FINAL REPORT

by

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I Executive Summary

A total of 21 reefs from nine (9) Natural Reserves were included in the 2015 Coral Reef Monitoring Program of Puerto Rico. Quantitative measurements of the percent substrate cover by sessile-benthic categories and visual surveys of fishes and motile megabenthic invertebrates for determinations of species richness, abundance and size-frequency distributions were performed along sets of five replicate permanent transects at each reef. The coral reef monitoring program is based on a stratified by geographic location, depth and distance from shore, non-random, sampling design with replicate permanent transects installed in areas of optimal coral growth.

The sessile-benthic community at the reef systems of Puerto Botes and Puerto Canoas (Isla Desecheo), Playa Mujeres and Carmelitas (Isla de Mona), Boya Esperanza and Canjilones (Vieques), Cayo Coral (Guánica), West Reef (Caja de Muerto – Ponce) and Derrumbadero (Ponce) presented statistically significant differences of live coral cover between annual surveys during the monitoring program 2000 - 2015. 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 variable and continued live coral cover losses were measured for the aforementioned reefs until 2008. 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 coral species. Corresponding increments of reef substrate cover by benthic algae, cyanobacteria, sponges and abiotic categories were measured. Coral reefs in oceanic islands (I. Mona, I. Desecheo), shelf-edge reefs (Derrumbadero) and the shallow reefs of Vieques (Boya Esperanza, Canjilones) were the most affected by the 2005 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 the 2005 regional bleaching event, and thereafter.

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) were detected, particularly on reefs strongly dominated by *O. annularis*, such as Desecheo 15, Desecheo 20, Tourmaline 10, Derrumbadero, Canjilones and Boya Esperanza. Shifts involved alternations of dominant coral species due to increased cover by growth and colonization of dead coral substrates by branching corals (Tourmaline 10, Des 15, 20) and/or differential (statistically significant) reductions of cover by previously dominant corals (Boya Esperanza, Canjilones, Derrumbadero). From baseline assessments at the Guayama reefs, the unusual dominance of corals other than *O. annularis* on a shelf-edge reef (Guayama 20m), stable coral cover over time relative to previous studies (Cayo Caribes) and high cover by *O. annularis* on a shallow coastal reef (Guayama Patch Reef 5m) support the contention that water turbidity and depth acted in protection of corals (particularly *O. annularis)* during the 2005 event, and that shelf-edge and oceanic island corals exposed to high water transparency were the most affected, leading to phase shifts of reef benthic community structure associated with the differential degradation of *O. annularis*.

Between 2009 and the present 2015 monitoring survey a moderate, yet consistent recuperation of live coral cover, in most cases driven by growth of *Orbicella annularis* has been measured in many reefs of the monitoring program (e.g. Cayo Coral, Desecheo 30, 20 and 15 m, Tourmaline 30 and 20m, Derrumbadero and Caja de Muerto). At Cayo Coral, live coral cover has increased 42.8 % from its lowest cover in 2008, reaching its pre-bleaching event level of 2005-06. Likewise, live coral cover has increased 40.9 % and 20 % at Tourmaline 30 and 20 m, respectively. At Derrumbadero, the 40 % increment of live coral cover from its lowest level in 2008 is now statistically significant. Live coral recuperation of reef substrate cover was initially noted on costal reefs, particularly Cayo Coral and Tourmaline 10 m, but now this trend of coral recuperation

includes shelf-edge and oceanic reefs as well. For the latter reefs, the highest increments of live coral cover have been measured during the last two surveys (2013 and 2015).

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 coral mortality can be expected. This condition has been noted since 2008 without leading to measurable effects on it’s mean live coral substrate cover. The Elkhorn Coral reef system at Cayo Aurora appeared healthy and with colonies of impressive size. Likewise, The Elkhorn Coral Reef system at Bajo Gallardo, although severely affected by mechanical damage and corallivorous gastropod infection appears to be thriving and still maintains very high live coral cover within its biotope zone.

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 coastal 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 influenced by the recruitment dynamics of numerically dominant populations with highly aggregated distributions and schooling behaviors, such as Masked Goby, *Coryphopterus personatus* and Blue Chromis, *Chromis cyanea*. Marked differences of fish community structure were evident between oceanic/shelf-edge reefs dominated by pelagic and demersal zooplanktivores assemblages (*Chromis spp*., Creole Wrasse, Masked Goby, Bicolor Damselfish) and coastal reefs, dominated by herbivorous assemblages (Parrotfishes, Doctorfishes, farmer Damselfishes). A statistically significant reduction of fish species richness has emerged from the monitoring data for several reef systems of the monitoring program. While elucidation of taxonomic structural patterns and drivers will require further observations and analyses, the substantial loss of live coral and the introduction and establishment of the Lionfish (*Pterois sp*.) stand as potential factors influencing of such trend. Nevertheless, the most recent assessments of Lionfish (*Pterois sp*.) size frequency distributions noted populations to be strongly skewed toward the larger adult sizes with very low density of small individuals, suggesting recruitment limitations or failure, particularly at the neritic reefs within this coral reef monitoring program.

Although in low abundance, large demersal (top predator) fishes have been observed during monitoring surveys in several reefs 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*). The status of Red Hind (*Epinephelus guttatus*) populations that led to the seasonal closure of several reefs within this reef monitoring program remain without any noticeable recuperation, with very low densities and negligible recruitment and/or population replenishment indicators.

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II Introduction

This is the final report corresponding to the 2015 annual survey of the Puerto Rico Coral Reef Monitoring Program, sponsored by NOAA and administered by the PR Department of Natural and Environmental Resources (PRDNER). The monitoring program includes quantitative and qualitative measurements of reef substrate cover (%) by sessile-benthic categories and characterizations of taxonomic composition, abundance and size frequency distributions of commercially important fishes and motile megabenthic invertebrates from a total of 21 reef stations within nine (9) Natural Reserve sites in Puerto Rico (Isla Desecheo, Rincon, Mayaguez, Guánica, Isla Caja de Muertos, Cabo Rojo, La Parguera, Ponce, Isla Verde). Initial baseline characterization surveys for reef sites in Natural Reserves of Isla Desecheo, Rincon, Mayaguez, Guánica, Isla Caja de Muertos, Cabo Rojo and Ponce were performed during the period between 1999 and 2004 (García-Sais et al., 2001 a, b, c; García-Sais et al., 2005). This report includes baseline characterizations of three reef stations within the La Parguera Natural Reserve, one at the Guanica Shelf-edge, Bajo Gallardo in Cabo Rojo and Isla Verde and the regular annual monitoring surveys for all other aforementioned sites. Summarized time series data for all reef sites are here presented and analyzed. Detailed monitoring data is included only for the most recent 2015 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 and 2014). Such information contributes to an existing network of U.S. coral reef monitoring sites sponsored by NOAA and administered by DNER.

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

as shelf edge reefs in Mayaguez and Ponce, and reefs all around Vieques (Garcia-Sais et al. 2004) maintained stable live coral cover.

A drastic decline of more than 50 % of live coral cover was measured from reefs in Mona and Desecheo islands during the 2006 monitoring survey after a severe coral bleaching event affected reef systems in the northern Caribbean during late 2005 (Miller et al. 2006; Garcia-Sais et al 2008). Sibling species of boulder star coral, *Montastraea annularis* and *M. faveolata* (genus now changed to *Orbicella spp*) were the most vulnerable to the bleaching event. Thus, reef systems strongly dominated in terms of substrate cover by these species, such as those of Mona and Desecheo, as well as the shelf-edge reefs of Derrumbadero in Ponce and Tourmaline Reef in Mayaguez were the most severely affected. Protection from bleaching with increasing depth from 20 to 30 m was observed at both Tourmaline Reef in Mayaguez and Puerto Canoas Reef in Desecheo. The Tres Palmas Reef system in Rincon, dominated in terms of substrate cover by Elkhorn coral, *Acropora palmata* at depths of 1-5 m and by *M. cavernosa* at 10 m did not show any statistically significant decline of live coral cover. After up to three consecutive years of measuring what appeared to be lingering effects of the 2005 coral bleaching event, subtle to moderate increments of live coral cover were noted in the 2008-09, 2009 -10, 2010-11 and 2012 -13 monitoring surveys (Garcia et al. 2008, 2009, 2010, 2012, 2014). Differences between years were not statistically significant, but the trend represented a reversal from the continued decline of live coral cover since the 2005 monitoring survey. An exception to this trend was observed at the fringing *Acropora palmata* reef of Tres Palmas in Rincon, which presented a declining trend of live coral cover associated with a widespread infection of what appears to be “white pox”, a disease also known as “patchy necrosis” (Garcia et al. 2008). Coral recuperation was highest at coastal reefs, such as Cayo Coral and Tourmaline, whereas oceanic and shelf-edge reefs evidenced minor or negligible live coral increments.

Phase shifts in the taxonomic composition of reef substrate cover by live corals have been detected at Tourmaline Reef 10m (Mayaguez) and at Puerto Botes Reef 20m (Isla Desecheo). In both cases, mortality of Boulder Star Coral (*Orbicella annularis*) has allowed branching corals to become the dominant coral taxa in terms of substrate cover. In the case of Tourmaline reef, Yellow Pencil Coral (*Madracis auretenra*) grew over dead coral

sections of *O. annularis* and other reef hard ground to the point where total cover by live coral has increased from its original condition before the 2005 bleaching induced mortality.

A total of 189 species of diurnal, non-cryptic fish species have been identified during the coral reef monitoring program at the reefs surveyed. Fish populations have presented in general a trend of fluctuating differences of abundance and species richness within belt-transects (García-Sais et al., 2007, 2008, 2009, 2010, 2012, 2014). Variations between surveys were mostly associated with fluctuations of abundance by numerically dominant populations that exhibit highly aggregated distributions, such as the Masked Goby (*Coryphopterus personatus*), Blue Chromis (*Chromis cyanea*) and Creole Wrasse (*Clepticus parrae*), but also appear to respond to variations in the physical conditions affecting the reef during the time of our survey, such as wave action. This is particularly relevant for shallow reefs, and more critically determinant for *Acropora* reefs, such as the Tres Palmas and Cayo Aurora reef systems.

III Approach and Methodology

A total of 21 reefs located within nine (9) Natural Reserves were included in the PR Coral Reef Monitoring Program 2015 survey. The geographic location coral reef sites is shown in Figures 1 - 2. Table 1 presents the geographic coordinates and depths of reefs monitored. Quantitative baseline characterizations following our standardized stratified depth and distance from shore sampling design with a five permanent transect array non-randomly placed in areas of optimal coral growth per reef was followed in all Natural Reserves where possible. Baseline characterizations were produced for Gallardo Reef in Cabo Rojo, Guanica Shelf-edge in Guanica, Isla Verde Reef in Carolina, and for three reefs within the La Parguera Natural Reserve in Lajas, including the Media Luna and La Boya Vieja (shelf-edge). Reef stations at La Parguera were established at 5, 10, and/or 20 m depths to expand and support the existing depth stratified sampling protocol already in place for Isla Desecheo, Isla de Mona, Rincon, Mayaguez, and now Guanica and Cabo Rojo. Such depth stratified sampling protocol has shown to be relevant for identification of patterns affecting coral health and fish population dynamics and community structure (Garcia-Sais 2012; Esteves 2014, Garcia-Sais and Williams, in preparation).

Sessile-benthic reef communities

At each reef, a set of five 10 m long transects were surveyed. Transects were permanently marked with metal rods hammered to the reef substrate at both ends. Sessile-benthic reef communities were characterized by the continuous intercept chain-link method (as modified from Porter, 1972), following the CARICOMP (1984) protocol. This method provides information on the percent linear cover by sessile-benthic biota and other substrate categories along transects. It allows construction of reef community profiles by assignment of metric units to each substrate transition, which serves as a high precision baseline for monitoring. The chain 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 hammered into available hard (abiotic) substrate at approximately every 1.0 m in the reef. Also, a thin nylon reference line was stretched from rod to rod to guide divers over the linear transect path. Individual measurements of substrate categories, as recorded from the number of chain links 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. 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. The mean coefficient of variation of live coral cover in set of replicate transects from all reefs surveyed was 27.0 %.

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 during 10 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, large groupers, hogfish, mackerel, large parrotfishes, etc.). During the next three 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 the transect was performed during the next three minutes of the survey in order to count demersal and territorial fishes (e.g. *Stegastes spp*, *Gramma loreto*, squirrelfishes, etc.) that remain within the transect area. The last two minutes were dedicated to counting the small gobies (e.g. *Coryphopterus spp*., *Elacatinus* spp.) associated with coral heads on both sides of transects. Fish species observed outside transect areas were reported to supplement the taxonomic assessment, but were not included in abundance determinations.

Density estimates and size distributions of commercially important reef fish species were produced from extension of the regular 10 x 3 m belt-transect (30 m^2) to 20 x 3 (60 m^2) belts along the same regular transect lines. All individuals were counted and length (in cms) visually estimated. Precision of length estimates allowed discrimination between new recruits, small juveniles, juveniles, adult and large adult size classes. All data was recorded in plastic paper.

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. Annual means of live coral cover and fish species richness and abundance with their respective 95% confidence interval were calculated from the mean square error of the ANOVA test. Multivariate analyses of fish community structure from a selected set of coral reef systems under this monitoring program were produced by Esteves (2014) using PRIMER statistics package.

Table 1. Geographic positions and depths of coral reefs monitored during 2015.

Site/Reef Stations	Depth (m)	Latitude (°N)	Longitude (°W)	Survey Date
Isla Desecheo				
Canoas	30	18°22.6480	67°29.0400	9/25/2015
Botes	20	18°22.8950	67°29.3160	9/25/2015
Botes	15	18°22.9200	67°29.3000	9/25/2015
Mayaguez				
Tourmaline	30	18°09.9850	67°16.5810	8/4/2015
Tourmaline	20	18°09.9100	67°16.5120	7/31/2015
Tourmaline	10	18°09.7919	67°16.4160	7/31/2015
Rincon				
Tres Palmas	20	18°20.7900	67°16.2480	8/4/2015
Tres Palmas	10	18°20.8320	67°16.2060	8/19/2015
Tres Palmas	4	18°21.0330	67°16.0160	8/19/2015
Ponce				
Derrumbadero	20	17°54.2400	66°36.5159	10/13/2015
Caja de Muerto				
West Reef	10	17°53.7000	66°31.7040	10/13/2015
Guanica				
Cayo Coral	10	17°56.1720	66°53.3040	7/24/2015
Cayo Aurora	3	17°56.2020	66°52.4340	10/6/2015
Wall	20	17°53.8550	66°57.5920	10/2/2015
Cabo Rojo				
Gallardo	5	18º00.0830	67º19.7960	8/19/2015
Rescuello	8	17º59.4700	67º13.9870	8/5/2015
El Palo	5	18º00.0340	67º12.6700	8/20/2015
Parguera				
Media Luna	5	17º56.3660	67º03.0530	7/16/2015
Media Luna	10	17º56.0790	67º02.8790	7/17/2015
La Boya Vieja	20	17º53.3020	66º59.8860	7/30/2015
Isla Verde				
Reserva	5	18º27.0380	66º01.10100	10/20/2015

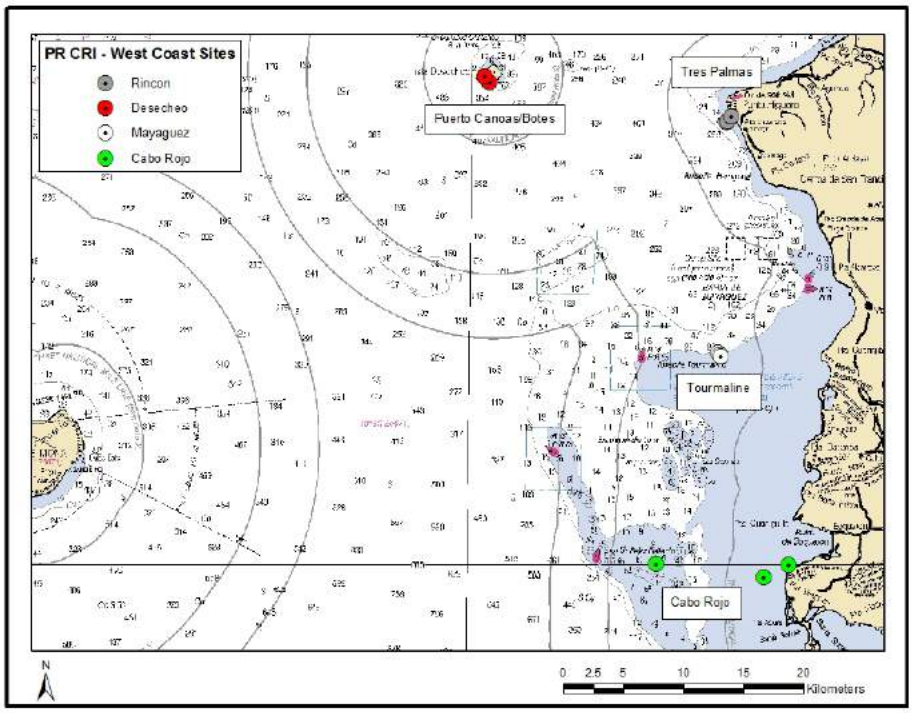


Figure 1. Location of west coast reef sites, Isla Desecheo, Mayaguez, Rincón and Cabo Rojo.

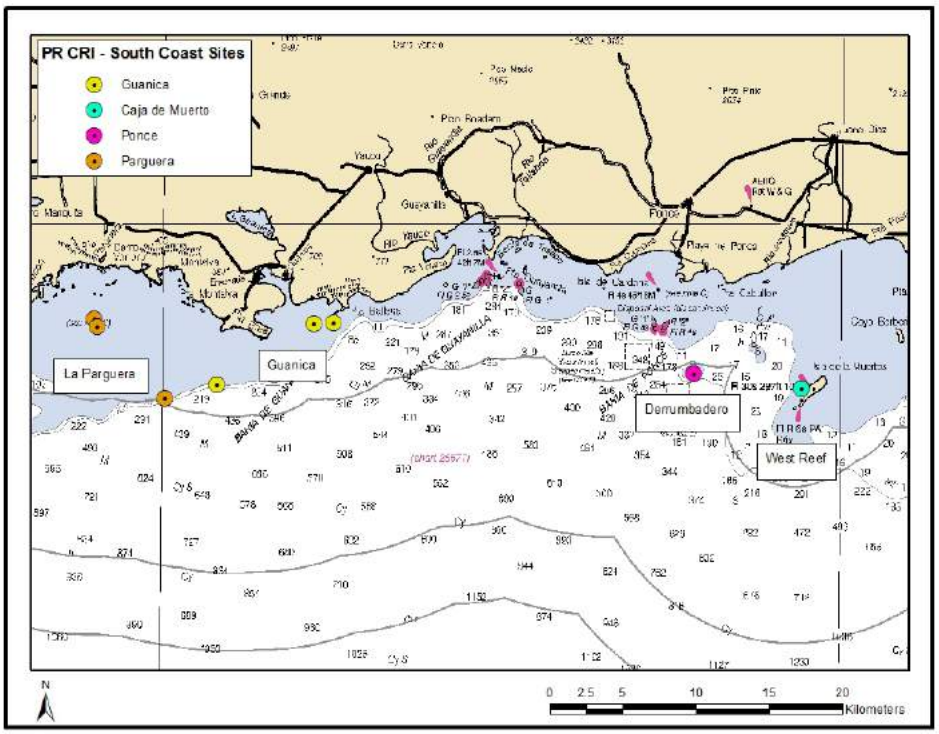


Figure 2. Location of south coast reef sites, Parguera, Guanica, Ponce and Caja de Muerto.

Results

IV Baseline Characterization and Monitoring of Coral Reef Communities 2015

A. Tres Palmas Reef System – Rincón

1.0 Fringing *Acropora palmata* (Elkhorn Coral) Reef

1.1 Sessile-benthic Reef Community

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 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 volunter 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 3). 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 destroyed and the

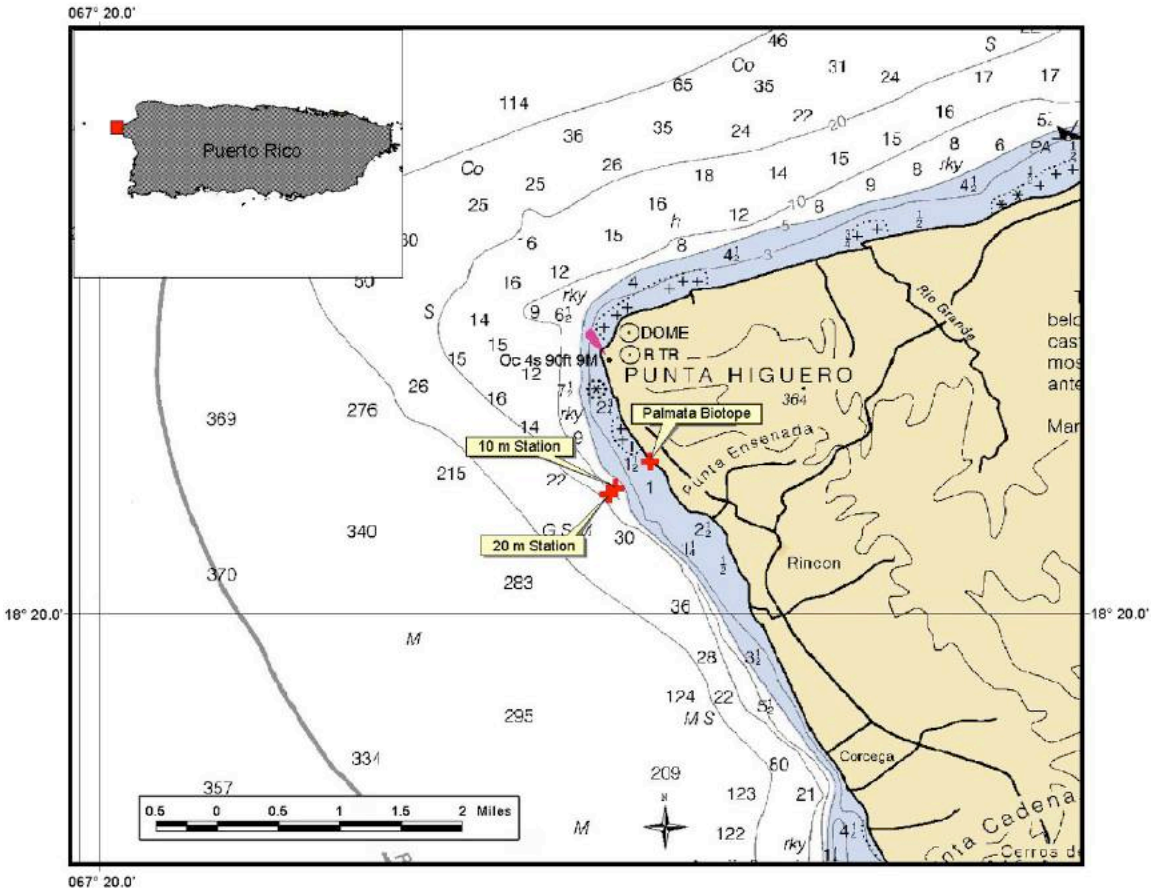


Figure 3. Location of coral reef monitoring stations off Tres Palmas, Rincón.

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 this 2015 survey. Figure 3 shows the location of monitoring stations at the Tres Palmas Reef system in Rincón. The new 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.

The percent substrate cover by sessile-benthic categories during the present 2015 survey are presented in Table 2. Live coral cover averaged 37.4% (range: 33.5 – 46.4 %). Elkhorn Coral (*A. palmata*) was the dominant species with a mean substrate cover of 32.5 % (range: 23.2 – 44.3 %), representing 86.9 % of the total live coral cover.

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

	1	2	3	4	5	**Mean**
Rugosity (m)	3.41	2.12	1.66	2.19	1.73	**2.22**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	20.25	10.85	21.97	3.44	8.95	**13.09**
Benthic Algae						
Turf	41.13	51.50	38.42	53.62	44.15	**45.76**
CCA			2.04	1.15		**0.64**
Galaxaura sp.	1.88					**0.38**
Total Benthic Algae	43.01	51.50	40.46	54.76	44.15	**46.78**
Live Corals						
Acropora palmata	33.40	33.37	28.33	23.19	44.27	**32.51**
Pseudodiploria strigosa	0.52	3.46	2.64	4.36	0.95	**2.39**
Porites astreoides	0.42	0.35	1.80	3.90		**1.29**
Diploria clivosa			2.40	2.07	1.19	**1.13**
Porites porites		0.46				**0.09**
Total Live Corals	34.34	37.64	35.17	33.52	46.42	**37.42**
Octocorals						
Gorgonia ventalina	0.21		0.24			**0.09**
Eunicea flexuosa					0.24	**0.05**
Eunicea tourneforti					0.24	**0.05**
Plexaura homomalla				0.23		**0.05**
Total Octocorals	0.21		0.24	0.23	0.48	**0.23**
Erect Gorgonians						
(#colonies/transect)	2	3	6	8	6	**5**
Sponges						
Amphimedon compressa	0.31					**0.06**
Verongula rigida	0.31					**0.06**
Total Sponges	0.63					**0.13**
Zoanthids						
Palythoa caribaeorum	1.57		2.16	8.04		**2.35**

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

Four additional coral species, including the Symmetrical Brain Coral (*Pseudodiploria strigosa*), Mustard Hill and Finger Corals (*Porites astreoides, P. porites*) and Knobby Brain Coral (*Diploria clivosa*) were also intercepted by transects during this survey.

A total of 17 species of stony corals were identified from the fringing reef. Hard ground substrates, including dead coral sections not colonized by corals were mostly covered b turf algae (mean cover: 45.8 %). Fleshy macroalgae (*Dictyota sp*., *Valonia sp Stypopodium sp*.) and red coralline algae (*Galaxaura sp*, *Amphiroa sp*.) were also present, but represented minor components of the benthic algae assemblage. Abiotic categories, largely associated with reef overhangs occupied 13.1 % of the reef substrate. Vertically projected soft corals (gorgonian) were present in all transects with a mean density of 5 colonies/transect. The Common Sea Fan, *Gorgonia ventalina,* Sea Rods (*Plexaura flexuosa, Eunicea spp*) were also present within transects (Table 2). Sponges were represented by two species within transects and comprised less than 2 % of the reef substrate cover.

Monitoring trends of the sessile-benthic community at the Tres Palmas fringing reef are presented in Figure 4. Mean live coral cover was stable during the 2004 – 2007 monitoring period (range: 38.6 % - 39.4 %), but declined 27.2 % during the period between 2008 and 2010. Differences between monitoring surveys were not statistically significant because of the high variability in live coral cover within replicate transects. There is also high variability associated with sampling at this reef because of the irregular (three-dimensional) shape of the elkhorn coral colonies and the difficulties in following chain paths throughout the shallow reef buttress with wave action. A marked decline of substrate cover by the main reef coral constituent, *Acropora palmata* was observed across all five transects during the 2008-09 survey (Figure 5) and continued until the 2011 survey (Garcia-Sais et al. 2012).

The reduction of reef substrate cover by *A. palmata* over this period could have been associated with loss of live tissue caused by an infectious disease. The irregular patterns

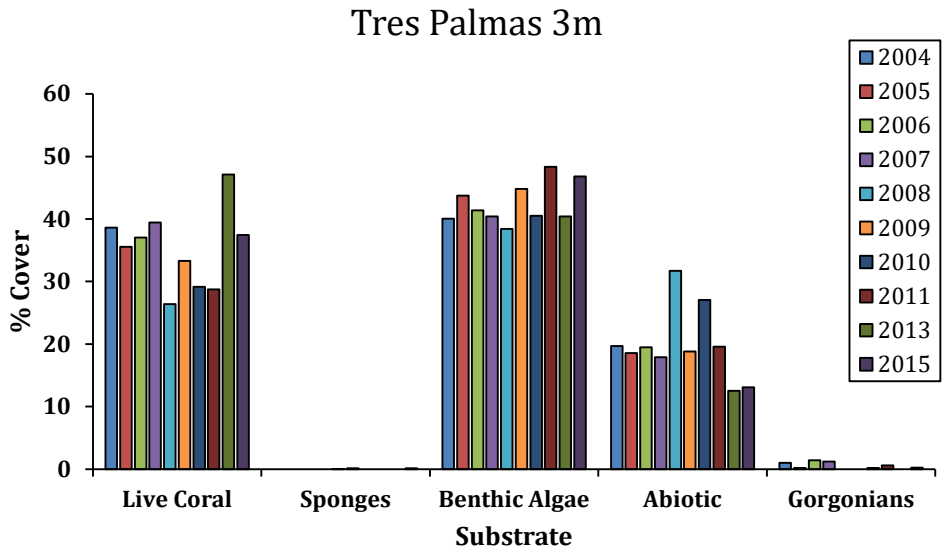


Figure 4. Monitoring trends (2004 – 2015) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon, 2 - 5 m depth.

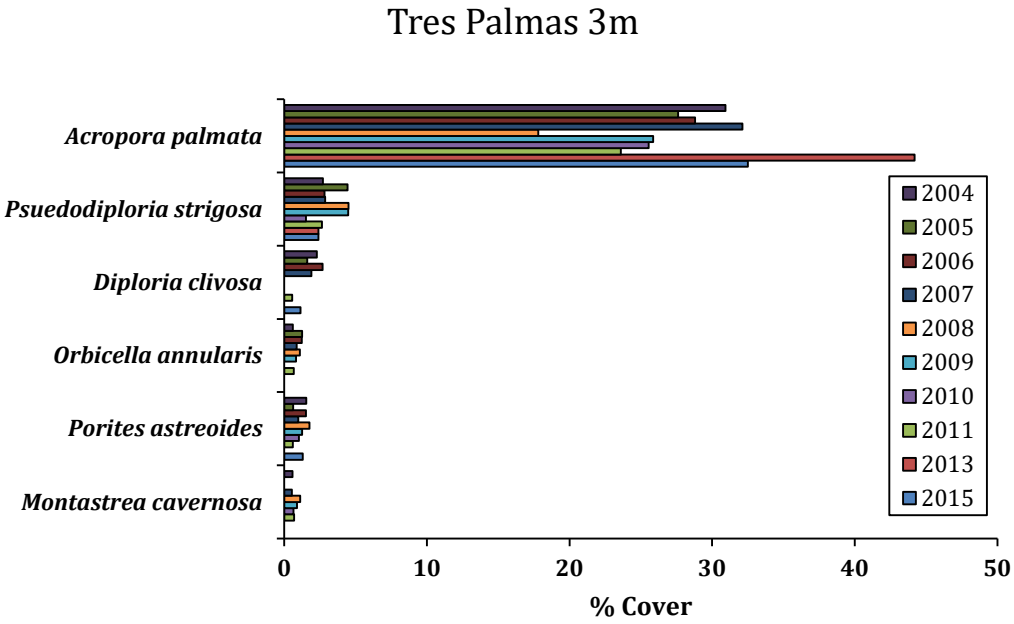


Figure 5. Monitoring trends (2004 – 2015) of mean substrate cover by stony coral species at Tres Palmas Reef, Rincon, 2 - 5 m depth.

of white spots and small patches of tissue necrosis suggest that it is an infection of white pox, caused by the coliform bacteria, *Serratia marcenscens*. 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. Despite very high infection prevalence (almost every colony), the Tres Palmas Reef appears to be resisting the infection with new growth until the present 2015 survey.

Variations of live coral substrate coral between the present and previous monitoring surveys were not statistically significant and thereby the 2015 data obtained from the new set of transects have been merged together with the previous baseline and monitoring data set.

1.2 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 1). During the 2015 monitoring survey, 21 fish species were observed within belt-transects. The mean abundance of individuals was 74.0 Ind/30 m^2 (range: 40 - 137 Ind/30 m^2), and the mean number of species per transect was 10 (range: 5 - 16). The combined abundance of five species represented 76.8 % of the mean abundance within belt-transects (Table 3). The most abundant species was the Bluehead Wrasse (*Thalassoma bifasciatum*), with a mean of 22.0 Ind/30 m^2, followed by the Blue Tang, (*Acanthurus coeruleus*) and the Dusky Damselfish (*Stegastes dorsopunicans*). The Yellowtail Damselfish (*Microspathodon chrysurus*) the Clown Wrasse (*Halichoeres maculipina*), Stoplight Parrotfish and the Doctorfish were observed in at least three 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, yellow goatfishes and parrotfishes were common.

Table 3. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef 5m, Rincon. 2015. Depth: 2-5 m

Depth: 5m

		TRANSECTS					
		1	2	3	4	5	
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	25	30	23	25	7	**22.0**
Acanthurus coeruleus	Blue Tang	4	52	2	20	4	**16.4**
Stegastes dorsopunicans	Dusky Damselfish	4	12	12	5	8	**8.2**
Microspathodon chrysurus	Yellowtail Damselfish	3	8	8	5	7	**6.2**
Halichoeres maculipina	Clown Wrasse	9	6	0	5	0	**4.0**
Sparisoma viride	Stoplight Parrotfish	5	5	0	3	0	**2.6**
Haemulon flavolineatum	French Grunt	5	7	0	0	0	**2.4**
Acanthurus bahianus	Doctorfish	4	0	0	3	4	**2.2**
Haemulon aurolineatum	Tomatate	5	6	0	0	0	**2.2**
Sparisoma rubripinne	Yellowtail Parrotfish	1	8	0	0	0	**1.8**
Abudefduf sexatilis	Sargent Major	0	0	0	0	7	**1.4**
Haemulon melanorum	Cottonwick	0	0	0	6	0	**1.2**
Alostomus maculatus	Trumpetfish	1	1	1	0	0	**0.6**
Stegastes partitus	Bicolor Damselfish	2	0	0	0	0	**0.4**
Bodianus rufus	Spanish Hogfish	2	0	0	0	0	**0.4**
Cantigaster rostrata	Sharpnose Puffer	1	1	0	0	0	**0.4**
Chaetodon striatus	Banded Butterflyfish	0	0	0	0	2	**0.4**
Chaetodon capistratus	Four-eye Butterflyfish	2	0	0	0	0	**0.4**
Ophioblennus atlanticus	Redlip Blenny	0	1	0	1	0	**0.4**
Cantherhines pullus	Orangespotted Filefish	1	0	0	0	0	**0.2**
Neoniphon marianus	Longjaw squirrelfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**74**	**137**	**46**	**73**	**40**	**74.0**
	TOTAL SPECIES	**16**	**12**	**5**	**9**	**8**	**10**

Schoolmaster and Mahogany snappers (*Lutjanus apodus, L. mahogony*) and parrotfishes (*Sparisoma rubripinne, S. viride*) were present along expanded 20 m transects surveyed for determinations of size distributions (Table 4). Both juvenile and young adult snappers and parrotfishes were observed.

Monitoring trends of fish abundance and species richness are presented in Figure 6. Relatively large (statistically significant) variations of mean abundance between monitoring surveys have been detected at this reef station (ANOVA; $p < 0.001$, see Appendix 3). Fluctuations of the mean fish abundance have been typically driven by transitory schooling species, mostly Blue Tangs and Glass-eye Sweepers, which occur in such high densities that influence (increase) abundances within belt-transects. Fishes also respond with lower occupancy of the Tres Palmas reef habitat during periods of heavy wave action and or surge associated with winter swells, as was the case during the 2011 and 2013 surveys. Typically, when the physical conditions are adverse, both fish abundance and species richness decline.

Table 4. Taxonomic composition, density and size of fishes within 20 m x 3 m belt-transects at Tres Palmas Reef 3m, August 2015

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Sparisoma viride	Stoplight Parrotfish	5 -5	5 - 3		3 - 5	
Lutjanus apodus	Schoolmaster Snapper	1-15		4 - 30		
Sparisoma rubripinne	Yellowtail Parrotfish	1-25	3 - 20 4 - 25 1 - 30			
Lutjanus mahogany	Mahogany Snapper			2 - 20		

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 present 2015 and previous surveys (García-Sais et al., 2004 a, 2005, 2006, 2007, 2009, 2010, 2012, 2014), 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. One Hawksbill Turtle (*Eretmochelys imbricata*) was reported during the 2004 baseline survey (García-Sais et al., 2004a).

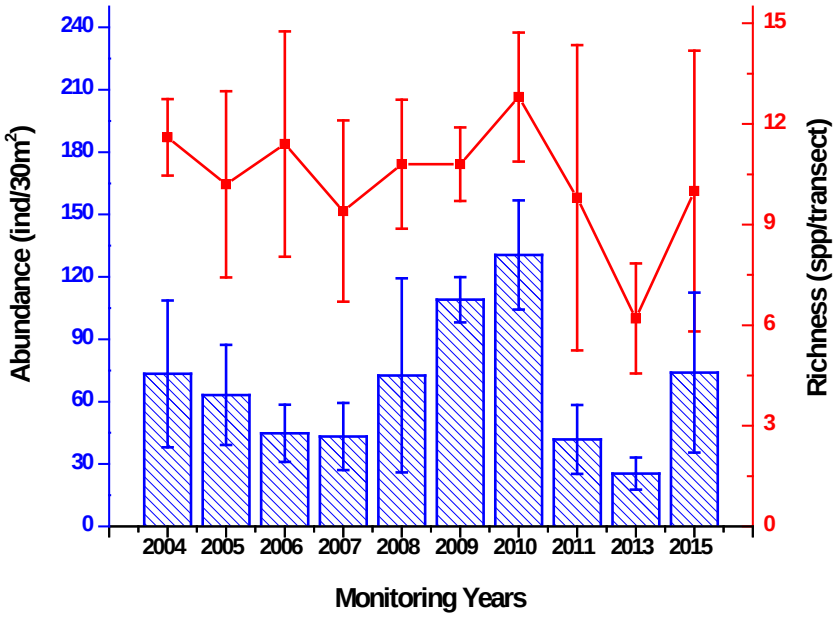


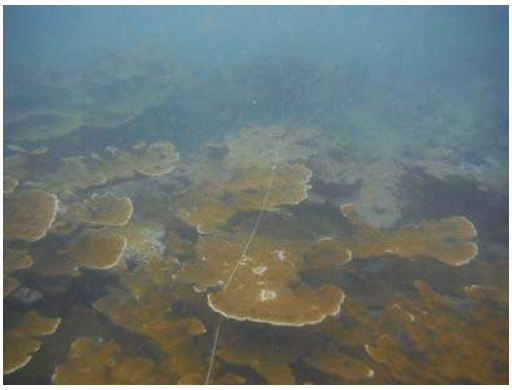
Figure 6. Monitoring trends (2004 – 2015) of fish species richness and abundance at Tres Palmas Elkhorn Coral Reef, 2-5 m, Rincon.

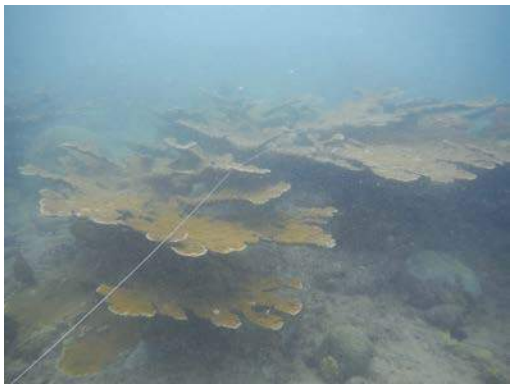
Motile megabenthic invertebrates observed within belt-transects during the 2015 monitoring survey are presented in Table 5. The Rock-boring sea urchin was the most abundant with a mean of 3.0 Ind/30 m^2. The Rustic and Caribbean Coral Shell were present in three out of the five transects surveyed. Juvenile Spiny Lobsters (*Panulirus argus*), Rock Lobsters (*P. guttatus*) and other sea urchins have been reported from previous surveys at this reef (García-Sais et al., 2009).

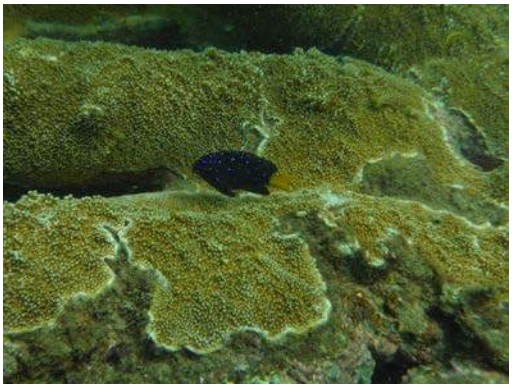
Table 5. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Elkhorn Coral Reef, 3 m, Rincon, 2015

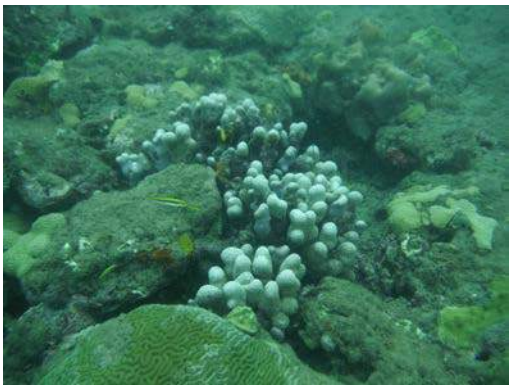
Depth: 2 - 5 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						
Coralliophila caribdea	Caribbean Coral Shell	3	1	4	3	1	**2.4**
Thais rustica	Rustic Shell		2	2	1		**1.0**
Echinometra lucunter	Rock boring Urchin	2	3	4	5	2	**3.2**
	TOTALS	5	6	10	9	3	**6.6**

Photo Album 1. Tres Palmas, Rincon Fringing *Acropora palmata* Reef









2.0 Outer Shelf Patch Coral Reefs

2.1 Sessile-benthic Community

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.

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 24.6 col./transect (range: 20 – 27 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* was present in one transect.\ and with a relatively low substrate cover (e.g. 1.7 %).

Stony corals occurred mostly as encrusting colonies of typically small size and low vertical relief. A total of 17 species of stony corals were identified from the patch reef community during our survey, including 13 species intercepted by line transects. Live stony coral cover averaged 23.7 % (range: 15.2 – 32.9 %). Mustard-Hill Coral, *Porites astreoides* and Great Star Coral, *Montastraea cavernosa* were the dominant species in terms of substrate cover with means of 5.8 and 5.0%, respectively. In addition to the aforementioned species, other three coral species that included *Pseudodiploria strigosa, Agaricia agaricites* and *Siderastrea siderea* were present in all transects. A few large colonies of Grooved Brain Coral, *Pseudodiploria labyrinthiformis*, Boulder Brain Coral, *Colpophyllia natans* and Pillar Coral, *Dendrogyra cylindrus* were present.

Table 6. Percent substrate cover by sessile-benthic categories at the Tres Palmas outer shelf reef, Rincon 10 m. 2015.

	Transects					
	1	2	3	4	5	**Mean**
Rugosity (m)	1.96	1.8	1.82	1.62	0.91	**1.622**
SUBSTRATE CATEGORIES						
Abiotic						
Sand	0.94	2.25	6.52	1.81	6.03	**3.51**
Reef overhang					1.28	**0.26**
Total Abiotic	0.94	2.25	6.52	1.81	7.32	**3.77**
Benthic Algae						
Dictyota spp.	37.00	23.13	27.73	19.76	22.85	**26.09**
Halimeda sp.	0.59			0.96	1.28	**0.57**
Turf	15.11	28.83	21.80	22.41	26.32	**22.89**
Galaxaura sp.		0.47		1.69		**0.43**
CCA	0.47		0.24	0.48	0.51	**0.34**
Red algae sp.	0.82					**0.16**
Jania sp.					0.39	**0.08**
Total Benthic Algae	53.98	52.43	49.76	45.30	51.35	**50.57**
Cyanobacteria	18.74	11.74	9.36	8.43	18.87	**13.43**
Live Corals						
Porites astreoides	5.04	8.19	2.61	7.35	5.78	**5.79**
Montastraea cavernosa	7.26	5.34	5.92	3.13	3.59	**5.05**
Pseudodiploria strigosa	3.28	2.14	4.38	0.36	0.39	**2.11**
Pseudodiploria labyrinthiformis			8.53		1.80	**2.07**
Agaricia agaricites	3.86	2.85	1.30	1.93	0.13	**2.01**
Siderastrea siderea	1.17	0.71	2.73	3.25	2.18	**2.01**
Colpophyllia natans				9.64		**1.93**
Dendrogyra cylindrus				4.46		**0.89**
Millepora alcicornis		1.54	0.24	0.72	1.28	**0.76**
Orbicella annularis complex		1.90				**0.38**
Stephanocoenia intersepta				1.81		**0.36**
Madracis decactis		0.95				**0.19**
Porites divaricata			0.59	0.24		**0.17**
Total Live Corals	20.61	23.61	26.30	32.89	15.15	**23.71**
Octocorals						
Erythropodium caribaeorum				1.69		**0.34**
Eunicea flexuosa	0.47	0.47	0.24			**0.24**
Gorgonia ventalina			0.24	0.24	0.26	**0.15**
Allotogorgia americana		0.36			0.26	**0.12**

Table 6. continued

Eunicea pallida		0.47				**0.09**
Plexaura homomalla					0.39	**0.08**
Allotogorgia acerosa				0.36		**0.07**
Pseudoplexaura flagellosa					0.26	**0.05**
Total Octocorals	0.47	1.30	0.47	2.29	1.16	**1.14**
Erect Gorgonians (#col/transect)	27	27	25	20	24	**24.60**
Sponges						
Xestopsongia muta		3.80	4.38	2.89		**2.21**
Neopetrosia proxima		4.03			0.77	**0.96**
Aiolochoria crassa	1.52			0.84		**0.47**
Aplysina fistularis	1.29	0.59	0.47			**0.47**
Amphimedon compressa				1.57	0.64	**0.44**
Ircinia brown sp.	0.59			1.08		**0.33**
Aplysina cauliformis	0.23			0.96	0.26	**0.29**
Neofibularia nolitangere					1.28	**0.26**
Monanchora arbuscula					1.03	**0.21**
Scopalina ruetzleri			0.24	0.24	0.51	**0.20**
Niphates erecta	0.47				0.51	**0.20**
Agelas conifera			0.95			**0.19**
Petrosia weinbergi				0.72		**0.14**
Higginsia coralloides	0.35	0.24				**0.12**
Mycale laevis	0.12				0.39	**0.10**
Petrosia pellasarca	0.47					**0.09**
Callyspongia vaginalis	0.23					**0.05**
Total sponges	5.27	8.66	6.04	8.31	5.39	**6.74**
Zoanthid						
Palythoa caribaeorum				0.96		**0.19**

Benthic algae, comprised by a mixed assemblage of turf, fleshy brown (mostly *Dictyota sp* and *Lobophora sp*.), red coralline (*Jania sp., Galaxaura sp*.) and green calcareous macroalgae (*Halimeda spp*) presented the highest percent of reef substrate cover by sessile-benthic categories with a combined mean of 50.6 % (range: 45.3 – 54.0 %). Turf algae and brown macroalgae were the main components of the algal assemblage and were present in all transects (Table 6).

Sponges, represented by at least 17 species within transects presented a mean substrate cover of 6.7 % (range: 5.3 – 8.7 %). The Giant Barrel Sponge, *Xestospongia muta* was present in three out of the five transects surveyed and with a mean reef

substrate cover of 2.2 % was the most prominent species. The encrusting zoanthid, *Palythoa caribbea,* was observed in one transect. Total abiotic cover averaged 3.8 %, 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 movement, transport and deposits over the mostly flat reef. As such, these variations of abiotic cover influence inter-annual variations of reef substrate cover by biotic benthic components.

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 maceroalgae 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 7 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 – 2015) were not statistically significant (ANOVA; $p = 0.232$). Some of these variations are influenced by sand transport and its effects in covering temporarily live coral colonies. Nevertheless the mean coral cover of 23.7 % measured during this 2015 survey is the highest recorded during the monitoring program. Analysis of variance procedures and graphs comparing variations of live coral cover between annual monitoring surveys are presented in Appendix 2.

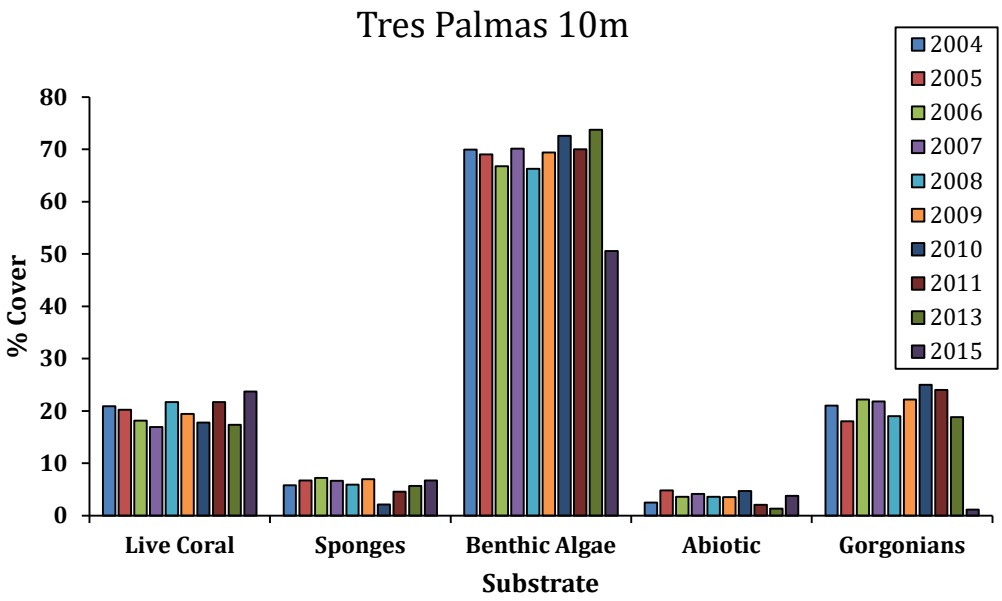


Figure 7. Monitoring trends (2004 – 2015) of mean substrate cover by sessile-benthic categories at Tres Palmas Outer Patch Reef – 10 m.

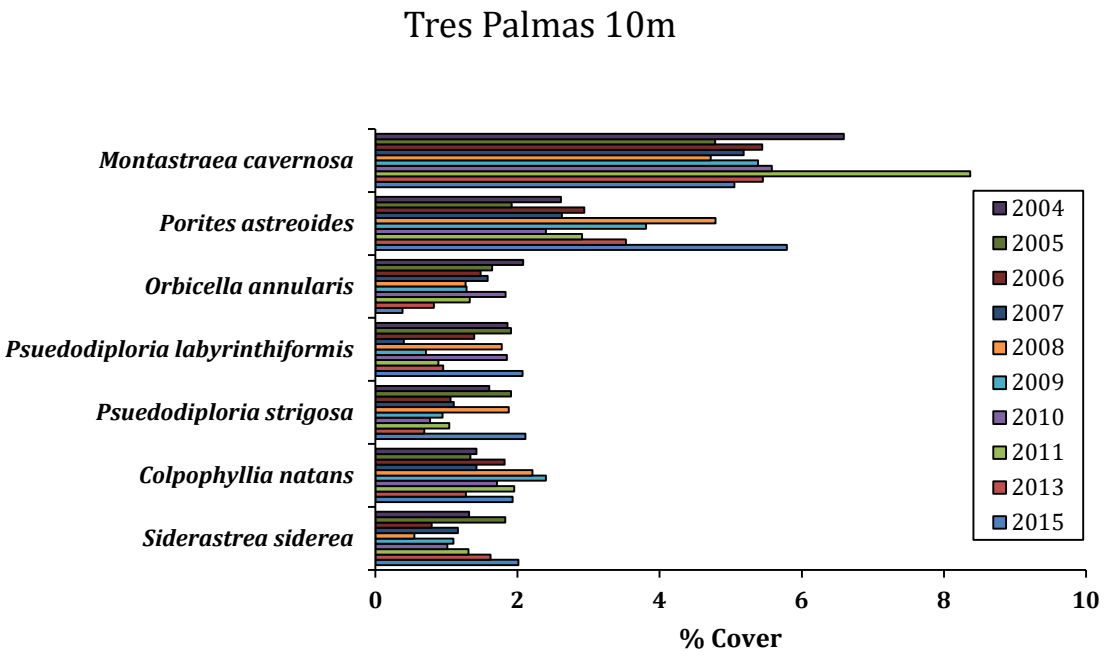


Figure 8. Monitoring trends (2004 – 2015) of mean substrate cover by stony coral species at Tres Palmas Outer Patch Reef – 10 m.

2.2 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 1). During the 2015 survey, mean abundance of individuals within belt-transects was 63.6 Ind/30 m^2 (range: 41 - 118 Ind/30 m^2). The mean number of species per transect was 10.8 (range: 10 - 13).

Two species, the Bicolor Damselfish (*Stegastes partitus*) and the Bluehead Wrasse (*Thalassoma bifasciatum*) were (as in previous surveys) numerically dominant within belt-transects with mean abundances of 18.6 and 17.6 Ind/30 m^2, respectively (Table 7). The combined abundance of these two species represented 56.9 % of the total fish abundance within belt-transects. In addition to the two aforementioned species, the Princess and Redband Parrotfishes, Yellowhead Wrasse, Coney, Blue Chromis and, Sharknose Goby were present in at least four of the five transects surveyed. Given their prevalence in previous surveys they 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, Spoted 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). Size distributions for Princess and Redband Parrotfishes are indicative that both small juveniles and young adults of these species were present at this reef (Table 8).

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 - 2015 survey (Figure 9). The interannual variations are statistically significant (ANOVA, $p < 0.0001$; see Appendices 3 and 4). This reef is frequently exposed to very high wave energy and the surge conditions 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.

Table 7. Taxonomic composition and abundance of fishes surveyed within belt-transects at the outer shelf reef of Tres Palmas, Rincon 10m. 2015.

Depth: 10m

		TRANSECTS					
		1	2	3	4	5	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Stegastes partitus	Bicolor Damselfish	16	12	20	22	23	**18.6**
Thalassoma bifasciatum	Bluehead Wrasse	5	10	11	60	2	**17.6**
Scarus taeniopterus	Princess Parrotfish	3	12	7	11	4	**7.4**
Sparisoma aurofrenatum	Redband Parrotfish	5	12	3	10	2	**6.4**
Halichoeres garnoti	Yellowhead Wrasse	3	0	5	7	2	**3.4**
Cephalopholis fulva	Coney	3	1	1	2	6	**2.6**
Chromis cyanea	Blue Chromis	2	3	0	2	2	**1.8**
Gobiosoma evelynae	Sharknose Goby	2	2	0	1	1	**1.2**
Stegastes leucostictus	Beugregory	1	2	0	0	1	**0.8**
Mullioides martinicus	Yellowtail Goatfish	0	0	4	0	0	**0.8**
Acanthurus chirurgus	Doctorfish	0	0	2	0	1	**0.6**
Serranus tigrinus	Harlequin Bass	1	0	0	1	1	**0.6**
Acanthurus coeruleus	Blue Tang	0	1	1	1	0	**0.6**
Holocentrus rufus	Squirrelfish	0	2	0	0	0	**0.4**
Epinephelus guttatus	Red Hind	0	0	1	0	0	**0.2**
Chaetodon capistratus	Four eye Butterflyfish	0	0	0	1	0	**0.2**
Microspathodon chrysurus	Yellowtail Damselfish	0	0	0	0	1	**0.2**
Amblichirinus pinos	Redspoted Hawlkfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**41**	**57**	**55**	**118**	**47**	**63.6**
	TOTAL SPECIES	**10**	**10**	**10**	**11**	**13**	**10.8**

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 common. Pelagic piscivores, such as barracudas (*Sphyraena barracuda*), mackerels (*Scomberomorus regalis*) and jacks (*Caranx crysos, C. ruber*) have been previously

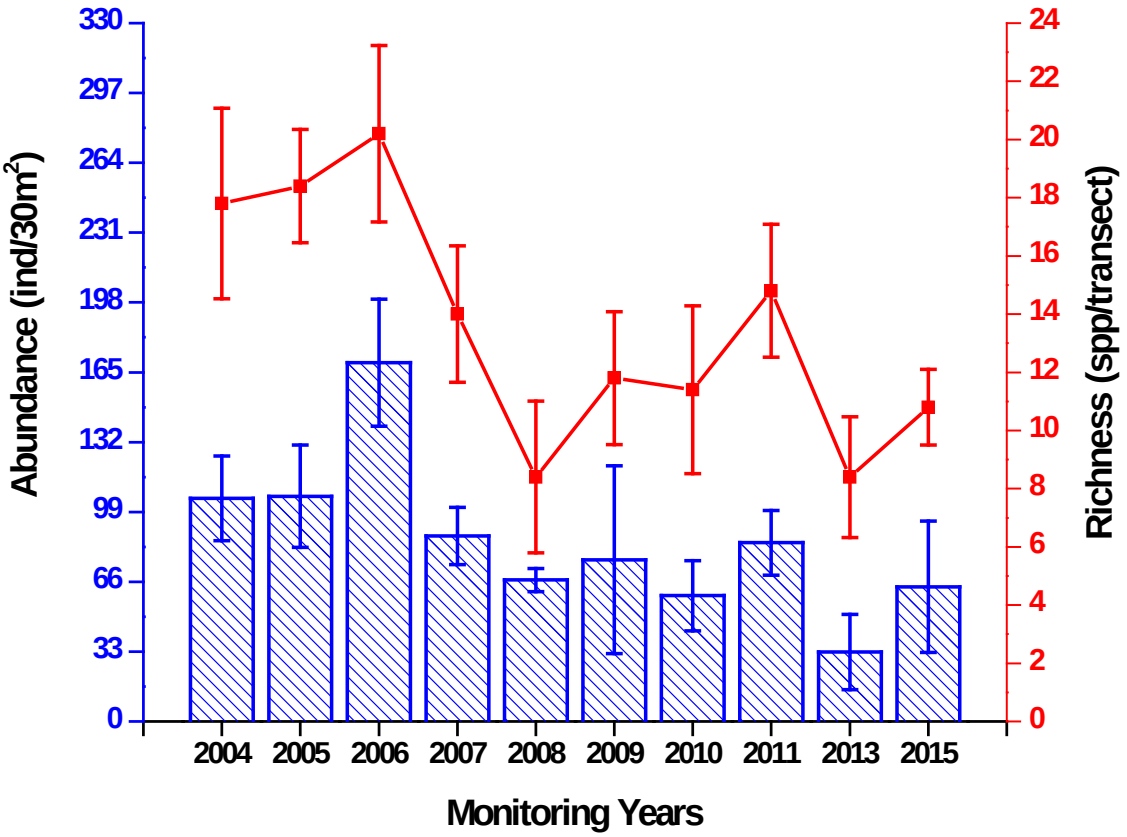


Figure 9. Monitoring trends (2004 – 2015) of fish species richness and abundance at Tres Palmas Outer Shelf Patch Reef, 10 m, Rincon.

reported from this reef (García-Sais et al., 2005, 2006, 2007, 2008, 2009, 2010, 2012). Mid size adult and juvenile Lane, Mahogany and Yellowtail snappers (*Lutjanus synagris, L. mahogony, Ocyurus chrysurus*) have been reported in previous surveys (Garcia-Sais et al. 2014).

Among motile megabenthic invertebrates, several spiny Lobsters (*Panulirus argus*) Slate-pencil Urchins (*Eucidaris tribuloides*), Cleaner Shrimps (*Periclimenes sp*., *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). One Arrow Crab was observed within belt-transects during the present 2015 survey (Table 9).

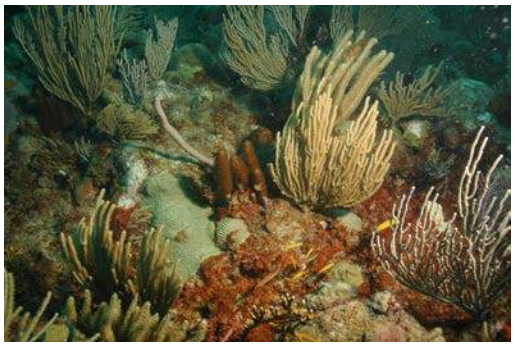
Table 8. Taxonomic composition, density and size of fishes within 20 m x 3 m belt-transects at Tres Palmas Reef 10m. 2015

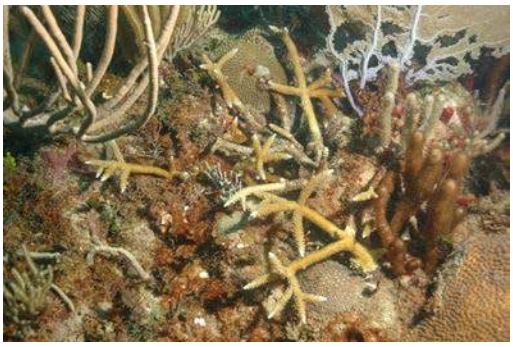
		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus taeniopterus	Princess Parrotfish	2 - 7 1 - 20	12 - 3	7 - 3	6 - 3 2 - 7 4 - 17	4 - 12
Sparisoma aurofrenatum	Redband Parrotfish	4 - 3 1 - 20	2 - 3 3 - 7	6 - 3 2 - 7 1 - 10 1 - 15		2 - 10
Epinephelus guttatus	Red Hind			1 - 25		
Cephalopholis fulva	Coney	1 - 7 1 - 12 1 - 15	1 - 10	1 - 15	2 - 12	3 - 7 1 - 10 2 - 15

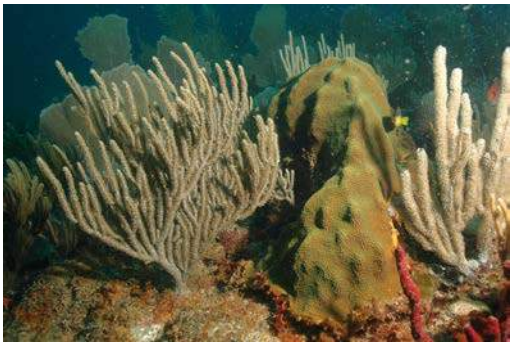
Table 9. Taxonomic composition and abundance of motile megabenthic invertebrates surveyed within belt-transects at Tres Palmas Outer Shelf Reef, Rincon 10m, 2015

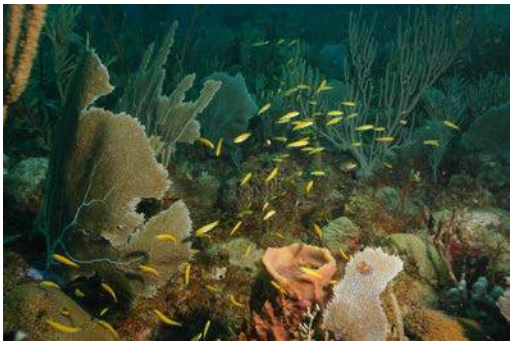
		TRANSECTS					
Depth: 10 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Stenorhynchus seticornis	Arrow Crab			1			**0.2**
	TOTALS	0	0	1	0	0	**0.2**

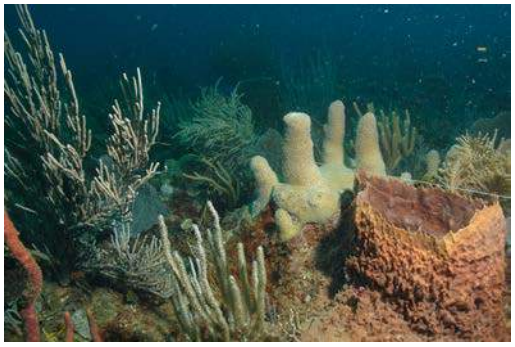
Photo Album 2. Tres Palmas, Rincon Outer Shelf Patch Reef

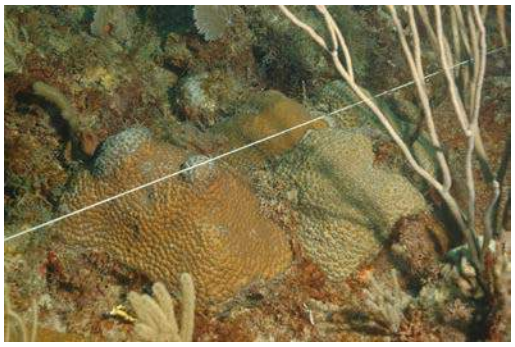












3.0 Shelf-edge Coral Reef

3.1 Sessile-benthic Community

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.

A total of 22 stony coral species (including two hydrocorals) have been identified from the shelf-edge reef off Tres Palmas, 14 of which were intercepted by line transects during the 2015 survey (Table 10). Stony corals occurred mostly as encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 23.2 % (range: 14.7 – 26.9 %). Boulder Star Coral, *Orbicella annularis* complex was the dominant species in terms of substrate cover with a mean of 9.6 % (range: 1.4 – 18.6 %), representing 41.6 % of the total cover by stony corals (Table 10). Colonies of *O. annularis* were present in all five transects. Also present in four out of the five transects were colonies of Maze Coral (*Meandrina meandrites*), Lettuce Coral, *Agaricia agaricites* ad Great Star Coral, *Montastraea cavernosa*. Soft corals (gorgonians) were moderately abundant, with an average of 18.4 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 and crevices. The encrusting gorgonian, *Erythropodium caribaeorum* was present in three transets with a mean cover of 3.9 %. Encrusting and erect sponges were represented by at least 18 species within transects, with an average cover of 11.7 %. Tube sponges, *Agelas spp*., Green Finger Sponge,

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

	Transects					
	1	2	3	4	5	**Mean**
Rugosity (m)	2.14	2.15	2.78	1.56	1.35	**2.00**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	2.65	5.53	1.31			**1.90**
Sand	3.00		1.10			**0.82**
Gap		1.15				**0.23**
Total Abiotic	5.65	6.68	2.41			**2.95**
Benthic Algae						
Turf	39.10	28.57	38.44	59.69	60.54	**45.27**
Lobophora variegata	6.34	17.86	4.71			**5.78**
*Dictyot*a spp.	3.11	3.80	0.66			**1.51**
CCA	0.81	1.84	2.30			**0.99**
Fleshy macroalgae		0.00		2.42	1.48	**0.78**
Galaxaura sp.		1.15	1.10			**0.45**
Halimeda spp.	0.23	1.15	0.44			**0.36**
Gracilaria sp.	1.04					**0.21**
Total Benthic Algae	50.63	54.38	47.65	62.11	62.02	**55.36**
Live Corals						
Orbicella annularis complex	11.07	10.14	18.62	7.02	1.36	**9.64**
Agaricia agaricites	4.73	4.15		2.30	7.89	**3.81**
Meandrina meandrites	3.11	2.07	5.70	2.42		**2.66**
Porites astreoides	3.00	3.11		3.63		**1.95**
Montastraea cavernosa		1.73	0.22	2.78	4.44	**1.83**
Siderastrea siderea				4.48	0.99	**1.09**
Pseudodiploria strigosa	2.65			2.30		**0.99**
Pseudodiploria labyrinthiformis				1.69		**0.34**
Madracis decactis		1.50				**0.30**
Colpophyllia natans	0.81					**0.16**
Agaricia fragilis			0.77			**0.15**
Leptoseris cucullata		0.69				**0.14**
Millepora alcicornis	0.23		0.22			**0.09**
Siderastrea radians				0.24		**0.05**
Total Live Corals	25.61	23.39	25.52	26.88	14.67	**23.21**
Cyanobacteria	8.65	1.96	5.91	2.30	3.70	**4.50**
Octocorals						
Erythropodium caribaeorum		3.11	12.27		4.19	**3.91**
Briareum asbestinum	0.81					**0.16**

Table 10. continued

Allotogorgia acerosa		0.81				**0.16**
Gorgonia ventalina	0.23					**0.05**
Plexaura kukenthali		0.23				**0.05**
Eunicea colombiana			0.22			**0.04**
Total Octocorals	1.04	4.15	12.49		4.19	**4.37**
Erect Gorgonians (#col/transect)	20	23	16	17	16	**18.4**
Sponges						
sponge (unidentified)				8.72	15.41	**4.83**
Agelas scept	2.42	3.11	2.41			**1.59**
Iotrochota birotulata	1.04	1.50	0.55			**0.62**
Agelas citrina	0.46	0.23	1.53			**0.45**
Amphimedon compressa	0.23	1.38				**0.32**
Niphates erecta	0.58	0.58	0.22			**0.27**
Aplysina cauliformis	0.46	0.58	0.22			**0.25**
Petrosia pellasarca	1.15					**0.23**
Agelas conifera		0.35	0.55			**0.18**
Agelas tubulata	0.23	0.58				**0.16**
Monanchora arbuscula	0.69					**0.14**
Scopalina ruetzleri	0.35	0.35				**0.14**
Callyspongia vaginalis	0.23	0.23				**0.09**
Cliona caribbaea		0.46				**0.09**
Neopetrosia proxima	0.35					**0.07**
Agelas dispar	0.23					**0.05**
Callyspongia fallax			0.22			**0.04**
Mycale laevis		0.12				**0.02**
Total Sponges	8.42	9.45	5.70	8.72	15.41	**9.54**
Zoanthid						
*Trididen*mum solidum			0.33			**0.07**

Iotrochota birotulata, Erect Rope Sponge, *Amphimedon compressa*, and an unidentified sponge comprised contributed most of thevreef substrate cover by sponges (Table 10) .

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 45.3 % (range: 28.6 – 60.5 %). Turf algae were found overgrowing rocky substrates, as well as dead coral sections and other hard ground. Fleshy brown

macroalgae, particularly *Lobophora variegata* and *Dictyota sp.* contributed an additional 5.8 % and 1.5 %, respectively to the reef substrate cover. 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 55.4 %. Patches of reddish, slimy mats of benthic cyanobacteria were observed over the reef, mostly covering sandy sediments. Reef overhangs averaged 1.9 % and contributed to a topographic rugosity of 2.0 m. Sand was observed in two transects with a mean cover of 0.8 %.

A mild, but consistent trend of declining mean coral cover between monitoring surveys was measured until 2008 (Figure 10). This pattern ended during 2009 with a minor increment of live coral cover until 2010. Since then small, statistically insignificant declines of coral cover were measured until the present 2015 survey, which registered a slight increment of cover. The variability in both magnitude and direction of live coral cover within transects is high enough to render the differences between monitoring years statistically insignificant (ANOVA; $p = 0.435$; see Appendix 2). The increasing trend of live coral cover has been influenced by an apparent recuperation of *Orbicella annularis* (complex) from its acute degradation after the 2005 coral bleaching event (Figure 11).

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 85 fish species have been identified from the shelf-edge reef off Tres Palmas (Appendix 1). Table 11 lists the 33 fish species observed within belt-transects during the 2015 survey in decreasing order of abundance. Mean abundance within belt-transects was 213.8 Ind/30 m^2 (range: 104 – 352 Ind/30 m^2). The mean number of species per transect was 17.2 (range: 14– 21). An assemblage consisting of seven species represented 86.2 % of the total fish individuals within belt-transects (Table 11). Mackerel Scad, Blue Chromis, Bicolor Damselfish, Bluehead and Creole Wrasses, Masked and Peppermint Gobies comprised the numerically dominant assemblage. In addition, the Sharknose Goby, Beau Gregory, Yellowhead Wrasse, Princess and Redband Parrotfishes and Four-eye Butterflyfish were present in at least four of the five transects surveyed.

