bar jack	16.7	-
	Caranx crysos	Blue Runner	83.3	66.7
	Seriola dumerili	Greater amberjack	33.3	100.0
	Seriola rivoliana	Almaco Jack	100.0	100.0
Centropomidae	*Centropomus undecimalis*	Common snook	83.3	-
Ephippidae	*Chaetodipterus faber*	Atlantic spadefish	33.3	33.3
Ginglymostomatidae	*Ginglymostoma cirratum*	Nurse shark	16.7	-
Haemulidae	*Haemulon aurolineatum*	Tomtate	100.0	100.0
	Haemulon parra	Sailor's choice	16.7	-
	Haemulon plumierii	White grunt	100.0	33.3
Lutjanidae	*Lutjanus buccanella*	Blackfin snapper	16.7	-
	Lutjanus griseus	Gray snapper	83.3	66.7
	Lutjanus jocu	Dog snapper	-	33.3
	Lutjanus synagris	Lane snapper	50.0	-
	Ocyurus chrysurus	Yellowtail snapper	33.3	-
	Rhomboplites aurorubens	Vermillion Snapper	50.0	-
Rachycentridae	*Rachycentron canadum*	Cobia	16.7	33.3
Serranidae	*Centropristis striata*	Black Sea Bass	33.3	-
	Cephalopholis cruentata	Graysby	16.7	-
	Epinephelus itajara	Goliath grouper	66.7	66.7
	Epinephelus morio	Red Grouper	16.7	-
	Mycteroperca phenax	Scamp	66.7	-
Sparidae	*Archosargus probatocephalus*	Sheepshead	100.0	66.7
	Calamus spp.	Saucereye/Sheepshead porgy	83.3	100.0

The fish community at both the new and old deployments was dominated by invertivores (**Figure 4**). There was larger portion of herbivores on the old (2006) artificial reefs than on the new deployments (22.0% compared to 7.4%). This difference was driven primarily by the abundance of small damselfish in the genus *Stegastes* on the old deployments. The invertivores on the new deployments was dominated mainly by small grunts (*Haemulon* spp.), mostly tomtate (*H. aurolineatum*). The presence or absence of piscivores can significantly affect the fish community on both artificial and natural reefs. At the new deployments, piscivores made up 1.6% of the total abundance, and at the old deployments, piscivores made up 1.8% of the fish by abundance.

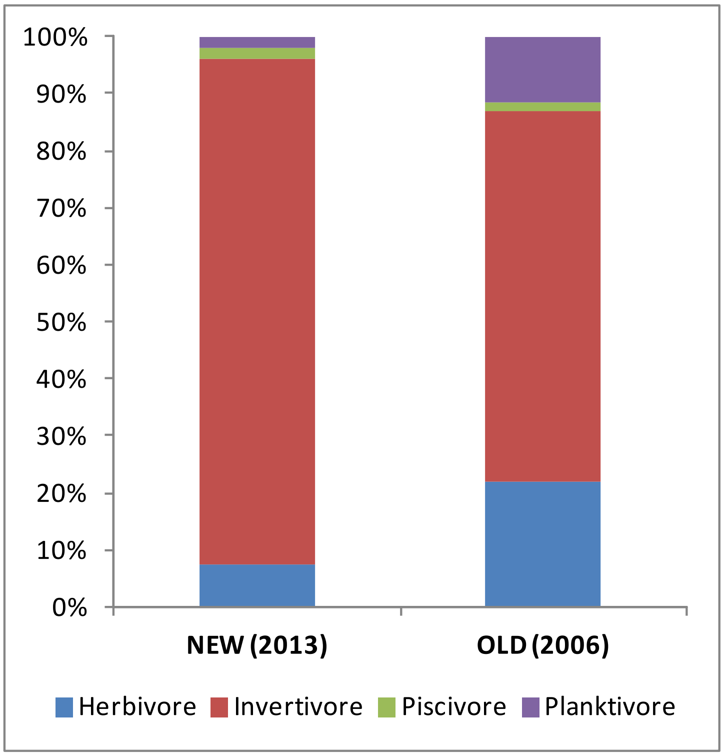


Figure 4. Percent of the fish community (by abundance) consisting of herbivores, invertivores, piscivores, and planktivores at the new (2013) and old (2006) Donaldson deployments.

When analyzed using multivariate analysis, there was no distinct separation in the structure of the fish community between the new deployments and the old deployment. Analysis of similarities (ANOSIM) using deployment age as a factor (old vs. new) showed there was no significant difference in the fish community between the new and old artificial reef deployments (Global R=0.321, p=0.107). SIMPROF analysis divided the community into three significant clusters, shown in **Figure 5** (Clusters A – C). SIMPER analysis showed that these clusters were separated by varying abundance of the genera *Haemulon* (grunts), *Stegastes* (damselfish), *Chromis* (damselfish/chromis), *Malacoctenus* (blennies), and *Labrisomus* (blennies). The surveys conducted at the PCL Shallow site were highly separated from each other. Surveyors observed a patchy distribution of fish within the PCL Shallow site, which is larger in size than the new deployments (over 1 acre vs. 0.4 acres). Some sites at PCL Shallow with a high cover and tall canopy of *Sargassum* sp. macroalgae (i.e. PCL Shallow 1) supported extremely dense populations of juvenile grunts (*Haemulon* sp.), juvenile damselfish (*Stegastes* sp.), juvenile chromis (*Chromis* sp.), and blennies (*Malacoctenus*, *Parablennius*, and *Labrisomus* sp.).

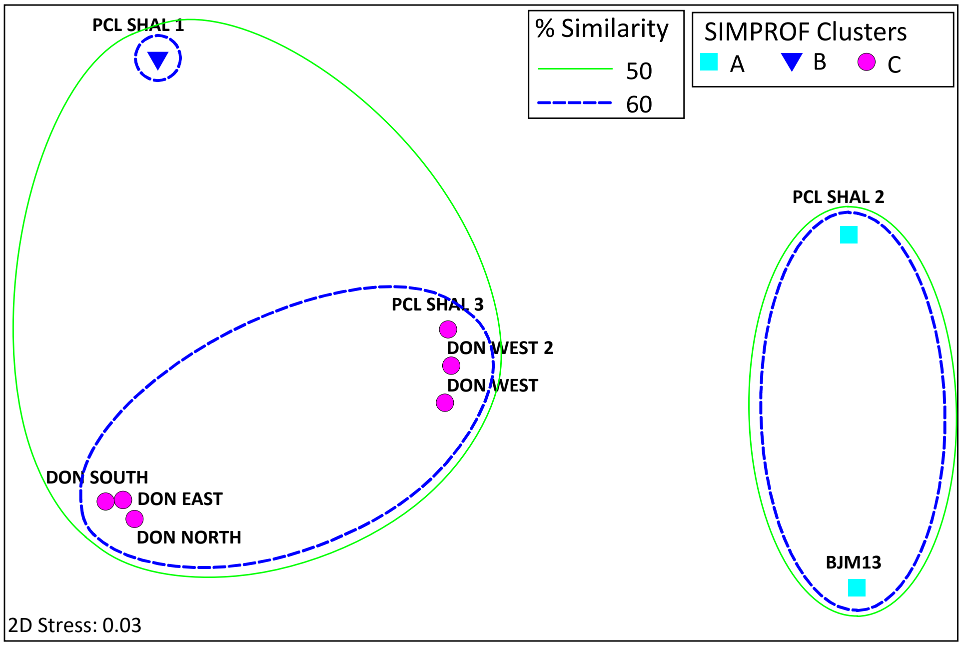


Figure 5. MDS plot of the fish community at the sites within the Donaldson reef area overlaid with significant clusters determined by SIMPROF analysis.

3.1.3 Benthic Community

The benthic community at the Donaldson artificial reef sites was dominated by macroalgae and turf algae. The most abundant benthic invertebrate groups were sponges, hydroids, bryozoans, and tunicates (**Figure 6**). Despite the difference in sample size, there was generally a similar level of variance in the cover of benthic functional groups within the different deployment age groups. There were no significant differences in the percent cover of any of the benthic functional groups between the old (2006) and new (2013) Donaldson deployments (*t*-test; $p>0.05$ for all).

The dominant macroalgae genera observed at the new and old Donaldson deployments are shown in **Table 6**. The macroalgal community at the 2013 Donaldson deployments was dominated by the genera *Caulerpa*, *Sargassum*, and *Gracilaria*. A lush canopy of macroalgae was observed at Donaldson North, Donaldson South, and PCL Shallow during the July and August surveys (**Photos 4** and **5**). The dominant macroalgal genera at the older deployment (PCL Shallow) were somewhat different than the newer (2014) deployments. *Sargassum*, *Gracilari*a, and *Dictyota* dominated the PCL Shallow site whereas *Caulerpa* had the highest cover at the newer Donaldson deployments. The algal genera *Botryocladia* and *Dictyopteris* were common on the new deployments, but were only present in low cover at PCL Shallow. Multiple *Gracilaria* species were present, but *Gracilaria mammalaris* was the most abundant. Although *Caulerpa racemosa* was the most abundant, the invasive species *Caulerpa brachypus* was also observed at the new Donaldson deployments (**Photo 6**).

Two octocoral genera were observed on the Donaldson artificial reefs deployed in 2014, *Carijoa* and *Leptogorgia* (**Photo 7**). Octocorals were observed only at BJM13 and Donaldson East. Although only a single *Leptogorgia* was observed in quadrats, several dense patches were observed on the artificial structure at BJM13 (**Photo 7**). No octocorals were observed at the PCL Shallow site. Several small stony coral colonies were also recorded at the BJM site; two small *Oculina diffusa* were recorded within quadrats and a *Siderastrea* sp. recruit was observed outside the quadrats (**Photo7**). A single *Siderastrea* sp. recruit was observed at PCL Shallow. A summary of the octocoral and stony coral species observed in surveys at the Donaldson sites is shown in **Table 7**.

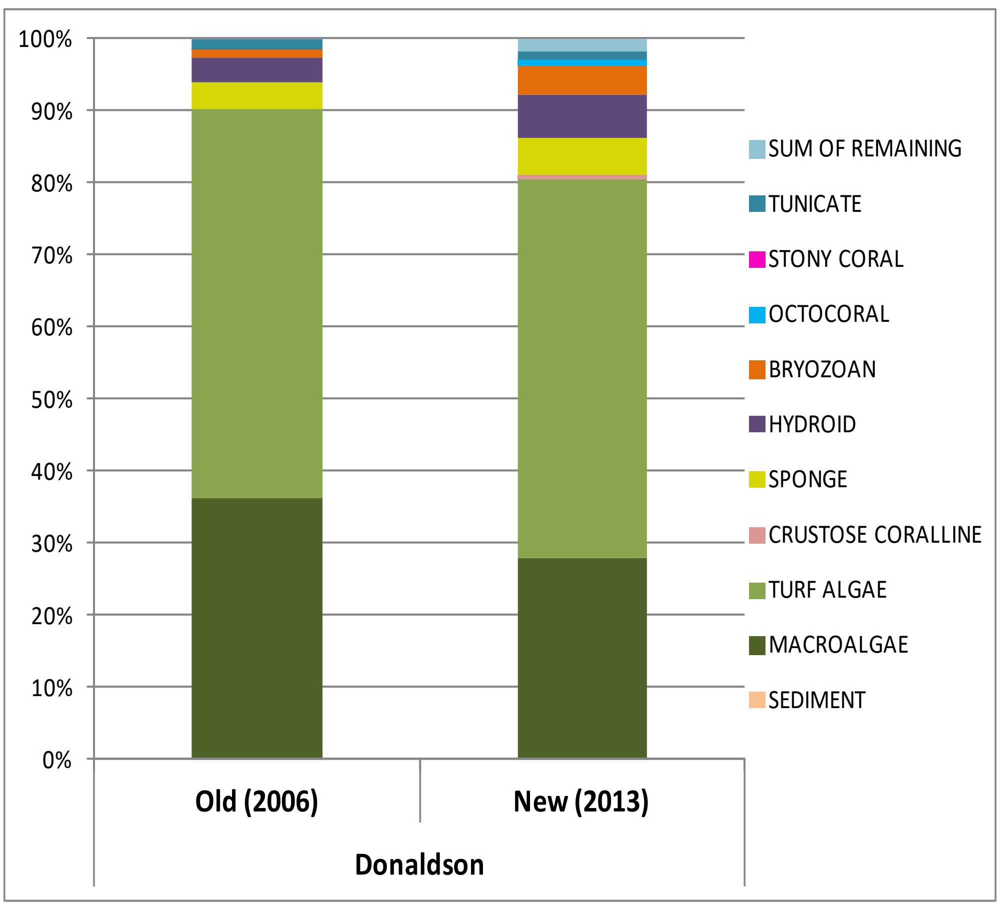


Figure 6. Percent cover of each benthic functional groups at the old and new Donaldson deployments. N=22 for new deployments and N=10 for old deployments.

Table 6. Percent cover of common macroalgae genus (only genera occurring at ≥ 1% cover in a single quadrat).

