FINAL REPORT

by

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I. Executive Summary

A total of 21 reef stations were scheduled during the 2016-17 coral monitoring cycle to complete the 42- reef station monitoring plan for Puerto Rico, including a set of five (5) stations from south coast sites (Salinas/Guayama and Guayanilla) that were exposed to severe wave and surge conditions during the pass of hurricane Matthew in October, shortly after their initial baseline characterization surveys were completed in 2016. The monitoring sampling protocol includes determinations of reef substrate cover by sessile-benthic and abiotic categories based on a continuous intercept (chain-link) technique on sets of five-10 m long permanent transects at various depths (within the 3 – 30 m range) on each reef. An assessment of the prevalence of infectious diseases on corals was added to the monitoring protocol. Surveys of the taxonomic composition, density, species richness/diversity indices, and size-distribution (selected species) of reef fishes and motile megabenthic invertebrates are also included as tasks of the monitoring protocol. Quantitative/qualitative assessments of reef fishes and motile invertebrates were based on sets of five 3 x 10 m belt-transects for small territorial, non-cryptic species and expanded to a 3 x 20 m belt for assessment of commercially important species, including ecologically important herbivores, such as doctorfishes (Acanthuridae) and parrotfishes (Scaridae). Digital photographic documentation of reef stations was produced for all reef stations.

The most important change in the community structure of coral reefs monitored during 2017 in PR was a marked decline (62.7%) of reef substrate cover by live corals, from 13.4% in 2016 to 5.0% in 2017 at the reef crest of Maria Langa 3m in Guayanilla. The drastic reduction of live coral cover was characterized by the disappearance of the dominant coral, *Acropora prolifera* from permanent transects apparently caused by the detachment and mortality of colonies exposed to conditions of extreme wave and surge action during the pass of Hurricane Matthew across the northern Caribbean and close to the south coast of PR during October 2016. Severe mechanical damage was also observed from Cayo Aurora's *Acropora palmata* reef biotope in Guanica. The very large Elkhorn Coral colonies were not detached from the base, but many of the large branches (arms) were broken. Survival rates of these fragments will be evaluated from prospective measurements during the next monitoring survey at this reef. Statistically significant reductions of soft coral (gorgonians) were measured at Tres Palmas Reef 3m in Rincon, Resuellos 10 m in Cabo Rojo, Tourmaline 20m in Mayaguez and Media Luna 10 m in La Parguera. Such reductions of gorgonian densities appear to be related to mechanical detachment during exposure to extreme wave and surge energy associated with the pass of Hurricane Matthew. Increasing trends of reef substrate cover by live corals were noted at Tres Palmas 10 and 20m, Tourmaline 10, 20 and 30m, Media Luna 10 and 5m. Boya Vieja 20m, Maria Langa 10 and 20m and Derrumbadero 20m. The main driver of the increasing trend of substrate cover by live corals at all reef stations except Tourmaline 10 (*Madracis auretenra*) was the consistent increase of cover by *Orbicella annularis* complex. Coral diseases were observed in 16 out of a total 1,132 coral colonies intercepted by transects during 2017, for a mean disease prevalence of 1.3%. Reefs with the highest disease prevalence were Cayo Caribes 10m in Salinas (4.5%), Boya Vieja 20m in La Parguera (4.1%), Bajo Gallardo in Cabo Rojo (4.0%), and Tres Palmas 3.0m in Rincon (3.0%).

Mean fish abundance surveyed within belt-transects declined in 11 out of the 21 reef stations surveyed during 2017 relative to previous surveys. The main factor influencing reductions of fish abundance in most reefs was the virtual absence of numerically dominant schooling zooplanktivore species, particularly Masked Goby, *Coryphopterus personatus*. Parrotfishes (Scaridae) were the most abundant commercially important fish assemblage observed within belt-transects, mostly driven by high prevalence and abundance of Stoplight, Redband, Princess and Stripped Parrotfish. Post settlement juvenile stages, particularly Stoplight and Redband were observed on most reefs surveyed evidencing the recruitment habitat role of these shallow reefs for these ecologically and commercially important species. Four juvenile Nassau Groupers (*Epinephelus striatus*) and two (2) Yellowfin Groupers (*Mycteroperca venenosa*) were observed from four different reef stations during 2017. This is the highest number recorded in the monitoring program and may be an indication of a good recruitment year for these species, particularly for Nassau Grouper. One adult Jewfish was observed out of transects at Maria Langa 20m. Spiny Lobsters (*Panulirus argus*) were observed from six reef stations, including several within belt-transects. This is the highest recorded in the reef monitoring program and appears to be an indication of a good recruitment year for this commercially important reef megabenthic invertebrate.

Table of Contents

II. Introduction

The Puerto Rico Coral Reef Monitoring Program sponsored by NOAA/CRCP and administered by the PR Department of Natural and Environmental Resources (PRDNER) was revised and modified in 2016 to expand the geographical range and number of reef monitoring sites to achieve a 42-reef station framework, with alternate year monitoring surveys at each reef. Additional coral reef monitoring sites now provide a more robust sampling design directed to analyze changes of live coral cover and taxonomic composition in relation to water turbidity and light penetration gradients associated with depth, distance from shore and location relative to major river discharges. Such gradients have been shown to be relevant as drivers of the spatial and temporal variability patterns of mortality, shifts of community structure and recuperation by corals and the coral reef community during the monitoring program (Garcia-Sais et al., 2017). This sampling 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 regarding coral reef ecological health.

The fish component of the coral reef monitoring program has also been expanded to provide a larger survey area and include size-frequency distributions of commercially important species, with particular attention to the herbivorous fish assemblage that is considered critically important in regulation of algal cover in the shallow (neritic) reefs surveyed. The species-specific size frequency observations contribute a new fisheries-independent data source that can used to support stock assessment analyses for the data-limited Puertorrican commercial fishery. Fish surveys are based on 20 m long belt-transects centered along the line transects used for the sessile-benthic community characterizations allowing discrimination of density-dependent versus density-independent factors regulating fish community structure (Esteves, 2013).

This is the final report corresponding to the 2016-17 coral reef monitoring event. Summarized time series data for all reef sites are here presented and analyzed. Detailed monitoring data is included only for the most recent 2016-17 survey. 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, 2015, 2016). Baseline characterization surveys are also available from García-Sais et al. (2001a,b,c, 2004).

III. Research Synthesis - Coral Reef Monitoring Program

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. During a similar 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. 2001d, 2004) maintained stable live coral cover. A drastic decline of live coral cover was measured from reefs in Desecheo, Ponce, Guanica and Mayaguez 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; Hernandez et al, 2006; García-Sais et al., 2008; Weil et al., 2009; Eakin et al., 2010). Posterior monitoring surveys in Mona (Garcia-Sais et al., 2010) and Vieques (Garcia-Sais et al., 2014) detected marked reductions of coral cover in the range previously noted for reefs in Desecheo and Ponce, suggesting that such declines of coral cover were probably associated with the 2005 coral bleaching event. 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 in the oceanic islands of Mona and Desecheo, the shelf-edge reefs of Derrumbadero in Ponce, Tourmaline Reef in Mayaguez and those in Vieques were the most severely affected.

Protection from bleaching with increasing depth from 20 to 30 m was observed at Tourmaline Reef in Mayaguez, Puerto Canoas Reef in Desecheo and the Canjilones and Boya Esperanza Reefs in Vieques. 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. Reefs located near the coastline and/or influenced by estuarine conditions (El Palo, Resuellos) exhibited low or negligible impacts to their mean coral cover after the bleaching event. A negative correlation between a satellite-derived light attenuation coefficient (Kd490) and the percent live coral loss was found, suggesting that protection from light penetration available both from water turbidity and depth contributed to the protection of corals from the mortality associated with the bleaching event (Garcia-Sais et al, 2017).

After two consecutive years of measuring what appeared to be lingering effects of the 2005 coral bleaching event, variable but continuous increments of live coral cover have been measured from impacted reefs in subsequent monitoring surveys until the present (Garcia-Sais et al. 2017, 2016 and references therein). Differences between years, while not statistically significant for most reefs, represent recuperation trends of live coral cover. A positive relationship was observed between coral recuperation and light attenuation coefficient (Kd490), suggesting that in most instances, estuarine conditions influencing reefs near the coast provided more favorable conditions for coral recuperation. Since phytoplankton biomass explained more than 90% of the spatial variability associated with light attenuation (turbidity) in the vicinity of our reefs monitored, it is possible that higher recuperation rates may be related to higher plankton food availability for corals. 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-Sais et al. 2008). Despite the infection prevalence to the present date, the Tres Palmas fringing reef keeps thriving with active growth.

Phase shifts in the taxonomic composition of reef substrate cover by live corals have been noted for Tourmaline Reef 10m (Mayaguez) and at Puerto Botes Reef 15 m and 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 corals has increased from its original condition before the 2005 bleaching induced mortality. Dead coral sections have been largely overgrown by turf and encrusting crustose algae (*Ramicrusta sp*) in other reefs stations (Garcia-Sais et al. 2017, 2016 and references therein). Still, subtle recuperation trends of reef substrate cover by *Orbicella* appear to be emerging from most ref sites.

A total of 210 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 (Esteves, 2013, García-Sais et al., 2016 and reference therein). 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*), Blue-head Wrasse (*Thalassoma bifasciatum*) and Creole Wrasse (*Clepticus parrae*). Such fluctuations appear to be related to density-independent factors affecting recruitment patterns of these short-lived populations. Variations also appear to respond physical conditions, such as wave action affecting the reef during the time of our survey. This was particularly relevant for shallow reefs (< 20 m) and more critically determinant for *Acropora* reefs, such as the Tres Palmas, Gallardo, Maria Langa, Ratones, Caribes, and Cayo Aurora reef systems. Depth, distance from shore, and substrate rugosity stand as the main factors explaining the variations of taxonomic composition and relative abundance of fish species at reefs studied (Garcia-Sais, 2010; Esteves, 2013).

IV. Approach and Methodology

A total of 21 reefs were monitored during the present 2016-17 survey to complete the 42-coral reef station plan for Puerto Rico, including a set of five (5) reef stations from south coast sites (Salinas/Guayama and Guayanilla) that were exposed to severe wave and surge conditions during the pass of hurricane Matthew close to the south coast of PR in October 2016, shortly after their initial baseline characterization surveys were completed. The geographic location coral reef stations are shown in Figure 1. Table 1 presents the geographic coordinates and depths of reefs monitored during the 2016-17 event.

The Puerto Rico coral reef monitoring program follows a depth, distance from shore and east-west sampling design that samples some of the main oceanographic gradients that appear to drive the ecological health and community structure of neritic coral reefs in Puerto Rico. Neritic coral reef systems included in this monitoring program are all shallower than 35m, and thus lie within the Caribbean Surface Mixed Layer water mass that varies seasonally at depth between 45 – 70 m. Due to the permanent stratification forces acting on this water mass, oceanic waters around Puerto Rico (and the northern Caribbean) remain highly oligotrophic, and the coastal estuarine influence of river discharge, watershed runoff and resuspension/remineralization processes from the insular shelf produce marked inshore-offshore gradients of water turbidity associated with both organic (phytoplankton) and inorganic (sediments) sources.

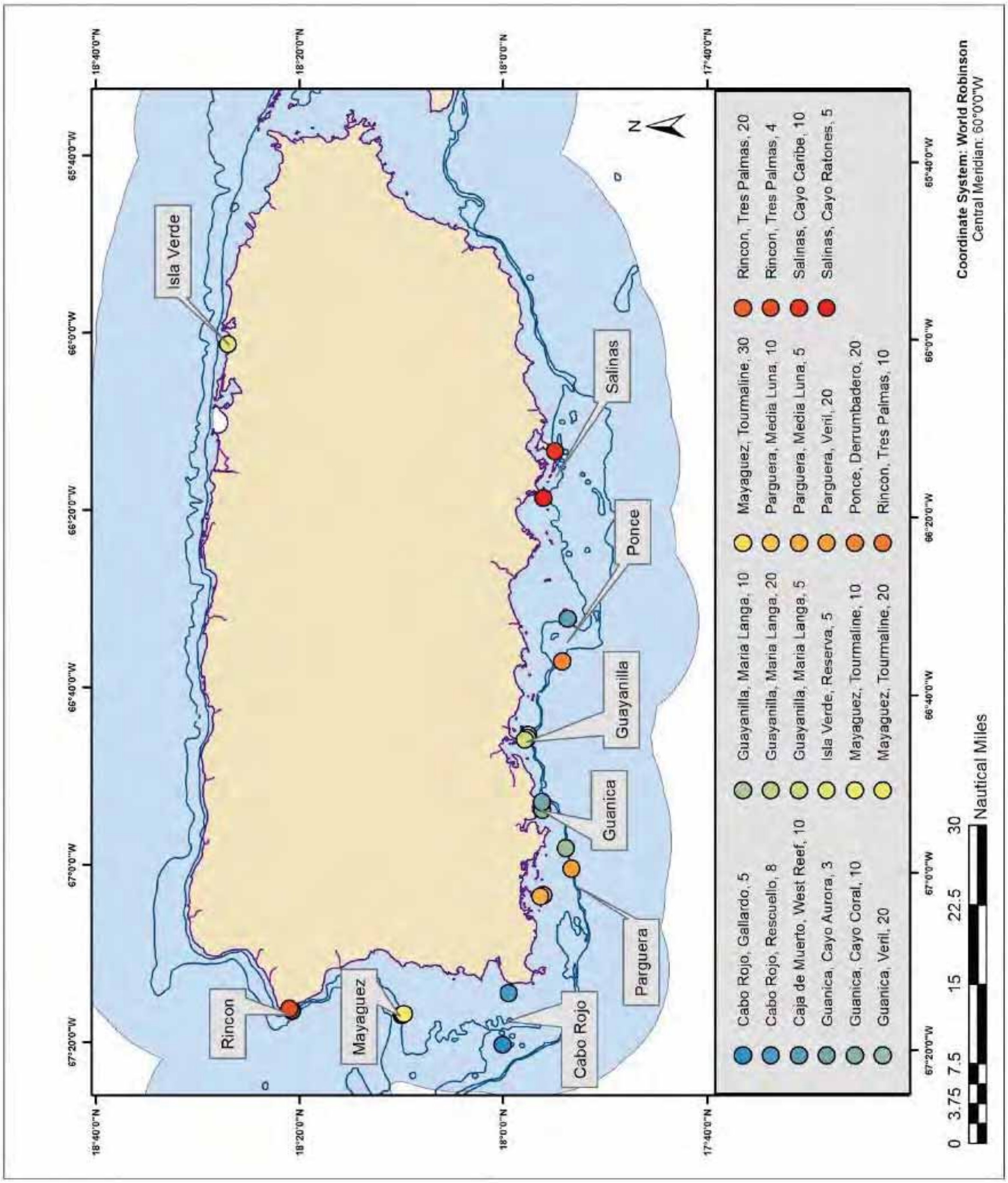


Figure 1. Map showing location of reef monitoring sampling stations 2016-17.

Table 1. Geographic positions and depths of coral reef stations included in the 2016-17 coral reef monitoring survey

Site/Reef Stations	Depth (m)	Latitude (°N)	Longitude (°W)
Mayaguez			
Tourmaline	30	18°09.9850	67°16.5810
Tourmaline	20	18°09.9100	67°16.5120
Tourmaline	10	18°09.7919	67°16.4160
Rincon			
Tres Palmas	20	18°20.7900	67°16.2480
Tres Palmas	10	18°20.8320	67°16.2060
Tres Palmas	4	18°21.0330	67°16.0160
Ponce			
Derrumbadero	20	17°54.2400	66°36.5159
Caja de Muerto	10	17°53.7000	66°31.7040
Guanica			
Cayo Coral	10	17°56.1720	66°53.3040
Cayo Aurora	3	17°56.2020	66°52.4340
Beril	20	17°53.8550	66°57.5920
Cabo Rojo			
Gallardo	5	18º00.0830	67º19.7960
Resuello	10	17º59.4700	67º13.9870
La Parguera			
Media Luna	5	17º56.3660	67º03.0530
Media Luna	10	17º56.0790	67º02.8790
La Boya	20	17º53.3020	66º59.8860
Guayanilla			
Maria Langa	5	17.96488	66.75647
Maria Langa	10	17.96093	66.75292
Maria Langa	20	17.95953	66.74698
Salinas			
Cayo Ratones	5	17° 56.075	66°18.148
Cayo Caribes	10	17° 54.920	66°12.844

Coral reefs located to the east of the mainland, such as those in the Cordillera de Fajardo (Palomino, Palominito, Diablo), and the islands of Vieques (Canjilones, Boya Esperanza and El Seco) and Culebra (Dakity, Carlos Rosario, Luis Pena) are at the head of the current and receive minor estuarine influence from land masses. Likewise, reefs located in the oceanic islands of Mona and Desecheo are also far from estuarine influences. Shelf-edge reefs associated with the mainland are intermediate across this inshore-offshore gradient and their estuarine influence is geographically variable, being higher in the west and north coasts, and lower in the south coast due to the presence/absence of major rivers.

The natural exponential decline of light penetration with depth creates another relevant gradient for coral reef ecology that needs to be addressed in the understanding of potential causes of reef degradation and management options. Thus, the coral monitoring program includes reefs located across inshore-offshore gradients, vertically stratified reef sampling stations on several sites, and at similar depths on the east, west and south coasts to enable comparative analyses between depths and across natural turbidity gradients associated with riverine influences and island mass effects.

A. Sessile-benthic reef communities

At each reef, a set of five-10m long transects were surveyed. Transects were positioned non-randomly in areas visually considered to be of optimal coral growth within similar depths (+/- 2m) and reef physiographic zones. All transects were permanently marked with metal rods set on naturally occurring crevices or holes in abiotic sections of the reef substrate at both ends. A thin white reference line was tied between the two end-markers to identify the transect path during reef monitoring activities and removed upon survey completion. 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 had links of 1.42 cm long, marked every 10 links for facilitation of counting underwater. The exact position of the chain was guided by a series of steel nails set into available hard (abiotic) substrates along transects.

Individual measurements of substrate categories, as recorded from the number of chain links were sorted, added and divided by the total distance (in chain links) on each transect to calculate the cumulative percent linear cover by each substrate category. Soft corals, with the exception of encrusting forms (e.g. *Erythropodium caribaeorum*) were counted as number of colonies intercepted per transect, whenever any of their branches crossed the transect reference line. Scleractinian coral colonies under the transect line were counted and examined visually for infectious diseases. Coral infections were noted with information on coral colony taxonomic identity and position along transects. Preliminary field identifications of potential diseases followed the photographic guidelines by Raymundo et al. (2008). From this data, the percent of coral disease prevalence was calculated foe each reef.

The vertical relief of the reef, or rugosity, was calculated by subtracting 10 meters from the total length (links) recorded with the chain at the 10-m marker of the reference line.

B. Reef fishes and motile megabenthic invertebrates

Demersal and territorial reef fish populations and motile megabenthic invertebrates were 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 was marked with flagging tape stretched and tied to weights on both transect ends. Each transect was surveyed for 15 minutes. The initial two minutes were 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, jacks, mackerels, groupers, hogfish, large parrotfishes, etc.). During the next four minutes, the diver swam over both sides of the transect area counting fishes that form schooling aggregations over the reef (e.g. *Chromis spp., Clepticus parrae, Bodianus*, 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 transects was performed during the next six 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 three 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 were reported to supplement the taxonomic assessment, but were not included in abundance determinations.

Upon completion of the 10m belt-transect survey the diver swam along the same depth and physiographic reef zone for an extra 10 m to identify fishes of commercial value (snappers, groupers, hogfishes, barracuda, mackerels, sharks, others) and/or fish species that are considered important reef herbivores (parrotfishes, doctorfishes). For each individual sighted, a length estimate was recorded. Length (in cms) was visually estimated and whenever possible, aided by a measuring rod with adjustable width. Precision of length estimates allowed discrimination between new recruits, small juveniles, juveniles, adult and large adult size classes.

The Shannon-Weiner Diversity Index was calculated for reef fish stations data sets following the formula: $H' = \Sigma \; Pi \; Ln \; Pi$, where Pi is the relative proportion of each (i) species into the total fish abundance at each reef station. Annual variations of the percent reef substrate cover by live corals and fish species richness and abundance were tested by Repeated Measurements Analysis of Variance (ANOVA) procedures on real values (un-transformed data) for each reef station.

V. Results and Discussion - Monitoring of Coral Reef Communities 2017

1.0 Tres Palmas Reef 3m – Rincón

1.1 Physical Description

The rocky shoreline of the Tres Palmas Marine Reserve leads to a narrow backreef lagoon with coarse sandy sediments. The lagoon is a semi-protected environment associated with an extensive *Acropora palmata* (elkhorn coral) reef formation that has developed along a hard ground platform fringing the shoreline. The top of the reef platform is found at depths between 2 - 5 m. The branching elkhorn coral colonies are large, rising more than one meter from the hard ground platform almost to the surface and wide, extending more than two meters horizontally in many cases. Where the hard ground platform is continuous, coral colonies grow close together forming a dense and intertwined elkhorn coral biotope. Sand pools and channels separate the reef where the hard ground platform breaks up. Interspersed within the *A. palmata* biotope are abundant colonies of encrusting corals, mostly *Diploria clivosa, D. strigosa* and *Porites astreoides*. These encrusting and mound shaped stony corals and gorgonians are more abundant on the seaward slope of the hard ground platform that ends in a sandy bottom at a depth of about six meters.

Rainfall runoff with heavy loads of terrestrial sediments has been previously reported to reach this fringing reef (García-Sais et al., 2004 a). Considerable amounts of garbage (cans, bottles, tires, etc.) are removed by volunteer groups (Surfrider, etc.) from the reef several times every year. The backreef lagoon is a popular place for bathers and divers, some of which have been observed fishing with spear guns within the no-take area.

A set of five permanent transects were established along one continuous hard ground section of the fringing *Acropora palmata* reef at depths between 2 – 5 m (Figure 2). During April 2008, this reef experienced the effect of exceptionally high waves, estimated in approximately 10 m (>30’) associated with a winter storm in the North Atlantic. As a result of this event, some of the permanent transect assemblage was

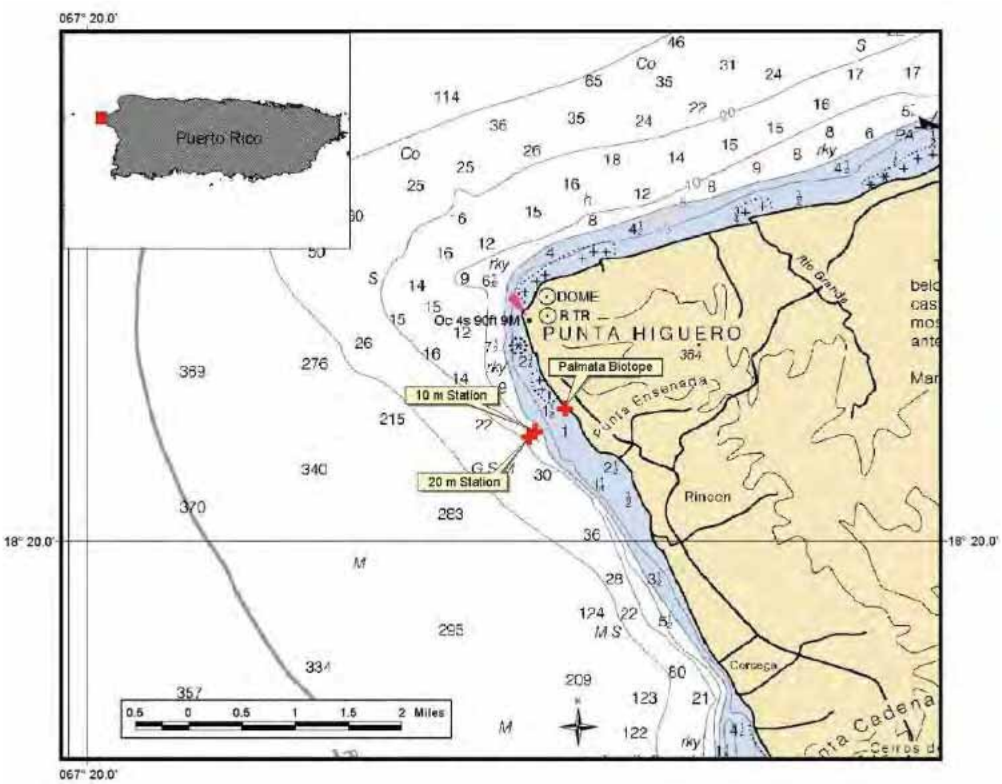


Figure 2. Location of coral reef monitoring stations off Tres Palmas, Rincón.

destroyed and the monitoring data for 2007-08 was gathered in error (out of transect lines) and removed from the data base. Partial reconstruction of the original transects was performed during the 2009 survey, but during the 2013 survey transects 1 and 5 could not be found. Thus, a new set of 5 permanent transects were installed in the general area of the original transects during the 2015 survey. Figure 3 shows the location of monitoring stations at the Tres Palmas Reef system in Rincón. The geographic coordinates of the permanent transects are shown in Table 1. Panoramic photos of the Tres Palmas fringing Elkhorn Coral reef are presented as Photo Album 1.

1.2 Sessile Benthic Reef Community

The percent substrate cover by sessile-benthic categories during the 2017 survey are presented in Table 2. Live coral cover averaged 28.9% (range: 20.0 – 39.4 %) with a mean of 6.6 colonies per transect (rough estimate due to colonies intertwined). Elkhorn Coral (*A. palmata*) was the dominant species with a mean substrate cover of 24.8 % (range: 14.7 – 34.8 %), representing 85.8 % of the total live coral cover.

Table 2. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon. 2015. Survey Date: May 2017. Depth: 2 - 5 m.

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.87	2.19	0.96	2.36	0.92	**1.86**
Benthic Categories						
Abiotic						
Reef overhang	17.95	11.25	20.31	6.23	3.59	**11.87**
Gap	4.13		6.39	1.13		**2.33**
Sand	1.52					**0.30**
Total Abiotic	**23.61**	**11.25**	**26.69**	**7.36**	**3.59**	**14.50**
Benthic Algae						
Turf with sediment	35.15	33.41	37.68	49.94	64.10	**44.06**
Dictyota spp.	7.07	4.48	1.28	3.40		**3.25**
CCA	3.05	3.79	4.47			**2.26**
Peyssonnelia sp.		1.15	1.79	1.13		**0.81**
Ramicrusta sp.		0.46	0.51			**0.19**
Total Benthic Algae	**45.27**	**43.28**	**45.72**	**54.47**	**64.10**	**50.57**
Hard Coral						
Acropora palmata	26.99	34.79	18.39	14.72	28.97	**24.77**
Pseudodiploria strigosa	1.85	0.34	0.89	2.72	1.28	**1.42**
Pseudodiploria clivosa			3.96	1.13		**1.02**
Porites astreoides		1.26	0.77		1.79	**0.76**
Orbicella annularis complex		1.72		1.47		**0.64**
Montastraea cavernosa		1.26				**0.25**
Siderastrea radians					0.26	**0.05**
Total Hard Coral	**28.84**	**39.38**	**24.01**	**20.05**	**32.31**	**28.92**
Coral Colonies/ transect	7	7	6	6	7	**6.6**
Diseased Coral Colonies	2	1	3	2	2	**2.0**
Zoanthids						
Palythoa caribaeorum	2.29	6.08	3.58	17.33		**5.85**
Octocoral						
Eunicea flexuosa				0.34		**0.07**
# Gorgonians/transect	1	2	4	4	2	**2.6**
Sponge						
Aplysina insularis				0.45		**0.09**

Coral Species Outside Transects: *Acropora cervicornis*, *Colpophyllia natans, D. labyrinthiformis, Millepora alcicornis*, *Mycetophyllia lamarckiana, Isophyllia rigida, I. sinuosa*, *Porites porites, Siderastrea siderea*

Four additional coral species, including the Symmetrical and Knobby Brain Corals (*Pseudodiploria strigosa, P. clivosa*), Mustard Hill Coral (*Porites astreoides*), Boulder Star Coral (*Orbicella annularis*), Great Star Coral (*Montastrea cavernosa*) and Lesser Starlet Coral (*SIderastrea radians*) were also intercepted by transects during this survey. A total of 16 species of stony corals have been identified from the fringing reef within the 2 – 5 m depth.

Hard ground substrates, including dead coral sections not colonized by corals were mostly covered by turf algae (mean cover: 44.1 %). Fleshy macroalgae (*Dictyota sp*., *Valonia sp Stypopodium sp*.), red coralline algae (*Galaxaura sp*, *Amphiroa sp*.) and encrusting crustose algae (*Peyssonnelia sp., Ramicrusta sp*.) were also present, but represented minor components of the benthic algae assemblage (Table 2). Abiotic categories, largely associated with reef overhangs occupied 14.5 % of the reef substrate. Vertically projected soft corals (gorgonian) were present in all transects with a mean density of 2.6 colonies/transect. The Common Sea Fan, *Gorgonia ventalina,* Sea Rods (*Plexaura flexuosa, Eunicea spp*) were present within transects. Sponges, represented within transects by *Aplysina insularis* comprised less than 1 % of the reef substrate cover.

Monitoring trends of the sessile-benthic community at the Tres Palmas fringing reef are presented in Figure 3. Mean live coral cover declined 23.7 % from 32,5 % in 2015 to 24.8 % in 2017. Differences between monitoring surveys were statistically significant (ANOVA; $p=0.046$; Appendix 1) and largely associated with a reduction of reef substrate cover by Elkhorn Coral (Figure 4). This decline of live coral cover is probably related to the breakage of large coral colony branches due to the exceptionally high wave action caused by the pass of hurricane Matthew south of Puerto Rico during October 2016. Previous declines of substrate cover by *Acropora palmata* at this reef were observed during the 2008-09 extending through the 2011 survey (Garcia-Sais et al. 2012). The reduction of reef substrate cover by *A. palmata* over the 2008-11 period could have been associated with loss of live tissue caused by an infectious disease. The irregular patterns of white spots and small patches of tissue necrosis suggest that it is an infection of

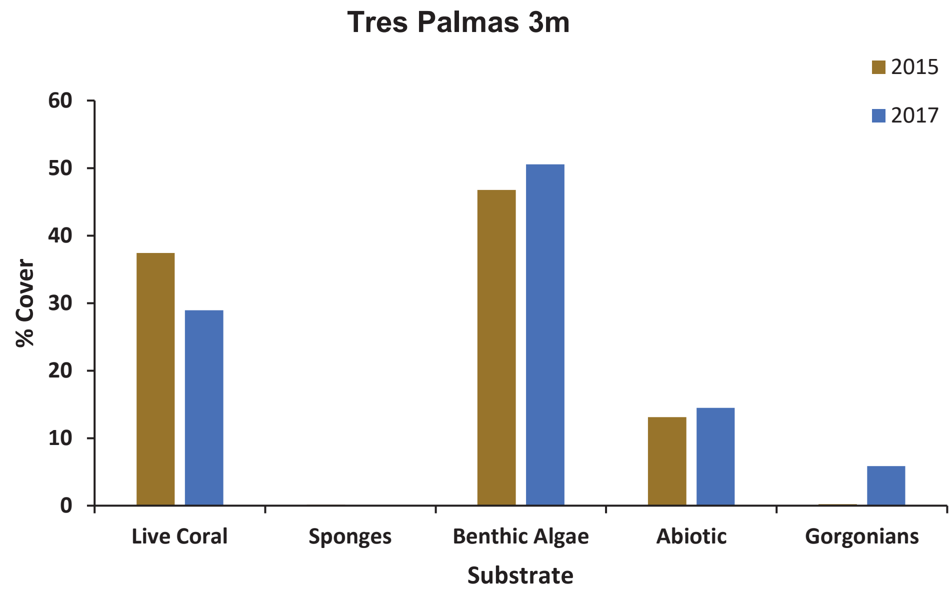


Figure 3. Monitoring trends (2004 – 2017) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon, 2 - 5 m depth.

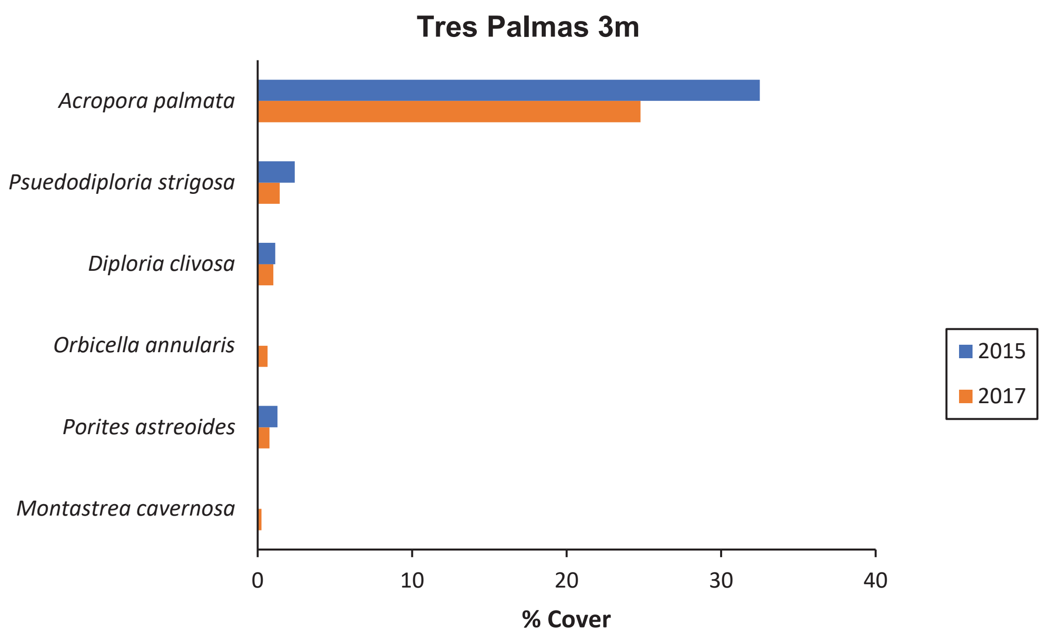


Figure 4. Monitoring trends (2004 – 2017) of mean substrate cover by stony coral species at Tres Palmas Reef, Rincon, 2 - 5 m depth.

white pox, caused by the coliform bacteria, *Serratia marcescens*. This disease has been identified as the main causal agent of the collapse of *A. palmata* reefs in the Florida Keys National Marine Sanctuary (Patterson et al. 2002). The bacteria are commonly found in the intestines of humans, insects and other animals, and in water, soil and plants (Grimont and Grimont, 1994). Thus, it is an agent with a possible link to human sewage pollution. An infection prevalence of 3.0% in Elkhorn Coral colonies intercepted by transects was measured during the 2017 monitoring survey (Appendix 2). The Tres Palmas Reef appears to be resisting the infection with new growth. Soft corals declined in abundance by almost 50% (from 5.0 col/transect in 2015 to 2.6 col/transect in 2017), but differences were not statistically significant (T-test, p=0.091; Appendix3).

1.3 Reef Fishes and Motile Megabenthic Invertebrates

A total of 77 fish species have been identified from the *Acropora palmata* fringing reef system off Tres Palmas, Rincón within a depth range of 2 – 5 meters (Appendix 4). During the 2017 monitoring survey, 22 fish species were observed within belt-transects. The mean abundance of individuals was 34.4 Ind/30 m^2 (range: 15 - 60 Ind/30 m^2), and the mean number of species per transect was 9.4 (H' = 76.3, Appendix 3). The combined abundance of five species represented 73.8 % of the mean abundance within belt-transects (Table 3). The most abundant species was the Bluehead Wrasse (*Thalassoma bifasciatum*), with a mean of 12.6 Ind/30 m^2, followed by the Dusky Damselfish (*Stegastes adustus*). The Yellowtail Damselfish (*Microspathodon chrysurus*), Slippery Dick (*Halichoeres bivittatus*) and Blue Tang (*Acanthurus coeruleus*) were observed in at least four transects. The aforementioned species have been consistently present at this reef and along with the Redlip Blenny, Ocean Surgeon, Bermuda Chub, Sweepers, Sargent Major and the Yellowtail Parrotfish appear to comprise the main resident demersal fish assemblage of the reef. Schools of juvenile grunts, particularly Stripped and French Grunts (*Haemulon chrysargyreum* and *H. flavolineatum*), yellow goatfishes and parrotfishes were common.

Schooling doctorfishes (*Acanthurus spp.*) were observed along expanded 20 m transects surveyed for determinations of size distributions (Table 4). Both juvenile (including recruitment juveniles) and adult Blue Tangs were present. Ocean Surgeons and Doctorfishes were observed as adults only.

Table 3. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef 3m, Rincon, May 2017

Depth: 3 m		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	18	18	10	12	5	**12.6**
Stegastes adustus	Dusky Damselfish	8	7	4	8	5	**6.4**
Haemulon chrysargyreum	Stripped Grunt	11					**2.2**
Haemulon flavolineatum	French Grunt	11					**2.2**
Acanthurus bahianus	Ocean Surgeon			1	7	2	**2.0**
Microspathodon chrysurus	Yellowtail Damselfish	2	4	1	1		**1.6**
Acanthurus coeruleus	Blue Tang	3	1	1	2		**1.4**
Halichoeres bivittatus	Slippery dick	1	1	2	2	1	**1.4**
Halichoeres maculipinna	Clown Wrasse	1	2	1			**0.8**
Pempheris sp	Sweeper			1	3		**0.8**
Bodianus rufus	Spanish Hogfish	2			1		**0.6**
Anisotremus virginicus	Porkfish		2				**0.4**
Halichoeres radiatus	Puddinwife	1	1				**0.4**
Holocentrus coruscus	Reef Squirrelfish			1		1	**0.4**
Acanthurus chirurgus	Doctorfish			1			**0.2**
Abudefduf sexatilis	Sargent Major		1				**0.2**
Caranx ruber	Bar Jack					1	**0.2**
Haemulon plumieri	White Grunt	1					**0.2**
Kyphosus bermudensis	Bermuda Chub			1			**0.2**
Lactophrys triqueter	Smooth Trunkfish	1					**0.2**
	TOTAL INDIVIDUALS	**60**	**37**	**24**	**36**	**15**	**34.4**
	TOTAL SPECIES	**12**	**9**	**12**	**8**	**6**	**9.4**

Table 4. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at Tres Palmas Reef 3 m, Rincon, May 2017

		TRANSECTS				
		1	2	3	4	5
		(Individuals/60 m^2)				
SPECIES	**COMMON NAME**					
Acanthurus coeruleus	Blue Tang	1 - 1	1 - 5	1 - 12	1 - 15	
		1 - 8	1 - 15	1 - 15	1 - 18	
		1 - 10		1 - 20		
Acanthurus bahianus	Ocean Surgeon			2 - 15	5 - 5	2-8
					2 - 12	
Acanthurus chirurgus	Doctorfish			1 - 12		
Sparisoma rubripinne	Yellowtail Parrotfish	1 - 18				

The shallow, high energy environment of the *A. palmata* fringing reef appears to be an ideal habitat for opportunistic carnivores, such as Wrasses (*Thalassoma bifasciatum, Halichoeres radiatus, H. maculipinna, H. bivittatus*) and Blennies (*Ophioblennius atlanticus*) which feed on small benthic (infaunal) invertebrates that become exposed upon disturbances of the substrate due to wave action. Also, herbivores (e.g.

parrotfishes, doctorfishes, and damselfishes) that feed on the turf algae are common. Large pelagic piscivores, such as Cero Mackerels, Bar Jacks and Blue Runners have been observed in the sand pools of the backreef feeding upon dense aggregations of zooplanktivorous anchovies and sardines (*Anchoa spp., Harengula spp*.) near the surface. Juvenile stages of snappers (*Lutjanus analis, L. apodus, L. synagris*) were observed during the 2015 and previous surveys (García-Sais et al., 2004 a, 2005, 2006, 2007, 2009, 2010, 2012, 2014, 2015), suggesting that this shallow reef functions as a nursery area for these commercially important species. This reef is also the recruitment, nursery and residential habitat of the Yellowtail Damselfish (*Microspathodon chrysurus*), which in its early juvenile stage (known as "Jewel Damselfish") is commercially important as an aquarium trade target species.

Statistically significant differences have been measured for both fish species richness and abundance during the monitoring time series (ANOVA; $p < 0.05$; Appendix 5 - 6). Such differences have been associated with fluctuations of numerically dominant species such as the Blue-head Wrasse (*Thalassoma bifasciatum*). Temporal fluctuations by these typically schooling species appear to be regulated by density-independent factors, such as recruitment, and physical conditions of the ref habitat at the time of the field surveys. Shallow reefs are particularly influenced by intense wave action and its effect upon surge and sediment resuspension. These factors force fishes to move out to deeper waters to avoid unfavorable conditions. Our most recent temporal series started with the 2015 baseline characterization followed by the present 2017 first monitoring survey. Variation of species richness was negligible between surveys, but mean abundance declined by 51.0% (Figure 5), driven by a decline of abundance by Blue-head Wrasse. Such differences were not statistically significant due to the relatively high variability within transects during both surveys.

Motile megabenthic invertebrates observed within belt-transects are presented in Table 5. The Rock-boring sea urchin was the most abundant with a mean of 1.2 Ind/30 m^2. Adult Spiny Lobsters (*Panulirus argus*) were present in transects 2 and 4. Rock Lobsters (*P. guttatus*) and other sea urchins have been reported from previous surveys at this reef (García-Sais et al., 2015 and references therein).

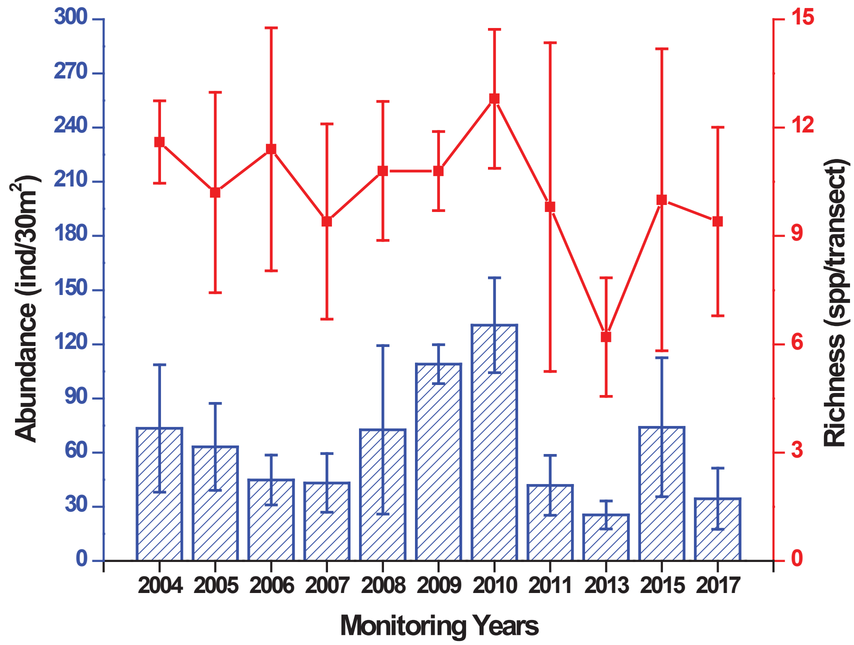


Figure 5. Temporal variations of mean abundance and species richness during monitoring surveys at the Tres Palmas Reef in Rincon 3m

Table 5. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Elkhorn Coral Reef, 3m, Rincon, 2017

Depth: 2 - 5 m		**TRANSECTS**					**MEAN ABUNDANCE (IND/30 m^2)**
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						
Panulirus argus	Spiny Lobster		1		1		**0.4**
Eucidaris tribuloides	Slate-pencil Urchin			1			**0.2**
Percnon gibbesi	Nimble Spray Crab					1	**0.2**
Echinometra lucunter	Rock boring Urchin	1			2	3	**1.2**
	TOTALS	**1**	**1**	**1**	**3**	**4**	**2.0**

1.4 Photo Album 1

Tres Palmas Reef - Rincon 3m











2.0 Tres Palmas 10m

2.1 Physical Description

A series of submerged patch reefs are located in the Tres Palmas outer shelf, at about 0.5 kilometers east from the shelf-edge. Patch reefs are associated with an irregular and discontinuous line of hard ground promontories that rise from a sandy bottom at depths of 12 -15 m. Our permanent transects were installed within one of these patch reef promontories at a depth of 10 m running east to west over the reef top. The reef rises from the bottom as a vertical wall on the eastern end, forming a sloping terrace toward the west. The east wall is about 5 meters high and exhibits deep crevices and overhangs. At the top, the reef platform is mostly flat, with some depressions, but without any prominent pattern of spurs and/or grooves. Large sand channels separate the reef promontories. Panoramic views of the outer shelf patch reefs are presented as Photo Album 2.

2.2 Sessile-benthic Community

A diverse and abundant assemblage of soft corals (gorgonians) was the most prominent feature of the sessile-benthic patch reef community. Soft corals were present at all transects surveyed with at least 8 species present within transects and a mean density of 19.8 col./transect (range: 15 – 23 col./transect) (Table 6). The most abundant taxa included Sea Rods, *Eunicea spp*, *Pseudoplexaura flagellosa*, *Plexaura sp*., and the Common Sea Fan, *Gorgonia ventalina* among others. The encrusting species, *Erythropodium caribaeorum* and *Briareum asbestinum* were present in two and one transect with low substrate cover (< 1%).

Stony corals occurred mostly as encrusting colonies of typically small size and low vertical relief. A total of 17 species of stony corals have been identified from the patch reef community, including 13 species intercepted by line transects. Live stony coral cover averaged 23.1 % (range: 18.8 – 29.4 %), with a mean of 15.2 colonies per transect. Mustard-Hill Coral, *Porites astreoides* and Great Star Coral, *Montastraea cavernosa* were the dominant species in terms of substrate cover with means of 5.63 and 5.60%, respectively (Table 6). In addition to the aforementioned species, other three coral species that included *Pseudodiploria strigosa, Agaricia agaricites* and *Siderastrea siderea* were present in at least four transects. A few large colonies of Grooved Brain

Table 6. Percent substrate cover by sessile-benthic categories at the Tres Palmas outer shelf reef, Rincon 10 m. Survey Date: May 2017.

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	1.90	2.66	1.76	1.07	0.93	**1.66**
Benthic Category						**0.00**
Abiotic						**0.00**
Rubble	4.47					**0.89**
Reef overhang				0.51	0.90	**0.28**
Total Abiotic	**4.47**			**0.51**	**0.90**	**1.17**
Benthic Algae						
Turf	49.18	48.89	42.38	35.78	35.34	**42.31**
Dictyota spp.	10.71	15.27	16.67	15.30	30.09	**17.60**
Martensia pavonia	4.12	1.99	2.02	1.90	2.30	**2.47**
Halimeda spp.	0.59		1.67	2.53	0.26	**1.01**
Ramicrusta sp.		0.44	0.24	1.26	1.54	**0.70**
CCA	0.94	1.88		0.38	0.26	**0.69**
Galaxaura sp.	0.59	1.55		0.76		**0.58**
Peyssonnelia sp.			0.83	0.63		**0.29**
Galaxaura marginata		0.55				**0.11**
Gracilaria sp.		0.22				**0.04**
Total Benthic Algae	**66.12**	**70.80**	**63.81**	**58.53**	**69.78**	**65.81**
Cyanobacteria			2.38			**0.48**
Hard Coral						
Porites astreoides	3.76	5.97	5.95	6.19	6.27	**5.63**
Montastraea cavernosa	4.35	3.76	7.38	3.92	8.58	**5.60**
Colpophyllia natans				11.38		**2.28**
Pseudodiploria strigosa		1.88	3.57	0.51	2.82	**1.75**
Agaricia agaricites	2.24	3.43	1.07	0.25	1.02	**1.60**
Orbicella annularis complex	5.29	1.99				**1.46**
Siderastrea siderea		0.77	2.86	1.39	1.54	**1.31**
Dendrogyra cylindrus				4.80		**0.96**
Diploria labyrinthiformis		0.33	2.14		2.18	**0.93**
Stephanocoenia intersepta	2.12			0.76		**0.58**
Millepora alcicornis	0.35	1.33	0.71	0.25		**0.53**
Madracis decactis	0.71				0.51	**0.24**
Porites divaricata			1.19			**0.24**
Total Hard Coral	**18.82**	**19.47**	**24.88**	**29.45**	**22.92**	**23.11**
Colonies per Transect	14	17	16	11	18	**15.2**
Invertebrate						
Palythoa caribaeorum	0.35			1.26		**0.32**
Palythoa grandis	0.24					**0.05**
Total Invertebrate	**0.94**	**1.33**	**0.71**	**1.52**		**0.90**
Octocoral						
Erythropodium caribaeorum	0.35			1.90		**0.45**
Briareum asbestinum					1.15	**0.23**
Gorgonia ventalina	0.24	0.33	0.24			**0.16**

Plexaura kuekenthali					0.38	**0.08**
Eunicea flexuosa		0.33				**0.07**
Plexaura homomalla					0.26	**0.05**
Antillogorgia americana				0.25		**0.05**
Muricea elongata			0.24			**0.05**
Total Octocoral	**0.59**	**0.66**	**0.48**	**2.15**	**1.79**	**1.13**
# Gorgonians/transect	21	23	19	15	21	**19.8**
Sponge						
Xestospongia muta	3.18	7.41	5.12	4.42	1.66	**4.36**
Amphimedon compressa		0.55		1.01	0.90	**0.49**
Neopetrosia proxima	0.94	1.00				**0.39**
Petrosia pellasarca	1.53		0.36			**0.38**
Cribochalina vasculum				1.52		**0.30**
Neopetrosia sp.			0.71		0.64	**0.27**
Placospherastra micraster	0.94			0.25		**0.24**
Cliona delitrix			1.19			**0.24**
Scopalina ruetzleri	0.47				0.64	**0.22**
Agelas tubulata			1.07			**0.21**
Aplysina cauliformis	0.94				0.13	**0.21**
Monanchora arbuscula	0.35				0.26	**0.12**
Niphates erecta				0.51		**0.10**
Ectyoplasia ferox	0.47					**0.09**
Yellow sponge				0.38		**0.08**
Callyspongia plicifera	0.35					**0.07**
Chondrilla caribensis					0.26	**0.05**
Mycale laevis		0.11			0.13	**0.05**
Agelas sventres	0.24					**0.05**
Total Sponge	**9.41**	**9.07**	**8.45**	**8.09**	**4.61**	**7.93**

Coral, *Pseudodiploria labyrinthiformis*, Boulder Brain Coral, *Colpophyllia natans* and Pillar Coral, *Dendrogyra cylindrus* were intercepted. Coral diseases were not observed affecting colonies intercepted by transects (see Appendix 2).

Benthic algae, comprised by a mixed assemblage of turf, fleshy brown (mostly *Dictyota sp* and *Martensia sp*.), red coralline and crustose (*Galaxaura sp*., *Gracilaria sp, Ramicrusta sp, Peyssonnelia sp*) and green calcareous macroalgae (*Halimeda spp*) presented the highest percent of reef substrate cover by sessile-benthic categories with a combined mean of 65.8 % (range: 58.5 – 70.8 %). Turf algae and brown macroalgae (*Dictyota sp*) were the main components of the algal assemblage and were present in all transects (Table 6).

Sponges, represented by at least 19 species within transects presented a mean substrate cover of 7.9 % (range: 4.6 – 9.4 %). The Giant Barrel Sponge, *Xestospongia muta* was present in all five transects surveyed with a mean reef substrate cover of 4.4 % and was the most prominent species. In general, most sponges were represented by small encrusting species with relatively low substrate cover. The encrusting zoanthid, *Palythoa sp.,* was observed in two transects. Total abiotic cover averaged 1.2 %, a marked decline from the 16.8 % reported in 2013. Such variations of sand cover are typical of this reef and are largely associated with sand transport and deposits over the mostly flat reef.

The sessile-benthic community at the patch reef surveyed is typical of high wave energy environments, dominated by encrusting stony corals, sponges and flexible soft corals. The high abundance of small coral colonies may be an indication of active recruitment. Mortality of coral colonies induced by mechanical detachment during heavy wave action is most likely to be a prevailing process in this reef which has probably led to the high species richness evidenced during the monitoring program. The reef hard ground was mostly colonized by brown macroalgae and turf algae, which is the dominant assemblage and a quasi-permanent feature of high energy reefs in the north coast of Puerto Rico (García-Sais et al., 2003).

Figure 6 shows the variations of reef substrate cover by sessile-benthic categories throughout the monitoring program starting with the baseline survey of 2004. Annual fluctuations of the mean reef substrate cover by (total) live corals between monitoring surveys (2004 – 2017) were not statistically significant (ANOVA; $p = 0.071$; Appendix 1). Some of these variations are influenced by sand transport and its effects in covering temporarily live coral colonies. Nevertheless, the mean coral cover of 23.1 % measured during this 2017 survey is similar to the highest recorded during the monitoring program in 2015 and appears to represent a trend toward increasing live coral cover at this reef. The positive trend was influenced by a consistent increase of cover by Mustard-Hill Coral, *Porites astreoides* since 2011 (Figure 7). A statistically significant decline of erect soft corals, from 24.6 in 2015 to 15.6 in 2017 was detected (T-test $p=0.023$; Appendix 3) and appears to be related to mechanical detachment by exceptionally high wave and surge action and associated with the pass of Hurricane Matthew close to the south coast of PR during October 2016.

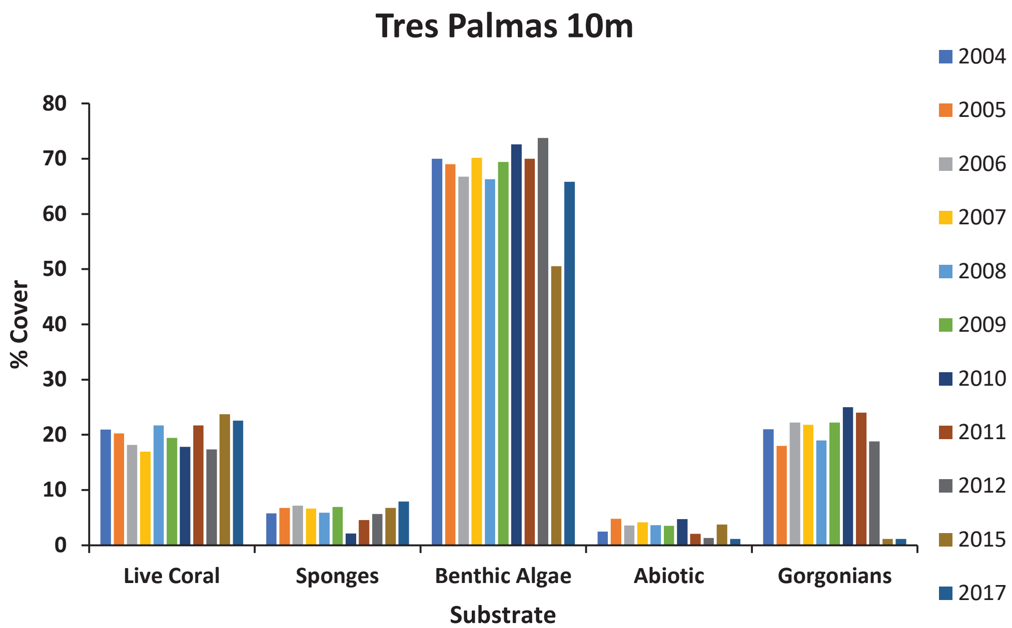


Figure 7. Monitoring trends (2004 – 2017) of mean substrate cover by sessile-benthic categories at Tres Palmas Outer Patch Reef – 10 m.

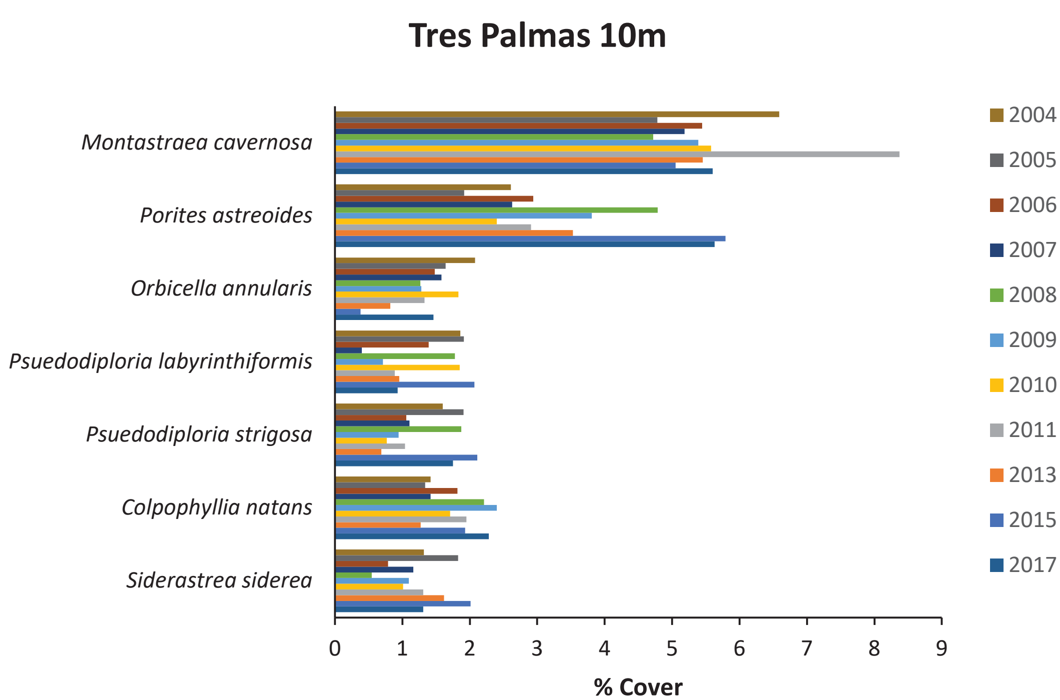


Figure 8. Monitoring trends (2004 – 2017) of mean substrate cover by stony coral species at Tres Palmas Outer Patch Reef – 10 m.

2.3 Fishes and Motile Megabenthic Invertebrates

A total of 113 fish species have been identified from the patch reef formation at the Tres Palmas Reef system of Rincón (Appendix 4). During the 2017 survey, mean abundance of individuals within belt-transects was 49.2 Ind/30 m^2 (range: 28 - 81 Ind/30 m^2). The mean number of species per transect was 12.8 (H'= 91.2).

Two species, the Bluehead Wrasse (*Thalassoma bifasciatum*) and the Bicolor Damselfish (*Stegastes partitus*) were (as in previous surveys) numerically dominant within belt-transects with mean abundances of 13.2 and 12.8 Ind/30 m^2, respectively (Table 7). The combined abundance of these two-species represented 52.8 % of the total fish abundance within belt-transects. In addition to the two-aforementioned species, the Ocean Surgeon, Blue Chromis, Beaugregory, Redband Parrotfish, Yellowhead Wrasse and Coney were present in at least four of the five transects surveyed. Given their prevalence in previous surveys they appear to represent a resident fish assemblage on this reef. Out of transects at the reef wall habitat there are several species of fish that are also reef residents, but not typical of the reef top. These include the Fairy Basslet, Barred Cardinalfish, Glasseye, Longspine Squirrelfish, Black-bar Soldierfish, Spotted Drum, Queen Angelfish and several species of grunts. Small demersal predators, such as the Red Hind and Lane and Schoolmaster Snappers have been observed over sandy bottom at the base of the wall in previous surveys (Garcia-Sais et al, 2014). The abundance of Coneys (*Cephalopholis cruentatus*) is of particular interest because it is one of the highest among the reefs surveyed. Size distributions are indicative that the Tres Palmas Reef at 10m is an important recruitment and residential habitat for Coneys as both early juveniles and adults were observed (Table 8). Juvenile and adult stages of Lane, Schoolmaster and Mahogoni Snappers and several species of Parrotfishes have been reported in previous surveys (Garcia-Sais et al., 2015 and references therein).

Fish abundance and species richness have shown wide fluctuations at this reef with a period of higher richness and mean abundance between 2004 – 2007, and a period of both lower richness and abundance between 2008 - 2017 survey (Figure 8). The inter-annual variations are statistically significant (ANOVA, $p < 0.0001$; see Appendices 5 and 6). This reef is frequently exposed to very high wave energy and the surge conditions

Table 7. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef 10m, Rincon, May 2017

Depth: 10 m

		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(Individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	5	6	14	6	35	**13.2**
Stegastes partitus	Bicolor Damselfish	8	6	17	11	22	**12.8**
Clepticus parrae	Creole Wrasse		14				**2.8**
Halichoeres garnoti	Yellow-head Wrasse	3	6	1		3	**2.6**
Acanthurus bahianus	Ocean Surgeon	3	3	2	2	2	**2.4**
Chromis cyanea	Blue Chromis		7	2	2	1	**2.4**
Stegastes leucostictus	Beaugregory	1	3	3	2	2	**2.2**
Cephalopholis fulva	Coney	2	2	3	3		**2.0**
Sparisoma aurofrenatum	Redband Parrotfish	2	1	1	1	3	**1.6**
Scarus taeniopterus	Princess Parrotfish			1	1	4	**1.2**
Scarus iserti	Stripped Parrotfish				1	4	**1.0**
Chaetodon capistratus	Four-eye Butterflyfish	2			2		**0.8**
Elacatinus evelynae	Sharknose Goby		2		1	1	**0.8**
Halichoeres maculipinna	Clown Wrasse	1				2	**0.6**
Holocentrus rufus	Longspine Squirrelfish		1	1		1	**0.6**
Serranus tigrinus	Harlequin Bass	1	1		1		**0.6**
Coryphopterus sp.	Goby		1		1		**0.4**
Amblycirrhitus pinos	Redspotted Hawkfish			1			**0.2**
Chromis multilineata	Brown Chromis					1	**0.2**
Epinephelus guttatus	Red Hind				1		**0.2**
Hypoplectrus unicolor	Butter Hamlet				1		**0.2**
Hypoplectrus puella	Barred Hamlet				1		**0.2**
Microspathodon chrysurus	Yellowtail Damselfish			1			**0.2**
	TOTAL INDIVIDUALS	**28**	**53**	**47**	**37**	**81**	**49.2**
	TOTAL SPECIES	**10**	**13**	**12**	**16**	**13**	**12.8**

Table 8. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3 m belt-transects at Tres Palmas Reef 10 m, Rincon. May 2017

		TRANSECTS				
		1	2	3	4	5
		(Individuals/60 m^2)				
SPECIES	**COMMON NAME**					
Acanthurus bahianus	Ocean Surgeon			3-15	1 - 10	2 - 15
				1 - 18	1 - 12	
					1 - 15	
Ocyurus chrysurus	Yellowtail Snapper		1 - 23			
Cephalopholis fulva	Coney	1 - 8	1 - 8	1- 8	1 - 28	1 - 30
		1 - 12	1 - 10	1 - 10	2 - 30	
		1 - 18		1 - 18	1 - 25	
				1 - 12		
Epinephelus guttatus	Red Hind				1 - 30	1 - 36
Scarus iserti	Striped Parrotfish				1 - 10	
Scarus taeniopterus	Princess Parrotfish					3 - 18
						1 - 28
Sparisoma aurofrenatum	Redband Parrotfish		1 - 12	1 - 12	1 - 15	1 - 10
			1 - 15	1 - 8		1 - 12
						1 - 30

that prevail during high wave action events appears to have an effect of forcing fish individuals to seek deeper areas within the Rincon narrow shelf. Differences observed during the monitoring program are in the 2-fold range for species richness and in the 3-fold range for mean abundance. Interannual variations of fish abundance have been associated with fluctuations by numerically dominant species and such differences are believed to be regulated by density-independent and physical forcing factors (Esteves, 2013).

The high energy environment at the top of the patch reef is an appropriate habitat for opportunistic carnivores, such as Wrasses (*Thalassoma bifasciatum, Halichoeres garnoti, H. maculipinna*) which feed on small benthic (infaunal) invertebrates that become exposed upon disturbances of the substrate due to wave action. Also, herbivores (e.g. parrotfishes, doctorfishes, damselfishes) that feed on the turf algae were

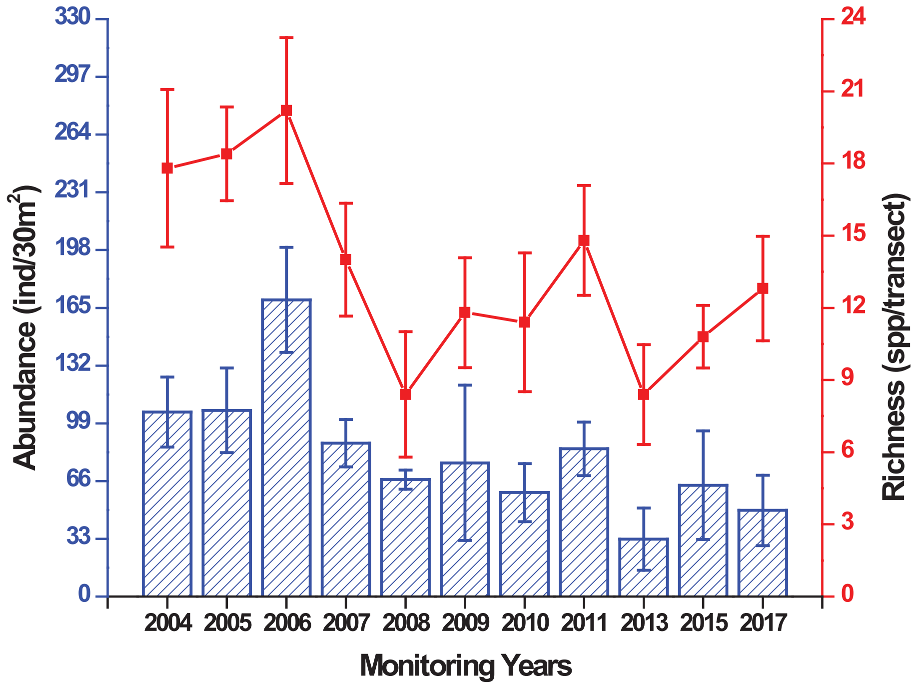


Figure 9. Monitoring trends (2004 – 2017) of fish species richness and abundance at Tres Palmas Outer Shelf Patch Reef, 10 m, Rincon.

common. Pelagic piscivores, such as barracudas (*Sphyraena barracuda*), mackerels (*Scomberomorus regalis*) and jacks (*Caranx crysos, C. ruber*) have been previously reported from this reef comprise the residential top predators of this reef (García-Sais et al., 2005, 2006, 2007, 2008, 2009, 2010, 2012, 2014, 2015). Mid-size adult and juvenile predators are represented by a rich assemblage of snappers, coneys and squirrelfishes, among others (Garcia-Sais et al. 2014).

Motile megabenthic invertebrates were represented within belt-transects by Cleaner Shrimps, *Periclimenes pedersoni* during the 2017 monitoring survey. Several spiny Lobsters (*Panulirus argus*), Slate-pencil Urchins (*Eucidaris tribuloides*), Banded-Coral Shrimps (*Stenopus hispidus*), Arrow and Hermit Crabs (*Stenorhynchus seticornis, Paguridae*) and Sponge Brittle Stars have been previously reported from this reef (Garcia-Sais et al., 2014).

Table 9. Taxonomic composition and abundance of motile megabenthic invertebrates surveyed within belt-transects at Tres Palmas Outer Shelf Reef, Rincon 10m, 2017

		TRANSECTS					
Depth: 10 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Periclimenes pedersoni	Cleaner Shrimp	1		1			**0.4**
	TOTALS	1	0	1	0	0	**0.4**

2.4 Photo Album 2

Tres Palmas 10m - Rincon











3.0 Tres Palmas 20m

3.1 Physical Description

A “spur-and-groove” coral reef formation is found associated with the shelf-edge off Tres Palmas within a depth range of 18 – 23 m. Spurs are oriented perpendicular to the shelf-edge. The shelf breaks in a series of irregular steps, forming narrow terraces at depths from 23 – 40 m. Coral growth below 20 m was observed to occur mostly as individual massive and encrusting colonies not forming any prominent reef buildup. There is substantial sediment transport down the shelf-edge and most of the rocky substrate is covered by fine sand and silt. Such heavy sedimentation may limit coral reef formation down the slope off Tres Palmas. The reef is not a continuous system along the shelf-edge, as there are wide sections of mostly uncolonized pavement covered by sandy-silt sediments with interspersed sponges and macroalgae. Panoramic views of the shelf-edge reef formation off Tres Palmas are presented in Photo Album 3.

3.2 Sessile-benthic Reef Community

A total of 22 stony coral species (including two hydrocorals) have been identified from the shelf-edge reef off Tres Palmas, 13 of which were intercepted by line transects during the 2017 survey (Table 10). Stony corals occurred mostly as encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 25.6 % (range: 15.7 – 30.4 %). Boulder Star Coral, *Orbicella annularis* complex was the dominant species in terms of substrate cover with a mean of 13.3 % (range: 4.3 – 24.8%), representing 51.9 % of the total cover by stony corals (Table 10). Colonies of *O. annularis* were present in all five transects. Maze Coral (*Meandrina meandrites*) and Mustard-Hill Coral (*Porites astreoides*) were present in at least four out of the five transects surveyed. A total of 70 coral colonies were intercepted by the five-transect survey yielding an average of 14 colonies per transect. One Lettuce Coral (*Agaricia agaricites*) in transect 5 was observed partially bleached and presumed stressed and/or affected by some infectious disease (Appendix 2).

Soft corals (gorgonians) were moderately abundant, with an average of 15.6 colonies/transect. The main assemblage included sea plumes (*Allotogorgia acerosa, P. americana*), the Corky Sea Finger, *Briareum asbestinum*, Knobby Sea Rods, *Eunicea spp*., and the Common Sea Fan, *Gorgonia ventalina*. The deep-water Sea Fan, *Iciligorgia schrammi* was common at the shelf-edge, particularly at the edge of rock walls

Table 10. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon 20m. Survey date: May 2015

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	1.77	3.02	2.45	1.37	1.82	**2.08**
Benthic Category						
Abiotic						
Reef overhang	1.19		0.90	1.60	0.95	**0.93**
Rubble	1.19					**0.24**
Total Abiotic	**2.38**		**0.90**	**1.60**	**0.95**	**1.17**
Benthic Algae						
Turf	46.25	52.90	30.71	37.07	38.15	**41.02**
Peyssonnelia sp.	8.32	3.12	5.51	5.79	5.45	**5.64**
Dictyota spp.	4.99	4.62	3.60	4.06	2.49	**3.95**
Martensia pavonia	0.48	3.66	4.61	3.08	5.81	**3.53**
Lobophora variegatus	1.19	0.75	7.99		3.44	**2.67**
Gracilaria sp.	2.14		2.25	1.23	2.13	**1.55**
Ramicrusta sp.	0.83		1.35	4.31	0.59	**1.42**
CCA	0.24	1.83		3.69		**1.15**
Galaxaura sp.	1.55					**0.31**
Halimeda spp.			0.34		0.71	**0.21**
Total Benthic Algae	**65.99**	**66.88**	**56.36**	**59.24**	**58.77**	**61.45**
Cyanobacteria	6.54					**1.31**
Hard Coral						
Orbicella annularis complex	4.28	13.66	24.75	11.33	12.44	**13.29**
Porites astreoides	0.95	2.26		4.31	4.98	**2.50**
Meandrina meandrites	1.07	2.47	4.61	1.60	1.78	**2.31**
Agaricia agaricites	0.83			3.45	3.91	**1.64**
Pseudodiploria strigosa		1.72			4.38	**1.22**
Colpophyllia natans		3.23			1.54	**0.95**
Siderastrea siderea	2.26	1.18			0.83	**0.85**
Agaricia grahamae	3.92					**0.78**
Montastraea cavernosa	0.71	1.72		1.23		**0.73**
Madracis decactis	0.95			1.11	0.24	**0.46**
Agaricia fragilis	0.71		1.01			**0.35**
Millepora alcicornis		0.65		0.37	0.36	**0.27**
Agaricia humilis				1.23		**0.25**
Total Hard Coral	**15.70**	**26.89**	**30.37**	**24.63**	**30.45**	**25.60**
Colonies per Transect	12	13	16	17	12	**14.0**
Octocoral						
Erythropodium caribaeorum	2.62	0.54	6.97	4.19		**2.86**
Briareum asbestinum		0.22			1.18	**0.28**
Gorgonia ventalina				0.62		**0.12**
Eunicea sp.		0.22				**0.04**

Total Octocoral	**2.62**	**0.97**	**6.97**	**4.80**	**1.18**	**3.31**
# Gorgonians/transect	12	13	8	22	23	**15.6**
Sponge						
Agelas conifera	1.66	1.51	0.22	1.48	1.07	**1.19**
Amphimedon compressa	0.24		1.35	2.96	0.24	**0.96**
Agelas sceptrum				2.96	1.30	**0.85**
Agelas sventres	1.43		1.46			**0.58**
Agelas citrina			1.01	0.49	0.83	**0.47**
Svenzea zeai		2.04				**0.41**
Petrosia pellasarca					1.66	**0.33**
Iotrochota birotulata	0.36			0.25	0.83	**0.29**
Agelas tubulata	1.31					**0.26**
Niphates erecta	0.83	0.22			0.24	**0.26**
Xestospongia muta	0.24	0.86				**0.22**
Scopalina ruetzleri	0.24			0.25	0.59	**0.22**
Monanchora arbuscula			0.45		0.36	**0.16**
Ectyoplasia ferox		0.32			0.36	**0.14**
Callyspongia fallax			0.56			**0.11**
Aplysina cauliformis					0.47	**0.09**
Ircinia strobilina				0.37		**0.07**
Callyspongia plicifera			0.34			**0.07**
Spirastrella coccinea		0.32				**0.06**
Biemna sp.	0.24					**0.05**
Verongula rigida	0.24					**0.05**
Desmapsamma anchorata					0.24	**0.05**
Total Sponge	**6.78**	**5.27**	**5.40**	**8.74**	**8.18**	**6.87**

and crevices. The encrusting gorgonian, *Erythropodium caribaeorum* was present in four transects with a mean cover of 2.9 %.

Encrusting and erect sponges were represented by at least 22 species within transects, with an average reef substrate cover of 6.9 %. Tube sponges, *Agelas spp*., and the Erect Rope Sponge, *Amphimedon compressa* contributed most of the reef substrate cover by sponges (Table 10). In general, sponges were represented by small encrusting species growing intermixed with the algal turf.

Turf algae, comprised by an assemblage of short filamentous red and brown macroalgae were the dominant sessile-benthic component in terms of substrate cover with an average of 61.4 % (range: 56.4 – 66.9 %). Turf algae were found overgrowing rocky substrates, as well as dead coral sections and other hard ground. Crustose red algae, *Peyssonnelia sp*. and *Ramicrusta sp*, were present in five and four transects, respectively with a combined mean substrate cover of 5.9%. Fleshy brown macroalgae, particularly *Dictyota sp.* and *Lobophora variegata* contributed an additional 6.6 % and to the total cover by benthic algae. Isolated tufts of red coralline alga (*Galaxaura sp*.) and other green calcareous algae (*Halimeda spp*.) were also present. The total reef substrate cover by benthic algae was 61.4 %. A large patch of benthic cyanobacteria was observed over transect 1. Reef overhangs averaged 0.9 % and contributed to a topographic rugosity of 1.2 m.

A mild, but consistent trend of declining mean coral cover between monitoring surveys was measured from 2005 and 2008 (Figure 9). This pattern ended during 2009 with a minor increment of live coral cover until 2010. Since then, small statistically insignificant fluctuations of coral cover have been measured until the present 2017 survey (ANOVA; $p= 0.355$; Appendix 1). Despite the interannual variability in both magnitude and direction, an increasing trend of live coral cover appears to be prevailing at Tres Palmas shelf-edge reef, largely influenced by an apparent recuperation of *Orbicella annularis* (complex) from its acute degradation after the 2005 coral bleaching event (Figure 10). Variations of soft coral (gorgonians) abundance between the 2015 and the 2017 monitoring surveys by were not statistically significant (T-test, $p=0.413$; Appendix 3), indicative that the increase in depth was effective in protecting gorgonians from the physical forces (wave action and surge) that appear to have impacted gorgonians at 10m during the pass of hurricane Matthew near the south coast of PR.

3.3 Fishes and Motile Megabenthic Invertebrates

A total of 87 fish species have been identified from the shelf-edge reef off Tres Palmas (Appendix 4), including 38 observed within belt-transects during the 2017 survey (Table 11). Mean abundance within belt-transects was 82.8 Ind/30 m^2 (range: 49 – 182 Ind/30 m^2). The mean number of species per transect was 17.6 (H'=179.0). An assemblage of three (3) numerically dominant species, with a combined abundance of 47.2 Ind/30 m^2 represented 57.0 % of the total fish individuals within belt-transects. These included the Blue Chromis, *Chromis cyanea*, Creole Wrasse, *Clepticus parrae* and the Bicolor Damselfish, *Stegastes partitus*. In addition, the Bluehead and Yellowhead Wrasses,

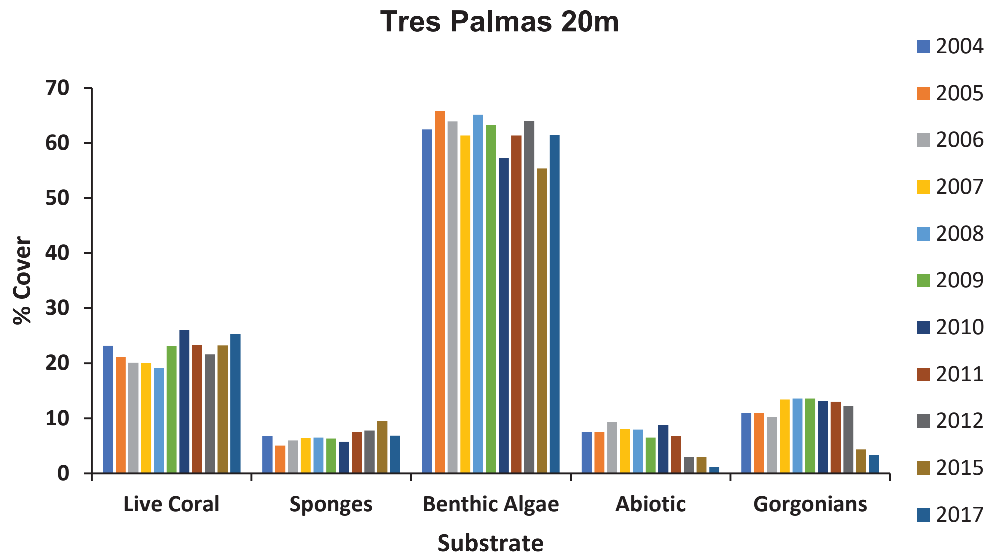


Figure 9. Monitoring trends (2004 – 2017) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef – 20 m.

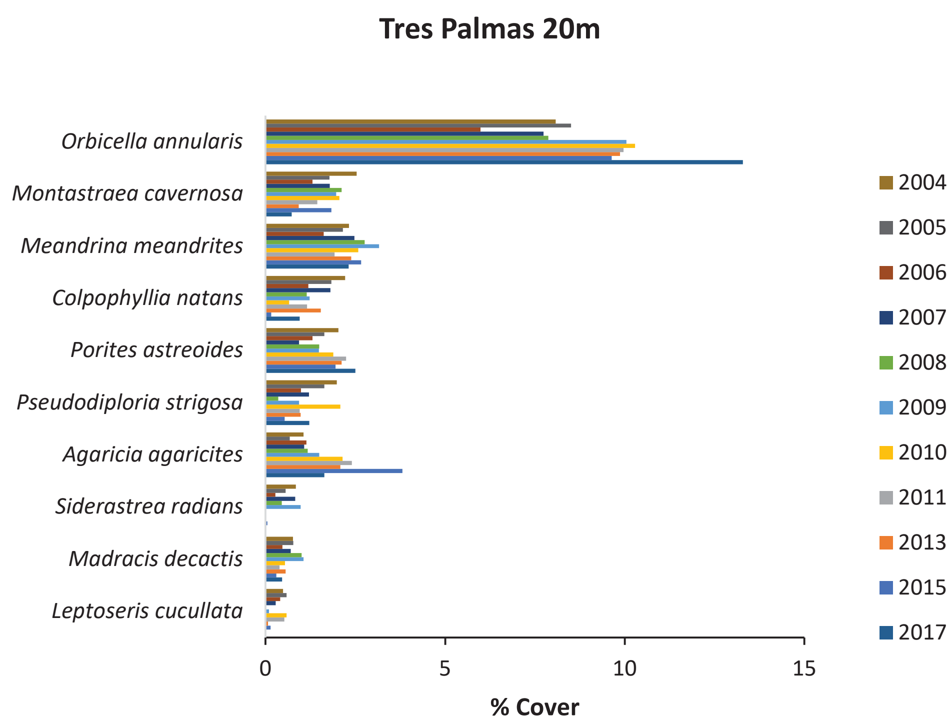


Figure 10. Monitoring trends (2004 – 2017) of mean substrate cover by stony coral species at Tres Palmas Reef – 20 m.

Table 11. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas

Reef 20m, Rincon. Survey date: May 2017

Depth: 20 m		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Chromis cyanea	Blue Chromis		66	10	11	21	**21.6**
Clepticus parrae	Creole Wrasse		25	40			**13.0**
Stegastes partitus	Bicolor Damselfish	15	17	3	17	11	**12.6**
Thalassoma bifasciatum	Bluehead Wrasse	9	6		6		**4.2**
Elacatinus evelynae	Sharknose Goby	2	7	4	4	3	**4.0**
Stegastes leucostictus	Beaugregory	7	3	2	3	2	**3.4**
Haemulon flavolineatum	French Grunt	1	11	1	1		**2.8**
Halichoeres garnoti	Yellow-head Wrasse	6	2	2	2	2	**2.8**
Haemulon chrysargyreum	Stripped Grunt		11	1	1		**2.6**
Coryphopterus personatus	Masked Goby		11				**2.2**
Cephalopholis cruentatus	Graysby	1	2	1	1	1	**1.2**
Myripristis jacobus	Black-bar Soldierfish			4	2		**1.2**
Scarus taeniopterus	Princess Parrotfish	1		5			**1.2**
Canthigaster rostrata	Caribbean Puffer	1	1	1	1	1	**1.0**
Chaetodon capistratus	Four-eye Butterflyfish	2	2		1		**1.0**
Chromis insolata	Sunshine Chromis		5				**1.0**
Acanthurus bahianus	Ocean Surgeon	1	1		1	1	**0.8**
Sparisoma aurofrenatum	Redband Parrotfish	1		2		1	**0.8**
Coryphopterus lipernes	Peppermint Goby		1			1	**0.4**
Coryphopterus sp.	Goby		1			1	**0.4**
Holocentrus rufus	Longspine Squirrelfish	1				1	**0.4**
Hypoplectrus puella	Barred Hamlet		1	1			**0.4**
Melichthys niger	Black Durgon	1		1			**0.4**
Pterois sp	Lionfish		2				**0.4**
Serranus tigrinus	Harlequin Bass	1	1				**0.4**
Acanthurus coeruleus	Blue Tang		1				**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish					1	**0.2**
Anisotremus virginicus	Porkfish					1	**0.2**
Aulostomus maculatus	Trumpetfish			1			**0.2**
Bodianus rufus	Spanish Hogfish		1				**0.2**
Caranx ruber	Bar Jack					1	**0.2**
Holacanthus ciliaris	Queen Angelfish		1				**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	1					**0.2**
Hypoplectrus sp.	Hamlet		1				**0.2**
Lactophrys triqueter	Smooth Trunkfish	1					**0.2**

Ocyurus chrysurus	Yellowtail Snapper		1				**0.2**
Pomacanthus ciliaris	French Angelfish				1		**0.2**
Scarus iserti	Stripped Parrotfish		1				**0.2**
	TOTAL INDIVIDUALS	**52**	**182**	**79**	**52**	**49**	**82.8**
	TOTAL SPECIES	**17**	**26**	**16**	**14**	**15**	**17.6**

Table 12. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3 m belt-transects at Tres Palmas Reef 20 m, Rincon. May 2017

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(individuals/60 m^2)				
SPECIES	**COMMON NAME**					
Acanthurus bahianus	Ocean Surgeon	2 - 15	1 - 12			1 - 12
			1 - 15			
Acanthurus coeruleus	Blue Tang		1 - 12		1 - 15	
			1 - 15			
Ocyurus chrysurus	Yellowtail Snapper		1 - 43			
Cephalopholis cruentatus	Graysbe	1 - 15	1 - 7	1 - 28	1 - 25	1 - 30
			1 - 10			
Scarus iserti	Striped Parrotfish		1 - 10			
Scarus taeniopterus	Princess Parrotfish	1 - 12	2 - 15	2 - 8		
		2 - 10		3 - 10		
				2 - 12		
Sparisoma aurofrenatum	Redband Parrotfish	1 - 12	1 - 12	1 - 10	1 - 12	1 - 18
				1 - 15		
Pterois sp.	Lionfish		1 - 12	1 - 30		
			1 - 20			

Sharknose Goby, Beau Gregory, French Grunt, Graysbe, Caribbean Puffer and Ocean Surgeon were present in at least four of the five transects surveyed. Other 13 species were only observed in one transect. Juvenile and adult doctorfishes, parrotfishes, Coneys, Graysbe, Lionfish and one adult Yellowtail Snapper were observed in extended transects (Table 12).

The fish community associated with the Tres Palmas shelf-edge reef appears to be strongly driven by pelagic and demersal zooplanktivores (e.g. *Chromis spp*., Creole Wrasse, Bicolor Damselfish, Mackerel Scad, Masked goby, others) which comprised approximately 47.2 % of the total individuals within transects. Large schools of Creole Wrasse, *Clepticus parrae* and Mackerel Scad, *Decapterus macarellus* were present at mid-water over the reef. These are zooplanktivores that serve as prey for pelagic predators, such as Cero Mackerels, Blue Runners and Barracudas that have been previously reported to occur at this reef (Garcia-Sais et al, 2014). A large variety of small invertebrate feeders, including wrasses, hamlets, gobies, and squirrelfishes were present with a combined abundance of approximately 20.0 % of the total. Larger invertebrate and small fish predators included the Schoolmaster and Mahogani snappers, Coney, Graysby and Red Hind groupers, Spanish Hogfish, lizardfishes and grunts. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous assemblage with a combined abundance of 8.2 % of the total.

Annual fluctuations of fish abundance and species richness from the baseline survey of 2004 to the present are presented in Figure 11. Both fish species richness and abundance within belt-transects presented statistically significant differences between survey years (ANOVA; $p < 0.0001$; Appendices 5-6). Mean fish abundance has shown 5-fold magnitude fluctuations from a baseline maximum of 531.4 Ind/30 m^2 in 2004 to a minimum of 82.6 Ind/30 m^2 during the present 2017 survey. The main species that has contributed to the variability of fish abundance between monitoring surveys is the Masked Goby, *Coryphopterus personatus*. This is a small carnivorous fish (< 2.0 cm) that at certain times forms swarms of hundreds of individuals below coral ledges and near the sand-coral interface of the spur and groove reef formation, thus it has highly aggregated or patchy distributions in the reef. The temporal abundance dynamics for this species has not been studied. Thus, the factors that influence its abundance fluctuations between annual surveys remain unclear. Given its small size and high density in swarms, this goby may be an important forage (prey) species for the small piscivores in the reef. During the 2017 survey the abundance of Masked Goby (2.2 Ind/30 m^2) was the lowest recorded from this reef.

