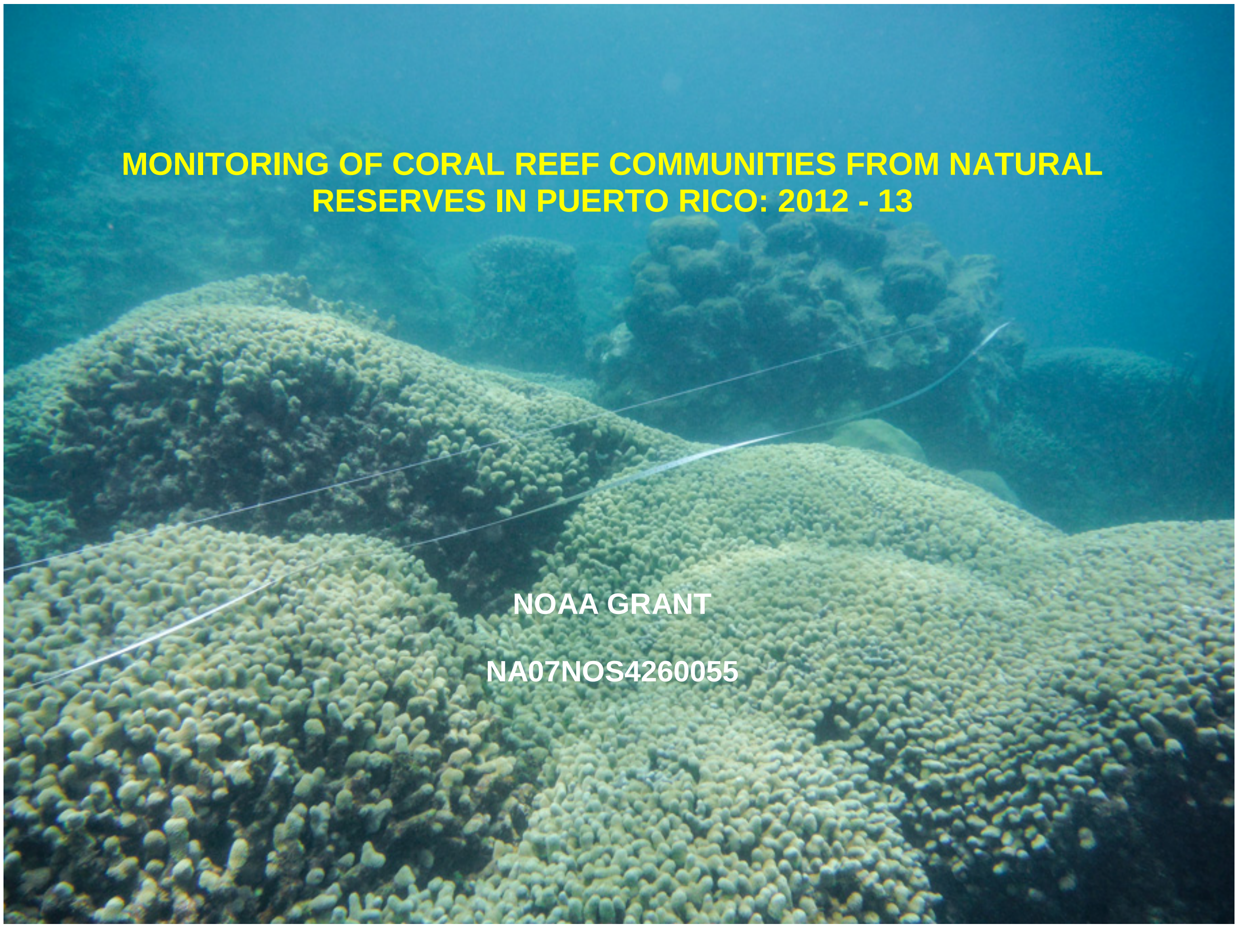
FINAL REPORT



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I Executive Summary

A total of 24 reefs from 10 Natural Reserves (Desecheo, Rincón, Mayaguéz, Guánica, Caja de Muerto, Ponce, Guayama, Cabo Rojo, Vega Baja and Vieques), including baseline characterizations at Gallardo Reef, Cayo Caribes, Guayama Shelf-Edge and Guayama Patch Reef were included in the 2013 National 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 and abundance were performed along sets of five replicate permanent transects at each reef. The coral reef monitoring program is based on a stratified depth and distance from shore, non-random, sampling design, with 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), Tourmaline Reef (Mayaguez), Cayo Coral (Guánica), West Reef (Caja de Muerto – Ponce), Derrumbadero Reef (Ponce), and the Canjilones and Boya Esperanza Reefs (Vieques) presented statistically significant differences of live coral cover between annual surveys during the monitoring program 2000 - 2013. 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 and the shallow reefs of Vieques were the most affected by the 2005 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 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 involve alternations of dominant coral species due to increased cover by growth and colonizations of dead coral substrates by branching corals (Tourmaline 10, Des 15, 20) and/or differential (statistically sugnifficant) reductions of cover by previously dominant corals (Boya Esperanza, Canjilones, Derrumbadero). From our new 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 very high cover by *O. annularis* on a shallow coastal reef (Guayama Patch Reef 5m) are in support of the contention that turbid water and depth acted in protection of corals (particularly *O. annularis)* during the 2005 event, 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*.

Between 2009 and the present 2013 monitoring survey a mild yet consistent recuperation of live coral cover, in most cases driven by growth of *Orbicella annularis* has been measured in some reefs (e.g. Cayo Coral, Desecheo 30m and 15 m, Tourmaline 30m, 20m and 10m), whereas recuperation has not been observed in others (e.g. Desecheo 20, Derrumbadero, Caja de Muerto). The *Acropora palmata* fringing reef of Tres Palmas in Rincon is infected by white band didsease and what appears to be white pox, an infectious disease also known as "patchy necrosis". The infection prevalence in colonies is very high (>80%) and although active growth by *A. palmata* is evident, given favorable conditions for the disease massive coral mortality can be expected. From the present (2013) baseline characterization of the Elkhorn coral reef at Gallardo we can infer that the reef has been exposed to severe degradation caused by mechanical (possibly wave action) damage as there are massive deposits of broken elkhorn coral fragments across the reef. Also, Elkhorn Corals at this reef appear to be impacted by predatory pressure by corallivorous gastropods.

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 zooplanktivore assemblages (*Chromis spp*., Creole Wrasse, Masked Goby, Bicolor Damselfish) and coastal reefs, dominanted by herbivorous assembalges (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.

Although in low abundance, large demersal (top predator) fishes have been observed during ASEC 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*).

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II Introduction

This is the final report corresponding to the 2012-13 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 and abundance of fishes and motile megabenthic invertebrates from a total of 24 reef stations within 10 Natural Reserve sites in Puerto Rico (Isla Desecheo, Rincon, Mayaguez, Guánica, Isla Caja de Muertos, Cabo Rojo, Vieques, Vega Baja, Guayama, and Ponce). Initial baseline characterization surveys for these sites were performed during 1999 – 2001 (García-Sais et al., 2001a,b,c). This report also includes baseline characterizations of 3 reef stations within the Jobos Bay Reserve (JOBANERR), Guanica Shelf-edge in Guanica, and Gallardo Reef in Cabo Rojo, and provides monitoring surveys at reefs in Vieques and Cabo Rojo that had not been surveyed in the last 9 - 13 years. Summarized time series data for all reef sites are here presented and analyzed. Detailed monitoring data is included only for the most recent 2012-13 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). 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. 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). Sybling 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 two consequtive years of measuring what appered to be lingering effects of the 2005 coral bleaching event, subtle increments of live coral cover were measured in the 2008-09, 2009 -10 and 2010-11 monitoring surveys (Garcia et al. 2008, 2009, 2010, 2012). Differences between years were not statistically significant, but the trend represented at least 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).

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 181 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). 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 24 reefs located within 10 Natural Reserves were included in the PR Coral Reef Monitoring Program 2012-13 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, and for three reefs within the Jobos Bay Natural Reserve (JOBANERR) in Salinas/Guayama, including Cayo Caribes, and the Guayama Reef system. Reef stations within these new sites have been 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). This 2013 survey includes the first monitoring effort of El Palo and Resuellos Reefs in Cabo Rojo after their baseline characterization during 2000, and the second monitoring run of the Canjilones and Boya Esperanza Reef systems in Vieques after the last monitoring survey in 2004 (Garcia-Sais et al (2004), before the 2005 regional coral bleaching event.

Sessile-benthic reef communities

At each reef, a set of five 10 m long transects were surveyed. Transects were permanently marked with metal rods drilled 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.

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

Large, elusive fish populations, which includes most of the commercially important and many recreationally valuable populations were surveyed using an Active Search Census (ASEC) technique. This is a non-random, fixed-time method designed to optimize information of the numbers of fish individuals present at each of the main reef habitats, providing simultaneous information on size frequency distributions. At each reef station, the total number of individuals of each particular species observed within a fixed time frame of 30 minutes was registered. Individuals were actively searched for in the water column and within crevices, ledges and potentially important hiding places. For each individual sighted, a length estimate was recorded. Length (in cms) was visually estimated and aided by a measuring rod with adjustable width. Precision of length estimates allowed discrimination between new recruits, small juveniles, juveniles, adult and large adult size classes. One ASEC survey was performed at each reef station included in this monitoring cycle. 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 2010-11

Site/Reef Stations		Depth (m)	Latitude (°N)	Longitude (°W)
Isla Desecheo				
	Canoas	30	18°22.7060	67°29.1990
	Botes	20	18°22.8950	67°29.3160
	Botes	15	18°22.9200	67°29.3000
Mayaguez				
	Tourmaline	30	18°09.9850	67°16.5810
	Tourmaline	20	18°09.9100	67°16.5120
	Tourmaline	10	18°09.7919	67°16.4160
Rincon				
	Tres Palmas	20	18°20.7900	67°16.2480
	Tres Palmas	10	18°20.8320	67°16.2060
	Tres Palmas	3	18°21.0230	67°15.9590
Ponce				
	Derrumbadero	20	17°54.2400	66°36.5159
Guanica				
	Shelf-Edge	20		
	Cayo Coral	10	17°56.1720	66°53.3040
	Cayo Aurora	3		
Caja de Muerto				
	West Reef	10	17°53.7000	66°31.7040
Vega Baja				
	Cibuco Reef	10	18°29.3460	66°22.4510
Isla de Vieques				
	El Seco	30	18°08.3214	65°11.8284
	Boya Esperanza	10	18°04.8320	65°29.2770
	Canjilones	15	18°05.3800	65°35.4130
Cabo Rojo				
	Gallardo	4		
	Rescuello	8	17°59.4700	67°13.9870
	El Palo	5	18°00.0340	67°12.6700
Guayama				
	Shelf-Edge	20	17°55.3912	66°07.9234
	Cayo Caribe	10	17°55.4435	66°12.0348
	Patch Reef	5	17°53.6668	66°05.6675

