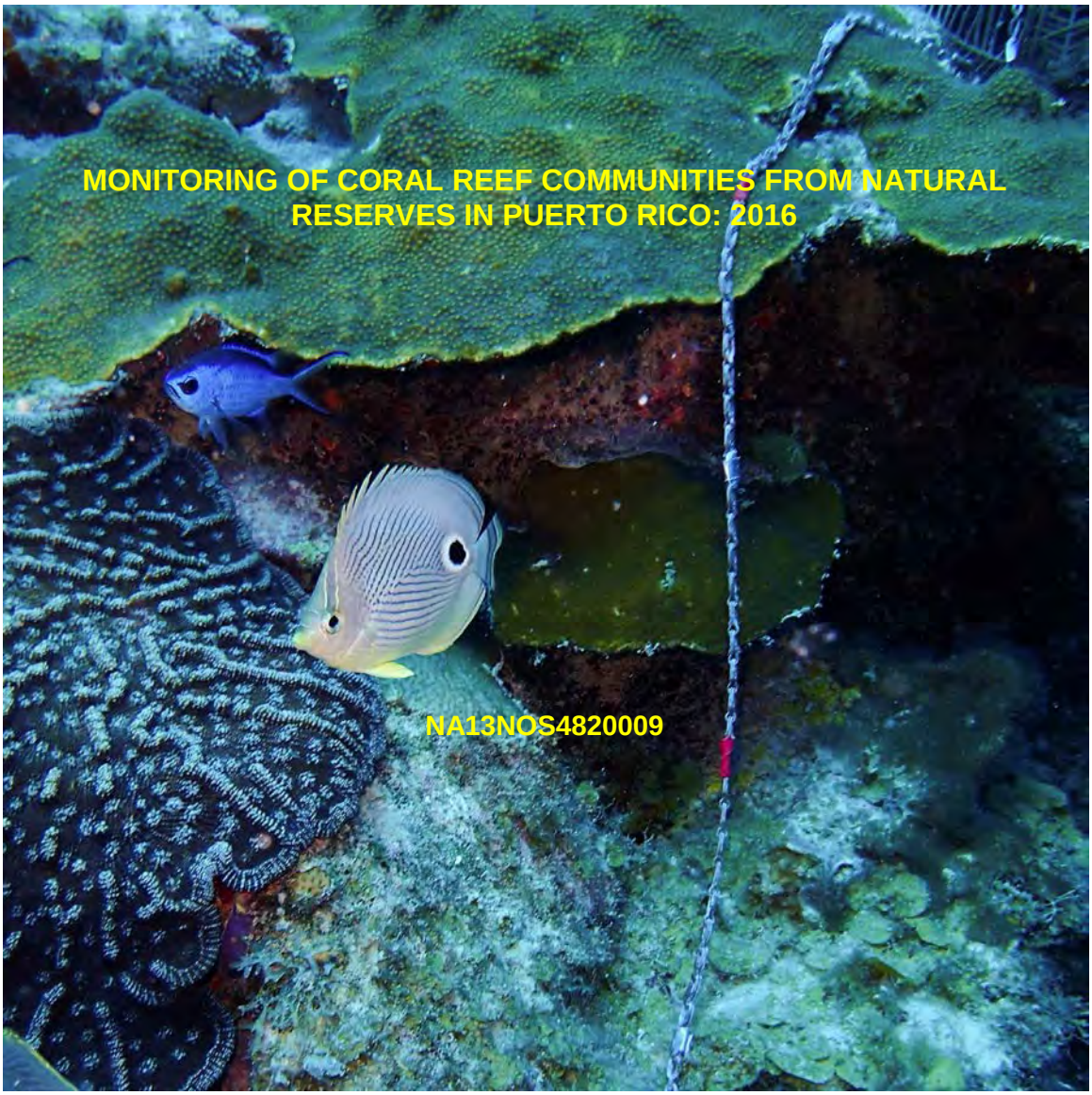
FINAL REPORT



by

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Executive Summary

A total of 21 coral reef stations were surveyed in the 2016 coral reef monitoring event. Baseline characterizations (17 reef stations) were produced for reef systems in Mayaguez Bay (Manchas Exteriores 20, 10, Rodriguez 5), Cabo Rojo (Guanajibo 20, El Negro10, 5), Guayanilla Bay (Maria Langa 20, 10, 5), Salinas (Cayo Coral 10, Cayo Ratones 5), Fajardo (Palominos 20, Palominitos 10, Cayo Diablo 5) and Isla de Culebra (Dakiti 20, Carlos Rosario 10, Luis Pena 5). Monitoring surveys were performed on the reefs stations of Isla de Vieques (El Seco30, Canjilones 20, Esperanza 10) and Vega Baja (Cibuco Reef 5). The Manchas Exteriores/Rodriguez Reef systems in Mayaguez and El Negro/Guanajibo in Cabo Rojo represent coastal coral reefs of the west coast with relatively high live coral cover (20 – 36 %) with strong dominance of *Orbicella annularis* and more than 10 coral species intercepted in the five permanent replicate transect set within the 5 – 20 m stratified depth format. Fringing reef systems at the outer sections of Guayama/Salinas (Cayo Caribe 10, Cayo Ratones 5) and Guayanilla Bays (Maria Langa 20, 10, 5) represent coastal reef systems of the south coast with a sessile-benthic community dominated by soft corals (gorgonians), with live cover by scleractinian corals in the 12 – 20% range, including one reef station dominated in terms of reef substrate cover by Fused Staghorn Coral, *Acropora prolifera* (Maria Langa 5). Reefs surveyed from the Cordillera de Fajardo (Palomino 20, Palominito 10, Cayo Diablo 5) represent coral reef systems of the east coast with high coral cover (20 – 32% range) with a history of intense recreational use. Reefs surveyed at Isla de Culebra (Dakiti 20, Carlos Rosario 10, Luis Pena 5) represent systems from an upstream location, under low recreational impact, within the Luis Pena Marine Reserve with extensive coral buildup, but highly degraded and overgrown by encrusting biota, particularly red algae (*Ramicrusta sp*).

From the monitoring surveys of the reefs in Vieques (El Seco 30, Canjilones 20, Boya Esperanza 10) and Vega Baja (Cibuco) live scleractinian coral cover remained statistically without significant change. Small increments of coral cover were measured at El Seco 30 and Esperanza 10, but these differences were within sampling variability error. Statistically significant variations of benthic community structure between monitoring surveys were detected for all of the three Vieques reefs (Permanova; $p < 0.001$). Differences were associated with a drastic decline (five to six fold) of reef substrate cover by turf algae, a previously dominant taxonomic category of reef substrate cover and a corresponding increase of cover by the previously unreported red crustose alga, *Ramicrusta sp*. with reef substrate cover as high as 58.7 % at Boya Esperanza 10. It is uncertain at this point if the displacement of turf algae by *Ramicrusta sp*. has had and/or is having any impact upon the Vieques reef corals, since substrate cover by corals at the reef stations monitored did not decline, but rather a mild increasing trend was observed. The implications of such colonization of hard bottom by encrusting red algae on coral growth, recruitment and competition for space are highly speculative at this point, but prospective monitoring of these reefs and others within the east coast (Fajardo, Culebra) will allow further assessments of these relationships.

The density of fishes, including commercially important groupers (*Epinephelus guttatus*), snappers (*Ocyurus chrysurus, Lutjanus jocu*) and Spiny Lobsters (*Panulirus argus*) and the size of spiny lobsters at Luis Pena 10 within the Luis Pena Marine Reserve are the highest and largest (in the case of spiny lobsters) ever recorded in the PR Coral Reef Monitoring Program. Thus, it is here proposed that the fishing closure at this reef is having positive impacts in terms of the fish community.

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II Introduction

This is the final report corresponding to the 2016 survey of the Puerto Rico Coral Reef Monitoring Program, sponsored by NOAA Coral Reef Conservation Program (CRCP) and administered by the PR Department of Natural and Environmental Resources (PRDNER). The monitoring program includes quantitative and qualitative measurements of reef substrate cover (%) by sessile-benthic categories and characterizations of taxonomic composition, abundance and size frequency distributions of commercially important fishes and motile megabenthic invertebrates from a total of 42 reef stations within 14 Natural Reserves in Puerto Rico. The coral monitoring program was modified in 2015 to increase the number of reef stations from 15 to 42, reducing the monitoring frequency from annual surveys to alternate year monitoring cycles.

Initial baseline characterization surveys for reef sites in Natural Reserves of Isla Desecheo, Rincon, Mayaguez, Guánica, Isla Caja de Muertos, Cabo Rojo and Ponce were performed during the period between 1999 and 2004 (García-Sais et al., 2001 a, b, c; García-Sais et al., 2005). Additional baseline characterizations have been included to enhance the geographical coverage of coral reefs around Puerto Rico and provide a more robust sampling design directed to analyze changes of live coral cover and taxonomic composition in relation to water turbidity gradients associated with depth, distance from shore and location relative to major river discharges. This design also aims to detect and discriminate changes of live coral cover associated with local environmental disturbances versus regional (climatological/oceanographic) factors to support and facilitate management actions and perspectives regarding coral reef ecological health.

This report includes new quantitative baseline characterizations of 17 coral reef stations within the Culebra, Cabo Rojo, Mayaguez, Guayanilla, Salinas and Fajardo Natural Reserves, and the regular annual monitoring surveys for the Vieques and Vega Baja Natural Reserves. Complete data sets for all reef sites can be found in previous annual monitoring reports prepared by García-Sais et al. (2004, 2005, 2006, 2007, 2008, 2009, 2010, 2012, 2014 and 2015). Upon request by DNER-CRCP representatives, comprehensive data bases prepared in excel format that are inclusive of all quantitative records on fish taxonomic composition and abundance, and sessile-benthic taxonomic composition and percent cover were produced and delivered to DNER. It is suggested that these data be converted into a GIS format for a more flexible manipulation by Natural Reserve managers and other stakeholders. Such information will contribute to an existing network of U.S. coral reef monitoring sites sponsored by NOAA and administered by DNER.

Coral Reef Monitoring Program Research Synthesis

Since the start of this monitoring program in 1999 coral reef systems in Puerto Rico have shown a variety of ecological health trends. Coastal shallow reefs of the south coast, such as Cayo Coral in Guanica and West Reef of Isla Caja de Muerto in Ponce exhibited a moderate, yet statistically significant decline of live coral cover between their baseline survey and 2005. Although we do not have any baseline data for the analysis of factors potentially influencing this trend, it is possible that these reefs were in some way affected by the regional coral bleaching event of 1998 (Williams and Bunkley-Williams, 1990). Such declining coral cover trends may represent lingering effects of the previous coral bleaching event influencing our baseline and initial monitoring surveys, particularly at Cayo Coral in Guanica, Isla Caja De Muerto and Derrumbadero in Ponce. During the same time frame, reefs in the oceanic islands of Mona and Desecheo as well as shelf edge reefs in Mayaguez and Ponce, and reefs all around Vieques (Garcia-Sais et al. 2004) maintained stable live coral cover.

A drastic decline of more than 50 % of live coral cover was measured from reefs in Mona and Desecheo islands during the 2006 monitoring survey after a severe coral bleaching event affected reef systems in the northern Caribbean during late 2005 (Miller et al. 2006; Garcia-Sais et al 2008). Sibling species of boulder star coral, *Montastraea annularis* and *M. faveolata* (genus now changed to *Orbicella spp*) were the most vulnerable to the bleaching event. Thus, reef systems strongly dominated in terms of substrate cover by these species, such as those of Mona and Desecheo, as well as the shelf-edge reefs of Derrumbadero in Ponce and Tourmaline Reef in Mayaguez were the most severely affected. In general, the magnitude of coral degradation declined with increasing depth and with increasing water turbidity, suggesting that light attenuation was a factor for coral protection during the bleaching event. Protection from bleaching with increasing depth from 20 to 30 m was observed at both Tourmaline Reef in Mayaguez and Puerto Canoas Reef in Desecheo. The Tres Palmas Reef system in Rincon, dominated in terms of substrate cover by Elkhorn coral, *Acropora palmata* at depths of 1-5 m and by *M. cavernosa* at 10 m did not show any statistically significant decline of live coral cover.

After up to three consecutive years of measuring what appeared to be lingering effects of the 2005 coral bleaching event, subtle to moderate increments of live coral cover were noted in the 2008-09, 2009 -10, 2010-11, 2012 -13 monitoring surveys (Garcia et al. 2008, 2009, 2010, 2012, 2014), and to a larger extent in the 2014-2015 monitoring survey (Garcia-Sais et al, 2015).

Differences between years were not statistically significant, but the trend represented a reversal from the continued decline of live coral cover since the 2005 monitoring survey. An exception to this trend was observed at the fringing *Acropora palmata* reef of Tres Palmas in Rincon, which presented a declining trend of live coral cover associated with a widespread infection of what appears to be "white pox", a disease also known as "patchy necrosis" (Garcia et al. 2008). Coral recuperation was highest at coastal reefs, such as Cayo Coral and Tourmaline, whereas oceanic and shelf-edge reefs evidenced minor or negligible live coral increments until 2013. During the last monitoring survey in 2014- 2015 (Garcia-Sais et al., 2015) both shelf-edge (Derrumbadero 20, Tourmaline 20, Tourmaline 30) and oceanic reef stations (Desecheo 15, Desecheo 20, Desecheo 30) evidenced a marked increment in live coral cover associated with what appears to be a recuperation of the original *Orbicella annularis* complex colonies.

Phase shifts in the taxonomic composition of reef substrate cover by live corals have been detected at Tourmaline Reef 10m (Mayaguez) and at Puerto Botes Reef 20m (Isla Desecheo). In both cases, mortality of Boulder Star Coral (*Orbicella annularis*) has allowed branching corals to become the dominant coral taxa in terms of substrate cover. In the case of Tourmaline reef, Yellow Pencil Coral (*Madracis auretenra*) grew over dead coral sections of *O. annularis* and other reef hard ground to the point where total cover by live coral has increased from its original condition before the 2005 bleaching induced mortality.

A total of 201 species of diurnal, non-cryptic fish species have been identified during the coral reef monitoring program at the reefs surveyed. Fish populations have presented in general a trend of fluctuating differences of abundance and species richness within belt-transects (García-Sais et al., 2007, 2008, 2009, 2010, 2012, 2014). Variations between surveys were mostly associated with fluctuations of abundance by numerically dominant populations that exhibit highly aggregated distributions, such as the Masked Goby (*Coryphopterus personatus*), Blue Chromis (*Chromis cyanea*) and Creole Wrasse (*Clepticus parrae*), but also appear to respond to variations in the physical conditions affecting the reef during the time of our survey, such as wave action. This is particularly relevant for shallow reefs, and more critically determinant for *Acropora* reefs, such as the Tres Palmas and Cayo Aurora reef systems. The lack of consistent patterns or temporal trends of fish abundance, species richness and the rank order of fish abundance at any given reef station suggest that the annual fluctuations of fish abundance and community structure are probably associated with density-independent factors, such as recruitment dynamics.

Clear trends of fish community structure between the different reef systems have emerged with depth, distance from shore and reef rugosity as the most important factors influencing the relative abundance and similarity/dissimilarity between reef stations. The most distinctive pattern separates the herbivore dominated neritic station cluster from a zooplanktivore dominated oceanic reef station cluster. Also, herbivores exhibited a statistically significant pattern of decreasing abundance with increasing depth, whereas the relative abundance of zooplanktivores, omnivores and carnivores increased with depth. Live coral cover explained a minor fraction of the variability associated with the variations of fish abundance and species composition. This may respond to the fact that the amount of coral loss associated with the 2005 bleaching mortality is still below a threshold driving phase shifts of fish community structure and/or that the time required for coral mortality to result in significant changes of benthic habitat complexity influencing fish abundance, species richness and taxonomic composition have not been reached.

III Approach and Methodology

A total of 21 reefs located within eight (8) Natural Reserves were included in the PR Coral Reef Monitoring Program 2016 survey. These include 14 baseline characterization surveys at Cabo Rojo (3 stations), Mayaguez (3 stations), Salinas (2 stations), Guayanilla (3 stations), Fajardo (3 stations), and Culebra (3 stations). Monitoring surveys were performed at Vieques (3 stations) and Vega Baja (1 station). Figure 1 presents the geographic location of the coral reef sites included in the PR coral reef monitoring program. Survey dates, depth and geographic coordinates of reefs sites included in this 2016 baseline characterization and monitoring survey are shown in Table 1.

The PR coral reef monitoring program follows a depth, distance from shore and east-west stratified sampling design with a five (replicate) permanent transect array per reef station non-randomly placed in areas of optimal coral growth. The depth stratification protocol typically includes a 3 - 5 m, 7-10 m, and 17 – 20 m array (where available). Mesophotic reef stations include the 27 – 30 m depth range at Desecheo, Tourmaline, Isla de Mona and El Seco in Vieques. Such depth stratified sampling protocol has shown to be relevant for identification of patterns affecting coral health and fish population dynamics and community structure (Garcia-Sais 2012; Esteves 2014, Garcia-Sais and Williams, in preparation). The distance from shore gradient includes reef stations positioned across the relatively narrow island shelf, from coastal

fringing reefs to shelf-edge and oceanic reef sites. Due to the lack of major rivers east of the mainland (Culebra and Vieques), the east to west longitudinal gradient exhibits an increasing (to the west) water turbidity gradient associated with watershed runoff and phytoplankton biomass (chlorophyll-a). The gradient is particularly evident at the extremes of the study area when comparing the Culebra and Vieques reefs with the west coast reefs at similar depths and distances from shore.

Sessile-benthic reef communities

At each reef, a set of five 10 m long transects were surveyed. Transects were permanently marked with metal rods hammered to the reef substrate at both ends. Sessile-benthic reef communities were characterized by the continuous intercept chain-link method (as modified from Porter, 1972), following the CARICOMP (1984) protocol. This method provides information on the percent linear cover by sessile-benthic biota and other substrate categories along transects. It allows construction of reef community profiles by assignment of metric units to each substrate transition, which serves as a high precision baseline for monitoring. The chain has links of 1.42 cm long, marked every 10 links for facilitation of counting underwater. On any given transect the minimum amount of data points recorded is 416, increasing with topographic rugosity. The exact position of the chain is guided by a series of steel nails hammered into available hard (abiotic) substrate at approximately every 1.0 m in the reef. Also, a thin nylon reference line is stretched from rod to rod to guide divers over the linear transect path. Individual measurements of substrate categories, as recorded from the number of chain links are sorted, added and divided by the total distance (in chain links) on each transect to provide data on the cumulative percent linear cover by each substrate category. Soft corals, with the exception of encrusting forms (e.g. *Erythropodium caribaeorum*) are counted as number of colonies intercepted per transect, whenever any of their branches cross the transect reference line. The vertical relief of the reef, or rugosity is calculated by subtracting 10 meters from the total length (links) recorded with the chain at the 10 m marker of the reference line. The mean coefficient of variation of live coral cover in sets of replicate transects from all reefs surveyed during the entire monitoring program is at 27.0 %.

Reef fishes and motile megabenthic invertebrates

Demersal and territorial reef fish populations and motile megabenthic invertebrates are surveyed by sets of five 10 m long by 3 m wide ($30m^2$) belt-transects centered along the reference line of

transects used for sessile-benthic reef characterizations at each reef station. Transect width is marked with flagging tape stretched and tied to weights on both transect ends. Each transect is surveyed during 10 minutes. The initial two minutes are dedicated to detection of elusive and/or transitory species that swim away of the "belt-transect" area as soon as they detect a diver (e.g. snappers, large groupers, hogfish, mackerel, large parrotfishes, etc.). During the next three minutes, the diver swims over both sides of the transect area counting fishes that form schooling aggregations over the reef (e.g. *Chromis spp., Clepticus parrae,* etc.) and other transitory species as they enter the survey area, including the wrasses (e.g. *Thalassoma, Halichoeres spp*.) which tend to be attracted to divers and thereby, may increase in density during the survey. A second run over both sides of the transect is performed during the next three minutes of the survey in order to count demersal and territorial fishes (e.g. *Stegastes spp*, *Gramma loreto*, squirrelfishes, etc.) that remain within the transect area. The last two minutes were dedicated to counting the small gobies (e.g. *Coryphopterus spp*., *Elacatinus* spp.) associated with coral heads on both sides of transects. Fish species observed outside transect areas are reported to supplement the taxonomic assessment, but are not included in abundance determinations.

Density estimates and size distributions of commercially targeted reef fish species and them main reef herbivores (Parrotfishes, Doctorfishes) are produced from extensions of the regular 10 x 3 m belt-transect (30 m^2) to 20 x 4 (80 m^2) belts along the same regular transect lines. All individuals are counted and length (in cms) visually estimated. Precision of length estimates allows discrimination between new recruits, small juveniles, juveniles, adult and large adult size classes. All data is recorded in plastic paper.

Annual variations of the percent reef substrate cover by live corals and fish species richness and abundance are tested by Repeated Measurements Analysis of Variance (ANOVA) procedures on real values (un-transformed data) for each reef station on normally distributed

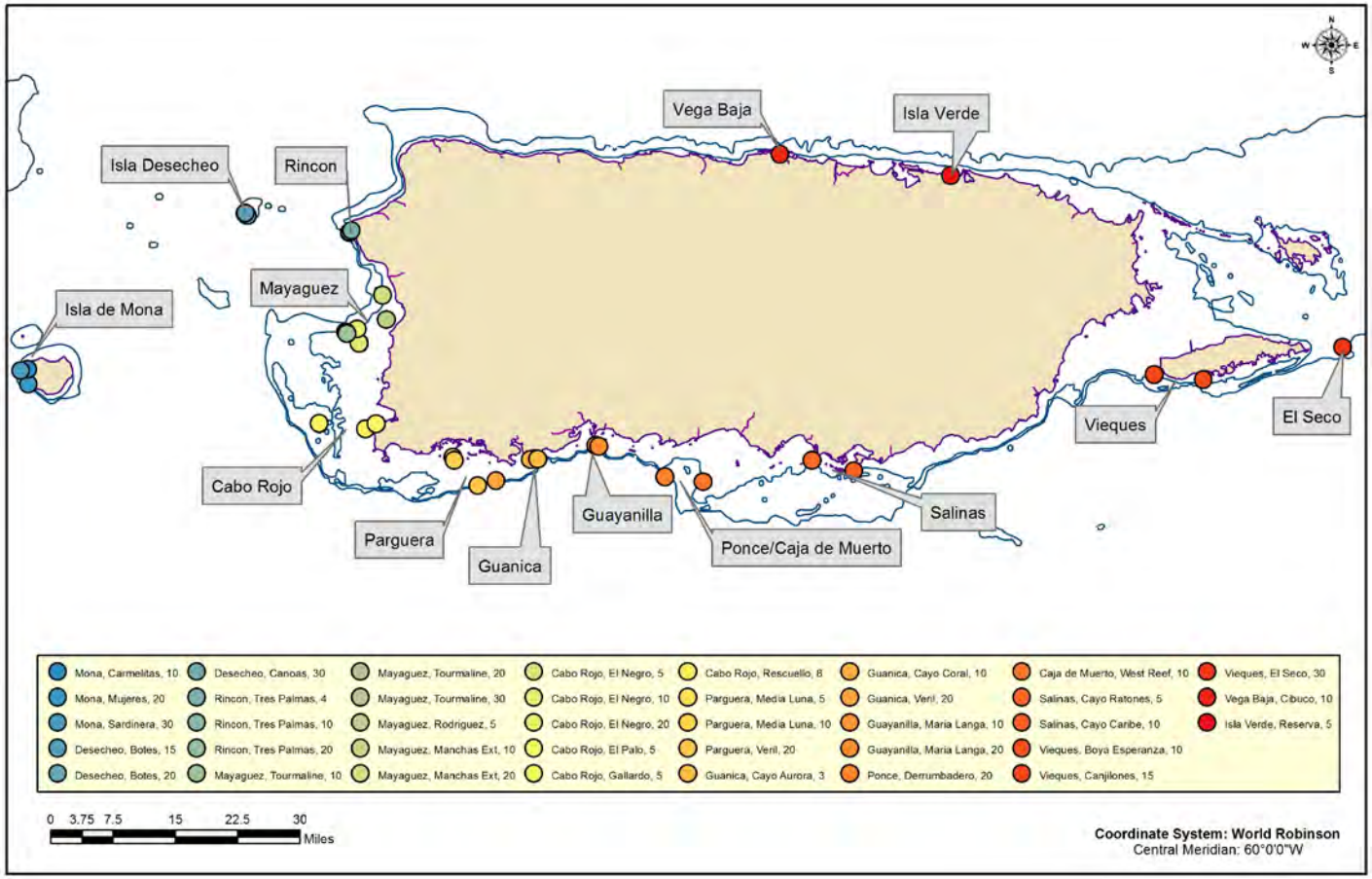


Figure 1. Map of reef stations included in the PR Coral Reef Monitoring Program

Table 1. Geographic positions and depths of coral reefs surveyed during 2016

Site/Reef Stations	Depth (m)	Latitude (°N)	Longitude (°W)	Survey Date
Cabo Rojo				
El Negro 5	4.6	18° 08.795	67° 14.855	7/6/2016
El Negro 10	7.8	18° 08.792	67° 14.862	7/6/2016
Guanajibo 20	18.0	18° 11.321	67° 15.178	7/8/2016
Mayaguez				
Rodriguez 5	3.8	18° 11.356	67° 11.511	7/7/2016
Manchas Exteriores 10	9.2	18° 14.012	67° 12.034	7/7/2016
Manchas Exteriores 20	18.5	18° 14.010	67° 12.055	7/8/2016
Guayanilla				
Maria Langa 5	3.1	17° 57.656	66° 45.175	9/5/2016
Maria Langa 10	8.9	17° 57.656	66° 45.175	8/8/2016
Maria Langa 20	15.8	17° 57.572	66° 44.819	8/8/2016
Salinas				
Cayo Ratones 5	4.0	17° 56.075	66° 18.148	8/4/2016
Cayo Caribes 10	9.1	17° 54.920	66° 12.844	8/4/2016
Fajardo				
Cayo Diablo 5	5.4	18.35487	65.56693	9/9/2016
Cayo Palominito	10.0	18° 20.125	65° 33.932	9/9/2016
Cayo Palomino	20	18° 21.627	65° 31.847	9/9/2016
Culebra				
Luis Pena 5	5.4	18.35487	65.56693	9/17/2016
Carlos Rosario 10	10.0	18° 20.125	65° 33.932	9/17/2016
Dakity 20	20	18° 21.627	65° 31.847	9/16/2016
Vieques				
Esperanza 10	9.4	18° 04.832	65° 29.277	9/18/2016
Canjilones 20	16.0	18° 05.380	65° 35.413	9/18/2016
El Seco 30	35.0	18° 08.321	65° 11.828	9/16/2016
Vega Baja				
Cibuco 5	10.0	18° 05.380	65° 35.413	9/18/2016

Results and Discussion

Manchas Exteriores 20, Mayaguez

Physical Description

Manchas Exteriores Reef is located approximately 1.5 NM northwest of Punta Algarrobo, at the entrance of Mayaguez Bay (Figure 2). The reef runs roughly parallel to the shoreline and sits at the north end of a series of elongated fringing reefs that include Manchas Interiores and Manchas Grandes off the Mayaguez coastline. Manchas Exteriores rises from a soft bottom with scattered patch reefs at a depth of approximately 31 m to a depth of approximately 2 m. Permanent transects were set along the 18 – 20 m depth contour at the base of an abrupt reef slope that breaks into small patch reef structures. Panoramic images of Manchas Exteriores 20 are shown in Photo Album 1.

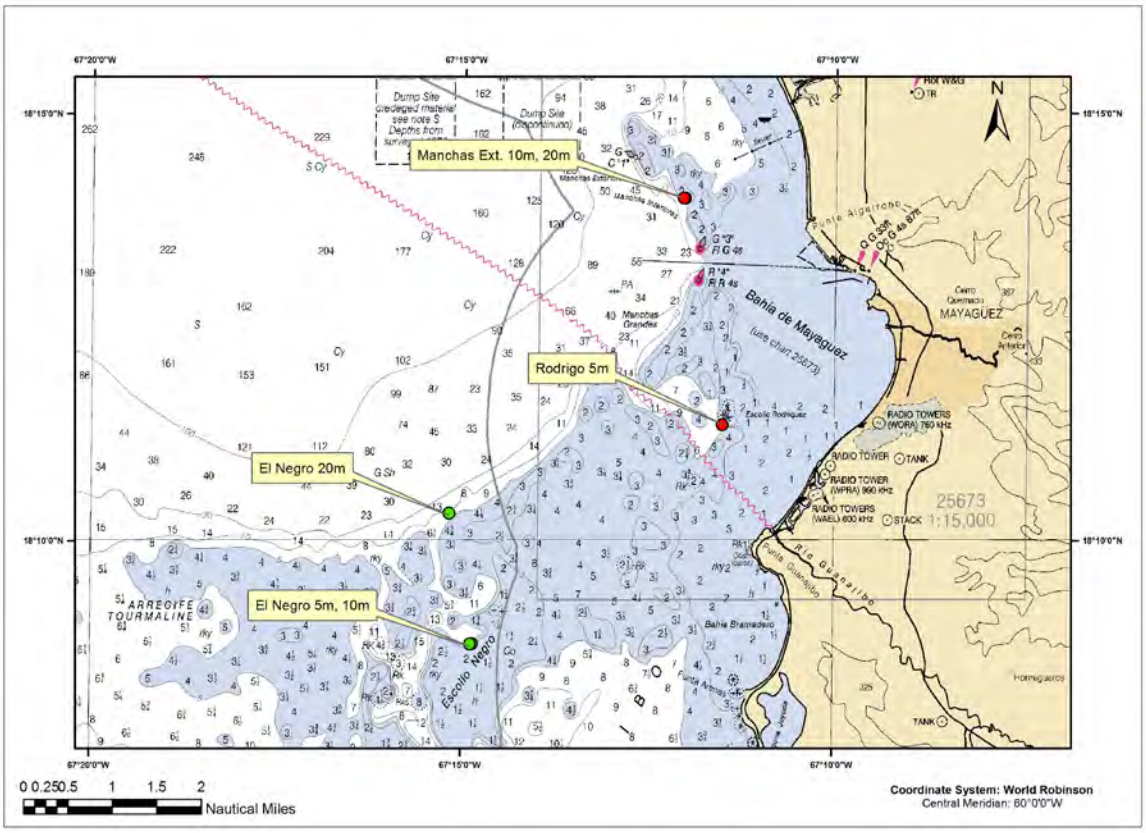


Figure 2. Location of coral reef monitoring stations in the Mayaguez and Cabo Rojo coastlines

Sessile-benthic Reef Community

Reef substrate cover at Manchas Exteriores 20 was dominated by benthic algae with a mean substrate cover of 48.7% (Figure 3). Turf algae, a mixed assemblage of short filamentous brown and red algae was the main component of the benthic algae with a mean cover of 35.4 %, representing 72.7% of the total cover by algae (Table 2). Fleshy brown macroalgae (*Dictyota sp*.) was also present in all transects surveyed with a mean cover of 12.0 %. Red crustose coralline algae, including the encrusting species *Peyssonnelia sp*. were also observed, but in relatively small patches along transects at Manchas Exteriores. Cyanobacterial films were present in all transects with a mean cover of 2.7%.

A total of 13 scleractinian coral species were intercepted by linear transects with a mean substrate cover of 20.4% (range: 16.2 – 25.2 %). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant coral in terms of reef substrate cover with 9.04 % (Figure 4) and was present in all five transects surveyed, along with lettuce corals *Agaricia lamarki* and *A. agaricites* (Table 2). The combined cover of these three species represented 75.8 % of the total cover by scleractinian corals in the reef. *Orbicella faveolata* and *O. franksi* were the prevailing species of Boulder Star Coral. Greater Starlet Coral, *Siderastrea siderea* and Great Star Coral, *Montastraea cavernosa* were present in four out of the five transects with mean substrate cover of 1.9 and 1.1 %, respectively (Figure 3).

Soft corals (gorgonians) were present in all transects, but in low density, with a mean cover of 1.8% and a mean density of 2.4 colonies per transect (Table 2). The encrusting species, *Erythropodium caribaeorum* was the main species present in four transects with a mean cover of 1.2 %. A total of 17 species of sponges, mostly represented by small encrusting individuals were present along transects with a combined substrate cover of 1.8%. The sponge species assemblage was highly variable between transects with only one species present in three transects (*Plaktoris sp*.) and three present in two transects. Eleven species were only observed in one transect.

Abiotic substrate categories presented a mean substrate cover of 24.6% (range: 18.0 – 32.7%). Reef overhangs, associated with ledges of Boulder Star Coral, Orbicella faveolata and O. franski were the main component of the abiotic category with a mean cover of 15.8%, representing 64.4% of the total abiotic cover (Table 2). Sand pockets were also present in all transects with a mean cover of 5.6 %. Reef rugosity averaged 4.4 m (range: 3.0 – 5.3 m).

Table 3. MEXT 20. Percent cover by sessile-benthic categories along permanent transects, Manchas Exteriores, Mayaguez, 20m. Survey date: July 7, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	5.23	3.97	3.05	5.34	4.55	**4.43**
Benthic Categories						
Abiotic						
Reef Overhang	22.61	16.43	14.06	12.77	13.38	**15.85**
Sand	3.31	2.61	7.08	5.20	9.62	**5.56**
Gap	1.29	2.20	2.36		4.72	**2.11**
Rubble	5.51					**1.10**
Total Abiotic	**32.72**	**21.24**	**23.50**	**17.97**	**27.72**	**24.63**
Benthic Algae						
Turf with sediment	40.17	33.17	34.76	38.14	30.99	**35.45**
Dictyota sp.	0.64	12.93	12.45	18.89	15.21	**12.02**
Peyssonnelia spp.	1.19		0.43	1.09	0.58	**0.66**
CCA	0.92	1.00	0.64	0.18		**0.55**
Total Benthic Algae	**42.92**	**47.09**	**48.28**	**58.30**	**46.78**	**48.68**
Hard Coral						
Orbicella annularis complex	1.84	12.83	11.16	8.12	11.26	**9.04**
Agaricia lamarcki	11.76	2.30	2.36	1.92	2.50	**4.17**
Agaricia agaricites	0.28	2.81	6.22	0.36	1.64	**2.26**
Siderastrea siderea	1.93	1.60		0.91	4.91	**1.87**
Montastraea cavernosa		0.80	3.00	1.64		**1.09**
Stephanocoenia intersepta	0.64		0.97	1.00	0.38	**0.60**
Meandrina meandrites				0.64	1.73	**0.47**
Porites astreoides			0.97	0.73		**0.34**
Madracis decactis	0.28			0.64		**0.18**
Agaricia fragilis	0.83					**0.17**
Madracis senaria		0.30		0.18		**0.10**
Leptoseris cucullata			0.32			**0.06**
Scolymia cubensis			0.21			**0.04**
Total Hard Coral	**17.56**	**20.64**	**25.21**	**16.15**	**22.43**	**20.40**
Cyanobacteria	5.15	4.21	1.07	1.92	1.15	**2.70**
#Gorgonians/transect	4	2	1	1	4	**2.40**
Octocoral						
Erythropodium caribaeorum		2.00	0.86	2.01	1.25	**1.22**
Briareum asbestinum		1.90	0.54			**0.49**
Eunicea *sp.*				0.18		**0.04**
Total Octocoral		**3.91**	**1.39**	**2.19**	**1.25**	**1.75**
Sponge						
Plaktoris sp.	0.37	0.30		0.73		**0.28**

Topsentia aphirophidites		0.80				**0.16**
Aplysina cauliformis		0.70				**0.14**
Amphimedon compressa	0.37				0.29	**0.13**
Aiocholoria crassa	0.64					**0.13**
Cinachyrella kuekenthali				0.64		**0.13**
Spirastrella hartmani				0.64		**0.13**
Neopetrosia proxima		0.60				**0.12**
Iotrochota birotulata	0.28		0.32			**0.12**
Niphates erecta		0.20		0.27		**0.09**
Scopalina ruetzleri				0.27	0.19	**0.09**
Agelas conifera				0.46		**0.09**
Monanchora arbuscula		0.30				**0.06**
Agelas dispar				0.27		**0.05**
Ircinia strobilina			0.21			**0.04**
Aiolochroia crassa					0.19	**0.04**
Verongula sp.				0.18		**0.04**
Total Sponge	**1.65**	**2.91**	**0.54**	**3.47**	**0.67**	**1.85**

Fishes and Motile Megabenthic Invertebrates

A total of 32 species of fish were identified within belt-transects from a depth of 18.5 m at Manchas Exteriores 20 (Table 3). Mean density was 367.6 Ind/transect (range: 213 – 488 Ind/transect) with a mean richness of 16.2 species per transect. The masked Goby, *Coryphopterus personatus* was the overwhelmingly dominant species present with a mean density of 310 Ind/transect, representing 84.3% of the total individuals. This is a small schooling zooplanktivore species that swarms over large coral colonies and below ledges. Other 10 species were present in at least four transects at Manchas Exteriores 20m. These include the Blue Chromis, *Chromis cyanea*, the Creole Wrasse, *Clepticus parrae*, the Peppermint and Sharknose Gobies*, Coryphopterus lipernes*, *Elacatinus evelynae*, the Princess, Stripped and Redband Parrotfishes, *Scarus taeniopterus, S. iserti*, *Sparisoma aurofrenatum*, the Beaugregory, *Stegastes leucostictus*, Fairy Basslet, *Gramma loreto*, and the Caribbean Puffer, *Canthigaster rostrata*. Twelve species were only present in one transect.

Despite the strong numerical dominance by zooplanktivore species that was largely driven by the abundance of *Coryphopterus personatus* the fish community structure at Manchas Exteriores presented a well-balanced assemblage of trophic groups. Herbivores were

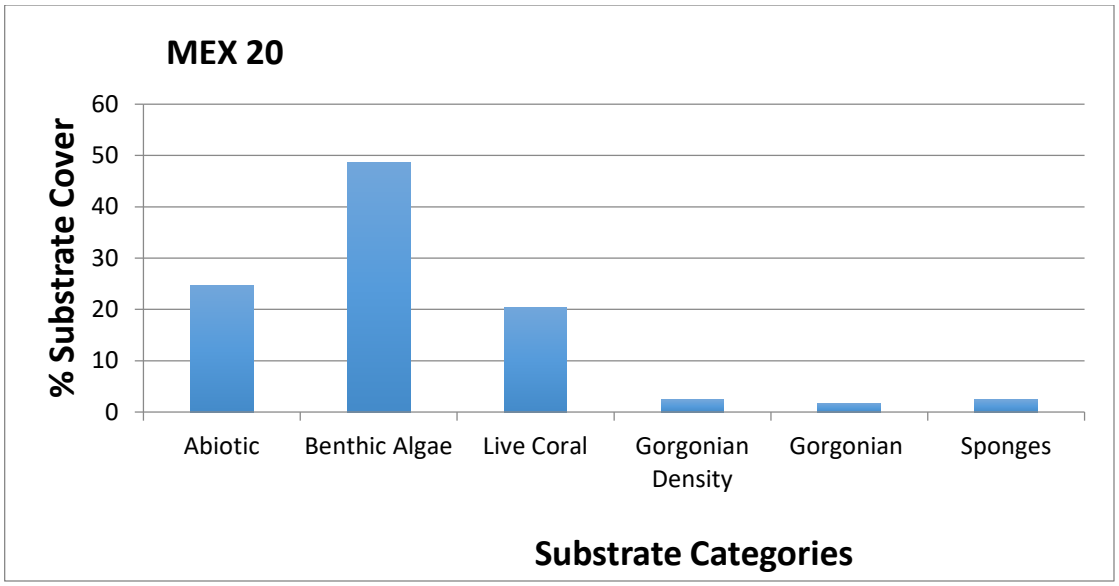


Figure 3. Mean substrate cover by benthic categories at Manchas Exteriores Reef 20m, Mayaguez, July 2016

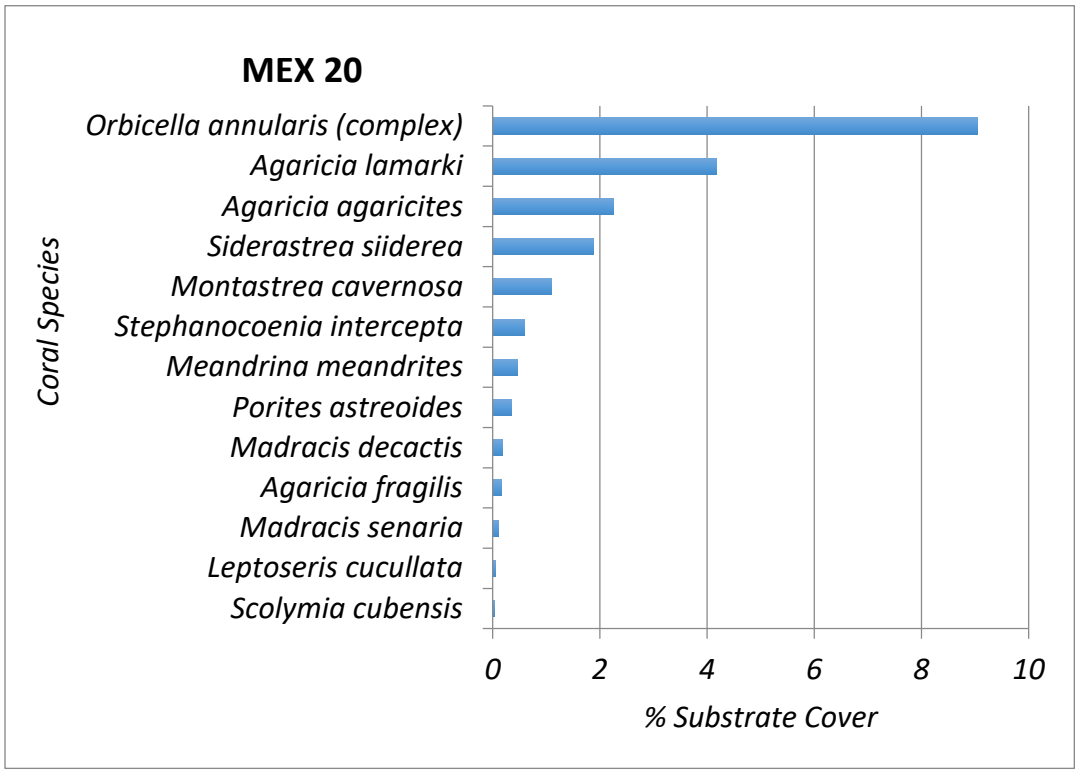


Figure 4. Mean substrate cover by coral species at Manchas Exteriores Reef 20, Mayaguez, July 2016

represented by four species of parrotfishes (Scaridae), three species of damselfishes (Pomacentridae) and one doctorfish (Acanthuridae). Small opportunistic carnivores were represented by two species of gobies (Gobiidae), two species of hamlets and two small groupers (Serranidae), one puffer (Tetraodontidae), one lionfish (*Pterois sp*) and one grunt (Haemulidae). Medium sized piscivores included at least three species of snappers (Lutjanidae) and two species of groupers (Serranidae), including one large Yellowfin Grouper, *Mycteroperca venenosa* observed outside transects.

The size-frequency distribution of parrotfishes (Scaridae) suggests that the reef serves largely as the habitat of adult individuals, with the exception of Princess Parrotfish, *Scarus taeniopterus* observed throughout its juvenile to adult size range (Table 4). Snappers (*Lutjanus synagris, L. jocu, L. mahogoni*) were present as late juveniles and young adults.

Motile megabenthic invertebrates included one juvenile Spiny Lobster, *Panulirus argus* observed outside transects.

Table 3. MEX 20. Taxonomic composition and abundance of fishes within 10 x 3 m belt-transects at Manchas Exteriores Reef, Mayaguez, 18.5 m. Survey date: July 8, 2016

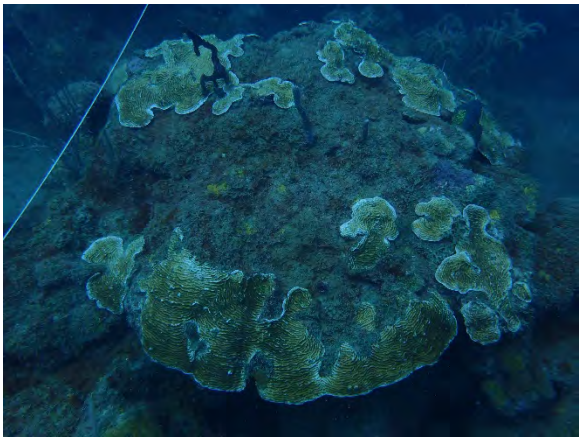
		Transects (Ind/30 m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	300	150	250	400	450	**310.0**
Chromis cyanea	Blue Chromis	25	11	7	21	10	**14.8**
Clepticus parrae	Creole Wrasse	10	16	25	15		**13.2**
Coryphopterus lipernes	Peppermint Goby	2	15	5	5	6	**6.6**
Scarus taeniopterus	Princess Parrotfish	4	3	5	3	3	**3.6**
Stegastes leucostictus	Beau Gregory	4	4	4	1	4	**3.4**
Scarus iserti	Stripped Parrotfish	2	1	8	1		**2.4**
Sparisoma aurofrenatum	Redband Parrotfish	3	1	2		3	**1.8**
Gobiosoma evelynae	Sharknose Goby	4		1	1	2	**1.6**
Gramma loreto	Fairy Basslet	2	1		1	2	**1.2**
Canthigaster rostrata	Caribbean Puffer		1	1	2	2	**1.2**
Chromis multilineata	Brown Chromis		2	3			**1.0**
Stegastes partitus	Bicolor Damselfish	2	1	1			**0.8**
Sparisoma viride	Stoplight Parrotfish	1			1	1	**0.6**
Acanthurus bahianus	Ocean Surgeon	2	1				**0.6**
Thalassoma bifasciatum	Bluehead Wrasse	1			1	1	**0.6**

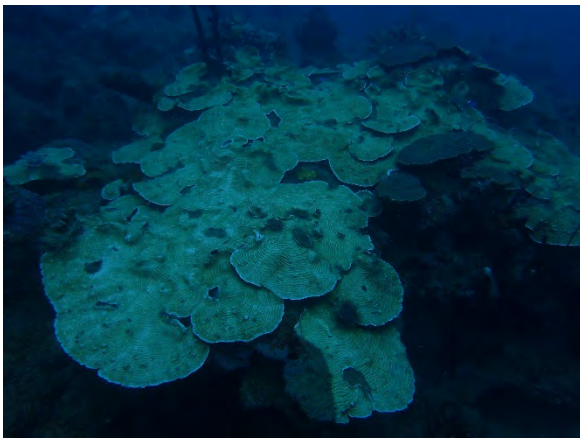
Stegastes adustus	Dusky Damselfish					2	**0.4**
Cephalopholis cruentatus	Graysby	1	1				**0.4**
Hypoplectrus sciurus	Yellowtail Hamlet		1	1			**0.4**
Hypoplectrus unicolor	Butter Hamlet	1			1		**0.4**
Pterois volitans	Lionfish			2			**0.4**
Cephalopholis fulva	Coney	1					**0.2**
Caranx ruber	Bar Jack		1				**0.2**
Haemulon flavolineatum	French Grunt	1					**0.2**
Anisotremus virginicus	Porkfish		1				**0.2**
Mulloides martinicus	Yellowfin Goatfish					1	**0.2**
Holacanthus tricolor	Rock Beauty		1				**0.2**
Bodianus rufus	Spanish Hogfish		1				**0.2**
Chaetodon aculeatus	Longsnout Butterflyfish				1		**0.2**
Lactophrys triqueter	Smooth Trunkfish	1					**0.2**
Neoniphon marianus	Longjaw Squirrelfish					1	**0.2**
Lutjanus synagris	Lane Snapper	1					**0.2**
	TOTAL INDIVIDUALS	**368**	**213**	**315**	**454**	**488**	**367.6**
	TOTAL SPECIES	**20**	**19**	**14**	**14**	**14**	**16.2**

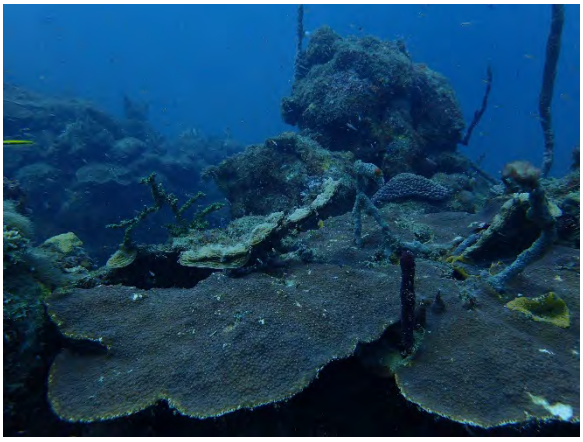
Table 4. MEX 20. Size frequency distribution of fishes within 20 x 4 m belt-transects at Manchas Exteriores, Reef, Mayaguez, 18.5 m. Survey date: July 8, 20

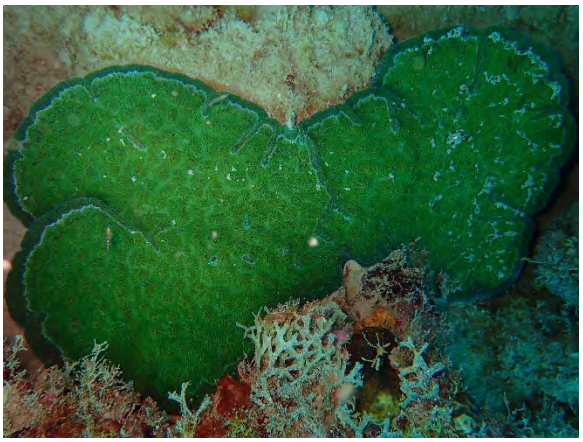
		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Scarus iserti	Stripped Parrotfish	1-6	1-12	6-10	1-12	
		1-8		2-12		
Sparisoma viride	Stoplight Parrotfish	1-30		1-20	1-10	1-20
Sparisoma aurofrenatum	Redband Parrotfish	3-10	1-12	1-5	1-15	2-6
		2-15		1-18		1-20
		1-20				
Epinephelus fulva	Coney	1-15				
Epinephelus cruentatus	Graysby	1-15	1-10	1-15		
Scarus taeniopterus	Princess Parrotfish	3-8	3-12	3-12	3-12	1-2
		5-18	3-15	2-18	1-18	2-10
				1-20		1-15
Lutjanus synagris	Lane Snapper	1-30				1-20
Lutjanus jocu	Dog Snapper				1-30	
Lutjanus mahogany	Mahogany Snapper				2-20	

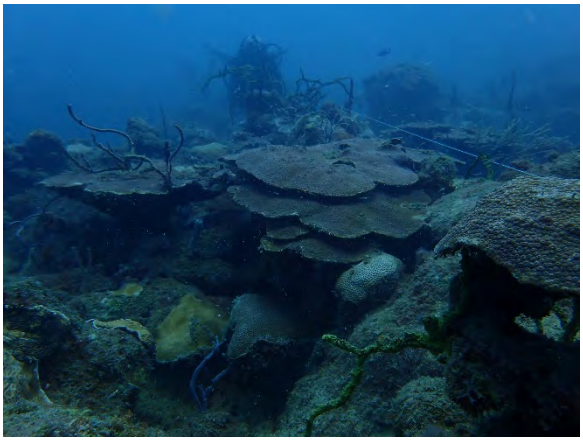
Photo Album 1.
Manchas Exteriores 20m











Manchas Exteriores 10, Mayaguez

Physical Description

Manchas Exteriores Reef at a depth of 10m corresponds to the mid-section of the fore-reef slope. It is a moderately abrupt slope with several narrow steps, one of which was at the 9-10 m contour where the five permanent transects were established (Figure 2). Panoramic images of Manchas Exteriores 10 are shown in Photo Album 2.

Sessile-benthic Community

Benthic algae, comprised by turf, fleshy brown, green calcareous and red macroalgae were the dominant biotic category covering reef substrate at Manchas Exteriores 10 with a combined mean cover of 56.7% (Figure 5). Turf algae, a mixed assemblage of short filamentous brown and red algae partially covered by fine sediments was the main component of the benthic algae, with a mean cover of 46.5 %, representing 82.0% of the total cover by algae (Table 5). Fleshy brown (*Dictyota sp*.), green calcareous (*Halimeda sp*) and red crustose coralline macroalgae were present in at least four out of the five transects surveyed with a combined mean cover of mean cover of 10.2%. The red encrusting species *Peyssonnelia sp*. was present in relatively small patches along three transects at Manchas Exteriores 10m. Cyanobacterial films were present in three transects with a mean cover of 2.1%.

With a mean density of 24.4 colonies per transect, large, vertically projected soft corals (gorgonians) were the main sessile-invertebrate assemblage contributing habitat complexity at Manchas Interiores 10m. Sea Rods, *Plexaura spp., Pseudoplexaura spp., Eunicea spp* were the most prominent, but Sea Fans, *Gorgonia ventalina* and Sea Plumes, *Antillogorgia spp*. were also present. The encrusting species, *Briareum asbestinum* and *Erythropodium caribaeorum* combined for a mean substrate cover of 3.0 % (Table 5).

Scleractinian corals, represented by 11 species intercepted by linear transects combined for a mean substrate cover of 24.4% (range: 20.4 – 33.2 %). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant coral in terms of reef substrate cover with a mean of 11.9 % (Figure 6) and was present in all five transects surveyed, along with Mustard-Hill Coral, *Porites astreoides* and lettuce coral, *Agaricia agaricites* (Table 5). Great Star Coral, *Montastrea cavernosa*, Greater Starlet Coral, *Siderastrea siderea* and Ten-Ray Coral, *Madracis decactis*

were also prominent with colonies intercepted by at least three transects. Three species were only represented by one colony along transects.

A total of 15 species of sponges were present along transects with a combined substrate cover of 3.3%. With the exception of one large Basket Sponge, *Xestospongia muta* in transect five, sponges were mostly represented by small encrusting individuals growing intermixed with algal turf and other encrusting biota. The sponge species assemblage was highly variable between transects with 11 out of the 15 species present in only one transect.

Abiotic substrate categories presented a mean substrate cover of 7.1% (range: 4.5 – 11.7%). Reef overhangs, associated with ledges of Boulder Star Coral, *Orbicella faveolata* were the main contribution to the abiotic category with a mean cover of 5.0%, representing 70.4% of the total (Table 5). Sand was present in four transects with a mean cover of 1.5 %. Reef rugosity averaged 3.5 m (range: 2.4 – 4.0 m).

Table 5. MEXT 10. Percent cover by sessile-benthic categories along permanent transects, Manchas Exteriores, Mayaguez, 10m. Survey date: July 7, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	3.69	3.51	3.71	2.36	4.04	**3.5**
Benthic Categories						
Abiotic						
Reef Overhang	6.44	5.39	6.33	2.27	4.79	**5.04**
Sand	3.07	1.04	1.23	2.27		**1.52**
Gap	2.15					**0.43**
Rubble		0.52				**0.10**
Total Abiotic	**11.66**	**6.94**	**7.56**	**4.53**	**4.79**	**7.09**
Benthic Algae						
Turf with sediment	48.26	58.45	34.12	48.70	42.87	**46.48**
Dictyota spp.	7.57	7.46	7.56	7.59	5.78	**7.19**
Halimeda spp.		2.49	3.78	3.74	0.30	**2.06**
CCA	0.61	1.35	0.61		1.00	**0.71**
Peyssonnelia spp.		0.21	0.20		0.70	**0.22**
Total Benthic Algae	**56.44**	**69.95**	**46.27**	**60.02**	**50.65**	**56.67**
Hard Coral						
Orbicella annularis complex	9.10	7.36	14.20	16.99	11.86	**11.90**

Porites astreoides	4.50	5.70	4.39	1.93	5.58	**4.42**
Montastraea cavernosa	5.21		6.54	1.13	5.88	**3.75**
Siderastrea siderea	0.61			4.53	2.69	**1.57**
Agaricia agaricites	0.92	3.32	1.23	0.45	1.69	**1.52**
Madracis decactis	1.43	1.24	1.23		0.80	**0.94**
Porites porites					4.69	**0.94**
Pseudodiploria strigosa	2.15		1.12			**0.65**
Dendrogyra cylindrus		2.80				**0.56**
Agaricia fragilis			0.82			**0.16**
Stephanocoenia intersepta				0.34		**0.07**
Total Hard Coral	**23.93**	**20.41**	**29.52**	**25.37**	**33.20**	**26.49**
Cyanobacteria	1.84		7.66		1.00	**2.10**
Invertebrate						
Palythoa caribaeorum				3.40		**0.68**
Millepora alcicornis			0.72			**0.14**
Total Invertebrate			**0.72**	**3.40**		**0.82**
#Gorgonians/transect	19.00	30.00	29.00	28.00	16.00	**24.40**
Octocoral						
Briareum asbestinum	0.61	0.31	1.53	5.44	1.60	**1.90**
Erythropodium caribaeorum	0.41	1.24	3.68			**1.07**
Pseudoplexaura wagenaari	0.20			0.57		**0.15**
Antillogorgia americana					0.70	**0.14**
Plexaura kuekenthali			0.51			**0.10**
Eunicea pallida?	0.41					**0.08**
Eunicea tourneforti				0.23		**0.05**
Plexaura homomalla			0.20			**0.04**
Total Octocoral	**1.64**	**1.55**	**5.92**	**6.23**	**2.29**	**3.53**
Sponge						
Xestospongia muta					6.38	**1.28**
Callyspongia vaginalis			2.15		1.00	**0.63**
Ectyoplasia ferox	2.25					**0.45**
Monachora arbuscula	0.41	0.41				**0.16**
Iotrochota birotulata	0.31			0.45		**0.15**
Chondrilla caribensis	0.61					**0.12**
Niphates erecta		0.21	0.20			**0.08**
Scopalina ruetzleri	0.41					**0.08**
Callyspongia armigera		0.31				**0.06**
Dictyonella	0.31					**0.06**
Amphimedon compressa					0.30	**0.06**
Aplysina lacunosa		0.21				**0.04**
Sponge	0.20					**0.04**
Callyspongia fallax					0.20	**0.04**
Neopetrosia proxima					0.20	**0.04**
Total Sponge	**4.50**	**1.14**	**2.35**	**0.45**	**8.08**	**3.30**

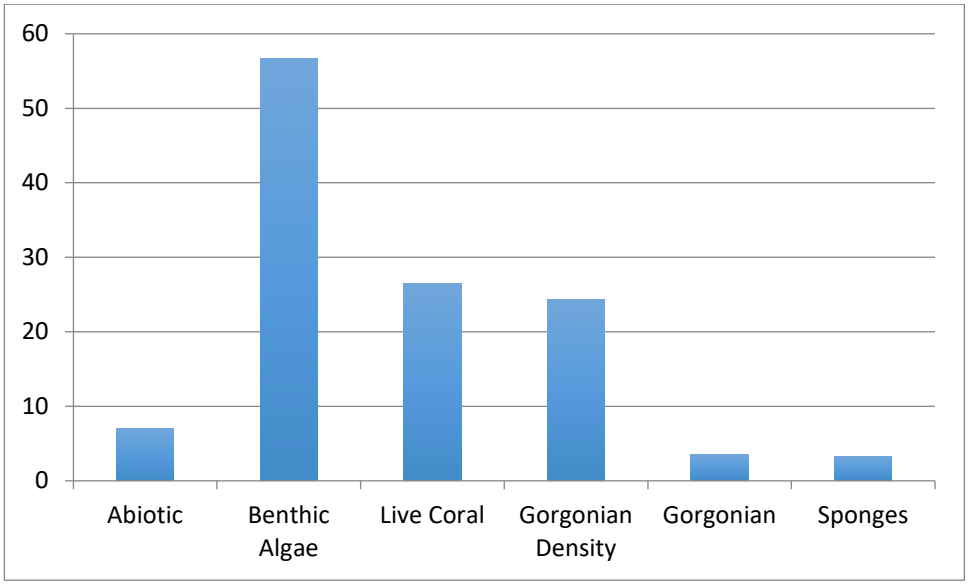


Figure 5. Mean substrate cover by benthic categories at Manchas Exteriores Reef 10, Mayaguez, July 2016

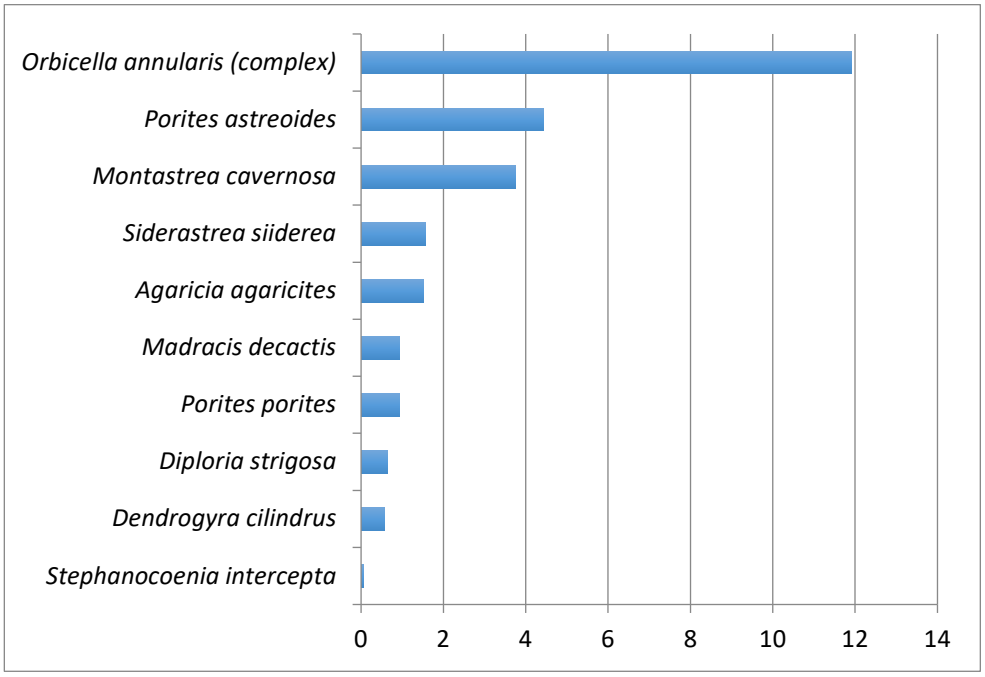


Figure 6. Mean substrate cover by coral species at Manchas Exteriores Reef 10, Mayaguez, July 2016

Fishes and Motile Megabenthic Invertebrates

A total of 35 species of fish were identified within belt-transects from a depth of 9.2 m at Manchas Exteriores 10 (Table 6). Mean density was 137.4 Ind/transect (range: 77 – 186 Ind/transect) with a mean richness of 16.8 species per transect. The Masked Goby, *Coryphopterus personatus* was numerically dominant with a mean density of 96.0 Ind/transect, representing 69.9% of the total individuals. This is a small schooling zooplanktivore species that swarms over large coral colonies and below ledges. Other eight species were present in at least four transects at Manchas Exteriores 10m. These include the Bluehead Wrasse, *Thalassoma bifasciatum*, Peppermint and Sharknose Gobies*, Coryphopterus lipernes*, *Elacatinus evelynae*, Stripped and Princess Parrotfishes, *Scarus iserti*, *S. taeniopterus*, Beaugregory and Bicolor Damselfishes, *Stegastes leucostictus*, *S. partitus*, Blackbar Soldierfish, *Myripristis jacobus* and Four-eye Butterflyfish, *Chaetodon capistratus*. Thirteen species were only present in one transect (Table 15).