Macroalgae Cover (Mean ± SE)		
Genus	**NEW (2014)**	**OLD (2006)**
Botryocladia	1.1 ± 0.4	
Bryothamnion	0.2 ± 0.1	
Caulerpa	7.3 ± 2.9	0.6 ± 0.3
Chaetomorpha		0.1 ± 0.1
Codium	0.9 ± 0.3	0.4 ± 0.2
Dictyopteris	0.6 ± 0.2	
Dictyota	1.9 ± 0.6	4.2 ± 1.5
Gelidiella	0.7 ± 0.3	0.4 ± 0.4
Gracilaria	3.8 ± 0.8	11.0 ± 1.7
Hypnea	1.7 ± 0.9	3.8 ± 1.9
Jania	1.0 ± 0.4	1.3 ± 0.9
Kallymenia		0.1 ± 0.1
Laurencia		0.1 ± 0.1
Lobophora	0.5 ± 0.2	
Rhodymenia	0.1 ± 0.1	
Sargassum	4.0 ± 1.4	13.6 ± 2.7
Spyridia	0.1 ± 0.1	

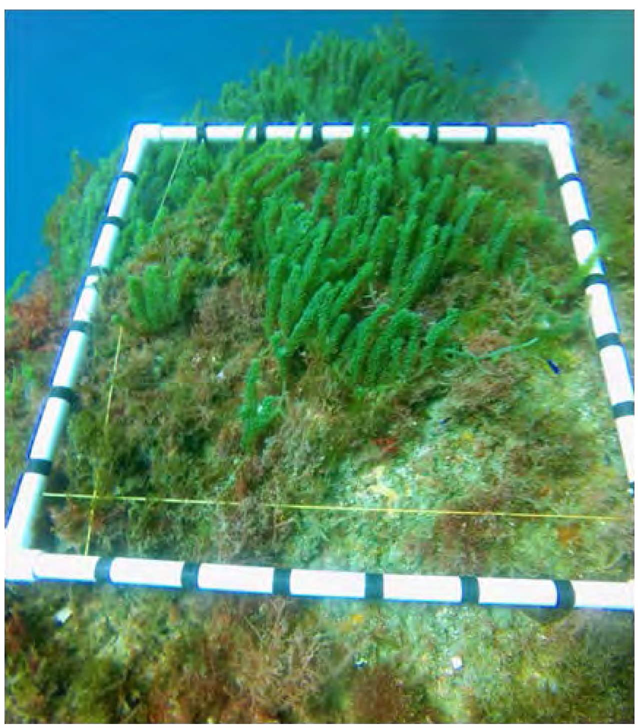


Photo 4. High percent cover of *Caulerpa racemosa* at Donaldson North. Photo taken on July 23, 2015.

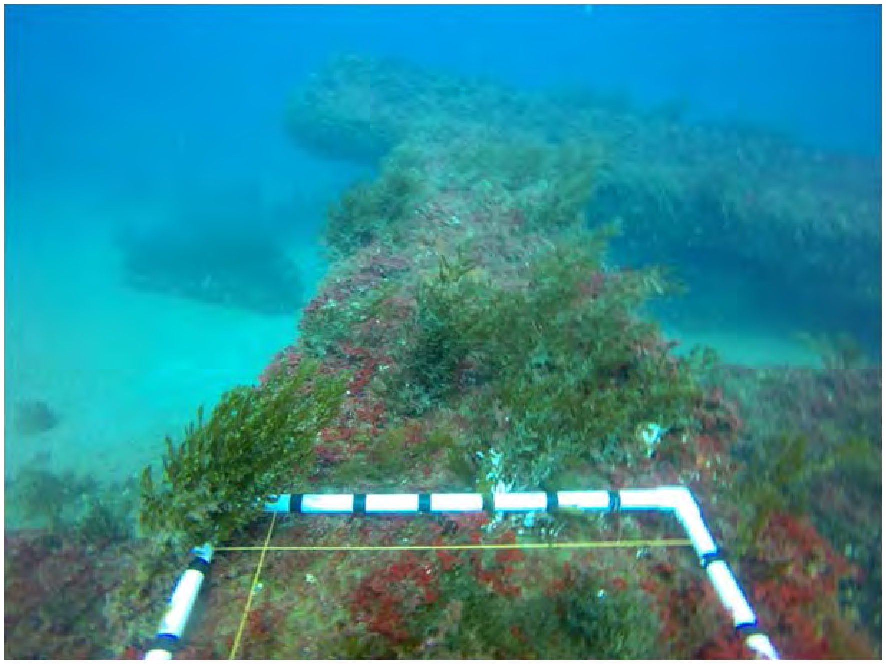


Photo 5. High percent cover of *Sargassum* sp. at PCL Shallow. Photo taken on July 23, 2015.

Photo 6. *Caulerpa brachypus* at the Donaldson East reef. Photo taken on August 11, 2015.

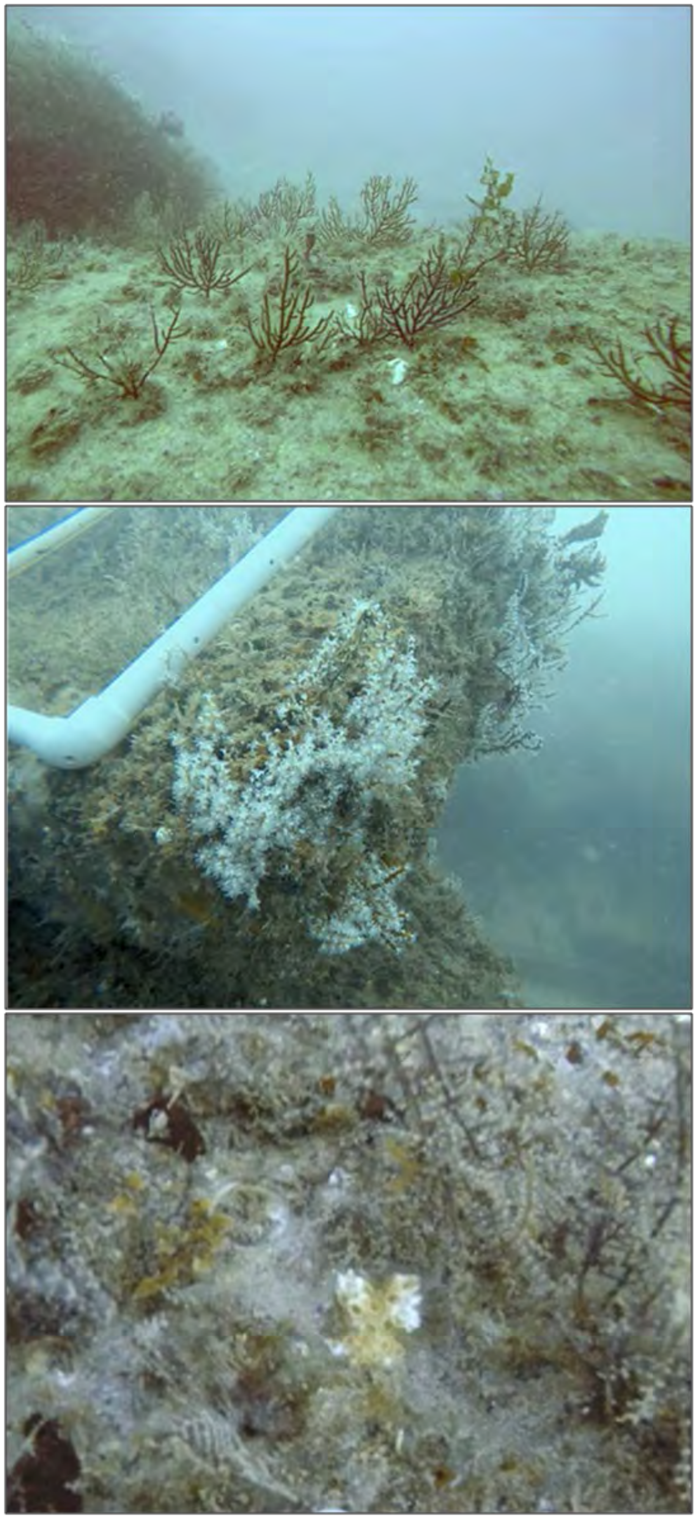


Photo 7. *Leptogorgia* sp. (top), *Carijoa riseii* (center), and *Oculina diffusa* (bottom) on the BJM13 artificial reef deployed in the Donaldson area in 2013. Photos taken November 20, 2015.

Table 7. Octocoral and stony coral abundance and density at Donaldson reef area sites where these taxonomic groups occurred.

Octocoral Genus	**BJM13**	**DON EAST**
Carijoa	2	2
Leptogorgia	1	
Total # Observed	3	2
Area Sampled (m^2)	1.5	2.0
Density (#/m^2)	2.0	1.0

Stony Coral Species	**BJM13**	**PCL SHALLOW**
Oculina diffusa	2	
Siderastrea cf. *siderea*		1
Total # Observed	2	1
Area Sampled (m^2)	1.5	5.0
Density (#/m^2)	1.3	0.2

3.2 South County

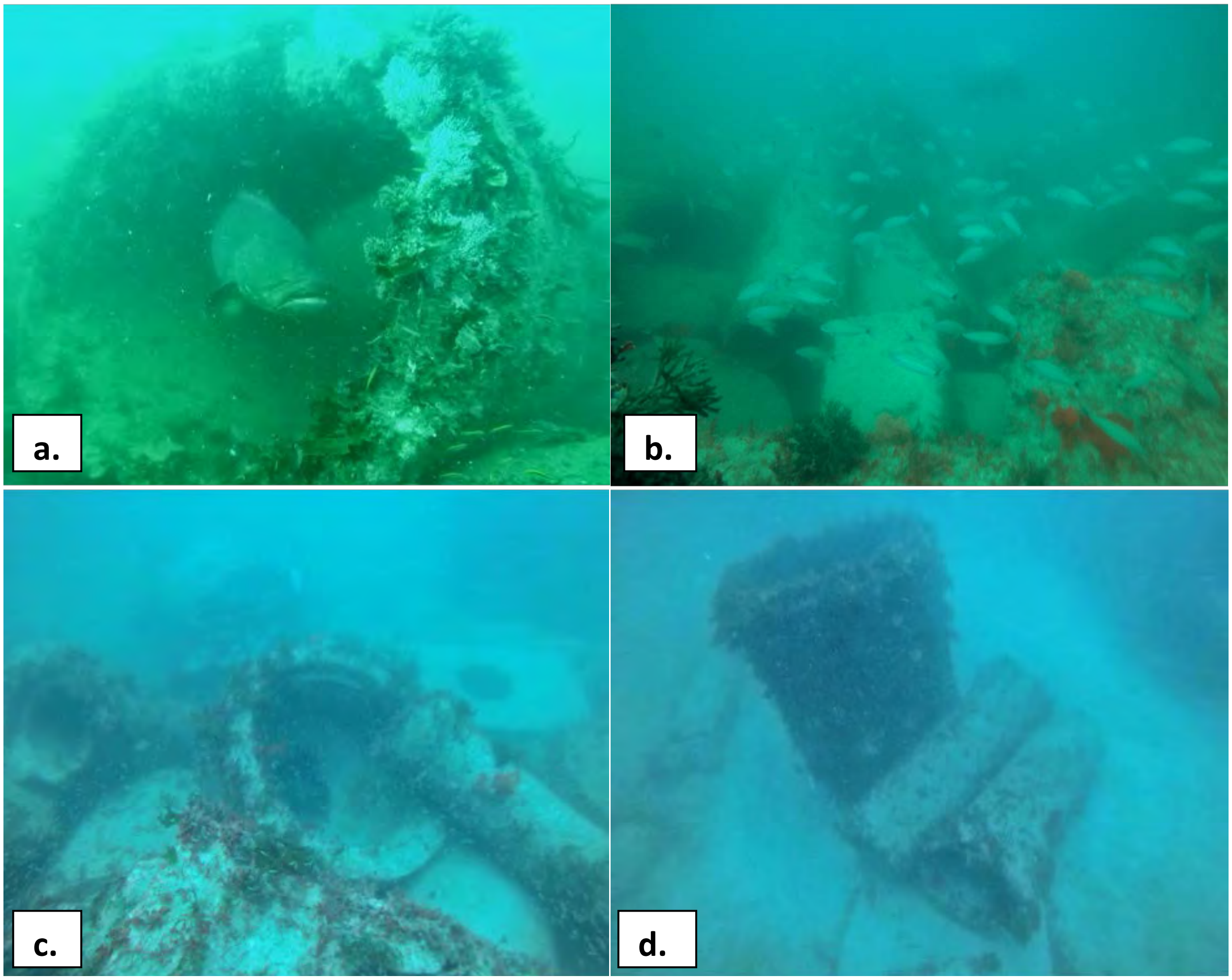
3.2.1 Structural Summary

The minimum and maximum recorded depth at each South County artificial reef site along with the maximum structural relief after deployment and during the 2015 surveys is shown in **Table 8**. The artificial reefs deployed in 2014 consist mainly of concrete culverts varying from 2 to 6 feet in diameter and up to 8 feet in length. Concrete slabs and cylinders were also used. All of the reefs were similar in visual appearance; there are multiple layers of material in the center portion of the structure and smaller clusters of material with lower relief around the perimeter. A selection of structural images from the 2014 South County area deployments are shown in **Photos 8a through 8d** and **Appendix C.** The maximum relief of the central portion ranges from 7 to 13 feet with numerous crevices, caves and other areas for sheltering. Large diameter culverts often harbored large goliath grouper. Several culvert pieces were observed to be standing upright and may possibly settle or fall over time.