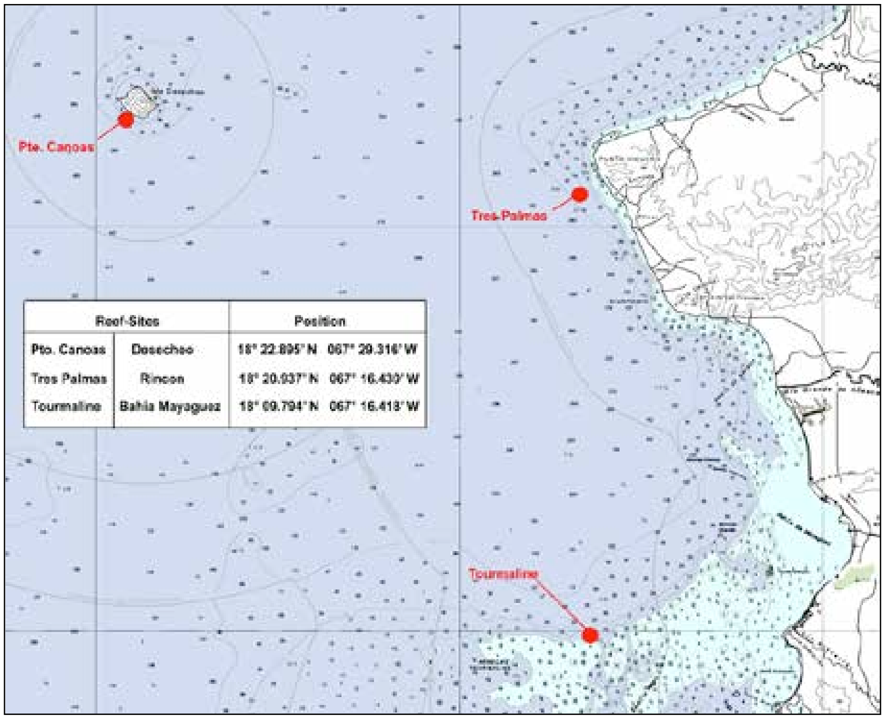


Figure 1. Location of west coast reef sites, Isla Desecheo, Mayaguez and Rincón

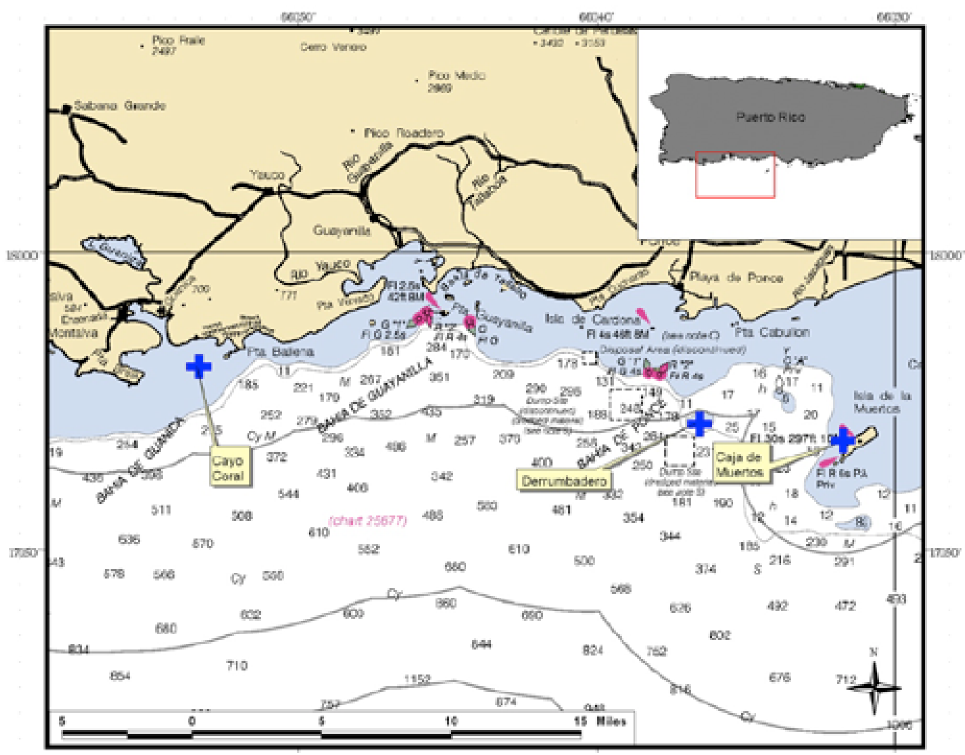


Figure 2. Location of south coast reef sites, Cayo Coral (Guánica), Derrumbadero and West Reef of Isla Caja de Muerto (Ponce)

Results

IV Baseline Characterization and Monitoring of Coral Reef Communities 2012-13

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

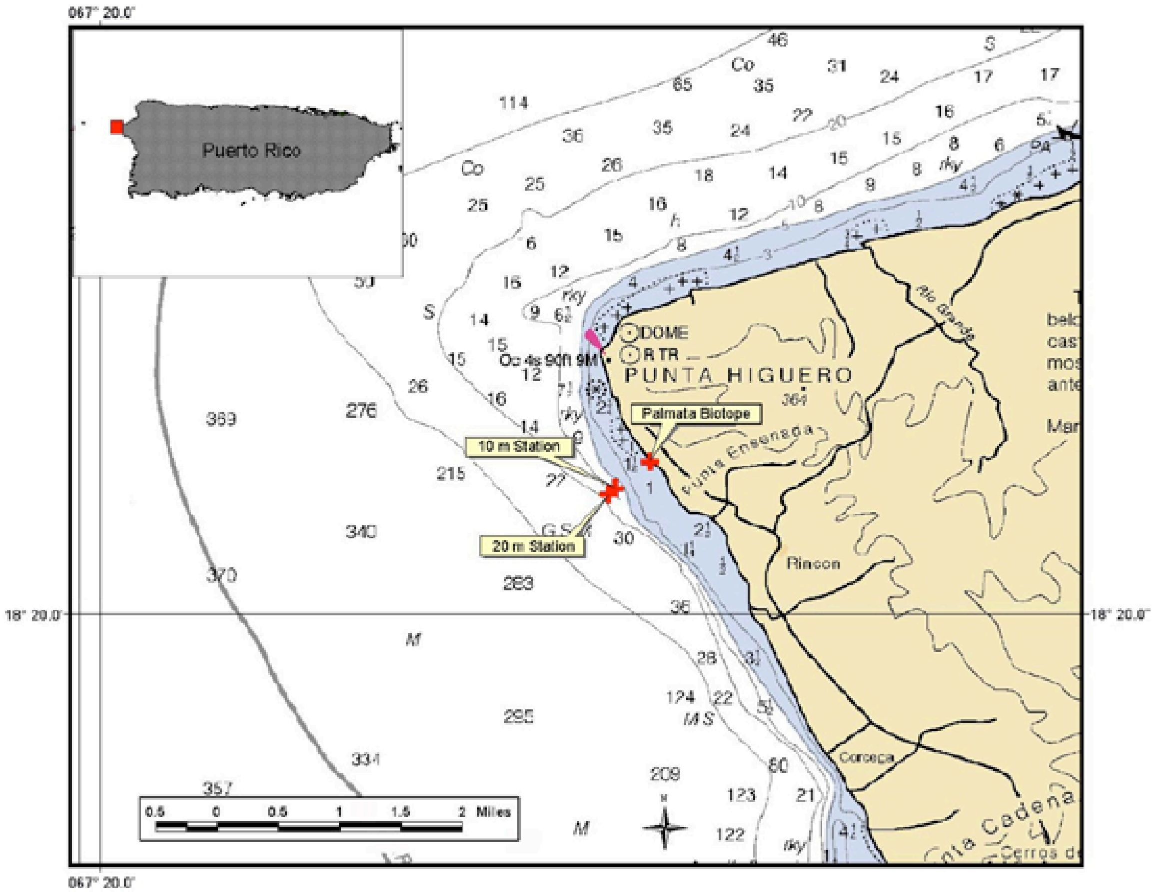


Figure 3. Location of coral reef monitoring stations off Tres Palmas, Rincón.

monitoring data for 2007-08 was gathered in error (out of transect lines) and removed from the data base. Reconstruction of the original transects was performed during the 2009 survey. During the present 2013 survey, transects 1 and 5 could not be found. These were reconstructed again in areas of optimal Elkhorn coral growth. Figure 3 shows the location of monitoring stations at the Tres Palmas Reef system in Rincón. 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 2013 survey are presented in Table 2. Live coral cover averaged 47.1% (range: 27.9 – 63.2 %). Elkhorn Coral (*A. palmata*) was the dominant species with a mean substrate cover of 44.2 % (range: 20.0 – 63.2 %), representing 93.8 % of the total live coral cover. Two additional coral species, Symmetrical Brain Coral (*Diploria strigosa*) and Mustard Hill Coral (Porites *astreoides*) were also intercepted by transects during this survey.

Table 2. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon. March 2014. Depth: 2 - 5 m.

	Transects					
	1	2	3	4	5	**MEAN**
Rugosity (m)	1.2	4.3	1.7	1.4	2.0	**2.1**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	15.2	11.3	19.8	22.0	7.6	**15.2**
Sand	1.1					**0.2**
Total Abiotic	16.3	11.3	19.8	22.0	7.6	**15.4**
Benthic Algae						
Turf-mixed assemblage	23.7	25.5	58.6	55.0	39.1	**40.4**
Total Benthic Algae	23.7	25.5	58.6	55.0	39.1	**40.4**
Live Stony Corals						
Acropora palmata	59.9	63.2	27.8	20.0	50.0	**23.6**
Diploria strigosa				8.8	3.3	**2.6**
Porites astreoides				2.5		**0.6**
Total Stony Corals	59.9	63.2	27.8	31.2	53.3	**47.1**

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*

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 by turf algae (mean cover: 40.4 %). Fleshy macroalgae (*Dictyota sp*., *Valonia sp., Stypopodium sp*.) and red coralline algae (*Amphiroa sp*.) were observed outside transect areas. The encrusting zoanthid, *Palythoa caribdea* and the encrusting gorgonian, *Erythropodium caribaeorum* were observed outside transects. Abiotic categories, associated with reef overhangs and sand occupied 15.4 % of the reef substrate. Vertically projected soft corals (gorgonian) were present but in very low abundance outside transects. This was expected in an environment seasonally affected by very strong wave action. The Common Sea Fan, *Gorgonia ventalina* and the Bent Sea Rod, *Plexaura flexuosa* were common in deeper sections of the forereef. Other erect gorgonian species observed out of transects included *Pseudopterogorgia americana*, *Plexaura homomalla*, *Muricea spp*. and *Eunicea spp.*

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 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 2013 survey.

Two new transets were established at the Tres Palmas fringing reef within the same study area to replace the ones that were dislodged and broken due to the extreme wave action conditions that impact the reef every year. Both transects had 50 % or more cover by live elkhorn coral, thus the increment of reef substrate cover by live coral is directly related to high live coral cover measured in the new line transects and do not imply new coral growth. Nevertheless, such high live coral cover measurements are indicative that elkhorn coral still retains sections of very high reef substrate cover.