The trophic structure of the fish community at Manchas Exteriores 10 was numerically dominated by zooplanktivore species, driven by the abundance of Masked Goby and Blue Chromis. These two species ranked first and nine in terms of fish abundance, representing a combined 71.0% of the total fish abundance within belt-transects. The herbivorous assemblage nevertheless was much more species rich, represented by 5 species of parrotfishes (Scaridae), five species of damselfishes (Pomacentridae), and two species of doctorfishes (Acanthuridae). All of these herbivore species grow to a much average larger size than the species of the zooplanktivorous assemblage, Thus, even thou the former dominate numerically, the latter probably dominate in terms of biomass. Small opportunistic carnivores were represented by three species of wrasses (Labridae), three species of hamlets and one small grouper (Serranidae), one puffer (Tetraodontidae), one Trumpetfish (Aulostomidae), one lizardfish (*Synodus intermedius*), one squirrelfish (*Neoniphon marianus*) and one grunt (*Haemulon flavolineatum*). Medium sized piscivores included Red Hinds, Coneys, Graysbes (*Epinephelus guttatus, Cephalopholis fulva, C. cruentatus)*, and Lionfish (*Pterois sp*.). One Great Barracuda (*Sphyraena barracuda*) was observed outside transects.

The size-frequency distribution of parrotfishes (Scaridae) suggests that the reef serves largely as a habitat for juvenile and adult individuals and the recruitment habitat for Stoplight Parrotfish (*Sparisoma viride*) (Table 7). Red Hinds, Coneys and Graysbes were all present as adult individuals.

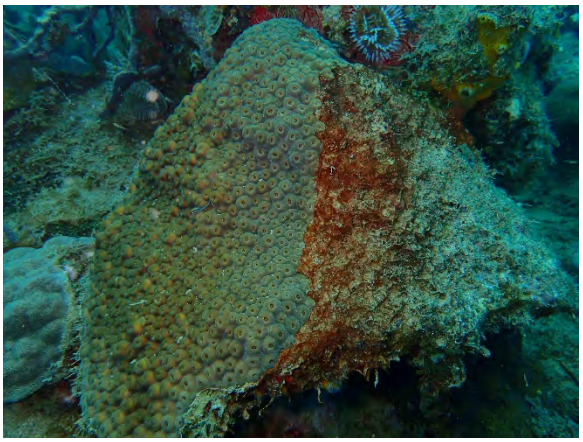
Table 6. MEX 10. Taxonomic composition and abundance of fishes within 10 x 3 m belt-transects at Manchas Exteriores Reef, Mayaguez, 9.7m. Survey date: July 8, 2016

		Transects (Ind/30 m^2)					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	145	100	110	100	25	**96.0**
Thalassoma bifasciatum	Bluehead Wrasse	6	17	2	15	15	**11.0**
Gobiosoma evelynae	Sharknose Goby		5	3	2	8	**3.6**
Stegastes partitus	Bicolor Damselfish	5	3		1	5	**2.8**
Coryphopterus lipernes	Peppermint Goby		3	1	6	3	**2.6**
Scarus taeniopterus	Princess Parrotfish	2	2	1		8	**2.6**
Scarus iserti	Stripped Parrotfish	3		5	2		**2.0**
Myripristis jacobus	Blackbar Soldierfish	2	1	1	4	2	**2.0**
Chromis cyanea	Blue Chromis	6	2				**1.6**
Stegastes leucostictus	Beau Gregory		2	2	3	1	**1.6**
Chaetodon capistratus	Four-eye Butterflyfish	2	2	1	1	1	**1.4**
Halichoeres garnoti	Yellow-head Wrasse	1	2	1			**0.8**
Sparisoma viride	Stoplight Parrotfish	2			1	1	**0.8**
Stegastes adustus	Dusky Damselfish		2	2			**0.8**
Acanthurus bahianus	Ocean Surgeon	2		1		1	**0.8**
Serranus tigrinus	Harlequin Bass	2	1		1		**0.8**
Sparisoma aurofrenatum	Redband Parrotfish	2		1	1		**0.6**
Cephalopholis cruentatus	Graysby				1	2	**0.6**
Acanthurus coeruleus	Blue Tang	1			1	1	**0.6**
Stegastes variabilis	Cocoa Damselfish	1			2		**0.6**
Halichoeres maculipinna	Clown Wrasse		2				**0.4**
Canthigaster rostrata	Caribbean Puffer			2			**0.4**
Aulostomus maculatus	Trumpetfish	2					**0.4**
Neoniphon marianus	Longjaw Squirrelfish			1	1		**0.4**
Coryphopterus glaucophraenum	Briddled Goby					1	**0.2**
Chaetodon striatus	Banded Butterflyfish					1	**0.2**
Haemulon flavolineatum	French Grunt					1	**0.2**
Holacanthus tricolor	Rock Beauty	1					**0.2**
Hypoplectrus nigricans	Black Hamlet		1				**0.2**
Hypoplectrus puella	White Hamlet		1				**0.2**
Hypoplectrus unicolor	Butter Hamlet				1		**0.2**
Sparisoma radians	Bucktooth Parrotfish	1					**0.2**
Stegastes planifrons	Three-spot Damselfish		1				**0.2**
Synodus intermedius	Lizardfish		1				**0.2**
Amblycirrhitus pinos	Red-spotted Hawkfish					1	**0.2**
	TOTAL INDIVIDUALS	**186**	**148**	**134**	**142**	**77**	**137.4**
	TOTAL SPECIES	**18**	**18**	**15**	**17**	**16**	**16.8**

Table 7. MEX 10. Size frequency distribution of fishes within 20 x 4 m belt-transects at Manchas Exteriores, Reef, Mayaguez, 9.7 m. Survey date: July 8, 2016

SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Scarus iserti	Stripped Parrotfish	2-12		5-7	1-10	
		1-15			1-15	
Sparisoma viride	Stoplight Parrotfish	1-10			1-3	1-15
		1-12			2-30	1-25
						1-30
						1-33
Sparisoma aurofrenatum	Redband Parrotfish	2-10		3-15	1-12	1-15
				1-20		
Epinephelus fulva	Coney				1-35	
Epinephelus guttatus	Red Hind	1-38				1-30
Epinephelus cruentatus	Graysby				1-12	2-10
Pterois volitans	Lionfish					
Scarus taeniopterus	Princess Parrotfish	2-7	1-5	2-20		3-10
			1-7			5-15
			2-12			5-25

Photo Album 2.
Manchas Exteriores 10m



Rodriguez Reef 5, Mayaguez

Physical Description

Rodriguez Reef 5, also known as Escollo Rodriguez is an emergent section of a discontinuous linear ridge that runs almost parallel to the Mayaguez coastline, approximately 1.5 NM offshore between the Yaguez and Guanajibo River mouths (Figure 2). Given the proximity of this reef to major rivers in Mayaguez Bay it is expected that it is seasonally influenced by estuarine conditions. The reef is a hard ground platform with coral outcrops of moderate to large size growing at depths from 5 m up to the surface. Our survey was performed within a depth range of 3 – 4m at the upper edge of the reef slope. Panoramic images of Rodriguez Reef 5 are shown in Photo Album 3.

Sessile-benthic Reef Community

Benthic algae, with a combined mean substrate cover of 52.1% were the dominant biotic category covering reef substrate at Rodriguez Reef (Figure 7). Turf algae, a mixed assemblage of short filamentous brown and red algae was the main component of the benthic algae, with a mean cover of 44.9%, representing 86.2% of the total cover by algae (Table 8). Green calcareous (*Halimeda sp*) macroalgae were present in all transects with a mean cover of 3.3%. Other minor components of the benthic algae assemblage included the fleshy brown macroalgae (mostly *Dictyota sp*) and red crustose coralline algae. Cyanobacterial films were present in four transects with a mean cover of 1.6%.

Scleractinian corals were represented by 11 species intercepted by linear transects with a combined mean substrate cover of 21.4% (range: 17.9 – 27.6 %). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant coral in terms of reef substrate cover with a mean of 9.1 % (Figure 8), representing 42.5% of the total cover by live corals. *Orbicella annularis* and *O. faveolata* were the main sibling species present in the *Orbicella* species complex. Greater Starlet Coral, *Siderastrea siderea* and Boulder Brain Coral, *Colpophyllia natans* ranked second and third in substrate cover at Rodriguez Reef, and along with Mustard-Hill Coral, *Porites astreoides* and Lettuce Coral, *Agaricia agaricites* comprised the main coral assemblage at Rodriguez Reef (Table 8). Very large and healthy colonies of Boulder Star Coral (*O. annularis*) were present growing close to the surface at Rodriguez Reef. Likewise, exceptionally large colonies of Greater Starlet Coral (*S. siderea*) were also present, suggesting that the 2005 coral

TABLE 8. ROD 5. Percent substrate cover by sessile-benthic categories along permanent transects, Rodriguez Reef 5m, Mayaguez. Survey date: July 8, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.45	4.67	2.7	16.29	4.29	**6.08**
Benthic Categories						
Abiotic						
Reef Overhang	2.92	19.75	6.17	24.54	9.70	**12.62**
Rubble	4.05	13.55	1.98	1.83	8.23	**5.93**
Sand	1.12	6.20		1.83		**1.83**
Gap					0.39	**0.08**
Total Abiotic	**8.10**	**39.50**	**8.16**	**28.21**	**18.32**	**20.46**
Benthic Algae						
Turf with sediment	61.98	28.44	59.21	30.49	44.37	**44.90**
Halimeda spp.	3.82	3.63	3.31	3.66	2.15	**3.32**
Dictyota spp.			3.97	6.96	5.00	**3.18**
CCA		1.91	0.22		0.98	**0.62**
Fleshy macroalgae					1.18	**0.24**
Peyssonnelia spp.		0.19				**0.04**
Total Benthic Algae	**65.80**	**34.16**	**66.70**	**40.02**	**53.67**	**52.07**
Hard Coral						
Orbicella annularis complex	10.12	8.30		13.19	13.81	**9.08**
Siderastrea siderea	2.02		9.37	10.44	4.11	**5.19**
Colpophyllia natans	5.17	5.25	5.40			**3.16**
Porites astreoides	0.67		1.32	2.20	0.59	**0.96**
Porites porites		2.67			1.96	**0.93**
Agaricia agaricites		0.95	1.21		2.45	**0.92**
Meandrina meandrites	1.91					**0.38**
Leptoseris cucullata			1.10			**0.22**
Siderastrea radians			0.33	0.46		**0.16**
Stephanocoenia intersepta		0.76				**0.15**
Montastraea cavernosa				0.18		**0.04**
Total Hard Coral	**19.91**	**17.94**	**18.74**	**27.56**	**22.92**	**21.41**
Cyanobacteria		1.62	0.99	3.66	1.96	**1.65**
Invertebrate						
Trididemnum solidum	0.45					**0.09**
Millepora squamosa					0.29	**0.06**
Total Invertebrate	**0.45**				**0.29**	**0.15**
Octocoral						

Briareum asbestinum	0.90	4.10	2.76	0.37	0.29	**1.68**
Erythropodium caribaeorum			2.09		0.29	**0.48**
Total Octocoral	**0.90**	**4.10**	**4.85**	**0.37**	**0.59**	**2.16**
#Gorgonians/transect	7	9	3	2	5	**5.20**
Sponge						
Chondrilla caribensis	0.34	0.48		0.18	1.47	**0.49**
Niphates erecta	1.91	0.48				**0.48**
Verongula rigida	1.69					**0.34**
Cinachyrella kuekenthali	0.90					**0.18**
Aplysina lacunosa					0.78	**0.16**
Mycale laevis		0.76				**0.15**
Verongula sp.		0.67				**0.13**
Ircinia strobilina			0.33			**0.07**
Dragmacidon reticulatum	0.00	0.29				**0.06**
Callyspongia fallax			0.22			**0.04**
Total Sponge	**4.84**	**2.67**	**0.55**	**0.18**	**2.25**	**2.10**

bleaching event had minor, if any degradation effect upon such massive corals at this reef. Four coral species were only represented by one colony along transects. Colonies of Elkhorn and Staghorn Corals (*Acropora palmata, A. cervicornis*) were observed outside transects at Rodriguez Reef 5m.

Vertically projected soft corals (gorgonians) were present in all five transects surveyed at Rodriguez Reef with a mean density of 5.2 colonies per transect. Sea Plumes (*Pseudopterogorgia spp*) and Sea Fans (*Gorgonia ventalina*) were the most common. The encrusting gorgonian species, *Briareum asbestinum* and *Erythropodium caribaeorum* combined for a mean substrate cover of 2.2% (Table 8). Sponges, represented by at least 10 species combined for a mean substrate cover of 2.1%. *Chondrilla caribensis* and *Niphates erecta* were the only ones present in more than one transect. In general, sponges were mostly represented by small encrusting individuals growing intermixed with algal turf and other encrusting biota.

Abiotic substrate categories presented a mean substrate cover of 20.5% (range: 8.1 – 39.5%). Reef overhangs, associated with ledges of Boulder Star Coral, *Orbicella faveolata* were the main contribution to the abiotic category with a mean cover of 12.6%, representing 61.4% of the total (Table 8). Sections of coral rubble (5.9%) and sand (1.8%) also contributed to the total cover by abiotic categories at Rodriguez reef. Reef rugosity, largely driven by tall and large *Orbicella* coral outcrops averaged 6.1 m (range: 2.4 – 16.3 m).

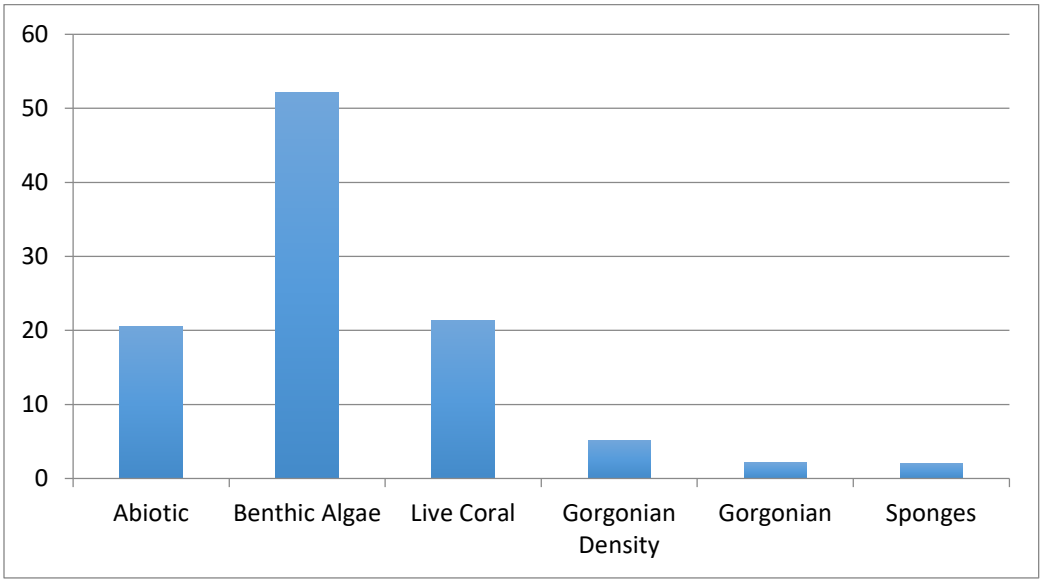


Figure 7. Mean substrate cover by benthic categories at Rodriguez Reef 5, Mayaguez, July 2016

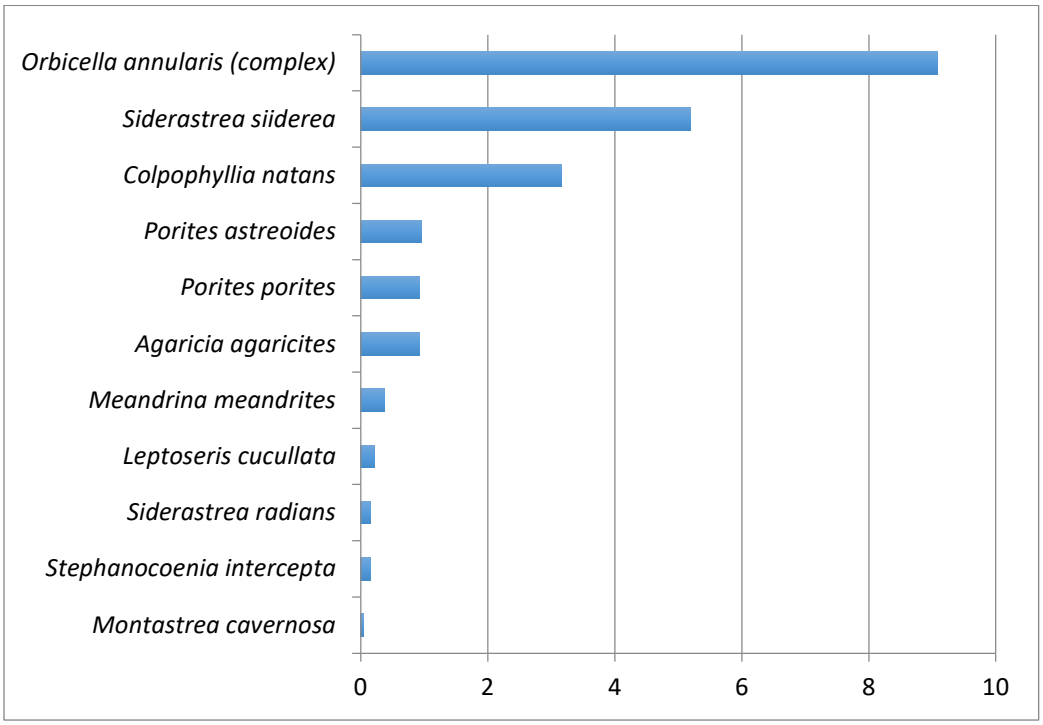


Figure 6. Mean substrate cover by coral species at Rodriguez Reef 5, Mayaguez, July 2016

Fishes and Motile Megabenthic Invertebrates

A total of 31 species of fish were observed within belt-transects from a depth of 3.8 m at Rodriguez Reef 5 (Table 9). Mean density was 56.6 Ind/transect (range: 31 – 97 Ind/transect) with a mean richness of 10.6 species per transect. An assemblage of five species combined for a cumulative density of 40.4 Ind/transect, representing 71.4% of the total individuals. The Bluehead Wrasse, *Thalassoma bifasciatum* was the numerically dominant species with a mean density of 11.0 Ind/transect, representing 19.4% of the total individuals. The Bluehead Wrasse is a small opportunistic carnivore that hovers over the reef in small to large guilds. The Masked Goby, *Coryphopterus personatus* was present in small schools at three transects with a mean density of 9.6 Ind/transect. Only the Dusky Damselfish, *Stegastes dorsopunicans* was observed in the five transects with a mean density of 9.4 Ind/transect. Twenty fish species were only present in one transect (Table 6).

Consistent with previous characterizations of the reef fish community structure in Puerto Rican reefs (Esteves, 2013), the herbivorous assemblage was prominent at Rodriguez Reef. Herbivores were represented by at least five species of parrotfishes (Scaridae), five species of damselfishes (Pomacentridae) and one doctorfish (Acanthuridae), with a combined density of 23.8 Ind/transect, representative of 42.0% of the total individuals within belt-transects. Conversely, zooplanktivores were represented by only two species (Masked Goby and Brown Chromis) with a mean density of 10 Ind/transect or 17.7 % of the total fish density. Small opportunistic carnivores were also very prominent, as is typical of shallow reefs with high wave energy. These were represented by three species of wrasses (Labridae), one hamlet and one small grouper (Serranidae), one puffer (Tetraodontidae), one goby (Gobiidae), one goatfish (Mullidae), one grunt (Haemulidae) and one squirrelfish (Holocentridae). Medium sized piscivores included the Yellowtail Snapper (*Ocyurus chrysurus*) and the Lionfish, *Pterois sp*. Red hinds (*Epinephelus guttatus*), Great Barracuda (*Sphyraena barracuda*) and Cero Mackerels represented the larger predators of the reef system, but were observed outside transects.

The size-frequency distribution of parrotfishes (Scaridae) suggests that the reef functions as a habitat for recruitment juveniles, particularly for *Scarus iserti* and *Sparisoma viride* and for adult individuals (Table 10). Both juvenile and young adult individuals of Yellowtail Snapper (*Ocyurus chrysurus)* and the Graysbe (*Cephalopholis cruentatus*) were present. Two Lionfishes (*Pterois sp*) were present as young adults. Motile megabenthic invertebrates were not observed.

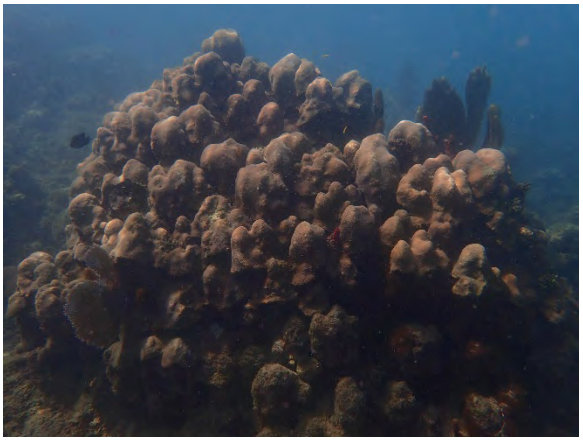
Table 9. ROD 5. Taxonomic composition and abundance of fishes within 10 x 3 m belt-transects at El Rodriguez Reef, Mayaguez, 3.8 m. Survey date: July 7, 2016

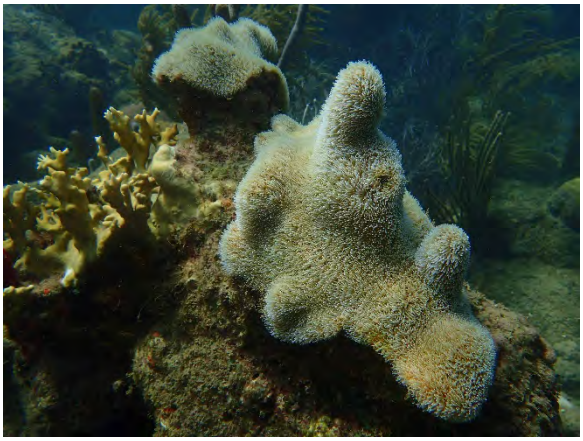
		Transects (Ind/30 m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse		15	9	9	22	**11.0**
Coryphopterus personatus	Masked Goby		20	12		16	**9.6**
Stegastes adustus	Dusky Damselfish	7	12	10	9	9	**9.4**
Caranx ruber	Bar Jack	25	1	1			**5.4**
Scarus iserti	Stripped Parrotfish		20	5			**5.0**
Stegastes planifrons	Three-spot Damselfish	5	7	2			**2.8**
Stegastes leucostictus	Beau Gregory		11				**2.2**
Canthigaster rostrata	Caribbean Puffer	2	4	1	1		**1.6**
Scarus taeniopterus	Princess Parrotfish				6		**1.2**
Chaetodon capistratus	Four-eye Butterflyfish	3				2	**1.0**
Halichoeres maculipinna	Clown Wrasse					4	**0.8**
Sparisoma aurofrenatum	Redband Parrotfish		1	2		1	**0.8**
Sparisoma viride	Stoplight Parrotfish			1	1	2	**0.8**
Chromis multilineata	Brown Chromis					2	**0.4**
Cephalopholis cruentatus	Graysby		2				**0.4**
Sparisoma radians	Bucktooth Parrotfish				2		**0.4**
Ocyurus chrysurus	Yellowtail Snapper				2		**0.4**
Stegastes variabilis	Cocoa Damselfish					2	**0.4**
Abudefduf sexatilis	Sargent Major					2	**0.4**
Pterois volitans	Lionfish			2			**0.4**
Halichoeres garnoti	Yellow-head Wrasse		1				**0.2**
Chaetodon striatus	Banded Butterflyfish					1	**0.2**
Stegastes partitus	Bicolor Damselfish			1			**0.2**
Acanthurus bahianus	Ocean Surgeon					1	**0.2**
Haemulon flavolineatum	French Grunt		1				**0.2**
Gobiosoma evelynae	Sharknose Goby					1	**0.2**
Mulloides martinicus	Yellowfin Goatfish		1				**0.2**
Hypoplectrus sciurus	Yellowtail Hamlet	1					**0.2**
Pseudupeneus maculatus	Spotted Goatfish				1		**0.2**
Serranus tigrinus	Harlequin Bass		1				**0.2**
Neoniphon marianus	Longjaw Squirrelfish			1			**0.2**
	TOTAL INDIVIDUALS	**43**	**97**	**47**	**31**	**65**	**56.6**
	TOTAL SPECIES	**6**	**14**	**12**	**8**	**13**	**10.6**

Table 10. ROD 5. Size frequency distribution of fishes within 20 x 4 m belt-transects at Rodriguez Reef, Mayaguez, 3.8 m. Survey date: July 7, 2016

		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Scarus iserti	Stripped Parrotfish	2-20	20-3	5-3	1-10	
			1-18	3-10		
Sparisoma viride	Stoplight Parrotfish	5-30		1-3	1-3	2-3
				3-10	1-12	
Sparisoma aurofrenatum	Redband Parrotfish	2-20	1-20	2-12		1-17
				2-18		
Ocyurus chrysurus	Yellowtail Snapper	1-15			2-7	
Epinephelus cruentatus	Graysby		1-10			
			1-15			
Pterois volitans	Lionfish		1-15			
			1-18			
Scarus taeniopterus	Princess Parrotfish	1-18			2-3	
					4-7	
Lutjanus apodus	Schoolmaster Snapper	1-18				

Photo Album 3.
Rodriguez Reef 5m





Guanajibo Reef 20, Cabo Rojo

Physical Description

Guanajibo Reef is a submerged coral bank formation that sits close to the shelf-edge approximately 4.2 NM off Pta. Guanajibo, Cabo Rojo. The reef sits on a narrow, gently sloping terrace that leads to the shelf break. Five permanent transects were laid out running east to west at a depth of 18 - 20 m. Panoramic images of Guanajibo Reef are shown in Photo Album 4.

Sessile Benthic Reef Community

Scleractinian corals, represented by 11 species intercepted by linear transects were the main benthic category contributing substrate cover at Guanajibo Reef with a combined mean cover of 36.6% (range: 23.9 – 49.3 %) (Figure 9). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant coral in terms of reef substrate cover with a mean of 31.7 %, representing 86.7% of the total cover by live corals (Figure 10). It was the only coral species present in all five transects (Table 11). *Orbicella franksi* and *O. faveolata* were the main sibling species present in the *Orbicella* species complex. Boulder Brain Coral, *Colpophyllia natans* and Great Star Coral, *Montastrea cavernosa* ranked second and third in substrate cover at Guanajibo Reef. Lettuce Coral, *Agaricia agaricites* and Mustard-Hill Coral, *Porites astreoides* were present in four and three transects, respectively (Table 8). Although at shallower depths within the euphotic range, the Guanajibo Reef system resembles mesophotic reefs, such as El Seco (Vieques) and Lang Bank (St. Croix) due to the strong dominance of *O. franksi* growing in horizontally projected, sometimes overlapping colonies. Also, the relatively high substrate cover by live coral suggests that bleaching events have had minor if any impact upon this reef system.

Benthic algae, comprised by an assemblage of turf algae, green calcareous (*Halimeda sp*), fleshy brown (*Lobophora variegata*, *Dictyota sp*) and red crustose coralline algae presented a combined mean substrate cover of 36.6% (Figure 9). Turf algae, a mixed assemblage of short filamentous brown and red algae was the main component of the benthic algae, with a mean cover of 18.0%, representing 49.2% of the total cover by algae (Table 11). The encrusting red alga, *Peyssonnelia sp*. was present in four transects with a mean cover of 0.9%. Cyanobacterial films were present in four transects with a mean cover of 0.6%.

Vertically projected soft corals (gorgonians) were present in all five transects surveyed at Guanajibo Reef with a mean density of 5.0 colonies per transect. Sea Plumes (*Pseudopterogorgia spp*) and Sea Fans (*Gorgonia ventalina*) were the most common. The encrusting gorgonian species, *Briareum asbestinum* and *Erythropodium caribaeorum* combined for a mean substrate cover of 3.0% (Table 11). Sponges, represented by at least seven species combined for a mean substrate cover of 1.6%. *Ectyoplasia ferox* and *Monachora arbuscula* were the species with highest substrate cover. In general, sponges were mostly represented by small encrusting individuals growing intermixed with algal turf and other encrusting biota. Only one species (*M. arbuscula*) was observed in more than one transect.

Abiotic substrate categories presented a mean substrate cover of 21.7% (range: 4.8 – 30.2%). Reef overhangs, associated with ledges of Boulder Star Coral, *Orbicella faveolata* and *O. franksi* were the main contribution to the abiotic category with a mean cover of 20.4%, representing 94.0% of the total (Table 1). Reef rugosity, largely driven by growth of *Orbicella* coral colonies averaged 5.7 m (range: 2.4 – 16.3 m).

TABLE 11. GUAN 20. Percent cover by sessile-benthic categories along permanent transects, Guanajibo Reef, 20. Cabo Rojo. Survey date: July 8, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	4.18	4.36	6.11	6.16	7.63	**5.69**
Benthic Categories						
Abiotic						
Reef Overhang	4.84	14.81	27.72	29.46	24.94	**20.35**
Gap		0.58	2.43		0.48	**0.70**
Sand					3.18	**0.64**
Total Abiotic	**4.84**	**15.40**	**30.15**	**29.46**	**28.59**	**21.69**
Benthic Algae						
Turf	36.62	16.57	7.21	14.90	14.85	**18.03**
Lobophora variegatus	4.54	12.77	5.99	18.63	15.89	**11.56**
CCA	3.46	3.22	0.43	0.61	1.11	**1.76**
Halimeda spp.		0.97		0.43	7.39	**1.76**
Turf with sediment			7.04			**1.41**
Dictyota spp.		0.68	0.87	3.99	0.40	**1.19**
Peyssonnelia spp.		0.49	0.43	1.73	1.99	**0.93**

Total Benthic Algae	**44.62**	**34.70**	**21.98**	**40.29**	**41.62**	**36.64**
Hard Coral						
Orbicella annularis complex	48.47	35.58	32.93	18.98	22.56	**31.70**
Colpophyllia natans		4.00	1.82			**1.16**
Montastraea cavernosa		2.34	3.13			**1.09**
Agaricia agaricites	0.49	0.29		1.99	0.71	**0.70**
Siderastrea siderea				2.86		**0.57**
Porites astreoides		1.07		1.39	0.32	**0.56**
Agaricia lamarcki				1.73		**0.35**
Meandrina meandrites			1.22			**0.24**
Madracis decactis			0.00		0.32	**0.06**
Porites porites	0.30					**0.06**
Stephanocoenia intersepta		0.29				**0.06**
Total Hard Coral	**49.26**	**43.57**	**39.10**	**26.95**	**23.91**	**36.56**
Cyanobacteria	0.39		0.87	0.87	0.71	**0.57**
# Gorgonians/transect	4	4	4	7	6	**5.00**
Octocoral						
Briareum asbestinum			4.26		3.57	**1.57**
Erythropodium caribaeorum	0.89	2.92	2.95	0.17	0.16	**1.42**
Total Octocoral	**0.89**	**2.92**	**7.21**	**0.17**	**3.73**	**2.99**
Sponge						
Ectyoplasia ferox		2.34				**0.47**
Monanchora arbuscula		1.07	0.35		0.64	**0.41**
Dictyonella funicularis				1.47		**0.29**
Cliona caribbaea					0.79	**0.16**
Chondrilla caribensis				0.78		**0.16**
Callyspongia fallax			0.17			**0.03**
Plaktoris sp.			0.17			**0.03**
Total Sponge		**3.41**	**0.70**	**2.25**	**1.43**	**1.56**

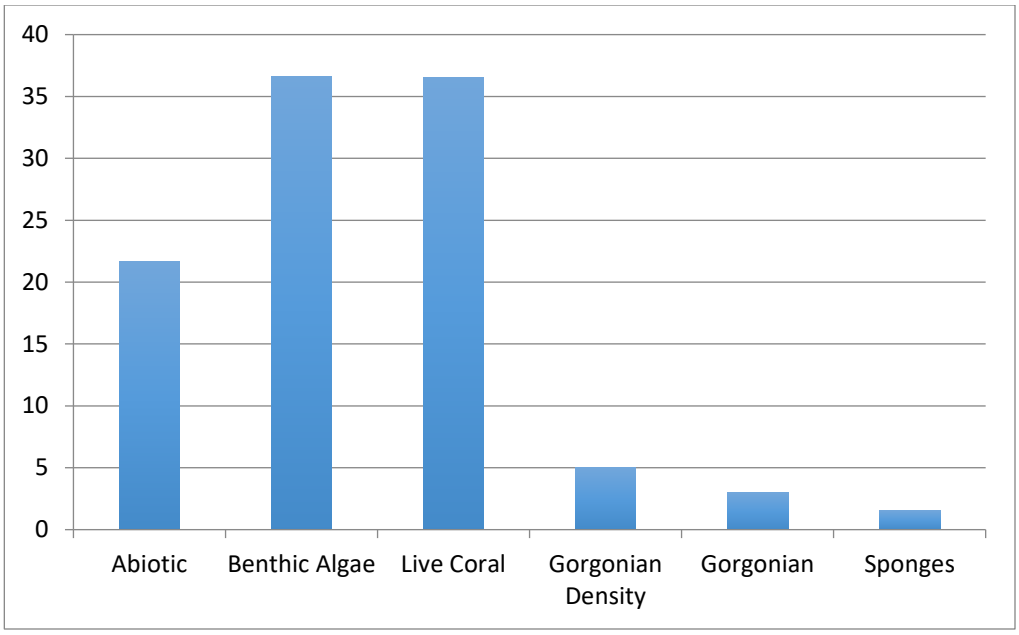


Figure 9. Mean substrate cover by benthic categories at Guanajibo Reef 20, Cabo Rojo, July 2016

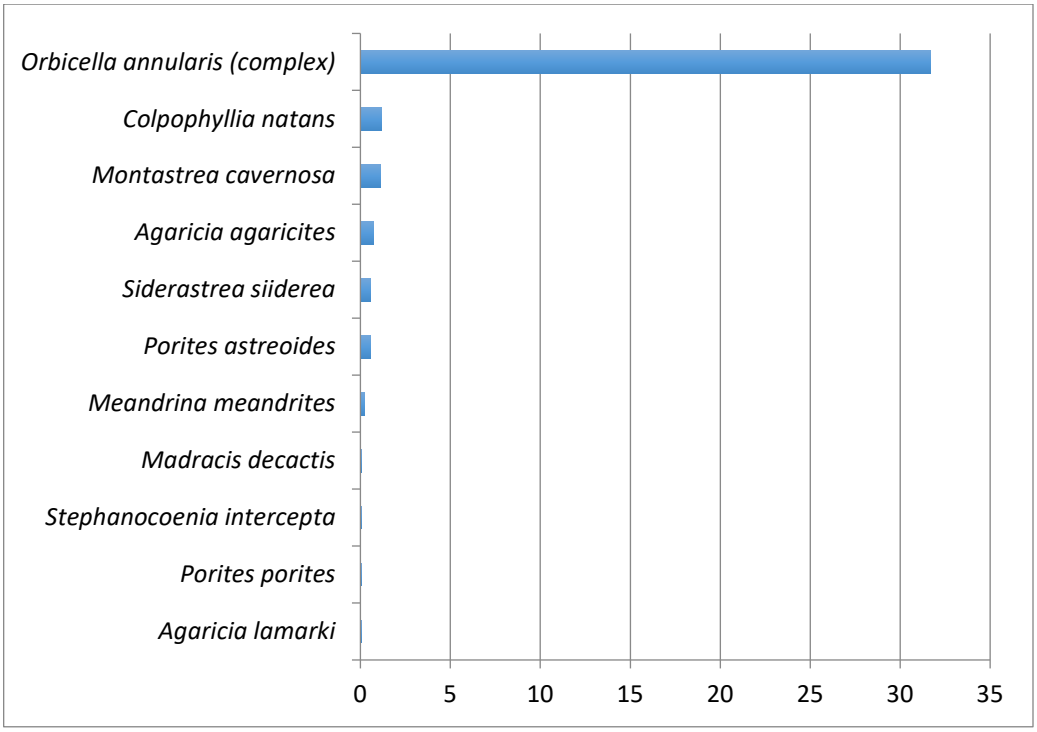


Figure 10. Mean substrate cover by coral species at Guanajibo Reef 20, Cabo Rojo, July 2016

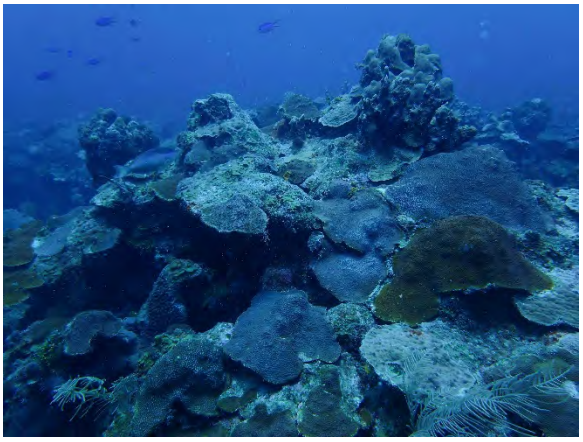
Fishes and Motile Megabenthic Invertebrates

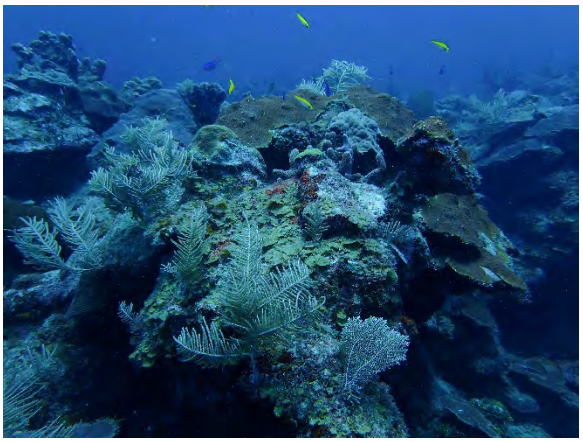
A total of 37 species of fish were observed within belt-transects from a depth of 18.0 m at Guanajibo Reef 20 (Table 12). Mean density was 148.2 Ind/transect (range: 94 – 288 Ind/transect) with a mean richness of 16.6 species per transect. An assemblage of six species, including the Masked Goby, *Coryphopterus personatus*, Mackerel scad, *Decapterus macarelus*, Peppermint Goby, *C. lipernes*, Blue Chromis, *Chromis cyanea*, Bluehead Wrasse, *Thalassoma bifasciatum*, and Bar Jack, *Caranx ruber* combined for a cumulative density of 123.2 Ind/transect, representing 83.0% of the total individuals. The Masked Goby was the numerically dominant species with a mean density of 70.2 Ind/transect, representing 47.4% of the total individuals (Table 12). Other species present in lower density, but present in all five transects included the Beaugregory, *Stegastes leucostictus*, Fairy Basslet, *Gramma loreto*, and the Princess Parrotfish, *Scarus taeniopterus*.

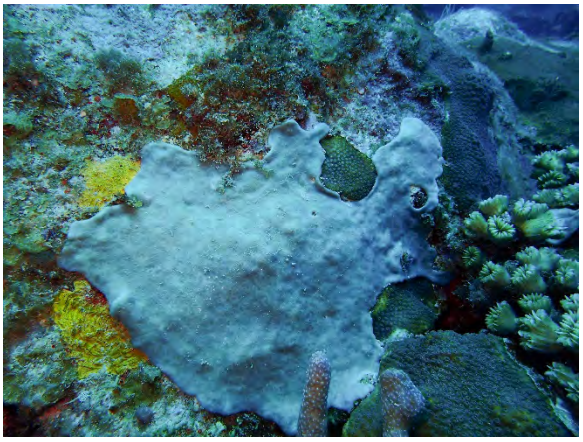
The zooplanktivorous fish assemblage strongly dominated the trophic structure at Guanajibo Reef, consistent with previous observations of shelf-edge and oceanic reefs (Esteves, 2013). The zooplanktivorous fish assemblage included four of the seven most abundant species with a combined density of 101.4 Ind/transect, representative of 68.4 % of the total individuals. Herbivores included four species of parrotfishes (Scaridae), three species of damselfishes (Pomacentridae) and three species of doctorfishes (Acanthuridae) with a combined density of 8.0 Ind/transect, representative of 5.4% of the total individuals within belt-transects. Small opportunistic carnivores were represented by two species of wrasses (Labridae), three hamlets and one small grouper (Serranidae), one puffer (Tetraodontidae), one goby (Gobiidae), and one goatfish (Mullidae). Medium sized piscivores included the Mahogany Snapper (*Lutjanus mahogoni*). Nurse Shark (*Ginglymostoma cirratum*), Nassau and Yellowfin Groupers (*Epinephelus striatus, Mycteroperca venenosa*), Great Barracuda (*Sphyraena barracuda*) and Cero Mackerels (*Scomberomorus regalis*) represented the larger predators of the reef system.

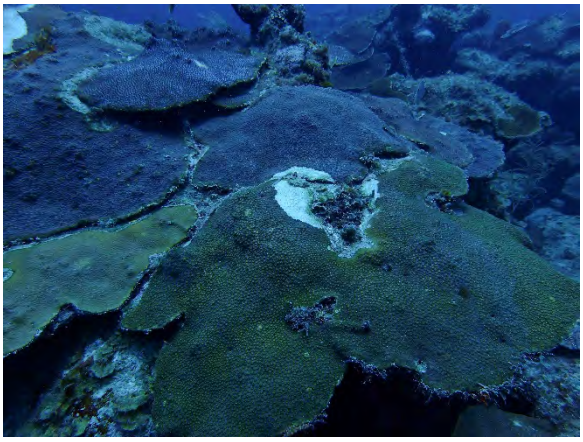
The size-frequency distribution of parrotfishes (Scaridae) suggests that the reef functions largely as a habitat for adult individuals (Table 13). One juvenile Nassau Grouper and one juvenile and one adult Yellowfin Grouper were present. Motile megabenthic invertebrates were not observed.

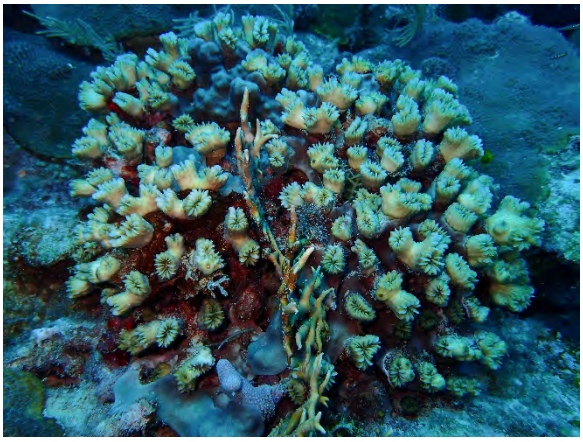
Photo Album 4.
Guanajibo Reef 20m

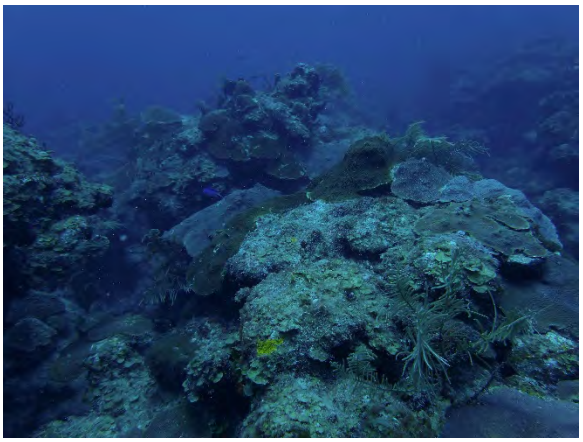


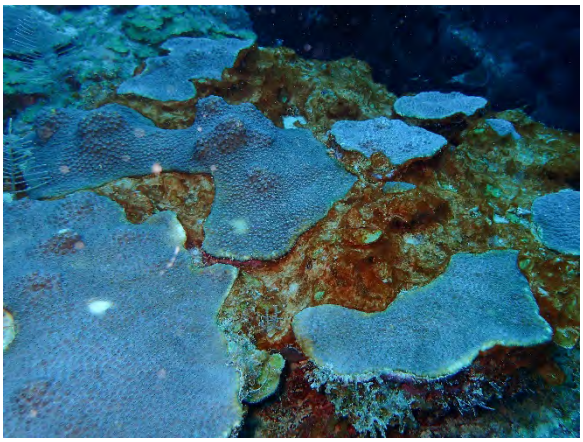


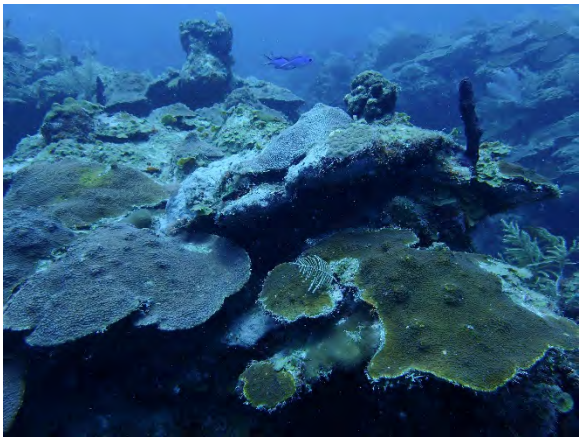


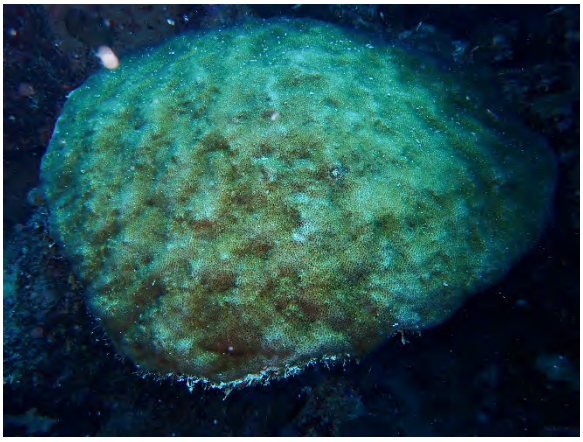












El Negro Reef 10, Cabo Rojo

Physical Description

El Negro Reef, also known as Escollo Negro is a partially emergent fringing reef that runs roughly parallel to the coastline, at about 3 NM west off Pta. Arenas, Cabo Rojo (Figure 2). The reef main structure appears to be of sedimentary origin with corals and other reef biota growing over a highly eroded submerged seascape. Transects were set along a 7 – 8m depth contour near the base of the fore-reef slope. Panoramic images of El Negro Reef 10m are included as Photo Album 5.

Sessile-Benthic Reef Community

Benthic algae, largely comprised by turf algae and fleshy brown (*Dictyota sp*) macroalgae were the dominant biotic category covering reef substrate at El Negro Reef 10 with a combined mean cover of 37.9% (Figure 11). Turf algae, a mixed assemblage of short filamentous brown and red algae was the main component of the benthic algae, with a mean cover of 32.2%, representing 85.0% of the total cover by algae (Table 14). Cyanobacterial films were prominent in four transects with a mean cover of 8.5%.

Scleractinian corals were represented by 10 species intercepted by linear transects with a combined mean substrate cover of 20.7% (range: 12.1 – 26.6 %). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant coral in terms of reef substrate cover with a mean of 9.2 % (Figure 12), representing 44.4% of the total cover by live corals. *Orbicella annularis* and *O. faveolata* were the main sibling species present in the *Orbicella* species complex. Mustard-Hill Coral, *Porites astreoides*, Lettuce Coral, *Agaricia agaricites* and Great Star Coral, *Montastrea cavernosa* were present in all transects and along with *O. annularis* complex comprised the main coral assemblage at El Negro Reef 10 (Table 14). Three coral species were only represented by one colony along transects.

Vertically projected soft corals (gorgonians) were present in all five transects surveyed at El Negro Reef 10 with a mean density of 1.6 colonies per transect. Sea Rods (*Plexaura spp*) and Sea Fans (*Gorgonia ventalina*) were the most common. The encrusting gorgonian species, *Briareum asbestinum* and *Erythropodium caribaeorum* combined for a mean substrate cover of

0.8% (Table 14). Sponges, represented by at least 17 species combined for a mean substrate cover of 4.0%. *Neopetrosia sp.* and *Monachora arbuscula* were the main species in terms of reef substrate cover. Along with the aforementioned species, *Chondrilla caribensis, Ircinia sp,* and *Plaktoris sp* were intercepted by at least three transects. In general, sponges were mostly represented by small encrusting individuals growing intermixed with algal turf.

Abiotic substrate categories presented a mean substrate cover of 27.4% (range: 20.3 – 32.3%). Reef overhangs, associated with ledges and overhangs of Boulder Star Coral, *Orbicella annularis* were the main contribution to the abiotic category with a mean cover of 13.4%, representing 48.9% of the total (Table 14). Sections of sand (7.8%) and gaps (4.3%) were also prominent at El Negro Reef 10. Reef rugosity, largely influenced by growth of *Orbicella* corals averaged 5.0 m (range: 4.0 – 7.2 m).

Table 14. NEG 10. Percent cover by sessile-benthic categories along permanent transects, El Negro Reef, 10 m. Survey date: July 6, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	4.18	7.18	3.97	4.62	5.27	**5.04**
Benthic Categories						
Abiotic						
Reef Overhang	19.84	23.23	3.31	9.48	10.91	**13.35**
Sand	2.67	8.39	5.81	15.52	6.42	**7.76**
Gap	7.21	0.65	3.21		10.63	**4.34**
Rubble			8.02	1.53		**1.91**
Total Abiotic	**29.71**	**32.27**	**20.34**	**26.53**	**27.96**	**27.36**
Benthic Algae						
Turf with sediment	45.11	28.69	30.86	31.03	25.48	**32.24**
Dictyota spp.	8.69	4.48	4.81	7.28	2.84	**5.62**
Total Benthic Algae	**53.80**	**33.17**	**35.67**	**38.31**	**28.32**	**37.86**
Hard Coral						
Orbicella annularis complex		10.43	13.03	13.60	8.80	**9.17**
Agaricia agaricites	5.53	4.07	9.02	0.96	4.12	**4.74**
Montastraea cavernosa	1.97	0.90	0.60	0.96	6.42	**2.17**
Porites astreoides	0.69	0.81	4.01	1.72	1.19	**1.69**
Siderastrea siderea	2.57	2.28		0.19		**1.01**

Agaricia lamarcki				0.67	2.29	**0.59**
Diploria labyrinthiformis					2.29	**0.46**
Porites porites				1.25	0.55	**0.36**
Stephanocoenia intersepta	1.38					**0.28**
Meandrina meandrites				1.25		**0.25**
Total Hard Coral	**12.14**	**18.50**	**26.65**	**20.59**	**25.66**	**20.71**
Cyanobacteria	0.49	12.31	12.83	9.10	7.79	**8.50**
Invertebrate						
Trididemnum solidum		*0.57*	*1.70*			***0.45***
Condominium sp.				*0.38*	*0.92*	***0.26***
Total Invertebrate		**0.57**	**1.70**	**0.38**	**0.92**	**0.71**
#Gorgonians/transect	2	2	1	2	1	**1.60**
Octocoral						
Briareum asbestinum	1.18		0.50		1.28	**0.59**
Erythropodium caribaeorum		0.24			0.73	**0.20**
Plexaura kuekenthali					0.18	**0.04**
Total Octocoral	**1.18**	**0.24**	**0.50**		**2.20**	**0.83**
Sponge						
Neopetrosia sp.		1.22			1.65	**0.57**
Monachora arbuscula		0.65	0.50		1.47	**0.52**
Smenospongia aurea				2.49		**0.50**
Chondrilla caribensis	0.99	0.16	0.40		0.55	**0.42**
Ircinia brown sp.			0.40	0.38	0.92	**0.34**
Aplysina lacunosa				1.63		**0.33**
Niphates erecta			0.10		0.92	**0.20**
Sponge					0.92	**0.18**
Aplysina cauliformis	0.59	0.24				**0.17**
Verongula sp.	0.79					**0.16**
Mycale laevis			0.70			**0.14**
Plaktoris sp.		0.24		0.19	0.18	**0.12**
Scopalina ruetzleri					0.55	**0.11**
Clathria sp.	0.30	0.16				**0.09**
Callyspongia vaginalis				0.38		**0.08**
Neopetrosia proxima		0.24				**0.05**
Mycale laxissima			0.20			**0.04**
Total Sponge	**2.67**	**2.93**	**2.30**	**5.08**	**7.15**	**4.03**

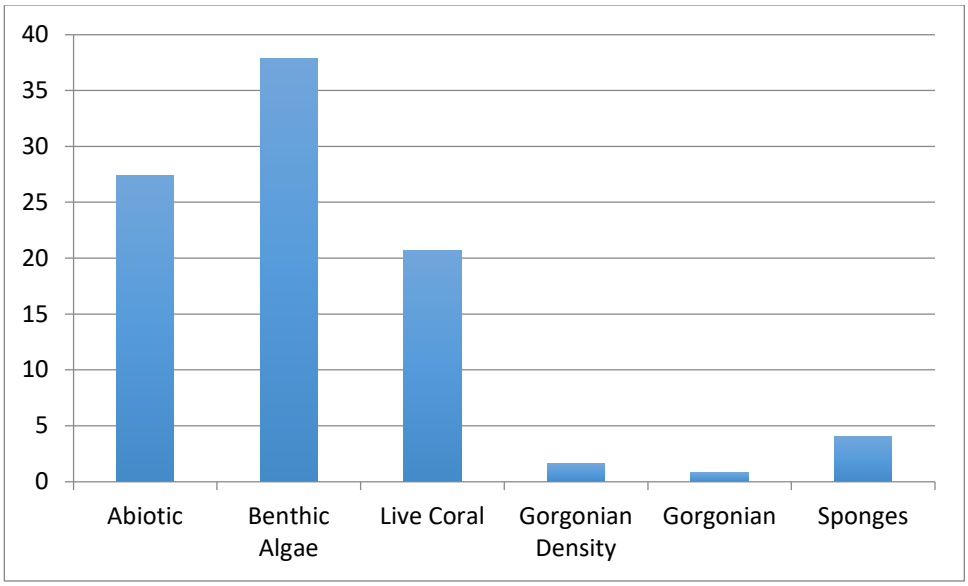


Figure 11. Mean substrate cover by benthic categories at El Negro Reef 10, Cabo Rojo, July 2016

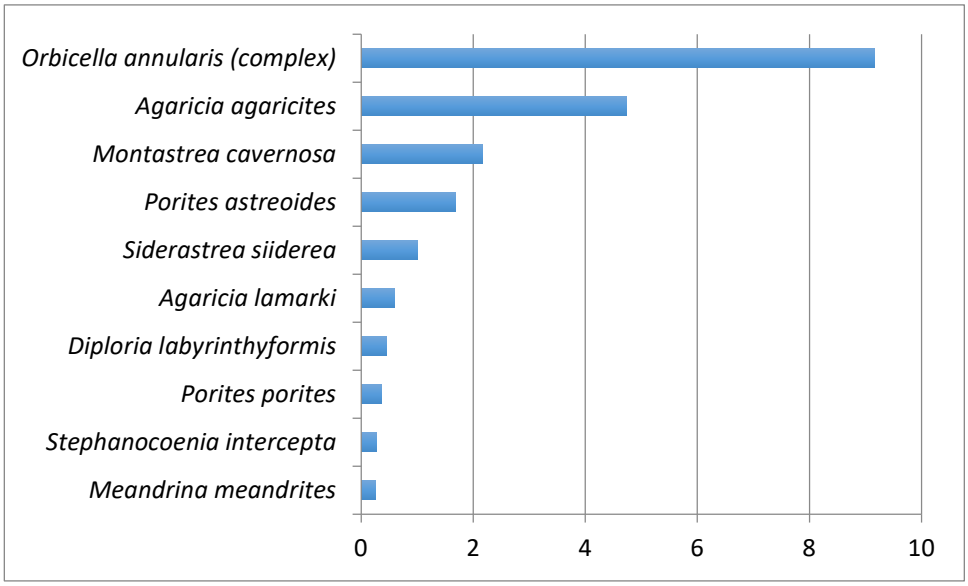


Figure 12. Mean substrate cover by coral species at El Negro Reef 10, Cabo Rojo, July 2016

Fishes and Motile Megabenthic Invertebrates

A total of 31 species of fish were identified within belt-transects from a depth of 7.8 m at El Negro Reef 10 (Table 15). Mean density was 137.6 Ind/transect (range: 100 – 210 Ind/transect) with a mean richness of 17.4 species per transect. The masked Goby, *Coryphopterus personatus* was numerically dominant with a mean density of 137.6 Ind/transect, representing 65.2% of the total individuals. This is a small schooling zooplanktivore species that swarms over large coral colonies and below ledges. Other 10 species were present in at least four transects at Negro Reef 10. These include the Blue Chromis, *Chromis cyanea*, the Bluehead Wrasse, *Thalassoma bifasciatum*, Peppermint Goby*, Coryphopterus lipernes*, Stripped and Redband Parrotfishes, *Scarus iserti*, *Sparisoma aurofrenatum*, Beaugregory, *Stegastes leucostictus*, Fairy Basslet, *Gramma loreto*, French Angelfish, *Holacanthus ciliaris,* Caribbean Puffer, *Canthigaster rostrata* and Trumpetfish, *Aulostomus maculatus*. Twelve species were only present in one transect (Table 15).

The zooplanktivore fish trophic assemblage, comprised by the two most abundant species within belt-transects (*Coryphopterus personatus* and *Chromis cyanea*) represented 76.0% of the total fish density at Negro Reef 10. Herbivores were represented by at least five species of parrotfishes (Scaridae), four species of damselfishes (Pomacentridae) and two doctorfishes (Acanthuridae). The combined density of herbivores species represented 19.0% of the total fish density. Small opportunistic carnivores were represented by two species of wrasses (Labridae), two species of hamlets and one small grouper (Serranidae), one puffer (Tetraodontidae), one Trumpetfish (Aulostomidae) and two squirrelfishes (Holocentridae). Medium sized piscivores included the Yellowtail Snapper (*Ocyurus chrysurus*) and red hinds (*Epinephelus guttatus*) and Great Barracuda (*Sphyraena barracuda*) observed outside transects. Given the smaller size of zooplanktivores relative to the herbivorous and carnivorous fish species present it can be argued that the trophic structure of fishes at Negro Reef 10 was fairy well balanced, only lacking the larger demersal predators.

The size-frequency distribution of parrotfishes (Scaridae) suggests that the reef serves largely as a habitat for juvenile and adult individuals (Table 16). Individuals of the Yellowtail Snapper (*Ocyurus chrysurus)* and the Graysbe (*Cephalopholis cruentatus*) were present as juveniles and young adults. One juvenile spiny lobster, *Panulirus argus* was observed in transect 3.

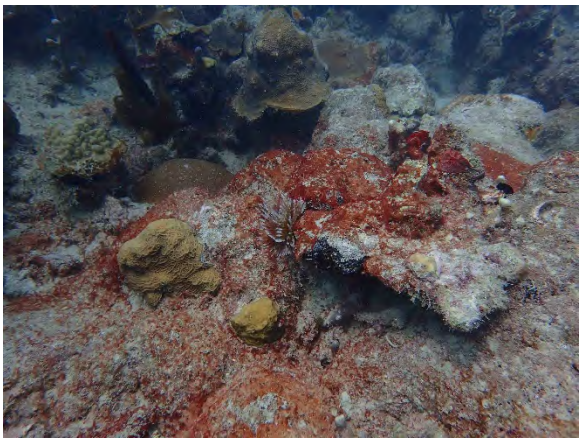
Table 15. NEG 10. Taxonomic composition and abundance of fishes within 10 x 3 m belt-transects at El Negro Reef 10, Cabo Rojo, 7.8 m. Survey date: July 6, 2016

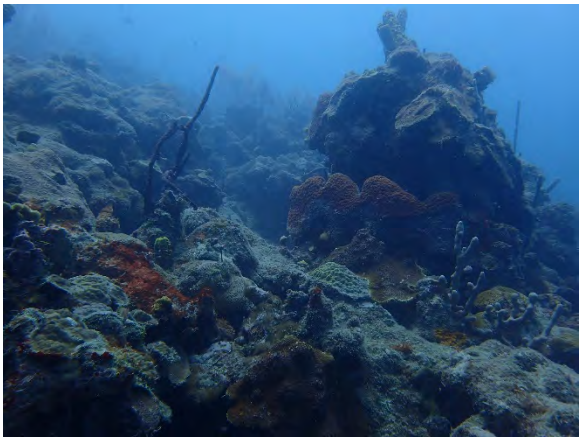
		Transects (Ind/30 m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	210	150	120	108	100	**137.6**
Chromis cyanea	Blue Chromis	30	3	5	25	52	**23.0**
Thalassoma bifasciatum	Bluehead Wrasse	3	5		15	10	**6.6**
Scarus iserti	Stripped Parrotfish	2	2	9	11	4	**5.6**
Gramma loreto	Fairy Basslet		14	6	1	7	**5.6**
Stegastes leucostictus	Beau Gregory	5	4	4	10	3	**5.2**
Coryphopterus lipernes	Peppermint Goby	5	3	8		6	**4.4**
Canthigaster rostrata	Caribbean Puffer	1	6	2	1	2	**2.4**
Ocyurus chrysurus	Yellowtail Snapper					12	**2.4**
Halichoeres garnoti	Yellow-head Wrasse		1	5	4	1	**2.2**
Stegastes partitus	Bicolor Damselfish		1		4	6	**2.2**
Caranx ruber	Bar Jack		8				**1.6**
Sparisoma aurofrenatum	Redband Parrotfish	2	1	2	4	2	**1.4**
Cephalopholis cruentatus	Graysby	2	2		2	1	**1.4**
Stegastes planifrons	Three-spot Damselfish			2	3	2	**1.4**
Scarus taeniopterus	Princess Parrotfish		1		1	4	**1.2**
Chaetodon capistratus	Four-eye Butterflyfish		1	2	2		**1.0**
Holacanthus ciliaris	Queen Angelfish	1	1	1		1	**0.8**
Aulostomus maculatus	Trumpetfish	1	1	1		1	**0.8**
Sparisoma viride	Stoplight Parrotfish		3				**0.6**
Holocentrus adcensionis	Squirrelfish	1			1	1	**0.6**
Pomacanthus paru	French Angelfish					3	**0.6**
Sparisoma radians	Bucktooth Parrotfish			2	1		**0.6**
Acanthurus bahianus	Ocean Surgeon		2				**0.4**
Abudefduf sexatilis	Sargent Major	2					**0.4**
Acanthurus chirurgus	Doctorfish				1		**0.2**
Pomacanthus arcuatus	Grey Angelfish	1					**0.2**
Equetus punctatus	Spotted Drum			1			**0.2**
Hypoplectrus sciurus	Yellowtail Hamlet			1			**0.2**
Hypoplectrus unicolor	Butter Hamlet					1	**0.2**
Neoniphon marianus	Longjaw Squirrelfish				1		**0.2**
	TOTAL INDIVIDUALS	**266**	**209**	**171**	**191**	**219**	**211.2**
	TOTAL SPECIES	**14**	**19**	**16**	**18**	**20**	**17.4**

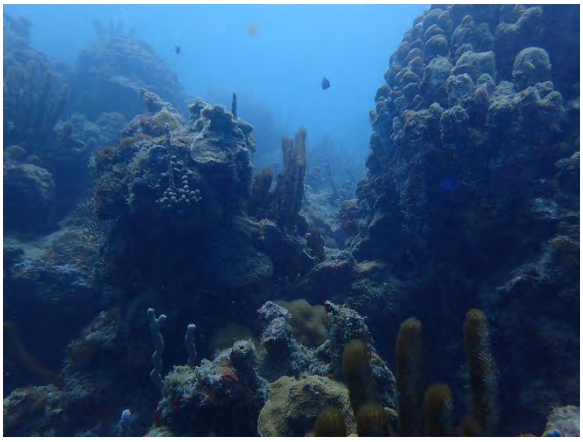
Table 16. NEG 10. Size frequency distribution of fishes within 20 x 4 m belt-transects at El Negro Reef 10, Cabo Rojo, 7.8 m. Survey date: July 6, 2016

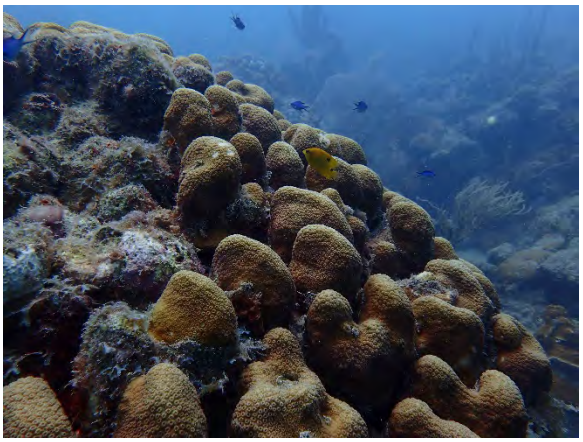
		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Scarus iserti	Stripped Parrotfish	3-15	2-10	5-12	8-8	6-7
		1-25		6-25	4-12	
					2-15	
					1-18	
					1-25	
Sparisoma viride	Stoplight Parrotfish		1-6			
			1-10			
			1-30			
			1-35			
Sparisoma aurofrenatum	Redband Parrotfish	1-15	2-15	1-20	2-13	2-15
		4-20	1-18	1-25	1-15	1-8
					1-18	
Ocyurus chrysurus	Yellowtail Snapper					12-15
						15-30
Epinephelus fulva	Coney					
Epinephelus cruentatus	Graysby	1-15	2-15		1-25	1-25
		1-20	1-19		1-35	
Scarus taeniopterus	Princess Parrotfish		2-15	3-20	1-18	1-10
			1-18	1-30	1-30	

Photo Album 5.
El Negro Reef 10m









El Negro 5, Cabo Rojo

Physical Description

El Negro Reef 5m is the same reef formation described for 10m, but permanent transects were established at the upper edge of the fore-reef slope along the 4 – 5m depth contour (Figure 2). Panoramic images of El Negro Reef 5 are included as Photo Album 6.