The bottom depth at Site 11 was unexpectedly deep with a maximum depth of 88 feet (27 meters) recorded by divers. Visibility at this location was greatly reduced compared to the other sites, where the maximum depth ranged from 71 to 76 feet (22-23 meters). During deployment, the bottom depth was not recorded at any site other than Site 7, where a bottom depth of 72 feet was recorded during deployment. Site 11 is the easternmost site in the group of six reefs deployed in 2014, and was deployed further east of the intended location. Water depth generally increased from the three reefs located to the west of the natural hardbottom ridge (Site 7, 8, and 9) to the three sites located to the east of the ridge (**Figure 3, Table 8**). Water depth and relief at the natural sites was comparable to the artificial reefs (**Table 8**, photographs in **Appendix D**).

Table 8. Minimum and maximum dive depth recorded from the South County artificial and natural survey sites in 2015 and the minimum and maximum depth recorded at deployment.

Area	Deploy Year	Name	2015 Min Depth	2015 Max Depth	2015 Max Relief	Deploy Min Depth	Deploy Max Depth	Deploy Max Relief	Other Relief Measures
South County	2014	Site 7	61	72	11	55	72	17	
		Site 8	58	71	13	-	-	-	
		Site 9	61	72	11	-	-	-	
		Site 10	65	74	9	-	-	-	
		Site 11	81	88	7	-	-	-	
		Site 12	66	76	10	-	-	-	
	2008	The Heap	67	74	7	63	68	5	4 ft (2010)
		Jack MacDonald	65	74	9	63	70	7	
		Lentine	68	73	5	62	68	6	
		Fogel Capital	66	75	9	60	67	7	11 ft (2010)
		Shirley Reef	68	74	6	61	66	5	
		Ann Marie	71	76	5	59	67	8	
	Natural	Natural Center	66	76	10	-	-	-	
		Natural North	68	77	9	-	-	-	



Photos 8a-d. Photographs of the overall structure of the 2014 South County area deployments. a.) Site 8, taken August 10, 2015; b.) Site 9, taken August 10, 2015; c & d.) Site 10, taken August 10, 2015.

3.2.2 Fish

A total of 90 fish species was observed from 28 families in 16 fish surveys conducted within the South County artificial reef area. Mean abundance of each fish species observed on the new (2014) and old (2008) South County deployments and on the natural reef are shown in **Table 9.** There were significant differences in fish abundance between treatment groups (ANOVA, p=0.011). The new and old deployments had a nearly equal overall species richness (58 and 59 species respectively); however, the older deployments had significantly lower average abundance of fish (Tukey HSD, p=0.049). Abundance at the old deployments was nearly half of the abundance at the new deployments (723.2 ± 117.9 versus 1334.5 ± 220.6 individuals per survey, **Figure 7**). In addition to the difference in age, the older deployments are located further from the natural reef than the new deployments. The mean abundance at the new deployments was also significantly greater than at the natural reefs (Tukey HSD, p=0.013).

There was no significant difference in abundance between the old artificial reef deployments and the natural reefs (Tukey HSD, *p*=0.596).

The difference in abundance is partially attributed to the very high density of juvenile grunts observed at the new South County deployments during the July and August surveys. The older South County deployments and the natural reefs were mostly surveyed in November 2015, and surveyors noted that the majority of *H. aurolineatum* had reached a larger size class and were present in lower abundance in November. When the abundance data were analyzed with survey month as a factor, there was a significant effect of survey month on fish abundance (*t*-test unequal variance, *p*=0.015) with surveys conducted in August having higher abundance than those conducted in November. However, when adult tomtate (*H. aurolineatum*) and juvenile *Haemulon* sp. were removed from the abundance numbers, the August surveys continued to have significantly higher abundance than the November surveys (*t*-test, *p*=0.022). Similarly, the new artificial reefs continued to have a significantly greater mean abundance than the old deployments (Tukey HSD, *p*=0.009); the mean difference was not as large after grunts were removed (**Figure 7**). The natural reefs had an intermediate abundance and were not significantly different than either the old or new deployments after grunts were removed (Tukey HSD, *p*=0.332 and 0.240). Abundance of individual fish species at each survey location is provided in **Appendix A**.

Other than *Haemulon* sp., the most abundant fish species at the South County artificial reef sites were scad (*Decapterus* spp.), small reef-associated species including chromis and damselfish (*Chromis* and *Stegastes* spp*.)* and bluehead wrasse (*T. bifasciatum*). Gray snapper were also relatively abundant and made up 1.8% of the community at the new deployments and 2.7% of the community at the old deployments. The most abundant species on the natural reefs were similar, but no *Decapterus* sp. were observed and the bicolor damselfish (*S. partitus*) was far more abundant on the natural reefs. In addition, the ocean surgeon and doctorfish (*Acanthurus bahianus* and *A. chirurgus*) were more abundant on the natural reefs than on the artificial structures.

The species richness and Shannon diversity index at each survey site are shown in **Table 10**. Species richness at an individual site ranged from 19 to 38. There was no significant difference in mean species richness between each treatment group (ANOVA p=0.188). The highest diversity indices were seen at the natural reef sites; this result is due to the lower abundance of *H. aurolineatum* at these sites, meaning that the community was more dispersed between other species. The lowest species richness and lowest diversity was observed at Site 11 and may have been affected by the low visibility and strong currents at this site. Site 11 was misplaced during deployment and is located approximately 1,968 ft (600 m) to the east of the natural reef at 88 ft (27 m) water depth, deeper than the other new (2014) deployments.

A total of 24 managed species were observed on the South County artificial reef sites; 13 species were observed on the new deployments, 18 species on the old deployments, and 13 species on the natural reef (**Table 11**). It is expected that fewer species would be found on the natural reef due to only four surveys being conducted versus 6 on the artificial reefs. Notable differences between the artificial reefs and natural reef included greater numbers of gray triggerfish (*Balistes capriscus*) and hogfish (*Lachnolaimus maximus*) on the natural reef and also a single large bull shark (*Carcharinus leucas*) and cobia (*Rachycentron canadum*) that swam through the survey cylinder at the Natural Center site. The managed species found in the highest frequency were tomtate (*H. aurolineatum*), gray snapper (*L. griseus*), sheepshead (*A. probatocephalus*) and blue runner (*C. crysos*). The mean abundance of goliath grouper at the old deployments was similar to the new deployments (1.5 ± 0.9 and 1.3 ± 0.4 individuals per survey respectively), but frequency of occurrence was higher on the new deployments (83%).

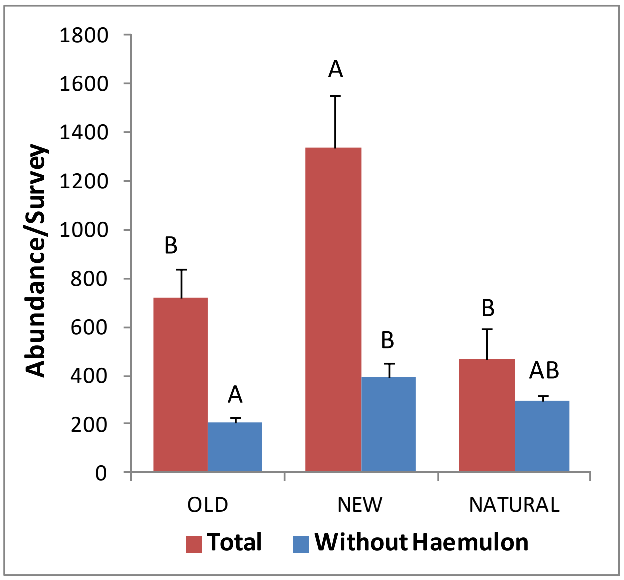


Figure 7. Mean fish abundance at each type of reef surveyed in the South County artificial area, with and without *Haemulon* spp.

Table 9. Mean (± SE) and relative abundance of fish species observed within the South County area. RA= Relative abundance.

Family	Latin Name	Common Name	Feeding Guild	NEW		OLD		NATURAL	
				Abundance	RA	Abundance	RA	Abundance	RA
Acanthuridae	*Acanthurus bahianus*	Ocean surgeon	Herbivore	0.2 ± 0.2	0.01	0.3 ± 0.3	0.05	18.0 ± 2.9	3.84
	Acanthurus chirurgus	Doctorfish	Herbivore	0.7 ± 0.4	0.05			13.5 ± 5.7	2.88
	Acanthurus coeruleus	Blue tang	Herbivore	0.2 ± 0.2	0.01	2.3 ± 0.6	0.32	0.5 ± 0.5	0.11
Apogonidae	*Apogon pseudomaculatus*	Twospot cardinalfish	Invertivore	0.2 ± 0.2	0.01	1.0 ± 0.6	0.14	0.8 ± 0.8	0.16
Balistidae	*Balistes capriscus*	Gray triggerfish	Invertivore			0.3 ± 0.3	0.05	6.3 ± 3.2	1.33
Blenniidae	*Parablennius marmoreus*	Seaweed blenny	Herbivore	2.5 ± 1.2	0.19	0.7 ± 0.3	0.09		
Carangidae	*Carangoides bartholomaei*	Yellow jack	Piscivore	0.2 ± 0.2	0.01			3.0 ± 1.5	0.64
	Carangoides ruber	Bar jack	Piscivore			1.0 ± 0.8	0.14	0.3 ± 0.3	0.05
	Caranx crysos	Blue Runner	Piscivore	12.2 ± 10.6	0.91	3.2 ± 1.6	0.44		
	Decapterus spp.	Mackerel/Round Scad	Planktivore	150.0 ± 56.3	11.24	64.7 ± 30.9	8.94		
	Seriola dumerili	Greater amberjack	Piscivore	2.0 ± 2.0	0.15	0.3 ± 0.3	0.05		
	Seriola rivoliana	Almaco Jack	Piscivore	6.7 ± 2.9	0.50				
Carcharhinidae	*Carcharhinus leucas*	Bull shark	Piscivore					0.3 ± 0.3	0.05
Centropomidae	*Centropomus undecimalis*	Common snook	Piscivore			0.5 ± 0.5	0.07		
Chaetodontidae	*Chaetodon sedentarius*	Reef butterflyfish	Invertivore	1.5 ± 0.6	0.11	1.2 ± 0.7	0.16	2.0 ± 0.8	0.43
Gobiidae	*Coryphopterus dicrus*	Colon goby	Herbivore			0.3 ± 0.2	0.05		
	Coryphopterus glaucofraenum	Bridled goby	Herbivore	1.3 ± 0.8	0.10			3.3 ± 2.0	0.69
	Coryphopterus hyalinus/personatus	Masked/Glass goby	Herbivore	2.0 ± 2.0	0.15	2.0 ± 2.0	0.28	0.5 ± 0.5	0.11
	Elacatinus oceanops	Neon goby	Invertivore					5.0 ± 5.0	1.07
	Gnatholepis thompsoni	Goldspot goby	Invertivore	0.2 ± 0.2	0.01	0.3 ± 0.2	0.05	3.0 ± 2.4	0.64
Haemulidae	*Anisotremus surinamensis*	Black margate	Invertivore	0.3 ± 0.3	0.02	1.3 ± 0.8	0.18		
	Anisotremus virginicus	Porkfish	Invertivore			2.8 ± 0.8	0.39	2.0 ± 1.2	0.43
	Haemulon aurolineatum	Tomtate	Invertivore	289.2 ± 86.1	21.67	463.3 ± 122.1	64.07	175.0 ± 118.1	37.35
	Haemulon flavolineatum	French grunt	Invertivore					0.5 ± 0.5	0.11
	Haemulon macrostomum	Spanish grunt	Invertivore					0.3 ± 0.3	0.05
	Haemulon plumierii	White grunt	Invertivore			1.2 ± 0.6	0.16	4.8 ± 2.6	1.01
	Haemulon sciurus	Bluestriped grunt	Invertivore					0.3 ± 0.3	0.05
	Haemulon spp.	Grunts, juvenile/Unid	Invertivore	649.2 ± 277.8	33.66	55.3 ± 49.2	7.65		
Kyphosidae	*Kyphosus sectatrix*	Chub	Herbivore	0.3 ± 0.3	0.02				
Labridae	*Bodianus pulchellus*	Spotfin hogfish	Invertivore	0.8 ± 0.3	0.06	3.2 ± 2.4	0.44	1.3 ± 0.9	0.27
	Bodianus rufus	Spanish hogfish	Invertivore	2.7 ± 1.7	0.20	4.0 ± 1.4	0.55	0.8 ± 0.5	0.16
	Halichoeres bivittatus	Slippery dick	Invertivore	18.5 ± 8.7	1.39	2.0 ± 1.6	0.28	15.0 ± 15.0	3.20
	Halichoeres garnoti	Yellowhead wrasse	Invertivore	3.5 ± 2.9	0.26	6.3 ± 3.9	0.88	6.3 ± 2.2	1.33
	Halichoeres poeyi	Blackear wrasse	Invertivore	0.3 ± 0.3	0.02				
	Halichoeres radiatus	Puddingwife	Invertivore	0.3 ± 0.3	0.02				
	Lachnolaimus maximus	Hogfish	Invertivore					0.8 ± 0.5	0.16
	Thalassoma bifasciatum	Bluehead wrasse	Invertivore	24.8 ± 5.7	1.86	23.7 ± 4.3	3.27	13.8 ± 4.7	2.93

Table 9 cont. Mean (± SE) and relative abundance of fish species observed within the South County area. RA= Relative abundance.