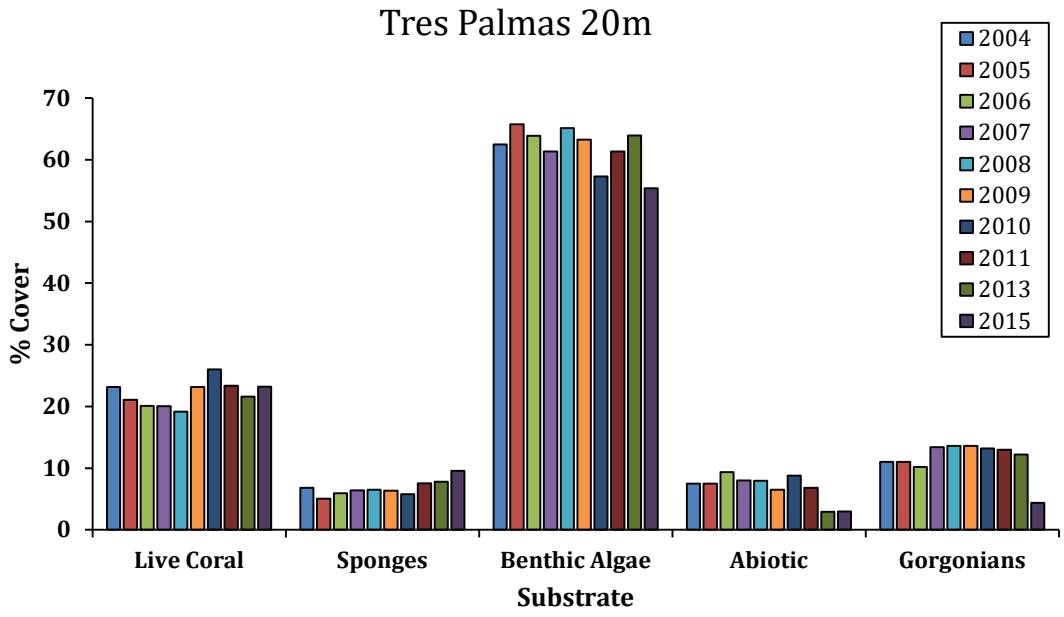


Figure 10. Monitoring trends (2004 – 2015) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef – 20 m.

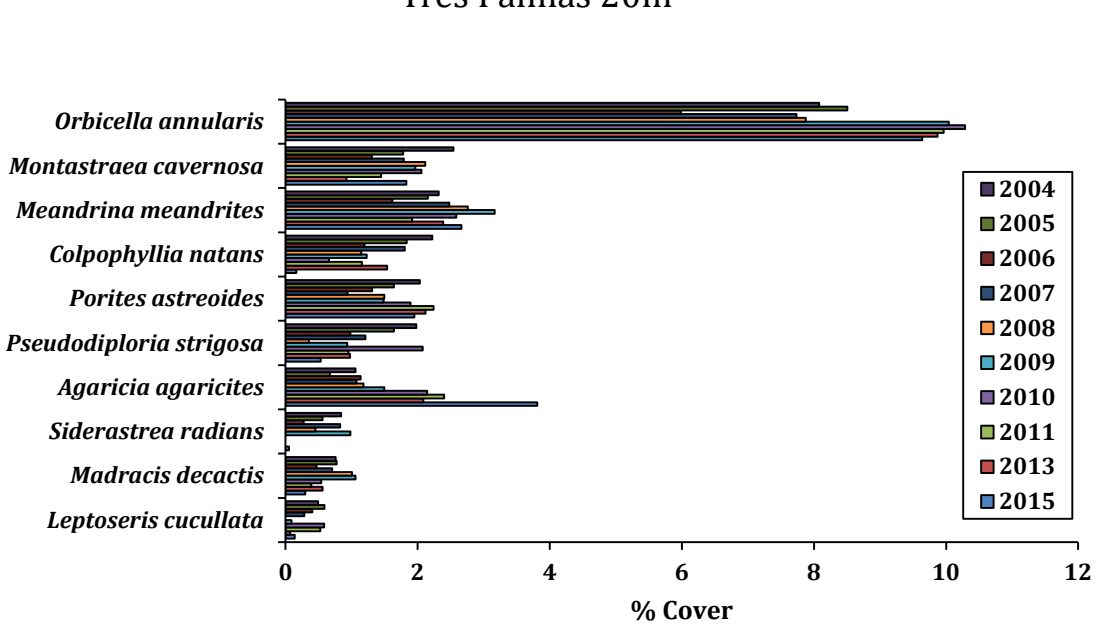


Figure 11. Monitoring trends (2004 – 2015) of mean substrate cover by stony coral species at Tres Palmas Reef – 20 m.

Table 11. Taxonomic composition and abundance of fishes surveyed within belt-transects at the shelf- edge reef off Tres Palmas, Rincón 20m. 2015.

Depth: 20m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Decapterus macarelus	Mackerel scad	0	0	200	0	0	**40.0**
Clepticus parrae	Creole wrasse	31	0	23	35	55	**28.8**
Chromis cyanea	Blue Chromis	34	28	21	25	35	**28.6**
Coryphopterus personatus	Masked Goby	34	29	0	72	2	**27.4**
Stegastes partitus	Bicolor Damselfish	22	12	29	29	26	**23.6**
Coryphopterus lipernes	Peppermint goby	15	12	33	17	24	**20.2**
Thalassoma bifasciatum	Bluehead Wrasse	23	5	18	11	22	**15.8**
Gobiosoma evelynae	Sharknose Goby	0	3	7	4	4	**3.6**
Stegastes leucostictus	Beau Gregory	3	5	2	3	3	**3.2**
Scarus taeniopterus	Princess Parrotfish	0	1	1	10	3	**3.0**
Sparisoma aurofrenatum	Redband Parrotfish	2	0	6	1	5	**2.8**
Mullioides martinicus	Yellowtail Goatfish	13	0	0	0	0	**2.6**
Haemulon flavolineatum	French grunt	9	0	1	0	0	**2.0**
Halichoeres garnoti	Yellow-head Wrasse	1	3	0	1	4	**1.8**
Myripristis jacobus	Blackbar Soldierfish	0	0	3	4	0	**1.4**
Chaetodon capistratus	Four-eye Butterflyfish	1	2	1	2	0	**1.2**
Neoniphon marianus	Longspine squirrelfish	2	0	1	2	0	**1.0**
Cephalopholis cruentatus	Graysby	1	1	0	2	1	**1.0**
Chromis multilineata	Brown chromis	0	0	5	0	0	**1.0**
Acanthurus coeruleus	Blue Tang	1	1	0	0	2	**0.8**
Melichtis niger	Black Durgeon	0	0	0	3	0	**0.6**
Sparisoma viride	Stoplight Parrotfish	2	0	0	0	0	**0.4**
Holocentrus rufus	Squirrelfish	0	0	1	1	0	**0.4**
Serranus tigrinus	Harlequin Bass	0	0	0	0	2	**0.4**
Carnax crysos	Blue Runner	1	0	0	1	0	**0.4**
Hypoplectrus unicolor	White Hamlet	1	0	0	0	1	**0.4**
Halichoeres maculipina	Clown Wrasse	1	0	0	0	0	**0.2**
Acanthurus bahianus	Ocean Surgeon	0	1	0	0	0	**0.2**
Pomacanthus paru	French Angelfish	0	0	0	0	1	**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish	1	0	0	0	0	**0.2**
Canthigaster rostrata	Caribbean Puffer	0	0	0	0	1	**0.2**
Michorpathodon chrysurus	Yellowtail Damselfish	0	1	0	0	0	**0.2**
Hypoplectrus puella	Barred Hamlet	1	0	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**199**	**104**	**352**	**223**	**191**	**213.8**
	TOTAL SPECIES	**21**	**14**	**16**	**18**	**17**	**17.2**

The size range of commercially important fish species in extended transects included both juvenile and adult parrotfishes, coneys, one adult Mahogany Snapper and an adult Lionfish, *Pterois sp.* (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. Mackerel Scad, Creole Wrasse, *Chromis spp*. Masked goby, bicolor damselfish), which comprised approximately 69 % 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 25 % 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, but their combined abundance (not counting the Bicolor damselfish) was less than 5 % of the total.

Annual fluctuations of fish abundance and species richness from the baseline survey of 2004 to the present are presented in Figure 12. Both fish species richness and abundance within belt-transects presented statistically significant differences between survey years (ANOVA; $p < 0.0001$). 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 106.2 Ind/30 m^2 during the 2013 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 importante forage (prey) species for the small piscivorous fishes in the reef.

Table 12. Taxonomic composition, density and size of fishes within 20 m x 3 m belt-transects at Tres Palmas Reef 20m. 2015

SPECIES	**COMMON NAME**	(Ind/60 m^2) - Length (cm)				
Sparisoma viride	Stoplight Parrotfish	1 - 7 1 - 12			1 - 30	
Sparisoma aurofrenatum	Redband Parrotfish	1 - 3 1 - 12		3 - 3 2 - 10	1 - 12	5 - 3
Epinephelus fulva	Coney					1 - 15
Epinephelus cruentatus	Graysby	1 - 10	1 - 12		2 - 12	1 - 17
Ptoris volitans	Lionfish				1 - 25	
Scarus taeniopterus	Princess Parrotfish		1 - 5	1 - 15 1 - 30	10 - 3	1 - 3 1 - 5 1 - 7
Lutjanus mahogany	Mahogany Snapper				2 - 20	

The 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. Nevertheless, 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, such as Arrow Crabs, Cleaner Shrimps, Common Octopus and Spiny Lobsters have been previously reported within belt-transects during previous surveys at this reef. Cleaner shrimps and one arrow crab were observed within belt-transects during 2015 (Table 13). One spiny lobster (*Panulirus argus*) was observed outside transects.

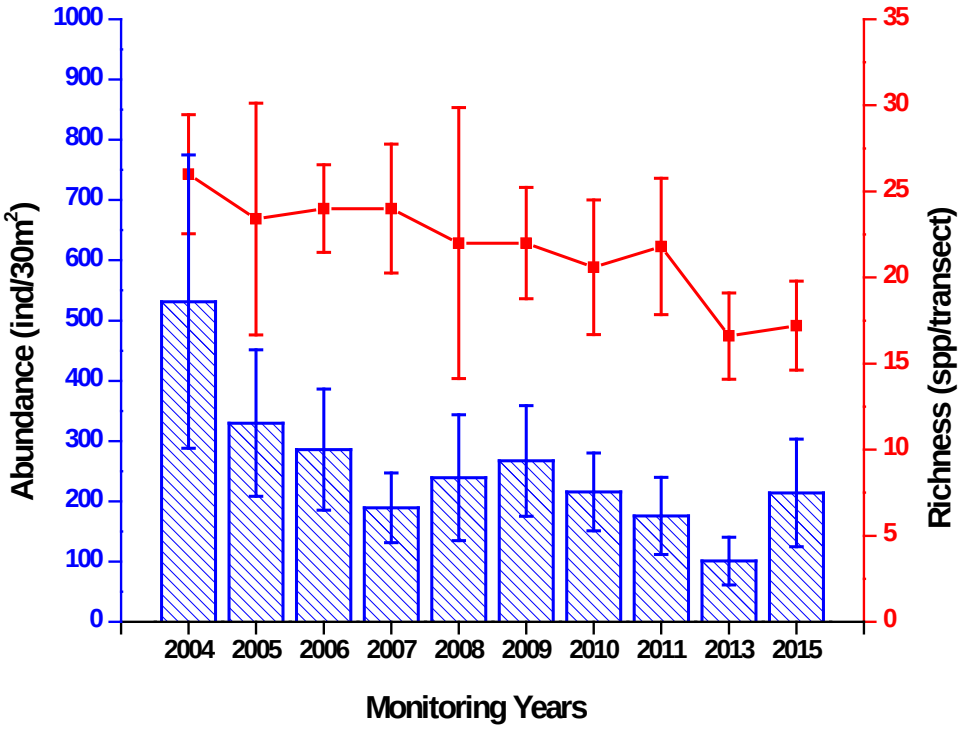
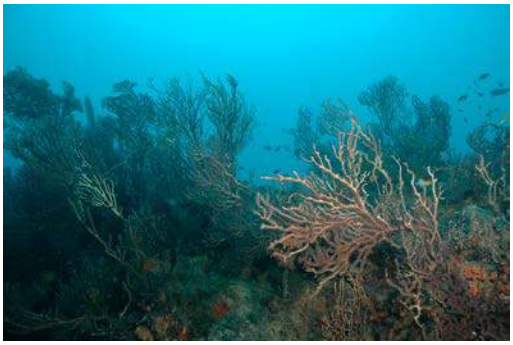


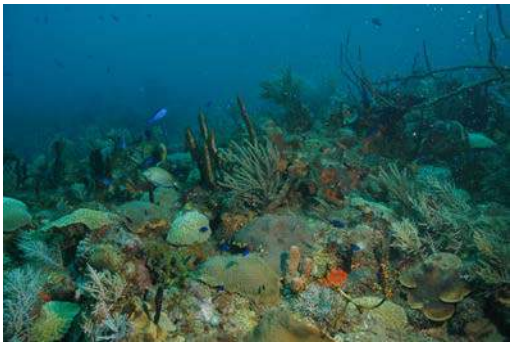
Figure 12. Monitoring trends (2004 – 2015) of fish species richness and abundance at Tres Palmas Shelf Edge Reef, Rincon, 20 m

Table 13. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Shelf-edge Reef, Rincon 20 m. 2015

Depth: 20 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	2	3	4	5	
SPECIES	**COMMON NAME**						
Stenorhynchus seticornis	Arrow Crab	1					**0.2**
Periclimenes pedersoni	Cleaner Shrimp		1	2		1	**0.8**
	TOTALS	1	1	2	0	1	**1.0**

Photo Album 3. Tres Palmas, Rincon Shelf edge Reef





B. Puerto Canoas /Puerto Botes Reefs - Isla Desecheo

Isla Desecheo is an oceanic island in Mona Passage, located approximately nine nautical miles off Rincón, northwest coast of Puerto Rico. The island, which used to be a U. S. Navy shooting range during the Second World War, was designated as a Natural Reserve in 1999. Marine communities at Isla Desecheo are influenced by clear waters, strong currents and seasonally high wave action from North Atlantic winter swells (cold fronts). Coral reefs are established off the west coast at depths between 15 and (at least) 50 m (García-Sais et al., 2005 b). Coral monitoring surveys were performed at depths of 15 and 20 m off Puerto Botes, and at 30 m off Puerto Canoas, on the southwest coast of Isla Desecheo. The baseline monitoring survey for the Puerto Botes Reef at a depth of 20 m was performed during 1999 by García-Sais et al. (2001 b). For Puerto Botes Reef at 15 m and for Puerto Canoas Reef at 30 m the baseline survey was performed during 2004 by García-Sais et al. (2004 a). Figure 13 shows the location of coral reef monitoring stations at Isla Desecheo.

1.0 Shelf-edge Reef Puerto Canoas, 30 m depth

1.1 Sessile-benthic Reef Community

The shelf-edge off Puerto Canoas is at the southwest end of a massive and impressive coral buildup that has developed as a series of patch reef promontories separated by coralline sand deposits. Coral promontories are typically comprised of several very large colonies of Boulder Star Coral (*Orbicella annularis* complex). There are colonies that rise from the bottom at least four meters and extend horizontally more than 5 meters, in some instances merging with other large colonies to form continuous laminar coral formations that are unique in Puerto Rico. Towards the northern end, the shelf-edge reef platform leads to an almost vertical wall with sparse coral growth down to a depth of 40 m. At the southern end, the reef platform ends in an extensive sand deposit that slopes down gently to a depth of about 70 m. Our survey was performed right at the end of the reef on the southern section. Transects were installed at a depth of 25 – 30 m, bordering the edge of three of the larger massive coral promontories. Panoramic views of the shelf edge reef at Puerto Canoas are presented as Photo Album 4.

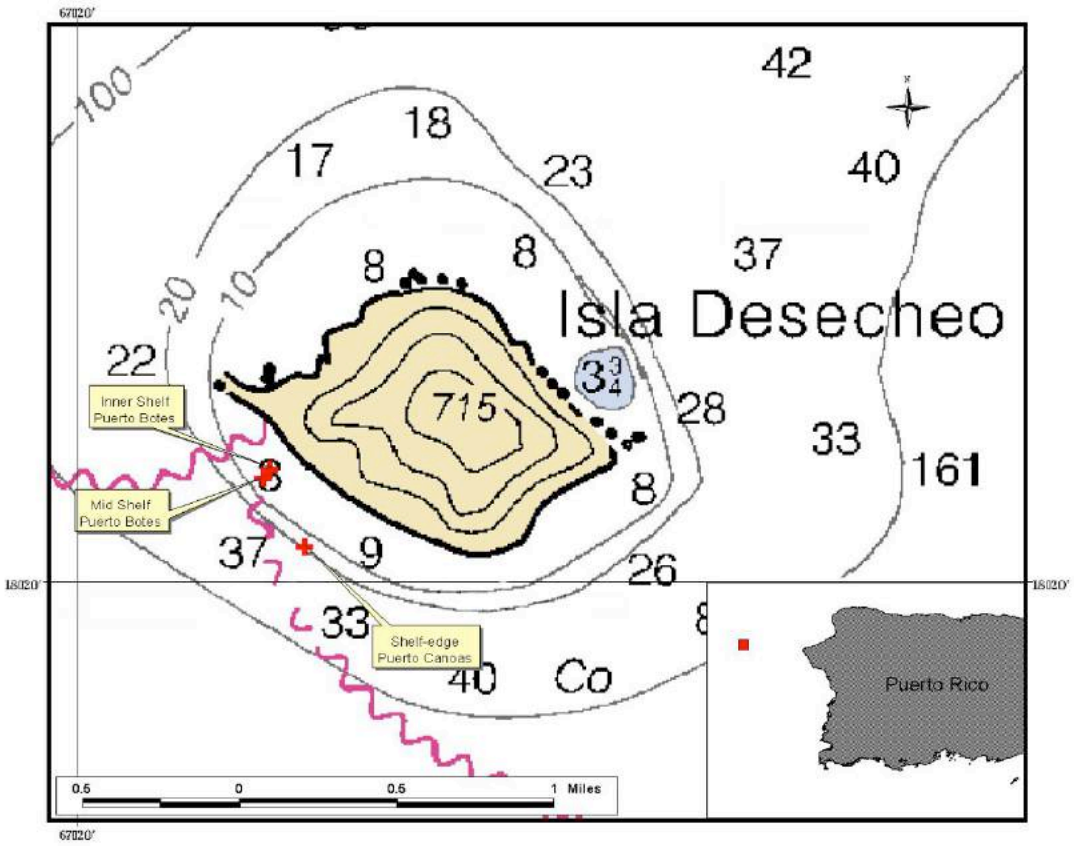


Figure 13. Location of coral reef survey stations at Puerto Canoas/Botes, Isla Desecheo.

Stony corals dominated reef substrate cover by benthic invertebrates along surveyed transects with a mean of 27.8 % (range: 21.9 – 33.3 %). Boulder Star Coral (*Orbicella annularis* complex), with a mean cover of 15.7 % represented 56.5 % of the total stony coral cover. In addition to *O. annularis*, Lettuce Coral (*Agaricia agaricites*) and Mustard-Hill Coral (*Porites astreoides*) were present in at least four transects at the shelf-edge reef of Puerto Canoas (Table 14). A total of 18 species of stony corals were identified, including 12 intersected by line transects. Several colonies of Black Coral, *Anthipathes sp*., and Wire Coral, *Stichopathes sp*. were observed near the base of the reef and within crevices. Soft corals (gorgonians) were not intercepted by transects and are not common at the shelf-edge reef.

Table 14. Percent substrate cover by sessile-benthic categories at Puerto Canoas Reef, Isla Desecheo 30 m. 2015

	1	2	3	4	5	Mean
Rugosity	1.99	2.73	3.59	2.61	3.07	**2.80**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	11.44	6.05	21.63	3.33	11.03	**10.69**
Gap	2.33			0.89		**0.64**
Sand					1.61	**0.32**
Total Abiotic	13.77	6.05	21.63	4.22	12.63	**11.66**
Benthic Algae						
Turf	37.34	20.46	16.48	38.29	20.66	**26.65**
Lobophora variegata	9.68	5.94	11.33	5.66	4.60	**7.44**
CCA	1.63	3.08		5.11	1.07	**2.18**
Dictyota spp.		1.32	1.24		3.53	**1.22**
Fleshy macroalgae	0.58				1.39	**0.40**
Total Benthic Algae	49.24	30.80	29.04	49.06	31.26	**37.88**
Live Corals						
Orbicella annularis complex	5.72	16.17	9.27	16.87	30.62	**15.73**
Agaricia agaricites	5.13	12.43	9.89	2.89	2.36	**6.54**
Porites astreoides	2.33	3.52	2.16	3.77		**2.36**
Colpophyllia natans	5.48	0.66				**1.23**
Meandrina meandrites				2.11		**0.42**
Millepora alcicornis	0.82		0.72		0.32	**0.37**
Montastraea cavernosa				1.44		**0.29**
Porites divaricata	1.40					**0.28**
Stephanocoenia intersepta	1.05		0.31			**0.27**
Porites porites				0.78		**0.16**
Eusmilia fastigiata		0.55				**0.11**
Coral				0.44		**0.09**
Total Live Corals	21.94	33.33	22.35	28.30	33.30	**27.84**
Cyanobacteria	6.88	13.09	12.15	9.21	14.99	**11.27**
Sponge	8.17	16.72	14.83	9.21	7.82	**11.35**

Benthic macroalgae, comprised by an assemblage of turf, fleshy and calcareous types presented a combined substrate cover of 37.9 % along permanent transects. *Lobophora variegata, Padina sp.* and *Ventricaria ventricosa* were some of the most common fleshy macroalgae present. Turf algae, the dominant component of the benthic algae assemblage included an unidentified variety of short filamentous red and brown macroalgae. A slimy red cyanobacterial film was present in all transects with a mean substrate cover of 11.3 % (range: 6.9 – 15.0 %; Table 14).

Encrusting and erect sponges included at least eight species within transects with a mean cover of 9.5 %. An assemblage comprised of several *Agelas* and *Haliclona* spp. was the most prominent sponge taxa at Desecheo 30 m. A small patch of encusting zoanthid, *Trididen*mum *sp*. was present in one transect with low substrate cover. Abiotic cover, mostly associated with reef overhangs averaged 11.7 % and contributed to a mean reef substrate rugosity of 2.8.

Figure 14 shows the annual variations of mean percent cover by the main sessile-benthic categories from the shelf-edge reef at Puerto Canoas. Differences of mean substrate cover by stony corals, sponges and benthic algae between the 2004 baseline characterization and the 2005 monitoring surveys were within 1 % and statistically insignificant. A sharp, statistically significant decline of mean live coral cover was observed between the 2005 (48.07 %) and the 2006 (37.50 %) survey (ANOVA; $p < 0.0001$). The decline of mean live coral cover was largely associated with the dominant reef building species, *Orbicella annularis*, which varied from a mean cover of 32.7 % in 2005 to 24.4 % in 2006 (Figure 15). At the time of the 2006 monitoring survey (mid June), *O. annularis* still showed partially bleached conditions representing 5.7 % of its mean reef substrate cover, equivalent to 23.4 % of the remaining live coral tissue within surveyed transects at 30 m. Since 2006, a mild (statistically insignificant) trend of decreasing live cover was observed until the 2010 survey. A corresponding increment of substrate cover by benthic algae, cyanobacteria, sponges and abiotic categories during this period was noted (Figure 14). A recuperation trend of live coral cover, in part driven by increased cover by *O. annularis* has been measured during the last three monitoring surveys at Desecheo 30 m (Figure 15). Such recuperation trend is still within sampling variability error and was not statistically significant (see Appendix 2).

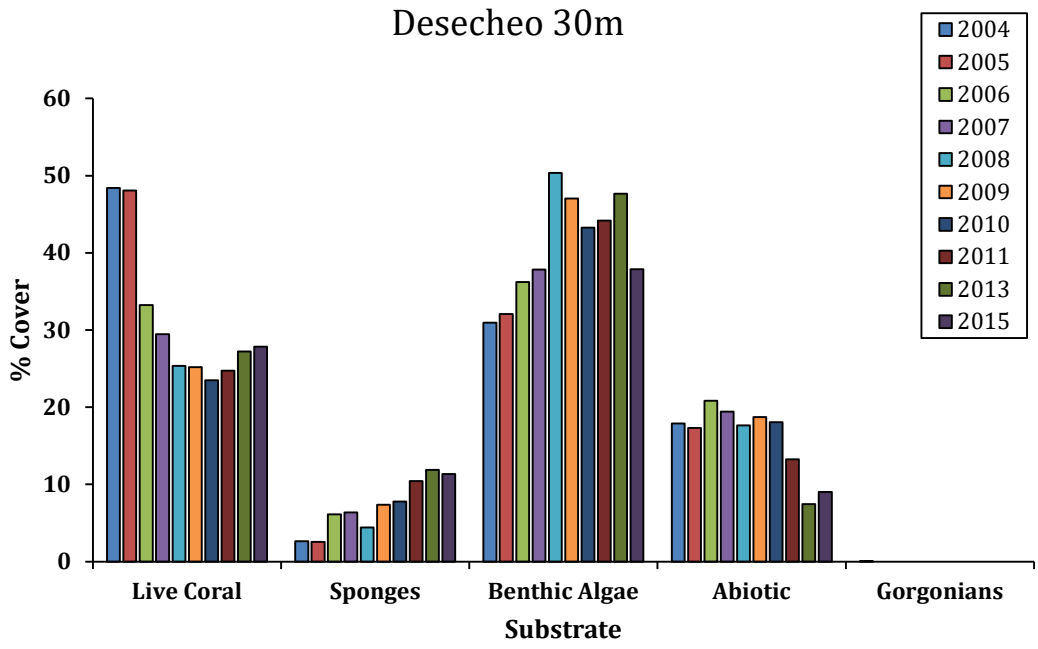


Figure 14. Monitoring trends (2004 -15) of substrate cover by sessile-benthic categories at Puerto Canoas Reef, Desecheo Island – 30 m.

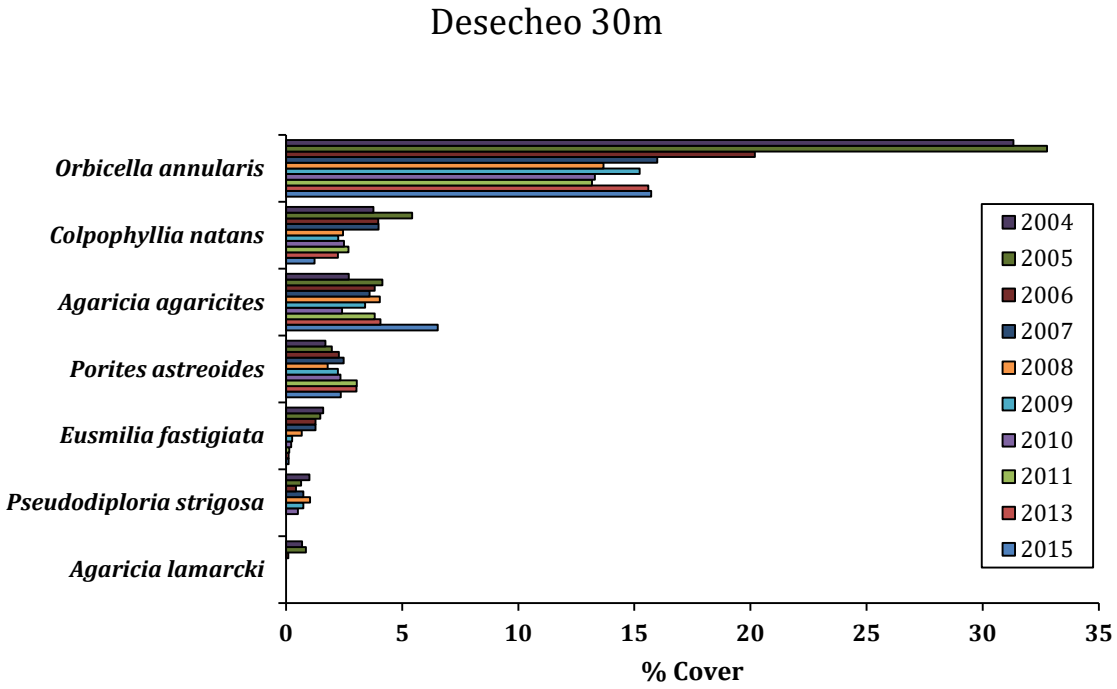


Figure 15. Monitoring trends (2004-15) of mean substrate cover by stony coral species at Puerto Canoas Reef, Desecheo Island – 30 m.

Lettuce Coral, *Agaricia agaricites* and Mustard-Hill Coral, *Porites astreoides* have also shown recuperation trends with small but consistent increments of substrate cover at Desecheo 30 m during the most recent monitoring surveys.

1.2. Fishes and Motile Megabenthic Invertebrates

A total of 97 fish species have been identified at the shelf-edge reef off Puerto Canoas, Isla Desecheo (Appendix 1). Mean abundance of fishes within belt-transects during this 2015 monitoring survey was 394.2 Ind/30 m^2 (range: 287 – 525 Ind/30 m^2). The mean number of species per transect was 23.6 (range: 19 – 29) (Table 15). An assemblage of seven species, including the Masked and Peppermint Gobies, Blue Chromis, Bluehead and Creole Wrasses, Fairy Basslet and Mackerel Scad represented 86.8 % of the total fish abundance within belt-transects. A total of six species were present within all five belt-transects and another 10 were present in four. The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 128.0 Ind/30 m^2 (range: 31 – 250 Ind/30 m^2), representing 32.5 % of the total (Table 15). This goby forms swarms of variable densities beneath coral ledges and crevices of the reef. Large streaming schools of adult Creole Wrasse were observed throughout the water column, making frequent incursions over the reef. Swarms of early juvenile Creole Wrasse were also observed close tio the reef top. Creole Wrasse is a zooplanktivore that serves as forage for pelagic predators, such as Cero Mackerels, Blue Runners, and Barracudas observed during outside transects in this reef. The Blue and Brown Chromis, Masked Goby and Bicolor Damselfish are also important zooplanktivores that were common over coral heads closer to the reef. Dense swarms of mysid shrimps were present below ledges and on crevices in the reef. These small shrimps appear to be important forage for zooplanktivorous fishes. Size distributions of fishes observed within extended belt-transect areas are indicative that this reef serves largely as habitat for adult fish populations (Table 16).

Variations of fish abundance and species richness between monitoring surveys at Puerto Canoas 30 m are presented in Figure 16. Between 2004 and 2008, mean fish abundance fluctuated between 400 – 500 Ind/30 m^2 to stand as one of the reefs with highest fish abundance studied in Puerto Rico. During 2009 a declining trend of fish abundance continued until 2010, but record high abundance was observed during the 2013 survey driven by abundance of Creole Wrasse. Lower species richness and

Table 15. Taxonomic composition and abundance of fishes within belt-transects at Puerto Canoas Reef, 30 m, Isla Desecheo. 2015

Depth: 30m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	45	189	31	125	250	**128.0**
Clepticus parrae	Creole Wrasse	102	63	15	78	75	**66.6**
Coryphopterus lipernes	Peppermint Goby	17	64	53	32	62	**45.6**
Gramma loreto	Fairy Basslet	28	69	83	37	0	**43.4**
Chromis cyanea	Blue Chromis	32	28	33	25	53	**34.2**
Decapturus macarelus	Mackrel scad	60	0	0	0	15	**15.0**
Thalassoma bifasciatum	Bluehead Wrasse	1	15	12	5	15	**9.6**
Chromis multilineata	Brown Chromis	22	0	10	8	5	**9.0**
Stegastes partitus	Bicolor Damselfish	18	4	9	5	8	**8.8**
Halichoeres garnoti	Yellow-head Wrasse	4	0	9	3	4	**4.0**
Gobiosoma evelynae	Sharknose Goby	2	0	6	7	1	**3.2**
Chromis	Sunshine Chromis	0	0	5	0	10	**3.0**
Paranthias fucifer	Creole Fish	1	2	0	1	6	**2.0**
Scarus iserti	Stripped Parrotfish	2	0	2	3	2	**1.8**
Halichoeres maculipinna	Clown Wrasse	2	0	0	3	4	**1.8**
Epinephelus cruentatus	Graysby	4	2	2	1	0	**1.8**
Sparisoma aurofrenatum	Redband Parrotfish	3	2	0	2	1	**1.6**
Sparisoma viride	Stoplight Parrotfish	2	1	2	2	0	**1.4**
Kyphosus bermudensis	Sea Chub	1	0	1	2	2	**1.2**
Melichthys niger	Black Durgon	1	1	3	0	1	**1.2**
Stegastes leucostictus	Beugregory	2	4	0	0	0	**1.2**
Ptoris volitans	Lionfish	2	1	2	0	0	**1.0**
Canthigaster rostrata	Caribbean Puffer	1	1	3	0	0	**1.0**
Acanthurus coeruleus	Blue Tang	1	1	1	1	0	**0.8**
Chaetodon aculeatus	Longsnout Butterflyfish	0	2	1	0	1	**0.8**
Epinaphelus fulva	Coney	1	0	0	0	2	**0.6**
Myripristis jacobus	Blackbar Soldierfish	0	0	1	0	2	**0.6**
Muilloides martinicus	Yellowfih Goatfish	0	3	0	0	0	**0.6**
Muilloides martinicus	Yellowfih Goatfish	3	0	0	0	0	**0.6**
Epinephelus cruentatus	Graysby	0	0	0	0	2	**0.4**
Microspathodon chrysurus	Yellowtail Damselfish	1	0	0	1	0	**0.4**
Neoniphon marianus	Longspine Squirrelfish	0	1	0	0	1	**0.4**
Chaetodon capistratus	Four-eye Butterflyfish	0	0	2	0	0	**0.4**
Stegastes dorsopunicans	Dusky Damselfish	2	0	0	0	0	**0.4**
Abudefduf sexatilis	Sargent Mayor	0	0	0	0	1	0.2

Table 15. continued

Caranx ruber	Bar Jack	1	0	0	0	0	**0.2**
Holocentrus rufus	Squirrelfish	0	1	0	0	0	**0.2**
Bodianus rufus	Spanish Hogfish	0	1	0	0	0	**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish	0	0	1	0	0	**0.2**
Scomberomorus regalis	Cero	0	0	0	0	1	**0.2**
Holacanthus tricolor	Rock Beauty	0	1	0	0	0	**0.2**
Ginglymostoma cirratum	Nurse Shark	1	0	0	0	0	**0.2**
Sparisoma chrysopterum	Redtail Parrotfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**362**	**456**	**287**	**341**	**525**	**394.2**
	TOTAL SPECIES	**29**	**22**	**23**	**19**	**25**	**23.6**

abundance were detected between the 2010 and all other surveys (Figure 16). The largest abundance decline was associated with Masked Goby, but Fairy Basslet and Blue Chromis also presented lower abundances during 2010, relative to 2009 and previous surveys. Such declines of abundance could have been associated to predation pressure imposed by Lionfishes (*Pterois sp.*), but the peak abundance measured during the 2013 survey suggests that recruitment dynamics play an important role regulating population abundance of zooplanktivorous fishes.

The fish community structure at shelf-edge reef off Puerto Canoas was characterized by the high relative abundance of pelagic and demersal zooplanktivores, which comprised approximately 80 % of the total individuals within transects. These serve as prey for large demersal and pelagic predators, such as Nassau and Yellowfin Groupers, Barracudas, Cero Mackerels, Blue Runners, and Black Jacks reported in previous surveys (Garcia-Sais et al. 2014). Yellowtail, Mahogany, Dog and Schoolmaster Snappers, Red Hind, Coney and Queen Triggerfish have been previously reported in full adult sizes. A large variety of small invertebrate feeders were present (c.a. 15% of total within transects), including wrasses, gobies, goatfishes and squirrelfishes, among others. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous assemblage, but represented a minor component (< 2%) of the reef fish community structure. Commercially important species for the aquarium trade market, such as the Fairy Basslet (*Gramma loreto*), Queen Angelfish (*Holacanthus ciliaris*), Rock Beauty (*Holacanthus tricolor*), Blue Chromis (*Chromis cyanea*), Yellow-head Jawfish (*Opistognathus aurifrons*) and Peppermint Bass (*Liopropoma rubre*) were common.

Table 16. Taxonomic composition, density and size of fishes within 20 m x 3 m belt-transects at Puerto Canoas Reef, Isla Desecheo 30m. 2015

		TRANSECTS				
		1	2	3	4	5
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped Parrotfish	1 - 10	1 - 35	2 - 7	3 - 15	2-10
		1 - 13				
Sparisoma viride	Stoplight Parrotfish	1 - 35	1 - 30	1 - 7		
			1 - 40	1 - 10		
Sparisoma aurofrenatum	Redband Parrotfish	1 - 10	1 - 12		2 - 16	1-15
		1 - 15	1 - 20			
		1 - 20				
Epinephelus fulva	Coney	1 - 10				
Epinephelus cruentatus	Graysby	1 - 10	1 - 15	1 - 15	1 - 10	1-15
			1 - 20	1 - 20		1-20
Ptoris volitans	Lionfish	1 - 15	1 - 35	2 - 12		
		1 - 30		2 - 38		
Lutjanus apodus	Schoolmaster	6 - 30			1 - 35	10 -30
	Snapper	8 - 40				10 -40
		6 - 50				3-50
Ginglymostoma cirratum	Nurse Shark			1 - 180		
Scomberomorus regalis	Cero	1 - 30				
Mycteroperca venenosa	Yellowfin Grouper		1 - 80			
Sparisoma rubripinne	Yellowtail Parrotfish				1 - 15	
Sparisoma chrysopterum	Redtail Parrotfish					1-35

Arrow Crabs, Cleaner Shrimps and one Spiny Lobster were the motile megabenthic invertebrates observed within belt-transects during the 2015 survey (Table 17). Several Queen Conch, *Strombus gigas* and one Common Octopus, *Octopus vulgaris* were observed outside transects.

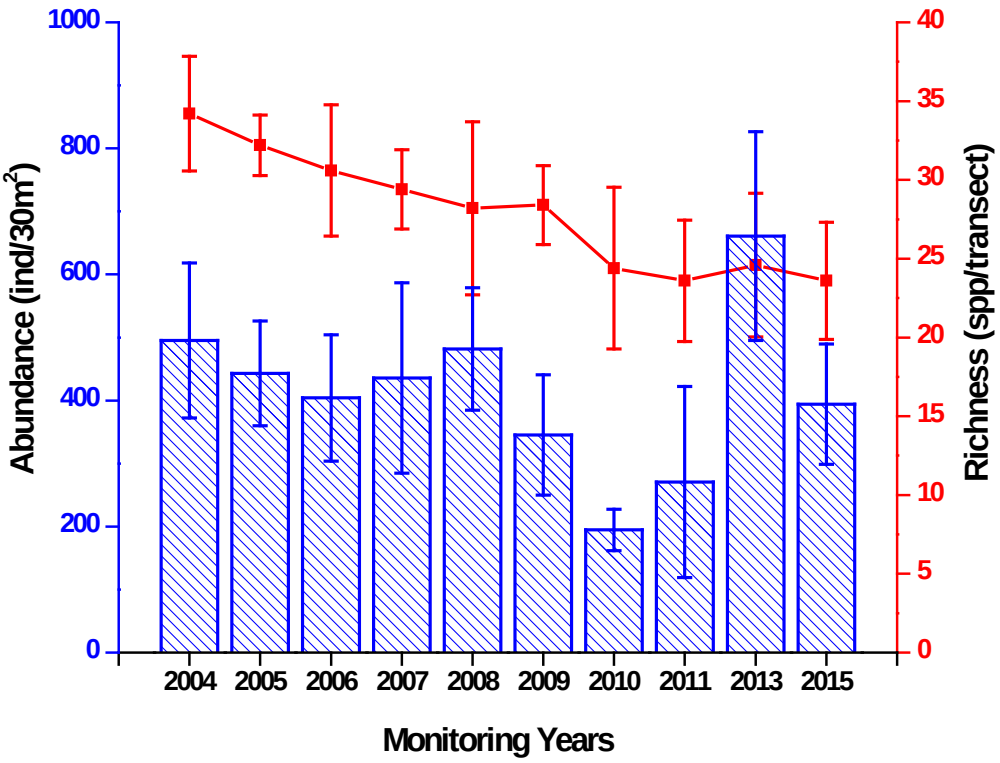


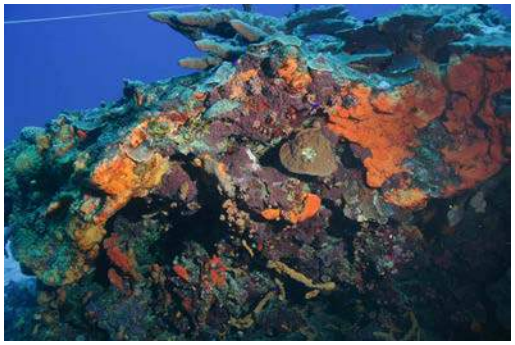
Figure 16. Monitoring trends (2004 – 2015) of fish species richness and abundance at Puerto Canoas Reef 30 m, Isla desecheo. September 2013.

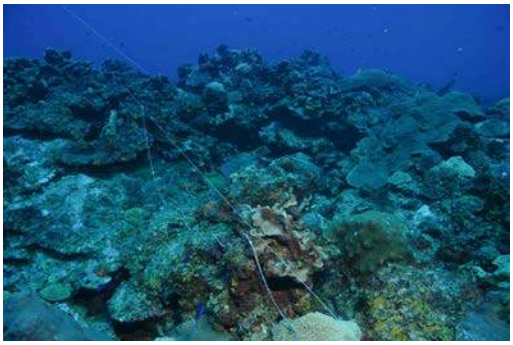
Table 17. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Puerto Canoas Reef, Isla Desecheo 30m, 2015

Depth: 25 – 30 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						
Stenorhynchus seticornis	Arrow crab			1		1	**0.4**
Panulirus argus	Spiny lobster		1				**0.2**
Stenopus hispidus	Banded coral Shrimp		1				**0.2**
	TOTALS	**0**	**2**	**1**	**0**	**1**	**0.8**

Photo Album 4. Desecheo, Puerto Canoas

Shelf Edge Reef





2.0 Mid-shelf Patch Reef - Puerto Botes

2.1 Sessile-benthic Reef Community

A series of large submerged reef patches of massive, branching and encrusting coral buildup occupy most of the mid-shelf section off Puerto Botes at depths between 17 -23 meters on the west coast of Isla Desecheo. The coral reef system is exuberant, with large stony corals growing close together and forming large promontories that provide very high topographic relief. At some points, sand channels cut through the sloping terrace of the reef towards the shelf-edge. Permanent transects were installed over two adjacent patch reef promontories separated by a narrow sand channel. The five transects lie close to the border of each patch reef at depths between 17 -19 m. The initial baseline characterization was performed in June, 2000 (García-Sais et al., 2001). This is the 11th monitoring survey of the mid-shelf patch reefs at Puerto Botes. Digital photos of the mid shelf patch reef at Puerto Botes are shown as Photo Album 5.

A total of 23 stony corals, including 11 intersected by line transects were identified during this 2015 survey. Live coral cover averaged 17.5 % (range (8.9 – 46.5 %) along transects (Table 18). Finger Coral, *Porites porites* was the species of highest mean percent substrate cover with a mean of 8.3 % (range: 0 – 38.0 %), representing a 2.6 fold increase from the 2013 survey. It was present as a large single colony and one smaller colony in two of the five transects surveyed. Boulder Star Coral, *Orbicella annularis* (complex), Lettuce Coral, *Agaricia agaricites*, and Mustard Hill Coral, *P. astreoides* comprised (with Finger Coral) the most prominent coral assemblage along transects representing 84.5 % of the total cover by live corals at Puerto Botes.

Recently dead corals, indicative of continued reef degradation were observed at this reef since the massive bleaching event of 2005-06 until 2009. The most affected was *O. annularis*, but the declining trend included other species as well. Mild fluctuations of reef substrate cover by *O. annularis* were measured between 2009 and the 2013 survey, but these were within sampling variability error (Appendix 2). During the present 2015 monitoring survey, *O. annularis* cover increased from 1.5 % in 2013 to 3.7 %. The increment represents a potential trend towards recuperation, but the absolute increment, although relatively large is within sampling variability error.

Table 18. Percent substrate cover by sessile-benthic categories at Puerto Botes Reef, Isla Desecheo 20 m. 2015

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.01	0.81	2.53	0.01	2.52	**1.58**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	1.05		6.48	5.59	2.91	**3.21**
Sand	1.63		0.34	2.52	0.89	**1.08**
Total Abiotic	2.68		6.82	8.11	3.80	**4.28**
Benthic Algae						
Turf	44.64	41.97	41.12	21.54	48.55	**39.56**
Fleshy macroalgae	22.38	39.12	23.69	11.05	26.40	**24.53**
CCA	2.80	2.33	2.35	8.67		**3.23**
Lobophora variegata	5.48		4.02		4.03	**2.71**
Dictyota spp.	1.40					**0.28**
Total Benthic Algae	76.69	83.42	71.17	41.26	78.30	**70.17**
Live Corals						
Porites porites				38.04	3.47	**8.30**
Orbicella annularis complex	5.94	3.76	3.91	3.22	1.79	**3.72**
Porites astreoides	2.10	3.11	1.79	1.68	0.45	**1.82**
Agaricia agaricites	3.61			0.84	0.45	**0.98**
Eusmilia fastigiata		3.24	1.45			**0.94**
Meandrina meandrites			1.79		0.67	**0.49**
Pseudodiploria labyrinthiformis				1.96		**0.39**
Montastraea cavernosa					1.90	**0.38**
Stephanocoenia intersepta					0.67	**0.13**
Millepora alcicornis	0.47					**0.09**
Siderastrea siderea				0.42		**0.08**
Total Live Corals	12.12	10.10	8.94	46.15	10.07	**17.48**
Cyanobacteria	7.69	2.33	3.46	1.40	3.58	**3.69**
Sponges	0.82	4.15	9.61	3.08	4.25	**4.38**

Erect and encrusting sponges presented a mean substrate cover of 4.4 % within line transects. *Agelas citrina* and *A. conifera* were visually the most abundant along transects surveyed. Reef hard-ground substrates not colonized by stony corals or sponges were mostly overgrown by a combination of fleshy macroalgae *Lobophora variegata, Dictyota sp., Padina sp*.) and turf algae (mean cover: 39.6 %). The assemblage of benthic algae represented the main substrate category at Puerto Botes with a combined mean cover of 70.2 % (Table 18). Cyanobacterial films were present in all five transects with a mean cover of 3.7 (range: 1.4 – 7.7 %). Erect gorgonians were not intersected by line transects. Reef overhangs, largely associated with skeletal buildups of *O. annularis* averaged 3.2 % of the reef substrate cover and contributed to the reef rugosity of 1.6 m.

From the initial baseline characterization of 2000 until the 2005 survey, stony corals represented the most prominent sessile-benthic component of the mid-shelf reef at Puerto Botes with a mean reef substrate cover that fluctuated slightly between 47.2 % and 48.0 %. Differences of live coral cover between monitoring surveys were minimal and statistically insignificant until the 2006 monitoring survey when live coral cover declined sharply to a mean of 22.4 %, a loss of 53.4% from the mean live coral cover in 2005. Live coral cover continued its consistent decline until 2013 to a historical minimum of 10.9 %. Differences of live coral during the 2000 – 2005 and the 2006 – 2015 monitoring surveys were statistically significant (ANOVA; $p < 0.0001$) reflecting the acute degradation experienced by the reef system after October 2005 (see Appendix 2). The 37 % increment in live coral during the present 2015 survey may represent a shift in the degradation trend. Nevertheless, total live coral cover it is mostly related to the increase in cover of Finger Coral, *Porites porites*, a especies that has previously shown marked annual fluctuations (Figure 17).

The sharp downfall of live coral at Puerto Botes Reef was triggered by the massive coral bleaching event reported for Puerto Rico and the USVI that started during late September through October 2005 (García et al., 2008; Rothenberger et al., 2008) and lingering effects that have carried further coral mortality up to the 2013 monitoring survey. The bleaching event affected several coral species in variable magnitude, but was mostly detrimental to the dominant species in terms of substrate cover, the Boulder Star Coral, *Orbicella annularis* (complex). This species declined in substrate cover from

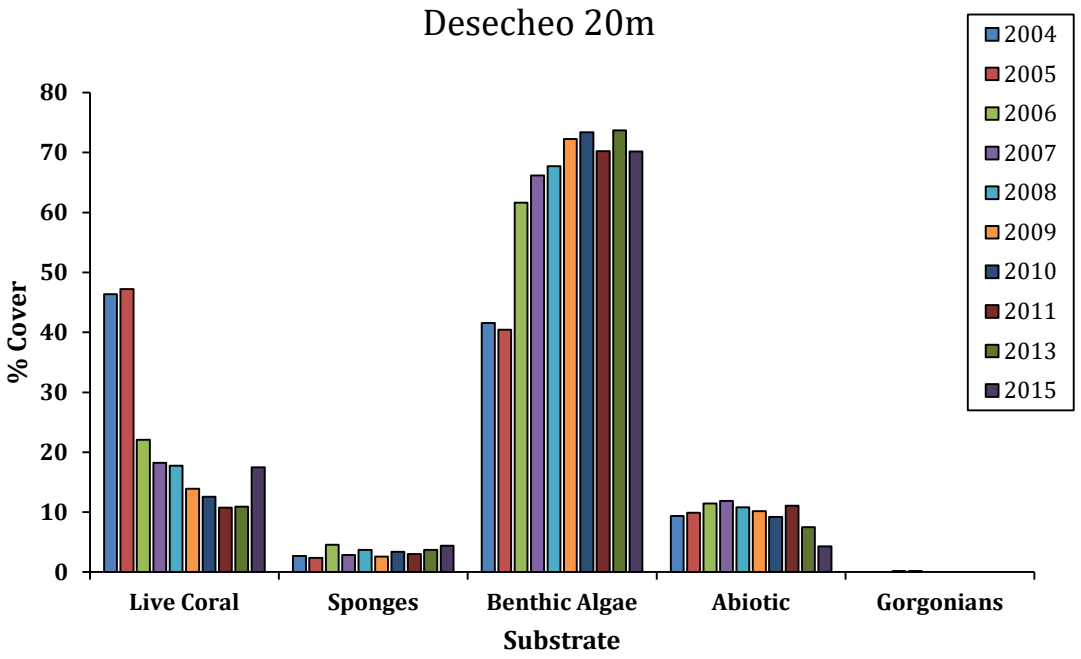


Figure 17. Monitoring trends (2000 - 15) of mean substrate cover by sessile-benthic categories at Puerto Botes Reef, Desecheo Island – 20 m.

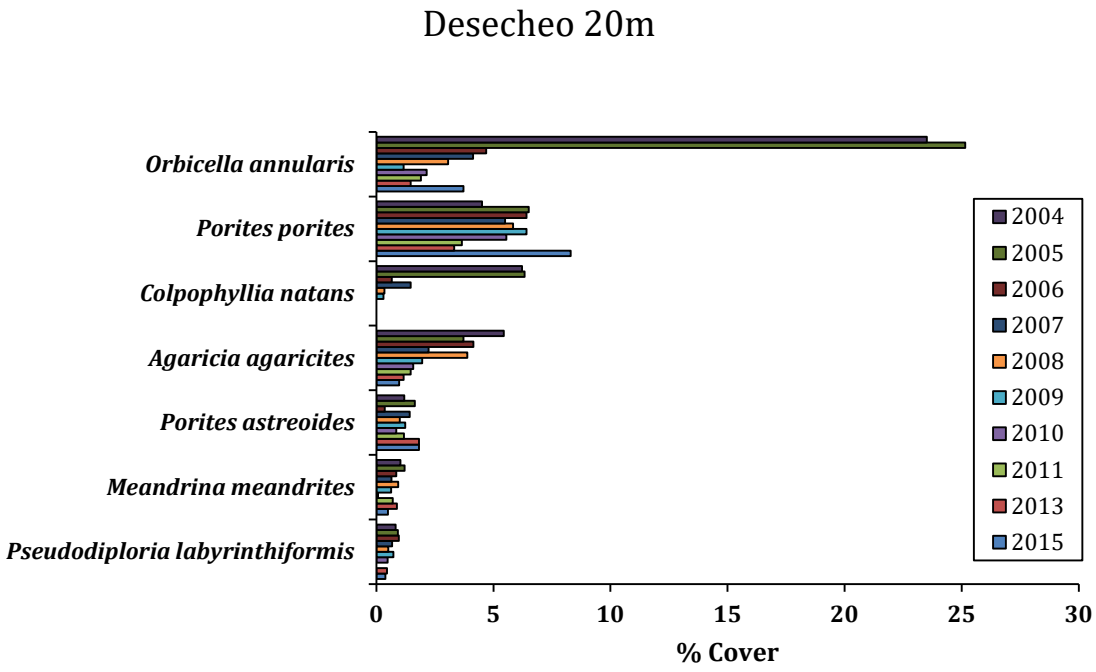


Figure 18. Monitoring trends (2000 – 15) of mean substrate cover by stony coral species at Puerto Botes Reef, Desecheo Island – 20 m.

a mean of 25.2% in 2005 to a mean of 1.2 in 2009 (Figure 18), a statistically significant reduction (ANOVA; p = < 0.001). Reef substrate cover by Boulder
Star Coral represented more than 53 % of the total cover by stony corals at Puerto Botes Mid-shelf Reef. Thus, its collapse after 2005 monitoring survey would be expected to have a profound ecological impact upon the coral reef system at Puerto Botes. Due to the marked decline of Boulder Star Coral, Finger Coral now stands as the main coral species in terms of live coral cover, which represents a taxonomic shift in the sessile-benthic community structure of the reef.

Benthic algae, seemingly the fastest growing component of the sessile-benthos at Puerto Botes Reef increased its substrate cover by 34.6 % between the 2005 and the 2006 monitoring surveys (Figure 17), colonizing recently dead coral sections. An additional increment in cover by benthic algae was measured during the 2007, proportional to the observed decline of live coral cover for this period. The fleshy brown macroalgal assemblage (particularly *L. variegata* + *Dictyota sp.*) reached its highest reef substrate cover (mean: 40.9 %) in 2013. Thus, the present average cover of 27.5 % represents a considerable reduction of cover by benthic algae, in part associated to coral growth.

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 50 fish species were identified within belt-transects from the mid-shelf patch reefs off Puerto Botes during 2015 (Table 19). During the 11 surveys, a total of 87 diurnal, non-criptic fishes have been reported from this reef (Appendix 1). Mean abundance of fishes within belt-transects was 246.0 Ind/30 m^2 (range: 173 - 433 Ind/30 m^2). The mean number of species per transect was 24.8 (range: 18 - 29). The combined abundance of six species that were present in all five transects surveyed, including the Blue Chromis, Bicolor Damselfish, Bluehead and Creole Wrasses, Masked and Peppermint Gobies represented 81.7 % of the total fish abundance within belt-transects. A total of 16 species were present in at least four transects, indicative of a species rich resident ichthyofauna at this reef site (Table 19). Size distributions of commercially important taxa (Table 20) show that this reef serves as habitat for early juvenile and adult parrotfishes (*Scarus iserti, S. taeniopterus, S. vetula, Sparisoma aurofrenatum, S.*

Table 19. Taxonomic composition and abundance of fishes within belt-transects at Puerto Botes Reef, Isla Desecheo, 20m. 2015

Depth: 20m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Chromis cyanea	Blue Chromis	55	31	23	90	53	**50.4**
Clepticus parrae	Creole Wrasse	21	20	35	110	45	**46.2**
Coryphopterus lipernes	Peppermint Goby	42	4	10	75	21	**30.4**
Coryphopterus personatus	Masked Goby	25	16	25	35	31	**26.4**
Stegastes partitus	Bicolor Damselfish	24	14	21	52	18	**25.8**
Thalassoma bifasciatum	Bluehead Wrasse	15	32	23	21	18	**21.8**
Gobiosoma evelynae	Sharknose Goby	12	1	2	13	7	**7.0**
Gramma loreto	Fairy Basslet	5	6	10	0	6	**5.4**
Halichoeres garnoti	Yellow-head Wrasse	2	12	2	6	0	**4.4**
Chromis multilineata	Brown Chromis	7	8	4	0	0	**3.8**
Scarus iserti	Stripped Parrotfish	0	4	3	8	0	**3.0**
Epinaphelus fulva	Coney	2	5	1	3	0	**2.2**
Acanthurus coeruleus	Blue Tang	1	2	1	1	2	**1.4**
Melichthys niger	Black Durgon	1	1	2	1	2	**1.4**
Microspathodon chrysurus	Yellowtail Damselfish	0	2	1	2	1	**1.2**
Sparisoma aurofrenatum	Redband Parrotfish	2	0	1	2	1	**1.2**
Caranx ruber	Bar Jack	3	1	0	0	1	**1.0**
Neoniphon marianus	Longspine Squirrelfish	0	1	2	2	0	**1.0**
Abudefduf sexatilis	Sargent Mayor	1	1	2	0	0	0.8
Halichoeres maculipinna	Clown Wrasse	0	0	2	1	1	**0.8**
Amblycirrhitus pinos	Redspotted Hawkfish	0	1	1	1	1	**0.8**
Muilloides martinicus	Yellowfih Goatfish	3	0	0	0	0	**0.6**
Haemulon flavolineatum	French Grunt	0	1	0	1	1	**0.6**
Ptoris volitans	Lionfish	0	0	3	0	0	**0.6**
Stegastes leucostictus	Beugregory	0	0	0	2	1	**0.6**
Canthigaster rostrata	Caribbean Puffer	0	2	0	1	0	**0.6**
Lactophrys triqueter	Smooth Trunkfish	0	0	1	1	1	**0.6**
Kyphosus bermudensis	Sea Chub	0	1	1	0	0	**0.4**
Sparisoma viride	Stoplight Parrotfish	0	0	0	0	2	**0.4**
Holocentrus rufus	Squirrelfish	0	0	1	0	1	**0.4**
Bodianus rufus	Spanish Hogfish	0	2	0	0	0	**0.4**
Scomberomorus regalis	Cero	0	0	0	0	2	**0.4**
Holocanthus ciliaris	Queen Angelfish	0	1	1	0	0	**0.4**
Acanthemblemaria aspera	Roughead Blenny	0	0	2	0	0	**0.4**

Table 19. continued

Haemulon melanurum	Cottonwick Grunt	0	0	2	0	0	**0.4**
Myripristis jacobus	Blackbar Soldierfish	0	0	0	1	0	**0.2**
Acanthurus chirurgus	Doctorfish	0	0	0	0	1	**0.2**
Scarus taeniopterus	Princess Parrotfish	0	0	0	1	0	**0.2**
Serranus tigrinus	Harlequin Bass	0	0	0	1	0	**0.2**
Lutjanus apodus	Schoolmaster Snapper	0	1	0	0	0	**0.2**
Haemulon macrustomus	Smanish Grunt	0	0	1	0	0	**0.2**
Ocyurus crysurus	Yellowtail Snapper	0	1	0	0	0	**0.2**
Epinephelus cruentatus	Graysby	0	1	0	0	0	**0.2**
Ginglymostoma cirratum	Nurse Shark	0	1	0	0	0	**0.2**
Alostumus maculatus	Trumpetfish	0	0	0	1	0	**0.2**
Pomacanthus paru	French Angelfish	0	0	1	0	0	**0.2**
Chaetodon aculeatus	Longsnout Butterflyfish	0	0	0	0	1	**0.2**
Equetus lanceolatus	Highhat	0	0	0	1	0	**0.2**
Scarus vetula	Queen Parrotfish	1	0	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**222**	**173**	**184**	**433**	**218**	**246**
	TOTAL SPECIES	**18**	**28**	**29**	**26**	**23**	**24.8**

viride), coneys (*Epinephelus fulva*), snappers (*L. apodus, L. mahogony*) and the residential and foraging habitat for full adult Queen Triggerfish, Yellowfin Grouper and Nurse Sharks (*Balistes vetula, Mycteroperca venenosa, Ginglymostoma cirratum*). The later statement applies for other snappers, groupers and sharks previously reported from surveys at this reef (Garcia-Sais et al., 2014). Lionfish (*Pterois sp*) were only observed in large adult sizes (Table 20).

Annual monitoring trends of fish species richness and abundance surveyed within belt-transects are presented in Figure 19. Mean abundance at 246.0 Ind/30 m^2 is within the upper range of previous surveys during the 11 year monitoring program. Fish species richness during the 2015 survey (e.g. 24.8 spp/transect) fell within the historical range recorded since the baseline survey in 2000 (species richness range: 21 - 28 species per transect). The 50 total species identified within the 5 belt-transect set is the highest recorded in the monitoring program. Differences of species richness and abundance between surveys were not statistically significant (ANOVA; $p > 0.05$, see Appendices 3 and 4).

The mid-shelf reef off Puerto Botes presented a fish community strongly driven by pelagic (Chromis spp, Creole Wrasse) and demersal (Masked Goby, Bicolor Damselfish) zooplanktivores species which comprised approximately 62 % of the total individuals within transects. Pelagic schools of adult Creole Wrasse (15 – 25 individuals) were observed throughout the water column, making frequent incursions over the reef. Schools of post-recruitment Creole Wrasse were observed intermixed with post-recruitment Blue Chromis close to the reef coral heads. Both of these fish taxa serve as forage for large pelagic predators, such as Cero Mackerels, Black Jacks and Great Barracudas observed during previous ASEC surveys in this reef (Garcia-Sais et al., 2015). Dense swarms of mysid shrimps were present below ledges and on crevices. These shrimps appear to be important forage for the demersal zooplanktivorous fishes.

A large variety of small invertebrate feeders were present (30 % of total individuals within transects), including wrasses, gobies, goatfishes and squirrelfishes, among others. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous assemblage, but represented less than 5 % of the total individuals within belt-transects.

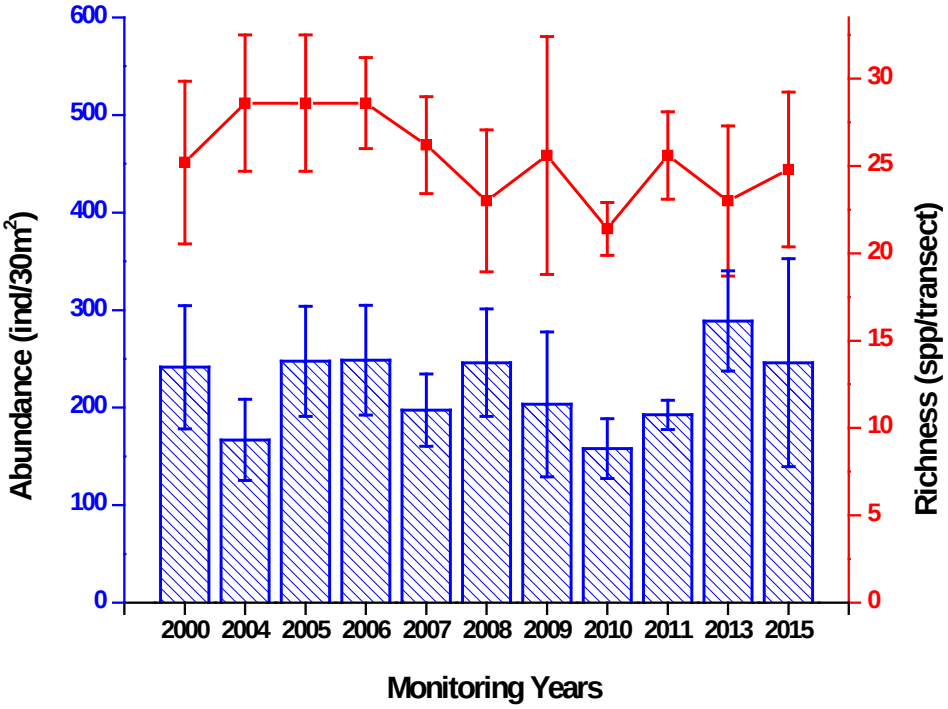


Figure 19. Monitoring trends (2000 – 2015) of fish species richness and abundance at the Mid-Shelf Reef, Puerto Botes, 20 m, Isla Desecheo.

Table 20. Taxonomic composition, density and size of fishes within 20 m x 3 m belt-transects at Puerto Botes Reef, Isla Desecheo 20m. 2015

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped Parrotfish		4 - 15	3 - 7	8 - 5	
			1 - 25		1 - 15	
Sparisoma viride	Stoplight Parrotfish			1 - 40	1 - 15	1-15
						1-40
Sparisoma aurofrenatum	Redband Parrotfish	1 - 15		1 - 5	1 - 10	1-20
		2 - 20			1 - 20	
Ocyurus chrysurus	Yellowtail Snapper		1 - 30			
Epinephelus fulva	Coney	1 - 7		1 - 10	1 - 7	
		1 - 15		1 - 15	3 - 15	
Epinephelus cruentatus	Graysby		1 - 20			
Ptoris volitans	Lionfish			1 - 25		
				2 - 30		
Scarus taeniopterus	Princess Parrotfish				1 - 10	
Lutjanus apodus	Schoolmaster Snapper		1 - 30			1-30
Balistes vetula	Queen Triggerfish		1 - 40			
Scarus vetula	Queen Parrotfish	1 - 40				
Ginglymostoma cirratum	Nurse Shark			1 - 150		
Scomberomorus regalis	Cero					1-40
						1-45
Mycteroperca venenosa	Yellowfin Grouper		1 - 80			

Commercially important species for the aquarium trade market, such as the Fairy Basslet (*Gramma loreto*), Queen Angelfish (*Holacanthus ciliaris*), Rock Beauty (*Holacanthus tricolor*), Blue Chromis (*Chromis cyanea*), Yellow-head Jawfish (*Opistognathus aurifrons*) and Peppermint Bass (*Liopropoma rubre*) were common. Lionfishes were observed within belt-transects and also outside transects, which indicates that they are established in this reef. Interestingly, their presence in the reef coincides with high fish abundance and species richness at Puerto Botes, suggesting that predation pressure by Lionfish is not having a noticeable effect at the fish community level.

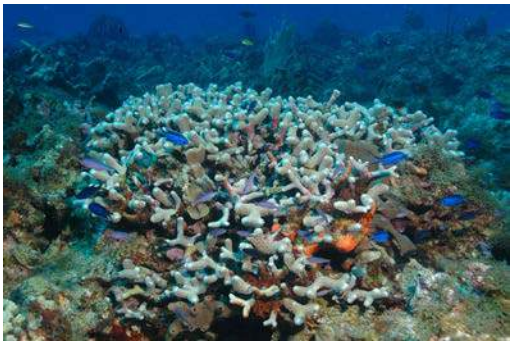
Motile, megabenthic invertebrates were represented by Arrow Crabs, Banded Coral and Cleaner Shrimps and one Queen Conch within belt-transects (Table 21). Spiny Lobsters (*Panulirus argus*), Sponge Brittle Stars (*Ophiothrix suensoni*) and Long-Spined Urchin (*Diadema antillarum*) were observed outside transects.

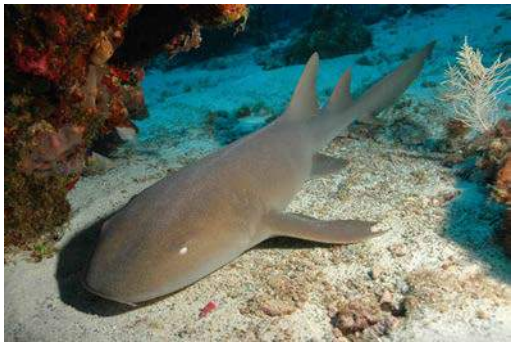
Table 21. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Puerto Botes Mid-shelf Reef. Isla Desecheo 20m, 2015

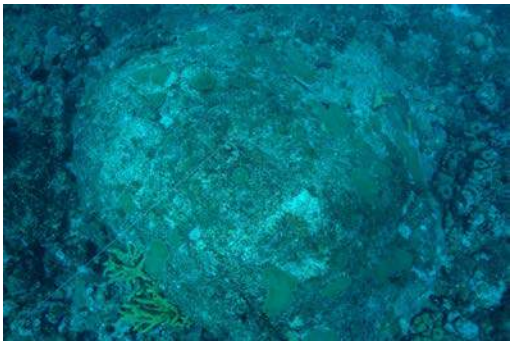
		TRANSECTS					
Depth: 20 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Stenorhynchus seticornis	Arrow Crab					1	**0.2**
Strombus gigas	Queen Conch	1					**0.2**
Periclimenes pedersoni	Cleaner Shrimp		2	1	1		**0.8**
Stenopus hispidus	Banded coral shrimp	1			1	1	**0.6**
	TOTALS	**2**	**2**	**1**	**2**	**2**	**1.8**

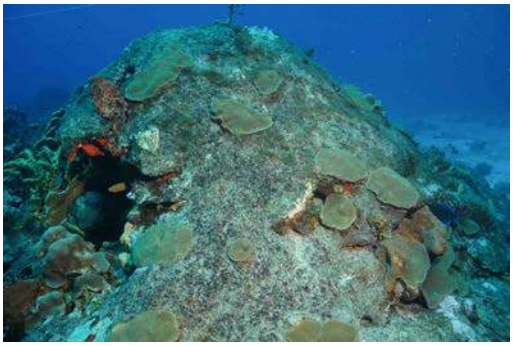
Photo Album 5. Desecheo, Puerto Botes

Mid Shelf Patch Reef









3.0 Inner Shelf Reefs – Puerto Botes

3.1 Sessile-benthic Reef Community

The rocky shoreline off Puerto Botes leads to a gently sloping hard ground terrace colonized by corals and other encrusting biota. With increasing depth, the hard ground terrace breaks into several large promontories with a marked increment of stony coral buildup. The southern section of the terrace presents a more abrupt slope from the shoreline towards deeper waters and is heavily colonized by soft corals (gorgonians). Our survey was performed along the northern section. Five permanent transects were installed almost parallel to each other oriented north-south. Panoramic views of the inner shelf reef at Puerto Botes are presented as Photo Album 6.

A total of 19 stony corals, including 13 intersected by line transects were identified during this 2015 monitoring survey at Puerto Botes Inner Reef. Stony corals presented a mean substrate cover of 14.0 % (range: 7.8 – 19.0 %). Mustard-Hill Coral, *Porites astreoides*, Boulder Star Coral, *Orbicella annularis* (complex), Great Star Coral, *Montastraea cavernosa*, and Massive Starlet Coral, *Siderastrea siderea* comprised the main coral assemblage with a combined reef substrate cover of 10.5 %, representative of 75.3 % of the total live coral cover in the reef (Table 22). Corals typically exhibited encrusting growth and small to moderate colony sizes, perhaps as adaptations to the strong wave and surge action seasonally acting at the shallower reef zone. Total abiotic cover averaged 9.04 %, mostly driven by included wide sand pockets (8.7 %). Sponges contributed a mean substrate cover of 4.5 %. The dominant assemblage included *Xestospongia muta*, *Haliclona sp*., *Aplysina spp*. and *Agelas spp*.

Benthic algae, represented by a mixed assemblage of turf, fleshy (brown and red), and coralline macroalgae were the main sessile-benthic reef component in terms of substrate cover with a combined mean of 71.3 % (Table 22). Turf algae, a mixed assemblage of short articulated and brown macroalgae were the dominant component of the benthic algae with a mean cover of 45.0 %. Fleshy macroalgae, mostly comprised by *Dictyota sp*., *Lobophora variegata* and *Padina sp*. contributed with a combined reef substrate cover of 25.6 %. Both turf and fleshy macroalgae were observed overgrowing dead sections of coral colonies in the reef.