Sessile-benthic Reef Community

Benthic algae, with a combined mean substrate cover of 43.3% were the dominant biotic category covering reef substrate at El Negro Reef 5 (Figure13). Turf algae, a mixed assemblage of short filamentous brown and red algae was the main component of the benthic algae, with a mean cover of 37.9%, representing 87.5% of the total cover by algae (Table 17). Fleshy brown macroalgae (mostly *Dictyota sp*) were present in all transects with a mean cover of 5.1%. Green calcareous (*Halimeda sp*) macroalgae and red crustose coralline algae were present in two transects each with a combined cover of 0.3%, representing minor components of the benthic algae assemblage. Cyanobacterial films were present in four transects with a mean cover of 2.4%.

Scleractinian corals were represented by 10 species intercepted by linear transects with a combined mean substrate cover of 28.2% (range: 16.9 – 37.8 %). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant coral in terms of reef substrate cover with a mean of 13.0 % (Figure 14), representing 46.1% of the total cover by live corals. *Orbicella annularis* and *O. faveolata* were the main sibling species present in the *Orbicella* species complex. Along with *O. annularis*, Lettuce Coral, *Agaricia agaricites* and Mustard-Hill Coral, *Porites astreoides* and Finger Coral, *P. porites* were present in all transects surveyed. The combined cover by these four species represented 87.3% of the total cover by live corals at El Negro Reef 5 (Table 13). The other five coral species were only observed in one transect. Colonies of Elkhorn and Staghorn Corals (*Acropora palmata, A. cervicornis*) were observed outside transects. As previously noted for Rodriguez Reef 5 in Mayaguez Bay, large and healthy colonies of Boulder Star Coral (*O. annularis*) were observed growing close to the surface suggesting that the 2005 coral bleaching event had minor, if any degradation effect upon such massive corals at this reef.

Also, the relatively high live coral cover by *O. annularis* in a shallow coastal reef supports the argument of limited impact by the 2005 coral bleaching phenomena.

Vertically projected soft corals (gorgonians) were present in all five transects surveyed at El Negro Reef 5 with a mean density of 5.2 colonies per transect. Sea Fans (*Gorgonia ventalina*) and Sea Rods (*Plexaura spp*) were the most common. The encrusting gorgonian species, *Briareum asbestinum* and *Erythropodium caribaeorum* combined for a mean substrate cover of 0.8% (Table 13). Sponges, represented by at least 12 species combined for a mean substrate cover of 3.0%. *Chondrilla caribensis*, *Amphimedon compressa* and Mycaele laevis were the most important in terms of reef substrate cover. Only *C. caribensis* was present in more than two transects. In general, sponges were mostly represented by small encrusting individuals growing intermixed with algal turf and other encrusting biota.

Abiotic substrate categories presented a mean substrate cover of 21.7% (range: 17.7 – 26.3%). Coral rubble was the main component the abiotic category with a mean cover of 13.3%, representing 61.3% of the total (Table 13). Reef overhangs, associated with ledges of Boulder Star Coral were also prominent with a mean cover of 6.6%. Reef rugosity averaged 7.4m, influenced both by large coral mounds and the irregular reef topography associated with relict erosive features.

TABLE 13. NEG 5. Percent cover by sessile-benthic categories along permanent transects, El Negro Reef 5. Survey date: July 6, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	6.38	16.24	4.52	4.78	5.08	**7.40**
Benthic Categories						
Abiotic						
Rubble	9.32	11.55	20.64	15.91	8.91	**13.27**
Reef Overhang	10.68	7.24	2.51	3.50	8.82	**6.55**
Sand		2.93	1.83	0.47	0.00	**1.05**
Gap		1.72	1.35	1.04	0.00	**0.82**
Total Abiotic	**20.00**	**23.45**	**26.33**	**20.93**	**17.73**	**21.69**
Benthic Algae						
Turf with sediment	43.76	32.50	22.95	33.81	56.36	**37.88**
Dictyota spp.	1.62	4.83	9.16	7.39	2.51	**5.10**
CCA				0.47	0.46	**0.19**

Halimeda spp.				0.19	0.28	**0.09**
Total Benthic Algae	45.38	37.33	32.11	41.86	59.61	**43.26**
Hard Coral						
Orbicella annularis complex	14.96	18.53	20.06	3.50	7.80	**12.97**
Agaricia agaricites	5.21	6.21	6.46	10.98	3.16	**6.40**
Porites astreoides	5.81	5.95	1.74	1.42	4.36	**3.86**
Montastraea cavernosa			8.00			**1.60**
Colpophyllia natans	2.05			5.59		**1.53**
Porites porites	0.68	2.59	1.25	0.95	1.58	**1.41**
Pseudodiploria strigosa	1.28					**0.26**
Stephanocoenia intersepta	0.43					**0.09**
Eusmilia fastigiata			0.29			**0.06**
Siderastrea radians				0.19		**0.04**
Total Hard Coral	**30.43**	**33.28**	**37.80**	**22.63**	**16.90**	**28.21**
Cyanobacteria		1.55	0.39	9.19	0.93	**2.41**
Invertebrate						
Tridemnum solidum	*0.77*		*0.77*	*0.09*		***0.33***
Millepora alcicornis		*0.86*				***0.17***
Tunicate					0.37	**0.07**
Total Invertebrate	**0.77**	**0.86**	**0.77**	**0.09**	**0.37**	**0.57**
#Gorgonians/transect	9	3	5	5	4	**5.20**
Octocoral						
Erythropodium caribaeorum			0.77	2.46		**0.65**
Briareum asbestinum	0.26			0.38		**0.13**
Gorgonia ventalina			0.29			**0.06**
Plexaura kuekenthali		0.17				**0.03**
Total Octocoral	**0.26**	**0.17**	**1.06**	**2.84**		**0.87**
Sponge						
Chondrilla caribensis	2.05	0.95	0.68	1.89	2.23	**1.56**
Amphimedon compressa	0.26	1.03			0.28	**0.31**
Mycale laevis				0.19	1.30	**0.30**
Smenospongia aurea		0.95				**0.19**
Aplysina lacunosa	0.26		0.19		0.28	**0.15**
Ircinia brown sp.	0.60					**0.12**
Sponge				0.38	0.19	**0.11**
Monanchora arbuscula			0.39			**0.08**
Callyspongia vaginalis			0.29			**0.06**
Agelas conifera		0.26				**0.05**
Aplysina cauliformis					0.19	**0.04**
Niphates erecta		0.17				**0.03**
Total Sponge	**3.16**	**3.36**	**1.54**	**2.46**	**4.46**	**3.00**

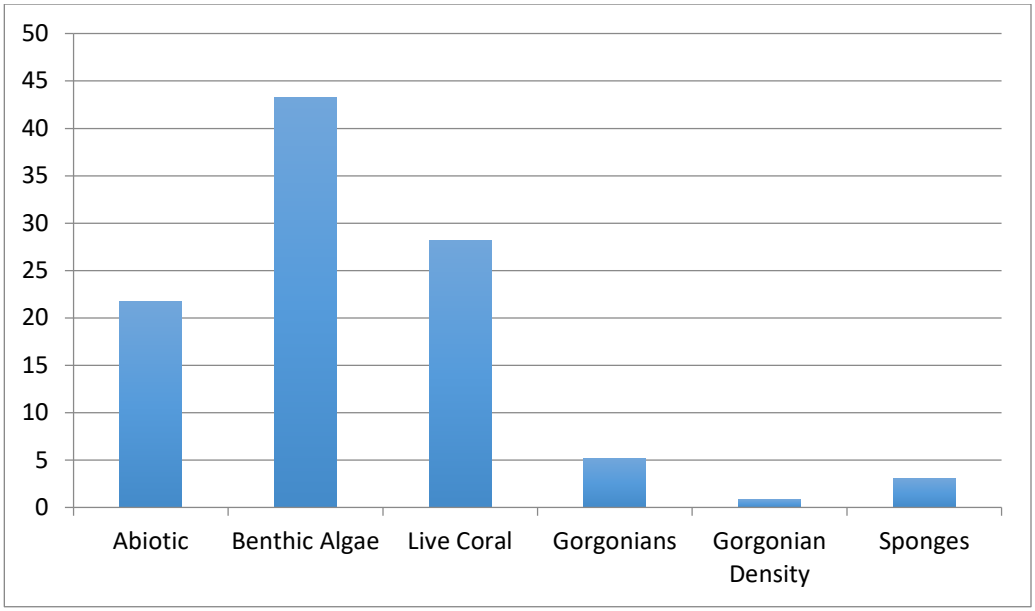


Figure 13. Mean substrate cover by benthic categories at El Negro Reef 5, Cabo Rojo, July 2016

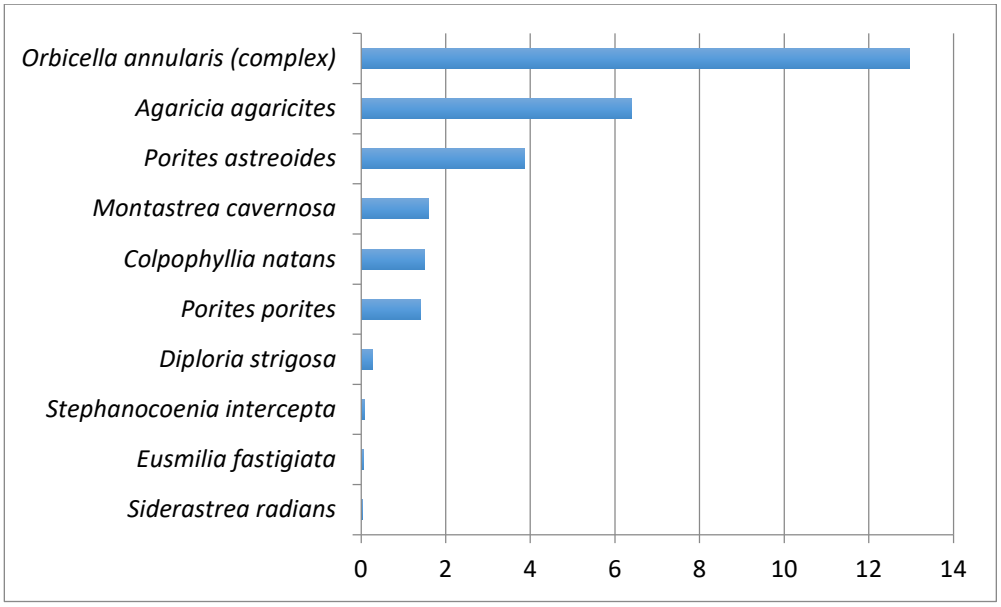


Figure 14. Mean substrate cover by coral species at El Negro Reef 5, Cabo Rojo, July 2016

Fishes and Motile Megabenthic Invertebrates

A total of 40 species of fish were identified within belt-transects from a depth of 4.6 m at El Negro Reef 5 (Table 18). Mean density was 223.0 Ind/transect (range: 143 – 356 Ind/transect) with a mean richness of 17.2 species per transect. The masked Goby, *Coryphopterus personatus* was numerically dominant with a mean density of 83.0 Ind/transect, representing 37.2% of the total individuals. In terms of fish density, an assemblage of four species accounted for 77% of the total fish density. These included (in addition to the Masked Goby) the Blue Chromis, *Chromis cyanea*, and the Creole and Bluehead Wrasses, *Thalassoma bifasciatum* and *Clepticus parrae*. Other 10 species, including three parrotfishes (*Scarus spp, Sparisoma spp*.), three damselfishes (*Stegastes spp*), the Yellowhead Wrasse, *Halichoeres garnoti*, the Harlequin Bass, *Serranus tigrinus*, the four-eye Butterflyfish, *Chaetodon capistratus*, and the Peppermint Goby, *C. lipernes* were present in at least four transects. Eleven species were only present in one transect (Table 18).

Zooplanktivorous fishes, comprised by the three most abundant species within belt-transects (*Coryphopterus personatus*, *Chromis cyanea* and *Clepticus parrae*) comprised the most prominent trophic assemblage in terms of fish density within belt-transects at El Negro Reef 5m, representing a combined density of 66.8% of the total fish density. Despite a combined density of only 12.1% of the total density within extended belt-transects (20 m x 4m) herbivores were represented by a highly species rich assemblage at El Negro Reef 5m. These included six parrotfishes (Scaridae), three damselfishes (Pomacentridae) and two doctorfishes (Acanthuridae). Small opportunistic carnivores comprised 15.6% of the total fish density and included at least 15 species within the Labridae (Wrasses), Serranidae (Hamlets and Sea Bases), Haemulidae (Grunts), Tetraodontidae (Puffers), and Holocentridae (Squirrelfishes) family groups. Medium sized piscivores included the Yellowtail Snapper, and Bar Jacks. One Great Barracuda (*Sphyraena barracuda*) and one Cero Mackerel were observed outside transects. Given the smaller size of zooplanktivores relative to the herbivorous and carnivorous fish species present it can be argued that the trophic structure of fishes at Negro Reef 5 was well balanced, only lacking the larger demersal predators.

The size-frequency distribution of parrotfishes (Scaridae) suggests that the reef serves largely as a habitat for juvenile and adult individuals. Individuals of the Yellowtail Snapper and the

Graysbe were present as juveniles and young adults (Table 19). One juvenile spiny lobster, *Panulirus argus* was present within belt-transect areas.

Table 18. Taxonomic composition and abundance of fishes within belt-transects at El Negro Reef 5m, Mayaguez, July 2016

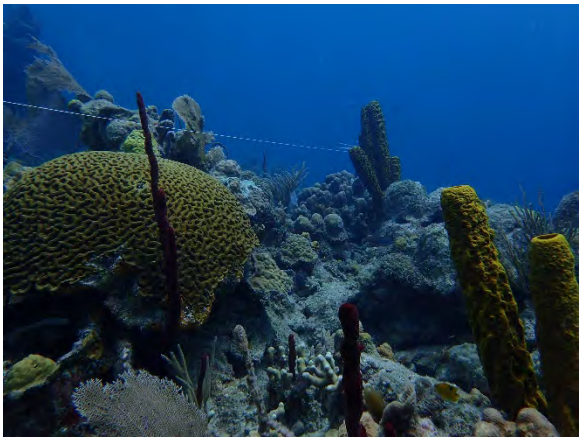
		Transects (Ind/30 m^2)					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	84	51	150	30	100	**83.0**
Chromis cyanea	Blue Chromis	33	35	54	10	60	**38.4**
Clepticus parrae	Creole Wrasse			38	100		**27.6**
Thalassoma bifasciatum	Bluehead Wrasse	30	21	35	3	25	**22.8**
Stegastes adustus	Dusky Damselfish	14	7	5		6	**6.4**
Stegastes partitus	Bicolor Damselfish		4	4	5	15	**5.6**
Scarus iserti	Stripped Parrotfish	1		10	8	3	**4.4**
Stegastes planifrons	Three-spot Damselfish	2		12	8		**4.4**
Halichoeres garnoti	Yellow-head Wrasse	3	3	6	2	1	**3.0**
Sparisoma viride	Stoplight Parrotfish	1		6	2	6	**3.0**
Stegastes leucostictus	Beau Gregory	1	1	6	7		**3.0**
Gramma loreto	Fairy Basslet	2		10		1	**2.6**
Coryphopterus lipernes	Peppermint Goby	3	3	1	2		**1.8**
Scarus taeniopterus	Princess Parrotfish		1	1	3	3	**1.6**
Chaetodon capistratus	Four-eye Butterflyfish	2	1	3		2	**1.6**
Sparisoma aurofrenatum	Redband Parrotfish		3	1	3		**1.4**
Serranus tigrinus	Harlequin Bass	1	4	1		1	**1.4**
Cephalopholis cruentatus	Graysby		2	3		1	**1.2**
Holocentrus adcensionis	Squirrelfish			1	1	4	**1.2**
Caranx ruber	Bar Jack				3	2	**1.0**
Neoniphon marianus	Longjaw Squirrelfish			2	1	2	**1.0**
Canthigaster rostrata	Caribbean Puffer	1		2	1		**0.8**
Gobiosoma evelynae	Sharknose Goby	1	2		1		**0.8**
Acanthurus coeruleus	Blue Tang	2		1		1	**0.8**
Chromis multilineata	Brown Chromis		2				**0.4**
Holocentrus rufus	Squirrelfish	2					**0.4**
Pomacanthus arcuatus	Grey Angelfish			1		1	**0.4**
Hypoplectrus unicolor	Butter Hamlet			1	1		**0.4**
Bodianus rufus	Spanish Hogfish			1		1	**0.4**
Acanthurus bahianus	Ocean Surgeon				1		**0.2**
Haemulon flavolineatum	French Grunt					1	**0.2**

Holacanthus ciliaris	Queen Angelfish		1				**0.2**
Pomacanthus paru	French Angelfish					1	**0.2**
Hypoplectrus puella	White Hamlet		1				**0.2**
Hypoplectrus sciurus	Yellowtail Hamlet				1		**0.2**
Halichoeres bivittatus	Slippery Dick	1					**0.2**
Ocyurus chrysurus	Yellowtail Snapper			1			**0.2**
Lactophrys triqueter	Smooth Trunkfish	1					**0.2**
Sparisoma chrysopterum	Redtail Parrotfish		1				**0.2**
Scarus vetula	Queen Parrotfish					1	**0.2**
	TOTAL INDIVIDUALS	**185**	**143**	**356**	**193**	**238**	**223.0**
	TOTAL SPECIES	**14**	**18**	**18**	**17**	**19**	**17.2**

Table 19. NEG 5. Size frequency distribution of fishes within 20 x 4 m belt-transects at El Negro Reef, Cabo Rojo, 4.6 m. Survey date: July 6, 2016

SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Scarus iserti	Stripped Parrotfish	4-15		10-10	7-8	1-5
		1-20			1-15	1-10
Sparisoma viride	Stoplight Parrotfish	1-5		5-5	1-10	3-10
		1-17		1-36	1-15	5 -15
				5-55	1-25	10-18
						15-22
						2 -38
Sparisoma aurofrenatum	Redband Parrotfish		1-5	1-20	1-10	
			1-10		2-15	
			1-15		3-18	
Epinephelus cruentatus	Graysby		1-7	1-10		1-30
			1-12	2-15		
Scarus taeniopterus	Princess Parrotfish	2-7	1-10	1-20	2-15	5-15
				5-25	1-18	5-18
					2-20	7-20
						5-25
Ocyurus chrysurus	Yellowtail Snapper			1-25		
Scarus vetula	Queen Parrotfish			1-30		1-40
Sparisoma chrysopterum	Redtail Parrotfish	1-15				
Panulirus argus	Spiny Lobster		1-5			

Photo Album 6.
El Negro 5m



Cayo Caribes 10, Salinas/Guayama

Physical Description

Cayo Caribes is an emergent fringing reef located approximately 1.5 NM off the Guayama/Salinas coastline. It is at the eastern margin of Boca del Infierno, the entrance channel to Jobos Bay (Figure 15). The reef sits in what appears to be a fairly extensive hard ground insular shelf at depths of 60 – 70 m and rises to the surface along a series of narrow steps or terraces producing a moderately steep fore-reef slope. Permanent transects were established along the 9 – 10 m contour. Photographic characterization of Cayo Caribes Reef and its representative reef community is included as Photo Album 7.

Sessile-benthic Reef Community

Benthic algae were the dominant biotic category covering reef substrate at Cayo Caribes Reef 10 with a combined mean cover of 58.4% (Figure 16). Turf algae, a mixed assemblage of short filamentous brown and red algae was the main component of the benthic algae, with a mean cover of 54.5% (range: 54.7 – 61.4 %), representing 93.3% of the total cover by algae (Table 20). Fleshy brown macroalgae, mostly *Dictyota sp*. and red crustose coralline algae were also present with a combined cover of 3.9%.

Scleractinian corals were represented by 10 species intercepted by linear transects with a combined mean substrate cover of 16.9% (range: 9.6 – 26.2 %). Great Star Coral, *Montastrea cavernosa* was the dominant coral in terms of reef substrate cover with a mean of 6.3 % (Figure 17), representing 37.3% of the total cover by live corals. Greater Starlet Coral, *Siderastrea siderea* and Mustard-Hill Coral, *Porites astreoides* were present (along with *M. cavernosa*) in all five transects, each with a mean cover of 2.8% (Table 20). Colonies of Boulder Star Coral, *Orbicella annularis* (complex) were only present in 2 transects with a mean cover of 2.6%. Small encrusting colonies of Symmetrical Brain Coral, Pseudodiploria strigosa were present in four transects with a mean cover of 1.1 %. Four coral species were only represented by one colony along transects.

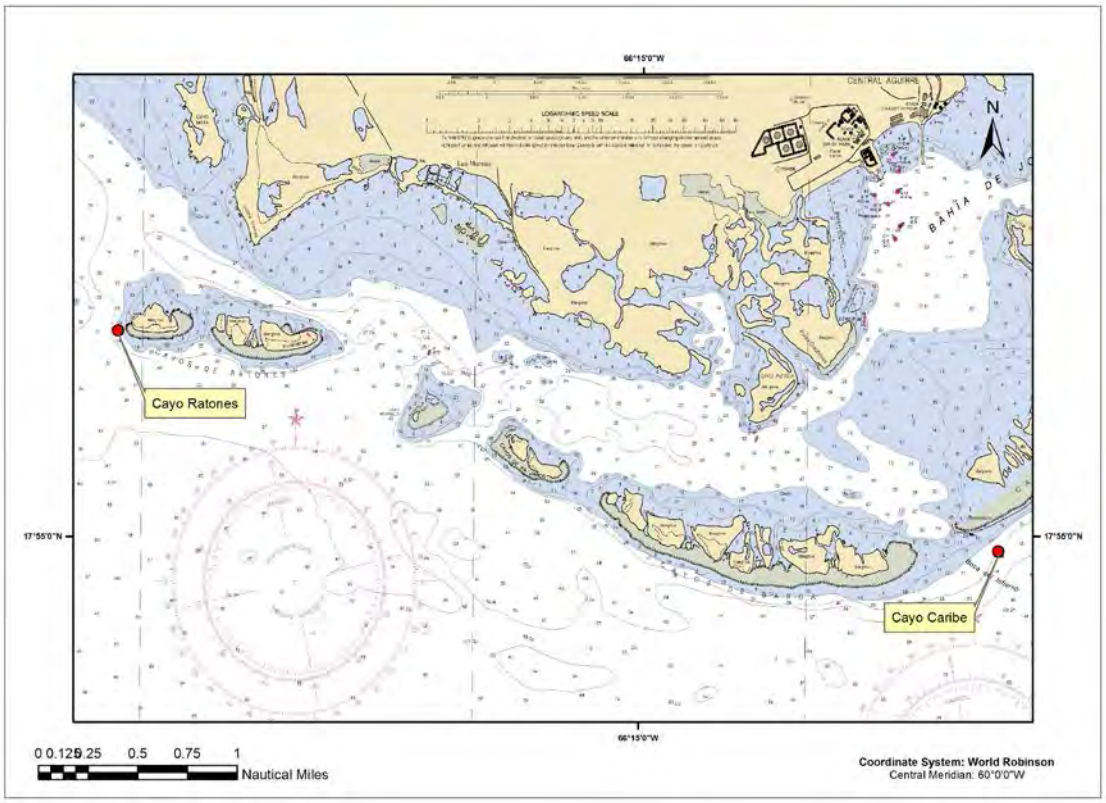


Figure 15. Location of sampling stations at coral reef in the Salinas/Guayama region

Vertically projected soft corals (gorgonians) were prominent at Cayo Caribes 10 with a mean density of 15.4 colonies per transect. Sea Rods (*Muriceopsis flavida*, *Muricea spp, Eunicea spp.*) and Sea Fans (*Gorgonia ventalina*) were the most common. The encrusting gorgonian species, *Erythropodium caribaeorum* and *Briareum asbestinum* combined for a mean substrate cover of 9.2% (Table 20). Sponges, represented by at least 22 species combined for a mean substrate cover of 12.6%. *Ircinia sp, Iotrochota birotulata* and *Niphates erecta* were all present in the five transects surveyed with a combined cover of 6.4 %, representing 51.1 % of the total cover by sponges at Cayo Caribe. Other seven species were present in at least three transects. Sponges were present in variable sizes and growth forms, including large erect colonies of *Xestospongia muta* and contributed significantly to the reef benthic habitat complexity.

Abiotic substrate categories at Cayo Caribes 10 presented a mean substrate cover of 1.4%, largely associated with small reef overhangs. Reef rugosity averaged 2.0 m, indicative of a mostly regular topography with relatively low contributions by coral structures to the underwater relief.

TABLE 20. CARI 10. Percent cover by sessile-benthic categories along permanent transects, Cayo Caribes 10, Salinas/Guayama. Survey date: August 4, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.67	1.96	0.95	1.48	2.75	**1.96**
Benthic Categories						
Abiotic						
Reef overhang	2.54	2.69				**1.05**
Sand	1.10		0.64			**0.35**
Total Abiotic	**3.65**	**2.69**	**0.64**			**1.40**
Benthic Algae						
Turf with sediment	56.24	51.17	48.08	59.76	57.19	**54.49**
Dictyota spp.	4.42	2.69	7.29		2.63	**3.41**
CCA	0.44	0.47		0.49	0.55	**0.39**
Galaxaura spp.		0.35				**0.07**
Peyssonnelia spp.	0.33					**0.07**
Total Benthic Algae	**61.44**	**54.68**	**55.37**	**60.24**	**60.37**	**58.42**
Hard Coral						
Montastraea cavernosa	4.31	6.32	5.50	4.63	10.87	**6.33**
Siderastrea siderea	6.63	0.70	1.79	3.54	1.54	**2.84**
Porites astreoides	4.42	1.41	2.05	5.00	1.21	**2.82**
Orbicella annularis complex	7.73				5.49	**2.64**
Pseudodiploria strigosa	1.55	0.59		2.56	0.66	**1.07**
Porites divaricata			2.69			**0.54**
Madracis decactis	1.22					**0.24**
Agaricia agaricites	0.33			0.73		**0.21**
Dichocoenia stokesi		0.59				**0.12**
Stephanocoenia intersepta				0.37		**0.07**
Total Hard Coral	**26.19**	**9.60**	**12.02**	**16.83**	**19.76**	**16.88**
Invertebrate						
Millepora alcicornis		1.05	0.90	0.61		**0.51**
Palythoa caribaeorum				1.59		**0.32**
Total Invertebrate		**1.05**	**0.90**	**2.20**		**0.83**
Octocoral						
Erythropodium caribaeorum	0.44	8.20	7.03	6.71	8.67	**6.21**
Briareum asbestinum	0.88	1.64	7.93	2.80	1.65	**2.98**
Muriceopsis flavida		0.70	0.38			**0.22**
Antillogorgia bipinnata			0.77			**0.15**
Eunicea sp.			0.26			**0.05**
Gorgonia ventalina			0.26			**0.05**
Muricea atlantica			0.26			**0.05**
Muricea pinnata		0.23				**0.05**

Pseudoplexaura wagenaari/flagellosa	0.22					**0.04**
Antillogorgia americana					0.22	**0.04**
Total Octocoral	**1.55**	**10.77**	**16.88**	**9.51**	**10.54**	**9.85**
# Gorgonians/transect	10	16	22	14	15	**15.40**
Sponge						
Ircinia brown sp.	1.55	4.68	3.71	4.76	0.99	**3.14**
Iotrochota birotulata	0.66	1.52	3.96	1.95	1.87	**1.99**
Niphates erecta	1.44	3.51	0.64	0.73	0.22	**1.31**
Xestospongia muta		4.33				**0.87**
Neopetrosia smooth sp.		0.59	2.05	0.61		**0.65**
Amphimedon compressa	0.99	1.17	0.51			**0.54**
Sponge	0.22	1.64			0.77	**0.53**
Chondrilla caribensis		1.87	0.38			**0.45**
Ircinia strobilina			0.77	0.49	0.99	**0.45**
Aplysina cauliformis	0.55	0.59		0.73		**0.37**
Smenospongia conulosa	0.66				1.10	**0.35**
Mycale laevis	0.22	0.23		0.98	0.22	**0.33**
Smenospongia aurea			0.38	0.24	0.88	**0.30**
Niphates digitalis		0.35	0.77	0.24		**0.27**
Spirastrella coccinea			0.26		1.10	**0.27**
Scopalina ruetzleri		0.70		0.24		**0.19**
Cinachyrella kuekenthali					0.77	**0.15**
Monanchora arbuscula				0.24	0.44	**0.14**
Desmapsamma anchorata	0.55					**0.11**
Cliona caribbaea			0.51			**0.10**
Plaktoris sp.	0.33					**0.07**
Amphimedon viridis			0.26			**0.05**
Total Sponge	**7.18**	**21.19**	**14.19**	**11.22**	**9.33**	**12.62**

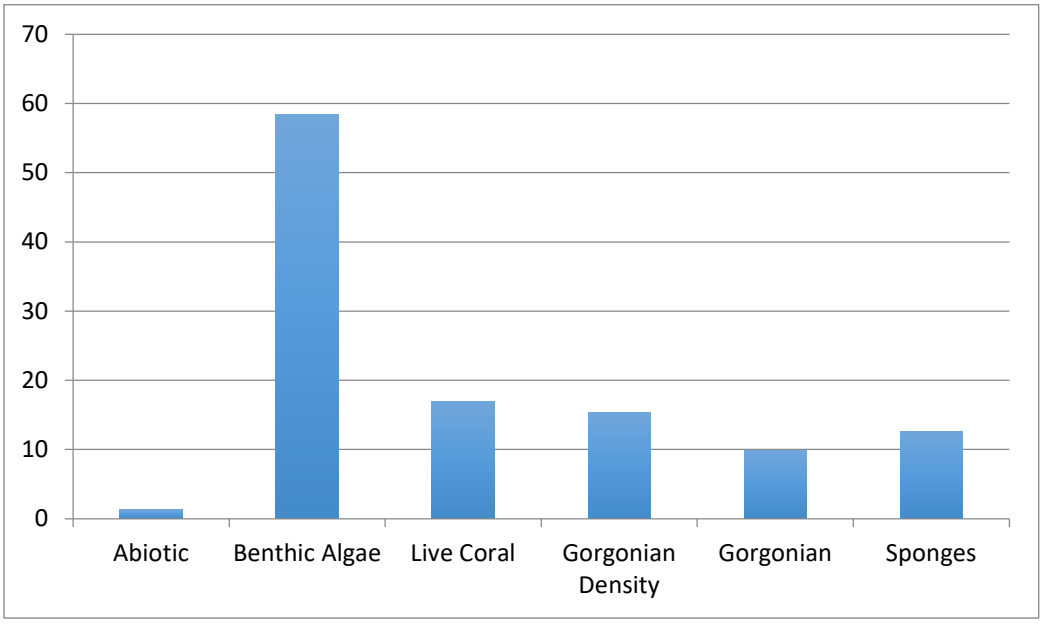


Figure 16. Mean substrate cover by benthic categories at Cayo Caribes Reef 10, Salinas/Guayama, August 2016

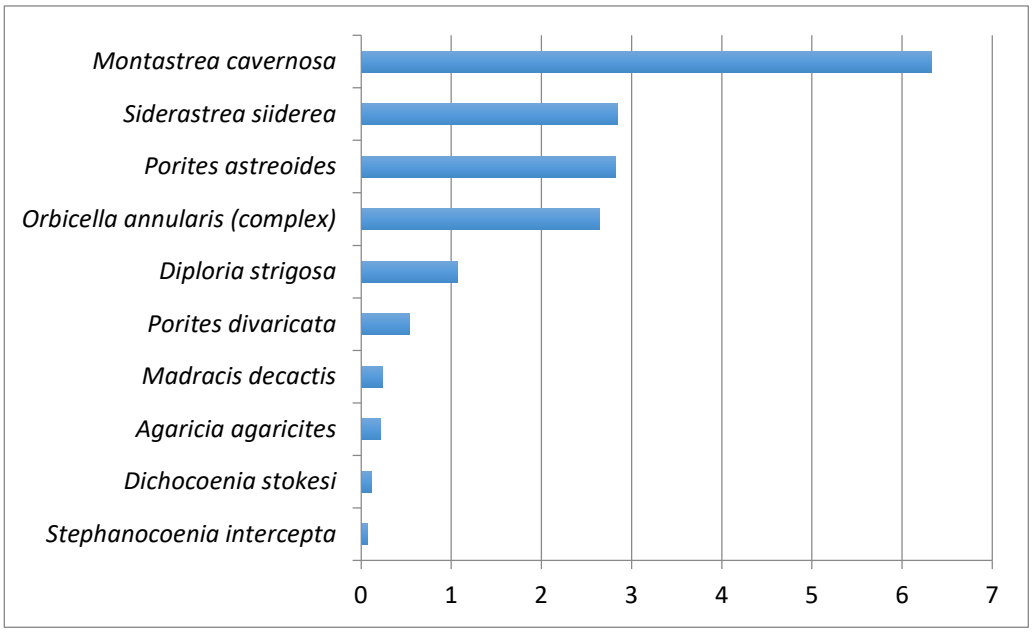


Figure 17. Mean substrate cover by coral species at Cayo Caribes Reef 10, Salinas/Guayama, August 2016

Fishes and Motile Megabenthic Invertebrates

A total of 22 species of fish were identified within belt-transects from a depth of 9 - 10 m at Cayo Caribes 10 (Table 21). Mean density was 43.2 Ind/transect (range: 26 – 60 Ind/transect) with a mean richness of 12.0 species per transect. The Bluehead Wrasses, *Thalassoma bifasciatum* was numerically dominant with a mean density of 13.2 Ind/transect, representing 30.6% of the total individuals. Another seven species were present in at least four transects. These included the Dusky, Bicolor and Beau Gregory Damselfishes (*Stegastes dorsopunicans, S. partitus, S. leucostictus)*), the Stripped and Redband Parrotfishes (*Scarus iserti, Sparisoma aurofrenatum*) the Ocean Surgeon (*Acanthurus bahianus*) and the Slippery Dick (*Halichoeres bivittatus*). Five species were only present in one transect (Table 21).

Herbivores, represented by four species of parrotfishes (Scaridae), four damselfishes (Pomacentridae) and three doctorfishes (Acanthuridae) were the most prominent trophic assemblage at Cayo Caribes 10m with a combined density of 23.4 Ind/transect, representing 54.1% of the total density within belt-transects. Small opportunistic carnivores, including the Bluehead Wrasse and Slippery Dick (*Thalassoma bifasciatum, Halichoeres bivittatus*), the squirrelfish (*Holocentrus rufus*), Redspotted Hawkfish (*Amblycirrhitus pinos*), Butter Hamlet (*Hypoplectrus unicolor*), Graysbe (*Cephalopholis cruentatus*) and the White grunt (*Haemulon plumieri*) combined for 39.8% of the total fish density. Medium sized piscivores included the Yellowtail Snapper (*Ocyurus chrysurus*), Nassau grouper (*Epinephelus striatus*) and Bar Jacks (*Caranx ruber*). Zooplanktivorous fishes were not observed within belt-transects at Cayo Caribes 10m during this baseline survey.

The size-frequency distribution of parrotfishes (Scaridae) suggests that the reef serves as a recruitment and residential habitat for the Stripped, Stoplight and Redband Parrotfishes (Table 22). Individuals of the Yellowtail Snapper (*Ocyurus chrysurus)* were mostly present as juveniles, as well as one individual Nassau Grouper. Motile megabenthic invertebrates were represented within belt-transects by one Arrow Crab, *Stenorhinchus seticornis*.

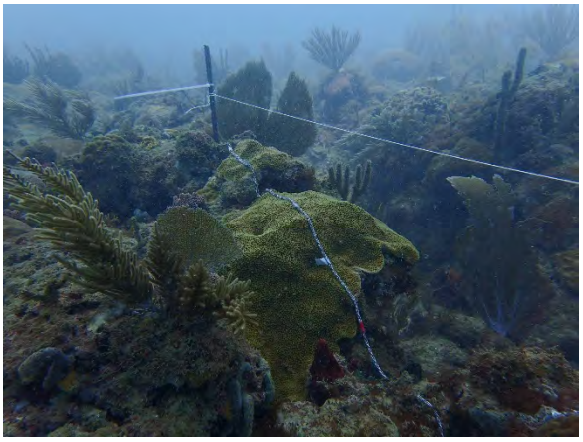
Table 21. CARI 10. Taxonomic composition and abundance of fishes within 10 x 3 m belt-transects at Cayo Caribes 10, Salinas/Guayama, 9.1 m. Survey date: August 4, 2016

		Transects (Ind/30 m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	6	21	25	12	2	**13.2**
Scarus iserti	Stripped Parrotfish	5	10	5		5	**5.0**
Stegastes leucostictus	Beau Gregory	9	4	6	3	2	**4.8**
Stegastes adustus	Dusky Damselfish	7	10	5		1	**4.6**
Stegastes partitus	Bicolor Damselfish	3	7	1	2	3	**3.2**
Halichoeres bivittatus	Slippery Dick	2		4	2	3	**2.2**
Acanthurus bahianus	Ocean Surgeon	5	1		1	2	**1.8**
Acanthurus coeruleus	Blue Tang			1	1	4	**1.2**
Halichoeres maculipinna	Clown Wrasse		4		1		**1.0**
Sparisoma aurofrenatum	Redband Parrotfish		1	3	1	1	**1.0**
Holocentrus rufus	Squirrelfish	2		1	2		**1.0**
Serranus tigrinus	Harlequin Bass			2		2	**0.8**
Acanthurus chirurgus	Doctorfish	1		1	1		**0.6**
Microspathodon chrysurus	Yellowtail Damselfish	1	1	1			**0.6**
Amblycirrhitus pinos	Redspotted Hawkfish				1	1	**0.4**
Ocyurus chrysurus	Yellowtail Snapper	1			1		**0.4**
Pterois volitans	Lionfish			2			**0.4**
Cephalopholis cruentatus	Graysby	1					**0.2**
Caranx ruber	Bar Jack	1					**0.2**
Haemulon plumieri	White Grunt		1				**0.2**
Hypoplectrus unicolor	Butter Hamlet	1					**0.2**
Sparisoma radians	Bucktooth Parrotfish			1			**0.2**
	TOTAL INDIVIDUALS	**45**	**60**	**58**	**27**	**26**	**43.2**
	TOTAL SPECIES	**14**	**10**	**13**	**12**	**11**	**12.0**

Table 22. CARI 10. Size frequency distribution of fishes within 20 x 4 m belt-transects at Cayo Caribes, Salinas/Guayama, 9.1 m. Survey date: August 4, 2016

		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Scarus iserti	Stripped Parrotfish	5-5	10-5	5-5		5-5
Sparisoma viride	Stoplight Parrotfish	1-30		3-5		
Sparisoma aurofrenatum	Redband Parrotfish	1-15	1-15		1-20	1-5
						1-10
Ocyurus chrysurus	Yellowtail Snapper	1-20	1-20			
Epinephelus cruentatus	Graysby	1-30				
Sparisoma chrysopterum	Redtail Parrotfish			1-30		
Epinephelus striatus	Nassau Grouper				1-35	

Photo Album 7.
Cayo Caribe 10m



Cayo Ratones 5, Salinas/Guayama

Physical Description

Cayo Ratones is one of the emergent islets or keys that run parallel to the coastline off the Guayama/Salinas coastline. It is located about 0.6 NM off Punta Arenas. Our survey was performed on the western side of the western section of the fore-reef, an area where the reef breaks into a series of small patch reef promontories surrounded by coralline sand. Transects were placed on adjacent coral promontories within a depth range of 4 – 5m. Panoramic views of Cayo Ratones coral reef community are included in Photo Album 8.

Sessile Benthic Reef Community

Benthic algae, with a combined mean substrate cover of 47.8% were the dominant biotic category covering reef substrate at Cayo Ratones 5 (Figure 18). Turf algae, a mixed assemblage of short filamentous brown and red algae was the main component of the benthic algae, with a mean cover of 23.6%, representing 49.4% of the total cover by algae (Table 23). Green calcareous (*Halimeda sp*) and fleshy brown macroalgae (mostly *Dictyota sp*) were present in all transects with a mean combined mean cover of 21.3%. Red coralline algae, Galaxaura sp. and Jania sp. were present in three transects in small patches, representing minor components of the benthic algae assemblage. Cyanobacterial films were only observed in two transects with a mean cover of 0.9%.

Scleractinian corals were represented by eight species intercepted by linear transects with a combined mean substrate cover of 19.9% (range: 16.2 – 27.0 %). Greater Starlet Coral, *Siderastrea siderea* was the dominant coral species in terms of reef substrate cover with a mean cover of 14.4%, representing 72.4% of the total cover by corals (Figure 19). Very large colonies (more than one meter in diameter) of *S. siderea* separated by sand patches were common at Cayo Ratones 5. Great Star Coral, *Montastrea cavernosa*, Boulder Star Coral, *Orbicella annularis*, and Lesser Starlet Coral, *S. radians* were present in at least four transects with a combined cover of 4.7% (Table 23).

Vertically projected soft corals (gorgonians) were highly prominent and present in all five transects at Cayo Ratones 5 with a mean density of 12.8 colonies per transect. Sea Plumes (Antillogorgia spp), Sea Rods (*Eunicea spp*) and Sea Fans (*Gorgonia ventalina*) were the most

common. The encrusting gorgonian species, *Briareum asbestinum* and *Erythropodium caribaeorum* were also present in all transects with a combined mean substrate cover of 4.5% (Table 23). Sponges, represented by five species intercepted by transects combined for a mean substrate cover of 1.7%. *Chondrilla caribensis* was the most important species in terms of reef substrate cover and the only one observed in more than two transects. In general, sponges were mostly represented by small encrusting individuals growing intermixed with algal turf and other encrusting biota.

Abiotic substrate categories presented a mean substrate cover of 24.0% (range: 16.6 – 28.5%). Coralline sand was the main component the abiotic category with a mean cover of 20.5%, representing 85.4% of the total (Table 23). Reef rugosity averaged 2.2m, influenced by large coral mounds of Greater Starlet Coral.

TABLE 23. RAT 5. Percent cover by sessile-benthic categories along permanent transects, Cayo Ratones, Salinas/Guayama, 5 m. Survey date: August 4, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.46	2.70	1.19	3.15	1.76	**2.25**
Benthic Categories						
Abiotic						
Sand	12.13	21.28	23.90	24.81	20.36	**20.50**
Reef overhang	1.12	2.76	2.13	3.73	2.38	**2.42**
Rubble	3.37	0.66			1.19	**1.04**
Total Abiotic	**16.63**	**24.70**	**26.03**	**28.54**	**23.93**	**23.97**
Benthic Algae						
Turf with sediment	26.97	21.61	27.28	20.66	21.31	**23.57**
Halimeda spp.	13.37	9.37	18.77	16.08	11.67	**13.85**
Dictyota spp.	3.71	11.47	4.26	9.16	8.81	**7.48**
Galaxaura spp.	8.20	0.88		0.21		**1.86**
Caulerpa spp.	1.12	0.77			0.60	**0.50**
Jania spp.	0.45		0.88			**0.27**
CCA		1.21				**0.24**
Total Benthic Algae	**53.82**	**45.31**	**51.19**	**46.11**	**42.38**	**47.76**
Hard Coral						
Siderastrea siderea	13.60	11.03	12.27	11.82	23.45	**14.43**
Montastraea cavernosa		7.72	1.75	5.22	2.26	**3.39**
Orbicella annularis complex	0.79		1.50	1.81	0.83	**0.99**

Agaricia agaricites	1.01	0.77			0.24	**0.40**
Siderastrea radians		0.33	0.63	0.32	0.24	**0.30**
Porites astreoides	1.35					**0.27**
Agaricia lamarcki	0.34					**0.07**
Pseudodiploria strigosa		0.33				**0.07**
Total Hard Coral	**17.08**	**20.18**	**16.15**	**19.17**	**27.02**	**19.92**
Cyanobacteria		2.76			1.67	**0.88**
Invertebrate						
Millepora alcicornis	3.37	0.33				**0.74**
Lebrunia danae		0.33				**0.07**
Palythoa caribaeorum				0.21		**0.04**
Total Invertebrate	**3.37**	**0.66**		**0.21**		**0.85**
Octocoral						
Briareum asbestinum	2.47	0.33	1.88	2.77	4.29	**2.35**
Erythropodium caribaeorum	4.72	2.76	1.13	1.92	0.36	**2.18**
Antillogorgia rigida			0.63			**0.13**
Antillogorgia americana					0.36	**0.07**
Eunicea succinea		0.33				**0.07**
Eunicea tourneforti				0.32		**0.06**
Plexaura kuekenthali		0.22				**0.04**
Total Octocoral	**7.19**	**3.64**	**3.63**	**5.01**	**5.00**	**4.89**
# Gorgonians/transect	17	19	9	10	9	**12.80**
Sponge						**0.00**
Chondrilla caribensis	0.90	1.10	0.88	0.64		**0.70**
Cinachyrella kuekenthali			1.75			**0.35**
Cliona caribbaea		1.65				**0.33**
Iotrochota birotulata	0.56		0.38			**0.19**
Ircinia felix	0.45			0.32		**0.15**
Total Sponge	**1.91**	**2.76**	**3.00**	**0.96**		**1.73**

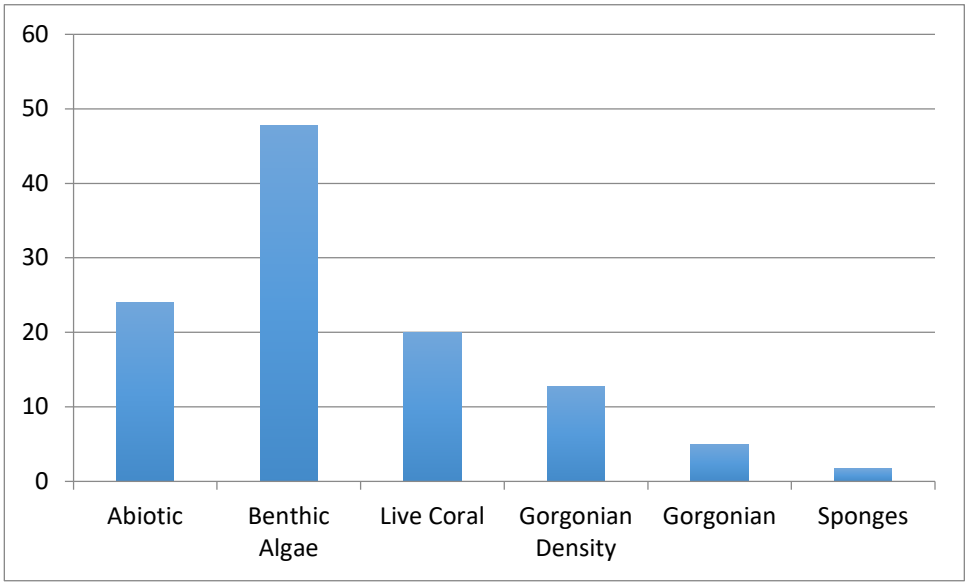


Figure 18. Mean substrate cover by benthic categories at Cayo Ratones 5, Salinas/Guayama, August 2016

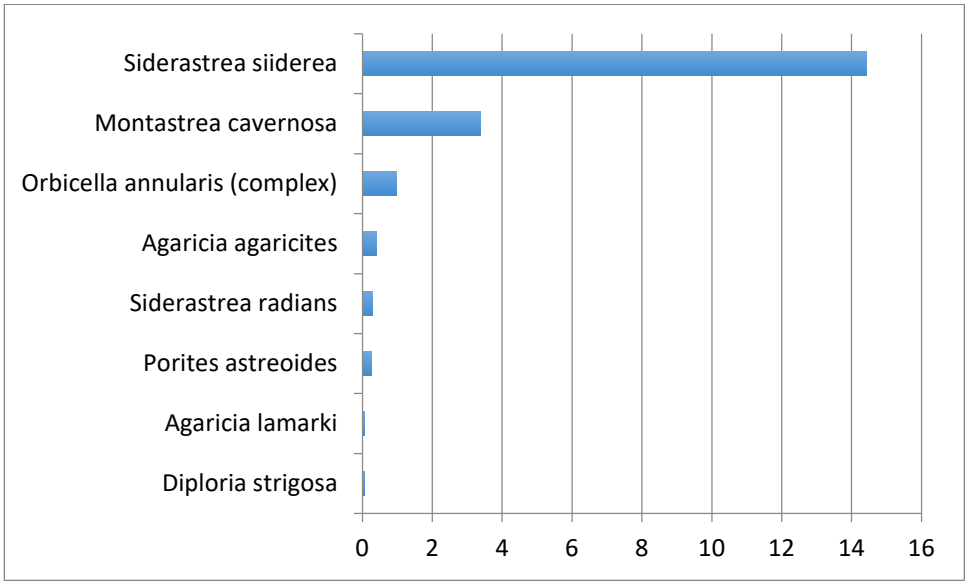


Figure 19. Mean substrate cover by coral species at Cayo Ratones 5, Salinas/Guayama, August 2016

Fishes and Motile Megabenthic Invertebrates

A total of 21 species of fish were identified within belt-transects from a depth of 4 - 5 m at Cayo Ratones 5m (Table 24). Mean density was 46.8 Ind/transect (range: 23 – 82 Ind/transect) with a mean richness of 10.0 species per transect. The Blue Tang, *Acanthurus coeruleus* was the dominant species with a mean density of 14.6 Ind/transect, representing 30.6% of the total individuals and was observed in schools over all five transects. The Bluehead Wrasses, *Thalassoma bifasciatum,* Dusky Damselfish, *Stegastes dorsopunicans*, Ocean Surgeon, *Acanthurus bahianus* and Slippery Dick, *Halichoeres bivittatus* were observed in at least four transects. Schools of recruitment juveniles and early juveniles of the Stripped Parrotfish, *Scarus iserti* were observed inside two belt-transects with a mean density of 5.0 Ind/transect. Eight species were only present in one transect (Table 24).

The trophic structure of Cayo Ratones 5 was strongly dominated by herbivores. Eight out of the 10 most abundant fish species were herbivores with a cumulative density of 32.2 Ind/transect, representing 68.8% of the total fish density within belt-transects. These included three species of parrotfishes (Scaridae), two damselfishes (Pomacentridae) and two doctorfishes (Acanthuridae), including the numerically dominant species, the Blue Tang. Small opportunistic carnivores were represented by three species of wrasses (*Thalassoma, Halichoeres spp*), two squirrelfishes (*Holocentrus rufus, H. adcensionis*), one puffer (*Canthigaster rostrata*), one drum (*Equetus punctatus*), one grunt (*Haemulon flavolineatum*), one hamlet (*Hypoplectrus indigo*) and one Goby (*Elacatinus evelynae*), for a combined density of 13.4 Ind/transect or 28.6% of the total fish density. Medium sized piscivores included the Yellowtail and Schoolmaster Snappers (*Ocyurus chrysurus*, *Lutjanus apodus*). Zooplanktivorous fishes were not observed within belt-transects at Cayo Ratones 5 during this baseline survey.

The size-frequency distribution of parrotfishes (Scaridae) suggests that the reef serves as a recruitment and residential habitat for the Stripped, Stoplight and Redband Parrotfishes (Table 25). Individuals of the Yellowtail and Schoolmaster Snappers were present as juveniles. Two juvenile lobsters were observed outside transects at Cayo Ratones 5.

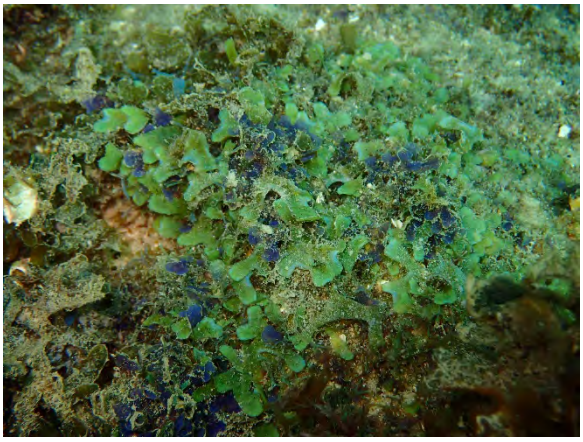
Table 24. RAT 5. Taxonomic composition and abundance of fishes within 10 x 3 m belt-transects at Cayo Ratones, Salinas/Guayama, 4.0 m. Survey date: August 4, 2016

		Transects (Ind/30 m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Acanthurus coeruleus	Blue Tang	15	18	15	20	5	**14.6**
Thalassoma bifasciatum	Bluehead Wrasse	8	3	20	6	1	**7.6**
Scarus iserti	Stripped Parrotfish			20	5		**5.0**
Stegastes adustus	Dusky Damselfish	10	3	2	3	3	**4.2**
Acanthurus bahianus	Ocean Surgeon		4	15	1	1	**4.2**
Halichoeres bivittatus	Slippery Dick	5		5	5	5	**4.0**
Sparisoma viride	Stoplight Parrotfish		1	1	1	5	**1.6**
Stegastes leucostictus	Beau Gregory	3	1			1	**1.0**
Sparisoma aurofrenatum	Redband Parrotfish	3	1				**0.8**
Stegastes partitus	Bicolor Damselfish	2			1	1	**0.8**
Haemulon flavolineatum	French Grunt		3				**0.6**
Halichoeres maculipinna	Clown Wrasse			1	1		**0.4**
Holocentrus rufus	Squirrelfish		1			1	**0.4**
Chaetodon striatus	Banded Butterflyfish				1		**0.2**
Canthigaster rostrata	Caribbean Puffer		1				**0.2**
Holocentrus adcensionis	Squirrelfish			1			**0.2**
Gobiosoma evelynae	Sharknose Goby		1				**0.2**
Hypoplectrus indigo	Indigo Hamlet			1			**0.2**
Equetus punctatus	Spotted Drum		1				**0.2**
Ocyurus chrysurus	Yellowtail Snapper	1					**0.2**
Lutjanus apodus	Schoolmaster Snapper			1			**0.2**
	TOTAL INDIVIDUALS	**47**	**38**	**82**	**44**	**23**	**46.8**
	TOTAL SPECIES	**8**	**12**	**11**	**10**	**9**	**10.0**

Table 25. RAT 5. Size frequency distribution of fishes within 20 x 4 m belt-transects at Cayo Ratones, Salinas, 4.0 m. Survey date: August 4, 2016

		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Scarus iserti	Stripped Parrotfish		5-10	20-5	5-8	
Sparisoma viride	Stoplight Parrotfish		1-15	1-5	1-3	
					5-20	5-3
Sparisoma aurofrenatum	Redband Parrotfish	3-5	1-20	1-20	1-15	
						1-25
Ocyurus chrysurus	Yellowtail Snapper	1- 15				1-20
Lutjanus apodus	Schoolmaster Snapper			1-25		

Photo Album 8.
Cayo ratones 5m



Maria Langa Reef 20, Guayanilla

Physical description

Maria Langa is a fringing reef complex bordering the east section of the entrance channel of Guayanilla Bay (Figure 20). The reef sits at the edge of the Guayanilla submarine canyon and is thereby influenced by both estuarine and oceanic conditions. Our survey was performed along a relatively flat terrace at the base of the fore-reef within a depth contour of 15 – 16m, close to the shelf-edge. Panoramic views of the reef community at Maria Langa 20 are shown as Photo Album 9.

Sessile Benthic Reef Community

The combined benthic algae were the most prominent benthic category in terms of reef substrate cover of Maria Langa Reef 20 (Figure 21). Turf algae, a mixed assemblage of short brown and red algae strongly dominated the benthic algal component with a mean substrate cover of 61.5 % (range: 43.9 – 76.5%), representing 97.6% of the total. Fleshy brown (mostly *Dictyota sp*) and red crustose coralline algae were also present as small patches in some transects but represented minor components of the benthic algae (Table 26). Cyanobacterial films were present in all five transects with a mean cover of 3.2%.

Scleractinian corals were represented by 10 species intercepted by linear transects with a combined mean substrate cover of 12.7% (range: 7.4 – 21.5 %). Boulder Star Coral, *Orbicella annularis* (complex), Lettuce Coral, *Agaricia agaricites*, Greater Starlet Coral, *Siderastrea siderea*, and Blushing Star Coral, *Stephanocoenia intersepta* were present in all five transects and comprised the main coral assemblage in terms of substrate cover with a combined mean cover of 10.3% or 81.0% of the total (Figure 22). Small encrusting colonies of Mustard-Hill Coral, *Porites astreoides*, and Great Star Coral, *Montastrea cavernosa* were present in four and three transects, respectively with minor contributions to the overall cover by live corals at Maria Langa 20. Two coral species were only represented by one colony along transects.

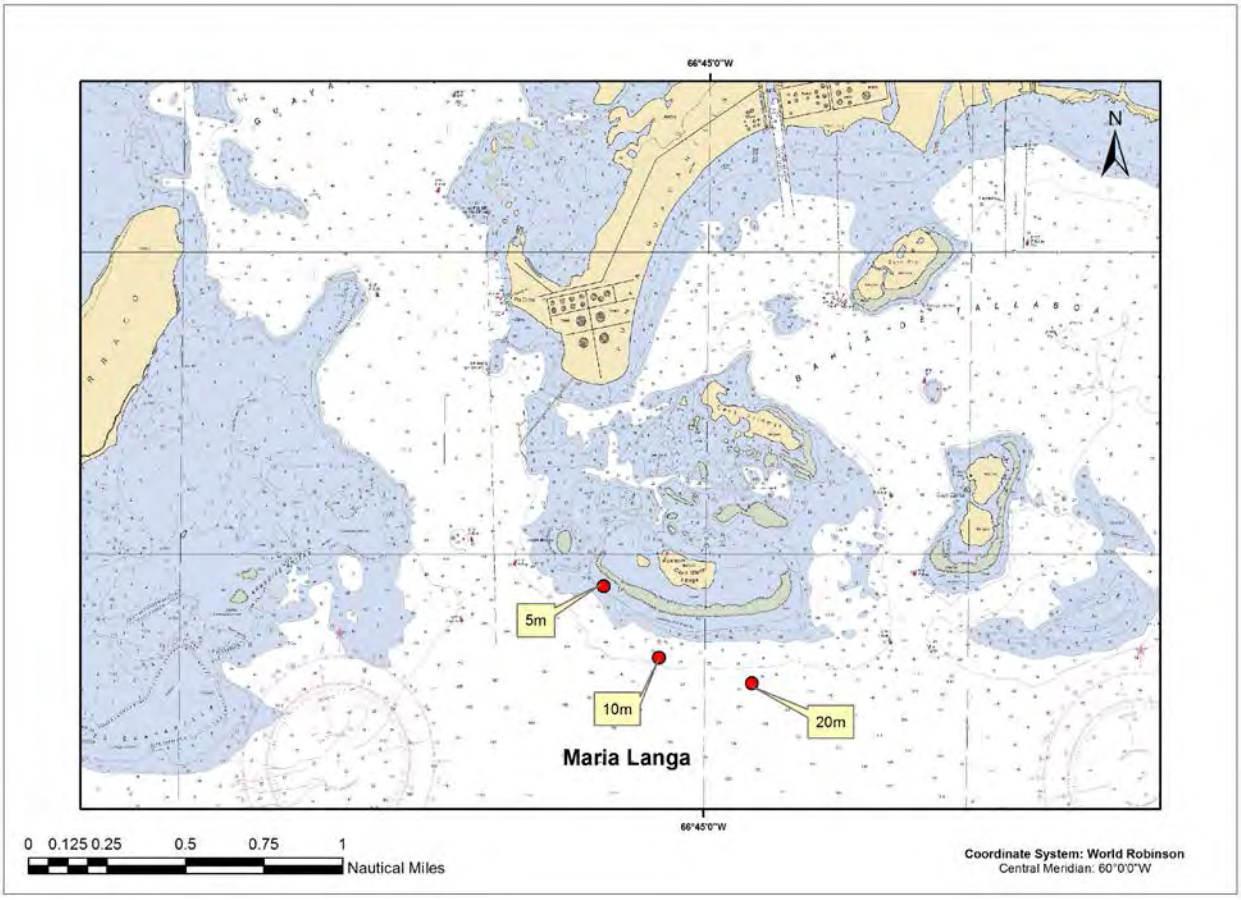


Figure 20. Map of Guayanilla Bay entrance channel showing location of coral reef monitoring stations

Vertically projected soft corals (gorgonians) were the most prominent sessile-benthic invertebrate component at Maria Langa 20 with a mean density of 22.4 colonies per transect. Sea Rods (*Eunicea spp.*) and Sea Fans (*Gorgonia ventalina*) were the most common. The encrusting gorgonian species, *Briareum asbestinum* and *Erythropodium caribaeorum* were present in four and three transects, respectively with a combined mean substrate cover of 2.5% (Table 26). Sponges, represented by at least eight species within belt-transects combined for a mean substrate cover of 1.3%. *Scopalina ruetzleri* was the only one observed in more than two transects, whereas a large colony of Agelas tubulata accounted for the highest cover amongst sponges. In general, sponges were mostly represented by small encrusting individuals growing intermixed with algal turf.

Abiotic substrate categories, mostly driven by the sand component presented a mean substrate cover of 4.1% (range: 1.0 – 12.8%). Reef rugosity averaged only 1.6m at this mostly flat and regular reef bottom topography where scleractinian corals were observed generally as encrusting colonies of low topographic relief.