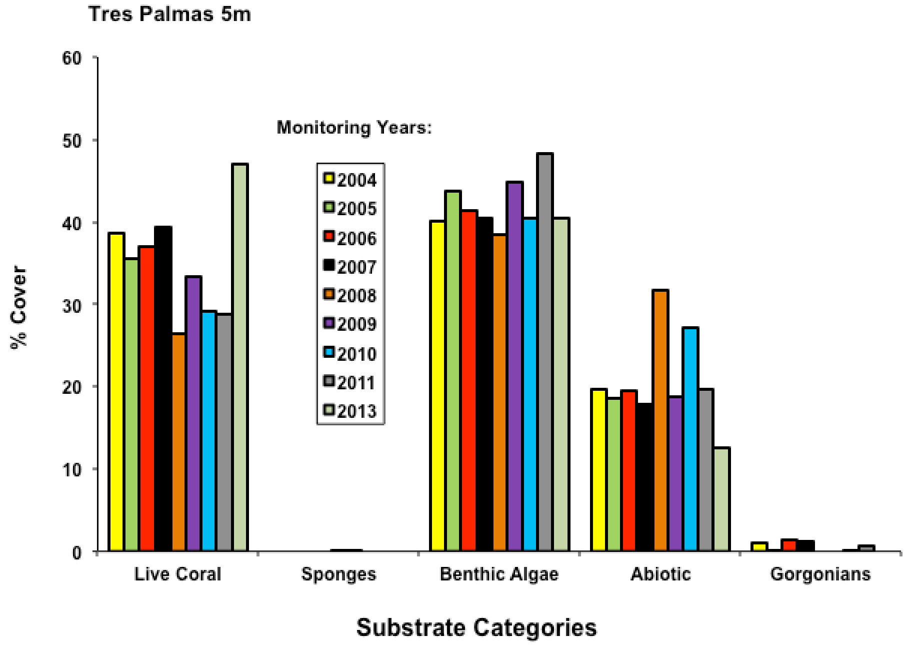


Figure 4. Monitoring trends (2004 – 2013) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon, 2 - 5 m depth.

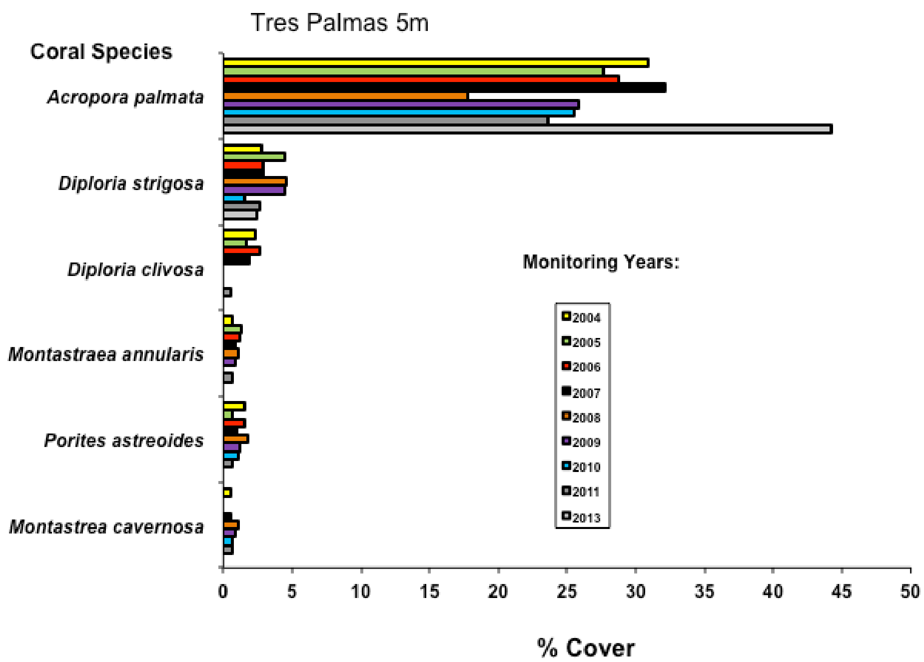


Figure 5. Monitoring trends (2004 – 2013) of mean substrate cover by stony coral species at Tres Palmas Reef, Rincon, 2 - 5 m depth.

1.2 Reef Fishes and Motile Megabenthic Invertebrates

A total of 74 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 2013 monitoring survey, 35 fish species, including 13 present within belt-transects were identified from the fringing reef. The mean abundance of individuals was 25.4 Ind/30 m^2 (range: 20 - 39 Ind/30 m^2), and the mean number of species per transect was 6.2 (range: 5 - 9). The combined abundance of three species represented 78.0 % of the mean abundance within belt-transects (Table 3). The most abundant species was the Dusky Damselfish (*Stegastes dorsopunicans*) with a mean of 9.4 Ind/30 m^2 followed by the Bluehead Wrasse (*Thalassoma bifasciatum*), and the Glass-eye Sweeper (*Pempheris schomburgki*). The Blue Tang, Sargent Major and Yellowtail Damselfish were observed in at least three transects. The aforementioned species have been consistently present at this reef and along with the Redlip Blenny, Clown Wrasse, Ocean Surgeon, Bermuda Chub and the Yellowtail and Stoplight Parrotfishes appear to comprise the main resident demersal fish assemblage of the reef. Large schools of Blue Tangs were observed in transit outside transect areas. Smaller schools of juvenile grunts, yellow goatfishes and parrotfishes were also common.

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 our survey performed on March 2014. Typically when the physical conditions are adverse, both fish abundance and species richness decline.

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*

Table 3. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef 5m, Rincon. March 2014. Depth: 2-5 m

Depth: 5m		TRANSECTS					
		1	2	3	4	5	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Stegastes dorsopunicans	Dusky Damselfish	12	8	11	8	8	**9.4**
Thalassoma bifasciatum	Bluehead Wrasse	5	8	3	4	12	**6.4**
Pempheris schomburgki	Glasseye Sweeper	0	0	20	0	0	**4.0**
Abudefduf sexatilis	Sargent Major	3	2	0	2	0	**1.4**
Acanthurus coeruleus	Blue Tang	2	1	2	1	1	**1.4**
Microspathodon chrysurus	Yellowtail Damselfish	0	1	0	1	2	**0.8**
Caranx ruber	Bar Jack	0	0	2	0	1	**0.6**
Kyphosys sectatrix	Bermuda Chub	0	1	0	1	0	**0.4**
Epinephelus cruentatus	Graysby	1	0	0	0	0	**0.2**
Sparisoma aurofrenatum	Redband Parrotfish	0	0	1	0	0	**0.2**
Sparisoma rubripinne	Yellowtail Parrotfish	0	0	0	1	0	**0.2**
Haemulon flavolineatum	French Grunt	0	0	0	1	0	**0.2**
Sparisoma viride	Stoplight Parrotfish	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	23	21	39	20	24	**25.4**
	TOTAL SPECIES	5	6	6	9	5	**6.2**

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. Large (adult) commercially important demersal fishes (snappers, groupers, hogfishes) were not observed. Juvenile stages of snappers (*Lutjanus analis, L. apodus, L. synagris*) were observed during the 2013 ASEC survey (Table 4), and during previous surveys (García-Sais et al., 2004 a, 2005, 2006, 2007, 2009, 2010, 2012), 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

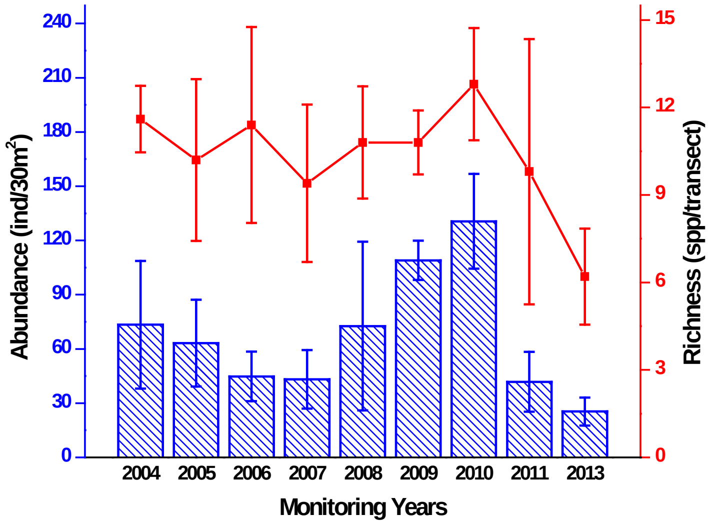


Figure 6. Monitoring trends (2004 – 2013) of fish species richness and abundance at Tres Palmas Elkhorn Coral Reef, 2-5 m, Rincon.

Table 4. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at the fringing Elkhorn Coral Reef of Tres Palmas Reef, Rincón. Survey Date: March 2014

Depth range : 2 – 5 m Duration – 30 min.

SPECIES	**COMMON NAME**		# - (cm)
Caranx crysos	Blue Runner	4 – (20)	1 – (30)
Lutjanus analis	Mutton Snapper	1 – (20)	
Lutjanus apodus	Schoolmaster	4 – (10)	2 – (20)
Ocyurus chrysurus	Yellowtail Snapper	2 – (15)	
Sphyraena barracuda	Great Barracuda	1 – (40)	

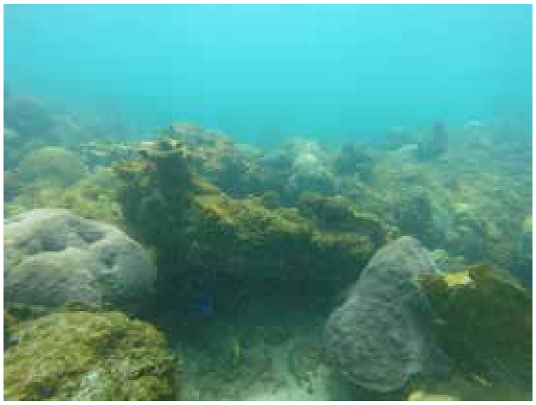
species. One Hawksbill Turtle (*Eretmochelys imbricata*) was reported during the 2004 baseline survey (García-Sais et al., 2004a).

Motile megabenthic invertebrates observed within belt-transects during the 2013 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, March 2014

		TRANSECTS					**MEAN**
Depth: 2 - 5 m		**1**	**2**	**3**	**4**	**5**	**ABUNDANCE (IND/30 m2)**
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 (Rincon 5m)
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 surveyed 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 18 species present and a mean density of 23.6 col./transect (range: 19 – 27 col./transect) (Table 6). The most abundant taxa included the Common Sea Fan *Gorgonia ventalina,* Sea Rods, *Eunicea spp,* Sea Plumes *Pseudopterogorgia acerosa, P. americana*, and *Plexaura spp*.

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 10 species intercepted by line transects. Live stony coral cover averaged 12.1 % (range: 9.8 – 16.6 %). Mustard-Hill Coral, *Porites astreoides* and Boulder Star Coral, *Orbicella annularis* were the dominant species in terms of substrate cover with means of 4.4 and 3.4%, respectively. The large increment of cover by *Montastraea cavernosa* reported during the 2011 survey was an error caused by the prevailing surge. Cover of *M. cavernosa* averaged 1.1 % within the range of reports previous to 2011. A total of 8 coral species were represented with less than 2% reef substrate cover.

Table 6. Percent substrate cover by sessile-benthic categories at the Tres Palmas outer shelf reef 10 m during May 2013.