Table 22. Percent substrate cover by sessile-benthic categories at Puerto Botes Reef, Isla Desecheo 15 m. 2015

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.22	2.59	2.75	2.01	2.82	**2.48**
SUBSTRATE CATEGORY						
Abiotic						
Sand	8.02	10.23	9.33	13.29	2.62	**8.70**
Reef overhang	1.72					**0.34**
Total Abiotic	9.74	10.23	9.33	13.29	2.62	**9.04**
Benthic Algae						
Turf	38.83	45.72	55.76	43.59	41.27	**45.03**
Fleshy macroalgae	17.87	26.14	12.95	25.06	34.83	**23.37**
Lobophora variegata			10.98			**2.20**
CCA	1.26		1.10	0.82	0.55	**0.74**
Total Benthic Algae	57.96	71.86	80.79	69.46	76.64	**71.34**
Live Corals						
Porites astreoides	6.53	6.56	1.21	3.61	2.62	**4.11**
Orbicella annularis complex			2.85	4.43	10.04	**3.47**
Montastraea cavernosa	2.98		1.65	1.98	2.73	**1.87**
Siderastrea siderea	3.89	0.56			0.98	**1.09**
Agaricia agaricites	1.72	1.22	1.32	0.70		**0.99**
Colpophyllia natans		4.23				**0.85**
Pseudodiploria labyrinthiformis	1.72					**0.34**
Millepora alcicornis	1.26		0.44			**0.34**
Eusmilia fastigiata				1.28		**0.26**
Meandrina meandrites	0.92					**0.18**
Pseudodiploria strigosa					0.87	**0.17**
Millepora complanata				0.82		**0.16**
Stephanocoenia intersepta				0.47		**0.09**
Juvenile coral			0.33			**0.07**
Total Live Corals	19.01	12.57	7.79	13.29	17.25	**13.98**
Cyanobacteria	2.75			1.63	1.09	**1.09**
Sponges	10.54	5.34	2.09	2.33	2.40	**4.54**

Figure 20 presents the variations of mean percent cover by the main sessile-benthic categories from the inner shelf reef off Puerto Botes surveyed during the period between 2004-15. Mean reef substrate cover by stony corals, sponges and benthic algae remained virtually stable between the 2004 baseline and the 2005 monitoring survey. Differences during 2005 were all within 1% of baseline and statistically insignificant (García-Sais et al., 2005). A reduction 49.4 % of mean live coral cover was measured during the 2006-monitoring event, from 19.5 % in 2005 to 9.9 % in 2006. Corresponding increments of substrate cover by benthic algae and abiotic categories were also recorded. An additional decline of 18.3 % mean live coral cover was measured during the 2007 survey, from 9.8 % in 2006 to 8.1 % in 2007. Differences of total live coral cover between surveys were statistically significant (ANOVA; $p = 0.007$; appendix 2). After 2007, statistically significant declines of substrate cover by live corals have not been observed. Conversely, an increasing trend of live coral cover, influenced by increments of cover by *O. annularis* and *P. astreoides* has been measured after the 2010 survey, but differences are still not statistically significant (Figures 20 and 21).

The decline of live coral cover at the inner shelf reef off Puerto Botes was largely associated with a reduction of cover by the dominant species, Boulder Star Coral, *Orbicella annularis* (complex), which as in the 20 m station, collapsed from a mean of 11.5 % in 2005 to a mean of 2.6 % in 2006 (Figure 21). The reduction of percent cover by Boulder Star Coral between the 2005 and the 2006 surveys was statistically significant (ANOVA; $p = 0.027$). Additional declines of substrate cover down to a minimum of 1.5 % were measured for *O. annularis* until the 2009 survey. The declining trend for this coral species ended during the 2010 survey with a mild, yet statistically insignificant fractional increment of 2.2 % mean substrate cover that has maintained stable until the present 2015 survey at a mean cover of 3.5 %. The dominant coral species in terms of reef substrate cover at present is the Mustard-Hill Coral, *Porites astreoides*, which implies a shift in the sessile-benthic community structure of the reef.

A total of 10 coral species were intercepted by transects at the inner shelf reef of Puerto Botes with a mean substrate cover lower than 1 % (Table 22). Some of the most common species include Lettuce Coral, *Agaricia agaricites*, Symmetrical and Grooved Brain Corals, *Pseudodiploria strigosa, P. labyrinthiformis*, Flower Coral, *Eusmilia fastigiata*, and Maze Coral, *Meandrina meandrites*.

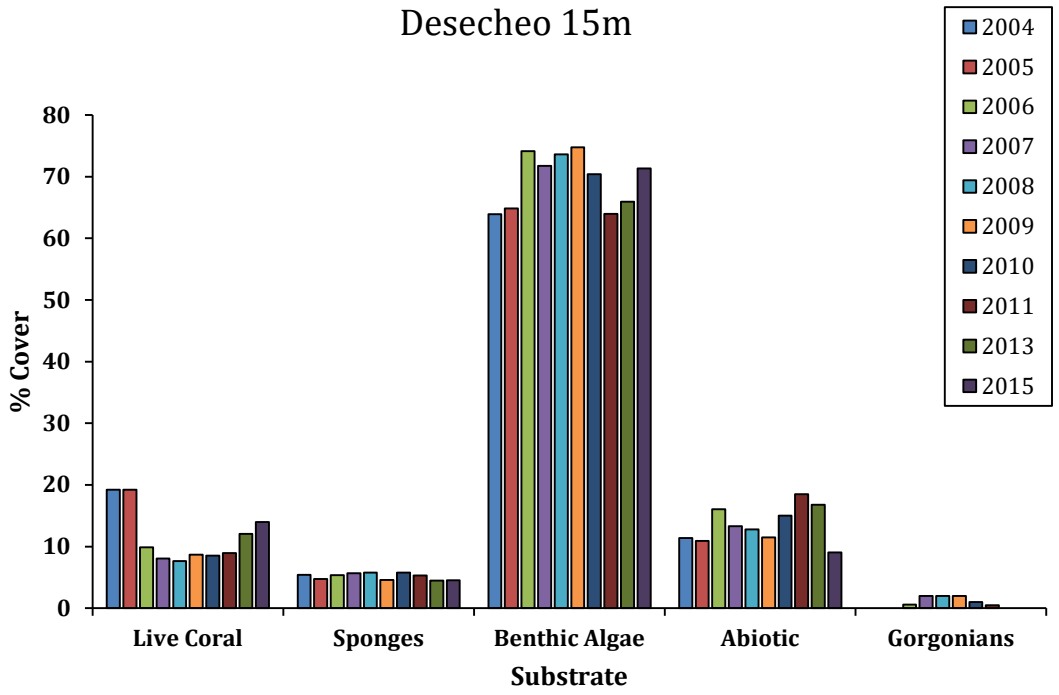


Figure 20. Monitoring trends (2004 -15) of mean substrate cover by sessile-benthic categories at Puerto Botes Inner Shelf Reef, Desecheo Island – 15 m.

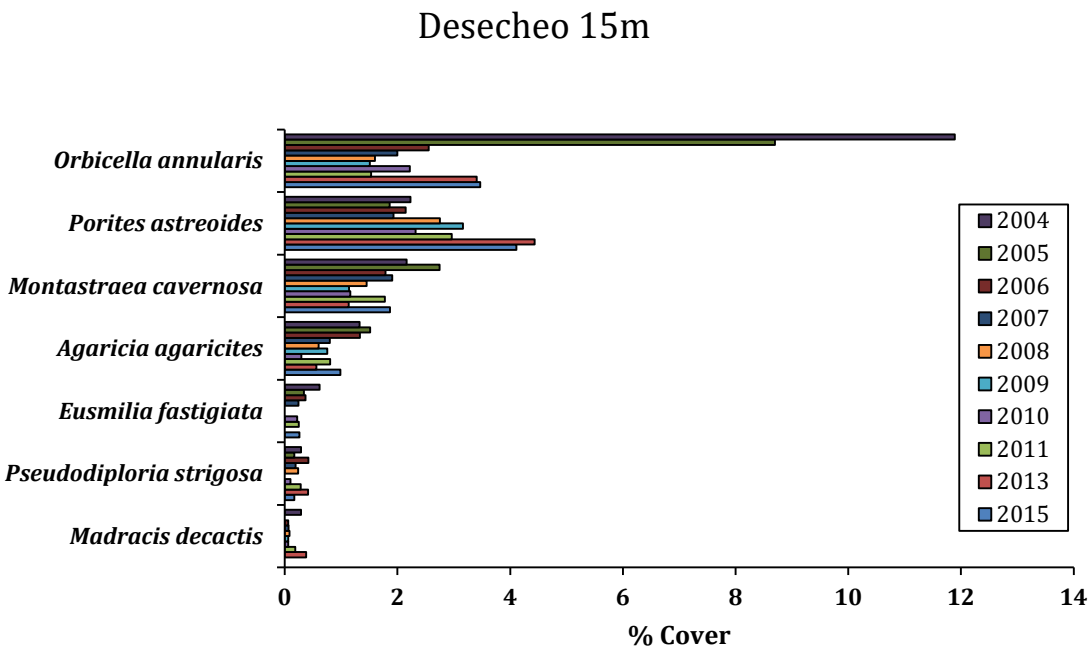


Figure 21. Monitoring trends (2004 -15) of mean substrate cover by stony coral species at Puerto Botes Inner Shelf Reef, Desecheo Island – 15 m.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 43 fish species were identified within belt-transects from the Inner-Shelf Reef off Puerto Botes, Isla Desecheo during the 2015 survey (Table 23). Mean abundance within belt-transects was 158.8 Ind/30 m^2 (range: 110 - 222 Ind/30 m^2). The mean number of species per transect was 21.8 (range: 16 - 29). The Bicolor Damselfish, Blue and Brown Chromis, Creole, Bluehead and Clown Wrasses and Peppermint Goby were the numerically dominant species with a combined abundance of 117.4 Ind/30 m^2, representing 73.9 % of the total fish abundance. Seven additional species were present in at least four out of the five transects. These included the Yellow-head Wrasse, Sharknose Goby, Coney, Princess and Redband Parrotfishes Black Durgon and Redspotted Hawkfish. Eleven species were represented by only one individual in the five belt-transects surveyed. Size distributions of commercially important fishes present within extended belt-transects surveyed at the inner shelf of Puerto Botes Reef are presented in Table 24. The data shows that both early juveniles and adult parrotfishes (*Scarus taeniopterus, S. iserti, Sparisoima aurofrenatum, S. viride, S. aurofrenatum*) and Coneys were present. Adult Yellowtail and Schoolmaster Snappers were also present.

From this and previous fish surveys at this reef, zooplankton feeders, such as the Blue and Brown Chromis, Bicolor Damselfish and Creole Wrasse comprise the most prominent fish assemblage in terms of abundance. These are important prey items of mid-size demersal piscivores that are commercially exploited, such as the Yellowtail and Schoolmaster Snappers, Red Hind and Coneys, as well as for juvenile and adult stages of pelagic fishes associated with the reef food web, such as the Great Barracuda, Cero Mackerels and jacks. Also, open water zooplanktivores, such as the Mackerel Scad (*Decapterus macarellus*) have been previously observed outside transects in large aggregations. This is consistent with fish surveys from the mid-shelf and shelf-edge reefs of Isla Desecheo (see previous sections).

The relatively high abundance of zooplanktivorous fish populations is quite interesting because Rodriguez (2004) sampled the macrozooplankton of Puerto Botes/Puerto Desecheo Reefs six times during a year and found that zooplankton populations are depauperate and unproductive with exception of fish eggs. At least three preliminary

Table 23. Taxonomic composition and abundance of fishes within belt-transects at the Inner Shelf Reef off Puerto Botes, Isla Desecheo 15m. 2015

Depth: 15m		Transects					
		1	2	3	4	5	
		(Individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Stegastes partitus	Bicolor Damselfish	39	41	38	28	20	**33.2**
Chromis cyanea	Blue Chromis	55	15	22	35	30	**31.4**
Thalassoma bifasciatum	Bluehead Wrasse	50	5	20	23	25	**24.6**
Clepticus parrae	Creole Wrasse	3	9	4	12	23	**10.2**
Halichoeres maculipinna	Clown Wrasse	15	4	4	4	5	**6.4**
Coryphopterus lipernes	Peppermint Goby	0	0	7	4	18	**5.8**
Chromis multilineata	Brown Chromis	15	8	0	0	6	**5.8**
Halichoeres garnoti	Yellow-head Wrasse	6	3	4	2	8	**4.6**
Gobiosoma evelynae	Sharknose Goby	1	2	5	4	9	**4.2**
Caranx ruber	Bar Jack	0	0	0	0	20	**4.0**
Gramma loreto	Fairy Basslet	0	1	0	5	11	**3.4**
Epinephelus fulva	Coney	5	3	4	4	1	**3.4**
Coryphopterus personatus	Masked Goby	0	0	0	0	15	**3.0**
Myripristis jacobus	Blackbar Soldierfish	0	0	0	0	9	**1.8**
Scarus taeniopterus	Princess Parrotfish	2	1	5	0	1	**1.8**
Scarus iserti	Stripped Parrotfish	2	0	1	3	2	**1.6**
Sparisoma viride	Stoplight Parrotfish	0	0	0	4	4	**1.6**
Melichthys niger	Black Durgon	1	1	3	1	0	**1.2**
Acanthurus coeruleus	Blue Tang	0	2	0	1	2	**1.0**
Holacanthus tricolor	Rock Beauty	2	0	0	1	2	**1.0**
Sparisoma aurofrenatum	Redband Parrotfish	0	1	3	0	0	**0.8**
Microspathodon chrysurus	Yellowtail Damselfish	0	2	0	1	1	**0.8**
Amblycirrhitus pinnos	Redspotted Hawkfish	0	1	1	1	1	**0.8**
Chaetodon capistratus	Foureye Butterflyfish	0	2	0	0	2	**0.8**
Xanthychys rigens	Sargassum Triggerfish	1	1	0	1	0	**0.6**
Ocyurus chrysurus	Yellowtail Snapper	0	1	0	1	0	**0.4**
Acanthostracion polygonia	Honeycomb Cowfish	1	1	0	0	0	**0.4**
Acanthurus chirurgus	Doctorfish	0	1	0	1	0	**0.4**
Neoniphon marianus	Longspine Squirrelfish	0	1	1	0	0	**0.4**
Serranus tigrinus	Harlequin Bass	0	1	0	1	0	**0.4**
Lutjanus apodus	Schoolmaster Snapper	0	1	1	0	0	**0.4**
Sparisoma radians	Bucktooth Parrotfish	2	0	0	0	0	**0.4**
Bodianus rufus	Spanish Hogfish	0	0	0	0	1	**0.2**

Table 23. continued

Holocentrus rufus	Squirrelfish	0	1	0	0	0	**0.2**
Lactophrys triqueter	Smooth Trunkfish	0	0	0	0	1	**0.2**
Sparisoma rubripine	Yellowtail Parrotfish	0	0	0	0	1	**0.2**
Chaetodon striatus	Banded Butterflyfish	0	1	0	0	0	**0.2**
Cantherhines pullus	Orange Spoted Filefish	0	0	1	0	0	**0.2**
Muilloides martinicus	Yellowfih Goatfish	0	0	0	1	0	**0.2**
Sparisoma chrysupterum	Redtail Parrotfish	0	0	0	0	1	**0.2**
Alostumus maculatus	Trumpetfish	0	0	0	0	1	**0.2**
Kyphosus bermudensis	Sea Chub	0	0	0	0	1	**0.2**
Equetus lanceolatus	Highhat	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	200	110	124	138	222	**158.8**
	TOTAL SPECIES	16	25	17	22	29	**21.8**

hypotheses or interplay of these can be advanced to explain such scenario: 1) zooplankton production is high, but is continuously being consumed as it grows to an optimal size for fish consumption; 2) fishes produce a very high abundance of pelagic eggs that support the large zooplanktivorous fish populations; 3) micronekton assemblages, such as mysid shrimps supplement, or sustain to a significant extent the diets of the markedly abundant zooplanktivorous fish populations at the Puerto Botes/Puerto Canoas Reef system of Isla Desecheo.

Annual monitoring trends of fish species richness and abundance surveyed within belt-transects are presented in Figure 22. The mean number of fish species within transects (species richness) has fluctuated historically between 17.6 and 25.2, and mean abundance has varied between 120.4 Ind/30 m^2 and 307.6 Ind/30 m^2 during the nine-year monitoring period at this reef. Abundance during the present survey at 158.8 Ind/30 m^2 fell within the low end of the historical range. A statistically significant decline of fish species richness and abundance was observed during the 2008 and 2010 surveys relative to previous surveys (ANOVA; $p < 0.005$). Differences of fish abundance are largely associated with species that display schooling behavior and thus, have highly aggregated spatial distribution patterns such as the Blue and Brown Chromis. Such distributions introduce high sampling variability and increased number of observations are needed to detect patterns.

Table 24. Taxonomic composition, density and size of fishes within 20 m x 3 m belt-transects at Puerto Botes Reef, Isla Desecheo 15m. 2015

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped Parrotfish	1 - 20		1 - 15	2 - 10	4 - 7
		1 - 25			1 - 20	4 - 10
					1 - 25	
Sparisoma viride	Stoplight Parrotfish				4 - 10	
Sparisoma aurofrenatum	Redband Parrotfish		1 - 10	1 - 10	1 - 25	
				4 - 15		
Ocyurus chrysurus	Yellowtail Snapper		1 - 30		1 - 30	
Epinephelus fulva	Coney	1 - 5	2 - 10	2 - 10	4 - 10	2 - 10
		4 - 15	1 - 17	4 - 15	2 - 15	2 - 15
						1 - 20
Scarus taeniopterus	Princess Parrotfish		1 - 10	3 - 10		3 - 10
			1 - 20	2 - 15		
Lutjanus apodus	Schoolmaster Snapper		7 - 25	1 - 20	1 - 20	1 - 30

Motile megabenthic invertebrates were represented within belt-transects by arrow crabs and cleaner shrimps (Table 25).

Table 25. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at the Puerto Botes Inner-Shelf Reef,15 m, Isla Desecheo, 2015

		TRANSECTS					
Depth: 15 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Stenorhynchus seticornis	Arrow Crab		1		1	1	**0.6**
Periclimenes pedersoni	Cleaner Shrimp		1	1		1	**0.6**
	TOTALS	**0**	**2**	**1**	**1**	**2**	**1.2**

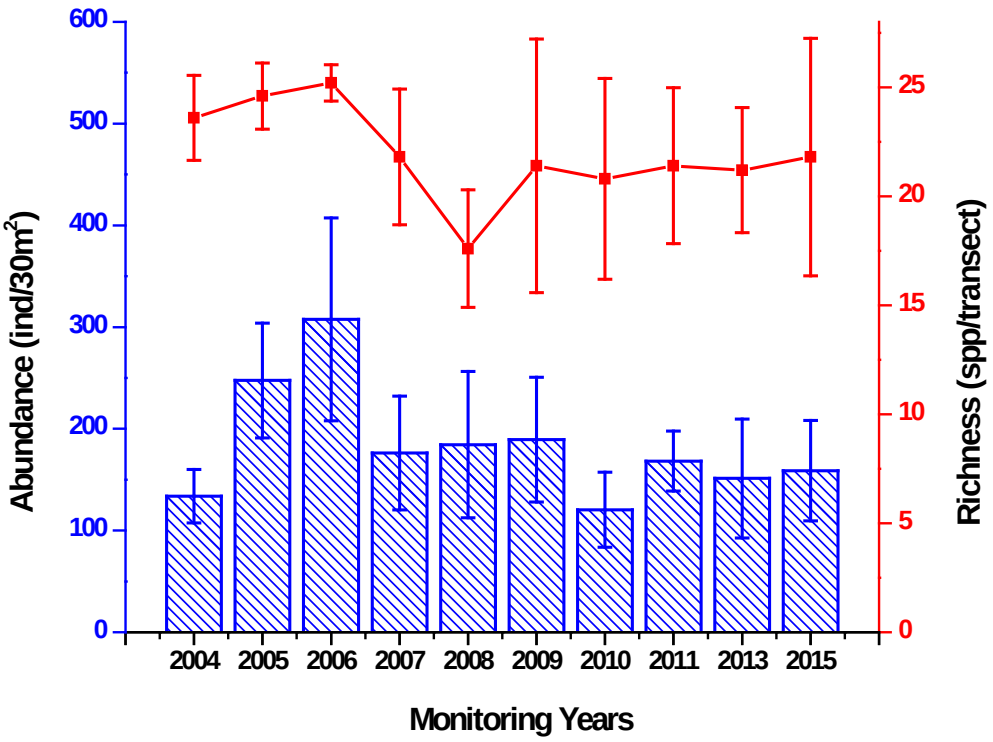
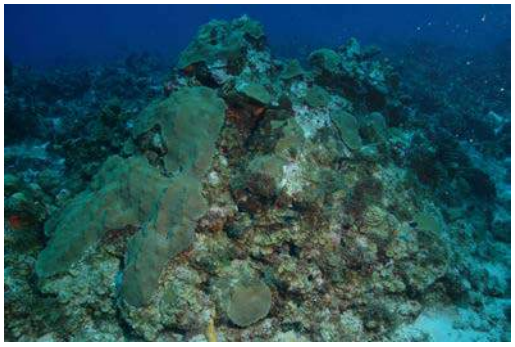
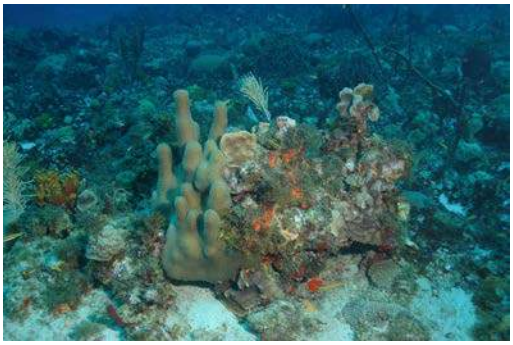


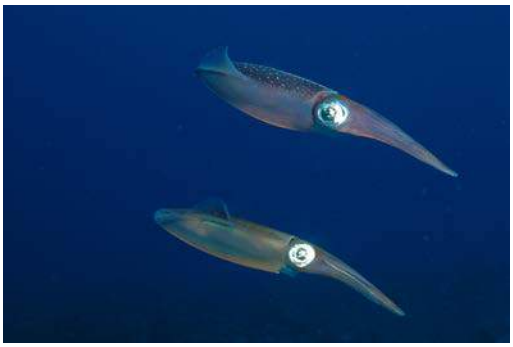
Figure 22. Monitoring trends (2004 – 2015) of fish species richness and abundance at Inner Shelf Reef, Puerto Botes, 15 m depth, Isla Desecheo.

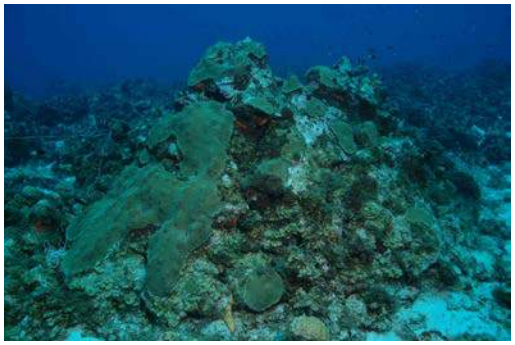
Photo Album 6. Desecheo, Puerto Botes

Inner Shelf Reef









C. Tourmaline Reef System – Mayaguez Bay

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 23).

Tourmaline Reef 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 very scarped and 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).

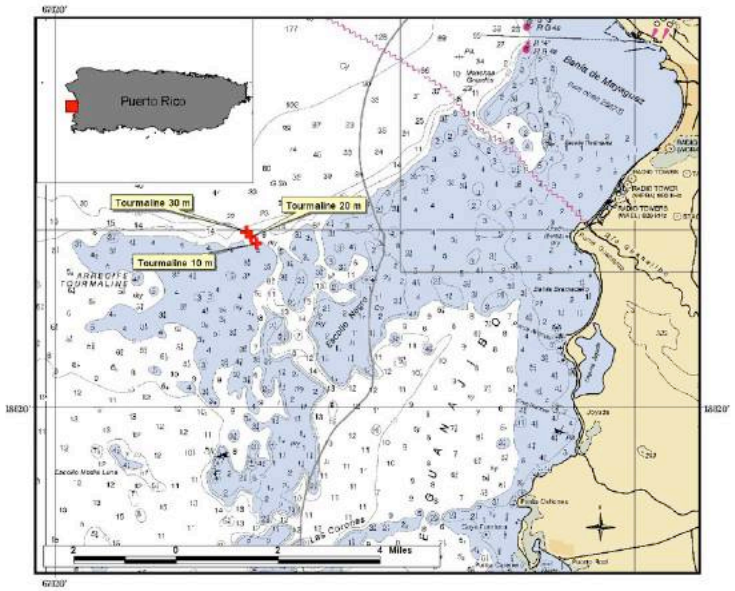


Figure 23. Location of coral reef survey stations at Tourmaline Reef, off Mayaguez Bay.

1.0 Shelf-edge Reef – 30 meters

1.1 Sessile-Benthic Reef Community

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 7.

A total of 21 stony corals and two black coral species have been identified from the shelf-edge off Tourmaline Reef, 15 of which were intercepted by line transects during our 2015 survey (Table 26). Stony corals occurred mostly as isolated encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 22.3 % (range: 18.8 – 26.3 %). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant species in terms of substrate cover with a mean of 6.6 % (range: 3.1 – 8.7 %), representing 29.6 % of the total cover by stony corals. Isolated colonies of lettuce corals, including Lamark's Sheet Coral, *Agaricia lamarcki,* Graham's Sheet Coral, *A. grahamae*, *A. fragilis*, and Lettuce Coral, *A. agaricites* were also prominent at the shelf-edge with a combined cover of 11.5 %. Soft corals (gorgonians) were present in all transects surveyed, but in relatively low densities with an average of 12.6 colonies/transect. The Corky Sea Finger, *Briareum asbestinum*, Encrusting Gorgonian, *Erythropodium caribaeorum* and the Sea Plume, *Pseudopterogorgia acerosa* were the most common. Colonies of Bushy Black Coral (*Antipathes sp*.) and Wire Coral (*Stichopathes lutkeni*) were present close to the deepest end of the reef at 32 m.

Encrusting and erect sponges were represented by at least 11 species along transects surveyed with an average substrate cover of 4.8 %. Some of the most prevalent along transects included Svenzea zeai, *Cliona caribbea*, *Plakortis halichondriodes*, *Iotrochota birotulata* and an unidentified species (Table 26). The Blue Bell Tunicate, *Clavelina puertosecensis* was very common throughout the shelf-edge reef. Reef overhangs, associated with substrate depressions and coral ledges averaged 12.8 % and contributed substantially to a topographic rugosity of 12.5 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 34.3 % (range : 16.3 – 53.2 %). Turf algae was found

Table 26. Percent substrate cover by sessile-benthic categories at Tourmaline Reef, Mayaguez, 30m. 2015

	Transects					
	1	2	3	4	5	**Mean**
	3.45	14.55	14.71	15.08	14.80	**12.52**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	4.37	23.00	9.04	15.04	12.58	**12.81**
Sand	2.81	6.74	2.19	1.86	9.46	**4.61**
Gap	4.27		2.85			**1.42**
Total Abiotic	11.45	29.74	14.08	16.90	22.04	**18.84**
Benthic Algae						
Turf	53.17	16.27	50.52	24.51	27.25	**34.34**
Dictyota spp.		4.23		8.73	11.92	**4.98**
CCA		7.41		6.96	7.95	**4.46**
Total Benthic Algae	53.17	27.91	50.52	40.20	47.11	**43.79**
Live Corals						
Orbicella annularis complex	3.12	8.18	7.61	8.73	5.58	**6.64**
Agaricia grahamae	12.70	1.25	1.05	4.36	3.22	**4.51**
Agarcia agaricites	4.16	5.29	6.09	2.51	3.50	**4.31**
Agaricia lamarcki		5.49	1.81	3.44		**2.15**
Madracis formosa		4.91				**0.98**
Porites astreoides	2.60	1.15			0.76	**0.90**
Montastraea cavernosa			0.76		3.12	**0.78**
Siderastrea siderea	1.66		0.67	0.93	0.19	**0.69**
Stephanocoenia intersepta	0.52				1.42	**0.39**
Agaricia sp.	1.04		0.86			**0.38**
Agaricia fragilis				0.93		**0.19**
Mycetophyllia aliciae			0.76			**0.15**
Meandrina meandrites					0.57	**0.11**
Madracis decactis					0.28	**0.06**
Millepora alcicornis					0.19	**0.04**
Total Live Corals	25.81	26.28	19.60	20.89	18.83	**22.28**
Cyanobacteria		5.10	4.76	1.39	4.07	**3.06**
Octocorals						
Briareum asbestinum		5.58		14.11	2.27	**4.39**
Erythropodium caribaeorum	6.56	2.41	3.90	0.46	0.95	**2.85**
Total Octocorals	6.56	7.99	3.90	14.58	3.22	**7.25**

Table 26. continued

Erect Gorgonians (#col/transect)	4	12	14	13	20	**12.6**
Sponges						
Sponge	3.02		7.14			**2.03**
Svenzea zeai		1.64		4.09		**1.14**
Cliona caribbaea				0.93	3.03	**0.79**
Plakortis halichondrioides				0.84	0.47	**0.26**
Iotrochota birotulata					0.85	**0.17**
Scopalina ruetzleri		0.19			0.38	**0.11**
Clathria sp.		0.38				**0.08**
Neopetrosia proxima		0.29				**0.06**
Plakortis angulospiculatus		0.29				**0.06**
Black encrusting sponge		0.19				**0.04**
Monachora arbuscula				0.19		**0.04**
Total Sponges	3.02	2.98	7.14	6.04	4.73	**4.78**

overgrowing rocky substrates, as well as dead coral sections and other hard bottom. The total cover by benthic algae was 43.8 % (range: 27.9 – 53.2).

Figure 24 shows the fluctuations of mean percent cover by sessile-benthic categories from the shelf-edge of Tourmaline Reef at 30 m depth. The mean percent cover by stony corals remained stable during the period between the baseline survey in 2004 and 2010. Since the 2011 survey until present there has been a consistent increment of live coral cover that now represents an accretion of approximately 36 %. Differences of live coral cover between monitoring surveys are still statistically insignificant, (ANOVA; p = 0.112, Appendix 2), but the live coral recuperation trend appears to be real and approaching statistical significance. Boulder Star Coral, *Orbicella annularis* maintained its status as the dominant coral species in terms of reef substrate cover at 30 m, but the combined cover by at least five species of lettuce corals *(Agaricia spp)* now leads reef substrate cover by stony corals (Figure 25). 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. Although partial bleaching was reported in one colony of *O. annularis* during the 2006 monitoring survey, widespread mortality associated with bleaching has not been observed at this reef.

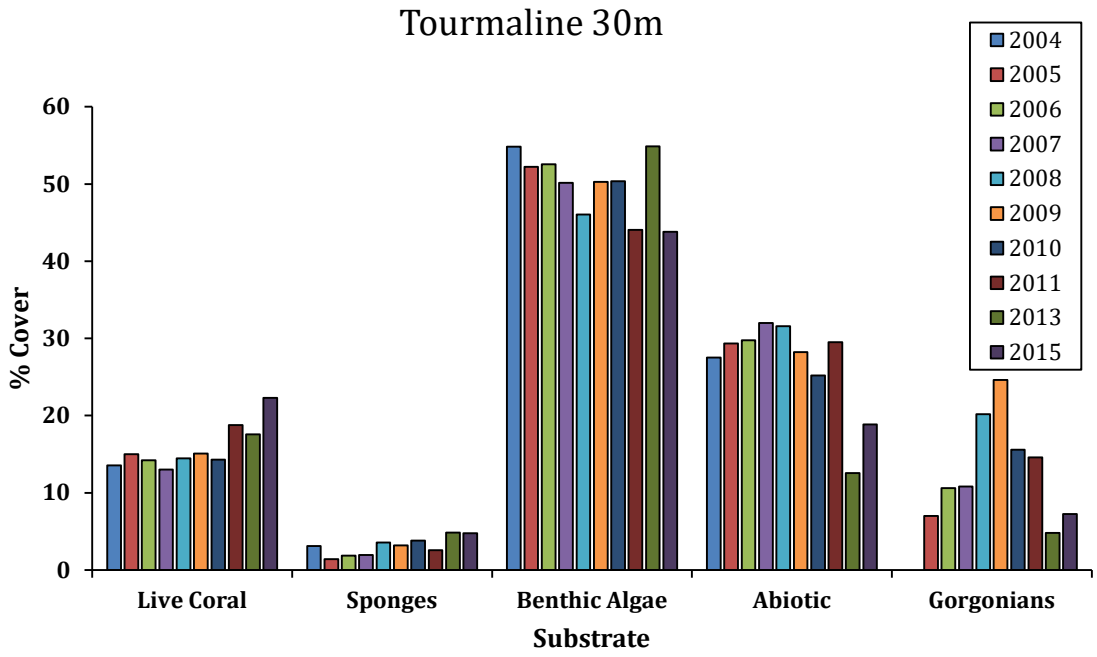


Figure 24. Monitoring trends (2004 – 2015) of mean substrate cover by sessile-benthic categories at Tourmaline Shelf-edge Reef – 30 m, Mayaguez Bay.

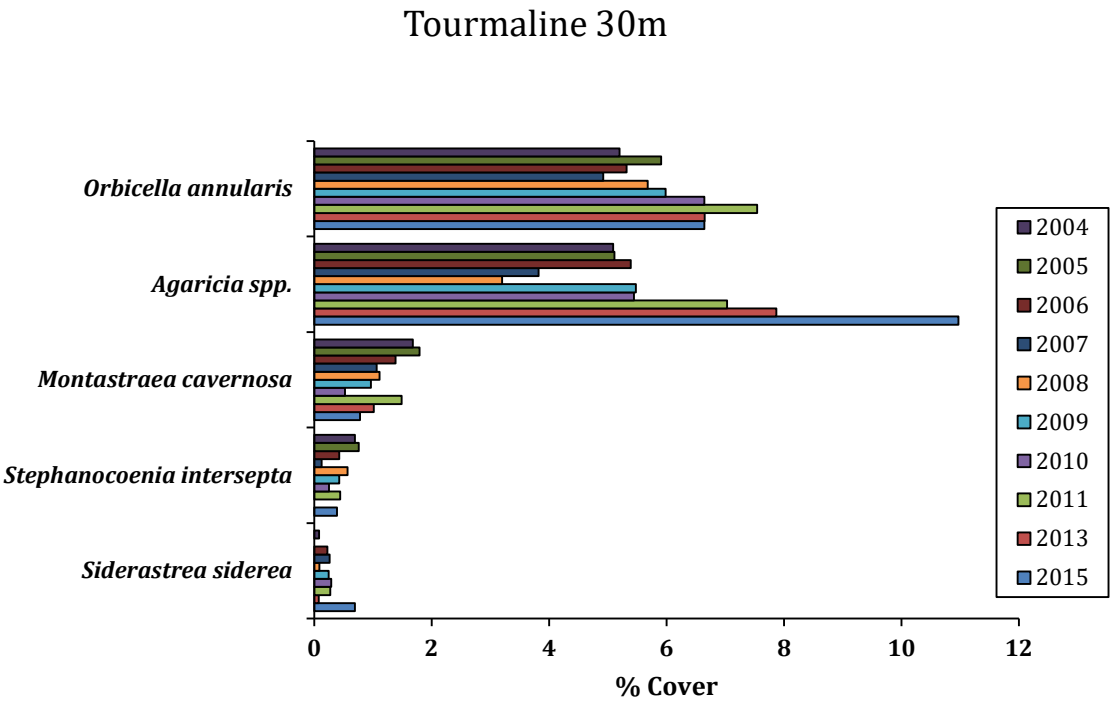


Figure 25. Monitoring trends (2004 – 2015) of mean substrate cover by stony coral species at Tourmaline Reef – 30 m, Mayaguez Bay.

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 114 fish species have been identified from Tourmaline Reef at depths of 25-30 m (Appendix 1). Mean abundance within belt-transects during the 2015 monitoring survey was 195.8 Ind/30 m^2 (range: 135 - 279 Ind/30 m^2). The mean number of species per transect was 19.2 (range: 15 - 24). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 91.0 Ind/30 m^2 (range: 60 - 110 Ind/30 m^2), representing 46.5 % of the total abundance within belt-transects (Table 27). The Masked Goby is a small demersal (< 2.0 cm) planktivore that aggregates in swarms below coral ledges and crevices near the sand-coral interface. The Peppermint and Masked Gobies, Creole and Bluehead Wrasses, Fairy Basslet, Blue Chromis, Stripped Parrotfish and Black-bar Soldierfish were present on at least four of the five transects surveyed and comprised the most abundant fish assemblage at the Tourmaline Reef shelf-edge.

Size distribution data of commercially important fishes surveyed along extended transects are presented in Table 28. Juvenile and adult parrotfishes (*Scarus iserti, S. taeniopterus, Sparisoma viride, S. aurofrenatum*) were the most abundant taxa. One juvenile Yellowfin Grouper and one adult Queen Triggerfish were also present within transects. Full adult stages of top demersal and pelagic predators, such as snappers, groupers and mackerels have been observed at the shelf-edge reef, but in low abundance (Garcia-Sais et al., 2014). Juvenile Nassau Groupers, Mutton, Schoolmaster and Yellowtail Snappers were previously reported from this reef (García-Sais et al., 2004, 2005), as well as the large pelagics, such as Cero Mackerel and Great Barracuda (García-Sais et al., 2004, 2005). Schools of Mackerel Scad, *Decapterus macarellus* have been observed at mid-water over the reef. Pelagic and demersal zooplanktivores (*Chromis spp.,* Creole Wrasse, Bicolor Damselfish) were highly prominent at the shelf-edge with a combined abundance representing approximately 72 % of the total individuals within belt-transects. These zooplanktivores serve as forage for pelagic predators, such as Almaco Jack, Cero Mackerels and Barracudas. A large variety of small invertebrate feeders, such as wrasses, gobies,basslets, goatfishes and squirrelfishes represent another prominent fish assemblage in this reef. Herbivores (parrotfishes, acanthurids, damselfishes) represented less that 5 % of the total fish abundance within belt-transects.

Table 27. Taxonomic composition and abundance of fishes within belt transects at Tourmaline Reef, Mayaguez Bay, 30m. 2015

		Transects					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	60	90	110	105	90	**91.0**
Clepticus parrae	Creole Wrasse	25	15	14	70	13	**27.4**
Chromis cyanea	Blue Chromis	15	10	24	25	28	**20.4**
Coryphopterus lipernes	Peppermint Goby	10	16	11	22	25	**16.8**
Thalassoma bifasciatum	Bluehead Wrasse	3	10	8	5	5	**6.2**
Gramma loreto	Fairy Basslet	5	2	1	10	7	**5.0**
Scarus iserti	Stripped Parrotfish	1	7	5	7	4	**4.8**
Myripristis jacobus	Blackbar Soldierfish	8	4	3	3	3	**4.2**
Caranx ruber	Bar Jack	0	0	0	9	0	**1.8**
Chaetodon capistratus	Four-eye Butterflyfish	0	6	2	0	0	**1.6**
Sparisoma aurofrenatum	Redband Parrotfish	0	0	2	2	4	**1.6**
Chromis insolata	Sunshine Chromis	0	5	0	0	2	**1.4**
Stegastes leucostictus	Beau Gregory	2	2	0	2	1	**1.4**
Canthigaster rostrata	Caribbean Puffer	1	1	4	1	0	**1.4**
Gobiosoma evelynae	Sharknose Goby	0	0	1	1	4	**1.2**
Scarus taeniopterus	Princess Parrotfish	0	0	4	0	0	**0.8**
Neoniphon marianus	Longspine Squirrelfish	0	1	1	2	0	**0.8**
Holocentrus rufus	Squirrelfish	0	0	1	3	0	**0.8**
Muilloides martinicus	Yellowfih Goatfish	0	0	0	4	0	**0.8**
Halichoeres garnoti	Yellow-head Wrasse	0	2	0	0	1	**0.6**
Holacanthus tricolor	Rock Beauty	1	1	1	0	0	**0.6**
Acanthurus chirurgus	Doctorfish	0	0	1	1	1	**0.6**
Stegastes partitus	Bicolor Damselfish	0	1	1	0	0	**0.4**
Epinephelus cruentatus	Graysby	0	0	0	1	1	**0.4**
Chaetodon acuelatus	Longsnout Butterflyfish	1	0	0	1	0	**0.4**
Sparisoma viride	Stoplight Parrotfish	0	0	0	0	2	**0.4**
Acanthurus coeruleus	Blue Tang	1	0	1	0	0	**0.4**
Heteropriacantus cruentatus	Glasseye Snapper	0	0	0	1	1	**0.4**
Aulostomus maculatus	Trumpetfish	1	0	0	0	1	**0.4**
Haemulon aurolineatum	Tomtate	0	0	0	1	0	**0.2**
Coryphopterus glaucofraenum	Briddled Goby	0	0	0	1	0	**0.2**
Haemulon flavolineatum	French Grunt	0	0	0	1	0	**0.2**
Acanthurus bahianus	Ocean Surgeon	0	0	1	0	0	**0.2**
Lactophrys triqueter	Smooth Trunkfish	0	1	0	0	0	**0.2**

Table 27. continued

Mycteroperca interstitialis	Yellowmouth Grouper	0	0	0	1	0	**0.2**
Pomacanthus paru	French Angelfish	1	0	0	0	0	**0.2**
Pomacanthus arcuatus	Grey Angelfish	0	0	1	0	0	**0.2**
Balistes vetula	Queen Triggerfish	0	1	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**135**	**175**	**197**	**279**	**193**	**195.8**
	TOTAL SPECIES	**15**	**18**	**21**	**24**	**18**	**19.2**

Table 28. Taxonomic composition, density and size of fishes within 20 m x 3 m belt-transects at Tourmaline Reef, 30 m, 2015

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped Parrotfish	1 - 20	5 - 7	2 - 7	5 - 7	8-7
			4 - 12	1 - 10	4 - 12	2-12
			2 - 15		2 - 15	1-15
Sparisoma viride	Stoplight Parrotfish			1 - 35		2-10
Sparisoma aurofrenatum	Redband Parrotfish			1 - 10	2 - 12	2-10
				1 - 17		2-15
Epinephelus cruentatus	Graysby				1 - 12	1-12
Scarus taeniopterus	Princess Parrotfish			1 - 12		
				1 - 17		
Mycteroperca interstitialis	Yellowmouth Grouper				1 - 33	
Balistes vetula	Queen Triggerfish		1 - 40			

Annual fluctuations of fish species richness and abundance at the Mayaguez 30 m reef are shown in Figure 26. Differences of fish abundance and species richness between annual surveys were statistically significant (Appendix 3 and 4). Fish species richness maintained a consistent decline after 2006, reaching a minimum of 13 species per transect in the 2013 survey. Annual variations of abundance are mostly driven by the fluctuations of Masked Goby, 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.

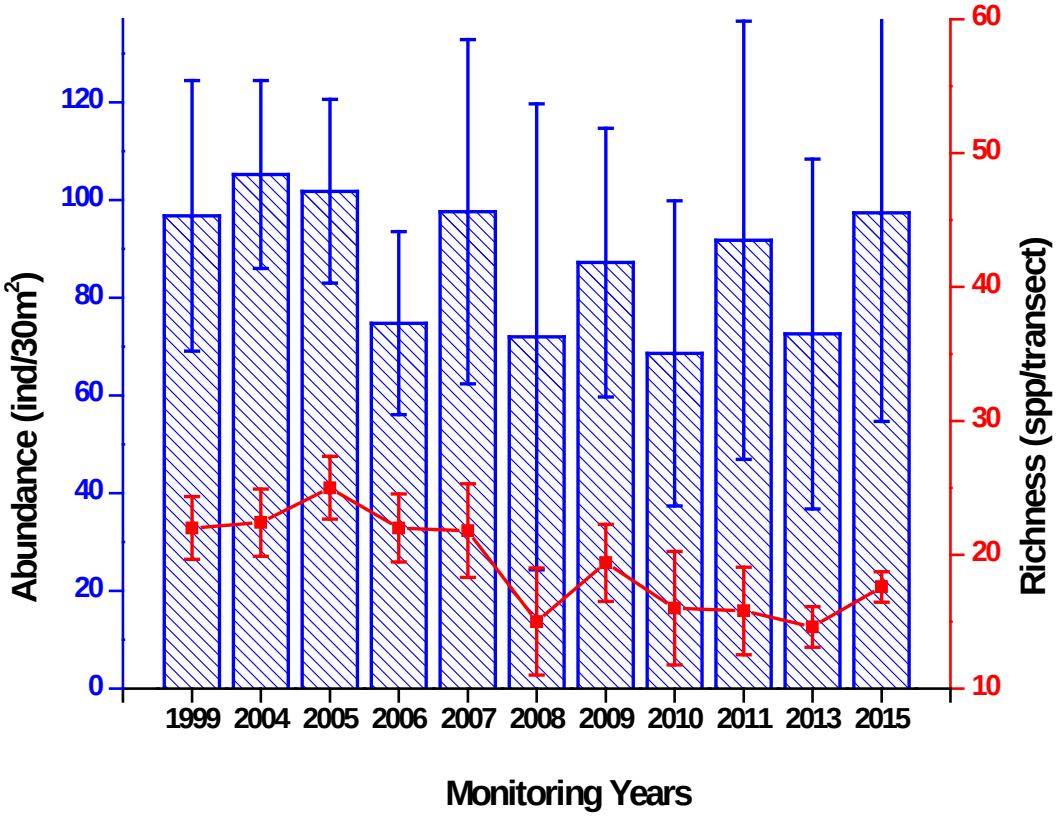


Figure 26. Monitoring trends (2004 – 2015) of fish species richness and abundance at Shelf-edge Reef Tourmaline, 30 m, Mayaguez Bay.

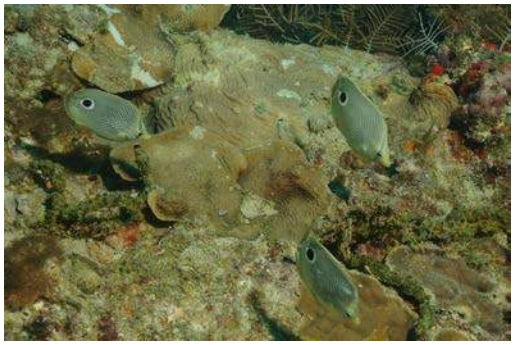
Motile megabenthic invertebrate observed within belt-transects at the Tourmaline shelf-edge reef during this survey included Famingo Tongue and Ceaner Shrimps (Table 29).

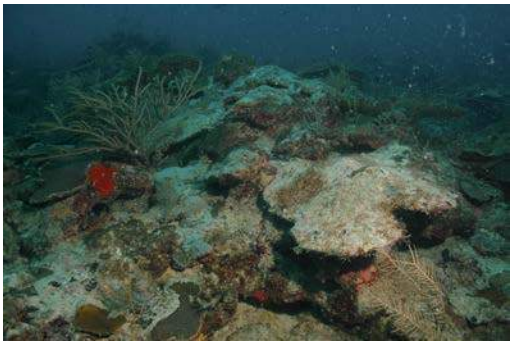
Table 29. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Shelf-edge Reef, 30 m, 2015

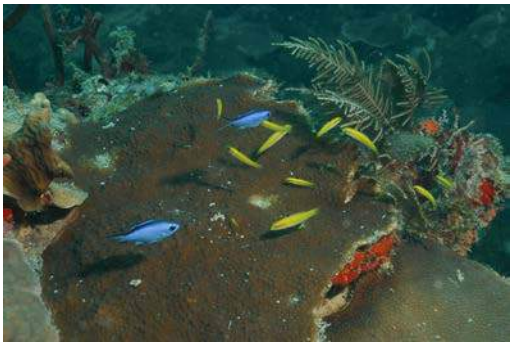
Depth: 30 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Ciphoma gibbosum	Flamingo Tongue				1	2	**0.6**
Periclimenes pedersoni	Cleaner Shrimp	1		1			**0.2**
	TOTALS	**0**	**0**	**1**	**1**	**2**	**0.8**

Photo Album 7. Tourmaline Reef System, 30m

Shelf edge Reef







2.0 Tourmaline Outer Shelf Reef – 20 m

2.1 Sessile-Benthic Reef Community

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 8.

A total of 18 stony corals and two black coral species (*Stichopathes lutkeni, Antipathes sp*.) were identified from the outer shelf reef, 15 of which were intercepted by line transects during our survey (Table 30). 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 28.7 % (range:22.9 – 30.9 %). 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 20.5 % (range: 15.5 – 26.0 %), representing 71.3 % of the total cover by stony corals. Colonies of Boulder Star were intercepted by all five transects. Massive Starlet Coral (*Siderastrea siderea*), Mustard Hill Coral (*Porites astreoides*), Great Star Coral (*M. cavernosa*) and an assemblage of at least three Lettuce Corals (*Agaricia spp*.) comprised the main stony coral assemblage at Tourmaline 20 m (Table 30).

Soft corals (gorgonians) were moderately abundant with an average of 19.6 colonies/transect and five species intercepted by transects (Table 30). The encrusting gorgonian, *Erythropodium caribaeorum*, *Briareum asbestinum,* and *Allotogorgia acerosa*

Table 30. Percent substrate cover by sessile-benthic categories at Tourmaline Reef, Mayaguez. 20 m. 2015

	Transects					
	1	2	3	4	5	**Mean**
Rugosity (m)	3.43	3.24	4.19	6.31	4.91	**4.42**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	1.81	1.64	14.79	3.30	2.87	**4.88**
Sand				0.42		**0.08**
Total Abiotic	1.81	1.64	14.79	3.72	2.87	**4.97**
Benthic Algae						
Turf	26.90	28.54	45.07	17.42	22.82	**28.15**
Lobophora variegata	18.98	9.20	12.03	22.75	13.62	**15.31**
CCA	1.25	1.59	0.99	0.60	2.63	**1.41**
Dictyota spp.		0.32		0.69	0.75	**0.35**
Total Benthic Algae	47.13	39.64	58.09	41.46	39.81	**45.23**
Cyanobacteria	0.60	0.42		0.24	0.14	**0.28**
Live Corals						
Orbicella annularis complex	25.03	19.03	15.48	26.01	17.00	**20.51**
Siderastrea siderea	0.63		2.96	1.89	1.88	**1.47**
Porites astreoides		3.07		0.94	2.44	**1.29**
Montastraea cavernosa	1.46		1.87		3.10	**1.29**
Agaricia grahamae		2.11			3.29	**1.08**
Colpophyllia natans		3.17				**0.63**
Meandrina meandrites		0.42			1.88	**0.46**
Madracis decactis		0.74		1.29		**0.41**
Madracis formosa	1.77					**0.35**
Agaricia agaricites	0.83	0.53				**0.27**
Agaricia lamarcki					1.31	**0.26**
Millepora alcicornis	0.52	0.21	0.30			**0.21**
Eusmilia fastigiata		0.32				**0.06**
Mycetophyllia aliciae			0.99			
Pseudodiploria labyrinthiformis			1.28			
Total Live Corals	30.24	29.60	22.88	30.13	30.89	**28.75**
Octocorals						
Erythropodium caribaeorum	0.14	1.40	3.45	0.28	0.10	**1.07**
Briareum asbestinum	0.24	0.48		0.10	0.81	**0.32**
Allotogorgia acerosa	0.07	0.03		0.04		**0.03**

Table 30. continued

Allotogorgia americana		0.03				**0.01**
Gorgonia ventalina		0.01				**0.00**
Total Octocorals	0.45	1.95	3.45	0.42	0.91	**1.44**
Erect Gorgonians (#col/transect)	20	30	13	20	15	**19.6**
Sponges						
Cliona caribbaea	0.08			0.04	0.20	**0.06**
Monanchora arbuscula	0.06			0.10	0.06	**0.04**
Agelas conifera					0.15	**0.03**
Topsentia ophiraphidites				0.11		**0.02**
Iotrochota birotulata					0.04	**0.01**
Black sponge		0.03				**0.01**
Mycale laevis	0.01					**0.00**
Sponge			0.79			
Total Sponges	0.15	0.03	0.79	0.25	0.45	**0.33**

were the most prominent soft coral species. Colonies of Bushy Black Coral (*Antipathes caribbeana*) were present at the reef base. Encrusting sponges were represented by at least eight species along transects with a mean cover of 0.3 %, and thus, comprised a minor component of the reef benthos. Reef overhangs, associated with live and dead ledges of Boulder Star Coral averaged 4.9 % of the reef substrate cover and contributed markedly to the topographic rugosity of 4.4 m. Abiotic cover categories included also a minor component of sand deposit for a mean composite of 5.0 % (Table 30).

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 45.2 % (range: 39.6 – 58.1 %). Turf algae, a mixed assemblage of short filamentous red and brown macroalgae contributed a reef substrate cover of 28.2%, representing 62.4% of the total benthic algae. The Encrusting Fan Alga, *Lobophora variegata* (mean cover: 15.3 %) was the main component of the fleshy algal assemblage.

Figure 27 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

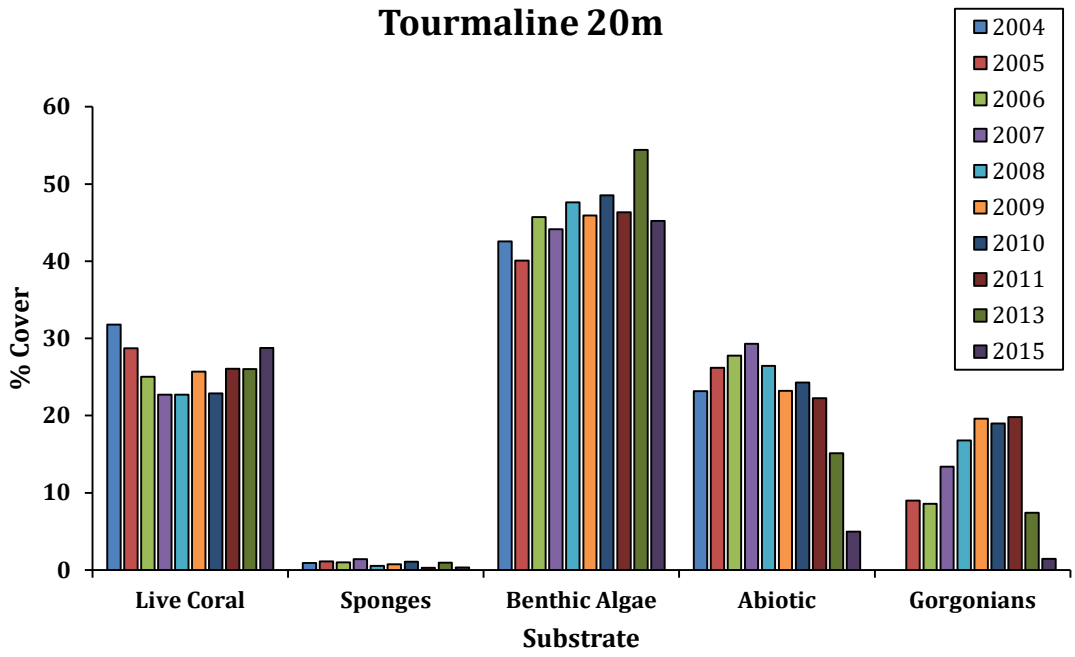


Figure 27. Monitoring trends (2004 – 2015) of mean substrate cover by sessile-benthic categories at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

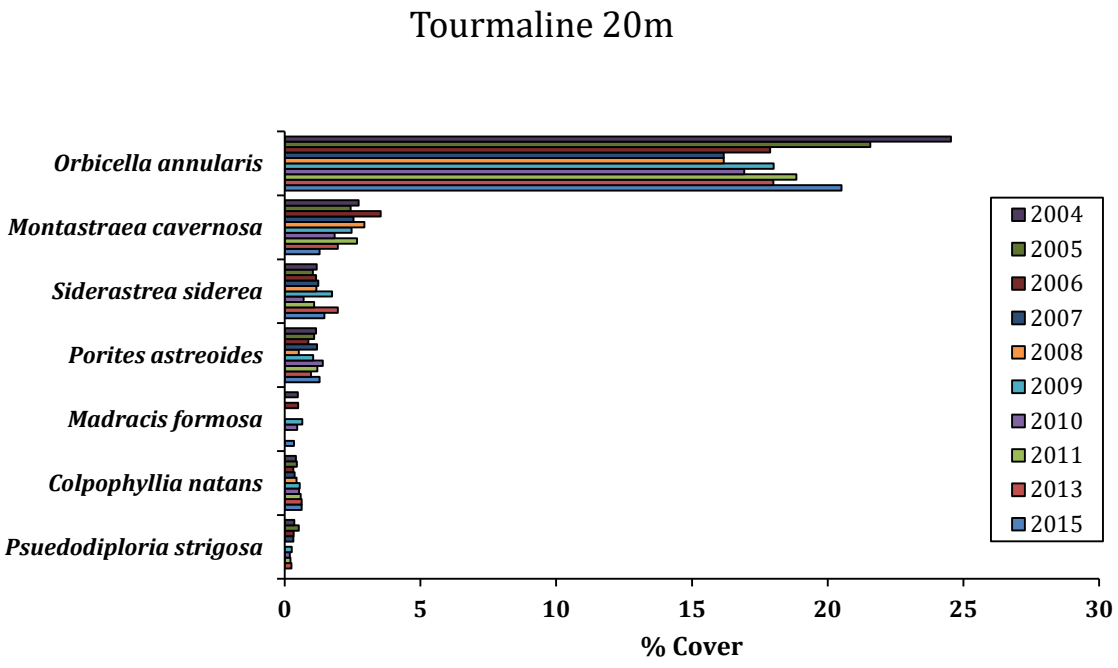


Figure 28. Monitoring trends (2004 – 2015) of mean substrate cover by stony coral species at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

22.8% in 2007. Due to the high variability within replicate transects, differences of live coral cover between monitoring surveys were not statistically significant (ANOVA, p = 0.114; Appendix 2). Live coral declined 9.5 % between 2004 and 2005, then declined 12.9 % between 2005 and 2006, and again 9.0 % between 2006 and 2007. After 2010 live coral cover has shown an increasing trend until the present survey, now evidencing a recuperation of 21.4 % from its lowest cover in 2010.

Orbicella annularis was the main driver of the declining trend of live coral at Tourmaline Reef between 2004 and 2007 because it was the dominant coral species (Figure 28). During the last three surveys (2011 – 2015) *O. annularis* has shown a slow, but consistent increment of reef substrate cover, influencing the overall cover by live corals in this reef.

2.2 Fishes and Motile Megabenthic Invertebrates-

A total of 101 fish species have been identified from Tourmaline outer shelf reef at 20 m (Appendix 1). Mean abundance within belt-transects during 2015 was 187.8 Ind/30 m^2 (range: 110 - 297 Ind/30 m^2). The mean number of species per transect was 17.2 (range: 14 - 19). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 70.0 Ind/30 m^2 (range: 0 – 120 Ind/30 m^2), representing 37.2 % of the total abundance within belt-transects (Table 31).

The Masked Goby is a small demersal zooplanktivore (< 2.0 cm) that was observed hovering in small to moderate aggregations below coral ledges and crevices near the sand-coral interface. The Creole Wrasse, Blue Chromis, Fairy Basslet, Peppermint Goby Bluehead Wrasse and the Striped and Princess Parrotfishes, along with the Masked Goby comprised the most abundant fish assemblage at 20 m (Table 31). A total of 10 species were present in at least four of the five transects surveyed.

Parrotfishes (*Scarus iserti, S. taeniopterus, Sparisoma viride, S. aurofrenatum*) were the most abundant commercially valuable fish species present within the extended belt-transects surveyed at Tourmaline 20 m (Table 32). Most individuals were late juveniles and adults, but previous size distribution observations have noted that parrotfishes recruit to this reef in early juvenile stages of < 2 cm SL (Garcia-Sais et al. 2014). Young

Table 31. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, Mayaguez Bay, 20 m. 2015

Depth: 20m

		TRANSECTS					
		1	2	3	4	5	
		(Ind/30m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	80	60	120	100	0	**70.0**
Clepticus parrae	Creole Wrasse	50	0	18	150	100	**67.0**
Chromis cyanea	Blue Chromis	5	5	17	8	12	**10.5**
Gramma loreto	Fairy Basslet	7	10	9	10	8	**9.3**
Coryphopterus lipernes	Peppermint Goby	6	8	17	3	4	**8.0**
Thalassoma bifassiatum	Bluehead Wrasse	19	0	0	7	5	**3.0**
Scarus taeniopterus	Princess Parrotfish	1	1	4	6	0	**2.8**
Scarus iserti	Stripped Parrotfish	1	5	0	0	4	**2.3**
Stegastes partitus	Bicolor Damselfish	0	4	3	1	0	**2.0**
Acanthurus chirurgus	Doctorfish	0	3	2	1	0	**1.5**
Sparisoma viride	Stoplight Parrotfish	4	0	1	0	4	**1.3**
Stegastes leucostictus	Beau Gregory	1	0	1	2	2	**1.3**
Halichoeres garnoti	Yellow-head Wrasse	2	2	1	0	1	**1.0**
Myripristis jacobus	Blackbar Soldierfish	0	0	1	2	1	**1.0**
Sparisoma aurofrenatum	Redband Parrotfish	0	3	0	1	0	**1.0**
Canthigaster rostrata	Caribbean Puffer	0	1	2	1	0	**1.0**
Holocentrus rufus	Squirrelfish	1	1	1	1	1	**1.0**
Chaetodon capistratus	Four-eye Butterflyfish	0	0	2	0	1	**0.8**
Acanthurus coeruleus	Blue Tang	2	1	0	2	0	**0.8**
Chaetodon acuelatus	Longsnout Butterflyfish	0	0	2	0	1	**0.8**
Chaetodon ocellatus	Spotfin Butterflyfish	0	2	0	0	0	**0.5**
Cephalopholis cruentatus	Graysby	1	0	0	1	1	**0.5**
Epinephelus guttatus	Red Hind	0	1	0	0	0	**0.3**
Carangoides ruber	Bar Jack	0	1	0	0	0	**0.3**
Haemulon flavolineatum	French Grunt	0	0	0	1	0	**0.3**
Anisotremus virginicus	Porkfish	0	0	1	0	0	**0.3**
Muilloides martinicus	Yellowfih Goatfish	0	0	0	0	1	**0.3**
Aulostomus maculatus	Trumpetfish	0	0	1	0	0	**0.3**
Pomacanthus arcuatus	Grey Angelfish	0	0	0	0	1	**0.3**
Holacanthus tricolor	Rock Beauty	0	0	0	0	1	**0.3**
Hypoplectrus unicolor	Butter Hamlet	0	1	0	0	0	**0.3**
Ocyurus chrysurus	Yellowtail Snapper	0	1	0	0	0	**0.3**
Bodianus rufus	Spanish Hoggfish	0	0	0	0	1	**0.3**
	TOTAL INDIVIDUALS	**180**	**110**	**203**	**297**	**149**	**187.8**
	TOTAL SPECIES	**14**	**18**	**18**	**17**	**19**	**17.2**

adult Yellowtail Snappers, one Graysbe and one adult Red Hind were also present within belt-transects. 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 the reef and the apparent cause for their absence is probably that the reef was severely overfished during the last decades and/or that recruitment overfishing is limiting the replenishment of commercially exploited snapper and grouper populations.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.

Small zooplanktivorous fishes, such as the Masked Goby, Blue Chromis, Bicolor Damselfish and micro-invertebrate predators, including wrasses, gobies, basslets, hamlets, and squirrelfishes numerically dominated the reef fish community. Parrotfishes (*Scarus spp., Sparisoma spp*.), represented by four species and doctorfishes (*Acanthurus spp*.), comprised the main herbivorous fish assemblage, but represented less than 5 % 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, 2014 and reports therein).

Annual variations of fish abundance and species richness are presented in Figure 29. Differences of fish abundance between surveys were statistically significant (ANOVA; $p < 0.0001$). Abundance was higher during 2005, 2006 and 2008 relative to other monitoring surveys. Species richness presented a consistent decline after 2006, but a slight increment was documented in 2010 and now again in the present 2015 survey. Differences of fish abundance at this reef have been historically driven by abundance fluctuations of the Masked Goby, a numerically dominant species with highly patchy 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 dynamicas play an important role.

Table 32. Taxonomic composition, density and size of fishes within 20 m x 3 m belt-transects at Tourmaline Reef, 20m. 2015

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped Parrotfish	1 - 25	5 - 12			1-5 6-10 1-20
Sparisoma viride	Stoplight Parrotfish	2 - 25 2 - 35		1 - 20		2-7 1-15 2-25 1-35
Sparisoma aurofrenatum	Redband Parrotfish		3 - 15		1 - 25	
Ocyurus chrysurus	Yellowtail Snapper		1 - 20	1 - 20		
Epinephelus guttatus	Red Hind		1 - 27			
Epinephelus cruentatus	Graysby					1-15
Scarus taeniopterus	Princess Parrotfish	1 - 25	1 - 25	4 - 15 1 - 17	4 - 20 2 - 25	

One Cleaner Shrimp was the only motile megabenthic invertebrate observed within belt-transects during 2015. Two Spiny Lobsters (*Panulirus argus*) were observed outside transects.

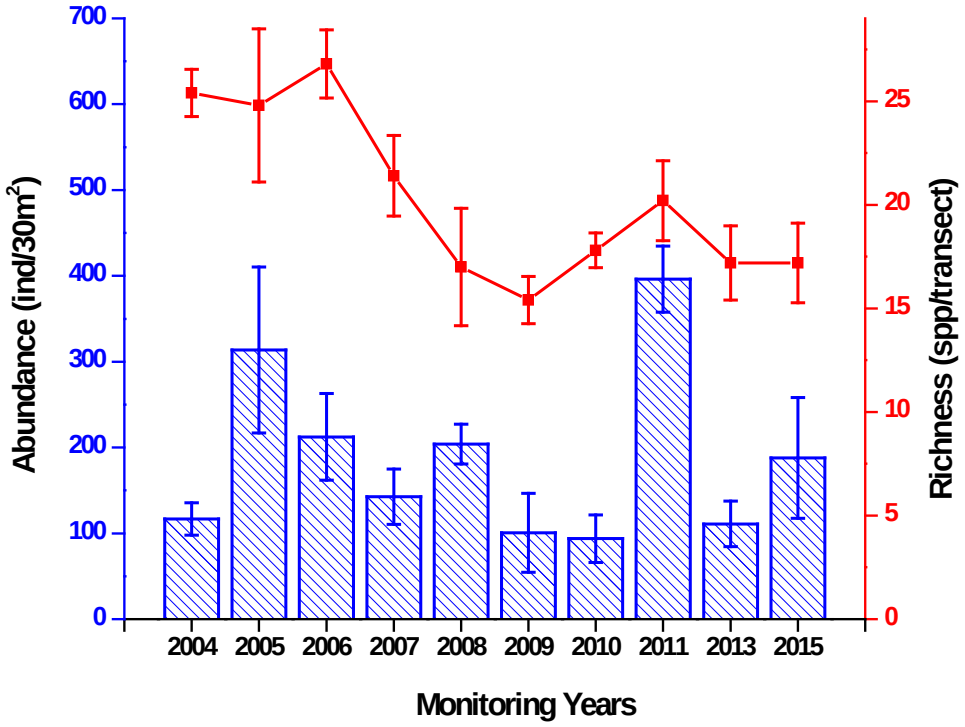


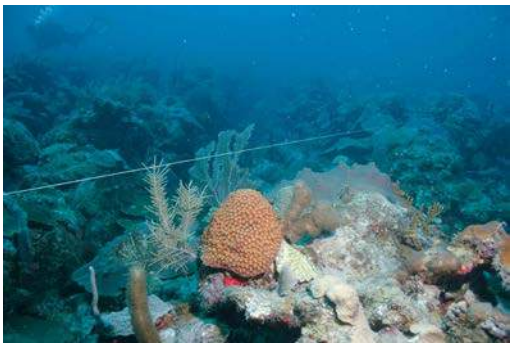
Figure 29. Monitoring trends (2004 – 2015) of fish species richness and abundance at outer shelf reef Tourmaline, 20 m, Mayaguez.

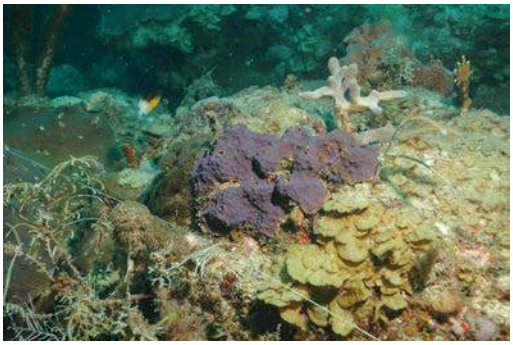
Table 33. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline 20 m, Mayaguez, 2015

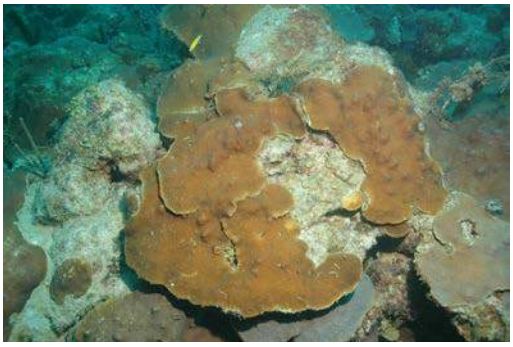
Depth: 20 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m²)
		1	2	3	4	5	
TAXA	**COMMON NAME**						
Periclimenes pedersoni	Cleaner Shrimp				1		**0.2**
	TOTALS	**0**	**0**	**0**	**1**	**0**	**0.2**

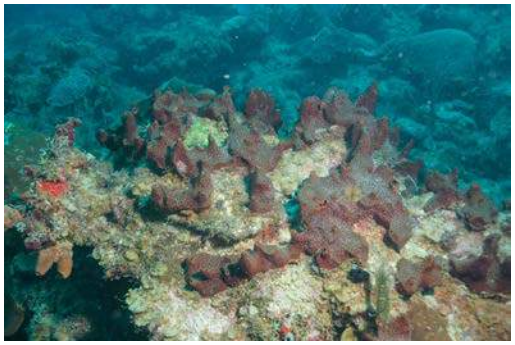
Photo Album 8 Tourmaline Reef System, 20m

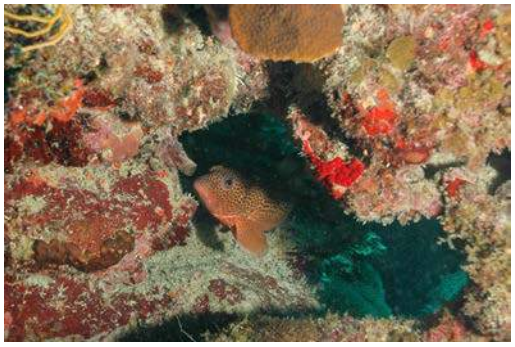
OuterShelf Reef











3.0 Tourmaline Outer Shelf Reef – 10 m

3.1 Sessile-benthic Reef Community

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 eleventh time during 2015. Panoramic views of Tourmaline outer shelf reef at a depth of 10 m are presented in Photo Album 9.