TABLE 26. MLAN 20. Percent cover by sessile-benthic categories along permanent transects, Maria Langa Reef. Guayanilla, 20 m. Survey date: August 8, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	3.78	1.75	2.49	2.14	1.33	**2.29**
Benthic Categories						
Abiotic						
Sand	6.50	7.15	25.45	2.65	12.98	**10.95**
Reef overhang	6.71		6.95	4.61	7.66	**5.19**
Gap					1.98	**0.40**
Total Abiotic	**13.21**	**7.15**	**32.40**	**7.27**	**22.62**	**16.53**
Benthic Algae						
Turf with sediment	76.52	74.02	44.51	68.63	43.88	**61.51**
Dictyota spp.				0.81	3.96	**0.95**
CCA	0.20		0.34	0.92		**0.29**
Peyssonnelia spp.				1.15	0.25	**0.28**
Total Benthic Algae	**76.73**	**74.02**	**44.84**	**71.51**	**48.08**	**63.04**
Hard Coral						
Orbicella annularis complex	1.73	5.48	7.74	2.19	3.34	**4.09**
Agaricia agaricites	0.30	3.81	1.91	4.96	5.56	**3.31**
Siderastrea siderea	1.52	1.55	0.22	1.27	2.84	**1.48**
Stephanocoenia intersepta	1.63	0.72	0.22	1.04	3.34	**1.39**
Colpophyllia natans	1.52				5.32	**1.37**
Porites astreoides		1.19	0.67	0.35	0.49	**0.54**
Madracis decactis			0.56	0.35		**0.18**
Montastraea cavernosa	0.41			0.23	0.25	**0.18**
Agaricia lamarcki					0.37	**0.07**
Meandrina meandrites	0.30					**0.06**
Total Hard Coral	**7.42**	**12.75**	**11.32**	**10.38**	**21.51**	**12.68**
Cyanobacteria	0.51	1.07	7.29	3.69	3.34	**3.18**
Invertebrate						
Palythoa caribaeorum					0.87	**0.17**
Millepora alcicornis	0.30					**0.06**
Total Invertebrate	**0.30**				**0.87**	**0.23**
Octocoral						

Erythropodium caribaeorum	0.20		0.45	6.34		**1.40**
Briareum asbestinum	0.30	1.07	2.13		1.98	**1.10**
Eunicea flexuosa		0.24	0.67	0.23		**0.23**
Eunicea calyculata		0.36				**0.07**
Gorgonia ventalina		0.36				**0.07**
Antillogorgia americana		0.24				**0.05**
Eunicea pallida		0.24				**0.05**
Plexaura kuekenthali	0.20					**0.04**
Total Octocoral	**0.71**	**2.50**	**3.25**	**6.57**	**1.98**	**3.00**
# Gorgonians/transect	25	19	21	28	19	**22.40**
Sponge						
Agelas tubulata		2.26				**0.45**
Scopalina ruetzleri	0.20	0.24	0.45		0.74	**0.33**
Amphimedon compressa					0.87	**0.17**
Plakortis sp.	0.61					**0.12**
Niphates caribica	0.20		0.22			**0.09**
Niphates erecta				0.35		**0.07**
Mycale laevis	0.10		0.22			**0.07**
Sponge				0.23		**0.05**
Total Sponge	**1.12**	**2.50**	**0.90**	**0.58**	**1.61**	**1.34**

Fishes and Motile Megabenthic Invertebrates

A total of 30 species of fish were identified within belt-transects from a depth of 15 - 16 m at Maria Langa 20m (Table 27). Mean density was 43.0 Ind/transect (range: 15 – 107 Ind/transect) with a mean richness of 13.8 species per transect. The Blue Runner, *Caranx crysos* was numerically dominant with a mean density of 16.0 Ind/transect, representing 37.2% of the total individuals. The Blue Runner is a transitory schooling pelagic species that forages on small reef fishes and crossed one of the transects in high numbers, but is not a resident demersal reef fish. Among the demersal species, the Bluehead Wrasse, *Thalassoma bifasciatum*, Bicolor Damselfish, *Stegastes partitus* and the Peppermint Goby were the most abundant at Maria Langa 20m (Table 27). Another three species were present in at least four transects. These included the Ocean Surgeon (*Acanthurus bahianus*), French Grunt (*Haemulon flavolineatum*) and the Beau Gregory (*Stegastes leucostictus*). Nine species were only present in one transect (Table 27).

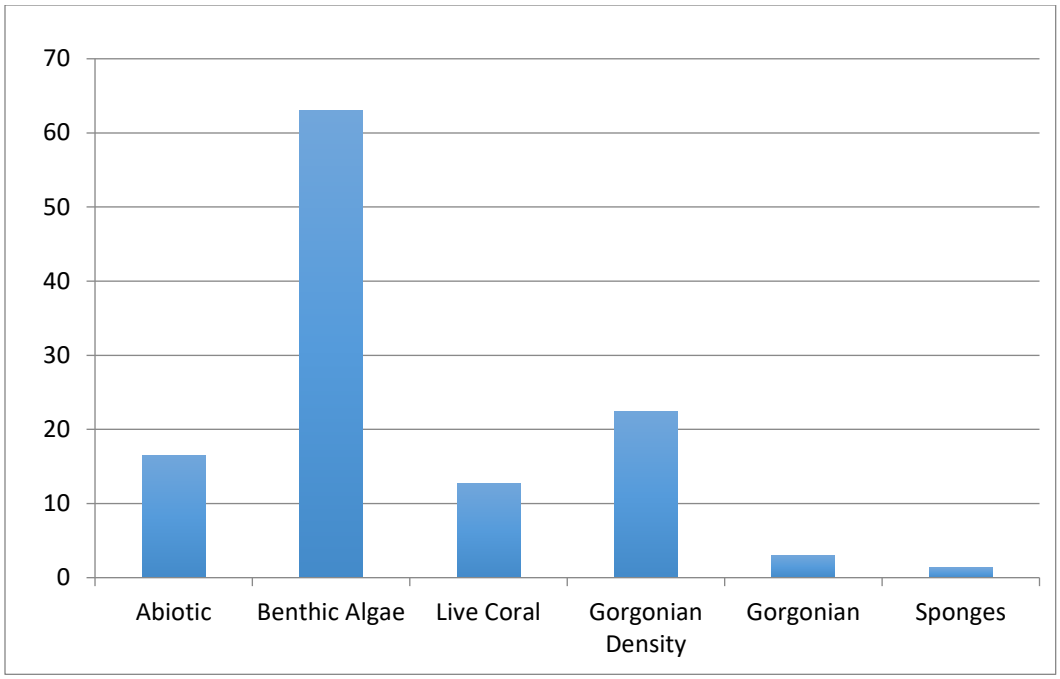


Figure 21. Mean substrate cover by benthic categories at Maria Langa Reef 20, Guayanilla. August 2016

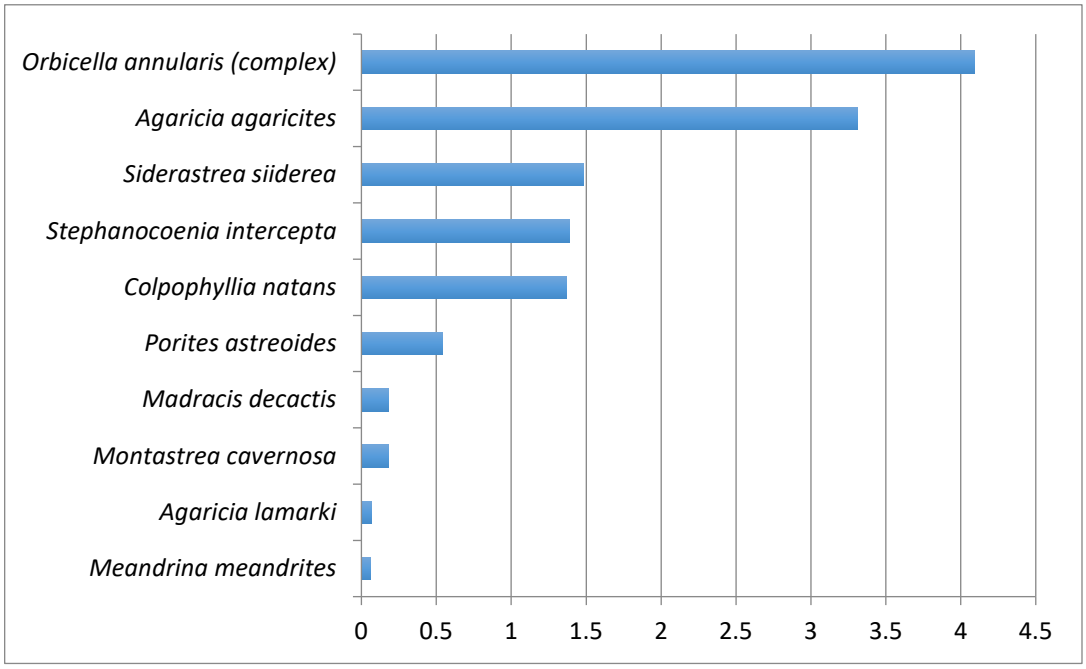


Figure 22. Mean substrate cover by coral species at Maria Langa Reef 20, Guayanilla. August 2016

Aside from the casual occurrence of the large school of Blue Runners, which are medium size piscivores, the ichthyofauna at Maria Langa 20m was best represented by a moderate richness of small carnivores and herbivores, with relatively low prevalence of zooplanktivores and large demersal predators. Small opportunistic carnivores included two species of wrasses (Labridae), three species of Grunts (Haemulidae), two squirrelfishes (Holocentridae), one Trumpetfish (Aulostomidae), one puffer (Tetraodontidae), two gobies (Gobiidae), and four small groupers and Sea Basses (Serranidae). Their combined density represented 36.3% of the total fish density within belt-transects. Herbivores were represented by three species of parrotfishes (Scaridae), three damselfishes (Pomacentridae) and two doctorfishes (Acanthuridae) with a combined density of 5.0 Ind/transect, representing 11.6% of the total density within belt-transects. Medium sized piscivores included the Yellowtail Snapper (*Ocyurus chrysurus*), Red Hind (*Epinephelus guttatus*) and Blue Runners (*Carangoides crysos*). Zooplanktivorous fishes were represented by the Blue Chromis, Masked Goby and Bicolor Damselfish, with a cumulative density of 4.2 Ind/transect or 9.8% of the total.

The size-frequency distribution of parrotfishes (Scaridae) suggests that the reef serves as a recruitment and residential habitat for the Stripped Parrotfish and the residential habitat for the Princess and Redband (Table 28). Individuals of the Yellowtail Snapper (*Ocyurus chrysurus)* and one Schoolmaster Snapper (*Lutjanus apodus*) were mostly present as juveniles and young adults. Graysbes, Coneys and the Red Hind were present as adults. Motile megabenthic invertebrates were represented within belt-transects by one Queen Conch, *Strombus gigas*.

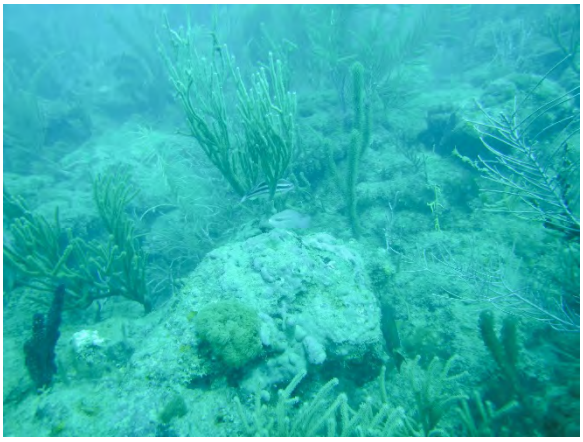
Table 27. MLAN 20. Taxonomic composition and abundance of fishes within 10 x 3 m belt-transects at Maria Langa Reef, Guayanilla, 15.8 m. Survey date: August 8, 2016

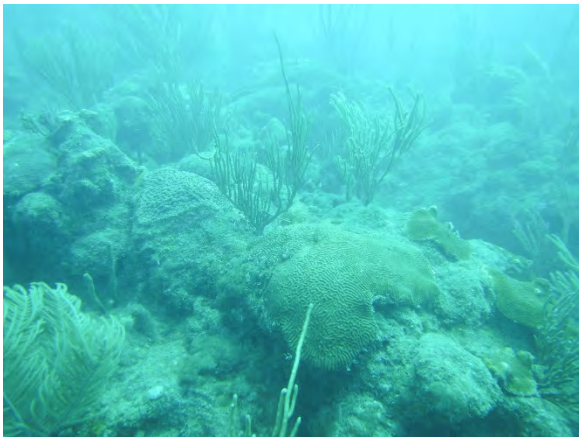
		Transects (Ind/30 m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Carangoides crysos	Blue Runner	80					**16.0**
Thalassoma bifasciatum	Bluehead Wrasse	1	20	2	1	6	**6.0**
Stegastes partitus	Bicolor Damselfish	2	2	6	3		**2.6**
Coryphopterus lipernes	Peppermint Goby	1	5	1		4	**2.2**
Chaetodon capistratus	Four-eye Butterflyfish	2		2		2	**1.2**
Coryphopterus personatus	Masked Goby		3			3	**1.2**
Elacatinus evelynae	Sharknose Goby	3		2		1	**1.2**
Acanthurus bahianus	Ocean Surgeon	1	2	1	1		**1.0**
Haemulon flavolineatum	French Grunt	2	1	1	1		**1.0**
Myripristis jacobus	Black-bar Soldierfish	1			1	3	**1.0**
Scarus taeniopterus	Princess Parrotfish	3	1		1		**1.0**
Stegastes leucostictus	Beau Gregory	1	1	1	2		**1.0**
Anisotremus virginicus	Porgy	1		1	2		**0.8**
Halichoeres garnoti	Yellow-head Wrasse			2		2	**0.8**
Scarus iserti	Stripped Parrotfish	2		1		1	**0.8**
Stegastes dorsopunicans	Dusky Damselfish	1	2	1			**0.8**
Canthigaster rostrata	Caribbean Puffer	1	1		1		**0.6**
Holocentrus rufus	Squirrelfish			1		2	**0.6**
Epinephelus cruentatus	Graysby	1		1			**0.4**
Chromis cyanea	Blue Chromis		2				**0.4**
Epinephelus guttatus	Red Hind	1				1	**0.4**
Sparisoma aurofrenatum	Redband Parrotfish	2					**0.4**
Acanthurus chirurgus	Doctorfish			1			**0.2**
Aulostomus maculatus	Trumpetfish		1				**0.2**
Haemulon macrostomum	Spanish Grunt		1				**0.2**
Haemulon plumieri	White Grunt				1		**0.2**
Hypoplectrus puella	Barred Hamlet				1		**0.2**
Ocyurus chrysurus	Yellowtail Snapper		1				**0.2**
Pomacanthus arcuatus	Grey Angelfish		1				**0.2**
Serranus tabacarius	Tobacco Fish	1					**0.2**
	TOTAL INDIVIDUALS	**107**	**44**	**24**	**15**	**25**	**43.0**
	TOTAL SPECIES	18	15	15	11	10	**13.8**

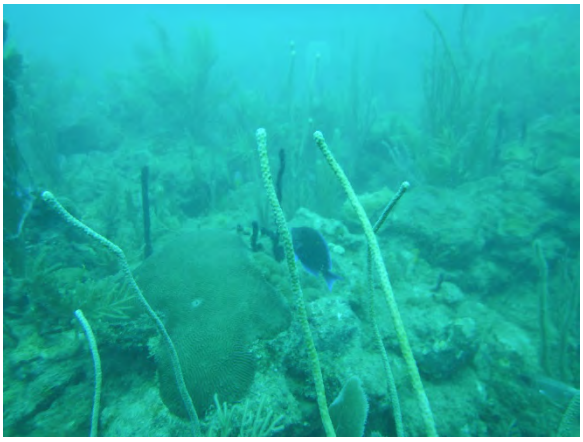
Table 28. MLAN 20. Size frequency distribution of fishes within 20 x 4 m belt-transects at Maria Langa Reef, Guayanilla, 15.8 m. Survey date: August 8, 2016

		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Acanthurus bahianus	Ocean Surgeon		1-12	4 - 25		2 - 20
Acanthurus chirurgus	Doctorfish	1- 15				
Acanthurus coeruleus	Blue Tang	1- 12				
Cephalopholis cruentatus	Graysby			1 - 10		
Cephalopholis fulva	Coney		1-28			
Epinephelus guttatus	Red Hind	1- 30				1 - 38
Lactophrys triqueter	Smooth Trunkfish				1 - 12	
Lutjanus apodus	Schoolmaster Snapper					1 - 25
Ocyurus chrysurus	Yellowtail Snapper	1- 18	1-18	1-28		2-15
Pterois volitans	Lionfish			1 - 30		
Scarus iserti	Stripped Parrotfish	2 - 5		1 - 10		1 - 30
Scarus taeniopterus	Princess Parrotfish	2- 10	1- 10		1 - 15	
Sparisoma aurofrenatum	Redband Parrotfish				1 - 23	

Photo Album 9.
Maria Langa 20m







Maria Langa 10, Guayanilla

Physical Description

The reef at Maria Langa 10 corresponds to a mid-slope section of the fore-reef at depths between 9 – 10m. Transects were established within a relatively wide terrace with a moderate to gentle slope (Figure 20). Panoramic views of the reef community at Maria Langa 10 are included as Photo Album 10.

Sessile Benthic Reef Community

Benthic algae were the dominant biotic category covering reef substrate at Maria Langa Reef 10 with a combined mean cover of 58.6% (Figure 23). Turf algae, a mixed assemblage of short filamentous brown and red algae was the main component of the benthic algae, with a mean cover of 55.0% (range: 50.9 – 57.3 %), representing 93.8% of the total cover by algae (Table 29). Crustose coralline algae were present in all five transects with a mean cover of 1,7%. Fleshy brown macroalgae, mostly *Dictyota sp*. were also present but with relatively low substrate cover (< 2%) at Maria Langa 10m. Small cyanobacterial patches were intercepted by four transects with a mean reef substrate cover of 0.6%.

Scleractinian corals were represented by 12 species intercepted by linear transects with a combined mean substrate cover of 17.3% (range: 11.2 – 21.9 %). An assemblage of five coral species with a combined cover of 15.6% represented 89.9% of the total cover by live scleractinian corals at Maria Langa 10 (Table 29). These included Boulder Star Coral, *Orbicella annularis* (complex), Greater Starlet Coral, *Siderastrea siderea,* Symmetrical Brain Coral, *Pseudodiploria strigosa,* Great Star Coral, *Montastrea cavernosa* and Mustard-Hill Coral, *Porites astreoides* (Figure 24). From the aforementioned species, only *P. astreoides* was observed in all five transects surveyed. Boulder Star Coral was only present in two transects. Four coral species were only represented by one colony along transects. The encrusting zoanthid *Palythoa caribaeorum* was present in four transects with an average cover of 2.5%.

Vertically projected soft corals (gorgonians) were exceptionally prominent at Maria Langa 10 with a mean density of 46.0 colonies per transect. Sea Rods (*Pseudoplexaura sp, Plexaura sp, Plexaurella sp, Eunicea spp),* Sea Plumes (*Antillogorgia spp*) and Sea Fans (*Gorgonia*

ventalina) were common. The encrusting gorgonian species, *Erythropodium caribaeorum* and *Briareum asbestinum* were present in all transects with a combined mean substrate cover of 10.8% (Table 29). Sponges, represented by 13 species combined for a mean substrate cover of 3.3%. *Iotrochota birotulata*, *Scopalina ruetzleri*, *Chondrilla caribensis* and *Niphates erecta* were the top four species with a combined cover of 2.0% or 61.5% of the total cover by sponges. Both *S. ruetzleri* and *N. erecta* was observed in all five transects.

Abiotic substrate categories at Maria Langa 10 presented a mean substrate cover of 4.1%, largely associated with sand patches (Table 29). Reef rugosity averaged 1.6 m, indicative of a mostly regular topography with relatively low contributions by coral structures to the underwater relief.

Table 29. MLAN 10. Percent cover by sessile-benthic categories along permanent transects, Maria Langa Reef. Guayanilla, 10 m. Survey date: August 8, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	1.91	0.86	0.54	2.25	2.47	**1.61**
Benthic Categories						
Abiotic						
Sand			12.75	1.14		**2.78**
Reef overhang	1.76	1.03			3.70	**1.30**
Total Abiotic	**1.76**	**1.03**	**12.75**	**1.14**	**3.70**	**4.08**
Benthic Algae						
Turf with sediment	55.35	50.90	55.11	57.26	56.12	**54.95**
CCA	5.88	1.03	0.27	0.80	0.45	**1.68**
Dictyota spp.	2.70		1.20	0.91	1.68	**1.30**
Peyssonnelia		0.39	2.66			**0.61**
Galaxaura spp.			0.13			**0.03**
Total Benthic Algae	**63.92**	**52.32**	**59.36**	**58.97**	**58.25**	**58.57**
Hard Coral						
Orbicella annularis complex	4.82	12.11			9.99	**5.38**
Siderastrea siderea	1.65	3.74	3.98	6.63		**3.20**
Pseudodiploria strigosa	2.00	2.58		5.49	5.27	**3.07**
Montastraea cavernosa	4.23	2.71	5.18		0.45	**2.51**
Porites astreoides	1.76	0.77	0.40	2.74	1.35	**1.40**
Dendrogyra cylindrus	2.70					**0.54**
Diploria labyrinthiformis				2.40		**0.48**

Stephanocoenia intersepta	0.94		0.40			**0.27**
Dichocoenia stokesi			0.66			**0.13**
Agaricia agaricites				0.34	0.22	**0.11**
Porites porites			0.53			**0.11**
Acropora cervicornis					0.45	**0.09**
Total Hard Coral	**18.10**	**21.91**	**11.16**	**17.60**	**17.73**	**17.30**
Cyanobacteria		0.26	0.93	0.91	1.12	**0.64**
Invertebrate						
Palythoa caribaeorum	1.76	5.54	3.72	1.37		**2.48**
Millepora alcicornis	0.59		1.06		0.22	**0.37**
Zoanthid				1.14	0.22	**0.27**
Ricordea floridea					0.90	**0.18**
Total Invertebrate	**2.35**	**5.54**	**4.78**	**2.51**	**1.35**	**3.31**
Octocorals						
Briareum asbestinum	4.11	5.80	0.27	11.43	9.09	**6.14**
Erythropodium caribaeorum	6.93	8.51	4.52	1.26	2.02	**4.65**
Pseudoplexaura wagenaari/flagellosa		0.39	1.46		0.67	**0.50**
Eunicea flexuosa	0.59		1.06	0.23	0.45	**0.47**
Antillogorgia americana		0.64		1.14		**0.36**
Eunicea tourneforti	0.24			0.23	0.45	**0.18**
Antillogorgia bipinnata	0.71					**0.14**
Plexaura homomalla		0.52				**0.10**
Gorgonia ventalina	0.47					**0.09**
Plexaurella nutans		0.39				**0.08**
Eunicea sp.			0.27			**0.05**
Plexaura kuekenthali				0.23		**0.05**
Total Octocoral	**13.04**	**16.24**	**7.57**	**14.51**	**12.68**	**12.81**
# Gorgonians/transect	49	32	50	52	47	**46**
Sponges						
Iotrochota birotulata			0.40	1.14	1.57	**0.62**
Scopalina ruetzleri	0.47	0.90	0.40	0.46	0.34	**0.51**
Chondrilla caribensis			2.26		0.22	**0.50**
Niphates erecta	0.35	0.77	0.13	0.34	0.56	**0.43**
Amphimedon compressa		0.26	0.27	0.46	0.90	**0.38**
Cinachyrella kuekenthali				0.46	0.67	**0.23**
Callyspongia vaginalis				0.69		**0.14**
Callyspongia fallax					0.67	**0.13**
Ircinia felix		0.52				**0.10**
Plaktoris sp.				0.46		**0.09**
Niphates caribica				0.34		**0.07**
Agelas sp.		0.26				**0.05**
Aplysina cauliformis					0.22	**0.04**
Total Sponge	**0.82**	**2.71**	**3.45**	**4.34**	**5.16**	**3.30**

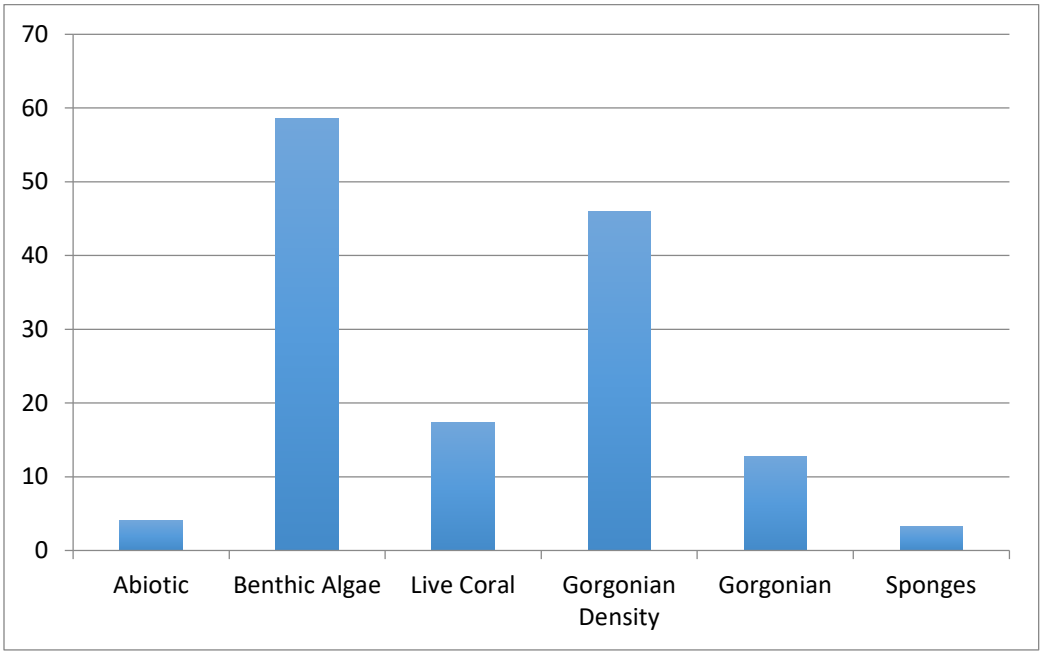


Figure 23. Mean substrate cover by benthic categories at Maria Langa Reef 10, Guayanilla. August 2016

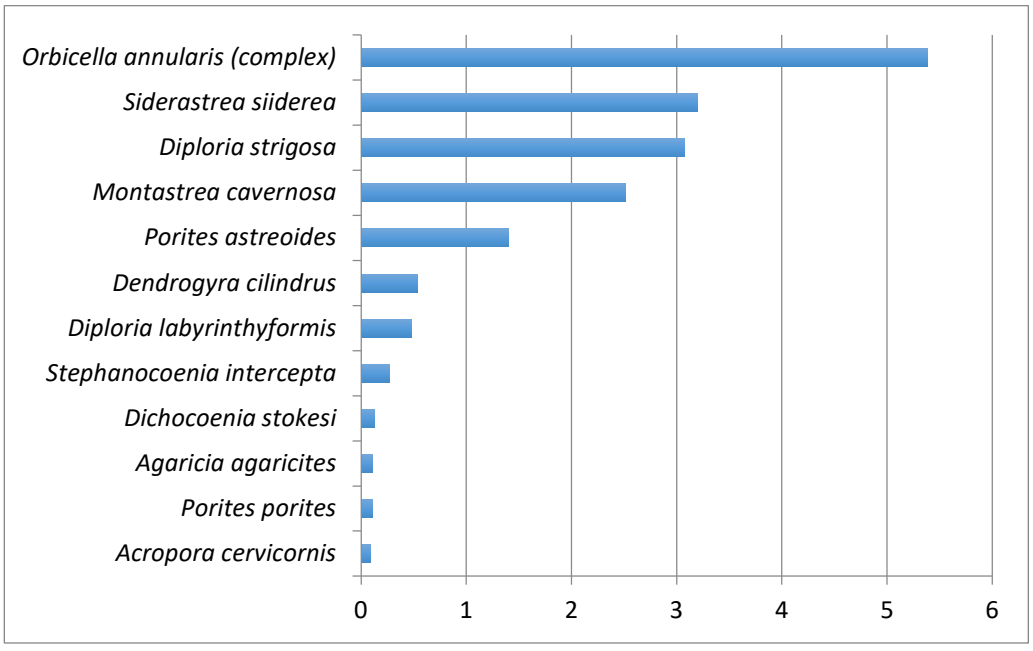


Figure 24. Mean substrate cover by coral species at Maria Langa Reef 10, Guayanilla. August 2016

Fishes and Motile Megabenthic Invertebrates

A total of 26 species of fish were identified within belt-transects from a depth of 9 - 10 m at Maria Langa 10 (Table 27). Mean density was 30.2 Ind/transect (range: 21 – 43 Ind/transect) with a mean richness of 10.6 species per transect. An assemblage of seven species with a combined density of 23.0 Ind/transect, represented 76.2% of the total fishes within belt-transects (Table 30). The Bluehead Wrasse, *Thalassoma bifasciatum* was the most abundant with a mean density of 7.8 Ind/transect, followed by the Bar Jack*, Caranx ruber*, Bicolor Damselfish, *Stegastes partitus*, Striped and Redband Parrotfishes, *Scarus taeniopterus*, *Sparisoma aurofrenatum*, Yellowhead Wrasse, *Halichoeres garnoti*, and the Ocean Surgeon, Acanthurus bahianus. Another three species were present in at least four transects. With the exception of the Bar Jack, all of the aforementioned species were observed in at least three transects. Nine species were only present in one transect (Table 30).

The ichthyofauna at Maria Langa 10 was best represented by a moderate richness of small carnivores and herbivores, with relatively low prevalence of zooplanktivores and large demersal predators. Small opportunistic carnivores represented 27.2% of the total individuals within belt-transects and included two species of wrasses (Labridae), two squirrelfishes (Holocentridae), one Grunt (Haemulidae), one puffer (Tetraodontidae), one goby (Gobiidae), and two small groupers and Sea Basses (Serranidae). Herbivores were represented by five species of parrotfishes (Scaridae), two doctorfishes (Acanthuridae) and one damselfish (Pomacentridae) with a combined density of 8.2 Ind/transect, representing 27.1% of the total density within belt-transects. Medium sized piscivores included the Yellowtail and Schoolmaster Snappers (*Ocyurus chrysurus, Lutjanus apodus*), and the Bar Jack (*Caranx ruber*) with a combined density of 21.8% of the total fish density. Zooplanktivorous fishes were represented by the Blue Chromis and the Bicolor Damselfish with a cumulative density of 2.6 Ind/transect or 8.6% of the total.

The size-frequency distribution of parrotfishes (Scaridae) suggests that the reef serves as a recruitment and residential habitat for the Stripped and Bucktooth Parrotfishes and the residential habitat for the Princess and Redband (Table 31). Individuals of the Yellowtail Snapper (*Ocyurus chrysurus)* and one Schoolmaster Snapper (*Lutjanus apodus*) were mostly present as juveniles and young adults. Motile megabenthic invertebrates were represented by one Common Octopus, *Octopus vulgaris*, and cleaner shrimps, *Periclimenes pedersoni*.

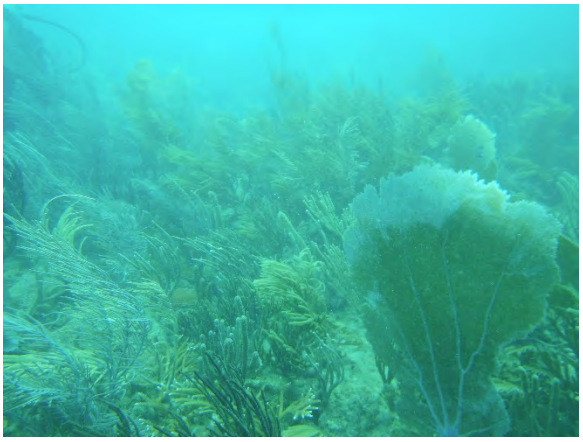
Table 30. MLAN 10. Taxonomic composition and abundance of fishes within 10 x 3 m belt-transects at Maria Langa Reef, Guayanilla, 8.9 m. Survey date: August 8, 2016

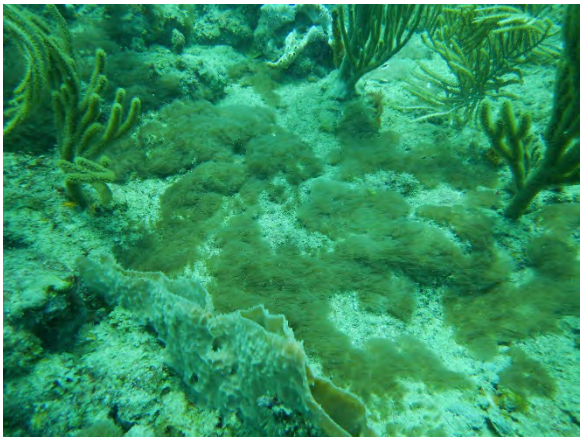
		Transects (Ind/30 m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	17	3	9	4	6	**7.8**
Caranx ruber	Bar Jack		25				**5.0**
Scarus iserti	Stripped Parrotfish	2	1	7	3	2	**3.0**
Stegastes partitus	Bicolor Damselfish			3	4	5	**2.4**
Halichoeres garnoti	Yellow-head Wrasse	2		2	5		**1.8**
Acanthurus bahianus	Ocean Surgeon	1	2		3	2	**1.6**
Sparisoma aurofrenatum	Redband Parrotfish	2	2	2	1	1	**1.4**
Lutjanus apodus	Schoolmaster Snapper	1				3	**0.8**
Ocyurus chrysurus	Yellowtail Snapper	2			2		**0.8**
Haemulon flavolineatum	French Grunt		1	2			**0.6**
Scarus taeniopterus	Princess Parrotfish		3				**0.6**
Stegastes leucostictus	Beau Gregory		1			2	**0.6**
Acanthurus chirurgus	Doctorfish	1	1				**0.4**
Epinephelus fulva	Coney		1		1		**0.4**
Chaetodon capistratus	Four-eye Butterflyfish		2				**0.4**
Serranus tigrinus	Harlequin Bass			1	1		**0.4**
Sparisoma radians	Bucktooth Parrotfish			1	1		**0.4**
Bodianus rufus	Spanish Hogfish	1					**0.2**
Canthigaster rostrata	Caribbean Puffer		1		1		**0.4**
Chromis cyanea	Blue Chromis			1			**0.2**
Elacatinus evelynae	Sharknose Goby			1			**0.2**
Melichthys niger	Black Durgon	1					**0.2**
Myripristis jacobus	Black-bar Soldierfish	1					**0.2**
Pseudupeneus maculatus	Spotted Goatfish			1			**0.2**
Sparisoma chrysopterum	Redtail Parrotfish	1					**0.2**
	TOTAL INDIVIDUALS	**32**	**43**	**30**	**25**	**21**	**30.2**
	TOTAL SPECIES	**12**	**12**	**11**	**11**	**7**	**10.6**

Table 31. MLAN 10. Size frequency distribution of fishes within 20 x 4 m belt-transects at Maria Langa 10, Guayanilla, 8.9 m. Survey date: August 8, 2016

		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Acanthurus chirurgus	Doctorfish	1 -10			2-10	
Acanthurus coeruleus	Blue Tang					1-8
Epinephelus fulva	Coney				1-18	1- 18
Lutjanus apodus	Schoolmaster Snapper	1 -10			1-18	3 -18
						1 -15
Ocyurus chrysurus	Yellowtail Snapper		3-18		1-10	
			1-10		1-12	
Sparisoma chrysopterum	Redtail Parrotfish	1 -18				1 -20
Scarus iserti	Stripped Parrotfish		1-10	4 -5	3-12	2 -8
				3 -10		
Scarus taeniopterus	Princess Parrotfish		3-10			
Sparisoma radians	Bucktooth Parrotfish			1 - 2	1 -8	
Sparisoma aurofrenatum	Redband Parrotfish	1 - 12	1-10	1 -10	1-18	
		1 -18	1-12	1 -12		

Photo Album 10.
Maria Langa 10m





Maria Langa 5, Guayanilla

Physical Description

Maria Langa 5 is at the reef crest of Maria Langa Reef (Figure 20). The reef crest is relatively broad and characterized by a gentle slope forming a shallow terrace where wave breakers mark the reef. This is a zone of strong wave action and surge. Transects were installed perpendicular to the reef face. Panoramic views of the Maria Langa 5 reef crest and associated reef community are included as Photo Album 11.

Sessile Benthic Reef Community

Turf algae, a mixed assemblage of short filamentous brown and red algae was the main component of the benthic algae substrate at Maria Langa 5, with a mean cover of 58.7%, representing 86.2% of the total cover by benthic algae (Table 32), the dominant category of reef substrate cover at this reef station (Figure 25). Crustose coralline algae were present in all five transects with a mean cover of 3.9%. The Tubular Thicket (red) Alga, *Galaxaura sp*. was observed in one transect. Cyanobacterial patches were intercepted by three transects with a mean reef substrate cover of 1.1%.

Scleractinian corals were represented by nine species intercepted by linear transects with a combined mean substrate cover of 13.4% (range: 6.6 – 19.9 %). The Fused Staghorn, *Acropora prolifera* was the dominant coral species intercepted by transects with a mean cover of 9.4%, representing 70.1% of the total live coral (Figure 26). Thickets of *A. prolifera* were the main biotic contribution to the underwater relief and habitat complexity at Maria Langa 5. In addition to *A. prolifera* the only other coral present in all transects was the Mustard-Hill Coral, *Porites astreoides* (Table 32). Five coral species, mostly growing as small encrusting colonies were only represented by one colony along transects. One large colony of Boulder Star Coral, *Orbicella annularis* was intercepted by transect 1. Two Fire corals, *Millepora spp*. and the encrusting zoanthid *Palythoa caribaeorum* were also present with a combined reef substrate cover of 1.2%.

Vertically projected soft corals (gorgonians) not prominent at the Maria Langa 5 reef crest with a mean density of 1.6 colonies per transect. Sea Fans (*Gorgonia ventalina*) were the most common. The encrusting gorgonian species, *Erythropodium caribaeorum* was present in three

transects with a mean cover of 1.5% (Table 32). Sponges, represented by 3 species intercepted by transects presented a combined mean substrate cover of 18.0%. The encrusting species, *Cliona caribbea* was prominent in all transects with a mean cover of 16.2, representing 90.0% of the total cover by sponges. *Chondrilla caribensis* was observed in three transects.

Abiotic substrate categories at Maria Langa 5 presented a mean substrate cover of 3.8%, largely associated with sand and coral rubble patches (Table 32). Reef rugosity averaged 1.3 m, indicative of a mostly regular topography with relatively low contributions by coral structures to the underwater relief.

TABLE 32. MLAN 5. Percent cover by sessile-benthic categories along permanent transects, Maria Langa Reef. Guayanilla, 5 m. Survey date: September 5, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	1.69	1.45	1.93	0.75	0.50	**1.26**
Benthic Categories						
Abiotic	2.63	2.44	1.53	1.30	1.60	**1.90**
Reef Overhang		1.83				**0.37**
Rubble	2.63	0.61	1.53	1.30	1.60	**1.53**
Total Abiotic	**5.27**	**4.89**	**3.05**	**2.60**	**3.20**	**3.80**
Benthic Algae						
CCA	4.91	5.62	2.11	2.73	4.27	**3.93**
Galaxaura sp.					0.93	**0.19**
Turf	57.96	59.17	66.67	54.95	54.67	**58.68**
Total Benthic Algae	**70.78**	**70.29**	**73.36**	**61.59**	**64.67**	**68.14**
Hard Coral						
Acropora prolifera	7.31	6.23	5.87	11.33	16.00	**9.35**
Agaricia agaricites	0.36	0.98				**0.27**
Orbicella annularis complex	5.99					**1.20**
Porites astreoides	2.28	1.22	0.70	1.43	1.87	**1.50**
Porites porites				0.26		**0.05**

Pseudodiploria strigosa	0.72			0.78		**0.30**
Siderastrea radians					0.13	**0.03**
Siderastrea siderea					1.87	**0.37**
Stephanocoenia intersepta				1.82		**0.36**
Total Hard Coral	**16.65**	**8.44**	**6.57**	**15.63**	**19.87**	**13.43**
Cyanobacteria		3.30		0.65	1.47	**1.08**
Invertebrate						
Millepora alcicornis	0.36					**0.07**
Millepora complanata		0.61	1.64			**0.45**
Palythoa caribaeorum	2.87	0.49				**0.67**
Total Invertebrate	**3.23**	**1.10**	**1.64**			**1.20**
Octocoral						
Erythropodium caribaeorum	1.44	3.67	2.58			**1.54**
Eunicea pallida	0.24					**0.05**
Total Octocoral	**1.68**	**3.67**	**2.58**			**1.59**
# Gorgonians/transect	1	0	0	3	4	**1.6**
Sponge						
Chondrilla caribensis	1.56	0.61		0.65		**0.56**
Cliona caribbaea	11.38	14.43	15.38	24.09	16.00	**16.25**
Cliona tenuis		1.22	3.52		1.20	**1.19**
Total Sponge	**12.93**	**16.26**	**18.90**	**24.74**	**17.20**	**18.01**

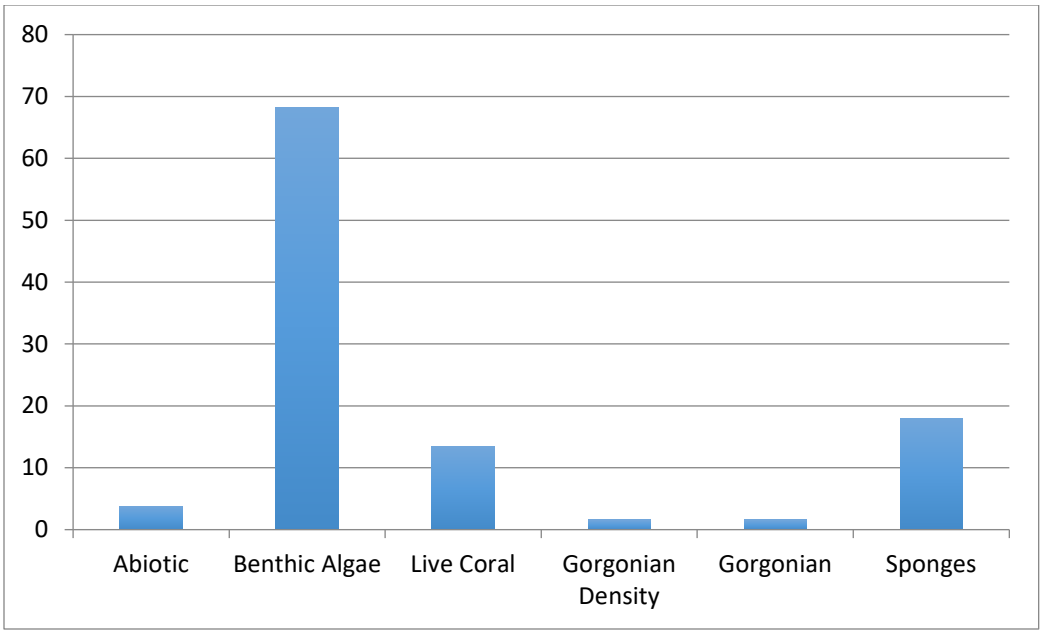


Figure 25. Mean substrate cover by benthic categories at Maria Langa Reef 5, Guayanilla. September 2016

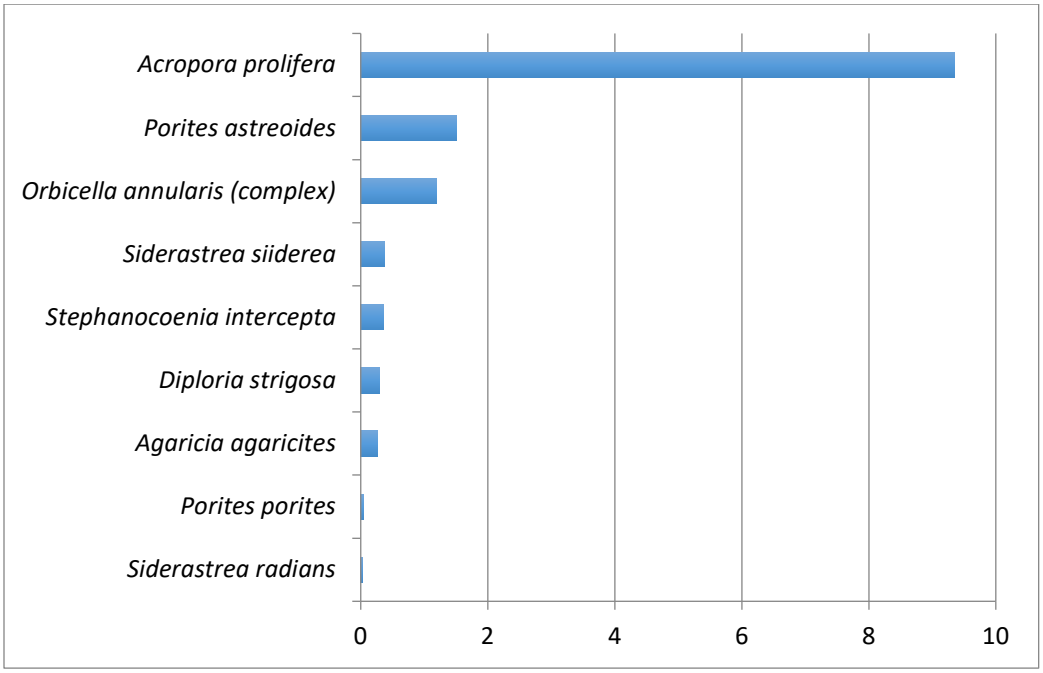


Figure 26. Mean substrate cover by coral species at Maria Langa Reef 5, Guayanilla. September 2016

Fishes and Motile Megabenthic Invertebrates

A total of 18 species of fish were identified within belt-transects from a depth of 3 - 4 m at Maria Langa 5 (Table 33). Mean density was 42.2 Ind/transect (range: 34 – 51 Ind/transect) with a mean richness of 8.8 species per transect. The Bluehead Wrasse, *Thalassoma bifasciatum* and the Dusky Damselfish, *Stegastes dorsopunicans* were the numerically dominant species with a combined density of 19.0 Ind/transect, representing 45.0% of the total. The Bicolor and Yellowtail Damselfishes, *Stegastes partitus*, *Microspathodon chrysurus,* the Slippery Dick, *Halichoeres bivittatus*, Graysbe, *Cephalopholis cruentatus* and the Redband Parrotfish, *Sparisoma aurofrenatum* were present in at least three transects (Table 33). Six species were only observed in one transect.

An assemblage of seven species with a combined density of 23.0 Ind/transect represented 76.2% of the total fishes within belt-transects (Table 30). The Bluehead Wrasse, *Thalassoma bifasciatum* was the most abundant with a mean density of 7.8 Ind/transect, followed by the Bar Jack*, Caranx ruber*, Bicolor Damselfish, *Stegastes partitus*, Striped and Redband Parrotfishes, *Scarus taeniopterus*, *Sparisoma aurofrenatum*, Yellowhead Wrasse, *Halichoeres garnoti*, and the Ocean Surgeon, Acanthurus bahianus. Another three species were present in at least four transects. With the exception of the Bar Jack, all of the aforementioned species were observed in at least three transects. Nine species were only present in one transect (Table 30).

The fish trophic structure at Maria Langa 5 was characterized by a balanced composition of small carnivores and herbivores, with absence of zooplanktivores and large demersal predators within belt-transects. Small opportunistic carnivores included 8 fish species with a combined density of 20.6 Ind/transect, representing 49.0% of the total fish density. Herbivores included nine species with a combined density of 21.0 Ind/transect, representing 49.8% of the total individuals. Small opportunistic carnivores included three species of wrasses (Labridae), two squirrelfishes (Holocentridae), one blenny (Blenniidae), one small grouper and one hamlet (Serranidae). Herbivores were represented by four damselfishes (Pomacentridae), three doctorfishes (Acanthuridae) and three parrotfishes (Scaridae). Medium sized piscivores included the Yellowtail Snapper (*Ocyurus chrysurus*) present in extended transects. Zooplanktivore fishes (*Chromis spp*) were observed outside transects. Large demersal predators were not observed.

The size-frequency distribution of Graysbes (Serranidae), doctorfishes (Acanthuridae) and parrotfishes (Scaridae) suggests that the reef serves as a residential habitat for these species (Table 34). One juvenile spiny lobster, *Panulirus argus* was present outside transects.

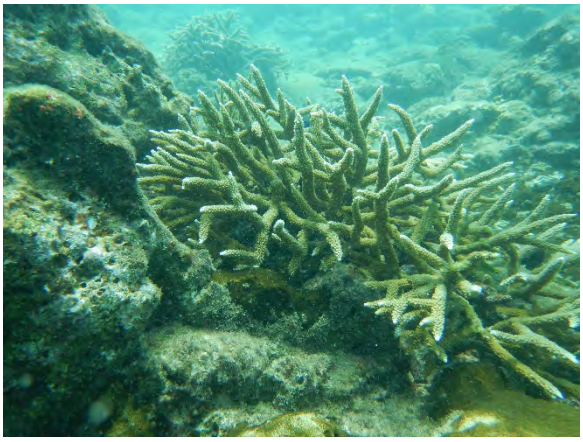
Table 33. MLAN 5. Taxonomic composition and abundance of fishes within 10 x 3 m belt-transects at Maria Langa Reef 5, Guayanilla, 3.1 m. Survey date: September 5, 2016

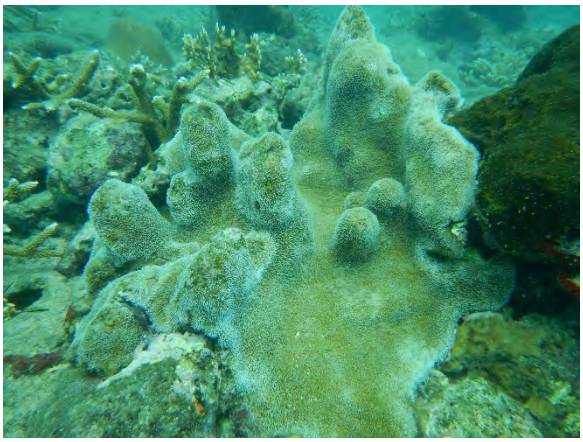
		Transects (Ind/30 m^2)				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Thalassoma bifasciatum	Bluehead Wrasse	3	20	24	13	23
Stegastes dorsopunicans	Dusky Damselfish	13	13	16	10	10
Stegastes partitus	Bicolor Damselfish	7	3	5	4	6
Halichoeres bivittatus	Slippery Dick		2	2	1	2
Microspathodon chrysurus	Yellowtail Damselfish		3	2	2	
Cephalopholis cruentatus	Graysby	2			1	2
Sparisoma aurofrenatum	Redband Parrotfish		2	1	2	
Scarus iserti	Stripped Parrotfish	2	2			
Ophioblennius macclurei	Redlip Blenny	2				2
Chaetodon capistratus	Four-eye Butterflyfish	2	1			
Acanthurus bahianus	Ocean Surgeon				2	
Acanthurus chirurgus	Doctorfish	1				1
Acanthurus coeruleus	Blue Tang		1			
Holocentrus adcensionis	Longjaw Squirrelfish	1				
Hypoplectrus indigo	Indigo Hamlet				1	
Halichoeres maculipinna	Clown Wrasse			1		
Sargocentron coruscus	Reef Squirrelfish	1				
Stegastes variabilis	Cocoa Damselfish		1		2	
	TOTAL INDIVIDUALS	**34**	**48**	**51**	**32**	**46**
	TOTAL SPECIES	**10**	**10**	**7**	**10**	**7**

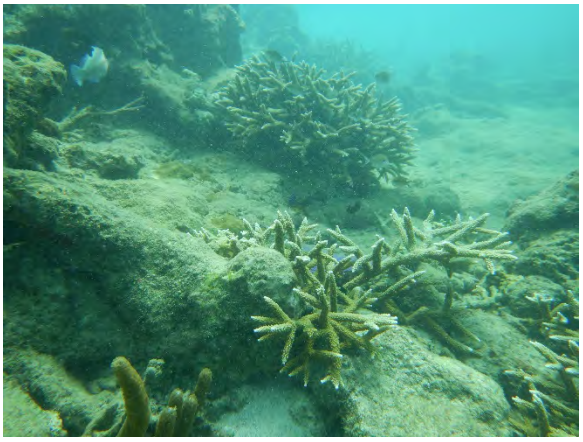
Table 34. MLAN 5. Size frequency distribution of fishes within 20 x 4 m belt-transects at Maria Langa Reef 5, Guayanilla, 3.1 m. Survey date: September 5, 2016

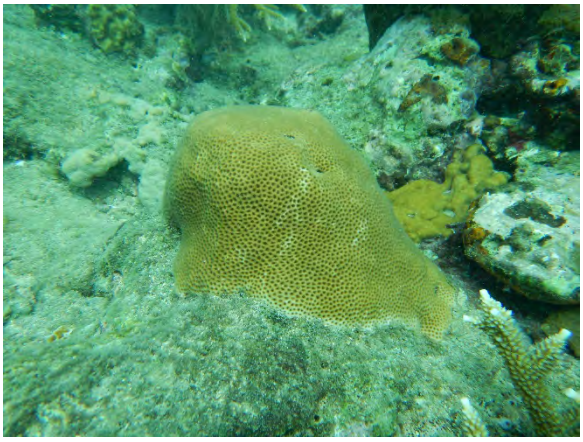
		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Acanthurus bahianus	Ocean Surgeon		2-15	2-15	2-15	1-12
Acanthurus chirurgus	Doctorfish		1-12			
Acanthurus coeruleus	Blue Tang		1-8			1-15
Cephalopholis cruentatus	Graysby	2-8			1-12	1-8
						1-15
Scarus iserti	Stripped Parrotfish	1-20	1-10		2-20	
		1-25	1-12			
Sparisoma viride	Stoplight Parrotfish	1-28				
Sparisoma aurofrenatum	Redband Parrotfish	1-15	2-18	1-18	2-12	
			1-12			
			1-20			

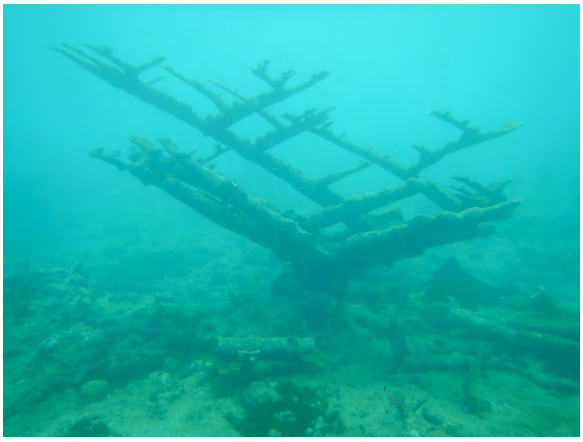
Photo Album 11.
Maria Langa 5m

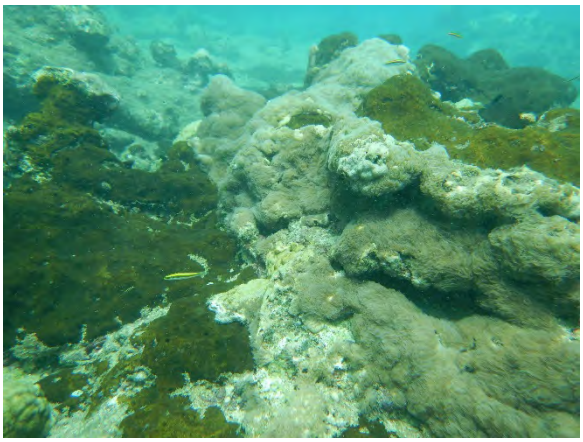












Palomino Reef 20, Fajardo

Physical Description

Isla Palominos is located inside the chain of island reefs that form the “Cordillera Natural Reserve”. The reef platform includes two emergent zones, the largest of which is Palominos, with the smaller sandy islet, Palominitos located due south of Palominos (Figure 27). Fringing and patch coral reef formations are found along the north and eastern sections of the island. Our survey was performed on the north section of Palominos Reef. Transects were set along the 16 – 17 m depth contour at the base of the fore-reef slope. Panoramic views of the reef community at Palomino are shown in Photo Album 12.

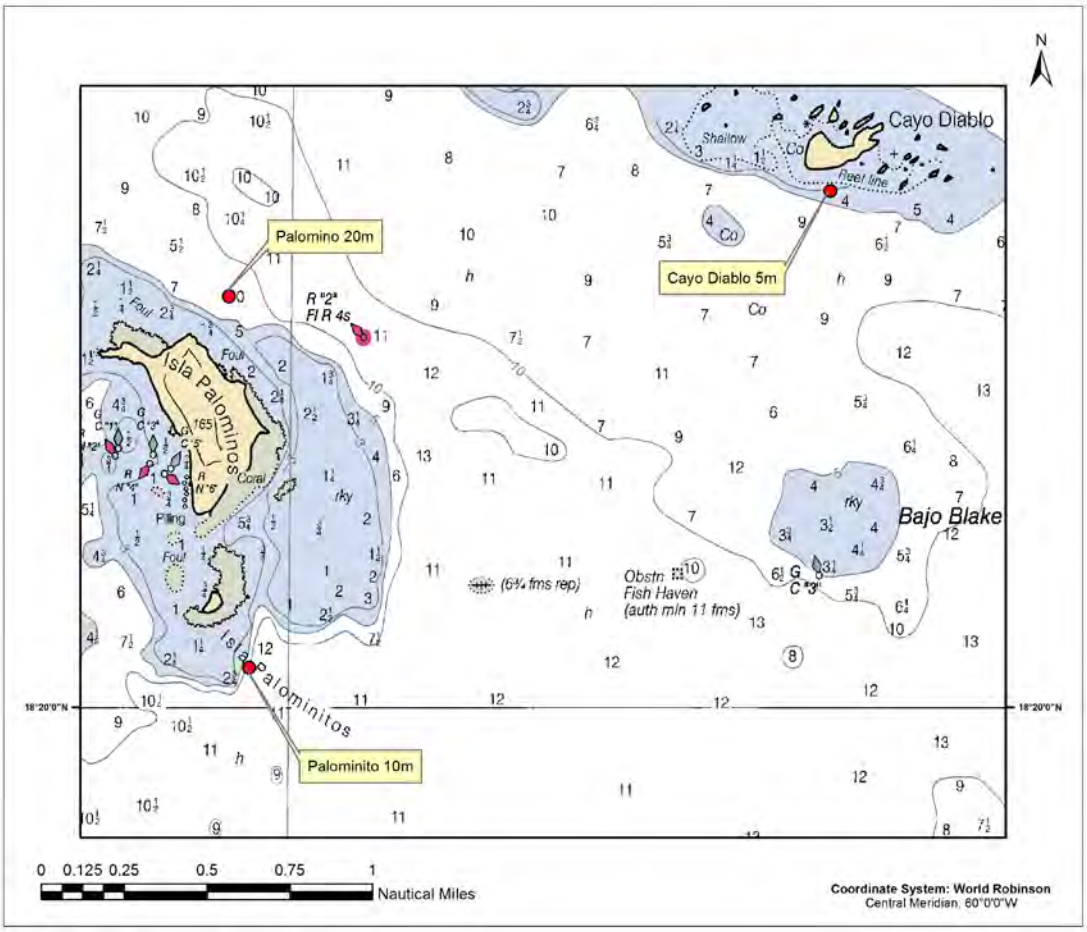


Figure 27. Location of coral reef monitoring stations within the Cordillera de Fajardo Natural Reserve

Sessile Benthic Reef Community

A mixed assemblage of benthic algae comprised by turf, encrusting red algae (mostly *Peyssonnelia sp*) and fleshy brown macroalgae (mostly *Dictyota sp*) was the dominant biological category covering substrate at Palomino Reef 20 with a combined mean cover of 43.4% (Figure 28). Turf algae were the largest component of the benthic algae with a mean cover of 25.4 %. The Burgundy Crust Algae, *Peyssonnelia sp*. was present in all transects with a mean cover of 17.4% (range: 11.8 – 37.7%). Small patches of cyanobacteria were present in four transects with a mean cover of 0.7% (Table 35).

Live scleractinian corals ranked second in linear cover with a mean of 30.7 % (range: 25.5 – 36.2%). A total of 14 coral species were intercepted by transects (Table 35). Dimpled Sheet Coral, *Agaricia grahamae* presented the highest mean reef substrate cover with 9.1%, representing 29.6% of the total. Along with *A. grahamae*, Mustard-Hill Coral, *Porites astreoides* and Great Star Coral, *Montastrea cavernosa* were present in all five transects with a combined cover of 6.3%. Finger Coral, *P. porites*, Lettuce Coral, *Agaricia agaricites*, and Ten-Ray Star Coral, *Madracis decactis* were all present in four transects. Large patches of Yellow-Pencil Coral, *Madracis auretenra* were intercepted by two transects for a mean cover of 7.4% (Table 35). The colonial zoanthid (*Palythoa caribaeorum*) and Fire Coral, *Millepora* spp. were also but with very low substrate cover at Palomino Reef 20.

Erect soft corals, or gorgonians (Order Octocorallia) were prominent in all transects surveyed with a mean density of 18 col/transect. Sea Rods (*Eunicea spp, Pseudoplexaura sp*), Sea Plumes (*Antillogorgia sp*.) and the Sea Fan, *Gorgonia ventalina* were the most abundant in transects. The encrusting species, *Briareum asbestinum* was present in all transects with a mean cover of 5.4% (Table 35). Sponges were represented by 12 species in transects with a combined mean cover of 2.2%. Five species were present in at least two transects, including *Chondrilla caribensis, Monachora arbuscula, Agelas tubulata, Aplysina cauliformis* and *Plaktoris sp*. In general, sponges were present as small and mostly encrusting growth forms with minor contributions to the overall reef benthic habitat complexity (Table 35).

Abiotic substrate categories were contributed by reef overhangs (8.8%), coral rubble (5.0%) and sand (2.3%). The mean reef rugosity of 3.5m was influenced by the irregular reef bottom topography and small to moderate sized coral colonies.