	Transects					
Depth: 10 m	1	2	3	4	5	**Mean**
Rugosity (m)	4.60	3.06	3.80	1.76	2.40	**3.12**
SUBSTRATE CATEGORY						
Abiotic						
Sand	29.8	12.4	9.6	11.9	8.2	**14.3**
Reef Overhang	1.6	3.3		3.6	2.1	**2.1**
Rubble			1.1			**0.2**
Total Abiotic	**31.4**	**15.8**	**10.8**	**15.5**	**10.4**	**16.8**
Benthic Algae						
Turf	25.8	28.9	46.3	29.8	33.5	**32.8**
Dictyota spp.	15.1	33.2	22.0	34.6	29.6	**26.7**
Lobophora spp.	6.1	6.2	4.4	2.5	6.9	**5.0**
Crustose coralline algae		1.7		2.4	2.3	**1.1**
Padina spp.		0.9			0.2	**0.2**
Total Benthic Algae	**47.1**	**70.9**	**72.7**	**69.3**	**72.5**	**65.9**
Sponges						
Xestospongia muta	4.7					**0.9**
Haliclona spp.	2.3	0.5	0.3			**0.6**
Aplysina cauliformis		0.9	0.7	1.0		**0.5**
Agelas citrina			0.6		1.6	**0.4**
Aplysina insularis	1.3	0.2		0.4		**0.4**
Agelas sceptrum		0.8	0.2		0.5	**0.3**
Agelas conifera	1.0			0.4		**0.3**
Aiolochoria crassa		1.3				**0.3**
Agelas dispar				1.7		**0.2**
Ecytoplasia ferox	0.8					**0.2**
Amphimedon compressa		0.3	0.1			**0.1**
Prosuberites laughlini	0.3					**0.1**
Spirastrella coccinea	0.3					**0.1**
Amphimedon compressa black		0.2				**0.0**
Scopalina ruetzleri		0.2				**0.0**
Total Sponges	**10.6**	**4.4**	**2.0**	**3.4**	**2.0**	**4.5**
Cyanobacteria	1.7		0.9	1.2	4.2	**1.6**
Erect Gorgonians	**25**	**27**	**24**	**19**	**23**	**23.6**
Live Stony Corals						
Porites astreoides	3.7	7.7	6.9	4.4	1.2	**4.4**
Orbicella annularis	0.8		8.0	2.4	6.8	**3.4**
Montastraea cavernosa	0.4			1.9	3.4	**1.1**
Siderastrea siderea	4.1	0.3				**0.9**
Agaricia agaricites	0.2	1.0		1.4	0.2	**0.6**
Diploria strigosa	0.5		0.9		0.7	**0.4**
Madracis decactis	0.2	0.8		1.0		**0.4**
Millepora alcicornis			0.8			**0.2**
Leptoseris cucullata		0.5				**0.1**
Porites porites				0.2		**0.0**
Total Stony Corals	**9.8**	**10.3**	**16.6**	**11.4**	**12.2**	**12.1**

Turf algae, a mixed assemblage of short filamentous red and brown macroalgae presented the highest percent of reef substrate cover by sessile-benthic components with a mean of 32.8 % (range: 25.8 – 46.3 %). Fleshy brown (*Dictyota sp.*), red (*Galaxaura sp.*) and calcareous (*Halimeda discoidea*) macroalgae were present within transects with a combined cover of 33.0 %, a drastic increment driven by colonization of brown macroalgae (*Dictyota sp.* + *Lobophora sp.*) . Encrusting sponges were intersected by all five transects with a mean substrate cover of 4.5 % (range: 2.0 – 10.6 %). A total of 15 species were identified within transects (Table 6). The encrusting gorgonian, *Erythropodium caribaeorum* and the encrusting zoanthid, *Palythoa caribbea,* were observed outside transects. Total abiotic cover averaged 16.8 %, an 8-fold increment from the 2.1 % reported in 2012. Such increment was largely associated with sand transport and deposits over the mostly flat reef relief. Reef rugosity, which is an indicator of underwater topographic relief, was 1.9 m.

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 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. Small annual variations of the mean reef substrate cover by (total) live corals between monitoring surveys (2004 – 2013) at this reef were not statistically significant (ANOVA; $p = 0.473$). Analysis of variance procedures and graphs comparing variations of live coral cover between annual monitoring surveys are presented in Appendix 2.

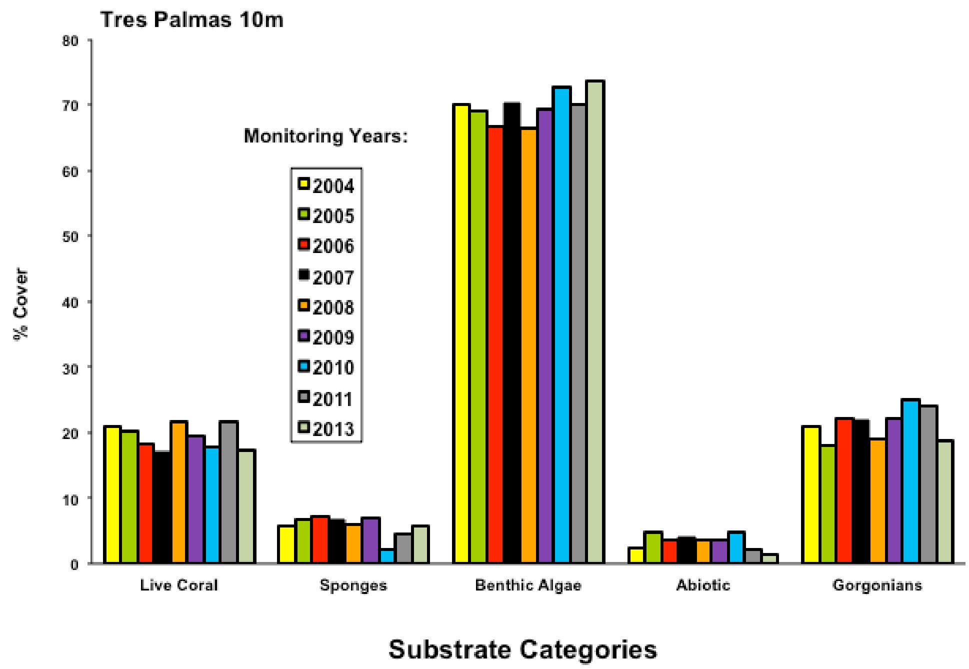


Figure 7. Monitoring trends (2004 – 2013) of mean substrate cover by sessile-benthic categories at Tres Palmas Outer Patch Reef – 10 m.

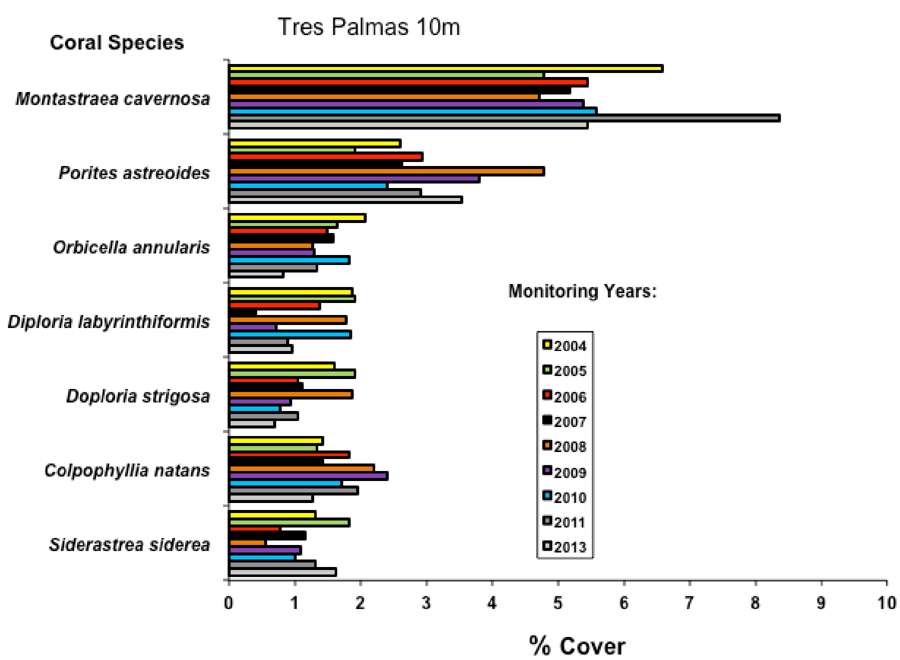


Figure 8. Monitoring trends (2004 – 2013) of mean substrate cover by stony coral species at Tres Palmas Outer Patch Reef – 10 m.

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 2012-13 survey, mean abundance of individuals within belt-transects was 32.8 Ind/30 m^2 (range: 8 - 52 Ind/30 m^2). The mean number of species per transect was 8.4 (range: 5 - 10).

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 11.2 and 9.6 Ind/30 m^2, respectively (Table 7). The combined abundance of these two species represented 63.4 % of the community mean abundance within belt-transects. In addition to the two aforementioned species, the Coney, Doctorfish, Redband Parrotfish 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 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 were observed over sandy bottom at the base of the wall during the ASEC survey (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 and the present 2013 survey (Figure 9). 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. Although differences observed during the monitoring program were in the 2-fold range for species richness and in the 3-fold range for mean abundance neither of these variations were statistically significant due to the relatively high variability within transects (Appendix 3 – 4).

Table 7. Taxonomic composition and abundance of fishes surveyed within belt-transects at the outer shelf reef of Tres Palmas, Rincon 10m during May 2013

Depth: 10m

		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Stegastes partitus	Bicolor Damselfish	3	19	9	13	12	**11.2**
Thalassoma bifasciatum	Bluehead Wrasse	0	6	0	22	20	**9.6**
Gobiosoma evelynae	Sharknose Goby	1	3	1	8	0	**2.6**
Cephalopholis fulva	Coney	2	3	0	3	1	**1.8**
Acanthurus chirurgus	Doctorfish	0	2	2	2	1	**1.4**
Halichoeres maculipinna	Clown Wrasse	0	3	0	2	1	**1.2**
Sparisoma aurofrenatum	Redband Parrotfish	1	1	2	0	1	**1**
Chromis cyanea	Blue Chromis	0	2	2	0	0	**0.8**
Sparisoma viride	Stoplight Parrotfish	0	0	0	0	3	**0.6**
Epinephelus guttatus	Red Hind	1	0	1	0	1	**0.6**
Scarus taeniopterus	Princess Parrotfish	0	0	0	1	1	**0.4**
Chaetodon capistratus	Four eye Butterflyfish	0	0	2	0	0	**0.4**
Serranus tigrinus	Harlequin Bass	0	1	0	0	0	**0.2**
Microspathodon chrysurus	Yellowtail Damselfish	0	0	0	0	1	**0.2**
Holocentrus rufus	Squirrelfish	0	1	0	0	0	**0.2**
Chaetodon striatus	Banded Butterflyfish	0	0	1	0	0	**0.2**
Canthigaster rostrata	Caribbean Puffer	0	0	0	1	0	**0.2**
Acanthurus coeruleus	Blue Tang	0	0	1	0	0	**0.2**
	TOTAL INDIVIDUALS	8	41	21	52	42	**32.8**
	TOTAL SPECIES	5	10	9	8	10	**8.4**

Table 8. Size-frequency distribution of commercially important reef fishes and shellfishes identified during an ASEC survey at the Tres Palmas, Rincon 10 m outer shelf reef during May 2013.