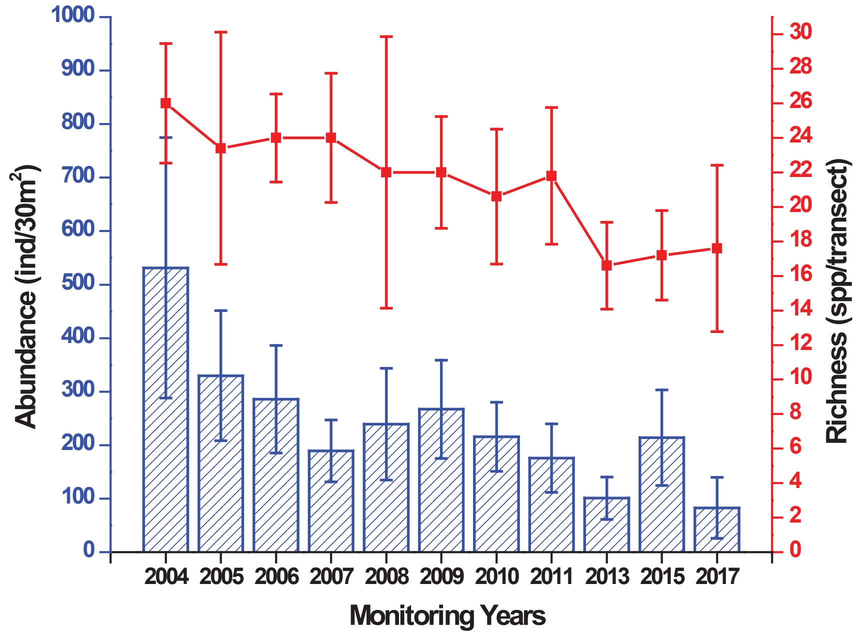


Figure 11. Monitoring trends (2004 – 2017) of fish species richness and abundance at Tres Palmas Shelf Edge Reef, Rincon, 20 m

The Tres Palmas shelf-edge reef is an ideal habitat for adult reef fishes, as evidenced by the presence of adult Lane and Schoolmaster snappers, Red Hinds, Great Barracuda, Cero Mackerels and Blue Runners. The absence of the larger demersal predators appears to be related to the high fishing pressure, since the physical habitat and potential food (fish forage) are available. This may be facilitated by the narrow nature of the shelf and the limited geographical extension of the coral reef resource. Large snappers and groupers may be using deeper sections of the upper insular slope as residential habitat or refuge, and the shelf-edge reef as foraging ground at night. One giant Hawksbill Turtle (*Eretmochelys imbricata*) was present at the shelf-edge reef during the 2005 monitoring survey. Commercially important species included aquarium trade targets, such as the Fairy Basslet, Queen and French Angelfishes, Rock Beauty, Blue Chromis and Swissguard Basslet.

Motile megabenthic invertebrates were represented by Channel Clinging and Arrow Crabs, and Cleaner and Banded Coral Shrimps (Table 13). Two Spiny Lobsters were observed outside belt-transects during 2017.

Table 13. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Shelf-edge Reef, Rincon 20 m. 2017

Depth: 20 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Stenopus hispidus	Banded Coral Shrimp		3				**0.6**
Mithrax spinosissimus	Channel Clinging Crab					1	**0.2**
Stenorhinchus seticornis	Arrow Crab				1		**0.2**
Periclimenes pedersoni	Cleaner Shrimp	1		1			**0.4**
	TOTALS	1	3	1	1	1	**1.4**

3.4 Photo Album 3

Tres Palmas 20m - Rincon
















4.0 Tourmaline 30m - Mayaguez

4.1 Physical Description

Tourmaline Reef, located due west of Bahía Bramadero, Cabo Rojo was designated as a Natural Reserve in 1996 in recognition of its ecological value as the most important coral reef system of the west coast of Puerto Rico. The total extension of the Natural Reserve is 19.43 square nautical miles. The reef sits at the northern section of the Cabo Rojo platform, approximately five miles away from the coastline (Figure 12).

Tourmaline is a submerged coral reef system comprised by a series of narrow hard ground terraces or steps fringing the edge of the Mayaguez Bay shelf along a depth range of 10 - 32 m. The reef starts at a depth of 10 m with a well-defined ”spur-and-groove” formation that follows a gentle slope towards the north, ending in a coralline sand pool at a depth of 13.3 m. A more diffuse ”spur-and-groove” reef formation of massive coral buildup is found at a depth of 17 m, extending due north to a depth of 21 m. This second terrace also ends in a fine sand-silt interface. The third and last hard ground terrace is narrow, breaking abruptly from 22 m down to 32 m along an irregular slope with high topographic relief given by large massive corals. Below 25 m, the slope rises somewhat and stony coral growth is more scattered and less massive than above. This last hard ground terrace leads to an extensive fine sand-silt bottom that drops gradually towards the insular slope (>50 m). Permanent transects were oriented south - north, perpendicular to the shelf-edge and on top of the spurs at a depth of 28 - 30 m. Panoramic views of Tourmaline shelf-edge reef are presented in Photo Album 4.

4.2 Sessile-Benthic Reef Community

A total of 21 stony corals and two black coral species have been identified from the Tourmaline shelf-edge reef, 12 of which were intercepted by line transects during our 2017 survey (Table 14). Substrate cover by stony corals along transects averaged 23.1 % (range: 19.3 – 30.6 %) with an average of 16 colonies intercepted per transect. Grahame Lettuce Coral, *Agaricia grahamae* and Boulder Star Coral, *Orbicella annularis* (complex) were the dominant species in terms of substrate cover with means of 9.2 and 7.2 % respectively. Their combined abundance represented 71.0 % of the total cover by stony corals. Colonies Mustard-Hill Coral (*Porites astreoides*), Greater Starlet Coral (*Siderastrea siderea*) and Ten-Ray Star Coral (*Madracis decactis*) were present in at

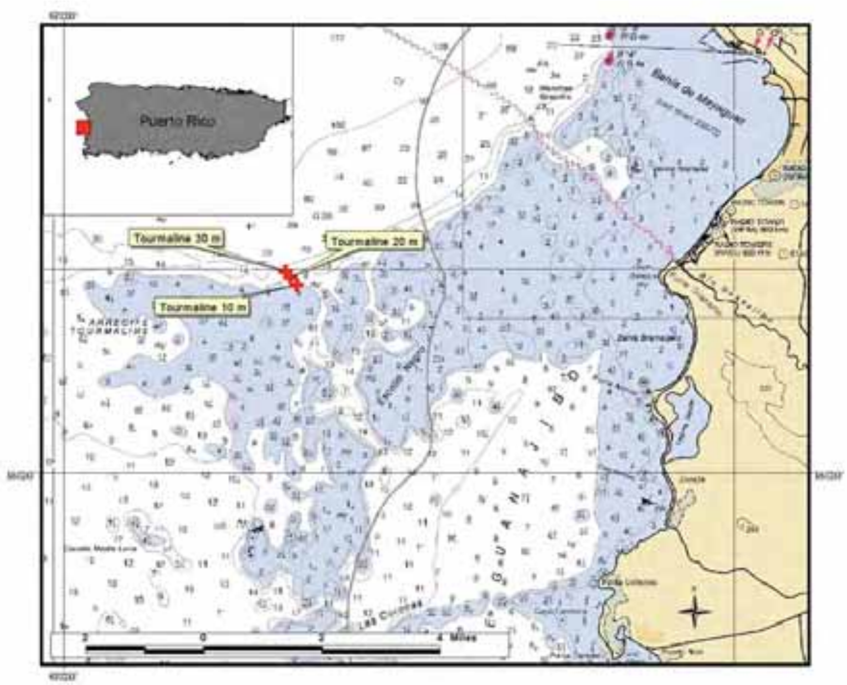


Figure 12. Location of coral reef survey stations at Tourmaline Reef, Mayaguez.

least four transects at the shelf-edge reef. Coral diseases were not observed from colonies intercepted by transects (Appendix 2). Soft corals (gorgonians) were present in all transects surveyed, but in relatively low densities with an average of 10.2 colonies/transect (Table 14). The Corky Sea Finger (*Briareum asbestinum*) and the Sea Plume (*Pseudopterogorgia acerosa*) were the most common. Colonies of Bushy Black Coral (*Antipathes caribbeana*) and Wire Coral (*Stichopathes lutkeni*) were present outside transects close to the deepest end of the reef at 32 m.

Encrusting and erect sponges were represented by 13 species along transects surveyed with an average substrate cover of 4.4 %. Some of the most prevalent along transects included *Agelas conifera*, *Svenzea zeai*, *Plakortis sp*, and *Scopalina ruetzleri* (Table 14). The Blue Bell Tunicate, *Clavelina puertosecensis* was very common throughout the shelf-edge reef. Reef overhangs, associated with substrate depressions and coral ledges averaged 16.3 % and contributed substantially to a topographic rugosity of 3.8 m.

Turf algae, comprised by an assemblage of short filamentous red and brown macroalgae was the dominant sessile-benthic component in terms of substrate cover at the shelf-edge reef with an average of 29.8 % (range: 25.4 – 34.7 %). Turf algae was found

Table 14. Percent substrate cover by sessile-benthic categories at Tourmaline Reef, Mayaguez, 30m. Survey Date: January 2017

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	3.44	3.71	5.06	3.89	2.98	**3.82**
Benthic Categories						
Abiotic						
Reef overhang	14.48	18.49	19.42	15.42	13.48	**16.26**
Sand		7.15	1.77	5.04	3.24	**3.44**
Gap	2.50	1.12	1.39	6.85	2.48	**2.87**
Total Abiotic	**16.98**	**26.76**	**22.58**	**27.32**	**19.20**	**22.57**
Benthic Algae						
Turf	29.90	29.93	34.67	25.40	29.13	**29.80**
CCA	9.79	9.19	12.08	13.00	10.57	**10.93**
Dictyota spp.			0.28	0.40		**0.14**
Total Benthic Algae	**39.69**	**39.12**	**47.03**	**38.81**	**39.70**	**40.87**
Hard Coral						
Agaricia grahamae	12.19	11.24	5.30	9.17	8.20	**9.22**
Orbicella annularis complex	3.13	7.46	4.74	7.16	13.59	**7.21**
Porites astreoides	1.67	1.02	4.65		0.76	**1.62**
Agaricia lamarcki		1.63	1.86	2.72		**1.24**
Montastraea cavernosa			0.84		3.56	**0.88**
Madracis carmabi		4.09				**0.82**
Siderastrea siderea	0.42		0.93	1.11	1.62	**0.81**
Stephanocoenia intersepta		0.20			2.48	**0.54**
Madracis decactis	1.67		0.09	0.30	0.43	**0.50**
Agaricia agaricites	1.35		0.93			**0.46**
Mycetophyllia sp.	0.42	0.82				**0.25**
Dichocoenia stokesii	0.83					**0.17**
Total Hard Coral	**21.67**	**26.46**	**19.33**	**20.46**	**30.64**	**23.71**
Coral Colonies/Transect	15	15	20	11	19	**16.0**
Encrusting tunicate					0.32	**0.06**
Octocoral						**0.00**
Briareum asbestinum	15.73	5.21	7.43	7.86	5.72	**8.39**
# Gorgonians/transect	5	8	12	12	14	**10.20**
Sponge						**0.00**
Agelas conifera	2.60		0.28	2.02	0.86	**1.15**
Svenzea zeai	1.15	1.02	0.84	0.71		**0.74**
Neopetrosia sp.	0.63		0.28		2.48	**0.68**
Plaktoris sp.		0.20	1.21	0.50	0.32	**0.45**

Niphates erecta			0.37	1.01		**0.28**
Iotrochota birotulata	0.94				0.43	**0.27**
Monanchora arbuscula		0.72	0.46			**0.24**
Scopalina ruetzleri	0.21	0.20		0.40	0.32	**0.23**
Amphimedon compressa				0.50		**0.10**
Halisarca caerulea	0.42					**0.08**
Neopetrosia proxima				0.40		**0.08**
Agelas sp.		0.31				**0.06**
Callyspongia fallax			0.19			**0.04**
Total Sponge	**5.94**	**2.45**	**3.62**	**5.54**	**4.42**	**4.40**

overgrowing rocky substrates, as well as dead coral sections and other hard bottom. Crustose coralline algae (CCA) and fleshy macroalgae (mostly *Dictyota sp*) were also present as part of the benthic algae assemblage at Tourmaline shelf-edge reef. The total cover by benthic algae was 40.9 % (range: 38.8 – 47.0) (Table 14).

Figure 13 shows the annual variations of mean percent cover by sessile-benthic categories at the Tourmaline shelf-edge reef at 30 m. Differences of live coral cover between monitoring surveys were statistically significant, (ANOVA; $p < 0.001$, Appendix 1). The mean percent cover by stony corals remained stable during the period between the baseline survey in 2004 and 2010. Since then, there has been a consistent increment of live coral cover until the present survey that now represents an accretion of approximately 43%, from 13.5% during the baseline survey to 23.7% in 2017. The increment of live coral is associated with increments by the two dominant corals, the *Agaricia spp* assemblage, of which *A. grahamae* is the main component, and Boulder Star Coral, *Orbicella annularis* (Figure 14). Since our baseline survey in 2004, many large colonies of *O. annularis* were dead and overgrown by turf algae on this reef, indicative of a major stress acting over this coral species some years before our original survey. During the monitoring program, live coral has re-colonized (previously) dead coral sections by displacing turf algae, which have shown a corresponding declining trend of reef substrate cover with time.

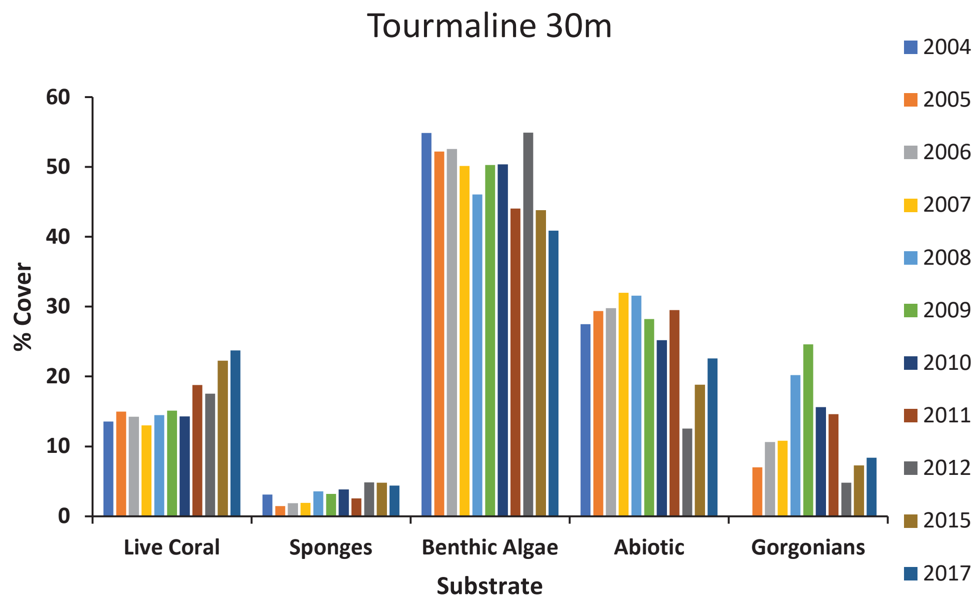


Figure 13. Monitoring trends (2004 – 2017) of mean substrate cover by sessile-benthic categories at Tourmaline Shelf-edge Reef – 30 m, Mayaguez Bay.

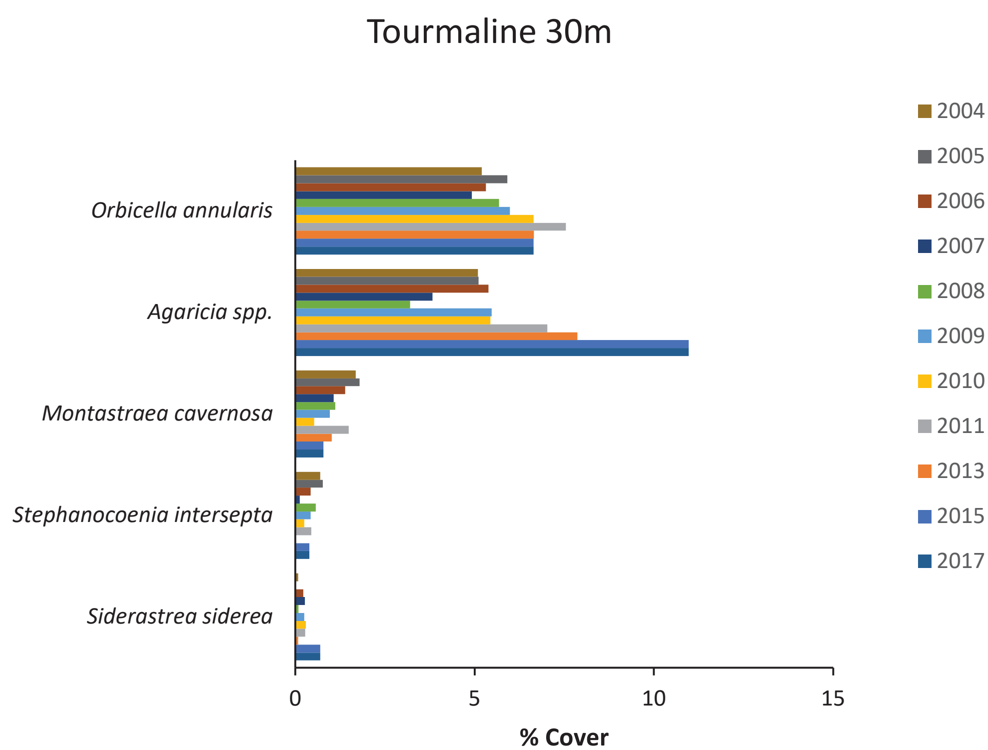


Figure 14. Monitoring trends (2004 – 2017) of mean substrate cover by stony coral species at Tourmaline Reef – 30 m, Mayaguez Bay.

4.3 Fishes and Motile Megabenthic Invertebrates

A total of 112 fish species have been identified from Tourmaline Reef at depths of 25-30 m (Appendix 4). Mean abundance within belt-transects during the 2017 monitoring survey was 51.4 Ind/30 m^2 (range: 36 - 72 Ind/30 m^2). The mean number of species per transect was 15.4 (H'= 147.1). The Blue Chromis, *Chromis cyanea* was the numerically dominant species with a mean abundance of 15.8 Ind/30 m^2 (range: 6 - 31 Ind/30 m^2), representing 30.7 % of the total abundance within belt-transects (Table 15). The combined abundance of eight species that were present in at least four transects represented 80.5% of the total individuals observed within belt-transects. The main assemblage included the Peppermint and Masked Gobies, Blue Chromis, Bicolor Damselfish, Fairy Basslet, Princess Parrotfish, Beaugregory, and Black-bar Soldierfish.

Size distribution data of commercially important fishes surveyed along extended transects are presented in Table 16. Mostly adult doctorfishes (*Acanthurus spp*) and juvenile and adult parrotfishes (*Sparisoma spp, Scarus sp*) were the most abundant taxa. One juvenile Lionfish and one adult Yellowtail Snapper were also present within transects. Full adult stages of top demersal and pelagic predators, such as snappers, groupers, mackerels and barracudas have been observed at the shelf-edge reef, but in low abundance (Garcia-Sais et al., 2014).

Demersal zooplanktivores, comprised in this survey by the four of the top six numerically dominant species (Blue Chromis, Masked Goby, *Stegastes partitus, Gramma loreto*) were as in previous surveys, the main trophic component within belt-transects, representing 63.6% of the total individuals. Schools of Mackerel Scad, *Decapterus macarellus* were observed at mid-water over the reef and along with other zooplanktivore species serve as forage for pelagic predators such as jacks, mackerels and barracudas. A large variety of small invertebrate feeders, such as wrasses, gobies, basslets, hamlets, small groupers, goatfishes and squirrelfishes represented another prominent fish assemblage in this reef with a combined abundance of 13.5 Ind/30 m^2, or 25.7% of the total. Herbivores were represented by parrotfishes, acanthurids and damselfishes with a combined abundance of 7.0 Ind/30 m^2, or 13.6% of the total.

Table 15. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef 30m. Mayaguez, January 2017

Depth: 30m		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m²)					
SPECIES	**COMMON NAME**						**MEAN**
Chromis cyanea	Blue Chromis	12	31	14	6	16	**15.8**
Coryphopterus personatus	Masked Goby	2	8	6	12	6	**6.8**
Coryphopterus lipernes	Peppermint Goby	5	6	5	5	2	**4.6**
Scarus taeniopterus	Princess Parrotfish	4	5	8	1	2	**4.0**
Gramma loreto	Fairy Basslet	1	2	6	8	1	**3.6**
Stegastes partitus	Bicolor Damselfish	2	1	9	1	1	**2.8**
Myripristis jacobus	Black-bar Soldierfish	2	5	2	2		**2.2**
Stegastes leucostictus	Beau Gregory	2	2	2	1	1	**1.6**
Sparisoma aurofrenatum	Redband Parrotfish		4		2	1	**1.4**
Halichoeres garnoti	Yellow-head Wrasse		1		4		**1.0**
Haemulon aurolineatum	Tomtate		1	1	2		**0.8**
Neoniphon marianus	Longjaw Squirrelfish	1	1	1		1	**0.8**
Acanthurus bahianus	Ocean Surgeon	1		1		1	**0.6**
Chaetodon capistratus	Four-eye Butterflyfish	1				2	**0.6**
Acanthurus coeruleus	Blue Tang					2	**0.4**
Chaetodon aculeatus	Longsnout Butterflyfish		1		1		**0.4**
Clepticus parrae	Creole Wrasse			2			**0.4**
Mulloides martinicus	Yellow Goatfish		1		1		**0.4**
Thalassoma bifasciatum	Bluehead Wrasse			2			**0.4**
Anisotremus surinamensis	Black Margate			1			**0.2**
Aulostomus maculatus	Trumpetfish		1				**0.2**
Canthigaster rostrata	Caribbean Puffer		1				**0.2**
Cephalopholis fulva	Coney					1	**0.2**
Chromis multilineata	Brown Chromis			1			**0.2**
Gymnothorax moringa	Spotted Moray				1		**0.2**
Haemulon flavolineatum	French Grunt	1					**0.2**
Holocentrus rufus	Squirrelfish					1	**0.2**
Hypoplectrus unicolor	Butter Hamlet				1		**0.2**
Pomacanthus arcuatus	Gray Angelfish	1					**0.2**
Pterois sp.	Lionfish	1					**0.2**
Scarus iserti	Stripped Parrotfish				1		**0.2**
Sparisoma radians	Bucktooth Parrotfish		1				**0.2**
Sparisoma viride	Stoplight Parrotfish					1	**0.2**
	TOTAL INDIVIDUALS	**36**	**72**	**61**	**49**	**39**	**51.4**
	TOTAL SPECIES	**14**	**17**	**15**	**16**	**15**	**15.4**

Table 16. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at Tourmaline Reef 30 m, Mayaguez, January 2017

		TRANSECTS				
		1	2	3	4	5
		(Individuals/60 m^2)				
SPECIES	**COMMON NAME**					
Acanthurus bahianus	Ocean Surgeon			1 - 15	1 - 13	
Acanthurus coeruleus	Blue Tang					2-3
Sparisoma viride	Stoplight Parrotfish			1 - 30	1 - 28	
Sparisoma aurofrenatum	Redband Parrotfish		1 - 10		1 - 10	
			1 - 15		1 - 15	
Pterois volitans	Lionfish	1 - 5				
Scarus taeniopterus	Princess Parrotfish	4 - 13	5 - 10	5 - 5	1 - 13	
				3 - 10		
Sparisoma radians	Bucktooth Parrotfish		1-3			
Lutjanus apodus	Schoolmaster Snapper	1 - 36				
Sphyraena barracuda	Great Barracuda		1 - 58			

Annual fluctuations of fish species richness and abundance at the Mayaguez 30 m reef are shown in Figure 15. Differences of fish abundance and species richness between annual surveys were statistically significant (Appendix 5 - 6). Variations of abundance between annual monitoring surveys are mostly driven by the fluctuations of Masked Goby (*Coryphopterus personatus*), which is a schooling species with highly aggregated or patchy distributions. Such contagious distributions introduce high sampling variability and many observations are needed within any given reef system to detect temporal abundance patterns. During the present 2017 survey the abundance of Masked Goby was very low, influencing the statistically significant differences relative to previous surveys. Annual fluctuations of species richness do not show any consistent pattern through time and may be related to variable physical conditions, such as surge, water currents, and/or underwater visibility.

Motile megabenthic invertebrates observed within belt-transects at the Tourmaline shelf-edge reef during this survey were represented by one Cleaner Shrimp (Table 17).

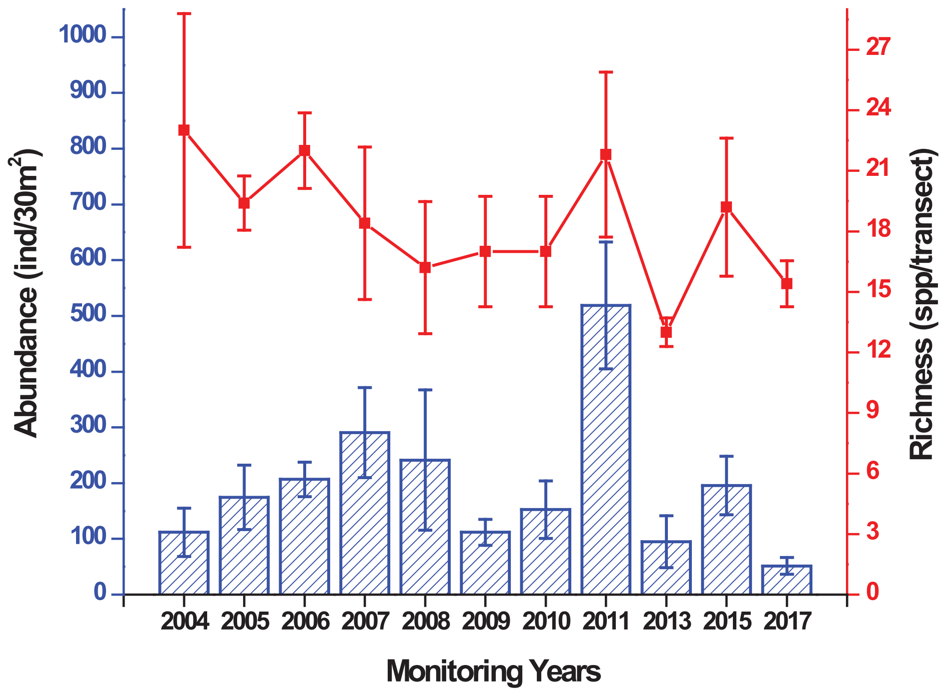


Figure 15. Monitoring trends (2004 – 2017) of fish species richness and abundance at Shelf-edge Reef Tourmaline, 30m, Mayaguez Bay.

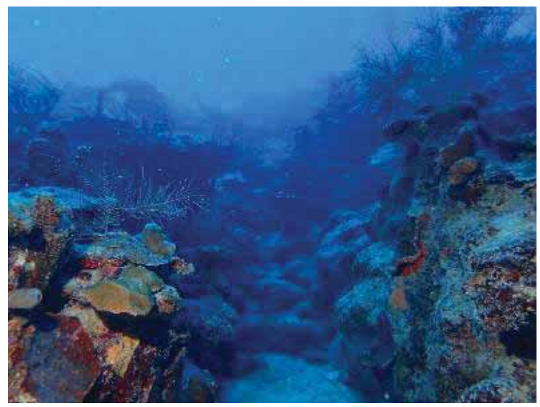
Table 17. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Shelf-edge Reef, 30 m, 2017

Depth: 30 m

		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Periclimenes pedersoni	Cleaner Shrimp	1					**0.2**
	TOTALS	**1**	**0**	**0**	**0**	**0**	**0.2**

4.0 Photo Album 4

Tourmaline 30 m - Mayaguez













5.0 Tourmaline 20 m

5.1 Physical Description

Tourmaline outer shelf reef is separated from the shelf-edge by an irregular fringe of sandy-silt bottom. Submerged at a depth of 16 m, the reef extends down a narrow and abrupt slope to a depth of 21 m. A rugged and diffuse ”spur-and-groove” formation of massive coral buildup is the main structural feature of the reef. The spurs are rather narrow (< 2 m) and rise from the sandy channels or grooves about 2 – 3 m. At the deeper edge of the reef, where the interface with the sandy bottom is reached, massive coral colonies have grown close together forming large coral promontories that partially mask the spur and groove pattern. Permanent transects were installed on top of consecutive spurs at a depth of 20 m. Panoramic views of Tourmaline outer shelf reef are presented in Photo Album 5.

5.2 Sessile-benthic Reef Community

A total of 18 stony corals and two black coral species (*Stichopathes lutkeni, Antipathes sp*.) were identified from the outer shelf reef, 10 of which were intercepted by line transects during our survey (Table 18). Stony corals occurred as massive (*Orbicella annularis* (complex), *Siderastrea siderea*, *Colpophyllia natans, Pseudodiploria labyrinthiformis*), branching (*Madracis spp., Porites porites*), encrusting (*Mycetophyllia spp.*) and mound shaped colonies (*P. astreoides, M. cavernosa, Dichocoenia stokesii*). Substrate cover by stony corals along transects averaged 30.8% (range: 25.9– 33.6%). Large and massive colonies of Boulder Star Coral, *Orbicella annularis* were the most prominent feature of the reef benthos. Boulder Star Coral was the dominant species in terms of substrate cover with a mean of 23.8 % (range: 17.3 – 27.2%), representing 77.3% of the total cover by stony corals. Colonies of Boulder Star were intercepted by all five transects. Mustard Hill Coral (*Porites astreoides*), Great Star Coral (*M. cavernosa*) and Massive Starlet Coral (*Siderastrea siderea*) comprised along with Boulder Star Coral the main stony coral assemblage at Tourmaline 20 m (Table 18). Infectious diseases were not observed in any coral colonies intercepted by line transects (Appendix 2).

Soft corals (gorgonians) were moderately abundant with an average of 11.0 colonies/transect. Some of the most common taxa included Sea Fans (*Gorgonia ventalina*) and Sea Plumes (*Antillogorgia sp*.) The encrusting gorgonians,

Table 18. Percent linear cover by sessile-benthic invertebrates at Tourmaline Reef 20m, Mayaguez.
Survey Date: January 3, 2017

	Transects					
	1	2	3	4	5	**Mean**
Rugosity	4.20	3.71	2.95	5.10	2.53	**3.70**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	6.21	10.32	5.73	3.86	3.80	**5.98**
Gap		1.02	3.03		9.50	**2.71**
Sand				0.40		**0.08**
Total Abiotic	**6.21**	**11.34**	**8.76**	**4.26**	**13.30**	**8.77**
Benthic Algae						
Turf	14.10	16.85	33.41	36.10	11.28	**22.35**
Lobophora variegatus	28.40	21.45	12.22	17.37	27.71	**21.43**
Dictyota spp.	7.69	8.48	14.27	1.54	6.82	**7.76**
CCA	5.52	2.45	1.73	1.93	1.68	**2.66**
Ramicrusta sp.					0.78	**0.16**
Total Benthic Algae	**55.72**	**49.23**	**61.62**	**56.95**	**48.27**	**54.36**
Hard Coral						
Orbicella annularis complex	25.54	22.68	17.30	27.22	26.15	**23.78**
Porites astreoides		2.15		3.09	3.80	**1.81**
Montastraea cavernosa	2.17		3.35		2.46	**1.60**
Siderastrea siderea	0.69		2.16	2.32	1.23	**1.28**
Colpophyllia natans		3.47				**0.69**
Madracis decactis		0.82	0.43	0.97		**0.44**
Agaricia agaricites	1.38	0.51				**0.38**
Millepora alcicornis	0.79		1.08			**0.37**
Dendrogyra cylindrus			1.62			**0.32**
Eusmilia fastigiata		0.61				**0.12**
Total Hard Coral	**30.58**	**30.23**	**25.94**	**33.59**	**33.63**	**30.79**
Colonies /Transect						
Octocoral						
Briareum asbestinum	4.14	5.62	1.08	4.63	4.80	**4.06**
Erythropodium caribaeorum		3.58	2.05			**1.13**
Antillogorgia americana	0.20					**0.04**
Gorgonia ventalina	0.20					**0.04**
Total Octocoral	**4.54**	**9.19**	**3.14**	**4.63**	**4.80**	**5.26**
# Gorgonians/transect	12	12	15	6	10	**11.00**
Sponge						
Neopetrosia sp.	1.97					**0.39**
Neopetrosia proxima			0.54	0.58		**0.22**
Monanchora arbuscula	0.99					**0.20**
Clathria sp.				0.39		**0.08**
Total Sponge	**2.96**		**0.54**	**0.97**		**0.89**

Erythropodium caribaeorum and *Briareum asbestinum* combined for a substrate cover of 5.2% (Table 18). Colonies of Bushy Black Coral (*Antipathes caribbeana*) and Wire Coral (*Stichopathes lutkeni*) were present at the reef base and associated with reef crevices and overhangs. Encrusting sponges were represented by four species along transects with a mean cover of 0.9 %, and thus, comprised a minor component of the reef benthos. Reef overhangs, associated with live and dead ledges of Boulder Star Coral averaged 6.0 % of the reef substrate cover and contributed markedly to the topographic rugosity of 3.7 m. Total abiotic cover averaged 8.8% (Table 18).

Benthic algae, comprised by turf, fleshy and coralline macroalgae algae were the dominant sessile-benthic component in terms of substrate cover at the outer shelf reef with an average of 54.4 % (range: 48.3 – 61.6 %). Turf algae, a mixed assemblage of short filamentous red and brown macroalgae contributed a reef substrate cover of 22.4%, representing 41.2% of the total benthic algae. The Encrusting Fan Alga, *Lobophora variegata* (mean cover: 21.4 %) was the main component of the fleshy algal assemblage.

Figure 16 presents the variations of mean percent substrate cover by sessile-benthic categories from Tourmaline outer shelf reef at 20 m. Reef substrate cover by live corals showed a gradual decline from a baseline mean of 31.8 % in 2004 to a minimum of 22.8% in 2007. Such decline was probably associated with coral bleaching-induced mortalities after the regional event of late August 2005, with lingering effects down to 2008. After 2010 live coral cover has shown a consistent increasing trend until the present survey, now evidencing a recuperation of 26.0 % from its lowest cover in 2010 and approaching its baseline cover at 31.8%. Differences associated with this recuperation trend were statistically significant (ANOVA, $p = 0.004$; Appendix 1).

Orbicella annularis was the main driver of the declining trend of live coral between 2004 and 2007 and also of its recuperation to date because it is the dominant keystone coral species at Tourmaline Reef (Figure 17). During the last four surveys (2011 – 2017), *O. annularis* has shown a slow, but consistent increment of reef substrate cover, influencing the overall cover by live corals in this reef.

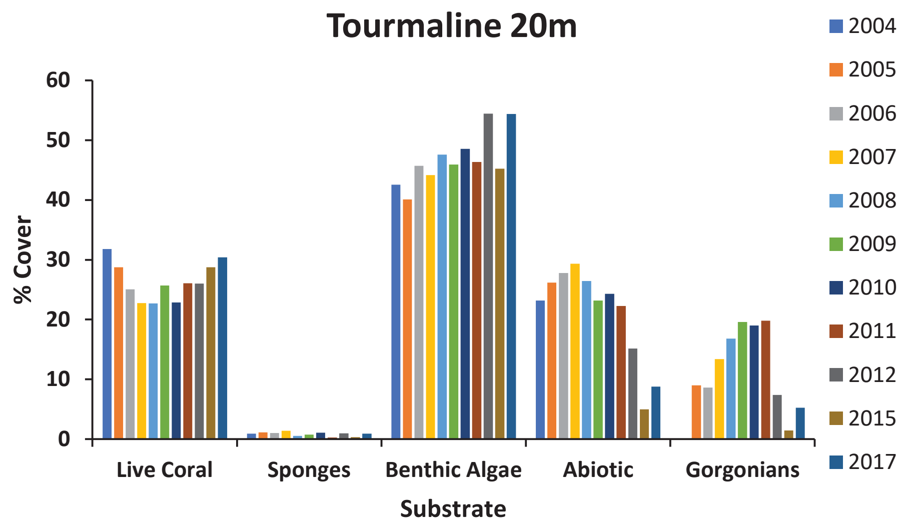


Figure 16. Monitoring trends (2004 – 2017) of mean substrate cover by sessile-benthic categories at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

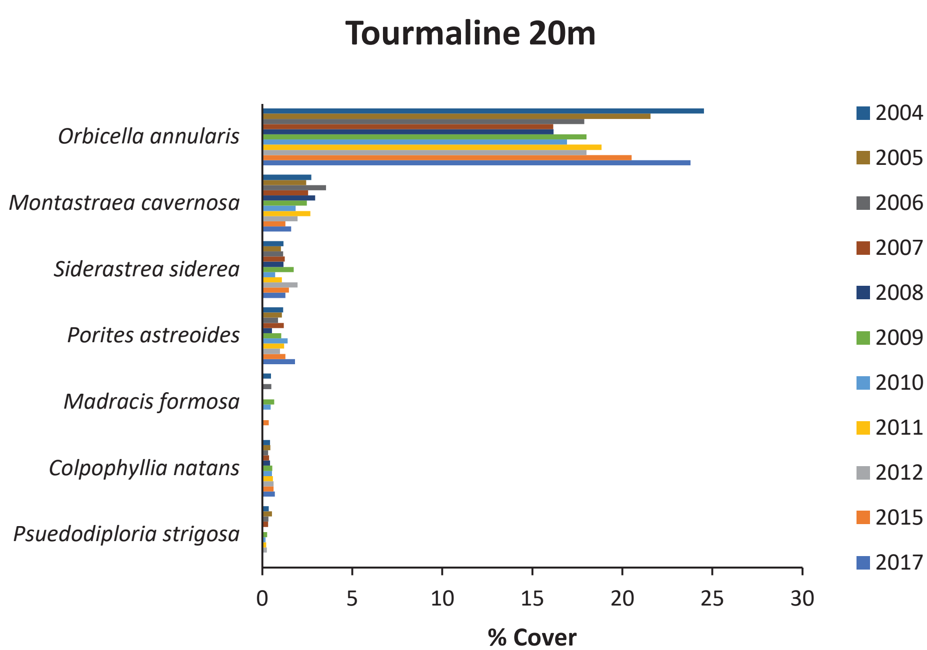


Figure 17. Monitoring trends (2004 – 2017) of mean substrate cover by stony coral species at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

The main variation of reef substrate cover by benthic categories measured during the 2017 monitoring survey at Tourmaline 20m was a sharp reduction of soft coral (gorgonians) density along transects, from a mean of 19.6 col/transect in 2015 to a mean of 11.0 col/transect during 2017. The difference was statistically significant (T-test, $p= 0.031$; Appendix 3), and probably caused by mechanical detachment and mortality due to conditions of extreme wave and surge action associated with the pass of Hurricane Mathew close to the south coast of PR during October 2016.

5.3 Fishes and Motile Megabenthic Invertebrates

A total of 102 fish species have been identified from Tourmaline outer shelf reef at 20 m (Appendix 4). Mean abundance within belt-transects during 2017 was 49.8 Ind/30 m^2 (range: 38 - 67 Ind/30 m^2). The mean number of species per transect was 16.4 (H'=153.3). An assemblage of eight (9) species were present in all five transects surveyed and represented 58.0% of the total individuals observed within belt-transects. This group included the Fairy Basslet, Peppermint Goby, Princess Parrotfish, Creole and Bluehead Wrasses, Blue Chromis, Caribbean Puffer and Beaugregory (Table 19). The Masked Goby, *Coryphopterus personatus* which was the numerically dominant species during the previous (2015) and many other previous surveys (Garcia-Sais et al 2015, and references therein) was observed in three transects, but in very low abundance (mean: 2.0 Ind/30 m^2).

Parrotfishes (*Scarus iserti, S. taeniopterus, Sparisoma viride, S. aurofrenatum*) and doctorfishes (*Acanthurus spp*) were the most abundant commercially valuable fish species present within the extended belt-transects surveyed at Tourmaline 20 m (Table 20). Most individuals were late juveniles and adults, but several early juvenile Stoplight and Redband parrotfishes were observed. Previous surveys have noted that parrotfishes recruit to this reef in early juvenile stages of < 2 cm SL (Garcia-Sais et al. 2014). One juvenile Nassau Groupers was observed within belt-transects and another juvenile was observed outside transects. Considering that our survey covers a limited geographic range, this observation within our survey area may be indicative of a good recruitment pulse for this overexploited species. One juvenile Yellowmouth Grouper (*Mycteroperca interstitialis*) was observed. Adult Lionfish and one Yellowtail Snapper were also present.

Table 19. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef 20m. Mayaguez, January 2017

Depth: 20m		TRANSECTS 1	2	3	4	5	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Gramma loreto	Fairy Basslet	11	5	2	5	6	5.8
Coryphopterus lipernes	Peppermint Goby	5	8	6	2	6	5.4
Scarus taeniopterus	Princess Parrotfish	8	1	6	8	2	5.0
Clepticus parrae	Creole Wrasse	9	15	1			5.0
Thalassoma bifasciatum	Bluehead Wrasse	1	15	2	1	6	5.0
Chromis cyanea	Blue Chromis	3	8	5	3	5	4.8
Canthigaster rostrata	Caribbean Puffer	2	2	2	2	1	1.8
Stegastes partitus	Bicolor Damselfish		2	3	6	4	3.0
Stegastes leucostictus	Beau Gregory	1	2	2	2	3	2.0
Scarus iserti	Stripped Parrotfish		4	1			1.0
Haemulon flavolineatum	French Grunt	2	1		1	1	1.0
Sparisoma aurofrenatum	Redband Parrotfish	1		2	2		1.0
Coryphopterus personatus	Masked Goby	2			4	4	2.0
Myripristis jacobus	Black-bar Soldierfish		1			5	1.2
Chaetodon capistratus	Four-eye Butterflyfish		1		2	1	0.8
Halichoeres garnoti	Yellow-head Wrasse			1		3	0.8
Holacanthus tricolor	Rock Beauty	1				1	0.4
Pterois sp.	Lionfish	1				1	0.4
Acanthurus chirurgus	Doctorfish			1			0.2
Acanthurus coeruleus	Blue Tang			1			0.2
Aetobatis narinari	Spotted Eagle Ray		1				0.2
Echeneis naucrates	Sharksucker		1				0.2
Elacatinus evelynae	Sharknose Goby	1					0.2
Lutjanus apodus	Schoolmaster	1					0.2
Neoniphon marianus	Longjaw Squirrelfish			1			0.2
Ocyurus chrysurus	Yellowtail Snapper	1					0.2
Sparisoma radians	Bucktooth Parrotfish			1			0.2
Sparisoma viride	Stoplight Parrotfish			1			0.2
Acanthurus bahianus	Ocean Surgeon				1		0.2
Cephalopholis cruentatus	Graysby				1		0.2
Chaetodon aculeatus	Longsnout Butterflyfish					1	0.2
Chaetodon ocellatus	Spotfin Butterflyfish					1	0.2
Holocentrus rufus	Squirrelfish				1		0.2
Hypoplectrus chlorurus	Yellowtail Hamlet					1	0.2
Mulloides martinicus	Yellow Goatfish					1	0.2
	TOTAL INDIVIDUALS	**53**	**41**	**38**	**67**	**50**	**49.8**
	TOTAL SPECIES	**16**	**15**	**17**	**15**	**19**	**16.4**

Table 20. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at Tourmaline Reef 20 m, Mayaguez, January 2017

		TRANSECTS				
		1	2	3	4	5
		(individuals/60 m2)				
SPECIES	**COMMON NAME**					
Acanthurus chirurgus	Doctorfish			1 - 15	1 - 10	
Acanthurus bahianus	Ocean Surgeon				1 - 13	
Acanthurus coeruleus	Blue Tang			1 - 15		1 - 15
Sparisoma viride	Stoplight Parrotfish			1 - 3		1 - 25
Scarus iserti	Stripped Parrotfish		4 - 5		1 - 10	
Sparisoma aurofrenatum	Redband Parrotfish			1 - 5	1 - 8	
				1 - 18	1 - 13	
Epinephelus striatus	Nassau grouper				1 - 40	
Epinephelus cruentatus	Graysby				1 - 15	
Pterois volitans	Lionfish	1 -33				1 - 28
Scarus taeniopterus	Princess Parrotfish	1 - 13	1 - 13	2 - 3	2 - 5	2 - 15
		4 - 13		2 - 8	5 - 8	
				5 - 13	8 - 13	
Lutjanus apodus	Schoolmaster Snapper	1 - 25				
Aetobatus narinari	Spotted Eagle Ray		1 - 170			
Ocyurus chrysurus	Yellowtail Snapper	1 - 30				
Scomberomorus regalis	Cero		1 - 72			

The high reef rugosity with sand channels, crevices, large coral ledges and holes makes Tourmaline outer shelf reef an ideal habitat for large demersal fishes, such as snappers, groupers, hogfishes and others. It is surprising not to see them in higher densities in the reef. The apparent cause for their absence is perhaps that the reef was severely impacted by intense fishing effort on snapper/grouper spawning aggregations known to have been occurring at Tourmaline Reef. During such seasonal reproductive events, these species are highly vulnerable to fishing mortality. The ecological implications of such fishing practices on recruitment dynamics and population replenishment need further investigation. Tourmaline outer reef has been identified as a Red Hind spawning aggregation site and since 1993 has been seasonally closed to fishing (December – February). Clear signs of recuperation of the Red Hind population at Tourmaline Reef are still not evident.

The fish trophic structure at Tourmaline Reef 20m presented a well-balanced assemblage. Demersal zooplanktivore species included four (*Gramma loreto, Clepticus parrae, Chromis cyanea*, *Stegastes partitus*) of the top ten abundance ranks within belt-transects. Their combined abundance represented 37.3% of the total. Micro-invertebrate predators, including wrasses, gobies, basslets, hamlets, and squirrelfishes were also prominent in the reef fish community with a combined abundance of 37.3%. Parrotfishes (*Scarus spp., Sparisoma spp*.), and doctorfishes (*Acanthurus spp*.), comprised the main herbivorous fish assemblage, with a combined abundance representative of 16% of the total individuals present within belt-transects. Among large invertebrate and small demersal fish predators, Coneys, Red Hinds and Nassau Groupers and Schoolmaster, Yellowtail, Cubera and Dog Snappers, Great Barracuda and Cero Mackerels have been previously reported to occur in this reef (García-Sais et al, 2015 and references therein).

Annual variations of fish abundance and species richness are presented in Figure 18. Differences of fish abundance between surveys were statistically significant (ANOVA; $p < 0.0001$; Appendix 5-6). Abundance was higher during 2005, 2006 and 2008 relative to other monitoring surveys. Species richness presented a consistent decline after 2006, but slight increments were noted in 2010 and 2015, but declined again during 2017. Differences of fish abundance at this reef have been historically driven by abundance fluctuations of the Masked Goby, a numerically dominant species with highly aggregated distributions. The decline of fish species richness may be associated with changes in the quality of the benthic habitat, but large abundance fluctuations, including peak values have been observed in highly degraded reefs, such as Desecheo 20 and 30 m, which suggests that recruitment dynamics play an important role. Another possibility is that the sharp declines of Masked Goby abundance may have implications on the presence of other small piscivores within transects due to the lack of potential prey.

One Arrow Crab was the only motile megabenthic invertebrate observed within belt-transects during 2017 (Table 21). One Spiny Lobster (*Panulirus argus*) was observed outside transects.

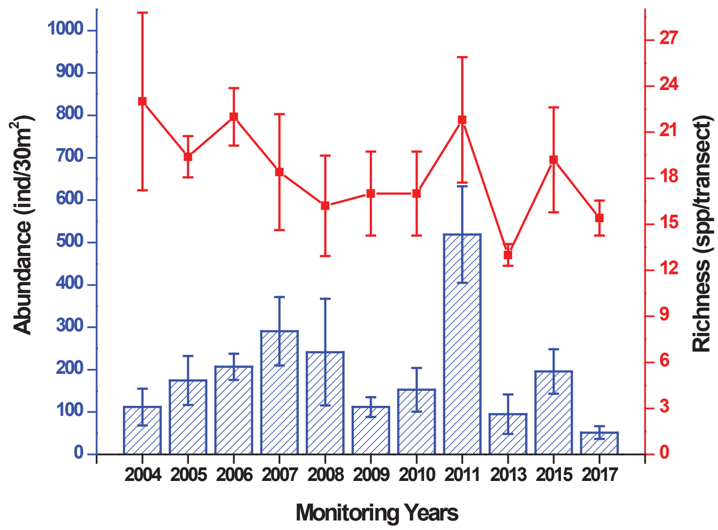


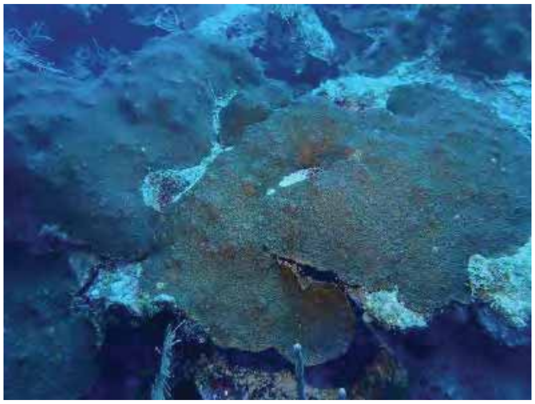
Figure 18. Monitoring trends (2004 – 2017) of fish species richness and abundance at outer shelf reef Tourmaline, 20 m, Mayaguez.

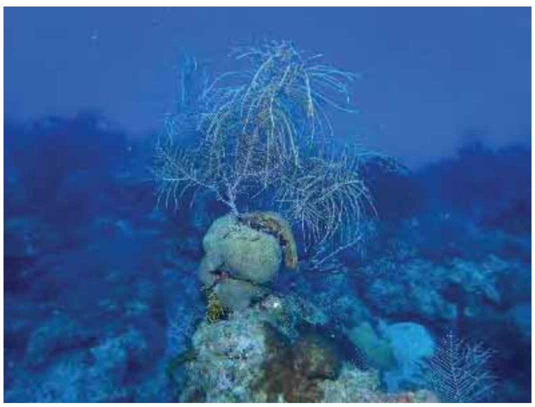
Table 21. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline 20 m, Mayaguez, 2017

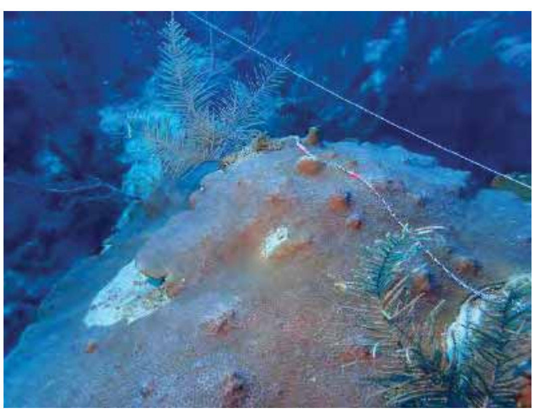
Depth: 20 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m^2)
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Stenorhinchus seticornis	Arrow Crab		1				**0.2**
	TOTALS	**0**	**1**	**0**	**0**	**0**	**0.2**

5.4 Photo Album 5

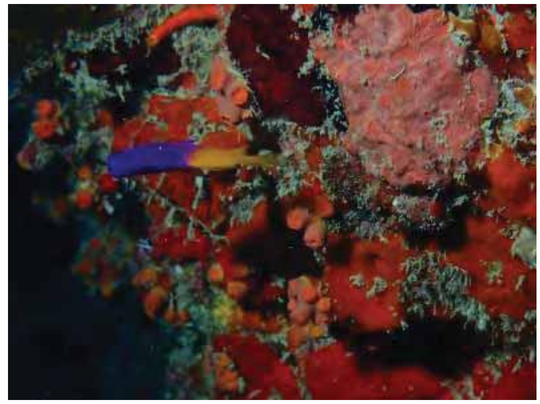
Tourmaline 20 m - Mayaguez













6.0 Tourmaline Reef – 10 m

6.1 Physical Description

At a depth of 10 m, Tourmaline Outer Shelf Reef exhibits a very well defined “spur-and-groove” formation that runs perpendicular to the shelf-edge and ends in a sandy-silt deposit at a depth of 14 m. Spurs are about 2 - 3 m tall, separated by coralline sand and coral rubble deposited at the grooves. Stony corals grow on top of the spurs and along the walls in massive, branching and encrusting colonies. Soft corals are common and a visually prominent feature of the reef benthos. An existing set of five permanent transects established on top of the spurs during the baseline characterization in 1999 by García et al. (2001) was monitored for the twelfth time during 2017. Panoramic views of Tourmaline outer shelf reef at a depth of 10 m are presented in Photo Album 6.

6.2 Sessile-benthic Reef Community

A total of 25 stony coral species were identified from the Outer Shelf Reef at a depth of 10 m, 13 of which were intercepted by line transects during this survey (Table 22). Stony corals occurred as massive (*Orbicella annularis*, *Colpophyllia natans, Montastrea cavernosa, Dendrogyra cylindrus*, branching (*Madracis spp., Porites porites, Acropora cervicornis*), encrusting (*P. astreoides, M. cavernosa, Millepora sp)* and mound shaped colonies (*P. astreoides, M. cavernosa*). Substrate cover by stony corals along transects averaged 42.1 % (range: 28.2 – 74.08 %), with an average of 24.4 colonies intercepted per transect, the highest in the coral monitoring program. Infectious diseases were observed affecting two coral colonies for an average prevalence of 1.6% (Appendix 2).

Yellow Pencil Coral, *Madracis mirabilis* was the numerically dominant species in terms of mean coral cover (mean: 12.21 %), representing 29% of the total live coral cover. Yellow Pencil Coral exhibited branching growth over the reef hard bottom and has kept an increasing pattern of reef substrate cover since 2006, reaching its maximum cover during this survey (12.2%). An extraordinarily large colony of Yellow Pencil Coral now covers more 60% of reef substrate in that transect, which is the highest in the monitoring program. An assemblage of four coral species were present in all five transects. These included Boulder Star Coral, *O. annularis*, Lettuce coral, *Agaricia agaricites*, Mustard-Hill and Finger Corals (*Porites astreoides, P. porites*). Colonies of Pillar Coral, *D. cylindrus* and Great Star Coral, *M. cavernosa* were also intercepted by four transects (Table 22).

Table 22. Percent linear cover by sessile-benthic invertebrates at Tourmaline Reef 10m, Mayaguez. Survey Date: January 3, 2017

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.08	2.59	1.93	2.98	2.71	**2.46**
Benthic Categories						
Abiotic						
Gap			0.35	1.83		**0.44**
Reef overhang					0.55	**0.11**
Total Abiotic			**0.35**	**1.83**	**0.55**	**0.55**
Benthic Algae						
Turf	39.28	12.12	28.76	29.77	39.10	**29.81**
Dictyota spp.	10.08	4.23	5.87	9.71	7.49	**7.47**
CCA	5.79	6.79	2.82	10.14	7.93	**6.69**
Ramicrusta sp.	1.16		1.41	1.08	1.65	**1.06**
Fleshy macroalgae	1.16					**0.23**
Halimeda spp.			0.35		0.77	**0.22**
Total Benthic Algae	**57.47**	**23.14**	**39.20**	**50.70**	**56.94**	**45.49**
Cyanobacteria	0.70		3.64			**0.87**
Hard Coral						
Madracis aurentenra		61.07				**12.21**
Orbicella annularis complex	6.60	7.01	11.85	9.39	7.16	**8.40**
Agaricia agaricites	5.33	0.44	7.28	11.54	5.62	**6.04**
Porites astreoides	6.14	1.45	11.50	2.37	8.04	**5.90**
Porites porites	6.95	1.22	2.58	0.43	2.97	**2.83**
Dendrogyra cylindrus	2.78		2.93	4.53	1.54	**2.36**
Meandrina meandrites		2.56		1.51	1.65	**1.14**
Colpophyllia natans			5.28			**1.06**
Acropora cervicornis			4.23			**0.85**
Montastraea cavernosa		0.33	1.41	1.29	0.44	**0.70**
Madracis decactis	0.70			0.97		**0.33**
Siderastrea siderea			0.59		0.44	**0.21**
Millepora alcicornis					0.33	**0.07**
Total Hard Coral	**28.51**	**74.08**	**47.65**	**32.04**	**28.19**	**42.10**
Colonies per Transect	23	15	30	25	29	**24.4**
Zoanthids						
Palythoa caribaeorum		0.22		1.29		**0.30**
Octocoral						
Briareum asbestinum	10.78	1.56	4.11	10.25	7.71	**6.88**
Erythropodium caribaeorum	0.70		4.81	2.91	5.73	**2.83**
Pseudoplexaura wagerni				0.54		**0.11**
Eunicea succinea		0.44				**0.09**
Gorgonia ventalina	0.23					**0.05**
Plexaura kuekenthali	0.23					**0.05**
Total Octocoral	**11.94**	**2.00**	**8.92**	**13.70**	**13.44**	**10.00**
# Gorgonians/transect	15	12	7	19	20	**14.60**

Sponges						
Niphates erecta	0.58				0.77	**0.27**
Monanchora arbuscula	0.81					**0.16**
Agelas tubulata		0.33				**0.07**
Mycale laevis				0.22	0.11	**0.07**
Neopetrosia sp.			0.23			**0.05**
Ircinia sp. brown		0.22				**0.04**
Scopalina ruetzleri				0.22		**0.04**
Total Sponge	**1.39**	**0.56**	**0.23**	**0.43**	**0.88**	**0.70**

Erect soft corals (gorgonians) were highly abundant with an average of 14.6 colonies/transect and along with stony corals were the most visually prominent assemblage of the reef benthos. The most abundant species included Sea Rods, *Plexaura spp*. *Pseudoplexaura spp*., and sea fans, *Gorgonia ventalina*. Encrusting gorgonians, *Erythropodium caribaeorum* and *Briareum asbestinum* were present with a combined reef substrate cover of 9.7%. Sponges were represented by seven species along transects with a combined mean cover of 0.7 %, and represented minor components of the reef benthos (Table 22).

Turf algae, comprised by a mixed assemblage of short filamentous red and brown macroalgae presented an average substrate cover of 29.8 % (range: 12.1 – 39.3 %), representing 65.4% of the total benthic algae assemblage. Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard ground. Total cover by benthic algae averaged 45.5 %. Cyanobacterial films were observed in two transects with a mean substrate cover of 1.4% (Table 22).

Figure 19 shows the monitoring trends of reef substrate cover by sessile-benthic categories from Tourmaline outer shelf reef at 10 m, including the baseline survey of 1999 and 12 annual monitoring surveys (2004-17). Overall, differences of substrate cover by live corals were not statistically significant (ANOVA; p = 0.662). During the 2006 monitoring survey, mean live coral cover declined 22.6%, from 44.3 % in 2005 to 34.2 %. This decline was measured after the regional coral bleaching event that affected most of the northern Caribbean (Garcia-Sais et al, 2008). An additional decline of 16.5 % was measured from 2006 to 2007 attributed to lingering effects of the late 2005-bleaching event. At the community level, the variation of total live coral cover was not statistically significant, perhaps due to the high variability associated with the magnitude (not direction) of the variations within transects. At the population level, a statistically significant decline of live coral cover (ANOVA; $p = 0.028$) was found for *Orbicella annularis* (complex), the dominant coral species in terms of reef substrate cover at Tourmaline 10 m (García-Sais et al., 2006). Reef substrate cover by *O. annularis* declined 46 % between 2005 and 2006, and was the main driver of the overall decline of live coral for this reef. After 2009, *O. annularis* presented a consistent pattern of increasing reef substrate cover until the 2015 survey. During the present 2017 survey, *O. annularis* exhibited a mild reduction of reef substrate cover, but the variation was statistically insignificant compared to previous surveys (Figure 20).

6.3 Fishes and Motile Megabenthic Invertebrates

A total of 109 diurnal, non-cryptic fish species have been identified during monitoring surveys from Tourmaline Outer Shelf Reef at a depth of 10 m (Appendix 4). Mean abundance during the 2017 survey was 60.2 Ind/30 m^2 (range: 28 – 73 Ind/30 m^2). A total of 32 species were observed within belt-transects and the mean number of species per transect was 15 (H'= 142.8). The Blue Chromis (*Chromis cyanea*) and Bluehead Wrasse (*Thalassoma bifasciatum*) were the numerically dominant species with a combined mean abundance of 29.0 Ind/30 m^2, representing 48.2 % of the total abundance within belt-transects (Table 23). In addition to the aforementioned species, six more species were present in at least four transects. These included the Bicolor Damselfish (*Stegastes partitus*), Princess, Redband and Stoplight Parrotfishes (*Scarus taeniopterus, Sparisoma aurofrenatum, S. viride*), Beau Gregory (*Stegastes leucostictus*), and French Grunt (*Haemulon flavolineatum*). Parrotfishes (*Sparisoma viride, S. taeniopterus, Sparisoma aurofrenatum*) and doctorfishes (*Acanthurus spp*) were the numerically dominant assemblage of commercially important fish species observed within extended belt-transects. Size distributions are in general indicative of a prevailing juvenile and young adult populations (Table 24). Recruitment juveniles of Stoplight Parrotfish (*Sparisoma viride*) were observed. Adult Coneys and Graysbes were the most common groupers in the reef. Two juvenile Nassau (*Epinephelus striatus*) and one juvenile Yellowfin Groupers (*Mycteroperca venenosa*) were present out of transects. This is particularly relevant as it may be indicative a good recruitment pulse for these overexploited species. Red hinds were not observed during this survey, but have been previously reported (Garcia-Sais et al, 2015 and references therein).

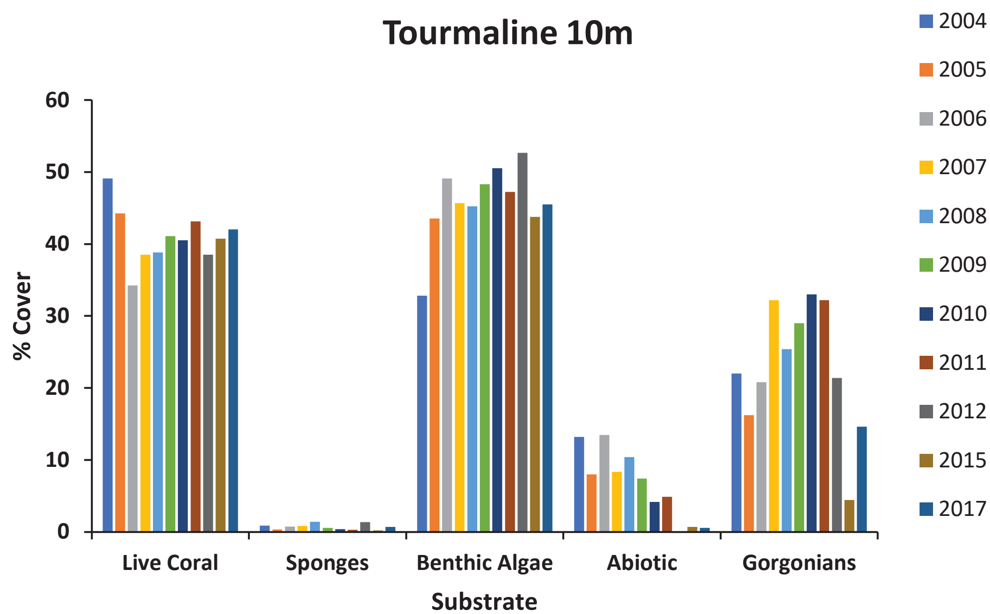


Figure 19. Monitoring trends (1999 – 2017) of mean substrate cover by sessile-benthic categories at Tourmaline Reef – 10 m, Mayaguez.

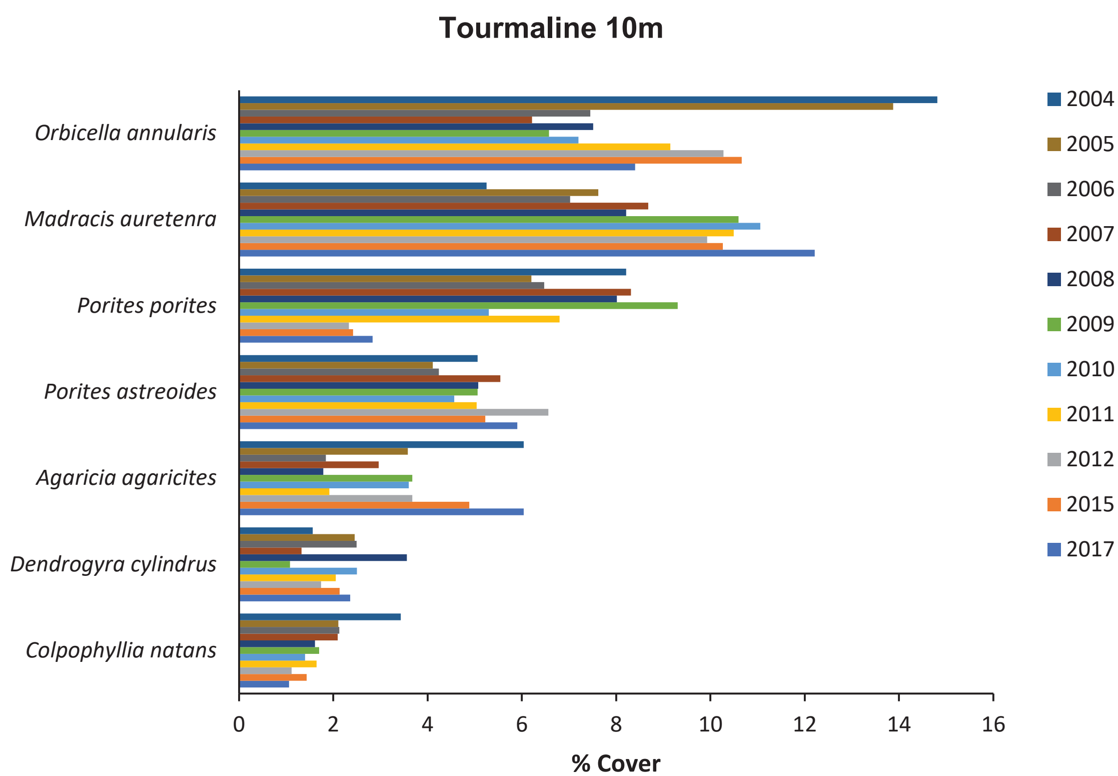


Figure 20. Monitoring trends (1999 – 2017) of mean cover by stony coral species at Tourmaline Reef – 10 m, Mayaguez.

Table 23. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef 10m. Mayaguez, January 2017

Depth: 10m		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Chromis cyanea	Blue Chromis	26	13	24	16		**15.8**
Thalassoma bifasciatum	Bluehead Wrasse	2	29	5	30		**13.2**
Stegastes partitus	Bicolor Damselfish	5	10	6	4	5	**6.0**
Scarus taeniopterus	Princess Parrotfish	15	1		1	4	**4.2**
Sparisoma aurofrenatum	Redband Parrotfish	2		2	7	3	**2.8**
Stegastes leucostictus	Beau Gregory	3	4	3	3	1	**2.8**
Sparisoma viride	Stoplight Parrotfish	3	2	2	3	1	**2.2**
Halichoeres garnoti	Yellow-head Wrasse	3	4			2	**1.8**
Haemulon flavolineatum	French Grunt		1	2	2	1	**1.2**
Acanthurus bahianus	Ocean Surgeon	2	2			1	**1.0**
Scarus iserti	Stripped Parrotfish			2		3	**1.0**
Sparisoma radians	Bucktooth Parrotfish	1			2	2	**1.0**
Stegastes planifrons	Three-spot Damselfish	2		3			**1.0**
Canthigaster rostrata	Caribbean Puffer	1	1		1	1	**0.8**
Chaetodon capistratus	Four-eye Butterflyfish	1		2			**0.6**
Coryphopterus lipernes	Peppermint Goby		2		1		**0.6**
Serranus tigrinus	Harlequin Bass	2				1	**0.6**
Amblycirrhitus pinos	Red-spotted Hawkfish	2					**0.4**
Cephalopholis fulva	Coney					2	**0.4**
Microspathodon chrysurus	Yellowtail Damselfish			1	1		**0.4**
Acanthurus chirurgus	Doctorfish		1				**0.2**
Acanthurus coeruleus	Blue Tang			1			**0.2**
Carangoides ruber	Bar Jack	1					**0.2**
Cephalopholis cruentatus	Graysby				1		**0.2**
Chaetodon striatus	Banded Butterflyfish				1		**0.2**
Elacatinus evelynae	Sharknose Goby			1			**0.2**
Pomacanthus paru	French Angelfish			1			**0.2**
Neoniphon marianus	Longjaw Squirrelfish			1			**0.2**
Scomberomorus regalis	Cero	1					**0.2**
Stegastes variabilis	Cocoa Damselfish	1					**0.2**
Holacanthus tricolor	Rock Beauty					1	**0.2**
Holocentrus rufus	Squirrelfish			1			**0.2**
	TOTAL INDIVIDUALS	**73**	**70**	**57**	**73**	**28**	**60.2**
	TOTAL SPECIES	**18**	**12**	**16**	**15**	**14**	**15.0**

Table 24. Taxonomic composition and size frequency of fishes of individuals (cm) within 20x3 meter belt-transects at Tourmaline Reef 10 m, Mayaguez, January 2017

		TRANSECTS				
		1	2	3	4	5
		(Individuals/60 m^2)				
SPECIES	**COMMON NAME**					
Acanthurus bahianus	Ocean Surgeon	1 - 8	2 - 15			1 - 10
Acanthurus coeruleus	Blue Tang		1 - 13	1 - 15	1 - 15	
Sparisoma viride	Stoplight Parrotfish	1 -3	1 - 10	2 - 5	3 - 4	1 - 3
		1 - 5	1 - 25			
		1- 10	1 - 30			
Sparisoma aurofrenatum	Redband Parrotfish	1 - 8		1 - 8	2 - 8	2 - 8
		1- 10		1 - 15	1 - 13	1 - 18
		1- 15				
Epinephelus fulva	Coney					1 - 25
						1 - 30
Epinephelus cruentatus	Graysby				1 - 25	
Scarus taeniopterus	Princess Parrotfish	12- 5	1 - 8		1 - 10	4 - 5
		2 - 8				
		1- 25				
Sparisoma radians	Bucktooth Parrotfish	1- 3			2 - 5	1 - 5
Scarus iserti	Stripped Parrotfish			2 - 10		2 - 8
						1 - 18
Scomberomorus regalis	Cero	1- 38				

The fish community of Tourmaline Reef 10m presented a well-balanced trophic assemblage. Demersal and pelagic schooling zooplanktivores, including the Blue Chromis, Creole Wrasse (out of transects) and Bicolor Damselfish dominated the Tourmaline 10m reef community structure in terms of trophic categories, representing approximately 36.2 % of the total individuals within belt-transects. Small, opportunistic micro-invertebrate predators (wrasses, gobies, basses, puffers, squirrelfish, hawkfish) were also a prominent trophic group, representing 32.5% of the total. Herbivores were represented within bel-transects by five species of parrotfishes (Scaridae), three doctorfishes (Acanthuridae) and three damselfishes (Pomacentridae), with a combined abundance of 16 Ind/30 m^2 or 26.6% of the total individuals. Among large invertebrate and small demersal fish predators, small groupers such as Coneys and Graysby were the most common. Adult and juvenile Red Hind, Nassau and Yellowfin Grouper, Schoolmaster, Mahogany and Yellowtail Snappers represented top demersal predators observed during this and/or previous surveys at this reef. Schools of Mackerel Scad, *Decapterus macarellus* and Ballyhoo, *Hemiramphus ballyhoo* were present near the reef surface over the reef. These serve as forage for pelagic predators, such as Cero Mackerels, Great Barracuda and Blue Runners.

Annual monitoring trends of fish species richness and abundance are presented in Figure 21. Minimum mean values of fish abundance and species richness were observed during 2008, when mean abundance declined 31.4 % relative to the baseline survey. Differences between annual surveys were statistically significant (ANOVA; $p < 0.001$; Appendix 6). Variations of abundance are influenced by schooling zooplanktivores with highly aggregated distributions, such as the Blue Chromis (*Chromis cyanea*), Masked Goby (*Coryphopterus personatus*), and Creole Wrasse (*Clepticus parrae*). Inter-annual fluctuations of these species appear to be related to density-independent factors and physical conditions at the time of survey. In the case of fish species richness, differences between annual surveys were statistically significant (ANOVA; $p < 0.001$; Appendix 5), influenced mostly by a sharp decline of species during 2008 and 2017 relative to all other surveys. These declines coincide with low abundance of Masked Goby (*Coryphopterus personatus*) and/or Creole Wrasse. It is possible that the abundance fluctuations of these forage species may affect the presence of potential predator species and thus influence fish species richness at the community level.

As in deeper zones of Tourmaline outer shelf reef, the high rugosity with sand channels, crevices, large coral ledges and holes makes this reef an ideal habitat for large demersal fishes, such as snappers, groupers, hogfishes and others. Their occurrence in very low abundance may be related to the intense fishing pressure that this reef has experienced over the last 20-30 years, since the seasonal spawning aggregations of Red Hind were detected by local fishermen. Tourmaline outer reef has been seasonally (December – February) closed to fishing since 1993 to protect the declining Red Hind stock, but an intense fishing effort for finfish, lobster and conch with fish traps and SCUBA is still ongoing during the open fishing season. Although our fish surveys have been performed previous to the group spawning aggregation from December to February, the relatively

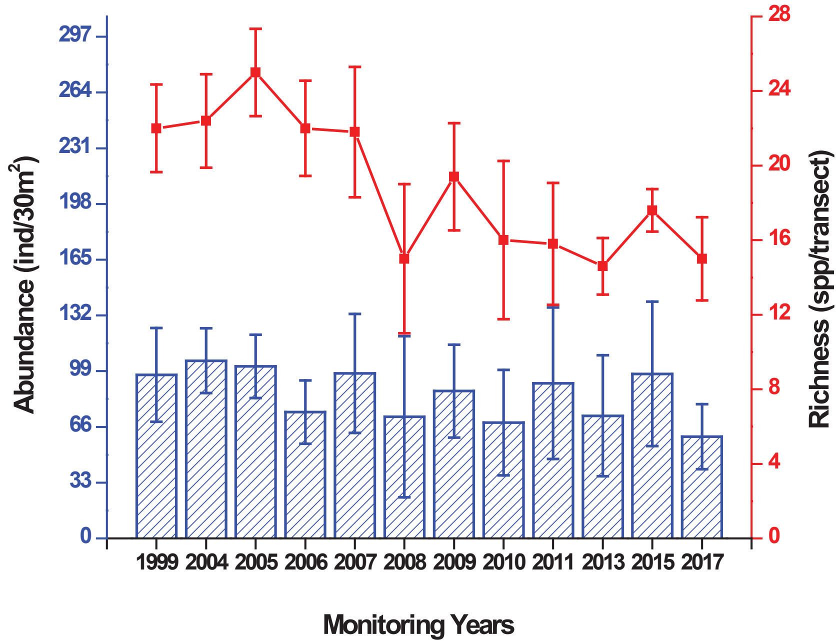


Figure 21. Monitoring trends (2004 – 2017) of fish species richness and abundance at Outer Shelf Reef Tourmaline, 10 m, Mayaguez.

low abundance of Red Hinds noted during our monitoring surveys is indicative that this fish population has not recovered from the intense fishing effort of the previous decade.

Motile megabenthic invertebrates were represented within belt-transects by one Long-Spined Urchin (Table 25). Spiny and Spotted Lobsters, *Panulirus argus*, *P. guttatus*, have been previously reported observed outside transects in previous surveys (Garcia-Sais et al., 2014 and references therein).

Table 25. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Reef 10 m, January 2017

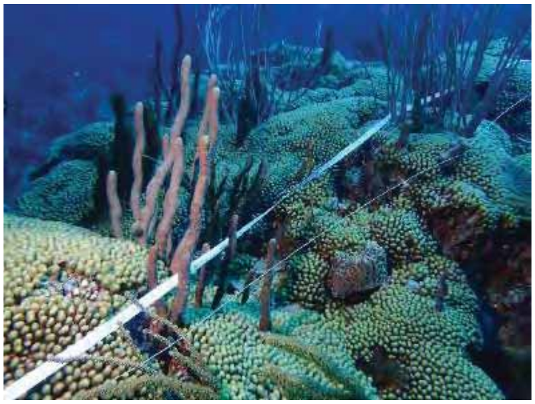
Depth: 10 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Diadema antillarum	Long-Spined Urchin	0	0	0	0	1	**0.2**
	TOTALS	**0**	**0**	**0**	**0**	**1**	**0.2**

6.4 Photo Album 6

Tourmaline 10m - Mayaguez








7.0 Gallardo Reef – Cabo Rojo

7.1 Physical Description

Bajo Gallardo is one of the more distant reefs from the southwest shoreline, located at approximately seven nautical miles due west off Pta. Melones, Cabo Rojo (Figure 22). The reef formation is a cluster of submerged patch reefs of variable dimensions sitting in an irregular hard-ground platform at a depth of about 13 meters. The shallower reef sections rise to less than two meters from the surface and are Elkhorn Coral, *Acropora palmata* reef zones. This reef is subject to intense seasonal wave action associated with winter cold fronts produced in the North Atlantic. Sandy-silt sediments and relict elkhorn coral fragments surround the patch reefs at the base. Our 2015 baseline survey was performed on top of low relief patch reefs at a depth of 4 meters within the *A. palmata* biotope. Panoramic views of Gallardo Reef are shown in Photo Album 7.

7.2 Sessile-Benthic Reef Community

Patchy growth of Elkhorn Coral, *Acropora palmata* was the most prominent feature of Gallardo Reef at depth between 2 – 5 meters. Elkhorn Coral was observed growing in tufts or patches of variable dimensions separated by stretches of hard ground or colonized pavement, sometimes comprised mostly of dead, relict Elkhorn coral fragments. Live Elkhorn Coral colonies were present in all transects surveyed with a mean substrate cover of 54.1 % (range: 40.1 – 68.0 %), representing 99.1 % of the total cover by corals along transects (Table 26). Only one other coral, Mustard-Hill Coral, *Porites astreoides* was intercepted by line transects. A total of 50 coral colonies were intercepted by transects of which two were observed to be infected by disease for a mean % prevalence of 4.0%.

Mean substrate cover by reef sessile-benthic categories are shown in Figure 23. Four other stony coral species (*Millepora alcicornis, Agaricia agaricites, Porites porites, Pseudodiploria strigosa*.) were observed within the 2-5 m depth outside transects. Massive colonies of Boulder Star Coral, *Orbicella annularis* (complex) and corals are present below the 5m depth growing on the backreef slope. Soft corals (gorgonians) were uncommon and absent along transects. The encrusting gorgonian, *Erythropodium caribaeorum* was present along two transects with a mean cover of 1.0 %. Colonial zoanthids (*Palythoa* sp.) and sponges were observed on one transect each, but were not prominent within the Elkhorn Coral biotope at Gallardo Reef (Table 26).

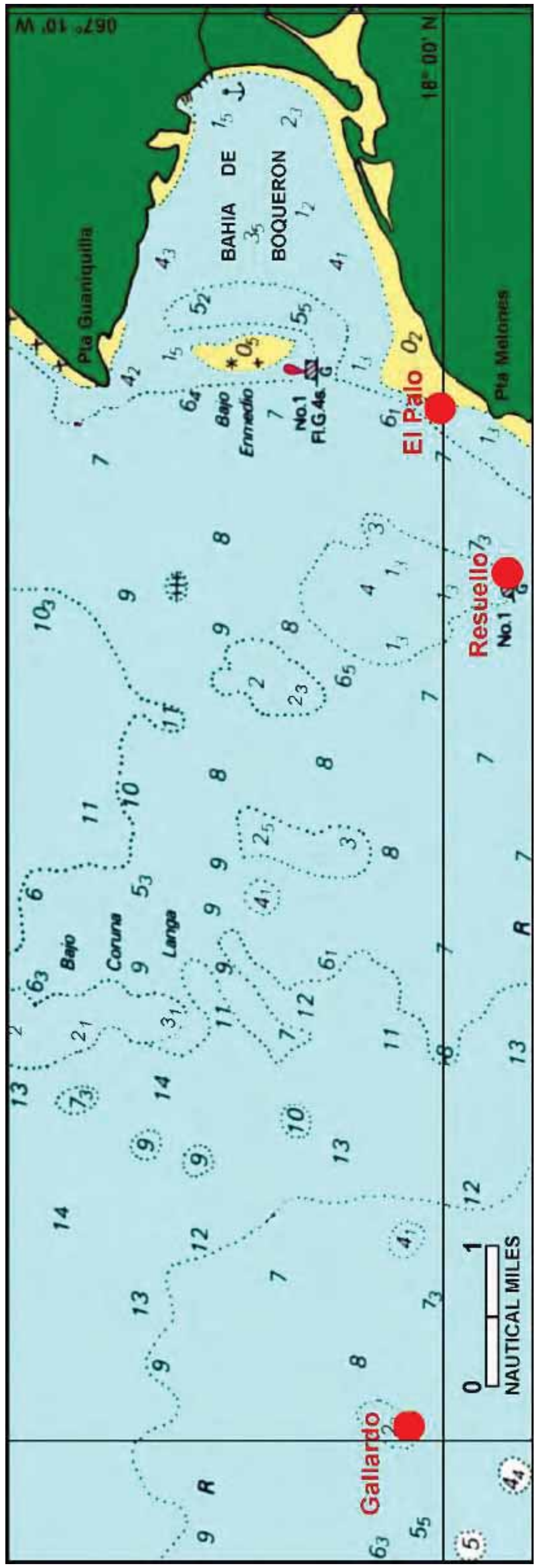


Figure 22. Location of reefs surveyed within the Boqueron (Cabo Rojo) Natural Reserve.

Table 26. Percent linear cover by sessile-benthic categories at Bajo Gallardo Reef. Cabo Rojo.
Survey Date: May 2017
Depth: 5 m

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	6.87	5.61	2.31	5.18	5.47	**5.09**
Benthic Categories						
Abiotic						
Reef overhang	14.02	9.78	13.08	10.33	11.76	**11.80**
Gap	0.83	3.86	1.48	3.04	1.18	**2.08**
Rubble			0.68			**0.14**
Total Abiotic	**14.85**	**13.63**	**15.24**	**13.38**	**12.94**	**14.01**
Benthic Algae						
Peyssonnelia sp.	1.24	4.66	14.33	13.93	6.79	**8.19**
Turf	2.24	7.98	11.26	13.65	4.80	**7.99**
CCA	4.32	4.30	3.07	16.24	4.71	**6.53**
Ramicrusta sp.	1.24	9.96	10.13		0.36	**4.34**
Dictyota spp.	9.05	1.35	3.87			**2.85**
Total Benthic Algae	**18.09**	**28.25**	**42.66**	**43.82**	**16.65**	**29.90**
Hard Coral						
Acropora palmata	62.49	57.67	42.09	40.13	67.96	**54.07**
Agaricia agaricites				2.68	0.18	**0.57**
Total Hard Coral	**62.49**	**57.67**	**42.09**	**42.80**	**68.14**	**54.64**
Coral Colonies/Transect	9	14	8	7	12	**10.0**
Zoanthids						
Palythoa caribaeorum					1.36	**0.27**
Octocoral						
Erythropodium caribaeorum	4.56	0.45				**1.00**
# Gorgonians/transect						
Sponge						
Cliona tenuis					0.90	**0.18**

Large sections of the hard ground not colonized by Elkhorn Coral were covered by encrusting growth of red crustose coralline algae, mostly *Peyssonnelia sp*. and *Ramicrusta sp*. These algae were particularly observed overgrowing dead sections and relict fragments of Elkhorn Coral. It was the dominant component of the reef sessile-benthos in terms of substrate cover with a combined mean of 19.0 %, representing 63.6 % of the total cover by benthic algae (Table 26). Turf algae, growing mostly intermixed with tufts of fleshy brown macroalgae (*Dictyota sp*) was present in all transects with a mean cover of 8.0 %. Abiotic substrates, particularly reef overhangs produced by Elkhorn Coral growth were also prominent in terms of reef substrate cover with a mean of 11.8 %. Such overhangs contributed to a mean substrate rugosity of 5.1 m.

Inter-annual variations of live coral cover were insignificant between the 2015 baseline and the present 2017 (first) monitoring survey (ANOVA; p = 0.877; Appendix 1). A trend of increasing cover by benthic algae appears was noted and appears to be associated with a decline of abiotic cover (Figure 23). Given the prominence of red crustose algae, it is possible that these later taxa are increasing their cover by colonizing abiotic areas. It has been also noted that both *Peyssonnelia sp*. and *Ramicrusta sp*. can expand their reef substrate cover also by displacing turf algae (Garcia-Sais et al., 2016). Coral community structure remained stable both in terms of substrate cover and taxonomic composition (Figure 24). Two out of the 50 (total) colonies intercepted by transects were infected with what appeared to be the disease “patchy necrosis”.

7.3 Fishes and Motile megabenthic Invertebrates

A total of 54 species of fish have been identified from Bajo Gallardo, including 25 observed within belt-transects during the 2017 monitoring survey (Table 27). The mean abundance was 38.2 Individuals/30 m^2 (range: 31 – 51) and the mean number of species per transect was 12.4 (H’= 131.4). The Yellowtail Damselfish (*Microspathodon chrysurus*) was the most abundant species within transects and along with Redlip Blenny, (*Ophioblennius atlanticus*), Bluehead Wrasse (*Thalassoma bifasciatum*) and Blue Tang (*Acanthurus coeruleus*) was observed in all five transects surveyed. Schools of Blue Chromis were present hovering over Elkhorn Coral colonies. Three other species were present in four transects, these included the Stoplight Parrotfish (*Sparisoma viride*), Dusky Damselfish (*Stegastes adustus*) and Four-eye Butterflyfish (*Chaetodon capistratus*). Black Durgon (*Melichthys niger*) and Bermuda Chubs (*Kyphosus*

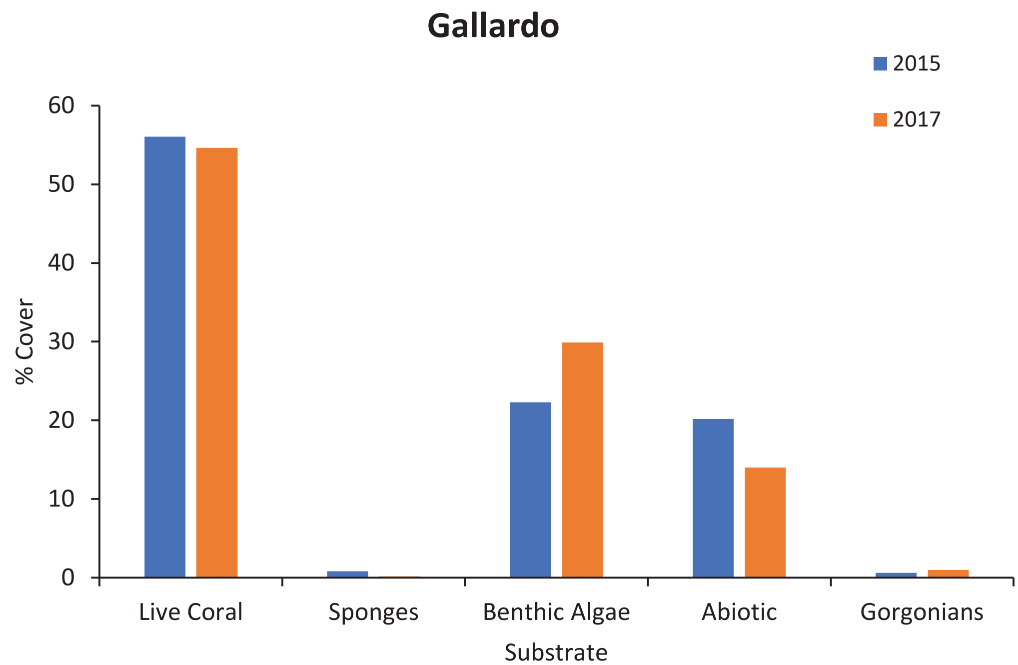


Figure 23. Monitoring trends (2015 – 2017) of mean substrate cover by sessile-benthic categories at Gallardo Reef, Cabo Rojo.

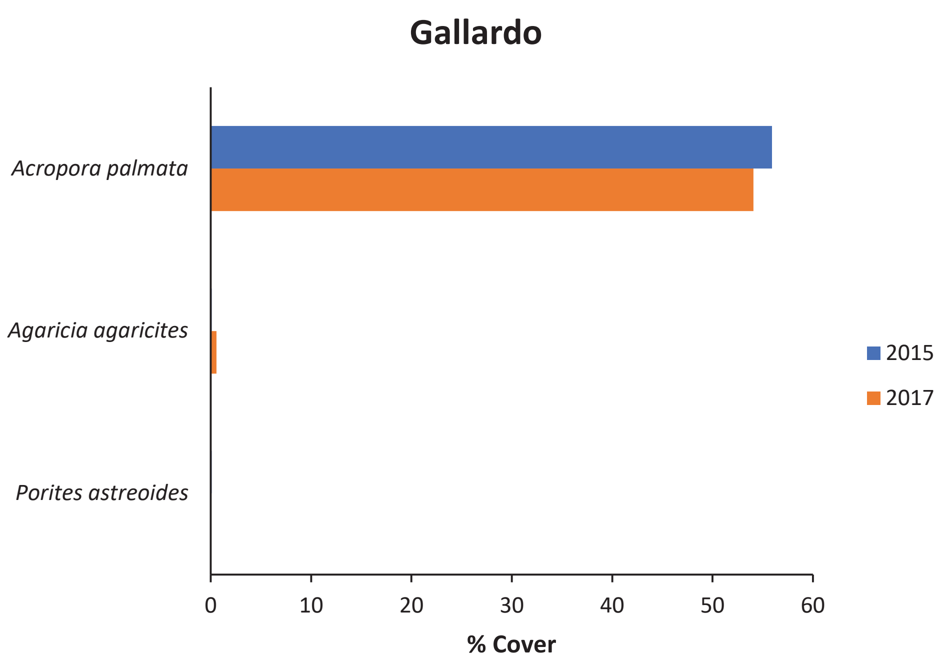


Figure 24. Monitoring trends (2015 – 2017) of mean substrate cover by stony coral species at Gallardo Reef, Cabo Rojo.

bermudensis) were common in mid-water and observed within several transects at Gallardo Reef.