TABLE 35. PALNO 20. Percent cover by sessile-benthic categories along permanent transects, Cayo Palomino. Fajardo, 20 m. Survey date: September, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	4.70	4.14	2.45	2.99	3.13	**3.48**
Benthic Categories						
Abiotic						
Reef Overhang	9.05	6.53	4.72	7.76	15.78	**8.77**
Rubble	7.71	3.96	13.50			**5.03**
Sand	4.48		3.37		3.73	**2.32**
Gap		4.36			1.07	**1.08**
Total Abiotic	**21.24**	**14.85**	**21.60**	**9.05**	**20.58**	**17.46**
Benthic Algae						
Turf with sediment	40.38	35.25	11.81	8.30	31.34	**25.42**
Peyssonnelia sp.	2.86	11.78	21.71	37.72	12.79	**17.37**
Dictyota spp.			1.46			**0.29**
CCA	0.19			0.54	0.64	**0.27**
Total Benthic Algae	**43.43**	**47.03**	**34.98**	**46.55**	**44.78**	**43.35**
Hard Coral						
Agaricia grahamae	14.10	7.82	9.45	2.80	11.30	**9.09**
Madracis auretenra			13.95	22.84		**7.36**
Porites astreoides	4.67	7.13	2.70	0.86	2.13	**3.50**
Montastraea cavernosa	1.52	0.69	6.64	3.45	1.81	**2.82**
Orbicella annularis complex				1.83	6.50	**1.67**
Porites porites	3.43	2.48	0.34		1.49	**1.55**
Siderastrea siderea	1.62	1.49			4.58	**1.54**
Madracis decactis	0.48	1.39	0.45	4.42		**1.35**
Agaricia agaricites	0.67	2.48	1.80		0.21	**1.03**
Leptoseris cucullata	0.29	1.49				**0.35**
Eusmilia fastigiata	0.76					**0.15**
Stephanocoenia intersepta	0.76					**0.15**
Meandrina meandrites		0.59				**0.12**
Agaricia lamarcki	0.19					**0.04**
Total Hard Coral	**28.48**	**25.54**	**35.32**	**36.21**	**28.04**	**30.72**
Cyanobacteria	0.67	0.99	1.12	0.54		**0.66**
Invertebrate						
Palythoa caribaeorum	0.38					**0.08**
Millepora alcicornis				0.22		**0.04**
Total Invertebrate	**0.38**			**0.22**		**0.12**
Octocoral						
Briareum asbestinum	2.67	6.73	4.16	8.30	5.22	**5.42**
Eunicea flexuosa	0.19	0.30				**0.10**

Eunicea tourneforti	0.38					**0.08**
Antillogorgia acerosa		0.30				**0.06**
Pseudoplexaura wagenaari flagellosa	0.19					**0.04**
Total Octocoral	**3.43**	**7.33**	**4.16**	**8.30**	**5.22**	**5.69**
# Gorgonians/transect	19	19	17	13	22	**18**
Sponge						
Verongula sp.			1.69			**0.34**
Chondrilla caribensis			1.12	0.43		**0.31**
Suberea sp.		1.49				**0.30**
Monanchora arbuscula	0.29	0.20			0.85	**0.27**
Agelas tubulata	0.76	0.30				**0.21**
Aplysina cauliformis	0.29	0.50				**0.16**
Aplysina fistularis		0.69				**0.14**
Smenospongia conulosa		0.69				**0.14**
Callyspongia fallax	0.67					**0.13**
Plaktoris sp.	0.19	0.40				**0.12**
Smenospongia aurea					0.53	**0.11**
Aiolochroia crassa	0.19					**0.04**
Total Sponge	**2.38**	**4.26**	**2.81**	**0.43**	**1.39**	**2.25**

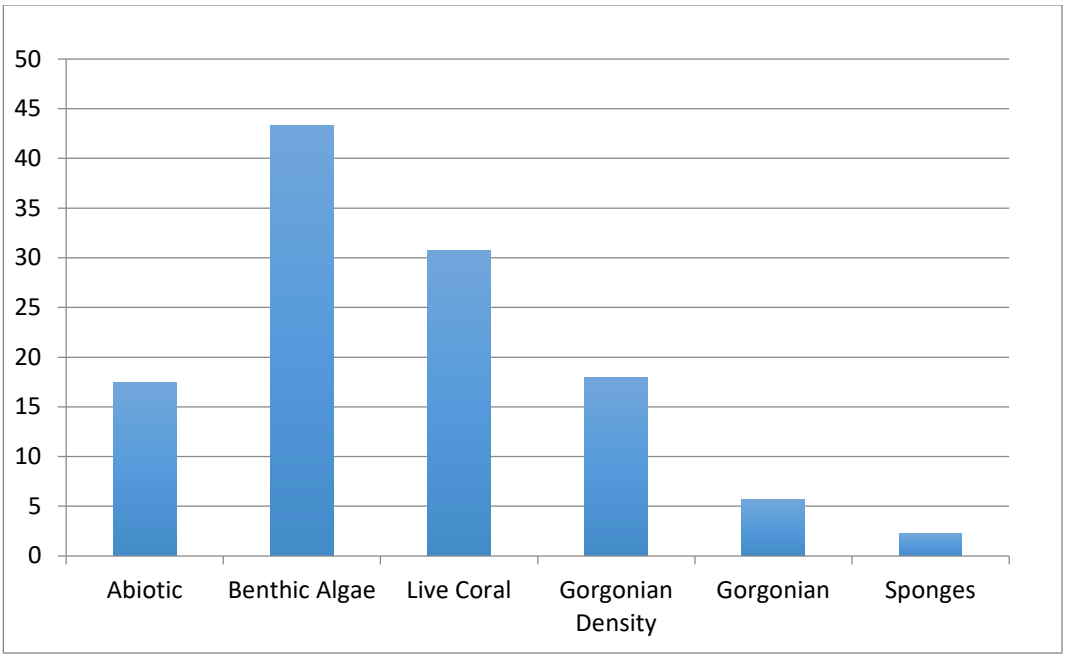


Figure 28. Mean substrate cover by benthic categories at Palomino Reef 20, Fajardo. September 2016

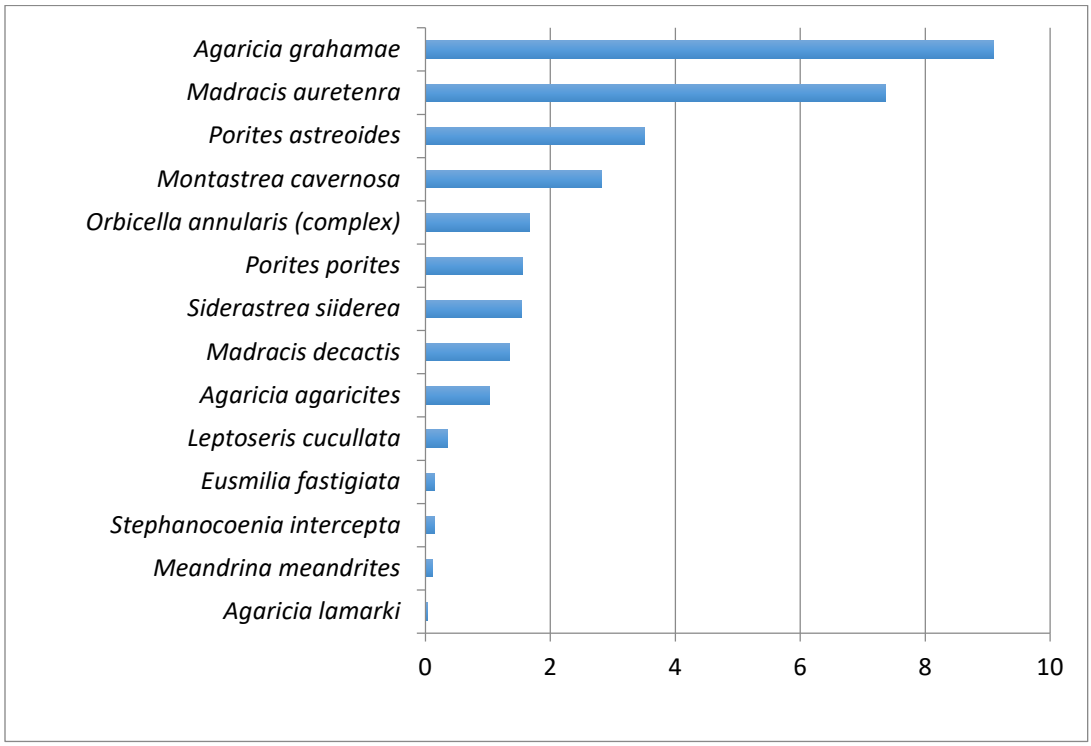


Figure 29. Mean substrate cover by coral species at Palomino Reef 20, Fajardo. September 2016

Fishes and Motile Megabenthic Invertebrates

A total of 38 species of fish were identified within belt-transects from a depth of 16 - 17 m at Palomino Reef 20 (Table 36). Mean density was 260.6 Ind/transect (range: 207 – 341 Ind/transect) with a mean richness of 19.0 species per transect. The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean density of 210.0 Ind/transect, representing 80.6% of the total fish density. Schools of Blue Chromis, *Chromis cyanea* were observed over three transects with an average density of 13.6 Ind/transect, ranking second. In addition to the aforementioned species, an assemblage of eight species were present in at least four transects with a combined density of 23.6 Ind/transects, contributing 9.0% to the total fish density. This assemblage included the Princess, Stripped, Stoplight and Redband Parrotfishes (*Scarus taeniopterus, S. iserti, Sparisoma viride, S. aurofrenatum*), Beau Gregory and Bicolor Damselfishes (*Stegastes leucostictus, S. partitus*) French Grunt (*Haemulon flavolineatum)* and Graysbe (*Cephalopholis cruentatus*). Ten species were only present in one transect (Table 36).

The trophic structure of fishes at Palomino Reef 20 was strongly represented by zooplanktivorous fishes due to the numerical dominance of the Masked Goby, Blue Chromis and Bicolor Damselfish with a cumulative density of 226.2 Ind/transect, representative of 86.8% of the total fishes within transects. Herbivores were represented by a highly specious assemblage, including six species of parrotfishes (Scaridae), three doctorfishes (Acanthuridae) and two damselfishes (Pomacentridae) with a combined density of 21.0 Ind/transect, representing 8.0% of the total density within belt-transects. Small opportunistic carnivores were represented by 11 species with a combined density of 0.6% of the total within belt-transects and included two species of wrasses (Labridae), two squirrelfishes (Holocentridae), two Grunts (Haemulidae), two gobies (Gobiidae), and four Sea Basses small groupers (Serranidae). Medium sized piscivores included the Yellowtail and Schoolmaster Snappers (*Ocyurus chrysurus, Lutjanus apodus*), and the Lizardfish (*Synodus intermedius*) with a combined density of less than 1% of the total fish density.

Doctorfishes (Acanthuridae) were all represented by late juvenile and adult individuals. The Stoplight and Princess Parrotfishes were observed throughout their entire size range, including recruitment juveniles and full adults (Table 37). Individuals of the Yellowtail Snapper and

Schoolmaster Snapper were mostly present as juveniles and young adults. Motile megabenthic invertebrates were not observed.

Table 36. PALNO 20. Taxonomic composition and abundance of fishes within 10 x 3 m belt-transects at Cayo Palomino, Fajardo, 20.0 m. Survey date: September 2016

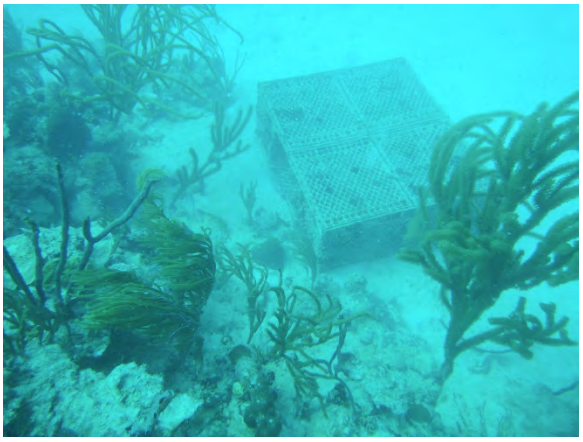
		Transects (Ind/30 m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	250	240	160	120	280	**210.0**
Chromis cyanea	Blue Chromis			30	26	12	**13.6**
Scarus taeniopterus	Princess Parrotfish	2	6	2	21	10	**8.2**
Scarus iserti	Stripped Parrotfish	3	1	2	5	2	**2.6**
Stegastes leucostictus	Beau Gregory	2	2	3	3	3	**2.6**
Stegastes partitus	Bicolor Damselfish	1	4	3	5		**2.6**
Sparisoma viride	Stoplight Parrotfish	1		4	3	3	**2.2**
Haemulon flavolineatum	French Grunt		2	4	1	2	**1.8**
Chaetodon capistratus	Four-eye Butterflyfish	2			2	3	**1.4**
Sparisoma aurofrenatum	Redband Parrotfish	1	1	1	2	2	**1.4**
Gramma loreto	Fairy Basslet		1	1	4		**1.2**
Cephalopholis cruentatus	Graysby	2	1	1	1		**1.0**
Halichoeres garnoti	Yellow-head Wrasse	1			2	2	**1.0**
Stegastes variabilis	Cocoa Damselfish	1		2		2	**1.0**
Holocentrus rufus	Squirrelfish			2	1	1	**0.8**
Hypoplectrus nigricans	Black Hamlet	1	1			2	**0.8**
Sparisoma chrysargyreum	Redtail Parrotfish		1		1	2	**0.8**
Sparisoma radians	Bucktooth Parrotfish			1	1	2	**0.8**
Haemulon aurolineatum	Tomtate		1			2	**0.6**
Hypoplectrus puella	Barred Hamlet		1	2			**0.6**
Serranus tigrinus	Harlequin Bass			1	2		**0.6**
Stegastes dorsopunicans	Dusky Damselfish		2	1			**0.6**
Thalassoma bifasciatum	Bluehead Wrasse	2		1			**0.6**
Acanthurus coeruleus	Blue Tang				1	1	**0.4**
Elacatinus evelynae	Sharknose Goby		1	1			**0.4**
Mulloides martinicus	Yellowtail Goatfish					2	**0.4**
Ocyurus chrysurus	Yellowtail Snapper		1		1		**0.4**
Acanthurus bahianus	Ocean Surgeon				1		**0.2**
Acanthurus chirurgus	Doctorfish			1			**0.2**
Anisotremus virginicus	Porgy					1	**0.2**
Coryphopterus lipernes	Peppermint Goby		1				**0.2**
Holacanthus tricolor	Rock Beauty			1			**0.2**

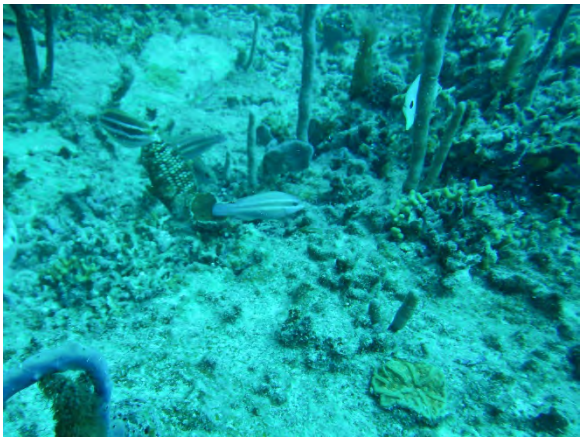
Hypoplectrus unicolor	Butter Hamlet			1			**0.2**
Lutjanus apodus	Schoolmaster			1			**0.2**
Myripristis jacobus	Black-Bar Soldierfish	1					**0.2**
Pomacanthus arcuatus	Gray Angelfish					1	**0.2**
Pseudupeneus maculatus	Spotted Goatfish					1	**0.2**
Synodus intermedius	Lizardfish		1				**0.2**
	TOTAL INDIVIDUALS	**270**	**270**	**229**	**207**	**341**	**260.6**
	TOTAL SPECIES	**14**	**17**	**23**	**20**	**21**	**19.0**

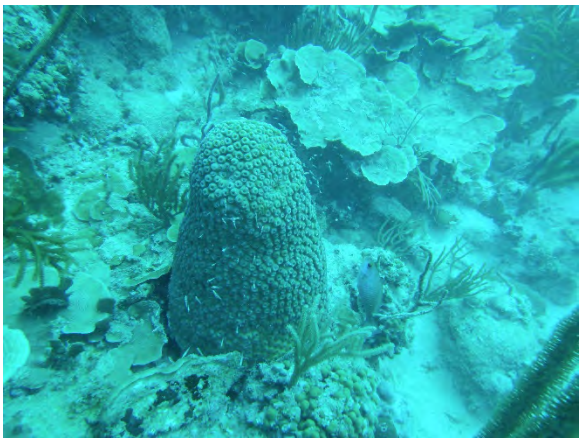
Table 37. PALNO 20. Size frequency distribution of fishes within 20 x 4 m belt-transects at Cayo Palomino, Fajardo, 20.0 m. Survey date: September 2016

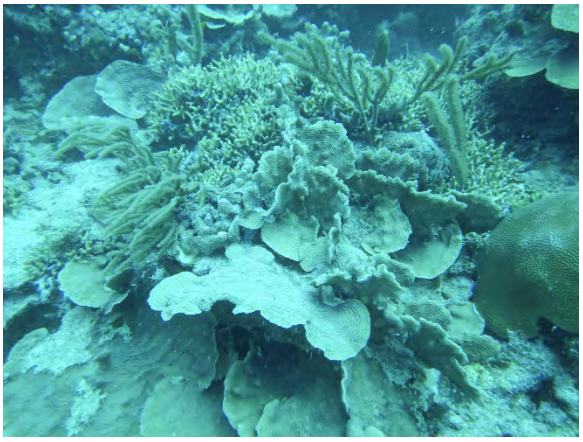
		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Acanthurus bahianus	Ocean Surgeon	2-12		1-8		1-20
Acanthurus coeruleus	Blue Tang	2-10	2-25			1-2
Acanthurus chirurgus	Doctorfish		1-18			
Cephalopholis cruentatus	Graysby	1-10	1-20	1-10		
		1-28				
Ocyurus chrysurus	Yellowtail Snapper	5-5				1-28
Scarus iserti	Stripped Parrotfish	3-10		2-13		2-23
Sparisoma viride	Stoplight Parrotfish	1-2	2-2	2-2	2-30	3-2
			1-23	2-20	3-2	
				1-25		
Lutjanus apodus	Schoolmaster		1-25	1-28		
Sparisoma aurofrenatum	Redband Parrotfish	1-15	1-15	1-20	2-15	1-10
				1-20		2-20
Scarus taeniopterus	Princess Parrotfish	1-18	4-2	4-5		10-5
		1-25	2-5			
Sparisoma radians	Bucktooth Parrotfish					2-2

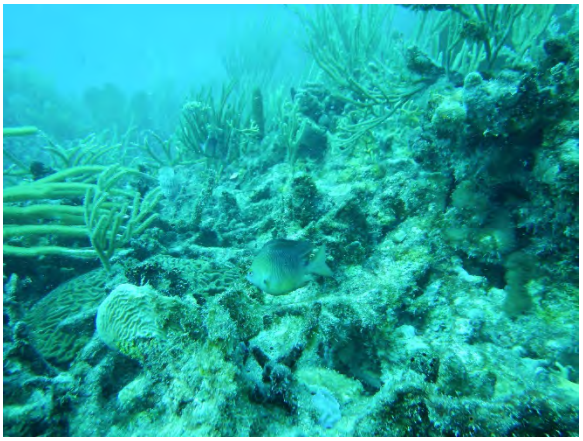
Photo Album 12.
Palomino 20m











Palominito Reef 10, Fajardo

Physical Description

Isla Palominitos sits in the same reef platform with Palominos (Figure 27). A shallow sand channel separates both islands. Coral reefs occur to the northeast, east and south of Palominitos. There is a large fringing reef that breaks down into a series of small submerged patch reefs, particularly to the east and south of the island. The largest and best developed coral reef is located to the northeast and it is the one included in our survey. This is a fringing coral formation overlying the fore-reef slope with massive coral build-up. The reef structure is characterized by steep spurs and deep grooves with sandy sediments. The height of the spurs reaches six meters close to the base of the reef at a depth of 18 meters. It was not possible to corroborate how much of this structure is actually coral build-up. Massive stony corals grow on top and along the sides of the spurs providing substantial topographic relief and habitat to the reef community. Turtle seagrass occurs along the south coast in close proximity with scattered patch reefs. The west section of the island presents scattered coral growth below depths of 5-6 m and features a small but impressively beautiful coralline sandy beach that is a recreational hotspot for tourists in the area. Panoramic views of the reef community at Palominito are shown in Photo Album 13.

Sessile Benthic Reef Community

A mixed assemblage of benthic algae comprised by encrusting red algae (mostly *Peyssonnelia sp*), turf algae, green calcareous algae (mostly *Halimeda spp*.) and fleshy brown macroalgae (mostly *Lobophora variegata* and *Dictyota sp*) was the dominant sessile-benthic category covering substrate at Palominito Reef 10 with a combined mean cover of 53.1% (Figure 30). The Burgundy Crust Algae, *Peyssonnelia sp*. was highly dominant in all transects with a mean cover of 45.1% (range: 39.5– 53.3%), representing 84.9% of the total cover by benthic algae (Table 38). Green calcareous algae (*Halimeda spp*) and fleshy brown (*Dictyota sp*) were also present in all transects surveyed. Patches of cyanobacteria were present in four transects with a mean cover of 2.7%. Turf algae, a highly dominant and resilient assemblage of short filamentous red and brown algae was only intercepted by three transects in very small cover

(mean: 0.6%). This algal component has probably been displaced and overgrown by *Peyssonnelia sp*. on Palominito Reef 10.

Scleractinian corals were represented by eight species with a combined mean substrate cover of 32.8% (range: 22.4 – 38.4%). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant coral intercepted by transects with a mean substrate cover of 19.9%, representing 60.7% of the total cover by corals (Figure 31). Mustard-Hill Coral, *Porites astreoides* and Finger Coral, *P. porites* were present in all transects with a combined mean cover of 7.6% (Table 38). Large massive colonies of Boulder Brain Coral, *Colpophyllia natans* were intercepted by three transects with an average cover of 3.2%. Fire Coral, *Millepora* spp. was present as small branching colonies with low substrate cover (0.5%).

Erect soft corals, or gorgonians (Order Octocorallia) were prominent in all transects surveyed with a mean density of 19.8 col/transect at Palominito Reef 10 (Table 38). Sea Rods (*Eunicea spp, Pseudoplexaura sp*) and the Sea Fan, *Gorgonia ventalina* were the most abundant in transects. The encrusting species, *Erythropodium caribaeorum* was present in all transects with a mean cover of 4.0%. Other encrusting species, *Briareum asbestinum* was observed in three transects with a mean cover of 1.3%. Sponges were represented by 6 species in transects with a combined mean cover of 0.6%. *Monachora arbuscula* was the only species observed in more than one transect. In general, sponges were present as small and mostly encrusting growth forms with minor contributions to the overall reef benthic habitat complexity.

Abiotic substrate categories were contributed by reef overhangs (3.1%), and gaps (1.0%). The mean reef rugosity of 2.8 was mostly influenced by coral ledges and overhangs.

TABLE 38. PALTO 10. Percent cover by sessile-benthic categories along permanent transects, Cayo Palominito. Fajardo, 10 m. Survey date: September 9, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.43	1.44	4.95	2.49	2.61	**2.78**
Benthic Categories						
Abiotic						
Reef Overhang		3.30	4.78	2.91	4.66	**3.13**
Gap	4.62		0.28			**0.98**

Total Abiotic	**4.62**	**3.30**	**5.06**	**2.91**	**4.66**	**4.11**
Benthic Algae						
Peyssonnelia sp.	39.53	45.90	43.26	43.39	53.27	**45.07**
Dictyota spp.	3.49	2.08	0.75	3.25	7.66	**3.45**
Lobophora variegata	8.78					**1.76**
Halimeda spp.	0.45	1.59	1.22	0.67	2.77	**1.34**
CCA		0.86	0.37	1.12	2.22	**0.91**
Turf	0.45	0.98	1.40			**0.57**
Total Benthic Algae	**52.70**	**51.41**	**47.00**	**48.43**	**65.93**	**53.09**
Hard Coral						
Orbicella annularis complex	25.00	30.72	23.22	18.61	1.78	**19.87**
Porites astreoides	3.04	0.98	2.72	10.43	7.55	**4.94**
Colpophyllia natans			6.27	4.82	5.11	**3.24**
Porites porites	2.14	1.35	2.62	0.45	6.88	**2.69**
Siderastrea siderea	4.17					**0.83**
Acropora cervicornis	3.72					**0.74**
Agaricia agaricites	0.34	0.49			0.55	**0.28**
Agaricia fragilis		0.24			0.55	**0.16**
Total Hard Cover	**38.40**	**33.78**	**34.83**	**34.30**	**22.42**	**32.75**
Cyanobacteria		2.33	5.71	2.58	2.77	**2.68**
Invertebrate		1.10		0.22	1.11	**0.49**
Millepora alcicornis		1.10		0.22	1.11	**0.49**
Octocoral						
Erythropodium caribaeorum	3.27	2.82	3.56	9.64	0.89	**4.03**
Briareum asbestinum	0.23	3.55	2.62			**1.28**
Gorgonian ventalina				1.23	1.55	**0.56**
Eunicea flexuosa		0.37	0.19	0.67		**0.25**
Pseudoplexaura wagenaari flagellosa	0.23		0.37			**0.12**
Eunicea succinea			0.19			**0.04**
Total Octocoral	**3.72**	**6.73**	**6.93**	**11.55**	**2.44**	**6.27**
# Gorgonians/transect	24	20	19	16	20	**19.8**
Sponge						
Monanchora arbuscula	0.56	0.61				**0.24**
Amphimedon compressa		0.49				**0.10**
Ectyoplasia ferox			0.47			**0.09**
Niphates erecta		0.24			0.22	**0.09**
Clathria sp.					0.22	**0.04**
Sponge					0.22	**0.04**
Total Sponge	**0.56**	**1.35**	**0.47**		**0.67**	**0.61**

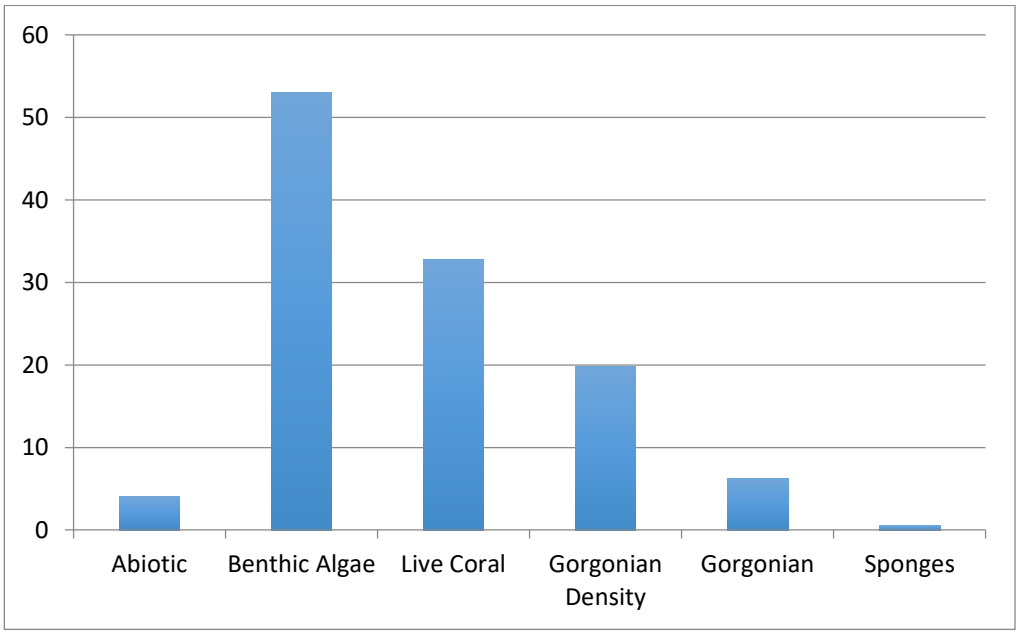


Figure 30. Mean substrate cover by benthic categories at Palominito Reef 10, Fajardo. September 2016

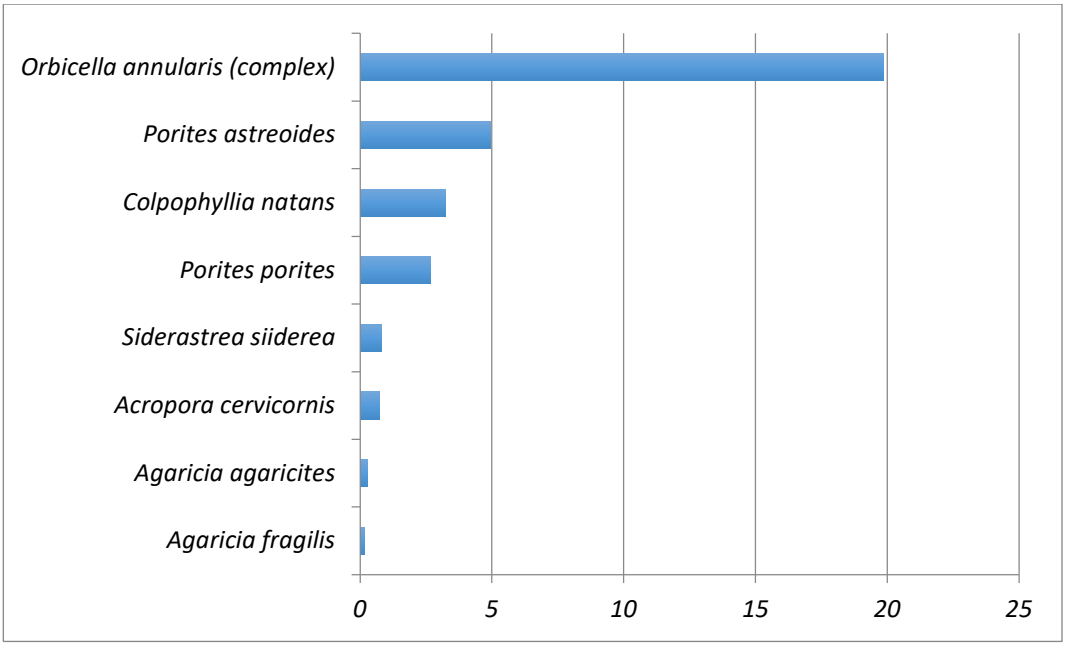


Figure 31. Mean substrate cover by coral species at Palominito Reef 10, Fajardo. September 2016

Fishes and Motile Megabenthic Invertebrates

A total of 26 species of fish were identified within belt-transects from a depth of 9 - 10 m at Palominito Reef 10 (Table 39). Mean density was 85.6 Ind/transect (range: 31 – 212 Ind/transect) with a mean richness of 13.2 species per transect. The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean density of 51.8 Ind/transect, representing 60.5% of the total fish density. Only three other species were present in all transects. These included the Princess and Stoplight Parrotfishes, *Scarus taeniopterus, Sparisoma viride* and the Sharknose Goby, *Elacatinus evelynae* (Table 39). Seven other species were present in three transects. These included three parrotfishes, two doctorfishes, one butterflyfish and one damselfish.

The trophic structure of fishes at Palominito Reef 10 was influenced by the numerical dominance of the Masked Goby, with minor contributions by the Blue Chromis and Bicolor Damselfish for a cumulative density of 54.2 Ind/transect, representative of 63.3% of the total fishes within transects. Herbivores were represented by a more specious assemblage of larger individuals, including five species of parrotfishes (Scaridae), five damselfishes (Pomacentridae), and two doctorfishes (Acanthuridae) with a combined density of 23.8 Ind/transect, representing 27.8% of the total density within belt-transects. Small opportunistic carnivores were represented by 11 species with a combined density of 6.4 % Ind/transect, representative of 7.5% of the total and included two species of wrasses (Labridae), two squirrelfishes (Holocentridae), three gobies (Gobiidae), one Hawkfish (Cirrhitidae), and three Sea Basses small groupers (Serranidae). Medium sized piscivores were represented within belt-transects only by the Yellowtail Snappers (*Ocyurus chrysurus*). Several juvenile and adult Schoolmaster Snappers (*L. apodus*) and one juvenile Nassau Grouper, *Epinephelus striatus* were observed outside transects.

Doctorfishes (Acanthuridae) were represented by adults and late juvenile stages of Blue Tang and Ocean Surgeon and by early recruitment juveniles of the latter (Table 40). The Stoplight and Princess Parrotfishes were observed throughout their entire size range, including recruitment juveniles and full adults. Individuals of the Yellowtail Snapper were mostly present as juveniles and young adults. Motile megabenthic invertebrates were represented by Banded Coral Shrimps, *Stenopus hispidus,* and one Arrow Crab, *Stenorhinchus seticornis.*

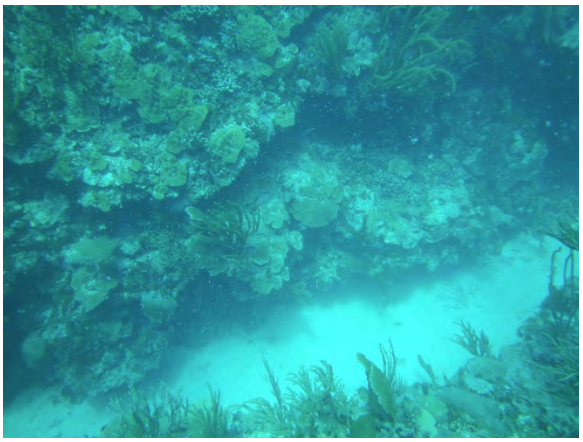
Table 39. PALTO 10. Taxonomic composition and abundance of fishes within 10 x 3 m belt-transects at Cayo Palominito, Fajardo, 10.0 m. Survey date: September 9, 2016

		Transects (Ind/30 m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	46	180	8	1	24	**51.8**
Scarus taeniopterus	Princess Parrotfish	4	5	16	7	8	**8.0**
Stegastes planifrons	Yellow-eye Damselfish	10	5	3	6		**4.8**
Sparisoma viride	Stoplight Parrotfish	2	2	2	3	3	**2.4**
Scarus iserti	Stripped Parrotfish	3	1			6	**2.0**
Stegastes adustus	Three-spot Damselfish			1		8	**1.8**
Chromis cyanea	Blue Chromis					8	**1.6**
Halichoeres maculipinna	Clown Wrasse	6	2				**1.6**
Elacatinus evelynae	Sharknose Goby	1	2	2	1	1	**1.4**
Thalassoma bifasciatum	Bluehead Wrasse		6				**1.2**
Acanthurus coeruleus	Blue Tang			1	2	2	**1.0**
Chaetodon capistratus	Four-eye Butterflyfish		2		1	2	**1.0**
Sparisoma aurofrenatum	Redband Parrotfish	1		2	2		**1.0**
Sparisoma radians	Bucktooth Parrotfish	2		2	1		**1.0**
Stegastes leucostictus	Beau Gregory	1	2		1		**0.8**
Stegastes partitus	Bicolor Damselfish		2		2		**0.8**
Acanthurus bahianus	Ocean Surgeon	1		1	1		**0.6**
Cephalopholis cruentatus	Graysby		2				**0.4**
Hypoplectrus nigricans	Black Hamlet	1				1	**0.4**
Hypoplectrus puella	Barred Hamlet	1			1		**0.4**
Abudefduf sexatilis	Sargent Major					1	**0.2**
Amblycirrhitus pinos	Hawkfish	1					**0.2**
Coryphopterus sp.	Goby					1	**0.2**
Coryphopterus lipernes	Peppermint Goby		1				**0.2**
Holocentrus rufus	Squirrelfish				1		**0.2**
Lactophrys triqueter	Smooth Trunkfish				1		**0.2**
Ocyurus chrysurus	Yellowtail Snapper					1	**0.2**
Stegastes variabilis	Cocoa Damselfish			1			**0.2**
	TOTAL INDIVIDUALS	**34**	**32**	**31**	**30**	**42**	**33.8**
	TOTAL SPECIES	**14**	**13**	**11**	**15**	**13**	**13.2**

Table 40. PALTO 10. Size frequency distribution of fishes within 20 x 4 m belt-transects at Palominito Reef 10, Fajardo, 10.0 m. Survey date: September 2016

		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Acanthurus bahianus	Ocean Surgeon			1-15	1-15	
Acanthurus coeruleus	Blue Tang		1-18	1-8	1-10	2-2
				1-5	1-12	
Cephalopholis cruentatus	Graysby	1-5				
		1-15				
Ocyurus chrysurus	Yellowtail Snapper			1-18		1-8
Scarus iserti	Stripped Parrotfish	3-5				6-8
Sparisoma viride	Stoplight Parrotfish	2-2	2-12	2-2	1-8	2-2
						1-12
						1-15
						2-30
Sparisoma aurofrenatum	Redband Parrotfish	1-18		1-10	1-12	
		1-25		1-25	1-18	
		1-12				
Scarus taeniopterus	Princess Parrotfish	3-5	5-5	16-5	7-2	8-2
		1-10				
Sparisoma radians	Bucktooth Parrotfish	2-2		2-2	2-2	

Photo Album 13
Palominito 10m



Cayo Diablo 5, Fajardo

Physical Description

Cayo Diablo is easternmost emergent key of the "Cordillera de Fajardo". It is a mostly un-vegetated island with many rocky outcrops and a sandy beach on the southeast coastline. The northern section of the island (windward) has a narrow reef platform with a rocky shoreline exposed to seasonally strong wave action. Coral reefs are found on the southern (leeward) section of the island. Patch reefs represent the main coral reef formation at Cayo Diablo. These reefs lie submerged at variable depths along the backreef zone intermixed with seagrass in some areas. Patch reefs emerge from a white coralline sandy bottom at depths of 10-12 meters. Transects were installed along an east-west axis on the top of adjacent patch reef promontories at a depth of 5 – 6m in the backreef of Cayo Diablo (Figure 27). Panoramic views of the Cayo Diablo 5 reef community are presented in Photo Album 14.

Sessile Benthic Reef Community

The reef substrate at Cayo Diablo 5 was largely covered by benthic algae (Figure 32). The mean cover by benthic algae was 73.0% (range: 59.2 – 78.2%). A highly calcified encrusting red algae (probably *Ramicrusta sp or Peyssonnelia sp.*) was found as a dark reddish paint overgrowing most available hard bottom with a mean cover of 63.0%, representing 86.3% of the total cover by benthic algae (Table 41). The encrusting red algae appeared to be mostly overgrowing dead coral sections. It is uncertain if the algae is displacing or affecting coral growth in any way, or just colonizing already dead sections. Green calcareous algae (mostly *Halimeda spp*.) were present in four transects with a mean cover of 4.2%. Fleshy brown macroalgae (mostly *Dictyota sp*), crustose coralline algae and turf algae were also intercepted by transects with a combined cover of 4.1% (Table 41). Turf algae, a highly dominant and resilient assemblage of short filamentous red and brown algae was only observed in two transects with limited cover (mean: 2.7%) and appears to have been displaced and overgrown by the encrusting red algae (*Ramicrusta/Peyssonnelia sp)* on Cayo Diablo 5. Patches of cyanobacteria were present in two transects with a mean cover of 0.5%.

Scleractinian corals were represented by five species with a combined mean substrate cover of 20.9% (range: 15.8 – 22.9%). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant coral intercepted by transects with a mean substrate cover of 11.9%, representing

56.9% of the total cover by corals (Figure 33). Finger Coral, *P. porites* was the only coral species present in all transects with a mean cover of 7.6% (Table 41). The combined cover of *O. annularis* and *P. porites* represented 93.3% of the total cover by live corals at Cayo Diablo 5. Small colonies of Staghorn Coral, *Acropora cervicornis* were intercepted by two transects and observed to be common in the reef. Dead and live colonies of Elkhorn Coral, *A. palmata* were observed in shallow sections of Cayo Diablo backreef. Massive coral promontories, most likely *O. annularis (faveolata*) buildups were seen in advanced stages of degradation and overgrown by the encrusting red algae (*Ramicrusta sp/ Peyssonnelia sp.*). Fire Coral, *Millepora* spp. was prominent in some reef sections an presented a mean cover of 1.7% in transects surveyed (Table 41).

Erect soft corals, or gorgonians (Order Octocorallia) were present in all transects surveyed with a mean density of 6.8 col/transect at Cayo Diablo (Table 41). Sea Rods (*Eunicea spp, Plexaura spp*) and the Sea Fan, *Gorgonia ventalina* were the most common. The encrusting species, *Briareum asbestinum* was observed in three transects with a mean cover of 0.5%. Sponges were represented by three species in transects with a combined mean cover of 0.4%. In general, sponges were present as small and mostly encrusting growth forms with minor contributions to the overall reef benthic habitat complexity.

Abiotic substrate categories were largely contributed by reef overhangs (2.0%), coral rubble (0.5%). The mean reef rugosity of 3.3 m was mostly influenced by coral ledges and overhangs.

TABLE 41. DIAB 5. Percent cover by sessile-benthic categories along permanent transects, Cayo Diablo. Fajardo, 5 m. Survey date: September 9, 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	5.23	1.86	2.19	2.85	4.42	**3.31**
Benthic Categories						
Abiotic						
Reef Overhang	8.36				1.55	**1.98**
Rubble			1.15		1.26	**0.48**
Total Abiotic	**8.36**		**1.15**		**2.82**	**2.47**
Benthic Algae						

Ramicrusta sp.	41.54	75.44	62.57	67.21	68.45	**63.04**
Halimeda spp.	7.44		2.41	3.38	7.96	**4.24**
Turf	8.46		5.05			**2.70**
Peyssonnelia sp.			4.36	3.81		**1.64**
Dictyota spp.	0.18			2.29	1.36	**0.77**
CCA	1.56			0.54		**0.42**
Galaxaura sp.		0.47			0.49	**0.19**
Total Benthic Algae	**59.19**	**75.91**	**74.40**	**77.23**	**78.25**	**73.00**
Hard Coral						
Orbicella annularis complex	19.58	11.45		19.83	8.74	**11.92**
Porites porites	1.75	10.86	21.35	0.87	3.01	**7.57**
Acropora cervicornis			0.57		4.08	**0.93**
Porites astreoides	1.56		0.57			**0.43**
Agaricia agaricites			0.23			**0.05**
Total Hard Coral	**22.89**	**22.31**	**22.73**	**20.70**	**15.83**	**20.89**
Cyanobacteria			1.26	1.09		**0.47**
Invertebrate						
Millepora alcicornis	6.89				1.55	**1.69**
Palythoa caribaeorum	2.11					**0.42**
Total Invertebrate	**9.01**				**1.55**	**2.11**
Octocoral						
Briareum asbestinum		1.77		0.44	0.39	**0.52**
Eunicea tourneforti			0.46			**0.09**
Eunicea sp.					0.29	**0.06**
Plexaura homomalla				0.22		**0.04**
Total Octocoral		**1.77**	**0.46**	**0.65**	**0.68**	**0.71**
# Gorgonians/transect	2	8	7	7	10	**6.8**
Sponge						
Callyspongia fallax					0.87	**0.17**
Cinachyrella kuekenthali	0.55					**0.11**
Spirastrella coccinea				0.33		**0.07**
Total Sponge	**0.55**			**0.33**	**0.87**	**0.35**

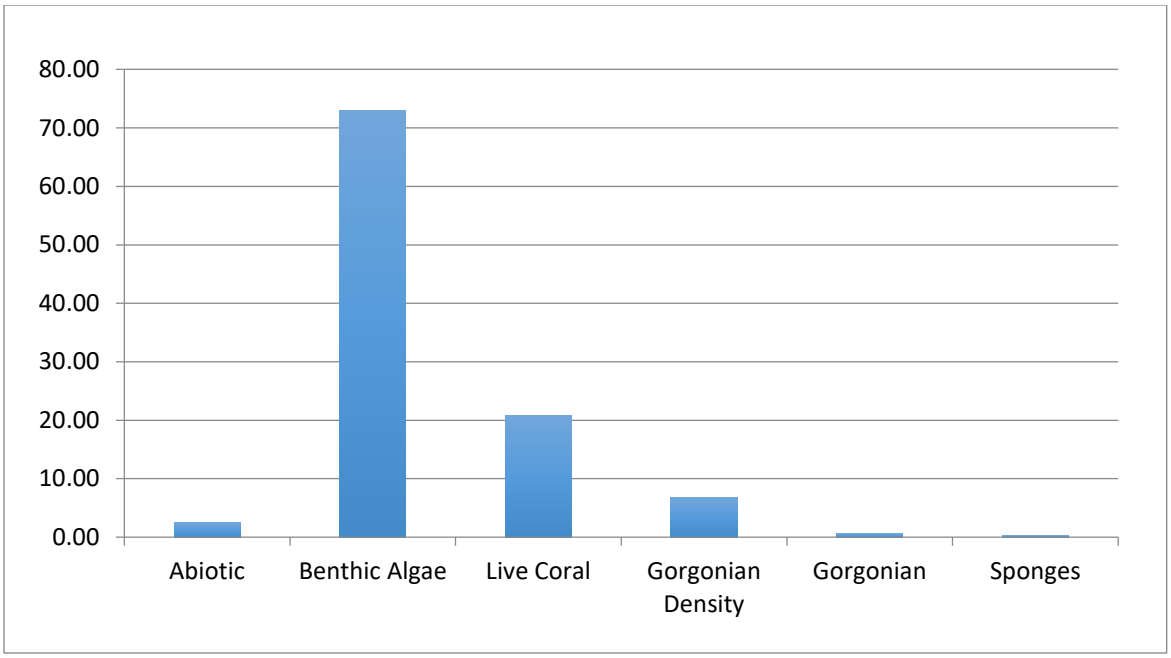


Figure 32. Mean substrate cover by benthic categories at Cayo Diablo 5, Fajardo. September 2016

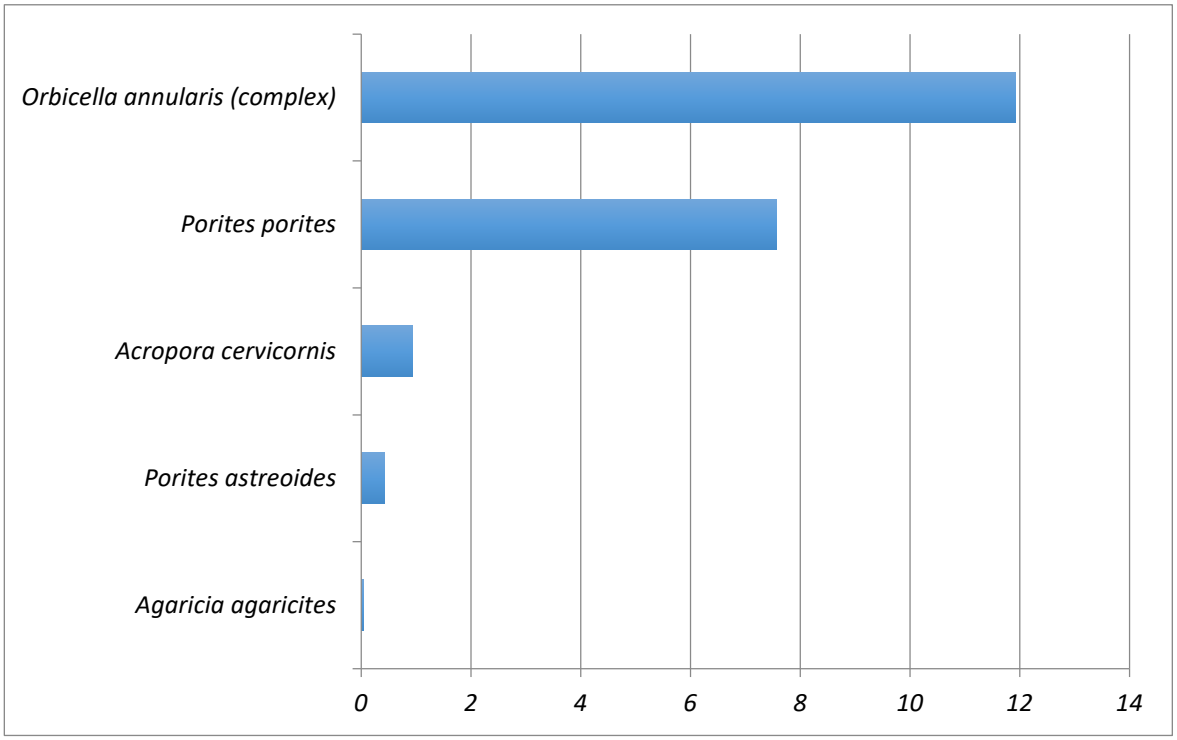


Figure 33. Mean substrate cover by coral species at Cayo Diablo 5, Fajardo. September 2016

Fishes and Motile Megabenthic Invertebrates

A total of 28 species of fish were identified within belt-transects from a depth of 5 - 6m at Cayo Diablo 5 (Table 42). Mean density was 49.8 Ind/transect (range: 33 – 66 Ind/transect) with a mean richness of 13.0 species per transect. An assemblage of seven species with a combined density of 41.4 Ind/transect, represented 83.1% of the total individuals within belt-transects. These included the Bluehead and Clown Wrasse, *Thalassoma bifasciatum*, *Halichoeres maculipinna*, Princess and Stoplight Parrotfish, *Scarus taeniopterus, Sparisoma viride* and the Dusky and Bicolor Damselfish, *Stegastes dorsopunicans*, *S. partitus* (Table 42). Twelve species were only observed in one transect.

The trophic structure of fishes at Cayo Diablo 5 was fairly well balanced between herbivores, small carnivores and zooplanktivores, mostly lacking the large demersal and/or pelagic predators. Herbivores were represented by 11 species, including five damselfishes (Pomacentridae), four parrotfishes (Scaridae) and two doctorfishes (Acanthuridae) with a combined density of 19.4 Ind/transect, representing 39.0% of the total density within belt-transects. Small opportunistic carnivores were represented by 12 species with a combined density of 17.6 Ind/transect, representative of 35.3% of the total and included four species of wrasses (Labridae), one blenny (Blenniidae), one Puffer (Tetraodontidae), one grunt (Haemulidae) and three Sea Basses small groupers (Serranidae). Medium and large sized piscivores not observed within belt-transects. Several juvenile and adult Schoolmaster Snappers (*L. apodus*) were observed outside transects.

The size frequency distributions of the commercially important fish species are presented in Table 42. Doctorfishes (Acanthuridae) were present across their entire size range from recruitment juveniles to adults. Parrotfishes were represented by six species. Early recruits of the Princess, Bucktooth and Stoplight Parrotfishes were present. Late juvenile and adult stages of the Redband and Stoplight, and Redtail were also present. Yellowtail snappers wee observed as early juveniles. Motile megabenthic invertebrates included the Long-spined Urchin, *Diadema antillarum* and the Fire Worm, *Hermodice carunculata*.

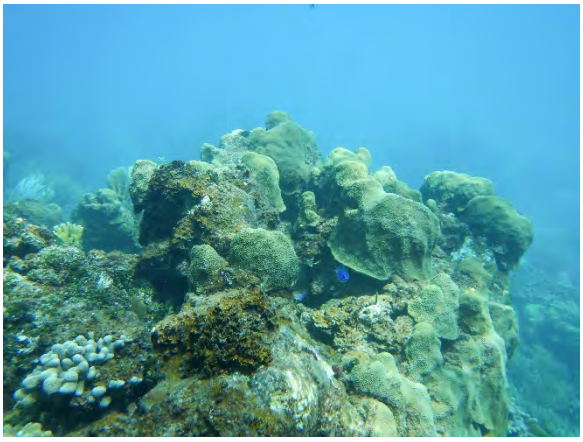
Table 42. DIAB 5. Taxonomic composition and abundance of fishes within 10 x 3 m belt-transects at Cayo Diablo, Fajardo, 5.4 m. Survey date: September 9, 2016

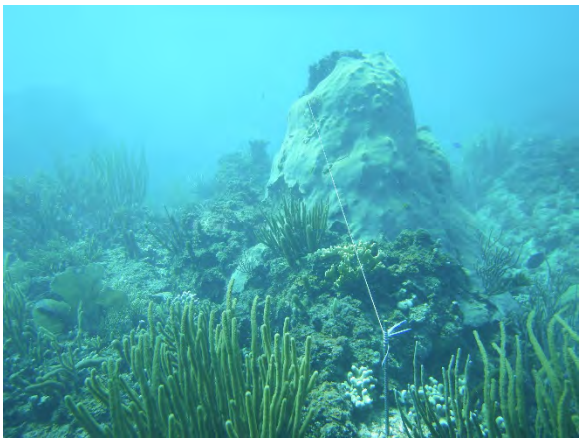
		Transects (Ind/30 m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	29	7	7	9	9	**12.2**
Chromis cyanea	Blue Chromis	3	16	18	5	4	**9.2**
Scarus taeniopterus	Princess Parrotfish	7	11	12		3	**6.6**
Stegastes dorsopunicans	Dusky Damselfish	10	6	3	6	7	**6.4**
Sparisoma viride	Stoplight Parrotfish	2	3	4	3	1	**2.6**
Stegastes partitus	Bicolor Damselfish	1	3	6	3		**2.6**
Halichoeres maculipinna	Clown Wrasse	1		3		5	**1.8**
Acanthurus coeruleus	Blue Tang	1	2		1	1	**1.0**
Chromis multilineata	Brown Chromis	5					**1.0**
Halichoeres garnoti	Yellow-head Wrasse	1	1	1	1	1	**1.0**
Acanthurus chirurgus	Doctorfish	1	1	1		1	**0.8**
Hypoplectrus nigricans	Black Hamlet	1	1	1	1		**0.8**
Stegastes planifrons	Yellow-eye Damselfish					3	**0.6**
Canthigaster rostrata	Caribbean Puffer		1			1	**0.4**
Sparisoma aurofrenatum	Redband Parrotfish	1		1			**0.4**
Sparisoma radians	Bucktooth Parrotfish				2		**0.4**
Abudefduf sexatilis	Sargent Major				1		**0.2**
Acanthurus bahianus	Ocean Surgeon		1				**0.2**
Cephalopholis cruentatus	Graysby					1	**0.2**
Haemulon flavolineatum	French Grunt	1					**0.2**
Halichoeres radiatus	Puddinwife					1	**0.2**
Lactophrys triqueter	Smooth Trunkfish			1			**0.2**
Malacoctenus triangulatus	Saddled Blenny				1		**0.2**
Microspathodon chrysurus	Yellowtail Damselfish	1					**0.2**
Priacanthus sp	Glasseye	1					**0.2**
Serranus tigrinus	Harlequin Bass		1				**0.2**
	TOTAL INDIVIDUALS	**66**	**54**	**58**	**33**	**38**	**49.8**
	TOTAL SPECIES	**16**	**13**	**12**	**11**	**13**	**13.0**

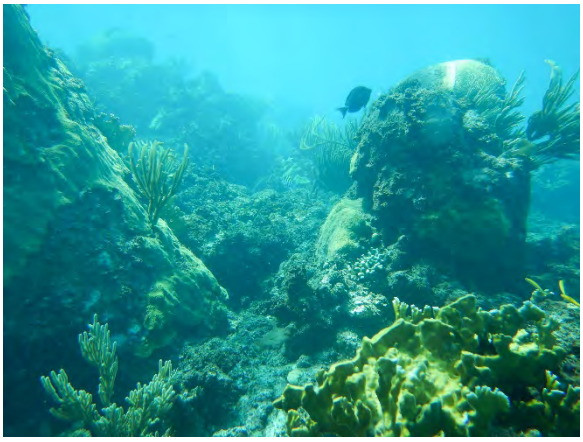
Table 43. DIAB 5. Size frequency distribution of fishes within 20 x 4 m belt-transects at Cayo Diablo Fajardo, 5.4 m. Survey date: September 9, 2016

		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Acanthurus bahianus	Ocean Surgeon		1-12			
Acanthurus chirurgus	Doctorfish	1-15		1-3		1-5
Acanthurus coeruleus	Blue Tang	1-5	1-12		2-15	1-8
			1-10		1-10	
			1-15			
			1-8			
Cephalopholis cruentatus	Graysby					1-12
Ocyurus chrysurus	Yellowtail Snapper	1-10				
Scarus iserti	Stripped Parrotfish					
Carangoides crysos	Bar Jack					3-33
Sparisoma chrysargyreum	Redtail Parrotfish			1-28		
Sparisoma viride	Stoplight Parrotfish	2-3	1-2	1-2	3-2	1-12
			1-10	2-12		
			1-18	1-25		
				1-30		
Sparisoma aurofrenatum	Redband Parrotfish	1-18		1-12		
Scarus taeniopterus	Princess Parrotfish	7-5	11-5	12-5		3-2
Sparisoma radians	Bucktooth Parrotfish				2-2	

Photo Album 14.
Cayo Diablo 5m







Dakiti Reef 20, Isla de Culebra

Physical Description

Dakiti Reef is a submerged coral reef formation located about 0.9 NM southwest of the entrance channel to Ensenada Honda, on the south coast of Isla de Culebra (Figure 34). The reef rises from a soft sediment bottom at a depth of 25 – 27 m and rises to a depth of about 3 m. There is a navigation buoy anchored in the reef to mark a pass through “Canal del Oeste”. The coral reef formation is continuous down to depths of at least 25 m. Transects were placed along the 20m depth contour. Panoramic views of the reef community at Dakiti 20 are shown in Photo Album 15.

Sessile-Benthic Reef Community

A mixed assemblage of benthic algae largely comprised by fleshy brown (mostly *Lobophora variegata* and *Dictyota sp*) and the encrusting red algae *Ramicrusta sp*. was the dominant biological category covering reef substrate at Dakiti 20 (Figure 35). The combined cover by fleshy algae and *Ramicrusta sp*. was 50.9%, representing 76.3% of the total cover by benthic algae. Turf algae and crustose coralline algae were also present in most transects, but with relatively lower reef substrate cover. Given the drastic reduction of reef substrate cover by turf algae at Dakiti 20 and other reefs of the east coast (this volume), it is evident that *Ramicrusta sp.* is displacing turf algae to colonize hard bottom at these reefs. It is uncertain at this point if *Ramicrusta sp.* has been displacing live corals as well, or affecting coral growth and coral recruitment in any way where present with such high substrate cover. Cyanobacterial patches of variable dimensions were intersected by all five transects with a mean cover 4.7% (Table 44).

A total of 15 coral species were intercepted by transects with a combined mean substrate cover of 15.1% (range: 7.8 – 21.3%). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant species with a mean cover of 10.3%, representing 68% of the total cover by corals (Figure 36). It was also the only coral species present in all five transects surveyed. Mustard-Hill Coral, *Porites astreoides,* Lettuce Coral, *Agaricia agaricites,* Greater Starlet Coral*, Siderastrea siderea,* and Finger Coral, *P. porites* were intersected by at least three transects with a combined cover of 2.9% (Table 46). Eight species were only represented by one colony. At some point, substrate cover by live corals was much higher at this reef, since a large fraction of

the cover by benthic algae has resulted from colonization over dead coral structures. The reef itself appears to be of sedimentary origin, but massive coral buildup is substantial and still represents an important contribution to the overall reef rugosity and habitat complexity.

Erect soft corals, or gorgonians (Order Octocorallia) were present in all transects surveyed with a mean density of 4.6 col/transect. Sea Plumes (*Antillogorgia sp*., *Pseudopterogorgia spp*) and the Sea Fan, *Gorgonia ventalina* were the most abundant in transects. The encrusting species, *Erythropodium caribaeorum* was present in two transects with a mean cover of 0.3% (Table 44). Sponges were represented by five species in transects with a combined mean cover of 1.1%. *Monachora arbuscula* and *Amphimedon compressa* were the only ones present in more than one transect. In general, sponges were present as small and mostly encrusting growth forms with minor contributions to the overall reef benthic habitat complexity.

Abiotic substrate categories presented a mean substrate cover of 11.9%. Reef overhangs were the main component of the abiotic category with a mean cover of 7.4%. Sand and gaps were also present in all transects with mean cover of 3.0% and 1.5%, respectively. The mean reef rugosity of 4.0m was influenced by the irregular reef bottom topography and massive coral colonies.

TABLE 44. DAKT 20. Percent cover by sessile-benthic categories along permanent transects, Dakiti Reef 20, Isla de Culebra. Survey date: September 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	3.99	5.36	2.60	3.44	4.66	**4.01**
Benthic Categories						
Abiotic						
Reef Overhang	8.51	7.20	6.67	4.48	10.12	**7.40**
Sand		4.83	1.11	4.38	4.78	**3.02**
Gap		2.28	0.78	1.98	2.48	**1.50**
Total Abiotic	**8.51**	**14.31**	**8.56**	**10.83**	**17.38**	**11.92**
Benthic Algae						
Lobophora variegata	23.92	34.46	29.89	23.13	30.66	**28.41**
Ramicrusta sp.	22.52	19.87	26.78	19.48	23.97	**22.53**
Dictyota spp.	12.21	3.83	10.89	13.02	9.55	**9.90**
Turf	3.10	1.37	2.78	9.69	5.25	**4.44**

CCA		1.82	1.11	1.67	0.96	**1.11**
Turf with sediment		1.82				**0.36**
Total Benthic Algae	**61.76**	**63.17**	**71.44**	**66.98**	**70.39**	**66.75**
Cyanobacteria	6.01	6.56	1.11	6.67	3.34	**4.74**
Hard Coral						
Orbicella annularis complex	18.42	9.30	13.33	7.81	2.48	**10.27**
Porites astreoides	1.00	3.01		0.52		**0.91**
Agaricia agaricites		0.64		1.35	2.39	**0.88**
Siderastrea siderea	1.50	0.91		0.52		**0.59**
Porites porites			0.33	1.67	0.38	**0.48**
Meandrina meandrites		0.27	1.89			**0.43**
Pseudodiploria strigosa				1.77		**0.35**
Mycetophyllia danaana					1.43	**0.29**
Colpophyllia natans			1.22			**0.24**
Diploria labyrinthiformis		0.91				**0.18**
Leptoseris cucullata		0.36		0.31		**0.14**
Montastraea cavernosa					0.67	**0.13**
Agaricia lamarcki					0.48	**0.10**
Mussa angulosa	0.40					**0.08**
Stephanocoenia intersepta				0.21		**0.04**
Total Hard Coral	**21.32**	**15.41**	**16.78**	**14.17**	**7.83**	**15.10**
Invertebrate						
Millepora alcicornis	0.40					**0.08**
Octocoral						
Erythropodium caribaeorum	1.00				0.48	**0.30**
# Gorgonians/transect	4	7	4	4	4	**4.6**
Sponge						
Monanchora arbuscula	0.20		1.67	0.31		**0.44**
Amphimedon compressa	0.80				0.57	**0.27**
Cliona caribbaea				1.04		**0.21**
Ircinia brown sp.		0.55				**0.11**
Clathria sp.			0.44			**0.09**
Total Sponge	**1.00**	**0.55**	**2.11**	**1.35**	**0.57**	**1.12**

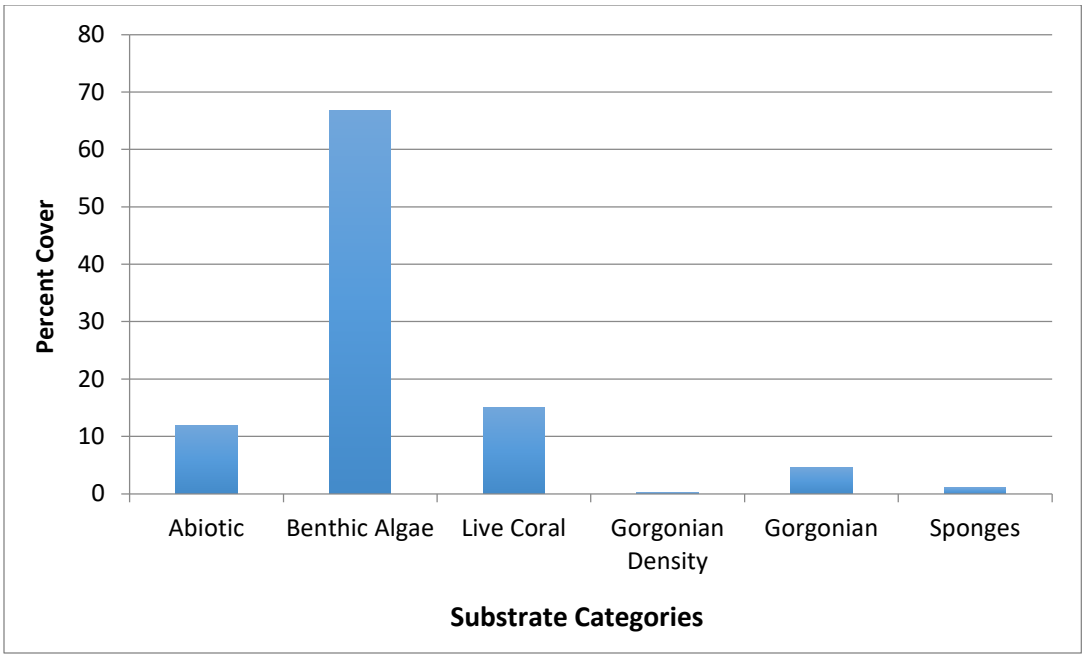


Figure 35. Mean substrate cover by benthic categories at Dakiti Reef 20, Culebra. September 2016

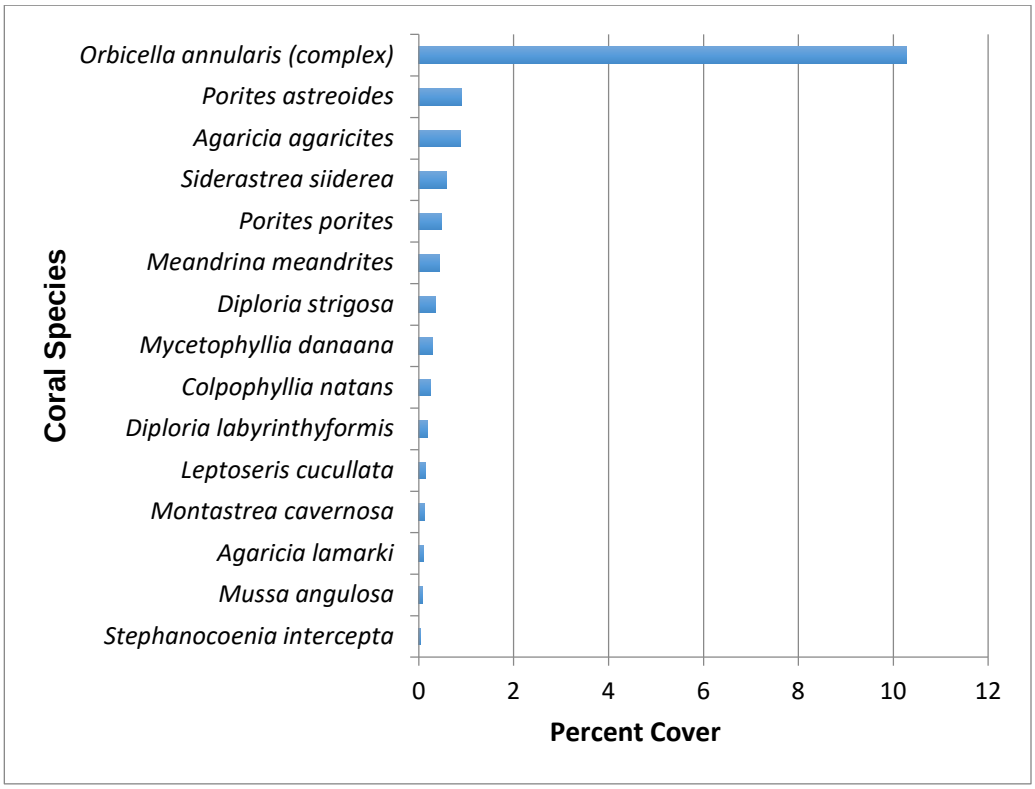


Figure 36. Mean substrate cover by coral species at Dakiti Reef 20, Culebra. September 2016

Fishes and Motile Megabenthic Invertebrates

A total of 32 species of fish were identified within belt-transects from a depth of 18 - 20 m at Dakiti Reef 20 (Table 45). Mean density was 284.2 Ind/transect (range: 132 – 443 Ind/transect) with a mean richness of 16.2 species per transect. The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean density of 238.4 Ind/transect, representing 83.9% of the total fish density. Schools of Creole Wrasse, *Clepticus parrae*, were observed over two transects with an average density of 11.0 Ind/transect, ranking second. In addition to the aforementioned species, an assemblage of nine species was present in at least four transects with a combined density of 16.6 Ind/transects, contributing 5.8% to the total fish density. This assemblage included the Stoplight and Redband Parrotfishes (*Sparisoma viride, S. aurofrenatum*), Three-spot Damselfish Damselfishes (*Stegastes planifrons),* Blue Tang (*Acanthurus coeruleus*), Squirrelfish (*Holocentrus rufus*), Sharknose Goby (*Elacatinus evelynae*), Bluehead and Yellowhead Wrasse (*Thalassoma bifasciatum, Halichoeres garnoti*), Fairy Basslet (*Gramma loreto*) and Caribbean Puffer (*Canthigaster rostrata*). Ten species were only present in one transect (Table 45).