A total of 25 stony coral species were identified from the Outer Shelf Reef at a depth of 10 m, 19 of which were intercepted by line transects during this survey (Table 34). Stony corals occurred as massive (*Orbicella annularis*, *Colpophyllia natans, Diploria 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 40.8 % (range: 30.0 – 70.4 %). Boulder Star Coral, *O. annularis* and Yellow Pencil Coral, *Madracis mirabilis* were the dominant coral species in terms of substrate cover with means of 10.7 and 10.3 %, respectively. Yellow Pencil Coral exhibited branching growth over the reef hard bottom and had kept an increasing pattern of substrate cover, reaching its maximum cover during the 2010 (10.5%). An extraordinarily large colony of Yellow Pencil Coral now covers more than four meters along transect two, contributing to a total cover by stony corals of 70.4 % in that transect, which is the highest in the monitoring program. Boulder Star Coral (*O. annularis* complex), Mustard Hill Coral (*Porites astreoides*), and Lettuce Coral (*Agaricia agaricites*) were intercepted by all five transects in the present 2015 monitoring survey and comprised in addition to *M. mirabilis* the main stony coral assemblage at this reef. A total of 11 coral species were represented with less than 1% substrate cover.

Table 34. Percent substrate cover by sessile-benthic categories at Tourmaline Reef, Mayaguez. 10m. 2015

	Transects					
	1	2	3	4	5	**Mean**
Rugosity	2.61	13.30	2.60	12.95	13.33	**8.96**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang		0.35	2.00	0.24	0.21	**0.56**
Sand			0.56			**0.11**
Total Abiotic		0.35	2.56	0.24	0.21	**0.67**
Benthic Algae						
Turf	46.61	13.89	43.56	41.84	38.76	**36.93**
Dictyota spp.	4.44	3.68	3.22	4.54	2.31	**3.64**
CCA	1.33	1.26	1.33	4.11	2.84	**2.17**
Halimeda sp.		0.32			2.52	**0.57**
Lobophora variegata	1.11					**0.22**
Ventricaria ventricosa		1.05				**0.21**
Total Benthic Algae	53.50	20.21	48.11	50.49	46.43	**43.75**
Live Corals						
Orbicella annularis complex	10.32	12.00	10.44	8.97	11.55	**10.66**
Madracis auretenra		50.21		1.08		**10.26**
Porites astreoides	3.22	3.68	10.44	4.22	4.52	**5.22**
Agaricia agaricites	4.33	0.53	5.00	8.43	6.09	**4.88**
Porites porites	7.66	1.79	2.67			**2.42**
Dendrogyra cylindrus	2.89		2.89	4.86		**2.13**
Colpophyllia natans			5.44		1.68	**1.43**
Meandrina meandrites		2.21	1.78	1.08	1.47	**1.31**
Montastraea cavernosa			1.22	1.08	1.47	**0.75**
Pseudodiploria strigosa	0.22		1.00		0.63	**0.37**
Pseudodiploria labyrinthiformis					1.58	**0.32**
Madracis decactis	0.33			0.22	0.74	**0.26**
Siderastrea siderea			0.89			**0.18**
Agaricia lamarcki					0.84	**0.17**
Eusmilia fastigiata			0.56			**0.11**
Millepora complanata	0.44					**0.09**
Stephanocoenia intersepta	0.44					**0.09**
Millepora alcicornis			0.33			**0.07**
Leptoseris cucullata	0.33					**0.07**
Total Live Corals	30.19	70.42	42.67	29.95	30.57	**40.76**

Table 34. continued

Cyanobacteria	1.00	0.42	4.33	0.65	0.42	**1.36**
Octocorals						
Briareum asbestinum	8.32	0.32		1.39	1.11	**2.23**
Erythropodium caribaeorum	5.77		1.67	0.15	1.13	**1.75**
Plexaura homomalla				0.07		**0.22**
Plexaura kuekenthali				0.06		**0.16**
Octocoral			0.67			**0.13**
Eunicea succinea		0.42				**0.08**
Gorgonia ventalina		0.32				**0.06**
Pseudoplexuara flagellosa		0.5263 15789		0.06	0.10	**0.03**
Eunicea tourneforti					0.04	**0.01**
Total Octocorals	14.10	1.58	2.33	1.72	2.38	**4.42**
Erect Gorgonians (#col/transect)	22	19	15	39	29	**24.80**
Sponges						
Agelas tubulata		0.27				**0.05**
Neopetrosia proxima					0.22	**0.04**
Monanchora arbuscula	0.06			0.07		**0.03**
Niphates erecta	0.06				0.07	**0.03**
Clathria sp.				0.10		**0.02**
Mycale laevis		0.04		0.04		**0.02**
Cliona tenuis		0.06				**0.01**
Amphimedon compressa				0.04		**0.01**
Agelas sp.					0.03	**0.01**
Callyspongia vaginalis		0.03				**0.01**
Phorbas amaranthus				0.03		**0.01**
Total Sponges	0.11	0.39	0.00	0.28	0.32	**0.22**

Erect soft corals (gorgonians) were highly abundant with an average of 24.8 colonies/transect and along with stony corals were the most visually prominent assemblage of the reef benthos. The most abundant species included the Corky Sea Finger, *Briareum asbestinum*, sea rods, *Plexaura spp*. *Pseudoplexaura spp*., and sea fans, *Gorgonia ventalina*. Encrusting gorgonians, *Erythropodium caribaeorum* were present with an average substrate cover of 1.8 %. Sponges were represented by at

least 11 species along transects with a combined mean cover of 0.2 %, and represented minor components of the reef benthos.

Turf algae, comprised by a mixed assemblage of short filamentous red and brown macroalgae presented an average substrate cover of 36.9 % (range: 13.9 – 46.6 %), representing 84.2% 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 43.8 %. Cyanobacterial films were observed in all five transects with a mean substrate cover of 1.4%.

Figure 30 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 10 annual monitoring surveys (2004-15). 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 (ANOVA; $p = 0.662$), 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 (Figure 31), and was the main driver of the overall decline of live coral for this reef. After 2009, *O. annularis* has shown a pattern of increasing reef substrate cover until the present survey (Figure 31).

The loss of reef substrate by *O. annularis* was aggressively colonized by the branching and fast growing Yellow Pencil Coral, *M. mirabilis,* which is now a co-dominant coral in terms of substrate cover at Tourmaline 10 m. The trend of increasing reef substrate cover by *M. mirabilis* stabilized during the 2010 survey and has prevailed within the 10.0 10.5 % cover until the present 2015 survey, perhaps due to the lack of additional hard ground space to grow. Between 1999 and 2015, *M. mirabilis* more than doubled its

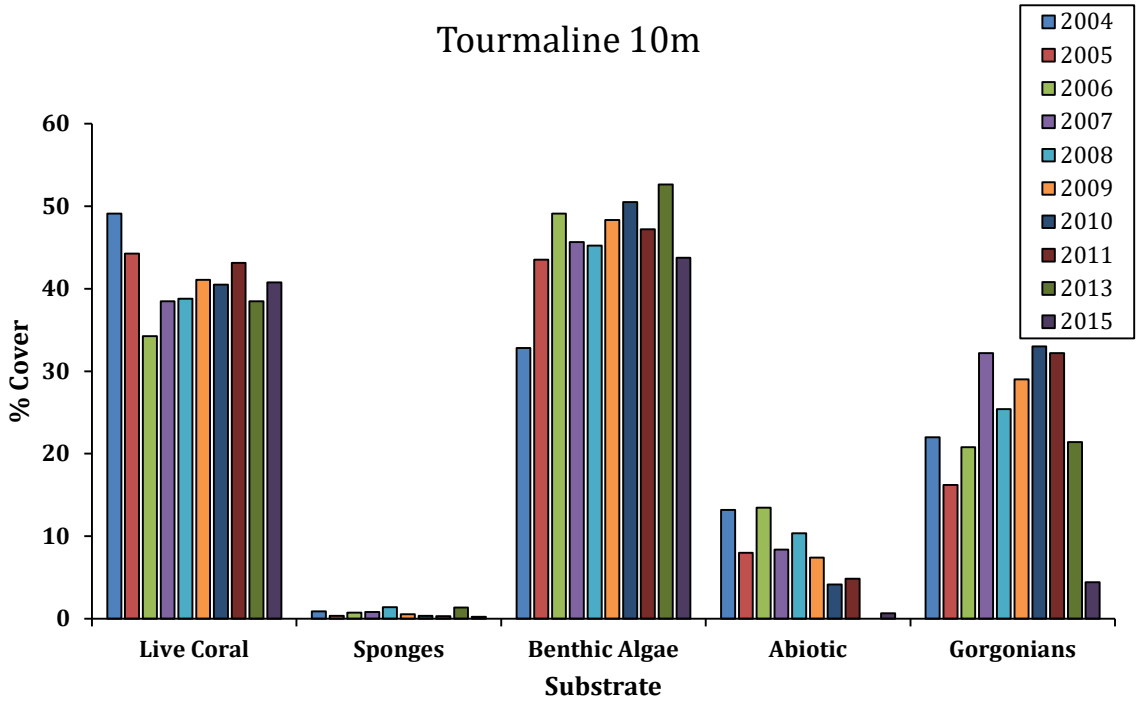


Figure 30. Monitoring trends (1999 – 2015) of mean substrate cover by sessile-benthic categories at Tourmaline Reef – 10 m, Mayaguez.

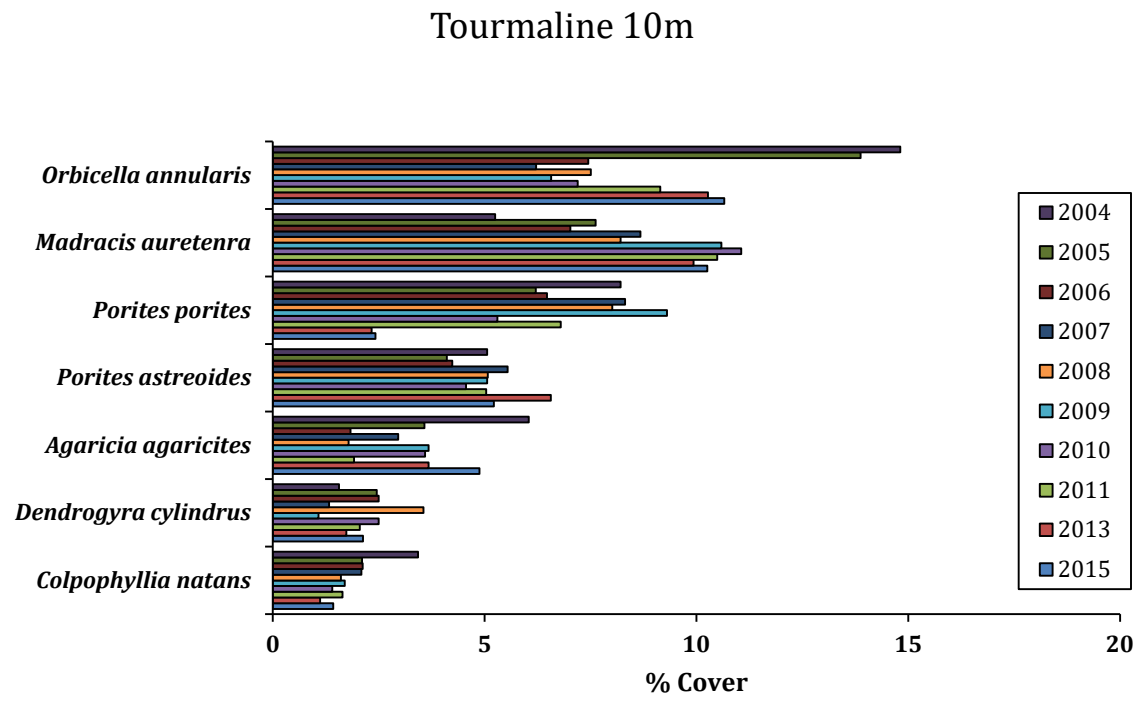


Figure 31. Monitoring trends (1999 – 2015) of mean cover by stony coral species at Tourmaline Reef – 10 m, Mayaguez.

substrate cover in transect 2 from 27.4% to 70.0 % (Figure 31). Such growth has contributed significantly to the sharp recuperation of live coral cover at Tourmaline 10 m. Finger Coral, *Porites porites* also displayed a very active growth pattern after the 2005-bleaching event, increasing cover from a baseline mean of 5.3 % to a peak of 9.3 % in 2009. After 2010, this species suffered from what appears to be an infectious disease and exhibited substantial colony degradation and loss of substrate cover. Partial recuperation was measured during the 2013 survey, but the species declined again after 2013, reaching a minimum cover of 2.4 % during the present 2015 survey.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 99 diurnal, non-criptic fish species have been identified during monitoring surveys from Tourmaline Outer Shelf Reef at a depth of 10 m (Appendix 1). Mean abundance during the 2015 survey was 97.4 Ind/30 m^2 (range: 62 – 170 Ind/30 m^2). A total of 32 species were observed within belt-transects and the mean number of species per transect was 18 (range: 16 - 19). The Blue Chromis (*Chromis cyanea*), Masked Goby (*Coryphopterus personatus*), Bluehead Wrasse (*Thalassoma bifasciatum*), Bicolor Damselfish (*Stegastes partitus*), Stripped and Redband Parrotfishes (*Scarus iserti, Sparisoma aurofrenatum*), were the numerically dominant species with a combined mean abundance of 64.0 Ind/30 m^2, representing 65.7 % of the total abundance within belt-transects (Table 35). In addition to the aforementioned species, four more species were present in at least four transects. These included the Stoplight Parrotfish, Beau Gregory, Yellowhead Wrasse, French Grunt, Four-eye Batterflyfish, Sharknose Goby, and Blue Tang. Parrotfishes (*Scarus iserti, S. taeniopterus, Sparisoma aurofrenatum*) were the numerically dominant assemblage of commercially important fish species observed within extended belt-transects (Table 36). One late juvenile Red Hind was present, along with a small adult Coney and Graysbe. Size distributions are in general indicative of a prevailing juvenile and young adult populations.

Small demersal and pelagic schooling zooplanktivores, including the Blue Chromis, Masked Goby, Creole Wrasse and Bicolor Damselfish dominated the Tourmaline 10m reef community structure in terms of trophic categories, representing approximately 56 % of the total individuals within belt-transects. Small, opportunistic micro-invertebrate predators (wrasses, gobies) were also prominent trophic groups. Herbivores were

Table 35. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, 10 m, Mayaguez Bay. 2015

Depth: 10m

		Transects					
		1	2	3	4	5	
		(Ind/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Chromis cyanea	Blue Chromis	0	52	21	12	0	**17.0**
Coryphopterus personatus	Masked Goby	15	50	0	0	0	**13.0**
Thalassoma bifasciatum	Bluehead Wrasse	8	23	18	0	8	**11.4**
Stegastes partitus	Bicolor Damselfish	6	14	9	4	8	**8.2**
Scarus iserti	Stripped Parrotfish	3	7	9	2	18	**7.8**
Sparisoma aurofrenatum	Redband Parrotfish	5	6	2	15	5	**6.6**
Clepticus parrae	Creole Wrasse	26	0	0	0	0	**5.2**
Scarus taeniopterus	Princess Parrotfish	9	0	0	12	0	**4.2**
Sparisoma viride	Stoplight Parrotfish	2	2	8	6	2	**4.0**
Stegastes leucostictus	Beau Gregory	4	1	1	4	4	**2.8**
Halichoeres garnoti	Yellow-head Wrasse	7	0	2	2	2	**2.6**
Choryphopterus lipernes	Peppermint Goby	6	1	0	1	0	**1.6**
Chaetodon capistratus	Four-eye Butterflyfish	2	2	0	2	2	**1.6**
Haemulon flavolineatum	French Grunt	0	3	1	1	2	**1.4**
Gobiosoma evelynae	Sharknose Goby	2	1	3	0	1	**1.4**
Acanthurus coeruleus	Blue Tang	0	2	2	1	2	**1.4**
Acanthurus chirurgus	Doctorfish	0	2	1	0	2	**1.0**
Myripristis jacobus	Blackbar Soldierfish	0	0	1	3	0	**0.8**
Amblycirrhitus pinos	Redspotted Hawkfish	0	0	2	1	1	**0.8**
Serranus tigrinus	Harlequin Bass	1	1	0	1	0	**0.6**
Epinephelus fulva	Coney	1	0	0	0	2	**0.6**
Stegastes variabilis	Cocoa Damselfish	0	0	2	0	0	**0.4**
Canthigaster rostrata	Caribbean Puffer	0	1	1	0	0	**0.4**
Holacanthus tricolor	Rock Beauty	0	1	0	0	1	**0.4**
Acanthurus bahianus	Ocean Surgeon	1	0	1	0	0	**0.4**
Flammeo marianus	Longspine Squirrelfish	0	0	0	2	0	**0.4**
Mycrospathodon chrysurus	Yellowtail Damselfish	0	0	0	2	0	**0.4**
Aulostomus maculatus	Trumpetfish	0	1	0	0	0	**0.2**
Holocentrus rufus	Squirrelfish	0	0	0	0	1	**0.2**
Epinephelus guttatus	Red Hind	0	0	0	1	0	**0.2**
Cephalopholis cruentatus	Graysby	0	0	0	0	1	**0.2**
Synodus intermedius	Lizardfish	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	98	170	84	73	62	**97.4**
	TOTAL SPECIES	16	18	17	19	18	**17.6**

Table 32. Taxonomic composition, density and size of fishes within 20 m x 3 m belt-transects at Tourmaline Reef, 10m. 2015

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped Parrotfish	5 - 5	5 - 5 5 - 7 2 - 10 4 - 12	6 - 5 3 - 12 4 - 25	2 - 10	9 - 5 4 - 7 9 - 12
Sparisoma viride	Stoplight Parrotfish	1 - 10 2 - 20 1 - 30	1 - 7 1 - 10 1 - 12	4 - 5 3 - 10 2 - 25	4 - 15 2 - 20	1 - 12 1 - 17
Sparisoma aurofrenatum	Redband Parrotfish	1 - 10 1 - 12	5 - 3 2 - 10 2 - 13	1 - 5 1 - 10 2 - 15	10 - 7 5 - 12	2 - 5 2 - 12 1 - 15
Epinephelus fulva	Coney					2 - 10
Epinephelus guttatus	Red Hind				1 - 20	
Epinephelus cruentatus	Graysby					1 - 7
Scarus taeniopterus	Princess Parrotfish	6 - 7 2 - 15			4 - 7 2 - 10 4 - 12 2 - 15	

represented by four species of parrotfishes, four species of damselfishes and three species of doctorfishes comprised approximately 29.4 % of the total assemblage within belt-transects. Among large invertebrate and small demersal fish predators, small groupers such as Coneys and Graysbys were common. Adult Red Hind, Schoolmaster, Mahogany and Yellowtail Snappers represented top demersal predators observed during this and previous surveys at this reef. Schools of Mackerel Scad, *Decapterus macarellus* and Ballyhoo, *Hemiramphus ballyhoo* were present near the reef surface over the. 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 32. 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 not statistically significant (ANOVA; $p > 0.05$). 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*). Aggregated or patchy distributions tend to increase the magnitude of sampling variability and thus, increase the statistical uncertainty associated with the means. In the case of fish species richness, differences between annual surveys were statistically significant (ANOVA; $p < 0.001$), influenced mostly by a sharp decline of species during 2008 relative to all other surveys.

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

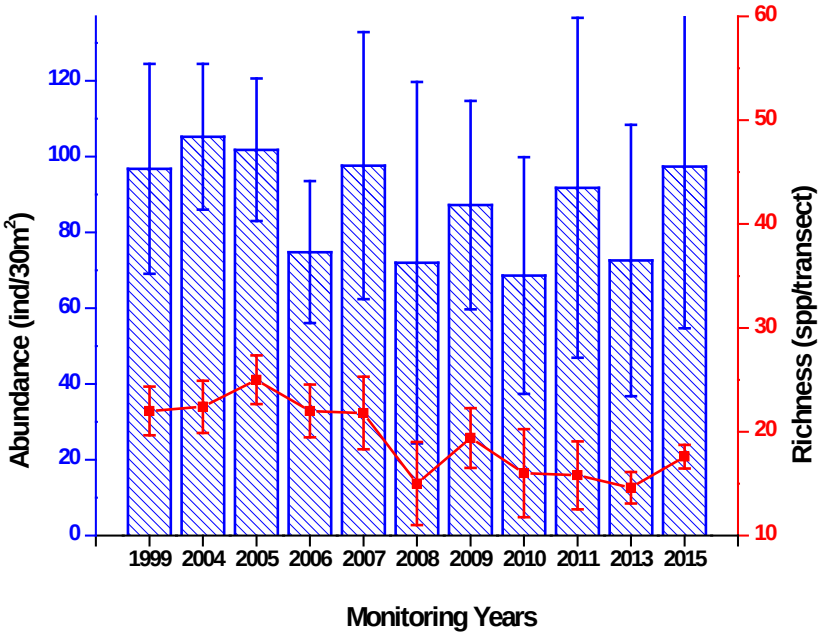


Figure 32. Monitoring trends (2004 – 2015) of fish species richness and abundance at Outer Shelf Reef Tourmaline, 10 m, Mayaguez.

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 Banded Coral Shrimp and Flamingo Toungues (Table 37). 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).

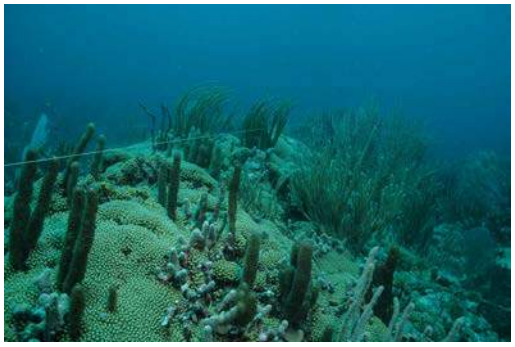
Table 37. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Reef, 10 m, 2015

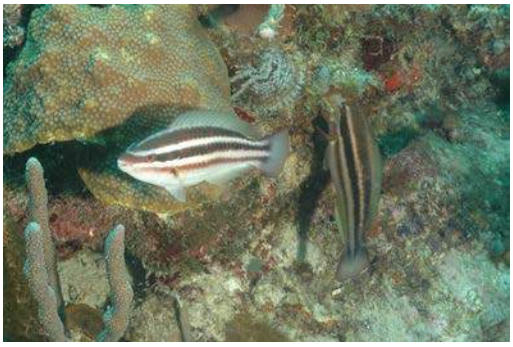
Depth: 10 m

TAXA	COMMON NAME	TRANSECTS 1	2	3	4	5	MEAN ABUNDANCE (IND/30 m2)
Cyphoma gibbosum	Flamingo Tongue	2	0	1		1	**0.8**
Stenophus hispidus	Banded Coral Shrimp					1	**0.2**
	TOTALS	**2**	**0**	**1**	**0**	**2**	**1.0**

Photo Album 9. Tourmaline Reef System, 10m

OuterShelf Reef





D. Guánica Natural Reserve

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 (Figure 33).

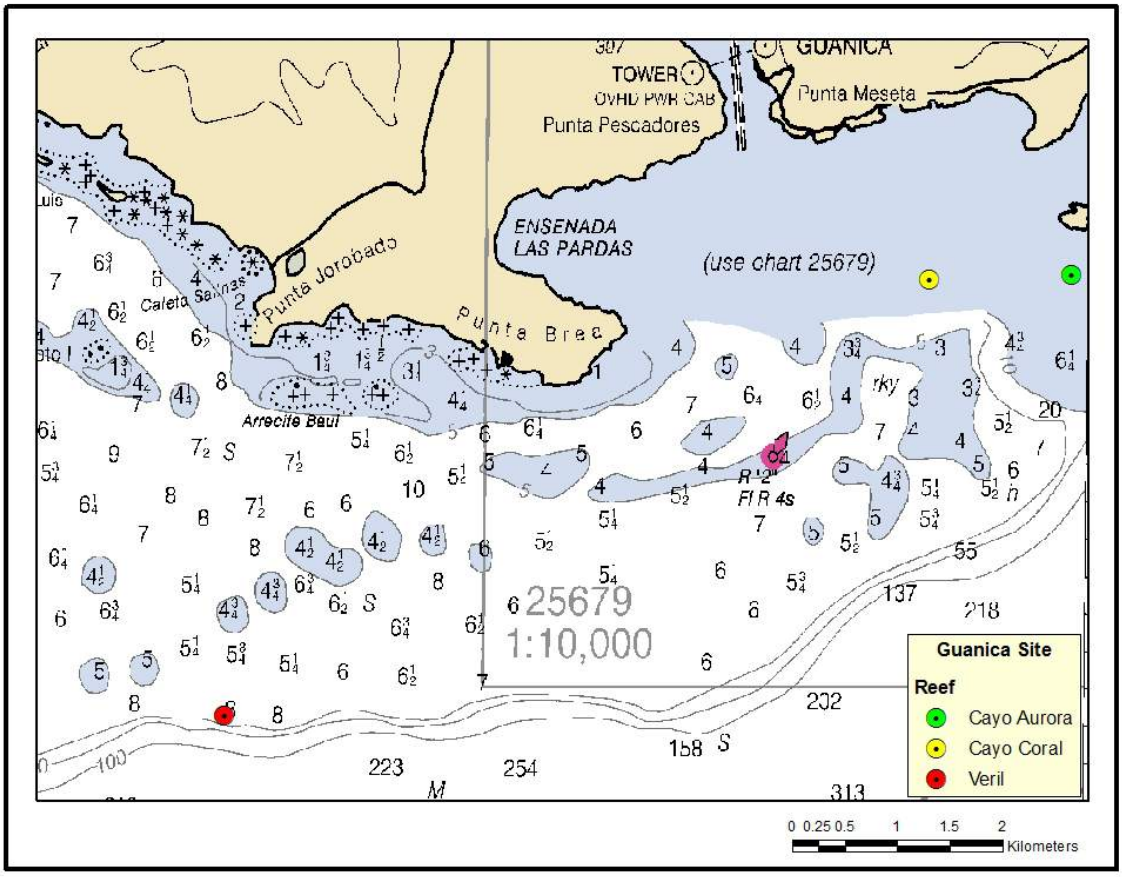


Figure 33. Location of coral reef survey stations at the Guanica Natural Reserve site.

1.0 Cayo Coral

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 34). The reef is about two kilometers long and sits in the same platform as Caña Gorda Reef, at the landward's (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 close to the base of Cayo Coral's fore reef. Panoramic views of Cayo Coral are presented as Photo Album 10.

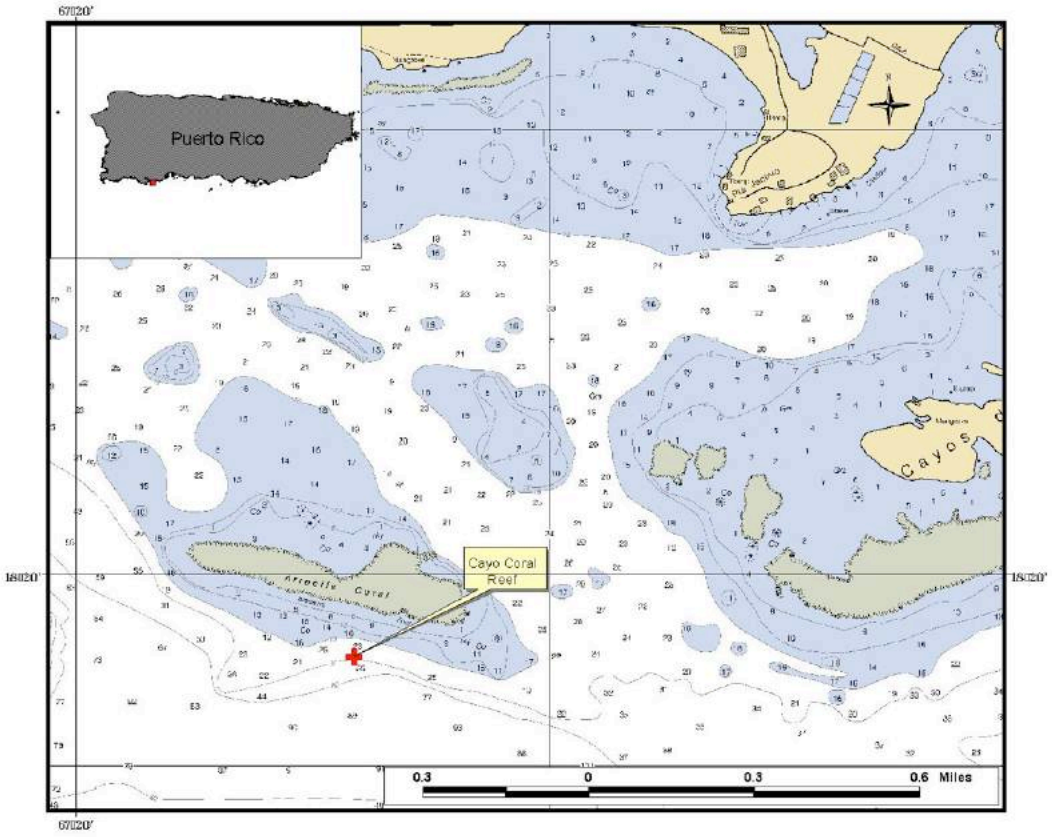


Figure 34. Location of coral reef survey stations at Cayo Coral Reef, Guánica.

1.1 Sessile**-benthic Reef Community**

A total of 17 stony corals, including 12 intersected by permanent line transects were identified from Cayo Coral Reef during the 2015 survey (Table 38). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 14.5 % (range: 7.5 – 19.7%). Boulder Star Coral,

Orbicella annularis (complex) was the main species in terms of substrate cover with a mean of 5.5% (range: 2.6 – 10.6 %), representing 37.9 % of the total cover by stony corals and was present in all five transects (Table 38). Mustard Hill Coral, *Porites astreoides*, Boulder Brain Coral, *Colpophyllia natans* and Symmetrical Brain Coral, *Diploria strigosa*, along with Boulder Star Coral and comprised the main coral assemblage of the reef at a depth of 7-10m.

Soft corals (gorgonians) were moderately abundant with an average of 24 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 species present included the Encrusting Gorgonian, *Erythropodim caribaeorum*, Corky Sea Finger, *Briareum asbestinum*, Sea Rods, *Eunicea sp*., *Plexaura spp*., and the Common Sea Fan, *Gorgonia ventalina*. 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 at least 15 species with an average cover of 5.7 %. Small patches of colonial zoanthid (*Palythoa sp*) represented minor components of the reef benthos with a mean cover of 0.8 %. Reef overhangs associated with mostly dead massive Boulder Star Coral colonies averaged a substrate cover of 5.8 % and contributed substantially to the mean rugosity of 3.3 m.

Benthic algae, comprised mostly by turf algae was the most prominent sessile-benthic category in terms of substrate cover with a mean of 57.2 % (range: 49.8 – 64.2 %). Turf algae was found colonizing hard ground substrates, particularly dead coral colonies. Some dead coral colonies were also colonized by cyanobacteria, which was present in all five transects surveyed with a mean cover of 2.1 %. The cyanobacterial cover was most prominent in deeper sections of the fore reef slope (15 – 20 m), where it was observed to cover extensive sections of dead Boulder Star Coral.

Figure 35 presents the variations of mean percent cover by sessile-benthic categories from Cayo Coral, including data from the original baseline survey in 1999, and subsequent monitoring surveys of 2005-15. Differences of reef substrate cover by live stony corals between surveys were statistically significant (ANOVA; $p < 0.0001$, Appendix 2) and constitute evidence of degradation of the coral reef community

Table 38. Percent substrate cover by sessile-benthic categories at Cayo Coral, Guanica. 8 m. 2015

	Transects					
	1	2	3	4	5	**Mean**
Rugosity	2.81	2.84	3.66	3.73	3.39	**3.286**
SUBSTRATE CATEGORY						
Abiotic						
Sand	8.85		6.15	12.13	7.84	**6.99**
Reef overhang	1.31	4.69	5.84	13.56	3.45	**5.77**
Rubble	0.66	3.05	8.30	2.04	6.06	**4.02**
Total Abiotic	10.82	7.74	20.29	27.73	17.35	**16.78**
Benthic Algae						
Turf	50.38	61.50	41.60	40.77	34.59	**45.77**
Dictyota spp.	9.29	0.65	4.82	13.35	15.05	**8.63**
CCA	1.09	0.55	2.66		1.36	**1.13**
Halimeda spp.	1.42	0.33	0.72	0.71	1.46	**0.93**
Caulerpa sp.				1.73		**0.35**
Lobophora variegata	1.31					**0.26**
Udotea sp.	0.66					**0.13**
Total Benthic Algae	64.15	63.03	49.80	56.57	52.46	**57.20**
Cyanobacteria	1.42	0.65	3.59	2.65	1.99	**2.06**
Live Corals						
Orbicella annularis complex	2.84	8.40	2.56	3.06	10.55	**5.48**
Porites astreoides	1.31	1.85	2.56		3.24	**1.79**
Colpophyllia natans			8.71			**1.74**
Pseudodiploria strigosa	2.40	1.09	0.41	4.08		**1.60**
Siderastrea siderea	0.98	3.82	0.72		0.21	**1.15**
Agaricia agaricites	2.08	0.33	0.41		2.82	**1.13**
Porites porites	0.22	0.65	3.38		0.31	**0.91**
Montastraea cavernosa	0.87		0.61		0.52	**0.40**
Madracis decactis	0.44					**0.09**
Millepora alcicornis				0.41		**0.08**
Eusmilia fastigiata		0.33				**0.07**
Meandrina meandrites			0.31			**0.06**
Total Live Corals	11.15	16.47	19.67	7.54	17.66	**14.50**
Octocorals						
Erythropodium caribaeorum	0.87	1.42	1.02	1.33	3.03	**1.53**
Briareum asbestinum	0.44	1.96	0.20		0.21	**0.56**
Allotogorgia americana					0.84	**0.17**
Eunicea flexuosa					0.63	**0.13**
Plexaura kuekenthali					0.63	**0.13**

Table 38. continued

Plexaura homomalla	0.11	0.33				**0.09**
Pseudoplexaura flagellosa		0.33				**0.07**
Gorgonia ventalina					0.31	**0.06**
Eunicea tourneforti					0.21	**0.04**
Total Octocorals	1.42	4.03	1.23	1.33	5.85	**2.77**
Erect Gorgonians (#col/transect)	28	29	22	21	20	**24**
Sponges						
Cliona tenuis	1.86	4.14	2.77	1.12	2.09	**2.40**
Petrosia pellasarca	2.62					**0.52**
Neopetrosia proxima	0.98	0.76	0.20		0.63	**0.52**
Xestospongia muta	2.30					**0.46**
Ectyoplasia ferox	0.87			1.12		**0.40**
Niphates erecta	0.77			0.51		**0.25**
Niphates digitalis	0.77		0.20			**0.19**
Mycale laevis	0.55	0.11	0.31			**0.19**
Ircinia strobilina	0.33			0.61		**0.19**
Scopalina ruetzleri		0.22	0.20		0.42	**0.17**
Chondrilla caribensis					0.84	**0.17**
Clathria sp.		0.44				**0.09**
Callyspongia fallax					0.42	**0.08**
Agelas sp.					0.31	**0.06**
Amphimedon compressa				0.20		**0.04**
Total Sponges	11.04	5.67	3.69	3.57	4.70	**5.73**
Zoanthid						
Palythoa caribaeorum		1.85	1.74	0.61		**0.84**

structure. Total live coral cover at Cayo Coral declined consistently throughout the monitoring program from a mean of 25.3 % in 1999 to a mean of 8.9 % in 2008, an overall reduction of 64.8 %. The reduction of live coral cover was evidenced across the five permanent transects surveyed. A corresponding increment of cover by benthic algae was documented (Figure 35). The aforementioned 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 for the first time during the monitoring program and this trend has continued up to the present monitoring survey (2015). The overall increment of live coral cover from the minimum measured in 2008 is now 34%. Such increasing trend was mostly driven by a mild but consistent recuperation of Boulder Star Coral, *Orbicella annularis*, but increased cover is also apparent for *C. natans* and *P. astreoides* (Figure 36).

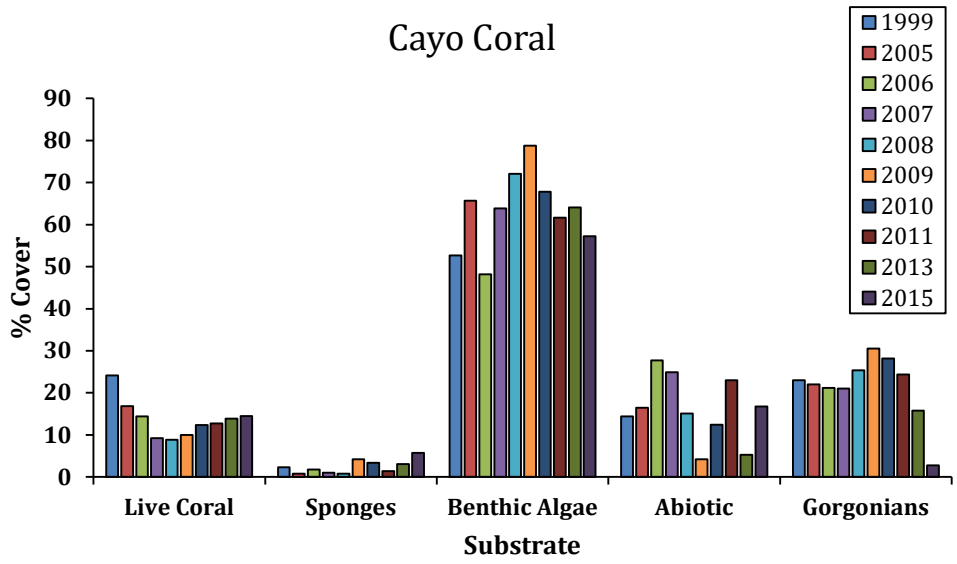


Figure 35. Monitoring trends (1999 – 2015) of mean substrate cover by sessile-benthic categories at Cayo Coral – 8 m, Guánica.

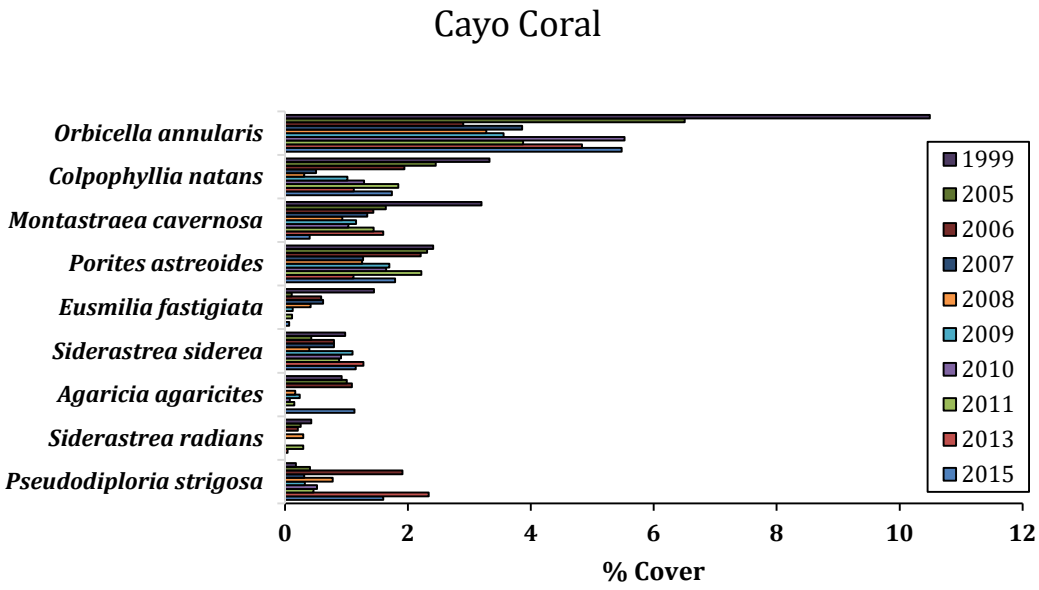


Figure 36. Monitoring trends (1999 – 2015) of mean substrate cover by stony coral species at Cayo Coral – 8 m, Guánica

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 102 fish species have been identified from Cayo Coral during monitoring surveys (Appendix 1). Mean abundance within belt-transects during the 2015 survey was 37.2 Ind/30 m^2 (range: 29 - 47 Ind/30 m^2). The mean number of species per transect was 14.0 (range: 13 - 15). Bluehead Wrasse (*Thalassoma bifasciatum*), Striped Parrotfish (*Scarus iserti*), Dusky and Bicolor Damselfishes (*Stegastes dorsopunicans, S. partitus*), Four-eye Butterflyfish (*Chaetodon capistratus*) and Sharknose Goby (*Elacatinus evelynae*). were the numerically dominant species with a combined mean abundance of 24.6 Ind/30 m^2, representing 66.1 % of the total abundance within belt-transects (Table 39). All of the aforementioned species were present in at least 4 transects and along with the Beaugregory, Redband and Stoplight Parrotfishes, Yellowhead Wrasse and Blue Chromis comprised the main reef fish assemblage at Cayo Coral.

Early juvenile and young adult parrotfishes (*Scarus iserti, S. taeniopterus, Sparisoma viride, S. aurofrenatum*) were the most abundant fish assemblage within extended belt-transects (Table 40). Adult Yellowtail Snapper (*Ocyurus chrysurus*), Lionfish (*Pterois sp*.) and Red Hind (*Epinephelus guttatus*) were also present.

The fish community structure of Cayo Coral apperars to be strongly driven by herbivores, including three species of parrotfishes, four species of damselfishes and two species of doctorfishes that comprised 41 % of the total fish individuals within belt-transects. Small, opportunistic micro-invertebrate predators (wrasses, gobies, puffers) were also prominent with approximately 37 % of the total individuals. Conversely, demersal and pelagic zooplanktivores represented less than 10 % of the total individuals within transects. Among large invertebrate and small demersal fish predators, small growing groupers such Graysby and Coneys were common. Juvenile Yellowfin Grouper and Jewfish, Red Hind, Nassau Grouper, Hogfish, Schoolmaster, Mahogany and Yellowtail Snappers have been previous reported during 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).

Table 39. Taxonomic composition and abundance of fishes within belt-transects at Cayo Coral, Guanica, 8 m. December 2012

Depth: 8 m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	0	2	0	12	25	**7.8**
Scarus iserti	Stripped Parrotfish	2	7	3	6	5	**4.6**
Stegastes dorsopunicans	Dusky Damselfish	5	6	5	4	2	**4.4**
Stegastes partitus	Bicolor Damselfish	6	2	3	5	1	**3.4**
Chaetodon capistratus	Four-eye Butterflyfish	2	2	2	4	1	**2.2**
Gobiosoma evelynae	Sharknose Goby	1	3	6	1	0	**2.2**
Halichoeres garnoti	Yellow-head Wrasse	2	2	1	1	3	**1.8**
Sparisoma aurofrenatum	Redband Parrotfish	2	1	3	1	1	**1.6**
Chromis cyanea	Blue Chromis	0	3	0	4	0	**1.4**
Sparisoma viride	Stoplight Parrotfish	1	2	0	1	2	**1.2**
Microspathodon chrysurus	Yellowtail Damselfish	1	1	1	1	1	**1.0**
Acanthurus bahianus	Ocean Surgeon	2	2	0	0	1	**1.0**
Abudefduf sexatilis	Sergeant Major	0	0	2	0	2	**0.8**
Stegastes leucostictus	Beau Gregory	1	0	1	0	1	**0.6**
Epinephelus cruentatus	Graysby	0	0	1	2	0	**0.6**
Acanthurus coeruleus	Blue Tang	0	1	0	1	1	**0.6**
Haemulon flavolineatum	French Grunt	0	0	1	1	0	**0.4**
Ocyurus chrysurus	Yellowtail Snapper	2	0	0	0	0	**0.4**
Holocentrus rufus	Squirrelfish	1	0	0	0	0	**0.2**
Chaetodon ocellatus	Spotfin Butterflyfish	1	0	0	0	0	**0.2**
Epinephelus guttatus	Red Hind	0	1	0	0	0	**0.2**
Ptorois sp.	Lionfish	0	0	0	0	1	**0.2**
Pomacanthus arcuatus	Grey Angelfish	0	0	0	1	0	**0.2**
Odontoscion dentex	Reef Croaker	0	0	1	0	0	**0.2**
	TOTAL INDIVIDUALS	29	35	30	45	47	**37.2**
	TOTAL SPECIES	14	14	13	15	14	**14**

Table 40. Taxonomic composition, density and size of fishes within 20 m x 3 m belt-transects at Cayo Coral Reef, 8 m. 2015

		TRANSECTS				
		1	2	3	4	5
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped Parrotfish	1 - 13 1 - 25	7 - 7	10 - 7 3 - 12 1 - 25	1 - 15	10 - 7
Sparisoma viride	Stoplight Parrotfish	1 - 7	1 - 12 1 - 15		1 - 30	1 - 25 1 - 30
Sparisoma aurofrenatum	Redband Parrotfish	1 - 7 1 - 13	1 - 12	3 - 12 1 - 15 1 - 20		1 - 12
Ocyurus chrysurus	Yellowtail Snapper	2 -13				
Epinephelus guttatus	Red Hind		1 - 38			
Epinephelus cruentatus	Graysby			1 - 7	2 - 12	
Ptoris volitans	Lionfish					1 - 20

Figure 37 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; $p < 0.05$, Appendix 3 - 4). Both species richness and abundance were significantly lower during the baseline survey in 1999 than in subsequent monitoring surveys. Such difference was biased by turbulent water conditions prevailing during the initial baseline survey. However, the declining trend of species richness after the 2005 survey appears to be real and may be more related to the collapse of live coral cover after the massive bleaching of late 2005. Interestingly, a mild, statistically insignificant increment of fish abundance was observed during the 2009 and 2010 survey, but this increasing pattern was again disrupted during the 2013 survey when fish abundance and species richness both declined. Such high variability of the fish community structure appears to be normal in shallow reef systems that are

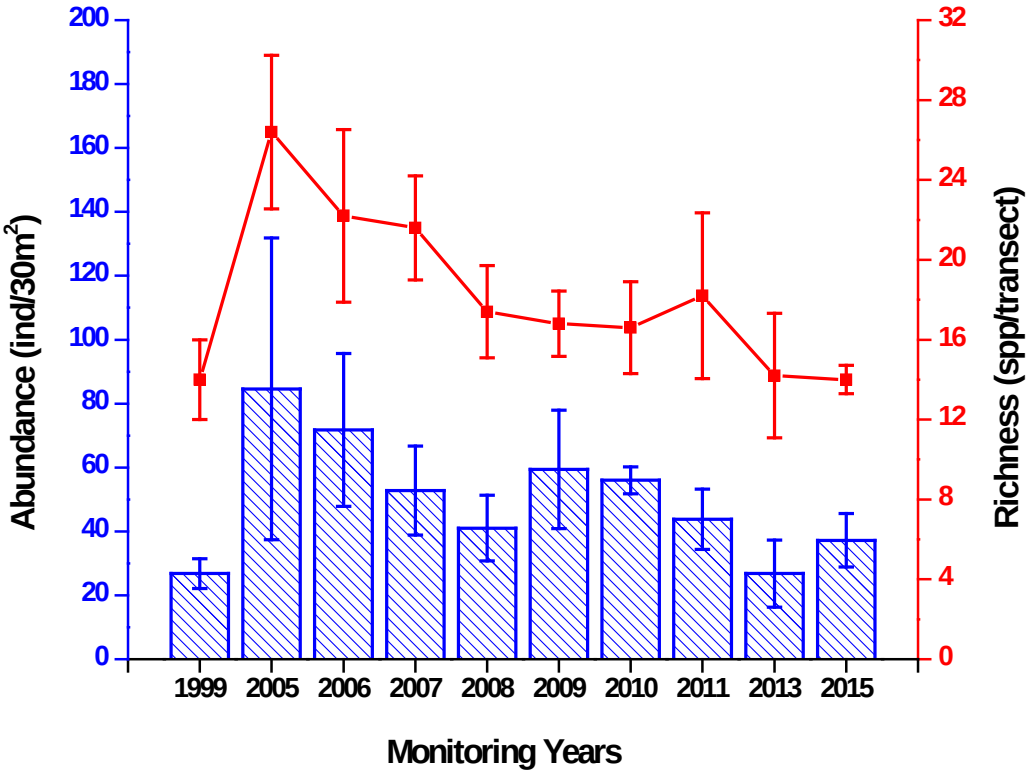


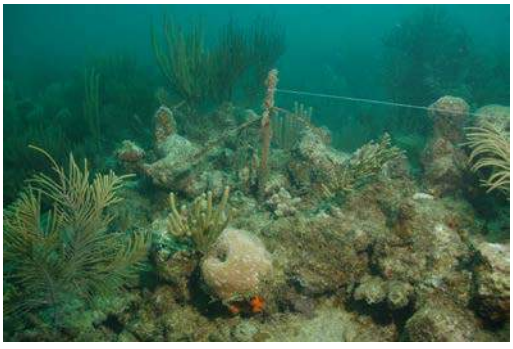
Figure 37. Monitoring trends (1999 – 2015) of fish species richness and abundance at Cayo Coral Reef, 8 m, Guanica Natural Reserve

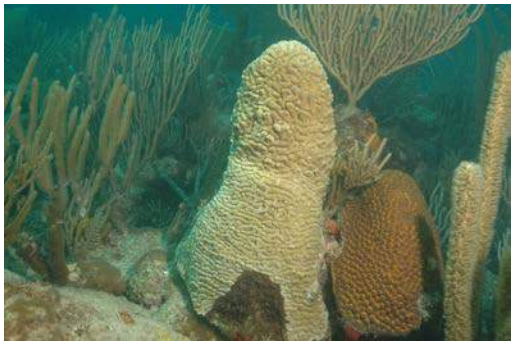
strongly influenced by wave action and the associated surge and substrate abrasion effects. Motile megabenthic invertebrates observed within belt-transects included the Flamingo Tongue, a predator of soft coral polyps and the Arrow Crab (Table 41).

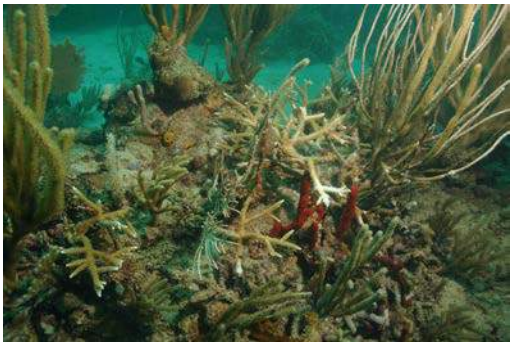
Table 41. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Coral 8 m, Guánica. December 2012

Depth: 7 -10 m		TRANSECTS					MEAN
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**ABUNDANCE (IND/30 m2)**
Cyphoma gibbosum	Flamingo Tongue	1	2	1	1	1	**1.2**
Stenorhinchus seticornis	Arrow Crab			1			**0.2**
	TOTALS	1	2	2	1	1	**1.4**

Photo Album 10. Guanica Natural Reserve
Cayo Coral Reef







2.0 Cayo Aurora

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 benthic habitat, 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 2013 baseline survey were not found, thus another set of transects were installed in the general vicinity of the previous set. No significant differences of total coral cover, nor of cover by the dominant A. palmata were found. Thus the data has been added into one monitoring unit. 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 38). Panoramic views of Cayo Aurora are shown in Photo Album 11.

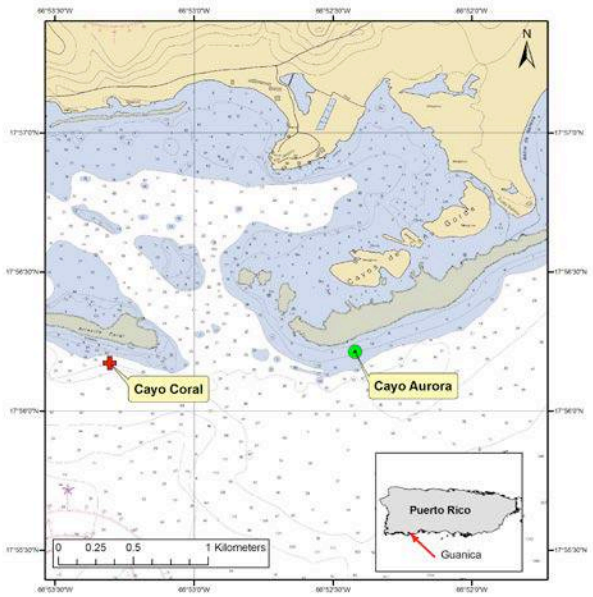


Figure 38. Location of coral reef monitoring station in Cayo Aurora, Guanica

2.1 Sessile-benthic Reef Community

A total of 15 stony corals, including six intersected by transects were identified from Cayo Aurora during the 2015 survey (Table 42). Substrate cover by stony corals along transects averaged 40.8 % (range: 36.1 – 44.7 %). Elkhorn Coral, *Acropora palmata* was the main coral species in terms of substrate cover with a mean of 36.8% (range: 20.4 – 43.2 %), representing 86.6 % of the total cover by stony corals (Table 42). Fused Staghorn, *Acropora prolifera*, Fire Coral, *Millepora complanata*, Mustard Hill Coral, *Porites astreoides*, and Symmetrical Brain Coral, *Pseudodiploria strigosa* comprised the main 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. No evidence of infectious diseases on Elkhorn Coral colonies was noted, nor presence of corallivorous gastropods was detected. In general, Elkhorn Coral colonies looked in very good health condition in an environment of strong wave action and surge. Standing dead or large broken fragments of Elkhorn Coral colonies were uncommon at Cayo Aurora.

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 0.2 colonies/transect. Also, the encrusting gorgonian, *Erythropodium caribaeorum* was present in two transects with low substrate cover (< 1%). Sponges, particularly the encrusting species, *Cliona* caribbaea were present in four out of the five transects surveyed with a mean substrate cover of 2.1 % (Table 42). Encrusting zoanthids (*Palythoa sp*.) was also present in three transects with a mean cover of 0.8 %. A mixed assemblage of short filamentous algae, or turf algae were the main biotic category colonizing hard ground devoid of corals at Cayo Aurora with a mean of 30.7 % (range: 19.2 – 51.1 %). Turf algae represented 99.3% of the total cover by benthic algae (Table 42). Abiotic cover, which averaged 20.1 % was mostly associated with the large overhangs created by Elkhorn Coral branches and gaps.

Figure 39 shows the mean cover by substrate categories at Cayo Aurora during the 2011, 2013 and 2015 surveys. Although transects were from diferent reef locations differences of total cover between surveys were not statistically different. Elkhorn Coral represented more than 86% of the total cover by corals in all three surveys (Figure 40).

Table 42. Percent substrate cover by sessile-benthic categories at Cayo Aurora, Guanica. 2015

	Transects					
	1	2	3	4	5	**Mean**
Rugosity	3.06	4.06	2.75	2.88	3.09	**3.17**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	9.11	14.44	18.55	13.91	28.88	**16.98**
Gap		2.09	4.72	4.78	4.06	**3.13**
Total Abiotic	9.11	16.53	23.27	18.70	32.94	**20.11**
Benthic Algae						
Turf	51.13	28.29	24.48	30.33	19.25	**30.69**
CCA	0.54	0.70				**0.25**
Total Benthic Algae	51.66	28.98	24.48	30.33	19.25	**30.94**
Live Corals						
Acropora palmata	20.36	39.64	43.25	40.87	39.79	**36.78**
Acropora prolifera	6.22	2.19	0.22	1.74		**2.07**
Millepora complanata	8.15	0.80	0.22		0.53	**1.94**
Porites astreoides	1.39	1.79	0.77		1.71	**1.13**
Pseudodiploria strigosa				1.41	1.07	**0.50**
Agaricia agaricites		0.30				**0.06**
Total Live Corals	36.12	44.72	44.46	44.02	43.10	**42.48**
Octocorals						
Erythropodium caribaeorum	0.21		1.65			**0.37**
Erect Gorgonians (#col/transect)					1	**0.20**
Sponges						
Cliona caribbaea		2.19		1.74	3.85	**1.56**
Ircinia felix			1.21	0.22		**0.28**
Chondrilla caribensis			0.33	1.09		**0.28**
Total Sponges		2.19	1.54	3.04	3.85	**2.12**
Zoanthids						
Palythoa caribaeorum	2.89	7.57	4.61	3.91	0.86	**3.97**

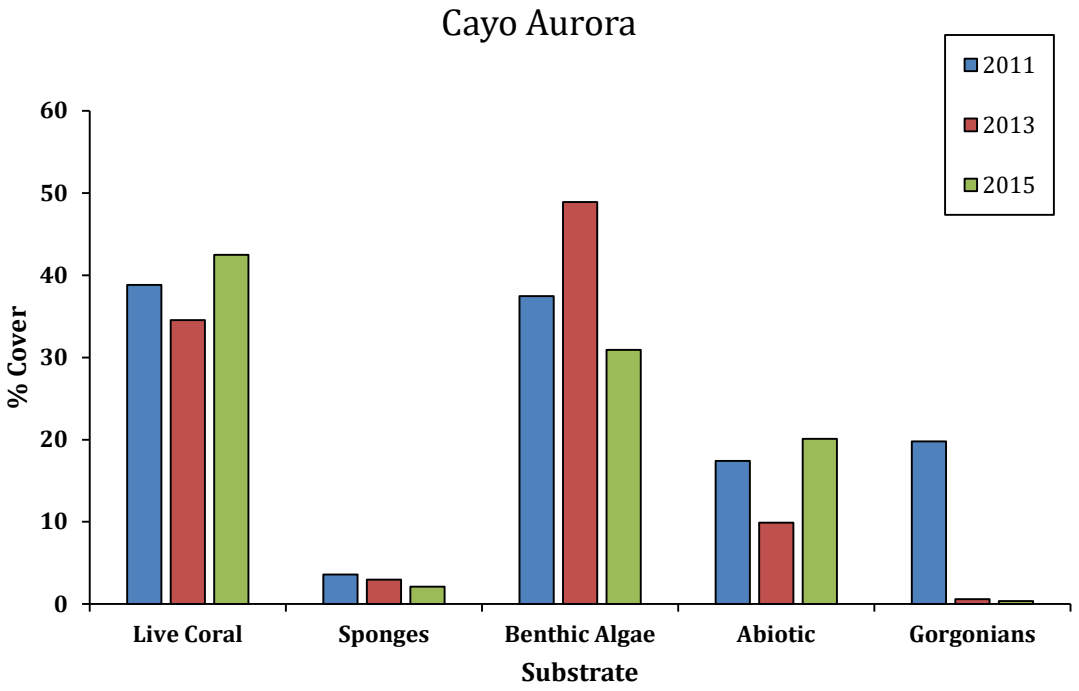


Figure 39. Monitoring trends (2011 – 2015) of mean substrate cover by sessile-benthic categories at Cayo Aurora– 3 m, Guánica.

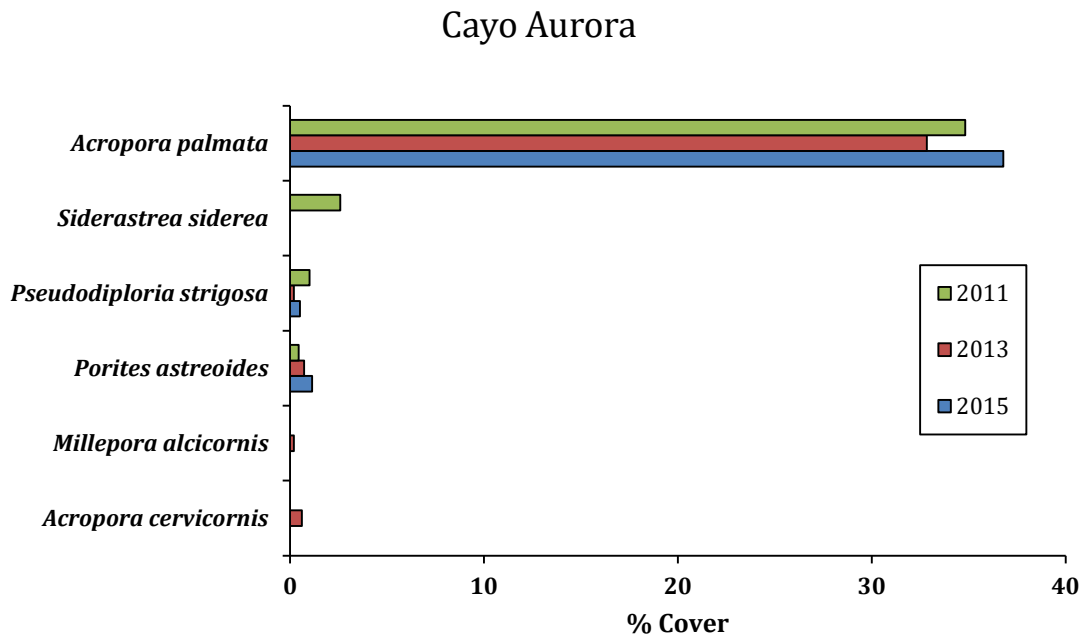


Figure 40. Monitoring trends (2011 – 2015) of mean substrate cover by stony coral species at Cayo Aurora – 3 m, Guánica

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 62 fish species were identified from the fore reef of Cayo Aurora, Guanica within a depth range of 2 – 5 meters (Appendix 1), including 24 present within belt-transects during this baseline survey. The mean abundance of individuals was 47.0 Ind/30 m^2 (range: 23 – 65 Ind/30 m^2), and the mean number of species per transect was 11 (range: 7 - 18). The combined abundance of two numerically dominant species, the Dusky Damselfish (*Stegastes dorsopunicans*) and the Bluehead Wrasse (*Thalassoma bifasciatum*) represented 53.7 % of the total mean abundance within belt-transects (Table 43). The Bicolor and Yellowtail Damselfishes (*Stegastes partitus, Microspathodon chrysurus*), and the Redband and Stoplight parrotfishes (*Sparisoma aurofrenatum, S. viride*) 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*), Clown Wrasse (*Halichoeres maculipinna*) and Brown Chromis (*Chromis multilineata*) 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 10 fish species were only represented by one individual within belt-transects. Differences of total fish abundance and species diversity between monitoring years are not statistically significant (ANOVA< $p > 0.05$).

Commercially important fish species were mostly represented by parrotfishes (*Scarus iserti, Sparisoma rubripinne, S. aurofrenatum, S. viride*) all of which presented mostly large juvenile and youg adult size ranges (Table 44). Likewise, juvenile and adult Schoolmaster snappers (*Lutjanus apodus*) and one adult Coney (*Cephalopholis fulva*) were observed within extended transect areas. One adult Lionfish (*Pterois sp*.) was also sighted.

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), two species of doctorfishes (Acanthuridae), and four species of damselfishes (Pomacentridae) that comprised approximately 46.8 % of the total individuals within belt-transects. A diverse assemblage of small opportunistic invertebrate feeders, such as the

Table 43. Taxonomic composition and abundance of fishes within belt-transects at the fringing Elkhorn Coral Reef Cayo Aurora Reef 3m, Guanica. 2015

Depth: 5 m		TRANSECTS					
		1	2	3	4	5	
		(Ind/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Stegastes dorsopunicans	Dusky Damselfish	23	11	10	8	12	**12.8**
Thalassoma bifasciatum	Bluehead Wrasse	15	20	16	10	1	**12.4**
Stegastes partitus	Bicolor Damselfish	6	12	7	1	1	**5.4**
Microspathodon chrysurus	Yellowtail Damselfish	5	5	0	8	3	**4.2**
Sparisoma aurofrenatum	Redband Parrotfish	6	0	3	1	0	**2.0**
Sparisoma viride	Stoplight Parrotfish	5	0	1	2	0	**1.6**
Acanthurus bahianus	Ocean Surgeon	1	1	2	4	0	**1.6**
Acanthurus coeruleus	Blue Tang	0	0	4	1	1	**1.2**
Chromis multilineata	Brown Chromis	0	5	0	0	0	**1.0**
Chaetodon capistratus	Four-eye Butterflyfish	0	0	2	2	1	**1.0**
Halichoeres maculipina	Clown Wrasse	2	1	0	0	0	**0.6**
Chaetodon striatus	Banded Butterflyfish	2	0	0	0	0	**0.4**
Epinephelus cruentatus	Graysby	0	0	1	1	0	**0.4**
Holocentrus rufus	Squirrelfish	0	0	1	1	0	**0.4**
Stegastes leucostictus	Beau Gregory	0	0	0	1	0	**0.2**
Halichoeres bivittatus	Slipery Dick	0	0	0	1	0	**0.2**
Bodianus rufus	Spanish Hogfish	0	0	0	1	0	**0.2**
Haemulon flavolineatum	French Grunt	0	0	0	0	1	**0.2**
Holocanthus ciliaris	Queen Angelfish	0	0	0	1	0	**0.2**
Caranx ruber	Bar jack	0	0	0	0	1	**0.2**
Heteropriacanthus cruentatus	Glasseye Snapper	0	0	0	1	0	**0.2**
Cantherhines pullus	Orange Spoted Filefish	0	0	0	0	1	**0.2**
Aulostomus maculatus	Trumpetfish	0	0	0	0	1	**0.2**
Pomacanthus arcuatus	Grey Angelfish	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	65	55	47	45	23	**47.0**
	TOTAL SPECIES	9	7	10	18	11	**11**

wrasses, squirrelfishe, blennies, grunts and small groupers was also prominent in the reef. Piscivores were best represented by snappers (Lutjanidae), barracuda (Sphyraenidae) and Jacks (Carangidae) previously reported. Motile megabenthic invertebrates were represented within belt-transects by Long-spined and Boring Sea Urchins, (Table 45).

Table 44. Taxonomic composition, density and size of fishes within 20 m x 3 m belt-transects at Cayo Aurora Reef, 3 m. 2015

		TRANSECTS				
		1	2	3	4	5
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped Parrotfish			6 - 7		
Sparisoma viride	Stoplight Parrotfish	2 - 15 3 - 20		2 - 25	1 - 10 1 - 15	
Sparisoma aurofrenatum	Redband Parrotfish	1 - 15		1 - 10 2 - 15	2 - 12 3 - 12	
Epinephelus cruentatus	Graysby			2 - 15	2 - 10	1 - 7
Ptoris volitans	Lionfish					
Sparisoma rubripinne	Yellowtail Parrotfish	1 - 25		1 - 20 1 - 25		
Lutjanus apodus	Schoolmaster Snapper				1 - 7	2 - 10 3 - 15

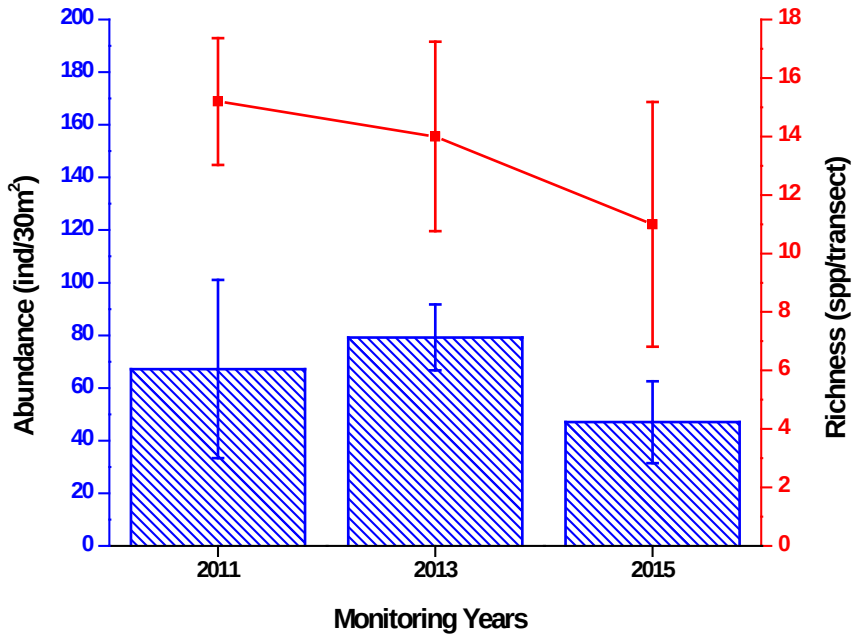
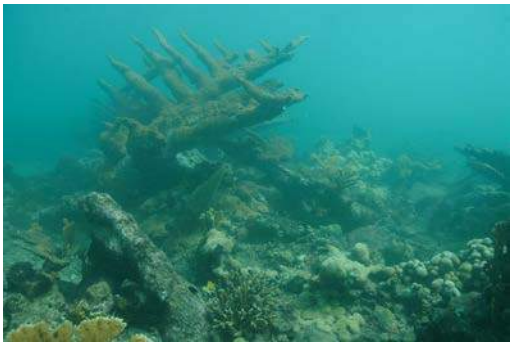


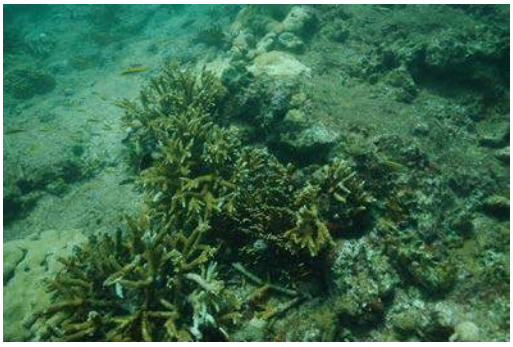
Figure 41. Monitoring trends (2011 – 2015) of fish species richness and abundance at Cayo Aurora Reef, 3 m, Guanica Natural Reserve

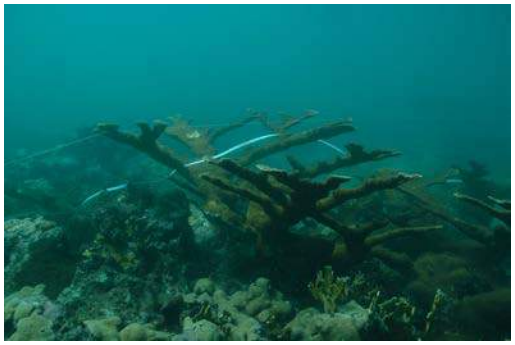
Table 45. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Aurora, Guanica. 2015.

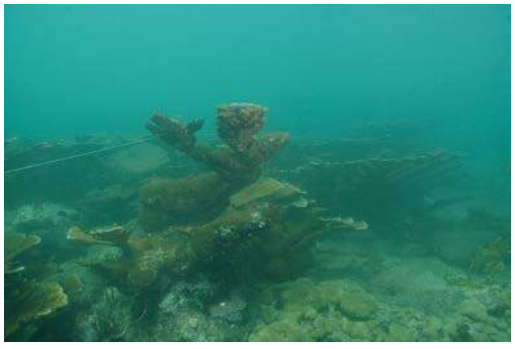
Depth: 2 - 5 m		TRANSECTS					MEAN ABUNDANCE
		1	**2**	**3**	**4**	**5**	**(IND/30 m2)**
TAXA	**COMMON NAME**						
Echinometra lucunter	Rock-boring Urchin	1	2	3	1	3	**1.0**
Diadema antillarum	Long-spined urchin	1		2		1	**0.8**
	TOTALS	**2**	**2**	**5**	**1**	**4**	**1.8**

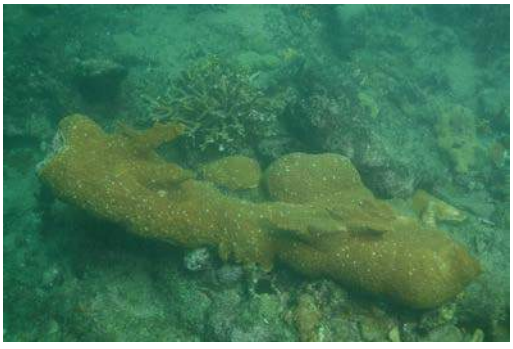
Photo Album 11. Guanica Natural reserve
Cayo Aurora











3.0 Guanica Shelf-Edge

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 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 between 1 – 2 m by sand channels. Five permanent transects were installed on top of the spurs about 20 m the shelf-edge at depths of 18 – 20 meters. This assessment represents the baseline characterization survey for this reef. Panoramic view of the Guanica shelf-edge reef is included here as Photo Album 12.