With a total of five species present within belt-transects, the parrotfish family (Scaridae) was the most specious taxonomic group, and combined with doctorfishes (Acanthuridae) and "farmer damselfishes" (e.g. *Stegastes adustus, M. chrysurus* - Pomacentridae) constituted the principal herbivorous fish assemblage. The combined abundance of herbivores represented 41.9% of the total individuals within belt-transect areas. Both juvenile and adult parrotfishes and doctorfishes were present (Table 28). Recruitment juveniles of Blue Tangs, Stoplight and Stripped Parrotfish were observed. Opportunistic carnivores which feed on small benthic invertebrates, such as Blennies (*Ophioblennius atlanticus*), wrasses (*Thalassoma, Halichoeres spp*), and puffers (*Canthigaster rostrata*) were prominent at this reef with two of the top five species in terms of abundance representing 26.2% of the total individuals. The zooplanktivorous fish assemblage comprised by the Blue and Brown Chromis (*Chromis cyanea, C. multilineata*), and the Bicolor Damselfish (*Stegastes partitus*) represented 18.3 % of the total individuals. Also present outside transects in large schools was the Mackerel Scad, *Decapterus macarellus*. These zooplanktivores fishes are mostly pelagic, and thus available as important forage species for larger pelagic predators, such as the Great Barracuda and the Bar Jack, both present outside transects at Gallardo Reef during our survey. Predators of larger reef invertebrates and small demersal fishes included a small assemblage of groupers (e.g. Graysbe), Bar Jack and Glasseye Snapper.

Fish abundance during the present 2017 and first monitoring survey was significantly lower than during 2015 (Figure 25) (ANOVA, p< 001; Appendix 6). There was an overall decline of schooling zooplanktivorous fishes, such as Brown and Blue Chromis, Creole Wrasse, schooling Bar Jacks, and Bluehead Wrasse, among others. Differences in zooplankton biomass may be influencing the recruitment and replenishment of such small fish populations that have very short generation times and that their abundances have been shown to vary independently from live coral cover and other benthic community attributes except depth, distance from shore and substrate rugosity (Esteves, 2013). Differences of fish species richness were not statistically significant (Appendix 5). More surveys need to be performed to elucidate temporal patterns of fish abundance and species richness at this reef.

Table 27. Taxonomic composition and abundance of fishes within belt-transects at Gallardo Reef 3m, Cabo Rojo, May 2017

Depth: 3 m		TRANSECTS				
		1	2	3	4	5
		(Individuals/30 m^2)				
SPECIES	**COMMON NAME**					
Microspathodon chrysurus	Yellowtail Damselfish	9	7	7	5	4
Chromis cyanea	Blue Chromis	18				6
Ophioblennius atlanticus	Redlip Blenny	3	5	4	6	5
Thalassoma bifasciatum	Bluehead Wrasse	8	3	5	4	3
Sparisoma viride	Stoplight Parrotfish	3	3	7	2	
Scarus taeniopterus	Princess Parrotfish	2	7			2
Stegastes dorsopunicans	Dusky Damselfish	1	3	4	2	
Acanthurus coeruleus	Blue Tang	1	1	3	2	2
Chromis multilineata	Brown Chromis	2		4		3
Chaetodon capistratus	Four-eye Butterflyfish	1		1	2	2
Kyphosus bermudensis	Bermuda Chub				1	4
Melichthys niger	Black Durgon	2			2	1
Canthigaster rostrata	Caribbean Puffer		1		2	
Cantherhines pullus	Tail-light Filefish			1	1	
Carangoides ruber	Bar Jack	1			1	
Ocyurus chrysurus	Yellowtail Snapper		1	1		
Stegastes partitus	Bicolor Damselfish					2
Cephalopholis cruentatus	Graysbe					1
Heteropriacanthus cruentatus	Glasseye Snapper					1
Holocentrus coruscus	Reef Squirrelfish					1
Holocentrus rufus	Longspine Squirrelfish					1
Lactophrys triqueter	Smooth Trunkfish			1		
Lactophrys bicaudalis	Spotted Trunkfish		1			
Pseudupeneus maculatus	Yellow Goatfish				1	
Sparisoma aurofrenatum	Redband Parrotfish		1			
	TOTAL INDIVIDUALS	**51**	**33**	**38**	**31**	**38**
	TOTAL SPECIES	**12**	**11**	**11**	**13**	**15**

One Long-spined Urchin was observed within belt-transect areas at Gallardo Reef (Table 29). One Spiny Lobster, *Panulirus argus* was present outside transects.

Table 28. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3 m belt-transects at Gallardo Reef 3m, Cabo Rojo, May 2017

		TRANSECTS				
		1	2	3	4	5
				(Individuals/60 m^2)		
SPECIES	**COMMON NAME**					
Acanthurus coeruleus	Blue Tang	1 - 2	3 - 10	1 - 8	2 - 10	1 - 8
		1 - 10	1 - 12	2 - 12	1 - 15	1 - 12
Cephalopholis cruentatus	Graysbe					1 - 12
Ocyurus chrysurus	Yellowtail Snapper			1 - 25		1 - 20
Scarus iserti	Stripped Parrotfish		1 - 28	2 - 5		1 - 8
						1 - 15
Scarus taeniopterus	Princess Parrotfish	2 - 8		1 - 23	1 - 28	1 - 8
						1 - 10
						1 - 25
Sparisoma aurofrenatum	Redband Parrotfish		1 - 8		1 - 25	
Sparisoma rubripinne	Yellowtail Parrotfish			1 - 30		
Sparisoma viride	Stoplight Parrotfish	1 - 5	2 - 2	2 - 1	1 - 25	
		1 - 8	1 - 25	1 - 2	2 - 30	
		1 - 25	1 - 28	1 - 8		
				1 - 15		
				2 - 25		
				1 - 33		

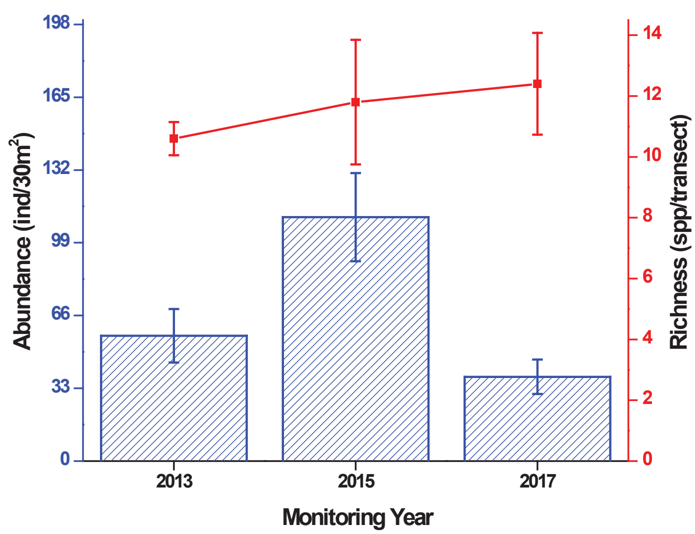


Figure 25. Monitoring trends (2013 – 2017) of fish species richness and abundance at Gallardo Reef, 5 m, Cabo Rojo.

Table 29 Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Gallardo Reef. May 2017.

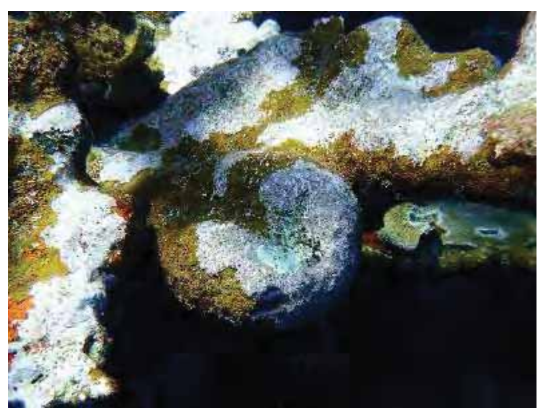
Depth: 5.0 m SPECIES	COMMON NAME	TRANSECTS 1	2	3	4	5	MEAN ABUNDANCE (IND/30 m^2)
Diadema antillarum	Long-spined Urchin	0	0	0	1	0	**0.2**
	TOTALS	**0**	**0**	**0**	**1**	**0**	**0.2**

7.4 Photo Album 7

Gallardo Reef – Cabo Rojo















8.0 Resuellos Reef – Cabo Rojo

8.1 Physical Description

Resuellos Reef is a hard-ground promontory located at about one nautical mile due west from Pta. Melones, Cabo Rojo (Figure 22). The reef emerges from a mostly flat platform covered by sandy-silt sediments at a depth of 12 meters to about 2 meters from the surface, where breakers form during events of heavy wave action. Stony and soft corals (gorgonians) provide substantial topographic relief to the reef, particularly on the slopes. The top section of the reef is a hard-ground platform with scattered stony coral colonies and dense growth of gorgonians. Very large colonies of Elkhorn Coral, *Acropora palmata* were observed within this upper reef section in an advanced stage of degradation (e.g. mostly overgrown by turf algae). Some were still standing, while others were overturned and rested broken on the reef bottom. Our baseline survey was performed on the reef slope, close to the base of the reef during May 2000 (Garcia-Sais et al., 2001). Transects were installed following the 8.0m depth contour along the reef slope. Panoramic views of Resuellos Reef are presented in Photo Album 8.

8.2 Sessile-Benthic Reef Community

The lush growth of soft corals was the most prominent feature of the sessile-benthic community at Resuellos Reef with a mean of 24.2 erect col/transect and a reef substrate cover of 31.4 % (range: 21.3 – 37.7 %) (Table 30). Some of the most abundant included *Briareum asbestinum*, *Antilligorgia acerosa, A. americana*, *Pseudoplexaura sp., Gorgonia ventalina* and *Eunicea spp*. The encrusting gorgonian, *Erythropodium caribaeorum* was present in all five transects surveyed with a mean linear cover of 19.0 % (range: 7.3 – 33.6 %). Stony corals, represented by at least 20 species, including nine along transects contributed a mean linear cover of 21.4 % (range: 10.9 – 31.7%), with a mean of 11.2 colonies/transect. Boulder Star Coral, *Orbicella annularis* was the dominant coral species with a mean cover of 8.0 %, representing 37.4 % of the total cover by stony corals. Massive Starlet Coral (*Siderastrea siderea*) and Mustard-Hill Coral (*Porites astreoides*) were present in all five transects with a combined cover of 7.3%. Boulder Brain Coral (*Colpophyllia natans*) and Great Star Coral (*Montastrea cavernosa*) were intercepted by at least three transects and along with the

Table 30. Percent linear cover by sessile-benthic categories at Resuellos Reef. Cabo Rojo. May 2017
Depth: 10 m

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.77	4.52	6.32	4.17	4.59	**4.47**
Benthic Category						
Abiotic						
Reef overhang	5.04	9.64	7.63	4.05	7.29	**6.73**
Gap		2.70				**0.54**
Sand					1.92	**0.38**
Total Abiotic	**5.04**	**12.34**	**7.63**	**4.05**	**9.21**	**7.66**
Benthic algae						
Turf	23.68	28.25	43.48	33.40	30.52	**31.87**
Peyssonnelia sp.		0.19	2.66	0.49	0.29	**0.73**
CCA	0.55	0.77			0.48	**0.36**
Total Benthic Algae	**24.23**	**29.22**	**46.14**	**33.89**	**31.29**	**32.95**
Cyanobacteria				0.10		**0.02**
Hard Coral						
Orbicella annularis complex	13.60	8.58	2.06	5.53	10.46	**8.05**
Siderastrea siderea	2.52	7.14	4.80	0.89	5.18	**4.11**
Colpophyllia natans	1.86	8.00		2.67	3.45	**3.20**
Montastraea cavernosa	8.22		1.37		1.15	**2.15**
Porites astreoides	0.22	3.76	1.11	4.35	0.58	**2.00**
Millepora alcicornis		3.18				**0.64**
Meandrina meandrites					2.50	**0.50**
Stephanocoenia intersepta			0.86	0.49	0.96	**0.46**
Agaricia agaricites		1.06	0.69			**0.35**
Total Hard Coral	**26.43**	**31.72**	**10.89**	**13.93**	**24.28**	**21.45**
Colonies per Transect	16	14	14	10	12	**11.2**
Octocoral						
Erythropodium caribaeorum	22.70	9.64	15.44	28.16	18.91	**18.97**
Briareum asbestinum	14.14	10.61	17.50	6.92	9.50	**11.73**
Antillogorgia acerosa	0.22		0.17	0.59		**0.20**
Antillogorgia americana					0.77	**0.15**
Pseudoplexaura wageneri flagellosa	0.66					**0.13**
Eunicea succinea		0.48				**0.10**
Eunicea sp.		0.39				**0.08**
Gorgonia ventalina		0.19				**0.04**
Total Octocoral	**37.72**	**21.31**	**33.10**	**35.67**	**29.17**	**31.40**
# Gorgonians/transect	28	19	34	14	15	**24.20**
Sponge						
Chondrilla caribensis	2.30	1.25		0.30	0.38	**0.85**
Cribrochalina vasulum				3.85		**0.77**
Aplysina fistularis				3.46	0.38	**0.77**
Aplysina cauliformis	0.77	0.19	0.43	0.30	1.25	**0.59**
Ircinia strobilina		1.45		1.19		**0.53**
Monanchora arbuscula	0.77		0.17	0.30	0.86	**0.42**
Niphates erecta		0.19	0.51	0.49	0.67	**0.37**
Mycale laevis	0.33	0.19		0.89	0.38	**0.36**
Agelas citrina	0.77	0.39			0.38	**0.31**
Dysidea etheria				0.89	0.58	**0.29**
Amphimedon compressa				0.69	0.77	**0.29**
Scopalina ruetzleri	0.77					**0.15**
Neopetrosia smooth sp.		0.29	0.34			**0.13**
Iotrochota arenosa		0.39			0.19	**0.12**

Plaktoris sp.	0.55					**0.11**
Cinachyrella kuekenthali		0.29				**0.06**
Dysidea janiae		0.29				**0.06**
Black sponge			0.26			**0.05**
Ircinia felix					0.19	**0.04**
Agelas sventres			0.17			**0.03**
Clathria sp.			0.17			**0.03**
Ircinia brown sp.			0.17			**0.03**
Total Sponge	**6.25**	**4.92**	**2.23**	**12.35**	**6.05**	**6.36**

aforementioned species comprised the main hard coral assemblage in terms of reef substrate cover at Bajo Resuellos (Table 30).

Sponges were also prominent components of the sessile-benthic community with 22 species intercepted by line transects and a mean linear cover of 6.4 % (Table 30). They were mostly present as small erect and encrusting colonies. *Chondrilla caribensis, Aplysina cauliformis, Monachora arbuscula, Mycaele laevis, Agelas citrina and Niphates erecta* were present in at least three transects and along with a large colony of *Cribrochalina vasculum* comprised the main taxonomic assemblage. Reef overhangs, largely associated with massive and laminar coral growth were the main contributor of abiotic cover with a mean of 6.7%. Otherwise, this reef was fully colonized by biotic components.

Figure 26 shows the temporal variations of mean percent substrate cover by reef sessile-benthic categories of Resuellos Reef. The first monitoring survey of this reef was performed more than a decade after the baseline survey of 2000 (Garcia-Sais et al., 2001). A mild reduction of live coral cover was measured in 2013, but such difference was not statistically significant (Garcia-Sais et al., 2014). Most of the difference was associated with the loss of reef substrate cover by Boulder Brain Coral, *Colpophyllia natans*, from an initial cover of 5.9 % down to 0 % along transects (Figure 27). Boulder Star Coral, *Orbicella annularis,* which suffered the most acute mortality during and after the 2005 regional coral bleaching event did not show any statistically significant loss of live coral cover between dates. Since then, a trend of increasing live coral (including both hard and soft taxa) appears to be emerging from the monitoring surveys, but differences are still statistically insignificant (ANOVA; $p = 0.792$; Appendix 1).

Because of the relatively shallow depth, strong prevailing wind energy and soft sediments at its base, Resuellos Reef is typically impacted by inorganic turbidity caused by suspended sediments. It is possible that such turbid conditions may have been instrumental in protecting corals from the bleaching effects of the 2005 event, which appears to have been triggered not only by the increased sea surface temperatures, but by the synergistic effects of UV radiation, as suggested by the most acute effects exhibited by corals from reefs in clear waters (Garcia-Sais et al, 2017). No infectious diseases were noted in any of the 56 total coral colonies intercepted by transects during this survey (Appendix 2).

The most relevant change in reef benthic community structure was a statistically significant decline in the number of soft corals (gorgonians) intercepted by transects, from a mean of 44.6 colonies/transect during 2015 to 24.2 colonies/transect during 2017 (T-test, p= 0.010); Appendix 3). Such drastic decline may be related to mechanical detachment and mortality associated with extreme surge conditions prevailing during the pass of Hurricane Matthew close to the south coast of PR during October 2016.

8.3 Fishes and Motile Megabenthic Invertebrates

A total of 68 fish species have been identified at Resuellos Reef, 33 of which were present within belt-transect during the 2017 survey (Table 31). The mean number of species per transect was 14.4 (H'= 131.4), with a mean abundance of 26.2 Individuals/30 m^2 (range: 20 - 37 Ind/30 m^2). Seven species were present in at least four transects and represented 58.8 % of the total individuals within transect areas. The numerically dominant fish assemblage included the Princess, Striped, Redband and Stoplight Parrotfishes (*Scarus taeniopterus*, *S. iserti, Sparisoma aurofrenatum, S. viride*), Sharknose goby (*Elacatinus sp*), Beaugregory (*Stegastes leucostictus*) and Four-eye Butterflyfish (*Chaetodon capistratus*) (Table 31).

The herbivorous fish assemblage was the most prominent trophic component at Resuellos reef. Herbivorous taxa included parrotfishes (Scaridae - 5 species), doctorfishes (Acanthuridae – 2 species) and "farmer damselfishes" (Pomacentridae – 3 species). The combined herbivorous assemblage represented approximately 59.5 % of the total individuals within belt-transect areas. Parrotfishes were present in their full range of sizes, including recruitment juvenile stages of Striped, Redband and Stoplight Parrotfishes. Snappers, hogfishes and Lionfish were only observed as adults (Table 32). Opportunistic carnivores which feed on small benthic invertebrates, such as wrasses (Labridae), hamlets (Serranidae), puffers (Tetraodontidae), gobies (Gobiidae) and squirrelfishes (Holocentridae) represented approximately 27.5 % of the total individuals. The zooplanktivorous fish assemblage recorded within transect areas included the

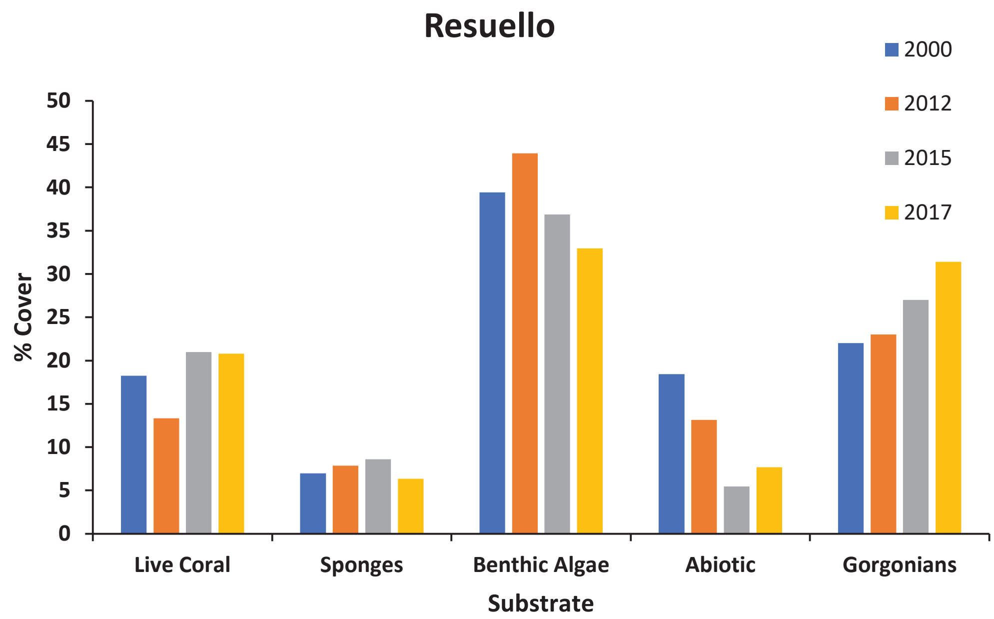


Figure 26. Monitoring trends (2000 – 2017) of mean substrate cover by sessile-benthic categories at Resuellos Reef, Cabo Rojo

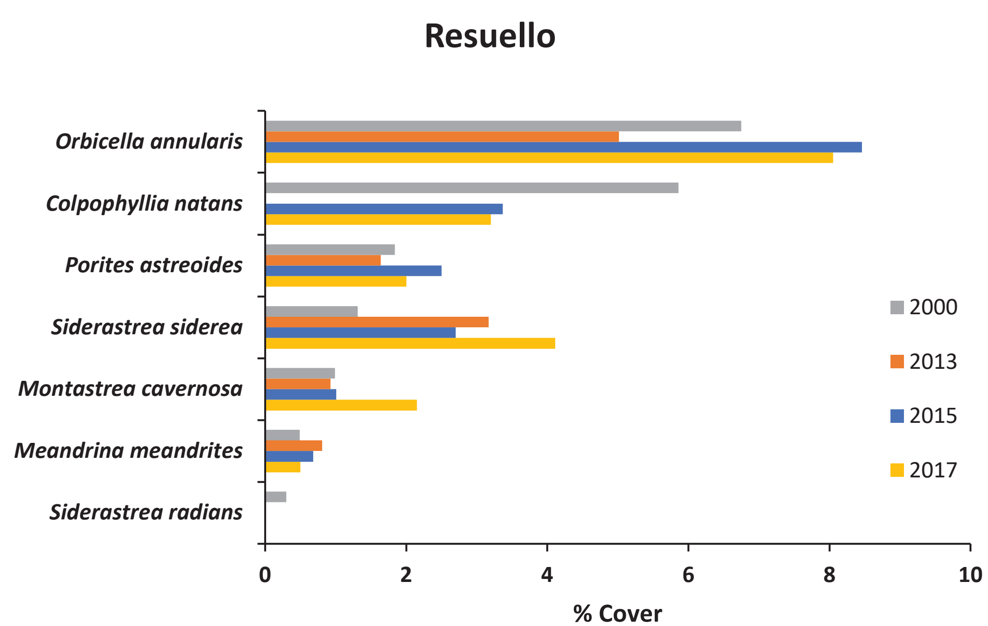


Figure 27. Monitoring trends (2000 – 2017) of mean substrate cover by coral species at Resuellos Reef, Cabo Rojo

Table 31. Taxonomic composition and abundance of fishes within belt-transects at Resuellos Reef 10m, Cabo Rojo, May 2017

Depth: 10 m

		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Scarus taeniopterus	Princess Parrotfish	3	8	1	2	5	**3.8**
Elacatinus evelynae	Sharknose Goby	2	4	1	5	3	**3.0**
Scarus iserti	Stripped Parrotfish	1	3	7	1	1	**2.6**
Sparisoma viride	Stoplight Parrotfish	2	3	3	2		**2.0**
Sparisoma aurofrenatum	Redband Parrotfish	2	2		1	4	**1.8**
Stegastes dorsopunicans	Dusky Damselfish	4			2	1	**1.4**
Thalassoma bifasciatum	Bluehead Wrasse	3	3			1	**1.4**
Stegastes leucostictus	Beaugregory	1	2		2	1	**1.2**
Chaetodon capistratus	Four-eye Butterflyfish	1	1	1	1	1	**1.0**
Holocentrus rufus	Longspine Squirrelfish		1	2	1		**0.8**
Ocyurus chrysurus	Yellowtail Snapper		3	1			**0.8**
Pomacanthus arcuatus	Grey Angelfish	2	1				**0.6**
Acanthurus coeruleus	Blue Tang		1			1	**0.4**
Halichoeres garnoti	Yellow-head Wrasse				1	1	**0.4**
Hypoplectrus puella	Barred Hamlet			1	1		**0.4**
Chaetodon striatus	Banded Butterflyfish	2					**0.4**
Diodon histrix	Porcupine Fish			1		1	**0.4**
Gramma loreto	Fairy Basslet		1	1			**0.4**
Pomacanthus ciliaris	French Angelfish		1	1			**0.4**
Stegastes partitus	Bicolor Damselfish		1			1	**0.4**
Chaetodon aculeatus	Longsnout Butterflyfish					1	**0.2**
Canthigaster rostrata	Caribbean Puffer				1		**0.2**
Haemulon flavolineatum	French Grunt			1			**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet			1			**0.2**
Hypoplectrus nigricans	Black Hamlet					1	**0.2**
Hypoplectrus unicolor	Butter Hamlet		1				**0.2**
Holocentrus coruscus	Reef Squirrelfish	1					**0.2**
Lachnolaimus maximus	Hogfish					1	**0.2**
Microspathodon chrysurus	Yellowtail Damselfish	1					**0.2**
Myripristis jacobus	Black-bar Soldierfish	1					**0.2**
Pterois sp	Lionfish		1				**0.2**
Sparisoma radians	Bucktooth Parrotfish					1	**0.2**
Stegastes planifrons	Yellow-eye Damselfish	1					**0.2**
	TOTAL INDIVIDUALS	**27**	**37**	**22**	**20**	**25**	**26.2**
	TOTAL SPECIES	**14**	**17**	**13**	**12**	**16**	**14.4**

Table 32. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3 m belt-transects at Resuellos Reef 10m, Cabo Rojo. May 2017

		TRANSECTS				
		1	2	3	4	5
		(Individuals/60 m^2)				
SPECIES	**COMMON NAME**					
Acanthurus coeruleus	Blue Tang		1 - 12			1 - 10
Acanthurus chirurgus	Doctorfish					1 - 15
Lachnolaimus maximus	Hogfish				1 - 36	
Lutjanus apodus	Schoolmaster Snapper	1 - 28				
Ocyurus chrysurus	Yellowtail Snapper	1 - 20	3 - 15	1 - 25		
Scarus iserti	Stripped Parrotfish		1 - 2	1 - 18	1 - 10	1 - 8
			2 - 15			
Scarus taeniopterus	Princess Parrotfish	3 - 5		1 - 12	2 - 8	4 - 5
		1 - 15		1 - 10		1 - 15
		1 - 20				
Sparisoma aurofrenatum	Redband Parrotfish	1 - 18	1 - 15	1 - 2	1 - 12	2 - 10
			1 - 25			2 - 12
Sparisoma viride	Stoplight Parrotfish	2 - 5	1 - 1	1 - 5	3 - 1	
			2 - 28	2 - 20	1 - 5	
Pterois sp			1 - 25		1 - 10	

Bicolor Damselfish (*Stegastes partitus*) and Fairy Basslet (*Gramma loreto*) with a combined abundance of less than 1% of the total individuals.

Predators of larger reef invertebrates and small demersal fishes observed within belt-transects included adult stages of the Yellowtail and Schoolmaster Snappers (*Ocyurus chrysurus, Lutjanus apodus*), Hogfish (*Lachnolaimus maximus*), and Graysbe (*Cephalopholis cruentatus*). Lane, Mutton and Cubera Snappers (*L. synagris, L. analis, L. cyanopterus*) were observed out of transects at Resuellos Reef during this 2017 survey. Other species of high commercial value observed during previous surveys include the Red Hind and Nassau groupers (*Epinephelus guttatus, E. striatus*), Dog and Mahogany Snappers (*Lutjanus jocu, L. mahogany)*, and pelagic predators, such as the Great Barracuda, Cero Mackerel and Bar Jack (Garcia-Sais et al., 2001, 2013).

Variations of fish abundance and species richness between monitoring surveys (Figure 28) have been relatively small and statistically insignificant (Appendix 5-6). One adult Spiny Lobster (*Panulirus argus*) was present within belt-transects (Table 33), and two others were observed outside transects in small adult sizes.

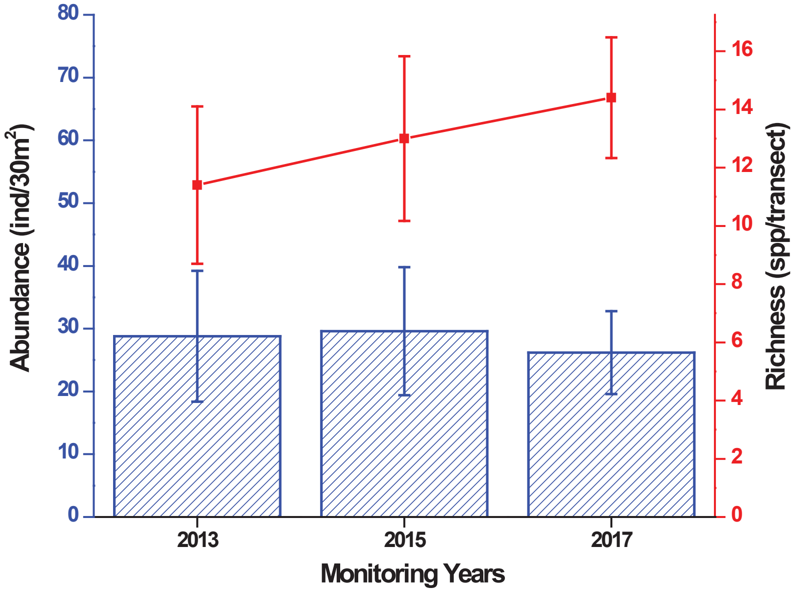


Figure 28. Monitoring trends (2000 – 2017) of fish species richness and abundance at Resuellos Reef, Cabo Rojo

Table 33. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Resuellos Reef. Cabo Rojo. May 2017.

Depth: 8.0 m		**TRANSECTS**					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
Panulirus argus	Spiny Lobster	0	0	1	0	0	**0.2**
	TOTALS	**0**	**0**	**1**	**1**	**0**	**0.4**

8.4 Photo Album 8
Resuellos Reef - Cabo Rojo
















9.0 Boya Vieja 20m - La Parguera

9.1 Physical Description

La Parguera Natural Reserve was designated in 1979 and amended in 1998 to expand its marine boundaries. Its total surface area includes 12,638 acres (DRNA, 1999). It is located due east of Cabo Rojo on the southwest corner of the island. Coral reefs, seagrass beds and mangrove forests coexist in La Parguera to form a marine ecosystem of unsurpassed biodiversity in Puerto Rico. The insular shelf is one of the broadest of the island extending up to 6 nautical miles offshore. There is an extensive coral reef system bordering the shelf-edge at a depth of about 20 m, a chain of emergent reefs, or keys near mid-shelf that run parallel to the coastline, and an interior set of fringing reefs also running parallel to the shoreline. Mixed seagrass beds are typically associated with the backreef zones of the main emergent coral reefs (Garcia-Sais and Sabater-Clavell, 2004). Most of the shoreline is bordered by red mangrove. A fringing mangrove forest with channels and bioluminescent lagoons are found along the western and eastern sections of the shoreline.

The original baseline characterization of La Parguera coral reefs was produced during 2000 by Garcia-Sais et al. (2001). An effort was made to find the initial transects but these had disappeared. Thus, a new baseline characterization based on new sets of transects was produced during 2015 at La Boya Vieja (shelf-edge), Media Luna 10m (fore reef) and Media Luna 5m (back reef) (Figure 29).

Boya Vieja is a section of the extensive coral reef system fringing the shelf-edge off La Parguera, submerged at a depth of 17 – 22 m (Figure 29). The coral reef is largely a spur and groove formation with spurs that reach 3 – 4 m in height separated by coralline sand channels of variable width dimensions. The shelf -edge exhibits an abrupt slope with coral development along the edge and down the upper insular slope. Our set of five transects were set at a depth of approximately 18 m on top of spurs at both sides of the buoy block. A general photographic documentation of Boya Vieja Reef system is presented as Photo Album 9.

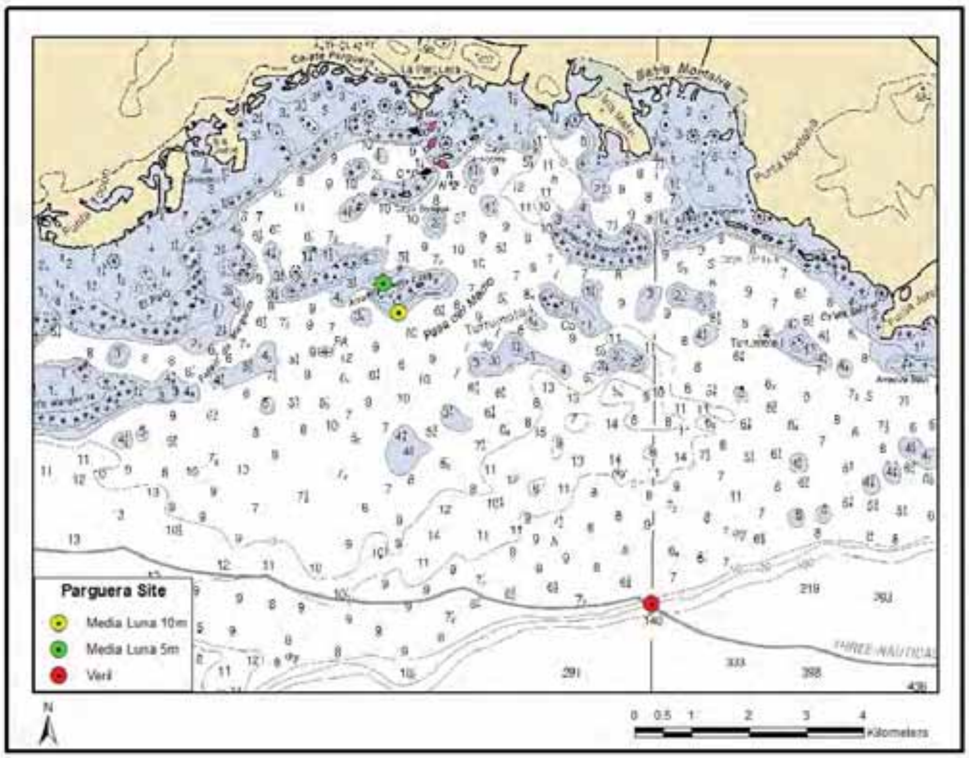


Figure 29. Location of reefs surveyed within the La Parguera Natural Reserve

9.2 Sessile-Benthic Reef Community

A total of 22 stony corals, including 13 intersected by line transects were identified from Boya Reef during 2017 (Table 34). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 22.0 % (range: 17.6 – 31.7 %), with a mean of 14.8 colonies intercepted per transect. Boulder Star Coral, *Orbicella annularis* (complex) was the dominant species in terms of substrate cover with a mean of 13.8 % (range: 8.2 – 24.2 %), representing 62.7 % of the total cover by stony corals. Mustard-Hill Coral (*Porites astreoides*) and Lettuce Coral (*Agaricia agaricites*) were present in at least four transects and along with Boulder Star Coral comprised the main stony coral assemblage at La Boya Reef (Table 34). Massive Starlet Coral (*Siderastrea siderea*) and Ten-Ray Coral (*Madracis decactis*) were present in three transects, but with relatively low reef substrate cover (mean < 1.0 %). Three coral colonies were observed to be infected by diseases out of a total of 74 intercepted by transects for a disease mean prevalence of 4.1% (Appendix 2).

Table 34. Percent linear cover by sessile-benthic invertebrates at La Boya Reef 20m, La Parguera. Survey Date: March 23, 2017

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	3.08	3.38	2.56	4.87	1.73	**3.12**
Benthic Category						
Abiotic						
Reef overhang	2.14	0.52	3.01	3.58		**1.85**
Rubble		7.32				**1.46**
Sand		1.05		0.47	3.58	**1.02**
Gap	2.14					**0.43**
Total Abiotic	**4.28**	**8.89**	**3.01**	**4.05**	**3.58**	**4.76**
Benthic Algae						
Lobophora variegatus	32.76	29.39	35.12	43.31	33.05	**34.73**
Turf	32.44	26.88	20.74	16.01	22.79	**23.77**
CCA	5.03	2.93	14.05	6.21	2.63	**6.17**
Dictyota spp.			1.67	1.22	1.19	**0.82**
Peyssonnelia sp.			0.89	1.32		**0.44**
Total Benthic Algae	**70.24**	**59.21**	**72.46**	**68.08**	**59.67**	**65.93**
Cyanobacteria		1.26				**0.25**
Live Coral						
Orbicella annularis complex	8.99	16.84	8.25	10.73	24.22	**13.81**
Porites astreoides	6.10	1.46	3.23	4.80	3.82	**3.88**
Agaricia agaricites		1.67	1.23	0.56	1.43	**0.98**
Siderastrea siderea			3.34	0.19	0.72	**0.85**
Diploria labyrinthiformis	1.39	0.94				**0.47**
Agaricia lamarcki		0.73		1.41		**0.43**
Dendrogyra cylindrus			2.12			**0.42**
Madracis decactis	0.32			0.75	0.36	**0.29**
Dictyota spp.					1.19	**0.24**
Pseudodiploria strigosa			1.11			**0.22**
Meandrina meandrites				0.94		**0.19**
Montastraea cavernosa	0.75					**0.15**
Porites porites				0.28		**0.06**
Total Live Coral	**17.56**	**21.65**	**19.29**	**19.68**	**31.74**	**21.98**
Colonies per Transect	13	18	14	15	14	**14.8**
Octocoral						
Erythropodium caribaeorum	2.14			1.22	1.19	**0.91**
Briareum asbestinum			0.67			**0.13**
Eunicea flexuosa		0.21		0.28		**0.10**
Total Octocoral	**2.14**	**0.21**	**0.67**	**1.51**	**1.19**	**1.14**
# Gorgonians/transect	15	6	14	10	9	**10.80**
Sponge						
Cliona caribbaea	0.32	6.69	3.79	0.75	0.84	**2.48**
Agelas dispar	0.54	0.52	0.56	1.69	0.48	**0.76**
Agelas conifera	2.14	1.05				**0.64**
Agelas sp.	1.07	0.52		0.47	0.95	**0.60**

Xestospongia muta				2.35		**0.47**
Neopetrosia proxima				0.47	0.95	**0.29**
Agelas clathrodes	1.07			0.19		**0.25**
Monanchora arbuscula					0.60	**0.12**
Scopalina ruetzleri			0.22	0.19		**0.08**
Aiolochroia crassa				0.38		**0.08**
Agelas citrina	0.32					**0.06**
Sponge	0.32					**0.06**
Amphimedon compressa				0.19		**0.04**
Total Sponge	**5.78**	**8.79**	**4.57**	**6.69**	**3.82**	**5.93**

Soft corals, or gorgonians were a prominent component of the La Boya Reef benthos with a mean density of 10.8 erect colonies per transect (range: 6 – 14) and a mean reef substrate cover of 1.1 % (Table 34). The main species in terms of reef substrate cover were the encrusting species, *Erythropodium caribaeorum* and *Briareum asbestinum*. Sponges, represented in transects by 13 species contributed a mean reef substrate cover of 5.9 %. *Cliona caribbaea, Agelas dispar, A. conifera* and *Agelas sp.* comprised the main sponge assemblage.

Benthic algae, comprised by a mixed assemblage of fleshy brown macroalgae (*Lobophora variegata*, *Dictyota sp*.), turf algae and crustose coralline algae (CCA) were the dominant biotic category in terms of substrate cover at La Boya reef with a combined mean of 65.9 % (range: 59.2 – 72.5 %). Both turf algae (mixed assemblage), Encrusting Fan Alga, *L. variegata* and red crustose coralline algae were intercepted by all five transects overgrowing many dead massive coral sections of the reef. Total abiotic cover averaged 4.8 %, mostly influenced by reef overhangs (1.8 %) produced by live and dead coral mounds and ledges. Sand and coral rubble were also present (Table 34).

Major changes of reef benthic community structure are evident at Boya Vieja Reef since our baseline survey in 2000. A total of 18 species were intercepted by transects, with a total live coral cover of 41.2 % (Garcia-Sais et al, 2001b). During 2015, the new baseline survey performed in the same reef locality and depth yielded a live coral cover of 19.6 % that represents a decline of 52.4 % of reef substrate cover over a period of 15 years. Likewise, the reduction of coral species intercepted by transects from 18 to 11 is also indicative of a major deterioration of benthic community structure associated with loss of coral species richness. The magnitude of live coral loss was similar to the pattern exhibited by other shelf-edge reefs in the south coast, such as Derrumbadero, and of reefs at oceanic islands such as Mona and Desecheo at similar depths after the 2005 regional coral bleaching event (Garcia-Sais et al., 2007, 2008, 2014, 2015 and references therein). As in these other shelf-edge and oceanic reefs the decline of live coral cover at Boya Vieja Reef was largely driven by mortality of the dominant coral species in terms of reef substrate cover *Orbicella annularis* (complex), which had a mean cover of 26.7 % in 2000 and declined to a mean of 11.7 % in 2015, a reduction of 56.2 %. During 2017, live coral cover showed a slight increase, from 19.6% to 22.0% (Figure 30), a difference that although statistically insignificant, may be the beginning of a recuperation trend that has been measured in other reefs of the south and west coasts of Puerto Rico (Garcia-Sais et al., 2017; Garcia-Sais et al., 2016 and references therein). As in many other reefs in the PR Coral Reef Monitoring program, the increasing trend of live coral cover was associated with an increase of cover by *Orbicella annularis* (Figure 31). No infectious diseases were observed in any of the 74 total coral colonies intercepted by transects during the 2017 survey at Boya Vieja Reef (Appendix 2).

9.3 Fishes and Motile Megabenthic Invertebrates

A total of 106 fish species, including 37 within belt-transects were identified from La Boya Vieja Reef during the 2017 (Table 35). Mean density within transects was 44.6 Ind/30 m^2 (range: 26 – 76 Ind/30 m^2). The mean number of species per transect was 17.2 (H'= 155.6). Bicolor Damselfish (*Stegastes partitus*), Blue Chromis (*Chromis cyanea*), Princess and Redband Parrotfishes (*Scarus taeniopterus, Sparisoma aurofrenatum*) were present in all five transects with a combined abundance of 18.4 Ind/30 m^2, or 41.2% of the total individuals. In addition, the Bluehead Wrasse, Four-eye Butterflyfish, and Longspine Squirrelfish were present in at least 4 transects and appear to form part of the main residential fish assemblage at La Boya Reef (Table 35).

Fish species of commercial value observed within expanded belt-transects included five species of parrotfishes (*Scarus iserti, S. taeniopterus, Sparisoma viride, S. aurofrenatum, S. radians*), three species of doctorfishes (*Acanthurus spp*), two species of snappers (*Ocyurus chrysurus, Lutjanus apodus*), one adult Lionfish (*Pterois sp*), one adult Great Barracuda (*Sphyraena barracuda*) and one juvenile Nassau Grouper

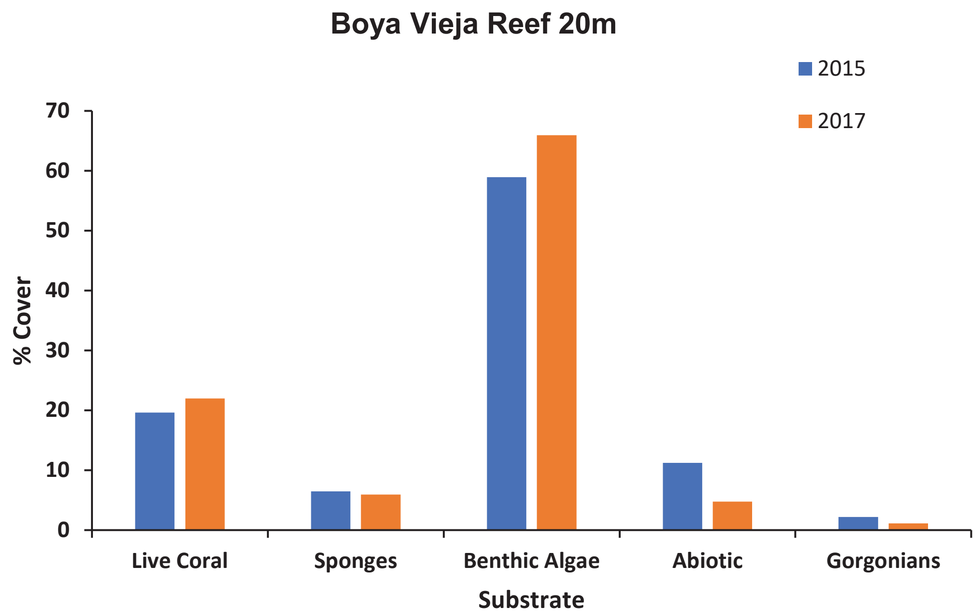


Figure 30. Monitoring trends (2015 – 2017) of mean substrate cover by sessile-benthic categories at Boya Vieja Reef, La Parguera.

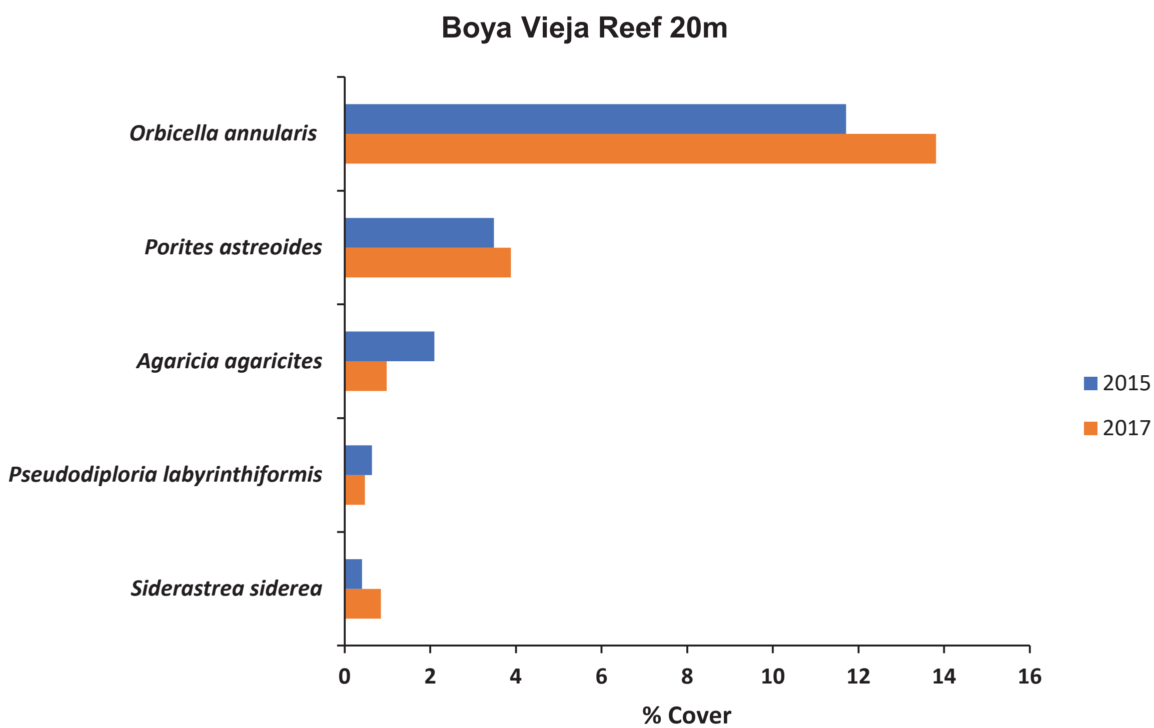


Figure 31. Monitoring trends (2015 – 2017) of mean substrate cover by stony coral species at Boya Vieja Reef, La Parguera.

(*Epinephelus striatus*). Parrotfishes and Acanthurids were present in both juvenile and adult stages (Table 36).

Zooplanktivores, such as Bicolor Damselfish, *Chromis spp*., and Creole Wrasse were the dominant assemblage at La Boya Vieja Reef representing approximately 45.3% of the total individuals within belt-transects. Small opportunistic invertebrate feeders, such as wrasses (Labridae), gobies (Gobiidae), squirrelfishes (Holocentridae), grunts (Haemulidae), and lizardfishes (Synodontidae) were also prominent, representing approximately 21.5 % of the total individuals. Herbivores, represented largely by parrotfishes, doctorfishes and farmer damselfishes accounted for 18.4 % of the total fish community within transects. During the 2017 monitoring survey large demersal predators were represented within transects by one juvenile Nassau Grouper (*Epinephelus striatus*). Adult Cubera, Mutton and Dog Snappers (*Lutjanus cyanopterus, L. analis, L. jocu*) have been previously reported (Garcia-Sais et al., 2015). Pelagic predators are also important constituents of the shelf-edge reef ichthyofauna. Some of these include Great Barracuda, Amberjacks, Cero and Great Mackerels, Wahoo, Dolphinfish and others. La Parguera shelf-edge reef is a well-known residential habitat of large groupers and snappers, reef, nurse, hammerhead and tiger sharks, hogfishes and others. It is also a spawning aggregation site for several commercially important species, such as the Red Hind (*E. guttatus*) and the Mutton Snapper (*L. analis*). DNER has established seasonal closures to protect snapper and grouper spawning aggregations.

Variations of fish species richness and abundance between the 2015 baseline and the 2017 monitoring survey are presented in Figure 32. Differences were not statistically significant (Appendix 5-6).

Motile-megabenthic invertebrates were represented within belt-transects by one Spiny Lobster (*Panulirus argus*) during this 2017 survey (Table 37).

Table 35. Taxonomic composition and abundance of fishes within belt-transects at La Boya Reef 20m La Parguera, March 2017

Depth: 20m		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m²)					
SPECIES	**COMMON NAME**						**MEAN**
Stegastes partitus	Bicolor Damselfish	10	12	6	6	8	**8.4**
Chromis cyanea	Blue Chromis	5	11	2	3	5	**5.2**
Chromis multilineata	Brown Chromis	5	13				**3.6**
Scarus taeniopterus	Princess Parrotfish	4	4	5	1	2	**3.2**
Clepticus parrae	Creole Wrasse	1	14				**3.0**
Sparisoma aurofrenatum	Redband Parrotfish	4	1	1	1	1	**1.6**
Sparisoma viride	Stoplight Parrotfish	3	1	4			**1.6**
Acanthurus bahianus	Ocean Surgeon	3		2	2		**1.4**
Canthigaster rostrata	Caribbean Puffer		3	1		3	**1.4**
Halichoeres garnoti	Yellow-head Wrasse				3	4	**1.4**
Cephalopholis cruentatus	Graysby	2	3		1		**1.2**
Chaetodon capistratus	Four-eye Butterflyfish		2	2	1	1	**1.2**
Scarus iserti	Stripped Parrotfish			2	1	3	**1.2**
Holocentrus rufus	Longspine Squirrelfish	1	1		2	1	**1.0**
Myripristis jacobus	Black-bar Soldierfish	1	3		1		**1.0**
Thalassoma bifasciatum	Bluehead Wrasse	2		2	3	1	**1.0**
Neoniphon marianus	Longjaw Squirrelfish	1		1		2	**0.8**
Acanthurus coeruleus	Blue Tang	1		1	1		**0.6**
Elacatinus evelynae	Sharknose Goby		1			2	**0.6**
Haemulon flavolineatum	French Grunt		1			2	**0.6**
Amblycirrhitus pinos	Red-spotted Hawkfish		1		1		**0.4**
Aulostomus maculatus	Trumpetfish			1		1	**0.4**
Carangoides ruber	Bar Jack	2					**0.4**
Coryphopterus glaucofraenum	Bridled Goby	2					**0.4**
Coryphopterus lipernes	Peppermint Goby				2		**0.4**
Ocyurus chrysurus	Yellowtail Snapper			1		1	**0.4**
Acanthurus chirurgus	Doctorfish	1					**0.2**
Anisotremus virginicus	Porkfish		1				**0.2**
Chaetodon striatus	Banded Butterflyfish	1					**0.2**
Gymnothorax funebris	Green Moray		1				**0.2**
Haemulon macrostomum	Spanish Grunt			1			**0.2**
Haemulon plumieri	White Grunt					1	**0.2**
Haemulon sciurus	Bluestriped Grunt			1			**0.2**
Holocentrus coruscus	Reef Squirrelfish	1					**0.2**
Melichthys niger	Black Durgon		1				**0.2**
Pseudupeneus maculatus	Spotted Goatfish		1				**0.2**
Synodus intermedius	Lizardfish		1				**0.2**
	TOTAL INDIVIDUALS	**50**	**76**	**33**	**26**	**38**	**44.6**
	TOTAL SPECIES	**19**	**20**	**16**	**15**	**16**	**17.2**

Table 36. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at La Boya Reef 20 m, La Parguera, March 2017

		TRANSECTS				
		1	2	3	4	5
		(Individuals/60 m^2)				
SPECIES	**COMMON NAME**					
Acanthurus bahianus	Ocean Surgeon	1 - 10		2 - 13	2 - 8	
		2 - 13				
Acanthurus coeruleus	Blue Tang	1 - 10		1 - 8		
Acanthurus chirurgus	Doctorfish	1 - 13				
Sparisoma viride	Stoplight Parrotfish	1 - 5	1 - 5	2 - 3		2 - 3
		2 - 30		1 - 13		1 - 20
				1 - 28		
Sparisoma aurofrenatum	Redband Parrotfish	1 - 8	1 - 23	1 - 13	1 - 13	1 - 20
		1 - 10				
		1 - 13				
		1 - 25				
Pterois volitans	Lionfish		1 - 30			
Scarus taeniopterus	Princess Parrotfish	1 - 8	3 - 13	5 - 13	1 - 8	2 - 15
		3 - 10	1 - 25		2 - 10	
Scarus iserti	Striped Parrotfish			2 - 15		3 - 13
Sparisoma radians	Bucktooth Parrotfish					
Epinephelus striatus	Nassau Grouper					1 - 40
Lutjanus apodus	Schoolmaster Snapper					
Ocyurus chrysurus	Yellowtail Snapper			1 - 13		1 - 28
Sphyraena barracuda	Great Barracuda			1 - 60		

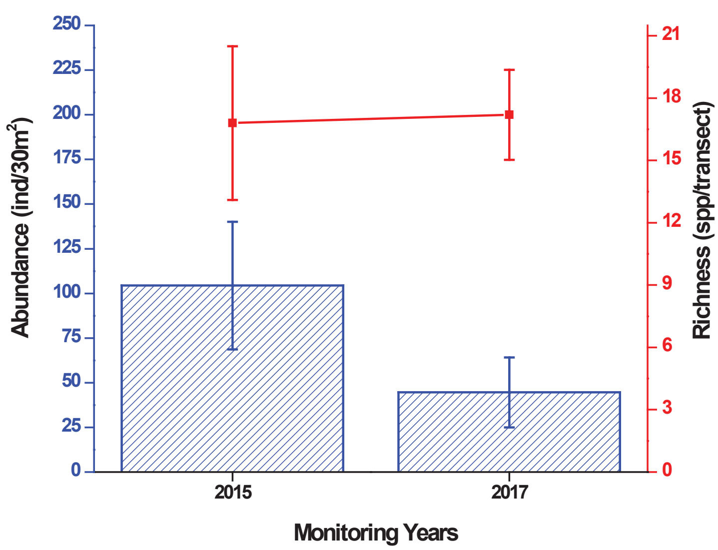


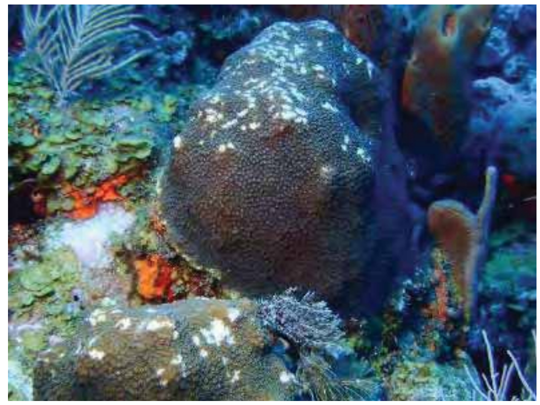
Figure 32. Monitoring trends (2015 – 2017) of fish species richness and abundance at Boya Vieja, La Parguera 20m. March 2017.

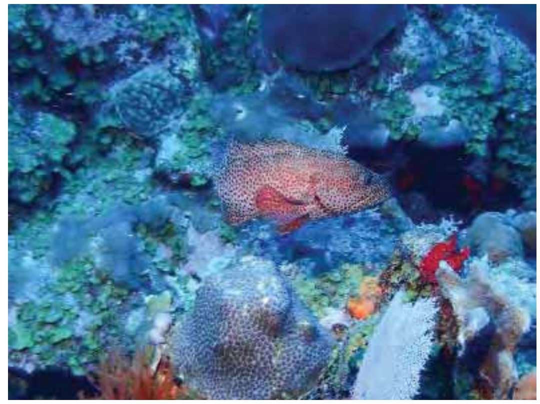
Table 37. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Boya Vieja, La Parguera 20m. March 2017.

Depth: 20m SPECIES	COMMON NAME	TRANSECTS 1	2	3	4	5	MEAN ABUNDANCE (IND/30 m2)
Panulirus argus	Spiny Lobster	0	1	0	0	0	**0.2**
	TOTALS	**0**	**1**	**0**	**0**	**0**	**0.2**

9.4 Photo Album 9

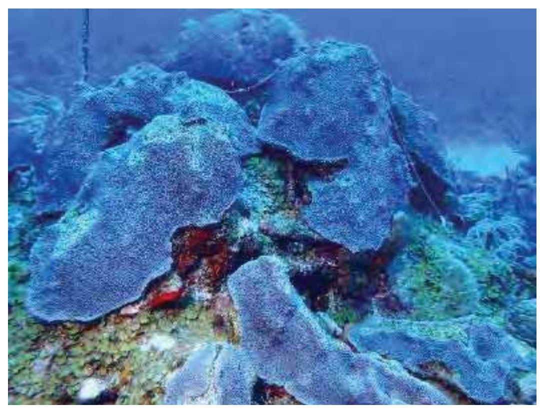
Boya Vieja Reef - La Parguera







10.0 Media Luna Fore-Reef 10m

10.1 Physical Description

With a longitudinal extension of approximately 1.2 Km, Media Luna is one of the largest emergent reefs of the La Parguera Marine Reserve. It is located due south of the town of La Parguera at a distance of about 3.5 km from the shoreline. There are two main emergent sections of low relief and devoid of mangrove development. The reef is highly exposed to wave action and there is substantial accumulation of broken coral fragments on its relatively narrow littoral zone. The fore-reef has a well-developed reef crest with some growth of Elkhorn Coral, but mostly colonized by colonial zoanthids, fire corals, encrusting corals and turf algae (Garcia-Sais and Sabater-Clavell, 2004). The fore-reef slope is moderately abrupt and heavily colonized by massive, branching and encrusting corals and gorgonians. The base of the reef is a sandy-silt basin at a depth of approximately 20 m. Five permanent transects were set along the mid-section of the fore-reef at 10 m in the same general location where the original CARICOMP baseline characterization of Media Luna Reef was performed in 1994 (Ogden et al.,1996). Panoramic views of the Media Luna fore-reef are shown in Photo Album 10.

10.2 Sessile-Benthic Reef Community

A total of 20 stony coral species, including 16 intercepted by transects were identified during the 2017 monitoring survey of the Media Luna Fore-reef (Table 38). The mean substrate cover by stony corals was 31.5 % (range: 21.9 – 36.7 %), with a mean of 14.4 colonies intercepted per transect. Boulder Star Coral, *Orbicella annularis* complex was the numerically dominant species in terms of reef substrate cover with a mean of 17.8 % (range: 5.4 – 27.9 %) that represented 56.6% of the total cover by live corals. Mustard-Hill Coral (*Porites astreoides*), Symmetrical Brain Coral (*Pseudodiploria strigosa*) and Lettuce Coral (*Agaricia agaricites*) were present in all five transects and along with Boulder Star Coral comprised the main stony coral assemblage of Media Luna Fore-reef at a depth of 10 m (Table 38). Finger Corals (*Porites furcata* and P. *porites*) were present in four transects, but with relatively low substrate cover (< 1%). None of the 72 coral colonies intercepted by transects were observed to be affected by diseases (Appendix 2).

Table 38. Percent linear cover by sessile-benthic invertebrates at Media Luna Reef 10m, La Parguera. Survey Date: March 23, 2017

	Transects					
	1	2	3	4	5	Mean
Rugosity	0.43	0.81	2.10	3.38	2.64	**1.87**
Benthic Category						
Abiotic						
Reef overhang	4.16	2.59	15.39	4.71	1.11	**5.59**
Gap	3.76				0.55	**0.86**
Total Abiotic	**7.92**	**2.59**	**15.39**	**4.71**	**1.66**	**6.45**
Benthic Algae						
Turf	36.24	33.55	40.39	26.99	37.10	**34.85**
Dictyota spp.		2.33		2.62		**0.99**
CCA		0.91		2.72		**0.73**
Total Benthic Algae	**36.24**	**36.79**	**40.39**	**32.32**	**37.10**	**36.57**
Cyanobacteria		2.33			0.55	**0.58**
Live Coral						
Orbicella annularis complex	27.92	5.44	9.03	26.15	20.71	**17.85**
Porites astreoides	2.01	8.42	3.70	6.17	4.98	**5.06**
Pseudodiploria strigosa	1.34	2.46	3.24	0.94	1.55	**1.91**
Agaricia agaricites	0.54	1.68	2.55	0.63	2.44	**1.57**
Colpophyllia natans			4.17			**0.83**
Montastraea cavernosa			2.55	0.73	0.89	**0.83**
Porites furcata		0.78	1.50	0.21	0.66	**0.63**
Siderastrea siderea	1.48		0.35	0.63		**0.49**
Porites porites	0.81	0.78	0.23		0.55	**0.47**
Meandrina meandrites		1.94	0.23			**0.43**
Dendrogyra cylindrus	1.61					**0.32**
Millepora alcicornis			1.39			**0.28**
Madracis decactis					1.33	**0.27**
Stephanocoenia intersepta		0.39		0.52	0.22	**0.23**
Agaricia fragilis				0.73		**0.15**
Leptoseris cucullata			0.69			**0.14**
Total Live Coral	**35.70**	**21.89**	**29.63**	**36.72**	**33.33**	**31.46**
Colonies/Transect	10	10	15	16	21	**14.4**
Zoanthids						
Palythoa caribaeorum		4.92		12.24	3.43	**4.12**
Octocoral						
Erythropodium caribaeorum	12.08	10.10	6.83	4.18	11.30	**8.90**
Briareum asbestinum		8.81	3.24	1.99	1.66	**3.14**
Eunicea flexuosa			0.23	0.31	0.44	**0.20**
Gorgonia ventalina	0.27		0.23		0.44	**0.19**

Pseudoplexaura flagellosa-wagenaari		0.26				**0.05**
Total Octocoral	**12.35**	**19.17**	**10.53**	**6.49**	**13.84**	**12.48**
#Gorgonians/transects	15	14	23	29	31	**22.40**
Sponge						
Chondrilla caribensis	7.52	5.44	2.20	3.35	4.98	**4.70**
Cliona caribbaea		3.89	0.23	3.35	2.44	**1.98**
Ircinia felix		0.52	1.16			**0.34**
Ircinia sp. brown					1.33	**0.27**
Mycale laevis					0.66	**0.13**
Amphimedon compressa	0.27				0.33	**0.12**
Spirastrella coccinea			0.46			**0.09**
Iotrochota birotulata		0.39				**0.08**
Plaktoris sp.					0.11	**0.02**
Total Sponge	**7.79**	**10.23**	**4.05**	**6.69**	**9.86**	**7.72**

Soft corals, both in erect and encrusting growth forms were present in all five transects with a mean density of 22.4 colonies/transect (range: 14 – 31 col/transect) and a mean substrate cover of 12.5 % (Table 38). The main assemblage of erect forms was comprised by *Pseudoplexaura spp., Plexaura spp., Eunicea spp.,* and *Gorgonia ventalina*. The Encrusting Gorgonian, *Erythropodium caribaeorum* and Corky Sea Finger, *Briareum asbestinum* were the main encrusting taxa with a combined cover of 13.0%. Gorgonians were found growing as very large colonies and contributed substantially to the reef structural complexity.

Sponges were represented by nine (9) species within transects with a combined mean substrate cover of 7.7 %. The most abundant sponges included *Chondrilla caribensis*, *Cliona caribbea, Ircinia spp*., and *Mycaele levis* (Table 38). The encrusting zoanthid, *Palythoa caribaeorum* was present in three transects with a mean cover of 4.1 %.

Turf algae, a mixed assemblage of short articulated red and brown macroalgae was the main component of the benthic algae with a mean cover of 34.8 %, representing 95.1 % of the total benthic algae. Crustose coralline algae and fleshy brown macroalgae (*Dictyota sp.*) were also present in transects with a lower substrate cover (< 1.0 %).

The benthic community structure at the Media Luna Fore Reef displayed similar patterns of reef degradation associated with severe live coral loss than La Boya Vieja Reef at the shelf-edge of La Parguera and other outer reefs of the south coast of Puerto Rico.

Consistent with previous observations, reef degradation was strongly influenced by the severe and widespread mortality of the dominant reef building species, the Boulder Star Coral, *Orbicella annularis* complex associated with the 2005 coral bleaching event and its lingering effects on the coral reef systems of Puerto Rico and the USVI (Garcia-Sais et al., 2007, 2008, 2015 and references therein). Live coral cover during 1994 in the same reef vicinity of the present transects at Media Luna 10m was 42.3 % (Ogden et al., 1996). During the baseline survey of 2015, live coral cover averaged 21.9 %, a loss of approximately 48% between surveys. In the present 2017 monitoring survey an increase of live cover of 30.5 % was measured at Media Luna Reef 10m (Figure 33). The increasing trend of live coral cover was strongly driven by recuperation of cover by *O. annularis* (Figure 34). Although differences were not statistically significant (ANOVA, $p = 0.062$; Appendix 1) relative to the 2015 survey we believe that differences between surveys may be in error. Transects are located along a fore-reef slope with very high rugosity, high density of gorgonians and high dead and live coral substrate. Such conditions make it difficult to establish a precise chain path for determination and measurements of intercepts. Better substrate markers are needed to increase the chain path. This task will be approached during the next monitoring survey.

Density of soft corals, or gorgonians declined by 51.3% between the baseline survey of 2015 and the present 2017 survey (from 46 to 22.4 col/transect). The difference was statistically significant (T-test, $p = 0.003$, Appendix 3) and probably related to the extreme wave action and associated surge effects caused by the pas of Hurricane Mathew along the south coast of Puerto Rico during October 2016.

10.3 Fishes and Motile Megabenthic Invertebrates

A total of 93 fish species have been identified from the Media Luna Fore-Reef, including 30 within belt-transects (Table 39). Mean abundance within transects was 29.6 Ind/30 m^2 (range: 23 – 38 Ind/30 m^2). Mean number of species per transect was 14.0 (range: 13 – 16). The Blue Chromis, Bluehead Wrasse, Bicolor and Dusky Damselfishes, and the Princess and Redband Parrotfishes were the most abundant species within transects with a combined abundance of 21.2 Ind/30 m^2, representing 71.6 % of the total individuals. In addition, the Blue Tang, Yellowtail Snapper and Yellowtail Damselfish were present in four transects (Table 39). A total of 12 species were only observed in

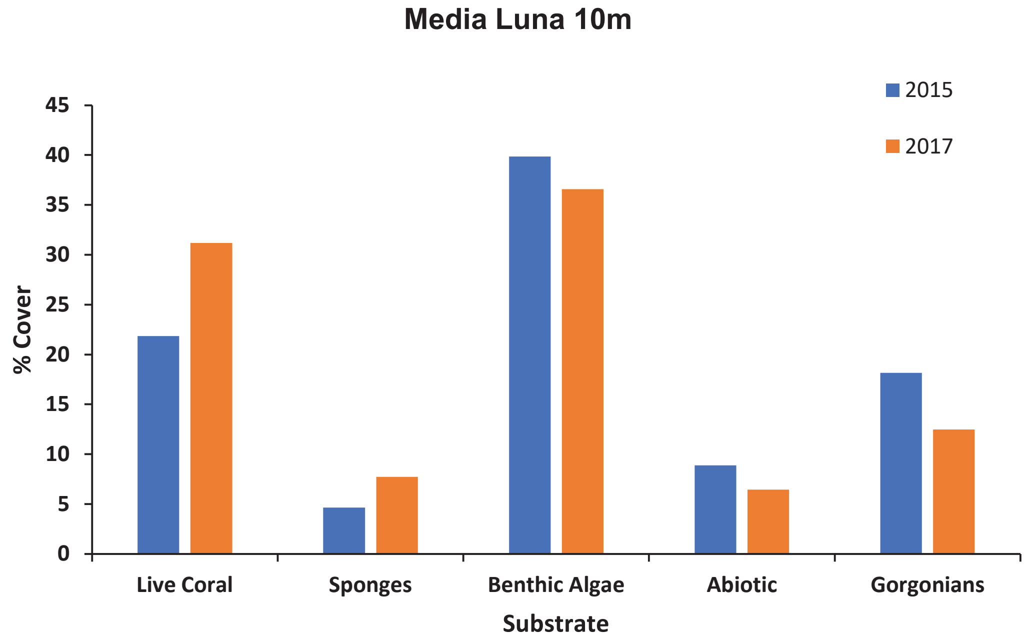


Figure 33. Monitoring trends (2015 – 2017) of mean substrate cover by sessile-benthic categories at Media Luna Reef 10m, La Parguera.

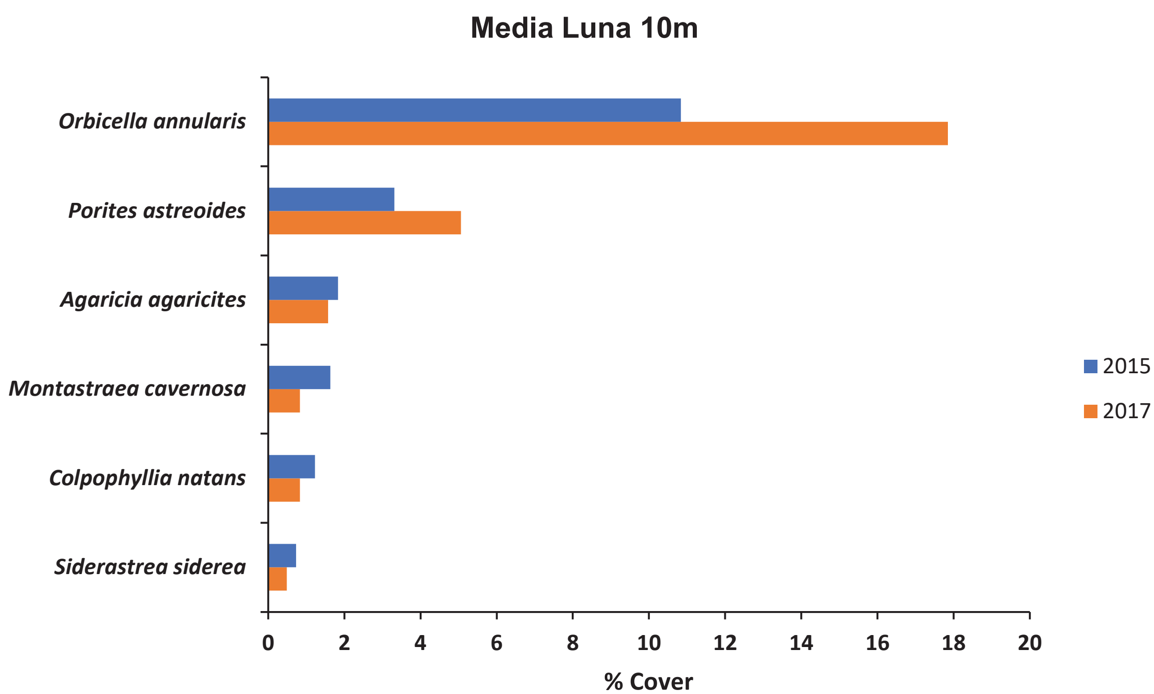


Figure 34. Monitoring trends (2015 – 2017) of mean substrate cover by stony coral species at Media Luna Reef 10m, La Parguera.

Table 39. Taxonomic composition and abundance of fishes within belt-transects at Media Luna Reef 10m La Parguera, March 2017

Depth: 10m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(Individuals/30 m²)					
SPECIES	**COMMON NAME**						**MEAN**
Chromis multilineata	Brown Chromis	5	4	6	12		**5.4**
Thalassoma bifasciatum	Bluehead Wrasse	5	8	6	14	2	**4.2**
Stegastes partitus	Bicolor Damselfish	3	5	5	3	3	**3.8**
Stegastes dorsopunicans	Dusky Damselfish	1	3	2	5	5	**3.2**
Scarus taeniopterus	Princess Parrotfish	2	8		2		**2.4**
Sparisoma aurofrenatum	Redband Parrotfish	1	2	1	4	3	**2.2**
Acanthurus coeruleus	Blue Tang	3	2	2		2	**1.8**
Ocyurus chrysurus	Yellowtail Snapper	2	3	1	3		**1.8**
Microspathodon chrysurus	Yellowtail Damselfish	1		2	1	4	**1.6**
Carangoides ruber	Bar Jack					4	**0.8**
Chaetodon capistratus	Four-eye Butterflyfish				3	1	**0.8**
Chromis cyanea	Blue Chromis	1	1		2		**0.8**
Halichoeres garnoti	Yellow-head Wrasse			2		2	**0.8**
Scarus iserti	Stripped Parrotfish		3			1	**0.8**
Sparisoma viride	Stoplight Parrotfish			1		3	**0.8**
Elacatinus evelynae	Sharknose Goby	1	1		1		**0.6**
Canthigaster rostrata	Caribbean Puffer			1	1		**0.4**
Myripristis jacobus	Black-bar Soldierfish	1			1		**0.4**
Abudefduf sexatilis	Sargent Major	1					**0.2**
Coryphopterus glaucofraenum	Bridled Goby		1				**0.2**
Gramma loreto	Fairy Basslet			1			**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet			1			**0.2**
Hypoplectrus unicolor	Butter Hamlet		1				**0.2**
Hypoplectrus puella	Barred Hamlet					1	**0.2**
Lutjanus apodus	Schoolmaster Snapper			1			**0.2**
Pomacanthus arcuatus	Gray Angelfish			1			**0.2**
Priacanthus sp	Glasseye			1			**0.2**
Scomberomorus regalis	Cero				1		**0.2**
Stegastes variabilis	Cocoa Damselfish	1					**0.2**
Stegastes planifrons	Yellow-eye Damselfish					1	**0.2**
	TOTAL INDIVIDUALS	**23**	**38**	**28**	**27**	**32**	**29.6**
	TOTAL SPECIES	**14**	**13**	**16**	**14**	**13**	**14.0**

one belt-transect. Commercially important species observed within extended belt-transects (Table 40). As in the previous baseline survey, post settlement (recruitment) stages (1 - 3 cm) of the Stoplight and Redband Parrotfishes were observed evidencing the function of the Media Luna Fore-Reef as a recruitment habitat for these species.

Fish community structure at Media Luna Fore-Reef was strongly influenced by herbivores and opportunistic carnivores. Parrotfishes, territorial (farmer) damselfishes and doctorfishes comprised the main herbivore assemblage with at least 10 species included within belt-transects representing 57.4 % of the total individuals. Likewise, small opportunistic carnivores, such as wrasses, basslets, squirrelfishes, gobies, juvenile snappers, puffers and grunts were represented by eight species and 24.3 % of the total individuals. The zooplanktivore assemblage was comprised by four species, that represented 22.3 % of the total individuals, including the Brown Chromis (*Chromis multilineata*), which was the most abundant within belt-transects (Table 39).

The strong wave and surge action prevailing during our 2017 survey at Media Luna Fore-Reef may have influenced the relatively low fish abundance and particularly of zooplanktivores that are typically observed in the water column over the reef, such as Creole Wrasse (*Clepticus parrae*) and Mackerel Scad (*Decapterus macarellus*). These zooplanktivores serve as the main forage species for large demersal and pelagic top predators of the reef, such as Great Barracuda (*Sphyraena barracuda*), Cero and Great Mackerel (*Scomberomorus regalis, S. cavalla*) and large snappers and groupers that have been previously reported for this reef (Garcia-Sais and Sabater-Clavell, 2004).

The composition and size-frequency distributions of commercially important fishes and the main reef herbivores observed within extended belt-transects at Media Luna 10m are shown in Table 40. Schoolmaster and Yellowtail snappers (*Lutjanus apodus, Ocyurus chrysurus*) were present mostly as juveniles. The parrotfish assemblage comprised by four species included both juvenile and adult individuals. Post settlement stages of Stoplight, Redband and Stripped Parrotfishes were present, evidencing the role of this reef as a recruitment habitat for these species. Temporal variations of fish species richness and abundance between the baseline (2015) and this (first) monitoring survey were statistically insignificant (ANOVA, $p > 0.05$; Appendix 5-6).

Motile megabenthic invertebrates present within belt-transects during the 2017 monitoring survey included Long-spined Urchins in all transects and one Rock Lobster (Table 41).

Table 40. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at Media Luna Reef 10 m, La Parguera, March 2017

		TRANSECTS (Individuals/60 m^2)				
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**
Acanthurus coeruleus	Blue Tang		2 - 10	2 - 10		2 - 8
Sparisoma viride	Stoplight Parrotfish			1 - 5		3 - 1
						2 - 25
						1 - 30
Sparisoma aurofrenatum	Redband Parrotfish	1 - 23		1 - 20	1 - 10	2 - 5
					2 - 15	1 - 10
Scarus taeniopterus	Princess Parrotfish	2 - 8	2 - 3		2 - 5	
			4 - 5			
			2 - 10			
Scarus iserti	Striped Parrotfish					3 - 10
Lutjanus apodus	Schoolmaster Snapper			1 - 13		
Ocyurus chrysurus	Yellowtail Snapper	1 - 10		1 - 8	2 - 8	
		1 - 15			1 - 10	

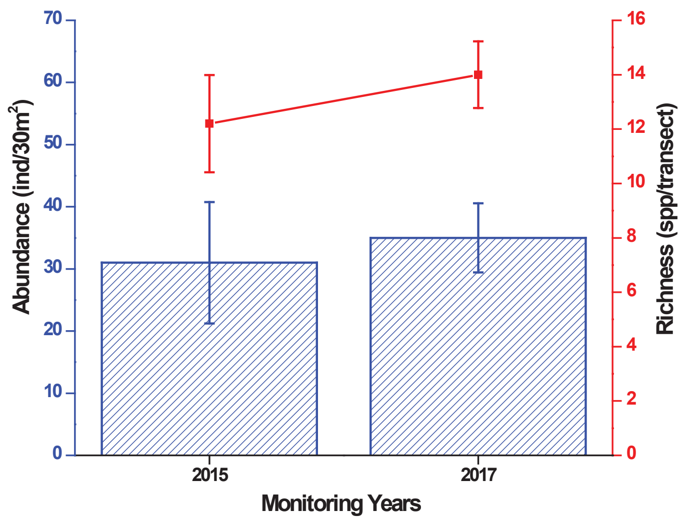


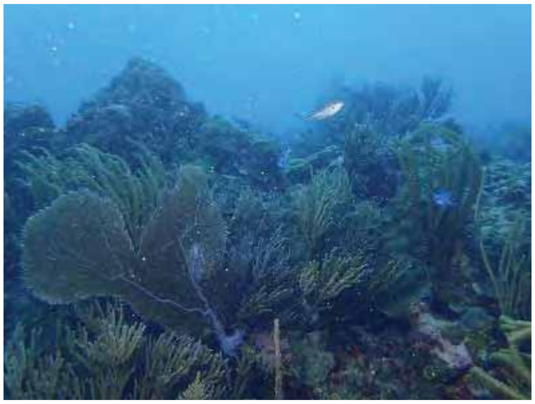
Figure 35. Monitoring trends (2015 – 2017) of fish species richness and abundance at Media Luna 10m, La Parguera. March 2017.

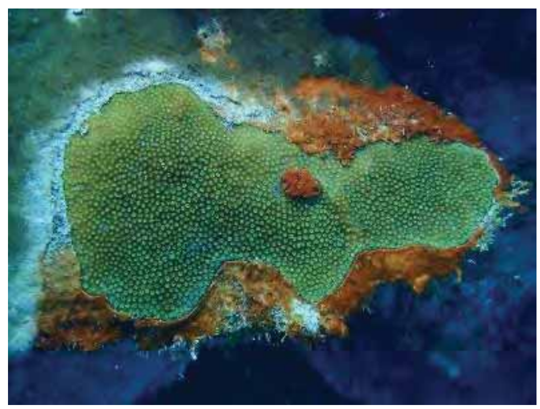
Table 41. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Media Luna 10m, La Parguera, 2017

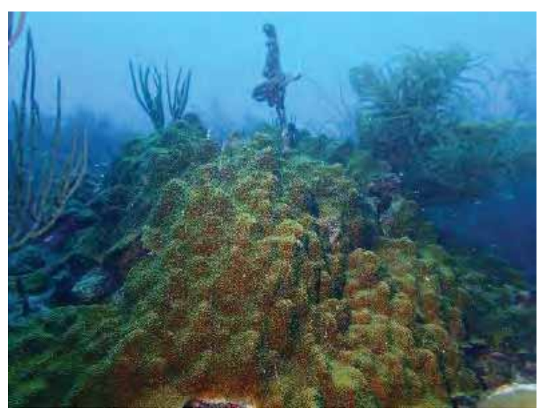
Depth: 8 -10 m		TRANSECTS					MEAN
		1	**2**	**3**	**4**	**5**	**ABUNDANCE**
TAXA	**COMMON NAME**						**(IND/30 m2)**
Diadema antillarum	Long-spined Urchin	9	4	5	6	8	**6.4**
Panulirus guttatus	Rock Lobster	1	0	0	0	0	**0.2**
	TOTALS	10	4	5	6	8	**6.6**

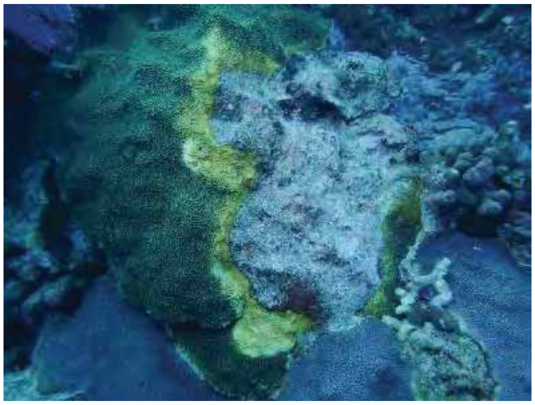
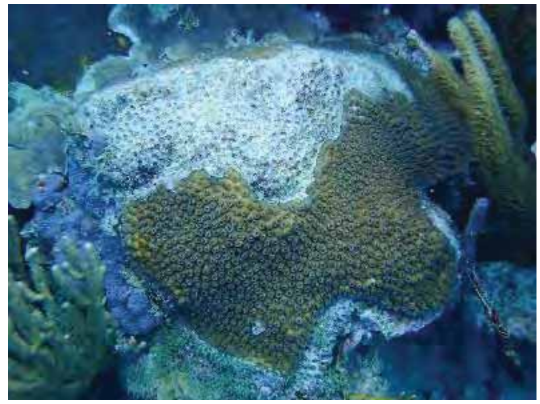
10.4 Photo Album 10

Media Luna 10m – La Parguera

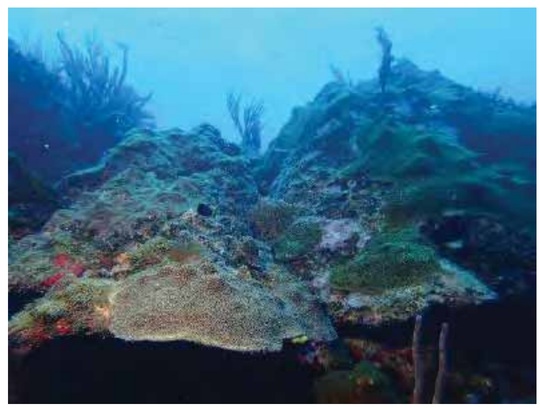










11.0 Media Luna Back-Reef

11.1 Physical Description

A series of patch reefs are found in the mid-section of the Media Luna back-reef at depths of 2 – 5 meters. The reef promontories are coral formations, mostly of Boulder Star Coral, *Orbicella annularis* that rise from the base of the reef to variable heights, some almost reaching the surface. The patch reefs are irregular formations separated by sandy-silt sediments. The backreef slopes down gradually to a depth of about 5 meters and then drops down more abruptly to a backreef basin reaching a sill depth of approximately 20 m. Our permanent transects were established in three of these patch reefs at depths of 3 – 5 meters. Panoramic documentation of the Media Luna Backreef is shown in Photo Album 11.

11.2 Sessile-Benthic Reef Community

Turf algae, a mixed assemblage of short filamentous algae growing intermixed with fleshy and red coralline macroalgae was the main biotic category in terms of substrate cover at Media Luna Back-Reef with a mean of 53.6 % (range: 24.0 – 55.8 %). Fleshy brown macroalgae (*Dictyota sp, Sargassum sp*) was present in all transects with a combined mean substrate cover of 7.2%. Calcareous green (*Halimeda sp*.) and red crustose coralline algae (including *Ramicrusta sp*) were other components of the benthic algae assemblage (Table 42). Cyanobacterial, or blue-green algal films were observed in one transect with a mean cover of 0.2 %.

A total of 16 stony corals, including six intercepted by line transects were identified from the Media Luna Back-Reef at depths of 2 – 5 m (Table 42). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant species in terms of reef substrate cover with a mean of 13.1 %, representing 92.2 % of the total cover by stony corals. Total live coral cover averaged 14.2% (range: 7.2 – 29.8 %), with a mean of 4.2 live colonies per transect. Large massive colonies of Boulder Star Coral were observed growing from the base of the reef and reaching almost to the surface. One partially degraded colony of Pillar Coral, *Dendrogyra cylindrus* present in transect 1, but could not be established if it was presently affected by some disease or if its degrades status was related to previous stress. Coral diseases were not observed in any of the 21 coral colonies intercepted by transects during 2017 (Appendix 2). Sparse colonies of Greater Starlet Coral, *Siderastrea siderea*, Boulder Brain Coral, *Colpophyllia natans* Flower Coral, *Eusmilia*

Table 42. Percent linear cover by sessile-benthic invertebrates at Media Luna Reef, La Parguera 5m. Survey Date: March 27, 2017

	Transects					
	1	2	3	4	5	Mean
Rugosity	6.88	4.49	2.53	4.81	5.20	**4.78**
Benthic Categories						
Abiotic						
Reef overhang	14.18	17.29	4.47	23.16	14.36	**14.69**
Sand	15.26		3.02	3.50	6.45	**5.64**
Rubble			1.90	5.39	1.84	**1.83**
Gap		3.96	0.67			**0.93**
Total Abiotic	**29.44**	**21.26**	**10.06**	**32.04**	**22.65**	**23.09**
Benthic Algae						
Turf	23.96	55.85	40.56	39.98	40.70	**40.21**
Dictyota spp.	1.49	3.09	23.80	3.50	2.95	**6.97**
Turf with sediment				5.58	6.45	**2.40**
Halimeda spp.	1.49		3.69	2.46	3.13	**2.15**
Jania spp.	6.97					**1.39**
Sargassum natans			0.89			**0.18**
CCA			0.67			**0.13**
Ramicrusta sp.	0.50					**0.10**
Red algae				0.28		**0.06**
Total Benthic Algae	**34.41**	**58.94**	**69.61**	**51.80**	**53.22**	**53.60**
Cyanobacteria			1.12			**0.22**
Live Coral						
Orbicella annularis complex	27.36	8.31	10.39	6.62	12.62	**13.06**
Dendrogyra cylindrus	2.49					**0.50**
Colpophyllia natans			1.12			**0.22**
Siderastrea siderea		0.77	0.34			**0.22**
Agaricia agaricites			0.22	0.19		**0.08**
Eusmilia fastigiata				0.38		**0.08**
Total Live Coral	**29.85**	**9.08**	**12.07**	**7.18**	**12.62**	**14.16**
Colonies/ Transect	3	5	5	4	4	**4.2**
Octocoral						
Briareum asbestinum	3.98	1.55	3.35	0.57	4.60	**2.81**
Erythropodium caribaeorum		3.77	0.78	1.98	0.74	**1.45**
Eunicea flexuosa				0.47		**0.09**
Antillogorgia americana			0.34			**0.07**
Plexaura homomalla			0.34			**0.07**
Total Octocoral	**3.98**	**5.31**	**4.80**	**3.02**	**5.34**	**4.49**
Total # Gorgonians/transect	13	24	10	19	18	**16.8**
Sponge						
Chondrilla caribensis	0.50	3.57	1.34	5.95	5.43	**3.36**
Cliona caribbaea		1.84				**0.37**
Ircinia strobilina	1.33					**0.27**
Ircinia sp. brown			1.01			**0.20**
Mycale laevis	0.17				0.74	**0.18**
Total Sponge	**1.99**	**5.41**	**2.35**	**5.95**	**6.17**	**4.37**

fastigiata and Lettuce Coral, *Agaricia agaricites* were also intercepted by transects, but represented minor components of the reef sessile-benthos.