The trophic structure of fishes at Dakiti Reef 20 was strongly represented by zooplanktivorous fishes due to the numerical dominance of the Masked Goby and to a lesser extent of Creole Wrasse, which combined for 87.8% of the total fishes within transects. Herbivores were represented by a highly specious assemblage, including five species of parrotfishes (Scaridae), two doctorfishes (Acanthuridae) and three damselfishes (Pomacentridae) with a combined density of 23.8 Ind/transect, representing 8.4% of the total density within belt-transects. Small opportunistic carnivores were represented by 14 species with a combined density of 9.4 Ind/transect, representing 3.3% of the total fishes within belt-transects and included two species of wrasses (Labridae), two squirrelfishes (Holocentridae), one grunt (Haemulidae), one Lionfish (*Pterois sp*), one goby (Gobiidae), and five hamlets and small groupers (Serranidae). Medium and large sized fish predators were represented by the Yellowtail and Dog Snappers (*Ocyurus chrysurus, Lutjanus jocu*) with combined densities lower than 1%.

The size-frequency distribution of commercially important fishes and the larger reef herbivores is presented in Table 46. Parrotfishes were in general represented by juveniles and young adults, but also included early recruitment juveniles of Stoplight and Princess parrotfishes. One adult Schoolmaster Snapper and young adult of the Lionfish and Graysbe were also present. Motile megabenthic invertebrates were not observed.

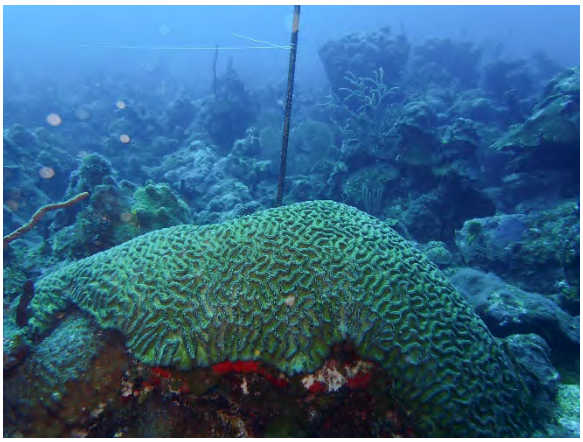
Table 45. Taxonomic composition and abundance of fishes within belt-transects at Dakiti Reef 20, Culebra, September 2016

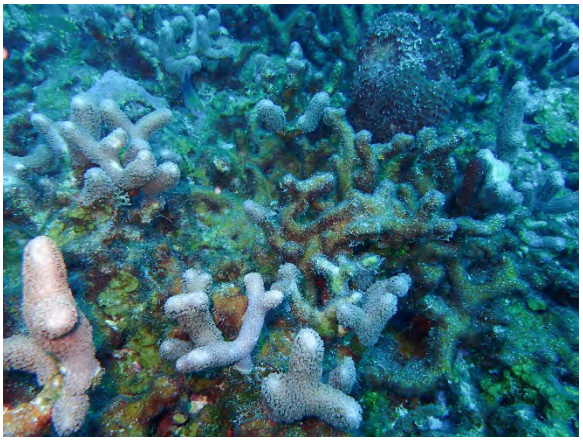
		Transects (Ind/30 m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	422	220	100	200	250	**238.4**
Clepticus parrae	Creole Wrasse				50	5	**11**
Scarus iserti	Stripped Parrotfish			12	13	16	**8.2**
Stegastes planifrons	Three-spot Damselfish	3	3	6	5	9	**5.2**
Sparisoma aurofrenatum	Redband Parrotfish	2	1	1	1	7	**2.4**
Scarus taeniopterus	Princess Parrotfish	4	6				**2**
Gramma loreto	Fairy Basslet	1		2	5	1	**1.8**
Canthigaster rostrata	Caribbean Puffer	1	1	2	1	3	**1.6**
Thalassoma bifasciatum	Bluehead Wrasse		3		5		**1.6**
Sparisoma viride	Stoplight Parrotfish	1		1	4	1	**1.4**
Gobiosoma evelynae	Sharknose Goby		3	1	1	2	**1.4**
Acanthurus coeruleus	Blue Tang	2		2	1	1	**1.2**
Halichoeres garnoti	Yellow-head Wrasse	1		1	1	1	**0.8**
Holocentrus rufus	Squirrelfish	1	1	1	1		**0.8**
Abudefduf sexatilis	Sargent Major		2	1		1	**0.8**
Stegastes adustus	Dusky Damselfish	2		1			**0.6**
Stegastes leucostictus	Beau Gregory	1	1	1			**0.6**
Hypoplectrus puella	White Hamlet		2		1		**0.6**
Hypoplectrus nigricans	Black Hamlet	1	1		1		**0.6**
Chromis cyanea	Blue Chromis				1	1	**0.4**
Chaetodon capistratus	Four-eye Butterflyfish				2		**0.4**
Hypoplectrus indigo	Indigo Hamlet				1	1	**0.4**
Acanthurus bahianus	Ocean Surgeon				1		**0.2**
Cephalopholis cruentatus	Graysby					1	**0.2**
Haemulon aurolineatum	Tomtate				1		**0.2**
Holacanthus ciliaris	Queen Angelfish				1		**0.2**
Aulostomus maculatus	Trumpetfish	1					**0.2**
Holacanthus tricolor	Rock Beauty				1		**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet		1				**0.2**
Hypoplectrus unicolor	Butter Hamlet				1		**0.2**
Sparisoma radians	Bucktooth Parrotfish				1		**0.2**
Pterois volitans	Lionfish					1	**0.2**
	TOTAL INDIVIDUALS	**443**	**245**	**132**	**300**	**301**	**284.2**
	TOTAL SPECIES	**14**	**13**	**14**	**24**	**16**	**16.2**

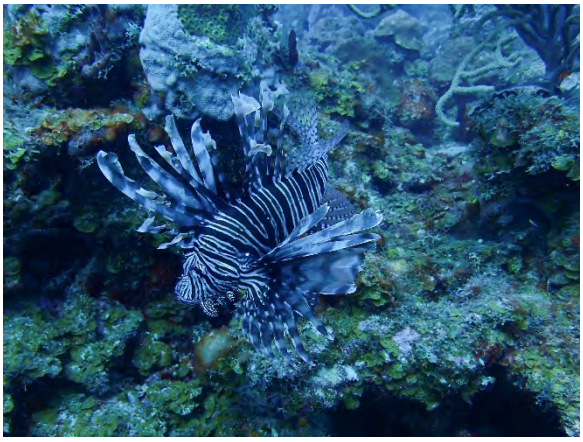
Table 46. DAKT 20. Size frequency distribution of fishes within 20 x 4 m belt-transects at Dakiti Reef 20, Culebra, September 9, 2016

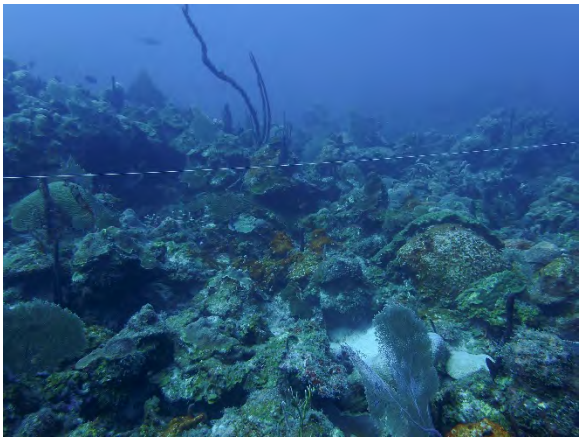
SPECIES	**COMMON NAME**	**Transects (# Ind - cm)**				
Scarus iserti	Stripped Parrotfish			14-10	13-5	14-5
						9-15
						1-20
Sparisoma viride	Stoplight Parrotfish	1-3		1-10	17-5	1-15
				1-20	2-25	2-20
				1-30		
Sparisoma aurofrenatum	Redband Parrotfish	1-10		1-10	2-15	1-15
		1-12				1-20
		1-15				
Epinephelus cruentatus	Graysby					1-20
Pterois volitans	Lionfish					1-20
Scarus taeniopterus	Princess Parrotfish	4-6	2-5			
			3-10			
			1-15			
Lutjanus apodus	Schoolmaster Snapper	1-45				
Lutjanus jocu	Dog Snapper					
Scarus vetula	Queen Parrotfish				1-25	

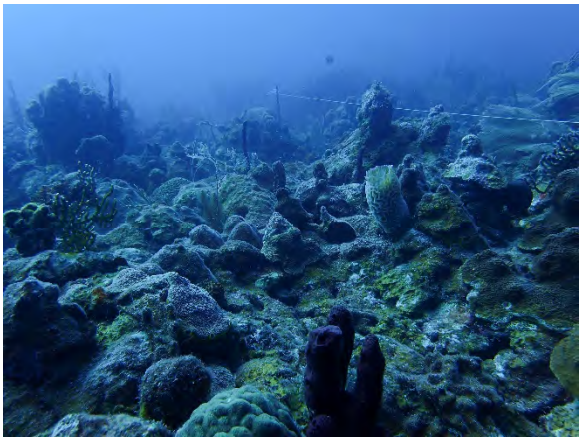
Photo Album 15.
Dakiti 20m

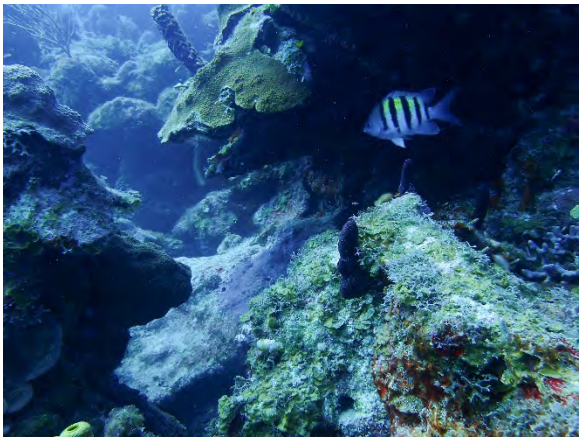


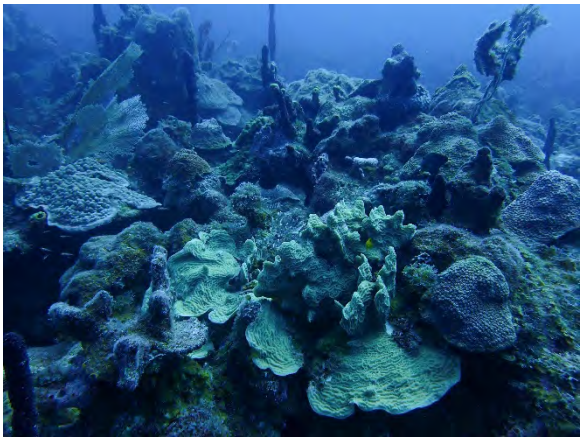












Carlos Rosario Reef 10, Isla de Culebra

Physical Description

Carlos Rosario is a coastal fringing reef within the Luis Pena Natural Reserve. It is located about 0.2 NM north of Pta. Tamarindo in the main island of Culebra (Figure 34). The reef rises from a sandy bottom at a depth of 9.0 m up to the surface across a steep fore-reef slope with several narrow terraces. The reef has significant structural buildup by scleractinian corals, particularly pillar growth of *Orbicella annularis*. The reef is an important tourist attraction and several anchoring buoys support charter operations that bring divers to the reef. Out transects were set very close to the reef base along the 7.0 m depth contour. Panoramic views of the Carlos Rosario Reef community are presented in Photo Album 16.

Sessile Benthic Reef Community

Benthic algae comprised by an assemblage of encrusting red algae (*Ramicrusta sp*), fleshy brown macroalgae (mostly *Lobophora variegata* and *Dictyota sp*), turf algae and crustose coralline algae was the dominant sessile-benthic category covering substrate at Carlos Rosario Reef 10 with a combined mean cover of 52.7% (Figure 37). The encrusting red alga, *Ramicrusta sp*. was prominent in all transects with a mean cover of 24.6% (range: 15.0–37.5%), representing 46.7% of the total cover by benthic algae (Table 47). Fleshy brown macroalgae were also prominent in all transects surveyed with a combined (*Lobophora* + *Dictyota*) of 22.1%. Turf algae presented a minor contribution to the benthic algae assemblage intercepted by transects with a mean cover of 5.3%. This algal component has probably been displaced and overgrown by the red encrusting alga, *Ramicrusta sp*. Patches of cyanobacteria were present in four transects with a mean cover of 2.2%.

Scleractinian corals were represented by 10 species with a combined mean substrate cover of 19.8% (range: 16.5 – 23.8%). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant coral intercepted by transects with a mean substrate cover of 9.4%, representing 47.5% of the total cover by corals (Figure 38). Mustard-Hill Coral, *Porites astreoides*, Greater Starlet Coral, *Siderastrea siderea* and Lettuce Coral, *Agaricia agaricites* were present in all transects with a combined reef substrate cover of 6.1%, representing an additional 30.7% of the

total cover by live scleractinian corals at Carlos Rosario Reef 10. As was noted for Dakiti Reef 20 (this volume), it is evident that this reef had a much higher cover by live corals, since the carbonate structural buildup, particularly of *O. annularis* is still standing but presently overgrown by the red alga, *Ramicrusta sp* and other encrusting reef biota. Fire Coral, *Millepora* spp. was present as small branching colonies with low substrate cover (0.2%).

Erect soft corals, or gorgonians (Order Octocorallia) were prominent in all transects surveyed with a mean density of 16.6 col/transect at Carlos Rosario Reef 10 (Table 47). Sea Rods (*Eunicea spp, Pseudoplexaura sp*) and the Sea Fan, *Gorgonia ventalina* were the most abundant in transects. The encrusting species, *Erythropodium caribaeorum* and Briareum asbestinum were present in all transects with a mean cover of 4.0%. Other encrusting species, *Briareum asbestinum* was observed in five and three transects, respectively with a combined mean cover of 5.0%. Sponges were represented by 15 species in transects with a combined mean cover of 2.0%. *Plakortis sp.* was the only species observed in more than two transects. In general, sponges were present as small and mostly encrusting growth forms with minor contributions to the overall reef benthic habitat complexity.

Abiotic substrate categories averaged a mean reef substrate cover of 18.0%, largely influenced by reef overhangs (10.5%). Sand and coral rubble were also present in most transects with a combined cover of 6.5%. The mean reef rugosity of 5.7m was mostly driven by coral ledges and overhangs (Table 47).

TABLE 47. CROS 10. Percent cover by sessile-benthic categories along permanent transects, Carlos Rosario Reef 20, Isla de Culebra. September 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	4.45	5.32	6.14	5.76	6.84	**5.70**
Benthic Categories						
Abiotic						
Reef overhang	7.95	14.44	8.93	8.61	12.39	**10.46**
Sand	5.91	1.83	8.15	0.00	6.32	**4.44**
Rubble	1.36	5.58	1.73	1.51		**2.04**
Gap		2.47		2.66		**1.03**
Total Abiotic	**15.21**	**24.31**	**18.82**	**12.79**	**18.70**	**17.97**
Benthic Algae						
Ramicrusta sp.	15.02	20.84	19.43	30.28	37.49	**24.61**
Dictyota spp.	20.83	21.21	18.13	11.90	9.56	**16.33**
Lobophora variegata	2.71	8.41	7.20	8.17	2.41	**5.78**
Turf	7.56	2.56	2.52	7.19	2.41	**4.45**
Turf with sediment	0.29	0.91	1.73		1.16	**0.82**
CCA	2.23		0.35	0.53	0.42	**0.70**
Total Benthic Algae	**48.64**	**53.93**	**49.35**	**58.08**	**53.45**	**52.69**
Cyanobacteria	2.81		2.52	1.42	4.49	**2.25**
Hard Coral						
Orbicella annularis complex	3.39	11.97	15.26	11.72	4.66	**9.40**
Porites astreoides	4.55	0.37	3.04	3.55	2.74	**2.85**
Siderastrea siderea	0.68	3.66	1.21	0.62	4.90	**2.21**
Montastraea cavernosa	8.72				0.33	**1.81**
Porites porites	2.52		3.21		1.41	**1.43**
Agaricia agaricites	0.97	0.64	0.78	2.40	0.33	**1.02**
Colpophyllia natans	2.23				1.33	**0.71**
Agaricia grahamae		0.91			0.00	**0.18**
Meandrina meandrites					0.75	**0.15**
Pseudodiploria strigosa			0.26			**0.05**
Total Hard Coral	**23.06**	**17.55**	**23.76**	**18.29**	**16.46**	**19.83**
Invertebrate						
Eudistoma sp.			0.35			**0.07**
Millepora alcicornis	0.19					**0.04**
Total Invertebrate	**0.19**		**0.35**			**0.11**
Octocoral						
Erythropodium caribaeorum	6.30	1.10	4.34	1.60	3.99	**3.46**
Briareum asbestinum			0.35	6.57	1.00	**1.58**
Pseudoplexaura flagellosa				0.36		**0.07**
Eunicea flexuosa		0.27				**0.05**

Gorgonia ventalina		0.18				**0.04**
Total Octocoral	**6.30**	**1.55**	**4.68**	**8.53**	**4.99**	**5.21**
# Gorgonians/transect	20	19	16	16	12	**16.6**
Sponge						
Plakortis sp.	0.87	0.27			0.33	**0.30**
Dictyonella funicularis				0.89	0.50	**0.28**
Amphimedon compressa		1.19				**0.24**
Monanchora arbuscula	0.29	0.46				**0.15**
Chondrilla caribensis		0.18			0.50	**0.14**
Cliona delitrix	0.68					**0.14**
Sponge	0.48		0.17			**0.13**
Verongula rigida	0.58					**0.12**
Niphates erecta		0.18	0.35			**0.11**
Mycale laevis					0.42	**0.08**
Aplysina cauliformis	0.39					**0.08**
Clathria sp.		0.37				**0.07**
Cliona aprica	0.29					**0.06**
Biemna sp.	0.19					**0.04**
Spirastrella coccinea					0.17	**0.03**
Total Sponge	**3.78**	**2.65**	**0.52**	**0.89**	**1.91**	**1.95**

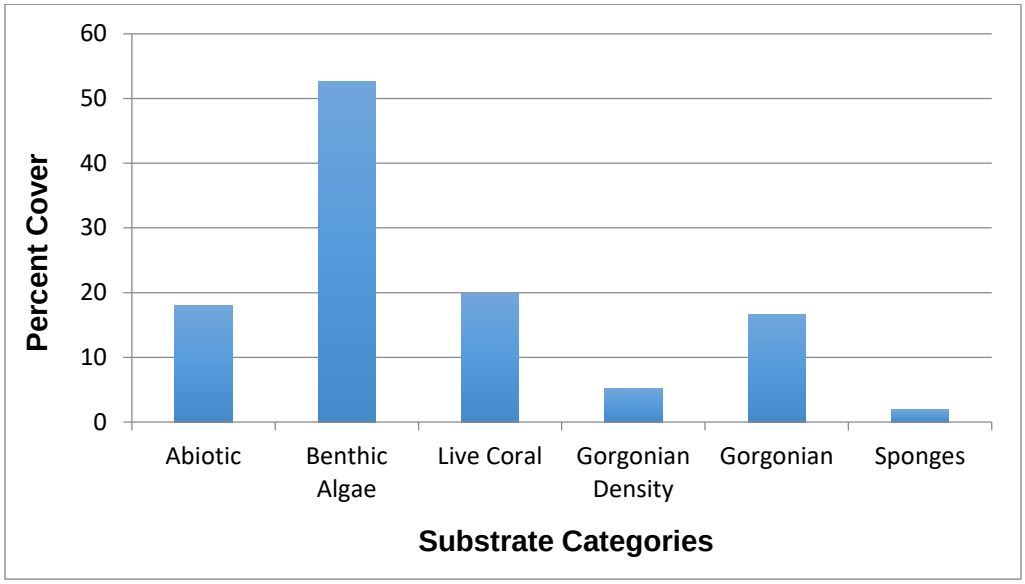


Figure 37. Mean substrate cover by benthic categories at Carlos Rosario Reef 20, Culebra. September 2016

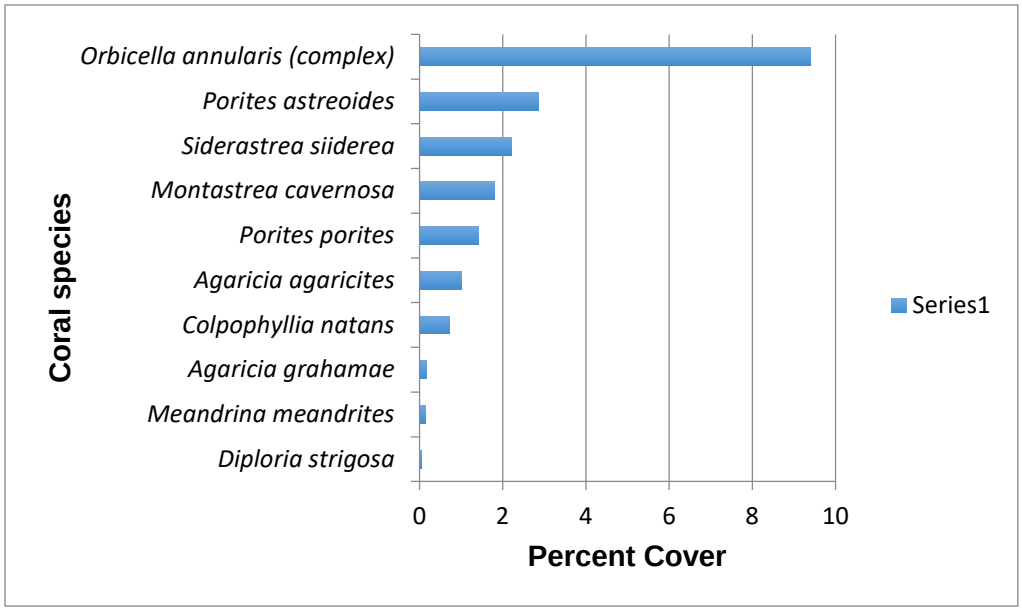


Figure 38. Mean substrate cover by coral species at Carlos Rosario Reef 20, Culebra. September 2016

Fishes and Motile Megabenthic Invertebrates

A total of 39 species of fish were identified within belt-transects from a depth of 7 - 9m at Carlos Rosario Reef 10 (Table 48). Mean density was 922.6 Ind/transect (range: 611 – 1102 Ind/transect) with a mean richness of 19.8 species per transect. This is the highest fish density ever recorded in the Puerto Rico Coral Monitoring Program. The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean density of 840.0 Ind/transect, representing 91.0% of the total fish density. Swarms of Masked Goby each with approximately 50 – 100 individuals were present in consecutive ledges and reef overhangs on all transects surveyed at Carlos Rosario Reef 10. Other 10 fish species were present in at least four out of the five transects surveyed. These included the Fairy Basslet (*Gramma loreto*), Stoplight, Redband and Striped Parrotfishes (*Sparisoma viride, S. aurofrenatum, Scarus iserti*), Beaugregory (*Stegastes leucostictus),* Blue Tang (*Acanthurus coeruleus*), Squirrelfish (*Holocentrus rufus*), Bridled Goby (*Coryphopterus glaucofraenum*), Yellowhead Wrasse (*Halichoeres garnoti*), French Grunt (*Haemulon flavolineatum*) and Graysbe (*Cephalopholis cruentatus*). Nine species were only present in one transect (Table 48).

The trophic structure of fishes at Carlos Rosario Reef 10 was strongly represented by zooplanktivorous fishes due to the numerical dominance of the Masked Goby and to a lesser extent of Creole Wrasse, Fairy Basslet and Blue Chromis, which combined for approximately 95% of the total fishes within transects. Herbivores were represented by a highly specious assemblage, including five species of parrotfishes (Scaridae), two doctorfishes (Acanthuridae) and three damselfishes (Pomacentridae) with a combined density of 24.8 Ind/transect, representing 2.6% of the total density within belt-transects. Small opportunistic carnivores were represented by 17 species with a combined density of 17.8 Ind/transect, representing 1.9% of the total fishes within belt-transects and included six species of hamlets and small groupers (Serranidae), one wrasse (Labridae), three squirrelfishes (Holocentridae), two grunts (Haemulidae), one puffer (Tetraodontidae), one goby (Gobiidae) and one goatfish (Mullidae). Medium and large sized fish predators were represented by the Yellowtail and Dog Snappers (*Ocyurus chrysurus, Lutjanus jocu*), one Green Moray Eel (*Gymnothorax moringa*) and Bar Jacks (*Caranx ruber*) with combined densities lower than 1% (Table 48). A large population of Yellowtail Snappers is associated with this reef.

The size-frequency distribution of commercially important fishes and the larger reef herbivores is presented in Table 49. Parrotfishes, represented by Princess, Striped and Stoplight (*Scarus taeniopterus, S. iserti, Sparisoma viride*) were present throughout most of their size range (3 – 27cm), from early recruitment juveniles to mid-sized adults. Young adults of Schoolmaster (25cm) and Dog Snappers (35cm) were observed as well as young adults of Graysbes (15 – 25cm), Coneys (25cm) and Red Hind (35cm). The Yellowtail Snapper population consists of approximately 100 individuals with a size distribution concentrated on young adults (12 – 35cm) (Table 49). Motile megabenthic invertebrates included three large Spiny Lobsters (*Panulirus argus*), including one within belt-transects.

Table 48. Taxonomic composition and abundance of fishes within belt-transects at Carlos Rosario Reef 10, Culebra, September 2016

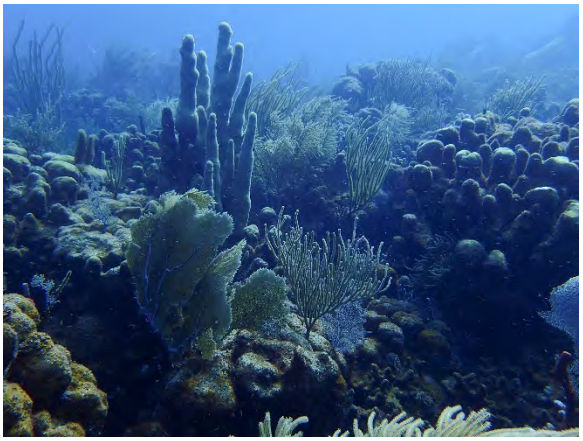
		Transects (Ind/30 m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	1000	1000	700	500	1,000	**840.0**
Gramma loreto	Fairy Basslet	13	46	31	20	12	**24.4**
Clepticus parrae	Creole Wrasse				50		**10.0**
Scarus taeniopterus	Princess Parrotfish	19		2		9	**6.0**
Stegastes leucostictus	Beau Gregory	7	3	6	6	6	**5.6**
Sparisoma viride	Stoplight Parrotfish	5	3		10	3	**4.2**
Haemulon aurolineatum	Tomtate		16				**3.2**
Scarus iserti	Stripped Parrotfish	1	4	5	3	2	**3.0**
Coryphopterus glaucofraenum	Bridled Goby	5	1	1	1	3	**2.2**
Chromis cyanea	Blue Chromis		3		4	2	**1.8**
Sparisoma aurofrenatum	Redband Parrotfish		3	3	3	3	**1.8**
Ocyurus chrysurus	Yellowtail Snapper	1	4	2		2	**1.8**
Canthigaster rostrata	Caribbean Puffer			3	4	1	**1.6**
Cephalopholis cruentatus	Graysby	2		3	2	1	**1.6**
Haemulon flavolineatum	French Grunt	2	2	1	1	1	**1.4**
Halichoeres garnoti	Yellow-head Wrasse	2	1	1	1	1	**1.2**
Holocentrus adcensionis	Squirrelfish		1	5			**1.2**
Chaetodon capistratus	Four-eye Butterflyfish	2	2		1		**1.0**

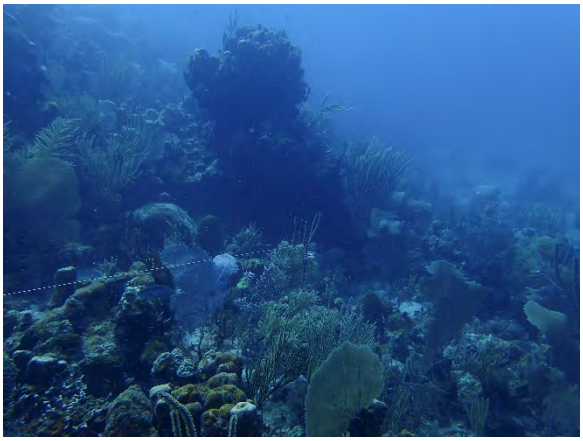
Hypoplectrus chlorurus	Yellowtail Hamlet	1		3		1	**1.0**
Sparisoma radians	Bucktooth Parrotfish	1	3			1	**1.0**
Stegastes planifrons	Three-spot Damselfish	2				3	**1.0**
Caranx ruber	Bar Jack				4		**0.8**
Mulloides martinicus	Yellowfin Goatfish		4				**0.8**
Hypoplectrus nigricans	Black Hamlet		2			2	**0.8**
Stegastes variabilis	Cocoa Damselfish	2				2	**0.8**
Stegastes adustus	Dusky Damselfish					3	**0.6**
Hypoplectrus unicolor	Butter Hamlet			1		2	**0.6**
Acanthurus bahianus	Ocean Surgeon		1	1			**0.4**
Holocentrus rufus	Squirrelfish				2		**0.4**
Acanthurus coeruleus	Blue Tang	1			1		**0.4**
Hypoplectrus puella	White Hamlet	1				1	**0.4**
Myripristis jacobus	Blackbar Soldierfish					1	**0.2**
Cephalopholis fulva	Coney		1				**0.2**
Holacanthus ciliaris	Queen Angelfish	1					**0.2**
Anisotremus virginicus	Porkfish	1					**0.2**
Lactophrys triqueter	Smooth Trunkfish				1		**0.2**
Lutjanus apodus	Schoolmaster Snapper		1				**0.2**
Lutjanus jocu	Dog Snapper		1				**0.2**
Gymnothorax funebris	Green Morey Eel			1			**0.2**
	TOTAL INDIVIDUALS	**1069**	**1102**	**769**	**611**	**1062**	**922.6**
	TOTAL SPECIES	**20**	**21**	**17**	**18**	**23**	**19.8**

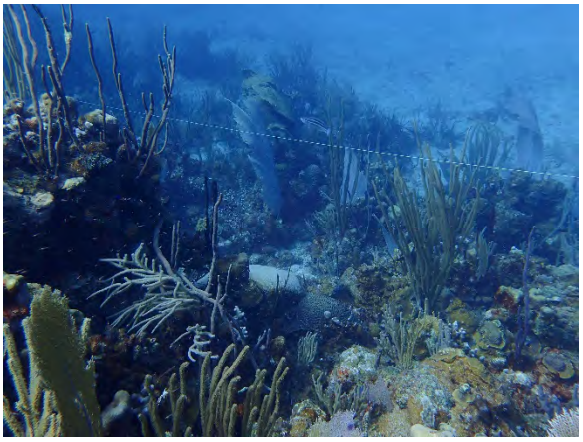
Table 49. CROS 10. Size frequency distribution of fishes within 20 x 4 m belt-transects at Carlos Rosario Reef 10, Culebra, September 2016

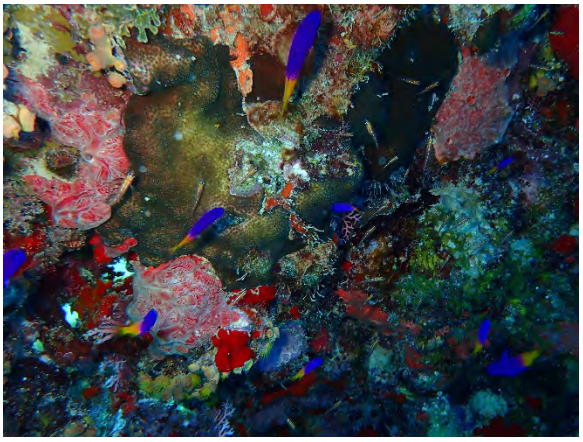
		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Scarus iserti	Stripped Parrotfish	1-10	1-3	5-3	3-3	2-5
		1-22	1-5			
			2-10			
Sparisoma viride	Stoplight Parrotfish	2-3	1-15		10-3	2-7
		1-12	1-18			2-22
		1-20	1-20			1-30
		1-27				
Sparisoma aurofrenatum	Redband Parrotfish		1-10	1-5	1-10	1-10
			1-12	2-10	1-12	1-15
			1-15	1-20	1-15	1-22
Ocyurus chrysurus	Yellowtail Snapper		2-25	1-25	1-25	2-12
			2-30	1-30	1-30	2-15
						2-25
						1-27
Epinephelus fulva	Coney		1-25			
Epinephelus guttatus	Red Hind			1-35		
Epinephelus cruentatus	Graysby	1-15		1-15	1-10	1-25
		1-17		1-20	1-15	
		1-20		1-25		
Scarus taeniopterus	Princess Parrotfish	12-3	2-17	2-25	1-25	5-3
		5-5				4-7
Sparisoma radians	Bucktooth Parrotfish	1-3				1-3
Lutjanus apodus	Schoolmaster Snapper	1-25				
Lutjanus jocu	Dog Snapper			1-35		
Ocyurus chrysurus	Yellowtail Snapper	3-25				
		1-30				
		1-35				

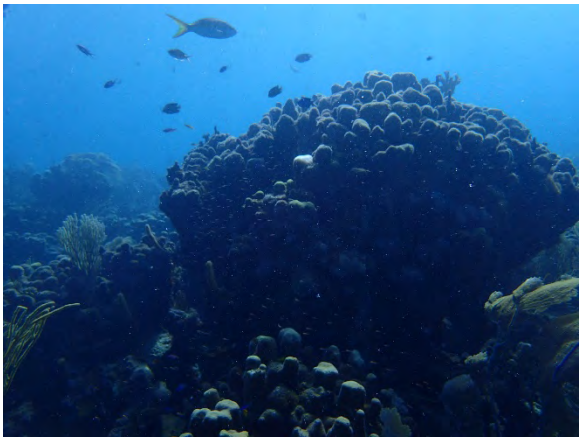
Photo Album 16.
Carlos Rosario 10m

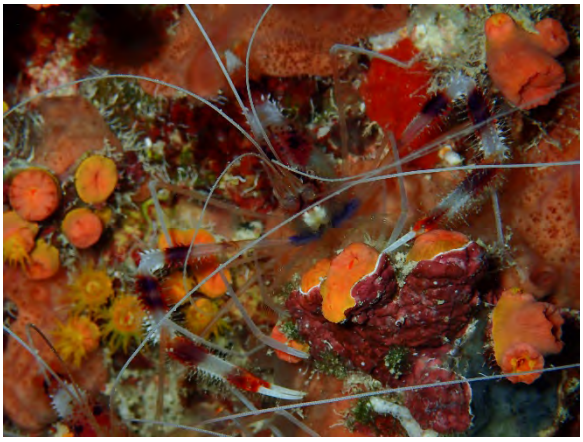












Luis Pena Reef 5, Isla de Culebra

Physical Description

The island of Luis Pena is located about 0.3 – 0.5 NM off the west coast of Culebra. Shallow water coral reefs fringe the eastern shoreline from the surface down to a depth of approximately 7m (Figure 34). The main coral formation is an irregular and patchy pillar growth of Boulder Star Coral, *Orbicella annularis*, with areas dominated by thickets of Finger Coral, *Porites porites*. Our survey was performed on the central eastern coastline of Cayo Luis Pena, within the LP Marine Reserve. Transects were run perpendicular to the shoreline over a set of discontinuous patches of *O. annularis* coral buildups. Panoramic views of the Luis Pena 5 Reef community are shown in Photo Album 17.

Sessile Benthic Reef Community

Benthic algae, a mixed assemblage of encrusting red alga (*Ramicrusta sp*), turf algae, green calcareous algae (mostly *Halimeda spp*), fleshy brown macroalgae (mostly *Dictyota sp*) and crustose coralline algae was the dominant sessile-benthic category covering the reef substrate at Luis Pena Reef 5 with a combined mean cover of 66.2% (Figure 39). The encrusting red alga, *Ramicrusta sp*. was strongly dominant in all transects with a mean cover of 56.8% (range: 51.6–61.7%), representing 85.9% of the total cover by benthic algae (Table 50). *Ramicrusta sp*. was observed as a coat of dark burgundy paint over all available hard surfaces, but particularly over abundant dead coral structures. As previously noted for other reefs in the east coast of PR (Fajardo and Culebra – this volume), it is unclear if *Ramicrusta* is displacing live coral, or affecting scleractinian coral growth and/or recruitment in any way. It is expected that this quantitative baseline characterization will allow such analysis during prospective monitoring surveys. Patches of cyanobacteria were present in all transects with a mean cover of 3.2%.

Scleractinian corals were represented by nine species with a combined mean substrate cover of 17.0% (range: 10.5 – 22.1%). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant coral intercepted by transects with a mean substrate cover of 10.2%, representing 60.1% of the total cover by corals (Figure 40). Mustard-Hill and Finger Corals, *Porites astreoides*, *P. porites* were present (along with *O. annularis*) in all five transects with a combined reef substrate cover of 3.2%, representing an additional 19.1% of the total cover by live scleractinian corals at Luis Pena Reef 5 (Table 50). Large colonies of Boulder Brain Coral,

Colpophyllia natans were intercepted by three transects with a combined mean cover of 1.8%. As was noted for Dakiti and Carlos Rosario Reefs of Isla de Culebra, it is evident that this reef had a much higher cover by live corals, since the carbonate structural buildup, particularly of *O. annularis* is still standing but presently overgrown by the red alga, *Ramicrusta sp* and other encrusting reef biota. Fire Coral, *Millepora* spp. was present as small branching colonies with low substrate cover (0.2%).

Erect soft corals, or gorgonians (Order Octocorallia) were prominent in all transects surveyed with a mean density of 19.2 col/transect at Luis Pena Reef 5 (Table 50). Sea Rods (*Eunicea spp, Pseudoplexaura sp*) and the Sea Fan, *Gorgonia ventalina* were the most abundant in transects. The encrusting species, *Erythropodium caribaeorum* and *Briareum asbestinum* were present in several transects with a combined mean cover of 1.5%. Sponges were represented by six species in transects with a combined mean cover of 1.1%. *Dictyonella funicularis* was the only species observed in more than two transects. In general, sponges were present as small and mostly encrusting growth forms with minor contributions to the overall reef benthic habitat complexity.

Abiotic substrate categories, mostly contributed by reef overhangs (5.2%) and sand (3.1%) averaged a mean reef substrate cover of 10.5%. The mean reef rugosity of 4.4m was mostly driven by coral ledges and overhangs (Table 50).

TABLE 50. LPEN 5. Percent cover by sessile-benthic categories along permanent transects, Luis Pena Reef 5, Isla de Culebra. September 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	4.69	4.34	2.94	5.26	4.69	**4.38**
Benthic Categories						
Abiotic						
Sand	7.05	5.37	0.32	10.18	3.05	**5.20**
Reef Overhang	4.39	1.76	0.54	3.30	5.82	**3.16**
Gap	0.38	2.05	0.65	0.73	2.29	**1.22**
Rubble	0.95				3.81	**0.95**
Total Abiotic	**12.77**	**9.18**	**1.52**	**14.22**	**14.97**	**10.53**
Benthic Algae						

Ramicrusta sp.	61.68	55.76	57.58	57.61	51.57	**56.84**
Turf with sediment	4.29	4.98	1.73	6.61	1.53	**3.83**
Turf	1.81	1.95	9.63	0.55		**2.79**
Halimeda spp.	1.05	2.34	2.38	1.65	3.72	**2.23**
Dictyota spp.	0.57			0.92	0.19	**0.34**
CCA	0.19				0.48	**0.13**
Total Benthic Algae	**69.59**	**65.04**	**71.32**	**67.34**	**57.48**	**66.15**
Cyanobacteria	3.62	2.93	3.90	2.11	3.62	**3.24**
Hard Coral						
Orbicella annularis complex	7.44	10.06	11.15	5.69	16.49	**10.16**
Porites astreoides	2.19	2.64	1.62	1.93	1.05	**1.89**
Colpophyllia natans		2.73	2.81	3.30		**1.77**
Porites porites	0.86	1.37	0.76	1.56	2.19	**1.35**
Siderastrea siderea		3.91	0.32			**0.85**
Diploria labyrinthiformis		0.68	1.95			**0.53**
Montastraea cavernosa			0.43	0.92		**0.27**
Porites furcata		0.68				**0.14**
Agaricia agaricites					0.19	**0.04**
Total Hard Coral	**10.49**	**22.07**	**19.05**	**13.39**	**19.92**	**16.98**
Invertebrate						
Millepora alcicornis			0.97			**0.19**
Octocoral						
Erythropodium caribaeorum	0.57		1.84	0.37	3.62	**1.28**
Briareum asbestinum		0.29	0.43	0.37		**0.22**
Eunicea flexuosa	0.29		0.32			**0.12**
Pseudoplexaura wagenaari flagellosa		0.20	0.22			**0.08**
Antillogorgia americana				0.37		**0.07**
Eunicea succinea				0.28		**0.06**
Total Octocoral	**0.86**	**0.49**	**2.81**	**1.38**	**3.62**	**1.83**
# Gorgonians/transect	20	21	16	20	19	**19.2**
Sponge						
Dictyonella funicularis		0.29		1.19	0.38	**0.37**
Iotrochota birotulata	1.62					**0.32**
Mycale laevis	0.38		0.43			**0.16**
Amphimedon compressa	0.38			0.37		**0.15**
Chondrilla caribensis		0.29				**0.06**
Niphates erecta	0.29					**0.06**
Total Sponge	**2.67**	**0.29**	**0.43**	**1.56**	**0.38**	**1.07**

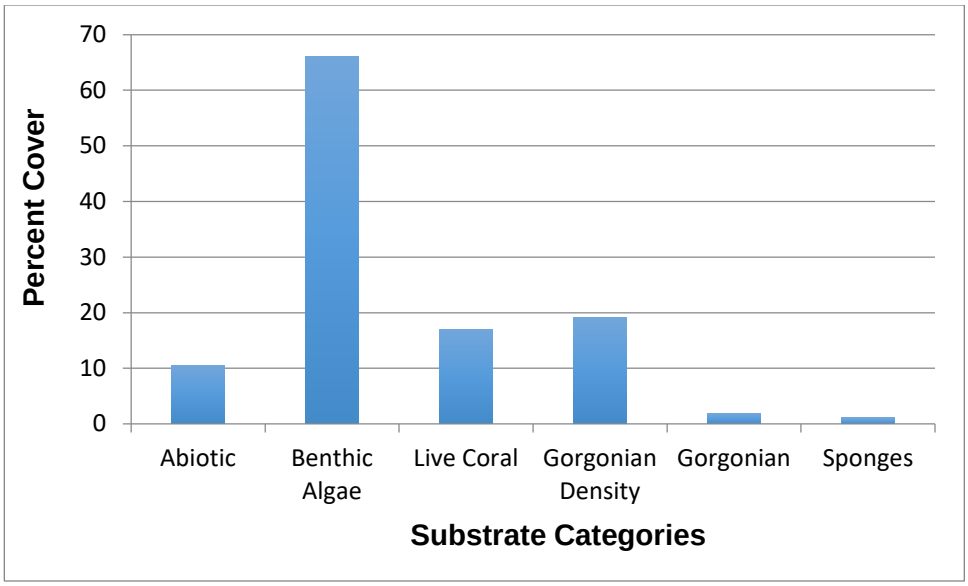


Figure 39. Mean substrate cover by benthic categories at Luis Pena Reef 5, Culebra. September 2016

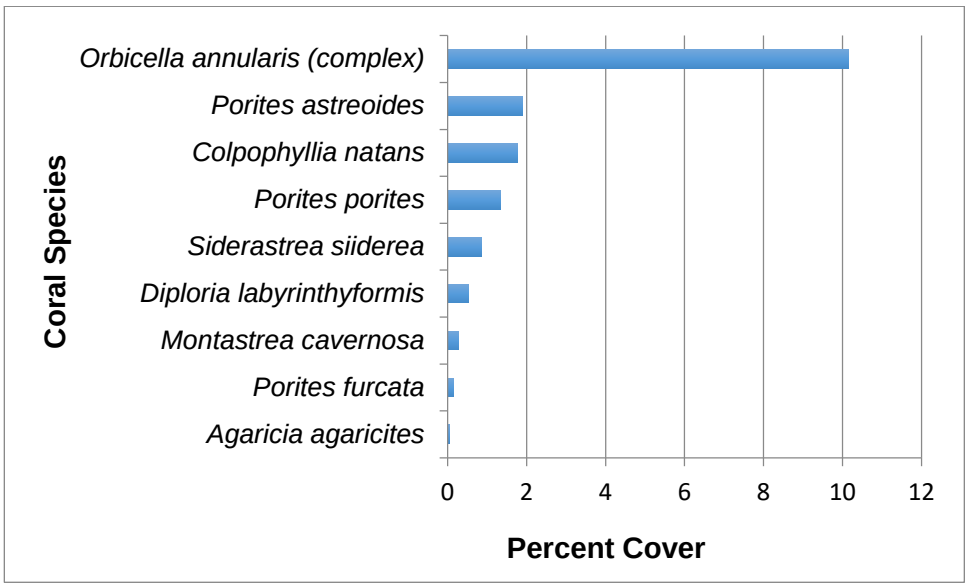


Figure 40. Mean substrate cover by coral species at Luis Pena Reef 5, Culebra. September 2016

Fishes and Motile Megabenthic Invertebrates

A total of 35 species of fish were identified within belt-transects from a depth of 5 - 6m at Luis Pena Reef 5 (Table 51). Mean density was 179.0 Ind/transect (range: 95 – 264 Ind/transect) with a mean richness of 18.4 species per transect. The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean density of 118.0 Ind/transect, representing 65.9% of the total fish density. An assemblage of nine fish species (including the Masked Goby) were present in at least four transects with a combined density of 159.2 Ind/transect, representing 88.9% of the total individuals within belt-transects. These included the Bluehead Wrasse, *Thalassoma bifasciatum*, Princess, Striped, Redband and Stoplight Parrotfishes, *Scarus taeniopterus, S. iserti, Sparisoma aurofrenatum, S. viride* and the Dusky and Three-spot Damselfishes, *Stegastes dorsopunicans*, *S. planifrons* and the Squirrelfish, *Holocentrus rufus* (Table 51). Four species were only observed in one transect.

The trophic structure of fishes at Luis Pena Reef 5 was dominated by zooplanktivores largely due to the numerical prominence of Masked Goby. Other lesser components of the zooplanktivore assemblage included the Blue and Brown Chromis, Bicolor Damselfish and Fairy Basslet. Herbivores were represented by 12 species, including five parrotfishes (Scaridae), five damselfishes (Pomacentridae), and two doctorfishes (Acanthuridae) with a combined density of 31.0 Ind/transect, representing 17.3% of the total density within belt-transects. Small opportunistic carnivores were represented by 13 species with a combined density of 23.8 Ind/transect, representative of 13.3% of the total and included two species of wrasses (Labridae), one Puffer (Tetraodontidae), one goatfish (Mullidae), one squirrelfish (Holocentridae), one grunt (Haemulidae), one goby (Gobiidae), one trumpetfish (Aulostomidae), and five hamlets and small groupers (Serranidae). Medium sized piscivores included the Red Hind and the Yellowtail Snappers. Several juvenile and adult Schoolmaster Snappers (*L. apodus*), and one Dog Snapper (*L. jocu*) were observed outside transects.

The size frequency distributions of the commercially important fish species are presented in Table 52. Parrotfishes were represented by five species. Early recruits (2-5cm) of the Princess, Striped, Bucktooth and Stoplight Parrotfishes were present. Late juvenile and adult stages (12-27cm) of the Redband, Stoplight and Yellowtail Parrotfish were also observed. Yellowtail snappers were observed both as recruitment juveniles (5 cm), juveniles and adults (20-35cm). Red Hinds were present as small to moderate sized adults (25 - 33cm). Motile megabenthic

invertebrates included the Long-spined Urchin, *Diadema antillarum* and the Fire Worm, *Hermodice carunculata*. One juvenile Spiny Lobster (*Panulirus argus*) was observed outside transects.

Table 51. Taxonomic composition and abundance of fishes within belt-transects at Luis Pena Reef 5, Culebra, September 2016

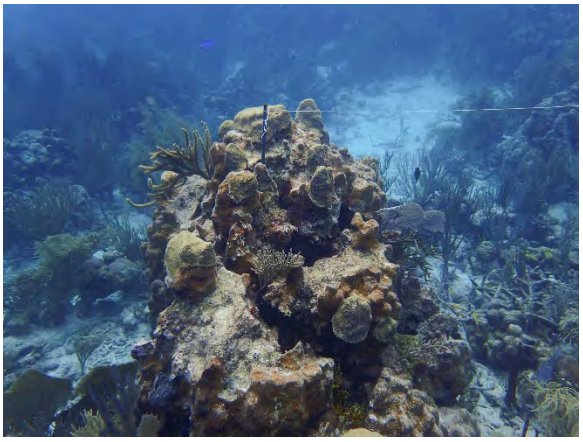
		Transects (Ind/30m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	200	50	60	160	120	**118.0**
Thalassoma bifasciatum	Bluehead Wrasse	15	20	10	18	24	**17.4**
Stegastes planifrons	Three-spot Damselfish	4	7	5	10	12	**7.6**
Scarus iserti	Stripped Parrotfish	8	5	7	2	4	**5.2**
Scarus taeniopterus	Princess Parrotfish		2		6	15	**4.6**
Stegastes adustus	Dusky Damselfish	5	6	5	3		**3.8**
Sparisoma viride	Stoplight Parrotfish	3	7		5	3	**3.6**
Chromis cyanea	Blue Chromis	5		1	2		**1.6**
Sparisoma aurofrenatum	Redband Parrotfish	2	1		2	2	**1.4**
Stegastes leucostictus	Beau Gregory	4	2	1			**1.4**
Acanthurus coeruleus	Blue Tang	2	2	1	1	1	**1.4**
Canthigaster rostrata	Caribbean Puffer	3		2	1		**1.2**
Mulloides martinicus	Yellowfin Goatfish		5			1	**1.2**
Microspathodon chrysurus	Yellowtail Damselfish	1	3			1	**1.0**
Chaetodon capistratus	Four-eye Butterflyfish		2		1	1	**0.8**
Stegastes partitus	Bicolor Damselfish	3	1				**0.8**
Caranx ruber	Bar Jack	4					**0.8**
Holocentrus rufus	Squirrelfish	1	1		1	1	**0.8**
Ocyurus chrysurus	Yellowtail Snapper	1	2	1			**0.8**
Gramma loreto	Fairy Basslet		1			1	**0.4**
Coryphopterus glaucofraenum	Bridled Goby		1		1		**0.4**
Halichoeres garnoti	Yellow-head Wrasse		2				**0.4**
Chaetodon ocellatus	Spotfin Butterflyfish		2				**0.4**
Acanthurus chirurgus	Doctorfish				1	1	**0.4**
Epinephelus guttatus	Red Hind				2		**0.4**
Cephalopholis cruentatus	Graysby				1	1	**0.4**
Haemulon flavolineatum	French Grunt	1		1			**0.4**
Aulostomus maculatus	Trumpetfish			1	1		**0.4**
Hypoplectrus puella	White Hamlet				1	1	**0.4**
Hypoplectrus unicolor	Butter Hamlet	1	1				**0.4**

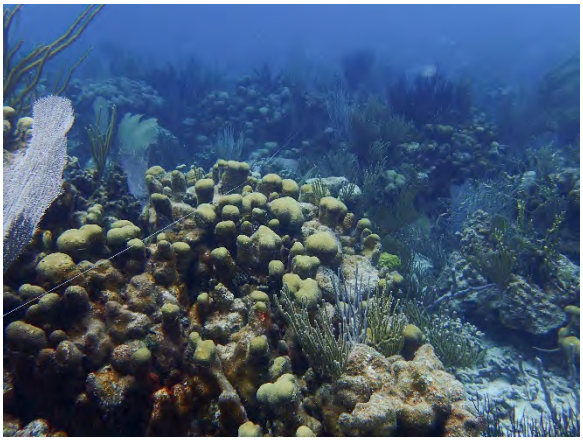
Sparisoma radians	Bucktooth Parrotfish				1	1	**0.4**
Chromis multilineata	Brown Chromis				1		**0.2**
Hypoplectrus nigricans	Black Hamlet					1	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	1					**0.2**
Stegastes variabilis	Cocoa Damselfish				1		**0.2**
	TOTAL INDIVIDUALS	**264**	**123**	**95**	**222**	**191**	**179.0**
	TOTAL SPECIES	**19**	**21**	**12**	**22**	**18**	**18.4**

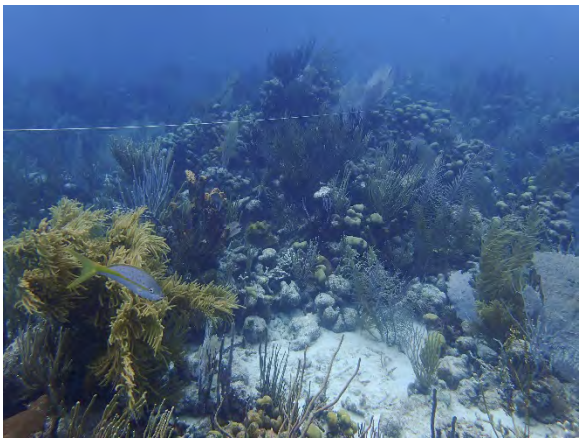
Table 52. LPEN. Size frequency distribution of fishes within 20 x 4 m belt-transects at Luis Pena Reef 5, Culebra, September 2016

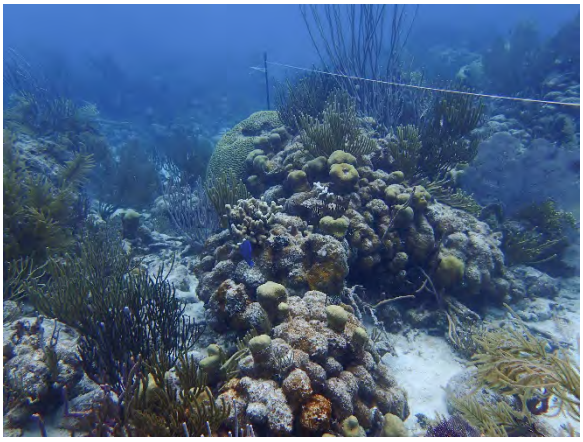
SPECIES	**COMMON NAME**	1	2	3	4	5
Scarus iserti	Stripped Parrotfish	6-5	5-6	5-3	2-3	3-2
		1-10		1-10		1-15
		1-15		1-15		
Sparisoma viride	Stoplight Parrotfish		5-3		3-3	1-3
			2-5		1-12	1-9
					1-27	1-15
Sparisoma aurofrenatum	Redband Parrotfish	1-12	1-5	1-20	3-15	3-15
		3-15	1-15			
Ocyurus chrysurus	Yellowtail Snapper	1-30	1-5	1-20		1-25
			1-30			
			1-35			
Epinephelus guttatus	Red Hind				1-25	
					1-33	
Epinephelus cruentatus	Graysby				1-17	
Scarus taeniopterus	Princess Parrotfish		1-5		5-3	3-3
			1-15		1-15	8-6
			1-20			4-9
Lutjanus jocu	Dog Snapper			1-35		
Sparisoma rubripinne	Yellowtail Parrotfish					1-27

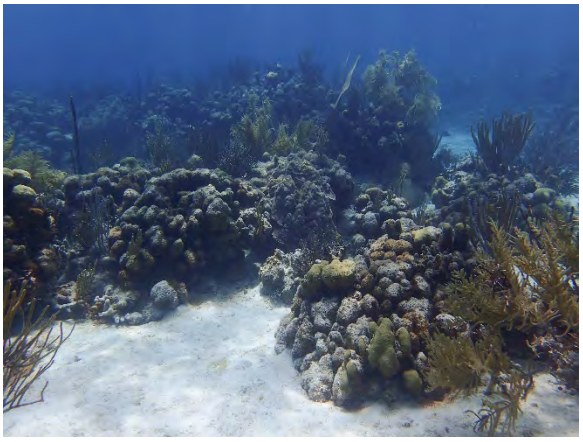
Photo Album 17.
Luis Peña 5m

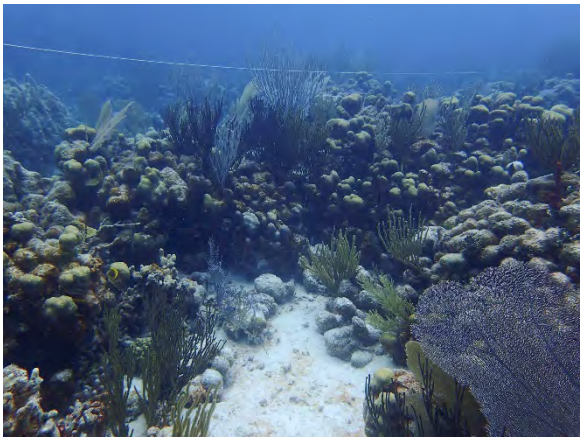


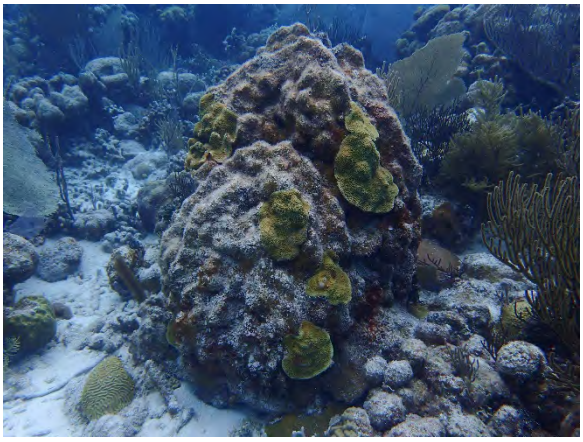


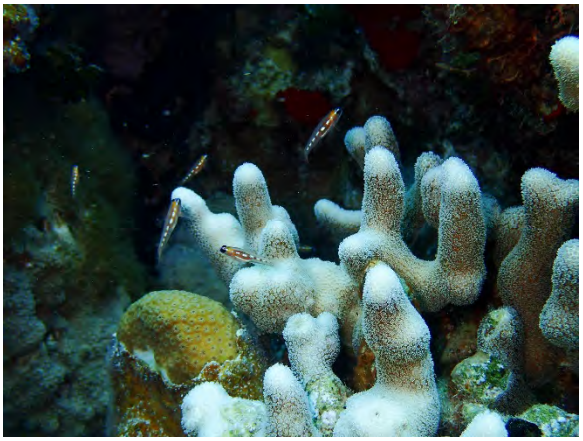












El Seco Reef-Vieques

Physical Description

"El Seco" is a submerged promontory, or ridge that rises from a deep outer shelf basin at the southeastern tip of the Vieques shelf, approximately 6 km from Punta del Este. The promontory with an elliptical shape runs along a north-south axis and rises from the basin at depths of 33 – 36 m to a mostly flat hard ground reef top at depths of 23 – 28 m (Figure 41). Depth increases towards the shelf-edge to the east and south of the ridge, and decreases towards the north, where an extensive mesophotic coral reef system consisting of several benthic habitats was discovered (Garcia-Sais et al. 2011). The coral reef system ends as patch reef spurs separated by coralline sand pools at depths between 40 – 45 m. Exceptionally clear waters prevail at "El Seco" with underwater visibility generally exceeding the 30 - 40 m range.

The coral bank reef habitat at El Seco is an impressive continuous formation of scleractinian corals growing at depths of 33 – 41 m (110 – 135') throughout the northern and northeastern sections of the study area. The coral reef is largely (almost a biotope) of Boulder Star Coral, *Orbicella franksi* growing as laminar planks of up to 1 m of diameter, supported by pedestals of unknown origin and variable heights. Even though its entire areal extension has not been mapped, the coral reef formation off southeast Vieques represents the largest continuous coral reef benthic habitat reported for Puerto Rico (Garcia-Sais et al. 2011). Panoramic views of the coral reef system of El Seco are presented as Photo Album 18.