3.1 Sessile Benthic Community

A total of 20 species of stony corals were identified from Efra's Wall Reef in Guanica, 11 of which were intercepted by line transects during the 2015 survey. The mean substrate cover by live corals was 18.2 % (range: 10.8 – 26.6 %). Boulder Star Coral, *Orbicella annularis* complex was the dominant coral species in terms of reef substrate cover with a mean of 9.3 % (range: 2.7 – 16.0 %), representing 51.1 % of the total cover by corals (Table 41). *Orbicella* was present in all transects along with Mustard Hill Coral, *Porites astreoides*. Great Star Coral, *Montastraea cavernosa* and Massive Starlet Coral, *Siderastrea siderera* were present in three transects with mean substrate cover of 2.1 and 1.2 %, respectively. Finger Coral, *Porites porites* was only present as one large colony in transect 5, but ranked third among coral species with an overall mean cover of 1.8 %. The aforementioned species comprised the main coral assemblage intercepted by transects at Efra's Wall Reef in Guanica. Other five species were present in one or two transects with an average cover of less than 1 %.

Soft corals or gorgonians were prominent at Efra's Wall Reef with a mean combined density of 22.8 colonies per transect. Some of the most abundant species included *Erythropodim caribaeorum, Pseudoplexaura flagellosa*, *Gorgonia ventalina, Eunicea spp*. and *Muricea sp*. At least 21 sponge species were intercepted by transects with a combined reef substrate cover of 8.1 % (range: 6.5 – 12.0%). The Giant Barrel Sponge, *Xestospongia muta*, an unidentified sponge, and several tube sponges, *Agelas spp* comprised the main taxonomic assemblage in terms of reef substrate cover (Table 46).

Table 41. Percent substrate cover by sessile-benthic categories at Efra's Wall Reef, Guanica's shelf-edge. 2015

	Transects					
	1	2	3	4	5	**Mean**
Rugosity	3.34	1.05	4.15	2.66	2.57	**2.75**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	1.26	1.90	6.43	0.66	4.79	**3.01**
Sand		1.01		6.31	5.90	**2.64**
Total Abiotic	1.26	2.92	6.43	6.97	10.69	**5.65**
Benthic Algae						
Turf	50.05	61.98	46.69	51.22	41.98	**50.38**
Dictyota spp.	5.35	0.76	6.92	6.86	4.57	**4.89**
CCA	6.72	5.96	4.75	5.09	0.67	**4.64**
Lobophora variegata			5.34	4.76	0.78	**2.18**
Fleshy macroalgae		2.28				**0.46**
Red fleshy algae			0.69	1.11		**0.36**
Caulerpa spp.	0.52		0.59	0.33	0.33	**0.36**
Halimeda spp.					1.00	**0.20**
Total Benthic Algae	62.64	70.98	64.99	69.36	49.33	**63.46**
Cyanobacteria	0.52	3.68	1.78	5.31	5.57	**3.37**
Live Corals						
Orbicella annularis complex	14.06	2.66	9.89	3.98	16.04	**9.33**
Montastraea cavernosa	5.04	1.65		4.09		**2.16**
Porites porites					8.91	**1.78**
Porites astreoides	1.68	4.31	1.88	0.22	0.56	**1.73**
Siderastrea siderea	2.20	3.80		0.22		**1.25**
Agaricia agaricites		2.03	0.40	1.77		**0.84**
Millepora alcicornis	1.47					**0.29**
Pseudodiploria strigosa			0.89		0.45	**0.27**
Madracis decactis	0.73			0.55		**0.26**
Meandrina meandrites	1.05					**0.21**
Stephanocoenia intersepta	0.31		0.30			**0.12**
Total Live Coral	26.55	14.45	13.35	10.84	25.95	**18.23**
Octocorals						
Erythropodium caribaeorum	0.63	1.01	0.49	0.44	0.78	**0.67**
Pseudoplexaura flagellosa	0.73			0.33	0.22	**0.26**
Gorgonia ventalina			0.20		0.22	**0.08**
Eunicea tourneforti			0.30			**0.06**
Muricea muricata			0.30			**0.06**
Eunicea sp.				0.22		**0.04**

Table 41. continued

Eunicea flexuosa			0.20			**0.04**
Total Octocorals	1.36	1.01	1.48	1.00	1.22	**1.22**
Erect Gorgonians (#col/transect)	25	29	22	18	20	**22.80**
Sponges						
Unidentified sponge		6.97				**1.39**
Xestopsongia muta	0.21		6.13			**1.27**
Agelas dispar	3.04		1.98	0.66		**1.14**
Agelas conifera			0.49	2.32	1.89	**0.94**
Ircinia felix	1.89		0.99		0.33	**0.64**
Iotrochota birotulata	2.10			0.22		**0.46**
Verongula encrusting sp.					1.78	**0.36**
Ecytoplasia ferox				0.22	1.34	**0.31**
Petrosia pellasarca				1.33		**0.27**
Desmapsamma anchorata			0.99			**0.20**
Chondrilla caribensis				0.66	0.22	**0.18**
Ircinia strobilina					0.78	**0.16**
Niphates erecta			0.20	0.33	0.22	**0.15**
Red encrusting sponge			0.40		0.22	**0.12**
Smenospongia aurea					0.45	**0.09**
Aplysina fistularis	0.42					**0.08**
Aiolochoria crassa			0.40			**0.08**
Mycale laevis			0.40			**0.08**
Callyspongia vaginalis				0.33		**0.07**
Plakortis sp.				0.22		**0.04**
Scopalina ruetzleri				0.22		**0.04**
Total Sponges	7.66	6.97	11.97	6.53	7.24	**8.07**

Benthic algae were the dominant category in terms of reef substrate cover with a combined mean of 63.5 % (range: 49.3 – 71.0 %). Turf algae (mixed assemblage) was the dominant component with a mean cover of 50.4 %, representing 79.4 % of the total cover by benthic algae. Fleshy macroalgae (*Dictyota sp., Lobophora variegata*), crustose coraline and green calcareous algae (*Halimeda spp., Caulerpa sp*.) were present in most transects surveyed. Cyanobacterial mats were present in all five transects with a mean reef substrate cover of 3.4 %. Abiotic cover included sand pockets and reef overhangs with a mean cover of 5.6 % (Table 41).

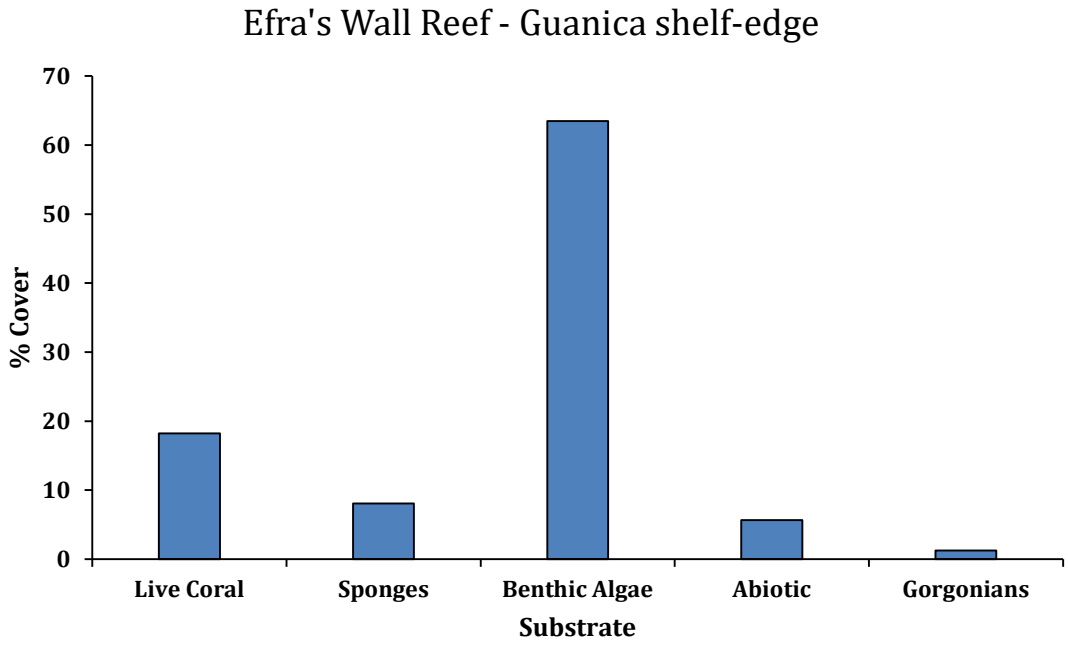


Figure 41 Mean substrate cover by sessile-benthic categories during the baseline survey at Efra's Wall Reef (Guanica shelf-edge). 2015

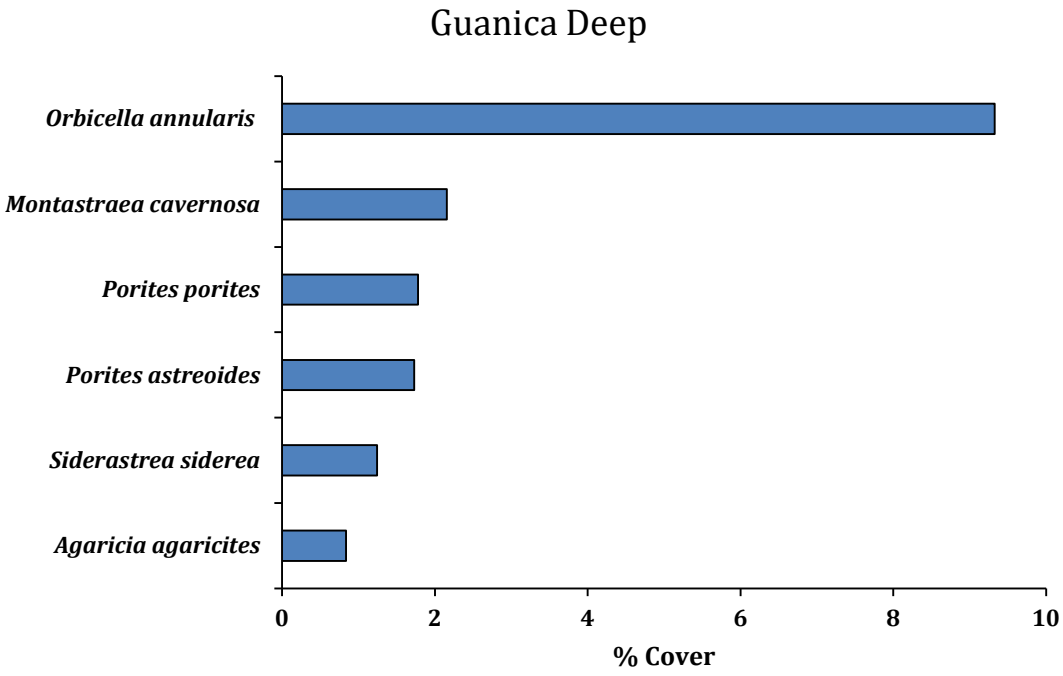


Figure 42. Mean substrate cover by stony coral species during the baseline survey at at Efra's Wall Reef (Guanica shelf-edge). 2015

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 47 fish species were identified from Efra's Wall Reef including 24 within belt-transects at a depths of 18 - 20 meters (Table 47). The mean abundance of individuals was 72.8 Ind/30 m^2 (range: 33– 118 Ind/30 m^2), and the mean number of species per transect was 13 (range: 10 - 16). The combined abundance of five species represented 71.7 % of the total mean abundance within belt-transects. The most abundant species (mean: 16 Ind/30 m^2) was the Mackerel Scad, *Decapterus macarelus*, a pelagic schooling species that was observed in transit over transect 5. Among the demersal reef fish assemblage, the Bicolor Damselfish (*Stegastes partitus)*, Bluehead Wrasse *(Thalassoma bifasciatum)*, Peppermint Goby (*Coryphopterus lipernes*) and Yellow-head Wrasse (*Halichoeres garnoti*) were the most abundant. Blue Chromis (*Chromis cyanea*) Graysbe (*Epinephelus cruentatus*) and Doctorfish (*Acanthurus coeruleus*) were present in all transects (Table 47).

Parrotfishes, represented by four species within extended belt-transects were the most abundant commercially important fish assemblage with size ranges in the juvenile and adult stages (Table 48). Juvenile small groupers, such as the Coney and Graysbe and Queen Triggerfish were present mostly as juveniles. One large adult Nurse Shark was observed at the end of transect 3 and one adult Lionfish was present in transect 4.

The fish community at Guanica's shelf-edge was comprised by a prominent assemblage of planktivores, represented by at least three numerically dominant species that account for approximately 43.1 % of the total fish abundance. A diverse assemblage of small opportunistic invertebrate feeders, such as the wrasses (Labridae), squirrelfishes (Holocentridae), grunts (Haemulidae) and small groupers (Serranidae) was also present. Herbivores were represented by four species of parrotfishes and two species of doctorfishes that accounted for approximately 12 % of the total fish abundance within belt-transects. Large demersal predators were represented by the Nurse Shark. One Great Barracuda was observed out of transects.

Flamingo Toungues and Arrow crabs were present within belt-transects at Efra's Wall Reef in Guanica during the baseline survey of 2015 (Table 49). One Spiny lobster (*Panulirus argus*) and one Common Octopus (*Octopus vulgaris*) were observed out of transects.

Table 47. Taxonomic composition and abundance of fishes within belt-transects at Efra's Wall Reef, Guanica shelf-edge. 2015

Depth: 20m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(Ind/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Decapterus macarelus	Mackrel scad	0	0	0	0	80	**16.0**
Stegastes partitus	Bicolor Damselfish	13	11	12	13	21	**14.0**
Thalassoma bifasciatum	Bluehead Wrasse	15	5	4	20	5	**9.8**
Coryphopterus lipernes	Peppermint Goby	20	0	11	6	0	**7.4**
Halichoeres garnoti	Yellow-head Wrasse	2	3	9	7	4	**5.0**
Scarus iserti	Stripped Parrotfish	6	3	3	9	0	**4.2**
Chromis cyanea	Blue Chromis	2	2	5	7	2	**3.6**
Acanthurus chirurgus	Doctorfish	2	2	4	3	1	**2.4**
Sparisoma aurofrenatum	Redband Parrotfish	4	3	3	0	0	**2.0**
Gobiosoma evelynae	Sharknose Goby	2	0	4	0	1	**1.4**
Serranus tigrinus	Harlequin Bass	3	1	0	2	1	**1.4**
Epinephelus cruentatus	Graysby	2	2	1	1	1	**1.4**
Holocentrus rufus	Squirrelfish	2	1	2	1	0	**1.2**
Chaetodon capistratus	Four-eye Butterflyfish	2	0	1	0	0	**0.6**
Ocyurus crysurus	Yellowtail Snapper	2	0	0	0	0	**0.4**
Cantherhines pullus	Orange Spoted Filefish	0	0	2	0	0	**0.4**
Epinaphelus fulva	Coney	0	0	0	0	1	**0.2**
Acanthurus coeruleus	Blue Tang	1	0	0	0	0	**0.2**
Sparisoma viride	Stoplight Parrotfish	0	0	0	1	0	**0.2**
Haemulon flavolineatum	French Grunt	0	0	1	0	0	**0.2**
Melichthys niger	Black Durgon	0	0	0	0	1	**0.2**
Ptoris volitans	Lionfish	0	0	0	1	0	**0.2**
Pseudupeneus maculatus	Spotted Goatfish	1	0	0	0	0	**0.2**
Balistes vetula	Queen Triggerfish	0	0	1	0	0	**0.2**
	TOTAL INDIVIDUALS	**79**	**33**	**63**	**71**	**118**	**72.8**
	TOTAL SPECIES	**16**	**10**	**15**	**12**	**12**	**13**

Table 48. Taxonomic composition, density and size of fishes within 20 m x 4 m belt-transects at Efra's Wall Reef, Guanica shelf-edge. 2015

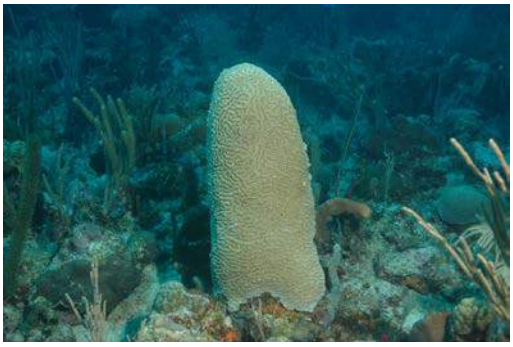
		TRANSECTS				
		1	2	3	4	5
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped	3 - 10		3 - 12	5 - 7	
	Parrotfish	4 - 15			4 - 10	
		1 - 20			2 - 12	
Sparisoma viride	Stoplight			3 - 12	1 - 10	1 - 15
	Parrotfish			1 - 17		
Sparisoma aurofrenatum	Redband	2 - 10	2 - 7	3 - 7		
	Parrotfish	2 - 12	3 - 7	1 - 12		
		1 - 15				
Ocyurus chrysurus	Yellowtail	4 - 15				
	Snapper	1 -17				
Epinephelus fulva	Coney					1 - 15
Epinephelus cruentatus	Graysby	1 - 7		1 - 10	1 - 12	1 - 10
		2 - 10				
Ptoris volitans	Lionfish				1 - 30	
Balistes vetula	Queen Triggerfish			1 - 15		
Ginglymostoma cirratum	Nurse Shark				1 - 170	
Sparisoma chrysopterum	Redtail Parrotfish			1 - 20		

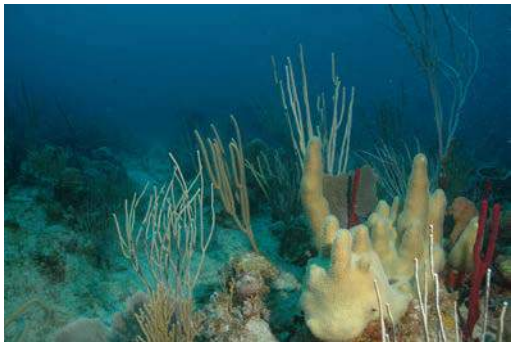
Table 49. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at at Efra's Wall Reef, Guanica shelf-edge. 2015

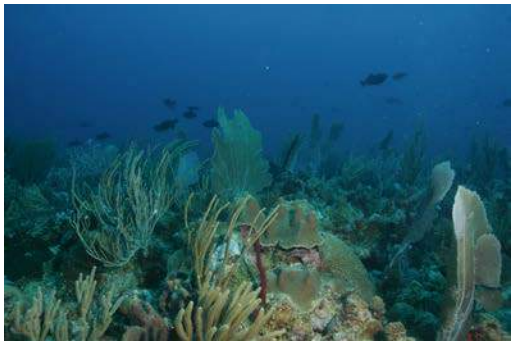
Depth: 20 m		TRANSECTS					MEAN ABUNDANCE
		1	**2**	**3**	**4**	**5**	**(IND/30 m2)**
TAXA	**COMMON NAME**						
Cyphoma gibbosum	Flamingo Tongue	2	1		2		**1.0**
Stenorhinchus seticornis	Arrow Crab		1	1			**0.4**
	TOTALS	**2**	**2**	**1**	**2**	**0**	**1.4**

Photo Album 12. Guanica Natural Reserve

Shelf Edge Reef







E. West Reef of Isla Caja de Muerto – Ponce

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 41). 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 13.

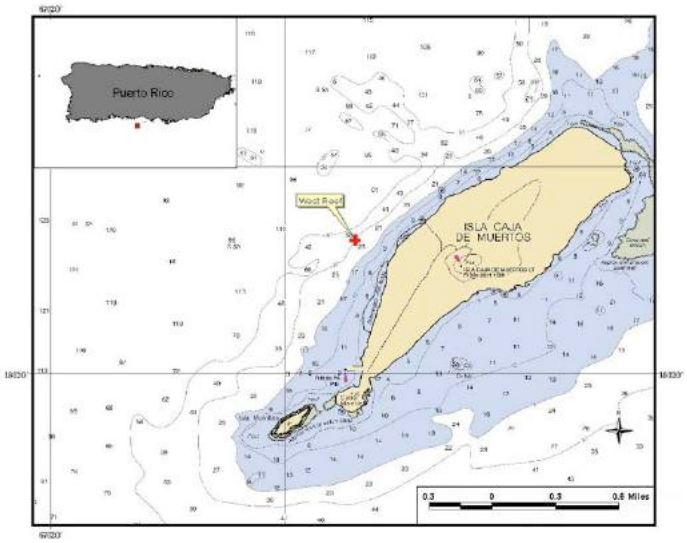


Figure 41. Location of coral reef monitoring stations at West Reef, Isla Caja de Muerto, Ponce.

1.0 Sessile-benthic Reef Communities

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 49.2 % (range: 44.7 – 52.7 %) along permanent transects and was observed colonizing dead coral colonies and other hard ground substrates in the reef (Table 50). Fleshy brown (*Dictyota sp*.) macroalgae represented a minor component of the benthic algae assemblage at West Reef. During the 2007 survey, cyanobacterial (blue-green algal) mats were prominent at the reef benthos with an average cover of 9.0 %, but declined in 2008 to a mean of 2.8 %, and disappeared from transects during the 2013 survey. The cyanobacterial bloom appeared to be associated and proportional to the amount of recently dead coral observed after the late 2005 massive coral-bleaching event that impacted reef systems of Puerto Rico and the USVI (García-Sais et al., 2006). During the present 2015 survey, cyanobacterial mats were present in four out of the five transects surveyed with a mean cover of 3.8 % (Table 50).

A total of 20 stony coral species, including 13 within transects were identified from West Reef in the 2015 survey (Table 50). Live stony corals presented a mean substrate cover of 15.4 % (range: 7.9 – 22.2 %). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant coral species with a mean substrate cover of 7.1 % (range: 1.1 – 17.2 %), representing 46.1 % of the total substrate cover by live stony corals. Great Star Coral (*M. cavernosa*), Mustard-Hill Coral (*Porites astreoides*), Lettuce Coral (*Agaricia agaricites*) and the Greater Starlet Coral, *Siderastrea siderea* were present in at least four out of the five transects surveyed, and along with Boulder Star Coral comprised the main coral assemblage of the West Reef (Table 50).

Soft corals (gorgonians) presented a mean density of 21.6 colonies/transect and included colonies of very large size. Some of the most abundant species included the Corky Sea Finger (*Briareum asbestinum*), Encrusting Gorgonian (*Erythropodium caribaeorum*), Slimy Sea Plumes (*Allotogorgia americana*), Porous Sea Rods (*Plexaura spp*.), and Knobby Sea Rods (*Eunicea spp*.). Sponges, represented along transects by at least 17 species were present with a mean substrate cover of 3.6 %. Abiotic categories combined for a mean substrate cover of 24.6 %. The high rugosity measured at 5.4 m was strongly influenced by large relict coral heads (mostly *Orbicella annularis*).

Table 50. Percent substrate cover by sessile-benthic categories at Caja de Muertos Reef, Ponce. 8 m. 2015

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	3.93	5.16	6.38	5.62	5.83	**5.38**
SUBSTRATE CATEGORY						
Abiotic						
Overhang	7.24	7.39	13.50	13.62	10.34	**10.42**
Sand	25.73	3.32	5.30	3.05	7.25	**8.93**
Rubble	2.91	6.74	8.12	3.58	0.88	**4.45**
Gap	0.80	0.65		1.52	1.24	**0.84**
Total Abiotic	36.68	18.10	26.92	21.77	19.72	**24.64**
Benthic Algae						
Turf	45.53	52.72	50.68	44.71	52.43	**49.22**
Dictyota spp.		2.22	0.85			**0.61**
CCA	2.71					**0.54**
Total Benthic Algae	48.24	54.94	51.54	44.71	52.43	**50.37**
Cyanobacteria	0.50	1.66	0.00	12.63	4.33	**3.83**
Live Corals						
Orbicella annularis complex	4.12	17.17	6.24	1.08	6.90	**7.10**
Montastraea cavernosa		2.40	0.43	5.11	2.30	**2.05**
Porites astreoides	0.50	0.46	1.62	0.54	4.16	**1.46**
Agaricia agaricites	0.40		0.43	1.16	3.63	**1.12**
Siderastrea siderea	0.60	2.22	0.85	0.54	0.62	**0.97**
Meandrina meandrites	2.01			1.70		**0.74**
Stephanocoenia intersepta	0.30		2.74			**0.61**
Agaricia lamarcki				1.97		**0.39**
Millepora alcicornis			1.03	0.72		**0.35**
Dendrogyra cylindrus			1.20			**0.24**
Pseudodiploria strigosa			0.77			**0.15**
Madracis decactis			0.26		0.27	**0.10**
Porites porites				0.36		**0.07**
Total Live Corals	7.94	22.25	15.56	13.17	17.86	**15.36**
Octocorals						
Briareum asbestinum	0.20			6.18	0.18	**1.31**
Erythropodium caribaeorum	0.50		0.85		1.24	**0.52**
Allotogorgia americana	0.40		0.17		0.18	**0.15**
Plexaura kuekenthali					0.71	**0.14**
Eunicea flexuosa					0.35	**0.07**
Total Octocorals	1.11		1.03	6.18	2.65	**2.19**
Erect Gorgonians (#col/transect)	18	11	24	18	37	**21.60**

Table 50. continued

Sponges						
Xestospongia muta	0.30		3.93			**0.85**
Aiolochroia crassa	0.80	0.92		0.63	0.35	**0.54**
Aplysina cauliformis	1.51		0.17	0.36		**0.41**
Chondrilla caribensis	1.11	0.46			0.44	**0.40**
Aplysina fistularis	0.60	0.92				**0.31**
Ircinia felix	0.90					**0.18**
Cliona caribbaea			0.43		0.35	**0.16**
Svenzea zeai					0.71	**0.14**
Monanchora arbuscula				0.27	0.27	**0.11**
Iotrochota birotulata					0.44	**0.09**
Ectyoplasia ferox			0.43			**0.09**
Agelas conifera	0.30					**0.06**
Callyspongia sp.		0.28				**0.06**
Iotrochota arenosa		0.28				**0.06**
Amphimedon compressa					0.27	**0.05**
Callyspongia vaginalis		0.18				**0.04**
Niphates erecta					0.18	**0.04**
Total Sponges	5.53	3.05	4.96	1.25	3.01	**3.56**

Figure 42 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 2005-15. Differences of reef substrate cover by stony corals between annual surveys were statistically significant (ANOVA; $p < 0.001$, Appendix 2), 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 (Appendix 2). 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 43). 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 seemed to be

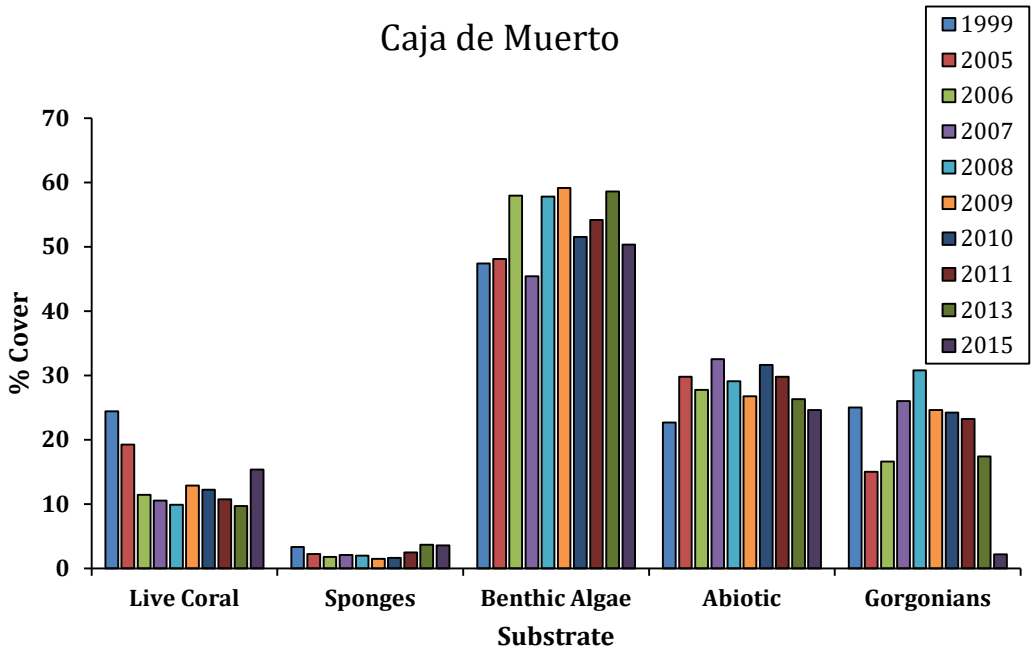


Figure 42. Monitoring trends (1999 - 2015) of mean substrate cover by sessile-benthic categories at West Reef, Isla Caja de Muerto, Ponce.

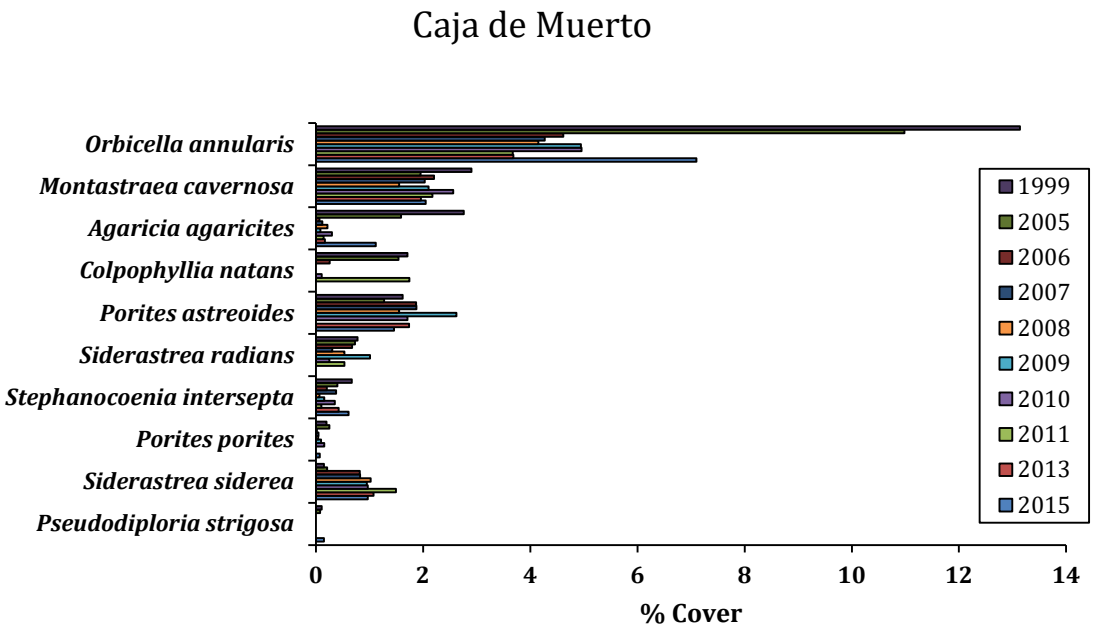


Figure 43. Monitoring trends (1999 – 2015) of mean substrate cover by stony coral species at West Reef, Isla Caja de Muerto, Ponce.

recuperating, but exhibited a gradual decreasing, yet statistically insignificant trend during the previous two surveys. As with most coral reef systems included in this monitoring program, live coral cover showed a marked resurgence during 2015, mostly driven by a sharp increment of cover by Boulder Star Coral, *Orbicella annularis* (Figure 43).

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 88 fish species have been identified during monitoring surveys from West Reef, Isla Caja de Muerto (Appendix 1). Mean abundance of fishes within belt-transects during 2015 was 155.2 Ind/30 m^2 (range: 107- 189 Ind/30 m^2). The mean number of species per transect was 16.6 (range: 14- 21). The Masked Goby (*Coryphopterus personatus*) was the numerically dominant species with a mean abundance of 102.0 Ind/30 m^2 (range: 60 - 130 Ind/30 m^2), representing 77.3 % of the total abundance within belt-transects (Table 51). The Masked Goby was present within all belt-transects 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. The Bluehead Wrasse, Bicolor Damselfish, Striped Parrotfish, Blue Chromis, Princess and Stoplight Parrotfishes, Doctorfish and Sargent Major were present in at least four of the five transects surveyed and comprised along with Masked Goby, the main fish assemblage of West Reef (Table 51).

Juvenile snappers (*Ocyurus chrysurus, Lutjanus apodus*) and Hogfish (*Lachnolaimus maximus*) one full adult Dog Snapper *(L. jocu*), and an assemblage of four parrotfishes present as juveniles and adults comprised the main commercially important fish component of West Reef during 2015 (Table 52). Juvenile and some adult 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 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 being observed foraging along with adult Lane Snappers aggregation during previous surveys (García-Sais et al., 2006, 2014).

Table 51. Taxonomic composition and abundance of fishes within belt-transects at West Reef, Isla Caja de Muerto, 8 m, Ponce. Survey Date: 2015

Depth: 8 m		TRANSECTS					
		1	2	3	4	5	
		(Ind/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	60	120	130	110	90	**102.0**
Thalassoma bifasciatum	Bluehead Wrasse	10	20	10	22	2	**12.8**
Stegastes partitus	Bicolor Damselfish	5	9	12	4	2	**6.4**
Scarus iserti	Stripped Parrotfish	7	0	1	3	6	**3.4**
Chromis cyanea	Blue Chromis	0	3	6	8	2	**3.8**
Scarus taeniopterus	Princess Parrotfish	3	0	9	3	0	**3.0**
Stegastes leucostictus	Beau Gregory	5	0	0	7	1	**2.6**
Sparisoma viride	Stoplight Parrotfish	3	1	3	0	2	**1.8**
Acanthurus chirurgus	Doctorfish	2	1	3	0	2	**1.6**
Chromis multilineata	Brown Chromis	0	8	0	0	0	**1.6**
Myripristis jacobus	Blackbar Soldierfish	0	1	4	3	0	**1.6**
Abudefduf sexatilis	Sargent Major	0	1	2	1	3	**1.4**
Cephalopholis cruentatus	Graysby	3	0	0	1	3	**1.4**
Stegastes variabilis	Cocoa Damselfish	3	0	2	0	0	**1.0**
Stegastes adustus	Dusky Damselfish	0	4	0	1	0	**1.0**
Hypoplectrus unicolor	Butter Hamlet	1	1	0	1	1	**0.8**
Sparisoma aurofrenatum	Redband Parrotfish	1	2	0	1	0	**0.8**
Caranx crysos	Blue runner	1	1	0	1	0	**0.6**
Haemulon flavolineatum	French Grunt	0	1	0	2	0	**0.6**
Chaetodon striatus	Banded Butterflyfish	0	0	0	0	2	**0.4**
Gobiosoma evelynae	Sharknose Goby	0	1	0	1	0	**0.4**
Haemulon aurolineatum	Tomtate	0	1	0	0	1	**0.4**
Heteropriacanthus cruentatus	Glasseye Snapper	1	0	0	0	0	**0.2**
Lachnolaimus maximus	Hogfish	1	0	0	0	0	**0.2**
Acanthurus coeruleus	Blue Tang	0	0	1	0	0	**0.2**
Canthigaster rostrata	Caribbean Puffer	0	0	0	1	0	**0.2**
Equetus lanceolatus	Jacknife	0	0	1	0	0	**0.2**
Haemulon plumieri	White Grunt	0	1	0	0	0	**0.2**
Haemulon sciurus	Bluestriped Grunt	0	0	0	1	0	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	1	0	0	0	**0.2**
Holocentrus rufus	Squirrelfish	0	0	1	0	0	**0.2**
Hypoplectrus nigricans	Black Hamlet	0	0	1	0	0	**0.2**
Neoniphon marianus	Longspine Squirrelfish	0	0	0	1	0	**0.2**
Ocyurus chrysurus	Yellowtail Snapper	0	0	0	0	1	**0.2**
Pseudupeneus maculatus	Spotted Goatfish	0	0	0	1	0	**0.2**
	Spotted Moray	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	**107**	**179**	**189**	**178**	**123**	**155.2**
	TOTAL SPECIES	**15**	**18**	**15**	**21**	**14**	**16.6**

Table 52. Taxonomic composition density and size distribution of fishes present within 3 x 20 m belt-transects at West Reef, CDM. 2015

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped Parrotfish	3 - 5 4 - 7		1 - 20	1 - 15	5 - 3 1 - 7
Sparisoma viride	Stoplight Parrotfish Parrotfish	2 - 5 1 - 10	1 - 10	3 - 10	2 - 8 1 - 10	1 - 10 2 - 20
Sparisoma aurofrenatum	Redband Parrotfish Parrotfish		1 - 10 1 - 15	1 - 10		1 - 10
Ocyurus chrysurus	Yellowtail Snapper	8 - 10	4 - 10	1 - 10	1 - 15	2 - 10
Lutjanus jocu	Dog Snapper					1 - 60
Lutjanus apodus	Schoolmaster Snapper					1 - 15
Epinephelus cruentatus	Graysby	2 - 7 1 - 10			1 - 10	1 - 7 2 - 10
Scarus taeniopterus	Princess Parrotfish Parrotfish	2 - 10 1 - 15		3 - 3 5 - 5 2 - 10	2 - 7 1 - 17	
Lachnolaimus maximus	Hogfish	1 - 15				

The fish community structure at West Reef is strongly represented by zooplankton feeders, including the Masked Goby, Blue and Brown Chromis, Bicolor Damselfish, Creole Wrasse and Mackerel Scad. The latter species were not prominent within belt-transects, but were observed forming large schooling aggregations in the water column over the reef. These species are known to 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., 2014).

A specious assemblage of herbivores, particularly parrotfishes, and small invertebrate feeders, such as wrasses, gobies, puffers, goatfishes and squirrelfishes, among others were also present. Mid-size carnivores that are commercially exploited, such as the Yellowtail, Mahogany, Lane, Grey and Schoolmaster Snappers, Red Hind, and Coney. Large Cubera Snapper (*Lutjanus cyanopterus*) and a juvenile Yellowfin Grouper (*Mycteroperca venenosa*) have been reported during previous surveys (Garcia-Sais et al., 2005*).* 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 44 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 3) were found. These differences were driven by abundance fluctuations of the Masked Goby, a dominant species 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 2015 survey.

Differences of fish species richness within belt-transects were also detected (ANOVA; $p < 0.001$). 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 the soft coral predator mollusk, the Flamingo Tongue (Table 53). 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).

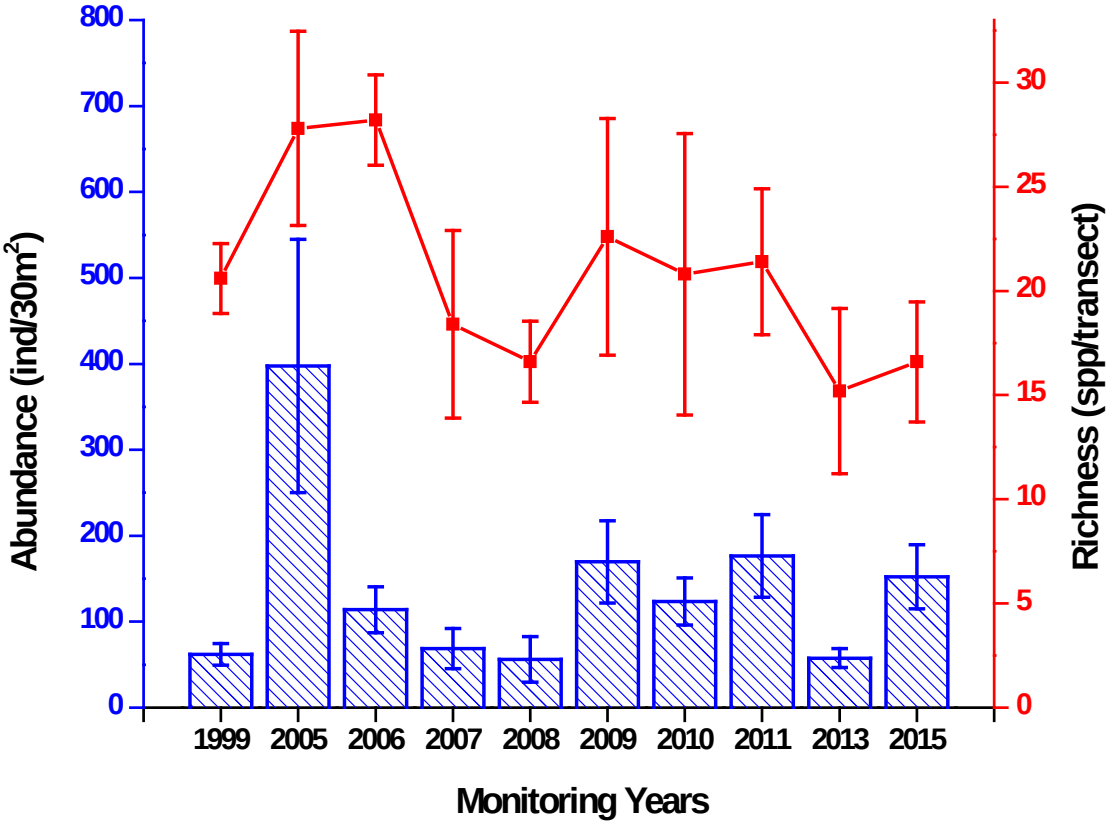
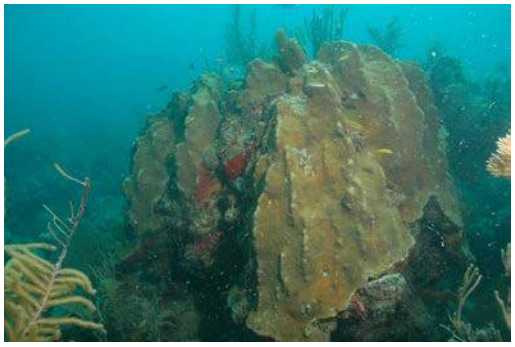


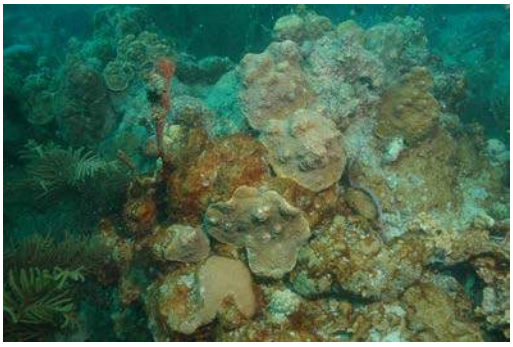
Figure 44. Monitoring trends (1999 – 2015) of fish species richness and abundance at West Reef, Isla Caja de Muerto, Ponce

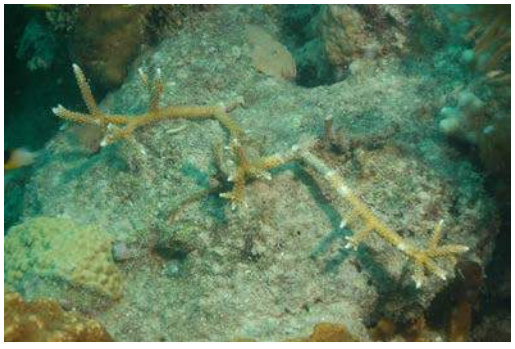
Table 53. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at West Reef, Caja de Muerto. 2015.

Depth: 8 m		TRANSECTS					MEAN ABUNDANCE
		1	2	3	4	5	(IND/30 m2)
TAXA	**COMMON NAME**						
Cyphoma gibbosum	Flamingo tongue			2		0	**0.4**
	TOTALS	**0**	**0**	**2**	**0**	**0**	**0.4**

Photo Album 13. Isla Caja de Muerto West Reef







F. Derrumbadero Reef – Ponce

Derrumbadero is a submerged promontory fringing the shelf-edge, 2.2 nautical miles southeast off from the mouth of Ponce Bay (Figure 45). 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 14.

1.0 Sessile-Benthic Reef Community

A total of 21 stony corals, including 12 intersected by line transects were identified from Derrumbadero Reef at a depth of 20 m during 2015 (Table 54). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 19.9 % (range: 11.1 – 27.1 %). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant species in terms of substrate cover with a mean of 8.8 % (range: 4.5 – 14.8 %), representing 45.6 % of the total cover by stony corals. Mustard-Hill Coral (*Porites astreoides*), Lettuce Coral (*Agaricia agaricites*) and Great Star Coral (*M. cavernosa*) were present in at least four transects and comprised the main stony coral assemblage at Derrumbadero Reef (Table 54).

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: 18.2 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. Sea

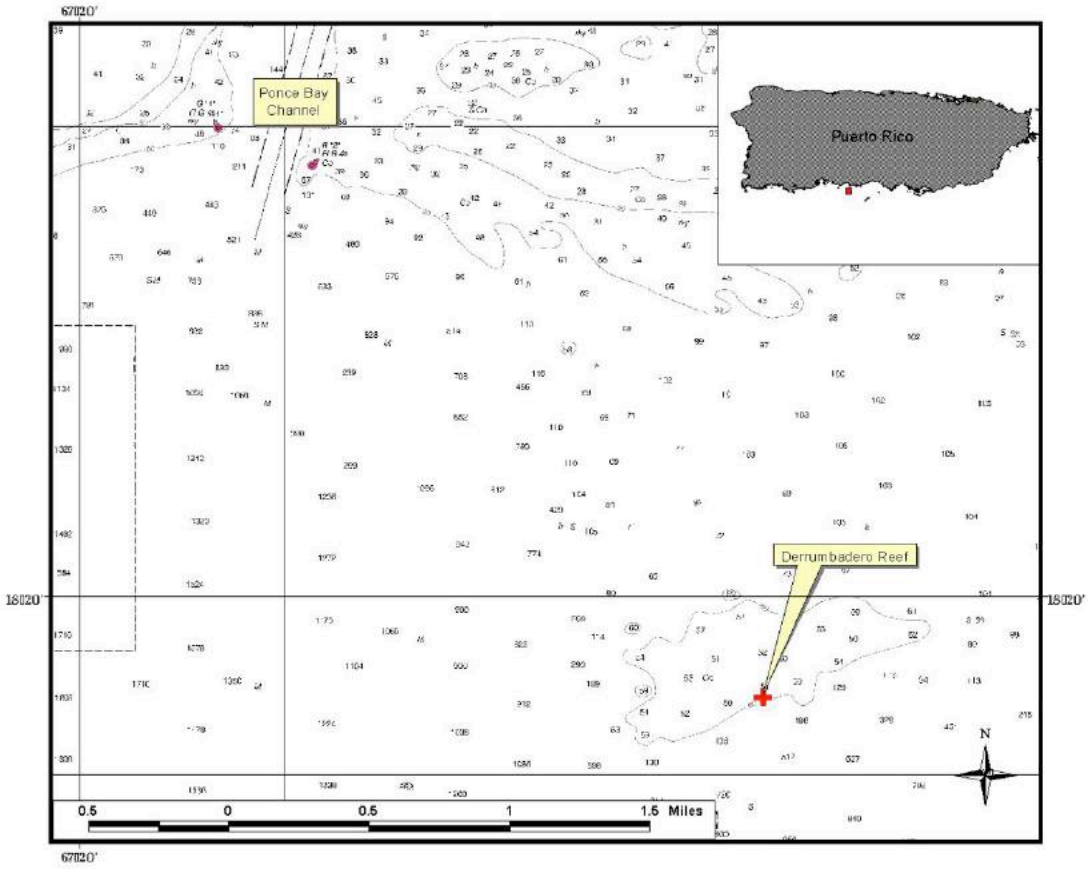


Figure 45. Location of the coral reef monitoring station at Derrumbadero Reef, Ponce.

Plumes, *Pseudopterogorgia acerosa, P. americana* Corky Sea Finger, *Briareum asbestinum*, Common Sea Fan, *Gorgonia ventalina* and Sea Rod, *Plexaura flexuosa* were the most abundant soft coral taxa.

At least 18 sponge species were intercepted by transects during the 2013 monitoring survey with a combined mean substrate cover of 3.5 %. The *Agelas spp*. assemblage was the most prominent in terms of reef substrate cover (Table 54).

Benthic algae comprised by an assemblage of turf, brown (*Lobophora sp*., *Dictyota sp*) and red coralline algae were the most prominent sessile-benthic category in terms of substrate cover at Derrumbadero Reef with a mean of 59.6 % (range: 56.7 – 62.3 %). Abiotic categories were measured mostly as reef overhangs mostly produced by mounds and ledges of Boulder Star Coral (*O. annularis*), sand and rubble (Table 54).

Table 54. Percent substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce, 20 m. Survey Date: 2015

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.94	2.73	2.85	1.48	2.66	**2.53**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	6.28	6.16	5.01	1.83	6.19	**5.09**
Sand					3.54	**0.71**
Gap					2.54	**0.51**
Total Abiotic	6.28	6.16	5.01	1.83	12.28	**6.31**
Cyanobacteria	3.68	3.30	1.85	0.49	3.32	**2.53**
Benthic Algae						
Turf	31.28	44.33	37.15	49.39	33.52	**39.13**
Lobophora variegata	11.90	3.30	10.57	6.83	15.93	**9.71**
CCA	9.31	6.60	5.77	4.63	7.63	**6.79**
Dictyota spp.	4.22	3.85	8.82		2.88	**3.95**
Total Benthic Algae	56.71	58.09	62.31	60.85	59.96	**59.58**
Live Corals						
Orbicella annularis complex	14.83	6.49	7.73	4.51	10.62	**8.84**
Porites astreoides	5.95	3.74	3.92	3.29	2.99	**3.98**
Agaricia agaricites	3.14	6.38	4.90	1.59	1.00	**3.40**
Montastraea cavernosa	1.73	2.31	4.58	0.49		**1.82**
Millepora alcicornis		1.10			1.33	**0.49**
Colpophyllia natans		2.09				**0.42**
Pseudodiploria labyrinthiformis				1.22		**0.24**
Meandrina meandrites	0.76	0.33				**0.22**
Acropora cervicornis					1.00	**0.20**
Pseudodiploria strigosa		0.66				**0.13**
Madracis decactis	0.32	0.11			0.22	**0.13**
Siderastrea siderea	0.32					**0.06**
Total Live Corals	27.06	23.21	21.13	11.10	17.15	**19.93**
Octocorals						
Erythropodium caribaeorum	2.27		1.20	17.56	0.44	**4.29**
Gorgonia sp.				2.44		**0.49**
Briareum asbestinum			0.98		0.22	**0.24**
Eunicea flexuosa		0.33	0.65			**0.20**
Gorgonia ventalina		0.55			0.22	**0.15**
Allotogorgia acerosa		0.44				**0.09**
Eunicea sp.					0.33	**0.07**
Pseudoplexaura flagellosa					0.22	**0.04**

Table 54. continued

Total Octocorals	2.27	1.32	2.83	20.00	1.44	**5.57**
Erect Gorgonians (#col/transect)	19	35	24	31	36	**29**
Sponges						
Sponge				5.73		**1.15**
Agelas citrina	3.25	1.65			0.44	**1.07**
Callyspongia plicifera		1.98				**0.40**
Agelas dispar	0.32	0.55	0.76		0.33	**0.39**
Agelas sventres	0.22	0.66	0.44		0.22	**0.31**
Monanchora arbuscula	0.22				1.11	**0.26**
Aplysina fistularis			1.31			**0.26**
Agelas tubulata					1.11	**0.22**
Ircinia strobilina		1.10				**0.22**
Amphimedon compressa		0.33			0.55	**0.18**
Niphates caribica			0.87			**0.17**
Neopetrosia proxima		0.33	0.44			**0.15**
Niphates digitalis		0.22	0.54			**0.15**
Mycale laevis					0.55	**0.11**
Petrosia pellasarca		0.55				**0.11**
Agelas sceptrum					0.44	**0.09**
Niphates erecta		0.33				**0.07**
Aplysina cauliformis		0.22				**0.04**
Total Sponges	4.00	7.92	4.36	5.73	4.76	**5.35**

Figure 46 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 2005-15. Differences of mean total percent cover by stony corals between monitoring surveys were statistically significant (ANOVA; $p < 0.0001$; Appendix 2), 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). From the reported live coral intercepted by transects during the 2006 monitoring survey, approximately 35.9 % was partially bleached. Most of the partially bleached coral colonies appear to have recuperated because during the 2007 survey, live coral cover remained virtually stable (mean: 14.2 %) as compared to the 2006 condition. Nevertheless, 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. A mild (statistically insignificant) increment of live coral cover was measured during the 2009 and 2010 surveys. The largest increment of total live coral cover was measured during the most recent 2015 survey (Figure 46).

Monitoring trends of mean substrate cover by coral species at Derrumbadero Reef are shown in Figure 47. 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 2006 (8.7 %) monitoring surveys had a profound 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. A mild increment of live cover by *O. annularis* was measured during the 2009 and 2010 monitoring surveys at Derrumbadero Reef, consistent with similar observations at several other reefs included in the monitoring program. A bold increase of reef substrate cover by *Orbicella annularis* was measured over the last two years (2013 – 2015) resulting in a partial recuperation of live coral cover at Derrumbadero Reef (Appendix 2).

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 90 fish species have been identified from Derrumbadero Reef during monitoring surveys (Appendix 1), including 35 within belt-transects during 2015 (Table 55). Mean abundance within belt-transects during 2013 was 91.8 Ind/30 m^2 (range: 48 - 145 Ind/30 m^2). The mean number of species per transect was 17 (range: 14 - 19). The Peppermint, Masked and Sharknose Gobies, Creole and Bluehead Wrasses, Bicolor Damselfish, Blue Chromis, and the Striped Parrotfish were the numerically dominant species with a combined mean abundance of 77.6 Ind/30 m^2 representing 84.5 % of the

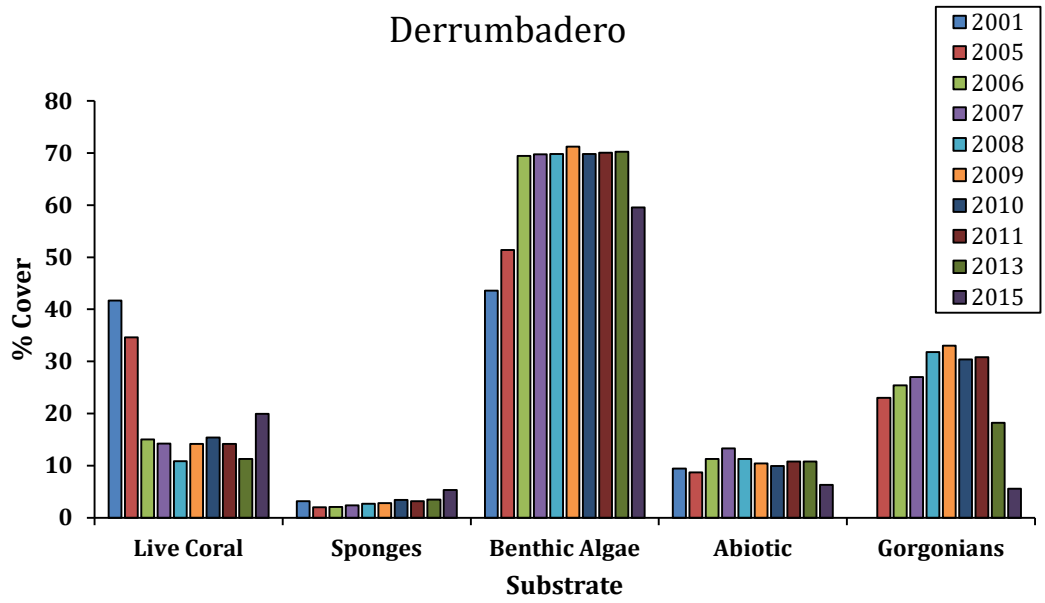


Figure 46. Monitoring trends (2001 – 2015) of mean substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce.

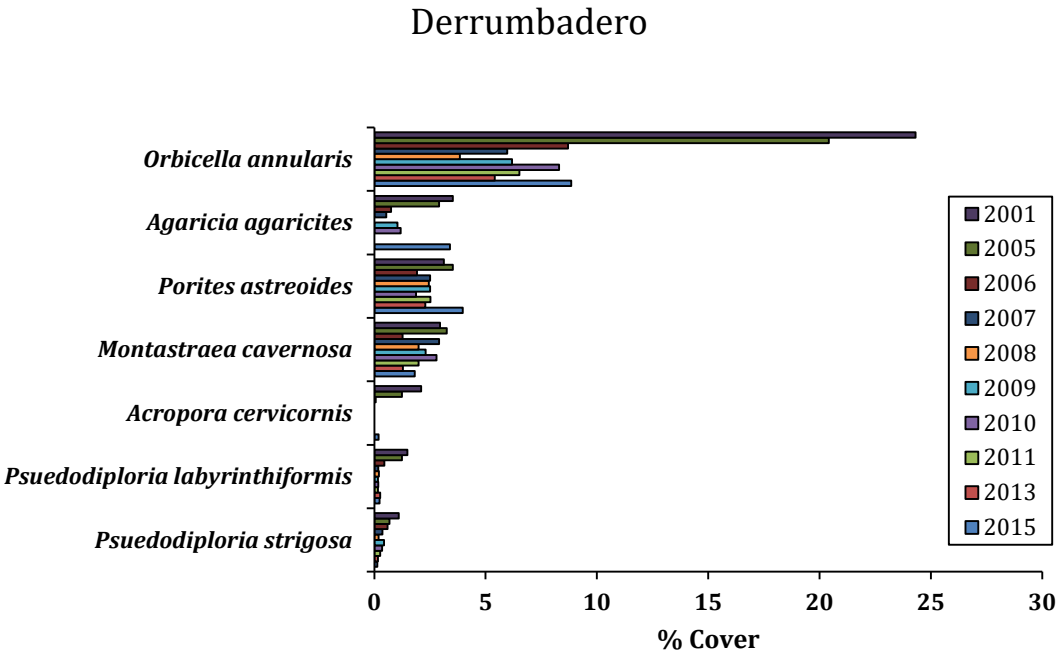


Figure 47. Monitoring trends (2001 – 2015) of mean substrate cover by coral species at Derrumbadero Reef, Ponce

Table 55. Taxonomic composition and abundance of fishes within belt-transects at Derrumbadero Reef, 20 m, Ponce. 2015

Depth: 20m

		TRANSECTS					
		1	2	3	4	5	
		(Ind/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	60	120	130	110	90	**102.0**
Thalassoma bifasciatum	Bluehead Wrasse	10	20	10	22	2	**12.8**
Stegastes partitus	Bicolor Damselfish	5	9	12	4	2	**6.4**
Scarus iserti	Stripped Parrotfish	7	0	1	3	6	**3.4**
Chromis cyanea	Blue Chromis	0	3	6	8	2	**3.8**
Scarus taeniopterus	Princess Parrotfish	3	0	9	3	0	**3.0**
Stegastes leucostictus	Beau Gregory	5	0	0	7	1	**2.6**
Sparisoma viride	Stoplight Parrotfish	3	1	3	0	2	**1.8**
Acanthurus chirurgus	Doctorfish	2	1	3	0	2	**1.6**
Chromis multilineata	Brown Chromis	0	8	0	0	0	**1.6**
Myripristis jacobus	Blackbar Soldierfish	0	1	4	3	0	**1.6**
Abudefduf sexatilis	Sargent Major	0	1	2	1	3	**1.4**
Cephalopholis cruentatus	Graysby	3	0	0	1	3	**1.4**
Stegastes variabilis	Cocoa Damselfish	3	0	2	0	0	**1.0**
Stegastes adustus	Dusky Damselfish	0	4	0	1	0	**1.0**
Hypoplectrus unicolor	Butter Hamlet	1	1	0	1	1	**0.8**
Sparisoma aurofrenatum	Redband Parrotfish	1	2	0	1	0	**0.8**
Caranx crysos	Blue runner	1	1	0	1	0	**0.6**
Haemulon flavolineatum	French Grunt	0	1	0	2	0	**0.6**
Chaetodon striatus	Banded Butterflyfish	0	0	0	0	2	**0.4**
Gobiosoma evelynae	Sharknose Goby	0	1	0	1	0	**0.4**
Haemulon aurolineatum	Tomtate	0	1	0	0	1	**0.4**
Heteropriacanthus cruentatus	Glasseye Snapper	1	0	0	0	0	**0.2**
Lachnolaimus maximus	Hogfish	1	0	0	0	0	**0.2**
Acanthurus coeruleus	Blue Tang	0	0	1	0	0	**0.2**
Canthigaster rostrata	Caribbean Puffer	0	0	0	1	0	**0.2**
Equetus lanceolatus	Jacknife	0	0	1	0	0	**0.2**
Haemulon plumieri	White Grunt	0	1	0	0	0	**0.2**
Haemulon sciurus	Bluestriped Grunt	0	0	0	1	0	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	1	0	0	0	**0.2**
Holocentrus rufus	Squirrelfish	0	0	1	0	0	**0.2**
Hypoplectrus nigricans	Black Hamlet	0	0	1	0	0	**0.2**
Neoniphon marianus	Longspine Squirrelfish	0	0	0	1	0	**0.2**

Table 55. continued

Ocyurus chrysurus	Yellowtail Snapper	0	0	0	0	1	**0.2**
Pseudupeneus maculatus	Spotted Goatfish	0	0	0	1	0	**0.2**
	Spotted Moray	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	**107**	**179**	**189**	**178**	**123**	**155.2**
	TOTAL SPECIES	**15**	**18**	**15**	**21**	**14**	**16.6**

total abundance within belt-transects (Table 55). In addition to the aforementioned species, the Blue Tang, Four-eye Butterflyfish, Squirrelfish, Yellow-head Wrasse, Yellowtail Snapper and Stoplight Parrotfish were present in at least four of the five transects surveyed and were also part of the resident demersal fish.

The fish community of Derrumbadero Reef appears to be well balanced in terms of trophic structure, including the presence of large demersal predators, such as large snappers and groupers. 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, such as the Masked Goby, Blue and Brown Chromis, Bicolor Damselfish, Bluehead, Yellowhead and Creole Wrasse, and juvenile snappers and grunts (which are piscivores or demersal feeders as adults) comprise the zooplanktivorous assemblage of the reef system. These in turn serve as forage for large pelagic species, such as Cero Mackerels and Barracudas observed during this and previous surveys in this reef. Large demersal predators previously reported from Derrumbadero Reef (García-Sais et al., 2006), such as Yellowfin and Tiger Groupers, Cubera, Mutton, Schoolmaster and Dog Snappers also feed from the small zooplanktivorous fishes that remain close to the reef benthos. A large variety of small invertebrate feeders were present, including wrasses, hamlets, gobies, squirrelfishes, and others. Larger invertebrate and small fish predators included the Hogfish, Schoolmaster and Mahogani snappers, Coney, Graysby and Red Hind groupers, lizardfishes and grunts. Parrotfishes, doctorfishes, and damselfishes comprised the main herbivorous assemblage.

Commercially important fishes observed within extended belt-transects included four species of parrotfishes present as juveniles and adults (Table 56), one adult Great Barracuda, juvenile yellowtail and Schoolmaster snappers, juvenile Graysbe, and one adult Dog Snapper.

Table 56. Taxonomic composition and size distributions of commercially important fish species present within expanded 3 x 20 m belt-transects at Derrumbadero Reef. 2015

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
SPECIES	**COMMON NAME**	(Ind/60 m^2) - Length (cm)				
Scarus iserti	Stripped Parrotfish	2 - 10 1 - 15 2 - 20	9 - 15 1 - 20	4 - 15	7 - 10 5 - 15	6 - 7 1 - 10 2 - 15
Sparisoma viride	Stoplight Parrotfish	3 - 15 1 - 20	1 - 10 1 - 15	1 - 10	2 - 7 1 - 30	1 - 12
Sphyraena barracuda	Great Barracuda					1 - 60
Sparisoma aurofrenatum	Redband Parrotfish			1 - 15	1 - 7	
Ocyurus chrysurus	Yellowtail Snapper		1 - 10	2 - 15		1 - 10
Lutjanus jocu	Dog Snapper					
Lutjanus apodus	Schoolmaster Snapper		1 - 33	1 - 35		1 - 15 1 - 30
Epinephelus cruentatus	Graysby				1 - 10	
Scarus taeniopterus	Princess Parrotfish	5 - 10 1 - 15				

Figure 48 presents the temporal trends of fish abundance and richness within belt-transects during the baseline characterization of 2001 and subsequent monitoring surveys of 2005-15. Statistically significant declines of fish abundance and species richness (ANOVA; $p < 0.001$) were detected. Higher fish abundance was observed during the 2001, 2005 and 2011 surveys compared to the 2006 - 10 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 and 2011 surveys. This is a small zooplanktivorous species that forms dense swarms 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 may be related to its recruitment dynamics or predation effects.

The Cleaner Shrimp and Arrow Crabs represented megabenthic invertebrates within belt transects during the 2015 survey (Table 57). Two spiny lobsters were observed outside transects.

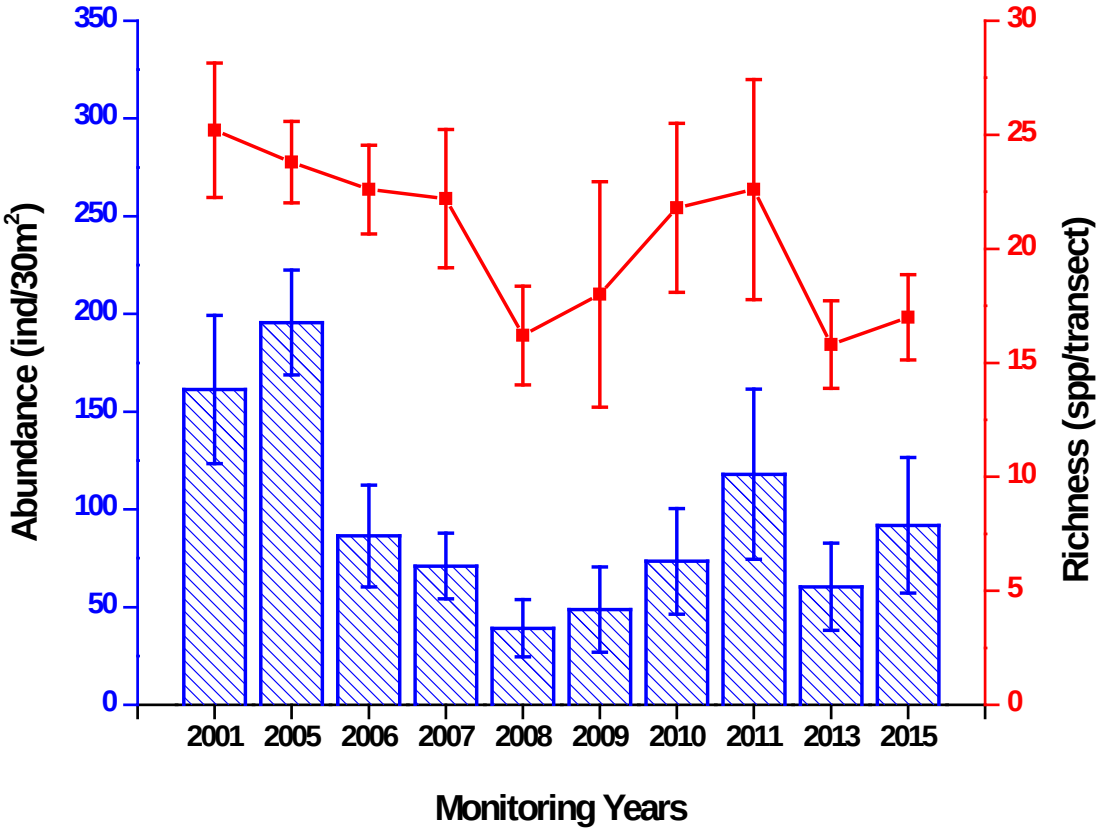
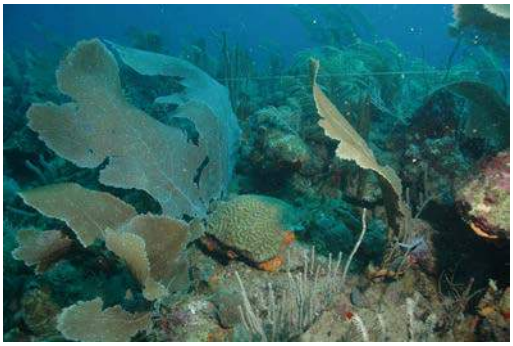


Figure 48. Monitoring trends (1999 – 2015) of fish species richness and abundance at Derrumbadero Reef, Ponce

Table 57. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Derrumbadero Reef, 20 m, Ponce, 2015

Depth: 20 m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	DEPTH (m) COMMON NAME						
Periclimenes pedersoni	Cleaner Shrimp	1					**0.2**
Stenorhynchus seticornis	Arrow Crab			1			**0.2**
	TOTALS	**1**	**0**	**1**	**0**	**0**	**0.4**

Photo Album 14. Ponce
Derrumbadero Reef



G. Cabo Rojo

1.0 Gallardo Reef – Cabo Rojo

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 49). 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 were dominated by dense stands of Elkhorn Coral, *Acropora palmata*. 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 2- 4 meters within the *A. palmata* biotope. Panoramic views of Gallardo Reef are shown in Photo Album 15.

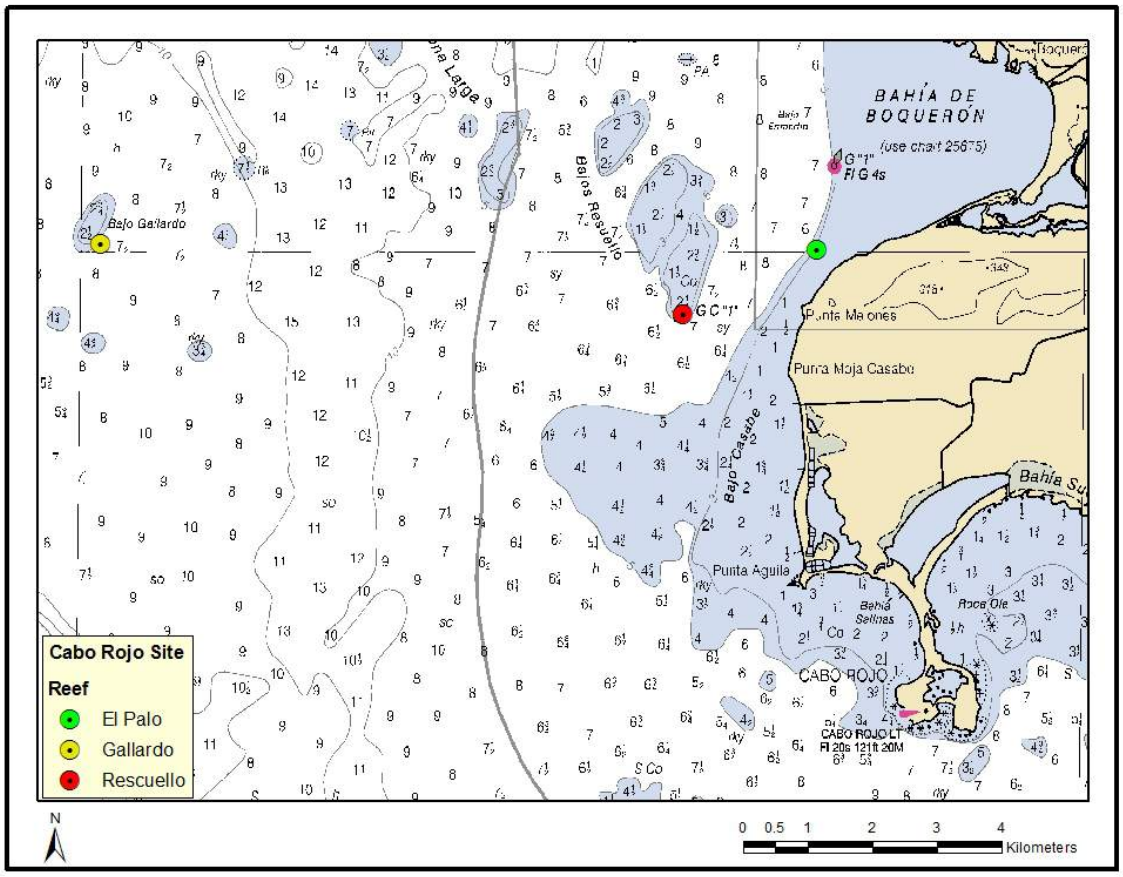


Figure 49. Location of reefs surveyed within the Boqueron (Cabo Rojo) Natural Reserve.