				NEW		OLD		NATURAL	
Family	**Latin Name**	**Common Name**	**Feeding Guild**	**Abundance**	**RA**	**Abundance**	**RA**	**Abundance**	**RA**
Labrisomidae	*Malacoctenus triangulatus*	Saddled blenny	Invertivore	2.5 ± 1.5	0.19	0.5 ± 0.2	0.07		
Lutjanidae	*Lutjanus apodus*	Schoolmaster	Piscivore			0.5 ± 0.3	0.07		
	Lutjanus griseus	Gray snapper	Piscivore	23.5 ± 7.2	1.76	19.3 ± 3.1	2.67	7.5 ± 2.5	1.60
	Lutjanus synagris	Lane snapper	Piscivore	1.5 ± 1.0	0.11	1.7 ± 0.9	0.23		
	Ocyurus chrysurus	Yellowtail snapper	Piscivore	0.2 ± 0.2	0.01	0.8 ± 0.4	0.12		
	Rhomboplites aurorubens	Vermilion Snapper	Piscivore	19.2 ± 6.8	1.44	1.8 ± 1.8	0.25	18.8 ± 11.3	4.00
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	Invertivore					0.3 ± 0.3	0.05
Muraenidae	*Gymnothorax moringa*	Spotted moray	Piscivore					0.3 ± 0.3	0.05
Ostraciidae	*Acanthostracion quadricornis*	Scrawled cowfish	Invertivore					0.3 ± 0.3	0.05
Pomacanthidae	*Holacanthus bermudensis*	Blue angelfish	Invertivore	0.2 ± 0.2	0.01			1.5 ± 0.5	0.32
	Holacanthus ciliaris	Queen angelfish	Invertivore			0.3 ± 0.2	0.05	0.8 ± 0.3	0.16
	Holacanthus tricolor	Rock beauty	Invertivore			0.2 ± 0.2	0.02	0.5 ± 0.3	0.11
	Pomacanthus arcuatus	Gray angelfish	Invertivore			0.3 ± 0.3	0.05		
	Pomacanthus paru	French angelfish	Invertivore			0.3 ± 0.2	0.05	1.0 ± 0.4	0.21
Pomacentridae	*Abudefduf saxatilis*	Sergeant major	Herbivore	0.7 ± 0.3	0.05	1.8 ± 1.6	0.25	1.3 ± 1.3	0.27
	Chromis cyanea	Blue chromis	Planktivore	2.5 ± 2.5	0.19				
	Chromis enchrysura	Yellowtail reeffish	Planktivore	23.5 ± 11.3	1.76			58.8 ± 27.1	12.54
	Chromis insolata	Sunshinefish	Planktivore	5.0 ± 4.0	0.37	0.5 ± 0.3	0.07		
	Chromis scotti	Purple reeffish	Planktivore	30.5 ± 11.9	2.29	13.5 ± 7.7	1.87	13.8 ± 9.4	2.93
	Microspathodon chrysurus	Yellowtail damselfish	Herbivore					0.5 ± 0.5	0.11
	Stegastes diencaeus	Longfin damselfish	Herbivore	0.7 ± 0.4	0.05	0.5 ± 0.5	0.07		
	Stegastes leucostictus	Beaugregory	Herbivore	15.7 ± 14.9	1.17	6.8 ± 2.0	0.94	18.8 ± 3.1	4.00
	Stegastes partitus	Bicolor damselfish	Herbivore	0.5 ± 0.3	0.04	0.5 ± 0.5	0.07	39.5 ± 6.8	8.43
	Stegastes variabilis	Cocoa damselfish	Herbivore	12.3 ± 6.8	0.92	1.7 ± 1.0	0.23	2.8 ± 1.7	0.59
Priacanthidae	*Heteropriacanthus cruentatus*	Glasseye	Invertivore					1.5 ± 0.9	0.32
	Priacanthus arenatus	Bigeye	Piscivore					5.0 ± 5.0	1.07
Rachycentridae	*Rachycentron canadum*	Cobia	Invertivore					0.8 ± 0.8	0.16
Scaridae	*Sparisoma atomarium*	Greenblotch parrotfish	Herbivore	3.2 ± 2.4	0.24	1.5 ± 1.0	0.21	0.8 ± 0.8	0.16
	Sparisoma aurofrenatum	Redband parrotfish	Herbivore	0.3 ± 0.3	0.02	0.7 ± 0.5	0.09	0.3 ± 0.3	0.05
	Sparisoma radians	Bucktooth parrotfish	Invertivore			3.3 ± 1.6	0.46		
	Sparisoma rubripinne	Redfin parrotfish	Herbivore					0.3 ± 0.3	0.05
	Sparisoma viride	Stoplight parrotfish	Herbivore	0.2 ± 0.2	0.01				
Sciaenidae	*Pareques umbrosus*	Cubbyu	Invertivore	1.2 ± 0.5	0.09	1.8 ± 1.1	0.25	1.3 ± 0.8	0.27
Scorpaenidae	*Pterois* spp.	Lionfish species	Piscivore	1.0 ± 0.4	0.07	1.3 ± 0.8	0.18	0.8 ± 0.5	0.16
	Scorpaena plumieri	Spotted scorpionfish	Invertivore	0.5 ± 0.2	0.04	2.8 ± 1.1	0.39	0.5 ± 0.3	0.11

Table 9 cont. Mean (± SE) and relative abundance of fish species observed within the South County area. RA= Relative abundance.

				NEW		OLD		NATURAL	
Family	**Latin Name**	**Common Name**	**Feeding Guild**	**Abundance**	**RA**	**Abundance**	**RA**	**Abundance**	**RA**
Serranidae	*Cephalopholis cruentata*	Graysby	Piscivore			1.3 ± 0.6	0.18		
	Cephalopholis fulva	Coney	Piscivore					0.3 ± 0.3	0.05
	Epinephelus itajara	Goliath grouper	Invertivore	1.3 ± 0.4	0.10	1.5 ± 0.9	0.21		
	Hypoplectrus unicolor	Butter hamlet	Invertivore	0.3 ± 0.2	0.02	0.5 ± 0.2	0.07	0.3 ± 0.3	0.05
	Mycteroperca bonaci	Black grouper	Piscivore			0.5 ± 0.5	0.07	0.5 ± 0.3	0.11
	Mycteroperca microlepis	Gag	Piscivore	0.2 ± 0.2	0.01			0.8 ± 0.8	0.16
	Mycteroperca phenax	Scamp	Piscivore			0.3 ± 0.3	0.05	1.0 ± 0.7	0.21
	Mycteroperca spp.	Grouper Unid	Piscivore	0.2 ± 0.2	0.01				
	Rypticus maculatus	Whitespotted soapfish	Piscivore			1.3 ± 0.2	0.18	0.5 ± 0.3	0.11
	Serranus baldwini	Lantern bass	Invertivore	0.2 ± 0.2	0.01	0.2 ± 0.2	0.02	0.3 ± 0.3	0.05
	Serranus phoebe	Tattler bass	Invertivore	0.2 ± 0.2	0.01	0.3 ± 0.2	0.05	0.3 ± 0.3	0.05
	Serranus subligarius	Belted sandfish	Invertivore	0.5 ± 0.2	0.04	0.8 ± 0.3	0.12	2.5 ± 1.9	0.53
	Serranus tigrinus	Harlequin bass	Invertivore					1.3 ± 0.6	0.27
	Serranus tortugarum	Chalk bass	Planktivore	0.8 ± 0.8	0.06	4.2 ± 2.0	0.58	1.5 ± 1.5	0.32
Sparidae	*Archosargus probatocephalus*	Sheepshead	Invertivore	4.8 ± 1.5	0.36	2.5 ± 1.0	0.35	2.8 ± 1.3	0.59
	Calamus spp.	Saucereye/Sheepshead porgy	Invertivore	0.7 ± 0.5	0.05	2.0 ± 0.4	0.28		
	Diplodus holbrookii	Spottail pinfish	Invertivore	3.3 ± 3.3	0.25				
Tetraodontidae	*Canthigaster rostrata*	Sharpnose puffer	Invertivore	7.0 ± 2.0	0.52	3.7 ± 1.6	0.51	3.0 ± 2.3	0.64
	Sphoeroides spengleri	Bandtail puffer	Invertivore	0.7 ± 0.4	0.05				
MEAN ABUNDANCE (± SE)				**1334.5 ± 220.6**		**723.2 ± 117.9**		**468.5 ± 125.7**	
OVERALL SPECIES RICHNESS				**58**		**59**		**63**	

Table 10. Species richness, abundance, and Shannon diversity index at each site within the South County artificial reef area.

AGE CLASS	SITE NAME	Species Richness (S)	Abundance (N)	Shannon Diversity (H')
New (2014)	Site 7	20	642	1.43
	Site 8	30	1287	1.70
	Site 9	27	729	1.71
	Site 10	31	1787	1.06
	Site 11	19	1720	0.54
	Site 12	27	1842	0.93
Old (2008)	Ann Marie	27	1150	0.73
	Fogel Capital	34	333	2.36
	The Heap	38	524	1.95
	Jack MacDonald	23	845	1.15
	Shirley	25	627	1.15
	Lentine	30	860	1.09
Natural	Natural Center (1)	37	806	1.72
	Natural Center (2)	31	496	2.35
	Natural North (1)	30	350	2.30
	Natural North (2)	29	222	2.55

Table 11. Frequency of occurrence (% of surveys in which species occurred) of each managed fish species within the South County artificial reef area.

Family	Latin Name	Common Name	Frequency of Occurrence		
			NEW	OLD	NATURAL
Balistidae	*Balistes capriscus*	Gray triggerfish		16.7	100.0
Carangidae	*Carangoides ruber*	Bar jack		33.3	25.0
	Seriola dumerili	Greater amberjack	16.7	16.7	
	Seriola rivoliana	Almaco Jack	66.7		
	Caranx crysos	Blue Runner	50.0	66.7	
Carcharhinidae	*Carcharhinus leucas*	Bull shark			25.0
Centropomidae	*Centropomus undecimalis*	Common snook		16.7	
Haemulidae	*Haemulon aurolineatum*	Tomtate	100.0	100.0	50.0
	Haemulon plumierii	White grunt		50.0	75.0
Labridae	*Lachnolaimus maximus*	Hogfish			50.0
Lutjanidae	*Lutjanus apodus*	Schoolmaster		33.3	
	Lutjanus griseus	Gray snapper	83.3	100.0	100.0
	Lutjanus synagris	Lane snapper	50.0	50.0	
	Ocyurus chrysurus	Yellowtail snapper	16.7	50.0	
	Rhomboplites aurorubens	Vermillion Snapper	100.0	16.7	50.0
Rachycentridae	*Rachycentron canadum*	Cobia			25.0
Serranidae	*Cephalopholis cruentata*	Graysby		50.0	
	Epinephelus itajara	Goliath grouper	83.3	66.7	
	Mycteroperca bonaci	Black grouper		16.7	50.0
	Mycteroperca microlepis	Gag	16.7		25.0
	Mycteroperca phenax	Scamp		16.7	50.0
	Mycteroperca spp.	Grouper Unid	16.7		
Sparidae	*Calamus* spp.	Saucereye/Sheepshead porgy	33.3	100.0	
Sparidae	*Archosargus probatocephalus*	Sheepshead	83.3	66.7	75.0

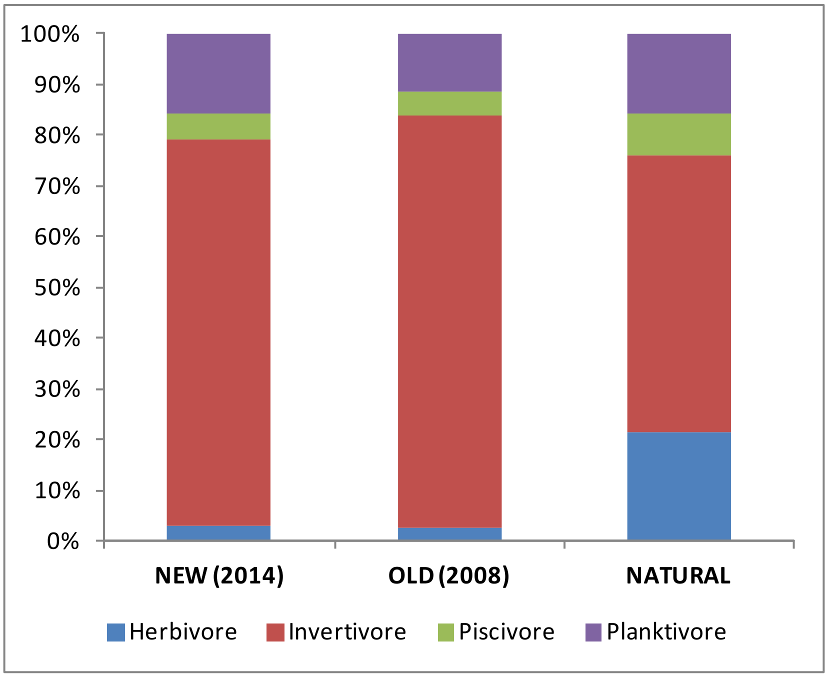


Figure 8. Percent of the fish community (by abundance) consisting of herbivores, invertivores, piscivores, and planktivores at the new (2014) and old (2008) and natural reef sites in the South County area.