Sessile-Benthic Reef Community

Substrate cover by sessile-benthic categories from transects surveyed at El Seco 30 are presented in Table 53. The combined assemblage of benthic algae, comprised by fleshy brown algae (*Lobophora sp*.), red encrusting algae, turf algae, and coralline red algae was the dominant category in terms of percent cover with a mean of 50.5% (range: 40.7 – 59.8%) (Figure 42). The Encrusting Fan Alga, *Lobophora variegata* was the main component of the benthic algae with an average cover of 24.8 %, representing 49.1% of the total cover by benthic macroalgae. The Burgundy Crust Alga, *Peyssonnelia sp*. was prominent in all transects with a mean cover of 17.5%, representing 34.6% of the total benthic algae. Turf algae, a mixed array of short filamentous algae were also present in all transects with a mean cover of 7.2%. This

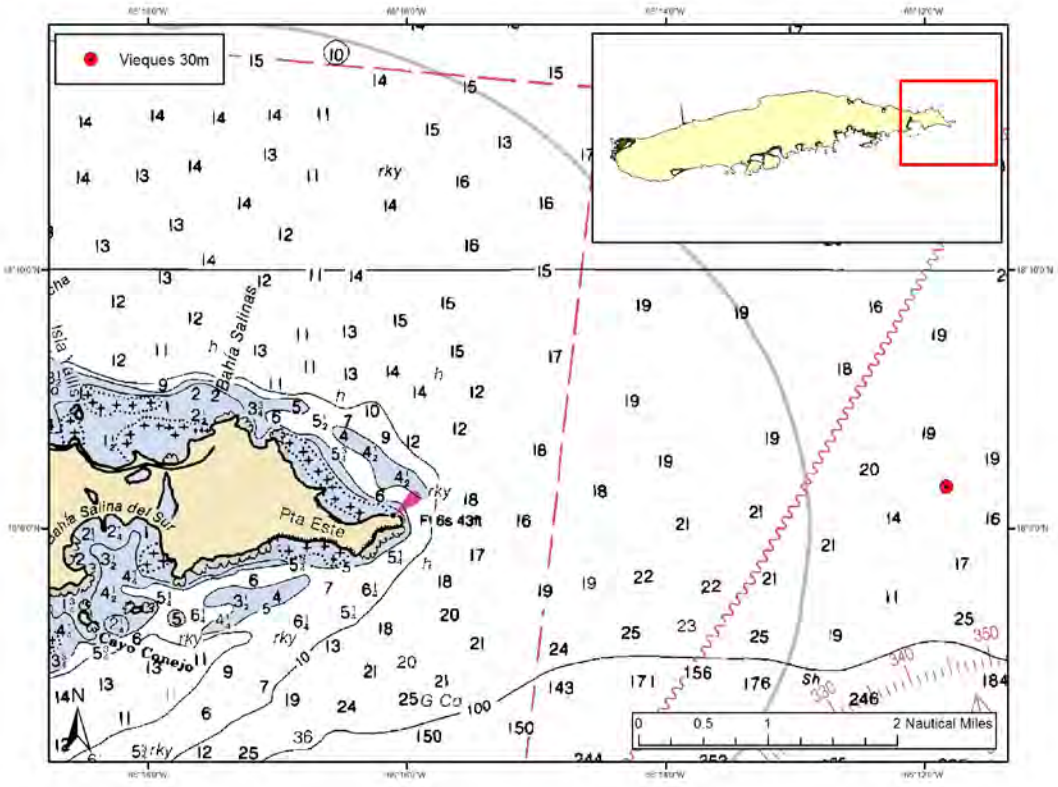


Figure 41. Location of coral reef monitoring station at El Seco Reef, Vieques.

represents a four fold decline relative to the previous monitoring survey during October 2013 (Garcia-Sais et al., 2014). The reduction of cover by turf algae was compensated by increments of cover by encrusting brown (*Lobophora variegata*) and the appearance of Burgundy Crust Alga, *Peyssonnelia sp*. Most of the substrate cover by benthic algae was associated with vertical surfaces of the coral colony's pedestal and the area underneath the table shaped colonies from which pedestals rise. Otherwise, there was limited algal cover associated with overgrowth of relict or recently dead coral at this habitat.

Live scleractinian coral was the dominant sessile-invertebrate taxa in terms of substrate cover at El Seco Reef 30 with an average of 41.1% (range: 33.1 – 52.0%). Coral cover was observed to be virtually a biotope of Boulder Star Coral, *Orbicella franksi* growing in table shaped colonies

Table 53. SECO 30. Percent cover by sessile-benthic categories along permanent transects, El Seco Reef 30. Vieques. September 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Benthic Categories						
Abiotic						
Sand	2.19		10.21	5.31	4.31	**4.40**
Benthic Algae						
Lobophora variegata	33.21	23.79	14.89	28.98	22.97	**24.77**
Peyssonnelia sp.	18.98	13.71	20.00	19.18	15.31	**17.44**
Turf	3.28	3.23	11.91	6.12	11.48	**7.21**
CCA	4.38		0.43	0.82		**1.12**
Total Benthic Algae	**59.85**	**40.73**	**47.23**	**55.10**	**49.76**	**50.54**
Cyanobacteria	1.09	0.40		4.49	3.35	**1.87**
Hard coral						
Orbicella annularis complex	32.12	50.81	39.15	31.02	35.89	**37.80**
Porites astreoides	2.19	0.81	1.28	0.82	1.91	**1.40**
Agaricia sp.	1.09	0.40		0.82	3.83	**1.23**
Agaricia lamarcki			0.43		0.48	**0.18**
Siderastrea siderea			0.85			**0.17**
Porites porites			0.43	0.41		**0.17**
Diploria labyrinthiformis	0.73					**0.15**
Total Hard Coral	**36.13**	**52.02**	**42.13**	**33.06**	**42.11**	**41.09**
Invertebrate		1.21	0.43	0.82		**0.49**
Tridemnum solidum		1.21	0.43	0.82	0.48	**0.59**
Octocoral	0.36	0.81		0.41		**0.32**
Erythropodium caribaeorum	0.36	0.81		0.41		**0.32**
# Gorgonians/transect				3		**0.60**
Sponge						
Cliona caribbaea		4.84				**0.97**
Svenzea zeai				0.82		**0.16**
Agelas sp.	0.36					**0.07**
Total Sponge	**0.36**	**4.84**		**0.82**		**1.20**

side by side, sometimes slightly overlapping and producing an impressive continuous live mesophotic coral system resembling that described by Smith et al. (2010) for the MCD Hind Bank in St. Thomas, USVI. Mean substrate cover by *M. franksi* was 37.8 % (range: 31.0 – 50.8%), representing 92.2% of the total cover by live corals at El Seco Reef (Figure 43). Mustard-hill coral, *Porites astreoides* was intersected (along with *O. franksi*) on all transects with a mean cover of 1.4%. A combined assemblage of Lettuce Corals, *Agaricia spp*. (including Whitestar Sheet Coral, *Agaricia lamarcki*) were also present in all transects with a combined cover of 1.4% (Table 53).

Octocorals (gorgonians) were present in very low abundance at El Seco 30. Mean density along transects was 0.6 colonies/transect (Table 53). The Encrusting gorgonian, *Erythropodium caribaeorum* was present in three transect with a mean cover of 0.3%. Likewise, sponges were observed in very low cover with a mean of 1.2 % with only three species identified within transects. The encrusting type, *Cliona caribbea* was the most prominent in terms of substrate cover with a mean of 1.0%.

This is the second monitoring survey of the sessile-benthic community at El Seco Reef. No statistically significant differences were detected during the 2013 survey, but differences of benthic community structure between the present and previous surveys have been now detected (Permanova; p = 0.11 (Appendix 1). The main contribution to dissimilarity between years was the relative composition of benthic algae, particularly the reduction of turf algae and increment of both *Peyssonnelia sp*. and *Lobophora* during the present survey, relative to previous assessments. Variations of substrate cover by total live corals between years (Figure 44) was not statistically significant (ANOVA, p= 0.506; see Appendix 2). The temporal variation of cover by the dominant coral species, *Montastraea franksi* was in the order of only 4%.

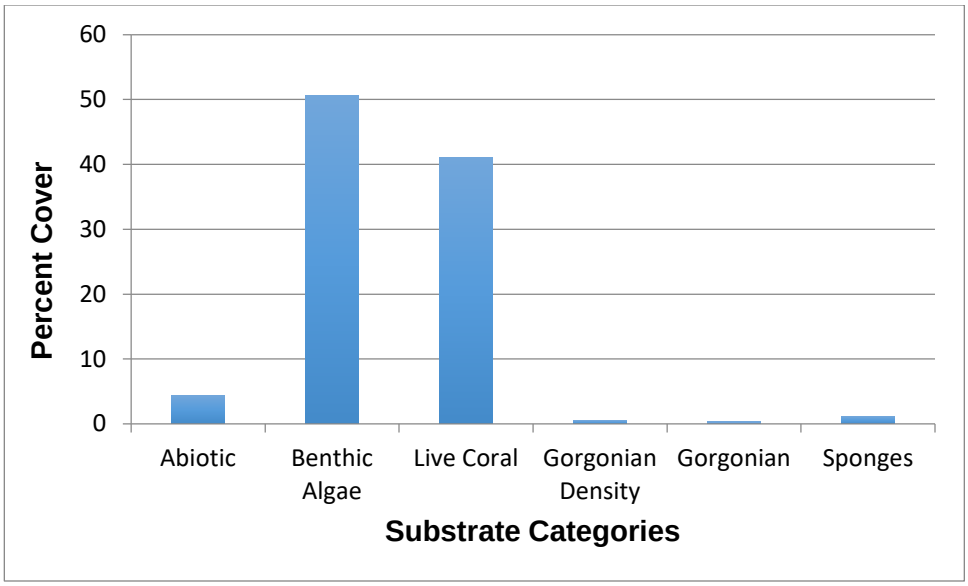


Figure 42. Mean substrate cover by benthic categories at El Seco Reef 30. September 2016

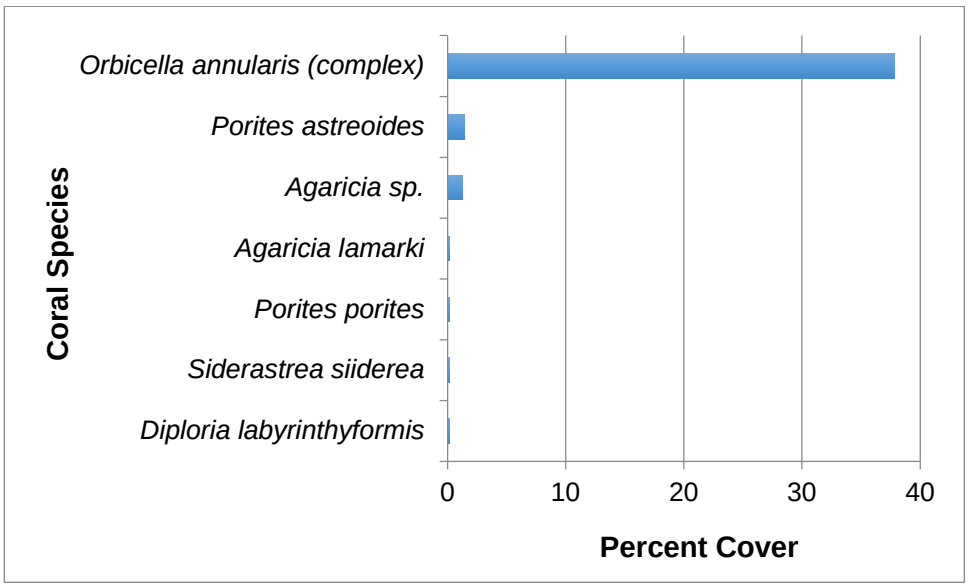


Figure 43. Mean substrate cover by coral species at El Seco Reef 30. September 2016

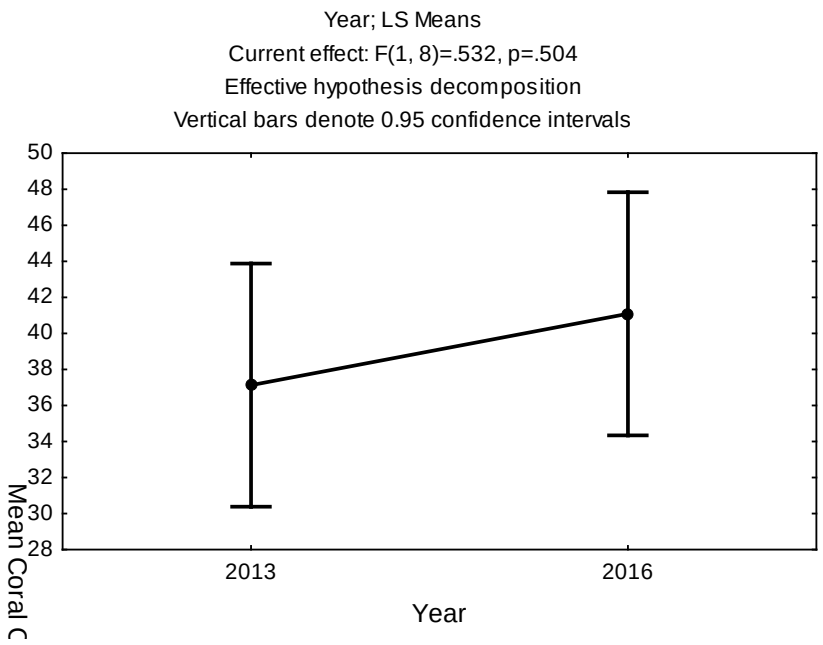


Figure 44. Temporal variations of total live coral cover at El Seco Reef 30, Vieques during monitoring surveys

Fishes and Motile Megabenthic Invertebrates

A total of 29 fish species were identified within belt-transects from El Seco Reef 30 (Table 54). A complete list of fish species observed from the different benthic habitats is included as Appendix 2. Mean abundance within belt-transects was 50.8 Ind/30m^2 (range: 36 - 74 Ind/30m^2). Mean species richness was 12.8 spp/30m^2 (range: 12 – 14 spp/30m^2). Fish species composition and abundance estimates from this reef must be evaluated with caution due to the high rugosity and labyrinth dimensions that constrain visual access of the reef seascape.

The Masked Goby, *Coryphopterus personatus* a species with highly aggregated distributions that forms swarms of dozens, sometimes hundreds of individuals beneath ledges and crevices in the reef accounted for 38.2 % of the total mean abundance within belt-transects (Table 54). Six additional species were present in at least four out of the five transects surveyed and along with Masked Goby comprised the numerically dominant small demersal fish assemblage of the El Seco Reef system. These included the Bluehead, Creole and Yellowhead Wrasses, (Thalassoma bifasciatum, Clepticus parrae, Halichoeres garnoti), Princess Parrotfish (*Scarus*

Taeniopterus), Blue Chromis (*Chromis cyanea*), Bicolor Damselfish (*Stegastes partitus*), and Fairy Basslet (*Gramma loreto*). Eleven species were only observed in one out of the ten transects surveyed.

Zooplanktivorous fishes dominated the trophic community structure at El Seco Reef 30. Four of the top six species in terms of density within belt-transects were zooplanktivores. The entire assemblage included six species: the Masked Goby, Blue and Brown Chromis, Creole Wrasse, Bicolor Damselfish and Fairy Basslet. Their combined abundance (29.8 Ind/transect) represented 58.7% of the total individuals. Herbivores were represented by five parrotfishes (Scaridae), two doctorfishes (Acanthuridae) and one damselfish (Pomacentridae) with a combined density of 13.4 Ind/transect, representative of 26.4% of the total individuals. Small opportunistic carnivores included nine species with a combined density of 5.6 Ind/transect, representative of 11.0% of the total fishes within belt-transects. The most abundant assemblage included the Bluehead Wrasse, Peppermint Goby Caribbean Puffer and Bluestriped Grunt. Medium size piscivores included the Schoolmaster and Dog Snappers, Lionfish, and Great Barracuda (Table 55).

Previous assessments of the fish community at El Seco have shown that this reef functions as the residential habitat of several commercially important medium and large demersal reef fish predators, such as Red Hind, *Epinephelus guttatus*, Hogfish, *Lachnolaimus maximus,* Schoolmaster, Dog and Cubera snappers, *Lutjanus apodus, L. jocu, L. cyanopterus*, Tiger and Yellowfin Groupers, *Mycteroperca tigris* and Nurse Shark, *Ginglymostoma cirratum*. The largest demersal predator of the reef at size distributions ranging between150 –250 cm appears to be the Nurse Shark, which appear to be common in the reef and were typically attracted to divers during previous surveys (Garcia-Sais et al., 2005, 2007, 2010). In addition to ballyhoo and flying-fishes (Exocoetidae) only small schools of mackerel scad, *Decapterus macarelus* and creole wrasse, *Clepticus parrae* have been observed in mid-water to serve as potential forage species for the larger pelagic predators, such as great barracuda and Cero Mackerel. Several large hawksbill turtles, *Eretmochelys imbricata* were present at El Seco Reef 30 during the baseline survey in 2011. No megabenthic invertebrates were observed within belt-transects.

A marked decline of fish abundance was measured during the present 2016 survey. Such decline was related with abundance fluctuations of the numerically dominant species, the Masked Goby. Temporal differences were within sampling variability error.

Table 54. Taxonomic composition and abundance of fishes within belt-transects at El Seco Reef 30, Vieques, September 2016

		Transects (Ind/30m2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	30	7	30	10	20	**19.4**
Scarus taeniopterus	Princess Parrotfish		8	5	4	18	**7.0**
Thalassoma bifasciatum	Bluehead Wrasse	3	4	3	3	5	**3.6**
Chromis cyanea	Blue Chromis	5	4		5	1	**3.0**
Clepticus parrae	Creole Wrasse					14	**2.8**
Stegastes partitus	Bicolor Damselfish	3	4	4	1	2	**2.8**
Acanthurus bahianus	Ocean Surgeon			3	2	4	**1.8**
Sparisoma viride	Stoplight Parrotfish		1	3	3		**1.4**
Gramma loreto	Fairy Basslet	1	1	1	3		**1.2**
Chaetodon capistratus	Four-eye Butterflyfish		2	2		2	**1.2**
Halichoeres garnoti	Yellow-head Wrasse	1		2	1	1	**1.0**
Chromis multilineata	Brown Chromis	3					**0.6**
Sparisoma aurofrenatum	Redband Parrotfish				1	2	**0.6**
Acanthurus coeruleus	Blue Tang	1	1		1		**0.6**
Coryphopterus lipernes	Peppermint Goby		2				**0.4**
Stegastes leucostictus	Beau Gregory			1	1		**0.4**
Hypoplectrus chlorurus	Yellowtail Hamlet		1			1	**0.4**
Scarus vetula	Queen Parrotfish					2	**0.4**
Canthigaster rostrata	Caribbean Puffer		1				**0.2**
Haemulon sciurus	Bluestriped Grunt	1					**0.2**
Holacanthus ciliaris	Queen Angelfish					1	**0.2**
Holocentrus adcensionis	Squirrelfish			1			**0.2**
Gobiosoma evelynae	Sharknose Goby	1					**0.2**
Sparisoma radians	Bucktooth Parrotfish	1					**0.2**
Bodianus rufus	Spanish Hogfish			1			**0.2**
Chaetodon aculeatus	Longsnout Butterflyfish		1				**0.2**
Lutjanus apodus	Schoolmaster Snapper	1					**0.2**
Cantherhines macrocerus	Whitespotted Filefish					1	**0.2**
Pterois volitans	Lionfish				1		**0.2**
	TOTAL INDIVIDUALS	**51**	**37**	**56**	**36**	**74**	**50.8**
	TOTAL SPECIES	**12**	**13**	**12**	**13**	**14**	**12.8**

Table 55. SECO 30. Size frequency distribution of fishes within 20 x 4 m belt-transects at El Seco Reef 30, Vieques, September 2016

SPECIES	**COMMON NAME**	1	2	3	4	5
Sparisoma viride	Stoplight Parrotfish		1-3	3-5	1-25	
					1-35	
					1-45	
Sparisoma aurofrenatum	Redband Parrotfish				1-15	1-10
						1-15
Scarus taeniopterus	Princess Parrotfish		3-5	3-5	4-15	8-10
			4-7	5-15	1-20	15-15
			2-10			
			2-12			
			1-17			
Sparisoma radians	Bucktooth Parrotfish	1-3				
Lutjanus apodus	Schoolmaster Snapper	1-38				
Lutjanus jocu	Dog Snapper		1-55			
Ocyurus chrysurus	Yellowtail Snapper				1-20	
Scarus vetula	Queen Parrotfish					1-25
Mycteroperca interstitialis	Yellowmouth Grouper				1-40	
Sparisoma chrysopterum	Redtail Parrotfish					
Sphyraena barracuda	Great Barracuda				1-50	

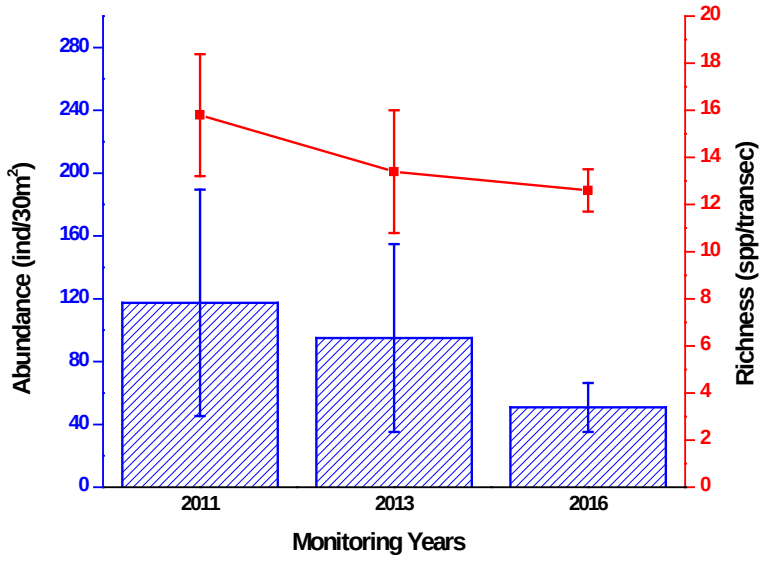
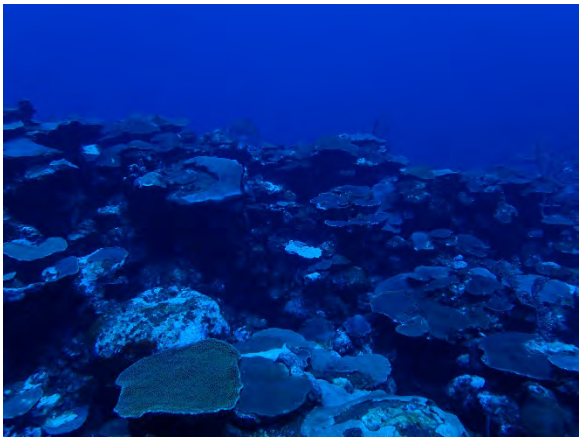
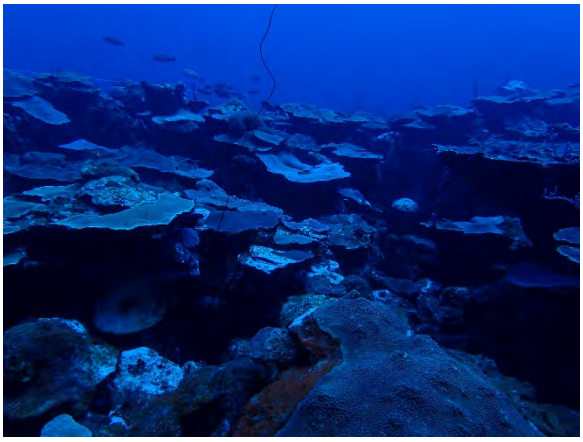
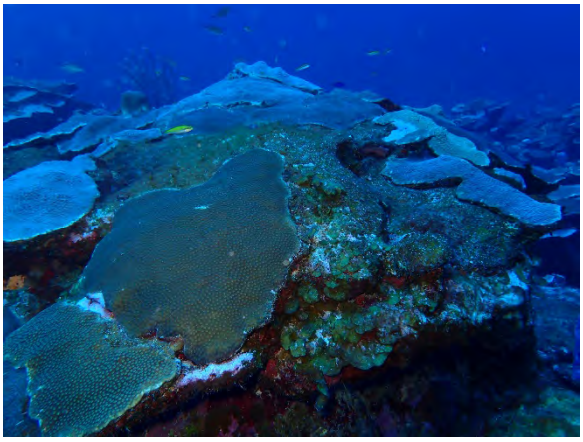


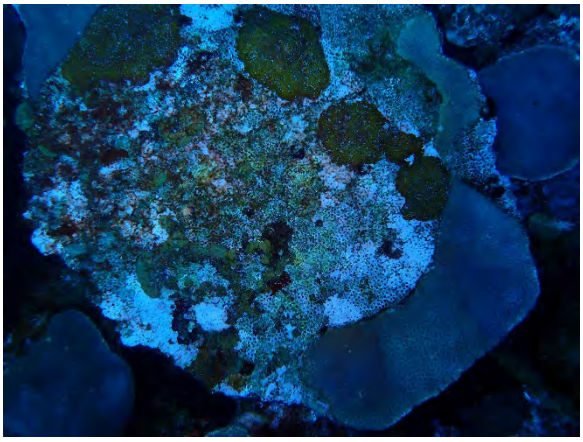
Figure 45. Temporal variations of fish species richness and abundance at El Seco Reef 30, Vieques during the baseline and monitoring surveys.

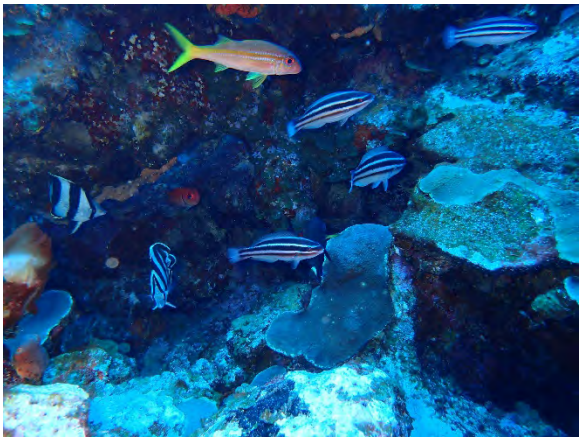
Photo Album 18.
El Seco Reef 30m

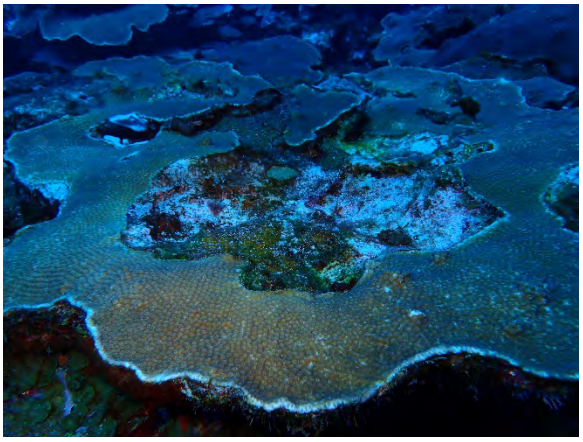


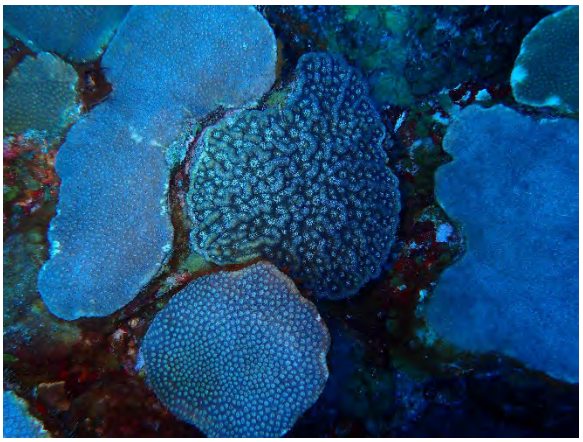












Canjilones Reef, Vieques

Physical Description

Canjilones is a diffuse “spur-and-groove” coral reef system located at the base of the southern edge of a rather long and narrow rocky ridge that runs along an east-west axis off Punta Arenas, on the southwest coast of Vieques (Figure 58). The ridge presents an almost flat, hard-ground terrace with sparse gorgonians and coral heads at depths of 9-11 meters and slopes down to a depth of 15 meters where the spur-and-groove coral reef formation has developed. The spurs rise only about 2-3 meters from the narrow sandy channels that separate them at the base. Our permanent transects were established along five consecutive spurs at a depth of 15.2 meters. Panoramic pictures of Canjilones Reef are included as Photo Album 19.

The quantitative baseline characterization of Canjilones Reef was executed on 2000 (Garcia-Sais et al. 2001) and the first monitoring survey performed on October 2004 (Garcia-Sais et al. 2004). This is the third monitoring survey of Canjilones Reef completed on September 2016.

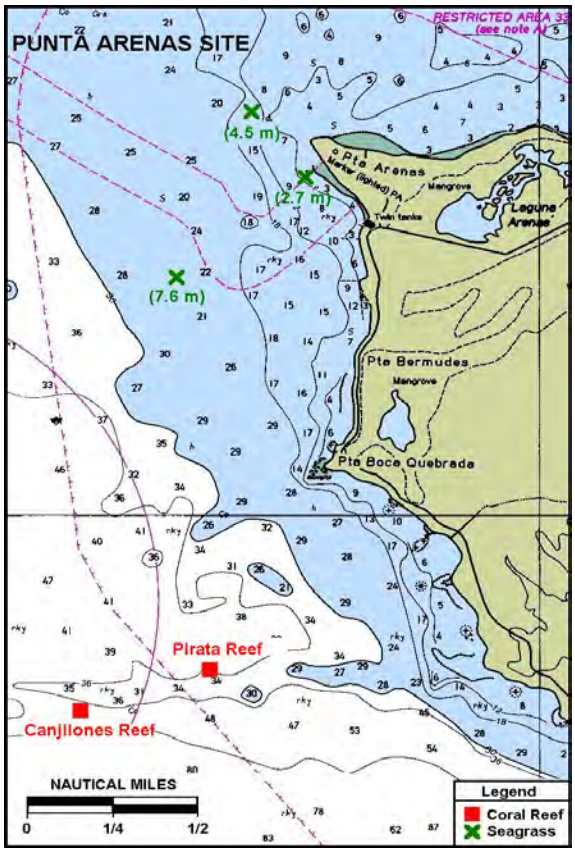


Figure 46. Location map of Canjilones Reef along the western coast of Vieques.

Sessile Benthic Reef Community

Reef substrate cover ay Canjilones Reef 20 was dominated by an assemblage of benthic algae that included the red encrusting alga, *Ramicrusta sp*., turf algae, fleshy brown, green calcareous and crustose coralline algae, with a combined mean of 66.32 % (range: 49.8 – 73.0 %). The percent composition by the main substrate categories at Canjilones Reef 20 is shown in Figure 47. *Ramicrusta sp*., not previously reported for Canjilones Reef was the dominant algal taxon in all transects with a mean cover of 34.6%, representing 52.1% of the total cover by benthic algae (Table 56). Turf algae, the dominant algal component in previous surveys declined its cover by 5-fold, from 58.3% in 2013 to 11.6% in the present 2016 survey. Fleshy brown macroalgae was mostly comprised by the Encrusting Fan-Leaf Alga, *Lobophora variegata* (11.6%) and the Y-Branched Alga, *Dictyota sp*. (3.8%). Crustose coralline algae and green calcareous algae (Halimeda sp) were also common in most transects with a combined cover of 4.9% Cyanobacterial films were present in all transects with a mean cover of 4.1% (Table 56).

The sessile-benthic community at Canjilones Reef was characterized by a high density and species rich assemblage of (erect) soft corals, or gorgonians with a mean of 22.2 colonies per transect (Figure 47). Sea Rods (*Plexaura spp, Pseudoplexaura spp*.), knobby Sea Rods (*Eunicea spp*) and Sea Fans (*Gorgonia ventalina*) were the most prominent in transects. The encrusting gorgonian, *Erythropodium caribaeorum* was present in all transects with a mean cover of 3.7 %. Erect and encrusting sponges were present in all five transects with a mean cover of 2.2 %.

A total of 24 species of stony corals have been identified from Canjilones Reef, including 11 intercepted by transects in this survey with a combined mean cover of 15.0% (range 11.9 – 18.8 %). Boulder Star Coral, *Orbicella annularis* was the main coral species with a mean cover of 9.1%, representing 60.7% of the total surface cover by stony corals (Figure 48). Mustard-Hill Coral (*Porites astreoides*), Great Star Coral (*Montastrea cavernosa*) and Lettuce Coral (*Agaricia agaricites*) were present in all transects with a combined cover of 3.8%. Massive Starlet Coral (*Siderastrea siderea*) and Finger Coral, *Porites porites* were intercepted by three transects.

Table 56. CANJ 20. Percent cover by sessile-benthic categories along permanent transects, Canjilones Reef 20. Vieques. September 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	4.29	4.25	4.45	5.23	4.22	4.49
Benthic Categories						
Abiotic						
Reef overhang	4.11	7.66	6.30	6.34	5.22	5.93
Sand	6.17					1.23
Rubble	4.31	1.77				1.22
Gap			0.78			0.16
Total Abiotic	**14.59**	**9.43**	**7.07**	**6.34**	**5.22**	**8.53**
Benthic Algae						
Ramicrusta sp.	38.20	30.06	38.37	38.79	27.36	34.56
Turf		14.34	10.85	18.75	14.17	11.62
Lobophora variegata	3.92	13.56	15.21	7.35	17.91	11.59
CCA	5.29	3.44	4.17	1.47	4.72	3.82
Dictyota spp.	0.29	3.24	4.36	3.68	5.81	3.48
Halimeda spp.	1.37	0.29		1.56	2.26	1.10
Fleshy macroalgae	0.78					0.16
Total Benthic Algae	**49.85**	**64.93**	**72.97**	**71.60**	**72.24**	**66.32**
Cyanobacteria	11.36	3.05	0.87	3.49	1.87	4.13
Hard Coral						
Orbicella annularis complex	15.96	5.80	9.59	8.27	5.91	9.11
Porites astreoides	0.69	2.95	2.03	0.92	3.44	2.01
Montastraea cavernosa	1.08	0.79	0.29	0.37	3.94	1.29
Siderastrea siderea		1.96		3.22	0.30	1.10
Agaricia agaricites	0.59	0.39	0.68	0.28	0.30	0.45
Colpophyllia natans				1.29		0.26
Agaricia fragilis			1.16	0.09		0.25
Porites porites			0.39	0.28	0.49	0.23
Leptoseris cucullata			0.29			0.06
Agaricia lamarcki					0.20	0.04
Madracis decactis	0.49					
Total Hard Coral	**18.81**	**11.89**	**14.44**	**14.71**	**14.57**	**14.88**
Invertebrate						
Palythoa caribaeorum			0.19			0.04
Octocoral						
Erythropodium caribaeorum	3.43	8.74	3.20	1.29	1.67	3.67
Plexaura kuekenthali			0.29		0.20	0.10
Pseudoplexaura wagenaari flagellosa					0.39	0.08

Gorgonian	0.29					0.06
Briareum asbestinum				0.18		0.04
Total Octocoral	**3.72**	**8.74**	**3.49**	**1.47**	**2.26**	**3.94**
# Gorgonians/transect	35	20	18	16	22	22.2
Sponge						
Sponge	1.67					0.33
Callyspongia vaginalis					1.38	0.28
Smenospongia aurea				1.10		0.22
Ircinia strobilina					0.89	0.18
Aplysina cauliformis			0.19	0.55		0.15
Callyspongia plicifera					0.69	0.14
Ectyoplasia ferox		0.39			0.30	0.14
Agelas dispar		0.69				0.14
Agelas tubulata		0.69				0.14
Mycale laevis			0.58			0.12
Diplastrella sp.				0.46		0.09
Niphates caribica		0.20			0.20	0.08
Scopalina ruetzleri			0.19		0.20	0.08
Niphates digitalis				0.28		0.06
Amphimedon compressa					0.20	0.04
Total Sponge	**1.67**	**1.96**	**0.97**	**2.39**	**3.84**	**2.17**

Figure 49 presents the time series measurements of substrate cover by sessile-benthic categories during the baseline and three monitoring surveys at Canjilones Reef. Live coral evidenced a sharp decline between the 2004 and 2013 monitoring surveys. As for other reefs in the monitoring program, such decline was largely associated with the reduction of reef substrate cover by Boulder Star Coral, *Orbicella annularis* which has been associated with the regional 2005 coral bleaching event (Garcia-Sais et al. 2015 and references therein). During the present survey live coral declined from 16.2% to 15.0%, but such small difference is within sampling variability error (Figure 49). Statistically significant variations of benthic community structure were detected between the 2013 and the present 2016 monitoring surveys (Permanova; $p < 0.001$, see Appendix 1). As was the case with El Seco Reef 30, the main factor driving dissimilarity between years was the phase shift of turf algal dominance towards *Ramicrusta sp*.

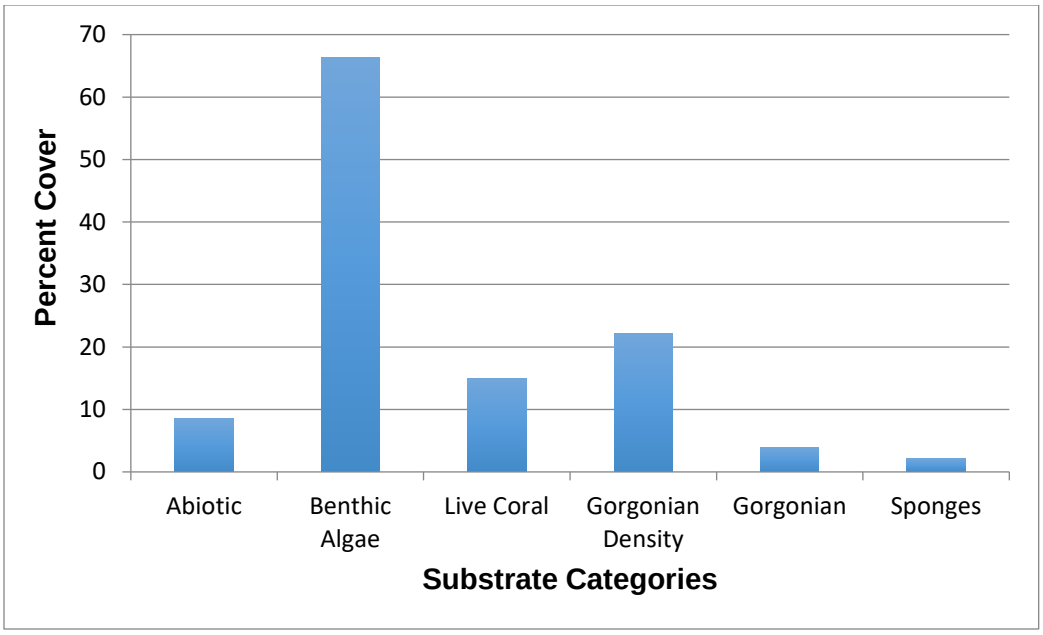


Figure 47. Mean substrate cover by benthic categories at Canjilones Reef 20. Vieques. September 2016

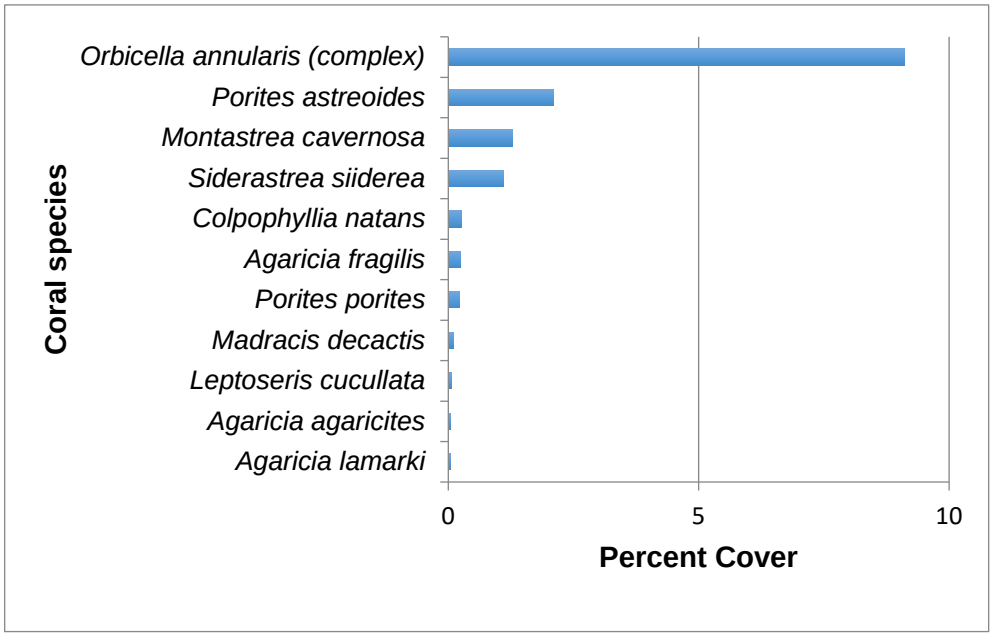


Figure 48. Mean substrate cover by coral species at Canjilones Reef 20. Vieques September 2016

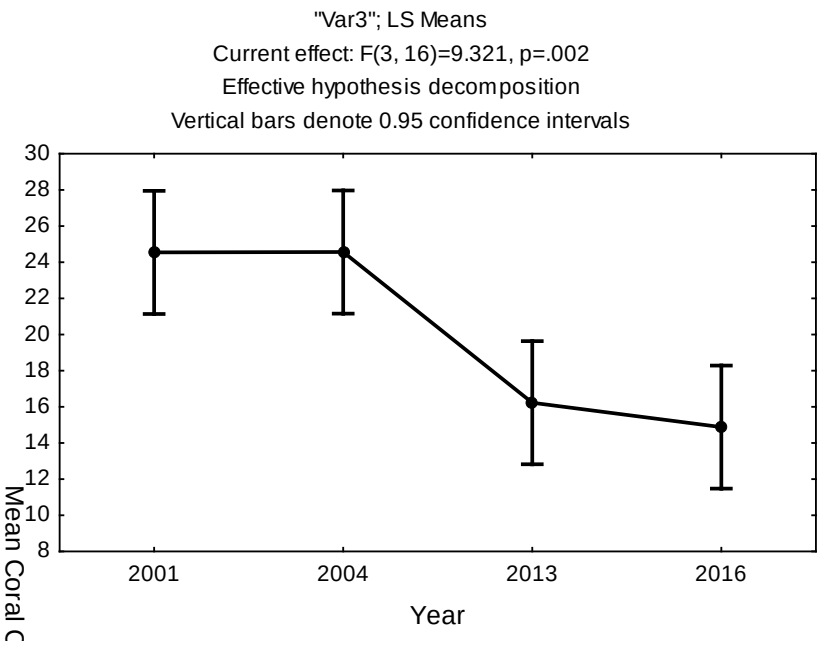


Figure 49. Temporal variations of total live coral cover from baseline and monitoring surveys at Canjilones Reef 20, Vieques (2001 – 2016)

Fishes and Motile Megabenthic Invertebrates

A total of 64 species of reef fishes have been identified during baseline and monitoring surveys at Canjilones Reef, including 34 species within transects during the 2016 survey (Table 57). The mean abundance of fishes within belt-transects was 88.0 Ind/30m^2 (range: 36 – 123 Ind/30m^2) and the mean number of species present per transect was 18.2. The most abundant species included the Masked Goby (*Coryphopterus personatus*), Princess, Striped, Stoplight and Redband Parrotfishes (*Scarus taeniopterus, S. iserti*, Sparisoma viride, S. *aurofrenatum*), Blue Chromis (*Chromis cyanea*), Bicolor Damselfish (*Stegastes partitus*), and the Bluehead and Creole Wrasses (*Thalassoma bifasciatum, Clepticus parrae*). The mean combined abundance of these nine species (70.8 Ind/transect) represented 80.0% of the total individuals within belt-transects. Other five species were present in at least four transects, including the Yellowhead Wrasse, Caribbean Puffer, Beau Gregory, Blue Tang and Ocean Surgeon (Table 57).

Table 57. Taxonomic composition and abundance of fishes within belt-transects at Canjilones Reef at 20m, Vieques, September 2016

		Transects (Ind/30m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	41	3	20	15	5	**16.8**
Scarus taeniopterus	Princess Parrotfish	4	5	30	15	11	**13.0**
Scarus iserti	Stripped Parrotfish	1		25	7	17	**10.0**
Clepticus parrae	Creole Wrasse				15	20	**7.0**
Chromis cyanea	Blue Chromis	4	7	16	3	3	**6.6**
Stegastes partitus	Bicolor Damselfish	7	6	9	4	4	**6.0**
Thalassoma bifasciatum	Bluehead Wrasse	15		3		3	**4.2**
Sparisoma viride	Stoplight Parrotfish	2	1		17		**4.0**
Sparisoma aurofrenatum	Redband Parrotfish	1	4	3	4	2	**2.8**
Halichoeres garnoti	Yellow-head Wrasse	5		2	1	3	**2.2**
Canthigaster rostrata	Caribbean Puffer	2		4	1	3	**2.0**
Stegastes leucostictus	Beau Gregory	3	1		1	2	**1.4**
Gobiosoma evelynae	Sharknose Goby			1	2	3	**1.2**
Acanthurus coeruleus	Blue Tang	1	1		2	2	**1.2**
Coryphopterus glaucofraenum	Bridled Goby	3			1		**0.8**
Stegastes adustus	Dusky Damselfish					4	**0.8**
Acanthurus chirurgus	Doctorfish	4					**0.8**
Acanthurus bahianus	Ocean Surgeon		1	1	1	1	**0.8**
Holocentrus rufus	Squirrelfish		1	2		1	**0.8**
Holacanthus tricolor	Rock Beauty	1	2			1	**0.8**
Chaetodon capistratus	Four-eye Butterflyfish	1		1		1	**0.6**
Sparisoma radians	Bucktooth Parrotfish	3					**0.6**
Coryphopterus lipernes	Peppermint Goby		1	1			**0.4**
Cephalopholis cruentatus	Graysby	1			1		**0.4**
Haemulon flavolineatum	French Grunt			2			**0.4**
Hypoplectrus chlorurus	Yellowtail Hamlet		1			1	**0.4**
Ocyurus chrysurus	Yellowtail Snapper	1	1				**0.4**
Neoniphon marianus	Longjaw Squirrelfish			1	1		**0.4**
Epinephelus guttatus	Red Hind			1			**0.2**
Haemulon plumieri	White Grunt				1		**0.2**
Aulostomus maculatus	Trumpetfish	1					**0.2**
Bodianus rufus	Spanish Hogfish			1			**0.2**
Pseudupeneus maculatus	Spotted Goatfish		1				**0.2**
Scarus vetula	Queen Parrotfish					1	**0.2**
	TOTAL INDIVIDUALS	**101**	**36**	**123**	**92**	**88**	**88**
	TOTAL SPECIES	**20**	**15**	**18**	**18**	**20**	**18.2**

Table 58. CANJ 20. Size frequency distribution of fishes within 20 x 4 m belt-transects at Canjilones Reef 20, Vieques, September 2016

		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Scarus iserti	Stripped Parrotfish	1-15	1-15	5-3	5-3	6-5
				5-10	2-15	6-10
				15-15		5-15
Sparisoma viride	Stoplight Parrotfish	3-3	1-25	1-35	2-5	3-35
					5-12	
					5-15	
					5-18	
Sparisoma aurofrenatum	Redband Parrotfish	1-12	3-3	1-5	2-5	2-15
			1-15	2-15	2-15	
			1-18		1-20	
			1-20			
Ocyurus chrysurus	Yellowtail Snapper		1-15		1-20	
					1-25	
Epinephelus fulva	Coney					1-25
Epinephelus guttatus	Red Hind	1-33		1-25		
Epinephelus cruentatus	Graysby	1-12			1-5	
Scarus taeniopterus	Princess Parrotfish	4-12	3-15	5-3	5-15	6-10
			2-20	5-10	5-15	5-15
				15-15	5-18	
Lutjanus apodus	Schoolmaster Snapper	1-20				
Ocyurus chrysurus	Yellowtail Snapper	1-15				

The trophic structure of the fish community at Canjilones Reef 20 was strongly driven by a numerically balanced zooplanktivore and herbivore assemblages. Zooplanktivores were represented by four species, all of which ranked at the top six of fish density within belt-transects. These included the Masked Goby, Creole Wrasse, Bicolor Damselfish and Blue Chromis with a combined density of 36.4 Ind/transect, representative of 41.4% of the total individuals. The herbivorous assemblage included 11 species, including seven parrotfishes (Scaridae), two damselfishes (Pomacentridae), and two doctorfishes (Acanthuridae). Their combined density within belt-transects (35.6 Ind/transect) represented 40.4% of the total individuals. Small opportunistic carnivores were represented by 15 species with a combined abundance of 9.0 Ind/transect =, or 10.2% of the total fishes. The most abundant from the small carnivorous assemblage included the Bluehead and Yellowhead Wrasses with a combined mean density of 6.4 Ind/transect. Medium sized piscivores included two adult Red Hinds, juvenile and young adult Yellowtail and Schoolmaster Snapper (Table 58).

Other species of commercial value previously reported from Canjilones 20 include the Hogfish (*Lachnolaimus maximus*), Coney (*Cephalopholis fulva*), Great Barracuda (*Sphyraena barracuda*). Reef and Nurse Sharks were observed during the baseline survey. No motile megabenthic invertebrates were recorded within belt-transects.

Figure 50 presents the variations of fish species richness and abundance between monitoring surveys. Significantly higher richness and abundance were observed during the 2004 survey relative to the baseline and the 2013 survey. Differences were influenced by abundance fluctuations of Masked Goby and Blue Chromis, both of which are schooling species with highly aggregated distributions. Such fluctuations are probably associated to density independent factors, including recruitment pulses and are common features of the inter-annual variations dynamics of fish community structure in Caribbean reefs (Esteves 2013). The higher species richness measured during the 2004 relative to other surveys was driven by the presence of 16 species represented by only one individual within belt-transects. This could have been influenced by the clear and calm conditions that prevailed during the 2004 survey (Garcia-Sais et al., 2004). A similar situation of calm sea conditions prevailed during the 2016 monitoring survey and higher fish densities species richness within belt-transects was measured.

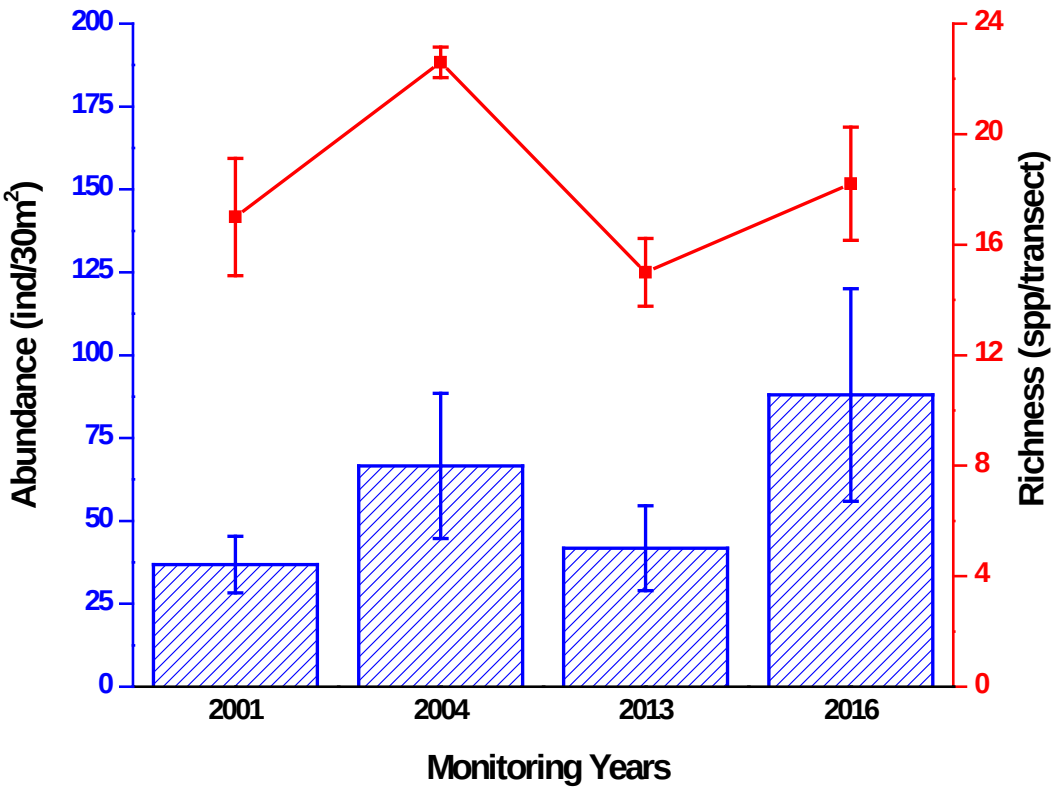
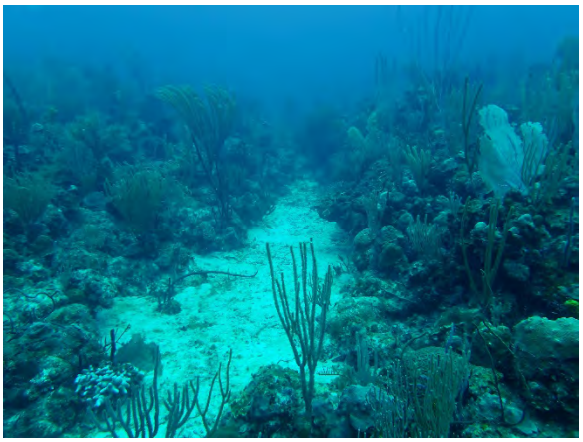
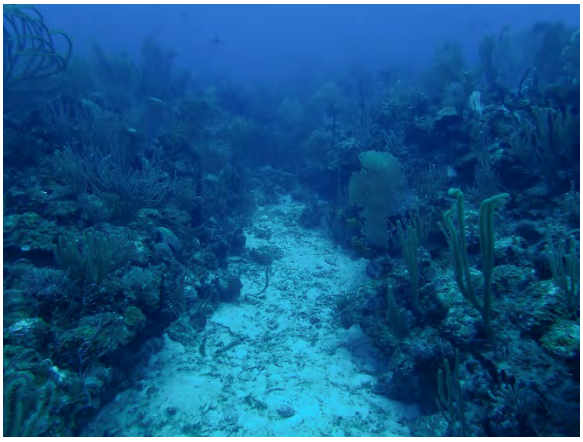
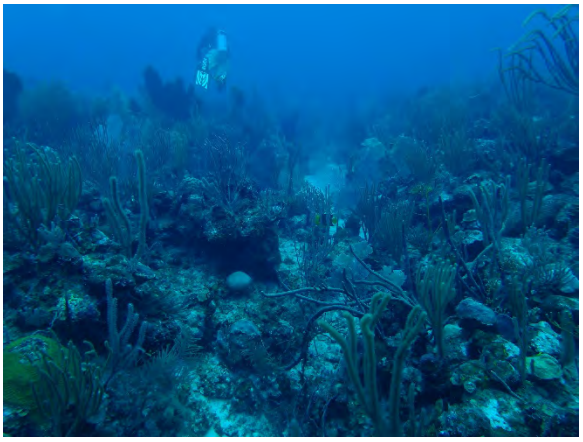


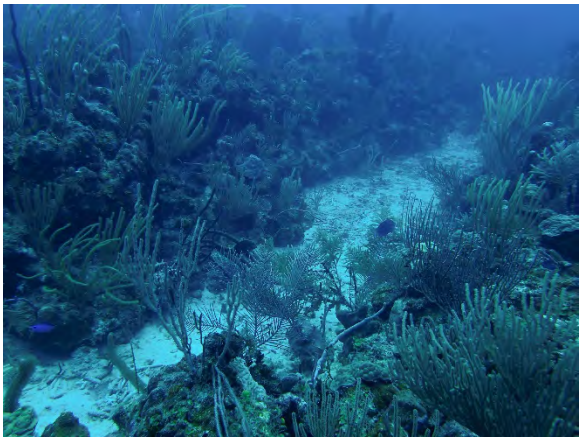
Figure 50. Temporal variations of fish abundance and species richness during Monitoring surveys (2001 – 2016)

Photo Album 19.
Canjilones Reef 20m









Boya Esperanza Reef – Vieques

Physical Description

Boya Esperanza Reef is a submerged patch reef sitting at the edge of a hard-ground platform located about 0.8 nautical miles off Puerto Esperanza, on the south coast of Vieques (Figure 51). A green navigation buoy marks the eastern boundary of the reef and the entrance channel to Puerto Esperanza. The reef has a highly irregular bathymetry, with large coral outcrops rising more than five meters from the base of the reef platform and reaching to about 2 meters from the surface. Extensive coralline sand pools (deposits) are found at the base of the reef on its northern boundary. Large crevices are found at the interface of the sandy bottom and the rock/coral outcrops. Transects were established in a north-south direction on top of large coral outcrops of Boulder Star Coral at a depth of 9 – 10m. This is the third monitoring survey of Boya Esperanza Reef. The baseline survey was performed during 2000 (Garcia-Sais et al. 2001). Panoramic images of the reef are included as Photo Album 20.

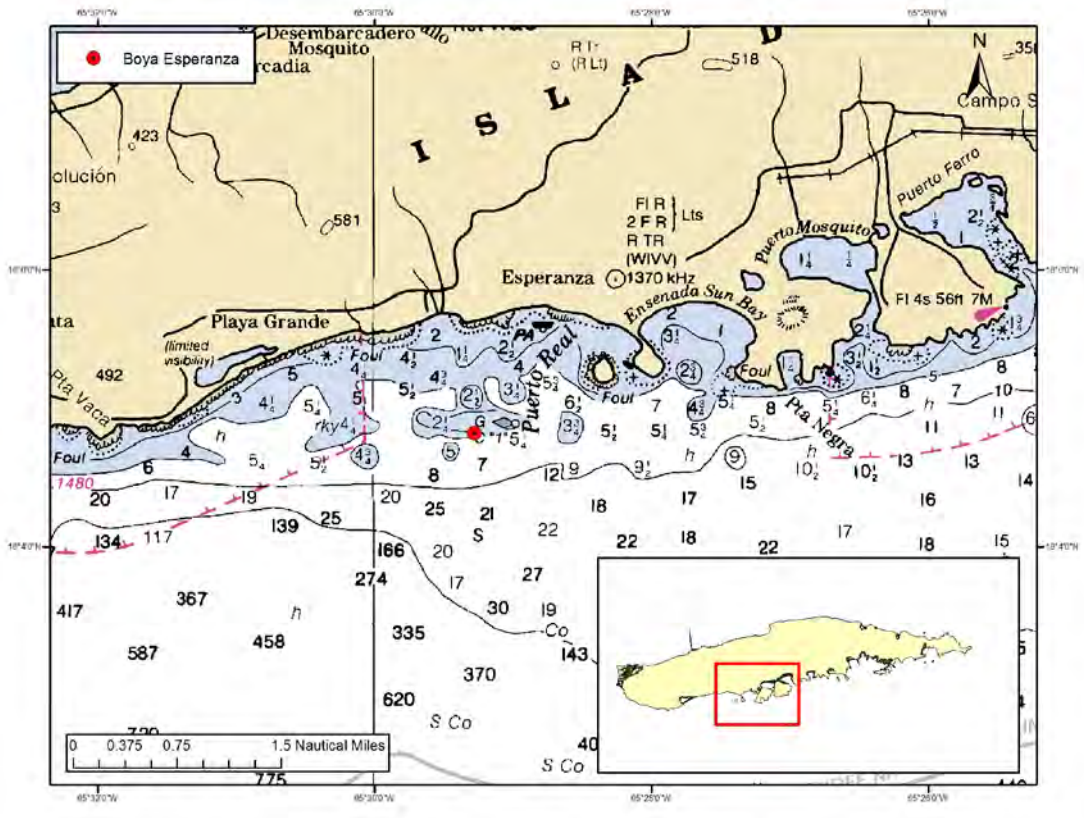


Figure 51. Location of the coral reef monitoring station at Boya Esperanza 10 Vieques.

Sessile-Benthic Reef Community

Reef substrate cover at Boya Esperanza Reef 10 was dominated by an assemblage of benthic algae that included the red encrusting alga, *Ramicrusta sp*., turf algae, fleshy brown, green calcareous, and crustose coralline algae (Figure 52), with a combined mean of 73.8 % (range: 63.6 – 79.9 %). *Ramicrusta sp*., not previously reported for this reef system was the dominant algal taxon in all transects with a mean cover of 58.7%, representing 79.5% of the total cover by benthic algae (Table 59). Turf algae, the dominant algal component in previous surveys declined its cover by more than 6-fold, from 73.6% in 2013 to 11.2% in the present 2016 survey. Green calcareous macroalgae (*Halimeda sp*) was intercepted by four transects with a mean cover of 2.3%. Fleshy brown macroalgae was mostly comprised by Encrusting Fan-Leaf Alga, *Lobophora variegata* with a mean cover of 1.0%. Crustose coralline algae were present in all transects with a mean cover of 0.5%. Cyanobacterial films were present in four transects with a mean cover of 3.8% (Table 59).

The sessile-benthic community at Boya Esperanza Reef 10 was characterized by high densities and a species rich assemblage of soft corals, or gorgonians with a mean of 22.6 colonies/transect (Figure 52). Sea Rods (*Plexaura spp, Pseudoplexaura spp*.), knobby Sea Rods (*Eunicea spp*) and Sea Fans (*Gorgonia ventalina*) were the most prominent in transects. The encrusting gorgonians, *Erythropodium caribaeorum* and *Briareum asbestinum* presented a combined reef substrate cover of 0.4%. Erect and encrusting sponges were represented by 10 species in all five transects with a mean cover of 1.7 %.

A total of 24 species of stony corals have been identified from Boya Esperanza Reef 10, including eight species intercepted by transects in this survey with a combined mean cover of 11.7% (range 3.4 – 21.2 %). Boulder Star Coral, *Orbicella annularis* was the main coral species with a mean cover of 6.4%, representing 54.7% of the total surface cover by stony corals (Figure 53). Mustard-Hill Coral (*Porites astreoides*), Massive Starlet Coral (*Siderastrea siderea*) and Symmetrical Brain Coral (*Pseudodiploria strigosa*) were present in at least three transects with a combined cover of 4.5%, representing an additional 38.9% to the total coral cover (Table 59).

Figure 54 presents the temporal variations of total live coral cover measured during the baseline and subsequent monitoring surveys. The sharp decline of total live coral between 2004 and 2013 was associated with the acute mortality of Boulder Star

Table 59. ESPE 10. Percent cover by sessile-benthic categories along permanent Boya Esperanza Reef 10. Vieques. September 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	1.86	4.74	4.39	3.83	3.79	**3.72**
Benthic Categories						
Abiotic						
Reef overhang	2.95	3.23	2.63	4.55	2.64	**3.20**
Sand	5.08	0.66	0.00	3.04	6.09	**2.97**
Rubble					0.51	**0.10**
Total Abiotic	**8.03**	**3.89**	**2.63**	**7.59**	**9.24**	**6.28**
Benthic Algae						
Ramicrusta sp.	54.07	64.96	65.66	58.50	50.46	**58.73**
Turf with sediment	18.54	8.55	10.02	7.69	10.25	**11.01**
Halimeda spp.	3.90	5.32	0.68	1.82		**2.34**
Lobophora variegata				3.04	2.13	**1.03**
CCA	0.35	0.57	0.10	0.81	0.71	**0.51**
Turf		0.47		0.40		**0.18**
Total Benthic Algae	**76.86**	**79.87**	**76.46**	**72.27**	**63.55**	**73.80**
Cyanobacteria	0.00	4.37	10.02	0.51	3.86	**3.75**
Hard Coral						
Orbicella annularis complex	2.72	2.66	3.02	6.38	17.06	**6.36**
Siderastrea siderea	2.01			6.17	3.45	**2.33**
Porites astreoides	2.72	0.76	0.88	0.91	0.71	**1.19**
Pseudodiploria strigosa	1.06		3.02	1.01		**1.02**
Diploria labyrinthiformis	1.53					**0.31**
Agaricia agaricites			0.88			**0.18**
Montastraea cavernosa			0.88			**0.18**
Agaricia fragilis				0.61		**0.12**
Total Hard Coral	**10.04**	**3.42**	**8.66**	**15.08**	**21.22**	**11.68**
Invertebrate						
Millepora alcicornis	0.24	3.32	0.58		0.91	**1.01**
Palythoa caribaeorum	1.53	1.61		0.30		**0.69**
Total Invertebrate	**1.77**	**4.94**	**0.58**	**0.30**	0.91	**1.70**
Octocoral						
Briareum asbestinum		0.95		0.40		**0.27**
Pseudoplexaura wagenaari flagellosa			0.19	0.61		**0.16**
Erythropodium caribaeorum			0.29	0.51		**0.16**
Eunicea flexuosa	0.35			0.30		**0.13**
Gorgonia ventalina			0.39			**0.08**
Eunicea succinea	0.35					**0.07**

Plexaura homomalla	0.24					**0.05**
Gorgonian					0.20	**0.04**
Eunicea sp.				0.20		**0.04**
Plexaura sp.				0.20		**0.04**
Total Octocoral	**0.94**	**0.95**	**0.88**	**2.23**	**0.20**	**1.04**
# Gorgonians/transect	29	17	28	23	16	**22.60**
Sponge						
Mycale laevis	0.12	0.38		1.11		**0.32**
Agelas citrina		1.23		0.20		**0.29**
Aplysina cauliformis		0.95		0.30		**0.25**
Chondrilla caribensis	1.18					**0.24**
Sponge					0.71	**0.14**
Verongula rigida	0.59					**0.12**
Niphates caribica				0.40		**0.08**
Desmapsamma anchorata			0.39			**0.08**
Verongula sp.			0.39			**0.08**
Dictyonella funicularis	0.24					**0.05**
Niphates erecta	0.24					**0.05**
Total Sponge	**2.36**	**2.56**	**0.78**	**2.02**	**0.71**	**1.69**

Coral, *Orbicella annularis* which presented a reduction of almost 6 fold, from 28.3 % in 2004 to 4.8 % in 2013. Since reef substrate cover by *O. annularis* represented 46.2 % of the total cover by live corals at Boya Esperanza Reef 10 in 2004, its acute mortality had very pronounced implications of coral cover loss at this reef. A slight increment of total live coral was measured during the present 2016 survey, from 10.4% (in 2013) to 11.7%, an increase of 11.1%. The variation although statistically insignificant, represents a recuperation trend, or stabilization from the previous measurement. Of particular interest is the fact that *O. annularis* was the main contribution to the increment of substrate cover by scleractinian corals as it evidenced a 25% increase of mean cover from 4.8% to 6.4% (Figure 54).