Species	
Ocyurus chrysurus	2-11"
Caranx crysos	
Lutjanus mahogany	2 – 10”
Lutjanus synagris	3- 10”, 1 – 12”
Pterois volitans	12"
Epinephelus guttatus	10",11"
E. imbricata	32"
D americana	30"

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 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*) were present (Table 8). Large (adult) commercially important demersal fishes were not observed.

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., 2006). Cleaner Shrimps and one Arrow Crab were observed within belt-transects during the present 2013 survey (Table 9).

Table 9. Taxonomic composition and abundance of motile megabenthic invertebrates Surveyed within belt-transects at Tres Palmas Outer Shelf Reef, Rincon 10m, May 2013

		TRANSECTS					
Depth: 10 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Periclimenes pedersoni	Cleaner Shrimp	2	1			1	**0.8**
Stenorhynchus seticornis	Arrow Crab			1		1	**0.4**
	TOTALS	2		1		2	**1.2**

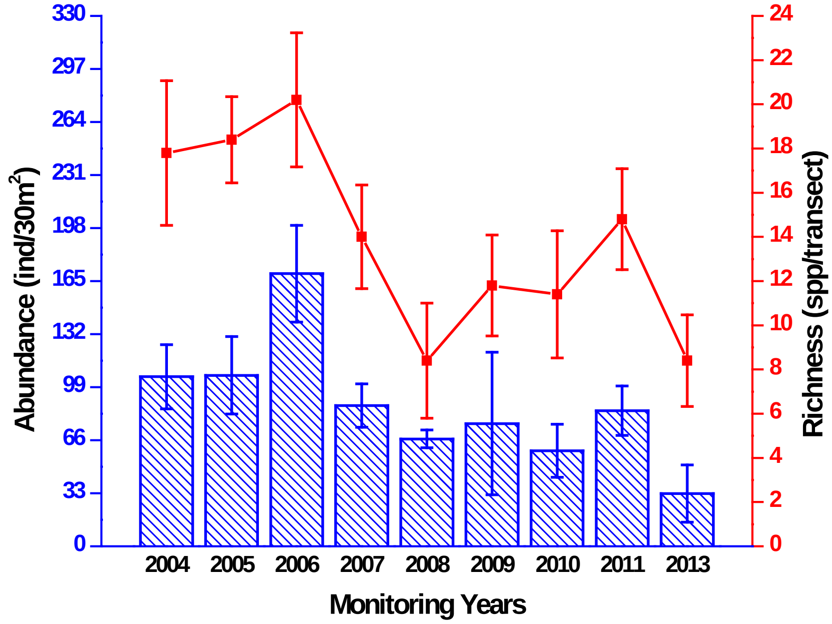
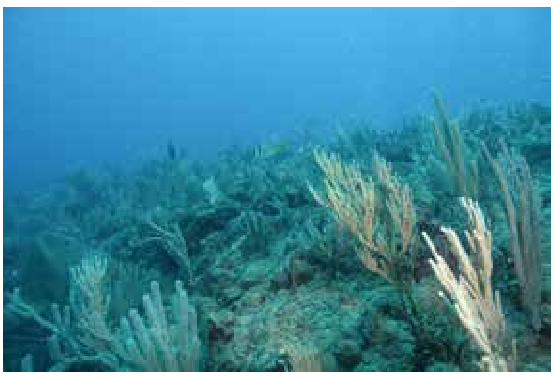


Figure 9. Monitoring trends (2004 – 2013) of fish species richness and abundance at Tres Palmas Outer Shelf Patch Reef, 10-15 m, Rincon.

Photo Album 2 (Rincon 10m)

Outer Shelf Patch Reef








3.0 Tres Palmas Shelf-edge 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, 13 of which were intercepted by line transects during the 2013 survey (Table 10). Stony corals occurred mostly as encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 21.6 % (range: 10.5 – 29.0 %). Boulder Star Coral, *Orbicella annularis* complex was the dominant species in terms of substrate cover with a mean of 9.9 % (range: 1.7 – 20.8 %), representing 45.8 % 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 Mustard-Hill Coral, *Porites astreoides*. Soft corals (gorgonians) were moderately abundant, with a total of at least 13 species within transects and an average of 12.2 colonies/transect. The main assemblage included sea plumes (*Pseudopterogorgia 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.

Table 10. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon. 20m. May 2013

	Transects					
	1	2	3	4	5	**Mean**
Rugosity (m)	1.80	2.22	2.57	2.03	2.56	**2.24**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhang	3.2	2.5	2.7	1.2	2.6	**2.4**
Sand			1.3	0.3	0.9	**0.5**
Total Abiotic	**3.2**	**2.5**	**4.0**	**1.5**	**3.5**	**2.9**
Benthic Algae						
Turf	38.8	36.6	31.0	30.2	36.0	**34.5**
Dictyota spp.	7.6	6.7	9.7	23.1	11.6	**11.7**
Macroalgae	18.5	23.7	7.6		5.0	**11.0**
Lobophora spp.	12.0	1.5	3.3	2.2	2.2	**4.2**
Halimeda spp.		4.2	0.0			**0.8**
Crustose coralline algae		0.9	0.3	2.6	0.2	**0.8**
Galaxaura spp.			1.1		1.1	**0.4**
Unknown red algae			1.1			**0.2**
Jania spp.		0.3	0.2			**0.1**
Caulerpa spp.					0.3	**0.1**
Total Benthic Algae	**76.9**	**73.9**	**54.3**	**58.0**	**56.5**	**63.9**
Cyanobacteria			2.0	5.8	1.0	**1.8**
Gorgonians						
Erythropodium caribaeorum		0.4	5.9	1.7		**1.6**
Briareum asbestinum					0.3	**0.1**
Eunicea flexuosa		0.3				**0.1**
Antillogorgia americana				0.1		**0.0**
Total Gorgonians		**0.7**	**5.9**	**1.9**	**0.3**	**1.8**
Erect Gorgonians						
(#col/transect)	6.0	10.0	18.0	15.0	12.0	**12.2**
Sponges						
Agelas sceptrum		1.3	0.7	4.0	1.3	**1.4**
Xestospongia muta		6.6				**1.3**
Petrosia pellasarca					5.5	**1.1**
Amphimedon compressa	1.2	0.2	2.3	0.7	0.6	**1.0**
Iotrochota birotulata	0.2	0.8	0.2	0.8	0.3	**0.5**
Agelas conifera		2.0				**0.4**
Plakortis halichondroides	1.1	0.6				**0.3**
Niphates erecta		0.2	0.3		0.9	**0.3**
Agelas citrina			1.0		0.3	**0.3**
Cliona spp.				0.5	0.6	**0.2**

Table 10. continued

Aplysina cauliformis				0.8	0.1	**0.2**
Verongula rigida	0.8					**0.2**
Callyspongia vaginalis		0.3			0.3	**0.1**
Agelas dispar				0.3	0.2	**0.1**
Desmapsamma anchorata					0.6	**0.1**
Scopalina ruetzleri					0.3	**0.1**
Iotrochota arenosa					0.2	**0.0**
Ptilocaulis walpersi			0.2			**0.0**
Aiolochroia crassa		0.2				**0.0**
Amphimedon compressa black	0.1					**0.0**
Total Sponges	**3.4**	**12.3**	**4.8**	**7.1**	**11.3**	**7.8**
Live Stony Corals						
Orbicella annularis	5.8	1.7	20.8	9.7	11.4	**9.9**
Meandrina meandrites	1.3		6.9	0.9	2.8	**2.4**
Porites astreoides	1.9		0.3	5.1	3.2	**2.1**
Agaricia agaricites	0.2	3.7		3.8	2.7	**2.1**
Colpophyllia natans	5.7		0.6		1.4	**1.5**
Diploria strigosa		0.3			4.6	**1.0**
Montastraea cavernosa	0.2	1.6		2.8		**0.9**
Madracis decactis		0.8		1.6	0.3	**0.6**
Siderastrea siderea	0.9	0.4			0.7	**0.4**
Agaricia humilis		2.0				**0.4**
Millepora alcicornis	0.4			0.2	0.3	**0.2**
Leptoseris cucullata				0.3		**0.1**
Agaricia lamarcki			0.3			**0.1**
Total Stony Corals	**16.5**	**10.5**	**29.0**	**24.6**	**27.4**	**21.6**

Encrusting and erect sponges were represented by at least 20 species within transects, with an average cover of 7.8 %. *Amphimedon compressa* and *Iotrochota birotulata* were present in all five transects surveyed, but Agelas sceptum and *Xestospongia muta* has the highest substrate cover with 1.4 and 1.3 %, respectively.

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 34.5 % (range: 30.2 – 38.8 %). Turf algae were found overgrowing rocky substrates, as well as dead coral sections and other hard ground. Fleshy brown macroalgae, particularly *Lobophora variegata* was common in the reef, contributing an additional 26.9 % to the reef substrate cover. Isolated tufts of red coralline alga (*Amphiroa sp*, *Galaxaura sp*.) and other green calcareous algae were also present. The total reef substrate cover by benthic algae was 63.9 %. Patches of reddish, slimy mats of benthic cyanobacteria were observed over the reef, mostly covering sandy sediments. Reef overhangs averaged 2.4 % and contributed to a topographic rugosity of 2.24 m.

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 have been measured (see Appendix 2). 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. 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 during the nine surveys (2004-13) from the shelf-edge reef off Tres Palmas (Appendix 1). Table 11 lists the 34 fish species observed within belt-transects during the 2013 survey in decreasing order of abundance. Mean abundance within belt-transects was 106.2 Ind/30 m^2 (range: 68 – 155 Ind/30 m^2). The mean number of species per transect was 16.6 (range: 13– 19). An assemblage consisting of six species represented 74.4 % of the total fish individuals within belt-transects (Table 11). The Blue Chromis, Bicolor Damselfish, Bluehead and Creole Wrasses, Masked and Peppermint Gobies comprised the numerically dominant assemblage. In addition, The Black-bar Souldierfish, Beau Gregory, Yellowhead Wrasse and Princess Parrotfish and Longspine Squirrelfish were present in at least four of the five transects surveyed. Ten juvenile and adult Lionfishes, *Pterois sp.* were observed out of transects (Table 12).