The fish communities at both the artificial and natural reefs were dominated by invertivores (**Figure 8**). At the natural reef sites, the second most abundant feeding guild was herbivores (21.3%), whereas the abundance of herbivores was lower at both the old and new artificial reef deployments (2.6% and 3.1% respectively). The herbivore community at the natural reef sites was dominated by damselfish (*Stegastes* spp., primarily bicolor and beaugregory) followed by surgeonfish (*Acanthurus* spp., primarily ocean surgeonfish and doctorfish). The bicolor damselfish was abundant on the natural reefs and relatively rare on the artificial reefs (8.4% on natural and 0.5% on both new and old artificial reefs, **Table 9**). *Acanthurus* spp. surgeonfish made up 6.8% of the community on the natural reefs and 1.1% and 2.6% of the community on the new and old artificial reef deployments, respectively. Although piscivores made up a larger portion of the community on the natural reefs (8.3%) than on the artificial reefs (5.0% and 4.7%), the actual abundance of piscivores was highest on the new artificial reefs (67 individuals recorded). The relative abundance of piscivores on the artificial reefs was skewed by the large number of invertivores observed at these sites.

Analysis of similarities (ANOSIM) using the categorical factor of reef age (new, old, natural) showed that there were significant differences in the fish community between the three treatment groups (Global R=0.525, p=0.001). Pairwise comparisons showed that the fish communities at the new and old artificial reefs were both significantly different from the natural reefs (Global R= 0.647 and 0.766; p=0.005 for both). The new and old deployments were also significantly different from each other; however, the new and old artificial reefs were more similar to one another than to the natural reefs (Global R=0.339, p=0.011). Genera that had the highest contribution to the dissimilarity between each of the three treatment groups are listed in **Table 12**.

Multivariate SIMPROF analysis grouped the 16 surveys conducted within the South County artificial reef area into four distinct clusters (**Figure 9**). The majority of the artificial reef sites formed a distinct grouping (Cluster D), with the exception of Site 11 and Site 12 (Cluster B). Sites 11 and 12, along with Site 10, are located on the eastern side of the natural reef ridge that runs through the center of the new artificial deployments in this area. These sites had the deepest bottom depth, most notable at Site 11 where a maximum bottom depth of 88 ft was recorded (**Table 8**). The natural reef surveys clustered separately from the artificial reefs and the duplicate surveys conducted at each natural reef location were highly similar. The fish community recorded at the 'Natural Center' site (Cluster C) was more closely related to the artificial sites than those at the 'Natural North' location (Cluster D).

Differences between the Natural Center location and the Natural North location indicate possible interactions between the artificial reef and the fish community along the nearby hardbottom ridge. The top contributors to the difference between the two natural reef locations were *Haemulon* (consisted largely of tomtate, *H. aurolineatum*) and *Rhomboplites* (consisted entirely of vermilion snapper, *R. aurorubens),* both of which were more abundant at the Natural Center location (closer to the artificial reefs) than at the Natural North location. Other major contributors included small reef-associated species including *Halichoeres* and *Coryphopterus*, which were more abundant at the natural site located further from the artificial reefs. These results should be taken with caution as the sample size within the natural reefs was very low, however, these results warrant further study on the interactions between the artificial reefs deployed in 2014 and the nearby reef ridge.

Consistent differences between natural sites (Clusters A and C) and artificial sites (Cluster D) included the presence of *Decapterus* sp. at the artificial reefs, a higher abundance of *Stegastes* sp. and *Chromis* sp. at the natural reefs, and a greater abundance of *Acanthurus* sp. at the natural sites. In addition, *Lutjanus* sp. were consistently more abundant on the artificial reefs than on the natural reefs. **Figure 10** shows the MDS plot of survey sites overlaid with the abundance of commercially important species that had the greatest level of influence on the difference between South County sites.

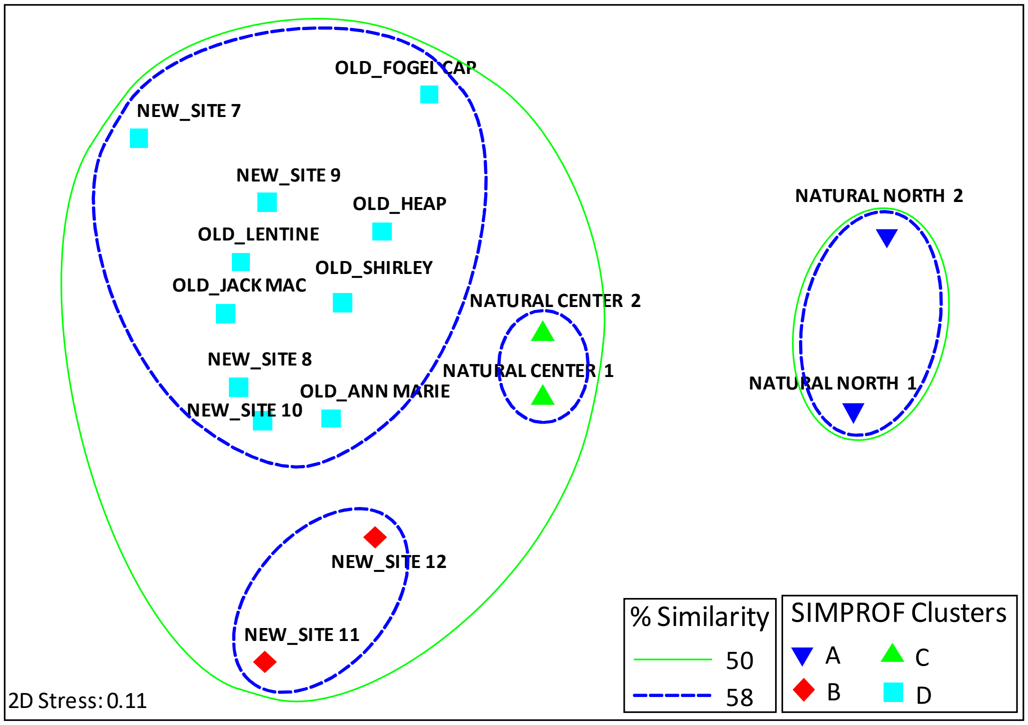


Figure 9. MDS plot based on abundance data (by genus) of the fish community at the sites within the South County reef area overlaid with significant clusters determined by SIMPROF analysis.

Table 12. Genera with the highest contribution to the differences (dissimilarity) in the fish community at the new, old, and natural sites. Top 10 genera listed. Asterisks (*) indicate genera with managed fisheries.

Species	Higher Group	Mean % Dissimilarity	% Contribution
NATURAL v. NEW			
*Haemulon**	New	11.97	21.22
Decapterus	New	6.05	10.72
Stegastes	Natural	3.08	5.46
Acanthurus	Natural	3.01	5.33
Chromis	Natural	2.06	3.66
*Rhomboplites**	New	1.98	3.52
Halichoeres	New	1.69	3
*Lutjanus**	New	1.66	2.94
Thalassoma	New	1.49	2.65
*Seriola**	New	1.33	2.36

Species	Higher Group	Mean % Dissimilarity	% Contribution
NATURAL v. OLD			
*Haemulon**	Old	8.99	16.89
Decapterus	Old	4.41	8.29
Chromis	Natural	3.61	6.78
Stegastes	Natural	3.14	5.9
Acanthurus	Natural	2.77	5.21
*Rhomboplites**	Natural	1.92	3.61
Halichoeres	Natural	1.8	3.37
Thalassoma	Old	1.39	2.61
*Lutjanus**	Old	1.36	2.55
*Balistes**	Natural	1.32	2.47

Species	Higher Group	Mean % Dissimilarity	% Contribution
NEW v. OLD			
*Haemulon**	New	7.08	17.03
Decapterus	New	4.79	11.52
Chromis	New	2.83	6.81
*Rhomboplites**	New	2.14	5.14
Halichoeres	New	1.66	3.99
*Caranx**	New	1.36	3.26
Stegastes	New	1.35	3.26
*Seriola**	New	1.26	3.03
*Lutjanus**	New	1.16	2.79
Thalassoma	Old	1.06	2.55

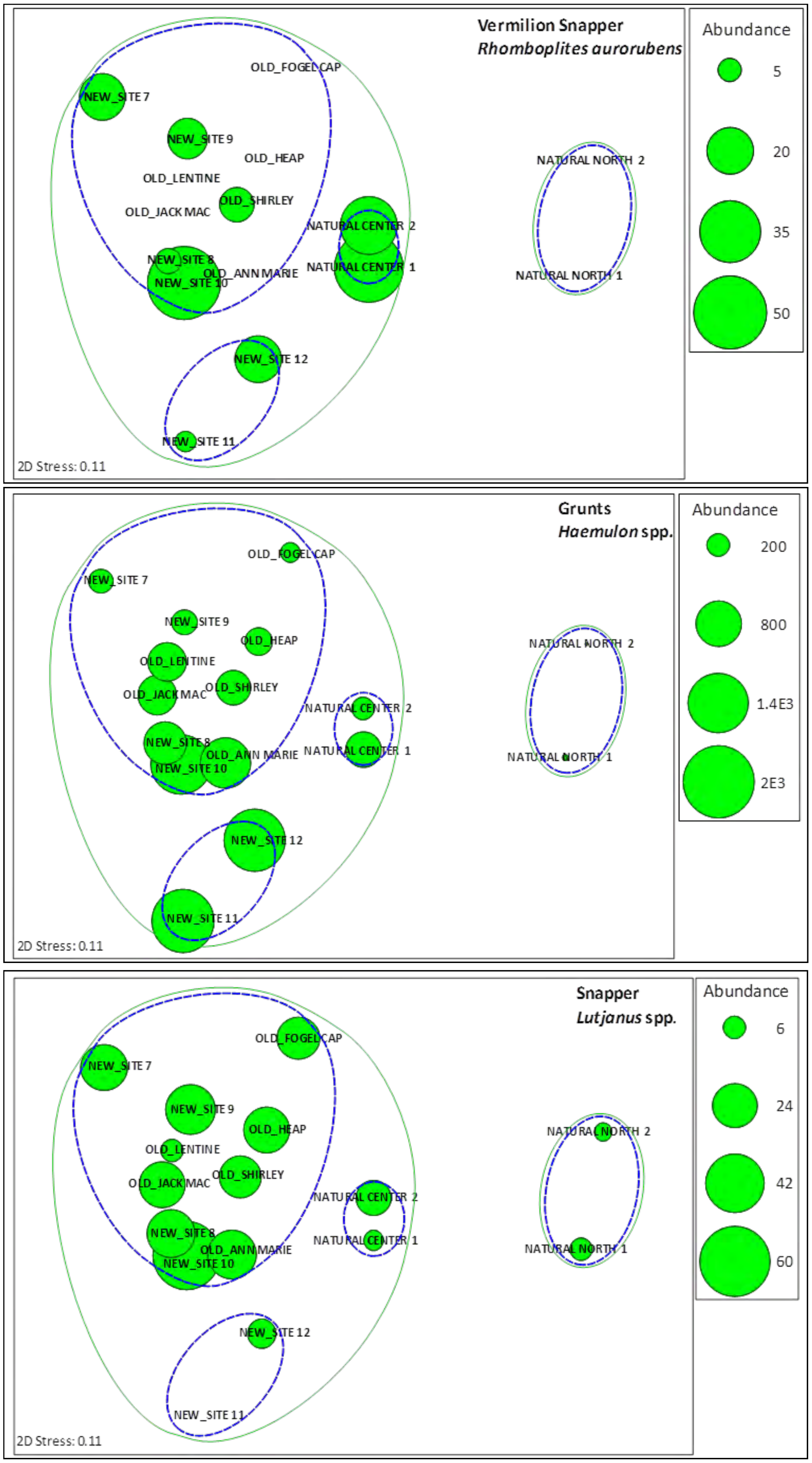


Figure 10. MDS plots from Figure 9 with abundance of several commercially important species overlaid in the form of bubbles; larger bubbles correspond to higher abundance of *Rhomboplites* sp. (top), *Haemulon* sp. (middle), and *Lutjanus* sp. (bottom).

3.2.3 Benthic Community

The benthic community at the South County artificial reef sites was dominated by macroalgae and turf algae. The most abundant benthic invertebrates were sponges, hydroids, bryozoans, and tunicates (**Figure 11**). A lush canopy of macroalgae was observed at all of the new deployments, but was most prominent at Site 7, Site 8, and Site 9, and also at Jack MacDonald reef (2008 deployment). The dominant macroalgae genera observed at the new and old South County deployments are shown in **Table 13**. The most common genera on the new deployments were *Dictyopteris*, *Gracilaria*, *Codium*, and *Agardhiella* (**Photo 9**). There was less macroalgal diversity on the older deployments; the genera *Gracilaria* and *Dictyopteris* were also dominant along with *Botryocladia*; however, the community was not as dense as on the new deployments (**Photo 10**). The benthic community had a high level of encrusting cover of sponges, hydroids, and bryozoans during all surveys. *Codium* and *Agardhiella* were not recorded on the old deployments.