Statistically significant variations of reef substrate cover by benthic categories between this 2016 survey and all other previous surveys was associated with differences in composition of benthic algae. Turf algae, the previously dominant component of reef substrate cover at Boya Esperanza 10 has been displaced by cover of the red encrusting alga, *Ramicrusta sp*. At this point, it is unclear if this encrusting alga is in any way affecting coral growth and/or recruitment.

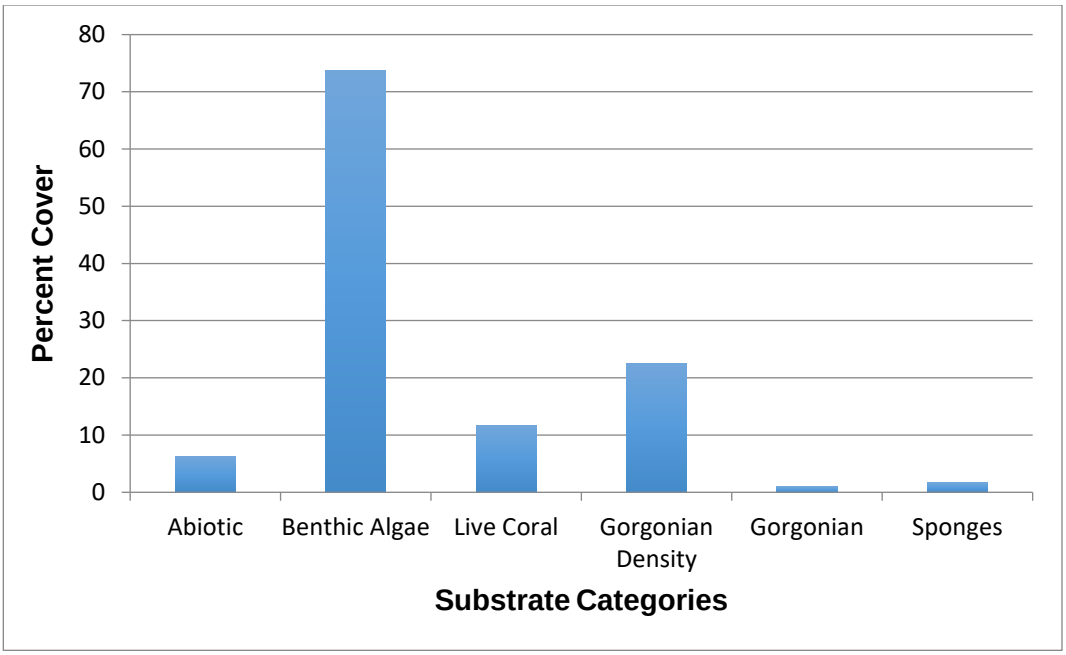


Figure 52. Mean substrate cover by benthic categories at Boya Esperanza Reef 10. Vieques, September 2016

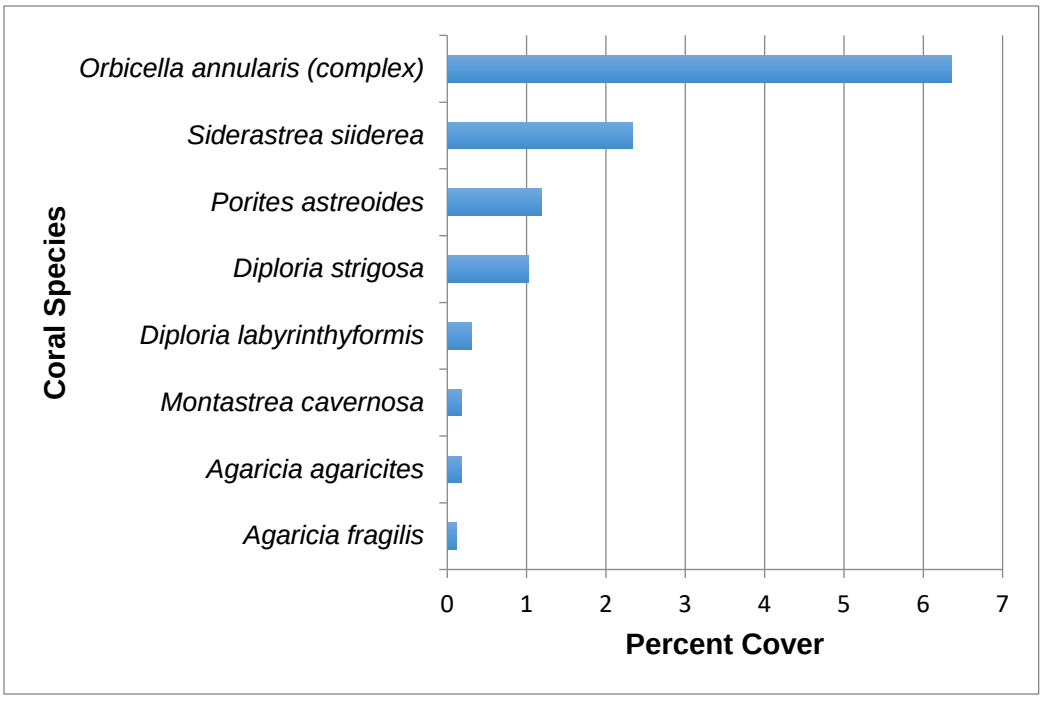


Figure 53. Mean substrate cover by coral species at Boya Esperanza Reef 10. Vieques, September 2016

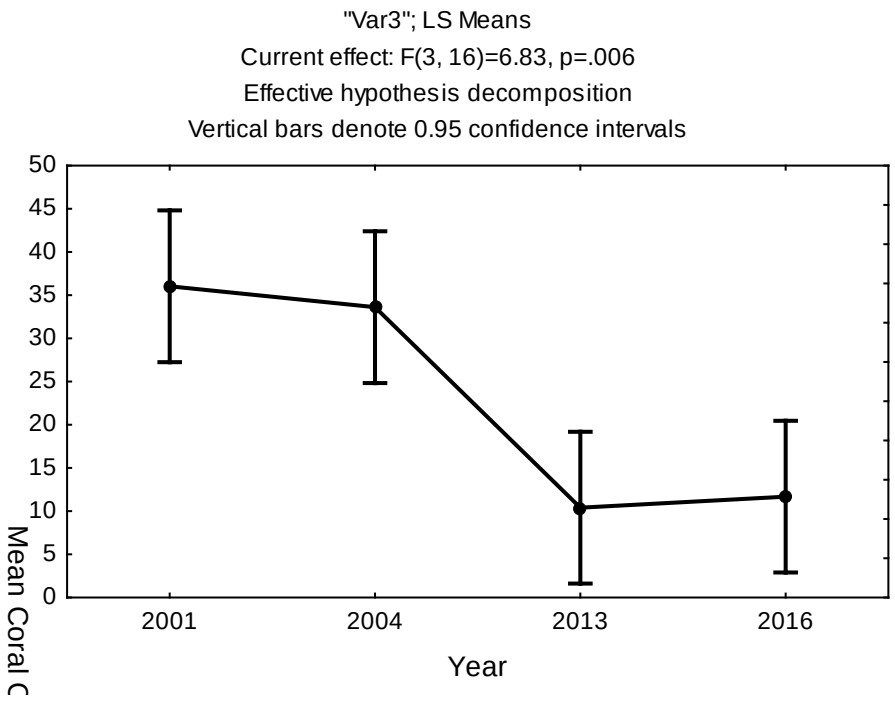


Figure 54. Temporal variations of total live coral cover from baseline and monitoring surveys at Boya Esperanza Reef 10, Vieques

Fishes and Motile Megabenthic invertebrates

A total of 63 reef fishes have been identified from Boya Esperanza Reef, 37 of which were observed within belt-transect areas during the present survey with a mean density of 101.6 Ind/transect and a mean richness of 18.6 species/transect (Table 60). The Bluehead Wrasse, *Thalassoma bifasciatum* was the numerically dominant species with a mean density of 29.0 Ind/transect, representing 28.5% of the total fishes within transects. In addition to the Bluehead Wrasse, other 10 species were present in at least 4 transects with a combined density of 48.4 Ind/transect, representing an additional 47.6% of the total. The assemblage included the Blue and Brown Chromis (*Chromis cyanea, C. multilineata*), Bicolor, Dusky and Yellowtail Damselfishes (*Stegastes partitus, S. dorsopunicans, Microspathodon chrysurus*), Stoplight, Redband and Princess Parrotfishes (*Sparisoma viride, S. aurofrenatum, Scarus taeniopterus*) and the Blue Tang (*Acanthurus coeruleus*).

Table 60. ESP 10. Taxonomic composition and abundance of fishes within belt-transects at Boya Esperanza Reef 10. Vieques, September 2016

		Transects (Ind/30m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	20	35	30	25	35	**29.0**
Chromis cyanea	Blue Chromis	5	20	15	25	37	**20.4**
Stegastes partitus	Bicolor Damselfish		14	15	8	6	**8.6**
Scarus iserti	Stripped Parrotfish		5	20		3	**5.6**
Acanthurus coeruleus	Blue Tang	3	7	3	3	4	**4.0**
Sparisoma viride	Stoplight Parrotfish	5	8	1	3	2	**3.8**
Scarus taeniopterus	Princess Parrotfish	2	9		5	1	**3.4**
Halichoeres garnoti	Yellow-head Wrasse	2	6	5		3	**3.2**
Sparisoma aurofrenatum	Redband Parrotfish	6	4	3		2	**3.0**
Chromis multilineata	Brown Chromis		5	3	3	3	**2.8**
Gramma loreto	Fairy Basslet		9	1		1	**2.2**
Stegastes adustus	Dusky Damselfish	1		3	4	2	**2.0**
Halichoeres maculipinna	Clown Wrasse			3	3	1	**1.4**
Acanthurus bahianus	Ocean Surgeon	3	1	2			**1.2**
Gobiosoma evelynae	Sharknose Goby	3	1		2		**1.2**
Microspathodon chrysurus	Yellowtail Damselfish	1	3		1	1	**1.2**
Chaetodon striatus	Banded Butterflyfish	2				2	**0.8**
Cephalopholis cruentatus	Graysby		1	1		2	**0.8**
Heteropriacanthus cruentatus	Glasseye Snapper		2	2			**0.8**
Stegastes leucostictus	Beau Gregory	1				2	**0.6**
Chaetodon capistratus	Four-eye Butterflyfish	1	2				**0.6**
Haemulon flavolineatum	French Grunt		1	1	1		**0.6**
Holocentrus rufus	Squirrelfish	2	1				**0.6**
Pseudupeneus maculatus	Spotted Goatfish				1	1	**0.4**
Serranus tigrinus	Harlequin Bass					2	**0.4**
Neoniphon marianus	Longjaw Squirrelfish	1		1			**0.4**
Amblycirrhitus pinos	Redspotted Hawkfish			1		1	**0.4**
Abudefduf sexatilis	Sargent Major			2			**0.4**
Canthigaster rostrata	Caribbean Puffer					1	**0.2**
Epinephelus guttatus	Red Hind					1	**0.2**
Cephalopholis fulva	Coney				1		**0.2**
Haemulon plumieri	White Grunt		1				**0.2**
Haemulon sciurus	Bluestriped Grunt					1	**0.2**
Haemulon melanorum	Cottonwick			1			**0.2**
Haemulon macrostomum	Spanish Grunt		1				**0.2**
Sparisoma radians	Bucktooth Parrotfish					1	**0.2**
Melichthys niger	Black Durgon			1			**0.2**
	TOTAL INDIVIDUALS	**58**	**137**	**114**	**85**	**115**	**101.6**
	TOTAL SPECIES	**16**	**21**	**21**	**14**	**24**	**19.2**

The Boya Esperanza fish community structure exhibited a well balanced composition of trophic groups. Small benthic invertebrate feeders were represented by 18 species within belt-transects including three Wrasses (Labridae), four grunts (Haemulidae), two Squirrelfishes (Holocentridae), one goby (Gobiidae), two sea basses and small groupers (Serranidae), one goatfish (Mullidae), one puffer (Tetraodontidae) and one Hawkfish (Cirrhitidae) with a combined density of 40.4 Ind/transect, representing 39.8% of the total community within transects. Zooplanktivores included four species with a cumulative density of 34.0 Ind/transect, representing 33.5% of the total. The zooplanktivorous assemblage included three damselfishes and the Fairy Basslet (Grammatidae). Herbivores were represented by 11 species with a combined density of 25.4 Ind/transect, representing 25.0% of the total. The herbivorous assemblage included six parrotfishes (Scaridae), two doctorfishes (Acanthuridae) and four Damselfishes (Pomacentridae). Piscivores and species of commercial value included one adult Red Hind (*Epinephelus guttatus*), and one juvenile Yellowtail Snapper (*Ocyurus chrysurus*). Parrotfishes (*Sparisoma viride, S. aurofrenatum*) were observed throughout most of their size range (Table 61). Great Barracuda, Jacks, Yellowtail, Lane and Gray Snappers, and the Cero Mackerel have been previously reported (Garcia-Sais et al., 2014).

Monitoring trends of fish abundance and species richness is shown in Figure 55. Differences between surveys were within sampling variability error. Motile megabenthic invertebrates were represented within belt-transects by one Long-Rock-boring Sea Urchin and Flamingo Tongue. One Spiny Lobster (*Panulirus argus*) and several juvenile Queen Conch (*Strombus gigas*) were observed outside transects.

Table 61. ESPE 10. Size frequency distribution of fishes within 20 x 4 m belt-transects at Boya Esperanza Reef 10, September 2016

		Transects				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Scarus iserti	Stripped Parrotfish		3-3	20-3	3-1	
Sparisoma viride	Stoplight Parrotfish	5-2	8-3	1-35	3-3	2-50
Sparisoma aurofrenatum	Redband Parrotfish	1-15 1-3	2-5	1-12	1-20	1-15
		2-10	2-15	2-15		1-20
		3-15	1-20	1-18		
Ocyurus chrysurus	Yellowtail Snapper					1-20
Epinephelus fulva	Coney				1-15	
Epinephelus guttatus	Red Hind					1-27
Cephalopholis cruentatus	Graysby		1-20	1-15		1-5
						1-15
Pterois volitans	Lionfish					
Scarus taeniopterus	Princess Parrotfish		8-3		5-3	4-3
			1-15			1-10
Sparisoma rubripinne	Yellowtail Parrotfish	1-20				

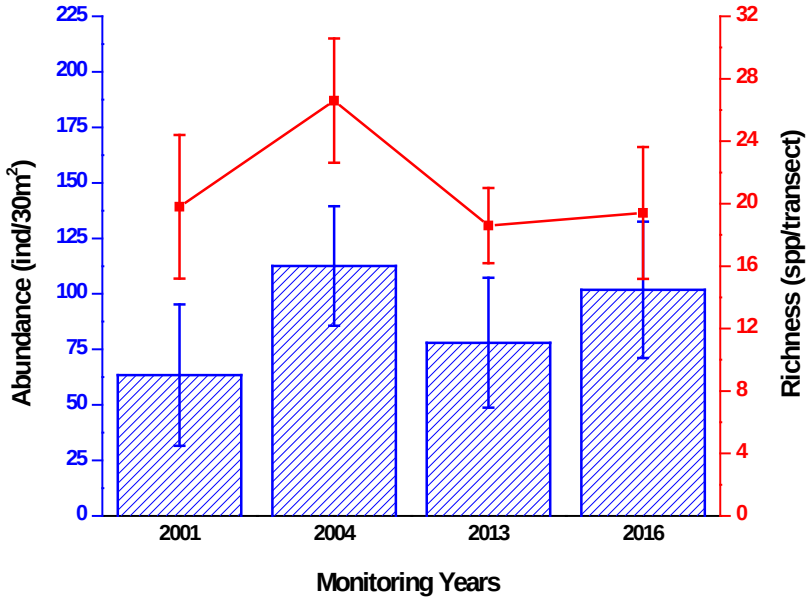
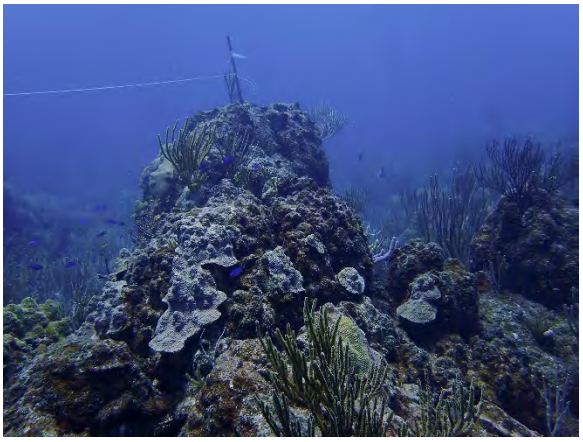
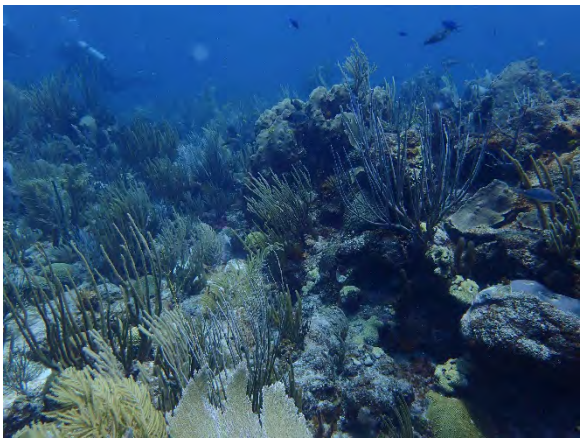
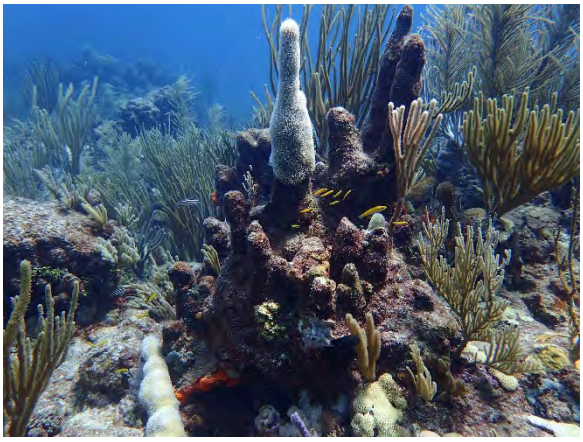


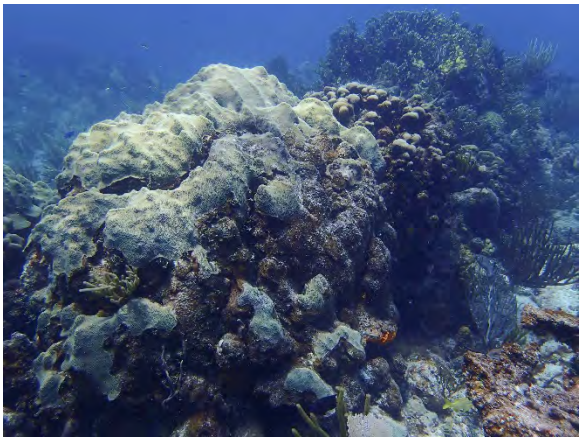
Figure 55. Temporal variations of fish abundance and species richness during monitoring surveys at Boya Esperanza Reef 10 (2001 – 2016)

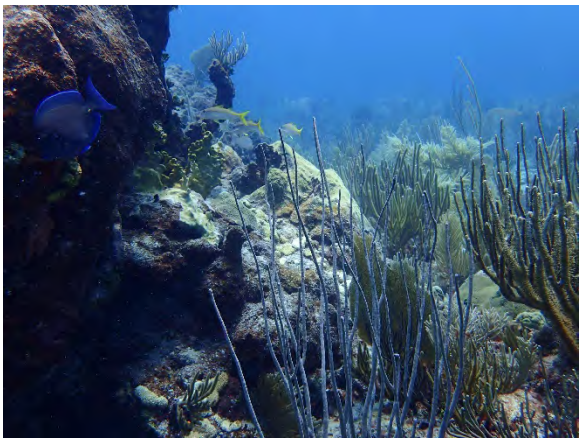
Photo Album 20.
Esperanza Reef 10m

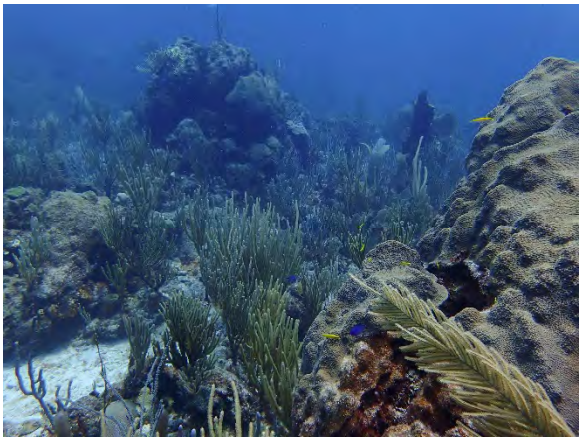


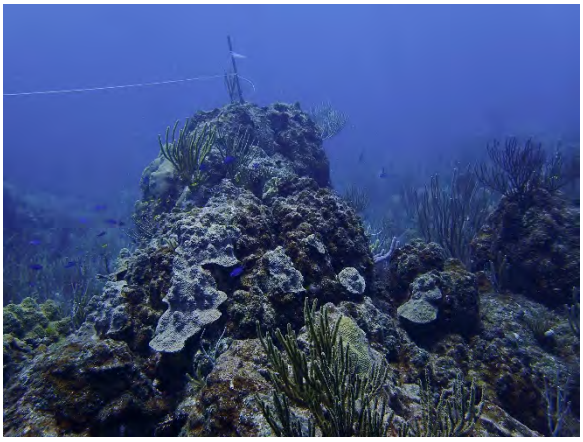












Cibuco Reef 5, Vega Baja

Physical Description

At approximately 0.5 km off the Vega Baja coastline lie a small group of emergent reefs known as Isletas de Garza (Figure 78). These appear to be the remains of cemented sand dunes or eolianites that run roughly parallel to the coastline. Due west of the isletas lies the mouth of Rio Cibuco, which discharges into a small embayment partially closed by an extensive sand bar. The reef community associated with the Isletas de Garza receives strong wave action from north Atlantic swells during the Winter (October – April) and is subjected to estuarine conditions during the rainy season. Despite such environmentally rough conditions an impressive coral reef system has been able to develop along the leeward section of the Isletas, and since it lies within the Cibuco River plume we have named this system as Cibuco Reef. The baseline characterization of Cibuco Reef was performed during October 2011 (Garcia-Sais et al., 2012). Panoramic views of the reef are shown in Photo Album 21.

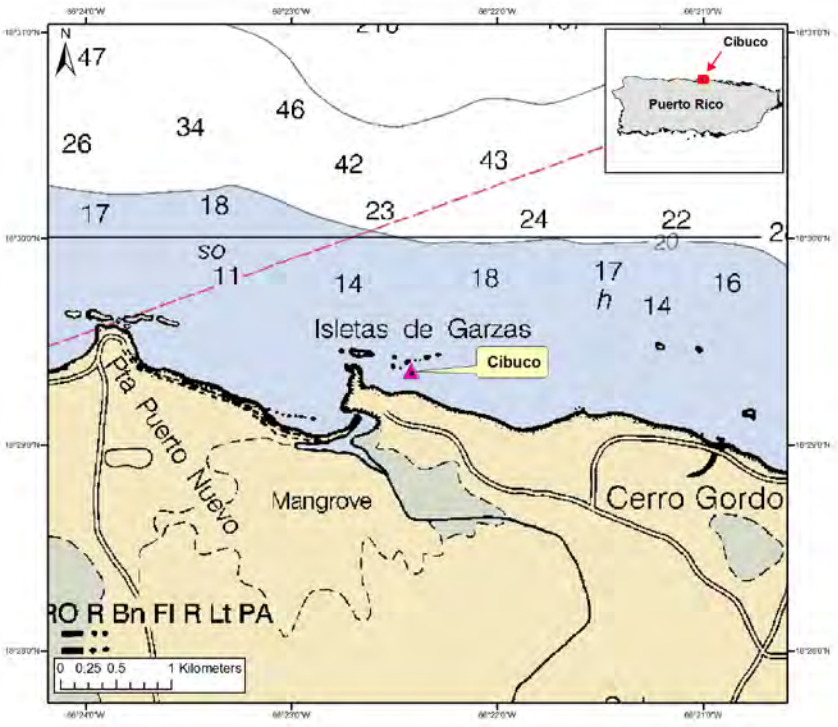


Figure 56. Location of Cibuco Reef at Isletas de Garza off Vega Baja in the north coast of Puerto Rico.

Sessile-Benthic Reef Community

Benthic algae, largely comprised by turf and brown fleshy macroalgae was the dominant substrate category intercepted by transects at Cibuco Reef 5 with a mean cover of 45.5% (range: 34.0 – 59.1%)(Figure 57). Turf algae, a mixed assemblage of short filamentous macroalgae that is highly resilient to wave action were present in all five transects with an average cover of 38.0 %, representing 83.5 % of the total cover by benthic macroalgae (Table 62). Fleshy brown macroalgae (mostly Dictyota sp) contributed a mean cover of 7.0%.

A total of 17 species of stony corals have been identified from Cibuco Reef, including six intersected by transects during this survey. Substrate cover by scleractinian corals along transects averaged 44.7 % (range: 39.2 – 61.8 %). Finger Coral, *Porites porites* was the main species in terms of substrate cover with a mean of 22.5 % (Figure 58), representing 50.3% of the total cover by stony corals (Table 62). Boulder Star Coral, *Orbicella annularis* (complex) was present along four transects with a mean cover of 16.6%. Colonies of Symmetrical Brain Coral, *Diploria strigosa,* Great Star Coral, *Montastraea cavernosa*, Mustard Hill Coral, *Porites astreoides* and Lettuce Coral, *Agaricia agaricites* were all intercepted by two transects. Soft corals (gorgonians) were present in very low density (1.6 Ind/transect).

Extensive thickets of Finger Coral growing as carpets were highly prominent at Cibuco Reef. These were observed overlying the eolianite rock at depths between 2 – 5 m. Thickets were at least 40 cm thick and exhibited continuous linear extensions of more than 10 m (3-4 m wide) in various sections of the reef. Boulder Star Coral was observed growing mostly as encrusting colonies of small to moderate size, but several massive boulders with overhangs were also present. Recently dead colonies and sections of live *O. annularis* colonies were observed, evidencing considerable tissue mortality during recent years. Symmetrical Brain Coral and Mustard-Hill Coral were found growing as round and mound colonies encrusted over the rocky substrate forming a “floor” of coral mosaics in very shallow sections of the reef. Also, encrusting colonies of Elkhorn Coral, *Acropora palmata* were present in the shallowest sections (less than one meter) of the reef crest. Encrusting zoanthids and sponges were present, but represented minor components of the reef benthic community (Table 62). Abiotic substrates, mostly reef overhangs were encountered in all five transects with a mean cover of 8.9 %.

Table 62. CIBU 5. Percent cover by sessile-benthic categories along permanent transects, Cibuco Reef 5. Vega Baja. September 2016

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	1.97	1.80	4.89	3.43	3.00	**3.02**
Benthic Categories						
Abiotic						
Reef overhang			1.88	19.92	10.96	**6.55**
Rubble				5.53		**1.11**
Sand	0.94			4.17		**1.02**
Gap		1.19				**0.24**
Total Abiotic	**0.94**	**1.19**	**1.88**	**29.61**	**10.96**	**8.91**
Benthic Algae						
Turf with sediment	57.31	31.79	26.97	14.91	33.97	**32.99**
Fleshy macroalgal mix with sediment			8.46	26.59		**7.01**
Turf	1.75	4.63	16.54			**4.58**
Dictyota spp.			2.35			**0.47**
CCA		0.59	1.41			**0.40**
Total Benthic Algae	**59.06**	**37.01**	**55.73**	**41.50**	**33.97**	**45.46**
Hard Coral						
Porites porites	15.09	61.80	26.13		9.59	**22.52**
Orbicella annularis complex	22.46		12.03	23.04	25.34	**16.57**
Pseudodiploria strigosa			0.75		17.81	**3.71**
Montastraea cavernosa			1.41	4.80		**1.24**
Porites astreoides	1.40		1.32			**0.54**
Agaricia agaricites	0.23		0.38			**0.12**
Total Hard Coral	**39.18**	**61.80**	**42.01**	**27.84**	**52.74**	**44.72**
# Gorgonians/transect		2		1	5	**1.6**
Invertebrate						
Palythoa caribaeorum	0.58		0.19		0.55	**0.26**
Seagrass						
Thalassia testudinum	0.23					**0.05**
Sponge						
Cliona caribbaea					1.37	**0.27**
Neopetrosia sp.				1.04		**0.21**
Ircinia brown sp.					0.41	**0.08**
Niphates erecta			0.19			**0.04**
Total Sponge			**0.19**	**1.04**	**1.78**	**0.60**

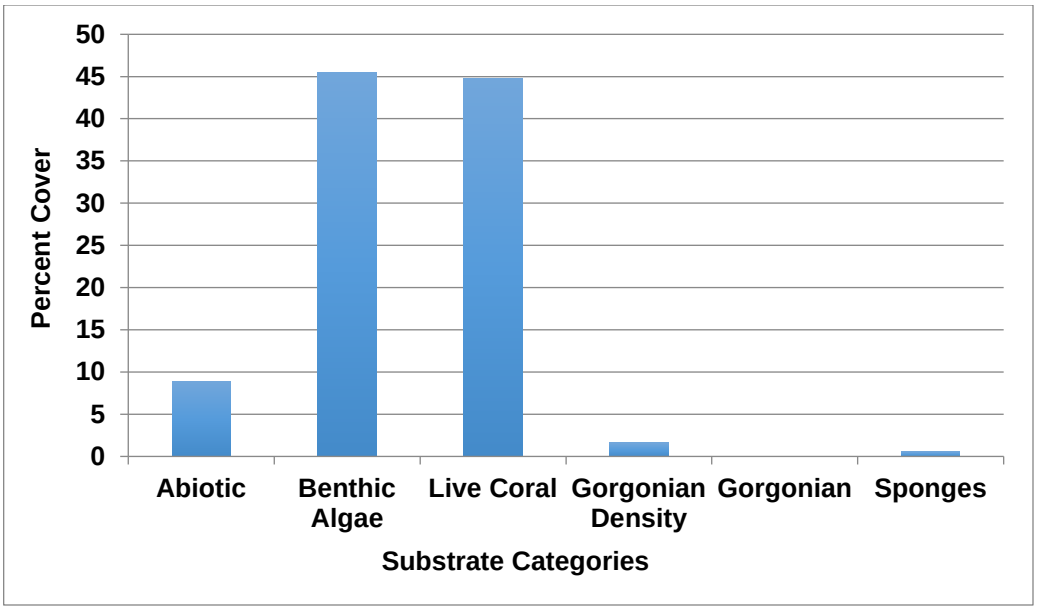


Figure 57. Mean substrate cover by benthic categories at Cibuco Reef 5. Vega Baja September 2016

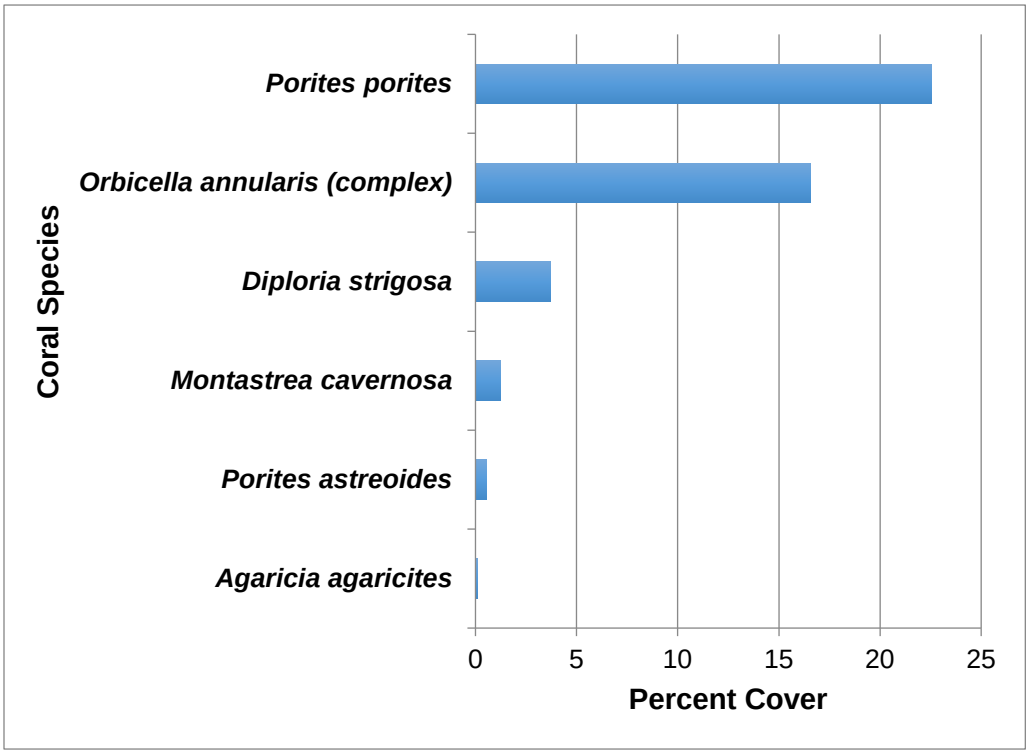


Figure 58. Mean substrate cover by coral species at Cibuco Reef 5. Vega Baja September 2016

Variations of live coral cover between monitoring surveys (Figure 59) were not statistically significant (ANOVA; p =0.917, see Appendix 2). Live coral cover varied by less than 3% between surveys and there was no evidence of bleaching and/or recent coral mortality between surveys.

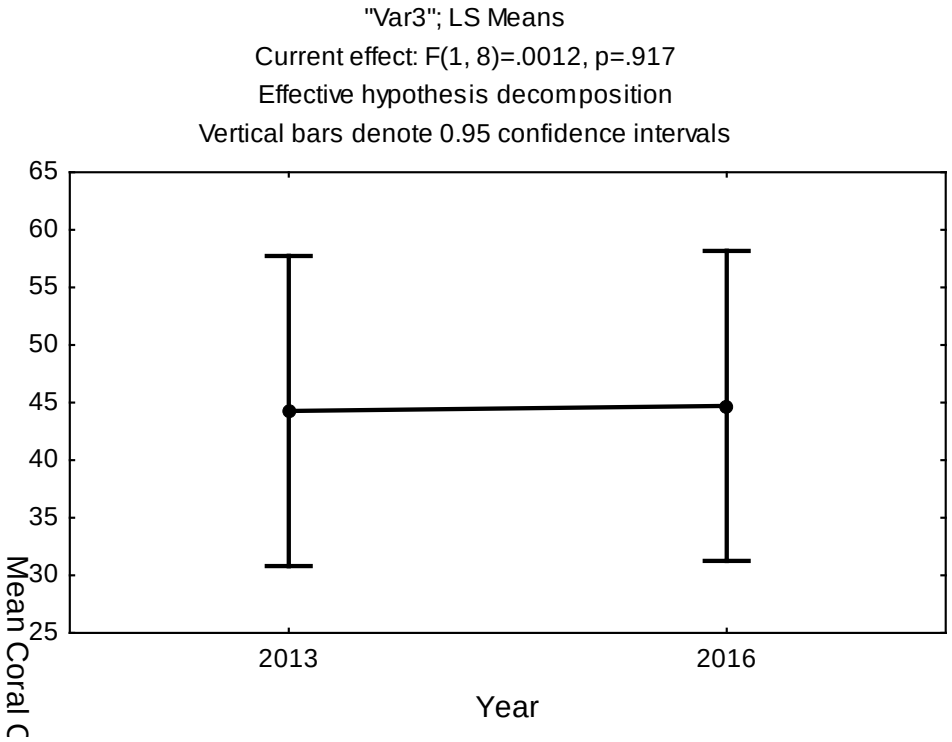


Figure 59. Temporal variations of total live coral cover from baseline and monitoring surveys at Cibuco Reef 5, Vega Baja.

Fishes and Motile Megabenthic Invertebrates

A total of 37 fish species have been identified from Cibuco Reef within a depth range of 2 – 5 meters during monitoring surveys, including 18 present within belt-transects during the 2016 survey (Table 63). The mean abundance of individuals was 35.6 Ind/30 m^2 (range: 31 - 49 Ind/30 m^2), and the mean number of species per transect was 7.2 (range: 5 - 10). The Bluehead Wrasse, *Thalassoma bifasciatum* was the numerically dominant species within belt-transects with a mean density of 22.4 Ind/transect, followed by the Dusky Damselfish (*Stegastes*

Table 63. CIBU 5. Taxonomic composition and abundance of fishes within belt-transects at Cibuco Reef 5. Vega Baja, September 2016

		Transects (Ind/30m^2)					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	18	19	34	22	19	**22.4**
Stegastes dorsopunicans	Dusky Damselfish	2	4	7	5	7	**5.0**
Halichoeres maculipinna	Clown Wrasse		2	3		2	**1.4**
Scarus taeniopterus	Princess Parrotfish	5					**1.0**
Sparisoma viride	Stoplight Parrotfish		2	2		1	**1.0**
Acanthurus chirurgus	Doctorfish	2			2		**0.8**
Cephalopholis fulva	Coney	1			1	1	**0.6**
Gerres cinereus	Yellowfin Mojarra	3					**0.6**
Microspathodon chrysurus	Yellowtail Damselfish		1	1		1	**0.6**
Scarus iserti	Stripped Parrotfish		2				**0.4**
Stegastes variabilis	Cocoa Damselfish			1		1	**0.4**
Abudefduf sexatilis	Sargent Major	1					**0.2**
Acanthurus bahianus	Ocean Surgeon		1				**0.2**
Acanthurus coeruleus	Blue Tang				1		**0.2**
Bodianus rufus	Spanish Hogfish			1			**0.2**
Canthigaster rostrata	Caribbean Puffer	1					**0.2**
Haemulon chrysargyreum	Stripped Grunt	1					**0.2**
Lutjanus apodus	Schoolmaster Snapper	1					**0.2**
	TOTAL INDIVIDUALS	**35**	**31**	**49**	**31**	**32**	**35.6**
	TOTAL SPECIES	**10**	**7**	**7**	**5**	**7**	**7.2**

dorsopunicans) with 5.0 Ind/transect. In addition to the aforementioned species, an assemblage of four species were present in at least three transects. These include the Clown Wrasse, *Halichoeres maculipinna*, Stoplight Parrotfish, *Sparisoma viride*, Coney, *Cephalopholis fulva*, and the Yellowtail Damselfish, *Microspathodon chrysurus* (Table 63).

The trophic structure of the fish community at Cibuco Reef was strongly influenced by the numerical dominance of opportunistic carnivores, such as the Bluehead and Clown Wrasses which presented a combined density of 23.8 Ind/transect, representing 66.8% of the total individuals within belt-transects. In addition, the yellowfin Mojarra, *Gerres cinereus*, Spanish Hogfish, *Bodianus rufus* and the Striped Grunt, *Haemulon chrysargyreum* were present in lower

density. The herbivorous assemblage was comprised by 10 species, including three parrotfishes (Scaridae), four damselfishes (Pomacentridae) and three doctorfishes (Acanthuridae) with a combined density of 9.8 Ind/transect, representing 27.5% of the total individuals. The zooplanktivorous component was comprised by estuarine species, such as anchovies (Engraulidae) observed in large aggregations in the vicinity of the reef over sandy bottom. Piscivores were represented by jacks (Carangidae) and Great Barracuda (Sphyraenidae). In previous surveys, mid-water piscivores were observed feeding on the school of anchovies in the vicinity of the reef. The Yellowfin Mojarra (*Gerres cinereus*) and other species of mojarras (*Eucinostomus spp*) were observed to be abundant over the sandy bottom surrounding the reef.

Cibuco Reef appears to be an important recruitment habitat for the Coney (*Epinephelus fulva*) and also for juvenile snappers (*Lutjanus analis, L. synagris, L. griseus*), parrotfishes (Sparisoma viride) and grunts (Haemulidae), observed in very small sizes at the reef and in the adjacent seagrass habitats.

The Long-spined urchin, *Diadema antillarum* was the most prominent motile megabenthic invertebrate present within belt-transects with a mean abundance of 4.4 Ind/30 m^2. One Spiny Lobster (*Panulirus argus*) and one Fire Worm (*Hermodice carunculata*) were observed outside transects in previous surveys. Several Flamingo Tongues (Gastropoda: *Cyphoma gibbosum*) were observed on soft corals. The adjacent seagrass habitat at the backreef of Cibuco Reef was observed to function as nursery habitat for juvenile Queen Conch (*Strombus gigas*).

The temporal variations of fish species richness and abundance during monitoring surveys at Cibuco Reef are presented in Figure 60. There was a marked decline of fish species richness between the baseline survey in 2011 and subsequent monitoring surveys in 2014 and the present 2016. Such difference may be related to the higher wave action and associated surge conditions that prevailed during the past monitoring events.

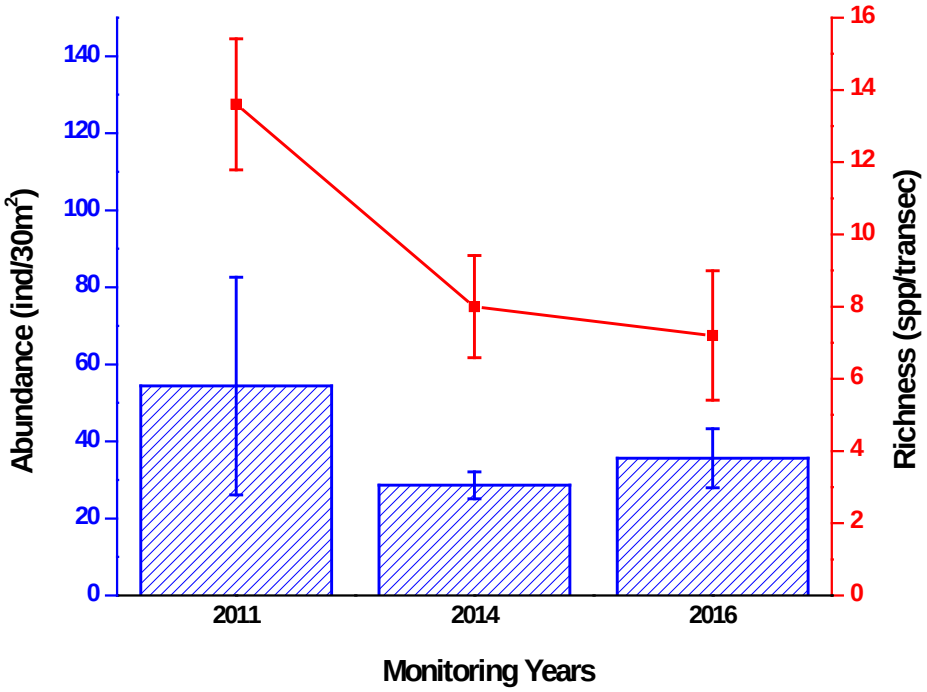
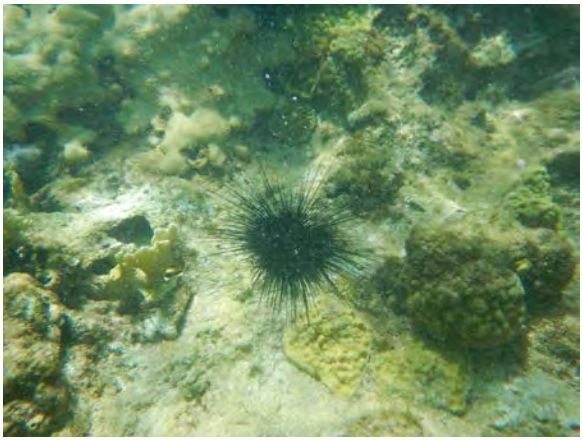


Figure 60. Temporal variations of fish abundance and species richness during monitoring surveys at Cibuco Reef 5, Vega Baja (2011 – 2016)

Photo Album 21.
Cibuco Reef 5m



General Conclusions

1. The sessile-benthic community at the reef systems of Puerto Botes and Puerto Canoas (Isla Desecheo), Tourmaline Reef (Mayaguez), Cayo Coral (Guánica), West Reef (Caja de Muerto – Ponce), Derrumbadero Reef (Ponce), Playa Mujeres (Isla de Mona) and the Canjilones and Boya Esperanza Reefs (Vieques) presented statistically significant differences of live coral cover between annual surveys during the monitoring program.
2. Differences of live coral cover between monitoring surveys were mostly associated with a sharp decline measured during 2006, after a severe regional coral bleaching event affected reef systems of Puerto Rico and the U. S. Virgin Islands during late 2005. Lingering effects with continued live coral cover losses were measured for the aforementioned reefs until 2008.
3. The decline of (total) live coral cover was largely driven by mortality of Boulder Star Coral, *Orbicella annularis* (complex), a highly dominant species in terms of reef substrate cover and the principal reef building species. Corresponding increments of reef substrate cover by benthic algae, cyanobacteria, sponges and abiotic categories were measured.
4. Coral reefs in oceanic islands (I. Mona, I. Desecheo), shelf-edge reefs and the shallow reefs of Vieques were the most affected by the regional coral bleaching event, whereas mesophotic reefs (El Seco-Vieques), Tourmaline 30m, Desecheo 30m, Elkhorn Coral Reefs (Tres Palmas, Aurora) and coastal reefs (Resuellos, Cibuco, El Palo, Caribes, Coral, Tres Palmas) were the least affected.
5. An inverse relationship between loss of substrate cover by live corals and a satellite derived light attenuation coefficient (Kd 490) was evidenced for reefs in the monitoring program, suggesting that water transparency played an important, perhaps synergistic role with increased sea surface temperature in coral degradation during and after the 2005 regional bleaching event. In this regards, water turbidity served as a “sun-block” effect in protection of coral degradation, particularly for coastal refs where the higher phytoplankton biomass influences light attenuation.
6. Major phase shifts of reef benthic community structure associated with acute mortality and loss of reef substrate cover by the dominant reef building Boulder Star Coral (*Orbicella annularis* complex) have been observed, particularly on reefs strongly dominated by *O. annularis*, such as Desecheo 15, Desecheo 20, Tourmaline 10, Derrumbadero, Canjilones and Boya Esperanza. Shifts involve alternations of coral dominant species due to increased cover by branching corals (Tourmaline 10, Des 15, 20) and/or differential (statistically significant) reductions of cover by previously dominant corals (Boya Esperanza, Canjilones, Derrumbadero).
7. Between 2009 and the 2016 monitoring surveys a mild to moderate and consistent recuperation of live coral cover, in most cases driven by growth of *Orbicella annularis* has been measured in most reefs (e.g. Cayo Coral, Desecheo 15, 20 and 30m, Tourmaline 30m, 20m, Derrumbadero 20, Caja de Muerto 10, Esperanza 10).
8. A positive correlation between live coral recuperation and water turbidity, as measured by the light attenuation coefficient Kd 490 has emerged, suggesting that coastal corals are growing faster than oceanic/shelf-edge and eastern reef corals.
9. The *Acropora palmata* fringing reef of Tres Palmas in Rincon is infected by white band disease and what appears to be white pox, an infectious disease also known as “patchy necrosis”. The infection prevalence in colonies is high (>60%) and although active growth by *A. palmata* is evident, given favorable conditions for the disease massive coral mortality can be expected.
10. From the 2015 baseline characterization of the Elkhorn coral reef at Gallardo we can infer that the reef has been exposed to severe degradation caused by mechanical damage as there are massive deposits of broken elkhorn coral fragments across the reef. Also, Elkhorn Coral at this reef appears to be suffering from a strong predatory pressure by corallivorous gastropods.
11. Reef fish community structure has shown a pattern of short-term, statistically significant fluctuations of abundance at most reefs surveyed during the monitoring program. On costal shallow reefs, fluctuations appear to be largely physically driven by wave energy and its associated surge action and turbulence. On deeper oceanic and shelf-edge reefs fluctuations of abundance appear to be driven by the recruitment dynamics of numerically dominant populations with highly patchy distributions and schooling behaviors, such as Masked Goby, *Coryphopterus personatus* and Blue Chromis, *Chromis cyanea*.

12. Marked differences of fish community structure are evident between oceanic/shelf-edge reefs dominated by pelagic and demersal zooplanktivore trophic assemblages (*Chromis spp*., Creole Wrasse, Masked Goby, Bicolor Damselfish) and coastal reefs, dominated by herbivorous assemblages (Parrotfishes, Doctorfishes, farmer Damselfishes).
13. The taxonomic composition and size structure of commercially important fishes was *dominated* by parrotfishes (Scaridae). These occurred mostly as early juvenile, juveniles and adults. Post settlement juveniles of several parrotfish species, including the Stoplight, Princess and Stripped (*Sparisoma viride, Scarus taeniopterus, S. iserti*) have been observed, indicative that some of these neritic reefs, particularly those at La Parguera serve as recruitment habitats for these species.
14. The size frequency distributions of the Lionfish (*Pterois sp*.) were strongly skewed towards the large adult size classes, suggesting a paucity of recruitment on local reefs.
15. Although in low abundance, large demersal (top predator) fishes have been observed during the last few surveys. These include Reef Shark (*Carcharhinus perezi*), Yellowfin, Yellowmouth, Tiger, Jewfish, and Nassau Groupers (*Mycteroperca venenosa, M. interstitialis, M. tigris, Epinephelus itajara, E. striatus*), and the Cubera, Dog and Mutton Snappers (*Lutjanus cyanopterus, L. jocu, L. analis*).
16. The status of the large demersal, commercially valuable and overfished grouper/snapper populations continues to be precarious and no signs of stock replenishment have been noted within Natural Reserve reef sites.
17. Comprised by at least 96 diurnal, non-cryptic species and including healthy populations of large demersal and pelagic predators, the upper mesophotic (30 m) fish community at the bank coral reef of El Seco, Vieques can be regarded as highly biodiverse, well balanced in terms of its trophic components and an important reservoir of commercially exploited coral reef fishes.

Conclusions from the 2016 Baseline Characterization and Monitoring Survey

1- A total of 21 coral reef stations were surveyed in the 2016 coral reef monitoring event. Baseline characterizations (17 reef stations) were produced for reef systems in Mayaguez Bay (Manchas Exteriores 20, 10, Rodriguez 5), Cabo Rojo (Guanajibo 20, El Negro10, 5), Guayanilla Bay (Maria Langa 20, 10, 5), Salinas (Cayo Coral 10, Cayo Ratones 5), Fajardo (Palominos 20, Palominitos 10, Cayo Diablo 5) and Isla de Culebra (Dakiti 20, Carlos Rosario 10, Luis Pena 5). Monitoring surveys were performed on the reefs stations of Isla de Vieques (El Seco30, Canjilones 20, Esperanza 10) and Vega Baja (Cibuco Reef 5).

2- The Manchas Exteriores/Rodriguez Reef systems in Mayaguez and El Negro/Guanajibo in Cabo Rojo represent coastal coral reefs of the west coast with relatively high live coral cover (20 – 36 %) with strong dominance of *Orbicella annularis* and more than 10 coral species intercepted in the five permanent transect within the 5 – 20 m stratified depth format.

3- Fringing reef systems at the outer sections of Guayama/Salinas (Cayo Caribe 10, Cayo Ratones 5) and Guayanilla Bays (Maria Langa 20, 10, 5) represent coastal reef systems of the south coast with a sessile-benthic community dominated by soft corals (gorgonians), with live cover by scleractinian corals in the 12 – 20% range, including one reef station dominated in terms of reef substrate cover by Fused Staghorn Coral, *Acropora prolifera* (Maria Langa 5).

4- Reefs surveyed from the Cordillera de Fajardo (Palomino 20, Palominito 10, Cayo Diablo 5) represent coral reef systems of the east coast with high coral cover (20 – 32% range) under intense recreational use.

5- Reefs surveyed at Isla de Culebra (Dakiti 20, Carlos Rosario 10, Luis Pena 5) represent systems from an upstream location, low recreational impact, within the Luis Pena Marine Reserve with extensive coral buildup, but highly degraded and overgrown by encrusting biota, particularly red algae (*Ramicrusta sp*).

6- From the monitoring survey of the reefs in Vieques (El Seco 30, Canjilones 20 and Boya Esperanza 10) live scleractinian coral cover remained stable at Canjilones 20. Small increments of coral cover were measured at El Seco 30 and Esperanza 10 were within sampling variability error. Statistically significant variations of benthic community structure between monitoring surveys were evidenced for all three reefs (Permanova; $p < 0.001$). Differences were associated with a drastic decline (five to six fold) of reef substrate cover by turf algae, a previously dominant taxonomic category of reef substrate cover and a corresponding increase of cover by the previously unreported red crustose alga, *Ramicrusta sp*. with reef substrate cover as high as 58.7 % at Boya Esperanza 10.
7- It is uncertain at this point if the displacement of turf algae by *Ramicrusta sp*. has had and/or is having any impact upon the Vieques reef corals, since substrate cover by corals at the reef stations monitored did not decline, but rather a mild increasing trend was observed. The implications of such colonization of hard bottom by encrusting red algae on coral growth, recruitment and competition for space are highly speculative at this point, but prospective monitoring of these reefs and others within the east coast (Fajardo, Culebra) will allow further assessments of these relationships.
8- The density of fishes, including commercially important groupers (*Epinephelus guttatus*), snappers (*Ocyurus chrysurus, Lutjanus jocu*) and Spiny Lobsters (*Panulirus argus*) and the size of spiny lobsters at Luis Pena 10 within the Luis Pena Marine reserve are the highest and largest (in the case of spiny lobsters) ever recorded in the PR Coral Reef Monitoring Program. Thus, it is here suggested that the fishing closure at this reef is having positive impacts in terms of the fish community.

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Appendix 1. Multivariate analyses of variations of benthic community structure between monitoring surveys at the Vieques and Cibuco reefs

El Seco - Permanova

Source	df	SS	MS	Pseudo-F	P(perm)	perms
Year	1	4433.1	4433.1	34.326	0.011	126
Res	8	1033.2	129.15			
Total	9	5466.3				

El Seco- SIMPER

Group 2013
Average similarity: 86.65

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Coral	37.13	36.26	28.23	41.85	41.85
Turf	32.78	29.86	4.31	34.46	76.31
CCA	12.03	11.38	5.29	13.14	89.45
Macroalgae	7.08	6.28	3.38	7.25	96.7

Group 2016
Average similarity: 83.05

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Coral	41.09	38.77	8.94	46.69	46.69
Macroalgae	24.77	21.58	4.23	25.98	72.67
Peyssonnelid	17.44	16.71	6.18	20.12	92.79

Groups 2013 & 2016
Average dissimilarity = 44.04

	Group 2013	Group 2016				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Turf	32.78	7.21	13.55	3.2	30.77	30.77
Macroalgae	7.08	24.77	9.36	2.73	21.25	52.01
Peyssonnelid	0	17.44	9.27	6.41	21.05	73.06
CCA	12.03	1.12	5.79	4.09	13.15	86.21
Coral	37.13	41.09	3.86	1.29	8.76	94.97

Canjilones 20m - Permanova

Source	df	SS	MS	Pseudo-F	P(perm)	perms
Ye	3	12797	4265.5	28.515	0.001	999
Res	16	2393.4	149.59			
Total	19	15190				

Pairwise-Canjilones

Groups	t	P(perm)	Unique perms
2013, 2016	6.0519	0.01	126
2013, 2001	2.204	0.032	126
2013, 2004	2.1543	0.025	126
2016, 2001	7.5908	0.005	126
2016, 2004	6.8957	0.007	126
2001, 2004	0.85201	0.59	126

SIMPER-Canjilones

Group 2013
Average similarity: 82.24

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Turf	58.27	56.27	5.36	68.43	68.43
Coral	16.23	15.5	6.21	18.85	87.28
Macroalgae	8.65	5.3	1.83	6.45	93.73

Group 2016
Average similarity: 80.40

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peyssonnelid	34.56	35.99	6.24	44.77	44.77
Coral	14.88	15.38	11.51	19.14	63.9
Macroalgae	16.32	13.3	2.34	16.54	80.45
Turf	11.62	8.47	1.13	10.53	90.98

Group 2001
Average similarity: 88.56

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Turf	47.35	52.75	18.68	59.57	59.57
Coral	24.54	30	13.9	33.87	93.44

Group 2004
Average similarity: 86.77

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Turf	44.81	52.22	8.83	60.18	60.18
Coral	24.56	26.29	6.19	30.3	90.48

Groups 2013 & 2016
Average dissimilarity = 57.41

	Group 2013	Group 2016				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Turf	58.27	11.62	26	3.86	45.29	45.29
Peyssonnelid	0	34.56	19.27	6.83	33.56	78.84
Macroalgae	8.65	16.32	5.32	1.48	9.26	88.11
Cyanobacteria	1.87	4.13	2.03	1.03	3.53	91.63

Groups 2013 & 2001
Average dissimilarity = 20.92

	Group 2013	Group 2001				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Turf	58.27	47.35	8.63	1.58	41.24	41.24
Coral	16.23	24.54	4.87	2.6	23.28	64.51
Macroalgae	8.65	5.07	3.08	1.07	14.72	79.23
Sponge	4.85	2.28	1.95	1.43	9.32	88.55
CCA	2.2	0	1.3	1.11	6.21	94.76

Groups 2016 & 2001
Average dissimilarity = 60.69

	Group 2016	Group 2001				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Turf	11.62	47.35	21.34	3.41	35.16	35.16
Peyssonnelid	34.56	0	20.78	6.59	34.24	69.4
Macroalgae	16.32	5.07	6.79	1.72	11.19	80.59
Coral	14.88	24.54	5.82	3.51	9.58	90.17

Groups 2013 & 2004
Average dissimilarity = 21.54

	Group 2013	Group 2004				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Turf	58.27	44.81	9.06	2	42.06	42.06
Coral	16.23	24.56	4.97	1.49	23.1	65.16
Macroalgae	8.65	8.22	3.13	1.29	14.55	79.71
Sponge	4.85	1.98	1.98	1.39	9.21	88.92
CCA	2.2	0	1.3	1.11	6.01	94.93

Groups 2016 & 2004
Average dissimilarity = 57.84

	Group 2016	Group 2004				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Peyssonnelid	34.56	0	20.71	6.8	35.8	35.8
Turf	11.62	44.81	19.93	3.85	34.45	70.25
Coral	14.88	24.56	5.83	1.7	10.08	80.33
Macroalgae	16.32	8.22	5.44	1.5	9.41	89.74
Cyanobacteria	4.13	0	2.51	1.06	4.35	94.09

Groups 2001 & 2004
Average dissimilarity = 12.00

	Group 2001	Group 2004				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Turf	47.35	44.81	5.03	1.24	41.89	41.89
Coral	24.54	24.56	2.93	1.69	24.45	66.35
Macroalgae	5.07	8.22	2.62	1.38	21.85	88.2
Sponge	2.28	1.98	1.42	1.25	11.8	100

Esperanza 10m - Permanova

Source	df	SS	MS	Pseudo-F	P(perm)	perms
Ye	3	21001	7000.2	39.477	0.001	999
Res	16	2837.2	177.32			
Total	19	23838				

Pairwise-Esperanza

Unique Groups	t	P(perm)	perms
2013, 2016	9.357	0.007	126
2013, 2001	2.6976	0.024	126
2013, 2004	2.7347	0.024	126
2016, 2001	8.7453	0.008	126
2016, 2004	8.6887	0.004	126
2001, 2004	0.34897	0.705	126

SIMPER-Esperanza

Group 2013
Average similarity: 83.49

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Turf	73.62	69.79	7.77	83.59	83.59
Coral	15.2	9.29	1.39	11.13	94.72

Group 2016
Average similarity: 83.68

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peyssonnelid	58.73	60.03	12.64	71.73	71.73
Turf	11.19	9.87	10.48	11.8	83.53
Coral	11.68	8.24	1.87	9.84	93.37

Group 2001

Average similarity: 82.48

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Turf	56.54	51.21	4.64	62.09	62.09
Coral	36.03	31.1	3.05	37.71	99.79

Group 2004
Average similarity: 83.23

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Turf	53.12	51.74	7.61	62.17	62.17
Coral	33.61	30.52	2.59	36.67	98.84

Groups 2013 & 2016
Average dissimilarity = 73.79

	Group 2013	Group 2016				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Turf	73.62	11.19	33.26	6.28	45.08	45.08
Peyssonnelid	0	58.73	31.27	10.39	42.38	87.46
Coral	15.2	11.68	4.99	1.45	6.77	94.23

Groups 2013 & 2001
Average dissimilarity = 25.46

	Group 2013	Group 2001				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Coral	15.2	36.03	11.52	1.68	45.23	45.23
Turf	73.62	56.54	10.1	1.38	39.66	84.89
Macroalgae	4.38	0.56	2.02	1.56	7.92	92.81

Groups 2016 & 2001
Average dissimilarity = 74.48

	Group 2016	Group 2001				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Peyssonnelid	58.73	0	31.86	10.26	42.78	42.78
Turf	11.19	56.54	24.51	3.45	32.91	75.69
Coral	11.68	36.03	13.4	2.02	17.99	93.68

Groups 2013 & 2004
Average dissimilarity = 26.17

	Group 2013	Group 2004				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Turf	73.62	53.12	11.87	1.79	45.36	45.36
Coral	15.2	33.61	10.87	1.77	41.53	86.89
Macroalgae	4.38	1.64	1.51	1.09	5.79	92.68

Groups 2016 & 2004
Average dissimilarity = 73.13

	Group 2016	Group 2004				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Peyssonnelid	58.73	0	32.72	10.55	44.74	44.74
Turf	11.19	53.12	23.37	3.49	31.95	76.7
Coral	11.68	33.61	12.5	2.02	17.1	93.79

Groups 2001 & 2004
Average dissimilarity = 15.16

	Group 2001	Group 2004				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Turf	56.54	53.12	7.93	1.43	52.28	52.28
Coral	36.03	33.61	6.33	1.17	41.74	94.01

Cibuco-5m -Permanova

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Ye	1	183.65	183.65	0.53837	0.78	126
Res	8	2729	341.12			
Total	9	2912.6				

Appendix 2. Repeated measures ANOVA testing differences of live coral cover between monitoring years for the reefs of Vieques and Cibuco

Year	SS	df	MS	F	p value
Seco	39.21	1	39.21	0.532	0.506
Canjilones	409.34	3	136.45	9.231	0.002
Esperanza	2331.67	3	777.22	6.83	0.006
Cibuco	0.487	1	0.487	0.012	0.917