Soft corals were moderately abundant (mean: 16.8 col/transect) and present as large colonies that contributed substantial reef substrate complexity. A total of 14 species of soft corals were identified. The most abundant erect forms included Sea Rods (*Plexaura spp*), Sea Plumes (*Pseudopterogorgia spp*) and Sea Fan (*Gorgonia ventalina*). The encrusting Gorgonian, *Erythropodium caribaeorum* and the Corky Sea Finger, *Briareum asbestinum* were the most prominent in terms of reef substrate cover with a combined average of 4.3% (Table 42). Sponges were present in all transects with a mean cover of 4.4 %. A total of 10 species were identified, including five intercepted by transects. Chondrilla caribensis was present in all transects and was the dominant species in terms of reef substrate cover with a mean of 2.8%. Abiotic categories, mostly reef overhangs and sand averaged 23.1%. Reef substrate rugosity averaged 4.8 m, indicative of the high topographic relief contributed by coral growth.

Variations of live coral cover between the 2015 baseline and this (first) monitoring survey (Figure 36) were not statistically significant (ANOVA, p=0.12; Appendix 1). The high relative composition of turf algae overgrowing standing dead coral sections, particularly of Boulder Star Coral are indicative of a major reef degradation event or series of events that occurred prior to our baseline survey (perhaps the 2005 coral bleaching event). An increase of cover by *Orbicella annularis* of 18.5% was measured between the baseline 2005 and the present survey (Figure 37). This finding is consistent with what appears to be one of the main trends of coral reef systems included in the PR Coral Reef Monitoring Program.

The density of soft corals (gorgonians) declined 26% between the 2015 baseline and the 2017 monitoring survey, but due to the high within station variability, the difference was not statistically significant (T-test, p= 0.200; Appendix 3).

11.3 Fishes and Motile Megabenthic Invertebrates

A total of 53 fish species, including 36 within belt-transects were identified from the Media Luna Back-Reef (Table 43). The total fish mean abundance was 68.6 Ind/30 m^2 (range: 47 – 88 Ind/30 m^2). The numerically dominant species within transects were the

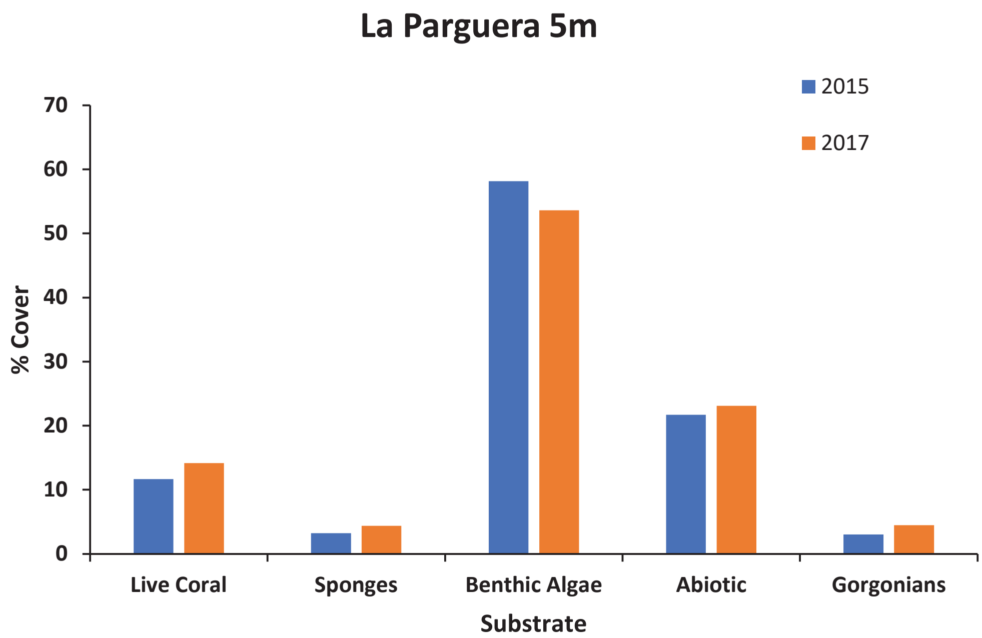


Figure 36. Monitoring trends (2015 – 2017) of mean substrate cover by sessile-benthic categories at Media Luna Back Reef 5m, La Parguera.

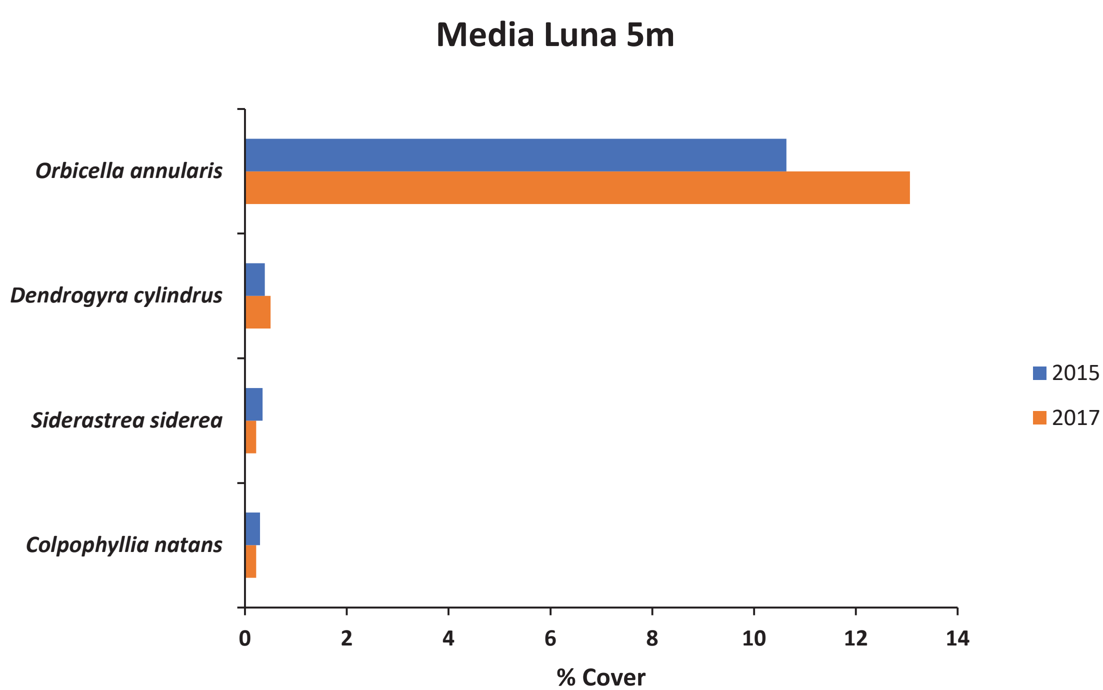


Figure 37. Monitoring trends (2015 – 2017) of mean substrate cover by stony coral species at Media Luna Back Reef 5m, La Parguera.

Princess Parrotfish (*Scarus taeniopterus*) and the Bluehead Wrasse (*Thalassoma bifasciatum*) with a combined abundance of 30.4 Ind/30 m^2, representative of 44.3 % of the total individuals within belt-transects. Stoplight Parrotfish (*Sparisoma viride*), Dusky and Yellow-eye Damselfishes (*Stegastes adustus, S. planifrons*), French Grunt (*Haemulon flavolineatum*) and Brown Chromis (*Chromis multilineata*) were observed in all transects and along with the aforementioned species comprised the main residential fish assemblage of the Media Luna Back-Reef (Table 43).

Fish species of commercial value observed within extended belt-transects are listed in Table 44. A total of four parrotfishes were present, and comprised the main assemblage in terms of density and species richness. Parrotfishes were largely present as juvenile and adults, including post-settlement juveniles (1 – 3 cm) of the Stoplight and Princess Parrotfishes (*Sparisoma viride, Scarus taeniopterus)*. Early juveniles and adult doctorfishes (*Acanthurus spp*) and Snappers (*Lutjanus apodus*, *Ocyurus chrysurus)* were also present.

The herbivorous fish assemblage was the most prominent in terms of their relative composition within belt-transects surveyed with at least 13 species representing 52.2 % of the total individuals. Parrotfishes were the main taxonomic group in terms of density of individuals and species richness, but doctorfishes (Acanthuridae) and territorial farmer damselfishes (Pomacentridae) were also present. Opportunistic carnivores, represented by wrasses, juvenile grunts, squirrelfish, jacks, hamlets, gobies, mojarras and Trumpetfish were also prominent at the Media Luna Back-Reef representing approximately 34.7 % of the total individuals within belt-transects. The density of zooplanktivores (*Chromis spp.,* Bicolor Damselfish, Sargent Major) represented less than 10 % of the total fish community. The relative abundance of herbivorous fish has been shown to increase towards the coastline possibly associated with the higher connectivity of recruitment and nursery habitats and/or the higher availability of benthic algae. Conversely, the relative abundance and species richness of zooplanktivorous fishes increase towards the outer shelf, shelf-edge and oceanic reefs (Esteves-Amador, 2013). The main piscivores, typically represented by the larger fishes of the reef community were mostly represented by snappers (*L. apodus, Ocyurus chrysurus*) and pelagic species, such as jacks (*Caranx crysos, Carangoides ruber*).

Table 43. Taxonomic composition and abundance of fishes within belt-transects at Media Luna Reef 3m La Parguera, March 2017

Depth: 3-5m

		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Scarus taeniopterus	Princess Parrotfish	12	15	16	21	13	**15.4**
Thalassoma bifasciatum	Bluehead Wrasse	10	24	27	14		**15.0**
Sparisoma viride	Stoplight Parrotfish	6	10	5	5	2	**5.6**
Stegastes adustus	Dusky Damselfish	6	3	6	3	3	**4.2**
Stegastes planifrons	Yellow-eye Damselfish	3	4	6	3	4	**4.0**
Chromis multilineata	Brown Chromis	8	3	1	3	4	**3.8**
Haemulon flavolineatum	French Grunt	5	6	1	6	1	**3.8**
Sparisoma aurofrenatum	Redband Parrotfish		6	1	1		**1.6**
Holocentrus rufus	Long-spined Urchin		3	2	1	2	**1.6**
Microspathodon chrysurus	Yellowtail Damselfish		4		1	2	**1.4**
Caranx crysos	Blue runner			2	3	2	**1.4**
Acanthurus coeruleus	Blue Tang	1	2		1	3	**1.2**
Carangoides ruber	Bar Jack			1		5	**1.2**
Scarus iserti	Stripped Parrotfish	2		1	3		**1.2**
Stegastes partitus	Bicolor Damselfish				3	2	**1.0**
Canthigaster rostrata	Caribbean Puffer			2	1	1	**0.8**
Chaetodon capistratus	Four-eye Butterflyfish	2	1				**0.6**
Haemulon aurolineatum	Tomtate	3					**0.6**
Abudefduf sexatilis	Sargent Major		2				**0.4**
Hypoplectrus chlorurus	Yellowtail Hamlet		1		1		**0.4**
Haemulon sciurus	Bluestriped Grunt	1	1				**0.4**
Cantherhines pullus	Tail-light Filefish				1		**0.2**
Hypoplectrus puella	Barred Hamlet				1		**0.2**
Hypoplectrus indigo	Indigo Hamlet					1	**0.2**
Lutjanus apodus	Schoolmaster Snapper			1			**0.2**
Myripristis jacobus	Black-bar Soldierfish		1				**0.2**
Ocyurus chrysurus	Yellowtail Snapper	1					**0.2**
Pomacanthus arcuatus	Gray Angelfish	1					**0.2**
Acanthurus bahianus	Ocean Surgeon				1		**0.2**
Aulostomus maculatus	Trumpetfish		1				**0.2**
Gerres cinereus	Yellowfin Mojarra	1					**0.2**
Haemulon plumieri	White Grunt					1	**0.2**
Holocentrus adcensionis	Squirrelfish	1					**0.2**
Halichoeres bivittatus	Slippery Dick			1			**0.2**
Hypoplectrus nigricans	Black Hamlet					1	**0.2**
Lutjanus mahogany	Mahogoni Snapper		1				**0.2**
	TOTAL INDIVIDUALS	**63**	**88**	**72**	**73**	**47**	**68.6**
	TOTAL SPECIES	**16**	**18**	**15**	**19**	**16**	**16.8**

Table 44. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3 m belt-transects at Media Luna Reef 3 m, La Parguera, March 2017

		TRANSECTS				
		1	2	3	4	5
		(Individuals/60 m^2)				
Acanthurus coeruleus	Blue Tang	1 - 3	2 - 8			1 - 8
						2 - 13
Acanthurus bahianus	Ocean Surgeon				1 - 15	
Sparisoma viride	Stoplight Parrotfish	3 - 3	1 - 1	2 - 1	2 - 1	1 - 15
		2 - 8	2 - 3	2 - 8	3 - 5	1 - 20
		1 - 15	1 - 10	1 - 30	1 - 13	
Sparisoma aurofrenatum	Redband Parrotfish	1 - 10		1 - 18		1 - 18
		2 - 15		1 - 25		
		1 - 20				
Scarus taeniopterus	Princess Parrotfish	4 - 3	4 - 3	2 - 1	11 - 3	8 - 3
		8 - 5	11 - 4	6 - 3	14 - 4	9 - 4
				8 - 5	2 - 10	3 - 8
Scarus iserti	Striped Parrotfish	2 - 15		1 - 10	1 - 8	
					2 - 10	
Lutjanus apodus	Schoolmaster Snapper			1 - 13		
Ocyurus chrysurus	Yellowtail Snapper	1 - 25				

Variations of fish species richness and abundance between the 2015 baseline and the present 2017 monitoring survey are presented in Figure 38. In both cases, differences were small and statistically insignificant (see Appendix 5-6).

Motile megabenthic invertebrates observed within belt-transects (Table 45) were represented by juvenile and adult Spiny Lobsters (*Panulirus argus*) and Long-spined Urchins (*Diadema antillarum*). The density of Long-spined Urchins at Media Luna backreef (8.0 Ind/30m^2) is the highest ever recorded in the monitoring program. This may be influenced by a restoration initiative that involved the out-planting of 340 urchins in this general locality in an attempt to reduce the high algal overgrowth at this reef after the marked mortality of live coral cover presumably related with the 2005 coral bleaching event (Williams, 2017).

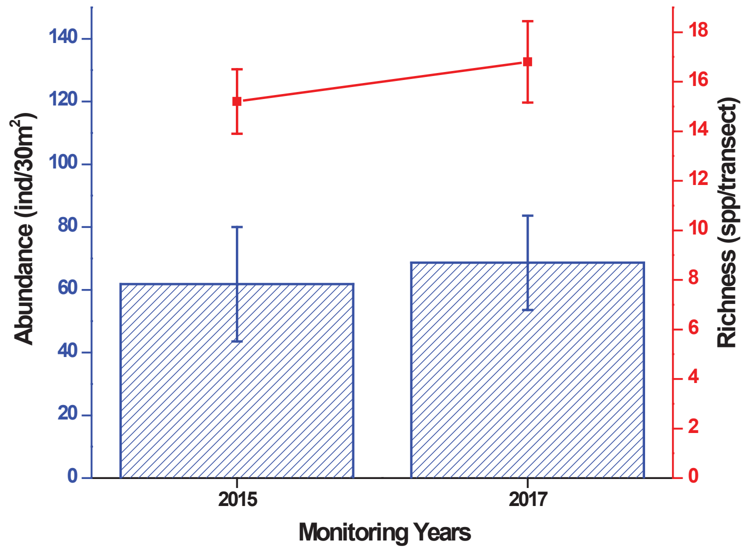


Figure 38. Monitoring trends (2015 – 2017) of fish species richness and abundance at Media Luna 3m, La Parguera. March 2017.

Table 45. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Media Luna 3m, La Parguera, 2017

		TRANSECTS					MEAN ABUNDANCE
Depth: 3 -5 m		**1**	**2**	**3**	**4**	**5**	
TAXA	**COMMON NAME**						**(IND/30 m2)**
Diadema antillarum	Long-spined Urchin	4	12	7	7	10	**8.0**
Panulirus guttatus	Rock Lobster	5	0	0	0	0	**1.0**
	TOTALS	9	12	7	7	10	**9.0**

11.4 Photo Album 11

Media Luna 5m - La Parguera

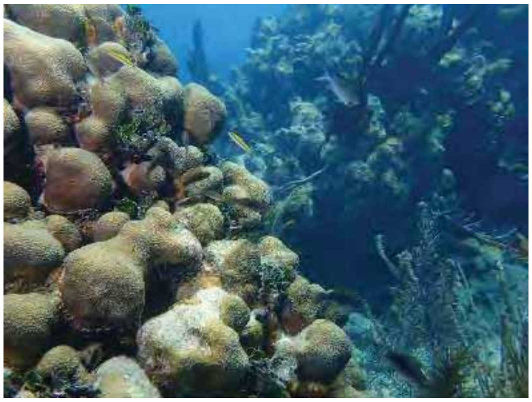















12.0 Cayo Coral - Guánica

12.1 Physical Description

Guánica is located on the southwest coast of Puerto Rico. The marine section of the Natural Reserve extends 8.9 kilometers along the coastline from the eastern corner of Guánica Bay in the West, almost to Punta Ventana in the East, and approximately 1.6 kilometers offshore from Punta Jacinto. There is a deep submarine canyon associated with Guánica Bay that cuts through the insular shelf and extends easterly towards the shelf-edge.

Cayo Coral is an emergent reef located to the west of Cayos de Caña Gorda, between Punta Ballena and the mouth of Guánica Bay (Figure 39). The reef is about two kilometers long and sits in the same platform as Caña Gorda Reef, at the northern edge of Guánica's submarine canyon. A series of submerged patch reefs are found to the north and east of Cayo Coral. Our survey was performed on the existing set of five permanent transects at a depth of 7 - 8 meters in the fore reef. Panoramic views of Cayo Coral are presented as Photo Album 12.

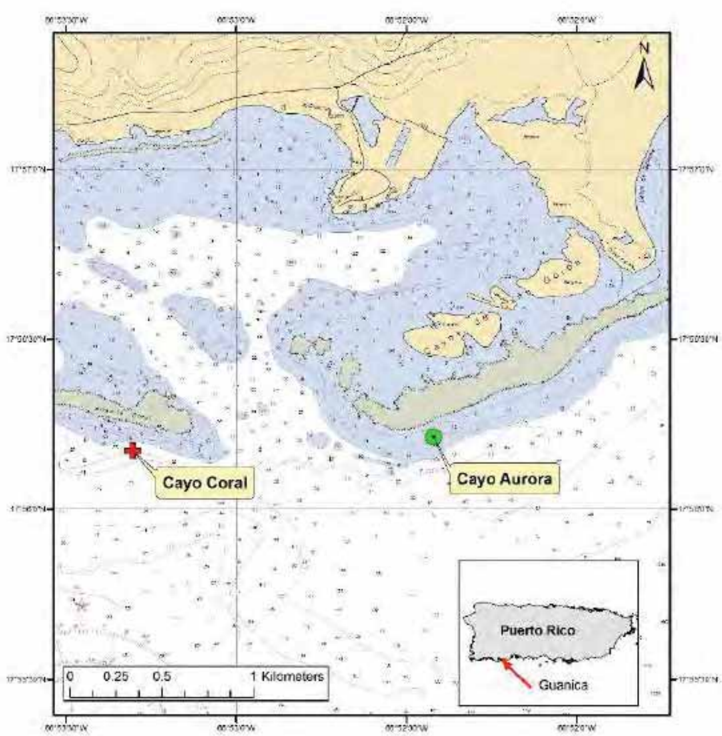


Figure 39. Location of coral reef survey stations at Cayo Coral Reef, Guánica.

12.2 Sessile-benthic Reef Community

A total of 17 stony corals, including 10 intersected by line transects were identified from Cayo Coral Reef during the 2017 survey (Table 46). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 14.3 % (range: 3.0 – 22.7%), with a mean of 7.8 Colonies/Transect. Boulder Star Coral, *Orbicella annularis* (complex) was the main species in terms of substrate cover with a mean of 5.5% (range: 1.6 – 11.5 %), representing 38.3 % of the total cover by stony corals and was present in all five transects. Boulder Brain Coral, *Colpophyllia natans, Massive Starlet Coral, Siderastrea siderea,* Mustard Hill Coral, *Porites astreoides,* Lettuce Coral, *Agaricia agaricites* and Symmetrical Brain Coral, *Pseudodiploria strigosa*, along with Boulder Star Coral comprised the main coral assemblage at Cayo Coral. Infectious diseases were observed in one of the 39 total coral colonies intercepted by transects at Cayo Coral during 2017 (Appendix 2).

Soft corals (gorgonians) were moderately abundant with an average of 23.4 colonies/transect. A total of 24 species of gorgonians are known to occur within the 7 – 10 m depth range at this reef (García-Sais et al. 2007). Some of the numerically dominant erect species present included the Sea Rods, *Eunicea sp*., *Plexaura spp*., and the Common Sea Fan, *Gorgonia ventalina*. Encrusting forms such as *Erythropodium caribaeorum* and *Briareum asbestinum* were intercepted in all transects with a combined mean substrate cover of 4.3 % (Table 46). The high abundance of gorgonians contributed substantial complexity and substrate heterogeneity to Cayo Coral, representing an important protective habitat to reef fishes and invertebrates. Sponges were represented within transects by 18 species with an average cover of 5.2 %. The encrusting species, *Cliona spp.* were the most prominent along transects. *Neopetrosia sp* and *Niphates erecta* were also common and present in four transects.

Benthic algae, comprised by turf, fleshy brown, green calcareous and crustose red macroalgae was the most prominent sessile-benthic category in terms of reef substrate cover with a combined mean of 53.9 % (range: 50.0 – 59.1 %). Turf algae, which represented 86.4% of the total benthic algae was found colonizing hard ground substrates, particularly dead coral colonies. Some dead coral colonies were also colonized by cyanobacteria, which was present in three transects surveyed with a mean

Table 46. Percent linear cover by sessile-benthic invertebrates at Cayo Coral, Guanica.
Survey date: March 28, 2017
Depth: 8m

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.95	2.712	3.034	3.034	4.644	**3.27**
Benthic Category						
Abiotic						
Rubble	13.84	6.83	14.39	15.57	6.98	**11.52**
Reef overhang		5.51	1.07	13.32	3.82	**4.74**
Sand	3.78	1.43	2.04	1.93	6.60	**3.16**
Total Abiotic	**17.62**	**13.77**	**17.51**	**30.83**	**17.40**	**19.42**
Benthic Algae						
Turf	44.76	55.95	43.18	42.86	46.46	**46.64**
Dictyota spp.	4.00	1.10	2.15	12.24	4.11	**4.72**
Peyssonnelia sp.	0.86	1.43	2.79	1.93	0.67	**1.54**
Halimeda spp.	0.22		0.75	0.97	0.48	**0.48**
Sargassum hystrix	0.32		1.07			**0.28**
Lobophora variegatus				0.75		**0.15**
CCA		0.66				**0.13**
Total Benthic Algae	**50.16**	**59.14**	**49.95**	**58.75**	**51.72**	**53.94**
Cyanobacteria	6.16	0.55			1.72	**1.69**
Live Coral						
Orbicella annularis complex	3.78	5.62	4.94	1.61	11.47	**5.48**
Colpophyllia natans			8.59			**1.72**
Siderastrea siderea	1.62	3.63	1.50	0.21		**1.39**
Porites astreoides	2.05		1.50		3.35	**1.38**
Agaricia agaricites	1.41	0.99	0.86		2.39	**1.13**
Pseudodiploria strigosa	2.92	1.54		1.18		**1.13**
Porites porites		0.88	2.58		1.15	**0.92**
Montastraea cavernosa		1.32	1.07		1.15	**0.71**
Meandrina meandrites			1.40			**0.28**
Madracis decactis	0.65		0.21			**0.17**
Total Live Coral	**12.43**	**13.99**	**22.66**	**3.01**	**19.50**	**14.32**
Coral Colonies/Transect	6	9	12	3	9	**7.8**
Octocoral						
Erythropodium caribaeorum	4.00	1.43	2.58	1.18	2.01	**2.24**
Briareum asbestinum	1.08	4.96	1.40	1.07	1.91	**2.08**
Pseudoplexaura flagellosa-wagenaari			0.86		0.19	**0.21**
Plexaura homomalla	0.32					**0.06**
Eunicea succinea		0.22				**0.04**
Gorgonia ventalina					0.19	**0.04**
Total Octocoral	**5.41**	**6.61**	**4.83**	**2.26**	**4.30**	**4.68**
# Gorgonians/transects	20	18	21	15	43	**23.40**
Sponge						
Cliona tenuis		2.42		0.43	1.82	**0.93**

Cliona caribbaea	1.08		1.93	0.64		**0.73**
Neopetrosia sp.	2.05	0.44		0.54	0.29	**0.66**
Petrosia pellasarca	2.92					**0.58**
Xestospongia muta	1.30			0.43		**0.35**
Chondrilla caribensis			0.21		1.15	**0.27**
Scopalina ruetzleri					1.34	**0.27**
Neopetrosia proxima			0.43	0.86		**0.26**
Niphates erecta	0.22	0.22	0.32	0.32		**0.22**
Aplysina fistularis			1.07			**0.21**
Niphates caribica		0.44			0.38	**0.16**
Amphimedon compressa		0.22		0.43		**0.13**
Ircinia strobilina				0.54		**0.11**
Clathria sp.		0.44				**0.09**
Ptilocaulis walpersii				0.43		**0.09**
Agelas sp.			0.32			**0.06**
Mycale laevis	0.22				0.10	**0.06**
Red sponge				0.21		**0.04**
Total Sponge	**7.78**	**4.19**	**4.30**	**4.83**	**5.07**	**5.23**

cover of 1.7 %. Abiotic substrates, contributed by reef overhangs, coral rubble and sand averaged 19.4%.

Figure 40 presents the variations of mean percent cover by sessile-benthic categories from Cayo Coral. Differences of reef substrate cover by live stony corals between surveys were statistically significant at a p-value of 0.085 (see Appendix 1). Total live coral cover at Cayo Coral declined after 2006 from 14.3% to 8.9 % in 2008, an overall reduction of 37.8 %. The reduction was associated with coral mortality (particularly Boulder Star Coral, *Orbicella annularis*) after the late 2005 coral bleaching event. The declining trend of live coral cover stabilized during 2009, with several massive coral species showing a recuperation trend. Since the 2010 survey, live coral cover at Cayo Coral exhibited an increasing trend that continued on to the 2015 monitoring survey and stabilized during 2017 at an average reef substrate cover of 14.3%, which is identical to the 2005 pre-bleaching status. The increasing trend was mostly driven by a consistent recuperation of reef substrate cover by Boulder Star Coral, *Orbicella annularis*, but contributions were also evident from *Colpophyllia natans*, *Porites astreoides* and *Siderastrea siderea* (Figure 35).

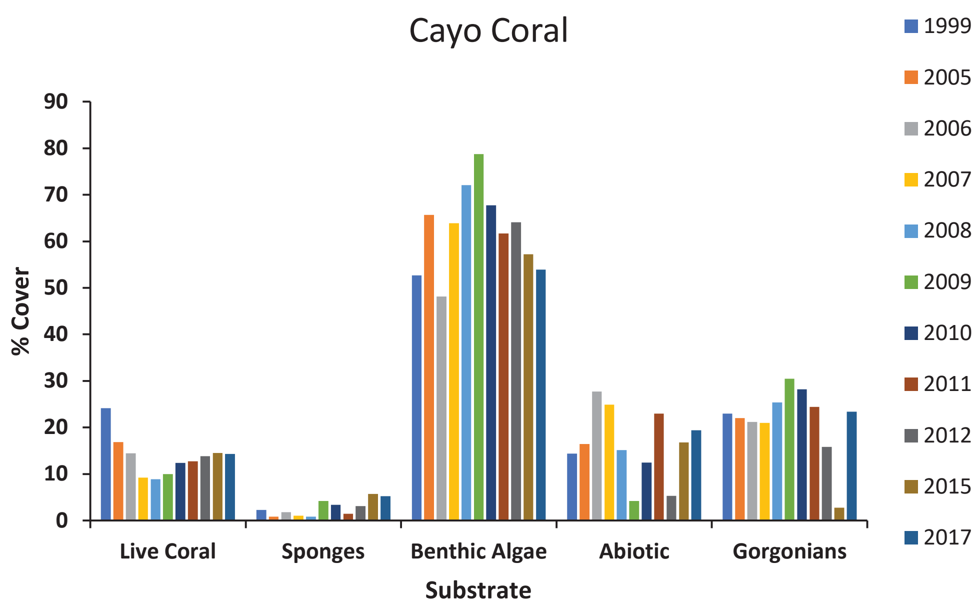


Figure 40. Monitoring trends (1999 – 2017) of mean substrate cover by sessile-benthic categories at Cayo Coral – 8 m, Guánica.

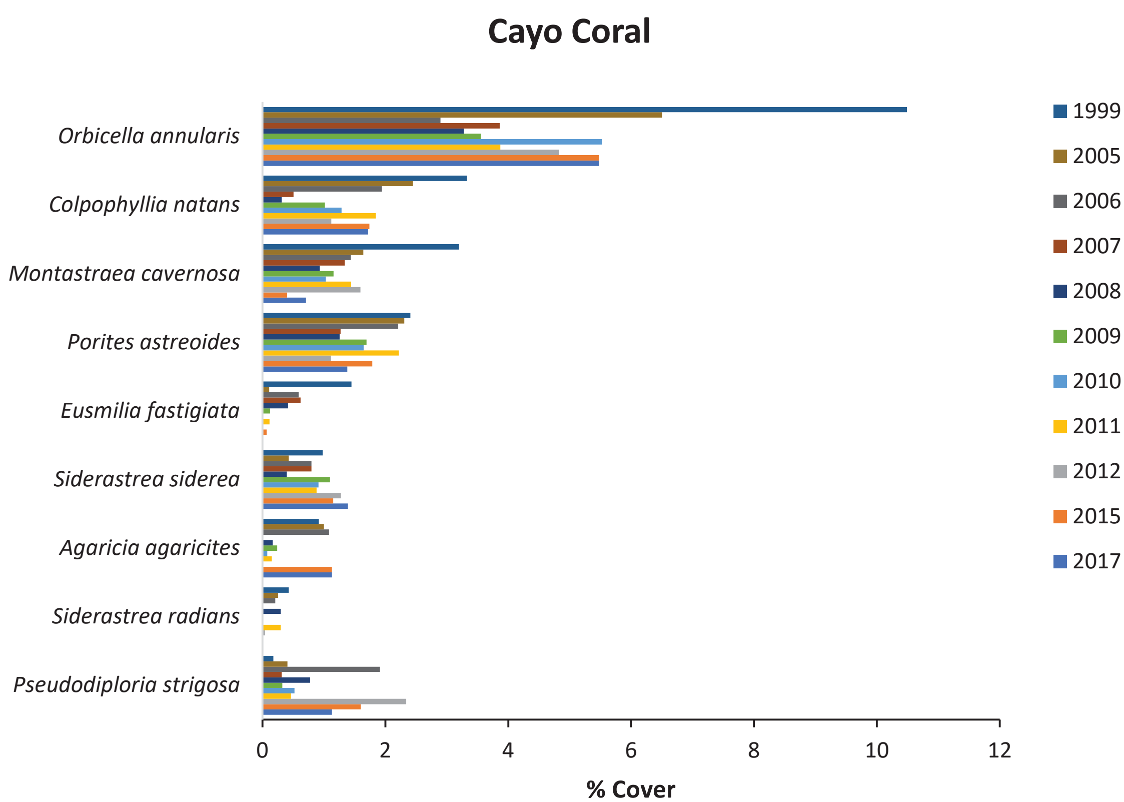


Figure 41. Monitoring trends (1999 – 2017) of mean substrate cover by stony coral species at Cayo Coral – 8 m, Guánica

12.3 Fishes and Motile Megabenthic Invertebrates

A total of 117 fish species have been identified from Cayo Coral during monitoring surveys (Appendix 4). Mean abundance within belt-transects during the 2017 survey was 35.0 Ind/30 m^2 (range: 20 - 46 Ind/30 m^2). The mean number of species per transect was 15.2 (H'= 118.9). Sharknose Goby (*Elacatinus evelynae*), Yellow-eye and Dusky Damselfishes (*Microspathodon chrysurus, Stegastes adustus),* Redband, Stoplight and Striped Parrotfishes (*Sparisoma aurofrenatum, S. viride, Scarus iserti*) were present in all transects and along with Princess Parrotfish (*S. taeniopterus*) and Bluehead Wrasse (*Thalassoma bifasciatum*) were the numerically dominant assemblage at Cayo Coral with a combined abundance of 22.2 Ind/30 m^2, representing 63.4% of the total abundance within belt-transects (Table 47).

Early juvenile and young adult parrotfishes (*Scarus iserti, S. taeniopterus, Sparisoma viride, S. aurofrenatum*) and doctorfishes (*Acanthurus spp*) were the most abundant fishes within extended belt-transects (Table 48). Juvenile and adult Graysbes (*Cephalopholis cruentatus*) and one adult Yellowtail Snapper (*Ocyurus chrysurus*) were also present at Cayo Coral. One Hogfish (*Lachnolaimus maximus*) was observed out of transects.

The fish community structure of Cayo Coral appears to be strongly driven by herbivores represented within extended belt-transects by four species of parrotfishes (*Scarus sp., Sparisoma sp*.), five damselfishes (*Stegastes spp., Microspathodon sp*), and three doctorfishes (*Acanthurus spp*) that comprised 55.4% of the total fish individuals. Small, opportunistic micro-invertebrate predators, such as wrasses (*Thalassoma sp., Halichoeres spp*), gobies (*Elacatinus, Coryphopterus spp*.), puffers (Canthigaster sp), Squirrelfishes (*Holocentrus spp*) and sea basses (*Serranus sp*) were also prominent with approximately 31.4% of the total individuals. Conversely, demersal and pelagic zooplanktivores (*Chromis spp, Stegastes partitus*) represented less than 10% of the total individuals within transects. Among large invertebrate and small demersal fish predators, small groupers such Graysby and Yellowtail Snappers were common. Juvenile Yellowfin Grouper and Jewfish, Red Hind, Nassau Grouper, Hogfish, Schoolmaster, Mahogany and Yellowtail Snappers have been previous reported during

Table 47. Taxonomic composition and abundance of fishes within belt-transects at Cayo Coral Guanica, March 2017

Depth: 10m

		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Elacatinus evelynae	Sharknose Goby	2	6	9	1	6	**4.8**
Scarus taeniopterus	Princess Parrotfish	14		3	2		**3.8**
Stegastes planifrons	Yellow-eye Damselfish	3	6	3	3	3	**3.6**
Stegastes dorsopunicans	Dusky Damselfish	4	1	6	5	1	**3.4**
Sparisoma aurofrenatum	Redband Parrotfish	2	3	3	1	3	**2.4**
Thalassoma bifasciatum	Bluehead Wrasse	4				7	**2.2**
Sparisoma viride	Stoplight Parrotfish	3	1	3	1	2	**2.0**
Chromis cyanea	Blue Chromis	3		3	1		**1.4**
Sparisoma radians	Bucktooth Parrotfish	2	1	1	2	1	**1.4**
Canthigaster rostrata	Caribbean Puffer	1	2			3	**1.2**
Coryphopterus sp.	Goby	2		1	1	2	**1.2**
Chaetodon capistratus	Four-eye Butterflyfish		1	2		2	**1.0**
Stegastes partitus	Bicolor Damselfish	1		2		2	**1.0**
Microspathodon chrysurus	Yellowtail Damselfish	1	1		1	1	**0.8**
Acanthurus bahianus	Ocean Surgeon	1	1	1			**0.6**
Acanthurus coeruleus	Blue Tang	2				1	**0.6**
Cephalopholis cruentatus	Graysby		1			1	**0.4**
Holocentrus coruscus	Reef Squirrelfish			2			**0.4**
Scarus iserti	Stripped Parrotfish			2			**0.4**
Stegastes leucostictus	Beaugregory		1			1	**0.4**
Odontoscion dentex	Reef Croaker			1			**0.2**
Chaetodon striatus	Banded Butterflyfish					1	**0.2**
Gymnothorax moringa	Spotted Moray				1		**0.2**
Coryphopterus glaucofraenum	Bridled Goby					1	**0.2**
Haemulon flavolineatum	French Grunt		1				**0.2**
Halichoeres garnoti	Yellow-head Wrasse	1					**0.2**
Holocentrus rufus	Longspine Squirrelfish					1	**0.2**
Pomacanthus arcuatus	Grey Angelfish					1	**0.2**
Pseudupeneus maculatus	Spotted Goatfish				1		**0.2**
Serranus tigrinus	Harlequin Bass					1	**0.2**
	TOTAL INDIVIDUALS	**46**	**26**	**42**	**20**	**41**	**35.0**
	TOTAL SPECIES	**16**	**13**	**15**	**12**	**20**	**15.2**

Table 48. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at Cayo Coral, Guanica, March 2017

		TRANSECTS				
		1	2	3	4	5
		(Individuals/60 m^2)				
SPECIES	**COMMON NAME**					
Acanthurus bahianus	Ocean Surgeon	1 - 13	2 - 15 1 - 10			1 - 15
Acanthurus coeruleus	Blue Tang	1 - 5 1 - 8			1 - 10	1 - 8
Cephalopholis cruentatus	Graysbe		1 - 15			1 - 30
Sparisoma viride	Stoplight Parrotfish	1 - 5 1 - 13	1 - 5	3 - 5 2 - 10 1 - 25	1 - 5 1 - 25	1 - 3 1 - 25
Sparisoma aurofrenatum	Redband Parrotfish	2 - 10	2 - 15 1 - 28 1 - 10		1 - 13 1 - 20	2 - 10 1 - 18
Scarus taeniopterus	Princess Parrotfish	12 - 5 2 - 8	3 - 8	3 - 5	2 - 10	
Scarus iserti	Striped Parrotfish		2 - 8			
Ocyurus chrysurus	Yellowtail Snapper					1 - 18

monitoring surveys at Cayo Coral (Garcia-Sais et al., 2006, 2014). Schooling zooplanktivore species, such as the Mackerel Scad are transitory at Cayo Coral and serve as forage for several pelagic predators, particularly Cero Mackerels and Great Barracudas. Several Bottlenose dolphins were reported from Cayo Coral during the 2010 survey (Garcia-Sais et al., 2012).

Figure 42 presents monitoring trends of fish abundance and species richness from Cayo Coral. Variations of fish abundance and species richness between monitoring surveys were statistically significant (ANOVA; $p < 0.001$, Appendix 5 - 6). Both species richness and abundance have shown marked fluctuations between monitoring surveys. Such high variability of the fish community structure appears to be associated in part with the physical conditions as influenced by wave action due to the relatively shallow depth. Another relevant factor is the natural abundance fluctuations of numerically dominant fishes, such as Masked Goby (*Coryphopterus personatus*), Creole Wrasse (*Clepticus parrae*) and *Chromis spp*. The temporal fluctuations of abundance by these small, short

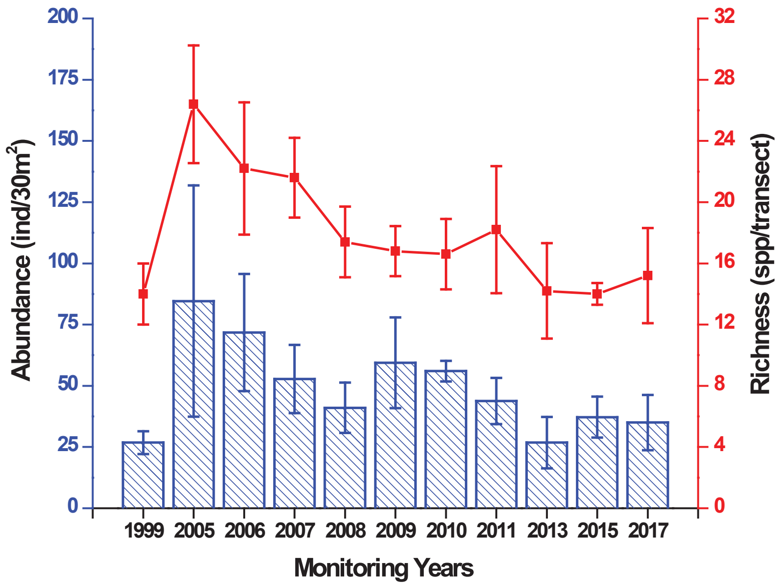


Figure 42. Monitoring trends (1999 – 2017) of fish species richness and abundance at Cayo Coral, Guanica Natural Reserve

generation schooling fishes appear to be strongly influenced by density independent factors, such as recruitment success (Esteves, 2013). More specific research needs to be address to this subject to explain the sharp inter-annual abundance variability exhibited by these numerically dominant populations in shallow reefs.

One Queen Conch was the only motile megabenthic invertebrate observed within belt-transects (Table 49).

Table 49. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Coral, Guánica. 2017

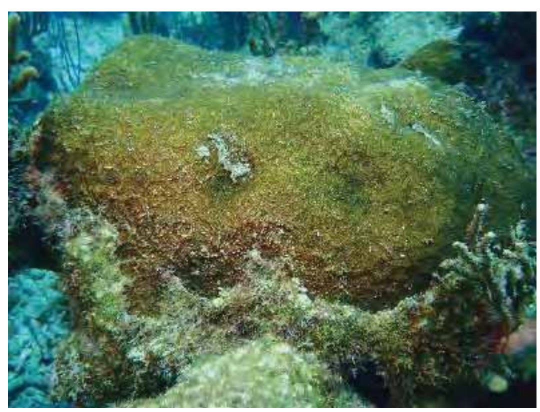
Depth: 7 -10 m

TAXA	COMMON NAME	TRANSECTS 1	2	3	4	5	MEAN ABUNDANCE (IND/30 m2)
Strombus gigas	Queen Conch	0	0	0	1	0	**0.2**
	TOTALS	0	0	0	1	0	**0.2**

12.4 Photo Album 12
Cayo Coral Reef – Guanica





13.0 Cayo Aurora – Guanica

13.1 Physical Description

Cayo Aurora, also known as “Gilligan Island” is an emergent section of Cayos de Caña Gorda, a fringing coral reef system that extends southwesterly from Punta Ballena in the east towards Punta Jacinto in the west. The reef is approximately 2.3 km long and at least 1 km wide. It is separated from Cayo Coral by a deep submarine canyon that cuts through the insular shelf and extends easterly towards the shelf-edge. A georeferenced map of benthic habitats and qualitative characterization of marine communities associated with the main benthic habitats at Cayo Aurora was prepared by Garcia-Sais et al. (2005). The fore-reef of Cayo Aurora is characterized by a gently sloping terrace where Elkhorn Coral, *Acropora palmata* represents the main reef structural component, creating a biotope intermixed with sparsely distributed massive and encrusting corals and gorgonians at depths between 2 – 5 m (Garcia-Sais et al, 2005). Transects installed during the 2011 baseline survey were not found, thus another set of transects were installed in the general vicinity of the previous set in 2013. No significant differences of coral cover, nor of cover by the dominant coral species, *A. palmata* were found. Thus, the data has been added to the present monitoring series. Transects were established at a depth of 3 - 4 m along the western section of Cayo Aurora ‘s fore-reef, at the deepest edge of a well-defined *A. palmata* zone (Figure 39). Panoramic views of Cayo Aurora are shown in Photo Album 13.

13.2 Sessile-benthic Reef Community

A total of 15 stony corals, including seven intersected by transects were identified from Cayo Aurora during the 2017 survey (Table 50). Substrate cover by stony corals along transects averaged 35.2 % (range: 23.6 – 46.4 %), with a mean of 9.2 colonies/transect. Elkhorn Coral, *Acropora palmata* was the main coral species in terms of substrate cover with a mean of 32.2% (range: 23.3 – 43.8 %), representing 91.5% of the total cover by stony corals (Table 50). Mustard Hill Coral, *Porites astreoides*, Massive Starlet Coral, *Siderastrea siderea*, Symmetrical Brain Coral, *Pseudodiploria strigosa*, Staghorn Coral, *Acropora cervicornis* and Fire Coral, *Millepora complanata* comprised the coral assemblage within transects. Elkhorn coral colonies were observed growing from a hard ground bottom covered by sand. Most colonies were very large, extending laterally and vertically more than two meters and in most instances, not overlapping with each other. During the baseline and previous monitoring surveys, Elkhorn Coral colonies were found in very good health condition and dead standing or large broken fragments were uncommon. During this 2017 survey, *A. palmata* fragments of variable dimensions, including many large branches were abundant over the reef bottom, but none were observed to be infected by coral diseases (Appendix 2). Many of these fragments were still alive and the larger fragments were counted as live coral substrate cover by *A. palmata* in this survey, since it is possible that these large fragments develop as new colonies in the reef. Evidently, this reef was exposed to extreme wave action between the 2015 and the present survey and the broken colonies appear to have resulted from mechanical damage.

Vertically projected soft corals (gorgonians), mostly the Common Sea Fan, *Gorgonia ventalina* and a few Sea Rods, *Eunicea spp*. were sparsely distributed within the hard bottom at Cayo Aurora with a mean of 0.4 colonies/transect. Also, the encrusting gorgonian, *Erythropodium caribaeorum* was present in four transects a mean substrate cover of 1.4%. Sponges were intercepted by all transects with a mean substrate cover of 2.1%. *Chondrilla caribensis* was present in four transects with a mean cover of 1.5%. The encrusting species, *Cliona caribbaea* and *C. tenuis* were also present. The encrusting zoanthid, *Palythoa sp.* was present in four transects with a mean cover of 4.7% (Table 50). A mixed assemblage of short filamentous algae, or turf algae were the main biotic category colonizing hard ground at Cayo Aurora with a mean of 33.1 % (range: 21.0 – 46.1 %). Turf algae represented 87.3% of the total cover by benthic algae (Table 50). Crustose red coralline algae, *Ramicrusta sp* and *Peyssonnelia sp*. were present in four and three transects, respectively with a combined reef substrate cover of 1.8%. Abiotic cover, which averaged 18.0 % was mostly associated with the large overhangs created by Elkhorn Coral branches and gaps.

Figure 43 shows the mean cover by substrate categories at Cayo Aurora during the 2011 baseline and subsequent monitoring surveys. Differences of total cover between surveys were not statistically different (ANOVA, $p = 0.553$; Appendix 2). Elkhorn Coral represented more than 86% of the total cover by corals in all four surveys and although substantial breakage of branches was noted for the 2017 survey, most fell along the transects and were still alive during the monitoring survey and were quantified as live coral cover, with only small reductions to the overall live coral cover (Figure 44).

Table 50. Percent linear cover by sessile-benthic invertebrates at Cayo Aurora Reef, Guanica 3 m. Survey date: March 28, 2017

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.98	2.46	2.15	2.99	3.89	2.89
Benthic Category						
Abiotic						
Reef overhang	12.51	4.94	10.25	12.07	38.81	15.72
Gap			3.92	0.97	3.73	1.72
Sand					1.51	0.30
Rubble				1.08		0.22
Total Abiotic	**12.51**	**4.94**	**14.17**	**14.12**	**44.05**	**17.96**
Benthic Algae						
Turf	42.83	34.04	21.54	46.12	20.97	33.10
CCA		3.15	5.18	4.53	2.32	3.03
Ramicrusta sp.	0.32	5.39	0.35	0.65		1.34
Peyssonnelia sp.		0.90	0.92		0.40	0.44
Total Benthic Algae	**43.15**	**43.48**	**28.00**	**51.29**	**23.69**	**37.92**
Live Corals						
Acropora palmata	33.87	30.45	43.78	23.28	29.84	32.24
Porites astreoides	1.29	2.02	2.30		0.20	1.16
Millepora alcicornis	0.97	1.91	0.35			0.65
Siderastrea siderea	2.27					0.45
Pseudodiploria strigosa		2.25				0.45
Acropora cervicornis	0.76					0.15
Agaricia agaricites		0.34		0.32		0.13
Total Live Coral	**39.16**	**36.97**	**46.43**	**23.60**	**30.04**	**35.24**
Coral Colonies /Transect	9	6	12	10	9	**9.2**
Zoanthids						
Palythoa caribaeorum	3.13	7.08	6.91	6.47		4.72
Octocorals						
Erythropodium caribaeorum	2.05	1.12	1.50		2.02	1.34
Plexaura homomalla		0.22				0.04
Total Octocoral	**2.05**	**1.35**	**1.50**		**2.02**	**1.38**
Coral Colonies/ Transect	9	6	12	10	9	9.2
Gorgonian Colonies/transect		1			1	0.40
Sponges						
Chondrilla caribensis		2.36	3.00	1.94		1.46
Cliona caribbaea		2.36		2.26		0.92
Cliona tenuis		1.46				0.29
Monanchora arbuscula				0.32		0.06
Ircinia sp. brown					0.20	0.04
Total Sponge		**6.18**	**3.00**	**4.53**	**0.20**	**2.78**

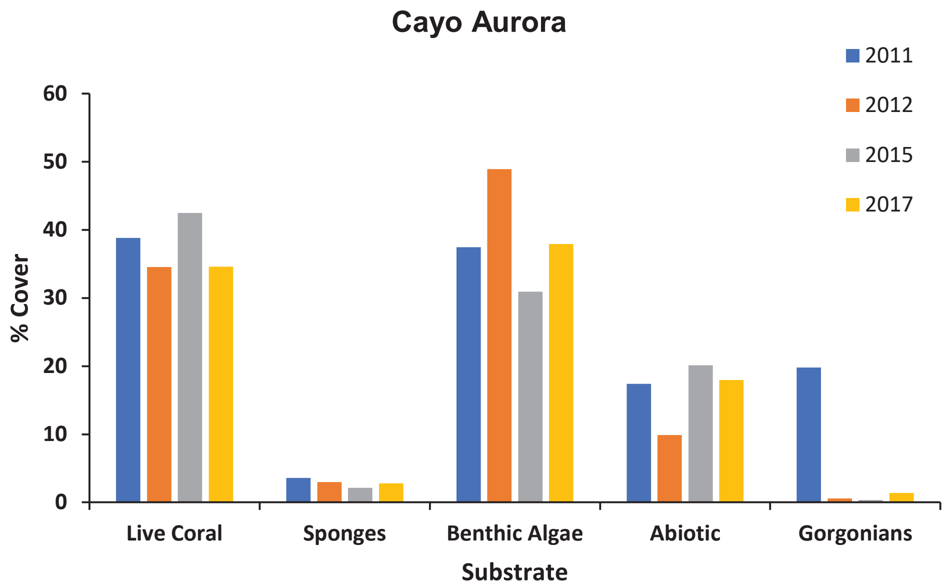


Figure 43. Monitoring trends (2011 – 2017) of mean substrate cover by sessile-benthic categories at Cayo Aurora– 3 m, Guánica.

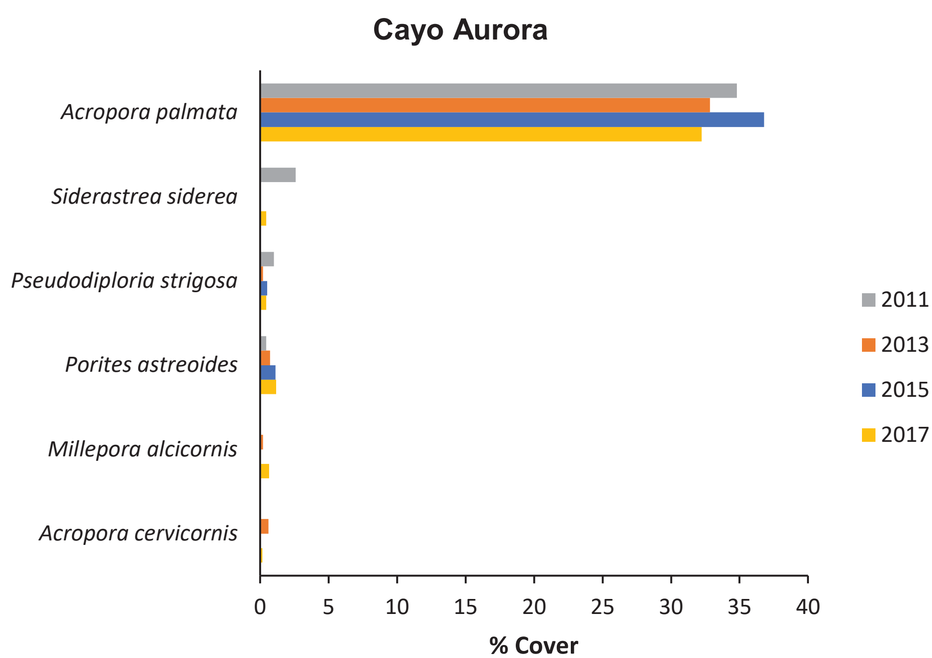


Figure 44. Monitoring trends (2011 – 2017) of mean substrate cover by stony coral species at Cayo Aurora – 3 m, Guánica

13.3 Fishes and Motile Megabenthic Invertebrates

A total of 78 fish species were identified from the fore reef of Cayo Aurora, Guanica within a depth range of 2–5 meters (Appendix 4), including 29 observed within belt-transects during this 2017 survey. The mean abundance of individuals was 48.8 Ind/30 m^2 (range: 41 – 55 Ind/30 m^2), and the mean number of species per transect was 13.8 (H'= 119.4). The combined abundance of four numerically dominant species, including the Bluehead Wrasse (*Thalassoma bifasciatum*) and the Dusky, Bicolor and Yellowtail Damselfish (*Stegastes adustus. S. partitus, Microspathodon chrysurus*) represented 61.1 % of the total mean abundance within belt-transects (Table 51). The Brown Chromis (*Chromis cyanea*), Reef Squirrelfish (*Holocentrus rufus*) and Saddled Blenny (*Malacoctenus triangulatus*) were present in four out of the five transects and along with the aforementioned numerically dominant species comprised the most common fish assemblage. The Redlip Blenny (*Ophioblennius atlanticus*), Yellowhead Wrasse (*Halichoeres garnoti*) and Clown Wrasse (*Halichoeres maculipinna*) have also been consistently observed within transects surveyed at Cayo Aurora and appear to be part also of the main residential fish assemblage. Schools of Blue Tangs (*Acanthurus coeruleus*) were observed in transit within and outside transect areas. A total of six fish species were only represented by one individual within belt-transects.

Commercially important fish species were mostly represented by parrotfishes (*Scarus iserti, Sparisoma rubripinne, S. aurofrenatum, S. viride*) and doctorfishes (*Acanthurus spp*), all of which were present as juvenile and small adults. Post-settlement juveniles of Stoplight Parrotfish were observed (Table 52). Juvenile and adult Schoolmaster snappers (*Lutjanus apodus*), one adult Coney (*Cephalopholis fulva*) and one juvenile Yellowfin Grouper (*Mycteroperca venenosa*) were observed within the extended belt-transect areas.

In general, the fish community at Cayo Aurora was comprised by a prominent assemblage of herbivores, represented by a total of four species of parrotfishes (Scaridae), three species of doctorfishes (Acanthuridae), and four species of damselfishes (Pomacentridae) that comprised approximately 39.8 % of the total individuals within belt-transects. A diverse assemblage of small opportunistic invertebrate feeders, such as the wrasses, squirrelfishes, blennies, grunts and small groupers was also prominent in the reef, representing 33.8% of the total.

Table 51. Taxonomic composition and abundance of fishes within belt-transects at Cayo Aurora 3 m Guanica, March 2017

Depth: 3m		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m²)					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	23	10	8	5	7	**10.6**
Stegastes adustus	Dusky Damselfish	9	8	14	9	8	**9.6**
Stegastes partitus	Bicolor Damselfish	2	10	11		5	**5.6**
Microspathodon chrysurus	Yellowtail Damselfish	5	4	3	6	2	**4.0**
Chromis multilineata	Brown Chromis	2	4	3		2	**2.2**
Halichoeres maculipinna	Clown Wrasse	2	3			4	**1.8**
Stegastes variabilis	Cocoa Damselfish	3		3		3	**1.8**
Holocentrus coruscus	Reef Squirrelfish		1	3	2	2	**1.6**
Ophioblennius macclurei	Redlip Blenny	3	3	1			**1.4**
Malacoctenus triangulatus	Saddled Blenny	1	3		2	1	**1.4**
Acanthurus bahianus	Ocean Surgeon			2	2	2	**1.2**
Lutjanus apodus	Schoolmaster Snapper				4		**0.8**
Sparisoma viride	Stoplight Parrotfish		1			3	**0.8**
Amblycirrhitus pinos	Redspotted Hawkfish	1		1	1		**0.6**
Lutjanus mahogoni	Mahogany Snapper				3		**0.6**
Scarus iserti	Stripped Parrotfish		3				**0.6**
Sparisoma aurofrenatum	Redband Parrotfish	1		1		1	**0.6**
Acanthurus coeruleus	Blue Tang			1		1	**0.4**
Chaetodon striatus	Banded Butterflyfish				2		**0.4**
Haemulon flavolineatum	French Grunt		1		1		**0.4**
Haemulon chrysargyreum	Stripped Grunt			1	1		**0.4**
Halichoeres bivittatus	Slippery Dick		2				**0.4**
Holocentrus adcensionis	Squirrelfish				2		**0.4**
Acanthurus chirurgus	Doctorfish	1					**0.2**
Cephalopholis fulva	Coney			1			**0.2**
Haemulon plumieri	White Grunt				1		**0.2**
Halichoeres radiatus	Puddinwife		1				**0.2**
Holocentrus rufus	Longspine Squirrelfish				1		**0.2**
Sparisoma rubripinne	Yellowtail Parrotfish		1				**0.2**
	TOTAL INDIVIDUALS	**53**	**55**	**53**	**42**	**41**	**48.8**
	TOTAL SPECIES	**12**	**15**	**14**	**15**	**13**	**13.8**

Table 52. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at Cayo Aurora 3 m, Guanica, March 2017

		TRANSECTS				
		1	2	3	4	5
		(Individuals/60 m^2)				
SPECIES	**COMMON NAME**					
Acanthurus bahianus	Ocean Surgeon			2 - 15	2 - 10	2 - 13
Acanthurus coeruleus	Blue Tang		1 - 10	1 - 8	2 - 10	1 - 15
Acanthurus chirurgus	Doctorfish					1 - 13
Sparisoma viride	Stoplight Parrotfish	1 - 20	1 - 1	1 - 30		1 - 3
						2 - 13
Sparisoma aurofrenatum	Redband Parrotfish	1 - 15		1 - 20		
				1 - 13		
Sparisoma rubripinne	Yellowtail Parrotfish		1 - 28			
Scarus iserti	Striped Parrotfish	3 - 5				
Lutjanus apodus	Schoolmaster Snapper			1 - 23	1 - 10	
					1 - 20	
Cephalopholis fulva	Coney			1 - 25		
Mycteroperca venenosa	Yellowfin Grouper				1 - 30	

Zooplanktivores were represented by the Bicolor Damselfish and Brown Chromis with a combined abundance of 7.8 Ind/30 m^2, or 16.0% of the total individuals within belt-transects. Large invertebrate and piscivores were best represented by snappers (Lutjanidae), one juvenile Yellowfin Grouper (Serranidae), Great Barracuda (Sphyraenidae) and Jacks (Carangidae).

Differences of total fish abundance and species diversity between monitoring surveys (Figure 45) were not statistically significant (ANOVA, $p > 0.05$; Appendix 5-6). Motile megabenthic invertebrates were not observed within belt-transects (Table 53).

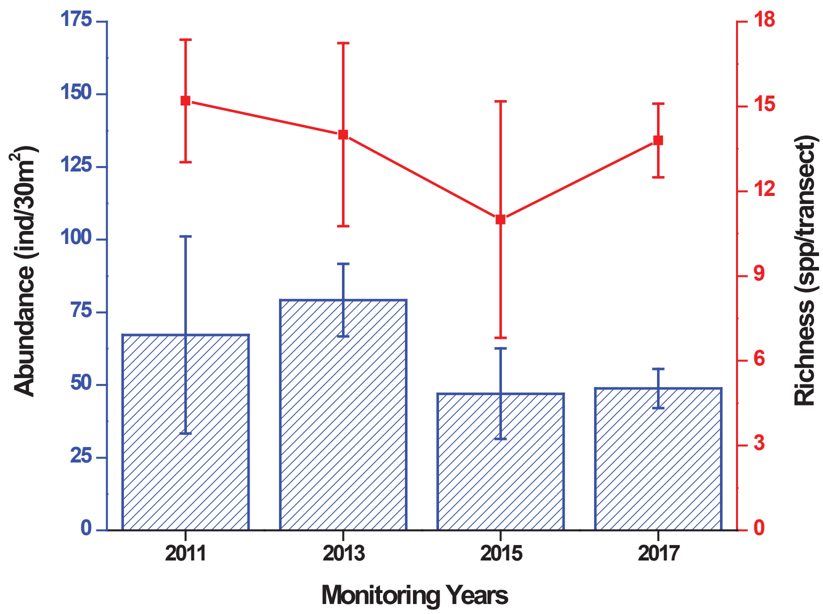


Figure 45. Monitoring trends (2011 – 2017) of fish species richness and abundance at Cayo Aurora Reef, 3 m, Guanica Natural Reserve

Table 53. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Aurora, Guanica. 2017.

Depth: 2 - 5 m		**TRANSECTS**					**MEAN ABUNDANCE**
		1	**2**	**3**	**4**	**5**	**(IND/30 m2)**
TAXA	**COMMON NAME**						
none		0	0	0	0	0	**0**
	TOTALS	**0**	**0**	**0**	**0**	**0**	**0**

13.4 Photo Album 13
Cayo Aurora - Guanica
















14.0 Efra's Wall Reef - Guanica

14.1 Physical Description

A spur and groove coral reef formation has developed at depths between 17 – 23 m along the shelf-edge of the southwest coast of Puerto Rico, from Guanica to La Parguera, Lajas. Spurs run north - south, perpendicular to the shelf-edge and present variable dimensions. Our reef monitoring station, known as Efra's Wall (Figure 39) is a popular dive site identified with a mooring buoy which facilitates diving activities without the anchoring effects. Spurs were of relatively low relief (about one meter) increasing towards the edge and separated by sand channels. Five permanent transects were installed on top of the spurs about 20 m from the shelf-edge at depths of 18 – 20 meters. The baseline characterization was performed during 2015 and this represents the first monitoring survey for this reef. Panoramic view of the Guanica shelf-edge reef is included here as Photo Album 14.

14.2 Sessile Benthic Community

A total of 20 species of stony corals were identified from Efra's Wall Reef in Guanica, 12 of which were intercepted by line transects during the 2017 monitoring survey. The mean substrate cover by live corals was 15.8 % (range: 13.6 – 18.5 %), with a mean of 9.0 colonies/transect. Boulder Star Coral, *Orbicella annularis* complex was the dominant coral species in terms of reef substrate cover with a mean of 7.9 % (range: 4.5 – 12.5 %), representing 50.0 % of the total cover by corals (Table 54). *Orbicella* was present in all transects along with Mustard Hill Coral, *Porites astreoides* and Lettuce Coral, *Agaricia agaricites* with mean substrate cover of 1.4 and 1.0 %, respectively. Great Star Coral, *Montastrea cavernosa*, Massive Starlet Coral, *Siderastrea siderea*, Blushing Starlet Coral, *Stephanocoenia intersepta,* Fire Coral*, Millepora alcicornis* and Ten-Ray Coral, *Madracis decactis* were present along three transects. The aforementioned species comprised the main coral assemblage intercepted by transects at Efra's Wall Reef in Guanica. Other four species were present in one or two transects with an average cover of less than 1%. Coral diseases were not observed in any of the 42 colonies intercepted by transects during 2017 (Appendix 2).

Soft corals or gorgonians were prominent at Efra's Wall Reef with a mean combined density of 26.8 colonies per transect (Table 54). Some of the most abundant species included *Pseudoplexaura flagellosa*, *Gorgonia ventalina, Eunicea spp*. and *Muricea sp*.

Table 54. Percent linear cover by sessile-benthic invertebrates at Guanica shelf-edge reef 20 m.

Survey date: March 27, 2017

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	12.92	11.26	13.02	12.60	11.89	**12.34**
Benthic Category						
Abiotic						
Rubble			1.94	7.89	10.95	**4.16**
Sand			1.61	2.00	6.01	**1.92**
Reef overhang				0.78		**0.16**
Gap					0.71	**0.14**
Total Abiotic			**3.55**	**10.67**	**17.67**	**6.38**
Benthic Algae						
Turf with sediment	24.27	13.81	19.25	24.00	17.20	**19.70**
Algal turf	12.68	18.66	19.68	14.67	17.43	**16.62**
Lobophora variegatus	10.40	40.05	11.61	11.00	9.66	**16.54**
Dictyota spp.	17.33	8.21	5.59	3.33	6.48	**8.19**
CCA				1.44	3.42	**0.97**
Red fleshy algae				2.56		**0.51**
Peyssonnelia sp.	0.54		1.08			**0.32**
Total Benthic Algae	**65.22**	**80.72**	**57.20**	**57.00**	**54.18**	**62.87**
Cyanobacteria	8.67		7.53	5.67	2.36	**4.84**
Live Coral						
Orbicella annularis complex	11.92	4.48	12.47	4.89	5.54	**7.86**
Montastraea cavernosa	3.14			4.67	1.77	**1.92**
Porites astreoides	0.54	3.11	1.94	1.11	0.35	**1.41**
Agaricia agaricites	0.87	0.25	1.51	1.56	1.06	**1.05**
Siderastrea siderea	0.33	4.23			0.59	**1.03**
Porites porites					3.30	**0.66**
Pseudodiploria strigosa			1.08		1.77	**0.57**
Stephanocoenia intersepta		1.24	0.22		0.47	**0.39**
Dichocoenia stokesi	0.22			1.33		**0.31**
Madracis decactis	0.43			0.56	0.35	**0.27**
Mycetophyllia aliciae	1.08					**0.22**
Millepora alcicornis		0.25	0.22	0.22		**0.14**
Total Live Coral	**18.53**	**13.56**	**17.42**	**14.33**	**15.19**	**15.81**
Coral Colonies/Transect	12	8	9	7	9	**9.0**
Octocoral						
Erythropodium caribaeorum			0.65		1.77	**0.48**
Briareum asbestinum				1.11		**0.22**
Eunicea flexuosa					1.06	**0.21**
Eunicea sp.			0.32		0.24	**0.11**
Muricea pinnata			0.54			**0.11**
Pseudoplexaura flagellosa-wagenaari	0.22			0.22		**0.09**
Eunicea tourneforti			0.43			**0.09**
Plexaura homomalla				0.33		**0.07**

Total Octocoral	**0.22**		**1.94**	**1.67**	**3.06**	**1.38**
# Gorgonians/transect	24	33	27	30	20	**26.80**
Sponge						
Agelas conifera		1.00	0.65	1.89	3.30	**1.37**
Xestospongia muta			4.84			**0.97**
Iotrochota birotulata	0.98	0.62		2.44		**0.81**
Agelas dispar	2.49			1.11		**0.72**
Dead Xestospongia muta			3.23			**0.65**
Plaktoris sp.		1.00		0.44	0.59	**0.41**
Neopetrosia sp.		0.50	1.08			**0.31**
Ectyoplasia ferox					1.53	**0.31**
Agelas sp.	0.22	0.62	0.65			**0.30**
Niphates caribica	0.43		0.32	0.56		**0.26**
Neopetrosia proxima		0.37		0.89		**0.25**
Ircinia felix		0.62	0.54			**0.23**
Agelas tubulata				1.11		**0.22**
Chondrilla caribensis				1.11		**0.22**
Black sponge	0.65			0.33		**0.20**
Ircinia sp. brown		0.25			0.71	**0.19**
Scopalina ruetzleri		0.25	0.22		0.47	**0.19**
Ircinia felix	0.87					**0.17**
Ircinia strobilina	0.54	0.25				**0.16**
Verongula sp.					0.71	**0.14**
Sponge			0.65			**0.13**
Clathria sp.				0.56		**0.11**
Aplysina fistularis	0.54					**0.11**
Amphimedon compressa				0.22	0.24	**0.09**
Agelas clathrodes	0.43					**0.09**
Aplysina cauliformis		0.25				**0.05**
Mycale laevis	0.22					**0.04**
Niphates erecta			0.22			**0.04**
Total Sponge	**7.37**	**5.72**	**12.37**	**10.67**	**7.54**	**8.73**

The encrusting types, *Erythropodium caribaeorum, and Briareum asbestinum* contributed a combined mean substrate cover of 0.7%.

At least 28 sponge species were intercepted by transects with a combined reef substrate cover of 8.7 % (range: 5.7 – 12.4%). The Brown Tube Sponge, *Agelas conifera*, Green Finger Sponge, *Iotrochota birotulata* and Giant Barrel Sponge, *Xestospongia muta* comprised the main taxonomic assemblage in terms of reef substrate cover (Table 54). In general, sponges were present as mostly small, encrusting forms with the exception of *X. muta*. One *X. muta* carcass (dead colony) was intercepted in transect 3. Benthic algae were the dominant category in terms of reef substrate cover with a combined mean of 62.9 % (range: 54.2 – 80.7 %). Turf algae (mixed assemblage) was the dominant component with a mean cover of 36.3 %, representing 57.7 % of the total cover by benthic algae. Fleshy brown macroalgae (*Dictyota sp., Lobophora variegata*), were present in al transects with a combined mean cover of 24.7%, or 39.3% of the total. Crustose red encrusting algae, *Peyssonnelia sp*. was intercepted by three transects, but with low substrate cover (<1%). Cyanobacterial mats were present in four transects with a mean reef substrate cover of 4.8 %. Abiotic cover included coral rubble and sand pockets and reef overhangs with a mean combined cover of 6.4% (Table 54).

The variations of reef substrate cover by sessile-benthic categories at the Guanica shelf-edge reef are presented in Figure 46. Differences were very small and within sampling variability error (ANOVA, p = 0.586; Appendix 1). Small variations of substrate cover were associated with reductions of cover by *Orbicella annularis* and *Porites porites* (Figure 47). Subsequent surveys are needed to evaluate if these variations represent real trends, or artifacts of sampling variability.

14.3 Fishes and Motile Megabenthic Invertebrates

A total of 49 fish species were identified from Efra's Wall Reef including 29 within belt-transects at depths of 18 - 20 meters (Table 55). The mean abundance of individuals was 28.2 Ind/30 m^2 (range: 16–47 Ind/30 m^2), and the mean number of species per transect was 11.6 (range: 10 - 12). The most abundant species was the Bicolor Damselfish (*Stegastes partitus*) with a mean of 8.6 Ind/30 m^2 or 30.5% of the total fish within belt-transects. Bluehead and Yellowhead Wrasses *(Thalassoma bifasciatum, Halichoeres garnoti*), were present in three and two transects with a combined abundance of 4.6 Ind/30 m^2, or 16.3% of the total. Redband Parrotfish (*Sparisoma aurofrenatum*), Ocean Surgeon (*Acanthurus bahianus*) and Graysbe (*Epinephelus cruentatus*) were present in four transects with a combined abundance of 4.2 Ind/30 m^2 or 14.9 % of the total mean abundance within belt-transects. Eleven species were only represented by one individual within transect areas.

Parrotfishes, represented by four species within extended belt-transects were the most abundant commercially important fish assemblage with size ranges in the juvenile and

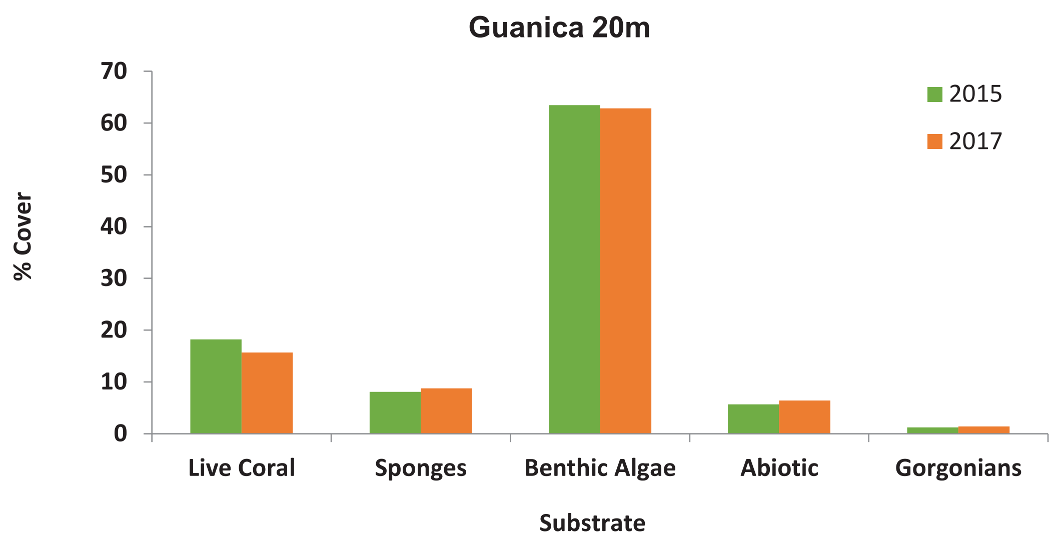


Figure 46. Monitoring trends (2015 – 2017) of mean substrate cover by sessile-benthic categories at Efra's Wall Reef (Guanica shelf-edge).

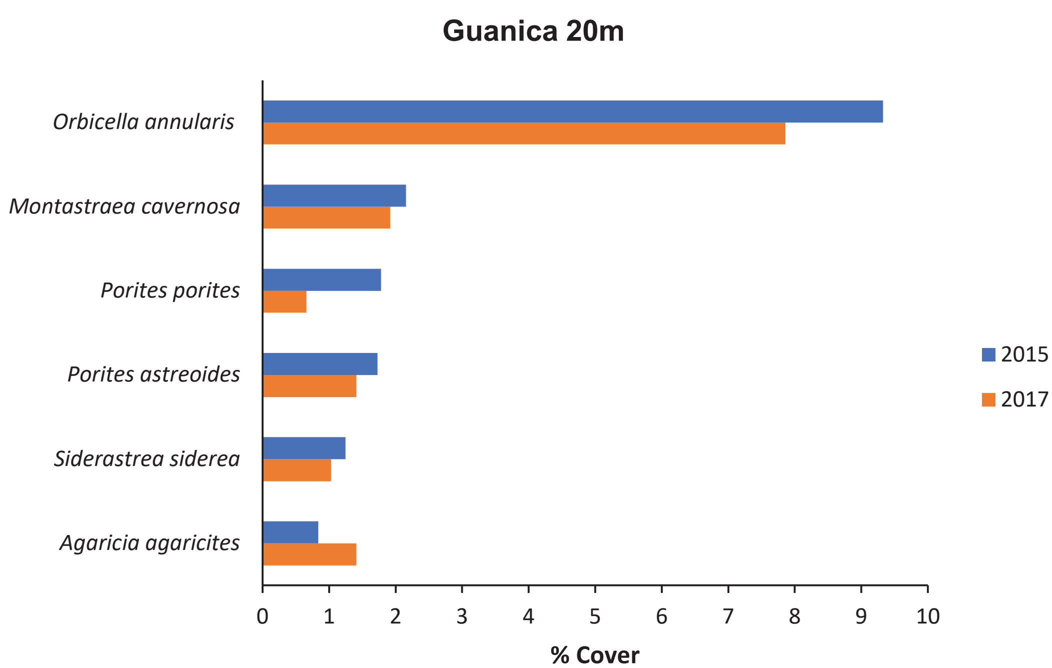


Figure 47. Monitoring trends (2015 – 2017) of mean substrate cover by stony coral species at Guánica Efra's Wall Reef (Guanica shelf-edge).

adult stages (Table 56). Small groupers, such as the Coney and Graysbe and the Yellowtail Snapper were present as juveniles. One adult Queen Triggerfish was also present within transects. Several other juvenile and adult Yellowfin Snappers and one Great Barracuda were observed outside transects.

During the baseline survey, the fish community at Guanica's shelf-edge was comprised by a prominent assemblage of planktivores, represented by at least three numerically dominant species, particularly the pelagic Mackerel Scad (*Decapterus macarelus*) that accounted for approximately 43.1 % of the total fish abundance. During this survey mackerel scad was not observed and the zooplanktivore trophic component of the reef was represented within belt-transects by the Bicolor Damselfish (*Stegastes partitus*) and the Blue Chromis (*Chromis cyanea*) with a combined abundance of 9.4 Ind/30 m^2, or 33.3% of the total fish within transects. A diverse assemblage of small opportunistic invertebrate feeders, such as the wrasses (Labridae), squirrelfishes (Holocentridae), grunts (Haemulidae), puffers (Tetraodontidae), and small groupers (Serranidae) represented 32.6% of the total. Herbivores were represented by four species of parrotfishes (Scaridae), three species of doctorfishes (Acanthuridae) and one damselfish (Pomacentridae) that accounted for approximately 24.1 % of the total fish abundance within belt-transects. Large demersal predators were represented by the Nurse Shark during the baseline survey. One Great Barracuda was observed out of transects.

Figure 48 shows the variations of mean fish species richness and abundance between the 2015 baseline and the first 2017 monitoring survey. A decline of both species richness and abundance was noted, but such variations were statistically insignificant due to the relatively high within sampling variability error (ANOVA, $p > 0.05$; see Appendices 5 - 6).

Flamingo Tongue, Arrow crabs and one Cleaner Shrimp were present within belt-transects at Efra's Wall Reef in Guanica during the 2017 survey (Table 57). One Spiny lobster (*Panulirus argus*) and one Common Octopus (*Octopus vulgaris*) were observed out of transects during the baseline survey.

Table 55. Taxonomic composition and abundance of fishes within belt-transects at Guanica Shelf-edge Reef 20m, Guanica, March 2017

Depth: 20m		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Stegastes partitus	Bicolor Damselfish	2	8	6	9	18	**8.6**
Thalassoma bifasciatum	Bluehead Wrasse		4	2		8	**2.8**
Halichoeres garnoti	Yellow-head Wrasse				4	5	**1.8**
Sparisoma aurofrenatum	Redband Parrotfish	1	3	2		2	**1.6**
Acanthurus bahianus	Ocean Surgeon	1	2	2		2	**1.4**
Acanthurus chirurgus	Doctorfish	1		2	3		**1.2**
Cephalopholis cruentatus	Graysby		1	1	1	3	**1.2**
Holocentrus rufus	Longspine Squirrelfish		2		2	2	**1.2**
Chromis cyanea	Blue Chromis	2	2				**0.8**
Sparisoma radians	Bucktooth Parrotfish		4				**0.8**
Cephalopholis fulva	Coney		1	1	1		**0.6**
Chaetodon capistratus	Four-eye Butterflyfish	1		1	1		**0.6**
Haemulon flavolineatum	French Grunt	3					**0.6**
Scarus iserti	Stripped Parrotfish		2			1	**0.6**
Scarus taeniopterus	Princess Parrotfish	1		2			**0.6**
Acanthurus coeruleus	Blue Tang	1		1			**0.4**
Carangoides ruber	Bar Jack					2	**0.4**
Chaetodon striatus	Banded Butterflyfish					2	**0.4**
Elacatinus evelynae	Sharknose Goby				2		**0.4**
Serranus tigrinus	Harlequin Bass	1			1		**0.4**
Bodianus rufus	Spanish Hogfish					1	**0.2**
Canthigaster rostrata	Caribbean Puffer				1		**0.2**
Caranx lugubris	Black Jack	1					**0.2**
Chaetodon ocellatus	Spotfin Butterflyfish	1					**0.2**
Ocyurus chrysurus	Yellowtail Snapper		1				**0.2**
Hypoplectrus unicolor	Butter Hamlet			1			**0.2**
Pseudupeneus maculatus	Spotted Goatfish			1			**0.2**
Stegastes planifrons	Yellow-eye Damselfish		1				**0.2**
Malacanthus plumieri	Sand Tilefish					1	**0.2**
	TOTAL INDIVIDUALS	**16**	**31**	**22**	**25**	**47**	**28.2**
	TOTAL SPECIES	**12**	**12**	**12**	**10**	**12**	**11.6**

Table 56. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at Guanica Shelf-edge Reef 20 m, Guanica, March 2017

		TRANSECTS				
		1	2	3	4	5
				(Individuals/60 m^2)		
SPECIES	**COMMON NAME**					
Acanthurus bahianus	Ocean Surgeon		2 - 13	2 - 10		2 - 13
Acanthurus coeruleus	Blue Tang	1 - 13		1 - 10	3 - 15	
		1 - 10				
Acanthurus chirurgus	Doctorfish	1 - 8		2 - 15		
Balistes vetula	Queen Triggerfish					1 - 36
Cephalopholis fulva	Coney		1 - 10	1 - 15	1 - 8	
Cephalopholis cruentatus	Graysbe		1 - 13	1 - 8	1 - 8	1 - 10
						2 - 13
Cephalopholis fulva	Coney		1 - 10	1 - 15	1 - 8	
Cephalopholis cruentatus	Graysbe		1 - 13	1 - 8	1 - 8	1 - 10
						2 - 13
Ocyurus chrysurus	Yellowtail Snapper		1 - 10		1 - 13	
Sparisoma viride	Stoplight Parrotfish				1 - 18	
Sparisoma aurofrenatum	Redband Parrotfish	1 - 15	3 - 8	2 - 10	1 - 15	1 - 13
			1 - 13	1 - 13		1 - 15
Scarus taeniopterus	Princess Parrotfish			2 - 5		
				2 - 13		
Scarus iserti	Striped Parrotfish		1 - 10			1 - 15
			1 - 15			

Table 57. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Efra's Wall Reef, Guanica shelf-edge. 2017

Depth: 20 m		TRANSECTS					MEAN ABUNDANCE
		1	2	3	4	5	(IND/30 m2)
TAXA	**COMMON NAME**						
Cyphoma gibbosum	Flamingo Tongue		1				**0.2**
Periclimenes pedersoni	Cleaner Shrimp	1					**0.2**
Stenorhinchus seticornis	Arrow Crab	1					**0.2**
	TOTALS	**2**	**1**	**0**	**0**	**0**	**0.6**

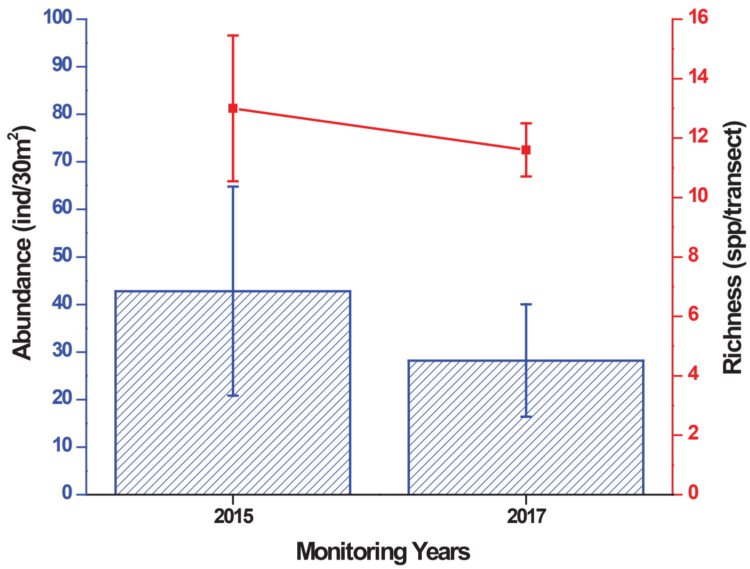


Figure 48. Monitoring trends (2015 – 2017) of fish species richness and abundance at Efra's Wall Reef, Guanica 20m.

14.4 Photo Album 14

Efra's Wall Reef – Guanica
















15.0 Maria Langa Reef 20 - Guayanilla

15.1 Physical description

Maria Langa is a fringing reef complex bordering the east section of the entrance channel of Guayanilla Bay (Figure 49). 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 15.

15.2 Sessile Benthic Reef Community

Vertically projected soft corals (gorgonians) were the most prominent sessile-benthic invertebrate component at Maria Langa 20 with a mean density of 24.6 colonies per transect. Sea Rods (*Eunicea spp.*) and Sea Fans (*Gorgonia ventalina*) were the most common. The encrusting gorgonians, *Briareum asbestinum* and *Erythropodium caribaeorum* were present in five and two transects, respectively with a combined mean substrate cover of 4.8% (Table 58).

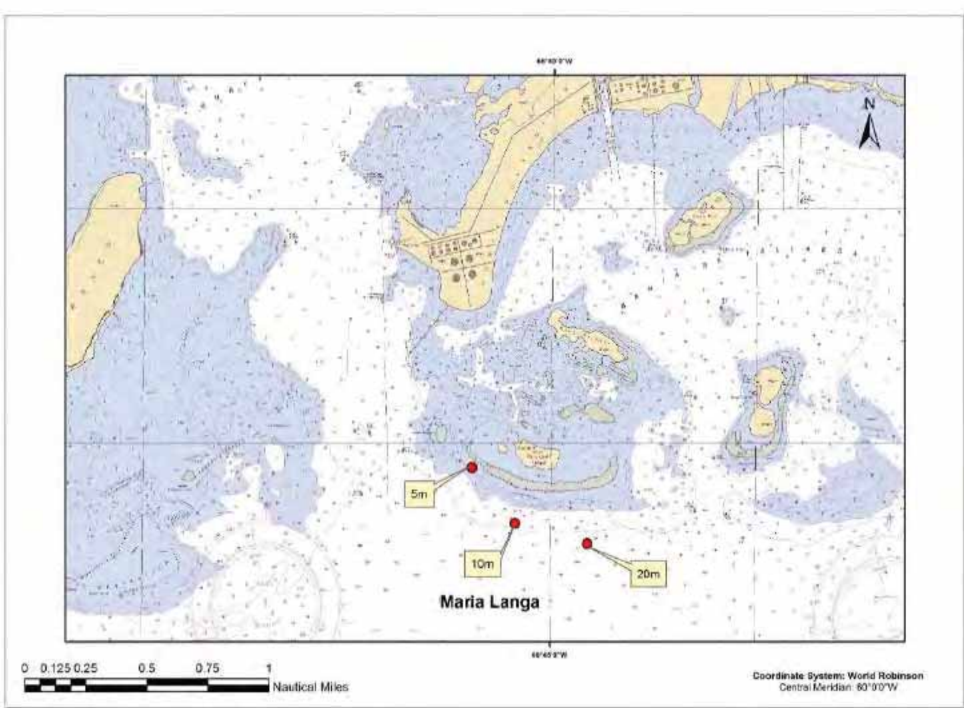


Figure 49. Map of Guayanilla Bay entrance channel showing location of coral reef monitoring stations

Table 58. Percent linear cover by sessile-benthic invertebrates at Maria Langa Reef 20, Guayanilla. Survey Date: March 29, 2017

Depth: 15-16m

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	4.57	2.43	2.10	3.52	2.18	**2.96**
Benthic Category						
Abiotic						
Sand	4.80	3.83	6.94	2.07	12.64	**6.06**
Reef overhang	5.38		0.69	4.66	9.08	**3.96**
Rubble	0.38	3.15				**0.71**
Gap		0.56	0.93		1.95	**0.69**
Total Abiotic	**10.57**	**7.55**	**8.56**	**6.73**	**23.68**	**11.42**
Benthic Algae						
Turf	60.52	51.13	63.77	58.59	41.38	**55.08**
Dictyota spp.	5.96		4.28	5.59	7.93	**4.75**
Turf with sediment		12.84	1.16			**2.80**
Peyssonnelia sp.	1.83	2.59	0.23	3.11	0.57	**1.67**
CCA	0.58	1.91	1.16	3.73		**1.47**
Ramicrusta sp.			0.23	3.00	1.15	**0.88**
Red alga		0.90		0.41	0.46	**0.35**
Total Benthic Algae	**68.88**	**69.37**	**70.83**	**74.43**	**51.49**	**67.00**
Live Coral						
Orbicella annularis complex	3.07	5.74	10.53	2.59	2.18	**4.82**
Agaricia agaricites	0.58	4.39	4.17	6.11	3.22	**3.69**
Siderastrea siderea	0.96	4.17	1.04	1.24	4.48	**2.38**
Colpophyllia natans	1.63				5.40	**1.41**
Stephanocoenia intersepta	1.73	0.45	0.35	0.93	2.53	**1.20**
Montastraea cavernosa	3.36	0.56		0.21	0.46	**0.92**
Madracis decactis		0.56	0.58			**0.23**
Porites astreoides		1.13				**0.23**
Agaricia lamarcki					0.80	**0.16**
Millepora alcicornis		0.23	0.23			**0.09**
Total Live Coral	**11.34**	**17.23**	**16.90**	**11.08**	**19.88**	**15.12**
Coral Colonies/Transect	9	12	6	8	7	**8.4**
Zoanthids						
Palythoa caribaeorum				0.21		**0.04**
Octocorals						
Briareum asbestinum	7.01	2.59	0.69	5.80	5.06	**4.23**
Erythropodium caribaeorum		0.34	2.78			**0.62**
Total Octocoral	**7.01**	**2.93**	**3.47**	**5.80**	**5.06**	**4.85**
# Gorgonians/transect	23	24	29	24	23	**24.60**
Sponge						
Agelas tubulata		2.59				**0.52**

Mycale laevis	0.29	0.34		0.41		**0.21**
Biemna sp.	0.96					**0.19**
Agelas dispar				0.41	0.46	**0.17**
Scopalina ruetzleri	0.29		0.23	0.21		**0.15**
Amphimedon compressa	0.67					**0.13**
Aiolochroia crassa				0.21	0.23	**0.09**
Niphates sp.				0.31		**0.06**
Niphates caribica				0.21		**0.04**
Total Sponge	**2.21**	**2.93**	**0.23**	**1.76**	**0.69**	**1.56**

Scleractinian corals were represented by 10 species intercepted by linear transects with a combined mean substrate cover of 15.1% (range: 11.0 – 19.9 %) and a mean density of 8.4 colonies per transect. Boulder Star Coral, *Orbicella annularis* (complex), Lettuce Coral, *Agaricia agaricites*, Massive Starlet Coral, *Siderastrea siderea*, and Blushing Star Coral, *Stephanocoenia intersepta* were present in all five transects and in addition to Boulder Brain Coral, *Colpophyllia natans* comprised the main coral assemblage in terms of substrate cover with a combined mean cover of 12.1%, or 80.0% of the total (Table 58). Small encrusting/branching colonies of Great Star Coral, *Montastrea cavernosa*, Ten-Ray Coral, *Madracis decactis* and Fire Coral, *Millepora alcicornis* were present in four and two transects, respectively with minor contributions to the overall cover by live corals at Maria Langa 20. Infectious diseases were not observed in any of the 42 coral colonies intercepted by transects during 2017 (Appendix 2).