The total mean cover of all non-algae fauna groups was over 20% on old deployments, attributed mostly to sponges, bryozoans, hydroids and tunicates. The arborescent bryozoan *Amathia* sp. was abundant on both the old artificial reef deployments and natural reefs during the November surveys (**Photo 11**). Colonies reach a maximum height of 30 cm and are common in Florida waters (Winston 2009). An extremely diverse community of tunicates and sponges was also present, and identification of individual genera or species is outside the scope of this work. A collection of photographs of the benthic community on the South County survey sites can be found in **Appendix C** and **D.**

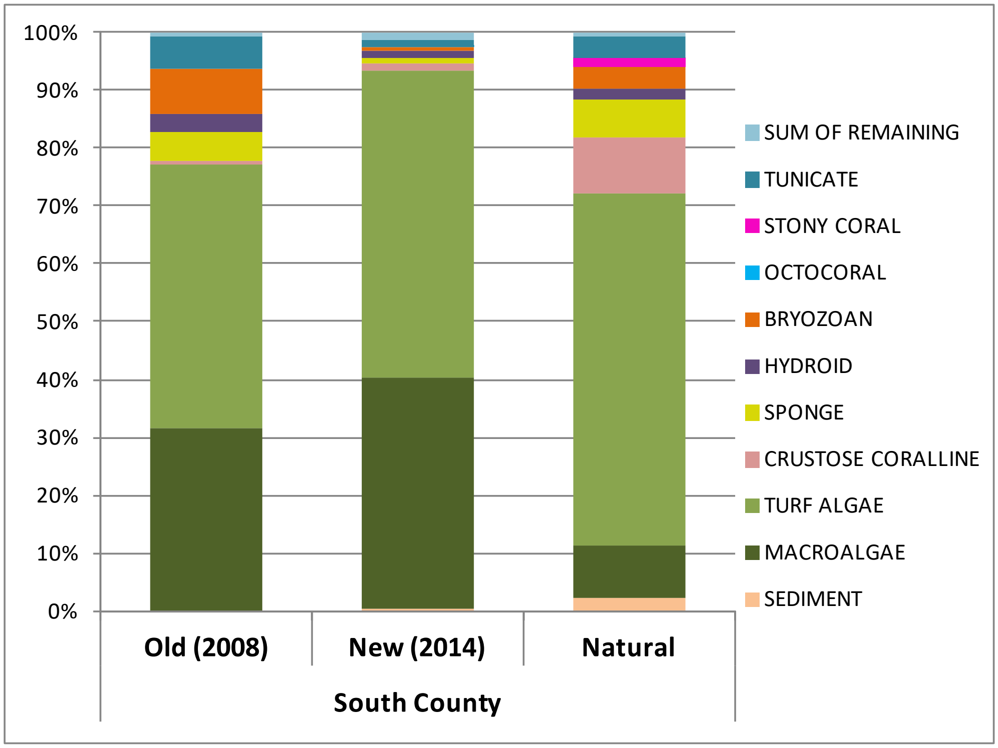


Figure 11. Percent cover of each benthic functional group at the old and new South County area deployments and the natural reef.

Table 13. Percent cover of each common macroalgae genus (only genera occurring at ≥ 1% cover in a single quadrat).

Macroalgae Cover (Mean ± SE)			
Genus	**NEW (2013)**	**OLD (2008)**	**NATURAL**
Acanthophora	1.7 ± 0.9		
Agardhiella	4.3 ± 2.6		
Botryocladia	2.0 ± 0.8	3.7 ± 1.4	0.2 ± 0.1
Caulerpa	0.8 ± 0.4	0.3 ± 0.2	
Codium	5.4 ± 3.2		
Dictyopteris	11.6 ± 2.9	3.5 ± 1.9	
Dictyota	1.0 ± 0.4	1.3 ± 0.5	
Galaxaura	0.3 ± 0.3	0.1 ± 0.1	
Gracilaria	9.7 ± 1.7	20.4 ± 4.9	6.9 ± 1.8
Halimeda	0.1 ± 0.1	0.7 ± 0.4	0.5 ± 0.3
Jania	0.6 ± 0.3	0.8 ± 0.4	
Kallymenia	0.6 ± 0.3		
Lobophora	0.3 ± 0.2	0.1 ± 0.1	
Rhodymenia			0.6 ± 0.4
Sargassum	0.9 ± 0.4	0.1 ± 0.1	
Udotea			0.1 ± 0.1
Unidentified		0.2 ± 0.2	

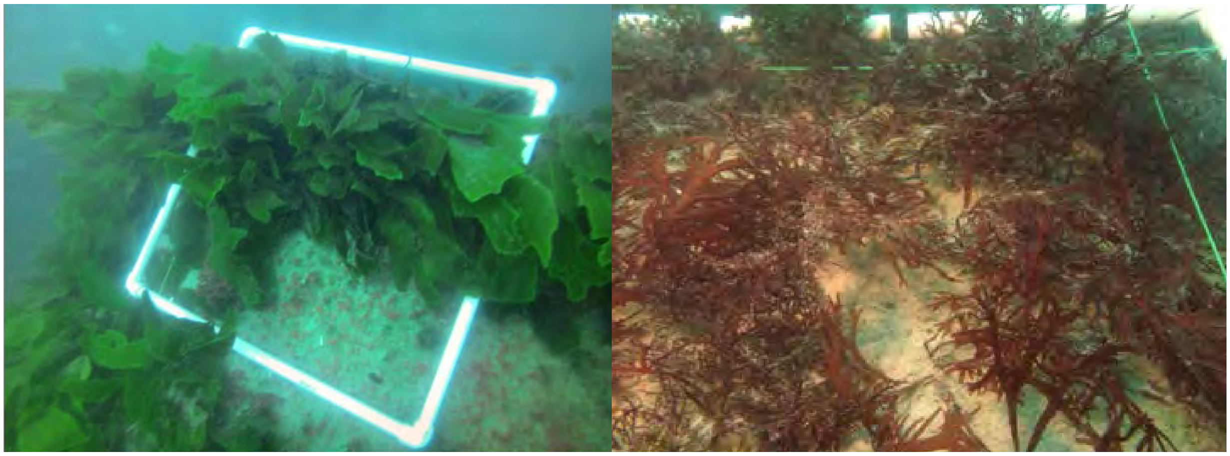


Photo 9. High cover of *Dictyopteris* sp. at Site 7 (left, taken on August 10, 2015) and high cover of *Agardhiella* and *Gracilaria* spp. at Site 8 (right, taken on August 11, 2015).

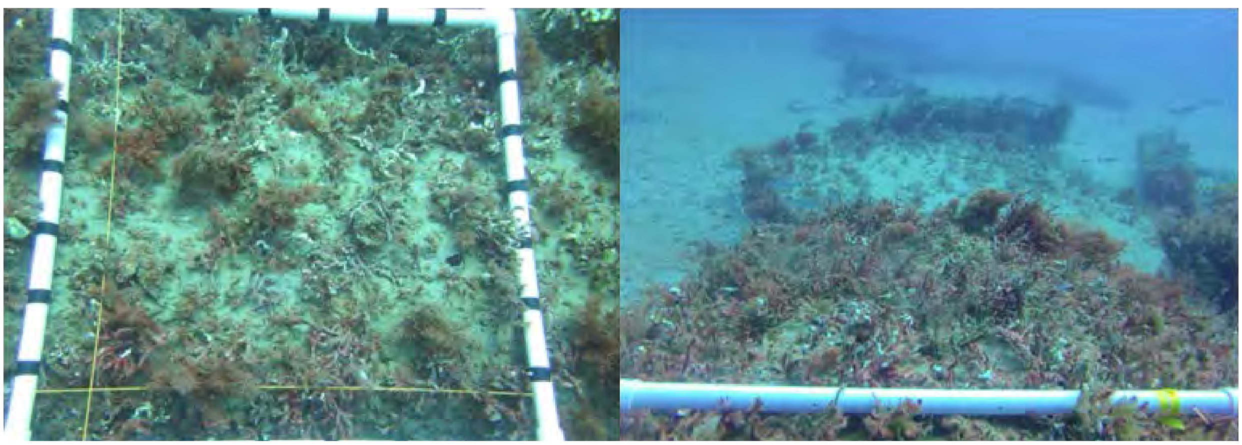


Photo 10. *Gracilaria* sp. macroalgae with high encrusting cover at Lentine Reef (left, taken on November 8, 2015) and The Heap (right, taken on November 8, 2015).

Photo 11. *Amathia* sp. bryozoan colony on Lentine Reef.
Photo taken on November 8, 2015

The season in which surveys were conducted is a potential confounding factor that may have contributed to the differences in the benthic community between the new and old South County artificial reef deployments. Surveys on all 2013 deployments were conducted in August 2015 whereas the majority of the old deployments were surveyed in November 2015 with the exception of Jack MacDonald reef. The mean macroalgae cover at Jack MacDonald reef in August was 73.2%, the highest of any site. This mean was much higher than the highest mean recorded during November (37.5% observed at The Heap). Therefore, direct statistical comparisons and discussion of differences in the benthic community will be limited to seasonally comparable surveys conducted in November. These include all quadrats from the old deployments except for Jack MacDonald reef (N=17 or 8.5 m^2) and all quadrats from the natural hardbottom reef (N=13 or 6.5 m^2). Because the new artificial reef deployments were only one year old at the time of the survey, it is also expected that the benthic community at these reefs would not be completely developed, and the old deployments that have been in place for seven years would better represent true differences in the benthic community on artificial reefs versus natural habitat.

The mean percent cover in seasonally comparable quadrats at the natural reef and 2008 artificial reef deployments and the results of statistical comparisons between the groups are shown in **Table 14**. Turf algae was the dominant benthic functional group at both locations, and there was no significant difference in the cover of turf algae. Macroalgae, bryozoan, and tunicate cover were all significantly greater on the artificial reefs than on the natural reef ridge. The cover of sediment over hardbottom, encrusting red algae, and stony coral was significantly greater on the natural reef than on the artificial reefs. Cover of sponges, hydroids, and other low-cover functional groups was comparable between the two locations.

Table 14. Mean (± SE) percent cover of functional groups in quadrats sampled in November only at the natural and old (2008) South County artificial reefs; p-values from t-tests comparing percent cover at the two sites, asterisks (*) indicate t-tests for unequal variances.

	Natural Mean ± SE	2008 Artifical Mean ± SE	*p*-value
Sediment	2.4 ± 0.8	0.0 ± 0.0	0.015
Macroalgae	9.0 ± 1.6	21.9 ± 4.2	0.016*
Turf Algae	60.9 ± 2.8	52.4 ± 3.5	0.079
Enc. Red Algae	9.7 ± 1.8	0.4 ± 0.3	<0.001*
Sponge	6.3 ± 0.9	5.8 ± 1.7	0.801
Bryozoan	3.8 ± 1.0	9.8 ± 1.8	0.008*
Tunicate	3.7 ± 0.6	6.5 ± 0.9	0.024
Hydroid	2.0 ± 0.5	2.8 ± 0.8	0.401
Stony Coral	1.5 ± 0.5	0.0 ± 0.0	0.008*
Barnacle	0.1 ± 0.1	0.2 ± 0.2	0.644
Zoanthid	0.5 ± 0.3	0.0 ± 0.0	0.057
Bare Hard Substrate	0.0 ± 0.0	0.1 ± 0.1	0.391
Bivalve	0.0 ± 0.0	0.1 ± 0.1	0.214

All octocoral and stony coral colonies recorded in quadrats in the South County area are shown in **Table 15**. Stony coral colonies were relatively abundant on the natural reef ridge, mean cover was 1.5 ± 0.5%, and overall density was 5.4 colonies per m^2. Numerous small recruits of *Siderastrea* cf. *siderea* were observed, along with several larger *Siderastrea siderea* and *Oculina diffusa* colonies (**Photo 12**). No stony corals were recorded in quadrats at either the new or old artificial reef deployments. No octocorals were recorded in quadrats at the natural reef ridge, although several colonies were seen in the area; density was very low. Several small (4 – 7 cm) recruits of *Pseudopterogorgia* sp. were recorded within the quadrats at Site 9, a new artificial reef deployment (**Table 15**).

Table 15. Octocoral and stony coral abundance and density at South County area sites where these taxonomic groups occurred.

Octocoral Genus	**SITE 9**
Pseudopterogorgia	4
Total # Observed	4
Area Sampled (m^2)	2.0
Density ($\#/m^2$)	2.0

Stony Coral Species	**NATURAL CENTER**	**NATURAL NORTH**
Oculina diffusa	2	1
Siderastrea cf. *siderea*	13	10
Siderastrea siderea	8	1
Total # Observed	23	12
Area Sampled (m^2)	2.5	4.0
Density ($\#/m^2$)	9.2	3.0

Photo 12. *Siderastrea* cf. *siderea* colony (left) and *Oculina diffusa* colony (right) observed in quadrats at the Natural North site. Photos taken on November 8, 2015.