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 present 2013 survey. The main species that has contributed to the variability of fish abundance between monitoring surveys is the Masked Goby,

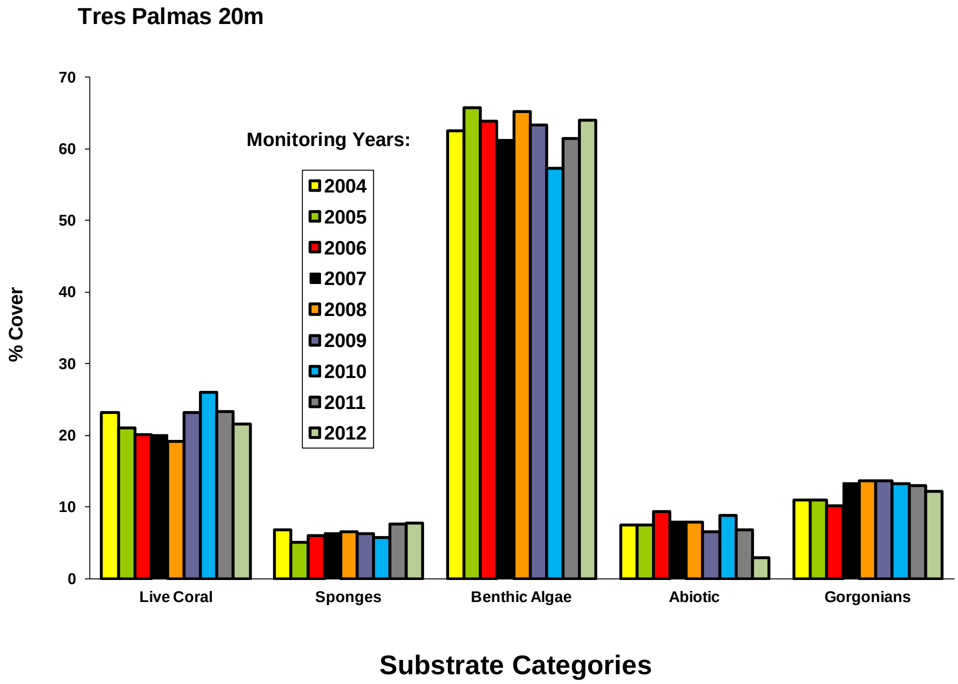


Figure 10. Monitoring trends (2004 – 2013) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef – 20 m.

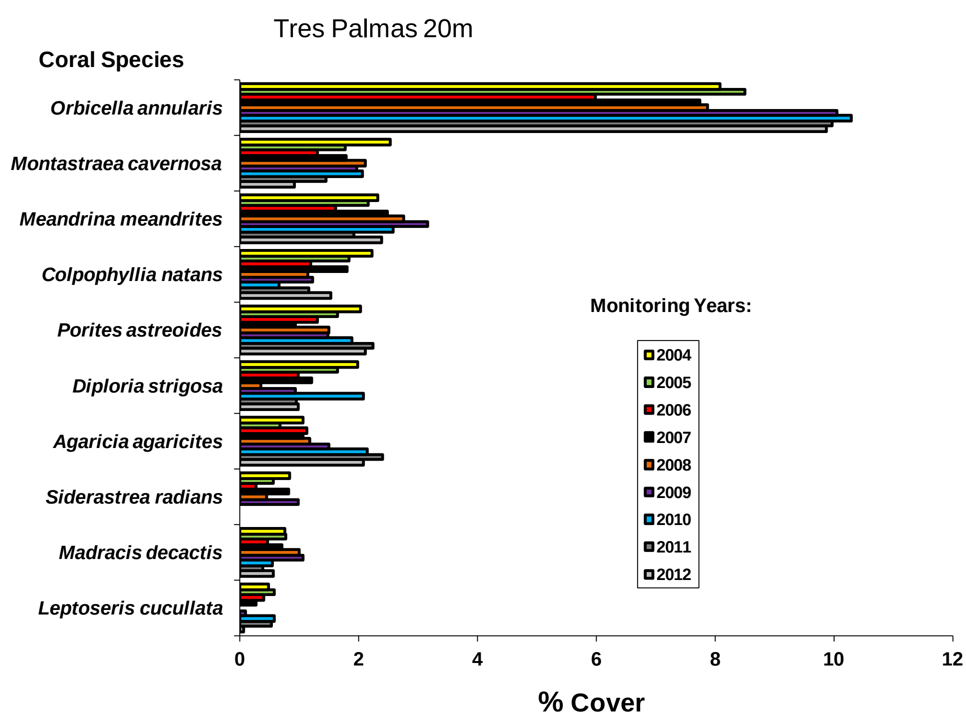


Figure 11. Monitoring trends (2004 – 2013) of mean substrate cover by stony coral species at Tres Palmas Reef – 20 m.

Table 11. Taxonomic composition and abundance of fishes surveyed within belt-transects at the shelf- edge reef off Tres Palmas, Rincón. May, 2013.

Depth: 20m

		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Chromis cyanea	Blue Chromis	40	22	17	4	22	**21.0**
Stegastes partitus	Bicolor Damselfish	27	12	3	14	16	**14.4**
Thalassoma bifasciatum	Bluehead Wrasse	8	40	5	5	11	**13.8**
Clepticus parrae	Creole Wrasse	50	0	5	0	0	**11.0**
Coryphopterus lipernes	Peppermint Goby	6	0	24	16	6	**10.4**
Coryphopterus personatus	Masked Goby	0	15	10	16	1	**8.4**
Haemulon flavolineatum	French grunt	3	0	11	0	1	**3.0**
Halichoeres garnoti	Yellow-head Wrasse	5	1	0	6	3	**3.0**
Myripristis jacobus	Blackbar Soldierfish	2	0	10	1	1	**2.8**
Gobiosoma evelynae	Sharknose Goby	0	0	3	9	1	**2.6**
Stegastes leucostictus	Beau Gregory	1	5	1	4	2	**2.6**
Scarus taeniopterus	Princess Parrotfish	0	2	3	2	2	**1.8**
Neoniphon marianus	Longspine Squirrelfish	1	1	3	3	0	**1.6**
Sparisoma viride	Stoplight Parrotfish	0	4	0	2	1	**1.4**
Cephalopholis cruentatus	Graysby	0	3	1	2	0	**1.2**
Acanthurus coeruleus	Blue Tang	0	2	0	1	1	**0.8**
Chaetodon capistratus	Four-eye Butterflyfish	2	0	2	0	0	**0.8**
Chromis multilineata	Brown chromis	0	2	0	2	0	**0.8**
Holocentrus rufus	Squirrelfish	0	1	1	1	0	**0.6**
Ocyurus chrysurus	Yellowtail Snapper	3	0	0	0	0	**0.6**
Cephalopholis fulva	Coney	0	0	0	2	0	**0.4**
Pomacanthus paru	French Angelfish	0	2	0	0	0	**0.4**
Serranus tigrinus	Harlequin Bass	2	0	0	0	0	**0.4**
Sparisoma aurofrenatum	Redband Parrotfish	0	2	0	0	0	**0.4**
Anisotremus virginicus	Yellowtail Goatfish	**0**	**0**	**0**	**1**	**0**	**0.2**
Acanthurus chirurgus	Doctorfish	0	0	1	0	0	**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish	1	0	0	0	0	**0.2**
Bodianus rufus	Spanish Hogfish	1	0	0	0	0	**0.2**
Canthigaster rostrata	Caribbean Puffer	0	0	1	0	0	**0.2**
Epinephelus guttatus	Redhind	1	0	0	0	0	**0.2**
Microspathodon chrysurus	Yellowtail Damselfish	0	0	1	0	0	**0.2**
Mycteroperca vennenosa	Yellowfih Grouper	1	0	0	0	0	**0.2**
Lutjanus mahogani	Mahogani Snapper	0	0	1	0	0	**0.2**
Coryphopterus glaucofraenum	Bridled Goby	1	0	0	0	0	**0.2**
	TOTAL INDIVIDUALS	155	114	103	91	68	**106.2**
	TOTAL SPECIES	18	15	19	18	13	**16.6**

Coryphopterus personatus. This is a small carnivorous fish (< 2.0 cm) that 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 of 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.

The fish community associated with the Tres Palmas shelf-edge reef appears to be strongly driven by pelagic and demersal zooplanktivores (e.g. *Chromis spp*. Masked goby, bicolor damselfish) which comprised approximately 53 % 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 observed during previous ASEC surveys in this reef.

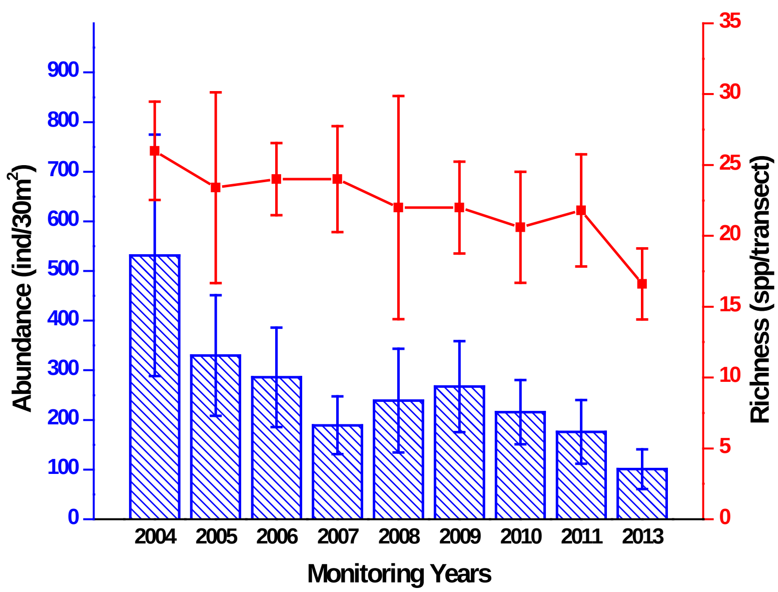


Figure 12. Monitoring trends (2004 – 2013) of fish species richness and abundance at Tres Palmas Shelf Edge Reef, Rincon, 20 m

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.

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, one arrow crab and one spiny lobster were observed within belt-transects during 2013 (Table 13).

Table 12. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at the shelf-edge off Tres Palmas Reef, Rincón, May, 2013

Depth range : 18 - 22 m

SPECIES	**COMMON NAME**		# - (cm)	
Epinephelus guttatus	Red Hind	1 – (20)	1 – (35)	
Pterois volitans	Lionfish	4 – (20)	3 – (25)	3 - (28)
Lutjanus mahogony	Mahogany Snapper	11 - (23)	2 - (28)	
Lutjanus synagris	Lane Snapper	1 – (20)	2 – (25)	
Scomberomorus regalis	Cero Mackerel	2 - (55)		
Sphyraena barracuda	Great Barracuda	1 - (40)		

Table 13. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Shelf-edge Reef, Rincon 20 m, May 2013

Depth: 20 m		**TRANSECTS**					**MEAN ABUNDANCE (IND/30 m2)**
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Stenorhynchus seticornis	Arrow Crab	1		1		1	**0.6**
Panulirus argus	Spiny Lobster				1		**0.2**
Periclimenes pedersoni	Cleaner Shrimp		1	2			**0.6**
	TOTALS	1	1	3	1	1	**1.4**

Photo Album 3 (Rincon 20m)

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.