Sponges, represented by at least nine species within belt-transects combined for a mean substrate cover of 1.6% (Table 58). Sponges were mostly present as small encrusting colonies growing intermixed with algal turf. *Scopalina ruetzleri* and *Mycale laevis* were the only ones observed in more than two transects, whereas one large colony of *Agelas tubulata* accounted for the highest cover amongst sponges. Turf algae, a mixed assemblage of short brown and red algae strongly dominated the benthic algal component with a mean substrate cover of 57.9 % (range: 41.4 – 64.9%), representing 86.4% of the total benthic algae. Fleshy brown macroalgae (*Dictyota sp*) was present in four transects with a mean cover of 4.8%. Red crustose encrusting algae (*Peyssonnelia sp, Ramicrusta sp*) were present in all five transects with a mean cover of 4.4% (Table 58). Abiotic substrate categories, mostly contributed by sand presented a mean substrate cover of 11.4% (range: 6.7 – 23.7%).

Variations of reef substrate cover by sessile-benthic categories between the 2016 baseline and the present 2017 (first) monitoring survey are shown in Figure 50. Differences were very small and statistically insignificant (ANOVA, p=0.115; Appendix 2). Variations of soft corals between monitoring surveys were also statistically insignificant (T-test, p= 0.326; Appendix 3), evidencing that the pass of hurricane Mathew along the south coast of Puerto Rico did not have any significant ecological implications on Maria Langa Reef at a depth of 15-16 m. The relative composition of coral species and variations of mean substrate cover between monitoring surveys are presented in Figure 51. There were no major differences in the composition of coral species and although mild trends of increasing cover were measured for several species these were statistically insignificant.

15.3 Fishes and Motile Megabenthic Invertebrates

A total of 54 species of fish were identified from Maria Langa Reef at a depth of 15 - 16 m, including 29 within belt-transects (Table 59). Mean density was 28.4 Ind/transect (range: 25– 32 Ind/transect) with a mean richness of 14.2 species per transect (H'= 112.2). The Sharknose and Peppermint Gobies (*Elacatinus evelynae, Coryphopterus lipernes*), Princess Parrotfish (*Scarus taeniopterus*) and Bluehead Wrasse, *Thalassoma bifasciatum* were the numerically dominant species with a combined abundance of 12.2 Ind/transect, representing 43.0% of the total individuals. The Redband parrotfish, Beaugregory, Caribbean Puffer Bicolor Damselfish and Ocean Surgeon were present in at least four transects (Table 59) and along with the Sharknose and Peppermint gobies comprised the main fish assemblage within belt-transects. Ten species were only observed in one transect.

The ichthyofauna at Maria Langa 20m was largely comprised by a species rich assemblage of small opportunistic carnivores and herbivores, with relatively low prevalence of zooplanktivores and large demersal predators. Small opportunistic carnivores included gobies (Gobiidae), wrasses (Labridae), grunts (Haemulidae), squirrelfishes (Holocentridae), puffers (Tetraodontidae), Hawkfish (Cirrhitidae) and blennies (Blenniidae) and small groupers and Sea Basses (Serranidae). Their combined abundance (16.0 Ind/transect) represented 56.3% of the total within belt-transects (Table 59). Herbivores were represented by parrotfishes (Scaridae), damselfishes (Pomacentridae) and doctorfishes (Acanthuridae) with a combined density of 6.8

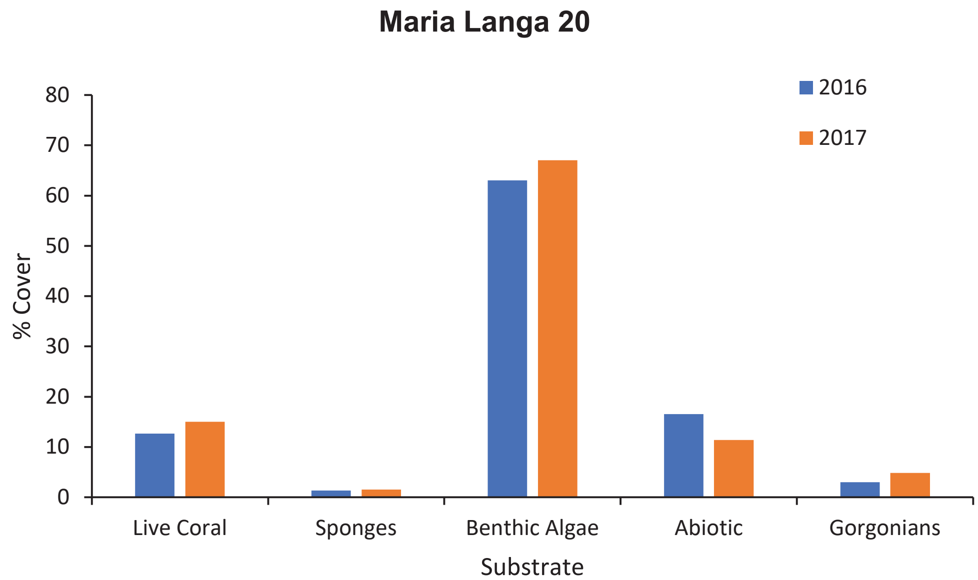


Figure 50. Monitoring trends (2016 – 2017) of mean substrate cover by sessile-benthic categories at Maria Langa 20m, Guayanilla

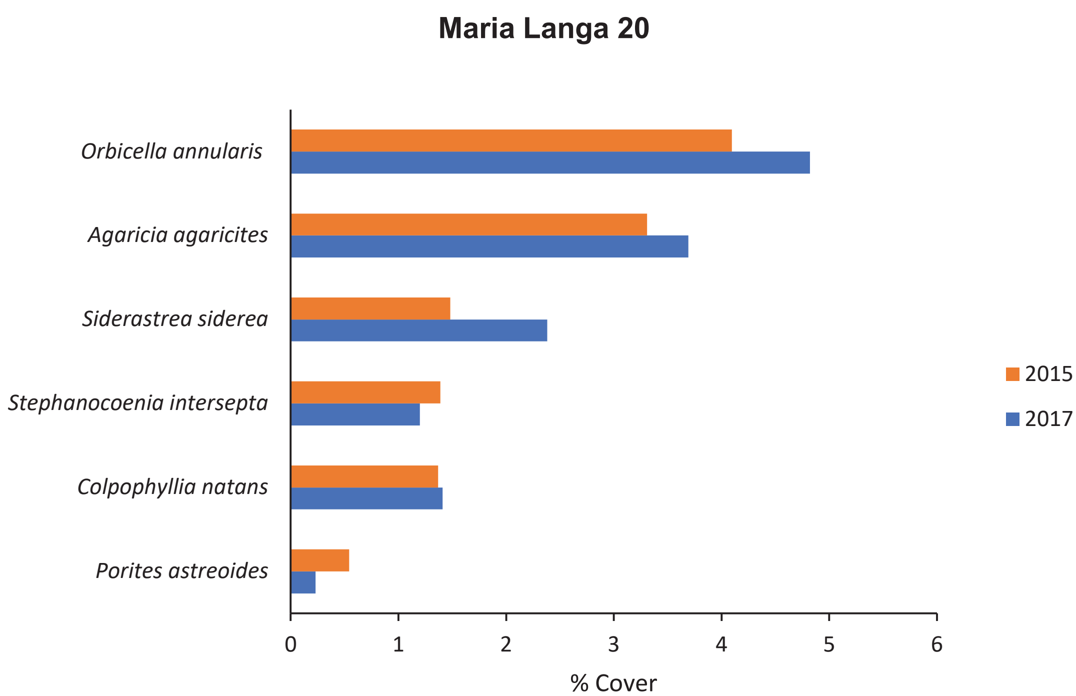


Figure 51. Monitoring trends (2016 – 2017) of mean substrate cover by stony coral species at Maria Langa 20m, Guayanilla

Ind/transect, representing 23.9% of the total density within belt-transects. Zooplanktivorous fishes were represented by the Masked Goby (*Coryphopterus personatus*) and Bicolor Damselfish (*Stegastes partitus*), with a cumulative density of 1.8 Ind/transect or 6.3% of the total. Medium sized piscivores included the Yellowtail Snapper (*Ocyurus chrysurus*), Red Hind (*Epinephelus guttatus*) and Cero Mackerel (*Scomberomorus regalis*) observed out of transects. One 100-pound Jewfish (*Epinephelus itajara*) was observed out of transects.

The size-frequency distribution of fishes within extended belt-transects suggests that the reef serves as a recruitment and residential habitat for an assemblage of Parrotfishes, including the Redband, Stoplight, Princess and Striped Parrotfishes that were observed during this and the previous baseline survey (Table 60). Juvenile Graysbes (*Cephalopholis cruentatus*) were present and young adults of the Hogfish (*Lachnolaimus maximus*), Yellowtail and Schoolmaster Snappers (*Ocyurus chrysurus, Lutjanus apodus*) adult Coneys (*Cephalopholis fulva*) and the Red Hind (*Epinephelus guttatus*) were present out of transects.

Variations of fish species richness and abundance between the 2016 baseline and the present 2017 (first) monitoring survey are shown in Figure 52. Differences of species richness were small and statistically insignificant (ANOVA, $p > 0.05$; Appendix 5 - 6). The marked reduction of abundance was largely related to the absence in this 2017 survey of Blue Runners (*Caranx crysos*), a transitory schooling pelagic species that penetrated transect areas during the baseline survey, but that are not part of the resident fish community at Maria Langa Reef.

Motile megabenthic invertebrates were represented within belt-transects by one Cleaner Shrimp, *Periclimenes pedersoni* (Table 61).

Table 59. Taxonomic composition and abundance of fishes within belt-transects at Maria Langa Shelf-edge Reef 20m, Guayanilla, March 2017

Depth: 15.5 m

		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Elacatinus evelynae	Sharknose Goby	4			1	13	**3.6**
Coryphopterus lipernes	Peppermint Goby	1	4	4	3	5	**3.4**
Scarus taeniopterus	Princess Parrotfish	3	3	3	4	2	**3.0**
Thalassoma bifasciatum	Bluehead Wrasse	2	3	1	5		**2.2**
Coryphopterus sp.	Goby	2	4		2	1	**1.8**
Sparisoma aurofrenatum	Redband Parrotfish	2	3		2	2	**1.8**
Stegastes leucostictus	Beaugregory	1	2	2	2	2	**1.8**
Canthigaster rostrata	Caribbean Puffer	1	2	2	1	1	**1.4**
Stegastes partitus	Bicolor Damselfish	3	2	1		1	**1.4**
Acanthurus bahianus	Ocean Surgeon	1		1	3	1	**1.2**
Halichoeres garnoti	Yellow-head Wrasse		1	3			**0.8**
Sparisoma radians	Bucktooth Parrotfish	1		3			**0.8**
Haemulon flavolineatum	French Grunt		2		1		**0.6**
Holocentrus rufus	Longspine Squirrelfish	1			1	1	**0.6**
Anisotremus virginicus	Porkfish	2					**0.4**
Cephalopholis cruentatus	Graysby	1				1	**0.4**
Coryphopterus personatus	Masked Goby				1	1	**0.4**
Coryphopterus glaucofraenum	Saddled Blenny				1	1	**0.4**
Hypoplectrus puella	Barred Hamlet			1	1		**0.4**
Acanthurus coeruleus	Blue Tang			1			**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish		1				**0.2**
Chaetodon capistratus	Four-eye Butterflyfish			1			**0.2**
Chaetodon ocellatus	Spotfin Butterflyfish	1					**0.2**
Myripristis jacobus	Black-bar Soldierfish		1				**0.2**
Mulloides martinicus	Yellow Goatfish			1			**0.2**
Scarus iserti	Stripped Parrotfish				1		**0.2**
Sparisoma viride	Stoplight Parrotfish			1			**0.2**
Stegastes dorsopunicans	Dusky Damselfish	1					**0.2**
Stegastes planifrons	Yellow-eye Damselfish		1				**0.2**
	TOTAL INDIVIDUALS	**27**	**29**	**25**	**29**	**32**	**28.4**
	TOTAL SPECIES	**16**	**13**	**14**	**15**	**13**	**14.2**

Table 60. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at Guanica Shelf-edge Reef 20 m, Guanica, March 2017

		TRANSECTS				
		1	2	3	4	5
				(Individuals/60 m^2)		
SPECIES	**COMMON NAME**					
Acanthurus bahianus	Ocean Surgeon	2 - 13	1 - 15	1 - 15	1 - 13	2 - 15
					2 - 15	
Acanthurus coeruleus	Blue Tang			3 - 15		
Cephalopholis cruentatus	Graysbe	1 - 10				1 - 8
Scarus taeniopterus	Princess Parrotfish	3 - 4	3 - 8	2 - 8	2 - 5	1 - 5
		1 - 25		1 - 25	1 - 25	1 - 13
Scarus iserti	Striped Parrotfish				1 - 18	
Sparisoma viride	Stoplight Parrotfish			1 - 32		
Sparisoma aurofrenatum	Redband Parrotfish	1 - 18	1 - 10		1 - 5	2 - 13
		1 - 13	1 - 15		1 - 10	1 - 20
			1 - 23		2 - 15	
Pterois sp.	Lionfish	1 - 28				

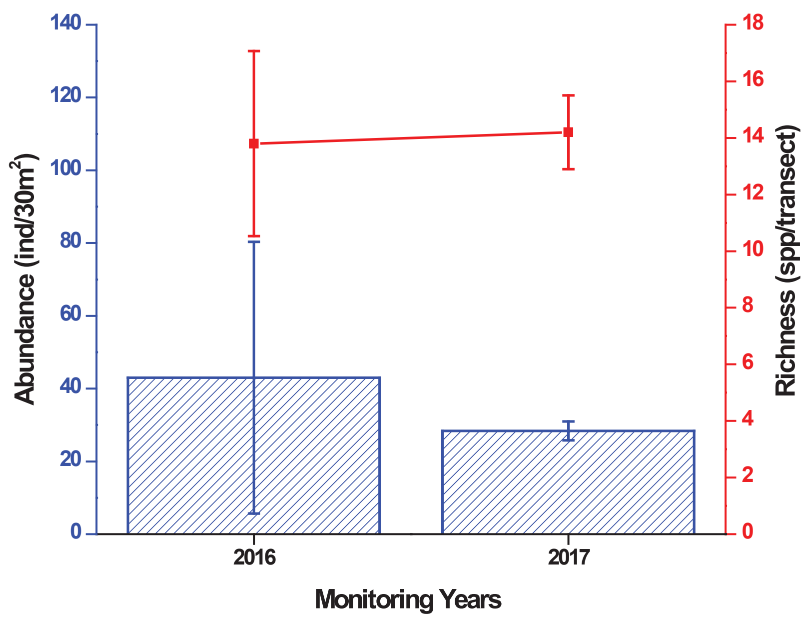


Figure 52. Monitoring trends (2016 – 2017) of fish species richness and abundance at Maria Langa Reef 20, Guayanilla

Table 61. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Maria Langa Reef 20, Guayanilla. 2017

Depth: 16 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	**2**	**3**	**4**	**5**	
TAXA	**COMMON NAME**						
Periclimenes pedersoni	Cleaner Shrimp	1					**0.2**
	TOTALS	**2**	**1**	**0**	**0**	**0**	**0.2**

15.4 Photo Album 15

Maria Langa Reef 20 - Guayanilla

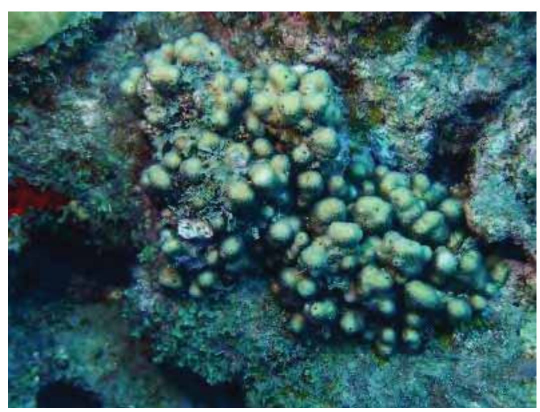

















16.0 Maria Langa Reef 10 - Guayanilla

16.1 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 49). Panoramic views of the reef community at Maria Langa 10 are included as Photo Album 16.

16.2 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 58.7% (Table 62). 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 52.1% (range: 44.2 – 60.9 %), representing 88.7% of the total cover by algae. Fleshy brown macroalgae, mostly *Dictyota sp*. were present in all transects with a mean cover of 3.6%. Crustose encrusting red algae, *Ramicrusta sp* was also present in four transects with a combined mean cover of 3.0%. Cyanobacterial patches were intercepted in transect 5, but overall presented a relatively low contribution to the reef substrate cover (< 1%).

Scleractinian corals were represented by 11 species intercepted by linear transects with a combined mean substrate cover of 21.7% (range: 17.4 – 26.8 %) and a mean of 9.2 colonies per transect. An assemblage of four coral species with a combined cover of 18.6% represented 87.7% of the total live coral cover at Maria Langa 10 (Table 62). These included Boulder Star Coral, *Orbicella annularis* (complex), Massive Starlet Coral, *Siderastrea siderea,* Symmetrical Brain Coral, *Pseudodiploria strigosa,* and Great Star Coral, *Montastrea cavernosa*. The two-latter species and Mustard-Hill Coral, *P. astreoides* were intercepted in all five transects. Boulder Star Coral was only present in three transects. Three coral species were only represented by one colony along transects. Infectious diseases were not observed in any of the 46 coral colonies intercepted by transects during 2017 (Appendix 2). The encrusting zoanthid *Palythoa caribaeorum* was present in all five transects with an average cover of 2.6%.

Table 62. Percent linear cover by sessile-benthic invertebrates at Maria Langa Reef 10m, Guayanilla. Survey Date: March 29, 2017

Depth: 10m

	Transects					
	1	2	3	4	5	**Mean**
Rugosity	2.84	1.59	1.87	1.55	1.75	**1.92**
Benthic Category						
Abiotic						
Sand	5.13		5.54			**2.13**
Rubble	0.76	1.45				**0.44**
Reef Overhang					2.15	**0.43**
Total Abiotic	**5.89**	**1.45**	**5.54**		**2.15**	**3.01**
Benthic Algae						
Turf with sediment	50.82	44.20	51.42	53.21	60.91	**52.11**
Dictyota spp.	1.20	2.78	6.13	5.09	2.86	**3.61**
CCA	2.73	5.68	0.94			**1.87**
Red alga		0.48		3.52		**0.80**
Ramicrusta sp.	0.33	0.36		0.61	0.36	**0.33**
Total Benthic Algae	**55.07**	**53.50**	**58.49**	**62.42**	**64.12**	**58.72**
Cyanobacteria					4.77	**0.95**
Live Coral						
Orbicella annularis complex	5.13	14.13			8.58	**5.57**
Siderastrea siderea	4.03	5.68	7.78	4.85		**4.47**
Montastraea cavernosa	5.89	1.33	8.37	5.21	0.72	**4.30**
Pseudodiploria strigosa	4.47	2.66	0.83	7.64	5.72	**4.26**
Porites astreoides	0.76	1.45	1.18	1.70	2.38	**1.49**
Millepora alcicornis	0.76		0.94	0.73		**0.49**
Diploria labyrinthiformis				2.42		**0.48**
Meandrina meandrites		1.09				**0.22**
Agaricia agaricites		0.48	0.24	0.24		**0.19**
Stephanocoenia intersepta	0.55					**0.11**
Porites porites				0.48		**0.10**
Total Live Coral	**20.83**	**26.81**	**18.40**	**22.55**	**17.40**	**21.69**
Coral Colonies/Transect	6	8	11	14	7	**9.2**
Zoanthids						
Palythoa caribaeorum	2.40	4.59	4.60	0.48	0.83	**2.58**
Octocoral						
Briareum asbestinum	2.84	10.99	1.53	6.30	4.65	**5.26**
Erythropodium caribaeorum	7.42		5.54	1.21	3.10	**3.45**
Gorgonia ventalina	1.09			0.36		**0.29**
Antillogorgia americana	0.55	0.85				**0.28**
Eunicea flexuosa			0.35	0.24	0.36	**0.19**
Eunicea tourneforti				0.36		**0.07**
Plexaura homomalla		0.36				**0.07**
Pseudoplexaura flagellosa-wagenaari	0.33					**0.07**
Plexaura keukenthali		0.24				**0.05**

Total Octocoral	**12.21**	**12.44**	**7.43**	**8.48**	**8.10**	**9.73**
# Gorgonians/transect	39	32	57	52	32	**42.40**
Sponge						
Chondrilla caribensis			2.48	0.36		**0.57**
Scopalina ruetzleri	0.65		0.59	0.97	0.48	**0.54**
Iotrochota birotulata	1.31		0.35	0.24	0.24	**0.43**
Amphimedon compressa	0.22			1.21	0.24	**0.33**
Niphates digitalis				1.58		**0.32**
Niphates erecta		0.36	0.47	0.48	0.24	**0.31**
Cliona caribbaea	0.55					**0.11**
Plaktoris sp.			0.47			**0.09**
Agelas dispar		0.36				**0.07**
Callysongia fallax	0.11			0.24		**0.07**
Mycale laevis				0.24		**0.05**
Neopetrosia proxima		0.24				**0.05**
Spirastrella coccinea		0.24				**0.05**
Aplysina cauliformis					0.24	**0.05**
Total Sponge	**2.84**	**1.21**	**4.36**	**5.33**	**1.43**	**3.03**

Vertically projected soft corals (gorgonians) were exceptionally prominent at Maria Langa 10 with a mean density of 42.4 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 five and four transects, respectively with a combined mean substrate cover of 8.7% (Table 62). Sponges, represented by 14 species along transects combined for a mean substrate cover of 3.0%. *Chondrilla caribensis*, *Scopalina ruetzleri*, *Iotrochota birotulata*, *Amphimedon compressa* and *Niphates erecta* were the most prominent species with a combined cover of 1.8% or 61.7% of the total cover by sponges. *Scopalina, Iotrochota* and *Niphates* were present in four transects.

Abiotic substrate categories at Maria Langa 10 presented a mean substrate cover of 3.0%, largely associated with sand patches (Table 62). Reef rugosity averaged 1.9 m, indicative of a mostly regular topography with relatively low contributions by coral structures to the underwater relief.

Variations of reef substrate cover by sessile-benthic categories between the 2016 baseline survey and the present 2017 monitoring survey are presented in Figure 53.

Differences of live coral cover were statistically significant at a p-value = 0.062; see Appendix 1). There was an 18.4% increase of substrate cover by live corals, particularly contributed by *Montastrea cavernosa, Pseudodiploria strigosa* and *Siderastrea siderea* (Figure 54). This result must be evaluated with caution and subject to future monitoring observations because it is marginally close to the experimental significance cut-off p-value of 0.05, and based on a small sample size and species with relatively low reef substrate cover. Differences in the density of soft corals (gorgonians) were small and statistically insignificant (T-test, p= 0.326; Appendix 3). In general, the main components of the reef sessile-benthos exhibited a mostly stable condition despite strong wave action associated with the pass of hurricane Mathew near the south coast of PR.

16.3 Fishes and Motile Megabenthic Invertebrates

A total of 25 species of fish were identified within belt-transects from a depth of 9 - 10 m at Maria Langa 10 (Table 63). Mean density was 21.4 Ind/transect (range: 19 – 25 Ind/transect) with a mean richness of 12.6 species per transect (H'= 89.5). An assemblage of four species with a combined density of 8.8 Ind/transect, represented 41.1% of the total fishes within belt-transects. These included the Princess Parrotfish, *Scarus taeniopterus,* Bicolor Damselfish, *Stegastes partitus* and the Yellow-head and Bluehead Wrasses, *Halichoeres garnoti*, *Thalassoma bifasciatum*. Striped and Redband Parrotfishes, *Scarus iserti*, *Sparisoma aurofrenatum*, Four-eye Butterflyfish, *Chaetodon capistratus* and the Ocean Surgeon, *Acanthurus bahianus* were present in at least four transects. Eight species were only present in one transect.

Fish community structure at Maria Langa 10 was comprised by a moderate richness of herbivores and small opportunistic carnivores, with relatively low prevalence of zooplanktivores and large demersal predators. Herbivores were represented by five species of parrotfishes (Scaridae), two doctorfishes (Acanthuridae) and one damselfish (Pomacentridae) with a combined density of 8.0 Ind/transect, representing 37.4% of the total abundance within belt-transects. Small opportunistic carnivores represented 34.5% 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). Zooplanktivorous fishes were only represented by the Bicolor Damselfish,

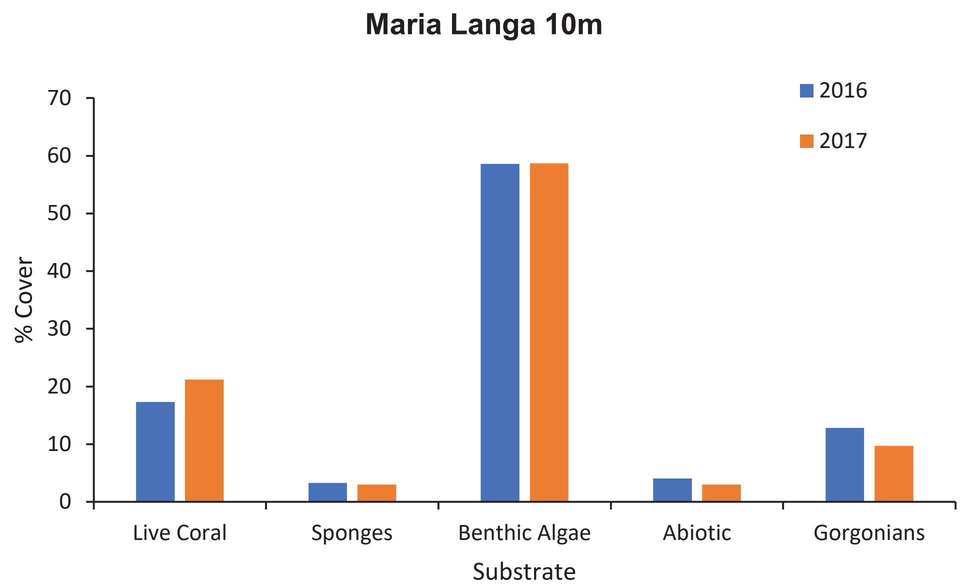


Figure 53. Monitoring trends (2016 – 2017) of mean substrate cover by sessile-benthic categories at Maria Langa 10, Guayanilla

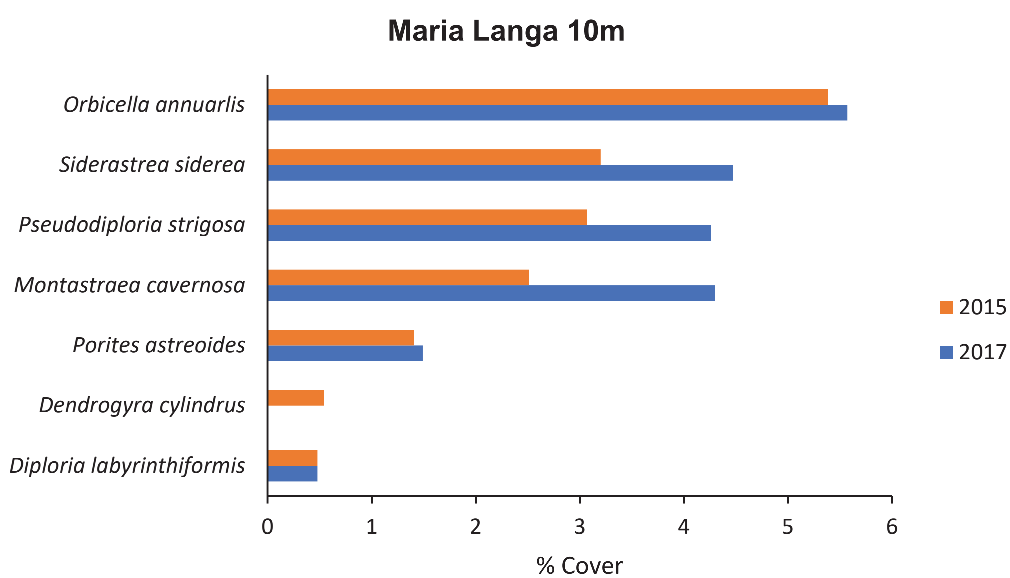


Figure 54. Monitoring trends (2016 – 2017) of mean substrate cover by stony coral species at Maria Langa 10m, Guayanilla

with 10.3% of the total individuals. Medium sized piscivores included the Yellowtail and Schoolmaster Snappers (*Ocyurus chrysurus, Lutjanus apodus*), and the Red Hind (*Epinephelus guttatus*) with a combined density of 0.8 Ind/transect, or 3.7% of the total fish density.

The size-frequency distribution of commercially important fishes and the main reef herbivores are presented in Table 64. The occurrence of juvenile and adult stages of parrotfishes (Scaridae) observed within transects identify this reef as a residential habitat for several species and a prime recruitment habitat for Stoplight and Bucktooth Parrotfishes. Post settlement juvenile stages of Striped and Redband Parrotfish were previously reported (Garcia-Sais et al, 2016). Individuals of the Yellowtail Snapper (*Ocyurus chrysurus)* and one Schoolmaster Snapper (*Lutjanus apodus*) were mostly present as juveniles and young adults (Table 64).

Variations of fish species richness and abundance between the 2016 baseline and the present 2017 (first) monitoring survey are shown in Figure 55. Differences of species richness were small and statistically insignificant (ANOVA, $p > 0.05$; Appendix 5 - 6). The decline of abundance was largely related to the absence in this 2017 survey of Bar Jacks (*Caranx ruber*), a transitory schooling pelagic species that penetrated transect areas during the baseline survey, but that are not part of the resident fish community at Maria Langa reef.

Motile megabenthic invertebrates were not observed within belt-transects at Maria Langa Reef 10 during this monitoring survey (Table 65).

Table 63. Taxonomic composition and abundance of fishes within belt-transects at Maria Langa Reef 10m. Guayanilla. March 2017

Depth: 10 m

		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Scarus taeniopterus	Princess Parrotfish	4	4	3		2	**2.6**
Stegastes partitus	Bicolor Damselfish	2	1	4	3	1	**2.2**
Halichoeres garnoti	Yellow-head Wrasse	1	2	3	1	4	**2.2**
Thalassoma bifasciatum	Bluehead Wrasse	1	3	2	3		**1.8**
Scarus iserti	Stripped Parrotfish		3	1	2	1	**1.4**
Chaetodon capistratus	Four-eye Butterflyfish	1	1	2	2	1	**1.4**
Sparisoma aurofrenatum	Redband Parrotfish		1	2	2	2	**1.4**
Acanthurus bahianus	Ocean Surgeon	2	1	1	1	1	**1.2**
Canthigaster rostrata	Caribbean Puffer	2		1	2		**1.0**
Serranus tigrinus	Harlequin Bass	1	2	1			**0.8**
Cephalopholis cruentatus	Graysby		2		1		**0.6**
Myripristis jacobus	Black-bar Soldierfish	1	2				**0.6**
Sparisoma radians	Bucktooth Parrotfish					3	**0.6**
Pseudupeneus maculatus	Spotted Goatfish	1	1			1	**0.6**
Chaetodon striatus	Banded Butterflyfish			2			**0.4**
Stegastes leucostictus	Beaugregory		2				**0.4**
Haemulon flavolineatum	French Grunt	1			1		**0.4**
Ocyurus chrysurus	Yellowtail Snapper			1		1	**0.4**
Acanthurus coeruleus	Blue Tang				1		**0.2**
Elacatinus evelynae	Sharknose Goby				1		**0.2**
Lutjanus apodus	Schoolmaster Snapper					1	**0.2**
Holocentrus rufus	Longspine Squirrelfish			1			**0.2**
Cephalopholis fulva	Coney					1	**0.2**
Epinephelus guttatus	Red Hind	1					**0.2**
Sparisoma viride	Stoplight Parrotfish	1					**0.2**
	TOTAL INDIVIDUALS	**19**	**25**	**24**	**20**	**19**	**21.4**
	TOTAL SPECIES	**13**	**13**	**13**	**12**	**12**	**12.6**

Table 64. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3 m belt-transects at Maria Langa Reef 10 m, Guayanilla, March 2017

		TRANSECTS				
		1	2	3	4	5
		(Individuals/60 m^2)				
SPECIES	**COMMON NAME**					
Acanthurus bahianus	Ocean Surgeon	2 - 10	1 - 13	1 - 8	1 -10	1 - 13
		1 - 8		1 - 15	1 - 8	
				1 - 13	1 - 13	
Acanthurus coeruleus	Blue Tang				1 - 15	
Cephalopholis fulva	Coney					2 - 25
Cephalopholis cruentatus	Graysbe		2 - 10		1 - 13	1 - 8
Epinephelus guttatus	Red Hind	1 - 15				
Lutjanus apodus	Schoolmaster Snapper					1 - 13
Ocyurus chrysurus	Yellowtail Snapper		1 - 13	1 - 13		2 - 10
Sparisoma radians	Bucktooth Parrotfish					3 - 3
Sparisoma viride	Stoplight Parrotfish	1 - 10		1 - 5		
Sparisoma aurofrenatum	Redband Parrotfish	1 - 8	1 - 8	1 - 5	1 - 8	2 - 8
			1 - 10	1 - 10	2 - 10	1 - 10
				1 - 18	1 - 13	
Scarus taeniopterus	Princess Parrotfish	4 - 5	2 - 3	3 - 8	1 - 8	1 - 5
		3 - 8	2 - 5			1 - 15
		1 - 13				
Scarus iserti	Striped Parrotfish		3 - 10		2 - 10	1 - 15
			2 - 13			

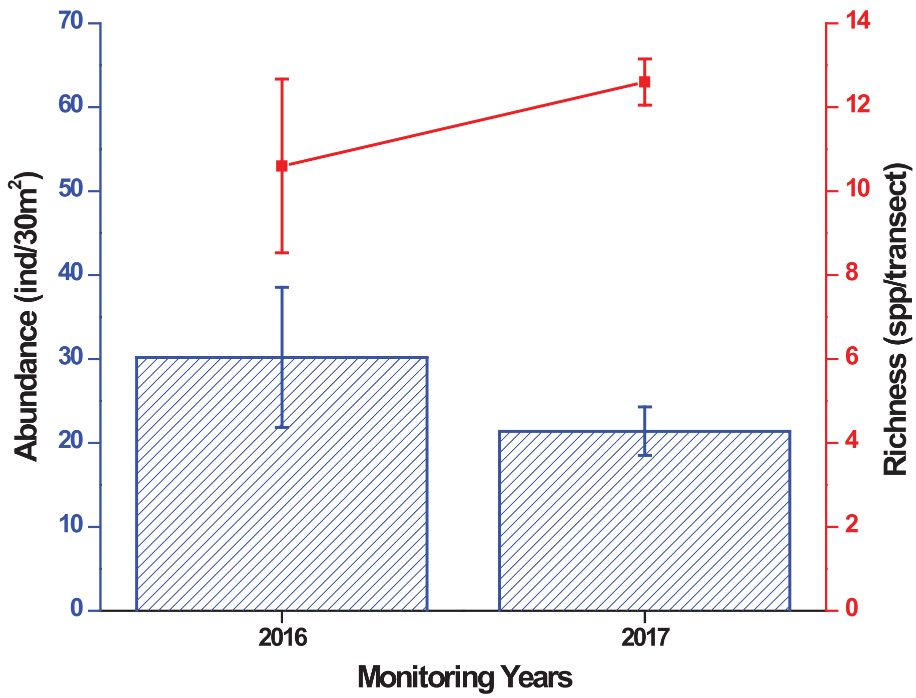


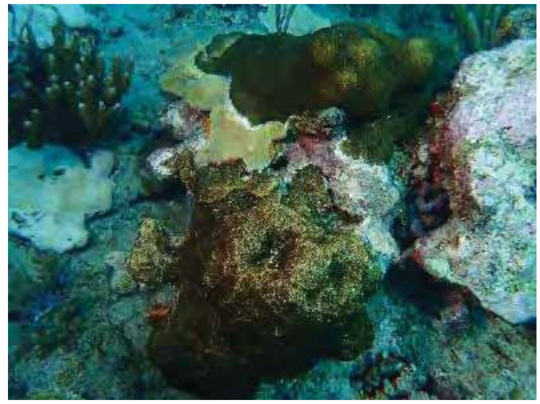
Figure 55. Monitoring trends (2015 – 2017) of fish species richness and abundance at Maria Langa Reef 10, Guayanilla

Table 65. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Maria Langa Reef 10, Guayanilla. 2017

Depth: 10 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	2	3	4	5	
TAXA	**COMMON NAME**						
None							
	TOTALS	**0**	**0**	**0**	**0**	**0**	**0**

16.4 Photo Album 16

Maria Langa Reef 10m - Guayanilla








17.0 Maria Langa Reef 3m, Guayanilla

17.1 Physical Description

Maria Langa 3m is at the reef crest of Maria Langa Reef (Figure 49). 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 17.

17.2 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 Reef 3, with a mean cover of 67.8%, representing 96.0% of the total cover by benthic algae (Table 66). Crustose red encrusting algae, including *Ramicrusta sp*. were present in four transects with a combined mean cover of 2.8%. Scattered patches of cyanobacteria were observed out of transects.

Scleractinian corals were represented by eight species intercepted by linear transects with a combined mean substrate cover of 5.0% (range: 1.7 – 9.0 %), and a mean of 3.4 colonies/transect. Mustard-Hill Coral, *Porites astreoides* was the dominant coral species intercepted by transects with a mean cover of 2.9%, representing 57.3% of the total live coral (Table 66). Lettuce Coral, *Agaricia agaricites* was the only other coral species intercepted by more than two transects. Corals occurred mostly as small to moderate and isolated encrusting colonies that contributed low topographic relief and reef structural complexity. Disease infected coral colonies were not observed (Appendix 2).

Vertically projected soft corals (gorgonians) were not prominent at Maria Langa 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* and *Briareum asbestinum* were present in three and two transects, respectively with a combined mean cover of 1.9%. Sponges, represented by six species intercepted by transects presented a combined mean substrate cover of 17.7%. The encrusting species, *Cliona caribbea* was prominent in all transects with a mean cover of 16.8, representing 94.9% of the total cover by sponges. *Chondrilla caribensis* was observed in four transects. The encrusting zoanthid *Palythoa caribaeorum* were also present with a

Table 66. Percent linear cover by sessile-benthic invertebrates at Maria Langa Reef 3m, Guayanilla. Survey Date: March 29, 2017

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	1.63	1.69	2.42	0.88	1.19	**1.56**
Benthic Category						
Abiotic						
Rubble	0.24			6.05	11.14	**3.49**
Sand					0.38	**0.08**
Total Abiotic	**0.24**			**6.05**	**11.51**	**3.56**
Benthic Algae						
Turf	63.66	69.10	30.10	15.83	18.40	**39.42**
Turf with sediment			44.98	52.90	43.80	**28.34**
CCA	3.85	5.75		2.83	1.00	**2.69**
Ramicrusta sp.	0.36			0.26		**0.12**
Total Benthic Algae	**67.87**	**74.85**	**75.08**	**71.81**	**63.20**	**70.56**
Live Coral						
Porites astreoides	3.49	1.92	1.24	2.19	5.63	**2.89**
Siderastrea siderea	3.97				2.38	**1.27**
Agaricia agaricites	0.60	0.96	0.23	0.26		**0.41**
Pseudodiploria strigosa	0.72			0.51		**0.25**
Porites porites				0.39		**0.08**
Millepora complanata			0.23			**0.05**
Acropora cervicornis	0.24					**0.05**
Siderastrea radians		0.24				**0.05**
Total Live Coral	**9.03**	**3.11**	**1.69**	**3.35**	**8.01**	**5.04**
Coral Colonies/Transect	5	4	1	2	5	**3.40**
Zoanthids						
Palythoa caribaeorum	2.77	2.51				**1.06**
Octocoral						
Erythropodium caribaeorum	1.81	3.59	3.83			**1.85**
Briareum asbestinum	0.24					**0.05**
Total Octocoral	**2.05**	**3.59**	**3.83**			**1.89**
# Gorgonians/transect	2	2		3	1	**1.60**
Sponge						
Cliona caribbaea	17.81	12.93	18.83	18.02	16.40	**16.80**
Chondrilla caribensis	0.24	1.56		0.13	0.88	**0.56**
Neopetrosia proxima				0.64		**0.13**
Amphimedon compressa		0.48				**0.10**
Scopalina ruetzleri		0.24				**0.05**
Agelas dispar			0.23			**0.05**
Total Sponge	**18.05**	**15.21**	**19.05**	**18.79**	**17.27**	**17.67**

combined reef substrate cover of 1.2% (Table 66). Abiotic substrate categories at Maria Langa 5 presented a mean substrate cover of 3.6%, largely associated coral rubble patches and sand. Reef rugosity averaged 1.6 m, indicative of a mostly regular topography with relatively low contributions by coral structures to the underwater relief.

Variations of reef substrate cover by sessile-benthic categories between the 2016 baseline and the present 2017 monitoring survey are presented in Figure 56. The most prominent difference between surveys was associated with a sharp decline (62.7%) of reef substrate cover by live corals, from 13.4% in 2016 to 5.0% in 2017. Such reduction of live coral cover was statistically significant (ANOVA, p = 0.002; Appendix 1) and explained by the disappearance of Fused Staghorn Coral, *Acropora prolifera* from permanent transects (Figure 57). Fused Staghorn Coral was the dominant coral in terms of reef substrate cover with a mean of 9.4% in 2016 and the main coral species contributing structural complexity at Maria Langa's reef crest. Such marked decline was driven by the detachment and mortality of colonies exposed to conditions of extreme wave and surge action during the pass of Hurricane Matthew across the northern Caribbean close to the south coast of PR. Large thickets of Fused Staghorn Coral were the most prominent feature of Maria Langa's reef crest and these biotopes were swept from this habitat, at least from depths shallower than 7-8m. Coral diseases were not observed in any of the 17 colonies remaining along transects (Appendix 2).

In part, the increase of coral rubble from the abiotic category responds to deposits of broken Fused Staghorn branches in reef crevices and gaps. Encrusting biota, such as corals and hydrocorals, encrusting gorgonian, sponges and turf algae were resilient to the event and did not exhibit any evident changes of reef substrate cover.

17.3 Fishes and Motile Megabenthic Invertebrates

A total of 44 species of fish have been identified from the reef crest of Maria Langa (Appendix 4), including 22 within belt-transects (Table 67). Mean abundance was 44.0 Ind/transect (range: 39 – 51 Ind/transect) with a mean richness of 11.6 species per transect (H'= 88.8). The Dusky and Bicolor Damselfishes (*Stegastes adustus, S. partitus)* and Bluehead Wrasse (*Thalassoma bifasciatum*) were the numerically dominant species with a combined density of 29.6 Ind/transect, representing 67.3% of the total. The Slippery Dick, (*Halichoeres bivittatus*), Redlip Blenny (*Ophioblennius*

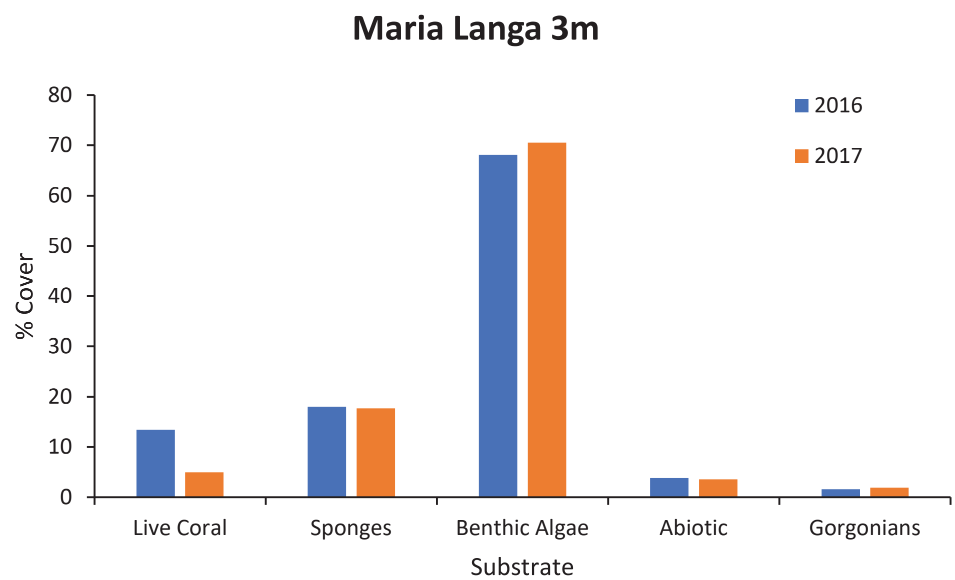


Figure 56. Monitoring trends (2016 – 2017) of mean substrate cover by sessile-benthic categories at Maria Langa 3, Guayanilla

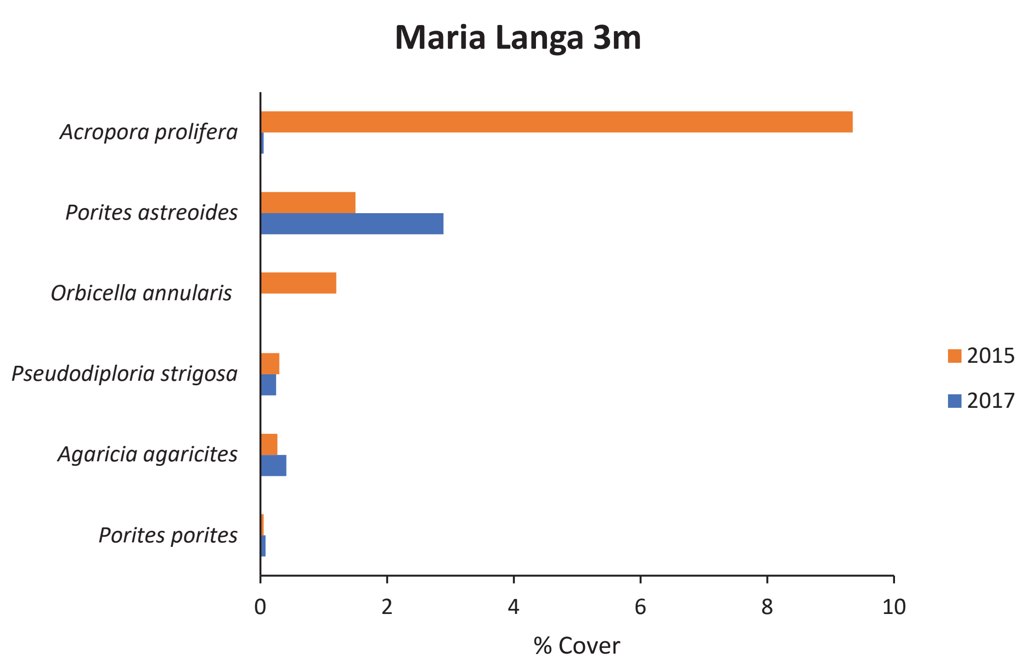


Figure 57. Monitoring trends (2016 – 2017) of mean substrate cover by stony coral species at Maria Langa 3m, Guayanilla

macclurei), Doctorfish (*Acanthurus chirurgus*) and Clown Wrasse (*Halichoeres maculipinna*) were present in at least four transects (Table 67). Six species were only observed in one transect.

The fish trophic structure at Maria Langa 3 was characterized by a balanced composition of herbivores and small carnivores, with low abundance of zooplanktivores and large demersal predators within belt-transects. Herbivores included three damselfishes (Pomacentridae), three doctorfishes (Acanthuridae) and three parrotfishes (Scaridae) with a combined abundance of 20.0 Ind/transect, representing 49.8% of the total individuals. Small opportunistic carnivores included four wrasses (Labridae), one squirrelfish (Holocentridae), one blenny (Blenniidae), two small groupers (Serranidae) and one puffer (Tetraodontidae) with a combined abundance of 14.6 Ind/transect, representing 33.2% of the total fish density. Demersal zooplanktivores were represented by the Bicolor Damselfish, with a mean abundance of 8.2 Ind/Transect, or 18.6 of the total fishes within transects. Medium sized piscivores included the Yellowtail Snapper (*Ocyurus chrysurus*). One Mutton snapper (*Lutjanus analis*), one Queen Triggerfish (*Balistes vetula*) and one Great Barracuda (*Sphyraena barracuda*) were observed out of transects.

The size-frequency distribution of doctorfishes (Acanthuridae), parrotfishes (Scaridae), Coneys and Graysbes (Serranidae), suggests that the reef serves mostly as a residential habitat for these species with most individuals as late juvenile and adult stages (Table 68). Motile megabenthic invertebrates were not observed within belt-transects. One juvenile spiny lobster, *Panulirus argus* was observed outside transects during the baseline 2016 survey (Garcia-Sais et al., 2016).

Variations of fish species richness and abundance between the 2016 baseline and the present 2017 monitoring survey are presented in Figure 58. There was a slight increase of mean richness and abundance, but differences were statistically insignificant (ANOVA, $p > 0.05$; Appendix 5 - 6). This is an interesting result in the sense that despite such drastic reduction of live coral cover the fish community structure did not respond with a proportional decline, but rather appeared to vary independently from the variation in coral cover.

Table 67. Taxonomic composition and abundance of fishes within belt-transects at Maria Langa Reef 3m Guayanilla. March 2017

Depth: 3-4m		TRANSECTS				
		1	2	3	4	5
		(Individuals/30 m²)				
SPECIES	**COMMON NAME**					
Stegastes adustus	Dusky Damselfish	17	16	14	13	9
Stegastes partitus	Bicolor Damselfish	11	7	7	6	10
Thalassoma bifasciatum	Bluehead Wrasse	9	8	7	6	8
Halichoeres bivittatus	Slippery Dick	3		2	6	4
Ophioblennius macclurei	Redlip Blenny	2	1	3	2	2
Acanthurus chirurgus	Doctorfish	3	2		1	2
Scarus iserti	Stripped Parrotfish				8	
Halichoeres maculipinna	Clown Wrasse	1	1		1	1
Microspathodon chrysurus	Yellowtail Damselfish		1	2	1	
Chaetodon capistratus	Four-eye Butterflyfish			1	2	
Sparisoma aurofrenatum	Redband Parrotfish		1	1	1	
Acanthurus bahianus	Ocean Surgeon		1			1
Acanthurus coeruleus	Blue Tang			1		1
Cephalopholis cruentatus	Graysby				1	1
Halichoeres radiatus	Puddinwife			1	1	
Scarus taeniopterus	Princess Parrotfish	1	1			
Stegastes variabilis	Cocoa Damselfish			1	1	
Canthigaster rostrata	Caribbean Puffer		1			
Cephalopholis fulva	Coney		1			
Calamus pluma	Pluma				1	
Holocentrus rufus	Longspine Squirrelfish	1				
Ocyurus chrysurus	Yellowtail Snapper			1		
	TOTAL INDIVIDUALS	**48**	**41**	**41**	**51**	**39**
	TOTAL SPECIES	**9**	**12**	**12**	**15**	**10**

Table 68. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at Maria Langa Reef 3 m, Guayanilla. March 2017

		TRANSECTS				
		1	2	3	4	5
				(Individuals/60 m^2)		
SPECIES	**COMMON NAME**					
Acanthurus bahianus	Ocean Surgeon		2 - 13	1 - 10	3 - 10	1 - 10
			1 - 10	1 - 15	1 - 15	
Acanthurus coeruleus	Blue Tang			1 - 13		1 - 15
Acanthurus chirurgus	Doctorfish	3 - 15	2 - 13	1 - 13	1 - 15	2 - 13
Sparisoma viride	Stoplight Parrotfish				1 - 30	
Sparisoma aurofrenatum	Redband Parrotfish		1 - 18	1 - 15	1 - 13	
Sparisoma rubripinne	Yellowtail Parrotfish					1 - 25
Scarus iserti	Striped Parrotfish				1 - 20	
Scarus taeniopterus	Princess Parrotfish	1 - 8	1 - 15			
Cephalopholis fulva	Coney		1 - 23			
Cephalopholis cruentatus	Graysbe				1 - 15	1 - 15
Ocyurus chrysurus	Yellowtail Snapper	1 - 20		1 - 13		

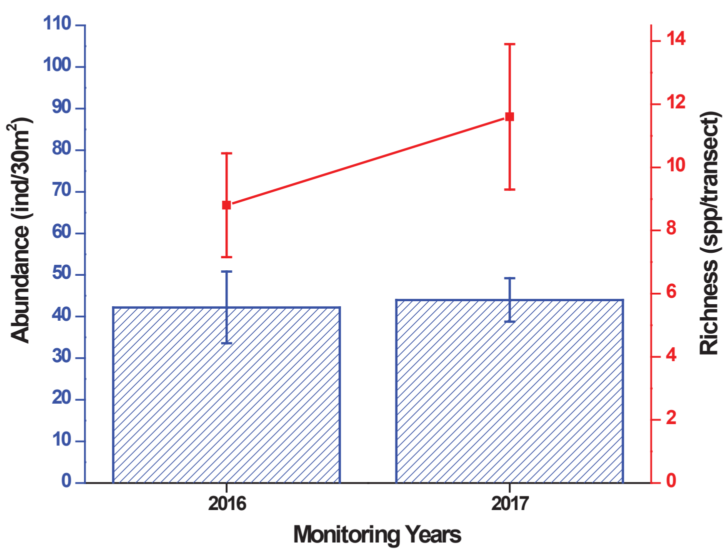


Figure 58. Monitoring trends (2015 – 2017) of fish species richness and abundance at Maria Langa Reef 20, Guayanilla

17.4 Photo Album 17

Maria Langa 3m - Guayanilla






18.0 West Reef of Isla Caja de Muerto – Ponce

18.1 Physical Description

Caja de Muerto is an island located approximately 8.5 km off the south coast of Puerto Rico, between Ponce and Santa Isabel, within the insular shelf. It is the largest emergent reef system of the south coast. The main reef platform includes Cayo Berbería, 5.5 km. to the northeast and Isla Morrillitos, adjacent to the main island, Caja de Muerto. The total surface area of the reserve is approximately 188.36 square kilometers (Villamil et al., 1980).

West Reef is located on the northwest coast of Caja de Muerto (Figure 59). It is a submerged patch coral reef formation that runs essentially parallel to the coastline. The base of the reef is a sandy-silt bottom at a depth of approximately 15 m. The reef rises to a depth of five meters from the surface. It consists of a shallow platform at the reef top and a drop-off wall with deep channels that run perpendicular to the wall facing down to the base of the reef. Most of the coral development occurs along the wall, with substantial stony coral and soft coral (gorgonians) growth into the channels. Goenaga and Cintrón (1979) described the geomorphology of this reef and provided the first taxonomic description of the benthic communities. Our survey was performed at a depth of 7.6 m on the fore reef slope. Transects were set roughly parallel to the coastline and perpendicular to the slope of the reef, following the seven (7.0) m depth contour. Panoramic views of West Reef are presented in Photo Album 18.

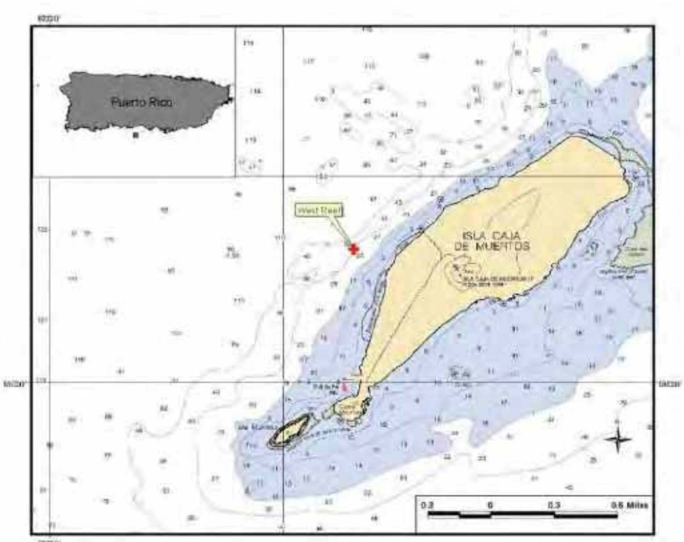


Figure 59. Location of coral reef monitoring stations at West Reef, Isla Caja de Muerto, Ponce.

18.2 Sessile-benthic Reef Communities

A total of 20 stony coral species, including 13 within transects were identified from West Reef in the 2017 survey. Live stony corals presented a mean substrate cover of 15.5 % (range: 11.3 – 22.1 %), with a mean of 13.0 colonies intercepted per transect (Table 69). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant coral species with a mean substrate cover of 5.3 % (range: 1.2 – 14.4 %), representing 33.1 % of the total substrate cover by live stony corals. Mustard-Hill Coral (*Porites astreoides*), Lettuce Coral (*Agaricia agaricites*) and Massive Starlet Coral, *Siderastrea siderea* were present in at least four out of the five transects surveyed, and along with Boulder Star Coral and Great Star Coral, *Montastrea cavernosa* comprised the main coral assemblage of West Reef (Table 69). An infectious disease was observed in one of the 65 coral colonies intercepted by transects during 2017, for a mean prevalence of 1.5% (Appendix 2).

Soft corals (gorgonians) presented a mean density of 20.8 colonies/transect and included colonies of very large size. Some of the most abundant erect species included Slimy Sea Plumes (*Allotogorgia americana*), Porous Sea Rods (*Plexaura spp*.), and Knobby Sea Rods (*Eunicea spp*.). Encrusting species, such as Corky Sea Finger (*Briareum asbestinum*) and Encrusting Gorgonian (*Erythropodium caribaeorum*) were present in all five transects with a combined mean cover of 3.2% (Table 69). Sponges, represented along transects by at least 14 species were present with a mean substrate cover of 3.5 %. Abiotic categories, mostly coral rubble and ref overhangs combined for a mean substrate cover of 25.0 %. The high rugosity measured at 5.0 m was strongly influenced by large relict coral heads (mostly *Orbicella annularis*).

A dense algal turf, comprised by a mixed assemblage of short filamentous coralline algae and brown macroalgae was the dominant component of the reef sessile-benthic biota in terms of substrate cover at West Reef. Turf algae averaged 45.6 % (range: 39.0 – 51.8 %), representing 91.8% of the total cover by benthic algae. Crustose red algae (*Ramicrusta, Peyssonnelia sp*) were present in all transects with a combined cover of 1.8 % (Table 69). Fleshy brown macroalgae was mostly comprised by the Y-Twig (*Dictyota sp.)* and the Encrusting Fan Algae (*Lobophora variegata*), but represented minor components of the benthic algae assemblage at West Reef (1.3%). Cyanobacterial patches were intercepted by four transects with a mean cover of 2.3%.

Table 69. Percent linear cover by sessile-benthic categories at Caja de Muerto Reef. Ponce

Survey Date: May 2017

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	3.17	5.09	5.39	5.95	5.64	**5.0**
Benthic Categories						
Abiotic						
Rubble	29.33	9.74	7.01	4.39	6.62	**11.4**
Reef overhang	6.16	6.49	14.83	12.47	12.44	**10.5**
Sand	1.06	2.41	7.28	3.25	0.00	**2.8**
Gap		1.48				**0.3**
Total Abiotic	**36.56**	**20.13**	**29.12**	**20.11**	**19.07**	**25.0**
Benthic Algae						
Turf with sediment	39.00	49.81	39.95	51.80	47.27	**45.6**
Ramicrusta sp.	2.76	0.65		2.02	2.51	**1.6**
Dictyota spp.		3.71		1.67		**1.1**
Jania spp.			1.82			**0.4**
Galaxaura marginata		0.65	1.09			**0.3**
Halimeda spp.		0.37	1.09			**0.3**
Lobophora variegatus			1.18			**0.2**
Peyssonnelia sp.			0.64		0.27	**0.2**
CCA		0.46				**0.1**
Total Benthic Algae	**41.76**	**55.66**	**45.77**	**55.49**	**50.04**	**49.7**
Cyanobacteria	2.44		4.55	0.88	3.85	**2.3**
Hard Coral						
Orbicella annularis complex	5.84	14.38	2.64	1.23	2.60	**5.3**
Porites astreoides	2.23	0.93	1.73	1.76	6.98	**2.7**
Montastraea cavernosa		4.45		5.44	3.49	**2.7**
Siderastrea siderea	0.85	0.19	1.82	2.63		**1.1**
Agaricia agaricites	0.85	0.93	1.46	0.61	1.52	**1.1**
Meandrina meandrites	1.81			1.67		**0.7**
Stephanocoenia intersepta	0.53	0.28	1.64		0.36	**0.6**
Millepora alcicornis			0.27	0.18	1.97	**0.5**
Agaricia fragilis	0.43		0.27		1.16	**0.4**
Agaricia lamarcki				1.67		**0.3**
Porites porites			1.18			**0.2**
Acropora cervicornis		0.93				**0.2**
Pseudodiploria strigosa			0.55		0.27	**0.2**
Madracis decactis				0.18	0.27	**0.1**
Total Hard Coral	**12.54**	**22.08**	**11.28**	**15.19**	**16.65**	**16.0**
Coral Colonies/Transect	9	14	13	13	16	**13.0**
Octocoral						
Antillogorgia americana					0.36	**0.1**
Briareum asbestinum	0.32	1.48	0.27	2.19	1.61	**1.2**
Erythropodium caribaeorum	2.13	0.46	0.91	4.39	1.97	**2.0**
Total Octocoral	**2.44**	**1.95**	**1.18**	**6.58**	**3.94**	**3.2**
# Gorgonians/transect	23	11	17	20	33	**20.8**
Sponge						
Xestospongia muta	1.06		4.82			**1.18**
Chondrilla caribensis	0.74		0.18		0.72	**0.33**
Cliona varians					1.52	**0.30**
Aiolochroia crassa	1.06			0.44		**0.30**
Aplysina cauliformis	0.64		0.36		0.27	**0.25**

Ircinia brown sp.					0.98	**0.20**
Ircinia felix			0.91			**0.18**
Monanchora arbuscula		0.09	0.45	0.18	0.18	**0.18**
Svenzea zeai	0.32				0.45	**0.15**
Ectyoplasia ferox			0.64			**0.13**
Scopalina ruetzleri	0.21	0.09			0.18	**0.10**
Niphates erecta				0.18	0.18	**0.07**
Sponge	0.21					**0.04**
Callyspongia plicifera				0.18		**0.04**
Total Sponge	**4.25**	**0.19**	**7.37**	**0.97**	**4.48**	**3.45**

Figure 60 presents the variations of mean percent cover by sessile-benthic categories from West Reef, including the original baseline survey of 1999 and annual monitoring surveys of 2005-17. Differences of reef substrate cover by stony corals between annual surveys were statistically significant (ANOVA; $p < 0.001$, Appendix 1), indicative of a degradation of the coral reef community structure. Such degradation was acute in 2006, after the massive coral bleaching event of October 2005 (Garcia-Sais et al., 2006). Live coral cover declined abruptly between the 2005 (19.32 %) and 2006 (11.42 %) monitoring surveys. The reduction represented a difference of 40.9 % of total live coral in only one year. Sharp reductions of live coral were measured in all transects surveyed. During 2007 live coral declined again, but the 6.3 % decline was relatively small compared to previous records and statistically similar to the 2006 condition. Recently dead coral accounted for a total of 7.7 % during 2007, associated with mortality of massive corals, such as *Orbicella annularis* and *Colpophyllia natans* after the late 2005 coral bleaching event (Figure 61). Partially bleached corals were observed during the 2007 survey and represented 1.5 % of the total cover by live corals at West Reef. Live coral cover stabilized since the 2008 monitoring survey and has shown a recuperation trend during the last two surveys, mostly driven by a sharp increment of cover by Boulder Star Coral, *Orbicella annularis* (Figure 61).

18.3 Fishes and Motile Megabenthic Invertebrates

A total of 101 fish species have been identified during monitoring surveys from West Reef, Isla Caja de Muerto (Appendix 4), including 42 within belt-transects during 2017. Mean abundance of fishes within belt-transects during 2017 was 56.6 Ind/30 m^2 (range: 39 - 93 Ind/30 m^2). The mean number of species per transect was 18.8 (H'= 190.5). The

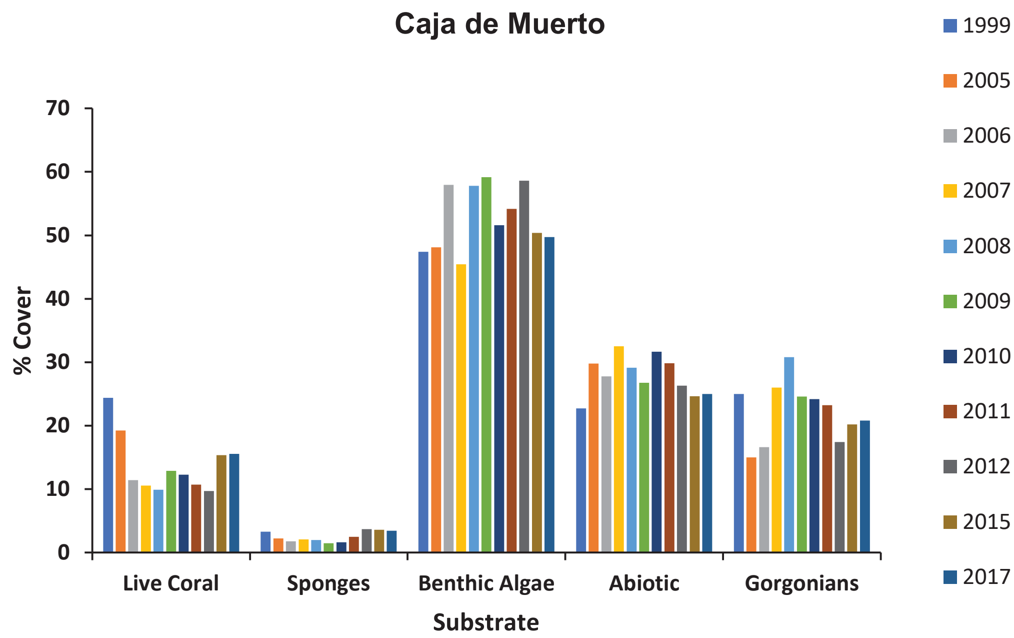


Figure 60. Monitoring trends (1999 - 2017) of mean substrate cover by sessile-benthic categories at West Reef, Isla Caja de Muerto, Ponce.

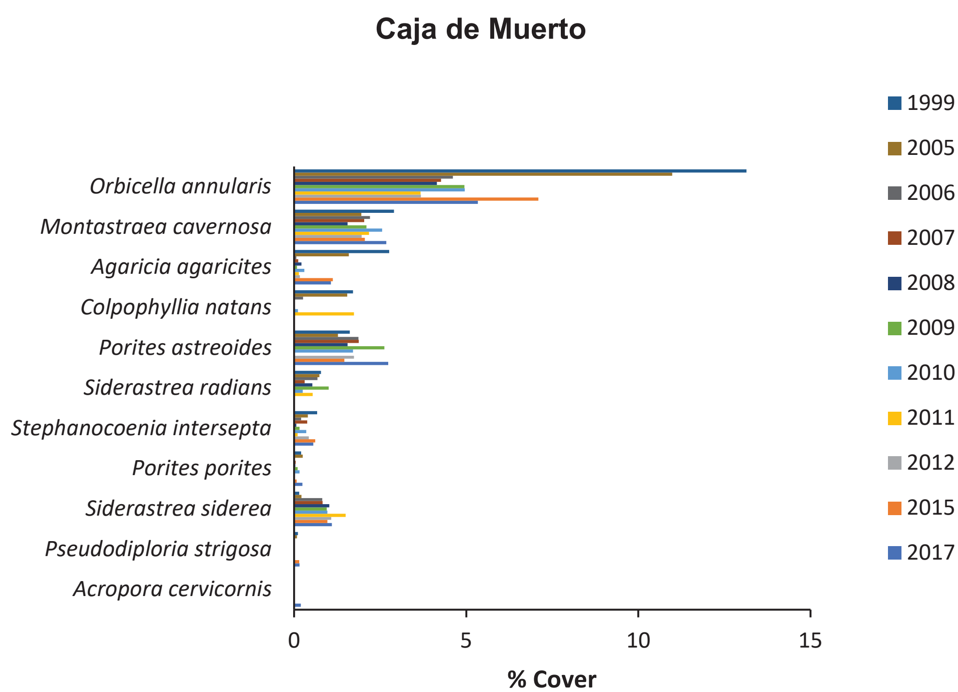


Figure 61. Monitoring trends (1999 – 2017) of mean substrate cover by stony coral species at West Reef, Isla Caja de Muerto, Ponce.

Masked Goby (*Coryphopterus personatus*) and the Bluehead Wrasse were the numerically dominant species with a combined abundance of 26 Ind/30 m^2, or 45.9% of the total individuals within belt-transects. Both species were present in all five transects surveyed. The Masked Goby was observed close to the reef substrate, below ledges, in front of crevices and other protective microhabitats of the reef, but in much smaller swarms than previously recorded. Seven other species were present in at least four transects, including the Princess and Redband Parrotfishes, Bicolor and Dusky Damselfishes, Blue Chromis, Tomtate and Ocean Surgeon and comprised along with Masked Goby and Bluehead Wrasse the main fish assemblage of West Reef (Table 70).

The size-frequency distribution of commercially important fishes, including the main reef herbivores is presented in Table 71. Doctorfishes were observed as full adult individuals in the 12 – 18 cm range (TL). Parrotfishes were present as juvenile and adults, including post-settlement stage juveniles of Stoplight, Redband and Bucktooth parrotfishes (*Sparisoma viride, S, aurofrenatum, S. radians*). Juvenile and adult Yellowtail, Grey, Lane and Schoolmaster Snappers (*Ocyurus chrysurus, Lutjanus griseus, L. synagris, L. apodus*) were present within belt-transects during this survey. Yellowtail snappers concentrate at the face of the fore-reef slope (wall), with small juveniles (< 5 cm) using the dense soft coral (gorgonian) forest as protective habitat. Schoolmasters and Grey Snappers were mostly observed swimming in and out of caves and crevices within the fore-reef slope. Juvenile and young adult Mutton Snappers (*L. analis*) have been observed foraging along with adult Lane Snapper aggregation during previous surveys (García-Sais et al., 2006, 2014).

The fish community structure at West Reef was strongly represented by zooplankton feeders, including the Masked Goby, Blue and Brown Chromis, Bicolor Damselfish with a combined abundance of 22.2 Ind/30m^2, representing 39.2% of the total individuals within belt-transects. Creole wrasse (*Clepticus parrae*) and Mackerel Scad (*Decapterus macarellus*) were observed out of transects. Many zooplanktivorous fish species serve as forage for a diverse assemblage of top pelagic and demersal predators, including barracudas, jacks, and large groupers and snappers observed during this and previous surveys (Garcia-Sais et al., 2015 and references therein). A specious assemblage of small invertebrate feeders, such as wrasses, gobies, puffers, goatfishes, grunts, trumpetfish, hamlets, squirrelfishes, and small groupers were also present with a

Table 70. Taxonomic composition and abundance of fishes within belt-transects at Caja de Muerto Reef 10m, Ponce, May 2017. Depth: 10 m

		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	14	36	9	14	7	**16.0**
Thalassoma bifasciatum	Bluehead Wrasse	13	18	3	13	3	**10.0**
Scarus taeniopterus	Princess Parrotfish	6	3		4	5	**3.6**
Stegastes partitus	Bicolor Damselfish	2	4		5	3	**2.8**
Stegastes dorsopunicans	Dusky Damselfish		5	2	4	2	**2.6**
Chromis cyanea	Blue Chromis	1	4		3	2	**2.0**
Stegastes planifrons	Yellow-eye Damselfish	3		3	3		**1.8**
Sparisoma viride	Stoplight Parrotfish		4		1	3	**1.6**
Haemulon aurolineatum	Tomtate		1	3	1	1	**1.2**
Coryphopterus sp	Goby		3	1	1		**1.0**
Sparisoma aurofrenatum	Redband Parrotfish	2	1	1		1	**1.0**
Acanthurus bahianus	Ocean Surgeon	1	1	1		1	**0.8**
Abudefduf sexatilis	Sargent Major		1	1	2		**0.8**
Chaetodon capistratus	Four-eye Butterflyfish			2		2	**0.8**
Elacatinus evelynae	Sharknose Goby	1			3		**0.8**
Ocyurus chrysurus	Yellowtail Snapper	3	1				**0.8**
Amblycirrhitus pinos	Red-spotted Hawkfish		2	1			**0.6**
Canthigaster rostrata	Caribbean Puffer	1		1		1	**0.6**
Chromis multilineata	Brown Chromis		2		1		**0.6**
Haemulon flavolineatum	French Grunt		1	2			**0.6**
Stegastes variabilis	Cocoa Damselfish	1		2			**0.6**
Cephalopholis cruentatus	Graysbe	1	1				**0.4**
Holocentrus rufus	Longspine Squirrelfish	1				1	**0.4**
Hypoplectrus unicolor	Butter Hamlet	1				1	**0.4**
Lutjanus apodus	Schoolmaster			1		1	**0.4**
Myripristis jacobus	Black-bar Soldierfish			2			**0.4**
Pterois sp	Lionfish		2				**0.4**
Scarus iserti	Stripped Parrotfish	1		1			**0.4**
Sparisoma radians	Bucktooth Parrotfish	2					**0.4**
Stegastes leucostictus	Beaugregory	1	1				**0.4**
Acanthurus coeruleus	Blue Tang					1	**0.2**
Acanthurus chirurgus	Doctorfish			1			**0.2**

Aulostomus maculatus	Trumpetfish		1				**0.2**
Chaetodon ocellatus	Spotfin Butterflyfish					1	**0.2**
Coryphopterus glaucofraenum	Saddled Goby					1	**0.2**
Halichoeres garnoti	Yellow-head Wrasse					1	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet			1			**0.2**
Hypoplectrus nigricans	Black Hamlet				1		**0.2**
Hypoplectrus puella	Barred Hamlet				1		**0.2**
Lutjanus synagris	Lane Snapper				1		**0.2**
Serranus tigrinus	Harlequin Bass		1				**0.2**
Synodus intermedius	Lizardfish			1			**0.2**
	TOTAL INDIVIDUALS	**55**	**93**	**39**	**58**	**38**	**56.6**
	TOTAL SPECIES	**18**	**21**	**20**	**16**	**19**	**18.8**

Table 71. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at Caja de Muerto Reef 10m, Ponce, May 2017

		TRANSECTS				
		1	2	3	4	5
				(Individuals/60 m^2)		
SPECIES	**COMMON NAME**					
Acanthurus coeruleus	Blue Tang	1 - 15	1 - 18	1 - 15		1 - 12
Acanthurus chirurgus	Doctorfish			1 - 12		1 - 18
Acanthurus bahianus	Ocean Surgeon	1 - 10	1 - 15	2 - 10	1 - 12	1 - 15
		2 - 12				
Cephalopholis cruentatus	Graysbe	1 - 12	1 - 15			
Lutjanus apodus	Schoolmaster Snapper			1 - 18		1 - 28
Lutjanus synagris	Lane Snapper				1 - 25	
Lutjanus griseus	Grey Snapper					4 - 25
						2 - 30
Ocyurus chrysurus	Yellowtail Snapper	3 - 15	1 - 20			
			1 - 22			
Scarus iserti	Stripped Parrotfish	1 - 18		3 - 15	1 - 15	
Scarus taeniopterus	Princess Parrotfish	5 - 5	2 - 8	2 - 18	3 - 5	4 - 5
		1 - 18	2 - 25		3 - 8	1 - 20
					1 - 25	

Sparisoma aurofrenatum	Redband Parrotfish	1 - 1	1 - 20	1 - 20		2 - 22
		1 - 12				
Sparisoma rubripinne	Yellowtail Parrotfish					
Sparisoma viride	Stoplight Parrotfish	1 - 5	1 - 2		1 - 8	1 - 15
			2 - 5		1 - 10	1 - 25
			1 - 15			2 - 30
Sparisoma radians	Bucktooth Parrotfish	2 - 1				
Pterois sp	Lionfish		1 - 15			
			1 - 25			

combined abundance of 17.8 Ind/30m^2, or 31.4% of the total individuals. Herbivores, comprised by three doctorfishes (*Acanthurus spp*), parrotfishes (*Sparisoma spp., Scarus spp*) and farmer damselfishes (*Stegastes spp*) presented a combined abundance of 13.6 Ind/30m^2, or 24.0% of the total individuals. Mid-size carnivores included the Yellowtail, Lane, Grey, and Schoolmaster Snappers, and Coney. Large Cubera Snapper (*Lutjanus cyanopterus*). Hogfish, Red Hind and a juvenile Yellowfin Grouper (*Mycteroperca venenosa*) have been reported during previous surveys (Garcia-Sais et al., 2005, Garcia-Sais et al., 2015 and references therein*).* Large aggregations of more than 700 juvenile and young adult Lane Snappers (*Lutjanus synagris*) were observed near the base of the reef, along the reef-sand interface during the 2006 survey, and again during the 2009 - 2013 surveys. The aggregation of these Lane Snappers at West Reef is most impressive and represents a highly valuable resource.

Figure 62 shows the annual trends of fish abundance and species richness during monitoring surveys at West Reef. Statistically significant differences of fish abundance (ANOVA; $p < 0.001$, Appendix 6) were found. These differences were driven by abundance fluctuations of the Masked Goby, a dominant species that forms large schooling aggregations of 100's of individuals within belt transects. Abundances were relatively lower during the baseline survey and then again in the period of 2006-08 relative to the period of 2009-2011 and the present 2017 survey. Differences of fish species richness within belt-transects were also detected (ANOVA; $p < 0.001$; Appendix 5). The main pattern was a decline of the number of species per transect during the 2007, 2008 and during the 2013 relative to other surveys.

Motile megabenthic invertebrates were represented within belt-transects by Brittle Stars (Ophiuoridea), Flamingo Tongue and one Sea Cucumber (Table 72). Juvenile and adult spiny lobsters, *Panulirus argus*, Arrow Crabs, Fire Worms and juvenile and adult Queen Conch, *Strombus gigas* have been reported in previous surveys (Garcia-Saia et al., 2014).

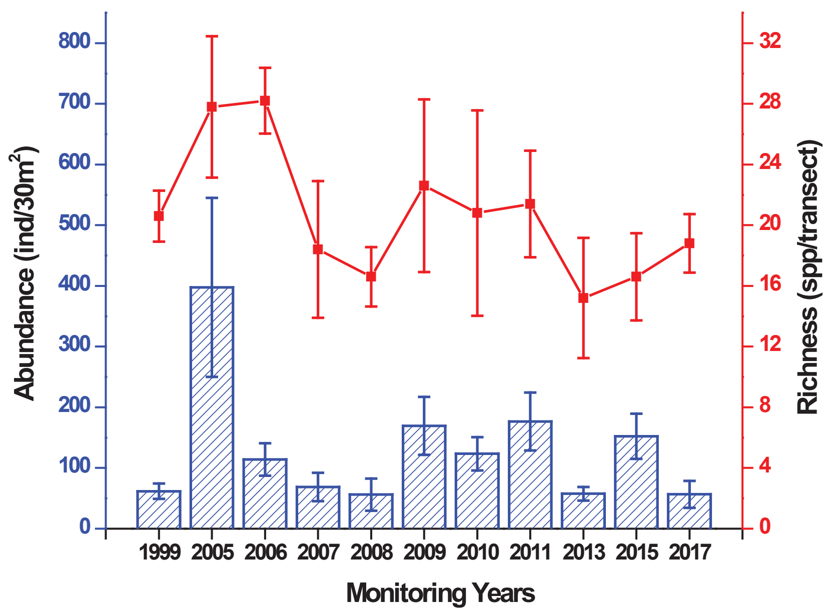


Figure 62. Monitoring trends (1999 – 2017) of fish species richness and abundance at West Reef, Isla Caja de Muerto, Ponce

Table 72. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at West Reef, Caja de Muerto. 2017.

Depth: 8 m		TRANSECTS					MEAN ABUNDANCE (IND/30m2)
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Ophiuoridea spp	Brittle Stars		3				**0.6**
Isostichopus badionotus	Three-Rowed Sea Cucumber	1					**0.2**
Cyphoma gibbosum	Flamingo tongue	1					**0.2**
	TOTALS	**2**	**3**	**0**	**0**	**0**	**1.0**

18.4 Photo Album 18
West Reef - Caja de Muerto











19.0 Derrumbadero Reef – Ponce

19.1 Physical Description

Derrumbadero is a submerged promontory fringing the shelf-edge, 2.2 nautical miles southeast off from the mouth of Ponce Bay (Figure 63). The promontory rises from the outer shelf at a depth of about 25 -30 m to a reef top at 15 m, and then drops down the insular slope along the south and west margins. The reef top platform has an irregular spherical shape. It measures approximately 2 kilometers from east to west and about 0.7 kilometers from north to south. Permanent transects were established at the southern edge of the reef, close to the shelf-edge drop-off wall.

Derrumbadero Reef exhibits an impressive spur-and groove coral reef formation that resembles the shelf-edge reef systems of La Parguera and Guánica. Coralline sand channels with coral rubble cut through the reef down to the shelf-edge, separating spurs of approximately 5 meters high. Massive, branching and encrusting corals and gorgonians colonize the spurs and grow towards the channels, creating a highly complex habitat of large coral mounds, ledges and overhangs. Baseline characterization of the reef community was performed during August 2001 by García-Sais et al. (2001 c). Panoramic views of Derrumbadero Reef are presented as Photo Album 19.

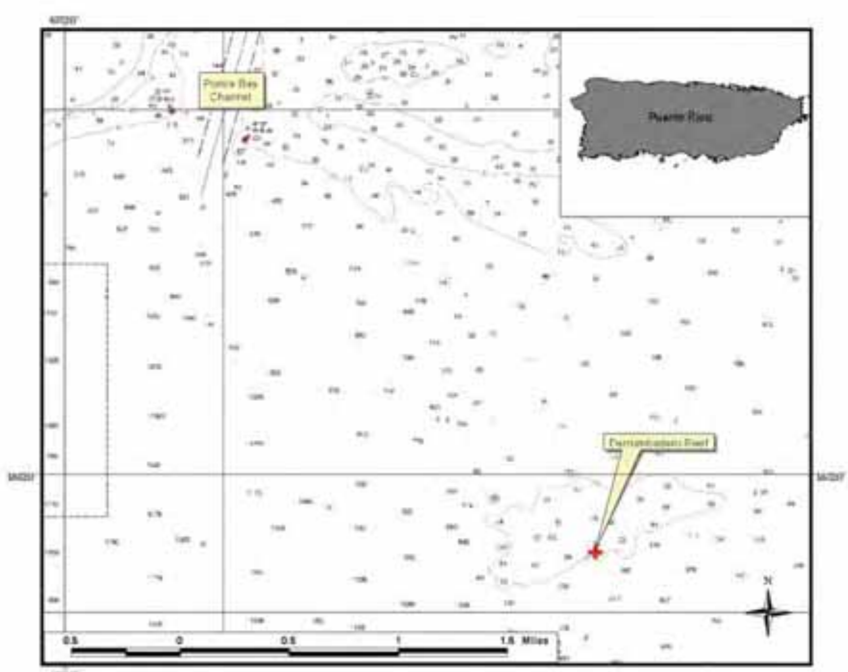


Figure 59. Location of the coral reef monitoring station at Derrumbadero Reef, Ponce.

19.2 Sessile-Benthic Reef Community

A total of 21 stony corals have been identified from Derrumbadero Reef at a depth of 20m, including 14 intersected by line transects during 2017 (Table 73). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 21.6 % (range: 10.4 – 31.4 %), with a mean of 14.6 colonies/ transect. Boulder Star Coral, *Orbicella annularis* (complex) was the dominant species in terms of substrate cover with a mean of 11.8 % (range: 4.6 – 20.3 %), representing 54.6 % of the total cover by stony corals. Mustard-Hill Coral (*Porites astreoides*) and Lettuce Coral (*Agaricia agaricites*) were present in all five transects with a combined mean substrate cover of 5.5% or 25.3 % of the total cover by live corals. Great Star Coral (*M. cavernosa*) was present in three transects and was the only other coral species with mean substrate cover above 1% (Table 73). One out of 73 coral colonies intercepted by transects was observed to be affected by an infectious disease (Appendix 2).

Black corals (Antipatharia) were observed off the shelf-edge at depths of 25 – 30 m. These included the Wire Black Coral (*Stichopathes lutkeni*), and the Bushy Black Coral (*Antipathes caribbeana*). Soft corals were abundant (mean: 33.6 col./transect) at Derrumbadero Reef and because of their large sizes and species richness contributed substantially to the biological diversity and structural complexity of the reef system. Among erect growth forms, Sea Plumes, *Antillogorgia acerosa, A. americana*, Sea Fan, *Gorgonia ventalina* and Sea Rods *Plexaura flexuosa*, *Eunicea spp*. were the most common. Encrusting species, such as the Corky Sea Finger, *Briareum asbestinum* and *Erythropodium caribaeorum* were present in four and five transects, respectively with a combined mean cover of 4.2% (Table 73). At least 22 sponge species were intercepted by transects with a combined mean substrate cover of 5.3 %. *Agelas spp*. were the most prominent in terms of substrate cover (Table 73). Infectious diseases were not observed in any of the 73 coral colonies intercepted in transects during 2017 (Appendix 2).

Benthic algae comprised by an assemblage of turf, brown (*Lobophora sp*., *Dictyota sp*) and red crustose (*Ramicrusta sp, Peyssonnelia sp*.) and coralline algae were the most prominent sessile-benthic category in terms of substrate cover at Derrumbadero with a mean of 63.2 % (range: 51.0 – 74.8 %). Abiotic categories were present mostly as reef overhangs mostly produced by mounds and ledges of Boulder Star Coral (*O. annularis*) (Table 73).