1.1 Sessile-Benthic Reef Community

Patchy growth of Elkhorn Coral, *Acropora palmata* was the most prominent feature of Gallardo Reef at depth between 2 – 4 meters. Live Elkhorn Coral colonies were present in all transects surveyed with a mean substrate cover of 55.9 % (range: 38.3 – 77.0 %), representing 99.6 % of the total cover by corals along transects (Table 58). Mean substrate cover by reef sessile-benthic categories are shown in Figure 50. 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. Two other stony coral species (*Agaricia agaricites. Porites*

Table 58. Percent substrate cover by sessile-benthic categories at Gallardo Reef, Cabo Rojo. 2015

	Transects					
	1	2	3	4	5	**Mean**
	5.51	5.88	3.37	3.44	3.94	**4.43**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	25.81	8.38	10.26	11.88	21.99	**15.66**
Gap	0.99	4.06	5.34	5.00	7.13	**4.50**
Total Abiotic	26.81	12.43	15.60	16.88	29.12	**20.17**
Benthic Algae						
Turf	18.95	10.32	21.99	44.58	13.96	**21.96**
Halimeda sp.		0.26	1.36			**0.33**
Total Benthic Algae	18.95	10.58	23.35	44.58	13.96	**22.29**
Live Corals						
Acropora palmata	49.19	76.98	58.43	38.33	56.73	**55.93**
Agaricia agaricites	0.18			0.21		**0.08**
Porites astreoides	0.27					**0.05**
Total Live Corals	49.64	76.98	58.43	38.54	56.73	**56.06**
Octocorals						
Erythropodium caribaeorum	3.16					**0.63**
Erect Gorgonians						
(#colonies/transect)	4	1				**1.00**
Sponges						
Cliona tenuis					0.20	**0.04**
Zoanthids						
Palythoa caribaeorum	1.44		2.62			**0.81**

astreoides) were intercepted by transects during the baseline survey, but were present with very low reef substrate cover (< 1.0 %) (Figure 51). Soft corals (gorgonians) were present in two transects with an overall mean density of 1 col/transect. The encrusting gorgonian, *Erythropodium caribaeorum* was present in one transect with a mean cover of 0.6 %. Colonial zoanthids (*Palythoa* sp.) and sponges were observed within transects, but were not prominent within the Elkhorn Coral biotope at Gallardo Reef.

Sections of the reef hard ground not colonized by Elkhorn Coral were covered by turf algae, a mixed assemblage of short articulated red and brown macroalgae. Mean cover by turf algae was 22.0 % (range: 10.3 – 44.6 %), representing 98.6 % of the total cover by the benthic algal assemblage (Table 58). Cyanobacterial films were also present, but with very low cover and out of transects. Abiotic substrates, particularly reef overhangs

produced by Elkhorn Coral growth were also prominent in terms of reef substrate cover with a mean of 20.2 %. Such overhangs contributed to a mean substrate rugosity of 4.4 m.

1.2 Fishes and Motile megabenthic Invertebrates

The taxonomic composition and abundance of fishes within belt-transects surveyed at Gallardo Reef during 2015 are presented in Table 59. A total of 60 species were identified, including 21 within belt-transects. The mean number of species per transect was 11.8 (range: 10 – 15) and the mean density of fishes was 110.6 Individuals/30 m^2 (range : 89 – 136 Individuals/30 m^2). Six species represented 76.3 % of the total individuals within transect areas. The main fish assemblage included the Brown and Blue Chromis (*Chromis multilineata, C. cyanea*), Bluehead Wrasse (*Thalassoma bifasciatum*), Stripped Parrotfish (*Scarus iserti*), Bar Jack (*Carangoides ruber*), and Yellowtail Damselfish (*Microspathodon chrysurus*). Redlip Blenny (*Ophioblennius atlanticus*), Stoplight Parrotfish (*Sparisoma viride*) and the Dusky Damselfish (*Stegastes adustus*) were present in at least four out of the five transects surveyed and appear to be part of the resident fish assemblage at Gallardo Reef.

Commercially important fishes observed within extended belt-transects surveyed included five parrotfish species (*Scarus iserti, S. vetula, Sparisoma aurofrenatum, S. viride, S. rubripinne*) present across a wide size range that included both juvenile and

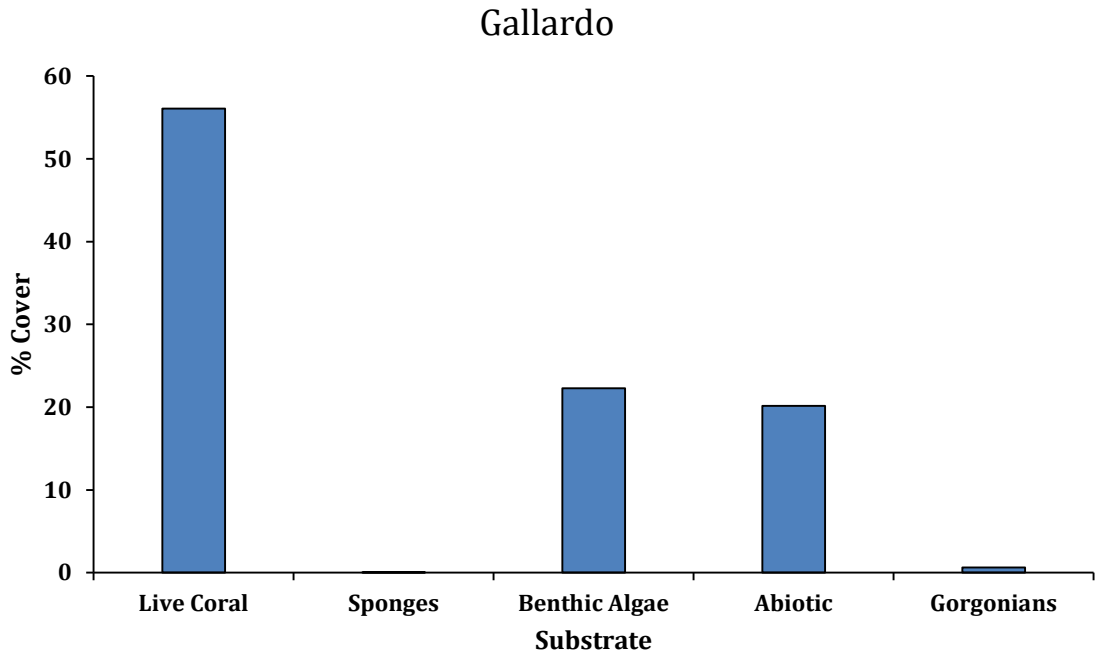


Figure 50. Mean substrate cover by sessile-benthic categories at Gallardo Reef, Cabo Rojo. Baseline survey: 2015.

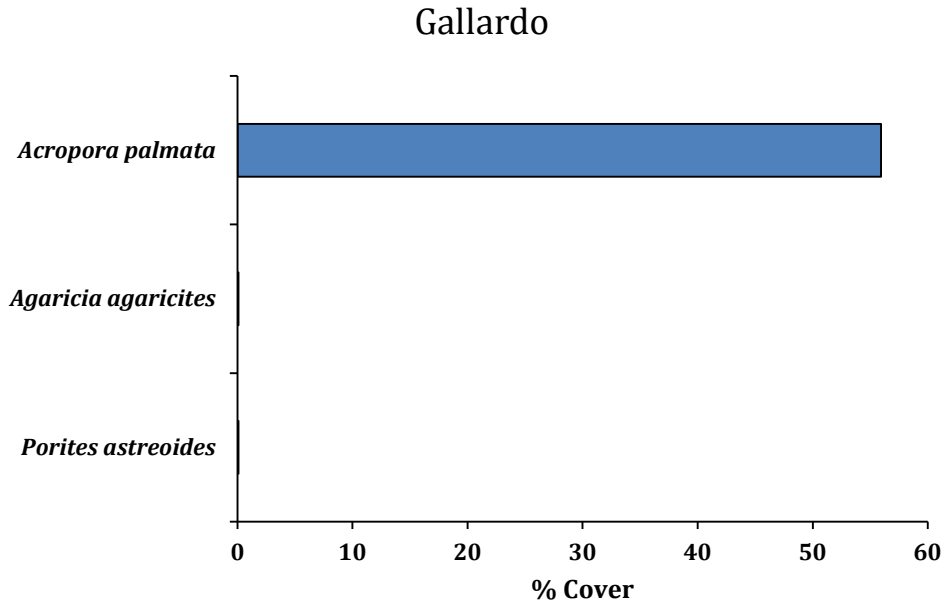


Figure 51. Mean substrate cover by stony coral spp. categories at Gallardo Reef, Cabo Rojo. Baseline survey: 2015.

Table 59 Taxonomic composition and abundance of fishes within belt-transects at Gallardo Reef, Cabo Rojo, 2015

Depth: 2 - 4m		TRANSECTS					
		1	2	3	4	5	
		(Ind30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Chromis multilineata	Brown Chromis	8	10	11	30	40	**19.8**
Thalassoma bifasciatum	Bluehead Wrasse	0	20	25	30	15	**18.0**
Scarus iserti	Stripped Parrotfish	50	10	2	0	10	**14.4**
Caranx ruber	Bar Jack	24	5	0	30	0	**11.8**
Microspathodon chrysurus	Yellowtail Damselfish	8	10	9	8	16	**10.2**
Chromis cyanea	Blue Chromis	0	20	26	0	5	**10.2**
Clepticus parrae	Creole Wrasse	28	0	0	0	0	**5.6**
Acanthurus coeruleus	Blue Tang	3	0	3	6	7	**3.8**
Sparisoma viride	Stoplight Parrotfish	9	3	3	1	0	**3.2**
Stegastes adustus	Dusky Damselfish	4	5	2	2	3	**3.2**
Melichthys niger	Black Durgon	0	0	0	10	6	**3.2**
Ophioblennius atlanticus	Redlip Blenny	1	4	3	4	1	**2.6**
Sparisoma aurofrenatum	Redband Parrotfish	0	2	4	0	2	**1.6**
Scarus vetula	Queen Parrotfish	0	0	2	1	3	**1.2**
Aulostomus maculatus	Trumpetfish	1	0	1	0	0	**0.4**
Chaetodon capistratus	Four-eye Butterflyfish	0	0	0	2	0	**0.4**
Halichoeres maculipinna	Clown Wrasse	0	0	0	1	0	**0.2**
Halichoeres garnoti	Yellowhead Wrasse	0	0	1	0	0	**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish	0	0	1	0	0	**0.2**
Ocyurus chrysurus	Yellowtail Snapper	0	0	0	0	1	**0.2**
Sparisoma rubripinne	Yellowtail Parrotfish	0	0	1	0	0	**0.2**
	TOTAL INDIVIDUALS	**136**	**89**	**94**	**125**	**109**	**110.6**
	TOTAL SPECIES	**10**	**10**	**15**	**12**	**12**	**11.8**

adult stages (Table 60). Parrotfishes (Scaridae) were the most specious taxonomic group, and combined with doctorfishes (Acanthuridae) and “farmer damselfishes” (e.g. *Stegastes adustus, M. chrysurus* - Pomacentridae) comprised the principal herbivore fish assemblage. The combined abundance of herbivores represented (at least) 34.0% of the total individuals within belt-transect areas. The zooplanktivorous fish assemblage comprised by the Blue and Brown Chromis (*Chromis cyanea, C. multilineata*), and the Creole Wrasse (*Clepticus parrae*) represented approximately 32.2 % of the total individuals. Also present outside transects in large schools was the Mackerel Scad, *Decapterus macarellus*. These zooplanktivores fishes serve as important forage species for larger pelagic predators, such as the Great Barracuda and the Bar Jack, both present at Gallardo Reef during our survey.

Table 60. Taxonomic composition, density and size distributions of commercially important fishes present within expanded belt-transects 3 x 20 m at Gallardo Reef, Cabo Rojo. 2015

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped	50 - 5	10 - 5	20 - 7		10 - 7
	Parrotfish			2 - 15		
Sparisoma viride	Stoplight	5 - 3	3 - 5	1 - 7	1 - 25	1 - 30
	Parrotfish	3 - 12	1 - 25	2 - 12	1 - 30	
		3 - 20		2 - 25		
Sparisoma aurofrenatum	Redband		2 - 12	1 - 7	1 - 25	3 - 12
	Parrotfish			2 - 15		1 - 15
				1 - 20		
Ocyurus chrysurus	Yellowtail				1 - 20	
	Snapper				1 - 25	
Scarus vetula	Queen	2 - 7	2 - 20	1 - 8	1 - 25	1 - 7
	Parrotfish		2 - 25	1 - 15	1 - 30	2 - 15
				3 - 20	1 - 35	1 - 20
				1 - 35		1 - 25
Sparisoma rubripinne	Yellowtail			1 - 25		
	Parrotfish			1 - 30		

Opportunistic carnivores which feed on small benthic invertebrates, such as wrasses (Labridae), Trumpetfish (Aulostomidae), gobies (Gobiidae) and hamlets (*Hypoplectrus* spp.- Serranidae) were prominent at this reef representing about 19.5 % of the total individuals. Predators of larger reef invertebrates and small demersal fishes included a small assemblage of grunts, groupers (e.g. Coney, Red Hind) and Spanish Hogfish, mostly observed outside transect areas.

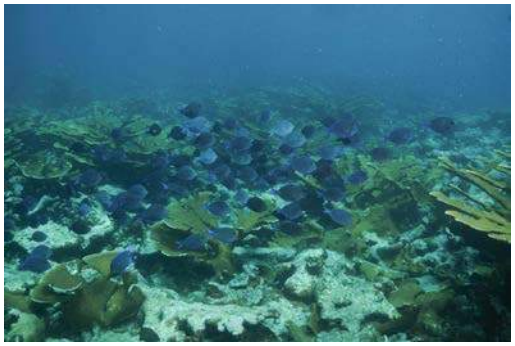
Corallivorous snails (*Coralliophila sp*.) and one Long-spined Urchin were observed within belt-transect areas at Gallardo Reef (Table 61). One Spiny Lobster, *Panulirus argus* was present outside transects.

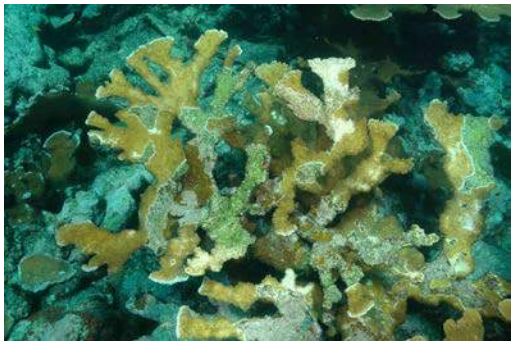
Table 61 Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Gallardo Reef. 2015

Depth: 2 - 4 m		**TRANSECTS**					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
SPECIES	**COMMON NAME**						
Diadema antillarum	Long-spined Urchin	1	1	0	1	3	**1.2**
Coralliphila spp	Gastropods	8	3	6	2	9	**5.6**
	TOTALS	**9**	**4**	**6**	**3**	**12**	**6.8**

Photo Album 15. Cabo Rojo

Gallardo Reef





2.0 Resuellos Reef – Cabo Rojo

Resuellos Reef is a hard-ground promontory located at about one nautical mile due west from Pta. Melones, Cabo Rojo (Figure 49). 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). This 2015 survey is the second monitoring effort at Resuellos Reef. Transects were installed following the 8.0 meter depth contour along the reef slope. Panoramic views of Resuellos Reef are presented in Photo Album 16.

2.1 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 44.6 erect col/transect and a reef substrate cover of 27.0 % (range: 22.4 – 35.2 %) (Table 62). Some of the most abundant included *Briareum asbestinum*, *Antilligorgia spp. Eunicea spp., Pterogorgia sp.,* and *Gorgonia ventalina*. The encrusting gorgonian, *Erythropodium caribaeorum* was present in all five transects surveyed with a mean linear cover of 14.9 % (range: 11.8 – 20.9 %). Stony corals, represented by at least 20 species, including 13 along transects contributed a mean linear cover of 21.0 % (range: 14.6 – 28.0%). Boulder Brain Coral, *Orbicella annularis* was the dominant coral species with a mean cover of 8.5 %, representing 40.5 % of the total cover by stony corals. Boulder Brain Coral (*Colpophyllia natans*), Massive Starlet Coral (*Siderastrea siderea*), and Mustard-Hill Coral (*Porites astreoides*) were present in at least four transects and along with Boulder Star Coral comprised the main coral assemblage in terms of reef substrate cover (Table 62).

Table 62. Percent substrate cover by sessile-benthic categories at Resuellos Reef, Cabo Rojo. 2015

	Transects					
	1	2	3	4	5	**Mean**
	4.83	3.12	4.09	3.3	1.98	**3.464**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	6.23	6.08	6.06	2.95	4.09	**5.08**
Rubble		1.92				**0.38**
Total Abiotic	6.23	8.00	6.06	2.95	4.09	**5.46**
Benthic Algae						
Turf	31.54	32.52	49.16	36.21	34.93	**36.87**
Cyanobacteria	0.94				1.75	**0.54**
Live Corals						
Orbicella annularis complex	15.01	3.94	4.67	5.26	13.43	**8.46**
Colpophyllia natans	0.94	8.53	1.99	5.37		**3.37**
Siderastrea siderea	1.51	5.76	3.67	0.95	1.64	**2.70**
Porites astreoides	0.57	3.20	2.58	2.42	3.74	**2.50**
Montastraea cavernosa	3.68		1.39			**1.01**
Mycetophyllia lamarckiana		3.84				**0.77**
Meandrina meandrites		1.28			2.10	**0.68**
Agaricia agaricites		0.85		0.63	0.35	**0.37**
Stephanocoenia intersepta					1.52	**0.30**
Pseudodiploria labyrinthiformis	1.51					**0.30**
Mycetophyllia aliciae					1.17	**0.23**
Madracis decactis			0.70			**0.14**
Millepora alcicornis		0.64				**0.13**
Total Live Corals	23.23	28.04	15.00	14.63	23.95	**20.97**
Octocorals						
Erythropodium caribaeorum	15.39	12.69	13.51	20.95	11.80	**14.87**
Briareum asbestinum	12.18	11.30	10.03	13.89	9.93	**11.47**
Allotogorgia acerosa	0.47			0.32	0.47	**0.25**
Allotogorgia americana	0.19	0.43	0.20			**0.16**
Pterogorgia sp.			0.40			**0.08**
Eunicea tourneforti	0.38					**0.08**

Table 62. continued

Eunicea colombiana		0.32				**0.06**
Gorgonia ventalina					0.23	**0.05**
Total Octocorals	28.61	24.73	24.13	35.16	22.43	**27.01**
Erect Gorgonians (#col/transect)	43	38	59	31	52	**44.60**
Sponges						
Chondrilla caribensis	2.55		0.40	1.58	7.71	**2.45**
Aplysina cauliformis	1.42	0.85	1.19	0.32	0.35	**0.83**
Monanchora arbuscula	1.23	0.21	0.20	1.37	0.70	**0.74**
Niphates erecta	0.19	0.21	0.50	1.05	0.93	**0.58**
Mycale laevis	0.19	1.28		0.74	0.35	**0.51**
Agelas citrina		1.17	0.40		0.82	**0.48**
Cinachyrella kuekenthali		0.43	0.89	0.32	0.35	**0.40**
Aplysina insularis				1.79		**0.36**
Cribrochalina vasculum			0.40	1.16		**0.31**
Sponge	0.47				1.05	**0.30**
Ircinia strobilina		0.53		0.63		**0.23**
Aplysina fistularis	0.19	0.53	0.40			**0.22**
Neopetrosia proxima			0.99			**0.20**
Callyspongia fallax		0.43			0.35	**0.16**
Verongula reiswigi	0.57					**0.11**
Agelas dispar				0.53		**0.11**
Aplysina fulva				0.53		**0.11**
Biemna sp.				0.53		**0.11**
Amphimedon compressa black	0.47					**0.09**
Amphimedon compressa				0.21	0.23	**0.09**
Ircinia brown sp.				0.32		**0.06**
Chondrosia collectrix			0.30			**0.06**
Agelas sp.	0.28					**0.06**
Dysidea janiae	0.19					**0.04**
Total Sponges	7.74	5.65	5.66	11.05	12.85	**8.59**
Zoanthid						
Palythoa sp.	1.70	1.07				**0.55**

Sponges were also prominent components of the sessile-benthic community with at least 24 species intercepted by line transects and a mean linear cover of 8.6 % (Table 62). They were present as erect and encrusting colonies. *Chondrilla caribensis, Aplysina cauliformis, Monanchora arbuscula* and *Niphates erecta* were present in at least four transects and comprised the main taxonomic assemblage.

Turf algae were the main biotic category in terms of reef substrate cover with a mean of 36.9 % and were present in all five transects surveyed. Reef overhangs, largely associated with massive and laminar coral growth were the main contributor of abiotic cover with a mean of 5.1 %. Otherwise, this reef was fully colonized by biotic components.

Figure 52 shows the variation of mean percent substrate cover by reef sessile-benthic categories of Resuellos Reef between the baseline survey in May 2000 and the present 2015 monitoring survey. It is truly remarkable that after 15 years some off the main reef sessile-benthic components, such as the cover by sponges, gorgonians and benthic algae remained virtually constant. The total variation of live coral cover was from 18.1% in 2000 to 21.0 % in 2015. Differences of total coral cover were statistically insignificant (ANOVA; p = 0.355; Appendix 2) relative to the natural variability of coral cover among replicate transects (see Appendix 2). Most of the difference was associated with the apparent mortality of Boulder Brain Coral, *Colpophyllia natans* from an initial cover of 5.9 % to the 2013 report of 0% cover along transects, but that appear to have been a sampling error now corrected by the present survey. Boulder Star Coral, *Orbicella annularis* which suffered the most acute mortality during and after the 2005 regional coral bleaching event did not exhibited any statistically significant loss of live coral cover between dates (Figure 53).

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 influenced by prevailing crystal clear waters.

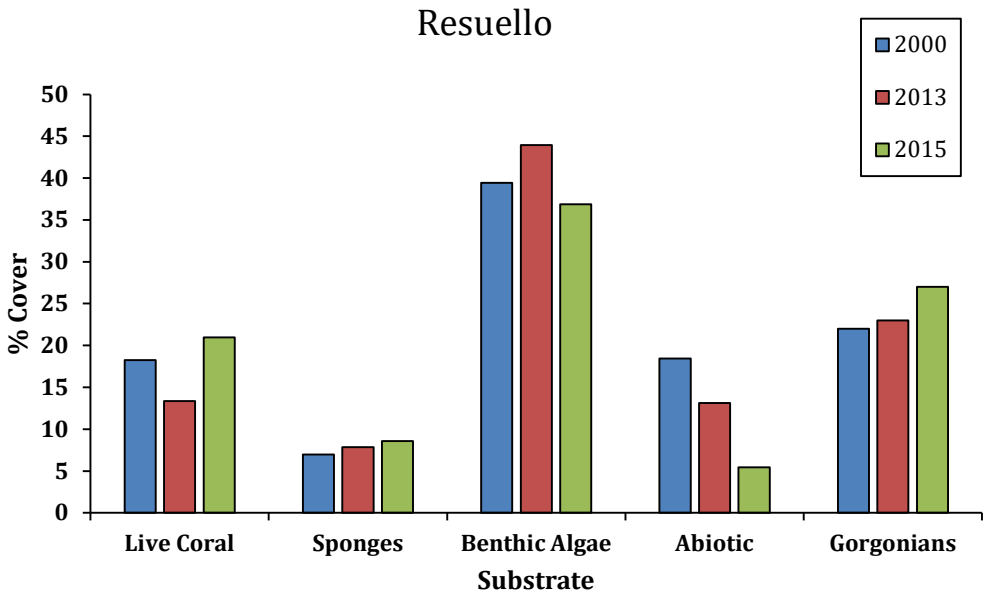


Figure 52. Monitoring trends (2000 – 2015) of mean substrate cover by sessile-benthic categories at Resuellos Reef, Cabo Rojo

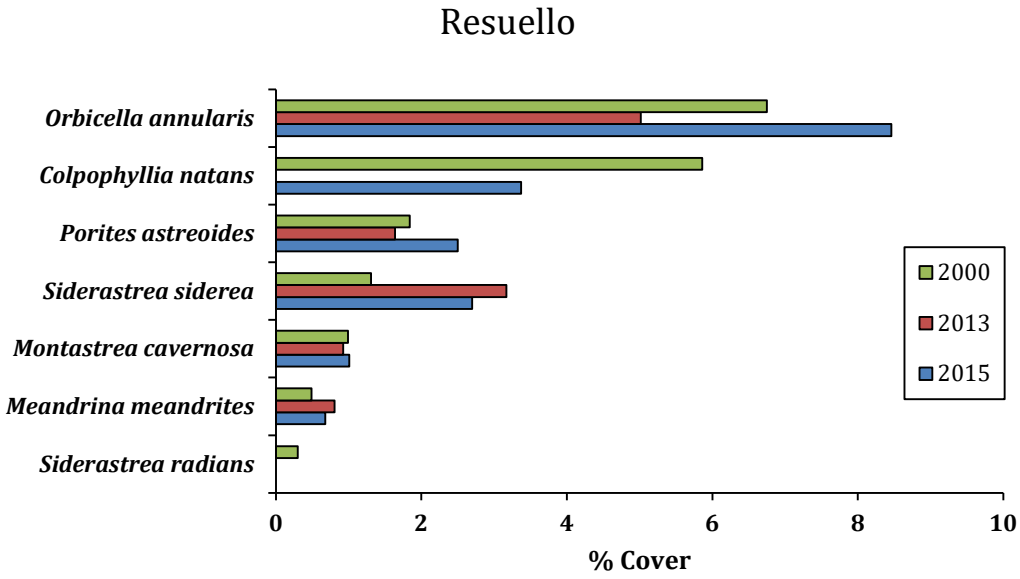


Figure 53. Monitoring trends (2000 – 2015) of mean substrate cover by coral species at Resuellos Reef, Cabo Rojo

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 51 fish species have been identified at Resuellos Reef, 26 of which were present within belt-transect during the 2015 survey (Table 63). The mean number of species per transect was 13 (range 10 – 16), and the mean density of fishes was 29.6 Individuals/30 m^2 (range: 20 - 46 Individuals/30 m^2). Eight species represented 70.3 % of the total individuals within transect areas. The numerically dominant fish assemblage included the Striped, Redband and Stoplight Parrotfishes (*Scarus iserti, Sparisoma aurofrenatum, S. viride*), the Sharknose goby (*Elacatinus sp*), Yellowtail Snapper (*Ocyurus chrysurus*), Beau-Gregory (*Stegastes leucostictus*) and Four-eye Butterflyfish (*Chaetodon capistratus*).

Damselfishes (Pomacentridae) and parrotfishes (Scaridae) were the most specious fish families with five and three species each. Herbivorous taxa included parrotfishes, doctorfishes (Acanthuridae) and "farmer damselfishes" (Pomacentridae). The combined herbivorous assemblage represented approximately 42.4 % of the total individuals within belt-transect areas. Opportunistic carnivores which feed on small benthic invertebrates, such as wrasses (Labridae), puffers (Tetraodontidae), gobies (Gobiidae), hamlets (*Hypoplectrus* spp.- Serranidae), squirrelfishes (Holocentridae) and goatfishes (Mullidae) represented about 32.6 % of the total individuals. The zooplanktivorous fish assemblage recorded within transect areas included the Masked Goby (*Coryphopterus personatus*) and the Bicolor Damselfish (*Stegastes partitus*), but these species were not observed in high relative abundance.

Fish species of commercial value present within extended belt-transects are presented in Table 64. Three parrotfishes, two snappers, one Red Hind, one Lionfish and one Graysbe comprise the list. Mutton Snapper (Lutjanus analis) and Lionfish were present in their full adult size, whereas parrotfishes and others were observed in juvenile and young adult stages (Table 64).

Table 63. Taxonomic composition and abundance of fishes within belt-transects at Resuellos Reef, Cabo Rojo, 2015

Depth: 12 m

		TRANSECTS					
		1	2	3	4	5	
		(Ind/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Lutjanus apodus	Schoolmaster Snapper	10	0	0	14	10	**6.8**
Scarus iserti	Stripped Parrotfish	2	0	1	4	4	**2.2**
Sparisoma viride	Stoplight Parrotfish	2	2	2	3	1	**2.0**
Thalassoma bifasciatum	Bluehead Wrasse	0	0	0	1	9	**2.0**
Elacatinus evelynae	Sharknose Goby	0	0	4	3	2	**1.8**
Sparisoma aurofrenatum	Redband Parrotfish	5	0	0	1	1	**1.4**
Coryphopterus personatus	Masked Goby	0	6	0	0	0	**1.2**
Canthigaster rostrata	Caribbean Puffer	1	1	1	2	0	**1.0**
Gramma loreto	Fairy Basslet	5	0	0	0	0	**1.0**
Haemulon aurolineatum	Tomtate	0	4	1	0	0	**1.0**
Scarus taeniopterus	Princess Parrotfish	1	2	0	2	0	**1.0**
Stegastes adustus	Dusky Damselfish	3	0	0	1	1	**1.0**
Stegastes partitus	Bicolor Damselfish	0	0	2	0	3	**1.0**
Chaetodon capistratus	Four-eye Butterflyfish	1	0	2	0	1	**0.8**
Ocyurus chrysurus	Yellowtail Snapper	4	0	0	0	0	**0.8**
Sparisoma radians	Bucktooth Parrotfish	1	2	0	0	0	**0.6**
Acanthurus chirurgus	Doctorfish	1	0	0	1	0	**0.4**
Acanthurus coeruleus	Blue Tang	1	0	0	0	1	**0.4**
Hypoplectrus unicolor	Butter Hamlet	1	0	1	0	0	**0.4**
Pomacanthus arcuatus	Grey Angelfish	2	0	0	0	0	**0.4**
Anisotremus virginicus	Porkfish	0	1	0	0	0	**0.2**
Aulostomus maculatus	Trumpetfish	0	0	0	1	0	**0.2**
Chaetodon striatus	Banded Butterflyfish	0	0	0	0	1	**0.2**
Haemulon flavolineatum	French Grunt	0	1	0	0	0	**0.2**
Holocentrus rufus	Squirrelfish	1	0	0	0	0	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	0	1	0	0	**0.2**
Hypoplectrus puella	Barred Hamlet	0	1	0	0	0	**0.2**
Stegastes leucostictus	Beau Gregory	0	0	1	0	0	**0.2**
	TOTAL INDIVIDUALS	**41**	**20**	**16**	**33**	**34**	**28.8**
	TOTAL SPECIES	**16**	**9**	**10**	**11**	**11**	**11.4**

Table 64. Taxonomic composition, density and size distributions of commercially important fishes present within expanded belt-transects 3 x 20 m at Resuellos Reef, Cabo Rojo. 2015

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped Parrotfish	4 - 3 2 - 12 1 - 20	4 - 5 1 - 15 1 - 20	2 - 8 2 - 15	8 - 3 4 - 10 1 - 15	2 - 10 5 - 15 1 - 20
Sparisoma viride	Stoplight Parrotfish	1 - 12 1 - 20	1 - 15 1 - 20	2 - 15	2 - 6 1 - 25	1 - 25
Sparisoma aurofrenatum	Redband Parrotfish	2 - 12 2 - 15	3 - 12 1 - 20	3 - 7 4 - 10	2 - 15	2 - 10 2 - 12
Epinephelus guttatus	Red Hind	1 - 20 1 - 23	1 - 20 1- 30			
Ocyurus chrysurus	Yellowtail Snapper		2 - 7 1 - 12	1 - 10	1 - 20	2 - 10 2 - 30
Epinephelus cruentatus	Graysby			1 - 10		
Pterois volitans	Lionfish	1 - 30				
Lutjanus analis	Mutton Snapper					1 - 45
Lutjanus apodus	Schoolmaster Snapper				1 - 15	1 - 20

Predators of larger reef invertebrates and small demersal fishes observed within and outside transects included several species of snappers (Lutjanidae), grunts (Haemulidae), groupers (Serranidae) and hogfishes (Labridae). Pelagic predators, such as the Great Barracuda and the Bar Jack were present at Resuellos Reef during our 2013 survey, along with two Hogfishes, Red Hind, Schoolmaster, Lane, Mutton and Yellowtail Snappers.

Variations of fish abundance and species richness between the baseline 2000 and the present 2015 monitoring survey are shown in Figure 54. Variations in abundance were negligible (Appendix 3). Fish species richness declined during the 2013 survey relative to the baseline, but the difference was statistically marginal at an alpha level of 0.05 (ANOVA; p = 0.150; see Appendix 4). Variations of fish abundance and species richness in shallow reefs have been observed to fluctuate markedly in relation to physical conditions, such as wind and wave action.

Motile megabenthic invertebrates observed within belt-transects were represented by several Flamingo Tongues, Arrow Crabs and one cleaner Shrimp (Table 65).

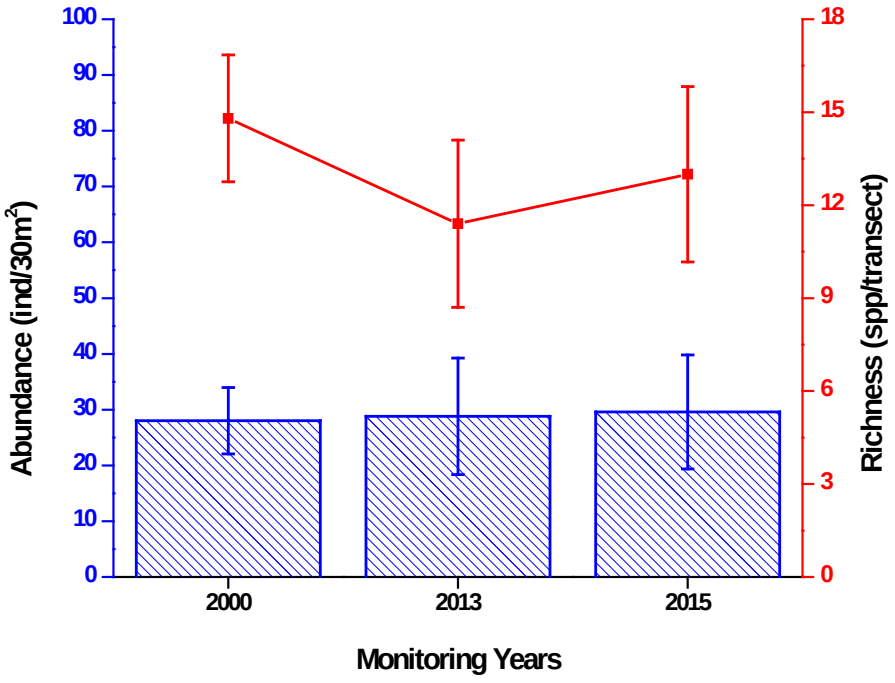
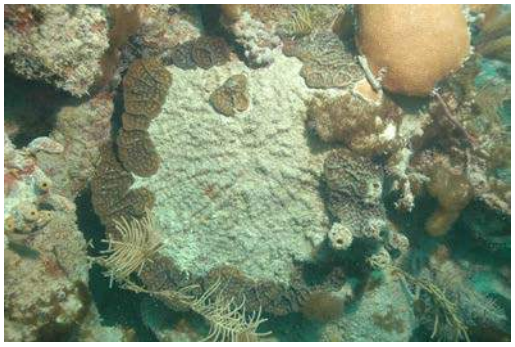


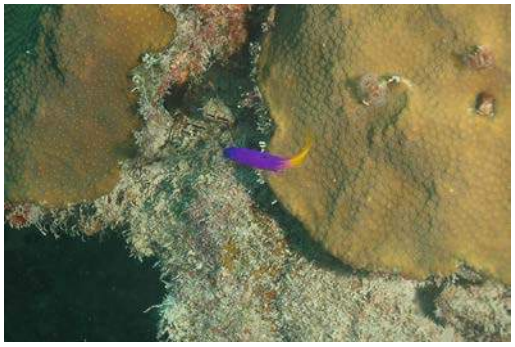
Figure 54. Monitoring trends (2000 – 2015) of fish species richness and abundance at Resuellos Reef, Cabo Rojo.

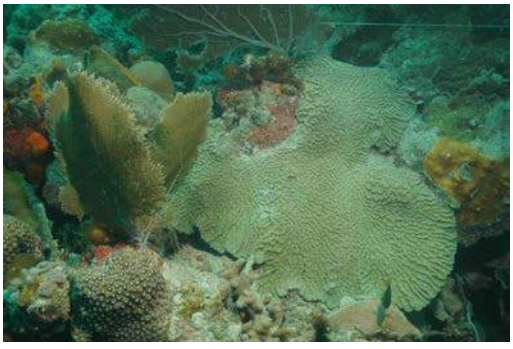
Table 65. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Resuellos Reef. Cabo Rojo. 2015

		TRANSECTS					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m^2)**
SPECIES	**COMMON NAME**						
Cyphoma gibbosum	Flamingo Tongue	2	0	1	0	1	**0.8**
Periclimenes pedersoni	Cleaner Shrimp					1	**0.2**
Stenorhynchus seticornis	Arrow Crab	0	1	0	1	0	**0.4**
	TOTALS	**0**	**0**	**1**	**1**	**0**	**0.4**

Photo Album 16. Cabo Rojo
Resuellos Reef







3.0 El Palo Reef – Cabo Rojo

El Palo Reef is a small fringing reef located due north of Punta Melones, at the entrance of Boquerón Bay (Figure 49). The reef rises to the surface forming a reef flat and has an irregular and abrupt fore-reef slope that drops down to a silty-sand bottom at a depth of 6 meters. Seagrass beds, mostly Turtle Grass, *Thalassia testudinum*, grow to the east and at the base of the reef. The best coral development was found at depths between 3 – 5 meters. Our line transects were positioned perpendicular to the shoreline, running down the slope and encompassing the 3 – 5 meter depth range. The baseline characterization was performed during May 2000 (Garcia-Sais et al., 2001). This is the second monitoring survey of the reef after 15 years of the initial assessment. Two of the five transects initially installed were not found and new transects had to be constructed in 2013. Thus, the comparative analysis is biased due to the transect modifications. Panoramic views of El Palo Reef are exhibited in Photo Album 17.

3.1 Sessile-Benthic Reef Community

A dense algal turf intermixed with clusters of calcareous macroalgae (mostly *Halimeda spp*) was the dominant biological assemblage at El Palo Reef with a mean linear cover of 42.5 %, representing 84.8 % of the total cover by benthic algae (Table 66). The algal turf was found overgrowing many dead massive coral colonies, some of which were of very large sizes. Erect soft coral (gorgonian) colonies were abundant (mean = 30.8 colonies/transect) and of variable sizes, including very large ones. Their combined mean abundance along transects was 10.3 %. Some of the most abundant included *Briareum asbestinum, Allotogorgia spp., Gorgonia ventalina* and *Eunicea spp*. The encrusting gorgonian, *Erythropodium caribaeorum* was present at all transects with a mean linear cover of 5.4 %. A total of 15 sponge species were intercepted by transects with a combined mean cover of 3.4 % (Table 66).

Abiotic substrates, largely represented by reef overhangs were prominent at El Palo Reef and presented a combined linear cover of 21.4 %. Most of the linear cover by reef overhangs was associated to dead and live massive coral colonies that produced ledges underneath the colonies. Also, the reef structure was discontinuous in many sections

Table 66. Percent substrate cover by sessile-benthic categories at El Palo Reef, Cabo Rojo. 2015

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.73	3.51	4.84	2.15	4.83	**3.61**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	7.15	16.89	9.62	26.27	6.89	**13.37**
Sand	2.20	6.53	0.94	9.56	4.34	**4.72**
Rubble		3.11	11.04			**2.83**
Gap		2.18				**0.44**
Total Abiotic	9.35	28.70	21.60	35.83	11.24	**21.35**
Benthic Algae						
Turf	42.68	38.76	41.60	35.14	54.30	**42.50**
Halimeda sp.	18.81	0.62	4.81		1.61	**5.17**
CCA				4.26	7.84	**2.42**
Total Benthic Algae	61.50	39.38	46.42	39.40	63.74	**50.09**
Cyanobacteria	0.99		0.19	3.69		**0.97**
Live Corals						
Orbicella annularis complex	4.40	1.04	7.36	9.91	12.84	**7.11**
Siderastrea siderea	7.15	6.94	3.21	1.96	2.93	**4.44**
Porites astreoides			4.91		0.76	**1.13**
Agaricia agaricites	2.31	0.83				**0.63**
Colpophyllia natans		1.97				**0.39**
Millepora alcicornis	1.10	0.62				**0.34**
Montastraea cavernosa				1.04		**0.21**
Stephanocoenia intersepta		1.04				**0.21**
Pseudodiploria strigosa			0.94			**0.19**
Porites porites					0.76	**0.15**
Total Live Corals	14.96	12.44	16.42	12.90	17.28	**14.80**
Octocorals						
Erythropodium caribaeorum	3.63	6.74	5.47	5.53	5.57	**5.39**
Briareum asbestinum	3.30	9.95	7.36			**4.12**
Eunicea flexuosa	0.44	0.21				**0.13**
Eunicea colombiana	0.55					**0.11**
Gorgonia ventalina		0.52				**0.10**
Allotogorgia americana			0.38			**0.08**
Allotogorgia acerosa	0.33					**0.07**
Eunicea pallida	0.33					**0.07**
Muriceopsis flavida	0.33					**0.07**
Total Octocorals	8.91	17.41	13.21	5.53	5.57	**10.13**

Table 66. continued

Erect Gorgonians (#col/transect)	37	42	32	18	25	**30.80**
Sponges						
Sponge				2.65	2.17	**0.96**
Iotrochota birotulata	1.65					**0.33**
Chondrilla caribensis	1.21					**0.24**
Cinachyrella kuekenthali		0.52	0.47			**0.20**
Niphates erecta		0.83				**0.17**
Mycale laevis	0.44		0.19			**0.13**
Verongula rigida			0.47			**0.09**
Aplysina cauliformis	0.44					**0.09**
Mycale laxissima		0.41				**0.08**
Ircinia felix			0.38			**0.08**
Ircinia strobilina			0.38			**0.08**
Ircinia brown sp.	0.33					**0.07**
Scopalina ruetzleri	0.22		0.09			**0.06**
Neopetrosia proxima		0.31				**0.06**
Aplysina fulva			0.19			**0.04**
Total Sponges	4.29	2.07	2.17	6.11	2.17	**3.36**

and unconsolidated sediments, including coral rubble, sand and silt were deposited in between the hard bottom sections. The mean substrate rugosity (3.6 m) was influenced by the presence of large (mostly dead), massive coral colonies.

A total of 18 species of stony corals, including 10 intercepted by line transects during the 2015 survey are reported for El Palo Reef. The combined mean live coral cover during the present 2015 survey was 14.8 % (range: 12.4 – 17.3%). Boulder Star Cora (*Orbicella annularis)* was the dominant species in terms of reef substrate cover with 7.1%, representing 48.0 % of the total cover by stony corals. Massive Starlet Coral (*Siderastrea siderea*), Mustard-Hill Coral (*Porites astreoides*), Lettuce Coral (*Agaricia agaricites*), and Fire Coral (*Millepora alcicornis*) were intercepted by more than one transect and along with *O. annularis* comprised the most prominent stony coral assemblage at El Palo Reef. Live coral sections of *O. annularis* were observed to be the remains of large, massive colonies, now mostly dead and overgrown by turf algae. Some very large colonies of Boulder Brain Coral (*Colpophyllia natans*) were in advanced

stages of degradation during 2000 (Garcia-Sais et al., 2001) but were now dead and entirely overgrown by turf algae and other encrusting biota.

Figure 55 shows the variations of mean substrate cover by reef sessile-benthic categories during the baseline and 2015 surveys. The comparative analysis must be evaluated with caution because two of the five transects are new and (although from the same reef location and depth) do not follow exact lines as the ones previously reported during the baseline survey. Nevertheless, variations of live coral cover between surveys were relatively small and within the sampling variability error (ANOVA $p = 0.185$). Scleractinian corals at El Palo Reef appear to have been resilient to the 2005 regional coral bleaching event. The high turbidity that prevails at this shallow coastal reef system may have protected corals from the synergistic effects of increased water temperature and UV radiation, and may have tolerated the probable impact of increased water temperature. Whereas the increment of mean cover by *Orbicella annularis* was influenced by higher prevalence in the new transects, none of the three other transects show a reduction of live cover. Likewise, Massive Starlet Coral (*Siderastrea siderea*) also exhibited similar or increased cover during 2013 and 2015 relative to the baseline survey (Figure 56).

3.2 Fishes and Motile Megabenthic Invertebrates

The taxonomic composition and abundance of fishes surveyed within belt-transects at El Palo Reef during the 2015 monitoring survey are presented in Table 67. A total of 47 species were identified, including 17 within belt-transects.

The mean number of species per transect was eight (range: 5 – 10) and the mean density of fishes was 20.0 Ind/30 m^2 (range: 9 – 30 Ind/30 m^2). Five species, with a combined abundance of 14.3 Ind/30 m^2 represented 71.5 % of the total abundance within transect areas. The main fish assemblage included the Striped and Stoplight Parrotfish (*Scarus iserti, Sparisoma viride*), Blue-head Wrasse (*Thalassoma bifasciatum*), Dusky Damselfish (*Stegastes dorsopunicans*), and Yellowtail Snapper (*Ocyurus chrysurus*). With a total of three species present, the parrotfish family (Scaridae) was the most specious taxonomic group, and combined with doctorfishes

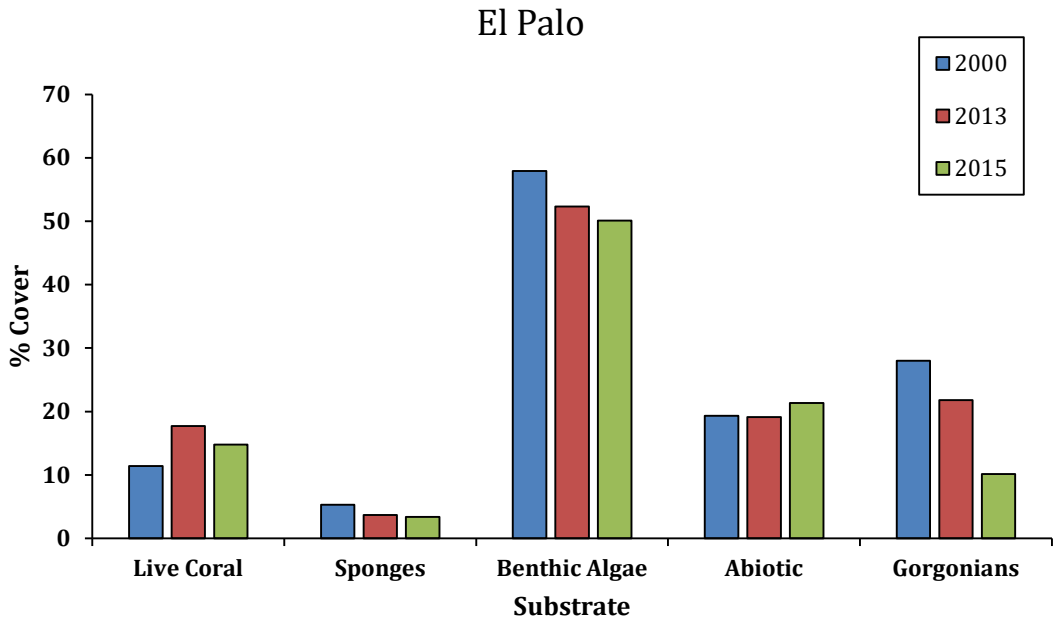


Figure 55. Monitoring trends (2000 – 2015) of mean substrate cover by sessile-benthic categories at El Palo Reef, Cabo Rojo

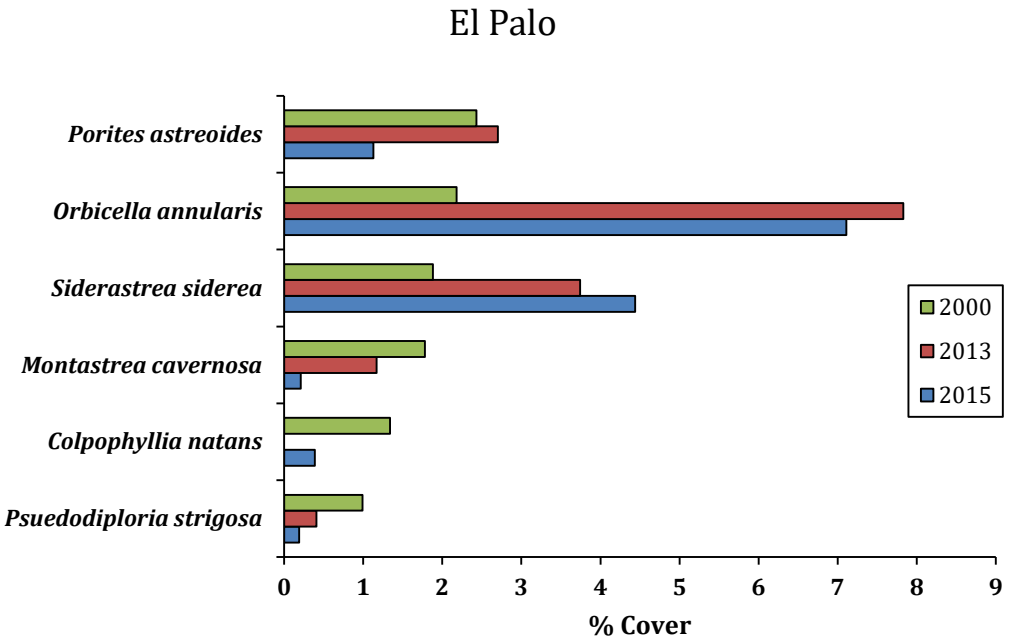


Figure 56. Monitoring trends (2000 – 2015) of mean substrate cover by coral species at El Palo Reef, Cabo Rojo

Table 67. Taxonomic composition and abundance of fishes within belt-transects at El Palo Cabo Rojo, 2015

Depth: 5 m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(Ind/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Scarus iserti	Stripped Parrotfish	12	3	1	7	11	**5.5**
Thalassoma bifasciatum	Bluehead Wrasse	3	13	1	3	2	**4.8**
Stegastes dorsopunicans	Dusky Damselfish	0	0	2	3	3	**2.0**
Sparisoma viride	Stoplight Parrotfish	2	4	2	0	1	**1.8**
Ocyurus chrysurus	Yellowtail Snapper	0	1	0	3	0	**1.0**
Stegastes leucostictus	Beaugregory	1	3	0	0	0	**0.8**
Stegastes planifrons	Threespot Damselfish	0	0	2	0	0	**0.5**
Acanthurus coeruleus	Blue Tang	0	1	0	0	1	**0.5**
Haemulon flavolineatum	French Grunt	0	1	0	0	1	**0.5**
Chaetodon capistratus	Four-eye Butterflyfish	0	1	0	0	1	**0.5**
Haemulon sciurus	Bluestriped Grunt	0	1	0	0	1	**0.5**
Lutjanus apodus	Schoolmaster Snapper	0	0	0	0	2	**0.5**
Sparisoma aurofrenatum	Redband Parrotfish	0	0	0	0	1	**0.3**
Gobiosoma evelynae	Sharknose Goby	0	0	0	1	0	**0.3**
Hypoplectrus sciurus	Yellowtail Hamlet	0	0	1	0	0	**0.3**
Myripristis jacobus	Blackbar Soldierfish	0	1	0	0	0	**0.3**
Pomacanthus arcuatus	Grey Angelfish	0	1	0	0	0	**0.3**
	TOTAL INDIVIDUALS	**18**	**30**	**9**	**17**	**24**	**20.0**
	TOTAL SPECIES	**6**	**11**	**6**	**5**	**10**	**8**

(Acanthuridae) and damselfishes (Pomacentridae) constituted the main herbivorous fish assemblage. The combined abundance of herbivores represented approximately 57.0 % of the total individuals within belt-transect areas. Opportunistic carnivores which feed on small benthic invertebrates, such as wrasses (Labridae), puffers (Tetraodontidae), grunts (Haemulidae), gobies (Gobiidae), squirrelfishes (Holocentridae) and hamlets (*Hypoplectrus* spp.- Serranidae) were common at this reef with nine species representing about 33.5% of the total individuals. The zooplanktivorous fish assemblage was best represented by schools of the Thread Herring (*Opisthonema oglinum*) outside belt-transect survey areas. Predators of larger reef invertebrates and small demersal fishes included a small assemblage of groupers (e.g. Graysbe, Red Hind) and snappers (Mangrove and Lane snappers) previously reported (Garcia-Sais et al,. 2014). Pelagic predators included the Houndfish, (*Tylosurus crocodilus*) and the Bar Jack (*Carangoides ruber*). One juvenile Hogfish and one Mutton Snapper were observed during 2013. Commercially important fishes observed within expanded belt-transects during 2015 (Table 68) included juvenile and adult parrotfishes (*Scarus iserti, Sparisoma aurofrenatum, S. viride*) juvenile Yellowtail Snappers (*Ocyurus chrysurus*) and young adult Schoolmaster Snapper (*L. apodus*).

Differences of fish abundance and species richness between the 2000 baseline and the 2013 and 2015 surveys are shown in Figure 57. Variations were both statistically insignificant (ANOVA; $p > 0.05$), although a marked reduction of species richness was observed during the 2013 survey as compared to the baseline assessment. Still, more observations are required to identify such decline as a real pattern, or just an artifact of small term fluctuations associated with surge, turbidity or other factors influencing short-term variability of fish species composition.

Two Arrow Crabs and several Flamingo Tongues were observed within belt-transects at El Palo Reef during the 2015 survey (Table 69).

Table 68. Taxonomic composition, density and size distributions of commercially important fishes present within expanded belt-transects 4 x 20 m at El Palo Reef, Cabo Rojo. 2015

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped Parrotfish	10 - 3 4 - 7	3 - 7 3 - 10	5 - 10 2 - 12	7 - 10	10 - 5 15 - 7 1 - 12
Sparisoma viride	Stoplight Parrotfish	6 - 5	2 - 7 5 - 10	2 - 12 1 - 20	1 - 15	1 - 25
Sparisoma aurofrenatum	Redband Parrotfish					1 - 12
Ocyurus chrysurus	Yellowtail Snapper		1 - 5		3 - 7	
Lutjanus apodus	Schoolmaster Snapper					2 - 25

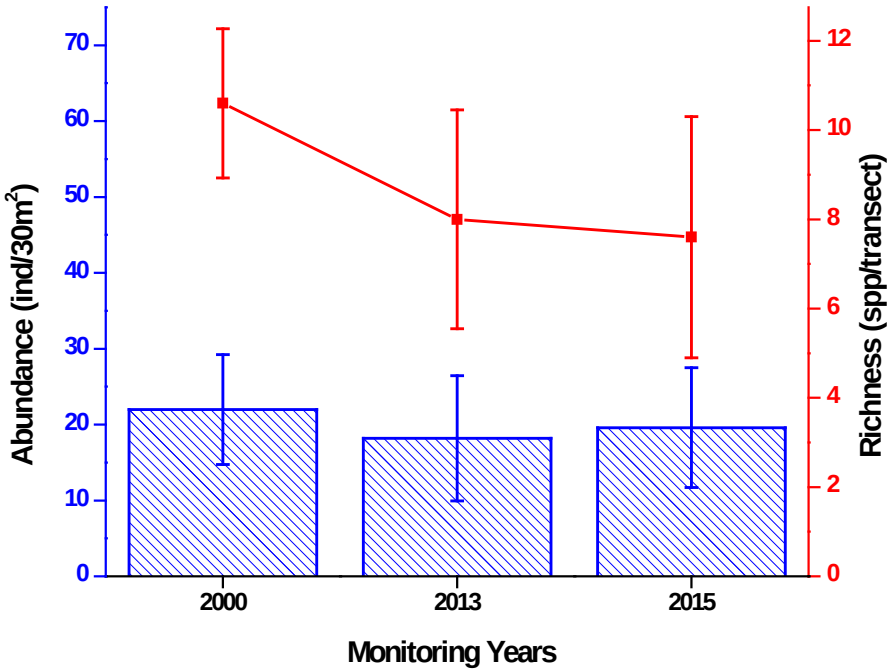


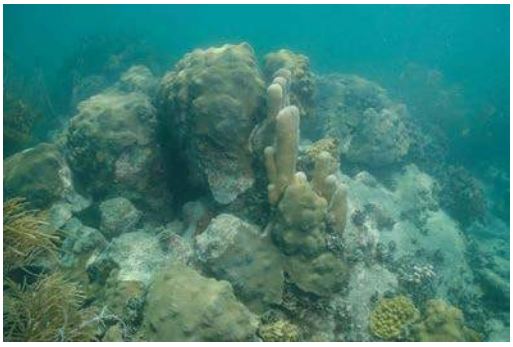
Figure 57. Monitoring trends (2000 – 2015) of fish species richness and abundance at El Palo Reef, Cabo Rojo

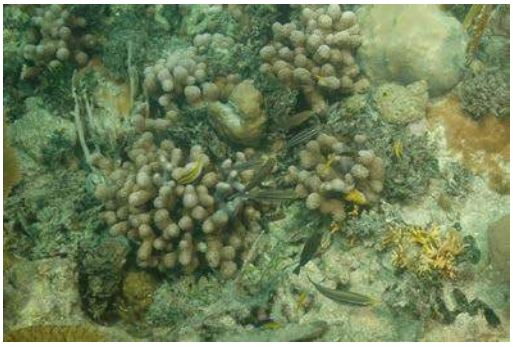
Table 69. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at El Palo Reef**,** Cabo Rojo, 2015

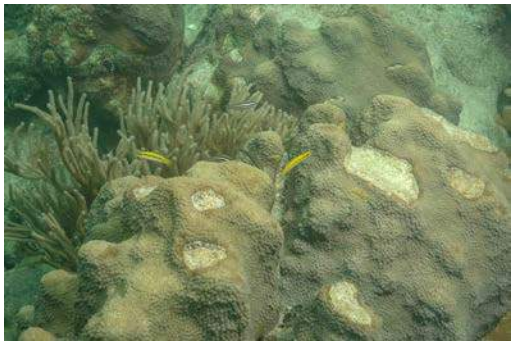
		TRANSECTS					MEAN ABUNDANCE
Depth: 8 -10 m		**1**	**2**	**3**	**4**	**5**	
TAXA	**COMMON NAME**						**(IND/30 m2)**
Cyphoma gibbosum	Flamingo Tongue		2		1	2	**1.0**
Stenorhynchus seticornis	Arrow Crab	1		1			**0.4**
	TOTALS	1	2	1	1	2	**1.4**

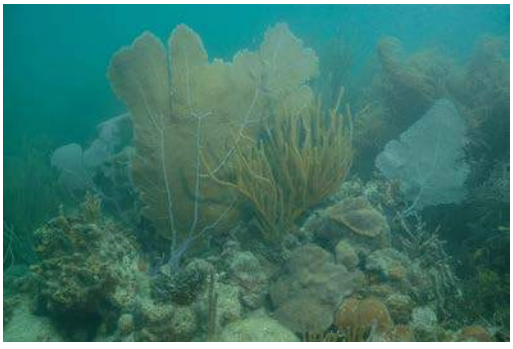
Photo Album 17. Cabo Rojo

El Palo Reef









H. La Parguera Natural Reserve

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 section 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.

A baseline coral reef 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, new baseline characterizations based on new sets of transects are here included for reef locations in the vicinity of the initial baseline surveys at La Boya Vieja (shelf-edge), Media Luna 10m (fore reef) and Media Luna 5m (back reef) (Figure 58).

1.0 La Boya Vieja

La 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 58). 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 break presents an abrupt slope with some coral development. 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 La Boya Vieja Reef system is presented as Photo Album 18.

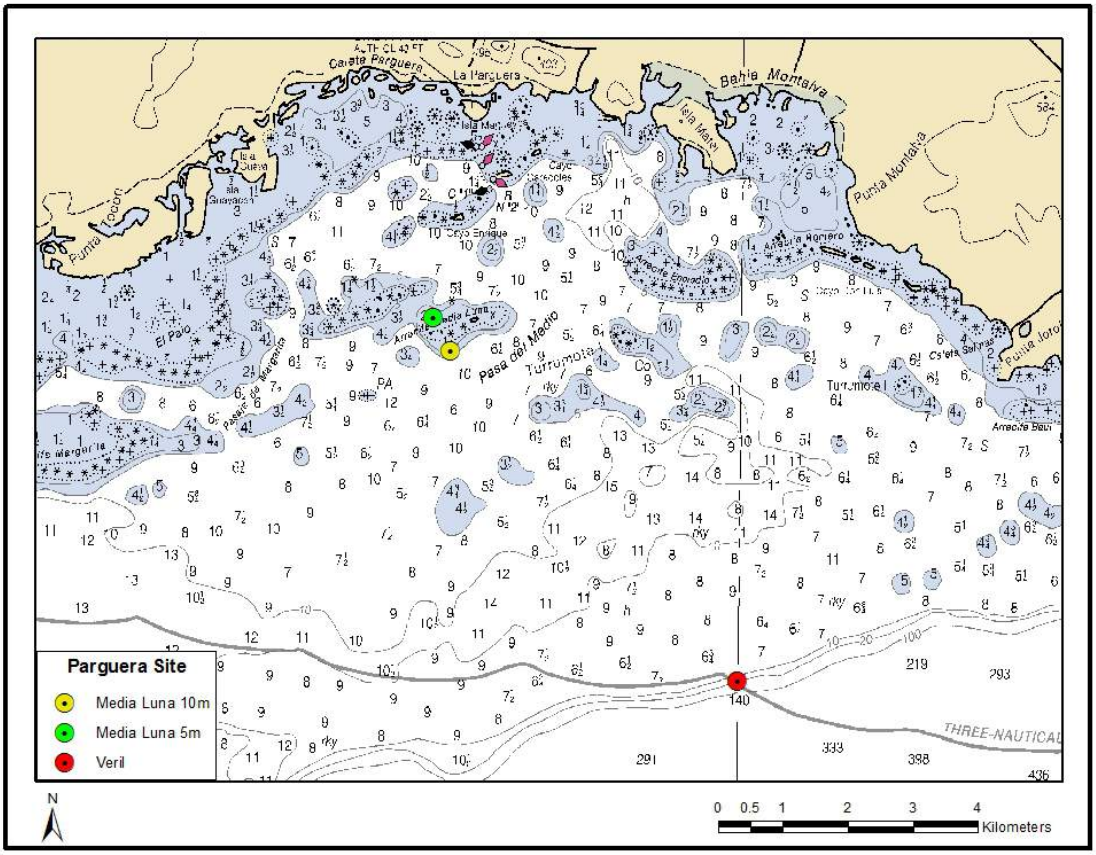


Figure 58. Location of reefs surveyed within the La Parguera Natural Reserve

1.1. Sessile-Benthic Reef Community

A total of 22 stony corals, including 11 intersected by line transects were identified from La Boya Reef during 2015 (Table 70). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 19.6 % (range: 17.2 – 22.2 %) (Figure 59). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant species in terms of substrate cover with a mean of 11.7 % (range: 8.8 – 18.1 %), representing 59.7 % of the total cover by stony corals (Figure 60). Mustard-Hill Coral (*Porites astreoides*) and Lettuce Coral (*Agaricia agaricites*) were present in all five transects and along with Boulder Star Coral comprised the main stony coral assemblage at La Boya Reef (Table 70). Grooved Brain Coral (*Diploria labyrinthiformis*)

Table 70. Percent substrate cover by sessile-benthic categories at La Boya Vieja Reef, La Parguera. 2015

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	3.89	3.73	4.59	4.64	4.01	**4.17**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	9.48	8.66	9.40	1.72	2.20	**6.29**
Rubble		6.42	2.88	0.96	5.39	**3.13**
Sand	5.24	0.82	2.30		0.60	**1.79**
Total Abiotic	14.72	15.90	14.59	2.68	8.19	**11.22**
Benthic Algae						
Lobophora variegata	11.39	22.53	27.54	34.23	17.68	**22.67**
Turf	35.79	12.44	8.93	18.26	23.08	**19.70**
Dictyota spp.	6.15	14.07	12.67	10.80	14.99	**11.73**
CCA	4.03	2.75	8.45	3.54	3.30	**4.41**
Fleshy macroalgae	2.02					**0.40**
Total Benthic Algae	59.38	51.78	57.58	66.83	59.04	**58.92**
Cyanobacteria	1.31	2.04	0.19	3.73		**1.45**
Live Corals						
Orbicella annularis complex	8.77	11.21	11.61	8.89	18.08	**11.71**
Porites astreoides	5.54	2.85	4.03	4.40	0.60	**3.49**
Agaricia agaricites	0.40	1.73	0.67	4.59	3.10	**2.10**
Diploria labyrinthiformis	1.11	0.82	1.25			**0.63**
Siderastrea siderea			1.06	0.96		**0.40**
Millepora alcicornis	1.41	0.31		0.29		**0.40**
Agaricia lamarcki		1.33	0.29			**0.32**
Montastraea cavernosa			0.58	0.96		**0.31**
Stephanocoenia intersepta			0.48			**0.10**
Meandrina meandrites					0.40	**0.08**
Madracis decactis			0.29			**0.06**
Total Live Corals	17.24	18.25	20.25	20.08	22.18	**19.60**
Octocorals						
Briareum asbestinum		0.41	0.77	2.01	2.30	**1.10**
Erythropodium caribaeorum	1.41		0.58	0.57	0.90	**0.69**
Plexaura kuekenthali			0.19		0.80	**0.20**
Gorgonia ventalina				0.19	0.50	**0.14**
Pseudoplexaura flagellosa					0.20	**0.04**
Allotogorgia acerosa			0.19			**0.04**
Total Octocorals	1.41	0.41	1.73	2.77	4.70	**2.20**

Table 70. continued

Erect Gorgonians (#col/transect)	15	12	15	9	8	**11.8**
Sponges						
Cliona caribbaea		8.05	2.59	0.48		**2.22**
Sponge	5.95					**1.19**
Agelas dispar		1.94		0.48	1.10	**0.70**
Petrosia pellasarca					3.20	**0.64**
Xestospongia muta				1.63		**0.33**
Agelas tubulata			0.58	0.67	0.30	**0.31**
Aiolochroia crassa yellow					1.00	**0.20**
Monanchora arbuscula			0.67	0.19		**0.17**
Cliona laticavicola			0.48			**0.10**
Scopalina ruetzleri			0.48			**0.10**
Agelas citrina		0.41				**0.08**
Mycale laevis		0.41				**0.08**
Clathria sp.			0.38			**0.08**
Iotrochota birotulata					0.30	**0.06**
Aiolochroia crassa			0.29			**0.06**
Agelas clathrodes				0.29		**0.06**
Phorbas amaranthus			0.19			**0.04**
Agelas sceptrum				0.19		**0.04**
Total Sponges	5.95	10.81	5.66	3.92	5.89	**6.45**
Zoanthid						
Tridemnum solidum		0.41				**0.08**

and Fire Coral (*Millepora alcicornis*) were present in three transects, but with relatively low reef substrate cover (mean < 1.0 %).

Soft corals, or gorgonians were a prominent component of the La Boya Reef benthos with a mean density of 11.8 erect colonies per transect (range: 8 – 15) and a mean reef substrate cover of 2.2 % (Table 70). The main species in terms of reef substrate cover were the encrusting species, *Briareum asbestinum* and *Erythropodium caribaeorum*. Sponges, represented in transects by 18 species contributed a mean reef substrate cover of 6.4 %. *Cliona caribbaea, Agelas dispar, Petrosia pellasarca* and an unidentified sponge comprised the main sponge assemblage. The encrusting zoanthid, *Tridemnum solidum* was observed in one transect with a cover of less than 1%.

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 58.9 % (range: 51.8 – 66.8 %). Both turf algae (mixed assemblage) and the Encrusting Fan Alga, *L. variegata* were observed overgrowing many dead massive coral sections of the reef.

Total abiotic cover averaged 11.2 %, mostly influenced by reef overhangs (6.3 %) produced by live and dead coral mounds and ledges. Sand and coral rubble were also present in most transects surveyed (Table 70).

Major changes of reef benthic community structure are evident at La Boya 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 %. The present live coral cover of 19.6 % 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 is 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 and references therein). As in these other shelf-edge and oceanic reefs the decline of live coral cover at La 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 %.

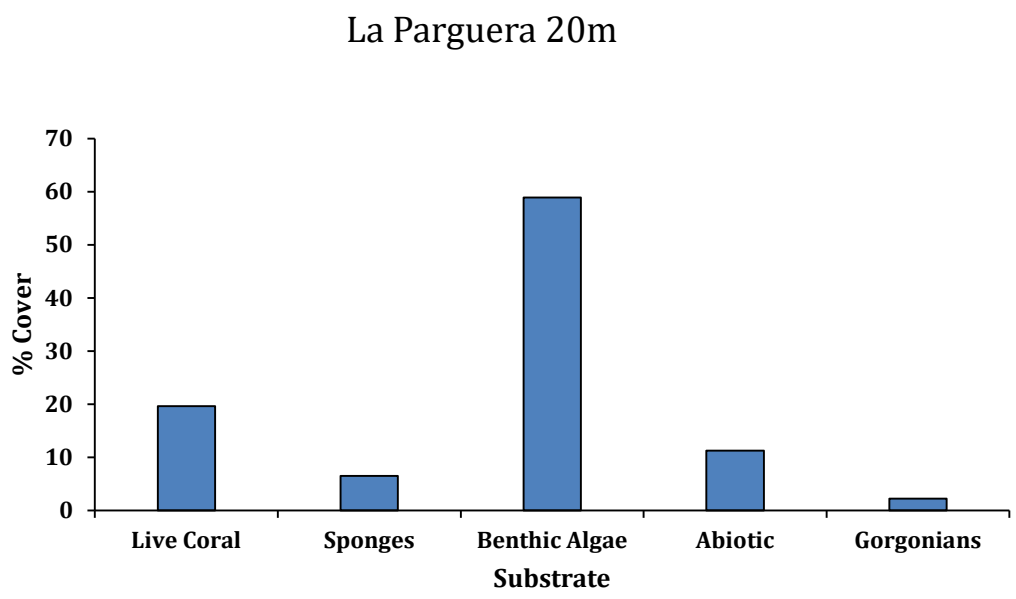


Figure 59. Mean substrate cover by sessile-benthic categories at La Boya Reef, La Parguera. Baseline survey: 2015.