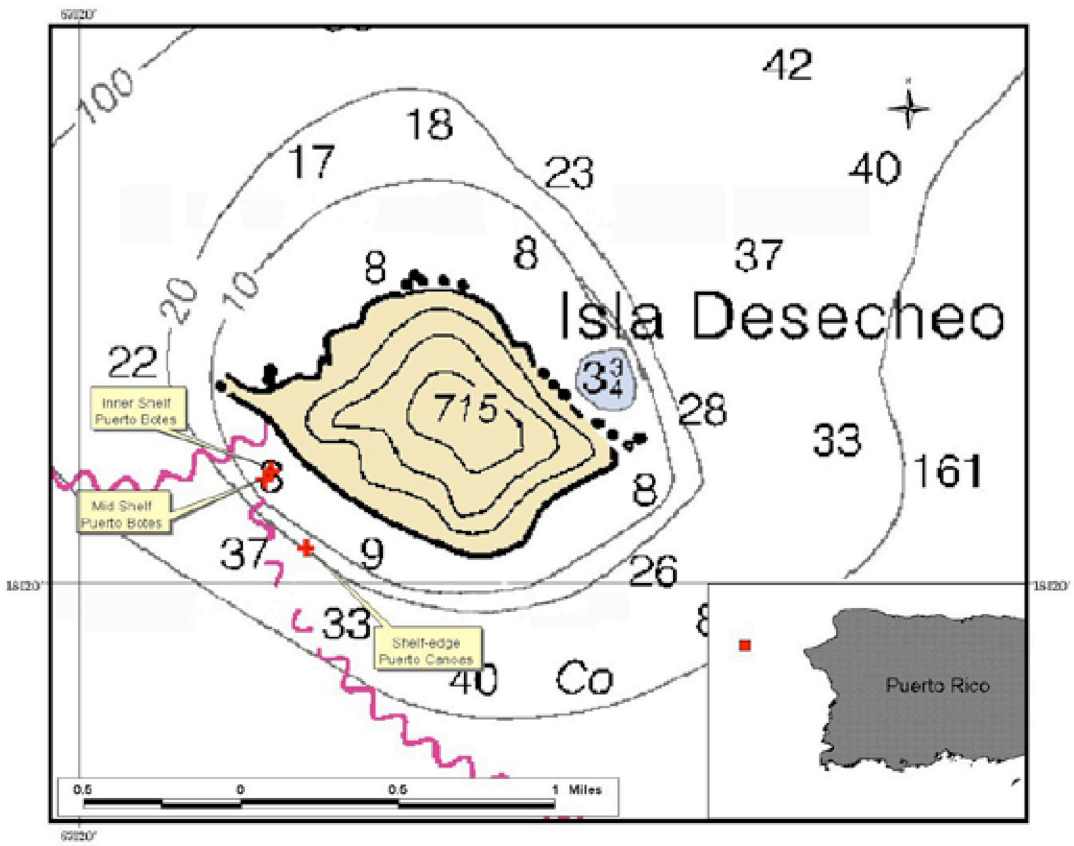


Figure 13. Location of coral reef survey stations at Puerto Canoas/Botes, Isla Desecheo.

Stony corals dominated reef substrate cover by benthic invertebrates along surveyed transects with a mean of 27.2 % (range: 8.0 – 38.9 %). Boulder Star Coral (*Orbicella annularis* complex), with a mean cover of 15.6 % represented 57.4 % 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 11 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 were not common at the shelf-edge reef. Abiotic cover, mostly associated with reef overhangs averaged 7.5 % and contributed to a mean reef substrate rugosity of 2.8. Encrusting

Table 14. Percent substrate cover by sessile-benthic categories at Puerto Canoas Reef, Isla Desecheo 30 m. Survey Date: September 2013

	Transects					
	1	2	3	4	5	**Mean**
	1.87	2.82	3.58	3.12	2.42	**2.8**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhang	5.9	8.0	14.9	2.8	6.5	**7.5**
Total Abiotic	**5.9**	**8.0**	**14.9**	**2.8**	**6.5**	**7.5**
Benthic Algae						
Lobophora spp.	23.6	24.7	36.5	42.5	32.7	**32.0**
Turf	21.7	11.4	5.7	16.2	6.3	**12.2**
Dictyota spp.	1.7	2.8		1.8	2.8	**1.8**
Ccoralline algae	0.1	0.9		6.2		**1.4**
Halimeda spp.					0.7	**0.1**
Macroalgae		0.3				**0.1**
Total Benthic Algae	**61.7**	**60.8**	**78.6**	**79.4**	**63.0**	**47.7**
Cyanobacteria	2.0	3.5		0.3	13.3	**5.6**
Sponges						
Agelas citrina	7.7	2.3	14.3	4.4		**5.7**
Agelas conifera		4.6	7.1		1.1	**2.5**
Haliclona spp.	2.5	1.3		4.3	3.2	**2.2**
Agelas clathrodes	0.1			3.4		**0.7**
Amphimedon compressa		1.5				**0.3**
Agelas sceptrum		0.9				**0.2**
Scopalina ruetzleri	0.5			0.2		**0.1**
Ircinia brown spp.				0.6		**0.1**
Total Sponge	**10.7**	**10.6**	**21.4**	**12.9**	**4.3**	**11.9**
Live Stony Corals						
Orbicella annularis	9.2	19.5	9.2	1.9	29.2	**15.6**
Agaricia agaricites	2.2	6.7	8.7	0.7	2.3	**4.1**
Porites astreoides	3.3	5.2	2.4	4.3		**3.0**
Colpophyllia natans	8.0	3.3				**2.2**
Porites porites	2.1	3.3				**1.1**
Meandrina sp				0.7	1.1	**0.4**
Leptoseris cucullata			0.5	0.3	0.5	**0.3**
Madracis decactis	0.6	0.3				**0.2**
Millepora alcicornis			0.8			**0.2**
Siderastrea siderea					0.8	**0.2**
Eusmilia fastigiata		0.5				**0.1**
Total Stony Corals	**25.5**	**38.9**	**21.5**	**8.0**	**33.9**	**27.2**

and erect sponges included at least eight species within transects with a mean cover of 11.9 % (range: 4.3 – 21.4 %). An assemblage comprised of several *Agelas* and *Haliclona* spp. was the most prominent sponge taxa at Desecheo 30 m (Table 14).

Benthic macroalgae, comprised by an assemblage of turf, fleshy and calcareous types presented a combined substrate cover of 43.3 % along permanent transects. *Lobophora variegata, Padina sp.* and *Ventricaria ventricosa* were some of the most common fleshy macroalgae present. Turf algae included an unidentified variety of short filamentous red and brown macroalgae. A slimy red cyanobacterial film was present in four transects with a mean substrate cover of 5.6 %.

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 two 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). Mustard-Hill Coral, *Porites astreoides* has shown small, but consistent increments of substrate cover at Desecheo 30 m during the two last monitoring surveys (2010 and 2013).

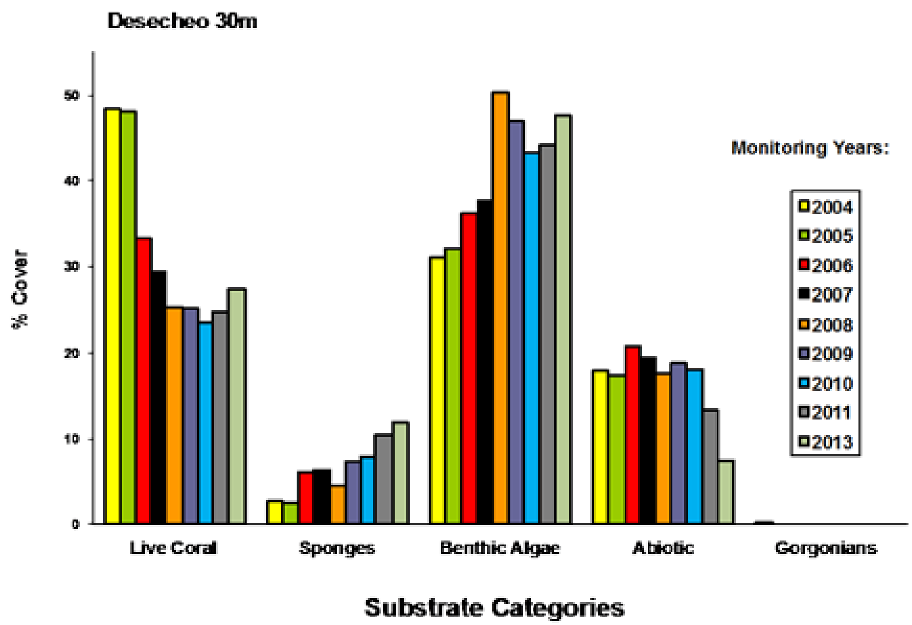


Figure 14. Monitoring trends (2004 -13) of substrate cover by sessile-benthic categories at Puerto Canoas Reef, Desecheo Island – 30 m.

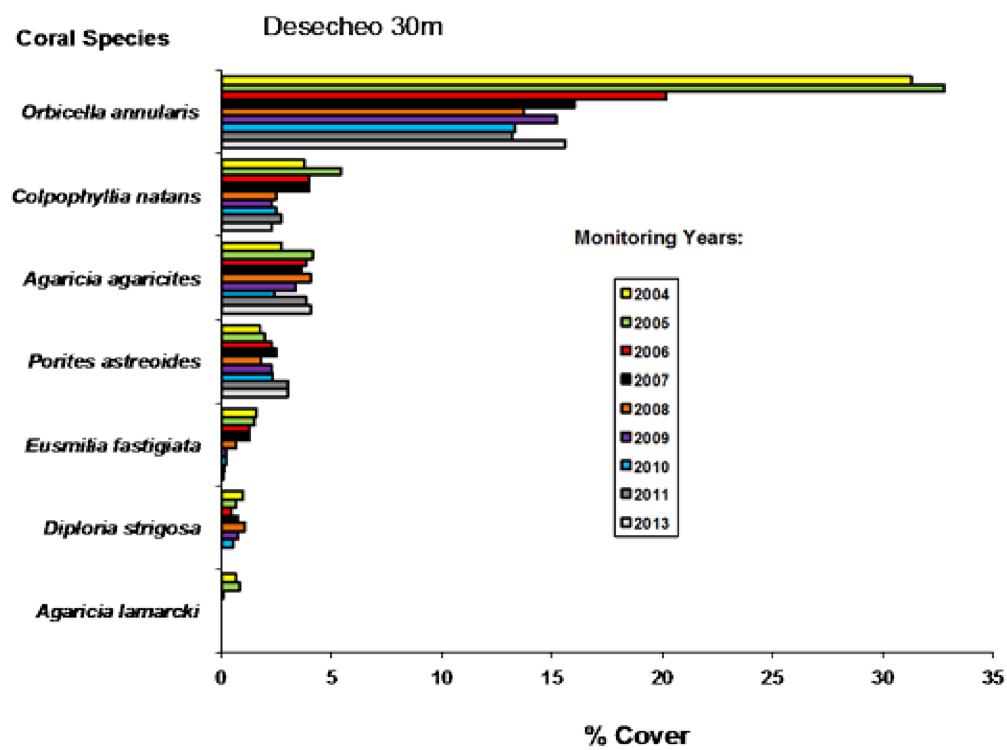


Figure 15. Monitoring trends (2004-13) of mean substrate cover by stony coral species at Puerto Canoas Reef, Desecheo Island – 30 m.

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 97 fish species have been identified during the nine surveys (2004-13) at the shelf-edge reef off Puerto Canoas, Isla Desecheo (Appendix 1). Mean abundance of fishes within belt-transects during September, 2013 was 660.8 Ind/30 m^2 (range: 421 – 855 Ind/30 m^2). The mean number of species per transect was 24.6 (range: 17 – 29) (Table 15). An assemblage of seven species, including the Masked and Peppermint Gobies, Blue and Brown Chromis, Bluehead and Creole Wrasse, and Fairy Basslet represented 92.6 % of the total fish abundance within belt-transects. A total of 10 species were present within all five belt-transects and another six were present in four. The Creole Wrasse, *Clepticus parrae* was the numerically dominant species with a mean abundance of 354.0 Ind/30 m^2 (range: 200 – 500 Ind/30 m^2), representing 53.6 % of the total (Table 15). 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 an ASEC survey in this reef (Table 16). 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.