Table 73. Percent linear cover by sessile-benthic categories at Derrumbadero Reef, Ponce. Survey Date: May 2017

Depth: 20m

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	3.03	2.14	1.82	2.42	3.34	2.5
Benthic Categories						
Abiotic						
Reef overhang	1.29	3.23	0.83	4.62	6.19	3.2
Rubble	1.07			1.58		0.5
Total Abiotic	**2.36**	**3.23**	**0.83**	**6.20**	**6.19**	**3.8**
Benthic Algae						
Turf	19.23	45.56	38.51	28.64	31.27	32.6
Lobophora variegatus	26.10	12.00	31.04	30.21	27.60	25.4
CCA	5.16	3.69	2.13	2.25	0.73	2.8
Dictyota spp.	0.54	0.35	1.90	1.13	3.78	1.5
Peyssonnelia sp.		1.15	1.18			0.5
Martensia pavonia		0.46			0.52	0.2
Ramicrusta sp.					0.73	0.1
Total Benthic Algae	**51.02**	**63.21**	**74.76**	**62.23**	**64.64**	**63.2**
Cyanobacteria	2.36	0.46		1.13	0.31	0.9
Hard Coral						
Orbicella annularis complex	20.30	12.11	8.29	4.62	13.75	11.81
Porites astreoides	5.37	3.58	4.50	2.03	4.20	3.94
Agaricia agaricites	2.15	0.46	1.66	2.03	1.47	1.55
Montastraea cavernosa	0.97	2.54	1.66			1.03
Meandrina meandrites	1.29				2.52	0.76
Colpophyllia natans		3.81				0.76
Diploria labyrinthiformis	0.21			1.47		0.34
Agaricia lamarcki			1.07			0.21
Millepora alcicornis	0.64	0.23				0.18
Porites porites					0.84	0.17
Stephanocoenia intersepta					0.84	0.17
Madracis decactis	0.43	0.35				0.16
Siderastrea siderea			0.24	0.23		0.09
Agaricia grahamae		0.35				0.07
Total Hard Coral	**31.36**	**23.41**	**17.42**	**10.37**	**23.61**	**21.64**
Coral Colonies/Transect	19	11	20	8	15	**14.6**
Octocoral						
Briareum asbestinum	2.90	0.23		10.71	0.31	2.83
Erythropodium caribaeorum	1.61	0.35	1.78	2.25	0.73	1.34
Gorgonia ventalina	0.32	0.46	0.59	0.68		0.41
Antillogorgia acerosa		0.58	1.07		0.31	0.39
Antillogorgia americana				0.23	0.73	0.19
Pseudoplexaura wagenaari flagellosa	0.32				0.21	0.11
Eunicea flexuosa		0.46				0.09
Eunicea sp.					0.42	0.08
Plexaura kuekenthali				0.23		0.05
Total Octocoral	**5.16**	**3.11**	**3.44**	**14.09**	**2.73**	**5.71**
# Gorgonians/transect	18	41	41	31	37	33.6
Sponge						
Agelas dispar	1.61	1.15	0.71	1.47		0.99
Agelas sventres	0.43	1.96	1.07	0.68	0.52	0.93
Agelas citrina	2.36	1.38	0.47			0.84
Agelas conifera	1.93				0.42	0.47
Agelas sceptrum	0.86	0.35		0.23		0.29
Aplysina fistularis				0.90		0.18

Petrosia pellasarca					0.84	0.17
Ircinia felix			0.83			0.17
Monanchora arbuscula	0.32	0.23	0.24			0.16
Agelas tubulata				0.79		0.16
Ectyoplasia ferox				0.79		0.16
Ircinia strobilina		0.46				0.09
Chondrilla caribensis		0.23		0.23		0.09
Neopetrosia rosariensis				0.45		0.09
Amphimedon compressa	0.21			0.23		0.09
Agelas clathrodes					0.42	0.08
Sponge		0.35				0.07
Callyspongia fallax					0.31	0.06
Niphates caribica			0.24			0.05
Ircinia brown sp.		0.23				0.05
Neopetrosia proxima		0.23				0.05
Scopalina ruetzleri				0.23		0.05
Total Sponge	**7.73**	**6.57**	**3.55**	**5.98**	**2.52**	**5.27**

Figure 64 presents the variations of mean percent cover by sessile-benthic categories from Derrumbadero Reef, including the original baseline survey in 2001 and subsequent monitoring surveys of 2005-17. Differences of mean total percent cover by stony corals between monitoring surveys were statistically significant (ANOVA; $p < 0.0001$; Appendix 1), indicative of a severe degradation of the reef coral community. The reduction of mean live coral cover between the baseline survey of 2001 (41.6 %) and the first monitoring survey of 2005 (34.6 %) represented a decline of 16.7 % over a period of four years. A much more drastic decline was observed between 2005 and the 2006 monitoring survey. Total live coral declined 59.1 %, from 34.6 % in 2005 to 14.2 % in 2006. A proportional increment of cover by benthic algae was measured. Such drastic, short-term collapse of the Derrumbadero coral reef system was associated with the massive regional coral bleaching event that affected Puerto Rico and the USVI during late September through October 2005 (García-Sais et al., 2006, 2007, 2008). Another decline of 24% from the mean cover in 2007 was measured during the 2008 survey. Partially bleached coral declined to a mean substrate cover of 0.6 % during 2008. Since 2012, a mild but consistent trend of increasing live coral cover has been measured until the present survey (Figure 64), reaching a recuperation of 62% from the pre-bleaching live coral cover of 2005. Monitoring trends of mean substrate cover by coral species at Derrumbadero Reef are shown in Figure 65. In 2005, Boulder Brain Coral was the dominant coral species in terms of reef substrate cover at Derrumbadero Reef, representing then almost 62 % of the total cover by live corals. Thus, its sharp decline of 57.4 % between the 2005 (20.4 %) and

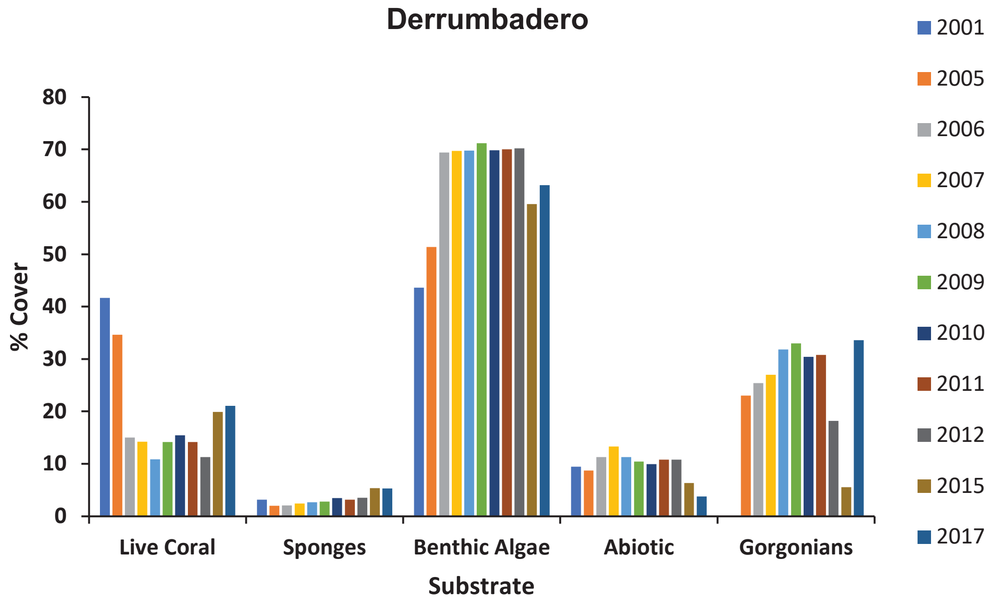


Figure 64. Monitoring trends (2001 – 2017) of mean substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce.

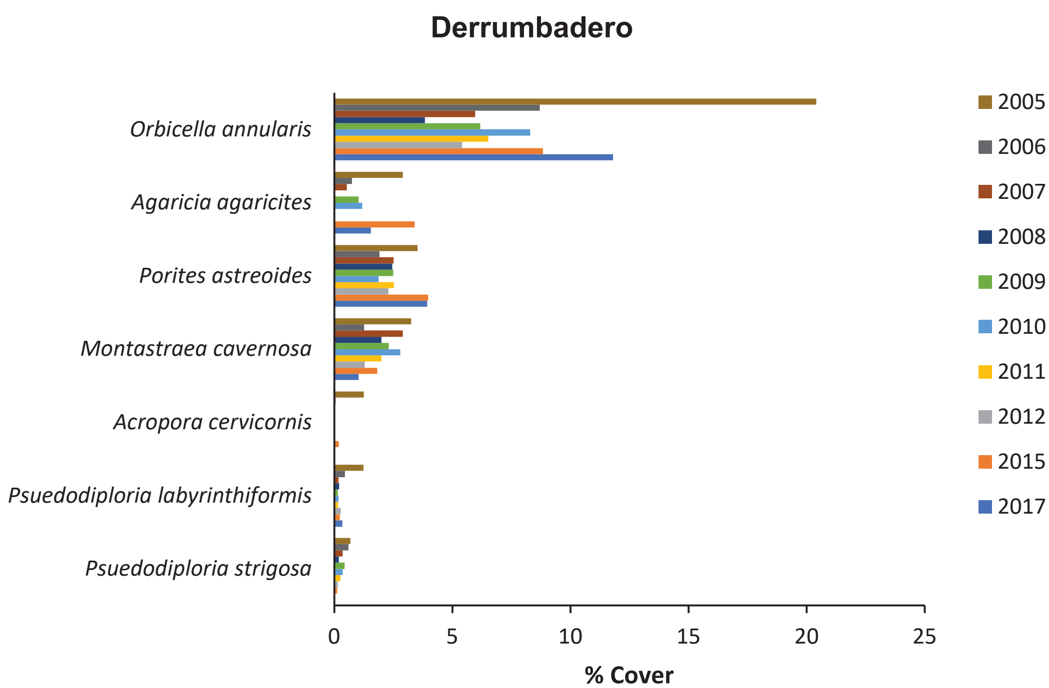


Figure 65. Monitoring trends (2001 – 2017) of mean substrate cover by coral species at Derrumbadero Reef, Ponce

2006 (8.7 %) monitoring surveys had a bold influence on the total live coral at the reef ecosystem level. Marked reductions of mean substrate cover by live corals were also measured for *Montastraea cavernosa*, *Agaricia agaricites, Diploria labyrinthiformis*, and *Acropora cervicorni*s. Since 2012, a mild but consistent increase of reef substrate cover by *Orbicella annularis* has been measured until the present survey and represents an important contribution to the overall recuperation of the coral community at Derrumbadero Reef.

19.3 Fishes and Motile Megabenthic Invertebrates

A total of 114 fish species have been identified from Derrumbadero Reef during monitoring surveys (Appendix 4), including 40 within belt-transects during 2017 (Table 74). Mean abundance within belt-transects was 43.6 Ind/30 m^2 (range: 30 - 54 Ind/30 m^2). The mean number of species per transect was 17.4 (range: 15 - 20). The Bicolor Damselfish, Sharknose Goby, Bluehead Wrasse, Princess Parrotfish and Blue Chromis were the numerically dominant species with a combined mean abundance of 22.4 Ind/30 m^2 representing 51.4 % of the total abundance within belt-transects (Table 74). In addition to the aforementioned species, the Redband, Striped and Bucktooth Parrotfishes, Ocean Surgeon and Blue Tang, Graysbe, Beaugregory and Peppermint Goby were present in at least three of the five transects surveyed and were also part of the resident demersal fish community.

Commercially important fishes observed within extended belt-transects included adult Hogfish (*Lachnolaimus maximus*), Red Hinds (*Epinephelus guttatus*) and juvenile Graysbes (*Cephalopholis cruentatus*) and Yellowtail Snapper (*Ocyurus chrysurus*). An assemblage of four species of parrotfishes (*Scarus spp., Sparisoma spp*.) and three doctorfishes (*Acanthurus spp*.) were present as juveniles and adults, including post-settlement juvenile stages of the Redband and Stoplight Parrotfishes (*Sparisoma aurofrenatum, S. viride*) (Table 75). Adult Great Barracuda (*Sphyraena barracuda*), Almaco Jack (*Seriola sp*) and juvenile Cubera and Schoolmaster snappers (*Lutjanus cyanopterus, L. apodus*) were observed out of transects.

Table 74. Taxonomic composition and abundance of fishes within belt-transects at Derrumbadero Reef 20m. Ponce, May 2017

Depth: 20m

		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Stegastes partitus	Bicolor Damselfish	7	7	6	7	7	**6.8**
Elacatinus evelynae	Sharknose Goby	9	9	6	2	2	**5.6**
Thalassoma bifasciatum	Bluehead Wrasse	4	11	4		5	**4.8**
Scarus taeniopterus	Princess Parrotfish	3	5	4		2	**2.8**
Chromis cyanea	Blue Chromis	7	2		2	1	**2.4**
Sparisoma radians	Bucktooth Parrotfish	5		1		3	**1.8**
Sparisoma aurofrenatum	Redband Parrotfish	2	1	2	1	2	**1.6**
Acanthurus bahianus	Ocean Surgeon	1	3	2	1		**1.4**
Stegastes leucostictus	Beau Gregory		1	1	2	3	**1.4**
Coryphopterus lipernes	Peppermint Goby	1	3	2			**1.2**
Scarus iserti	Stripped Parrotfish		2	1		3	**1.2**
Cephalopholis cruentatus	Graysby	1	1	1		2	**1.0**
Clepticus parrae	Creole Wrasse	5					**1.0**
Holocentrus rufus	Squirrelfish				3	2	**1.0**
Acanthurus coeruleus	Blue Tang		1	1		2	**0.8**
Chaetodon capistratus	Four-eye Butterflyfish	2	2				**0.8**
Sparisoma viride	Stoplight Parrotfish		3			1	**0.8**
Chaetodon ocellatus	Spotfin Butterflyfish				1	2	**0.6**
Coryphopterus sp.	Goby				3		**0.6**
Halichoeres garnoti	Yellow-head Wrasse				1	2	**0.6**
Myripristis jacobus	Black-bar Soldierfish				1	2	**0.6**
Chaetodon striatus	Banded Butterflyfish				2		**0.4**
Microspathodon chrysurus	Yellowtail Damselfish	1				1	**0.4**
Serranus tigrinus	Harlequin Bass			1	1		**0.4**
Stegastes planifrons	Yellow-eye Damselfish					2	**0.4**
Acanthurus chirurgus	Doctorfish					1	**0.2**
Anisotremus virginicus	Porkfish					1	**0.2**
Canthigaster rostrata	Caribbean Puffer				1		**0.2**
Coryphopterus personatus	Masked Goby	1					**0.2**
Echenes naucrates	Sharksucker	1					**0.2**
Epinephelus guttatus	Red Hind			1			**0.2**
Haemulon flavolineatum	French Grunt	1					**0.2**
Haemulon sciurus	Bluestriped Grunt				1		**0.2**
Holocentrus coruscus	Reef Squirrelfish	1					**0.2**
Hypoplectrus unicolor	Butter Hamlet		1				**0.2**
Lachnolaimus maximus	Hogfish		1				**0.2**

Melichthys niger	Black Durgon	1					**0.2**
Ocyurus chrysurus	Yellowtail Snapper	1					**0.2**
Pomacanthus arcuatus	Grey Angelfish				1		**0.2**
Pomacanthus ciliaris	French Angelfish			1			**0.2**
Pseudupeneus maculatus	Yellow Goatfish		1				**0.2**
	TOTAL INDIVIDUALS	**54**	**54**	**34**	**30**	**46**	**43.6**
	TOTAL SPECIES	**19**	**17**	**15**	**16**	**20**	**17.4**

Table 75. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at Derrumbadero Reef 20 m, Ponce, May 2017

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Individuals/60 m^2)				
SPECIES	**COMMON NAME**					
Acanthurus chirurgus	Doctorfish					1 - 18
Acanthurus bahianus	Ocean Surgeon	1 - 12	1 - 7	1 - 7	1 - 10	
		1 - 15	1 - 12	1 - 12	1 - 15	
			2 - 15			
Acanthurus coeruleus	Blue Tang		1 - 10	2 - 12		1 - 10
				1 - 15		1 - 15
Cephalopholis cruentatus	Graysbe			1 - 12		
Epinephelus guttatus	Red Hind			1 - 36		
Epinephelus cruentatus	Graysby					2 - 10
						1 - 12
Lachnolaimus maximus	Hogfish		1 - 36			
Ocyurus chrysurus	Yellowtail Snapper	1 - 18				
Sparisoma viride	Stoplight Parrotfish		1 - 12			1 - 1
			2 - 30			
Scarus iserti	Stripped Parrotfish		2 - 12	1 - 15		2 - 8
						1 - 25
Sparisoma aurofrenatum	Redband Parrotfish	1 - 10		1 - 1	1 - 10	1 - 15
		1 - 15		1 - 15		1 - 10
Scarus taeniopterus	Princess Parrotfish	2 - 12	2 - 7	3 - 8	1 - 8	1 - 8
		2 - 25	3 - 10	1 - 10		1 - 10
						1 - 25
Sparisoma radians	Bucktooth Parrotfish	2 - 1		1 - 1		2 - 1
		2 - 2				1 - 2

The fish community of Derrumbadero Reef appears to be well balanced in terms of trophic structure, including the presence of large demersal and pelagic predators, such as large snappers and groupers, barracudas, mackerels and jacks. There is a strong plankton based food web that serves to transfer energy up to the top predators of the reef system. Numerically dominant species in previous monitoring surveys (Garcia-Sais et al, 2015 and references therein), such as the Masked Goby, Blue and Brown Chromis, Bicolor Damselfish, Bluehead, Yellowhead and Creole Wrasse. These in turn serve as forage for large pelagic predators. During 2017 the zooplanktivorous fish component present within belt-transects represented only 23.8%. Small invertebrate feeders, including wrasses, hamlets, gobies, squirrelfishes, and others represented 40.4% of the total. Larger invertebrate and small fish predators included the Hogfish, Graysby and Red Hind groupers. Parrotfishes, doctorfishes, and damselfishes comprised the main herbivorous assemblage representing 29.8% of the total.

Figure 66 presents the temporal trends of fish abundance and richness within belt-transects during the baseline characterization of 2001 and subsequent monitoring surveys of 2005-17. Statistically significant declines of fish abundance and species richness (ANOVA; $p < 0.001$; Appendix 5 - 6) were detected. Higher fish abundance was observed during the 2001, 2005 and 2011 surveys compared to the 2006 – 10, 2013 and 2017 surveys. Differences have been largely associated to abundance fluctuations by Masked Goby, *Coryphopterus personatus*, a species that was numerically dominant during the baseline (2001) and the 2005, 2011 and 2015 surveys. This is a small zooplanktivorous species that forms dense swarms of 100' of individuals below coral ledges. Its mean abundance within belt-transects has varied more than 10-fold between monitoring surveys. Such marked fluctuations of abundance by Masked Goby are unaccounted for and beyond the scope of this monitoring work, but appear to be related to density-independent factors, such as its recruitment dynamics (Esteves, 2013).

One Channel Clinging Crab and one Cleaner Shrimp represented megabenthic invertebrates within belt transects during the 2017 survey (Table 76). One spiny lobster (*Panulirus argus*) were observed outside transects.

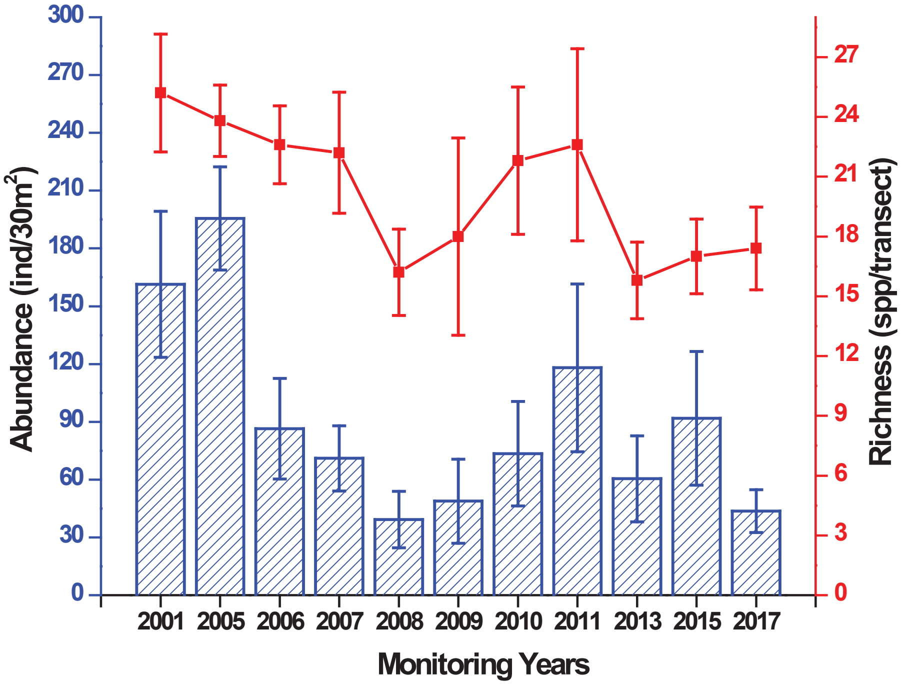
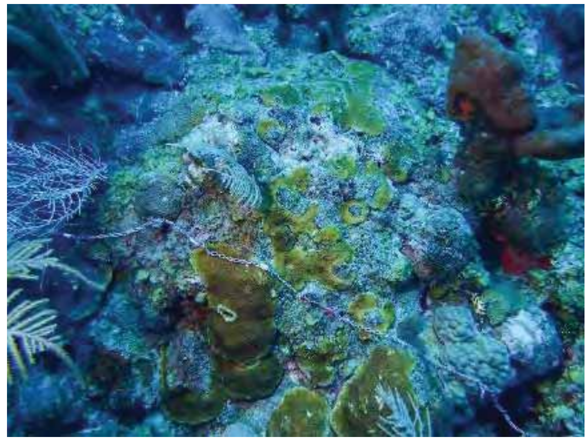


Figure 66. Monitoring trends (1999 – 2017) of fish species richness and abundance at Derrumbadero Reef, Ponce

Table 76. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Derrumbadero Reef, 20 m, Ponce, 2017

Depth: 20 m		TRANSECTS					
TAXA	**DEPTH (m) COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
Mithrax spinosissimus	Channel Clinging Carb	1					**0.2**
Periclimenes pedersoni	Cleaner Shrimp		1				**0.2**
	TOTALS	**1**	**1**	**0**	**0**	**0**	**0.4**

19.4 Photo Album 19
Derrumbadero Reef - Ponce








20.0 Cayo Caribes 10 - Salinas
20.1 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 67). 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 depth contour. Photographic characterization of Cayo Caribes Reef and its representative reef community is included as Photo Album 20.

20.2 Sessile-benthic Reef Community

Benthic algae were the dominant biotic category covering reef substrate at Cayo Caribes 10 with a combined mean cover of 52.2% (Table 77). 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 50.9% (range: 44.1 – 55.0 %), representing 95.8% of the total cover by algae. Fleshy brown macroalgae, mostly *Dictyota sp*. and red crustose coralline (CCA) and encrusting algae (*Ramicrusta sp., Peyssonnelia sp.*) were also present with low substrate cover of (<1%).

Scleractinian corals were represented by nine species intercepted by linear transects with a combined mean substrate cover of 16.9% (range: 9.6 – 25.7 %) and a mean of 9.6 colonies/transect. Great Star Coral, *Montastrea cavernosa* was the dominant coral in terms of reef substrate cover with a mean of 6.3 %, representing 37.3% of the total cover by live corals (Table 77). Mustard-Hill Coral, *Porites astreoides* and Massive Starlet Coral, *Siderastrea siderea* were present (along with *M. cavernosa*) in all five transects with a combined mean cover of 6.4 % and along with Boulder Star Coral, *Orbicella annularis* (complex) represented the main coral assemblage in terms of substrate cover by live corals at Cayo Caribes 10. Small encrusting colonies of Symmetrical Brain Coral, *Pseudodiploria strigosa* were present in four transects with a mean cover of 0.6 %. Infectious diseases were observed in two of the 44 coral colonies intercepted by transects during 2017 for a mean prevalence of 4.5% (Appendix 2).

Vertically projected soft corals (gorgonians) were prominent at Cayo Caribes 10 with a mean density of 21.4 colonies per transect (Table 77). Sea Rods (*Muriceopsis flavida*, *Muricea spp, Eunicea spp.*) and Sea Fans (*Gorgonia ventalina*) were the most common. The encrusting

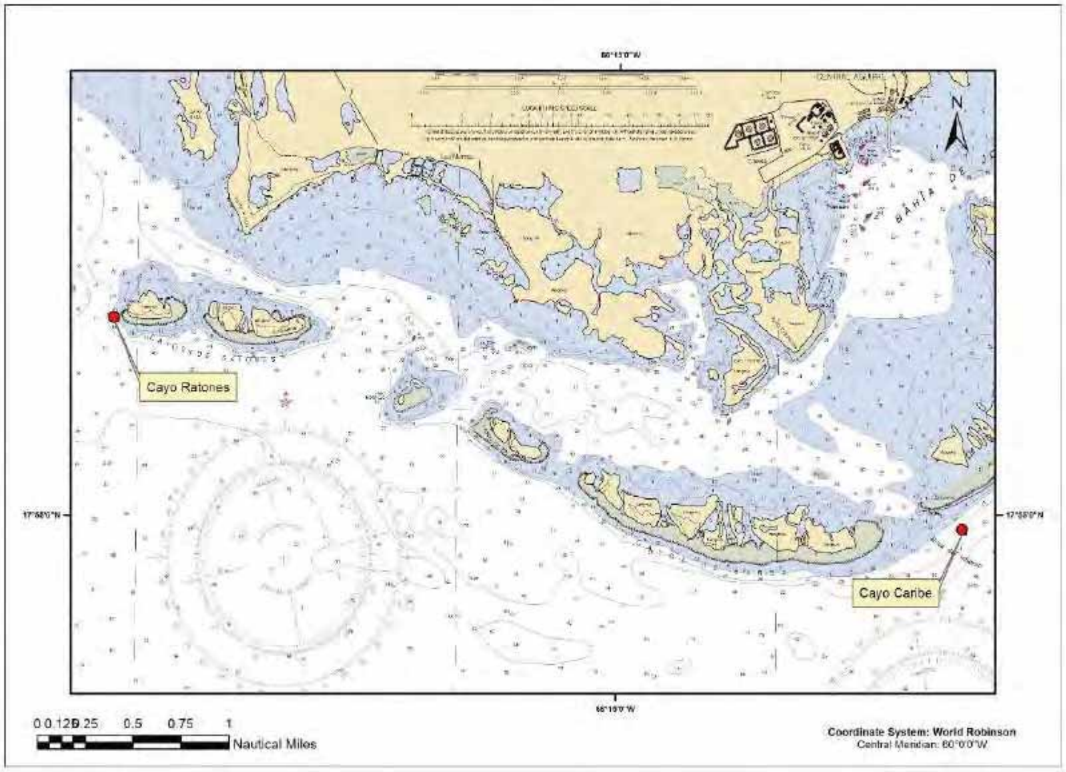


Figure 67. Location of sampling stations at coral reef in the Salinas/Guayama region

gorgonian species, *Erythropodium caribaeorum* and *Briareum asbestinum* combined for a mean substrate cover of 11.9% (Table 77).

Sponges, represented by at least 28 species combined for a mean substrate cover of 15.6%. *Ircinia sp, Iotrochota birotulata*, *Neopetrosia sp*. and *Niphates erecta* were the dominant assemblage in transects surveyed with a combined cover of 8.7 %, representing 51.5 % of the total cover by sponges at Cayo Caribe. Other five species were present in at least three transects. Sponges were present in variable sizes and growth forms, including large erect colonies of Giant Basket Sponge, *Xestospongia muta* and contributed significantly to the reef benthic habitat complexity (Table 77).

Abiotic substrate categories at Cayo Caribes 10 presented a mean substrate cover of 2.5%, largely associated with sand and coral rubble. Reef rugosity averaged 2.1 m, indicative of a mostly regular topography with relatively low contributions by coral structures to the underwater relief.

Table 77. Percent linear cover by sessile-benthic categories at Cayo Caribes 10. Salinas
Survey Date: May 2017

Depth: 10 m

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.04	1.76	1.77	2.59	2.25	**2.08**
Benthic Category						
Abiotic						
Sand	3.49				2.86	**1.27**
Rubble	2.33	1.19				**0.70**
Reef overhang		1.90		0.78		**0.54**
Total Abiotic	**5.81**	**3.10**		**0.78**	**2.86**	**2.51**
Benthic Algae						
Turf with sediment	55.00	51.19	49.58	54.62	44.11	**50.90**
Dictyota spp.	1.98		1.19		0.34	**0.70**
CCA		0.36		0.44	0.69	**0.30**
Peyssonnelia sp.	0.58				0.23	**0.16**
Galaxaura sp.				0.56		**0.11**
Total Benthic Algae	**57.56**	**51.55**	**50.77**	**55.62**	**45.37**	**52.17**
Hard Coral						
Montastraea cavernosa	3.95	6.79	4.99	4.00	11.89	**6.32**
Porites astreoides	5.58	2.62	1.90	7.56	2.17	**3.97**
Orbicella annularis complex	6.40				6.17	**2.51**
Siderastrea siderea	7.09	0.71	1.55	1.78	1.03	**2.43**
Pseudodiploria strigosa	0.93	0.60	0.83	0.78		**0.63**
Madracis decactis	1.74					**0.35**
Millepora alcicornis		1.19		0.44		**0.33**
Porites divaricata		1.19	0.36			**0.31**
Agaricia agaricites		0.24				**0.05**
Total Hard Coral	**25.70**	**12.14**	**9.63**	**14.57**	**21.26**	**16.90**
Coral Colonies/Transect	7	12	7	6	12	**9.6**
Zoanthids						
Palythoa caribaeorum				2.34		**0.47**
Octocoral						
Erythropodium caribaeorum	1.16	10.48	16.53	8.57	12.11	**9.77**
Briareum asbestinum	0.58	0.48	3.92	0.89	4.57	**2.09**
Eunicea sp.		0.48				**0.10**
Gorgonia ventalina			0.24	0.22		**0.09**
Muriceopsis flavida		0.24				**0.05**
Muricea elongata					0.23	**0.05**
Total Octocorals	**1.74**	**11.67**	**20.69**	**9.68**	**16.91**	**12.14**
# Gorgonians/transect	18	20	26	20	23	**21.4**
Sponge						
Ircinia brown sp.	2.56	3.81	3.45	4.56	1.37	**3.15**

Iotrochota birotulata	2.21	1.19	3.45	3.00	3.09	**2.59**
Neopetrosia sp.		0.83	5.23	1.56		**1.52**
Niphates erecta	1.28	3.21	0.24	0.89	1.37	**1.40**
Niphates digitalis		1.19	1.19	1.56	1.83	**1.15**
Xestospongia muta		4.05		0.67		**0.94**
Smenospongia aurea	1.40		0.36	0.89	1.83	**0.89**
Amphimedon compressa	0.23	2.14	1.07	0.22		**0.73**
Mycale laevis		0.48	0.71	1.00	0.69	**0.58**
Cinachyrella kuekenthali		1.19			1.14	**0.47**
Desmanthus sp.	0.35		1.31		0.23	**0.38**
Smenospongia conulosa					1.14	**0.23**
Chondrilla caribensis		1.07				**0.21**
Scopalina ruetzleri	0.23			0.78		**0.20**
Niphates alba			0.71			**0.14**
Niphates caribica			0.36	0.33		**0.14**
Ircinia strobilina			0.59			**0.12**
Aplysina fulva	0.35	0.24				**0.12**
Desmapsamma anchorata	0.58					**0.12**
Plaktoris sp.				0.44		**0.09**
Spirastrella coccinea				0.44		**0.09**
Agelas dispar		0.36				**0.07**
Ptilocaulis walpersii					0.34	**0.07**
Black sponge		0.24				**0.05**
Callyspongia armigera			0.24			**0.05**
Aplysina cauliformis				0.22		**0.04**
Monanchora arbuscula				0.22		**0.04**
Sponge				0.22		**0.04**
Total Sponges	**9.19**	**20.00**	**18.91**	**17.02**	**13.03**	**15.63**

Variations of reef substrate cover by sessile-benthic categories between the 2016 baseline survey and the 2017 (first) monitoring survey are presented in Figure 68. Differences of live coral cover were very small and statistically insignificant (ANOVA, p = 0.806; Appendix 1). Reef substrate cover by scleractinian corals remained stable between both surveys (Table 69).

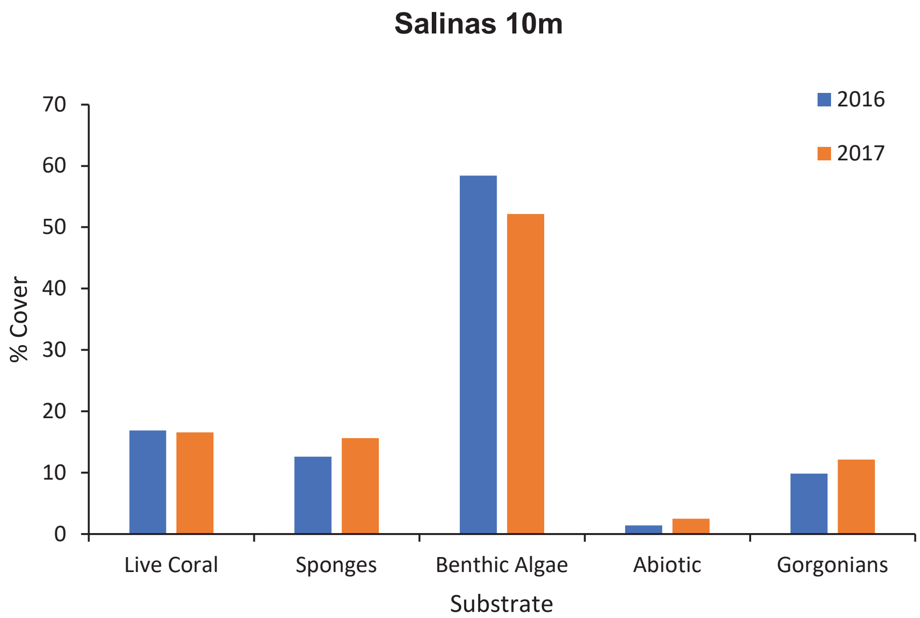


Figure 68. Monitoring trends (2001 – 2017) of mean substrate cover by sessile-benthic categories at Cayo Caribes 10, Salinas/Guayama

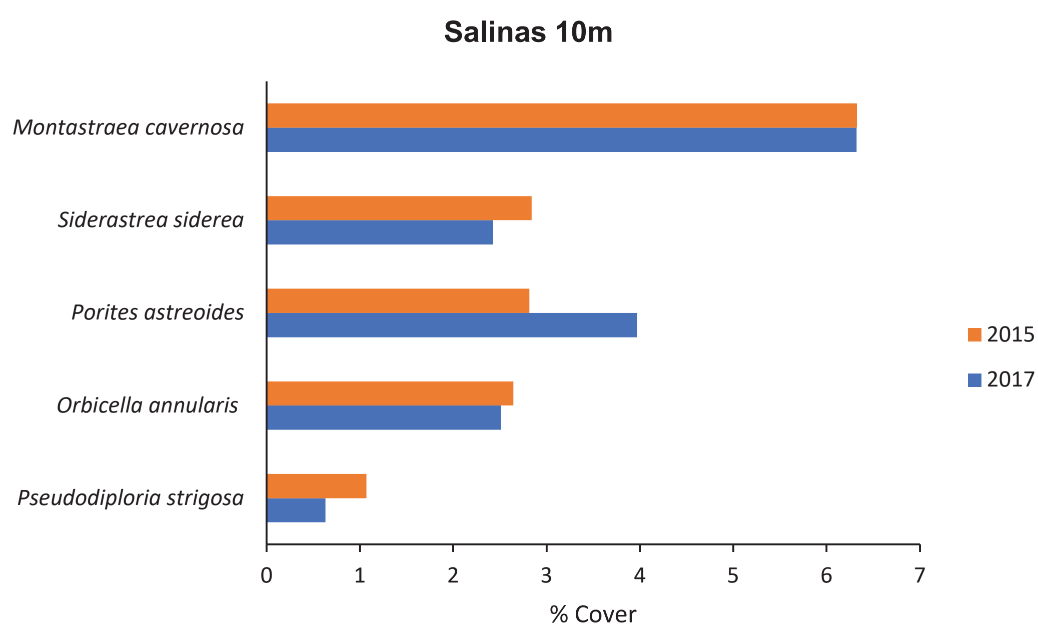


Figure 69. Monitoring trends (2001 – 2017) of mean substrate cover by coral species at Cayo Caribes 10, Salinas/Guayama

20.3 Fishes and Motile Megabenthic Invertebrates

A total of 44 species of fish were identified from Cayo Caribes 10, including 33 within belt-transects (Table 78). Mean density was 40.8 Ind/transect (range: 34 – 47 Ind/transect) with a mean richness of 15.8 species per transect (H'= 132.9). The Bluehead Wrasses (*Thalassoma bifasciatum)* Princess parrotfish (*Scarus taeniopterus*) and Dusky Damselfish (*Stegastes adustus*) were the numerically dominant species with a combined mean abundance of 18.8 Ind/transect, representative of 46.1% of the total individuals. Another five species were present in at least four transects. These included the Beau Gregory and Cocoa Damselfishes (*Stegastes leucostictus, S. variabilis),* Clown Wrasse *(Halichoeres maculipinna*), Redband Parrotfish (*Sparisoma aurofrenatum*) and Doctorfish (*Acanthurus chirurgus*). Thirteen species were only observed in one transect (Table 78).

The size-frequency distribution of commercially important fishes, including the main reef herbivores is presented in Table 79. Juvenile Red Hinds (10 – 12 cm) and one Nassau Grouper (25 cm) were observed within belt-transects. One juvenile Yellowfin Grouper (*Mycteroperca venenosa*) of approximately 45 cm and one 150 cm Nurse Shark (*Ginglymostoma cirratum*) were observed out of transects. Parrotfishes (Scaridae) and Doctorfishes (Acanthuridae) were present across their entire size range, including post settlement juveniles of the Stoplight, Redband and Bucktooth Parrotfishes (*Sparisoma viride, S. aurofrenatum, S. radians*) and the Blue Tang and Doctorfish (*Acanthurus coeruleus, A. chirurgus*) evidencing that this reef serves as a recruitment and residential habitat for these species. Individuals of the Yellowtail Snapper (*Ocyurus chrysurus)* were mostly present as juveniles.

Herbivores, represented by five species of parrotfishes (Scaridae), three damselfishes (Pomacentridae) and three doctorfishes (Acanthuridae) were the most prominent trophic assemblage at Cayo Caribes 10m with a combined density of 22.0 Ind/transect, representing 53.9% of the total density within belt-transects. Small opportunistic carnivores, including the wrasses (Labridae), gobies (Gobiidae), squirrelfishes (Holocentridae), Hawkfish (Cirrhitidae), grunts (Haemulidae), hamlets, small groupers and sea basses (Serranidae) and blennies (Blenniidae) combined for 39.7% of the total fish density. Medium sized piscivores included the Yellowtail Snapper (*Ocyurus chrysurus*), and the Nassau and Red Hind groupers (*Epinephelus striatus, E. guttatus*). Zooplanktivorous fishes were only represented within belt-transects by the Bicolor Damselfish.

Table 78. Taxonomic composition and abundance of fishes within belt-transects at Cayo Caribes Reef 10m Salinas. May 2017

Depth: 10 m

		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	5	14	6	9	8	**8.4**
Scarus taeniopterus	Princess Parrotfish	7	1	7	5	7	**5.4**
Stegastes dorsopunicans	Dusky Damselfish	9	5	3	7	1	**5.0**
Acanthurus chirurgus	Doctorfish		4	6	2	3	**3.0**
Halichoeres maculipinna	Clown Wrasse		3	4	2	2	**2.2**
Sparisoma aurofrenatum	Redband Parrotfish	3	2		3	1	**1.8**
Scarus iserti	Stripped Parrotfish			2	4		**1.2**
Ocyurus chrysurus	Yellowtail Snapper	1			4	1	**1.2**
Stegastes variabilis	Cocoa Damselfish	1	2	1	1	1	**1.2**
Sparisoma viride	Stoplight Parrotfish	2	2	2			**1.2**
Stegastes partitus	Bicolor Damselfish	2	2		2		**1.2**
Serranus tigrinus	Harlequin Bass	1			2	2	**1.0**
Stegastes leucostictus	Beaugregory		1	2	1	1	**1.0**
Elacatinus evelynae	Sharknose Goby	3		1	1		**1.0**
Amblycirrhitus pinos	Red-spotted Hawkfish		1	1	2		**0.8**
Holocentrus rufus	Longspine Squirrelfish	1	2	1			**0.8**
Coryphopterus sp	Goby	1		1		1	**0.6**
Halichoeres bivittatus	Slippery Dick				1	1	**0.4**
Sparisoma radians	Bucktooth Parrotfish					2	**0.4**
Acanthurus coeruleus	Blue Tang		2				**0.4**
Cantherhines pullus	Tail-light Filefish			1			**0.2**
Haemulon sciurus	Bluestriped Grunt			1			**0.2**
Hypoplectrus puella	Barred Hamlet					1	**0.2**
Malacoctenus triangulatus	Saddled Blenny					1	**0.2**
Pomacanthus paru	French Angelfish			1			**0.2**
Sparisoma rubripinne	Yellowtail Parrotfish				1		**0.2**
Acanthurus bahianus	Ocean Surgeon	1					**0.2**
Aulostomus maculatus	Trumpetfish	1					**0.2**
Chaetodon striatus	Banded Butterflyfish		1				**0.2**
Epinephelus striatus	Nassau Grouper					1	**0.2**
Halichoeres garnoti	Yellow-head Wrasse		1				**0.2**
Halichoeres radiatus			1				**0.2**
Ophioblennius atlanticus	Red-lip Blenny	1					**0.2**
	TOTAL INDIVIDUALS	**39**	**44**	**40**	**47**	**34**	**40.8**
	TOTAL SPECIES	**15**	**16**	**16**	**16**	**16**	**15.8**

Variations of fish species richness and abundance between the 2016 baseline and the 2017 (first) monitoring survey are presented in Figure 70. Higher richness and abundance were noted during the 2017 survey, but more observations are needed to consider any real trend as physical conditions of wave, currents and underwater visibility influence abundance and species richness in shallow reefs. Motile megabenthic invertebrates were represented within belt-transects by one Spiny Lobster (Table 80).

Table 79. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at Cayo Caribes Reef 10m, Salinas, May 2017

		TRANSECTS				
		1	2	3	4	5
				(Individuals/60 m^2)		
SPECIES	**COMMON NAME**					
Acanthurus coeruleus	Blue Tang		1 - 5	1 - 8		
Acanthurus chirurgus	Doctorfish		1 - 2	5 - 2	2 - 2	
			2 - 8	1 - 5	1 - 8	
Cephalopholis cruentatus	Graysbe					
Epinephelus guttatus	Red Hind	1 - 12		1 - 10		
Epinephelus striatus	Nassau Grouper					1 - 25
Ocyurus chrysurus	Yellowtail Snapper				4 - 10	1 - 15
					1 - 18	
Scarus iserti	Stripped Parrotfish				4 - 8	
Scarus taeniopterus	Princess Parrotfish		1 - 8	12 - 5	2 - 2	4 - 3
					3 - 5	5 - 5
Sparisoma aurofrenatum	Redband Parrotfish		1 - 5		1 - 2	1 - 10
			1 - 18		1 - 8	
					1 - 15	
Sparisoma viride	Stoplight Parrotfish		1 - 5	1 - 1		
			1 - 8	1 - 8		
Sparisoma radians	Bucktooth Parrotfish			1 - 1		

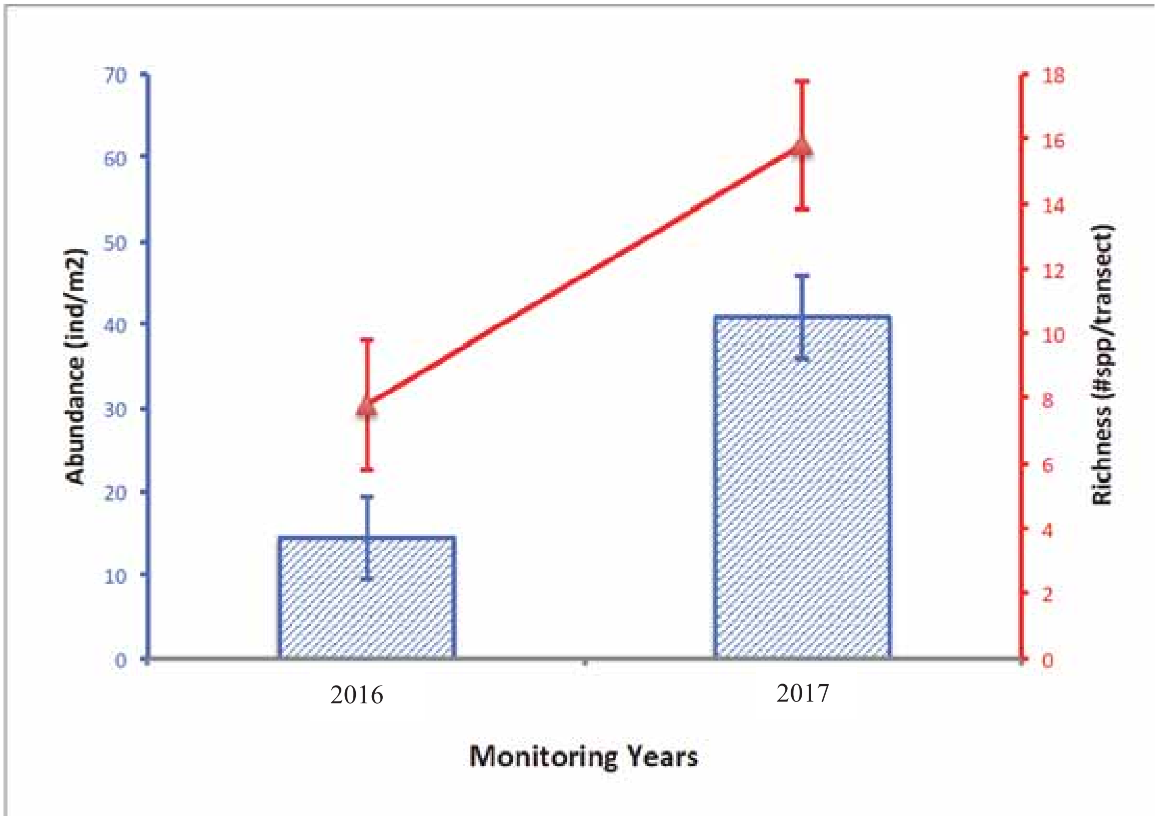


Figure 70. Monitoring trends (2016 – 2017) of fish species richness and abundance at at Cayo Caribes 10, Salinas/Guayama

Table 80. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Caribes 10, Salinas/Guayama

Depth: 10 m		TRANSECTS 1	2	3	4	5	MEAN ABUNDANCE (IND/30 m2)
TAXA	**COMMON NAME**						
Panulirus argus	Spiny Lobster					1	**0.2**
	TOTALS	**0**	**0**	**0**	**0**	**1**	**0.2**

20.4 Photo Album 20
Cayo Caribes 10 – Salinas

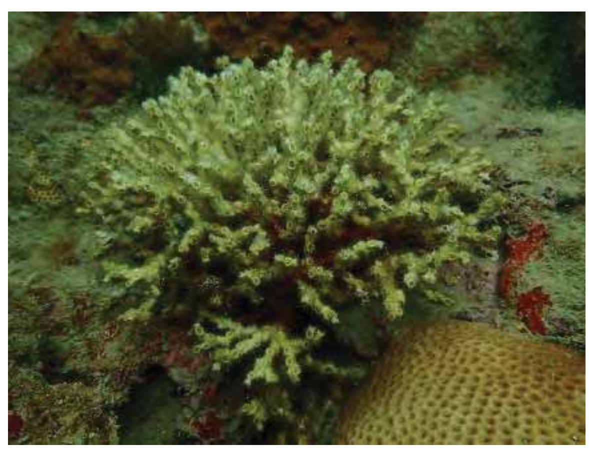












21.0 Cayo Ratones 3, Salinas

21.1 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 (Figure 67). Our survey was performed on the western side 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 3 – 4 m. Panoramic views of Cayo Ratones coral reef community are included in Photo Album 21.

21.2 Sessile Benthic Reef Community

Benthic algae, with a combined mean substrate cover of 56.0% were the dominant biotic category covering reef substrate at Cayo Ratones 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 34.3%, representing 61.2% of the total cover by algae (Table 81). Green calcareous (*Halimeda sp*) and fleshy brown macroalgae (mostly *Dictyota sp*) were present in all transects with a mean combined mean cover of 19.6%. Small patches of red coralline algae, *Galaxaura sp*. and *Jania sp*. were present in three and one transects, respectively with a combined cover of 1.3%. The crustose encrusting red alga, *Ramicrusta sp.* was intercepted by one transect with very low reef substrate cover (< 1%). Cyanobacterial films were observed in three transects with a mean cover of 1.7%.

Scleractinian corals were represented by 11 species intercepted by linear transects with a combined mean substrate cover of 17.4% (range: 12.7 – 25.2 %), and a mean of 10.2 colonies per transect (Table 81). Massive Starlet Coral, *Siderastrea siderea* was the dominant coral species in terms of reef substrate cover with a mean cover of 11.9%, representing 68.5% of the total cover by corals. Very large colonies (more than one meter in diameter) of *S. siderea* separated by sand patches were common at Cayo Ratones 3. Great Star Coral, *Montastrea cavernosa*, and Boulder Star Coral, *Orbicella annularis* were present in four transects with a combined cover of 4.2%. Symmetrical Brain Coral, *Pseudodiploria strigosa* and Lettuce Coral, *Agaricia agaricites* were present in three transects, but with very low reef substrate cover. Five coral species were only present in one transect with mean substrate cover <1%. An infectious disease was observed in one of the 51 coral colonies intercepted by transects during 2017, for a mean disease prevalence of 2.0% (Appendix 2).

Table 81. Percent linear cover by sessile-benthic categories at Cayo Ratones 3. Survey Date: May 2017. Depth: 3-4 m. Salinas

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	1.90	2.73	3.62	3.05	2.39	**2.74**
Benthic Category						
Abiotic						
Sand	1.18	10.12	23.43	21.67	14.24	**14.13**
Reef overhang	1.18	3.74	1.03	8.05		**2.80**
Rubble	4.71	2.20	2.57			**1.90**
Total Abiotic	**7.06**	**16.06**	**27.03**	**29.72**	**14.24**	**18.82**
Benthic Algae						
Turf with sediment	34.35	37.40	36.07	28.11	35.59	**34.31**
Halimeda spp.	15.65	11.66	17.06	17.38	10.17	**14.38**
Dictyota spp.	4.00	7.04	1.54	3.22	10.06	**5.17**
Galaxaura sp.	3.53	1.10		1.50		**1.23**
CCA	0.59	2.42				**0.60**
Ramicrusta sp.					0.79	**0.16**
Jania sp.					0.56	**0.11**
Total Benthic Algae	**58.12**	**59.63**	**54.68**	**50.21**	**57.18**	**55.96**
Cyanobacteria	3.53	3.30		1.72		**1.71**
Hard Coral						
Siderastrea siderea	14.12	11.00	9.66	9.12	15.71	**11.92**
Montastraea cavernosa		3.30	2.36	0.97	6.55	**2.64**
Orbicella annularis complex	3.53		0.72	1.72	1.92	**1.58**
Pseudodiploria strigosa	0.59	0.55		0.54		**0.33**
Porites astreoides	1.06					**0.21**
Stephanocoenia intersepta					1.02	**0.20**
Agaricia agaricites	0.24	0.33		0.21		**0.16**
Millepora alcicornis	0.82					**0.16**
Porites porites				0.32		**0.06**
Porites divaricata	0.24					**0.05**
Siderastrea radians				0.21		**0.04**
Total Hard Coral	**20.58**	**15.18**	**12.74**	**13.09**	**25.20**	**17.36**
Coral Colonies/Transect	12	10	9	8	12	**10.2**
Octocoral						
Briareum asbestinum	3.29	2.20	3.70	3.86	3.05	**3.22**
Erythropodium caribaeorum	6.12	0.66	1.03		0.34	**1.63**
Gorgonia ventalina	0.35	0.33		0.54		**0.24**
Antillogorgia americana			0.21			**0.04**
Total Octocorals	**9.76**	**3.19**	**4.93**	**4.40**	**3.39**	**5.14**
# Gorgonians/transect	20	12	6	13	8	**12.2**
Sponge						
Chondrilla caribensis		1.54	0.41	0.64		**0.52**
Cliona caribbaea		1.10				**0.22**
Iotrochota birotulata	0.35					**0.07**

Callyspongia armigera				0.21		**0.04**
Ircinia brown sp.			0.21			**0.04**
Total Sponge	**0.35**	**2.64**	**0.62**	**0.86**		**0.89**

Vertically projected soft corals (gorgonians) were highly prominent and present in all five transects at Cayo Ratones 3 with a mean density of 10.2 colonies per transect. Sea Fans (*Gorgonia ventalina*) and Sea Plumes (*Antillogorgia spp*) were the most common erect forms. The encrusting gorgonian species, *Briareum asbestinum* and *Erythropodium caribaeorum* were present in five and four transects, respectively with a combined mean substrate cover of 4.8% (Table 81). Sponges, represented by five species intercepted by transects combined for a mean substrate cover of 0.9%. *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 another encrusting biota.

Abiotic substrate categories presented a mean substrate cover of 18.8% (range: 7.1 – 29.7%). Coralline sand was the main component the abiotic category with a mean cover of 14.1%, representing 75.0% of the total (Table 81). Reef rugosity averaged 2.7m, influenced by large coral mounds of Massive Starlet Coral, *Siderastrea siderea*.

Variations of reef substrate cover by sessile-benthic categories between the 2016 baseline and the present 2017 (first) monitoring survey are presented in Figure 71. Differences between surveys were small and statistically insignificant (ANOVA, p = 0.15, Appendix 1). Variations in the number of erect gorgonians intercepted per transect between surveys were also statistically insignificant (T-Test, p= 0.765, Appendix 3). Interannual variations of coral taxonomic composition and mean substrate cover are shown in Figure 72. The taxonomic composition of the main coral species remained stable and differences of mean substrate cover were small and within sampling variability error.

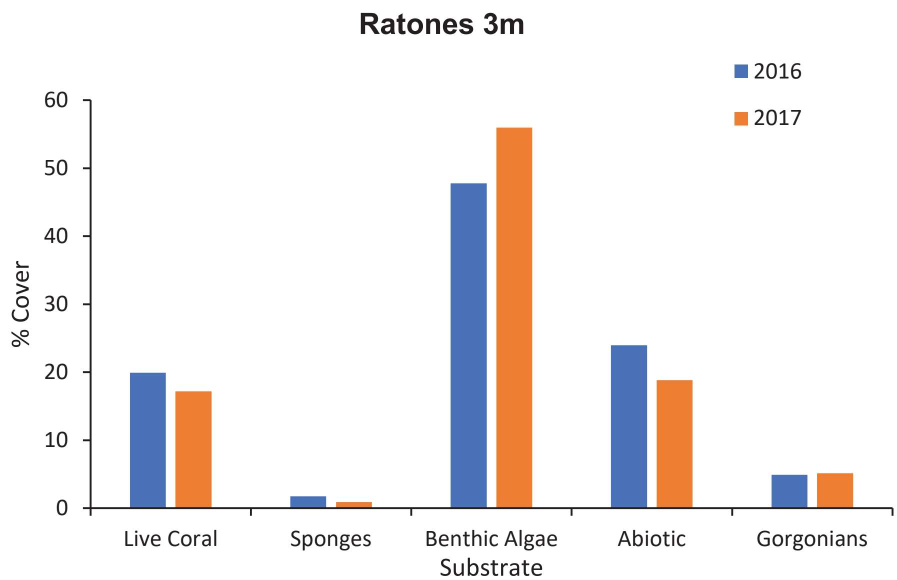


Figure 71. Monitoring trends (2001 – 2017) of mean substrate cover by sessile-benthic categories at Cayo Ratones 3, Salinas/Guayama

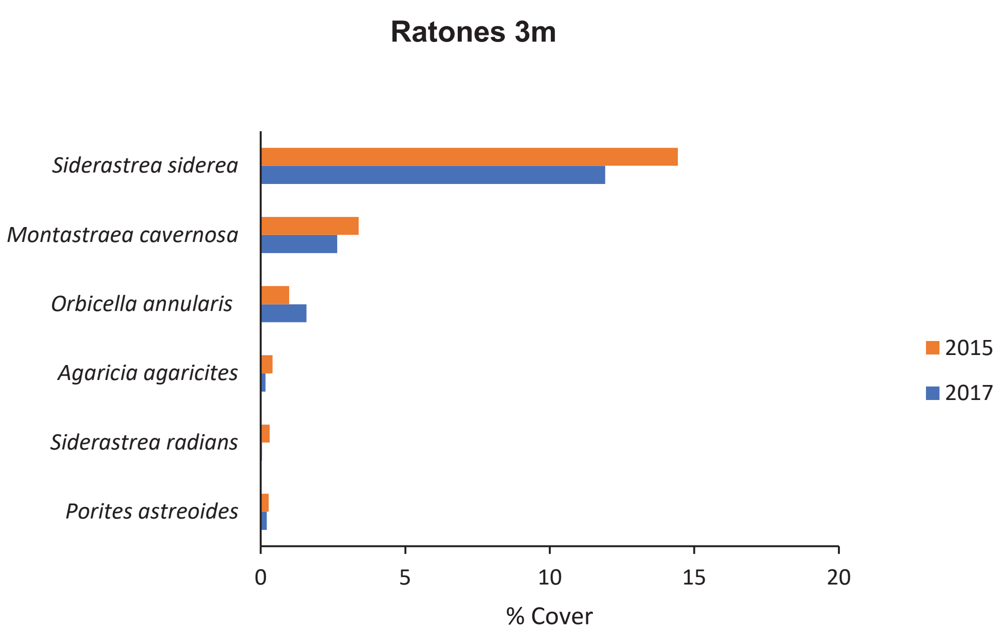


Figure 72. Monitoring trends (2001 – 2017) of mean substrate cover by coral species at Cayo Ratones 3, Salinas/Guayama

21.3 Fishes and Motile Megabenthic Invertebrates

A total of 44 species of fish were identified from Cayo Ratones 3 during the baseline and the present 2017 monitoring survey (Appendix 4), including 39 within belt-transects from a depth of 4 - 5 m (Table 82). Mean density was 33.0 Ind/transect (range: 17 – 45 Ind/transect) with a mean richness of 14.4 species per transect (H'= 119.6). The Bluehead Wrasses (*Thalassoma bifasciatum*) was the dominant species with a mean density of 8.4 Ind/transect, representing 25.4% of the total individuals and was observed in all five transects. The Doctorfish and Blue Tang (*Acanthurus chirurgus*, *A. coeruleus*), Dusky Damselfish (*Stegastes adustus*), Redband and Stoplight Parrotfishes (*Sparisoma aurofrenatum, S. viride*), Longspine Squirrelfish (*Holocentrus rufus*) and Slippery Dick (*Halichoeres bivittatus*) were observed in at least four transects with a combined density of 13 Ind/transect, representing 39.4% of the total individuals. Nine species were only present in one transect (Table 82).

The trophic structure of Cayo Ratones 3 was strongly dominated by small opportunistic carnivores represented within belt-transects by five species of wrasses (*Thalassoma, Halichoeres spp*), two hamlets (Serranidae), two grunts (*Haemulon spp*), one squirrelfish (*Holocentrus rufus*) and one Goby (*Elacatinus evelynae*), for a combined density of 16.2 Ind/transect, or 49.1% of the total fish density. Herbivores were also prominent with a cumulative density of 14.4 Ind/transect, representing 43.6% of the total fish density within belt-transects. These included five species of parrotfishes (Scaridae), three damselfishes (Pomacentridae) and three doctorfishes (Acanthuridae). Zooplanktivorous fishes were only represented within belt-transects by the Bicolor and Sargent Major Damselfishes with a cumulative density of less than 1% of the total. Medium sized piscivores included the Yellowtail and Schoolmaster Snappers (*Ocyurus chrysurus*, *Lutjanus apodus*).

Table 83 presents the size-frequency distribution of commercially important within extended belt-transects at Cayo Ratones 3. Post settlement (recruitment) juveniles (1 - 3 cm TL) of doctorfishes (*Acanthurus coeruleus, A. chirurgus*) and parrotfishes (*Sparisoma viride, S. aurofrenatum, Scarus taeniopterus*) were observed. Juveniles and adult stages of doctorfishes and parrotfishes were also present. Yellowtail and Schoolmaster Snappers were observed as juveniles. Megabenthic invertebrates were not observed within belt-transects at Cayo Ratones 3. One juvenile Spiny Lobster (*Panulirus argus*) was observed out of transects.

Table 82. Taxonomic composition and abundance of fishes within belt-transects at Cayo Ratones Reef 3m, Salinas. May 2017

Depth: 3-4 m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	5	13	1	10	13	**8.4**
Acanthurus chirurgus	Doctorfish	4	2	2	9	1	**3.6**
Stegastes adustus	Dusky Damselfish	5	1	3	4	4	**3.4**
Scarus taeniopterus	Princess Parrotfish	1			6	4	**2.2**
Sparisoma aurofrenatum	Redband Parrotfish	3	2	1		2	**1.6**
Sparisoma viride	Stoplight Parrotfish	1	1	1	1	3	**1.4**
Holocentrus rufus	Longspine Squirrelfish		1	2	2	1	**1.2**
Halichoeres garnoti	Yellow-head Wrasse	1			2	2	**1.0**
Acanthurus coeruleus	Blue Tang		1	1	2	1	**1.0**
Halichoeres poeyi	Black-ear Wrasse		1	2	2		**1.0**
Halichoeres bivittatus	Slippery Dick	1	1		1	1	**0.8**
Lutjanus apodus	Schoolmaster		3			1	**0.8**
Halichoeres radiatus	Puddinwife		1		2	1	**0.8**
Haemulon plumieri	White Grunt		2	1			**0.6**
Elacatinus evelynae	Sharknose Goby		3				**0.6**
Stegastes partitus	Bicolor Damselfish	2	1				**0.6**
Acanthurus bahianus	Ocean Surgeon	1	1				**0.4**
Halichoeres maculipinna	Clown Wrasse					2	**0.4**
Scarus iserti	Stripped Parrotfish	2					**0.4**
Microspathodon chrysurus	Yellowtail Damselfish		1	1			**0.4**
Ocyurus chrysurus	Yellowtail Snapper	1			1		**0.4**
Abudefduf sexatilis	Sargent Major				1		**0.2**
Carangoides ruber	Bar Jack				1		**0.2**
Chaetodon capistratus	Four-eye Butterflyfish					1	**0.2**
Haemulon flavolineatum	French Grunt		1				**0.2**
Hypoplectrus indigo	Indigo Hamlet			1			**0.2**
Hypoplectrus nigricans	Black Hamlet			1			**0.2**
Sparisoma radians	Bucktooth Parrotfish				1		**0.2**
Stegastes leucostictus	Beaugregory	1					**0.2**
Stegastes variabilis	Cocoa Damselfish		1				**0.2**
	TOTAL INDIVIDUALS	**28**	**37**	**17**	**45**	**37**	**33.0**
	TOTAL SPECIES	**13**	**18**	**12**	**15**	**14**	**14.4**

Table 83. Taxonomic composition and size frequency of fishes of individuals (cm) within 20 x 3m belt-transects at Cayo Ratones Reef 3m, Salinas, May 2017

		TRANSECTS				
		1	2	3	4	5
		(Individuals/60 m^2)				
SPECIES	**COMMON NAME**					
Acanthurus coeruleus	Blue Tang		2 - 8	1 - 1	2 - 1	1 - 1
				1 - 5	1 - 2	
Acanthurus chirurgus	Doctorfish	3 - 2	2 - 2	1 - 1	4 - 1	1 - 2
		1 - 5	1 - 10	1 - 12	5 - 2	
Acanthurus bahianus	Ocean Surgeon	2 - 10	1 - 5			
Lutjanus apodus	Schoolmaster Snapper		2 - 12	1 - 10		1 - 8
			1 - 15			
Ocyurus chrysurus	Yellowtail Snapper	1 - 12		1 - 8	1 - 12	
					2 - 15	
Scarus iserti	Stripped Parrotfish	1 - 5		2 - 8		
Scarus taeniopterus	Princess Parrotfish	1 - 8			3 - 2	4 - 5
					3 - 5	
Sparisoma aurofrenatum	Redband Parrotfish	2 - 5	1 - 8	1 - 20	1 - 18	1 - 8
		1 - 18	1 - 10			1 - 10
		1 - 23	1 - 28			
Sparisoma rubripinne	Yellowtail Parrotfish					
Sparisoma viride	Stoplight Parrotfish	1 - 20	2 - 8	1 - 5	1 - 2	1 - 2
			1 - 12	1 - 10		1 - 5
						1 - 12

Table 84. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Ratones 3, Salinas/Guayama

Depth: 10 m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m^2)**
TAXA	COMMON NAME						
None							
	TOTALS	**0**	**0**	**0**	**0**	**0**	**0**

Variations of fish species richness and abundance between the 2016 baseline and the present 2017 monitoring survey are shown in Figure 73. Differences were small and statistically insignificant (ANOVA, $p > 0.05$; Appendix 5 - 6).

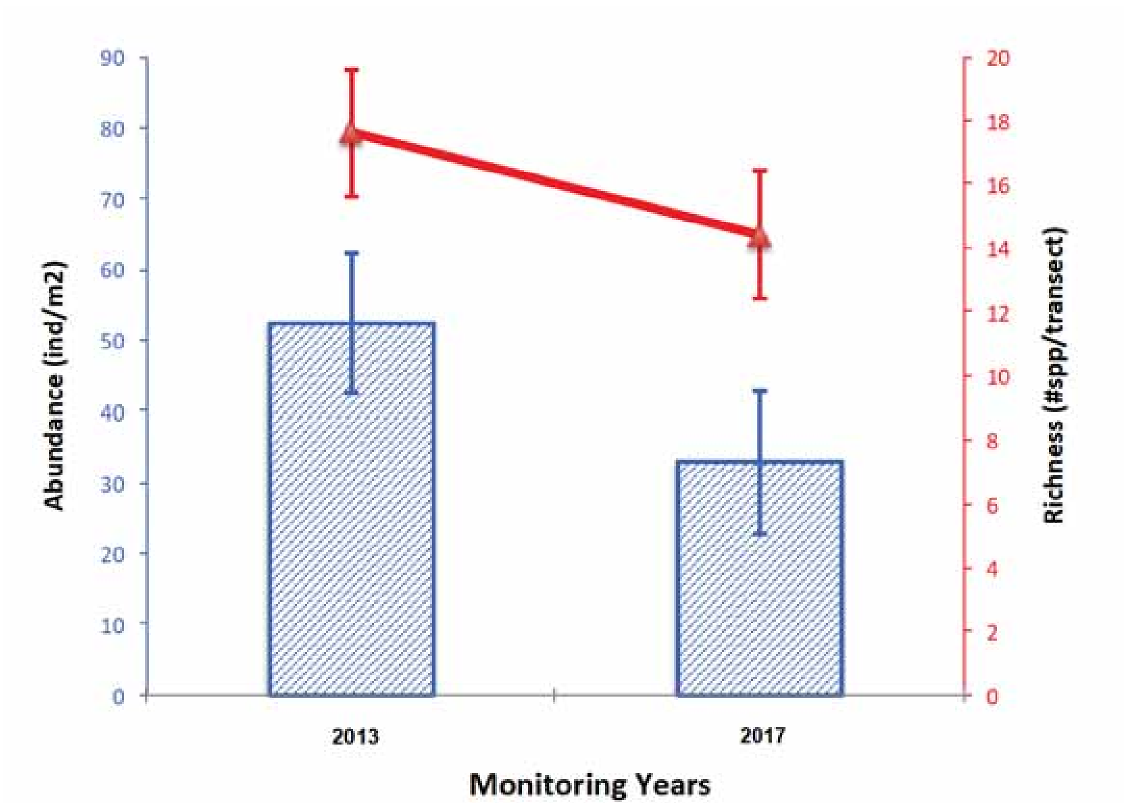
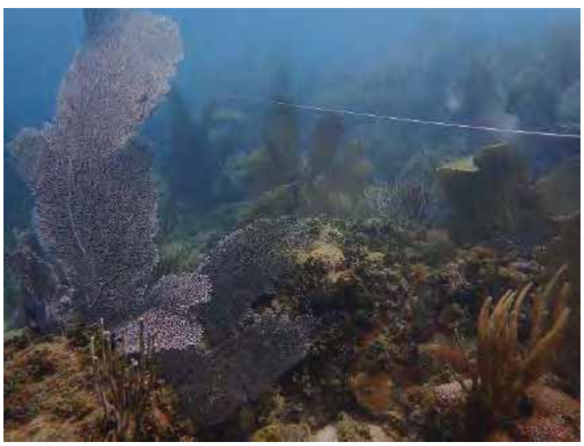


Figure 73. Monitoring trends (2016 – 2017) of fish species richness and abundance at at Cayo Ratones 3, Salinas/Guayama

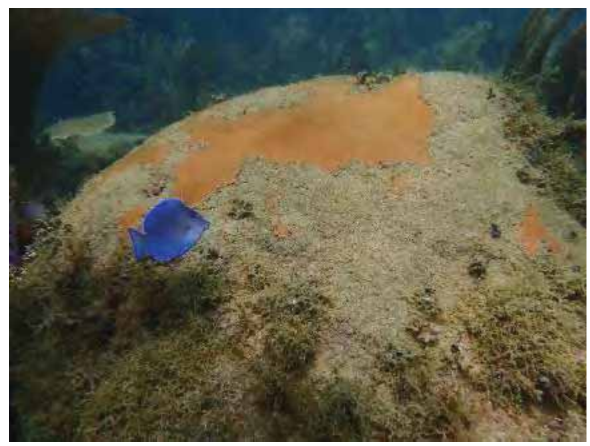
21.4 Photo Album 21

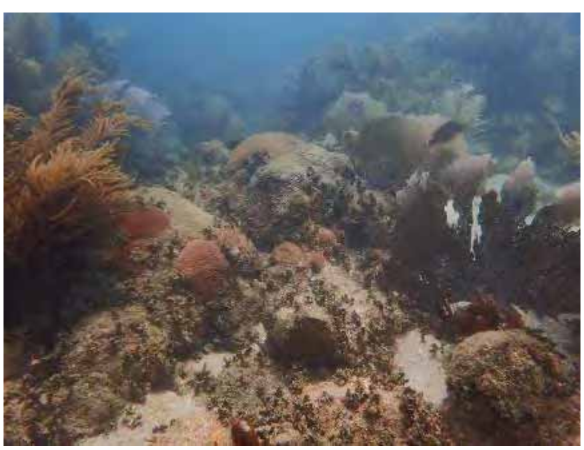
Cayo Ratones 3 – Salinas









VI. 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 1999 - 2017.
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, Elkhorn Coral Reefs (Tres Palmas, Aurora) and coastal reefs (Resuellos, Cibuco, El Palo, Caribes, Coral, Tres Palmas) were the least affected, 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.
5. A pattern of decreasing coral mortality with increasing depth was evidenced from stratified samplings at Desecheo, Mayaguez and Vieques. Given the exponential decline of light penetration with depth, such decreasing coral mortality with increasing depth supports the contention that both temperature and light influenced the coral bleaching related mortalities on these reefs.
6. The late August 2005 coral bleaching event coincided in time and space with the pass of a mesoscale anticyclonic eddy along the northern Caribbean. The prolonged calm sea conditions with high water temperatures and water transparency associated with the eddy system could have acted as the main driver of the bleaching event.
7. 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).
8. Since the 2009 monitoring survey 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, Caja de Muerto).
9. A positive correlation between live coral recuperation and water turbidity, as measured by the light attenuation coefficient Kd 490 has emerged

10. 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.
11. From the 2015 baseline characterization of the Elkhorn coral reef at Gallardo, it can be inferred that the reef has been exposed to severe mechanical damage as there are massive deposits of broken elkhorn coral fragments across the reef.
12. 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*.
13. 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).
14. 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.
15. 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.
16. 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*).
17. 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.
18. 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.

VII. Conclusions from the 2017 Monitoring Survey

1. The most ecologically relevant change in the community structure of coral reefs monitored during 2017 in PR was a marked decline (62.7%) of reef substrate cover by live corals, from 13.4% in 2016 to 5.0% in 2017 at the reef crest of Maria Langa 3m in Guayanilla. The drastic reduction of live coral cover was characterized by the disappearance of the dominant coral, *Acropora prolifera* from permanent transects apparently caused by the detachment and mortality of colonies exposed to conditions of extreme wave and surge action during the pass of Hurricane Matthew across the northern Caribbean and close to the south coast of PR during October 2016.

2. Severe mechanical damage was also observed from Cayo Aurora's *Acropora palmata* reef biotope in Guanica. The very large Elkhorn Coral colonies were not detached from the base, but many of the large branches (arms) were broken. No major differences of live coral cover were measured because many large coral fragments fell along transect lines and were counted as live coral colonies. Survival rates of these fragments will be inferred from prospective measurements during the next monitoring survey at this reef.
3. Statistically significant reductions of soft coral (gorgonians) densities that appear to be associated with mechanical detachment during extreme wave and surge energy exposure during the pass of Hurricane Matthew were measured at Tres Palmas Reef 3m in Rincon, Resuellos 10 m in Cabo Rojo, Tourmaline 20m in Mayaguez and Media Luna 10 m in La Parguera.
4. Increasing trends of live coral cover were noted at Tres Palmas 10 and 20m, Tourmaline 10, 20 and 30m, Media Luna 10 and 5m. Boya Vieja 20m, Maria Langa 10 and 20m and Derrumbadero 20m. Such increases in reef substrate cover by live corals were not statistically different from previous surveys except at Tourmaline 20 and 30m, where the 2017 mean was higher than the lowest mean after the 2005 bleaching event.
5. The main driver of the increasing trend of substrate cover by live corals in all reef stations, except Tourmaline 10 (*Madracis auretenra*), was the consistent increase of cover by *Orbicella annularis* complex.
6. Coral diseases were observed in 16 out of a total 1,132 coral colonies intercepted by transects during 2017, for a mean disease prevalence of 1.3%. Reefs with the highest disease prevalence were Cayo Caribes 10m in Salinas (4.5%), Boya Vieja 20m in La Parguera (4.1%), Bajo Gallardo in Cabo Rojo (4.0%), and Tres Palmas 3.0m in Rincon (3.0%).
7. Mean fish abundance surveyed within belt-transects during 2017 declined in 11 out of the 21 reef stations, and remained stable or did not vary significantly relative to previous surveys. The main factor influencing reductions of fish abundance in most reefs was the virtual absence of numerically dominant schooling zooplanktivore species, particularly Masked Goby, *Coryphopterus personatus*.
8. Four juvenile (<40cm) Nassau Groupers (*Epinephelus striatus*) and two (2) Yellowfin Groupers (*Mycteroperca venenosa*) were observed from four different reef stations during 2017. This is the highest number recorded in the monitoring program and may be an indication of a good recruitment year for these species, particularly for Nassau Grouper. One adult Jewfish was observed out of transects at Maria Langa 20m.
9. Parrotfishes (Scaridae) represented the main commercially important fish assemblage observed within belt-transects, mostly driven by high prevalence and abundance of Stoplight, Redband, Princess and Stripped Parrotfish.
10. Post settlement juvenile stages, particularly Stoplight and Redband were observed on most reefs surveyed evidencing the recruitment habitat role of these shallow reefs for these ecologically and commercially important species.
11. Spiny Lobsters (*Panulirus argus*) were observed from six reef stations, including several within belt-transects. This is the highest recorded in the reef monitoring program and appears to be an indication of a good recruitment year for this commercially important reef megabenthic invertebrate.
12. A total of 40 Longspine Urchins, *Diadema antillarum* (mean: 8 Ind/transect) were observed within belt-transects at Media Luna 5. This is the highest recorded in the reef monitoring program for any reef and monitoring survey and is an indication that the out-planting project for ref restoration at this reef has stimulated the density of this important herbivore at this locality.