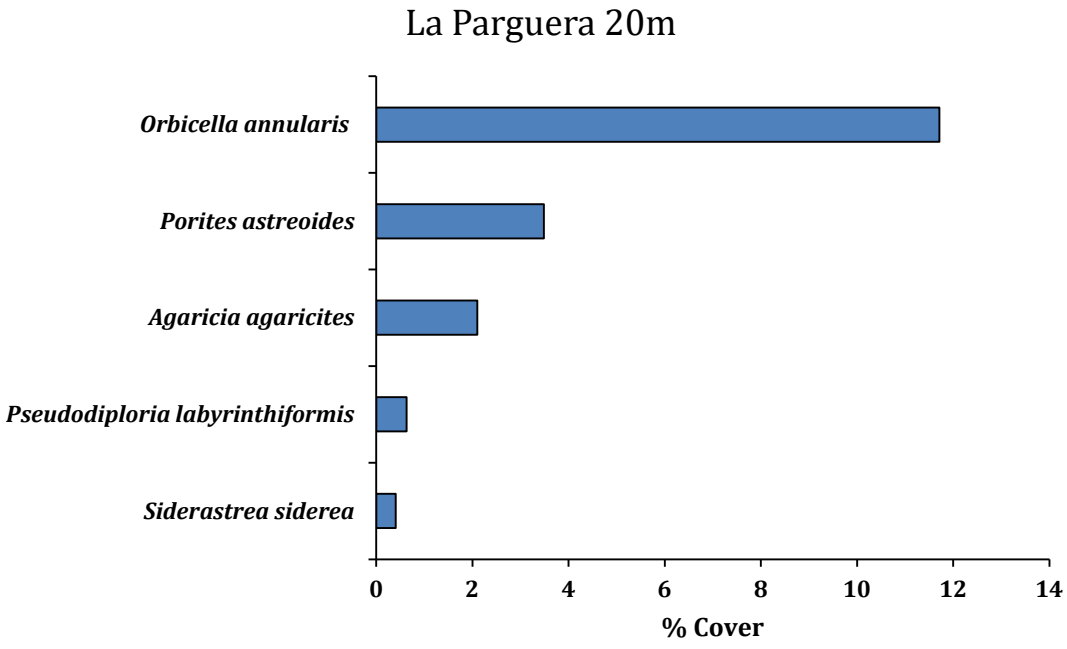


Figure 60. Mean substrate cover by stony coral spp. categories at La Boya Reef, La Parguera. Baseline survey: 2015.

1.2. Fishes and Motile Megabenthic Invertebrates

A total of 63 fish species, including 31 within belt-transects were identified from La Boya Vieja Reef during the baseline survey of 2015 (Table 71). Mean density within transects was 104.4 Ind/30 m^2 (range: 67 – 160 Ind/30 m^2). The mean number of species per transect was 17 (range: 13 – 21). Four species presented a combined abundance of 71.6 Ind/30 m^2, accounting for 68.6 % of the total individuals within transects. These were the Blue Chromis (*Chromis cyanea*), Bicolor Damselfish (*Stegastes partitus*), Bluehead Wrasse (*Thalassoma bifasciatum*), and Creole Wrasse (*Clepticus parrae*). In addition, the Peppermint Goby, Four-eye Butterflyfish, Redband, Stoplight and Stripped Parrotfishes, Doctorfish, Squirrelfish, Graysbe and Yellowtail Snapper were present in at least 4 transects and appear to form part of the main residential fish assemblage at La Boya Reef (Table 71).

Fish species of commercial value observed within expanded belt-transects included four species of parrotfishes (*Scarus iserti, S. vetula, Sparisoma viride, S. aurofrenatum*). These parrotfishes were present in both juvenile and adult stages (Table 72). Early juveniles and adult Graysbe, juvenile Yellowtail Snappers and Lionfish, and one large adult Great Barracuda were also present. Zooplanktivores, such as Chromis spp., Creole Wrasse Bicolor Damselfish and Masked Goby were the dominant assemblage at La Boya Vieja Reef representing approximately 55 % of the total individuals within belt-transects. Small opportunistic invertebrate feeders, such as the Bluehead and Yellowhead Wrasse, Peppermint and Sharknose Goby, Squirrelfish, grunts and juvenile Lionfish were also prominent, representing approximately 25 % of the total individuals. Herbivores, represented largely by parrotfishes, doctorfishes and farmer damselfishes accounted for 15 % of the total fish community within transects. Large demersal predators were not observed within transect areas, but adult Cubera and Dog Snappers (*Lutjanus cyanopterus, L. jocu*) were observed outside transects. The shelf-edge reef is a well known residential habitat of the full assemblage of large groupers and snappers, reef, nurse, hammerhead and tiger sharks, hogfishes and others. 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. Many of these large pelagic predators are associated with the coral reef zooplanktivorous food web.

Table 71. Taxonomic composition and abundance of fishes within belt-transects at La Boya Vieja Reef, La Parguera. 2015

Depth: 18m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(Ind/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Chromis cyanea	Blue Chromis	40	45	6	14	0	**21.0**
Stegastes partitus	Bicolor Damselfish	14	15	12	20	33	**18.8**
Thalassoma bifasciatum	Bluehead Wrasse	21	15	3	10	35	**16.8**
Clepticus parrae	Creole Wrasse	15	0	0	0	60	**15.0**
Scarus taeniopterus	Princess Parrotfish	1	0	9	0	9	**3.8**
Coryphopterus lipernes	Peppermint Goby	4	0	5	5	3	**3.4**
Sparisoma aurofrenatum	Redband Parrotfish	3	4	1	5	3	**3.2**
Acanthurus chirurgus	Doctorfish	4	5	5	1	0	**3.0**
Scarus iserti	Stripped Parrotfish	4	1	3	4	0	**2.4**
Chaetodon capistratus	Four-eye Butterflyfish	4	1	4	2	0	**2.2**
Gobiosoma evelynae	Sharknose Goby	0	0	4	1	4	**1.8**
Sparisoma viride	Stoplight Parrotfish	1	0	6	1	1	**1.8**
Chromis multilineata	Brown Chromis	0	0	2	5	0	**1.4**
Holocentrus rufus	Squirrelfish	0	2	1	2	2	**1.4**
Ocyurus chrysurus	Yellowtail Snapper	3	0	1	1	1	**1.2**
Epinephelus cruentatus	Graysby	1	1	1	2	1	**1.2**
Coryphopterus personatus	Masked Goby	0	0	0	5	0	**1.0**
Pterois volitans	Lionfish	1	2	0	0	1	**0.8**
Myripristis jacobus	Blackbar Soldierfish	0	1	1	0	2	**0.8**
Halichoeres garnoti	Yellow-head Wrasse	0	0	1	1	1	**0.6**
Acanthurus coeruleus	Blue Tang	0	1	0	0	1	**0.4**
Abudefduf sexatilis	Sargent Mayor	0	0	0	2	0	**0.4**
Haemulon macrostomum	Spanish Grunt	0	0	1	1	0	**0.4**
Melichthys niger	Black Durgon	0	0	1	0	0	**0.2**
Haemulon flavolineatum	French Grunt	0	0	0	0	1	**0.2**
Stegastes leucostictus	Beaugregory	0	1	0	0	0	**0.2**
Canthigaster rostrata	Caribbean Puffer	0	0	0	0	1	**0.2**
Sphyraena barracuda	Great Barracuda	0	0	0	1	0	**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish	0	0	0	1	0	**0.2**
Pomacanthus arcuatus	Gray Angelfish	0	0	0	0	1	**0.2**
Anisotremus virginicus	Porkfish	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	**116**	**94**	**67**	**85**	**160**	**104.4**
	TOTAL SPECIES	**14**	**13**	**19**	**21**	**18**	**17**

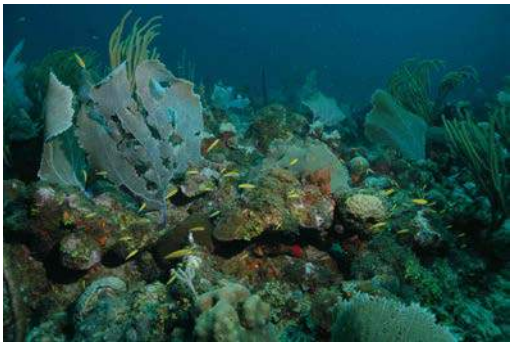
Table 72. Taxonomic composition, density and size distributions of commercially important fishes present within expanded belt-transects 3 x 20 m at La Boya Vieja Reef, La Parguera. 2015

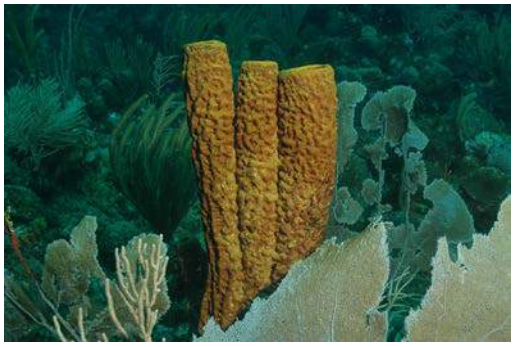
		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped Parrotfish	1 - 6 3 - 10	1 - 10	3 - 12	3 - 10 1 - 15	
Sparisoma viride	Stoplight Parrotfish	1 - 30		3 - 6 3 - 10	1 - 12	1 - 8
Sparisoma aurofrenatum	Redband Parrotfish	2 - 10 1 - 15	2 - 12 2 - 15	1 - 6	4 - 8 1 - 10	2 - 10 1 - 15
Ocyurus chrysurus	Yellowtail Snapper	1 - 10 1 - 15 1 - 20		1 - 12	1 - 10	1 - 12
Epinephelus cruentatus	Graysby	1 - 15	1 - 10	1 - 6	2 - 12	1 - 8
Pterois volitans	Lionfish	1 - 30	1 - 10 1 - 15			1 - 10
Scarus taeniopterus	Princess Parrotfish	1 - 15		7 - 8 2 - 15		9 - 8
Sphyraena barracuda	Great Barracuda				1 - 66	

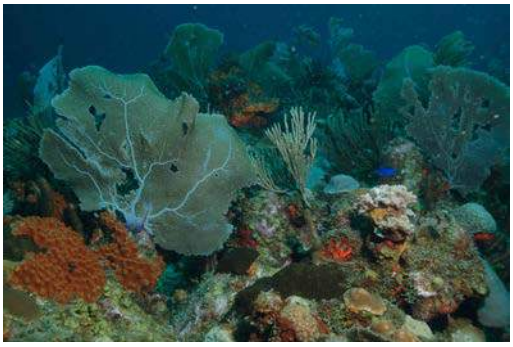
The La Parguera shelf-edge is a known spawning aggregation site for several commercially important species, such as the Red Hind (*Epinephelus guttatus*) and the Mutton Snapper (*Lutjanus analis*). The DNER has put in place seasonal closures to protect these snapper and grouper spawning aggregations. Motile-megabenthic invertebrates were not observed within belt-transects during this 2015 survey.

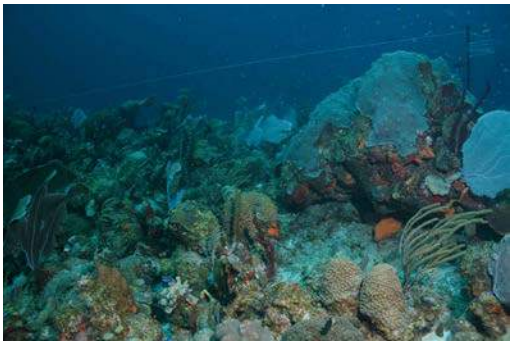
Photo Album 18. La Parguera Natural Reserve

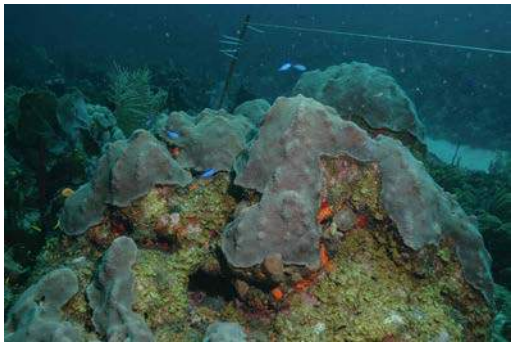
Boya Vieja Shelf-edge Reef











2.0. Media Luna Fore-Reef 10m

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, *Acropora palmata*, but mostly colonized by the colonial zoanthid (*Palythoa sp*.), fire corals, (*Millepora spp*.), encrusting corals (*Porites astreoides, Diploria strigosa, Montastraea cavernosa*) and turf algae. 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 a depth of 10 m in the same general location and depth where the original CARICOMP baseline characterization of Media Luna Reef was performed in 1994 (Ogden et al., 1996). Panoramic documentation of the Media Luna fore-reef is presented as Photo Album 19.

2.1. Sessile-Benthic Reef Community

Soft corals, or gorgonians with a mean density of 46 colonies/transect (range: 30 – 55 col/transect) and a mean substrate cover of 18.2 % represented the most prominent benthic component of the Media Luna Fore-reef (Table 73). The main assemblage of erect forms was comprised by *Pseudoplexaura flagellosa, Plexaura spp., Eunicea spp.,* and *Gorgonia ventalina*. The Corky Sea Finger, *Briareum asbestinum*, and the Encrusting gorgonian *Erythropodium caribaeorum* were the main taxa in terms of reef substrate cover with a combined cover of 16.2%. Gorgonians were found growing as very large colonies and contributed substantially to the reef structural complexity.

A total of 19 stony coral species, including 13 intercepted by transects were identified during the 2015 baseline survey of the Media Luna Fore-reef (Table 73). The mean substrate cover by stony corals was 21.9 % (range: 14.5 – 33.8 %, Figure 61). Boulder Star Coral, *Orbicella annularis* complex was the numerically dominant species in terms

Table 73. Percent substrate cover by sessile-benthic categories at Media Luna Fore-Reef 10 m, La Parguera. 2015

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	3.40	4.06	1.84	2.78	6.76	**3.77**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	6.27		6.97	10.73	20.38	**8.87**
Benthic Algae						
Turf	35.63	47.51	40.54	28.48	37.09	**37.85**
CCA	2.72	1.29			4.01	**1.60**
Dictyota spp.	1.04	0.70	0.24			**0.40**
Total Benthic Algae	39.39	49.50	40.78	28.48	41.10	**39.85**
Anemones						
Lebrunia danae					0.33	**0.07**
Epicystis crucifer		0.20				**0.04**
Total Anemones		0.20			0.33	**0.11**
Live Corals						
Orbicella annularis complex	8.88	9.86	5.08	24.10	6.27	**10.84**
Porites astreoides	5.12	3.88	4.37	1.75	1.42	**3.31**
Agaricia agaricites	4.28	1.00	0.24	0.99	2.67	**1.84**
Montastraea cavernosa	0.52	0.50	3.90		3.84	**1.63**
Colpophyllia natans		3.88	2.25			**1.23**
Siderastrea siderea	0.31	0.20		2.96	0.17	**0.73**
Porites porites	1.04		1.06	1.42		**0.71**
Pseudodiploria strigosa	1.00	0.80		1.31		**0.42**
Millepora alcicornis	0.42	1.00		0.33		**0.35**
Porites furcata	0.31		0.71			**0.20**
Mycetophyllia ferox				0.99		**0.20**
Stephanocoenia intersepta		0.30				**0.06**
Dendrogyra cylindrus					0.17	**0.03**
Total Live Corals	21.90	21.41	17.61	33.84	14.54	**21.86**
Corallimorphs						
Ricordea florida			0.24			**0.05**
Octocorals						
Erythropodium caribaeorum	13.27	19.32	7.21	10.19	16.29	**13.26**
Briareum asbestinum	2.51	1.99	2.96	5.04	2.34	**2.97**
Pseudoplexaura flagellosa			1.42	1.31		**0.55**
Allogorgia americana			1.77			**0.35**
Gorgonia ventalina				0.99		**0.20**

Table 73. continued

Eunicea flexuosa	0.52		0.35			**0.18**
Plexaura homomalla	0.63			0.22		**0.17**
Eunicea tourneforti	0.63					**0.13**
Muriceopsis flavida	0.42					**0.08**
Plexaura kuekenthali	0.31					**0.06**
Total Octocorals	19.33	21.31	13.71	17.74	18.63	**18.15**
Erect Gorgonians (#col/transect)	55	30	54	48	43	**46**
Sponges						
Chondrilla caribensis	4.00	2.39	0.59	2.85	5.01	**2.94**
Ircinia brown sp.	0.94		1.42			**0.47**
Cliona caribbaea	0.84			0.66		**0.30**
Mycale laevis	0.21		0.47	0.66		**0.27**
Plakortis halichondrioides		0.60	0.24			**0.17**
Ircinia felix				0.66		**0.13**
Iotrochota birotulata		0.50				**0.10**
Monanchora arbuscula		0.50				**0.10**
Niphates erecta			0.24			**0.05**
Amphimedon compressa	0.10					**0.02**
Total Sponges	5.96	3.98	3.55	4.82	5.01	**4.66**
Zoanthid						
Palythoa caribaeorum	8.05	3.59	17.73	4.38		**6.75**

of reef substrate cover with a mean of 10.8 % (range: 5.1 – 24.1 %, Figure 62). Mustard-Hill Coral (*Porites astreoides*), Lettuce Coral (*Agaricia agaricites*), Great Star Coral (*Montastraea cavernosa*) and Greater Starlet Coral (*Siderastrea siderea*) were present in at least four out of the 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.

Sponges were represented by at least 10 species within transects with a combined mean substrate cover of 4.7 %. The most abundant sponges included *Chondrilla caribensis*, *Ircinia sp*., *Cliona caribbea* and *Mycaele levis* (Table 73). The encrusting zoanthid, *Palythoa caribaeorum* was present in four transects with a mean cover of 6.8 %. 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 37.8 %, representing 95.0 % of the total benthic algae. Crustose coralline algae and fleshy brown macroalgae

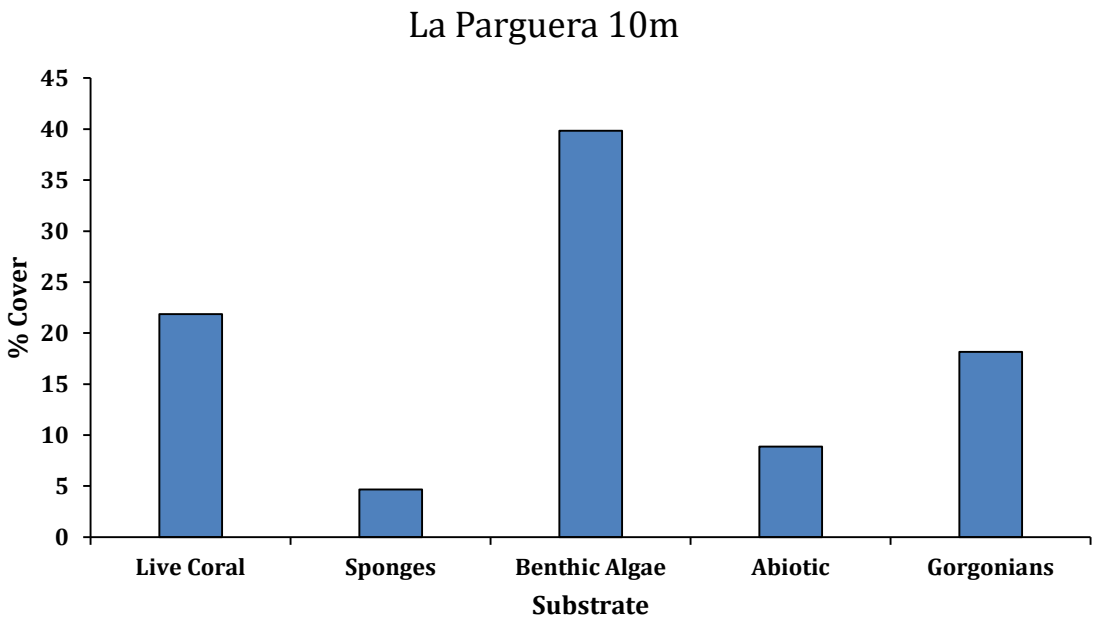


Figure 61. Mean substrate cover by sessile-benthic categories at Media Luna Fore Reef, La Parguera. Baseline survey: 2015.

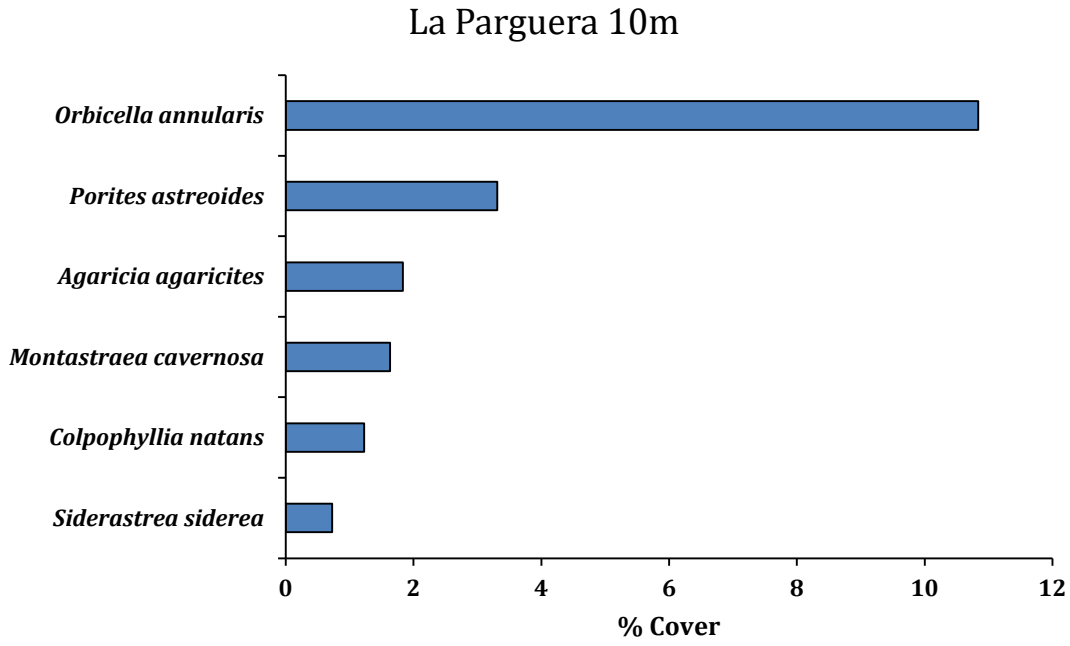


Figure 62. Mean substrate cover by stony coral spp. categories at Media Luna Fore Reef, La Parguera. Baseline survey: 2015.

(*Dictyota sp*.) were also present in transects with a much lower substrate cover (< 2.0 %).

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. Live coral cover during 1994 in the same reef vicinity of the present transects was 42.3 % (Ogden et al., 1996). The present 2015 cover of 21.9 % represents a loss of approximately 48 %. Consistent with previous observations, reef degradation appears to be strongly influenced by the decline of cover by the dominant reef building species, the Boulder Star Coral, *Orbicella annularis* complex associated with the 2005 regional coral bleaching event and its lingering effects on the coral reef systems of Puerto Rico and the USVI (Garcia-Sais et al., 2007, 2008, 2014 and references therein).

2.2. Fishes and Motile Megabenthic Invertebrates

A total of 58 fish species were identified from the Media Luna Fore-Reef, including 25 within belt-transects (Table 74). Mean abundance within transects was 31.0 Ind/30 m^2 (range: 21 – 41 Ind/30 m^2). Mean number of species per transect was 12.2 (range: 10 – 14). The Bluehead Wrasse, Bicolor, Yellowtail and Dusky Damselfishes, Brown and Blue Chromis and the Princess and Stoplight Parrotfishes were the most abundant species within transects representing 76.7 % of the total individuals. Commercially important species observed within extended belt-transects included six parrotfishes (*Scarus iserti, S. vetula, S. taeniopterus, Sparisoma viride, S. chrysopterum, S. aurofrenatum*), one young adult Coney and four juvenile Yellowtail Snappers (Table 75). Post settlement (recruitment) stages (1 - 3 cm) of the Stoplight, Redband and Stripped 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 eight species included within belt-transects representing 37.4 % of the total individuals. Likewise, small

Table 74. Taxonomic composition and abundance of fishes within belt-transects at Media Luna Fore-Reef, La Parguera. 2015

Depth: 10m

		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(Ind/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	7	10	6	3	6	**6.4**
Stegastes partitus	Bicolor Damselfish	3	4	2	4	5	**3.6**
Stegastes dorsopunicans	Dusky Damselfish	5	1	3	0	9	**3.6**
Chromis multilineata	Brown Chromis	5	3	0	0	5	**2.6**
Scarus taeniopterus	Princess Parrotfish	3	10	0	0	0	**2.6**
Microspathodon chrysurus	Yellowtail Damselfish	1	1	1	3	1	**1.4**
Chromis cyanea	Blue Chromis	3	0	0	0	3	**1.2**
Scarus iserti	Stripped Parrotfish	0	3	1	1	1	**1.2**
Sparisoma viride	Stoplight Parrotfish	2	0	1	2	1	**1.2**
Chaetodon capistratus	Four-eye Butterflyfish	0	2	1	3	0	**1.2**
Gramma loreto	Fairy Basslet	0	1	0	0	4	**1.0**
Holocentrus rufus	Squirrelfish	0	1	2	1	0	**0.8**
Halichoeres garnoti	Yellow-head Wrasse	0	0	1	1	1	**0.6**
Sparisoma aurofrenatum	Redband Parrotfish	2	0	0	0	1	**0.6**
Acanthurus coeruleus	Blue Tang	0	1	0	1	0	**0.4**
Abudefduf sexatilis	Sargent Mayor	0	0	0	0	2	**0.4**
Ocyurus chrysurus	Yellowtail Snapper	0	0	1	0	1	**0.4**
Aulostomus maculatus	Trumpetfish	0	0	1	0	1	**0.4**
Gobiosoma evelynae	Sharknose Goby	0	1	0	0	0	**0.2**
Haemulon flavolineatum	French Grunt	0	0	1	0	0	**0.2**
Stegastes planifrons	Three-spotted Damselfish	0	0	0	1	0	**0.2**
Canthigaster rostrata	Caribbean Puffer	0	1	0	0	0	**0.2**
Haemulon sciurus	Bluestriped Grunt	1	0	0	0	0	**0.2**
Pomacanthus paru	French Angelfish	0	1	0	0	0	**0.2**
Sparisoma chrysopterum	Redtail Parrotfish	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	**32**	**40**	**21**	**21**	**41**	**31.0**
	TOTAL SPECIES	**10**	**14**	**12**	**11**	**14**	**12.2**

Table 75. Taxonomic composition, density and size distributions of commercially important fishes present within expanded belt-transects 3 x 20 m at Media Luna Fore Reef, 10 m. La Parguera. 2015

		TRANSECTS				
		1	**2**	**3**	**4**	**5**
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped Parrotfish		2 - 5 1 - 18	1 - 10	1 - 10	1 - 10
Sparisoma viride	Stoplight Parrotfish	2 - 10		1 - 3	1 - 17	1 - 15
Sparisoma aurofrenatum	Redband Parrotfish	1 - 6 1 - 30				2 - 12
Ocyurus chrysurus	Yellowtail Snapper			1 - 10		2 - 10 1 - 17
Epinephelus fulva	Coney					
Scarus taeniopterus	Princess Parrotfish		3 - 1 7 - 6			
Scarus vetula	Queen Parrotfish			1 - 10		
Sparisoma chrysopterum	Redtail Parrotfish				1 - 20	

opportunistic carnivores, such as wrasses, basslets, squirrelfishes, gobies, juvenile snappers, puffers and grunts were represented by 10 species and 37.4 % of the total individuals. Zooplanktivores were represented by only three species, with 23.9 % of the total individuals with transects. The strong wave and surge action prevailing during our baseline 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*), Mackerel Scad (*Decapterus macarellus*) and the *Chromis spp*. 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).

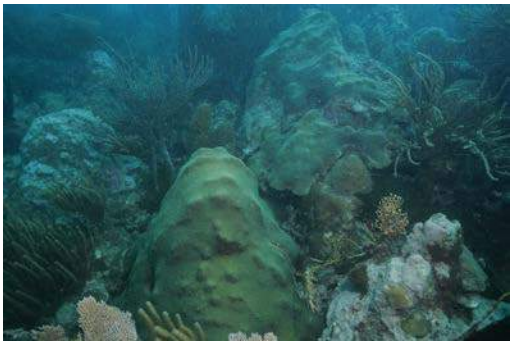
Motile megabenthic invertebrates present within belt-transects during the baseline 2015 survey included several Flamingo Tongues, one basket star and two Cleaner Shrimps. Adult and juvenile Spiny, Spotted and Spanish Lobsters (*Panulirus argus. P. guttatus, Scyllarides sp.*) and other motile megabenthic invertebrates were previously reported (Garcia-Sais and Sabater-Clavell, 2004).

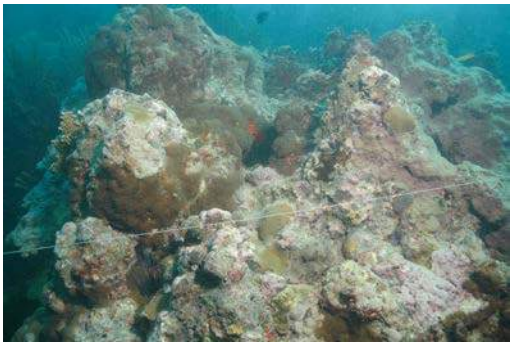
Table 76. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Media Luna Fore- Reef**,** La Parguera, 2015

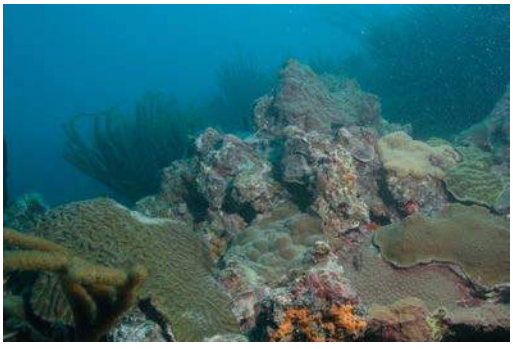
		TRANSECTS					**MEAN ABUNDANCE**
Depth: 8 -10 m		**1**	**2**	**3**	**4**	**5**	
TAXA	**COMMON NAME**						**(IND/30 m2)**
Cyphoma gibbosum	Flamingo Tongue		2		1	2	**1.0**
Stenorhynchus seticornis	Arrow Crab	1		1			**0.4**
	TOTALS	1	2	1	1	2	**1.4**

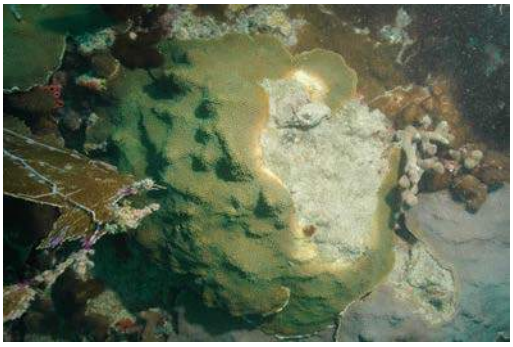
Photo Album 19. La parguera Natural Reserve

Media Luna Fore-Reef









3.0. Media Luna Back-Reef

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 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 down 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 20.

3.1. **Sessile-Benthic Reef Community**

Turf algae, growing intermixed with fleshy (*Dictyota sp*.) and calcareous (*Halimeda spp*.) macroalgae was the main biotic category in terms of substrate cover at Media Luna Back-Reef with a combined mean of 58.2 % (range: 38.1 – 76.4 %) (Table 77). Cyanobacterial, or blue-green algal films were observed overgrowing hard ground substrates in all five transects surveyed with a mean cover of 1.8 %.

A total of 16 stony corals, including four intercepted by line transects were identified from the Media Luna Back-Reef at depths of 2 – 5 m. (Table 77). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant species in terms of reef substrate cover with a mean of 10.6 %, representing 90.6 % of the total cover by stony corals. 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. Sparse colonies of Greater Starlet Coral, *Siderastrea siderea*, and Boulder Brain Coral, *Colpophyllia natans* were also intercepted by transects, but represented minor components of the reef sessile-benthos.

Soft corals were moderately abundant (mean: 22 col/transect) and present as large colonies that contributed substantial reef substrate complexity. A total of 14 species of soft corals were identified including seven intercepted by transects. The encrusting Gorgonian, *Erythropodium caribaeorum* and the Corky Sea Finger, *Briareum asbestinum* were the most prominent in terms of reef substrate cover (Table 77). Sponges were

Table 77. Percent substrate cover by sessile-benthic categories at Media Luna Back-Reef 5 m, La Parguera. 2015

Depth 2 – 5 m	Transects					
	1	2	3	4	5	**Mean**
Rugosity	6.51	6.35	5.08	5.23	6.21	**5.88**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	11.96	13.70	4.64	18.75	13.04	**12.42**
Sand	14.42		4.36	12.13	14.68	**9.12**
Rubble			2.79			**0.56**
Total Abiotic	24.40	13.70	11.79	30.88	27.72	**21.70**
Benthic Algae						
Turf	35.03	57.45	58.12	34.65	40.33	**45.12**
Dictyota spp.	2.21	10.27	15.04	19.76	6.39	**10.73**
Halimeda spp.	0.85		2.79	2.57	4.92	**2.23**
Udotea sp.			0.46			**0.09**
Total Benthic Algae	38.08	67.72	76.42	56.99	51.64	**58.17**
Cyanobacteria	2.80	0.86	2.79	0.37	2.16	**1.79**
Live Corals						
Orbicella annularis complex	28.07	3.08	3.71	5.79	12.52	**10.64**
Dendrogyra cylindrus	1.95					**0.39**
Siderastrea siderea		1.71				**0.34**
Colpophyllia natans			1.49			**0.30**
Total Live Corals	30.03	4.79	5.20	5.79	12.52	**11.67**
Octocorals						
Erythropodium caribaeorum	0.42	6.51		0.18		**1.42**
Briareum asbestinum	1.27	0.43		1.93	0.52	**0.83**
Pseudoplexaura flagellosa				1.38		**0.28**
Eunicea flexuosa		0.86	0.28			**0.23**
Eunicea succinea	0.25	0.43				**0.14**
Gorgonia ventalina		0.17			0.26	**0.09**
Plexaura kuekenthali				0.28		**0.06**
Total Octocorals	1.95	8.39	0.28	3.77	0.78	**3.03**
Erect Gorgonians (#col/transect)	18	20	21	34	18	**22**
Sponges						
Chondrilla caribensis	0.42	3.60	2.79	2.21	5.18	**2.84**
Cliona caribbaea		0.94				**0.19**

Table 77. continued

Clathria venuosa			0.74			**0.15**
Mycale laevis	0.34					**0.07**
Total Sponges	0.76	4.54	3.53	2.21	5.18	**3.24**

present in all transects with a mean cover of 3.2 %. A total of 10 species were identified, including four intercepted by transects. Abiotic categories, mostly reef overhangs and sand averaged 21.7 %. Reef substrate rugosity averaged 5.9 m, indicative of the high topographic relief contributed by coral growth. Although this survey stands as the baseline characterization, the recent degradation of this reef is evidenced by the high relative composition of encrusting algae overgrowing standing dead coral sections, particularly of Boulder Star Coral.

3.2. Fishes and Motile Megabenthic Invertebrates

A total of 53 fish species, including 31 within belt-transects were identified from the Media Luna Back-Reef (Table 78). The total fish mean abundance was 61.8 Ind/30 m^2 (range: 48 – 86 Ind/30 m^2). The numerically dominant species within transects were The Bluehead Wrasse (*Thalassoma bifasciatum*), Princess Parrotfish (*Scarus taeniopterus*) and French Grunt (*Haemulon flavolineatum*) with a combined abundance of 36.2 Ind/30 m^2, representative of 58.6 % of the total individuals. Other seven species were present in at least four transects and comprised along with the aforementioned species the main residential fish assemblage of the Media Luna Back-Reef (Table 78).

Fish species of commercial value are listed in Table 79. A total of six parrotfishes were present, and comprised the main assemblage in terms of density and species richness. Parrotfishes were largely present as juvenile and adults, but post-recruitment juveniles (1 – 3 cm) were observed for Stoplight, Princess and Stripped Parrotfishes (*Sparisoma viride, Scarus taeniopterus, S. iserti)*. One adult Graysbe (*Epinephelus cruentatus*) and adult Yellowtail and Schoolmaster Snappers (*Ocyurus chrysurus, Lutjanus apodus*) were also present.

Table 78. Taxonomic composition and abundance of fishes within belt-transects at Media Luna Back-Reef, La Parguera. 2015

Depth: 5 m		Transects					
		1	**2**	**3**	**4**	**5**	
		(Ind/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	17	7	26	9	13	**14.4**
Scarus taeniopterus	Princess Parrotfish	16	16	17	14	6	**13.8**
Haemulon flavolineatum	French Grunt	32	2	2	2	2	**8.0**
Chromis multilineata	Brown Chromis	8	0	4	1	8	**4.2**
Stegastes dorsopunicans	Dusky Damselfish	5	3	5	0	3	**3.2**
Stegastes partitus	Bicolor Damselfish	1	4	3	5	2	**3.0**
Stegastes planifrons	Three-spotted Damselfish	0	3	4	2	3	**2.4**
Scarus iserti	Stripped Parrotfish	0	1	0	3	4	**1.6**
Sparisoma viride	Stoplight Parrotfish	1	2	5	1	0	**1.8**
Holocentrus rufus	Squirrelfish	1	2	2	1	1	**1.4**
Acanthurus coeruleus	Blue Tang	2	1	0	1	0	**0.8**
Sparisoma aurofrenatum	Redband Parrotfish	0	0	0	3	1	**0.8**
Chaetodon capistratus	Four eye Butterflyfish	0	0	1	2	1	**0.8**
Caranx ruber	Bar Jack	1	1	0	1	0	**0.6**
Coryphopterus personatus	Masked Goby	0	0	0	3	0	**0.6**
Myripristis jacobus	Blackbar Soldierfish	0	2	0	1	0	**0.6**
Microspathodon chrysurus	Yellowtail Damselfish	1	1	0	0	1	**0.6**
Scarus vetula	Queen Parrotfish	0	0	2	0	0	**0.4**
Hypoplectrus unicolor	Butter Hamlet	0	1	0	0	1	**0.4**
Gobiosoma evelynae	Sharknose Goby	0	0	1	0	0	**0.2**
Epinephelus cruentatus	Graysby	0	0	0	1	0	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	0	0	0	1	**0.2**
Acanthurus bahianus	Ocean Surgeon	0	0	1	0	0	**0.2**
Haemulon chrysargyreum	Smallmouth Grunt	1	0	0	0	0	**0.2**
Ocyurus chrysurus	Yellowtail Snapper	0	1	0	0	0	**0.2**
Acanthurus chirurgus	Doctorfish	0	1	0	0	0	**0.2**
Lutjanus apodus	Schoolmaster Snapper	1	0	0	0	0	**0.2**
Cantherhines pullus	Orange Spotted Filefish	1	0	0	0	0	**0.2**
Pseudupeneus maculatus	Redspotted Goatfish	0	0	0	0	1	**0.2**
Sparisoma chrysopterum	Redtail Parrotfish	0	0	1	0	0	**0.2**
Aulostomus maculatus	Trumpetfish	0	1	0	0	0	**0.2**
	TOTAL INDIVIDUALS	88	49	74	50	48	**61.8**
	TOTAL SPECIES	14	17	14	16	15	**15.2**

Table 79. Taxonomic composition, density and size distributions of commercially important fishes present within expanded belt-transects 3 x 20 m at Media Luna Back Reef, 5 m. La Parguera. 2015

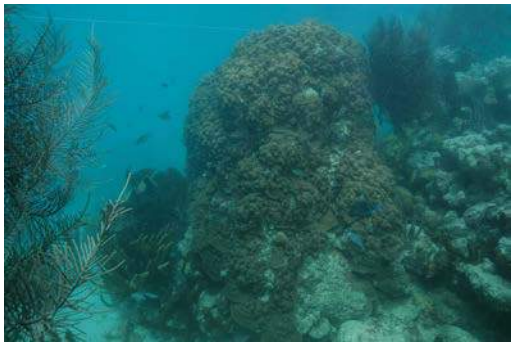
		TRANSECTS				
		1	2	3	4	5
		(Ind/60 m^2) - Length (cm)				
SPECIES	**COMMON NAME**					
Scarus iserti	Stripped		1 - 12	2 - 3		2 - 10
	Parrotfish					2 - 15
Sparisoma viride	Stoplight	2 - 3	1 - 5	2 - 3	1 - 5	1 - 5
	Parrotfish	1 - 30	1 - 32	2 - 10	1 - 7	1 - 15
				1 - 35		1 - 30
Sparisoma aurofrenatum	Redband	2 - 30	1 - 20		2 - 5	1 - 12
	Parrotfish				2 - 20	
Ocyurus chrysurus	Yellowtail Snapper		1 - 35			
Epinephelus cruentatus	Graysby		1 - 35			
Scarus taeniopterus	Princess	16 - 8	12 - 7	15 - 5	8 - 3	2 - 6
	Parrotfish		10 - 10	2 - 7	6 - 6	2 - 15
Lutjanus apodus	Schoolmaster	1 - 17	1 - 15			
	Snapper					
Sparisoma chrysopterum	Redtail		1 - 20			
	Parrotfish					
Scarus vetula	Queen Parrotfish			2 - 30		

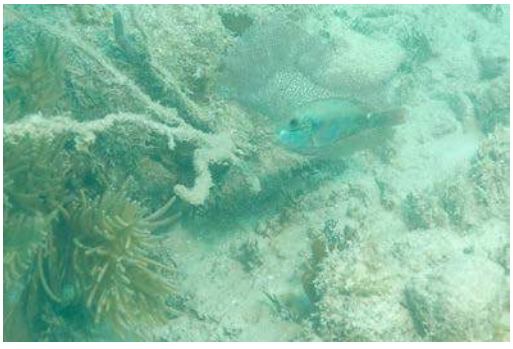
The herbivorous fish assemblage was the most prominent in terms of their relative composition within belt-transects surveyed with at least 13 species representing 46.9 % of the total individuals. Parrotfishes were the main taxonomic group in terms of density of individuals and species richness, but doctorfishes (Acanthuridae) and territorial farmer damselfishes (Pomacentridae) were also present. Opportunistic carnivores, represented by wrasses, juvenile grunts, squirrelfish, jacks, hamlets, gobies, Trumpetfish and Graysby were also prominent at the Media Luna Back-Reef representing approximately 42 % of the total individuals within belt-transects. The density of zooplanktivores (*Chromis spp.,* Masked Goby) represented less than 10 % of the total fish community. The relative abundance of herbivorous fish has been shown to increase towards the

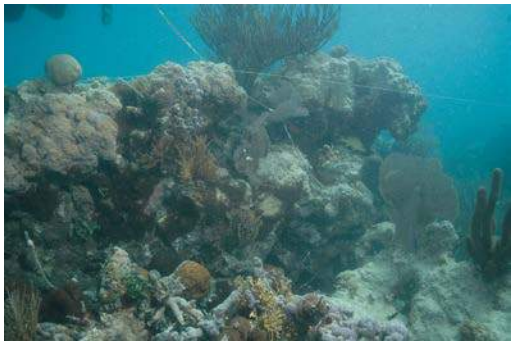
coastline possibly associated with the higher connectivity of recruitment and nursery habitats and/or the higher availability of benthic algae. Conversely, the relative abundance and species richness of zooplanktivorous fishes increase towards the outer shelf, shelf-edge and oceanic reefs (Esteves-Amador, 2013).

Photo Album 20. La Parguera Natural Reserve

Media Luna Back-Reef 5m







I. Isla Verde Reef

The Isla Verde Marine Reserve was designated as a closed fishing area in 2012 to protect a marine community that is representative of the north coast reefs of Puerto Rico, and that includes ESA coral species, such as *Acropora palmata* and *A. cervicornis* (ENDI, 2012). The Isla Verde Reef is part of a much larger ecosystem off the northeast coast of Carolina that includes rocky and sandy beaches, seagrass beds, outer shelf rock reefs and the near shore reefs, many of these rock reefs appear to be relict cemented sand dunes or eolianites that run parallel to the coastline, now forming a barrier of submerged and emergent reefs. The Isla Verde Reef formation is a highly eroded and discontinuous hard ground platform of sedimentary origin patchily distributed at depths between the surface and a maximum depth of about 5.0 meters. This reef is seasonally exposed to very strong wave and surge action associated with winter swells that break over the reef due to its shallow depth. Our baseline survey based on five permanent transects was performed on October 2015 at a depth of 4.0 m in front of Casa Cuba, near a sand islet (Figure 63). Panoramic documentation of the Isla Verde Reef is included as Photo Album 21.

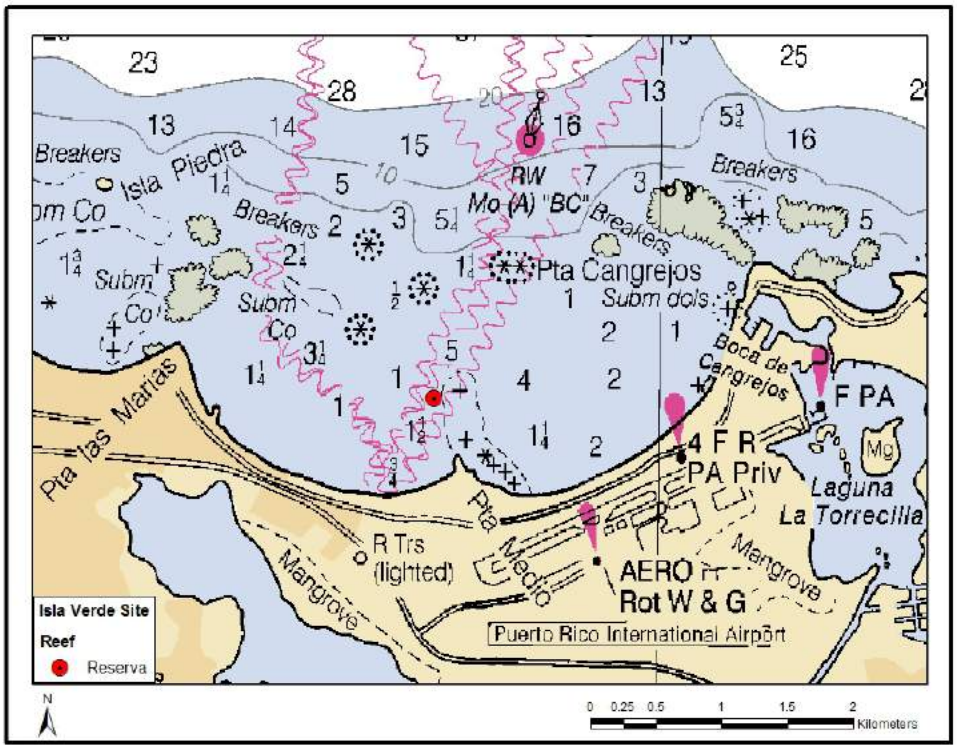


Figure 63. Location of the Isla Verde Reserve Reef site on the North Coast (Carolina).

1.0. Sessile-Benthic Reef Community

The sessile-benthic community of Isla Verde Reef was strongly dominated by turf algae growing as a carpet over most of the available hard ground substrate (Figure 64). The mean cover by turf algae was 69.3 % (range: 44.4 – 78.5 %) (Table 81). Crustose coralline algae, calcareous macroalgae (*Halimeda sp, Caulerpa spp*.) and brown macroalgae were also present as part of the benthic algae assemblage. At least 19 sponge species growing mostly embedded and encrusted over the hard ground were intercepted by transects during our survey with a combined mean cover of 3.7 % (range: 2.5 – 5.4 %). Vase Sponges (*Callyspongia sp*.), *Spirastrella coccinea*, *Iotrochota arenosa* and *Mycaele laevis* were observed in at least three out of the five transects surveys and appear to comprise the main sponge assemblage.

A total of 11 stony coral species were identified, including three intercepted by transects during the baseline survey (Table 81). The combined mean cover by stony corals was 3.3 % (range: 0.6 – 8.6 %). Knobby and Symmetrical Brain Corals (*Diploria clivosa, Pseudodiploria strigosa*) and the Lesser Starlet Coral, *Siderastrea radians* comprised the main assemblage along transects (Figure 65). Coral colonies were observed growing as mostly isolated and encrusted, without providing much topographic relief nor structural complexity. Some moderately and large colonies of Great Star Coral (*Montastraea cavernosa*), and Symmetrical Brain Coral were observed, particularly along the northwestern boundary of the Reserve. Several colonies of Elkhorn Coral (*Acropora palmata*) were observed in shallow sections of the reef, but we were unable to approach these shallow areas because of the prevailing strong wave action. Soft corals, or gorgonians were common along transects with a mean density of 5 colonies/transect. The main species was the Wide-Mesh Sea Fan, *Gorgonia mariae*. Sea Plumes (*Pseudopterogorgia spp*.) and Sea Rods (*Eunicea spp*). were present in the deeper sections of the reef near the northwestern border.

Table 81. Percent substrate cover by sessile-benthic categories at Isla Verde Reef, Carolina. 2015

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	0.68	1.73	0.22	0.96	0.14	**0.75**
SUBSTRATE CATEGORY						
Abiotic						
Sand	46.66	19.09	14.38	4.98		**17.02**
Reef overhang			4.38	2.30	1.93	**1.72**
Gap		0.48				**0.10**
Total Abiotic	46.66	19.57	18.77	7.28	1.93	**18.84**
Benthic Algae						
Turf with sand	44.30	74.82	70.41	75.48	70.44	**67.09**
CCA	1.57	0.48	2.47	4.98	1.66	**2.23**
Turf				2.55	8.56	**2.22**
Halimeda sp.	0.79	0.95	1.51		1.52	**0.95**
Caulerpa sp.					2.90	**0.58**
Dictyota spp.				1.02		**0.20**
Caulerpa racemosa			0.82			**0.16**
Total Benthic Algae	46.66	76.25	75.21	84.04	85.08	**73.45**
Cyanobacteria	0.66	0.00	0.00	0.00	0.83	**0.30**
Live Corals						
Diploria clivosa				2.94	7.04	**2.00**
Pseudodiploria strigosa	3.01				1.52	**0.91**
Siderastrea radians	0.26	0.60	0.68	0.38		**0.39**
Total Live Corals	3.28	0.60	0.68	3.32	8.56	**3.29**
Octocorals						
Gorgonia mariae	0.26					**0.05**
Erect Gorgonians	1	5	9	5	5	**5**
Sponges						
Callyspongia sp.	1.44	0.60		0.64		**0.54**
Cinachyrella apion			1.64		0.41	**0.41**
Orange encrusting sponge					1.52	**0.30**
Spirastrella coccinea	0.26	0.36	0.27	0.51		**0.28**
Ircinia felix				1.40		**0.28**
Ircinia brown sp.		0.48		0.89		**0.27**
Desmapsamma anchorata			0.82		0.41	**0.25**

Table 81. continued

Mycale laevis	0.39		0.27	0.51		**0.24**
Iotrochota arenosa	0.13	0.48	0.27		0.28	**0.23**
Niphates erecta				0.77	0.00	**0.15**
Neopetrosia sp.					0.69	**0.14**
Scopalina ruetzleri		0.24		0.38		**0.12**
Ircinia strobilina			0.55			**0.11**
Sponge		0.36				**0.07**
Tedania klausi					0.28	**0.06**
Callyspongia tenerrima			0.27			**0.05**
Monanchora arbuscula	0.26					**0.05**
Amphimedon viridis				0.26		**0.05**
Cliona varians		0.24				**0.05**
Total Sponges	2.49	2.74	4.11	5.36	3.59	**3.66**

Abiotic categories, mostly sand were observed in all transects with a mean substrate cover of 18.8 % (range: 1.9 – 46.7 %). It was evident that a very dynamic sand transport is one of the most relevant driving forces at this reef because of the strong wave action and the shallow reef condition surrounded by sand and sand patches.

2.0. Fishes and Motile Megabenthic Invertebrates

A total of 35 fish species, including nine within belt-transects were identified during the baseline survey of the Isla Verde (Table 82). Mean abundance within transects was 9.3 Ind/30 m^2 (range: 4 – 12 Ind/30 m^2). The Slippery Dick (*Halichoeres bivittatus*), Doctorfish (*Acanthurus chirurgus*) and Dusky Damselfish (*Stegastes dorsopunicans*) were the most prominent within transects with a combined abundance of 7.1 Ind/30 m2, representing 76.3 % of the total individuals within transects (Table 82). One juvenile Redtail Parrotfish (*Sparisoma chrysopterum*) and several Coneys and Graysbe (*Epinephelus fulva, E. cruentatus*) were the main commercially important fish species present within extended transects at Isla Verde (Table 83). Also, one adult Spotted Eagle Ray (*Aetobatus narinari*) was observed.

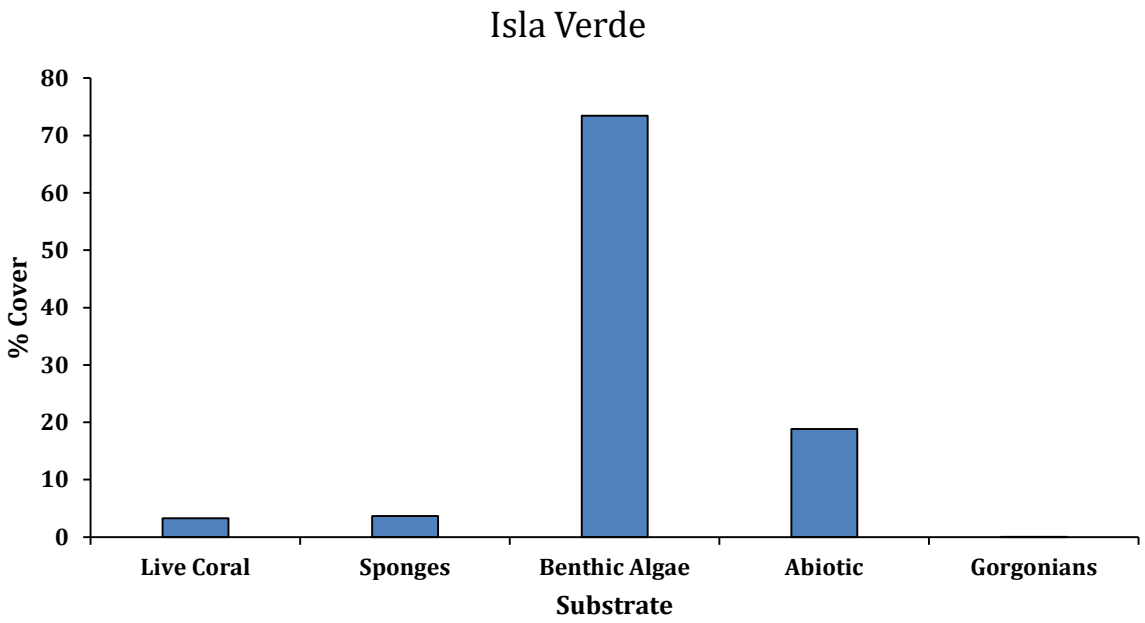


Figure 64. Mean substrate cover by sessile-benthic categories at Isla Verde Reef, Carolina. Baseline survey: 2015.

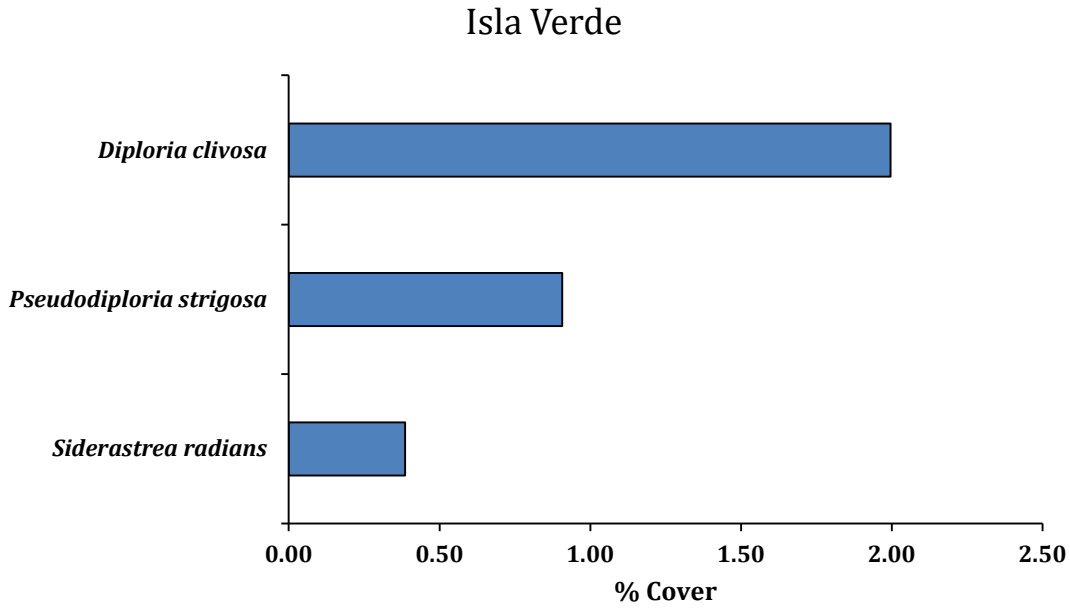


Figure 65. Mean substrate cover by stony coral spp. categories at Isla Verde Reef, Carolina. Baseline survey: 2015.

Table 82. Taxonomic composition and abundance of fishes within belt-transects at Isla Verde Reef, Carolina. 2015

Depth: 5 m

		TRANSECTS					
		1	2	3	4	5	
		(Ind/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Halichoeres bivittatus	Slippery Dick	2	1	3	3	7	**3.5**
Acanthurus chirurgus	Doctorfish	0	2	3	0	2	**1.8**
Stegastes dorsopunicans	Dusky Damselfish	2	0	3	2	2	**1.8**
Chaetodon striatus	Banded Butterflyfish	0	2	0	0	0	**0.5**
Thalassoma bifasciatum	Bluehead Wrasse	0	0	2	0	0	**0.5**
Haemulon flavolineatum	French Grunt	0	2	0	0	0	**0.5**
Canthigaster rostrata	Sharpnose puffer	0	0	0	1	0	**0.3**
Holocentrus rufus	Squirrelfish	0	1	0	0	0	**0.3**
Gobiosoma evelynae	Sharknose Goby	0	0	1	0	0	**0.3**
	TOTAL INDIVIDUALS	**4**	**8**	**12**	**6**	**11**	**9.3**
	TOTAL SPECIES	**3**	**5**	**5**	**3**	**3**	**4**

Table 83. Taxonomic composition, density and size distributions of commercially important fishes present within expanded belt-transects 3 x 20 m at Isla Verde Reef, Carolina, 2015

		TRANSECTS				
		1	2	3	4	5
SPECIES	**COMMON NAME**	(Ind/60 m^2) - Length (cm)				
Epinephelus cruentatus	Graysby			1 - 10	2 - 10	
Epinephelus fulva	Coney	2 - 10	2 - 10			1 - 15
Sparisoma chrysopterum	Redtail Parrotfish					1 - 7
Ocyurus chrysurus	Yellowtail Snapper		1 - 7			
Aetobatus marinari	Spotted Eagle Ray	1 - 90				

The fish community structure at the Isla Verde Reef was strongly dominated by small opportunistic carnivores, such as Wrasses, grunts, puffers, squirrelfishes, gobies and small groupers that represented 78 % of the species present and 63% of the total individuals within belt-transects. This fish assemblage is typical of rock reefs that are exposed to high wave and surge action. Herbivores, comprised within transects by parrotfishes and doctorfishes were the other trophic group that was prominent in the reef, representing 38.7 % of the total individuals. Zooplanktivores were present in very low species richness and abundance at this reef, probably because of the shallow depth and the prevailing strong wave and surge conditions.

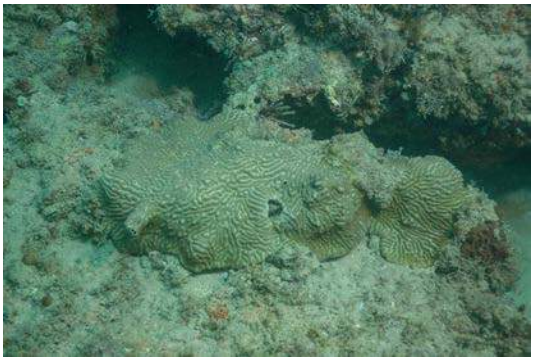
Motile megabenthic invertebrates, represented by four sea urchin species within belt-transects were highly prominent in the Isla Verde Reef (Table 84). The Slate-Pencil Urchin was the most abundant with a mean of 7.6 Ind/30 m^2 and was present in all transects. The Rock-boring Urchin was also present in all transects with a mean abundance of 3.6 Ind/30m^2. These two urchins are important herbivores that bore themselves into the reef as an adaptation to withstand the strong surge associated with wave action.

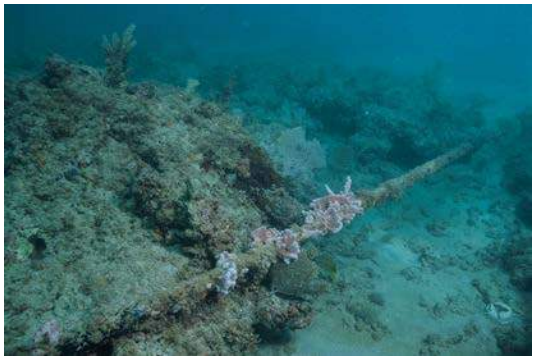
Table 76. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Isla Verde Reef, Carolina, 2015

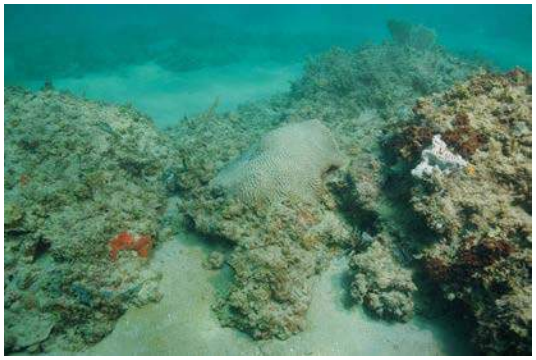
Depth: 3 -5 m		TRANSECTS					MEAN
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**ABUNDANCE (IND/30 m2)**
Eucidaris tribuloides	Slate-Pencil Urchin	5	6	12	10	5	**7.6**
Diadema antillarum	Long-Spined Urchin	1	2	1		2	**1.2**
Echinometra lucunter	Rock-boring Urchin		2	5	5	6	**3.6**
Echinometra viridis	Reef Urchin		1	1		2	**0.8**
Cyphoma gibbosum	Flamingo Tongue		1				**0.2**
Hermodice carunculata	Fire Worm	1					**0.2**
	TOTALS	6	12	19	15	15	**13.6**

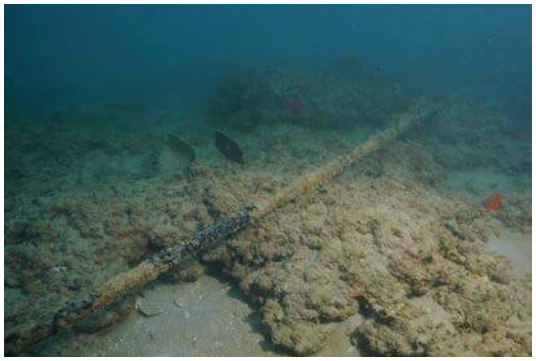
Photo Album 21. Isla Verde, Carolina

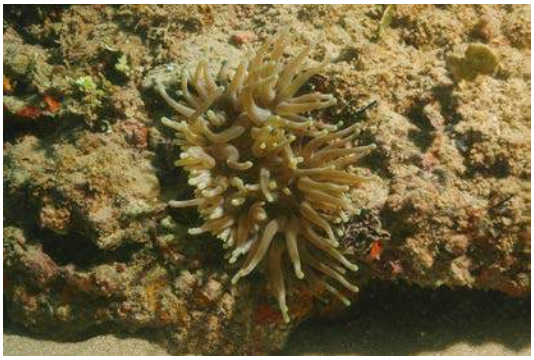
Isla Verde Reef











V 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 2001 - 2015.
2. Differences of live coral cover between monitoring surveys were mostly associated with a sharp decline measured during 2006, after a severe regional coral bleaching event affected reef systems of Puerto Rico and the U. S. Virgin Islands during late 2005. Lingering effects with continued live coral cover losses were measured for the aforementioned reefs until 2008.
3. The decline of (total) live coral cover was largely driven by mortality of Boulder Star Coral, *Orbicella annularis* (complex), a highly dominant species in terms of reef substrate cover and the principal reef building species. Corresponding increments of reef substrate cover by benthic algae, cyanobacteria, sponges and abiotic categories were measured.
4. Coral reefs in oceanic islands (I. Mona, I. Desecheo), shelf-edge reefs and the shallow reefs of Vieques were the most affected by the regional coral bleaching event, whereas mesophotic reefs (El Seco-Vieques), Tourmaline 30m, Desecheo 30m, Elkhorn Coral Reefs (Tres Palmas, Aurora) and coastal reefs (Resuellos, Cibuco, El Palo, Caribes, Coral, Tres Palmas) were the least affected, 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. 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).
6. From our baseline assessments at the Guayama reefs, the unusual dominance of corals other than *Orbicella annularis* on a shelf-edge reef (Guayama 20m), stable coral cover over time relative to previous studies (Cayo Caribes, Resuellos, El Palo) and very high cover by *O. annularis* on a shallow coastal reef (Guayama Patch Reef 5m) support the contention that turbid water and depth acted in protection of corals, particularly *O. annularis*, and that exposed shelf-edge corals to high water transparency were the most affected, leading to phase shifts of reef benthic community structure associated with the differential degradation of *O. annularis*.
7. Between 2009 and the present 2015 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).
8. A positive correlation between live coral recuperation and water turbidity, as measured by the light attenuation coefficient Kd 490 has emerged

9. The *Acropora palmata* fringing reef of Tres Palmas in Rincon is infected by white band disease and what appears to be white pox, an infectious disease also known as “patchy necrosis”. The infection prevalence in colonies is high (>60%) and although active growth by *A. palmata* is evident, given favorable conditions for the disease massive coral mortality can be expected.
10. From the present (2015) baseline characterization of the Elkhorn coral reef at Gallardo we can infer that the reef has been exposed to severe degradation caused by mechanical damage as there are massive deposits of broken elkhorn coral fragments across the reef. Also, Elkhorn Corals at this reef appear to be suffering from a strong predatory pressure by corallivorous gastropods.
11. Reef fish community structure has shown a pattern of short-term, statistically significant fluctuations of abundance at most reefs surveyed during the monitoring program. On costal shallow reefs, fluctuations appear to be largely physically driven by wave energy and its associated surge action and turbulence. On deeper oceanic and shelf-edge reefs fluctuations of abundance appear to be driven by the recruitment dynamics of numerically dominant populations with highly patchy distributions and schooling behaviors, such as Masked Goby, *Coryphopterus personatus* and Blue Chromis, *Chromis cyanea*.
12. Marked differences of fish community structure are evident between oceanic/shelf-edge reefs dominated by pelagic and demersal zooplanktivore trophic assemblages (*Chromis spp*., Creole Wrasse, Masked Goby, Bicolor Damselfish) and coastal reefs, dominated by herbivorous assemblages (Parrotfishes, Doctorfishes, farmer Damselfishes).
13. The taxonomic composition and size structure of commercially important fishes was *dominated* by parrotfishes (Scaridae). These occurred mostly as early juvenile, juveniles and adults. Post settlement juveniles of several parrotfish species, including the Stoplight, Princess and Stripped (*Sparisoma viride, Scarus taenioptrus, S. iserti*) have been observed, indicative that some of these neritic reefs, particularly those at La Parguera serve as recruitment habitats for these species.
14. The size frequency distributions of the Lionfish (*Pterois sp*.) were strongly skewed towards the large adult size classes, suggesting a paucity of recruitment on local reefs.
15. Although in low abundance, large demersal (top predator) fishes have been observed during the last few surveys. These include Reef Shark (*Carcharhinus perezi*), Yellowfin, Yellowmouth, Tiger, Jewfish, and Nassau Groupers (*Mycteroperca venenosa, M. interstitialis, M. tigris, Epinephelus itajara, E. striatus*), and the Cubera, Dog and Mutton Snappers (*Lutjanus cyanopterus, L. jocu, L. analis*).
16. The status of the large demersal, commercially valuable and overfished grouper/snapper populations continues to be precarious and no signs of stock replenishment have been noted within Natural Reserve reef sites.
17. Comprised by at least 96 diurnal, non-cryptic species and including healthy populations of large demersal and pelagic predators, the upper mesophotic (30 m) fish community at the bank coral reef of El Seco, Vieques can be regarded as highly biodiverse, well balanced in terms of its trophic components and an important reservoir of commercially exploited coral reef fishes.