4.0 DISCUSSION

4.1 Donaldson Artificial Reef Sites

Artificial reef structures deployed in the Donaldson area in 2013 showed a high level of diversity in the fish and benthic community in the second year post-deployment. The five new deployments in the Donaldson area appear to be structurally stable and had similar vertical relief in 2015 compared to measurements taken during deployment. A small amount of scouring is suggested by increases in maximum depth of 2 to 7 ft in 2015 when compared to the post-deployment survey. However, because water depth was recorded from the vessel during deployment and by divers on bottom during the 2015 survey, depth measurements are not directly comparable and do not indicate substantial scour and settlement.

4.1.1 Donaldson Fish Community

The maximum species richness observed at a single site during the 2015 surveys was 46 species, which is comparable to historical surveys in the Donaldson reef area. A review of historical monitoring reports showed a high of 49 species observed at the Ralph Evinrude Reef in 2013 (Maxwell Marine Consulting Engineers, Inc. 2013). However, previous surveys were completed using a roving diver technique, which allows for more searching for rare and cryptic species than the point count method used for the 2015 survey.

The extremely high number of juvenile grunts observed on the 2013 (new) Donaldson deployments indicates that recruitment of larval fish is occurring. Tomtate are commonly reported in high abundance on artificial reefs and are often the first species to colonize artificial structures. It is unclear why this species is attracted to artificial habitat and seems to settle onto artificial reefs in high density. Juvenile tomtate (*H. aurolineatum*) are likely an important source of prey to resident predatory fish species due to their overwhelming abundance. In addition to grunts, numerous juvenile damselfish (Pomacentridae) as small as 1 – 2 cm in length were observed, often found in high density within areas in a tall macroalgal canopy. This indicates that settlement of these small reef-associated species is occurring.

The relative abundance of piscivores was similar on the new and old deployments (1.6% and 1.8%, respectively). The most abundant piscivores were members of the Carangidae (Jacks) and Lutjanidae (snappers). The large number of juvenile fish observed on the artificial reefs would serve as a prey base for these species. A large number of juvenile *Stegastes* spp. were observed on the older artificial reef, and a large number of juvenile grunts (*Haemulon* sp.) were present on the new artificial reefs, although both groups were present on both artificial reef age classes. *Stegastes* sp. are territorial damselfish that feed primarily on benthic diatoms and filamentous algae, but also consume detritus and invertebrates (Feitosa et al. 2012). Juvenile tomtate are reported to feed primarily on small demersal zooplankton (Alheit and Scheibel 1982).

Multivariate analysis indicated that there was no distinct difference in the fish community at the old and new Donaldson area deployments. The fish community on the 2013 reefs is well established and similar to the community on an older structure. This result indicates that colonization of artificial structures is occurring rapidly, and newly placed structures can be expected to support a diverse fish community within two years post-placement.

Although there were no clear differences between old and new deployments, there was some structure in the data found by cluster analysis. However, these differences were driven by low-biomass groups such as juvenile grunts, damselfish, and blennies. Although high numbers of juvenile Haemulidae (grunts), Pomacentridae (damselfish and chromis), and Labrisomidae (blennies) were found regularly throughout the artificial reef structures, their distribution was somewhat patchy, indicating other factors (i.e. macroalgal canopy height, structural differences, temporal variation in settlement, or predator/prey interactions) may influence settlement or post-settlement survival and small-scale habitat use by these important forage species.

4.1.2 Donaldson Benthic Community

Despite the relatively young age of the new deployments, the benthic community on the artificial reefs was well developed, providing ample prey items and shelter for fish species. The benthic community included a low abundance of stony corals and octocorals; these taxonomic groups were most abundant on the BJM13 reef. The absence of stony corals and octocorals on the other new deployments may have been an artifact of the dense canopy of macroalgae at some sites during the summer surveys; high cover of other benthic groups may have obscured small coral colonies.

The coral species found on the artificial reefs are generally considered to be tolerant of stressful conditions. *Carijoa riseii* is an azooxanthellate octocoral that is commonly found in turbid waters with strong water flow and on artificial structures including pilings, seawalls, and oil platforms. *Leptogorgia* sp. octocorals are common in estuaries and on shallow hardbottom habitats from the Chesapeake Bay to Brazil and are known to be tolerant of high sediment loads and fluctuating salinity (Williamson et al. 2011). Octocorals are known to have slow recruitment to artificial reefs (Gilliam 2012).

Comparisons of the benthic community between the older PCL Shallow site and the new 2013 deployments showed no significant differences in percent cover of any benthic functional group. This suggests that the Donaldson artificial reefs reached a stable benthic biological community within two years following deployment. Slight differences in the macroalgal community may be due to differences in predation or nutrient input to individual sites.

4.2 South County Artificial and Natural Reef Sites

Surveys of the artificial reef structures deployed in the South County area in 2014 showed high density and diversity of fishes and a well-developed benthic community in the first year post-deployment. The six new deployments in the South County area appear to be structurally stable and have similar vertical relief compared to measurements taken during deployment. Increases in the maximum depth of 4 to 9 feet recorded by divers in 2015 suggest scouring; however, as described above in Section 4.1, the difference in depth measurement methods likely accounts for most of the differences in measurements. The older (2008) artificial reef deployments had somewhat lower vertical relief and less structural complexity than the new 2014 deployments.

The location of the South County artificial reef deployments in close proximity to natural reef habitats presents a unique opportunity to directly compare replicated reefs of different ages with the nearby natural hardbottom community. The South County artificial reefs are also located different distances from the natural ridge (200 m for new deployments and 385 m for the old deployments). The two are not directly compared in this report because the factor of distance from the natural reef is confounded within the factor of reef age, as the old (2008) deployments are all located further from the reef than the new (2014) deployments (with the exception of Site 11). Therefore, differences between the old (2008) and new (2014) artificial reef deployments could be attributed to the distance to natural reef and/or the age of the deployments and seasonal difference between surveys at the new and old deployments.

The natural reef ridge had comparable vertical relief to the artificial structures (9 to 10 feet) and similar water depth, although the natural reef structure provides a different level of complexity and refuge space than the artificial habitats. The continuous, linear nature of the ridge presents an opportunity to study the fish community at different distances from the artificial reefs and to monitor changes in the local fish community post-deployment.

4.2.1 Seasonal Differences

Surveys in the South County area were conducted partially in August 2015 and partially in November 2015, which resulted in several significant differences that may be attributed to temporal differences between surveys. These differences included higher macroalgae cover and a greater abundance of juvenile *Haemulon* sp. during the August surveys. Due to these differences, direct comparisons of the fish and benthic community between the new deployments (surveyed in August) and the old deployments and natural reef (both surveyed mostly in November) were limited. Surveys in August 2015 were likely influenced by residual effects of the upwelling and cold bottom temperatures in July 2015.

Offshore conditions in Martin County present a challenging environment for recreational SCUBA diving. Wind and wave conditions along with reduced visibility often limit the number of suitable survey days within a given time period. These conditions are made even more variable by periodic upwelling events and shifts in the position of the Gulf stream current, which can result in fluctuating bottom temperatures and periods of extremely high visibility (as was seen during the November surveys). Bottom temperatures during the current study ranged from 68°F (20°C) in July to 85°F (29°C) in November and visibility ranged from 10 ft (3 m) to over 80 ft (24 m). However, in order to minimize the number of confounding factors in a direct comparison of two ecological communities, it is essential to minimize seasonal differences and other sources of variability in the dataset. Future monitoring should take care to conduct surveys within the same season, or to randomize the order in which sites are visited, in order to prevent a single treatment group from being surveyed entirely within one season.

4.2.2 South County Fish Community

The fish community on the South County reefs was highly diverse with 90 species observed overall. The maximum number observed on a single reef was 38 species observed at The Heap. A review of previous monitoring reports from the 2008 deployments showed a high of 36 species, also observed at The Heap in 2009. Overall, species richness values from the new 2014 deployments were comparable to richness values observed at the 2008 deployments in the first year post-deployment (Hesperides Group, 2010). There were no significant differences in species richness between the old and new deployments or the natural reef, indicating that colonization of the artificial reefs occurred very rapidly.

The large decrease in the abundance of juvenile *Haemulon* sp. (mostly tomtate) from August to November indicates that many of these juvenile fish may have been consumed with only a fraction of individuals reaching the larger size classes observed in November. Juvenile tomtate less than 5 cm TL were shown to have a high degree of site fidelity by Tupper and Juanes (1999), often being re-captured within 5 m of their original location. This suggests that juveniles likely did not migrate from the reef structures in the current study.

Significant differences were found in the fish community at the new and old artificial reef deployments; however, some of these differences may be attributed to seasonal differences, residual effects of the summer upwelling event, and/or distance to the natural reef. The majority of genera that contributed to the difference were more abundant on the new 2014 deployments, and the new deployments had significantly greater abundance of fish even after *Haemulon* spp. were removed. This result could be due to a variety of factors, including distance to the natural reef, season of sampling, or any combination of these. Upwelling events are well documented in the southeastern United States and generally occur during the summer months. Upwelling occurred in July of 2015, just prior to sampling of the new deployments. These events bring nutrient-rich Gulf Stream water onto the continental shelf and are associated with large increases in the abundance and biomass of phytoplankton, zooplankton, and fish larvae (Pitts 1999).

Results from this study show that there were significant differences in the fish community at the artificial reefs and natural reef ridge. The fish community at the natural site located close to several artificial reef structures (Natural Center, 200 m from 4 artificial structures) was more similar to the nearby artificial reefs than the community at the natural site located to the north of the new deployments (approximately 300 m north of Site 9). These results indicate that, although there are persistent differences in the fish community utilizing the artificial reef habitat, there may be some level of mixing between the natural reef ridge and artificial reefs.

The overall goal of the South County artificial reef area is to provide recruitment space for obligate hardbottom species such as grouper and snapper. In order to determine whether the reefs in this area are achieving this goal, and if recruitment onto the artificial reefs results in changes to the fish community on nearby hardbottom, it is necessary to compare the natural fish community in Martin County, both inside and outside the influence of the artificial reefs.

Baseline data from the region-wide Southeast Florida Coral Reef Fishery-Independent monitoring program provides an additional resource for comparing the fish community found on natural hardbottom in Martin County.

The primary contributors to the difference between the artificial reefs and the natural reef were the genera *Haemulon* and *Decapterus.* Both of these genera are commonly found in high abundance on artificial reefs. *H. aurolineatum* (tomtate) were a primary contributor to the difference between artificial and natural reefs in previous studies in south Florida (Walker et al. 2002, Thanner et al. 2006, Arena et al. 2007, Kilfoyle et al. 2013), although it is still unclear why this species is frequently dominant on artificial structures and whether the population on natural reefs is in any way influenced by the construction of artificial reefs. Although *Decapterus* sp. (scad) are frequently reported in high abundance on artificial reefs, spikes in fish abundance due to high numbers of this genera were also recorded on natural reefs in Martin County during the 2013 Southeast Florida Coral Reef Fishery-Independent monitoring surveys (Kilfoyle et al. 2015).

The vermilion snapper is a commercially important species, and the distribution of this species shows an interesting pattern that may be indicative of interactions between artificial structures and nearby natural reef. This species was consistently a top contributor to the difference between treatments, and was found in high abundance on both the new artificial reefs and the Natural Center site. Vermilion snapper were absent from the Natural North site, located further from the 2013 deployments (new artificial reefs in South County). The length of the vermilion snapper observed on the new deployments (average length 20 – 25 cm) indicates that this species was likely attracted to the artificial structure rather than recruits; the first-year age class reach a maximum size of 10 cm (Grimes 1978). Vermilion snapper spawn multiple times per season, from late spring to early fall (Grimes and Huntsman, 1980). The species also shows a high degree of site fidelity with tagged fishes often recaptured at the same site (Grimes et al. 1982). Limited resources and competition on the artificial structures may have led to an increase of this species on the nearby reef. Vermillion snapper were previously observed in historical monitoring surveys on Martin County artificial reefs in both the Donaldson and Sirotikin reef areas. The 2016 surveys of natural hardbottom sites and comparison with historical RVC data from natural hardbottom may further elucidate the effect of artificial reef placement on this species.

The lower abundance of herbivores on the artificial reefs was mainly attributed to the bicolor damselfish (*Stegastes partitus*) and *Acanthurus* spp. (surgeonfish); both were more abundant on the natural reef. *Acanthurus* spp. surgeonfishes have been reported in lower abundance on artificial structures than on natural reefs (Randall 1963, Bohnsack et al. 1994) and it has been suggested that this is due to isolation of small artificial reefs and the lack of overall grazing area (Bohnsack et al. 1994). The survival of juvenile bicolor damselfish is strongly related to the availability of small crevices for shelter (Nemeth 1998). It is possible that bicolor damselfish that settle on the artificial reefs are more heavily preyed upon than those on the natural reef.

The distinct separation of the Natural North and Natural Center sites and higher similarity between the Natural Center site and both the old and new artificial reefs was somewhat unexpected in the current study, but suggests that there is mixing in the fish community between the natural reef and the artificial reef deployments. In addition to the abundance of vermilion snapper on the artificial and Natural Center sites, there was also a greater abundance of tomtate at the Natural Center site; this species was not present at the Natural North site. Considering the well documented settlement and abundance of this species on artificial structures, it is likely that tomtate associating with the artificial reef are moving between the artificial structure and the natural reef. It remains unclear to what extent these species are moving to the north and south along the reef ridge, or whether the natural ridge is a "stop-over" site for fish migrating between artificial structures to the east and west of the ridge. Additional surveys to the north and south in 2016, at variable distances to the artificial reef, will help to determine if species that are abundant on the artificial reefs, such as vermilion snapper, tomtate, and gray snapper, are recruiting or migrating along the reef ridge.