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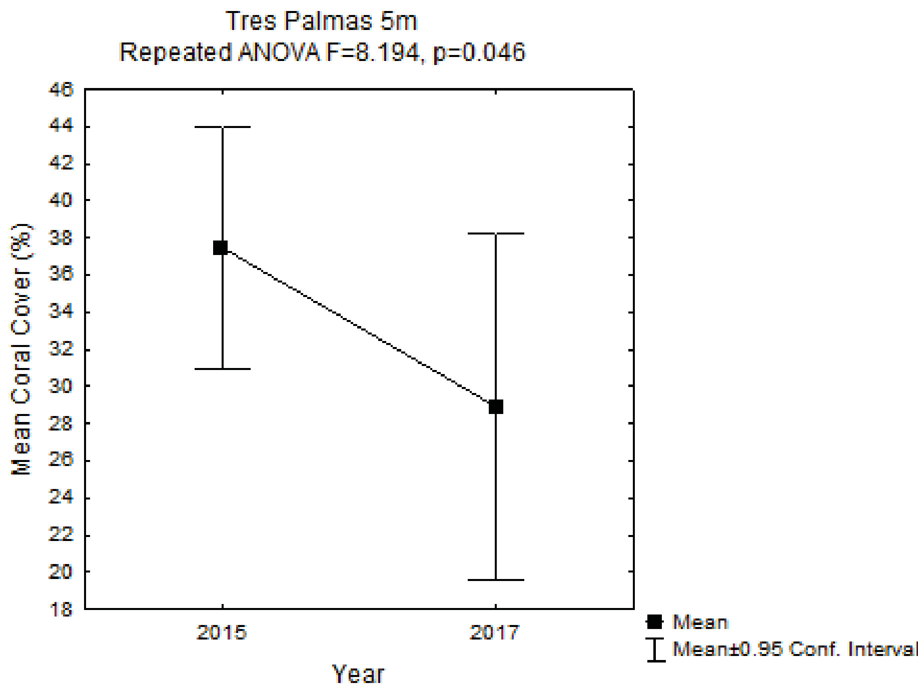
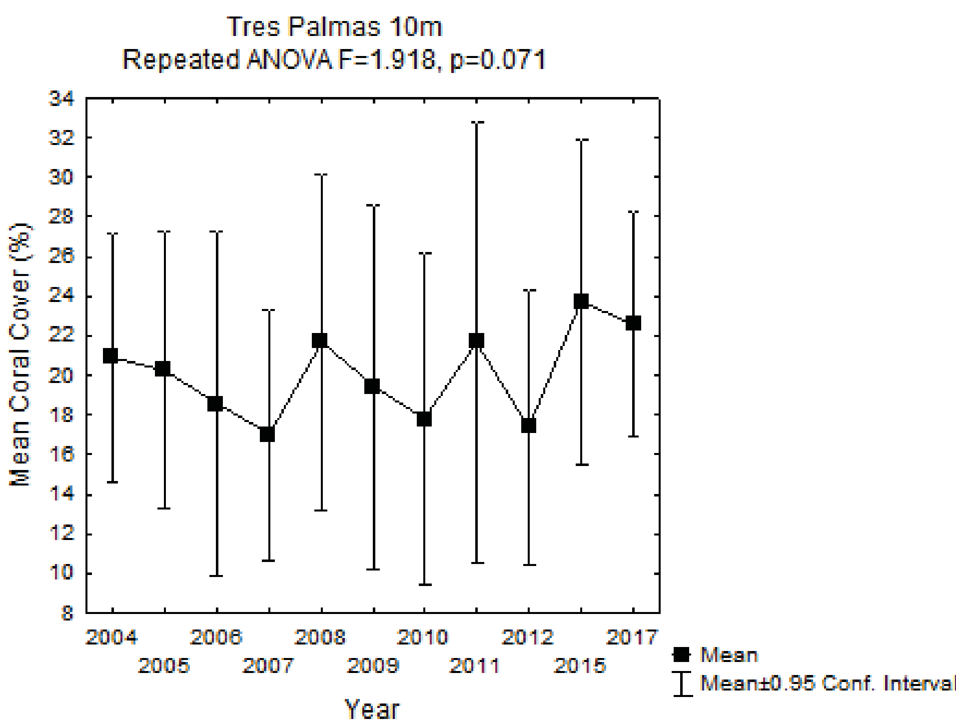
APPENDIX 1. ANOVA testing temporal variations of reef substrate cover by live corals at reefs monitored

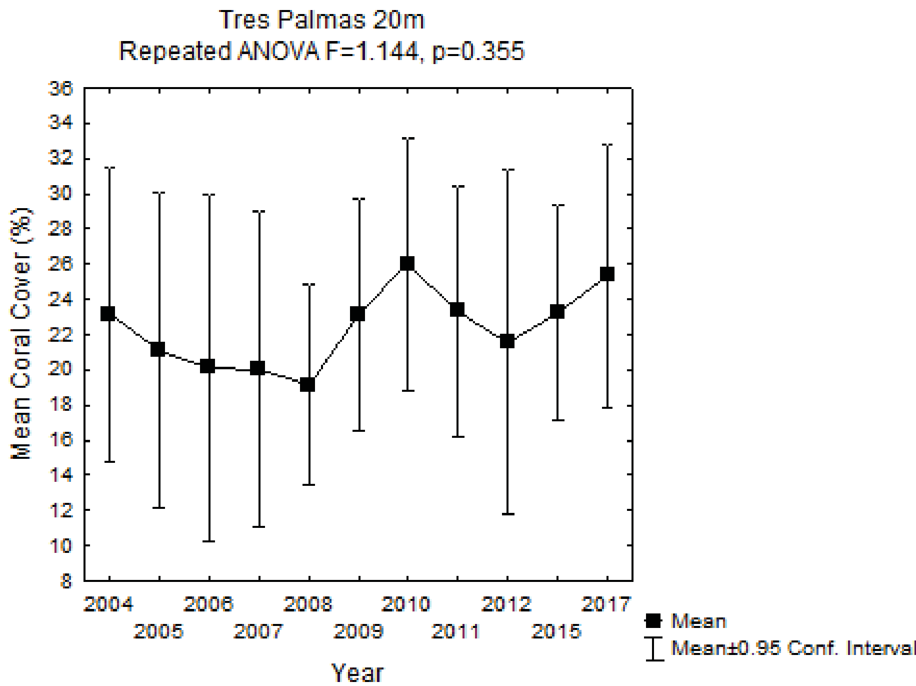
1. Tres Palmas 3m - Rincon



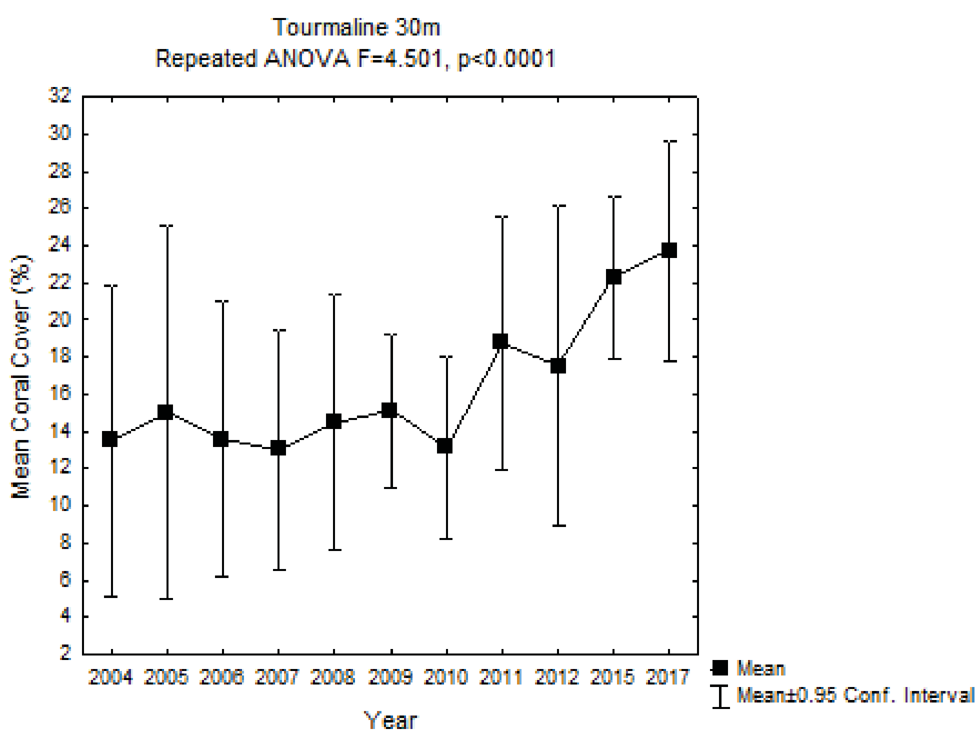
2. Tres Palmas 10m - Rincon



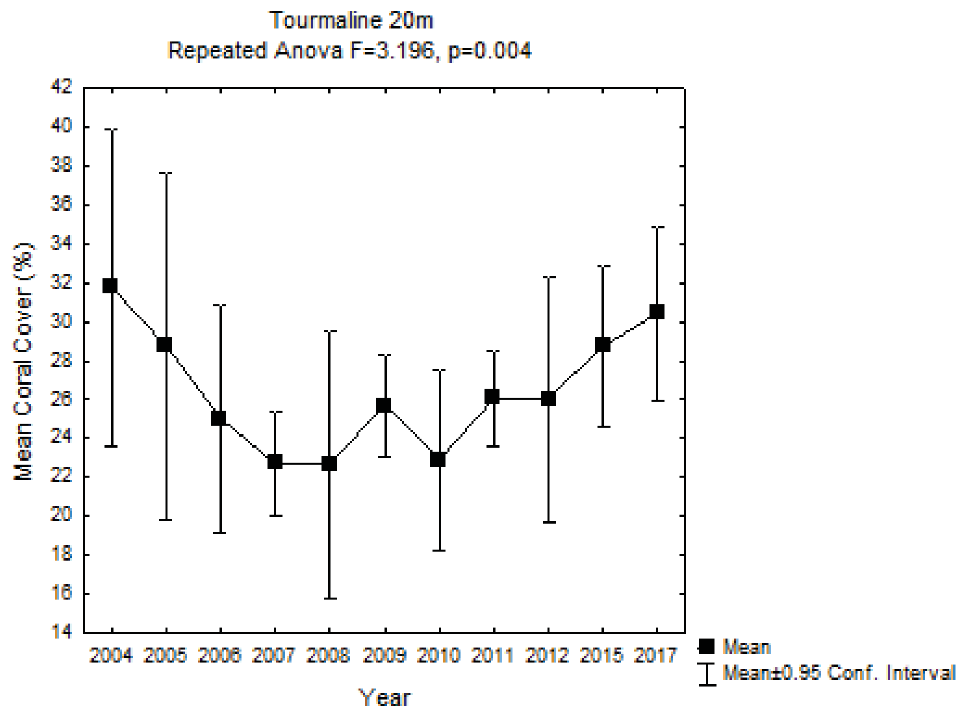
3. Tres Palmas 20m - Rincon



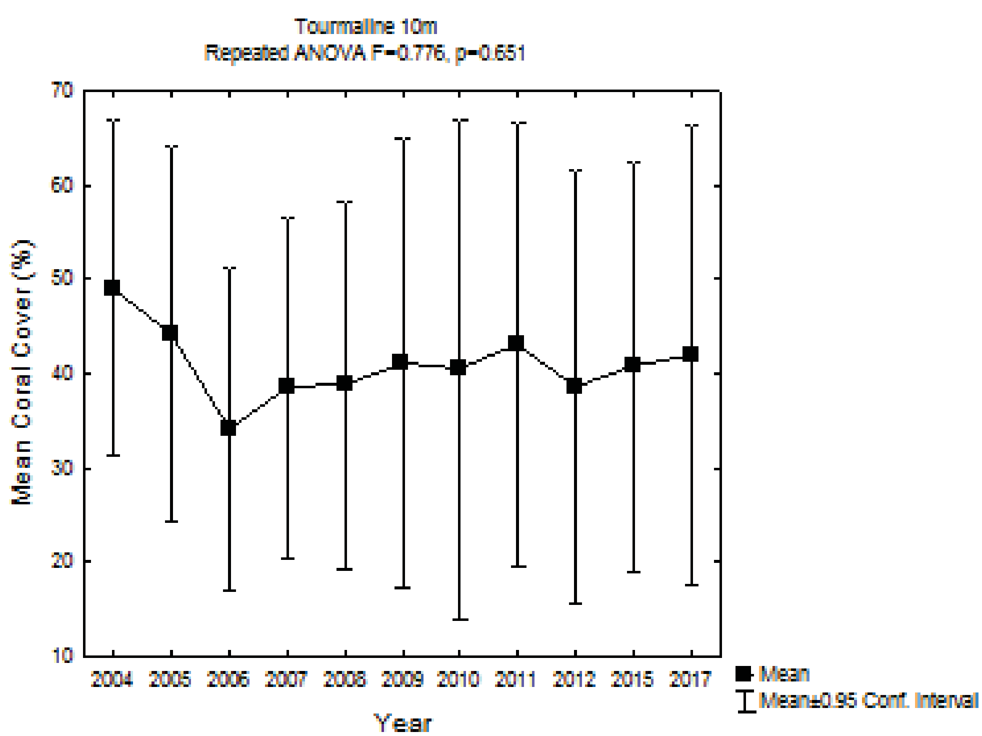
4. Tourmaline 30m – Mayaguez



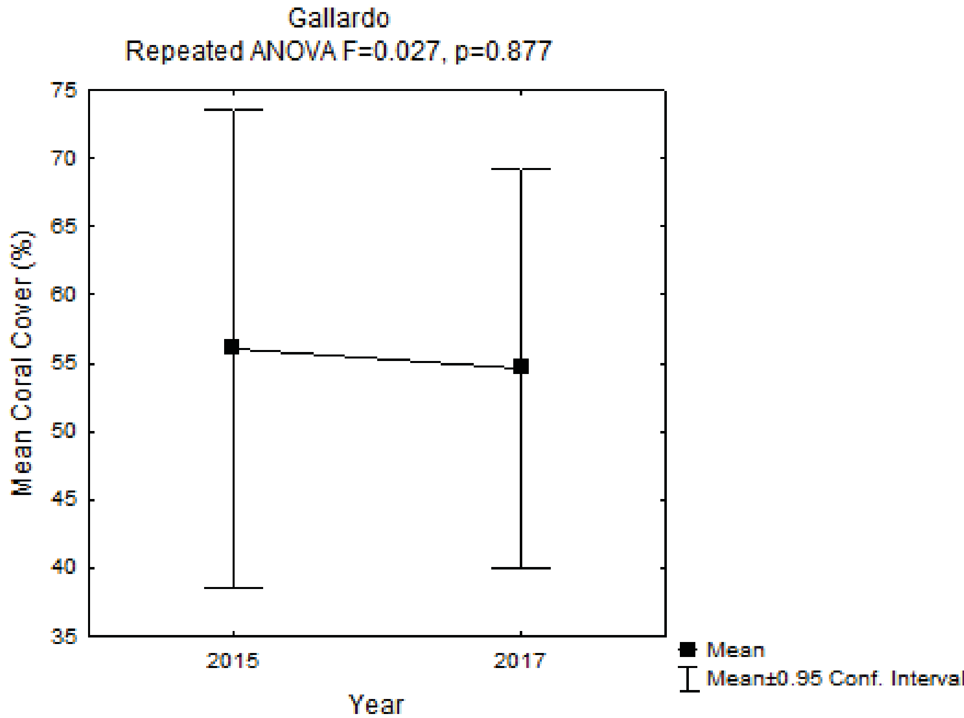
5. Tourmaline 30m – Mayaguez



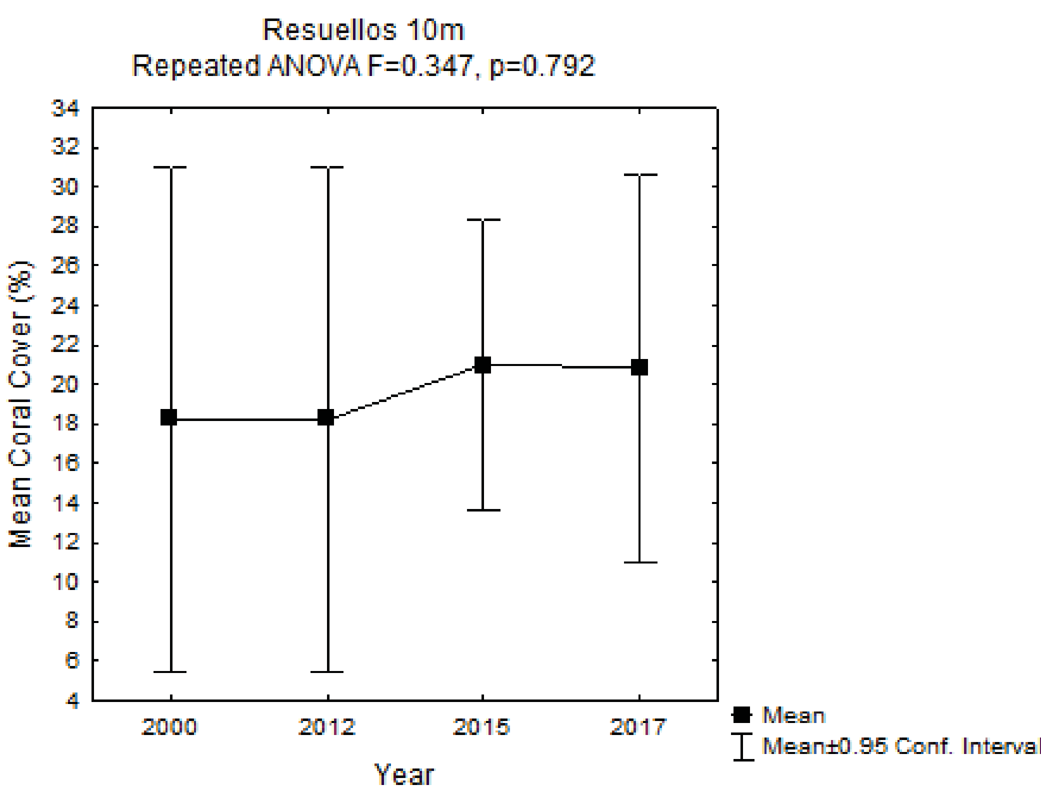
6. Tourmaline 10 - Mayaguez



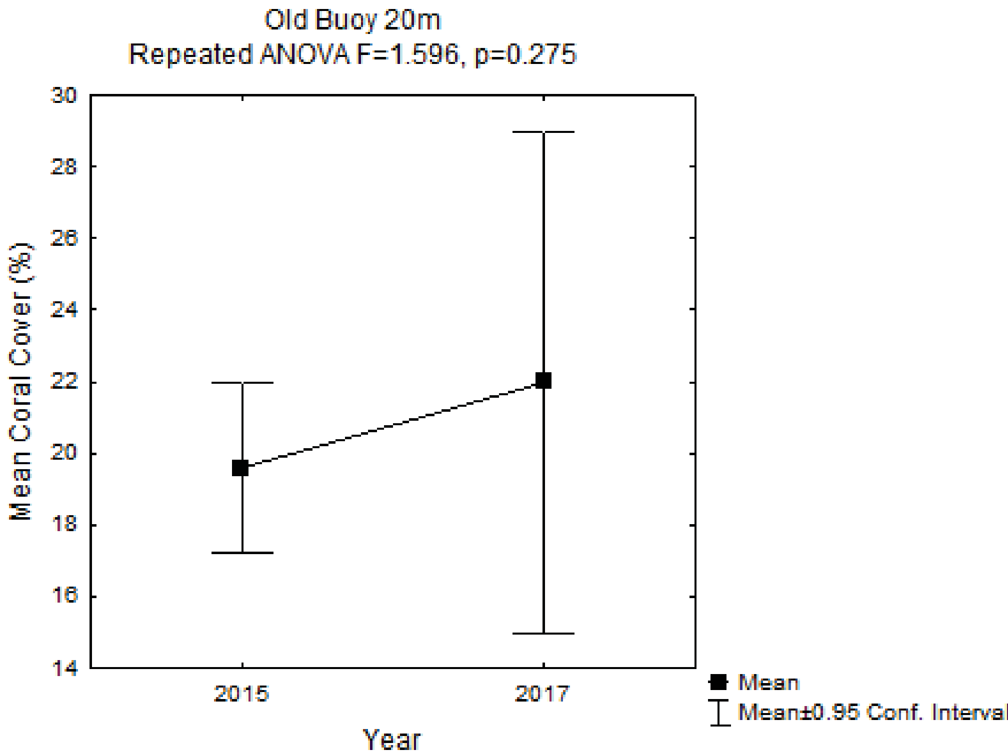
7. Gallardo 5 – Cabo Rojo



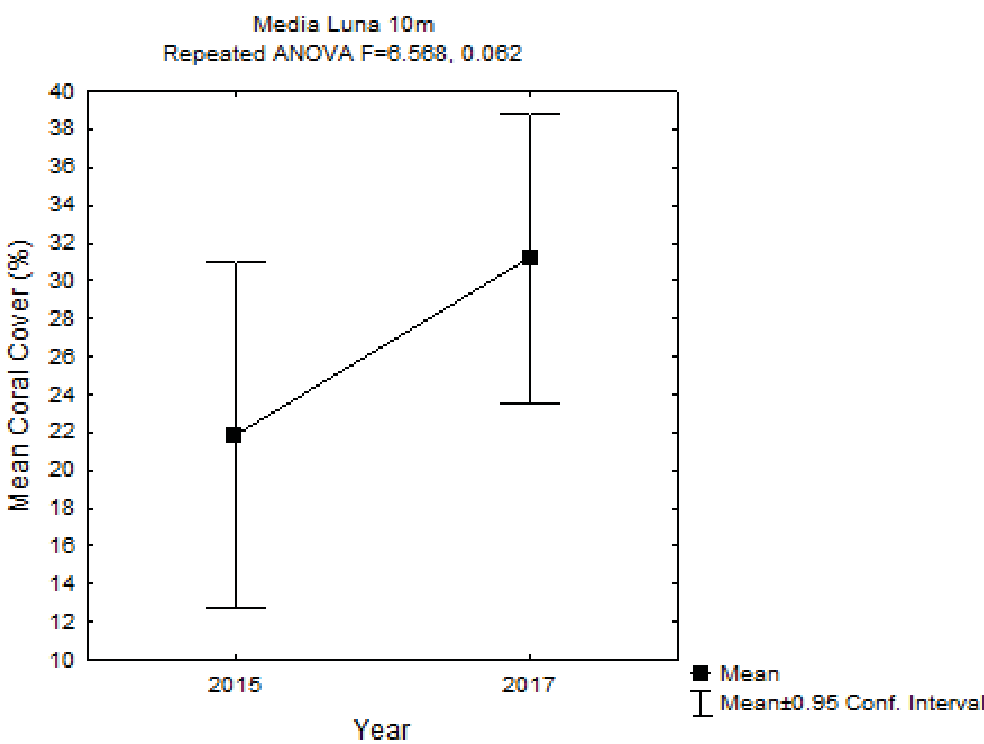
8. Resuellos 10 – Cabo Rojo



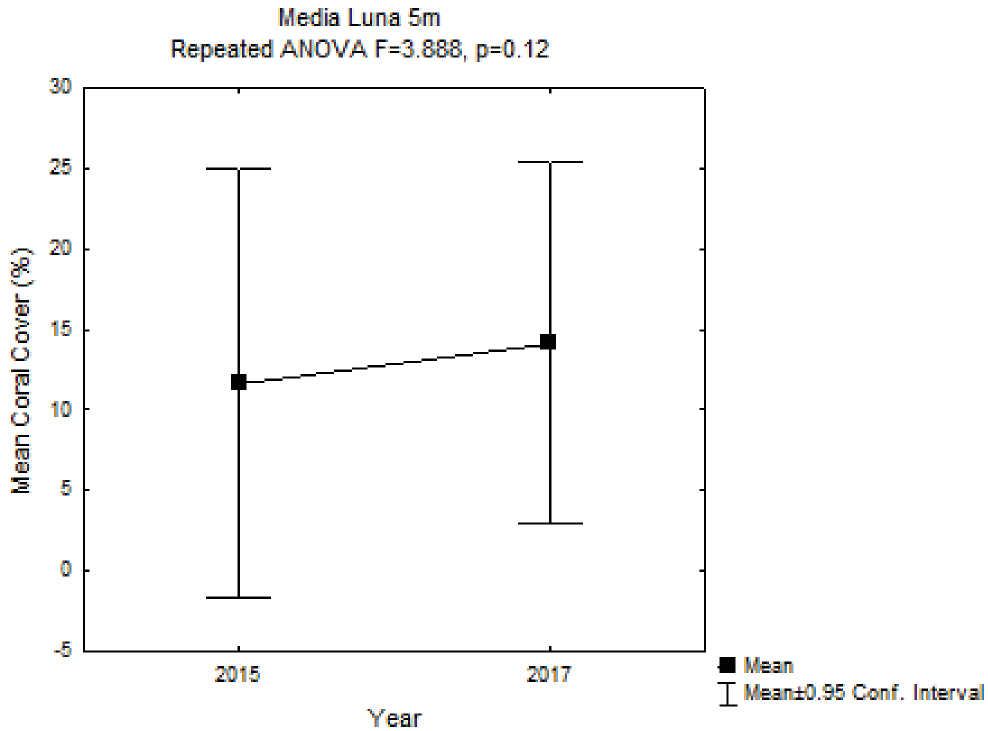
9. Boya Vieja 20m – La Parguera



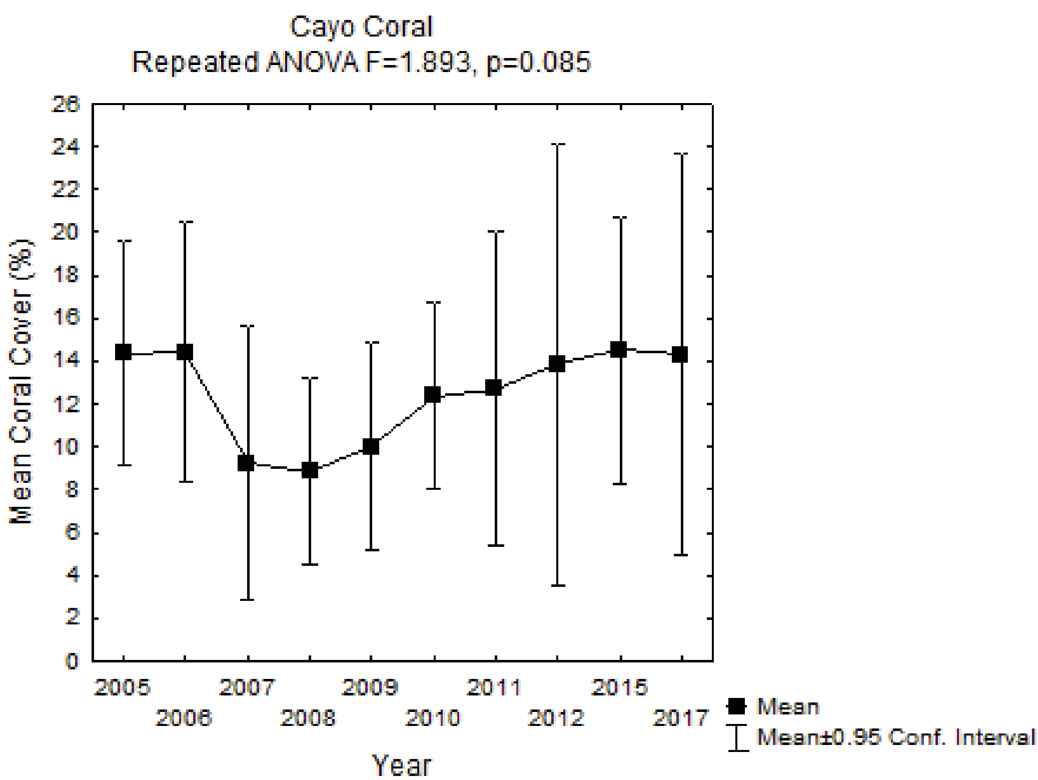
10. Media Luna 10 – La Parguera



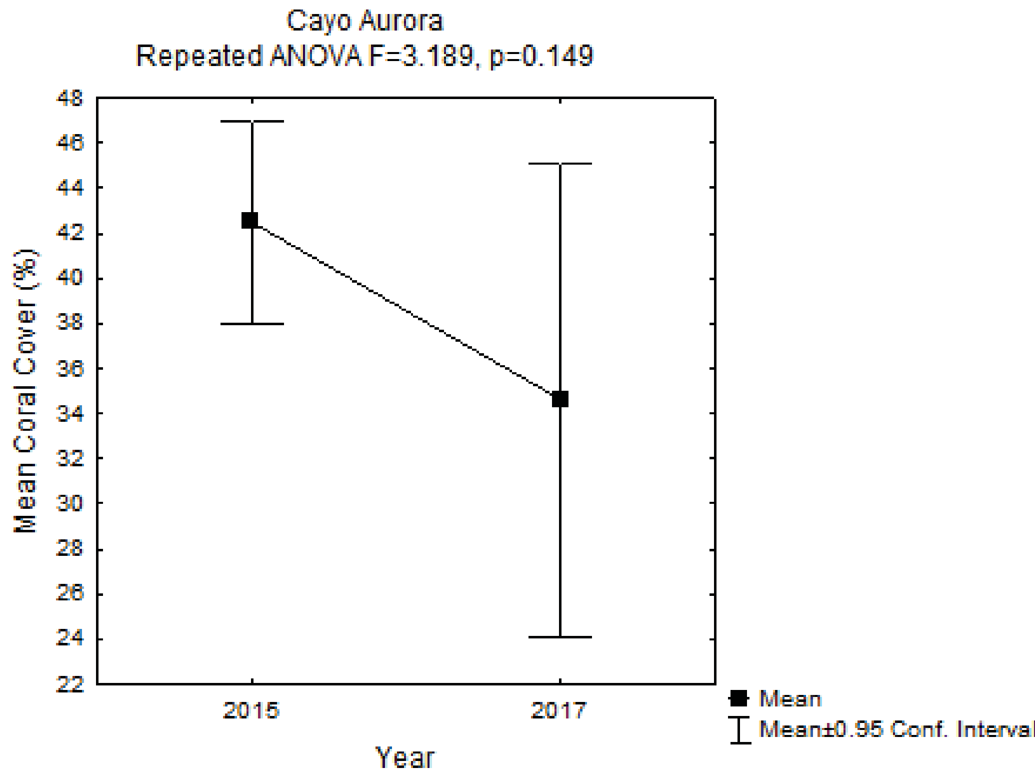
11. Media Luna 5 – La Parguera



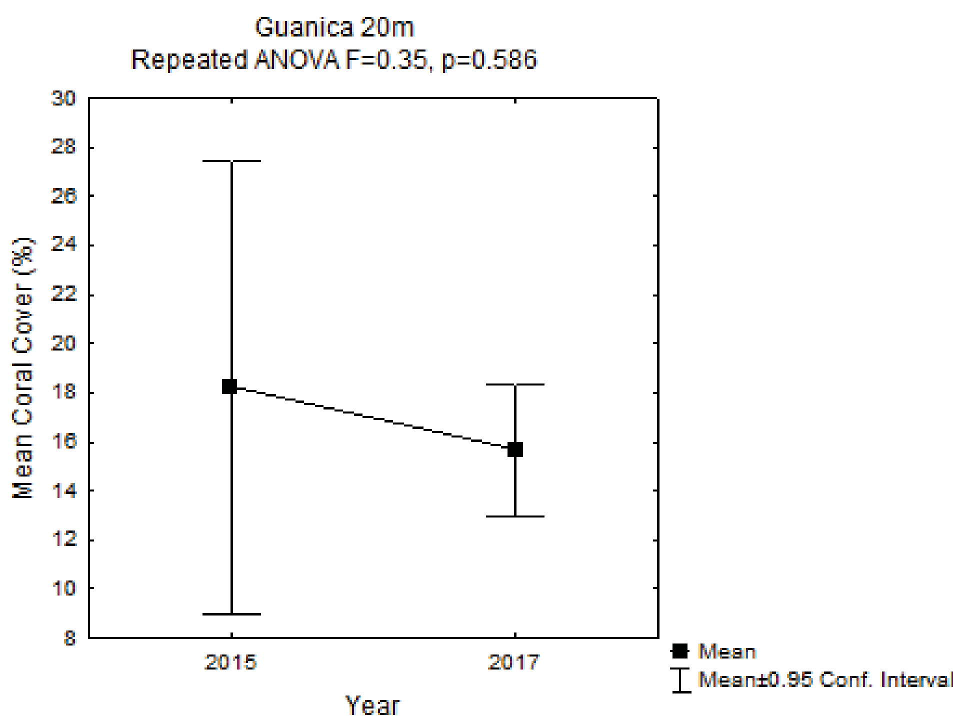
12. Cayo Coral 10m – Guanica



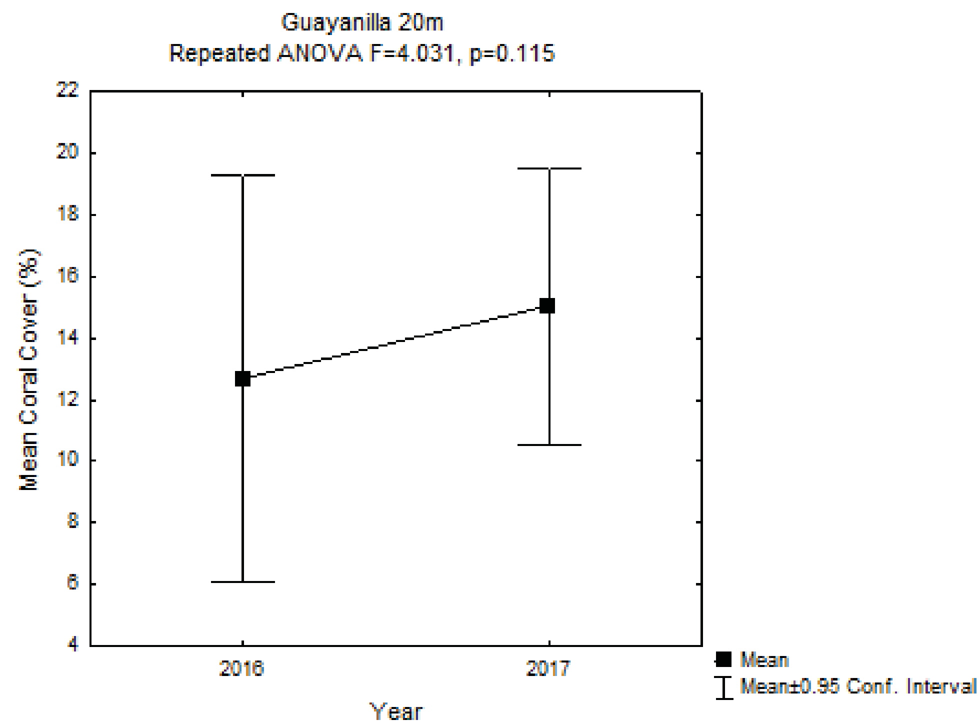
13. Cayo Aurora – Guanica



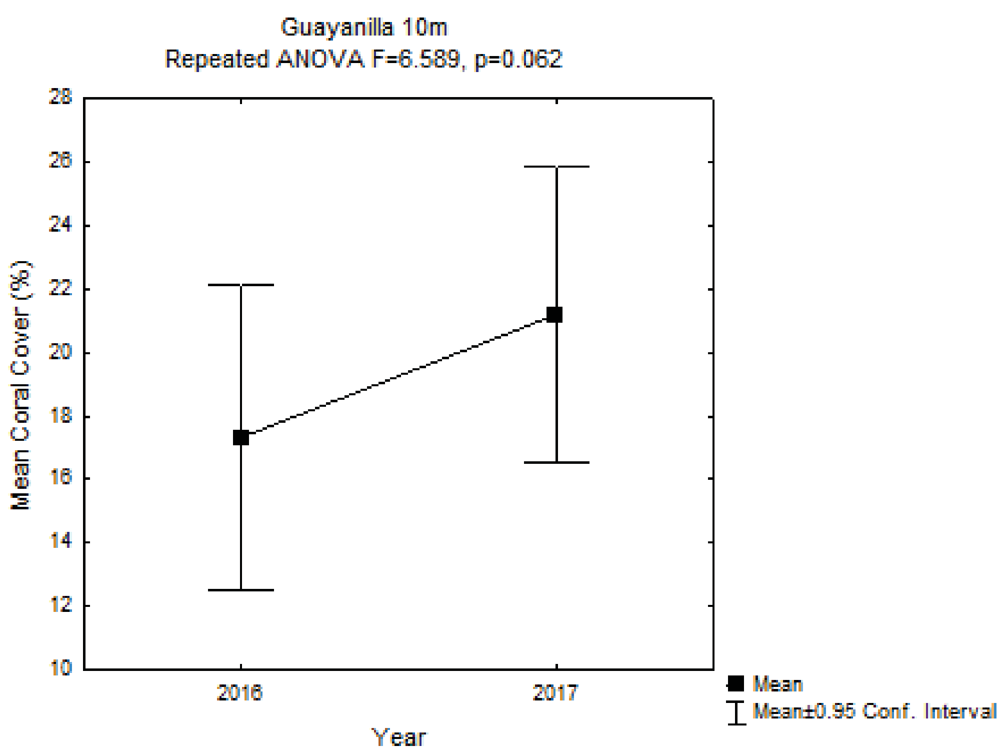
14. Efra's Wall 20m – Guanica



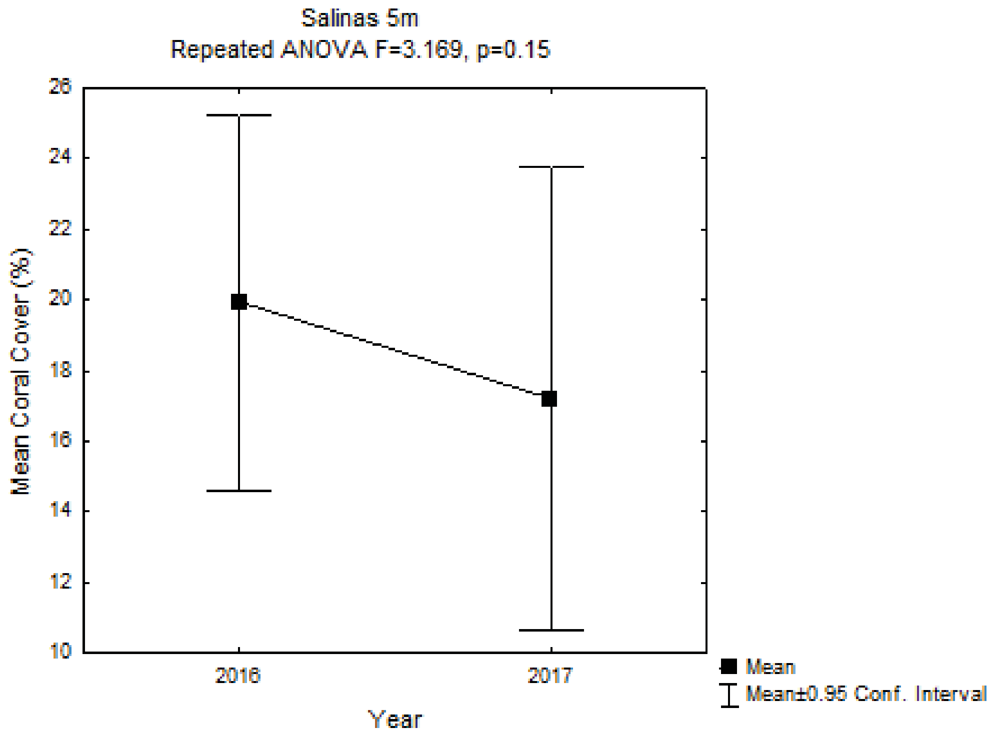
15. Maria Langa 20 – Guayanilla



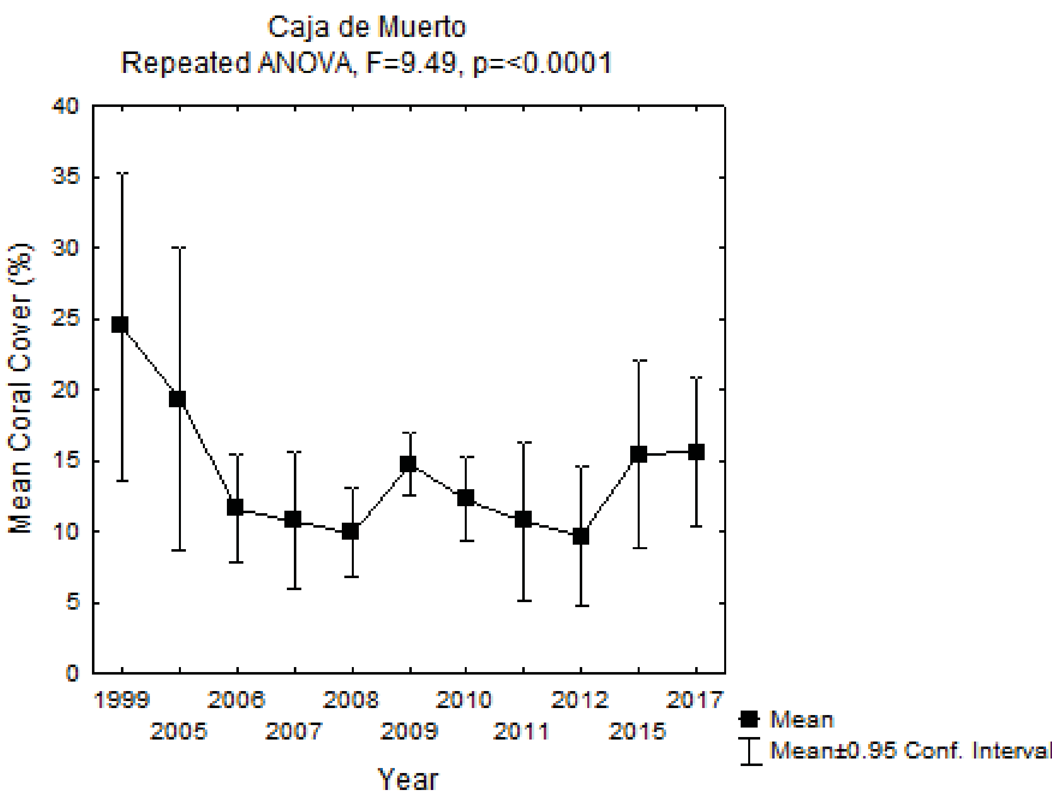
16. Maria Langa 10 – Guayanilla



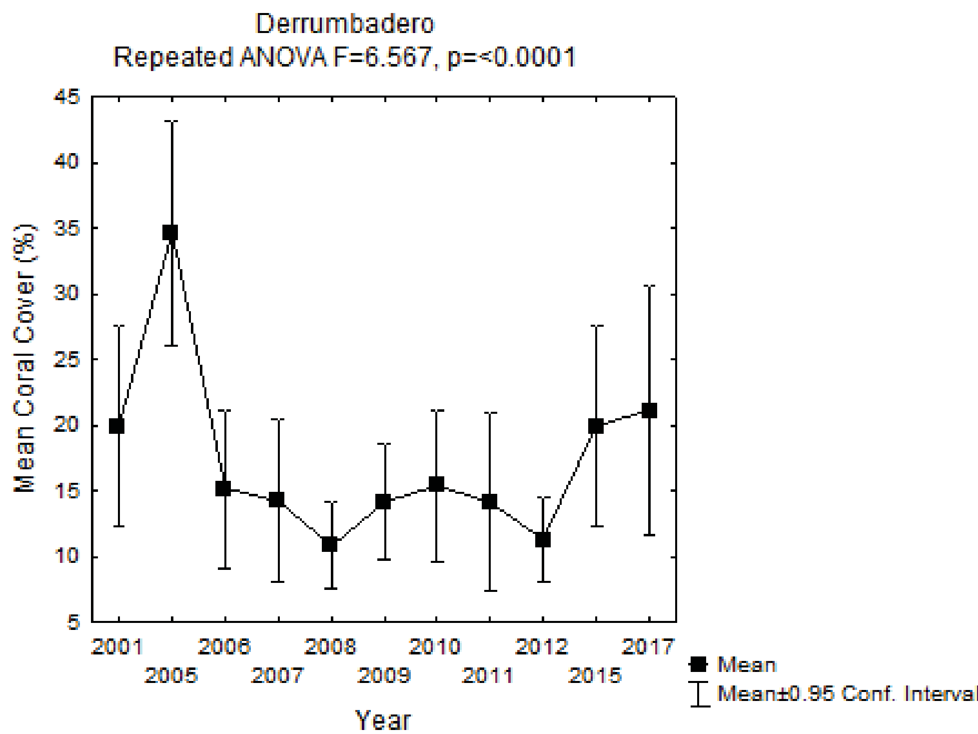
17. Maria Langa 3 - Guayanilla



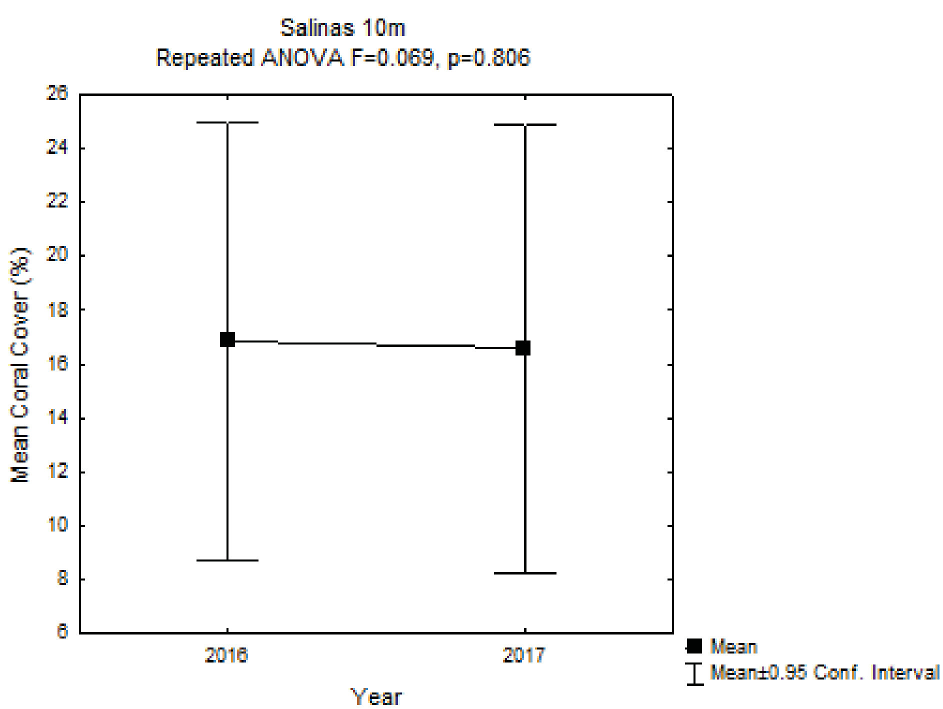
18. Caja de Muerto 10m – Ponce



19. Derrumbadero 20m – Ponce



20. Cayo Caribes 10 – Salinas



Repeated ANOVA Tables

La Parguera	SS	df	MS	F	p value
Depth	0.682	2	0.341	6.103	0.025
Year	0.089	1	0.089	17.677	0.014
Depth*Year	0.019	2	0.009	1.068	0.388
Cayo Aurora	**SS**	**df**	**MS**	**F**	**p value**
Year	0.023	1	0.023	3.189	0.149
Cayo Coral	**SS**	**df**	**MS**	**F**	**p value**
Year	0.322	9	0.036	1.893	0.085
Guanica 20m	**SS**	**df**	**MS**	**F**	**p value**
Year	0.004	1	0.004	0.35	0.586
Derrumbadero	**SS**	**df**	**MS**	**F**	**p value**
Year	0.931	10	0.093	6.567	<0.0001
Caja de Muerto	**SS**	**df**	**MS**	**F**	**p value**
Year	0.745	10	0.074	9.49	<0.0001
Tourmaline	**SS**	**df**	**MS**	**F**	**p value**
Depth	4.11	2	2.055	15.757	0.002
Year	0.352	10	0.035	5.465	<0.0001
Depth*Year	0.329	20	0.016	1.688	0.053
Tres Palmas 3m	**SS**	**df**	**MS**	**F**	**p value**
Year	0.034	1	0.034	8.194	0.046
Tres Palmas	**SS**	**df**	**MS**	**F**	**p value**
Depth	0.066	1	0.066	1.321	0.315
Year	0.149	10	0.015	1.348	0.239
Depth*Year	0.08	10	0.008	1.729	0.108
Salinas	**SS**	**df**	**MS**	**F**	**p value**
Depth	0.016	1	0.016	0.939	0.387
Year	0.007	1	0.007	1.951	0.235
Depth*Year	0.004	1	0.004	1.637	0.27
Gallardo	**SS**	**df**	**MS**	**F**	**p value**
Year	0	1	0	0.027	0.877
Resuellos	**SS**	**df**	**MS**	**F**	**p value**
Year	0.049	3	0.016	0.347	0.792
Guayanilla	**SS**	**df**	**MS**	**F**	**p value**
Depth	0.71	2	0.355	8.059	0.012
Year	0.047	1	0.047	7.705	0.05
Depth*Year	0.406	2	0.203	42.514	<0.0001

Appendix 2. Prevalence of infectious diseases in coral colonies intercepted by transects during 2017

Reef Stations	T1	T2	T3	T4	T5	TOTAL # COLONIES	MEAN	TOTAL DISEASED COLONIES	% DISEASE PREVALENCE
Tres Palmas 3	7	7	6	6	7	33	**6.6**	1	3.03
Tres Palmas 10	14	17	16	11	18	76	**15.2**	0	0.00
Tres Palmas 20	12	13	16	17	12	70	**14.0**	1	1.43
Tourmaline 30	15	15	20	11	19	80	**16.0**	0	0.00
Tourmaline 20	nd	nd	nd	nd	nd	n/d	**n/d**	n/d	n/d
Tourmaline 10	23	15	30	25	29	122	**24.4**	2	1.64
Gallardo	9	14	8	7	12	50	**10.0**	2	4.00
Resuellos	16	14	14	10	12	66	**13.2**	0	0.00
Boya Vieja	13	18	14	15	14	74	**14.8**	3	4.05
MLuna 10	10	10	15	16	21	72	**14.4**	0	0.00
MLuna 5	3	5	5	4	4	21	**4.2**	0	0.00
Cayo Coral	6	9	12	3	9	39	**7.8**	1	2.56
Cayo Aurora	9	6	12	10	9	46	**9.2**	0	0.00
Guan 20	12	8	9	7	9	45	**9.0**	0	0.00
MLanga 20	9	12	6	8	7	42	**8.4**	0	0.00
MLanga 10	6	8	11	14	7	46	**9.2**	0	0.00
Mlanga 3	5	4	1	2	5	17	**3.4**	0	0.00
CDM	9	14	13	13	16	65	**13.0**	1	1.54
Derrumbadero	19	11	20	8	15	73	**14.6**	1	1.37
Cayo Coral	7	12	7	6	12	44	**8.8**	2	4.55
Cayo Ratones	12	10	9	8	12	51	**10.2**	1	1.96
					TOTAL =	**1,132**		**15**	
						MEAN =	**11.3**	**MEAN (%) =**	**1.31**

Appendix 3. Comparative analyses of soft coral (gorgonian) densities between the 2017 and the previous survey at reef stations. T-test results.

Sites	Previous survey	2017 Survey	t-value	df	p-value
Tres Palmas 5m	5.00	2.60	1.92	8	0.091
Tres Palmas 10m	**24.60**	**15.60**	**2.80**	**8**	**0.023**
Tres Palmas 20m	18.40	15.60	0.86	8	0.413
Tourmaline 30m	12.60	10.20	0.79	8	0.452
Tourmaline 20m	**19.60**	**11.00**	**2.61**	**8**	**0.031**
Tourmaline 10m	24.80	14.60	2.10	8	0.068
Gallardo	1.00	0.00	1.29	8	0.233
Resuellos	**44.60**	**24.20**	**3.36**	**8**	**0.010**
Old Buoy 20m	11.80	10.80	0.45	8	0.663
Media Luna 10m	**46.00**	**22.40**	**4.12**	**8**	**0.003**
Media Luna 5m	22.20	16.80	1.40	8	0.200
Cayo Coral	24.00	23.40	0.11	8	0.913
Cayo Aurora	0.20	0.40	-0.45	8	0.667
Guanica 20m	22.80	26.80	-1.34	8	0.216
Maria Langa 20m	22.40	24.60	-1.05	8	0.326
Maria Langa 10m	46.00	42.40	0.57	8	0.583
Maria Langa 5m	1.60	1.60	0.00	8	1.000
Caja de Muerto	21.60	20.80	0.14	8	0.892
Derrumbadero	29.00	33.60	-0.85	8	0.420
Salinas 10m	**15.40**	**21.40**	**-2.51**	**8**	**0.036**
Salinas 5m	12.80	11.80	0.31	8	0.765

Appendix 4. List of fish species identified at coral reef monitoring sites

Species Name	Common Name	MLAN 20	MLAN 10	MLAN 3	CARIB 10	RATN3	CDM 10	DER20	MEXT 30	MEXT20	ROD3
Abudefduf sexatilis	Sergeant Major		x	x		x	x		x	x	x
Abudefduf taurus	Night Sergeant										
Acanthemblemaria aspera	Roughhead Blenny										
Acanthemblemaria chaplini	Papillose Blenny										x
Acanthemblemaria spinosa	Sinyhead blenny										
Acanthostracion polygonia	Scrawled Cowfish										
Acanthostrascion quadricornis	Honeycomb Cowfish										
Acanthurus bahianus	Ocean Surgeon	x	x	x	x	x	x	x	x	x	x
Acanthurus chirurgus	Doctorfish	x	x		x	x	x	x	x	x	x
Acanthurus coeruleus	BlueTang	x	x		x	x	x	x	x	x	x
Aetobatus narinari	Spotted Eagle Ray						x	x		x	
Alutherus scriptus	Scrawled Filefish						x	x	x		x
Amblicirrhitos pinnos	Redspotted Hawkfish	x			x		x	x	x	x	x
Anchoa sp.	Anchovy										
Anisotremus surinamensis	Black Margate										
Anisotremus virginicus	Porkfish	x		x	x		x	x	x	x	x
Apogon townsendi	Belted Cardinalfish										
Aulostomus maculatus	Trumpetfish	x			x	x	x	x	x	x	x
Balistes vetula	Queen Triggerfish	x		x			x	x			
Bodianus rufus	Spanish Hogfish	x		x	x		x	x	x	x	x
Bothus lunatus	Peacock Flounder								x	x	
Calamus calamus	Saucereye Porgy							x			
Calamus pennatula	Pluma						x	x			x
Cantherhines macrocerus	Whitespotted Filefish						x	x			x
Cantherhines pullus	Orangespotted Filefish	x			x		x	x	x	x	x
Cantherhines surinamensis	Ocean Triggerfish							x	x	x	x
Canthigaster rostrata	Caribbean Puffer	x	x		x	x	x	x	x	x	x
Caranx bartholomaei	Yellow Jack				x		x	x			
Caranx crysos	Blue Runner	x	x		x		x	x	x	x	x
Caranx hippos	Horse-eye Jack						x	x	x		
Caranx latus	Crevalle Jack										
Caranx lugubris	Black Jack							x	x	x	x
Carangoides ruber	Bar Jack	x	x	x		x	x	x	x	x	x
Carcharhinus limbatus	Caribbean Reef Shark										
Chaenopsis ocellata	Bluethroat Pikeblenny							x			
Chaetodipterus faber	Atlantic Spadefish								x		
Chaetodon aculeatus	Longsnout Butterflyfish							x	x	x	x
Chaetodon capistratus	Four-eye Butterflyfish	x	x		x	x	x	x	x	x	x
Chaetodon ocellatus	Spotfin Butterflyfish	x					x	x	x	x	x
Chaetodon sedentarius	Reef Butterflyfish								x		
Chaetodon striatus	Banded Butterflyfish	x	x		x	x	x	x	x	x	x
Chromis cyanea	Blue Chromis	x	x				x	x	x	x	x
Chromis insolata	Sunshine Chromis							x	x		
Chromis multilineata	Brown Chromis		x	x			x	x	x	x	x
Clepticus parrae	Creole Wrasse							x	x	x	x
Coryphopterus glaucofraenum	Bridled Goby	x			x		x	x	x	x	x
Coryphopterus lipernes	Peppermint Goby						x	x	x	x	x
Coryphopterus personatus	Masked goby	x					x	x	x	x	x
Coryphopterus sp	Goby					x					
Criptoptomus roseus	Bluelip Parrotfish										
Ctenogobius saepepallens	Dashed Goby										
Dasyatis americana	Southern Stingray										
Decapterus macarelus	Mackerel Scad				x		x	x	x	x	
Diodon holacanthus	Balloonfish										
Diodon hystrix	Porcupinefish				x		x	x			
Echenes naucrates	Sharksucker							x			
Echidna catenata	Chain Moray										
Caranx crysos	Blue Runner	x	x		x		x	x	x	x	x
Caranx hippos	Horse-eye Jack						x	x	x		
Caranx latus	Crevalle Jack										

Species Name	**Common Name**	**MLAN20**	**MLAN10**	**MLAN3**	**CARIB10**	**RATN#**	**CDM10**	**DER20**	**MEXT30**	**MEXT20**	**ROD3**
Caranx lugubris	Black Jack							x	x	x	x
Carangoides ruber	Bar Jack	x	x	x		x	x	x	x	x	x
Carcharhinus limbatus	Caribbean Reef Shark										
Chaenopsis ocellata	Bluethroat Pikeblenny							x			
Chaetodipterus faber	Atlantic Spadefish								x		
Chaetodon aculeatus	Longsnout Butterflyfish							x	x	x	x
Chaetodon capistratus	Four-eye Butterflyfish	x	x		x	x	x	x	x	x	x
Chaetodon ocellatus	Spotfin Butterflyfish	x					x	x	x	x	x
Chaetodon sedentarius	Reef Butterflyfish								x		
Chaetodon striatus	Banded Butterflyfish	x	x		x	x	x	x	x	x	x
Chromis cyanea	Blue Chromis	x	x				x	x	x	x	x
Chromis insolata	Sunshine Chromis							x	x		
Chromis multilineata	Brown Chromis		x	x			x	x	x	x	x
Clepticus parrae	Creole Wrasse							x	x	x	x
Coryphopterus glaucofraenum	Bridled Goby	x			x		x	x	x	x	x
Coryphopterus lipernes	Peppermint Goby						x	x	x	x	x
Coryphopterus personatus	Masked goby	x					x	x	x	x	x
Coryphopterus sp	Goby					x					
Criptoptomus roseus	Bluelip Parrotfish										
Ctenogobius saepepallens	Dashed Goby										
Dasyatis americana	Southern Stingray										
Decapterus macarelus	Mackerel Scad				x		x	x	x	x	
Diodon holacanthus	Balloonfish										
Diodon hystrix	Porcupinefish				x		x	x			
Echenes naucrates	Sharksucker							x			
Echidna catenata	Chain Moray										
Elagatis bipinnulata	Rainbow Runner							x			
Epinephelus adcensionis	Rock Hind								x	x	
Epinephelus cruentatus	Graysby	x	x	x			x	x	x	x	x
Epinephelus itajara	Jewfish	x									
Epinephelus fulva	Coney	x	x	x			x	x	x	x	x
Epinephelus guttatus	Red Hind	x	x		x		x	x	x	x	x
Epinephelus striatus	Nassau Grouper				x			x	x	x	
Equetus acuminatus	Highhat						x	x	x	x	x
Equetus lanceolatus	Jackknife Fish								x	x	
Equetus punctatus	Spotted Drum					x	x	x			
Gerres cinereus	Yellowfin Mojarra						x	x	x	x	x
Ginglymostoma cirratum	Nurse Shark				x			x	x		x
Elacatinus evelynae	Sharknose Goby	x	x		x	x	x	x	x	x	x
Gobiosoma hoorsti	Yellowline Goby						x				
Gobiosoma saucrum	Leopard Goby						x	x	x	x	x
Gramma loreto	Fairy Basslet	x					x	x	x	x	x
Gymnothorax funebris	Green Moray							x			x
Gymnothorax miliaris	Goldentail Moray										
Gymnothorax moringa	Spotted Moray							x	x	x	x
Haemulon aurolineatum	Tomtate	x			x		x	x	x	x	x
Haemulon carbonarium	Caesar's Grunt										x
Haemulon chrysargyreum	Smallmouth Grunt		x	x			x		x	x	x
Haemulon flavolineatum	French grunt	x	x	x	x	x	x	x	x	x	x
Haemulon macrostomum	Spanish Grunt			x			x	x	x	x	x
Haemulon melanurum	Cottonwick								x	x	x
Haemulon parra	Sailors Choice										
Haemulon plumieri	White Grunt	x				x	x	x			x
Haemulon sciurus	Bluestriped Grunt				x			x	x	x	x
Haemulon steindachneri	Latin grunt										
Halichoeres bivitatus	Slippery Dick			x	x	x	x				x
Halichoeres cyanocephalus	Yellowcheek Wrasse							x			
Halichoeres garnoti	Yellow-head Wrasse	x	x	x	x	x	x	x	x	x	x
Halichoeres maculipinna	Clown wrasse			x	x	x	x	x	x	x	x
Halichoeres poeyi	Black-ear Wrasse				x	x					
Halichoeres radiatus	Puddinwife			x	x	x	x	x	x	x	x
Heteropriacanthus cruentatus	Bigeye										
Hemiramphus ballyhoo	Ballyhoo		x	x		x	x	x			x
Holacanthus ciliaris	Queen Angelfish						x	x	x	x	x
Holacanthus tricolor	Rock Beauty	x					x	x	x	x	x
Holocentrus adscensionis	Longjaw Squirrelfish			x		x	x	x			x

Species Name	Common Name	MLAN20	MLAN10	MLAN3	CARIB10	RATN#	CDM10	DER20	MEXT30	MEXT20	ROD3
Holocentrus coruscus	Reef Squirrelfish						x	x	x	x	x
Holocentrus rufus	Squirrelfish	x	x	x	x	x	x	x	x	x	x
Holocentrus vexillarius	Dusky Squirrelfish										
Hypoplectrus aberrans	Yellowbelly hamlet								x	x	x
Hypoplectrus chlorurus	Yellowtail Hamlet	x			x		x	x			x
Hypoplectrus guttavarius	Shy Hamlet						x	x	x	x	x
Hypoplectrus indico	Indigo Hamlet					x	x	x	x	x	x
Hypoplectrus nigricans	Black Hamlet					x	x	x	x	x	x
Hypoplectrus puella	Barred Hamlet	x			x	x	x	x	x	x	x
Hypoplectrus unicolor	Butter Hamlet	x					x	x	x	x	x
Kyphosus sp.	Bermuda Chub							x	x	x	x
Lachnolaimus maximus	Hogfish	x			x		x	x	x		x
Lactophrys bicaudalis	Spotted Trunkfish						x	x	x	x	x
Lactophrys polygonia	Honeycomb Cowfish							x	x	x	x
Lactophrys trigonus	Trunkfish										
Lactophrys triqueter	Smooth Trunkfish						x	x	x	x	x
Liproma carmabi	Candy Basslet								x		
Liopropoma rubre	Swissguard Basslet							x	x	x	x
Lutjanus analis	Mutton Snapper			x			x				
Lutjanus apodus	Schoolmaster Snapper			x	x	x	x	x	x	x	x
Lutjanus cyanopterus	Cubera Snapper						x	x	x	x	
Lutjanus jocu	Dog Snapper		x				x	x	x	x	
Lutjanus mahogani	Mahogani Snapper	x					x	x	x	x	x
Lutjanus synagris	Lane snapper				x		x		x	x	x
Malacanthus plumieri	Sand Tilefish			x							
Malacoctenus triangulatus	Saddled Blenny	x		x	x				x	x	x
Malacoctenus versicolor	Barfin Blenny										
Melichthys niger	Black Durgon			x				x	x	x	x
Microspatodon chrysurus	Yellowtail damselfish		x	x	x	x	x	x	x	x	x
Mlacoctenus gelli	Dusky blenny										
Mulloides martinicus	Yellowtail Goatfish						x	x	x	x	x
Muraena robusta	Stout Moray						x				
Mycteroperca interstitialis	Yellowmouth Grouper									x	
Mycteroperca tigris	Tiger Grouper							x			
Mycteroperca venenosa	Yellowfin Grouper				x		x	x	x		
Myripristis jacobus	Blackbar Soldierfish		x	x	x		x	x	x	x	x
Neoniphon marianus	Longjaw Squirrelfish						x	x	x	x	x
Ocyurus chrysurus	Yellowtail Snapper	x	x	x	x	x	x	x	x	x	x
Odontoscion dentex	Reef Croaker						x		x	x	x
Ophioblennius atlanticus	Redlip Blenny			x		x	x		x	x	x
Paranthias fucifer	Creolefish							x	x	x	x
Pempheris schomburgki	Glassy Sweeper								x	x	
Pomacanthus paru	French Angelfish				x	x		x			x
Pomacanthus arcuatus	Gray Angelfish	x		x	x		x	x	x	x	x
Priacanthus arenatus	Glasseye						x	x	x	x	x
Pseudopeneus maculatus	Spotted Goatfish	x					x	x	x	x	x
Pterois volitans	Lionfish	x	x	x	x			x		x	x
Rypticus saponaceous	Soapfish						x				
Sanopus greenfieldorum	Whitelined Toadfish										
Scarus coelestinus	Midnight Parrotfish										
Scarus coeruleus	Blue Parrotfish						x	x	x	x	x
Scarus guacamaia	Rainbow Parrotfish										
Scarus iserti	Stripped Parrotfish	x	x	x	x	x	x	x	x	x	x
Scarus taeniopterus	Princess Parrotfish	x	x	x	x	x	x	x	x	x	x
Scarus vetula	Queen Parrotfish						x	x	x	x	x
Scomberomorus regalis	Cero Mackerel	x		x	x		x	x	x	x	x
Scorpaena plumieri	Spotted Scorpionfish						x	x			
Seriola rivoliana	Almaco Jack						x	x			
Serranus baldwini	Lantern Bass										
Serranus chionaraia	Snow Bass										
Serranus dewegeri	Vieja										
Serranus tabacarius	Tobacco Fish	x									
Serranus tegrinus	Harlequin Bass	x	x	x	x	x	x	x	x	x	x
Sparisoma atomarium	Greenblotch Parrofish										
Sparisoma aurofrenatum	Redband Parrotifish	x	x	x	x	x	x	x	x	x	x
Sparisoma chrysopterum	Redtail Parrotfish	x									
Sparisoma radians	Bucktootth Parrotfish	x	x	x	x	x	x	x	x	x	x

Species Name	Common Name	MLAN 20	MLAN 10	MLAN 3	CARIB 10	RATON 3	CDM 10	DERR 20	MEXT 30	MEXT20	RODR 3
Sparisoma rubripinne	Yellowtail Parrotfish		x	x	x	x					
Sparisoma viride	Stoplight Parrotfish	x	x	x	x	x	x	x	x	x	x
Chilomycterus antillarum	Web Burrfish								x	x	
Sphoeroides greeleyi	Green Puffer										
Sphoeroides testudineus	Checkered Puffer								x	x	x
Sphyraena barracuda	Great Barracuda	x	x	x	x		x	x	x	x	x
Stegastes adustus	Dusky Damselfish	x	x	x	x	x	x	x	x		x
Stegastes leucostictus	Beaugregory	x	x		x		x	x	x	x	x
Stegastes partitus	Bicolor Damselfish	x	x	x	x	x	x	x	x	x	x
Stegastes planifons	Yellow-eye Damselfish	x			x	x	x	x	x	x	x
Stegastes variabilis	Cocoa Damselfish		x	x	x	x	x	x	x	x	x
Stephalnolepis setifier	Pygmy Filefish								x		x
Strongylura timucu	Houndfish										
Synodus intermedius	Sand Diver						x	x	x	x	x
Thalasoma bifaciatum	Bluehead wrasse		x	x	x	x	x	x	x	x	x
Urolophus jamaicensis	Yellowspotted Stingray										
Xanthichthyis ringens	Sargassum Triggerfish										
	TOTALS	**54**	**37**	**44**	**57**	**44**	**101**	**114**	**112**	**102**	**109**

Species Name	Common Name	DES 30	DES 20	DES 15	RIN 5	RIN 10	RIN 20	COR 10	AURO 3	GUAN 20	GALLA 5
Abudefduf sexatilis	Sergeant Major		x		x	x	x	x	x		x
Abudefduf taurus	Night Sergeant				x	x					
Acanthemblemaria aspera	Roughhead Blenny										
Acanthemblemaria chaplini	Papillose Blenny										
Acanthemblemaria spinosa	Sinyhead blenny										
Acanthostracion polygonia	Scrawled Cowfish										
Acanthostrascion quadricornis	Honeycomb Cowfish	x	x				x	x			
Acanthurus bahianus	Ocean Surgeon	x	x	x	x	x	x	x	x	x	
Acanthurus chirurgus	Doctorfish	x	x	x	x	x	x	x	x	x	x
Acanthurus coeruleus	BlueTang	x	x	x	x	x	x	x	x	x	x
Aetobatus narinari	Spotted Eagle Ray							x			
Alutherus scriptus	Scrawled Filefish	x	x			x		x			
Amblicirrhitos pinnos	Redspotted Hawkfish	x	x	x		x	x	x	x		x
Anchoa sp.	Anchovy				x						
Anisotremus surinamensis	Black Margate	x				x	x				
Anisotremus virginicus	Porkfish				x	x	x	x	x		
Apogon townsendi	Belted Cardinalfish	x	x			x	x				
Aulostomus maculatus	Trumpetfish	x	x	x	x	x	x	x	x	x	x
Balistes vetula	Queen Triggerfish	x	x	x				x		x	
Bodianus rufus	Spanish Hogfish	x	x	x	x	x	x	x	x	x	x
Bothus lunatus	Peacock Flounder						x				
Calamus calamus	Saucereye Porgy				x			x			
Calamus pennatula	Pluma	x			x			x	x	x	
Cantherhines macrocerus	Whitespotted Filefish	x	x	x	x		x	x			
Cantherhines pullus	Orangespotted Filefish				x	x		x		x	x
Cantherhines surinamensis	Ocean Triggerfish	x	x			x		x			
Canthigaster rostrata	Caribbean Puffer	x	x	x	x	x	x	x	x	x	x
Caranx bartholomaei	Yellow Jack							x	x	x	
Caranx crysos	Blue Runner	x	x		x	x	x	x	x	x	x
Caranx hippos	Horse-eye Jack	x			x	x	x	x	x		
Caranx latus	Crevalle Jack	x									x
Caranx lugubris	Black Jack	x	x		x	x		x			
Carangoides ruber	Bar Jack	x	x	x	x	x	x	x	x		x
Carcharhinus limbatus	Caribbean Reef Shark	x						x			
Chaenopsis ocellata	Bluethroat Pikeblenny							x			
Chaetodipterus faber	Atlantic Spadefish							x			
Chaetodon aculeatus	Longsnout Butterflyfish	x	x			x	x	x			
Chaetodon capistratus	Four-eye Butterflyfish	x	x	x	x	x	x	x	x	x	x
Chaetodon ocellatus	Spotfin Butterflyfish							x			
Chaetodon sedentarius	Reef Butterflyfish		x				x				
Chaetodon striatus	Banded Butterflyfish		x	x		x	x	x	x		x

Species Name	Common Name	DES 30	DES 20	DES 15	RIN 5	RIN 10	RIN 20	COR 10	AURO 3	GUAN 20	GALLA 5
Chromis cyanea	Blue Chromis	x	x	x		x	x	x		x	x
Chromis insolata	Sunshine Chromis	x					x				
Chromis multilineata	Brown Chromis	x	x	x	x	x	x	x	x		x
Clepticus parrae	Creole Wrasse	x	x	x		x	x	x		x	x
Coryphopterus glaucofraenum	Bridled Goby	x				x		x		x	
Coryphopterus lipernes	Peppermint Goby	x	x	x		x	x	x		x	
Coryphopterus personatus	Masked goby	x	x	x		x	x	x			
Coryphopterus sp	Goby										
Criptoptomus roseus	Bluelip Parrotfish			x							
Ctenogobius saepepallens	Dashed Goby						x				
Dasyatis americana	Southern Stingray	x	x		x						
Decapterus macarelus	Mackerel Scad	x		x			x	x	x		
Diodon holacanthus	Balloonfish	x			x	x					
Diodon hystrix	Porcupinefish	x		x				x	x		
Echenes naucrates	Sharksucker							x			
Echidna catenata	Chain Moray			x							
Elagatis bipinnulata	Rainbow Runner	x									
Epinephelus adsensionis	Rock Hind				x	x					
Epinephelus cruentatus	Graysby	x	x	x		x	x	x	x	x	x
Epinephelus itajara	Jewfish							x			
Epinephelus fulvus	Coney	x	x	x	x	x	x	x	x	x	x
Epinephelus guttatus	Red Hind	x	x	x		x	x	x	x	x	x
Epinephelus striatus	Nassau Grouper	x	x					x			
Equetus acuminatus	Highhat	x	x	x		x	x	x			
Equetus lanceolatus	Jackknife Fish					x	x				
Equetus punctatus	Spotted Drum							x			
Gerres cinereus	Yellowfin Mojarra				x	x	x	x	x		
Ginglymostoma cirratum	Nurse Shark			x			x	x		x	
Elacatinus evelynae	Sharknose Goby	x	x	x	x	x	x	x		x	
Gobiosoma hoorsti	Yellowline Goby										
Gobiosoma saucrum	Leopard Goby	x			x	x		x			
Gramma loreto	Fairy Basslet	x	x		x	x	x	x		x	
Gymnothorax funebris	Green Moray	x					x		x	x	
Gymnothorax miliaris	Goldentail Moray					x	x				
Gymnothorax moringa	Spotted Moray		x	x		x	x	x			
Haemulon aurolineatum	Tomtate		x			x		x	x	x	
Haemulon carbonarium	Caesar's Grunt				x		x		x		
Haemulon chrysargyreum	Smallmouth Grunt				x	x	x	x	x	x	
Haemulon flavolineatum	French grunt	x	x	x	x	x	x	x	x	x	x
Haemulon macrostomum	Spanish Grunt		x	x	x	x	x	x			
Haemulon melanurum	Cottonwick					x	x		x		
Haemulon parra	Sailors Choice										
Haemulon plumieri	White Grunt				x	x	x	x	x		
Haemulon sciurus	Bluestriped Grunt	x		x	x		x	x			
Haemulon steindachneri	Latin grunt							x			
Halichoeres bivitatus	Slippery Dick				x	x		x	x		x
Halichoeres cyanocephalus	Yellowcheek Wrasse										
Halichoeres garnoti	Yellow-head Wrasse	x	x	x	x	x	x	x	x	x	x
Halichoeres maculipinna	Clown wrasse	x	x	x	x	x	x	x	x		x
Halichoeres poeyi	Black-ear Wrasse				x			x			x
Halichoeres radiatus	Puddinwife		x	x	x	x		x	x		x
Heteropriacanthus cruentatus	Bigeye								x		
Hemiramphus ballyhoo	Ballyhoo	x	x	x		x	x	x	x	x	x
Holacanthus ciliaris	Queen Angelfish	x	x	x		x	x	x	x		
Holacanthus tricolor	Rock Beauty	x	x	x		x	x	x	x	x	
Holocentrus adscensionis	Longjaw Squirrelfish		x		x	x		x	x		x
Holocentrus coruscus	Reef Squirrelfish							x	x		x

Species Name	**Common Name**	**DES 30**	**DES 20**	**DES 15**	**RIN 5**	**RIN 10**	**RIN 20**	**COR 10**	**AURO 3**	**GUAN 20**	**GALLA 5**
Holocentrus rufus	Squirrelfish	x	x	x	x	x	x	x	x	x	x
Holocentrus vexillarius	Dusky Squirrelfish				x				x		
Hypoplectrus aberrans	Yellowbelly hamlet							x			
Hypoplectrus chlorurus	Yellowtail Hamlet					x	x	x			
Hypoplectrus guttavarius	Shy Hamlet					x		x			
Hypoplectrus indico	Indigo Hamlet							x			
Hypoplectrus nigricans	Black Hamlet	x				x	x	x	x		
Hypoplectrus puella	Barred Hamlet					x	x	x			
Hypoplectrus unicolor	Butter Hamlet	x				x	x	x		x	x
Kyphosus sp.	Bermuda Chub	x	x	x	x	x		x			x
Lachnolaimus maximus	Hogfish							x	x	x	
Lactophrys bicaudalis	Spotted Trunkfish			x				x			x
Lactophrys polygonia	Honeycomb Cowfish	x	x			x		x			
Lactophrys trigonus	Trunkfish	x					x				
Lactophrys triqueter	Smooth Trunkfish	x	x	x	x	x		x	x	x	x
Liproma carmabi	Candy Basslet										
Liopropoma rubre	Swissguard Basslet	x	x			x	x	x			
Lutjanus analis	Mutton Snapper				x		x	x	x	x	
Lutjanus apodus	Schoolmaster Snapper	x	x	x	x	x	x	x	x	x	
Lutjanus cyanopterus	Cubera Snapper										
Lutjanus jocu	Dog Snapper	x									
Lutjanus mahogani	Mahogani Snapper	x	x			x	x	x	x		
Lutjanus synagris	Lane snapper					x	x	x	x		
Malacanthus plumieri	Sand Tilefish					x	x	x			
Malacoctenus triangulatus	Saddled Blenny	x	x	x	x	x		x	x		
Malacoctenus versicolor	Barfin Blenny					x					
Melichthys niger	Black Durgon	x	x	x	x	x	x	x	x	x	x
Microspatodon chrysurus	Yellowtail damselfish	x	x	x	x	x	x	x	x		x
Mlacoctenus gelli	Dusky blenny				x						
Mulloides martinicus	Yellowtail Goatfish	x	x	x	x	x	x	x	x		
Muraena robusta	Stout Moray			x							
Mycteroperca interstitialis	Yellowmouth Grouper										
Mycteroperca tigris	Tiger Grouper										
Mycteroperca venenosa	Yellowfin Grouper	x						x	x		
Myripristis jacobus	Blackbar Soldierfish	x	x	x	x	x	x	x	x		
Neoniphon marianus	Longjaw Squirrelfish	x	x	x	x		x	x	x		
Ocyurus chrysurus	Yellowtail Snapper	x	x	x		x	x	x	x	x	x
Odontoscion dentex	Reef Croaker				x	x		x			
Ophioblennius atlanticus	Redlip Blenny		x	x	x	x	x		x		x
Paranthias fucifer	Creolefish	x	x			x	x	x			
Pempheris schomburgki	Glassy Sweeper				x						
Pomacanthus paru	French Angelfish							x	x		
Pomacanthus arcuatus	Gray Angelfish	x	x	x		x	x	x	x	x	
Priacanthus arenatus	Glasseye		x		x	x	x	x			
Pseudopeneus maculatus	Spotted Goatfish			x	x	x	x	x	x	x	x
Pterois volitans	Lionfish		x				x		x	x	
Rypticus saponaceous	Soapfish								x		
Sanopus greenfieldorum	Whitelined Toadfish					x					
Scarus coelestinus	Midnight Parrotfish				x						x
Scarus coeruleus	Blue Parrotfish					x		x			
Scarus guacamaia	Rainbow Parrotfish								x		
Scarus iserti	Stripped Parrotfish	x	x	x	x	x	x	x	x	x	x
Scarus taeniopterus	Princess Parrotfish		x	x	x	x	x	x	x		x
Scarus vetula	Queen Parrotfish	x	x		x	x	x	x	x		
Scomberomorus regalis	Cero Mackerel	x	x		x	x	x	x	x		x
Scorpaena plumieri	Spotted Scorpionfish			x							
Seriola rivoliana	Almaco Jack							x			

Species Name	Common Name	DES 30	DES 20	DES 15	RIN 5	RIN 10	RIN 20	COR 10	AURO 3	GUAN 20	GALLA 5
Serranus baldwini	Lantern Bass	x									
Serranus chionaraia	Snow Bass					x					
Serranus dewegeri	Vieja										
Serranus tabacarius	Tobacco Fish	x			x						
Serranus tegrinus	Harlequin Bass	x	x	x		x	x	x	x	x	
Sparisoma atomarium	Greenblotch Parrofish									x	
Sparisoma aurofrenatum	Redband Parrotifish	x	x	x	x	x	x	x			x
Sparisoma chrysopterum	Redtail Parrotfish	x	x				x			x	
Sparisoma radians	Bucktootth Parrotfish	x	x	x	x	x	x	x	x		x
Sparisoma rubripinne	Yellowtail Parrotfish	x	x		x	x		x	x		x
Sparisoma viride	Stoplight Parrotfish	x	x	x	x	x	x	x	x	x	x
Chilomycterus antillarum	Web Burrfish					x					
Sphoeroides greeleyi	Green Puffer					x					
Sphoeroides testudineus	Checkered Puffer					x					
Sphyraena barracuda	Great Barracuda	x	x	x	x	x	x	x	x	x	
Stegastes adustus	Dusky Damselfish			x	x			x	x		x
Stegastes leucostictus	Beaugregory	x				x	x	x	x		
Stegastes partitus	Bicolor Damselfish	x	x	x	x	x	x	x	x	x	
Stegastes planifons	Yellow-eye Damselfish	x	x			x	x	x	x	x	
Stegastes variabilis	Cocoa Damselfish			x	x	x		x			x
Stephalnolepis setifier	Pygmy Filefish										
Strongylura timucu	Houndfish								x		x
Synodus intermedius	Sand Diver			x	x	x	x				
Thalasoma bifaciatum	Bluehead wrasse	x	x	x	x	x	x	x	x	x	x
Urolophus jamaicensis	Yellowspotted Stingray										
Xanthichthyis ringens	Sargassum Triggerfish			x							
	TOTALS	**89**	**78**	**67**	**74**	**105**	**87**	**118**	**78**	**49**	**54**

Species Name	Common Name	MLUN 5	MLUN 10	BOYA 20	RESU 10	MON30	MON20	MON10	CIBU 3	SECO 30
Abudefduf sexatilis	Sergeant Major		x	x	x			x	x	
Abudefduf taurus	Night Sergeant									
Acanthemblemaria aspera	Roughhead Blenny						x			
Acanthemblemaria chaplini	Papillose Blenny									
Acanthemblemaria spinosa	Sinyhead blenny						x			
Acanthostracion polygonia	Scrawled Cowfish					x	x			
Acanthostrascion quadricornis	Honeycomb Cowfish									
Acanthurus bahianus	Ocean Surgeon	x	x	x	x	x		x	x	x
Acanthurus chirurgus	Doctorfish	x	x	x	x		x	x		
Acanthurus coeruleus	BlueTang		x	x	x	x	x	x	x	
Aetobatus narinari	Spotted Eagle Ray		x							
Alutherus scriptus	Scrawled Filefish						x	x		
Amblicirrhitos pinnos	Redspotted Hawkfish		x	x	x	x	x	x	x	
Anchoa sp.	Anchovy				x					
Anisotremus surinamensis	Black Margate		x				x			x
Anisotremus virginicus	Porkfish		x	x	x		x	x	x	
Apogon townsendi	Belted Cardinalfish						x			
Aulostomus maculatus	Trumpetfish	x	x				x			
Balistes vetula	Queen Triggerfish		x	x		x	x			
Bodianus rufus	Spanish Hogfish		x	x	x	x	x	x	x	x
Bothus lunatus	Peacock Flounder						x			
Calamus calamus	Saucereye Porgy						x			
Calamus pennatula	Pluma			x	x					
Cantherhines macrocerus	Whitespotted Filefish		x						x	

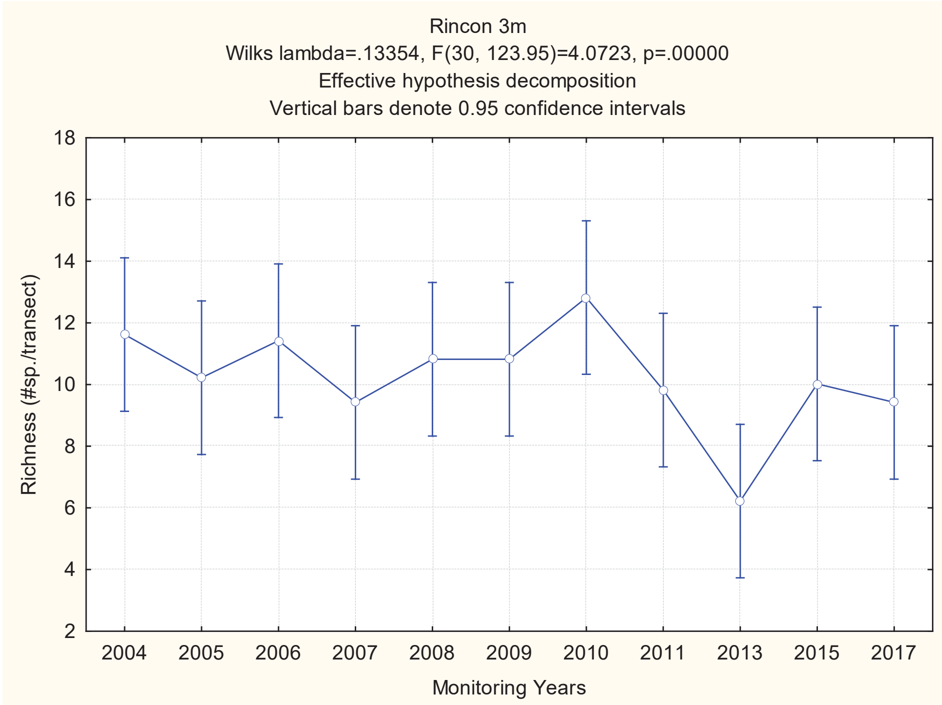
Species Name	Common Name	MLUN 5	MLUN 10	BOYA 20	RESU 10	MON30	MON20	MON10	CIBU 3	SECO 30
Cantherhines pullus	Orangespotted Filefish	x	x							
Cantherhines surinamensis	Ocean Triggerfish						x			x
Canthigaster rostrata	Caribbean Puffer		x	x	x	x	x	x	x	x
Caranx bartholomaei	Yellow Jack		x	x	x	x				x
Caranx crysos	Blue Runner		x	x	x					x
Caranx hippos	Horse-eye Jack			x			x			x
Caranx latus	Crevalle Jack		x	x						x
Caranx lugubris	Black Jack			x		x	x			x
Carangoides ruber	Bar Jack	x	x	x	x		x	x		x
Carcharhinus limbatus	Caribbean Reef Shark									
Chaenopsis ocellata	Bluethroat Pikeblenny									
Chaetodipterus faber	Atlantic Spadefish		x	x						
Chaetodon aculeatus	Longsnout Butterflyfish			x		x				x
Chaetodon capistratus	Four-eye Butterflyfish	x	x	x	x	x	x	x		x
Chaetodon ocellatus	Spotfin Butterflyfish		x							
Chaetodon sedentarius	Reef Butterflyfish			x		x				
Chaetodon striatus	Banded Butterflyfish		x	x	x		x	x	x	
Chromis cyanea	Blue Chromis		x	x	x	x	x	x		x
Chromis insolata	Sunshine Chromis			x		x				x
Chromis multilineata	Brown Chromis	x	x	x	x	x	x	x		x
Clepticus parrae	Creole Wrasse		x	x	x	x	x	x		x
Coryphopterus glaucofraenum	Bridled Goby		x	x	x	x	x			
Coryphopterus lipernes	Peppermint Goby		x	x	x	x	x	x		x
Coryphopterus personatus	Masked goby	x	x	x	x	x	x	x		x
Coryphopterus sp	Goby									
Criptoptomus roseus	Bluelip Parrotfish									
Ctenogobius saepepallens	Dashed Goby								x	
Dasyatis americana	Southern Stingray									
Decapterus macarelus	Mackerel Scad			x	x					x
Diodon holacanthus	Balloonfish									
Diodon hystrix	Porcupinefish		x	x	x					
Echenes naucrates	Sharksucker			x						
Echidna catenata	Chain Moray									
Elagatis bipinnulata	Rainbow Runner		x	x						
Epinephelus adsensionis	Rock Hind			x			x	x		
Epinephelus cruentatus	Graysby	x	x	x	x	x	x	x	x	x
Epinephelus itajara	Jewfish									
Epinephelus fulvus	Coney		x	x	x	x	x	x	x	
Epinephelus guttatus	Red Hind		x	x	x	x	x	x		x
Epinephelus striatus	Nassau Grouper		x	x						
Equetus acuminatus	Highhat									
Equetus lanceolatus	Jackknife Fish									
Equetus punctatus	Spotted Drum									
Gerres cinereus	Yellowfin Mojarra		x	x	x					
Ginglymostoma cirratum	Nurse Shark			x						
Elacatinus evelynae	Sharknose Goby	x	x	x	x	x	x	x	x	x
Gobiosoma hoorsti	Yellowline Goby									
Gobiosoma saucrum	Leopard Goby						x			
Gramma loreto	Fairy Basslet		x	x	x	x	x	x		x
Gymnothorax funebris	Green Moray			x						
Gymnothorax miliaris	Goldentail Moray						x			
Gymnothorax moringa	Spotted Moray				x		x			
Haemulon aurolineatum	Tomtate		x	x	x				x	
Haemulon carbonarium	Caesar's Grunt			x				x		
Haemulon chrysargyreum	Smallmouth Grunt	x	x	x	x					
Haemulon flavolineatum	French grunt	x	x	x	x	x	x	x	x	x
Haemulon macrostomum	Spanish Grunt		x	x	x			x	x	
Haemulon melanurum	Cottonwick									
Haemulon parra	Sailors Choice								x	
Haemulon plumieri	White Grunt		x	x	x		x			
Haemulon sciurus	Bluestriped Grunt		x	x						
Haemulon steindachneri	Latin grunt									

Species Name	Common Name	MLUN 5	MLUN 10	BOYA 20	RESU 10	MON30	MON20	MON10	CIBU 3	SECO 30
Halichoeres bivitatus	Slippery Dick		x	x			x	x	x	
Halichoeres cyanocephalus	Yellowcheek Wrasse									
Halichoeres garnoti	Yellow-head Wrasse		x	x	x	x	x	x		x
Halichoeres maculipinna	Clown wrasse					x	x	x	x	
Halichoeres poeyi	Black-ear Wrasse									
Halichoeres radiatus	Puddinwife							x		
Heteropriacanthus cruentatus	Bigeye									
Hemiramphus ballyhoo	Ballyhoo		x	x	x					
Holacanthus ciliaris	Queen Angelfish		x	x						
Holacanthus tricolor	Rock Beauty		x	x	x	x	x	x		x
Holocentrus adscensionis	Longjaw Squirrelfish		x	x	x	x	x	x	x	
Holocentrus coruscus	Reef Squirrelfish		x	x	x					
Holocentrus rufus	Squirrelfish	x	x	x	x	x	x	x		
Holocentrus vexillarius	Dusky Squirrelfish			x						
Hypoplectrus aberrans	Yellowbelly hamlet									
Hypoplectrus chlorurus	Yellowtail Hamlet	x	x	x	x					x
Hypoplectrus guttavarius	Shy Hamlet									
Hypoplectrus indico	Indigo Hamlet			x						
Hypoplectrus nigricans	Black Hamlet		x	x						
Hypoplectrus puella	Barred Hamlet		x	x	x					
Hypoplectrus unicolor	Butter Hamlet	x	x	x	x		x			
Kyphosus sp.	Bermuda Chub		x	x		x	x	x	x	
Lachnolaimus maximus	Hogfish		x	x	x					
Lactophrys bicaudalis	Spotted Trunkfish		x	x						
Lactophrys polygonia	Honeycomb Cowfish			x		x	x			
Lactophrys trigonus	Trunkfish									
Lactophrys triqueter	Smooth Trunkfish		x		x		x	x		
Liproma carmabi	Candy Basslet									
Liopropoma rubre	Swissguard Basslet									
Lutjanus analis	Mutton Snapper		x	x	x					x
Lutjanus apodus	Schoolmaster Snapper	x	x	x	x		x		x	
Lutjanus cyanopterus	Cubera Snapper		x	x						x
Lutjanus jocu	Dog Snapper		x	x						x
Lutjanus mahogoni	Mahogani Snapper		x	x	x				x	
Lutjanus synagris	Lane snapper		x	x	x					
Malacanthus plumieri	Sand Tilefish			x						
Malacoctenus triangulatus	Saddled Blenny		x	x		x	x	x		
Malacoctenus versicolor	Barfin Blenny									
Melichthys niger	Black Durgon		x	x		x	x	x		x
Microspatodon chrysurus	Yellowtail damselfish	x	x	x	x		x	x	x	
Mlacoctenus gelli	Dusky blenny									
Mulloides martinicus	Yellowtail Goatfish						x			
Muraena robusta	Stout Moray									
Mycteroperca interstitialis	Yellowmouth Grouper									
Mycteroperca tigris	Tiger Grouper						x			x
Mycteroperca venenosa	Yellowfin Grouper		x	x						x
Myripristis jacobus	Blackbar Soldierfish	x		x		x	x	x		x
Neoniphon marianus	Longjaw Squirrelfish		x	x	x	x	x	x		x
Ocyurus chrysurus	Yellowtail Snapper	x	x	x	x		x			x
Odontoscion dentex	Reef Croaker									
Ophioblennius atlanticus	Redlip Blenny						x			
Paranthias fucifer	Creolefish			x		x				
Pempheris schomburgki	Glassy Sweeper			x				x	x	
Pomacanthus paru	French Angelfish		x	x						
Pomacanthus arcuatus	Gray Angelfish		x	x	x					x
Priacanthus arenatus	Glasseye			x		x				
Pseudopeneus maculatus	Spotted Goatfish	x	x	x		x	x		x	
Pterois volitans	Lionfish		x	x	x	x				
Rypticus saponaceous	Soapfish									
Sanopus greenfieldorum	Whitelined Toadfish									
Scarus coelestinus	Midnight Parrotfish									
Scarus coeruleus	Blue Parrotfish									

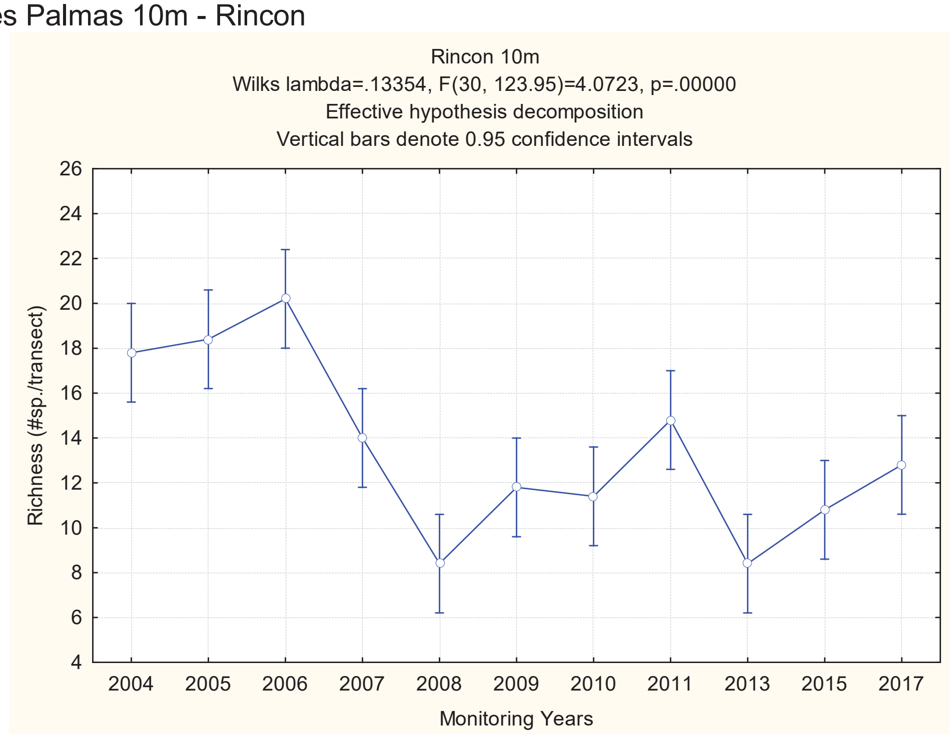
Species Name	Common Name	MLUN 5	MLUN 10	BOYA 20	RESU 10	MON30	MON20	MON10	CIBU 3	SECO 30
Scarus guacamaia	Rainbow Parrotfish						x			
Scarus iserti	Stripped Parrotfish	x	x	x	x	x	x	x	x	x
Scarus vetula	Queen Parrotfish	x	x				x	x		x
Scomberomorus regalis	Cero Mackerel		x	x	x					
Scorpaena plumieri	Spotted Scorpionfish									
Seriola rivoliana	Almaco Jack			x						
Serranus baldwini	Lantern Bass									
Serranus chionaraia	Snow Bass									
Serranus dewegeri	Vieja					x				
Serranus tabacarius	Tobacco Fish									
Serranus tegrinus	Harlequin Bass		x	x		x				
Sparisoma atomarium	Greenblotch Parrofish						x			
Sparisoma aurofrenatum	Redband Parrotifish	x	x	x	x	x	x	x		x
Sparisoma chrysopterum	Redtail Parrotfish	x	x	x						
Sparisoma radians	Bucktootth Parrotfish		x	x	x	x	x	x		x
Sparisoma rubripinne	Yellowtail Parrotfish		x	x	x			x		
Sparisoma viride	Stoplight Parrotfish	x	x	x	x	x	x	x	x	x
Chilomycterus antillarum	Web Burrfish									
Sphoeroides greeleyi	Green Puffer									
Sphoeroides testudineus	Checkered Puffer									
Sphyraena barracuda	Great Barracuda		x	x	x	x				
Stegastes adustus	Dusky Damselfish	x	x	x	x		x	x	x	
Stegastes leucostictus	Beaugregory		x	x	x			x	x	x
Stegastes partitus	Bicolor Damselfish	x	x	x	x	x	x	x		x
Stegastes planifons	Yellow-eye Damselfish	x	x	x	x		x	x		
Stegastes variabilis	Cocoa Damselfish									
Stephalnolepis setifier	Pygmy Filefish									
Strongylura timucu	Houndfish									
Synodus intermedius	Sand Diver		x							
Thalasoma bifaciatum	Bluehead wrasse	x	x	x	x	x	x	x	x	
Urolophus jamaicensis	Yellowspotted Stingray					x	x	x		
Xanthichthyis ringens	Sargassum Triggerfish									
	TOTALS	**30**	**93**	**106**	**68**	**52**	**74**	**55**	**31**	**46**