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Appendix 1. List of fish species identified at coral reef monitoring sites: 1999-2015

Total Species **REEF**
Database **SITES**

Species Name	M30	M20	M10	D30	D20	D15	R5	R10	R20	CdM	Coral	Der	Auro	Gu20	Gall	ML-5	ML10	BoyVi	Palo	Resu	ISV
Haemulon sciurus	1		1					1		1	1			1	1					1	
Abudefduf se1atilis	1	1	1		1		1	1	1	1	1		1		1		1	1	1	1	1
Abudefduf taurus							1	1													1
Acanthemblemaria aspera																					
Acanthemblemaria chaplini			1																		
Acanthemblemaria spinosa																					
Acanthostracion plygonia																					
Acanthostrascion quadricornis				1.0	1			1	1		1										
Acanthurus bahianus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1
Acanthurus chirurgus	1	1	1	1.0	1	1	1	1	1	1	1	1	1	1	1	1		1		1	1
Acanthurus coeruleus	1	1	1	1.0	1	1	1	1	1	1	1	1		1	1		1	1	1	1	
Aetobatus narinari				1.0				1						1							1
Alutherus scriptus	1		1	1	1			1		1	1	1									
Amblicirrhitos pinnos	1	1	1	1.0	1	1		1	1	1	1	1			1			1			
Anchoa sp.							1														
Anisotremus surinamensis				1				1	1												
Anisotremus virginicus	1	1	1				1	1	1	1	1	1	1		1			1	1		1
Apogon townsendi				1	1			1	1												
Aulostomus maculatus	1	1	1	1.0	1	1	1	1	1	1	1	1	1		1	1	1		1	1	
Balistes vetula				1.0	1	1		1				1		1							
Bodianus rufus	1	1	1	1	1	1	1	1	1	1	1	1	1		1					1	1
Bothus lunatus	1	1							1												

Species Name	**M30**	**M20**	**M10**	**D30**	**D20**	**D15**	**R5**	**R10**	**R20**	**CdM**	**Coral**	**Der**	**Auro**	**Gu20**	**Gall**	**ML-5**	**ML10**	**BoyVi**	**Palo**	**Resu**	**ISV**
Calamus calamus							1				1	1									
Calamus pennatula				1			1	1					1	1							
Cantherhines macrocerus				1	1	1	1	1	1		1	1									
Cantherhines pullus	1	1	1				1	1			1			1		1				1	
Cantherhines surinamensis	1	1	1	1.0	1			1			1	1									
Canthigaster rostrata	1	1	1	1.0	1	1	1	1	1	1	1	1	1	1			1	1		1	1
Caran1 bartholomaei			1				1				1				1						
Caran1 crysos	1	1	1	1	1		1	1	1	1	1	1	1	1						1	
Caran1 hippos	1			1	1		1	1	1		1				1						
Caran1 latus				1																	1
Caran1 lugubris	1	1	1	1	1		1	1			1	1									
Caran1 ruber	1	1	1	1.0	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1
Carcharhinus limbatus				1																	
Chaenopsis ocellata											1	1									
Chaetodipterus faber	1													1							
Chaetodon aculeatus	1	1	1	1	1			1	1		1	1									
Chaetodon capistratus	1	1	1	1.0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Chaetodon ocellatus	1	1	1								1	1		1						1	
Chaetodon sedentarius	1				1			1	1												
Chaetodon striatus	1	1	1		1	1	1	1	1	1	1	1	1							1	1
Chromis cyanea	1	1	1	1.0	1	1	1	1	1	1	1	1		1	1		1	1	1		
Chromis insolata	1			1					1												
Chromis multilineata	1	1	1	1.0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Clepticus parrae	1	1	1	1	1	1		1	1	1	1	1		1	1			1	1		
Coryphopterus glaucofraenum	1	1	1	1.0			1	1		1	1	1		1	1				1		
Coryphopterus lipernes	1	1	1	1	1	1		1	1	1	1	1		1				1		1	

Species Name	**M30**	**M20**	**M10**	**D30**	**D20**	**D15**	**R5**	**R10**	**R20**	**CdM**	**Coral**	**Der**	**Auro**	**Gu20**	**Gall**	**ML-5**	**ML10**	**BoyVi**	**Palo**	**Resu**	**ISV**
Coryphopterus personatus	1	1	1	1.0	1	1		1	1	1	1	1		1		1		1		1	
Criptoptomus roseus						1															
Ctenogobius saepepallens									1												
Dasyatis americana				1	1		1			1											
Decapterus macarelus	1	1	1	1		1		1	1		1			1	1						
Diodon holacanthus				1.0			1	1													
Diodon hystri1				1		1	1	1		1					1					1	
Echenes naucrates											1			1							
Echidna catenata						1															
Elagatis bipinnulata				1					1			1		1							
Epinephelus adsensionis	1	1					1	1													
Epinephelus cruentatus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1	1
Epinephelus fulvus	1	1	1	1.0	1	1	1	1	1	1	1	1		1	1		1			1	1
Epinephelus guttatus	1	1	1	1	1	1		1	1	1	1	1	1	1						1	1
Epinephelus striatus	1	1		1	1																
Equetus acuminatus	1	1	1	1	1	1	1	1	1	1	1	1									
Equetus lanceolatus	1	1	1					1	1	1											
Equetus punctatus										1	1	1									
Gerres cinereus	1	1	1				1	1		1	1		1		1						
Ginglymostoma cirratum	1		1			1				1				1							
Gobiosoma evelynae	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1
Gobiosoma hoorsti										1											
Gobiosoma saucrum	1	1	1	1			1	1		1	1	1									
Gramma loreto	1	1	1	1	1		1	1	1	1	1	1					1			1	
Gymnothora1 funebris			1	1.0									1	1							
Gymnothora1 miliaris								1	1												1
Gymnothora1 moringa	1	1	1		1	1		1	1		1	1									

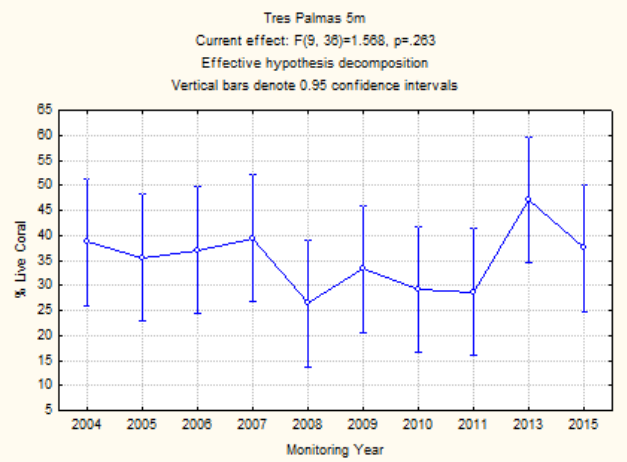
Species Name	**M30**	**M20**	**M10**	**D30**	**D20**	**D15**	**R5**	**R10**	**R20**	**CdM**	**Coral**	**Der**	**Auro**	**Gu20**	**Gall**	**ML-5**	**ML10**	**BoyVi**	**Palo**	**Resu**	**ISV**
Haemulon aurolineatum	1	1	1		1			1		1	1		1	1						1	1
Haemulon carbonarium							1		1				1								
Haemulon chrysargyreum	1	1	1				1	1	1	1	1				1	1				1	1
Haemulon flavolineatum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Haemulon macrostomum	1	1	1		1	1	1	1	1	1	1	1			1			1		1	1
Haemulon melanurum	1	1	1					1	1				1								
Haemulon parra																					
Haemulon plumieri							1	1		1	1		1							1	1
Haemulon sciurus	1	1	1	1		1					1	1			1		1		1		1
Haemulon steindachneri											1										
Halichoeres bivitatus							1	1		1	1		1		1				1		1
Halichoeres cyanocephalus												1			1						
Halichoeres garnoti	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	
Halichoeres maculipinna	1	1	1	1.0	1	1	1	1	1	1	1	1	1		1				1	1	
Halichoeres pictus							1												1		
Halichoeres radiatus	1	1	1		1	1	1	1		1	1	1	1		1					1	
Heteropriacanthus cruentatus													1							1	
Hemiramphus ballyhoo			1	1	1	1		1					1		1				1	1	1
Holacanthus ciliaris	1	1	1	1	1	1		1	1	1	1	1	1								
Holacanthus tricolor	1	1	1	1.0	1	1		1	1	1	1	1	1		1				1	1	
Holocentrus adscensionis					1			1			1	1	1		1						1
Holocentrus coruscus	1	1	1							1	1	1									
Holocentrus marianus																					
Holocentrus rufus	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1
Holocentrus ve1illarius							1						1		1						
Hypoplectrus aberrans	1	1	1								1										
Hypoplectrus chlorurus								1	1	1	1	1				1			1	1	

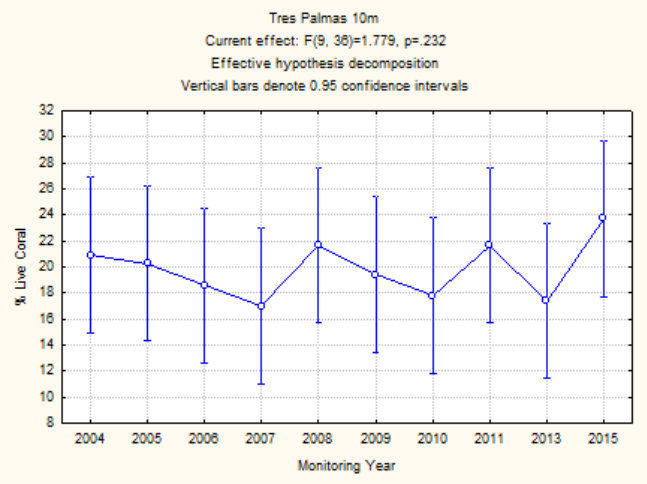
Species Name	**M30**	**M20**	**M10**	**D30**	**D20**	**D15**	**R5**	**R10**	**R20**	**CdM**	**Coral**	**Der**	**Auro**	**Gu20**	**Gall**	**ML-5**	**ML10**	**BoyVi**	**Palo**	**Resu**	**ISV**
Hypoplectrus guttavarius	1	1	1					1		1	1	1									
Hypoplectrus indico	1	1	1							1	1	1									
Hypoplectrus nigricans	1	1	1	1				1	1	1	1	1									
Hypoplectrus puella	1	1	1					1	1	1	1	1			1				1		
Hypoplectrus unicolor	1	1	1	1				1	1	1	1	1				1				1	
Kyphosus sp.	1	1	1	1.0	1	1	1	1			1	1									
Lachnolaimus ma1imus	1											1	1						1	1	
Lactophrys bicaudalis	1	1			1	1															
Lactophrys polygonia	1	1	1	1	1			1			1	1									
Lactophrys trigonus				1	1				1												
Lactophrys triqueter	1	1		1	1	1	1	1			1	1			1				1		
Lioproma carmabi	1																				
Liopropoma rubre	1	1	1	1	1			1	1		1	1									
Lutjanus analis							1		1				1							1	
Lutjanus apodus	1	1	1	1	1	1	1	1	1	1	1	1	1			1			1	1	
Lutjanus cyanopterus	1	1										1									
Lutjanus jocu	1	1		1																	
Lutjanus mahogani	1	1	1	1	1			1	1	1	1	1	1		1				1		
Lutjanus synagris	1	1	1					1	1	1	1		1		1				1		1
Malacanthus plumieri				1	1			1	1												
Malacoctenus triangulatus	1	1	1	1	1	1	1	1					1								
Malacoctenus versicolor								1													
Melichthys niger	1	1	1	1	1	1	1	1	1		1	1		1	1			1			
Microspatodon chrysurus	1	1	1	1.0	1	1	1	1	1	1	1	1	1		1	1	1		1	1	
Mlacoctenus gelli							1														
Mulloides martinicus	1	1	1	1	1	1	1	1	1	1	1	1	1								
Muraena robusta						1				1											

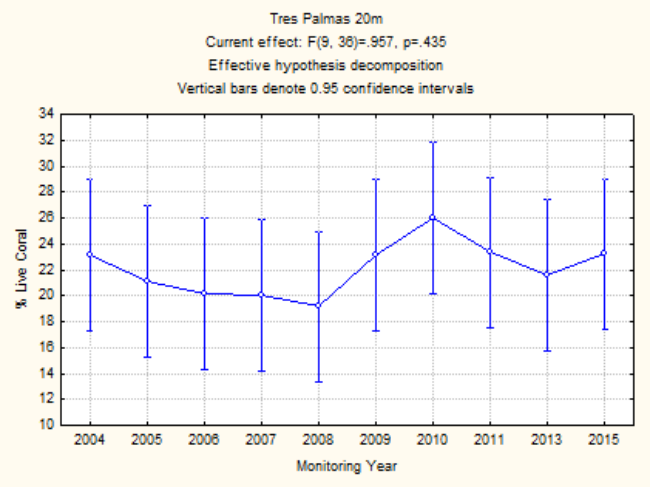
Species Name	**M30**	**M20**	**M10**	**D30**	**D20**	**D15**	**R5**	**R10**	**R20**	**CdM**	**Coral**	**Der**	**Auro**	**Gu20**	**Gall**	**ML-5**	**ML10**	**BoyVi**	**Palo**	**Resu**	**ISV**
Mycteroperca tigris												1									
Mycteroperca venenosa	1			1	1						1										
Myripristis jacobus	1	1	1	1.0	1	1	1	1	1	1	1	1	1			1		1	1		
Neoniphon marianus	1	1	1	1.0	1	1	1		1	1	1	1	1						1	1	
Ocyurus chrysurus	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Odontoscion dente1	1	1	1				1	1		1	1								1		
Ophioblennius atlanticus	1	1	1		1	1	1	1		1			1		1						
Paranthias fucifer	1	1	1	1	1			1	1		1	1									
Pempheris schomburgki	1	1					1														
Pomacanthus paru				1	1								1				1				
Pomacanthus arcuatus	1	1		1	1	1		1	1	1	1	1	1					1	1	1	1
Priacanthus arenatus	1	1	1	1	1		1	1	1	1	1	1									
Pseudopeneus maculatus	1	1	1	1	1	1		1	1	1	1	1	1	1		1					1
Pterois volitans	1	1	1	1	1				1	1				1	1			1	1	1	
Sanopus greenfieldorum								1													
Scarus coelestinus							1								1						
Scarus coeruleus	1	1	1					1		1	1										
Scarus guacamaia													1								
Scarus iserti	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Scarus taeniopterus	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1		
Scarus vetula	1	1	1	1	1		1	1	1	1	1	1	1		1	1					
Scomberomorus regalis	1	1	1	1	1		1	1	1	1	1	1			1				1	1	
Scorpaena plumieri						1				1		1									
Seriola rivoliana				1						1											
Serranus baldwini				1																	
Serranus chionaraia								1													
Serranus dewegeri																					

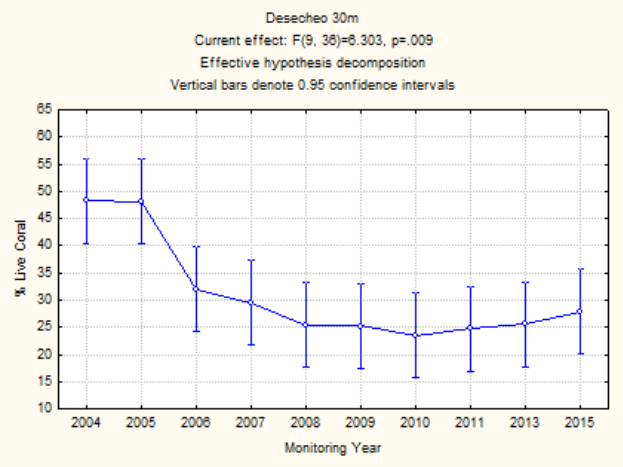
Species Name	**M30**	**M20**	**M10**	**D30**	**D20**	**D15**	**R5**	**R10**	**R20**	**CdM**	**Coral**	**Der**	**Auro**	**Gu20**	**Gall**	**ML-5**	**ML10**	**BoyVi**	**Palo**	**Resu**	**ISV**
Serranus tabacarius				1																	
Serranus tegrinus	1	1	1	1	1	1		1	1	1	1	1	1	1							
Sparisoma atomarium														1							
Sparisoma aurofrenatum	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	
Sparisoma chrysopterum				1	1				1					1	1	1	1				
Sparisoma radians	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1		
Sparisoma rubripinne			1	1.0	1		1	1					1	1	1				1		
Sparisoma viride	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Chilomycterus antillarum	1	1						1													
Sphoeroides greeleyi								1													
Sphoeroides testudineus	1	1	1					1													
Sphyraena barracuda	1	1	1	1	1	1	1	1	1			1		1	1			1	1		1
Stegastes dorsopunicans	1		1			1	1			1	1		1		1	1	1		1		1
Stegastes leucostictus	1	1	1	1	1			1	1	1	1	1	1					1	1	1	
Stegastes partitus	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1		1	
Stegastes planifons	1	1	1	1.0	1			1	1	1	1	1	1			1	1		1		
Stegastes variabilis	1	1	1			1	1	1		1	1	1			1						1
Stephalnolepis setifier	1		1																		
Strongylura timucu	1												1		1						
Synodus intermedius	1	1	1	1	1	1	1	1		1	1	1									
Thalasoma bifaciatum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Urolophus jamaicensis																					
1anthichthyis ringens						1															
	113	100	100	97	87	67	77	113	85	87	102	90	62	47	60	30	26	31	47	52	35

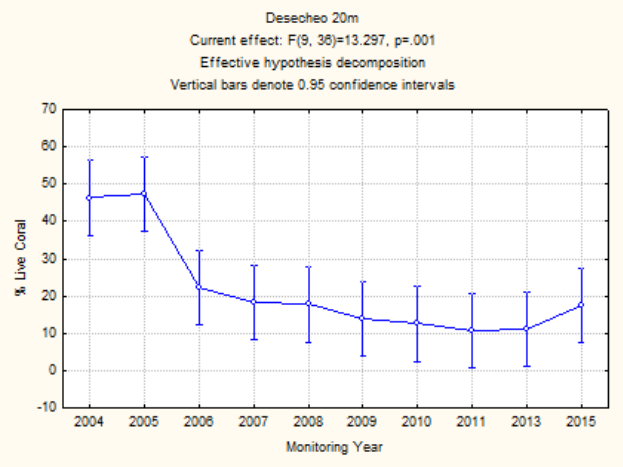
Appendix 2. One-way ANOVA testing for differences in live coral cover between annual surveys

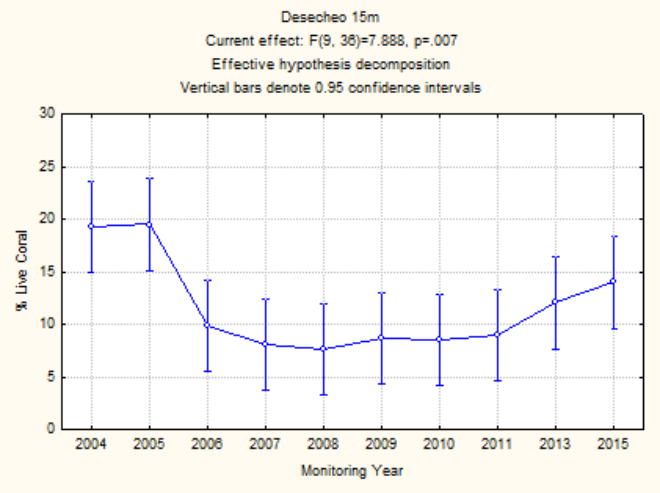


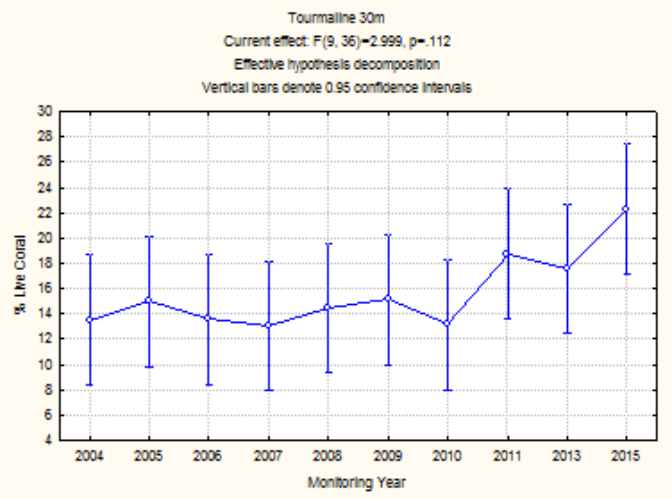


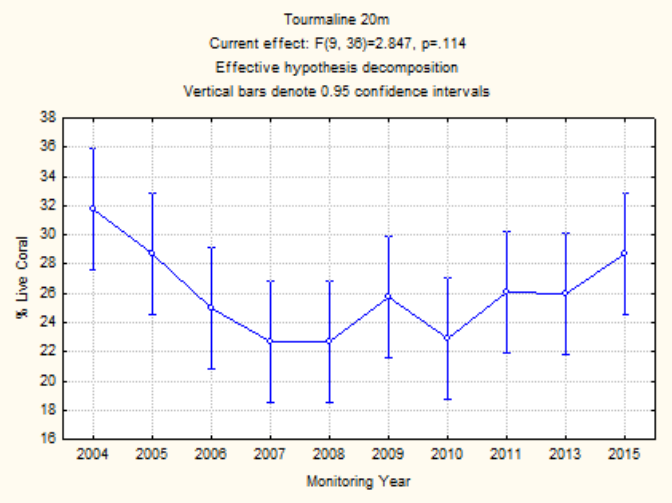


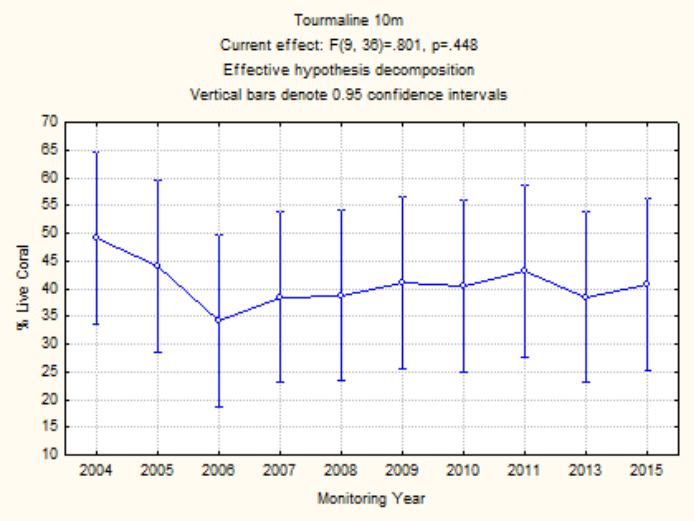

Desecheo 30m
Current effect: F(9, 36)=6.303, p=.009
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
65
60
55
50
45
40
35
30
25
20
15
10
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Year

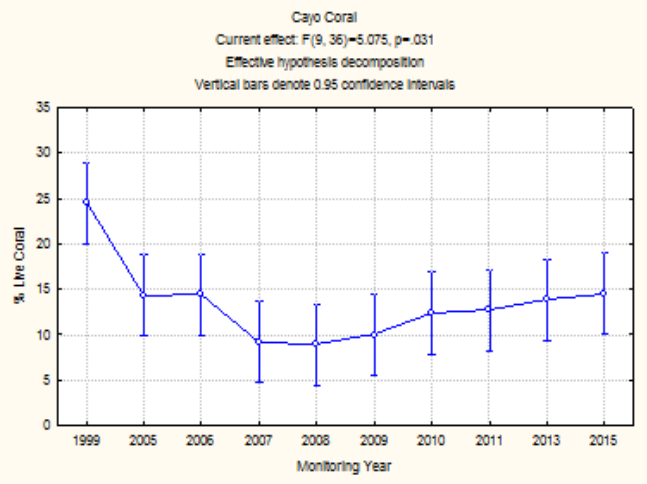

Desecheo 20m
Current effect: F(9, 36)=13.297, p=.001
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
70
60
50
40
30
20
10
0
-10
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Year

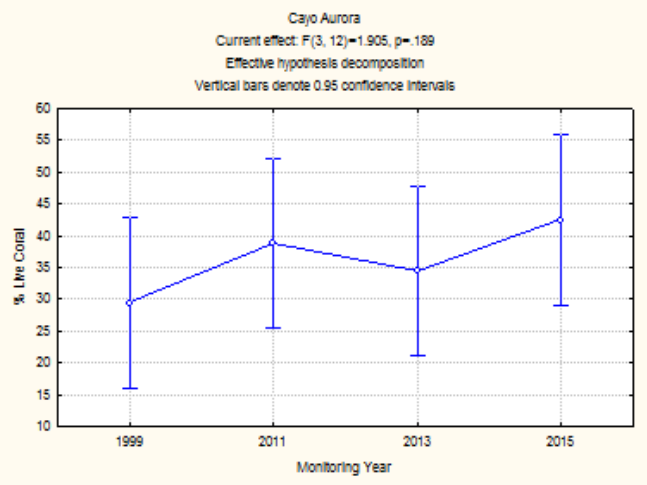

Desecheo 15m
Current effect: F(9, 36)=7.888, p=.007
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
30
25
20
15
10
5
0
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Year

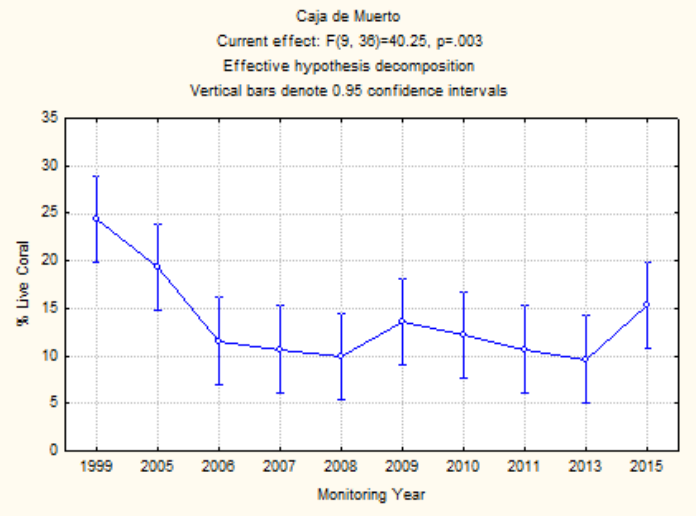

Tourmaline 30m
Current effect: F(9, 36)=2.999, p=.112
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
Monitoring Year

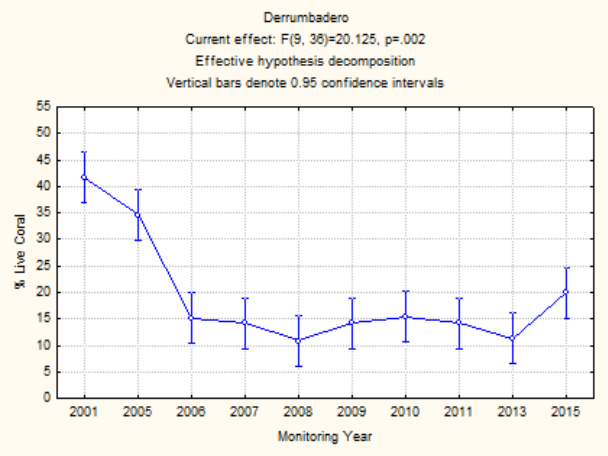

Tourmaline 20m
Current effect: F(9, 36)=2.847, p=.114
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
Monitoring Year

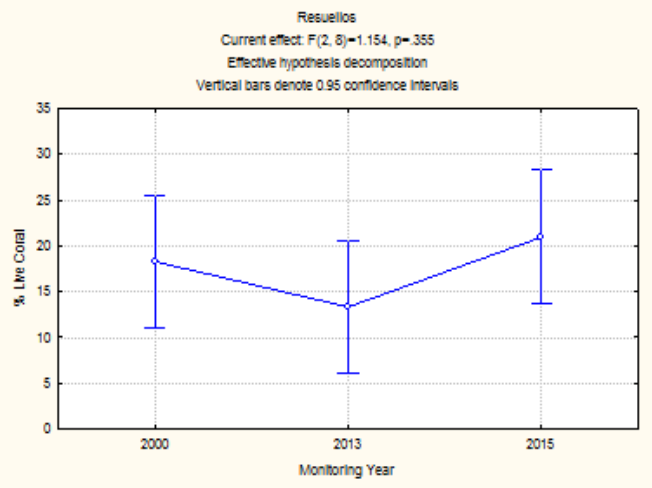

Tourmaline 10m
Current effect: F(9, 36)=.801, p=.448
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
Monitoring Year

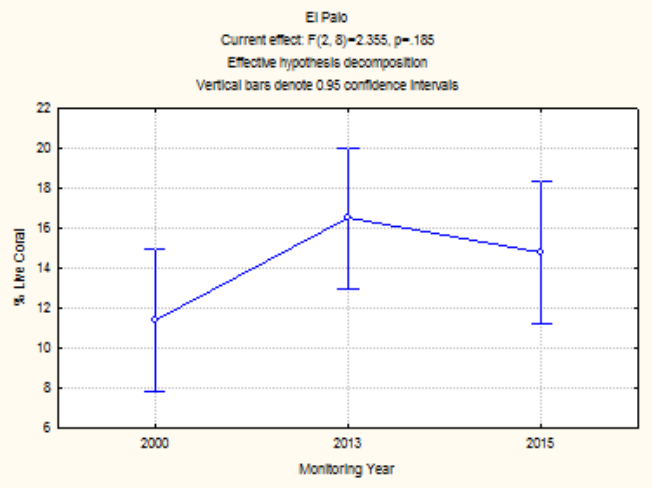

Cayo Coral
Current effect: F(9, 36)=5.075, p=.031
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
0
5
10
15
20
25
30
35
1999
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Year


Cayo Aurora
Current effect: F(3, 12)=1.905, p=.189
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
10
15
20
25
30
35
40
45
50
55
60
1999
2011
2013
2015
Monitoring Year

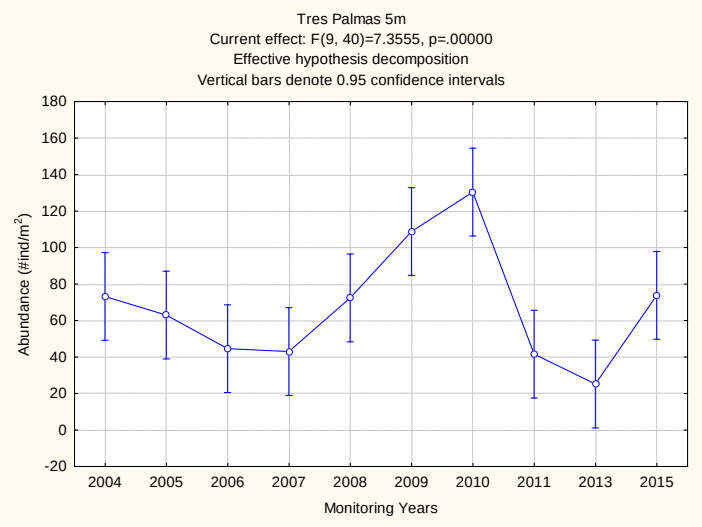

Caja de Muerto
Current effect: F(9, 36)=40.25, p=.003
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
0
5
10
15
20
25
30
35
1999
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Year

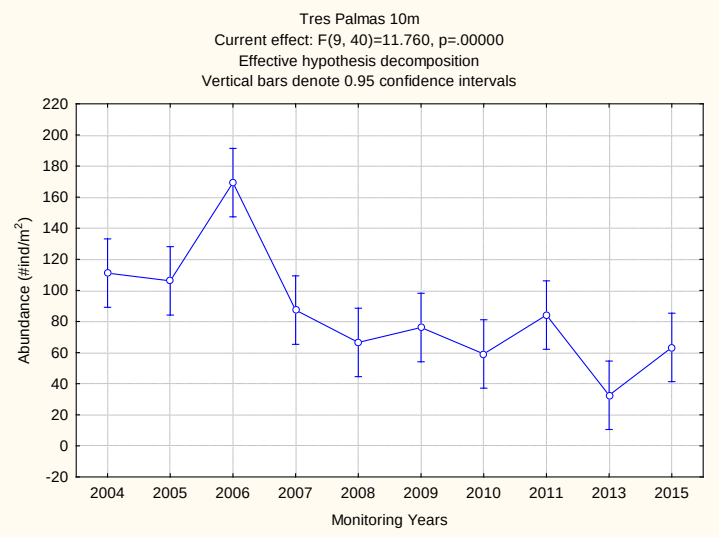

Derrumbadero
Current effect: F(9, 36)=20.125, p=.002
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
55
50
45
40
35
30
25
20
15
10
5
0
2001
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Year

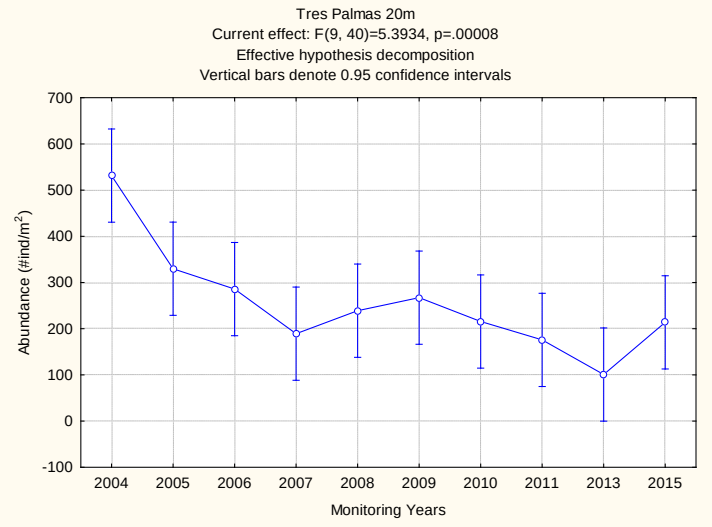

Resuellos
Current effect: F(2, 8)=1.154, p=.355
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
35
30
25
20
15
10
5
0
2000
2013
2015
Monitoring Year

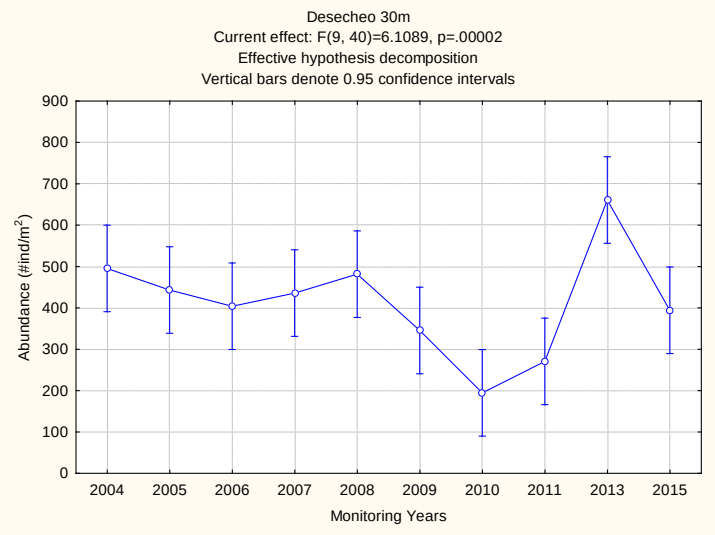

El Palo
Current effect: F(2, 8)=2.355, p=.155
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
22
20
18
16
14
12
10
8
6
2000
2013
2015
Monitoring Year

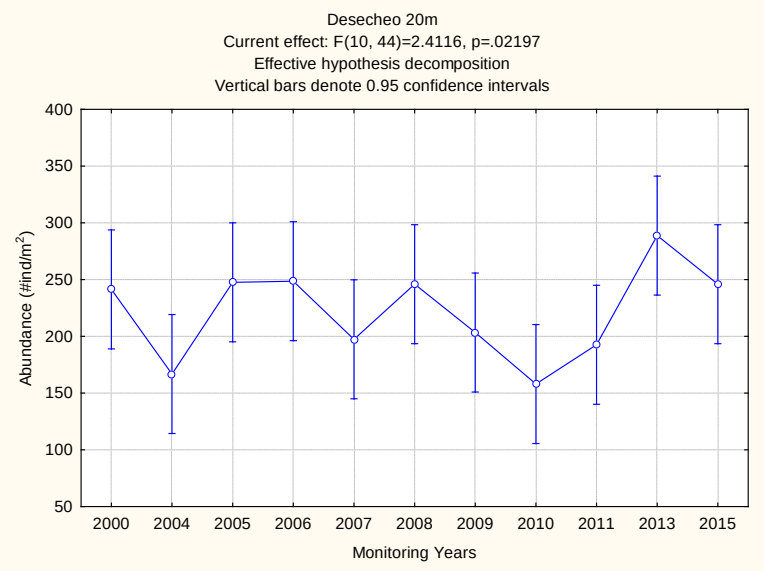
Appendix 3. Fish abundance ANOVAS

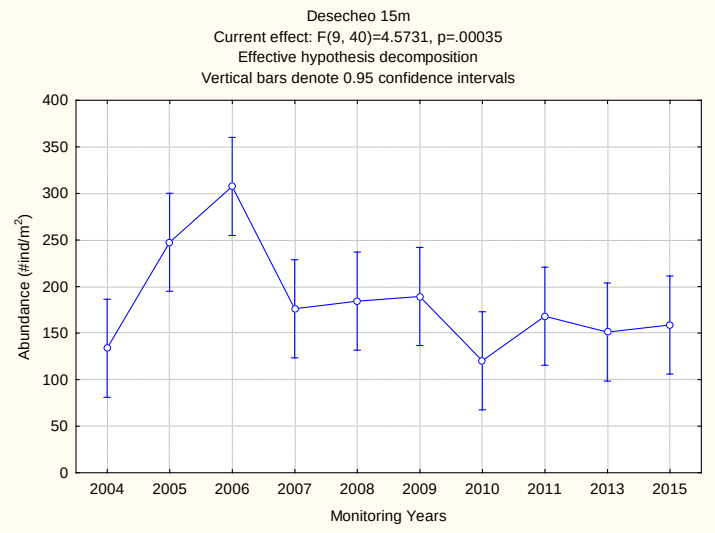


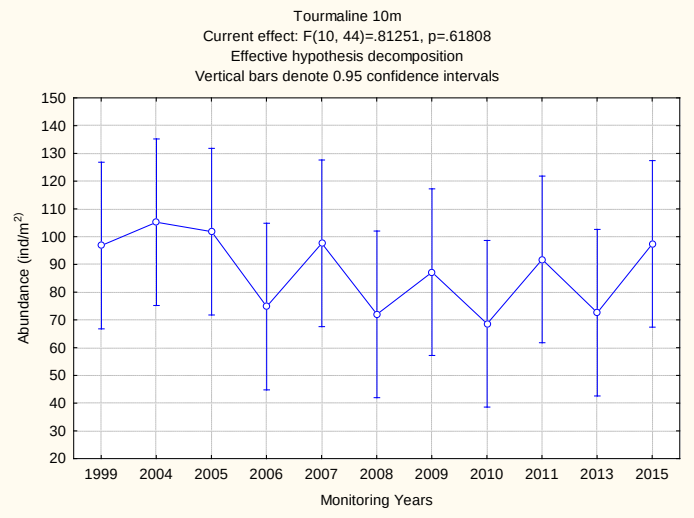


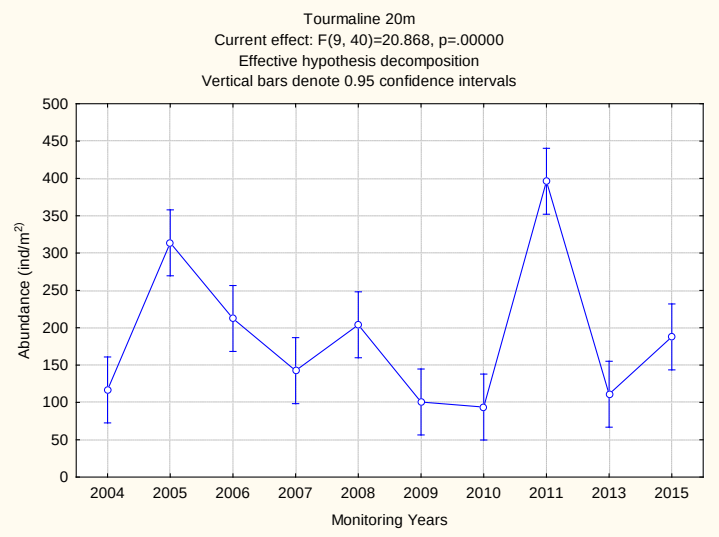


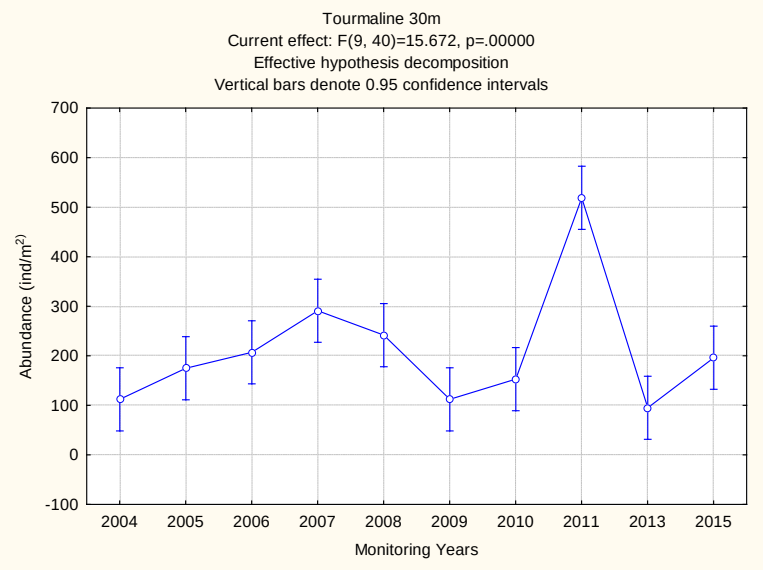

Desecheo 30m
Current effect: F(9, 40)=6.1089, p=.00002
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
900
800
700
600
500
400
300
200
100
0
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

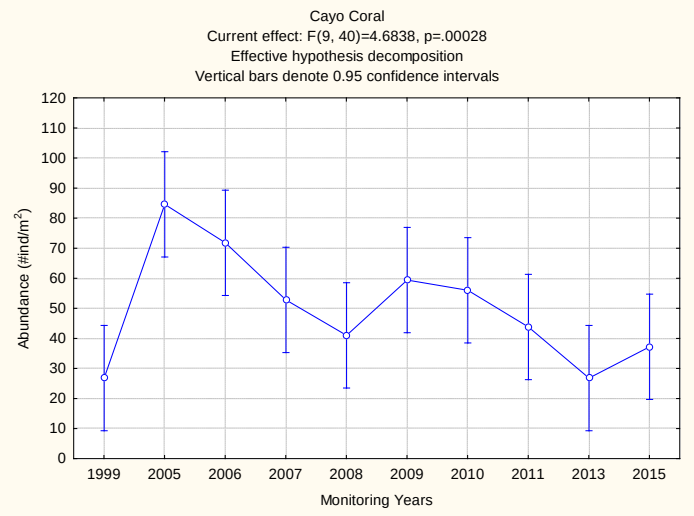

Desecheo 20m
Current effect: F(10, 44)=2.4116, p=.02197
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
400
350
300
250
200
150
100
50
2000
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

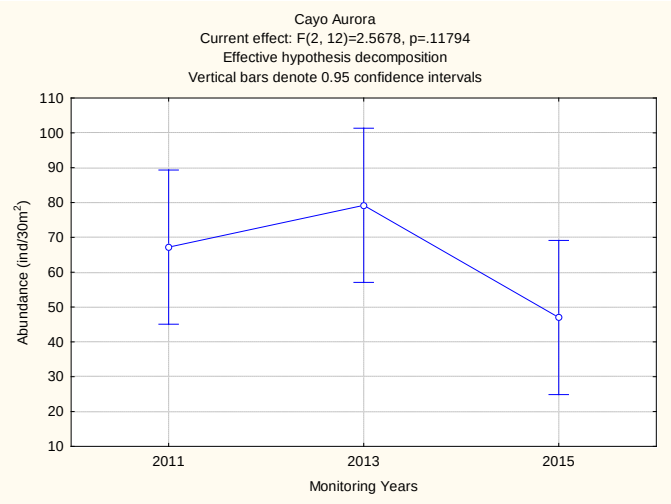

Desecheo 15m
Current effect: F(9, 40)=4.5731, p=.00035
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
400
350
300
250
200
150
100
50
0
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

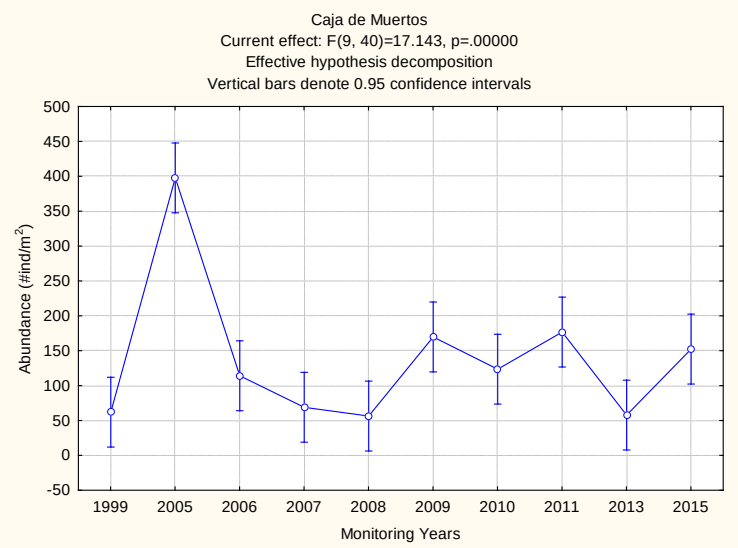

Tourmaline 10m
Current effect: F(10, 44)=.81251, p=.61808
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/m2)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
1999
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

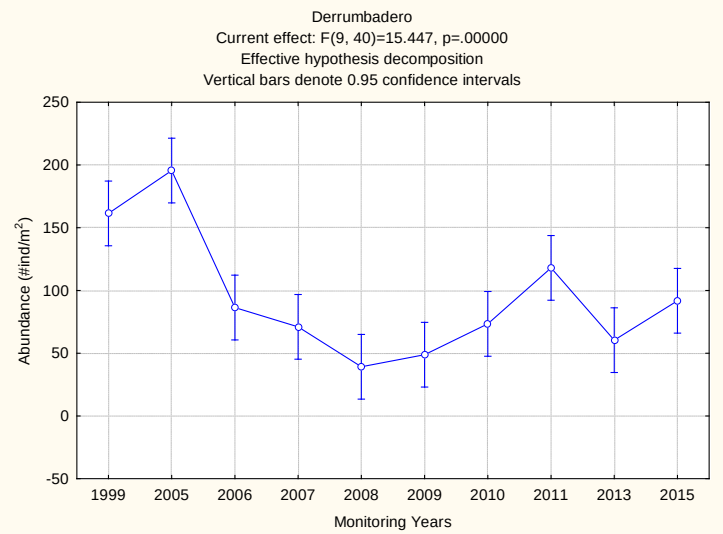

Tourmaline 20m
Current effect: F(9, 40)=20.868, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/m2)
500
450
400
350
300
250
200
150
100
50
0
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

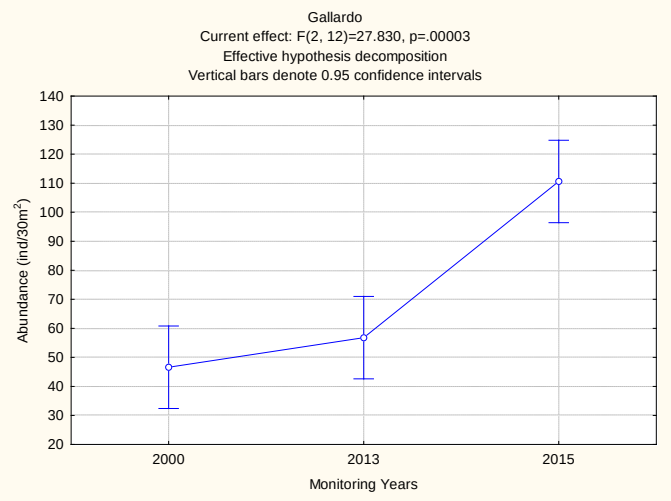

Tourmaline 30m
Current effect: F(9, 40)=15.672, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/m2)
700
600
500
400
300
200
100
0
-100
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

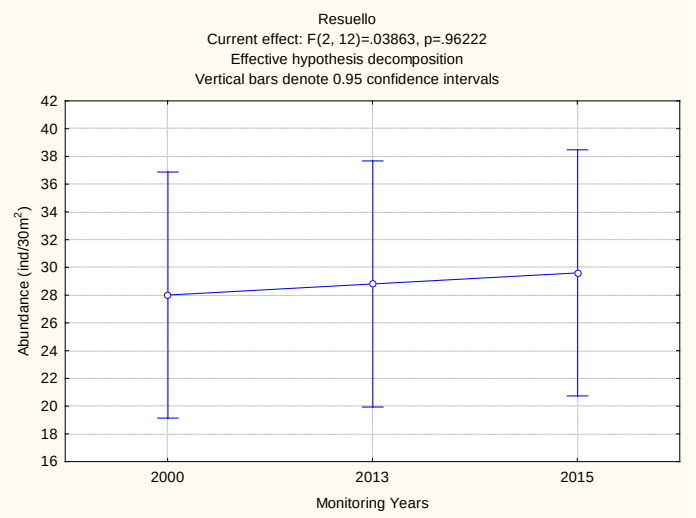

Cayo Coral
Current effect: F(9, 40)=4.6838, p=.00028
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
120
110
100
90
80
70
60
50
40
30
20
10
0
1999
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

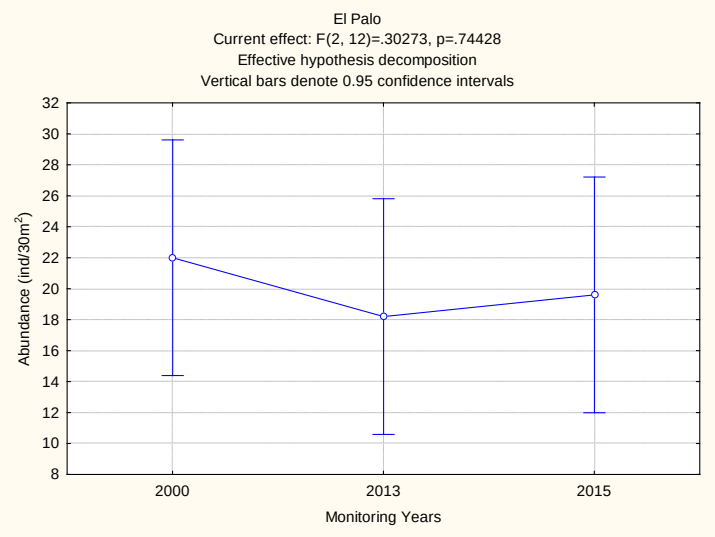

Cayo Aurora
Current effect: F(2, 12)=2.5678, p=.11794
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/30m2)
110
100
90
80
70
60
50
40
30
20
10
2011
2013
2015
Monitoring Years


Caja de Muertos
Current effect: F(9, 40)=17.143, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
500
450
400
350
300
250
200
150
100
50
0
-50
1999
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

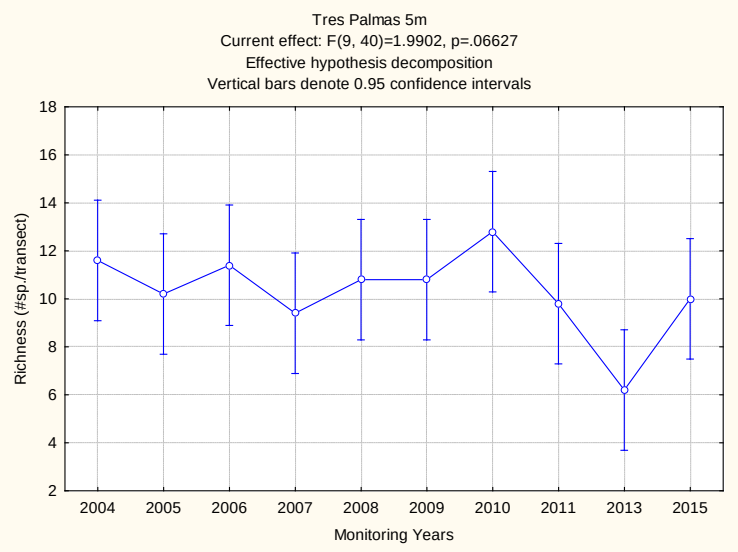

Derrumbadero
Current effect: F(9, 40)=15.447, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
250
200
150
100
50
0
-50
1999
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

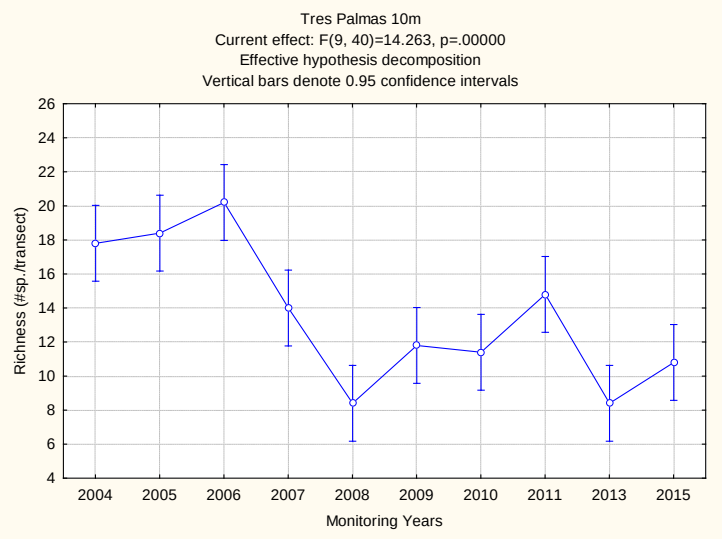

Gallardo
Current effect: F(2, 12)=27.830, p=.00003
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/30m2)
140
130
120
110
100
90
80
70
60
50
40
30
20
2000
2013
2015
Monitoring Years

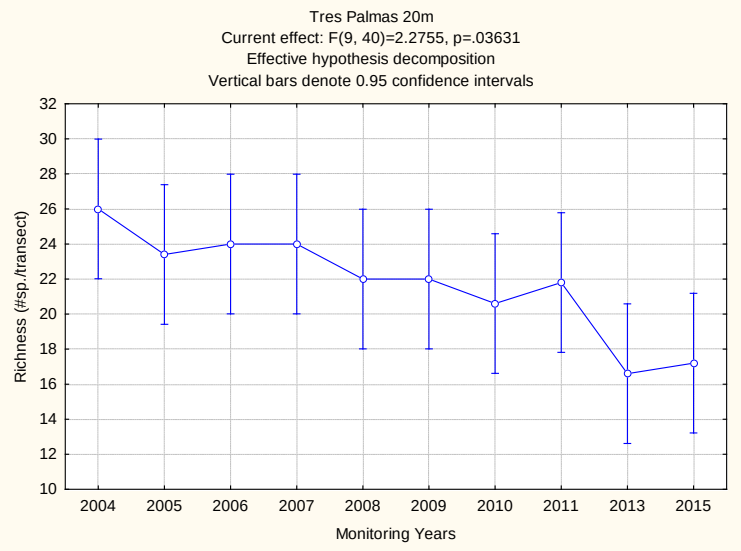

Resuello
Current effect: F(2, 12)=.03863, p=.96222
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/30m2)
42
40
38
36
34
32
30
28
26
24
22
20
18
16
2000
2013
2015
Monitoring Years

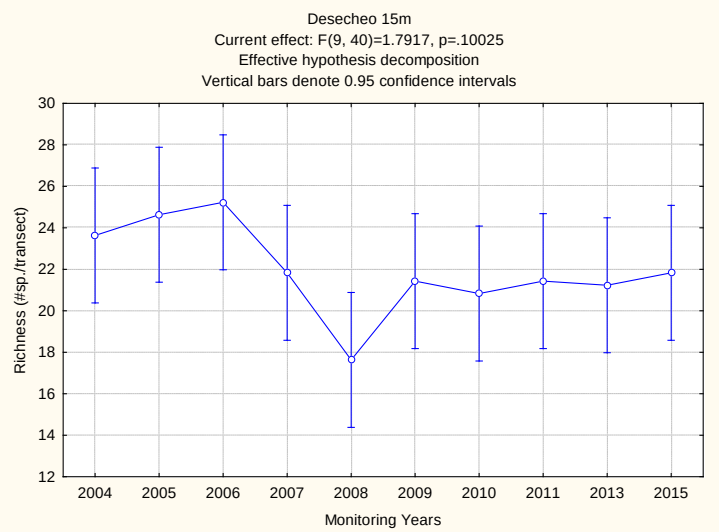

El Palo
Current effect: F(2, 12)=.30273, p=.74428
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/30m2)
32
30
28
26
24
22
20
18
16
14
12
10
8
2000
2013
2015
Monitoring Years

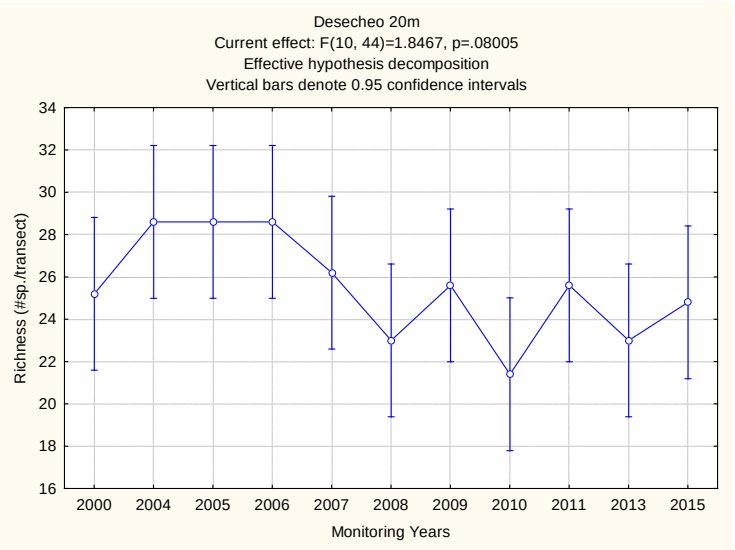
Appendix 4. Fish Species Richness ANOVAS

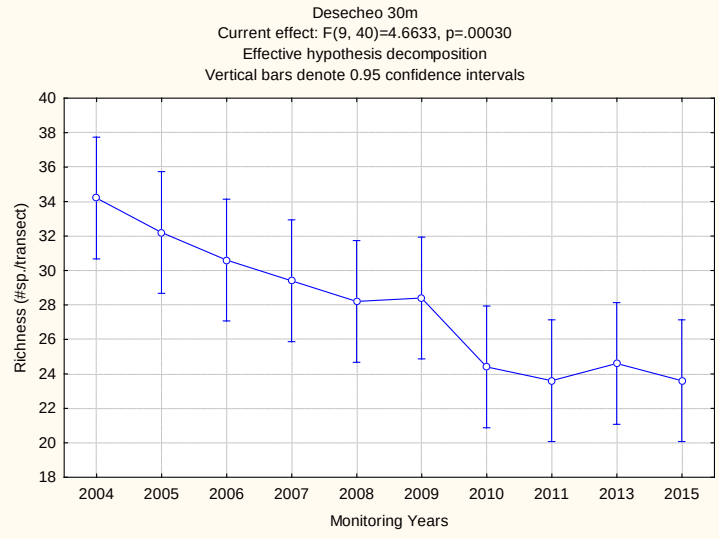


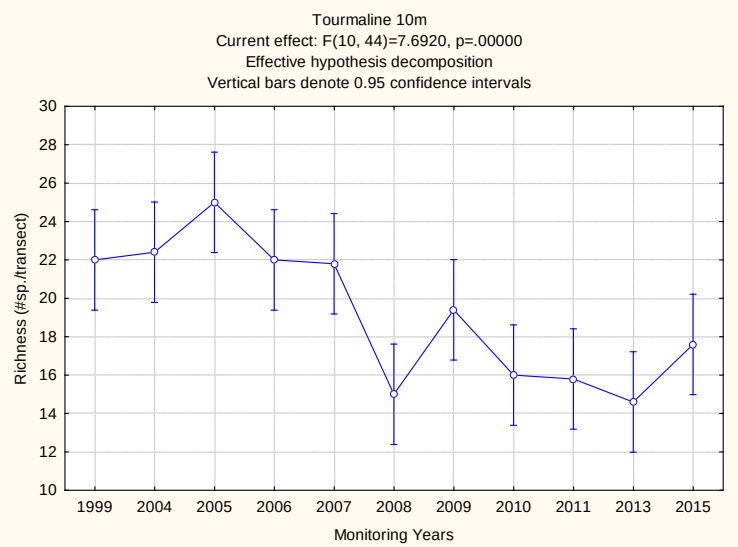


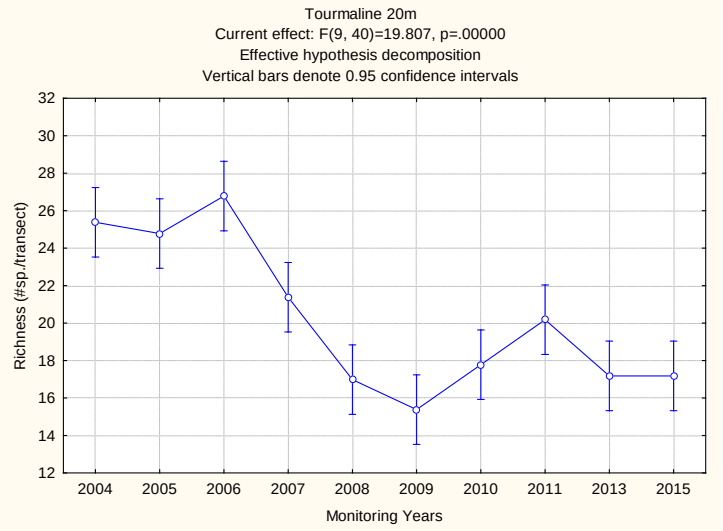


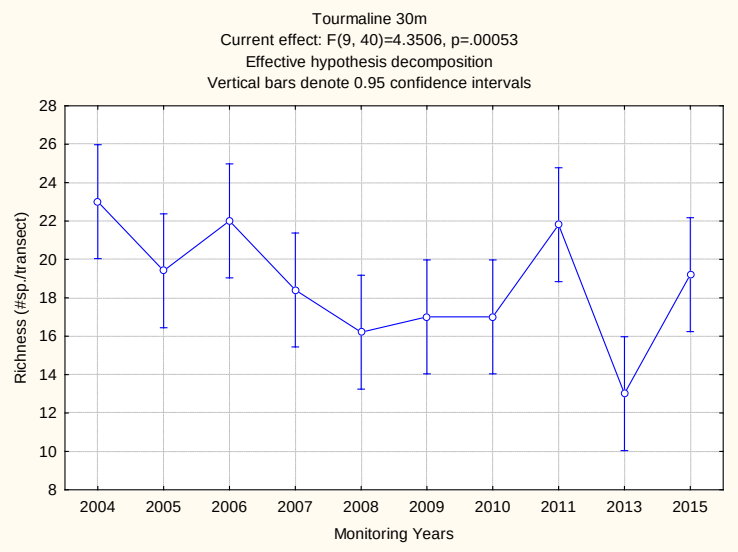

Desecheo 15m
Current effect: F(9, 40)=1.7917, p=.10025
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
30
28
26
24
22
20
18
16
14
12
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

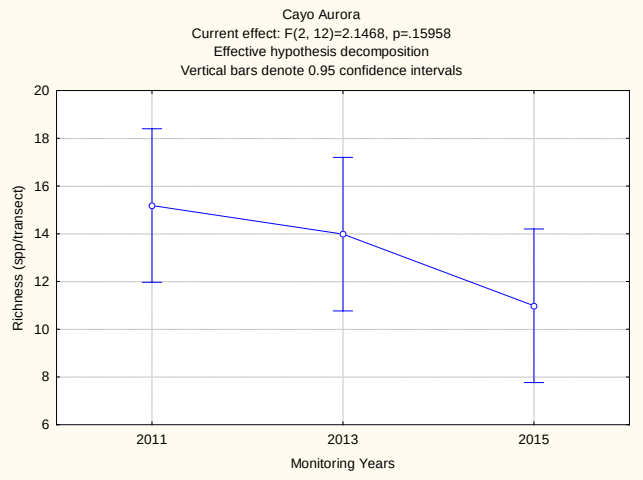

Desecheo 20m
Current effect: F(10, 44)=1.8467, p=.08005
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
34
32
30
28
26
24
22
20
18
16
2000
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

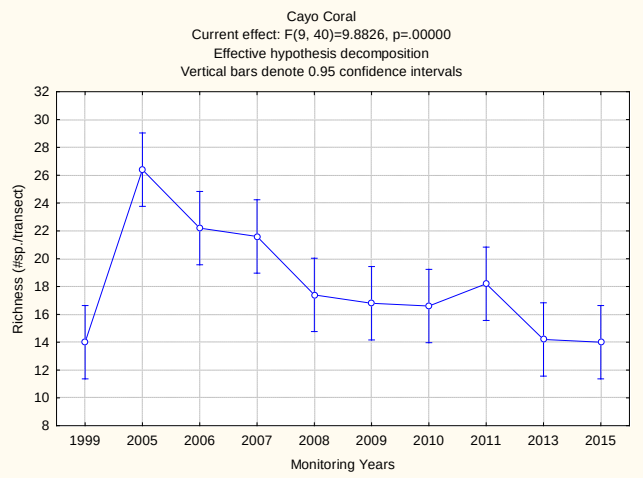

Desecheo 30m
Current effect: F(9, 40)=4.6633, p=.00030
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
40
38
36
34
32
30
28
26
24
22
20
18
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

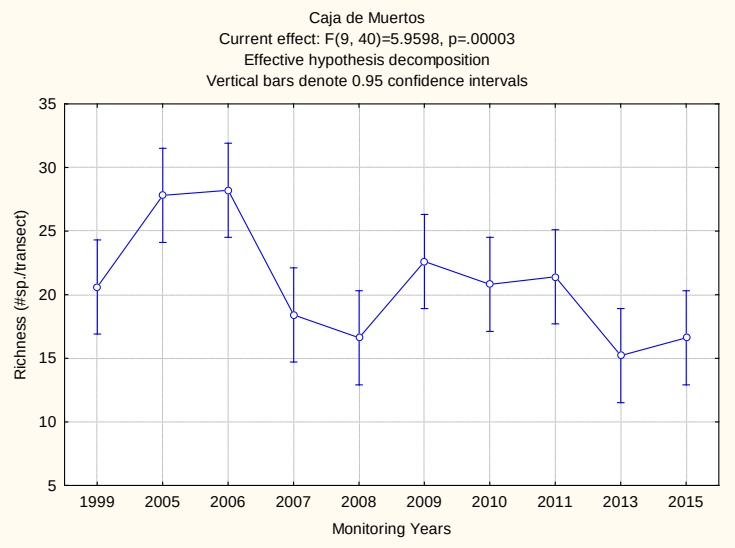

Tourmaline 10m
Current effect: F(10, 44)=7.6920, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
30
28
26
24
22
20
18
16
14
12
10
1999
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

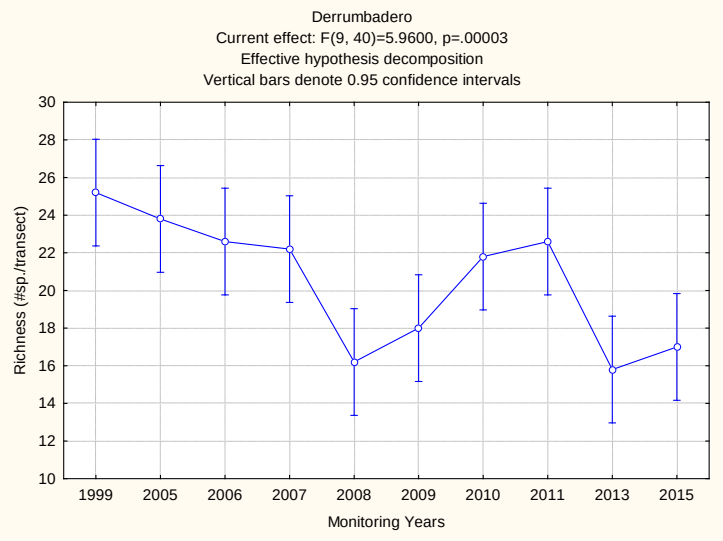

Tourmaline 20m
Current effect: F(9, 40)=19.807, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
32
30
28
26
24
22
20
18
16
14
12
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

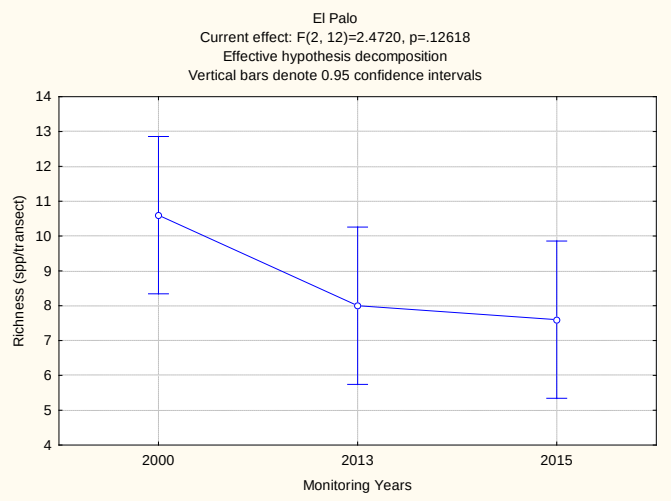

Tourmaline 30m
Current effect: F(9, 40)=4.3506, p=.00053
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
28
26
24
22
20
18
16
14
12
10
8
2004
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years

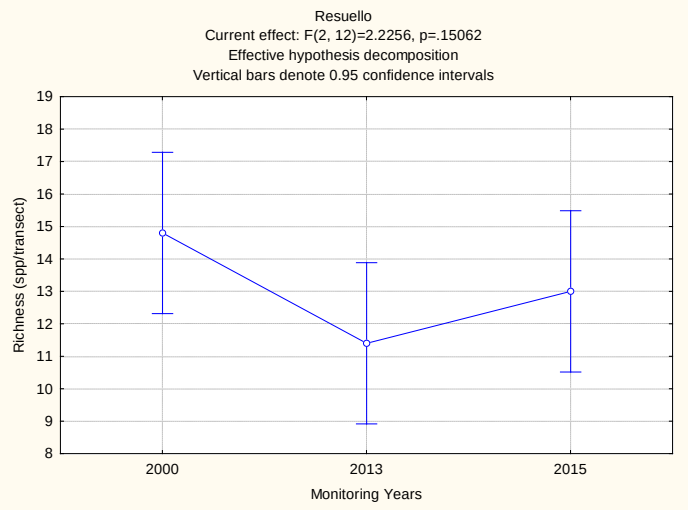

Cayo Aurora
Current effect: F(2, 12)=2.1468, p=.15958
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (spp/transect)
20
18
16
14
12
10
8
6
2011
2013
2015
Monitoring Years

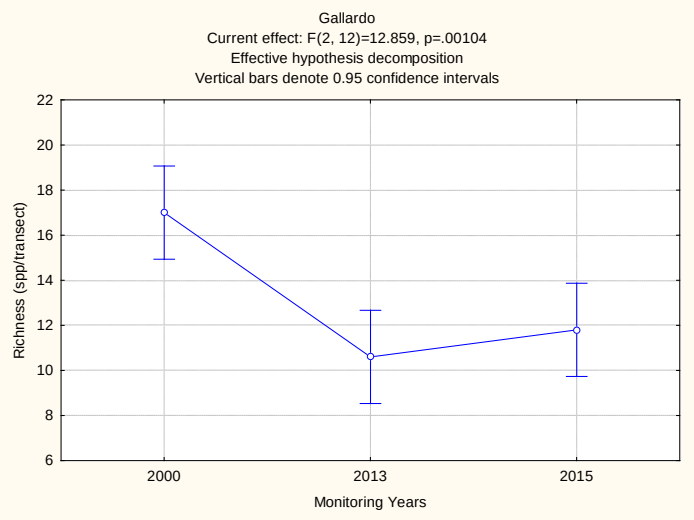

Cayo Coral
Current effect: F(9, 40)=9.8826, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
32
30
28
26
24
22
20
18
16
14
12
10
8
1999
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years


Caja de Muertos
Current effect: F(9, 40)=5.9598, p=.00003
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
35
30
25
20
15
10
5
1999
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years


Derrumbadero
Current effect: F(9, 40)=5.9600, p=.00003
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
30
28
26
24
22
20
18
16
14
12
10
1999
2005
2006
2007
2008
2009
2010
2011
2013
2015
Monitoring Years


El Palo
Current effect: F(2, 12)=2.4720, p=.12618
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (spp/transect)
14
13
12
11
10
9
8
7
6
5
4
2000
2013
2015
Monitoring Years


Resuello
Current effect: F(2, 12)=2.2256, p=.15062
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (spp/transect)
19
18
17
16
15
14
13
12
11
10
9
8
2000
2013
2015
Monitoring Years


Gallardo
Current effect: F(2, 12)=12.859, p=.00104
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (spp/transect)
22
20
18
16
14
12
10
8
6
2000
2013
2015
Monitoring Years