4.2.3 South County Benthic Community

The benthic community on the old and new artificial reefs in the South County area was dominated by turf and macroalgae, along with a highly diverse community of tunicates, bryozoans, sponges, and hydroids. The tall macroalgae canopy provided cover for juvenile grunts, damselfish, and other reef-associated species. Macroalgae cover was highest on the new reef deployments while cover of other groups was lower; this result is expected as the new reefs had only been in place for one year, and development of higher cover of sponges, tunicates, and other benthic groups is expected with more time.

There was a significant, and somewhat large, difference in macroalgae cover between the artificial reefs and the natural reef; cover on the artificial reefs was significantly higher. The relatively high cover of macroalgae on the new deployments may be an artifact of seasonal differences between surveys, as the single old deployment that was surveyed during the summer had the highest macroalgae cover of any site (Jack MacDonald Reef; 73.2%; dominated by *Gracilaria* and *Dictyopteris*). Macroalgal cover on the old deployments surveyed in November was also higher than on the natural hardbottom, although the dominant species were similar.

Surgeonfishes (*Acanthurus* spp.) are important herbivores, and the natural hardbottom may have a higher grazing pressure compared to the artificial reefs, which were dominated by planktivores and invertivores. *Acanthurus* spp. surgeonfishes feed primarily on turf and filamentous algae; however, coarsely-branched, sheet-like, articulated calcareous and thick-leathery algae forms are also found in gut contents (Ferreira and Gonçalves 2006). All of the common macroalgae genera found on the artificial reefs have been documented in the stomach contents of Atlantic *Acanthurus* spp., including *Gracilaria*, *Dictyopteris*, *Botryocladia*, and *Caulerpa* (Dias et al. 2001). However, Peterson et al. (2013) showed that snapper and grunts attracted to newly deployed artificial structures resulted in increased nutrient concentration due to excretory products produced by resident fish. This, in turn, led to increased productivity in the benthic plant community. It is likely that the artificial reefs are influenced by a combination of reduced grazing pressure and increased local nutrient supply, leading to a higher level of macroalgal productivity. In addition, differences in macroalgal cover may be attributed to differences in rugosity or material of the artificial reefs

Both *Oculina diffusa* and *Siderastrea siderea* were abundant on the natural reef ridge and are known to recruit to artificial structures. Given the young age of the new reefs at the South County site, the absence of stony coral recruits is not surprising; however, coral recruitment was expected at the 2008 South County reefs. It is possible that the higher cover of macroalgae and other benthic groups on the artificial structures limits the space suitable for coral settlement, or that increased grazing pressure by invertivores occurs on the artificial reef structures.

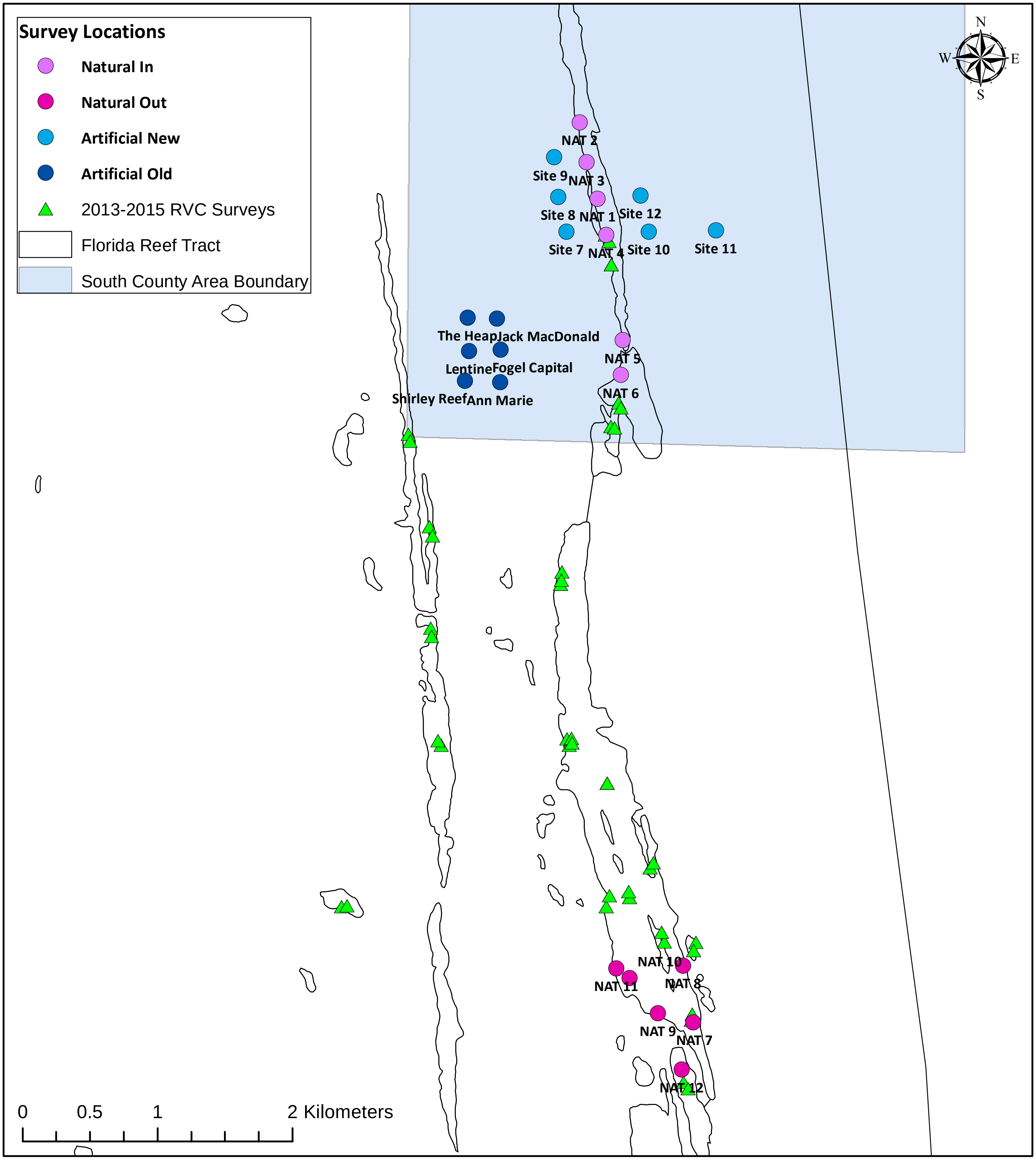
4.3 2016 Monitoring Design and RVC Comparison

The 2016 artificial reef monitoring program was designed in order to gather more information on the differences and similarities in the fish community on artificial and natural hardbottom habitats in Martin County. Four treatment groups will be sampled, with six surveys in each treatment group. The treatment groups consist of "old" artificial reefs deployed in 2008, "new" artificial reefs deployed in 2014, natural reefs within the South County artificial reef area, and natural reefs further away from the artificial reefs.

Data collected during the 2016 monitoring surveys will also be compared to the Southeast Florida Coral Reef Initiative's (SEFCRI) Reef fish Visual Census (RVC) surveys. The RVC project is a joint effort by partner agencies of SEFRCI with the majority of the funding provided by the NOAA Coral Reef Conservation Program. This monitoring program was put in place to assess the reef fish resources of the Northern Florida Reef Tract. Surveys were conducted annually between the Government Cut Inlet in Miami-Dade County and the Port St. Lucie Inlet in Martin County. The robust dataset provides an opportunity to mine data to examine individual species and assemblage correlations with various abiotic and biotic variables (Kilfoyle et al., 2015). A total of 64 RVC samples were conducted between 2013 and 2015 in a similar location, depth range and habitat type to the natural reef sites in the 2016 artificial reef monitoring program. These samples, as well as any collected during the 2016 sampling season, will be used as further comparison between the reef fish assemblages present on the artificial reefs versus those on the natural hardbottom habitats of Martin County. The locations of the 2016 sampling sites along with the locations of historical RVC surveys are shown in **Figure 12**.

In a summary report of RVC data collected between 2012 and 2014, the northern areas of the survey frame (North Palm Beach and Martin) contained relatively fewer species than the southern areas (Broward-Miami, Deerfield and South Palm Beach). The RVC data has been used to show significant differences in assemblage structure between the northernmost sites and the southern sites on the Northern Florida Reef tract (Fisco 2016). The strongest differences were attributed to the significant increase in the number of temperate species such as the tomtate (*H. aurolineatum*) on the northern reefs with a decrease in the number of tropical reef species such as the Bicolor Damselfish (*Stegastes partitus*) (Fisco 2016, Kilfoyle et al. 2015).

Figure 12
2016 Survey Locations



5.0 CONCLUSIONS

The artificial reefs in Martin County support a diverse community of fish and benthic invertebrates, and provide additional hardbottom habitat to serve as a refuge for numerous commercially important fish species. Artificial reefs in the Donaldson reef site are not located in close proximity to natural hardbottom. The 2013 Donaldson deployments showed rapid development of the benthic community in 2015 (two years post-deployment), and fish populations and epibiota were similar to the 2006 Donaldson reefs. This shows a rapid development of the artificial reef community within two years post-deployment.

Artificial reef deployments in the South County area are located in close proximity to nearby natural hardbottom, and therefore it is likely that there is some degree of interaction with the nearby hardbottom community. The minimum distance between the natural reef ridge and the artificial reef structures is 590 ft (180 m). This report represents the first monitoring effort that includes both the artificial reef deployments (2008 and 2014) and the natural hardbottom ridge in the South County area and discusses preliminary findings regarding similarities and differences between the artificial and natural habitats in Martin County. The following summarizes the results of the 2015 monitoring for the Martin County Artificial Reef Program:

Donaldson Area 2013 Deployments

- Artificial reefs deployed in the Donaldson area in 2013 supported a diverse community of fish; 80 species were recorded and 24 of these are managed species.
- The new (2013) Donaldson deployments had greater mean abundance of fish (# of fish per survey) than the old deployment (2006, PCL Shallow). The difference in abundance was largely attributed to the very high density of juvenile grunts observed at the new Donaldson deployments during the July and August 2015 surveys. The PCL Shallow site also differs from the new deployments in size (i.e. one large deployment vs. several smaller deployments).
- Multivariate analysis indicated that there was no distinct difference in the structure of the fish community at the old and new Donaldson area deployments. This shows that the fish community on the two-year post-deployment structures is well established and similar to the community on an older structure.
- Despite the relatively young age of the new deployments, the benthic community on the artificial reefs was well developed, providing ample prey and shelter for fish species. The benthic community was characterized by low abundance of stony corals and octocorals, which were most abundant on the BJM13 reef at 1.3 and 2.0 colonies per m^2 respectively.
- Comparisons of the benthic community between the PCL Shallow site and the new 2013 deployments showed no significant differences in the cover of any benthic functional groups. This suggests that the artificial reefs in the Donaldson area reach a stable benthic biological community within two years post-deployment.

South County 2014 Deployments, 2008 Deployments, and Natural Hardbottom

- Artificial reefs deployed in the South County site in 2014 supported 58 species of fish and 13 managed fish species. Artificial reefs deployed in 2008 supported 59 species and 18 managed fish species.
- There were no significant differences in species richness between the old and new deployments or the natural reef, indicating that colonization of the artificial reefs occurred very rapidly within the first year.
- There were significant differences in the fish community at the artificial reefs and the natural reef ridge. The primary contributors to the difference between the artificial reefs and the natural reef were the genera *Haemulon* (grunts) and *Decapterus* (scad). Both of these genera are commonly found in high abundance on artificial reefs. The gray snapper (*Lutjanus griseus*) was also more abundant on the artificial reefs. The ocean surgeon and doctorfish (*Acanthurus bahianus* and *A. chirurgus*) were more abundant on the natural reefs than on the artificial structures.
- The natural reef site located 200 m from four artificial reef structures was more similar to the artificial reefs than the natural site located 300 m to the north of the new artificial reef deployments. Both vermillion snapper and tomtate were abundant at the natural site located closer to the artificial reefs, and absent from the site located further away.
- Higher macroalgal cover and greater abundance of juvenile *Haemulon* sp. were observed on the artificial reefs during the August surveys compared to the November surveys.
- When comparing only seasonally comparable quadrats, macroalgae, bryozoan, and tunicate cover were all significantly greater on the artificial reefs than on the natural reef ridge. Cover of sediment over hardbottom, encrusting red algae, and stony coral was significantly higher on the natural reef than on the artificial reefs. Cover of turf algae, sponges, hydroids, and other low-cover functional groups was comparable between the two locations.
- Stony coral colonies on the natural reef ridge were relatively abundant and consisted of *Oculina diffusa* and *Siderastrea* sp. No stony corals were recorded in quadrats on the South County artificial reefs.
- Additional surveys to the north and south, at variable distances to the artificial reef, will help to determine if species that are abundant on the artificial reefs, such as vermilion snapper, tomtate, and gray snapper, are recruiting or migrating along the natural reef ridge and will assist with future artificial reef siting and design.

6.0 LITERATURE CITED

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