Appendix 5. Fish species richness ANOVA testing time series at reefs surveyed

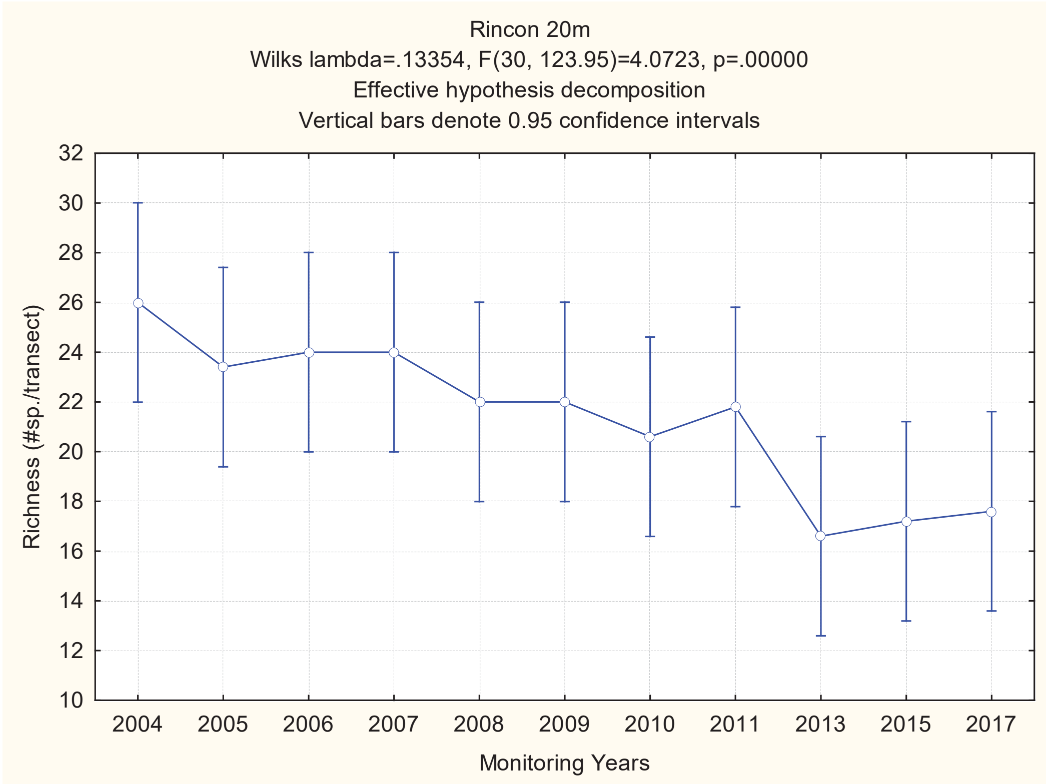
1. Tres Palmas 3m - Rincon



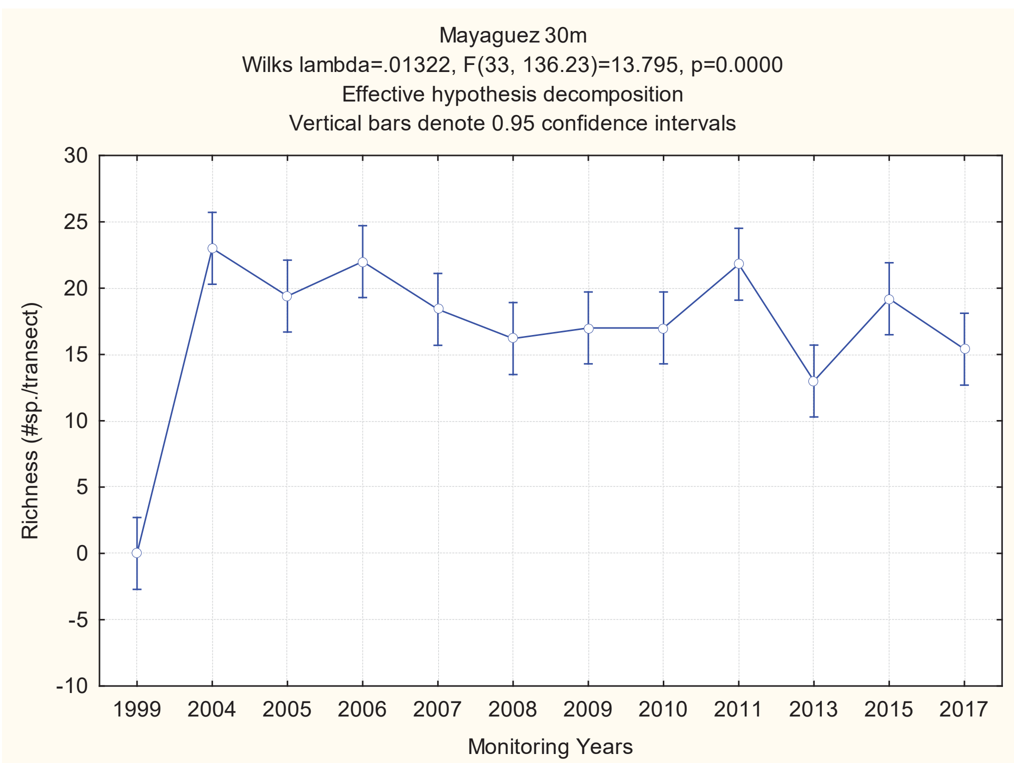
2. Tres Palmas 10m - Rincon



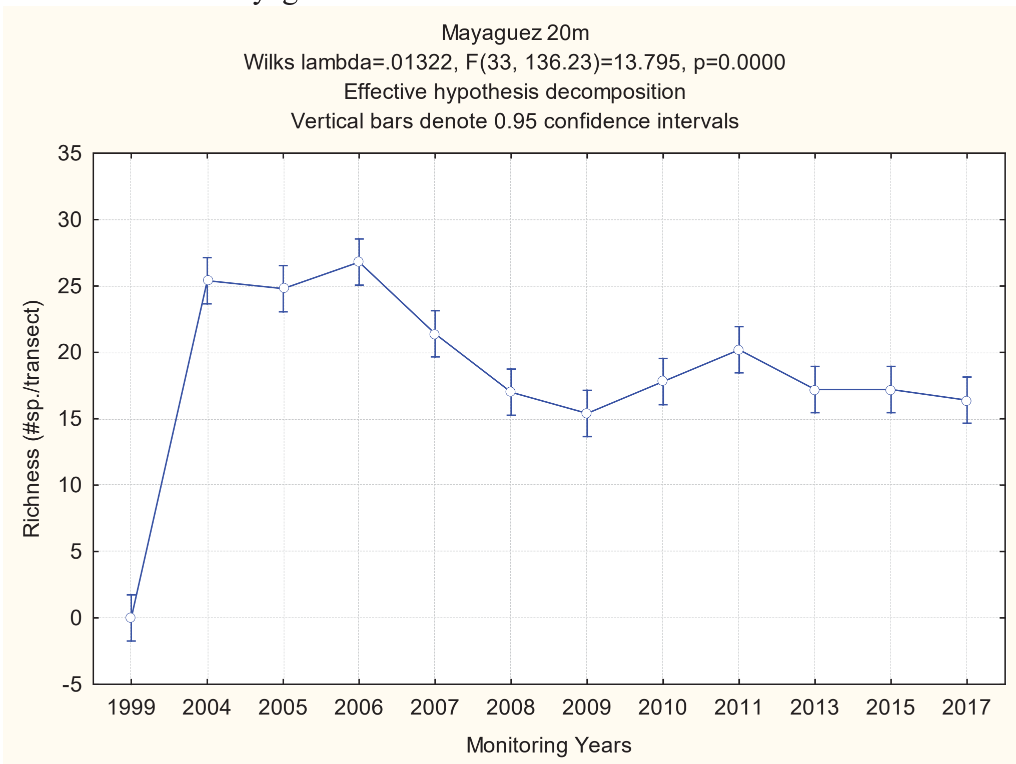
3. Tres Palmas 20m – Rincon



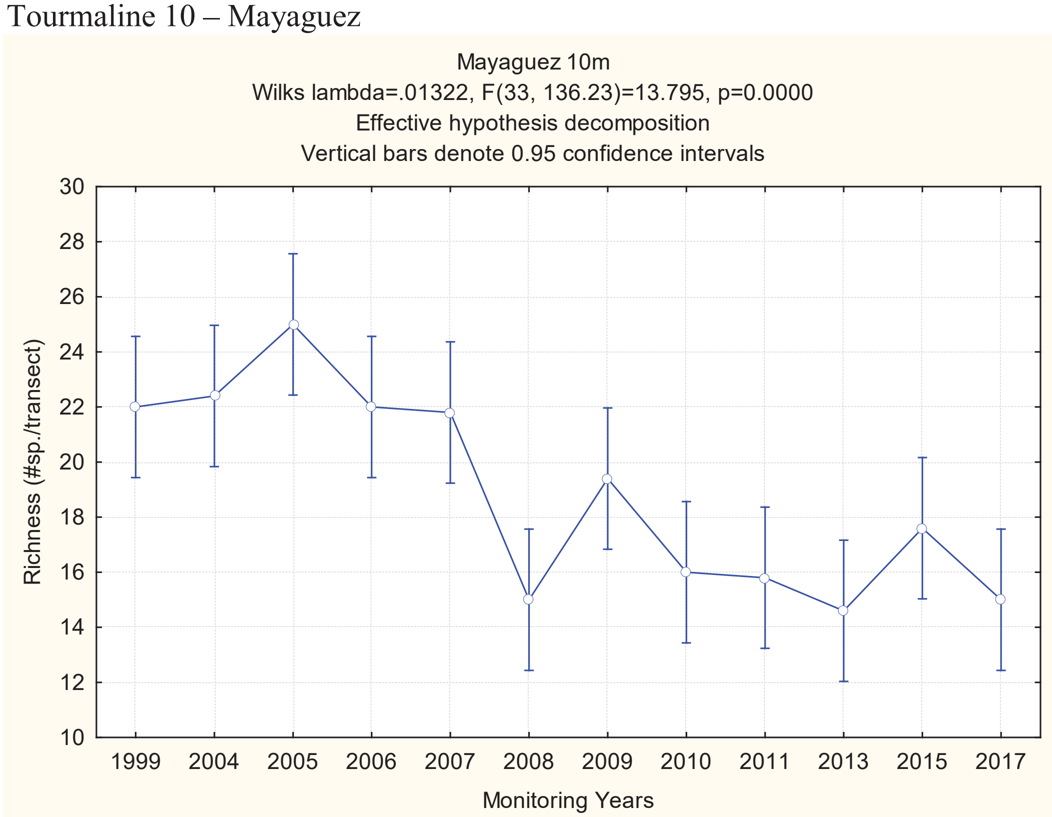
4. Tourmaline 30m Mayaguez



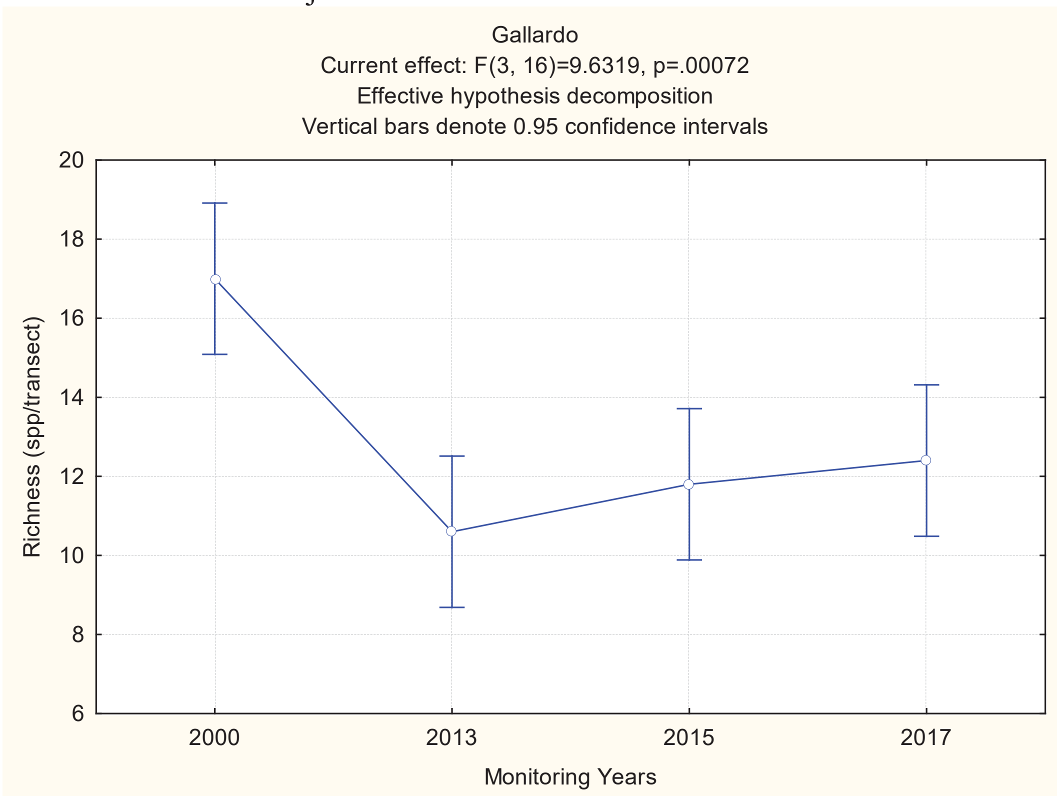
5. Tourmaline 20 – Mayaguez



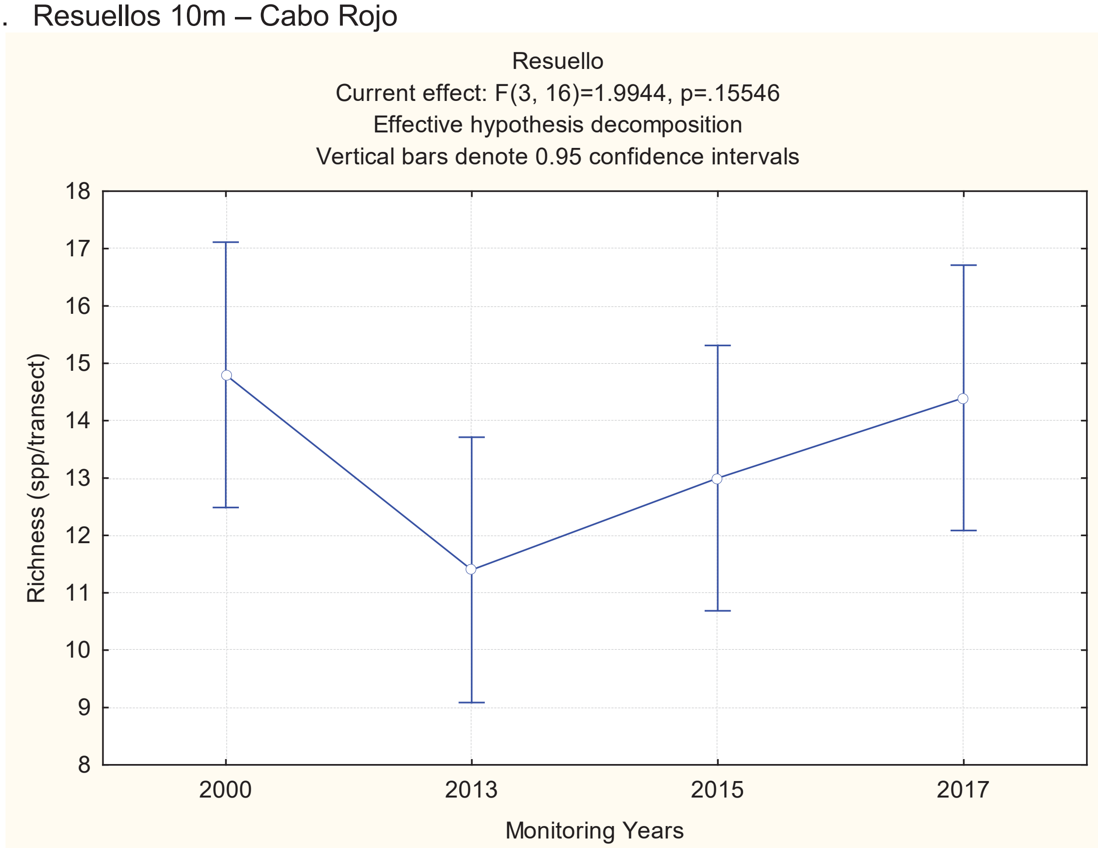
6. Tourmaline 10 – Mayaguez



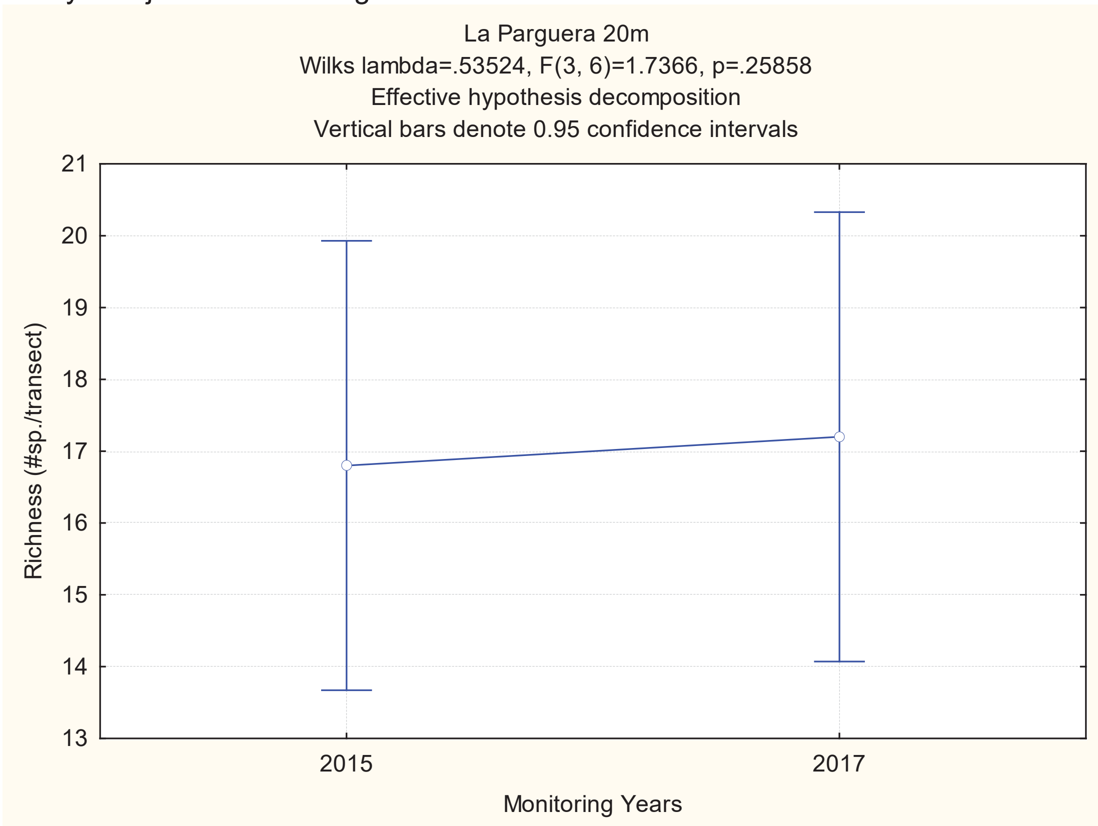
7. Gallardo 5m – Cabo Rojo



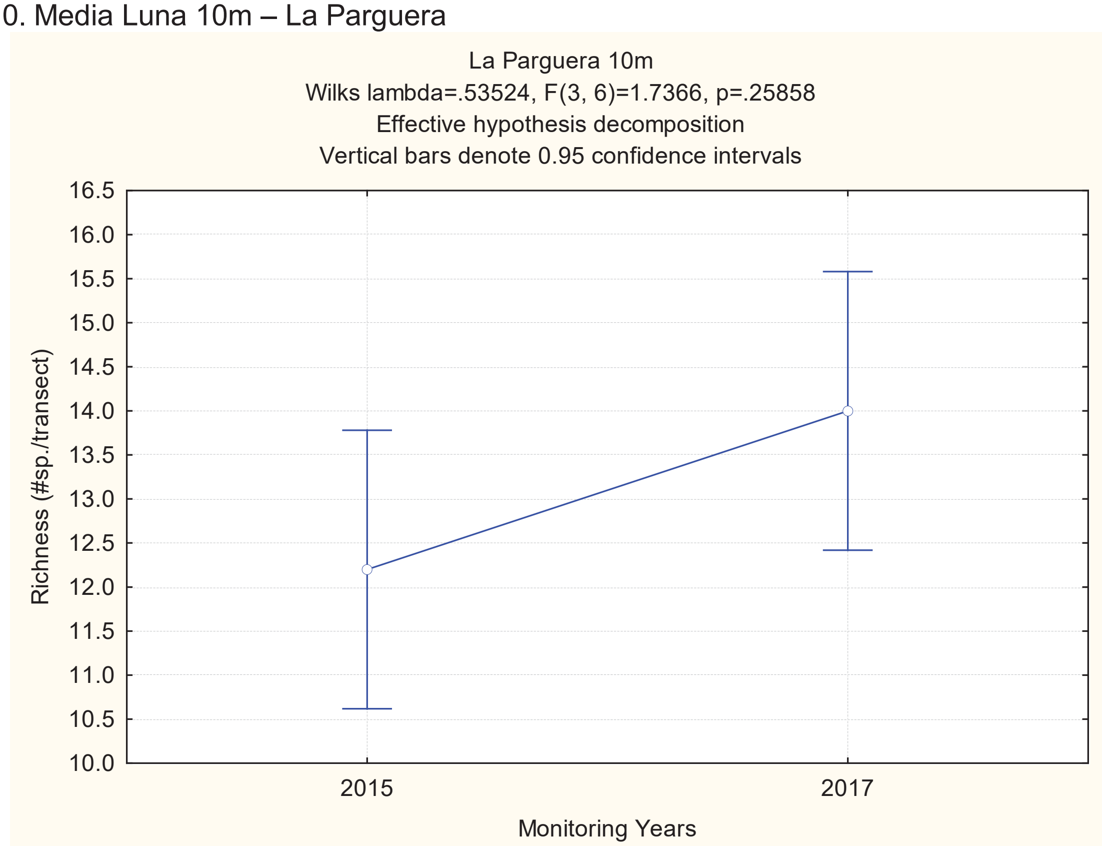
8. Resuellos 10m – Cabo Rojo



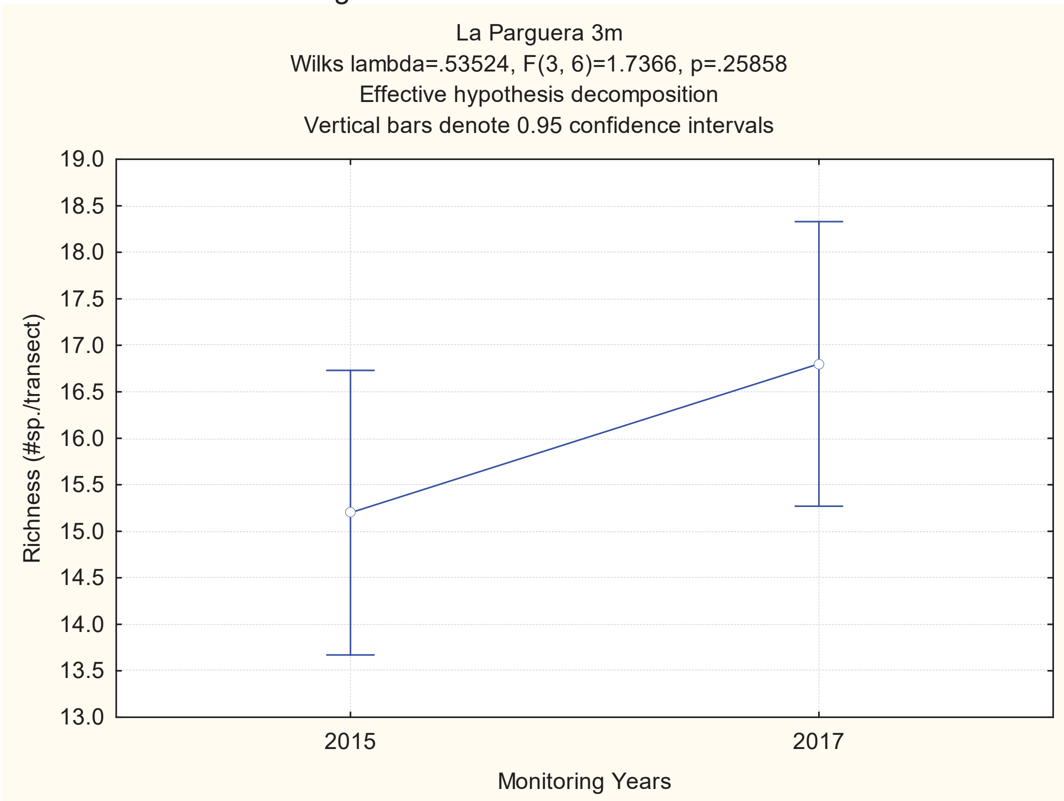
9. Boya Vieja 20m – La Parguera



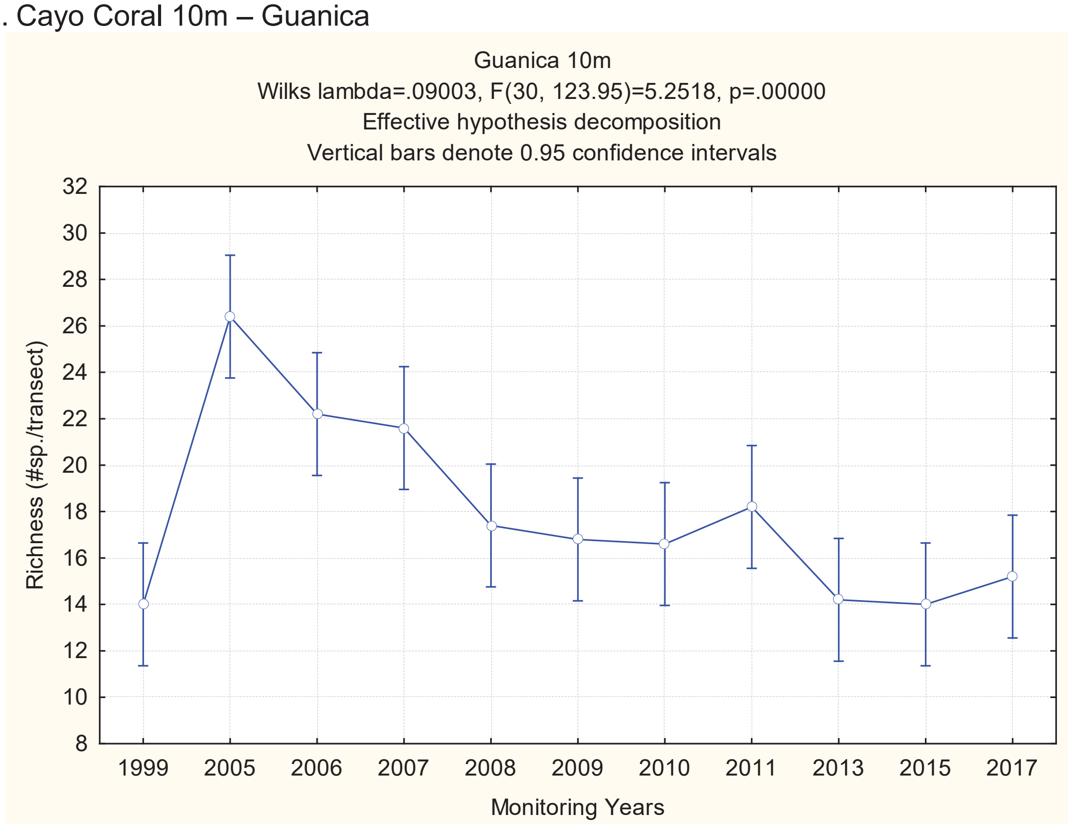
10. Media Luna 10m – La Parguera



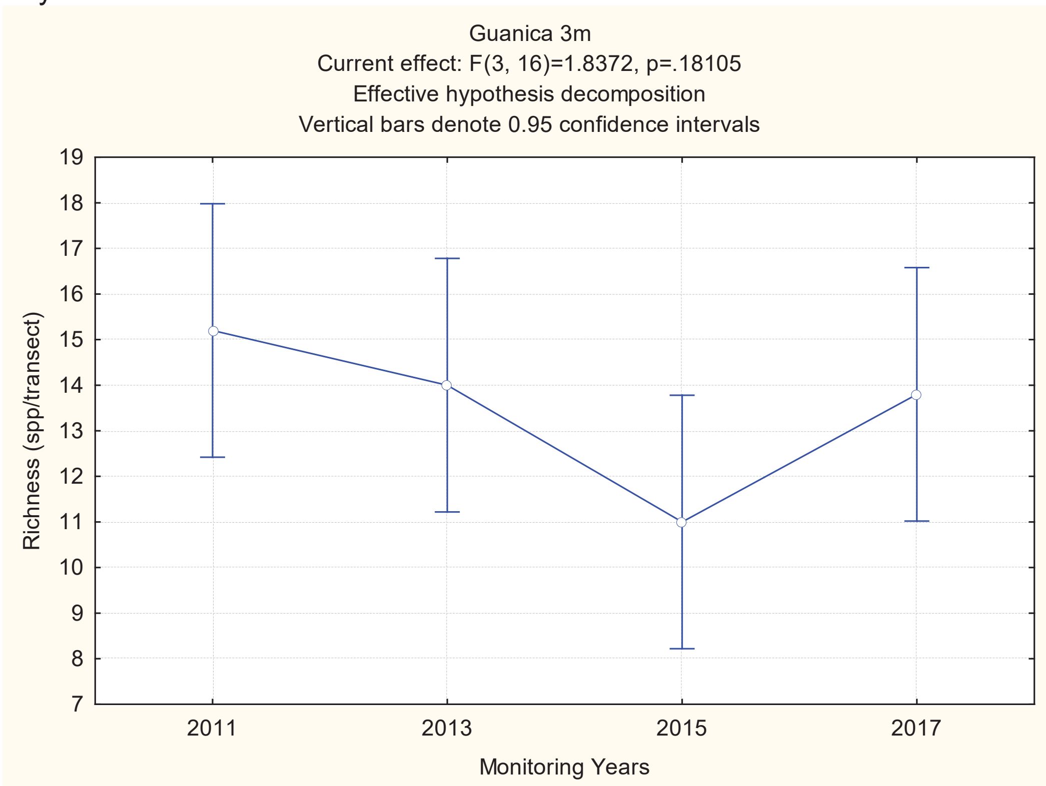
11. Media Luna 3m – La Parguera



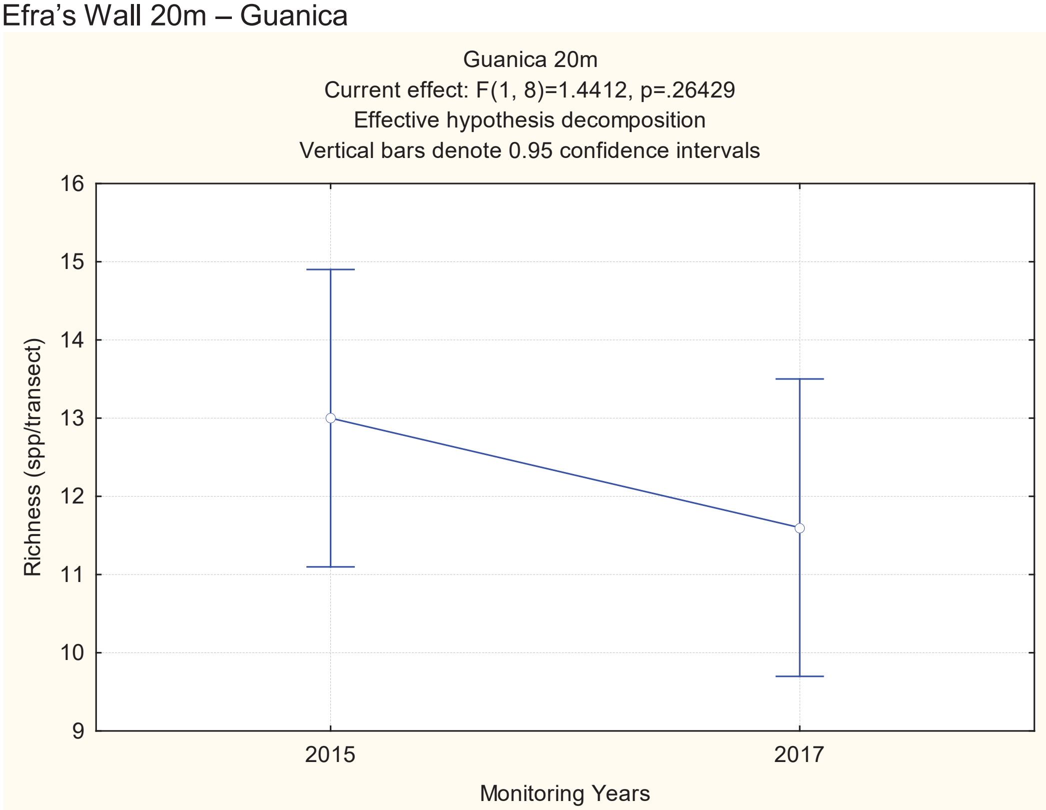
12. Cayo Coral 10m – Guanica



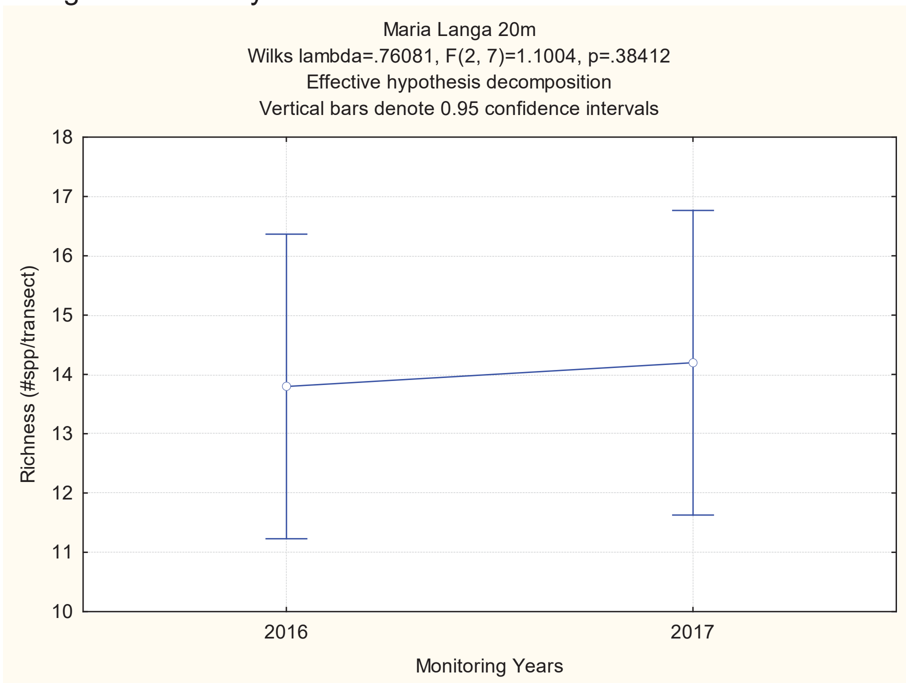
13. Cayo Aurora 3m – Guanica



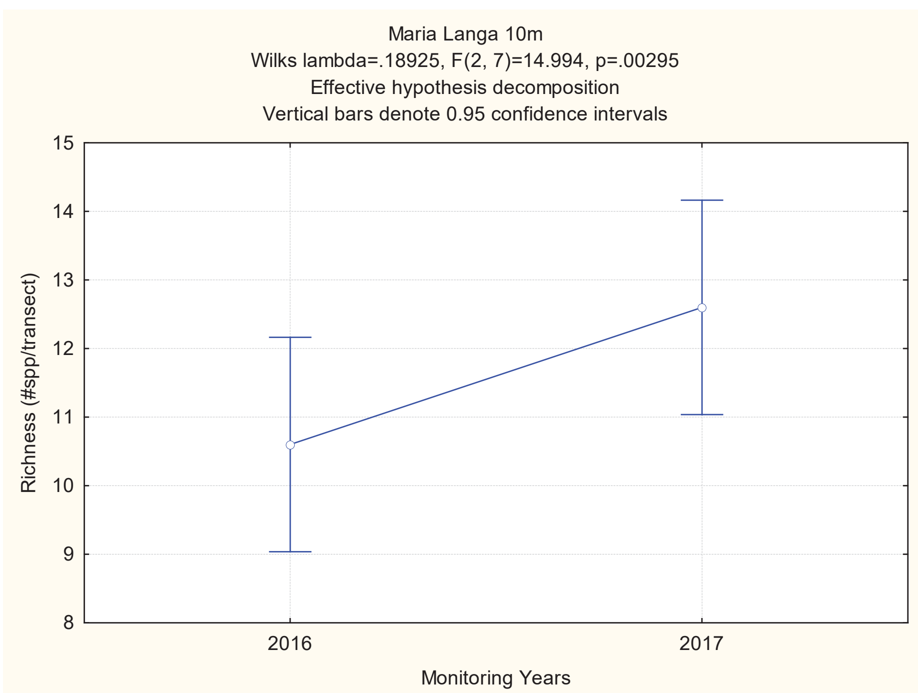
14. Efra's Wall 20m – Guanica



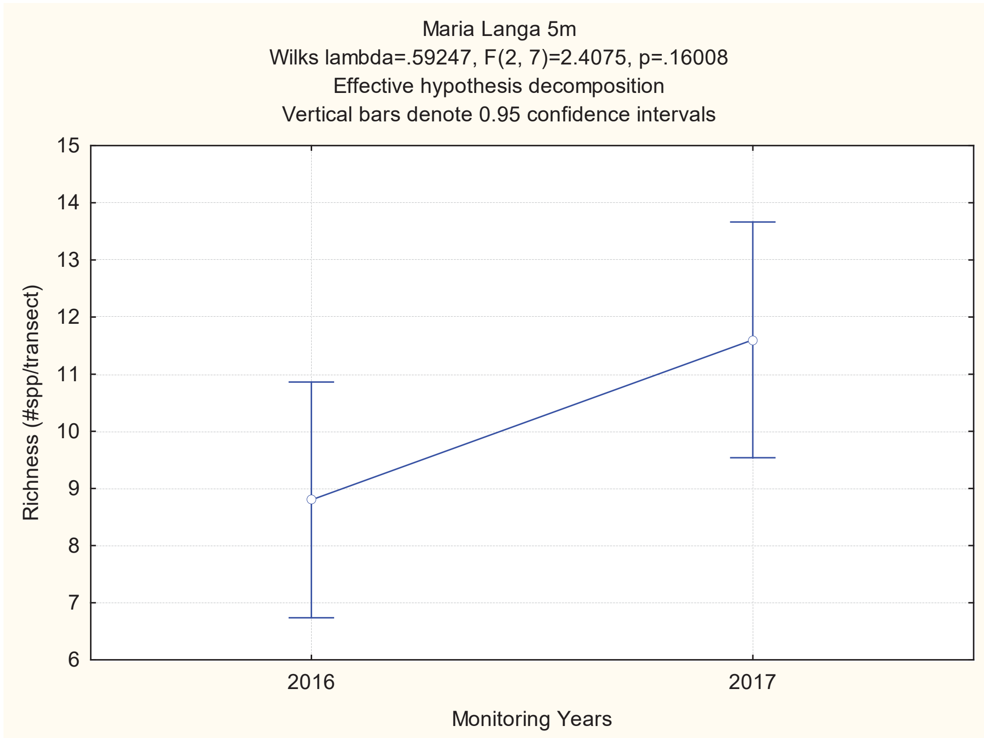
15. Maria Langa 20m – Guayanilla



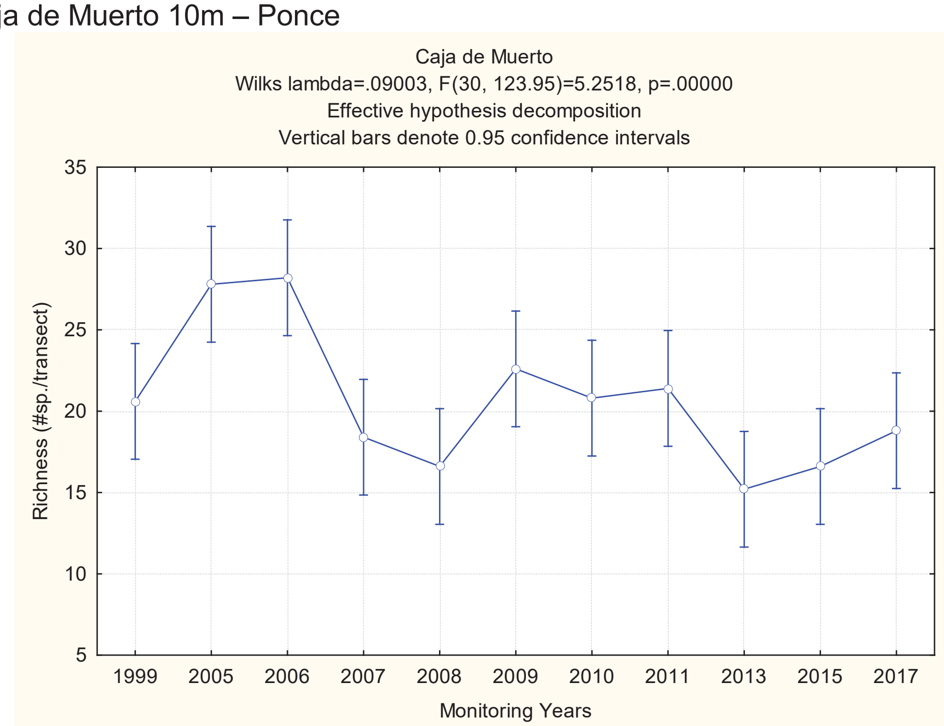
16. Maria Langa 10m – Guayanilla



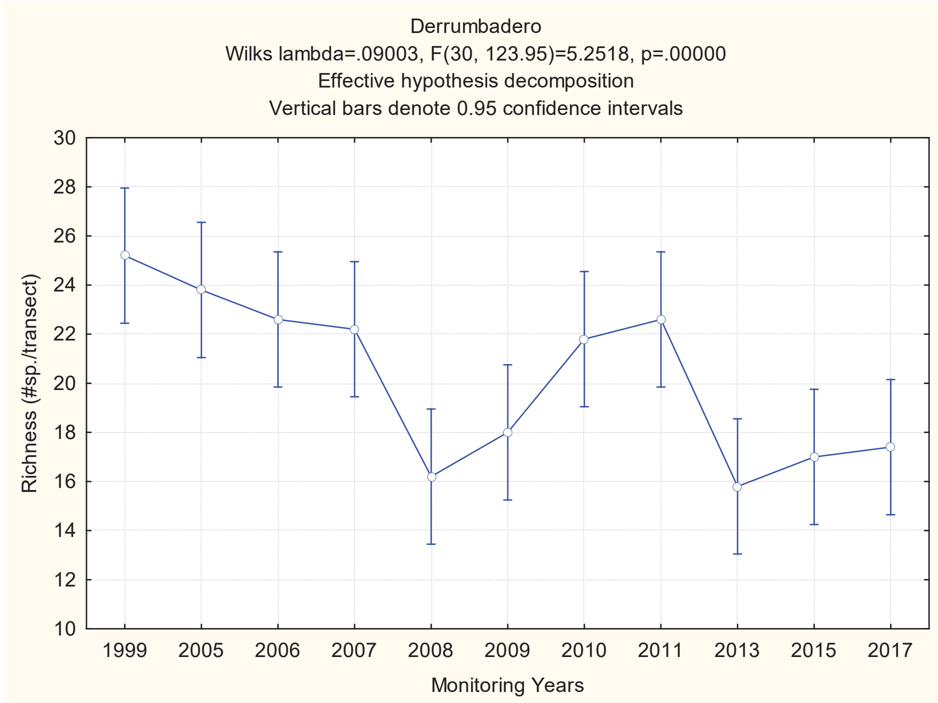
17. Maria Langa 3 – Guayanilla



18. Caja de Muerto 10m – Ponce

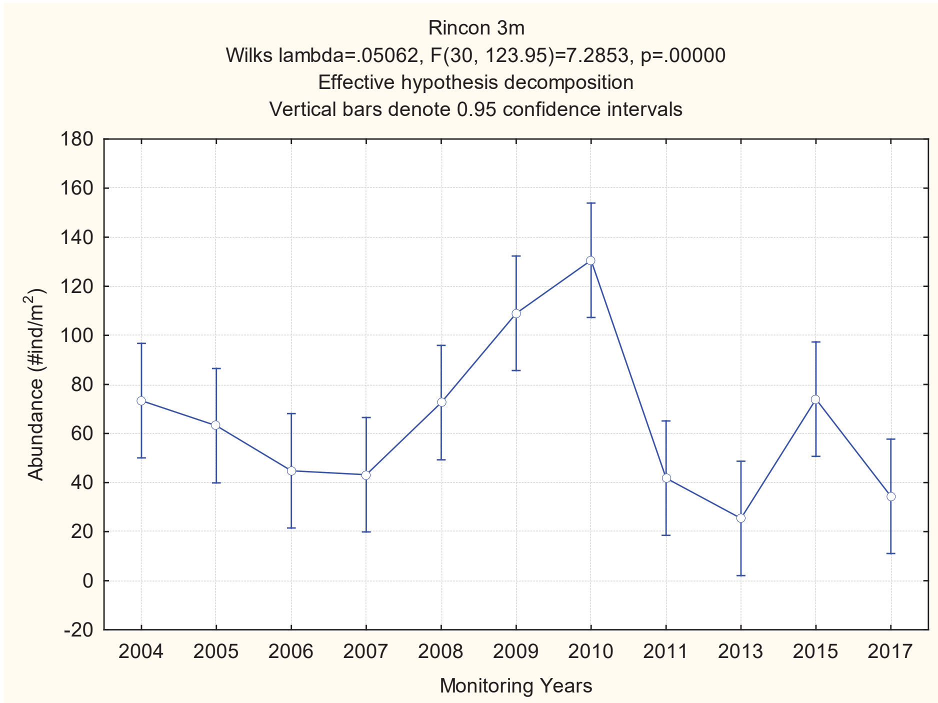


19. Derrumbadero 20m – Ponce

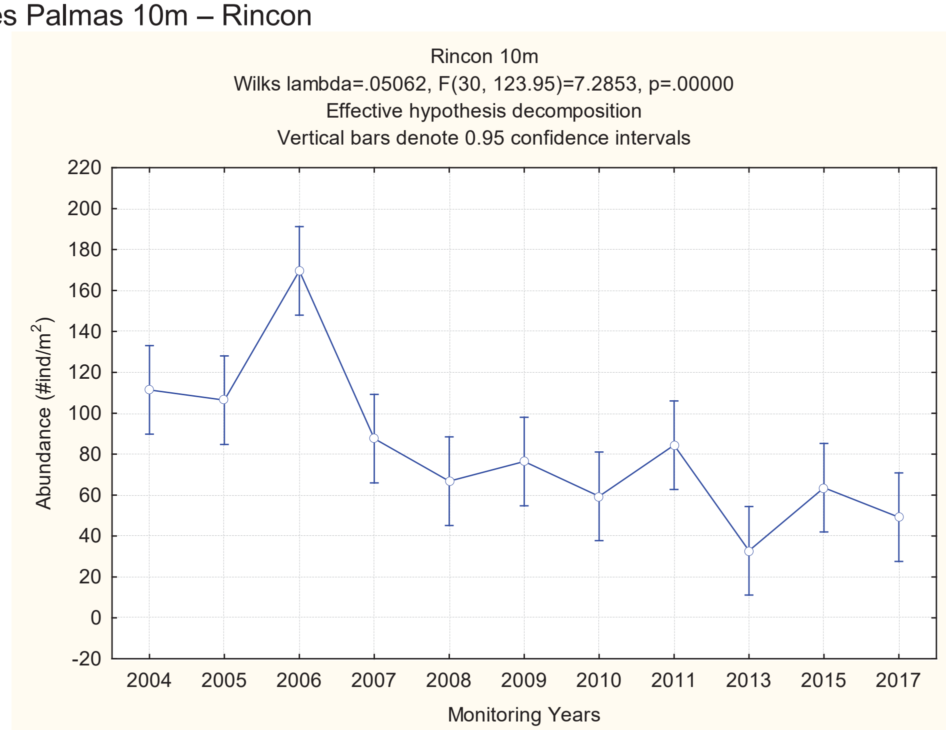


Appendix 6. Fish abundance ANOVA testing time series at reefs surveyed

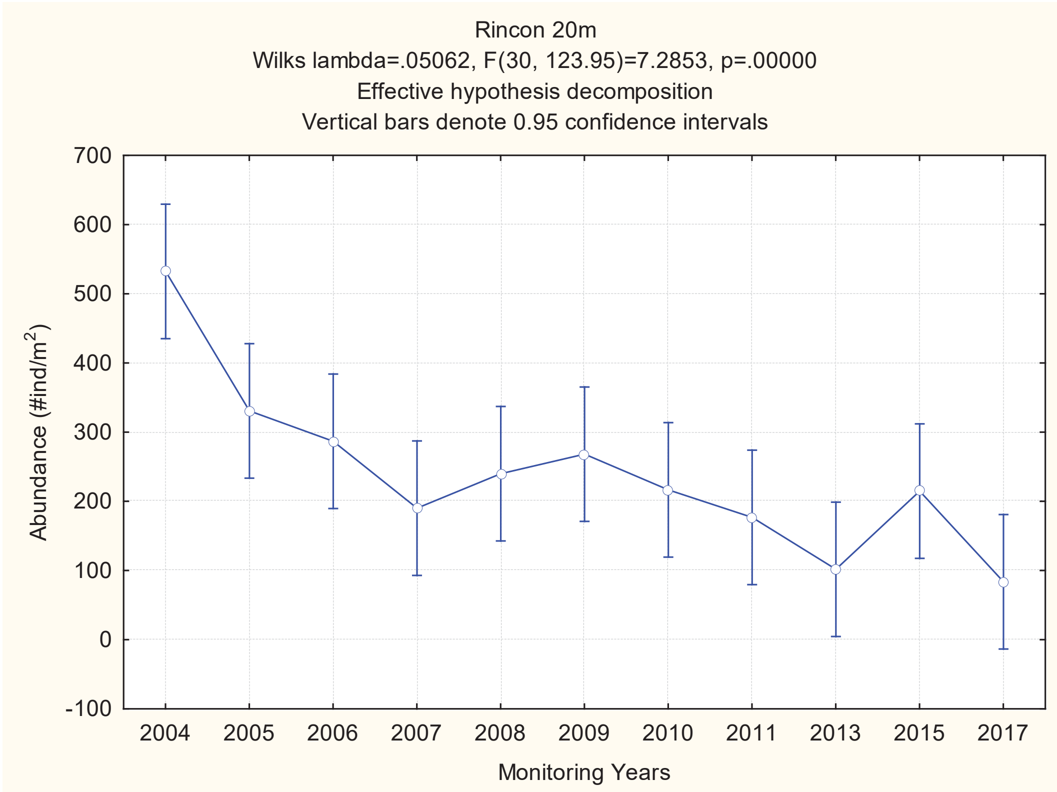
1. Rincon 3m



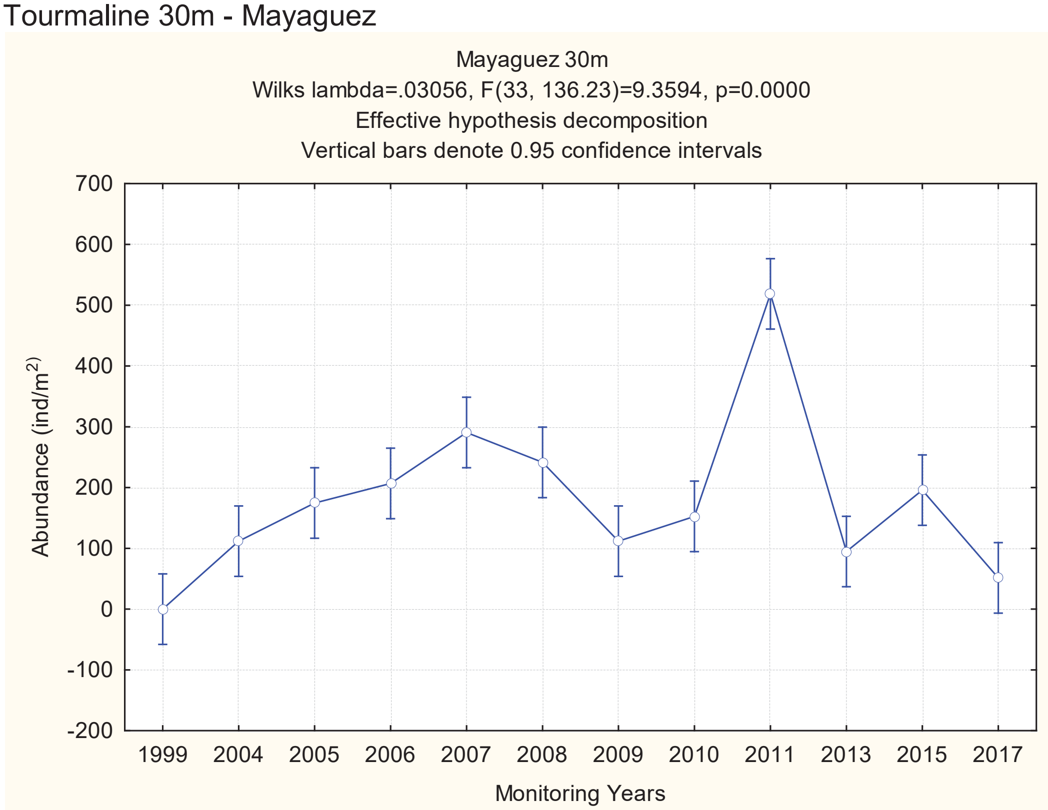
2. Tres Palmas 10m – Rincon



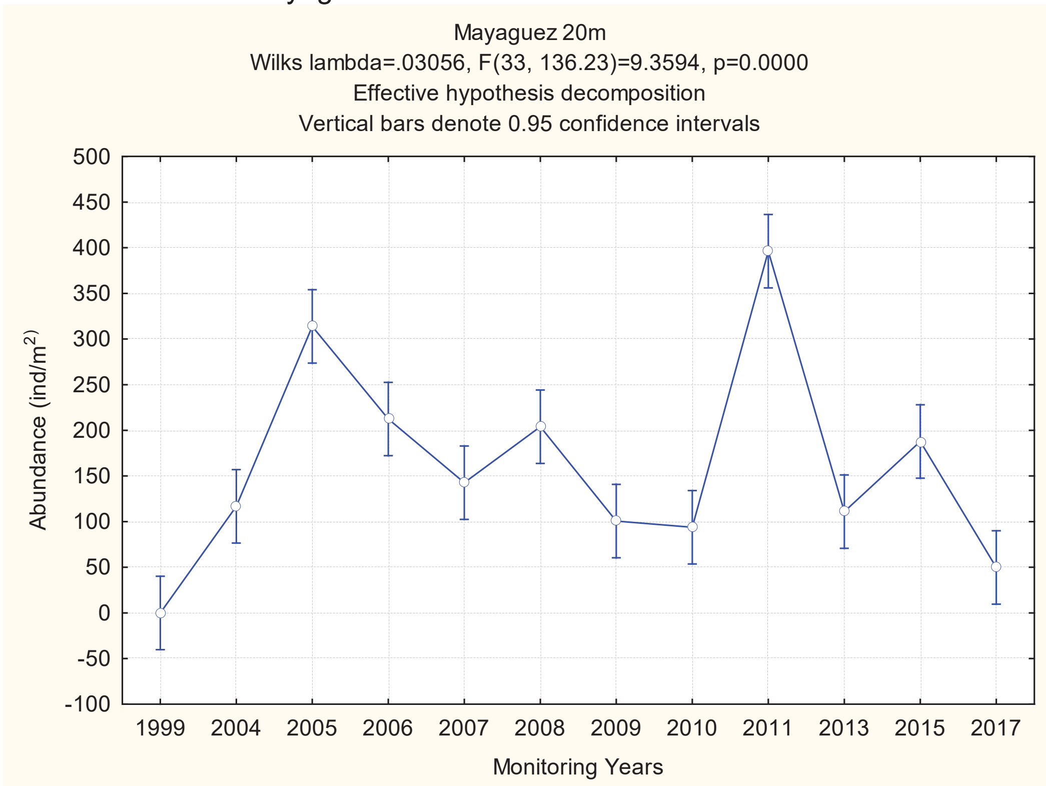
3. Tres Palmas 20m – Rincon



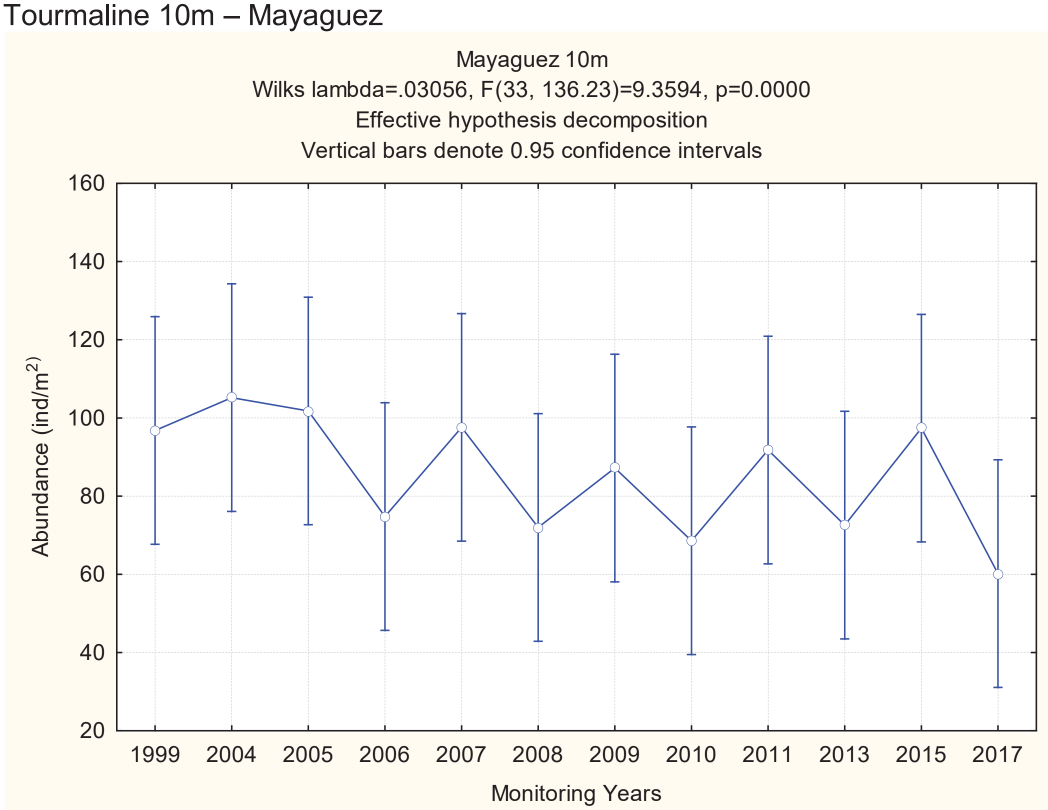
4. Tourmaline 30m - Mayaguez



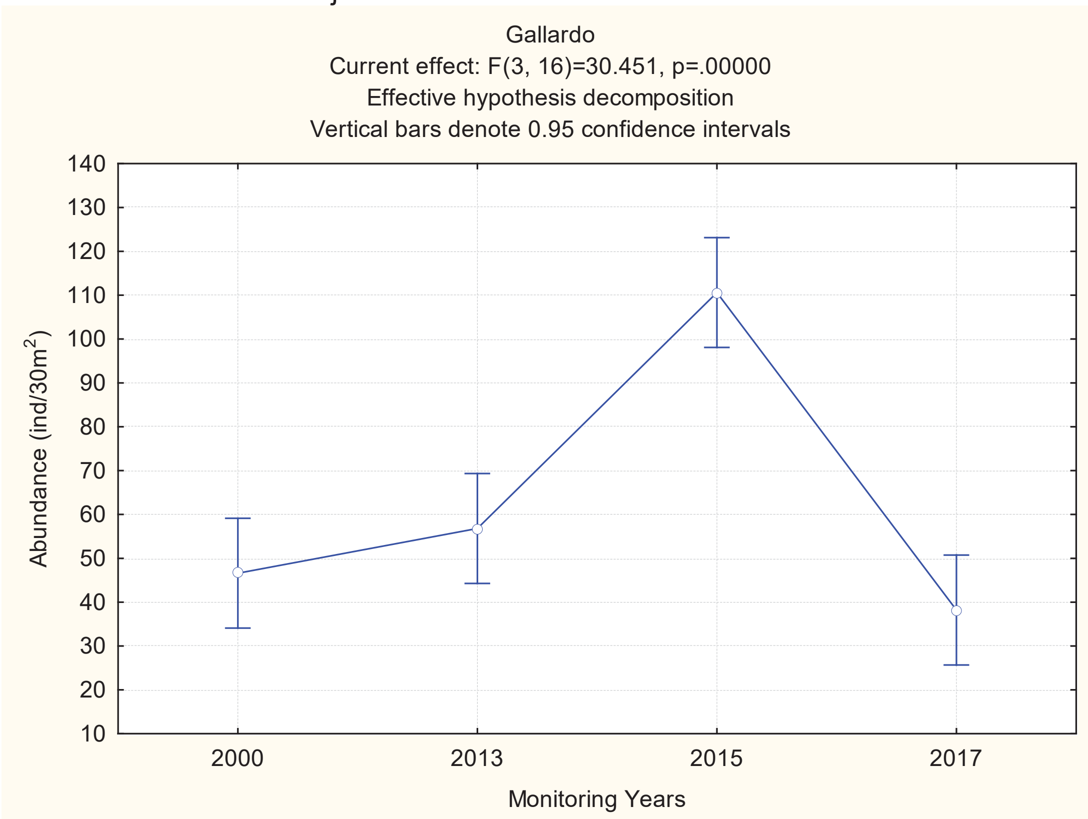
5. Tourmaline 20m – Mayaguez



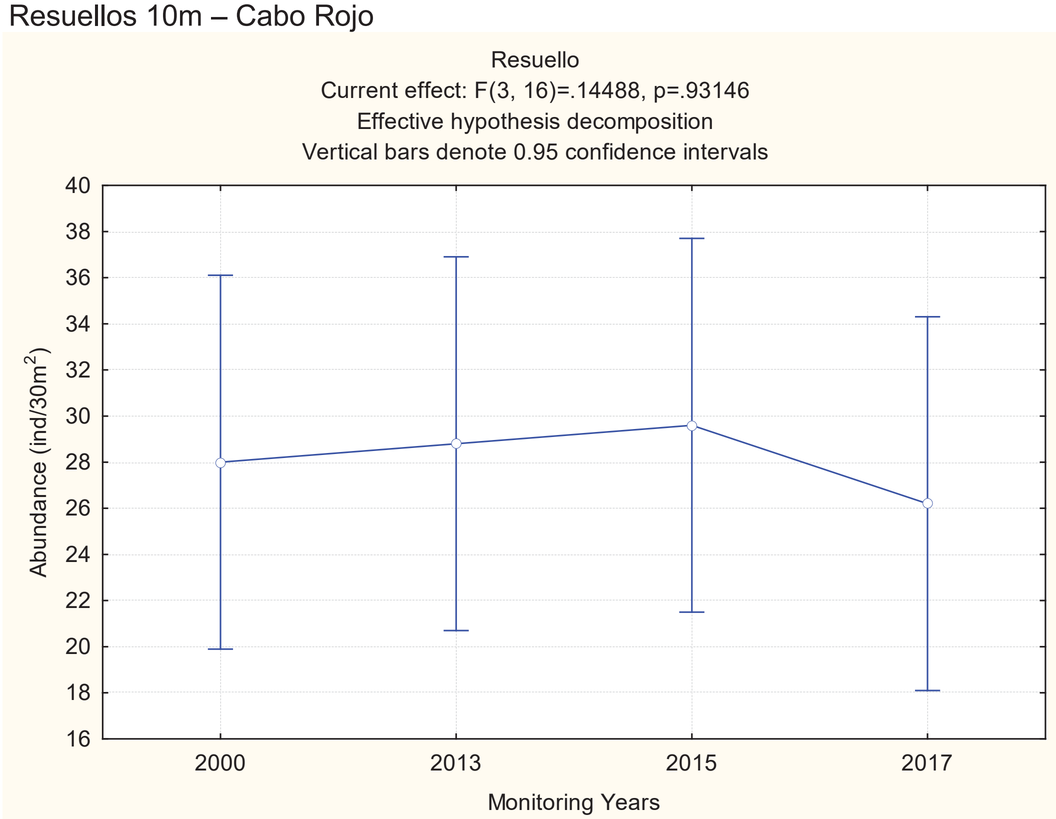
6. Tourmaline 10m – Mayaguez



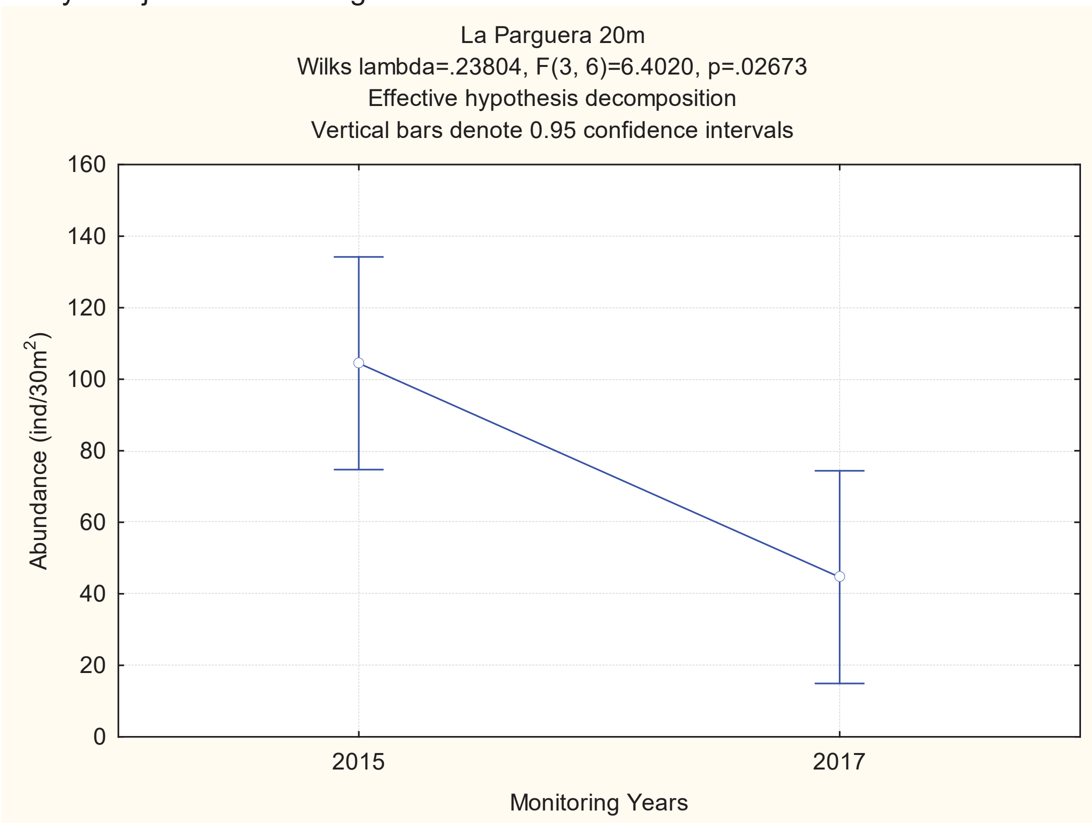
7. Gallardo 5m – Cabo Rojo



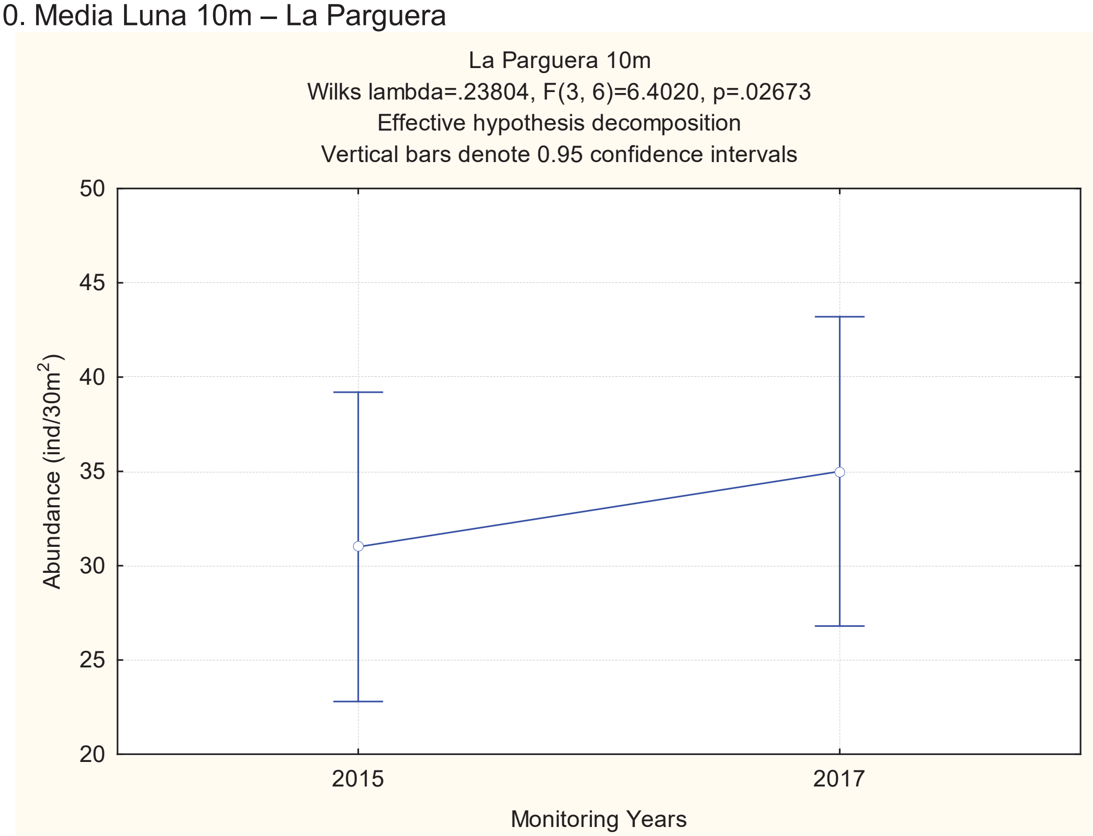
8. Resuellos 10m – Cabo Rojo



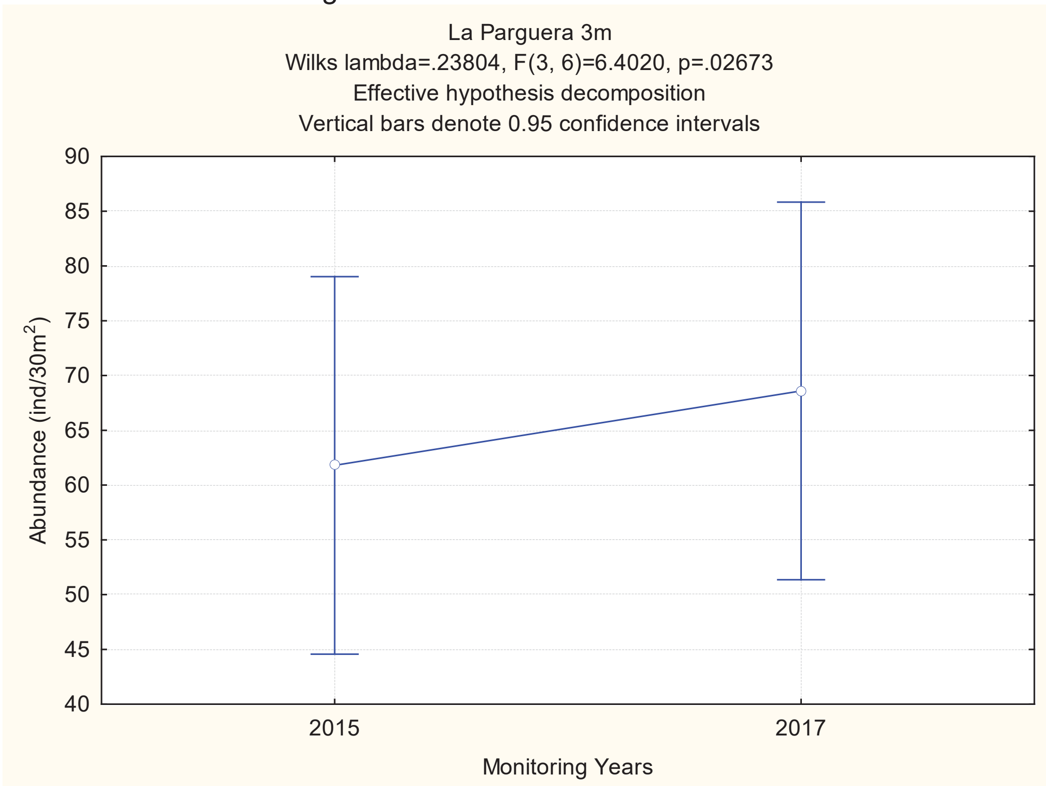
9. Boya Vieja 20m – La Parguera



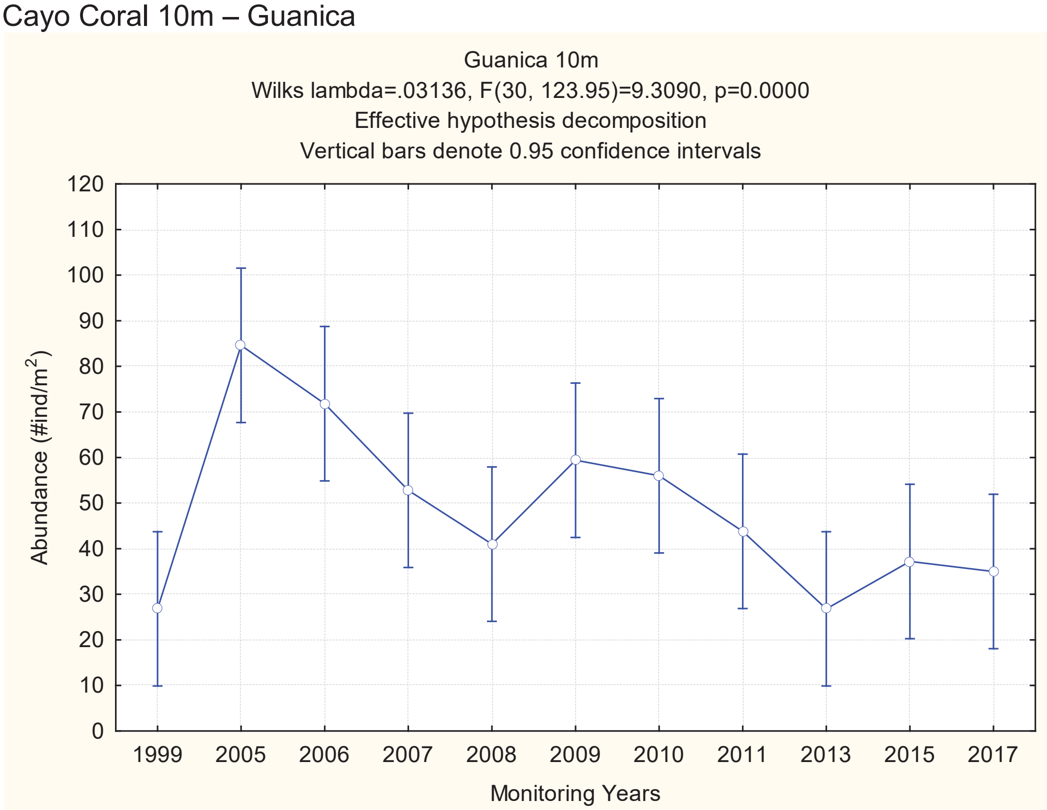
10. Media Luna 10m – La Parguera



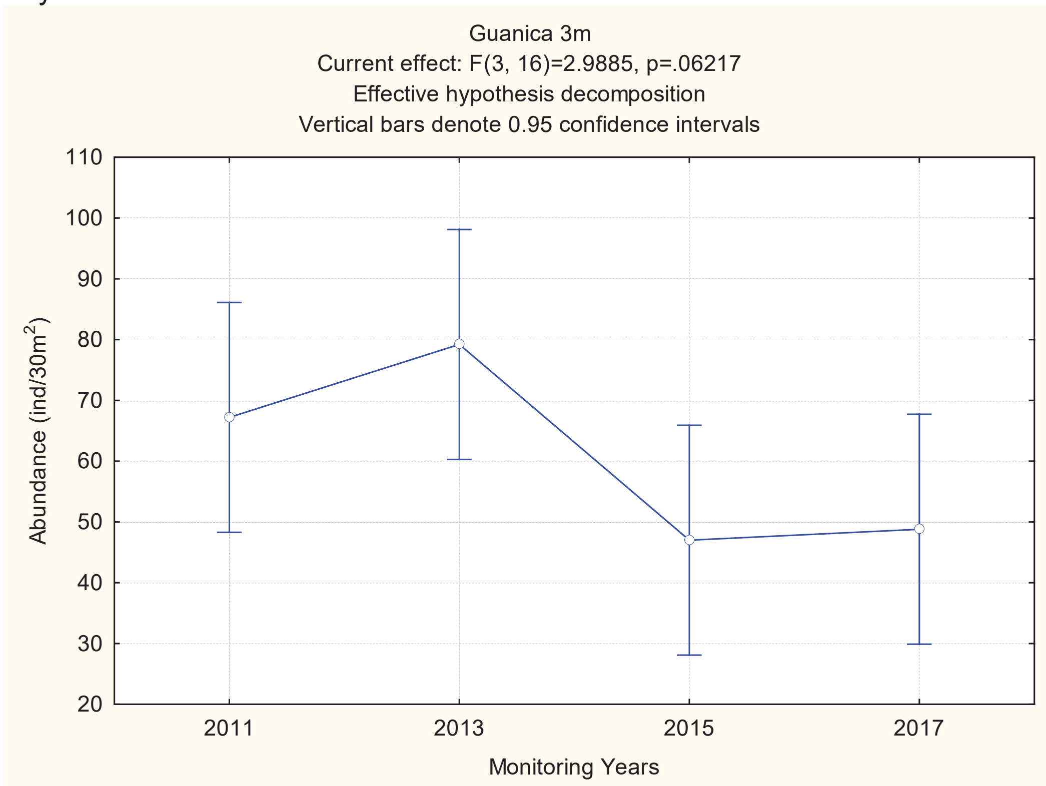
11. Media Luna 3m – La Parguera



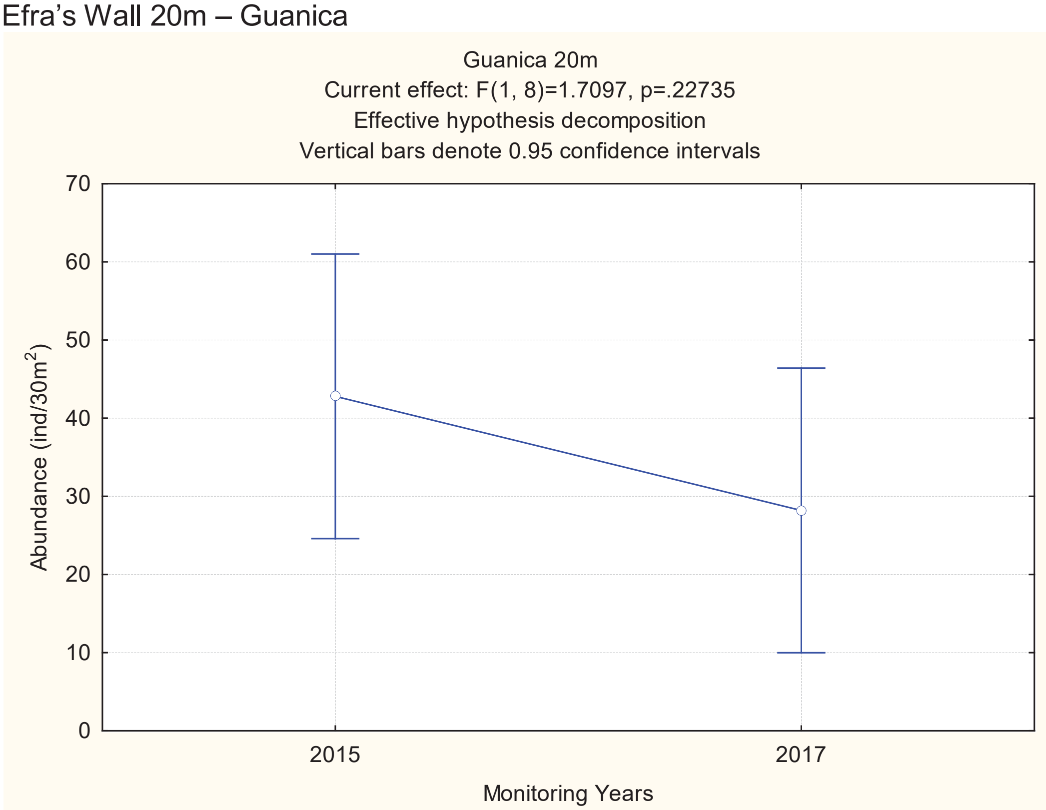
12. Cayo Coral 10m – Guanica



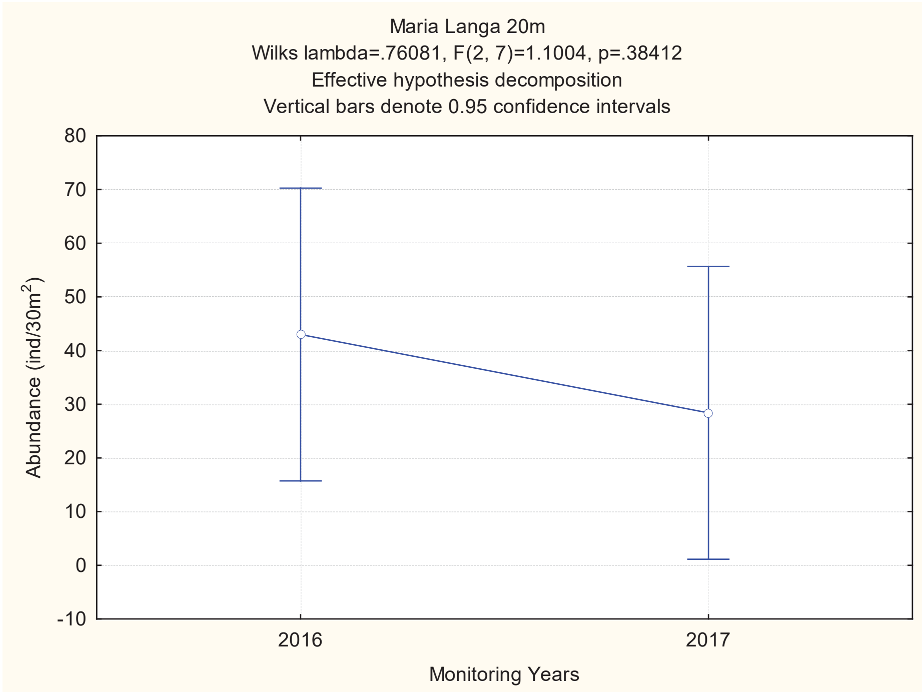
13. Cayo Aurora 3m – Guanica



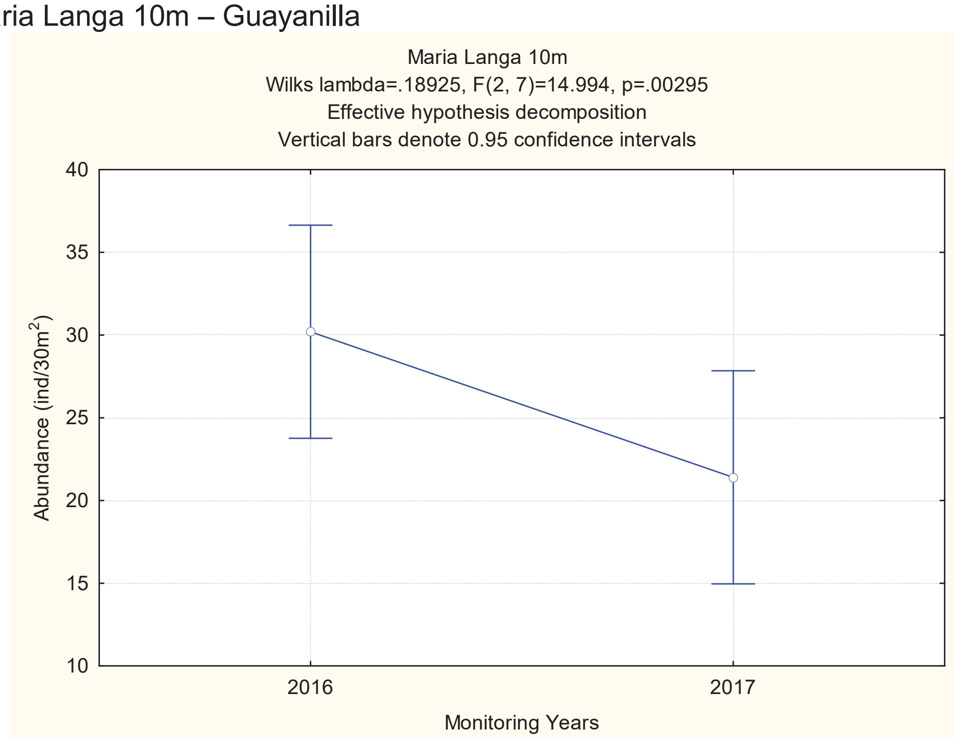
14. Efra's Wall 20m – Guanica



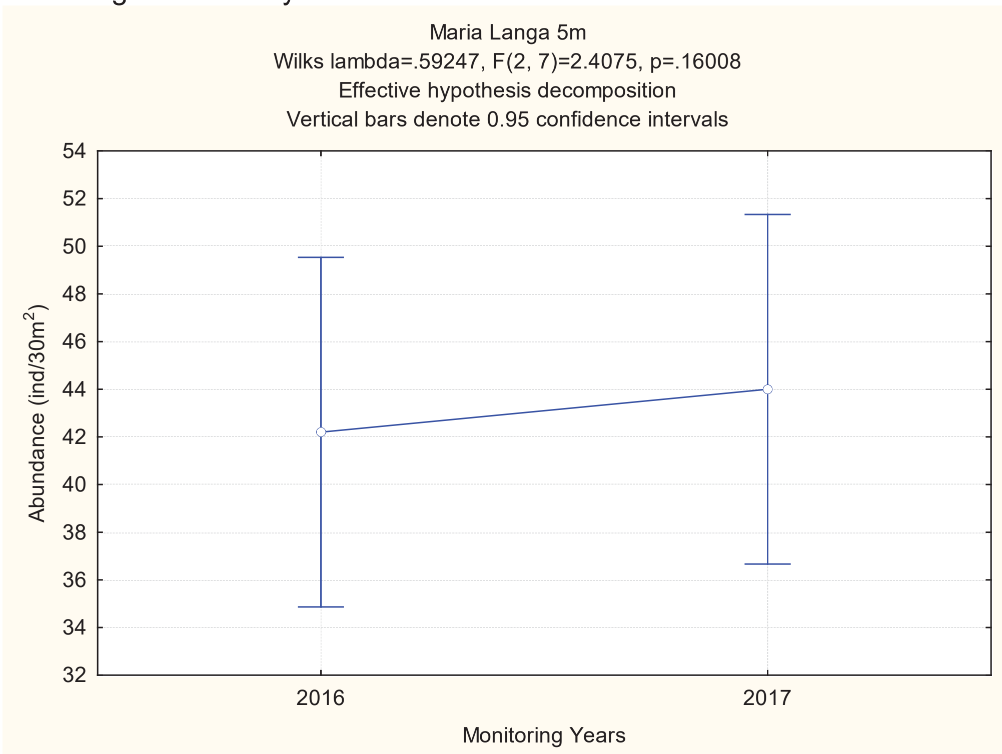
15. Maria Langa 20m – Guayanilla



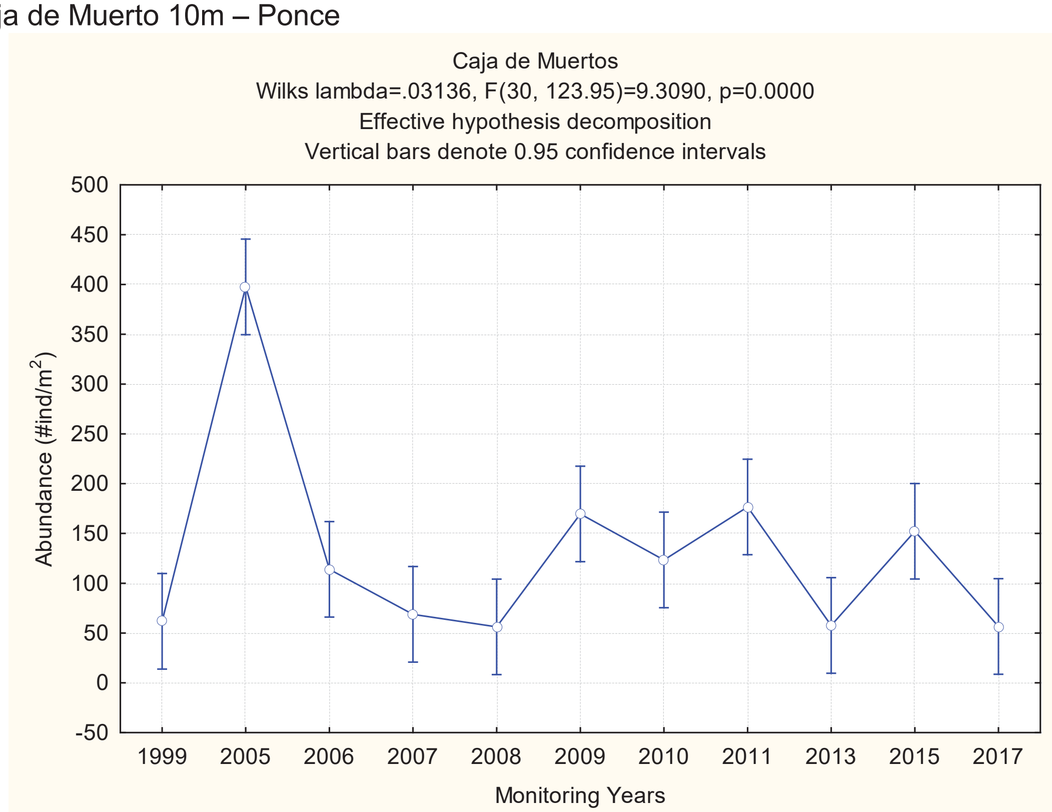
16. Maria Langa 10m – Guayanilla



17. Maria Langa 3m – Guayanilla



18. Caja de Muerto 10m – Ponce



19. Derrumbadero 20m – Ponce