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 present 2013 survey driven by abundance of Creole Wrasse. Lower species richness and abundance were detected between the 2010 and all other surveys previous to 2009 (Figure 16). The largest 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 present survey suggests that recruitment dynamics play an important role regulating population abundance of zooplanktivorous fishes.

Table 15. Taxonomic composition and abundance of fishes within belt-transects at Puerto Canoas Reef, 30 m, Isla Desecheo. September 2013

Depth: 30m		TRANSECTS					
		1	2	3	4	5	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Clepticus parrae	Creole Wrasse	300	330	500	440	200	**354.0**
Coryphopterus lipernes	Peppermint Goby	93	140	120	40	66	**91.8**
Coryphopterus personatus	Masked Goby	200	160	80	0	0	**88.0**
Chromis cyanea	Blue Chromis	18	1	30	30	50	**25.8**
Gramma loreto	Fairy Basslet	21	17	42	25	14	**23.8**
Thalassoma bifasciatum	Bluehead Wrasse	18	17	23	17	15	**18.0**
Chromis multilineata	Brown Chromis	10	18	18	0	8	**10.8**
Stegastes partitus	Bicolor Damselfish	13	4	8	5	6	**7.2**
Halichoeres garnoti	Yellow-head Wrasse	6	3	6	5	14	**6.8**
Kyphosus bermudensis	Sea Chub	12	2	2	0	2	**3.6**
Halichoeres maculipinna	Clown Wrasse	6	0	1	6	0	**2.6**
Paranthias fucifer	Creolefish	1	4	0	2	5	**2.4**
Scarus iserti	Stripped Parrotfish	3	4	4	1	0	**2.4**
Gobiosoma evelynae	Sharknose Goby	0	0	0	0	10	**2.0**
Stegastes planifrons	Damselfish	3	5	0	0	2	**2.0**
Caranx latus	Horse-eye Jack	0	1	0	0	8	**1.8**
Acanthurus coeruleus	Blue Tang	2	2	2	2	0	**1.6**
Neoniphon marianus	Squirrelfish	1	2	2	0	2	**1.4**
Pterors sp.	Lionfish	2	0	4	0	1	**1.4**
Caranx lugubris	Black Jack	0	6	0	0	0	**1.2**
Sparisoma viride	Stoplight Parrotfish	1	1	1	1	2	**1.2**
Epinephelus cruentatus	Graysby	0	1	2	0	2	**1.0**
Epinephelus fulva	Coney	1	0	1	1	2	**1.0**
Melichthys niger	Black Durgon	2	1	0	0	2	**1.0**
Lutjanus apodus	Schoolmaster	0	1	1	2	0	**0.8**
Caranx ruber	Bar Jack	1	0	2	0	0	**0.6**
Holocentrus adcencionis	Squirelfish	2	0	0	1	1	**0.8**
Myripristis jacobus	Blackbar Soldierfish	2	0	0	0	1	**0.6**
Canthigaster rostrata	Caribbean Puffer	0	1	1	0	0	**0.4**
Chaetodon capistratus	Four-eye Butterfly	0	2	0	0	0	**0.4**
Holacanthus tricolor	Rock Beauty	0	1	0	0	1	**0.4**
Liopropoma rubre	Swissguard Basslet	0	0	2	0	0	**0.4**
Microspathodon chrysurus	Yellow Damselfish	0	0	1	1	0	**0.4**
Mulloidichthys martinicus	Yellow Goatfish	0	0	0	2	0	**0.4**
Bodianus rufus	Spanish Hogfish	0	1	0	0	0	**0.2**
Chaetodon aya	Longsnout Butterfly	0	1	0	0	0	**0.2**
Chaetodon striatus	Banded Butterflyfish	0	1	0	0	0	**0.2**
Chromis inslolata	Sunshine Chromis	0	0	0	0	1	**0.2**
C.glaucophraenum	Briddled Goby	1	0	0	0	0	**0.2**
Epinephelus striatus	Nassau Grouper	0	0	0	0	1	**0.2**
Gymnothorax moringa	Moray eel	0	0	0	0	1	**0.2**
Lutjanus jocu	Dogg Snapper	0	0	0	0	1	**0.2**
Mycteroperca vannenosa	Yelllowfih Grouper	0	0	0	0	1	**0.2**
Sparisoma rubripinne	Yellowtail Parrotfish	0	0	0	0	1	**0.2**
Amblycirrhitus pinos	Redspotted Hawk	1	0	1	0	1	**0.6**
Anisotremus suranimense	Black Margate	0	0	1	0	0	**0.2**
	TOTAL INDIVIDUALS	**720**	**727**	**855**	**581**	**421**	**660.8**
	TOTAL SPECIES	**25**	**27**	**25**	**17**	**29**	**24.6**

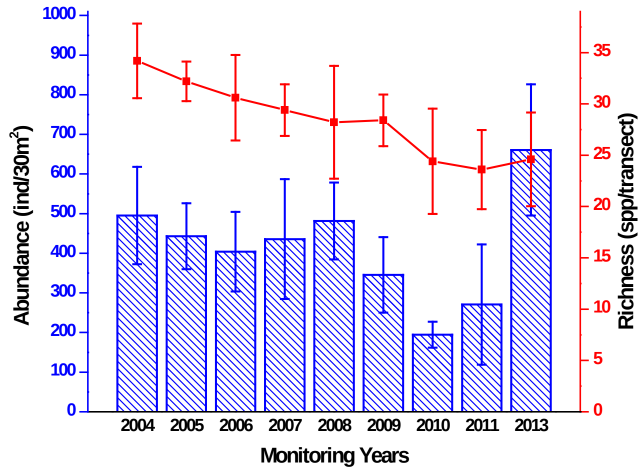


Figure 16. Monitoring trends (2004 – 2013) of fish species richness and abundance at Puerto Canoas Reef 30 m, Isla desecheo. September 2013.

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 72 % 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 (Table 16). Yellowtail, Mahogany, Dog and Schoolmaster Snappers, Red Hind, Coney and Queen Triggerfish were observed in full adult sizes. The Caribbean Reef Shark (*Carcharhinus perezi*) was reported in a previous survey of this reef (García-Sais et al., 2004). A large variety of small invertebrate feeders were present (c.a. 23% 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 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. Arrow Crabs, Cleaner Shrimps and one Queen Conch were the motile megabenthic invertebrates observed within belt-transects during the 2010 survey (Table 17). One Spiny Lobster and several Queen Conch were observed outside transects during the ASEC survey.

Table 16. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Puerto Canoas Reef, Isla Desecheo, 30m. September, 2013

Depth range : 25 -30 m

SPECIES	**COMMON NAME**		# - (cm)	
Caranx lugubris	Black Jack	1 - (50)	2 – (60)	
Elagatis bipinnulata	Rainbow Runner	1 – (70)		
Epinephelus guttatus	Red Hind	1 – (20)	2 - (25)	1 - (30)
Lutjanus apodus	Schoolmaster	5 - (20)	7 - (30)	3 - (40)
Lutjanus mahogany	Mahogani Snapper	6 - (20)	3 - (30)	
Mycteroperca venenosa	Yellowfin Grouper	1 - (60)	1 - (75)	
Pterois volitans	Lionfish	1 – (25)	3 - (30)	
Scomberomorus regalis	Cero Mackerel	1 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (80)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (30)		

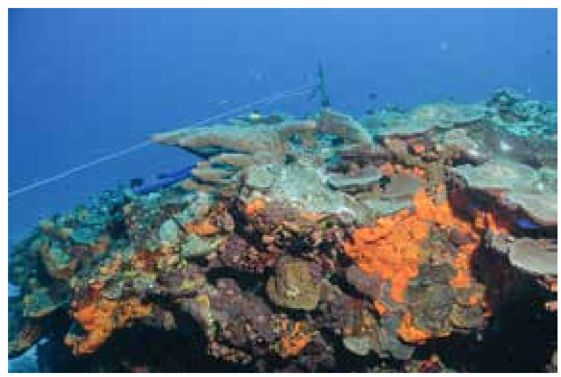
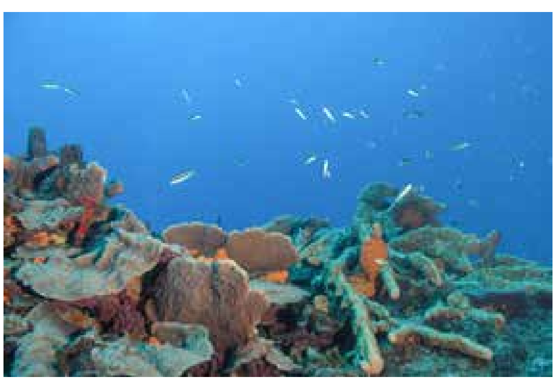
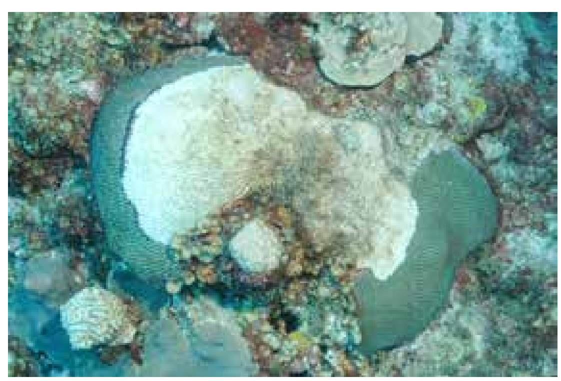
Table 17. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Puerto Canoas Shelf-edge Reef, Isla Desecheo 30m, September 2013

Depth: 25 – 30 m		TRANSECTS					**MEAN ABUNDANCE (IND/30 m2)**
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Stenorhynchus seticornis	Arrow crab			1			**0.2**
Periclimenes pedersoni	Cleaner Shrimp	1	1	2		1	**1.0**
Stenopus hispidus	Banded Coral Shrimp		1	1			**0.4**
	TOTALS	**1**	**2**	**4**	**0**	**1**	**1.6**

Photo Album 4 (Desecheo 30m)

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 ninth 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 13 intersected by line transects were identified during this 2013 survey. Live coral cover averaged 10.9 % (range (6.4 – 23.9 %) along transects (Table 18). Finger Coral, *Porites porites* was the species of highest mean percent substrate cover with a mean of 3.3 % (range: 0 – 15.7 %). 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 71.6 % of the total cover by live corals at Puerto Botes (Table 18). 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* have been measured between 2009 and the present 2013 survey, but these were within sampling variability error (Appendix 2).

Table 18. Percent substrate cover by sessile-benthic categories at Puerto Botes Reef, Isla Desecheo 20 m. Survey Date: September 2013.

	Transects					
	1	2	3	4	5	**Mean**
	3.94	4.15	2.82	2.49	3.44	**3.4**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhang	5.6	3.6	7.5	5.7	8.1	**6.1**
Sand	3.5			3.6		**1.4**
Total Abiotic	**9.1**	**3.6**	**7.5**	**9.2**	**8.1**	**7.5**
Benthic Algae						
Turf	33.3	3.4	26.7	29.9	34.9	**31.0**
Dictyota spp.	32.3	43.7	28.5	27.1	21.1	**30.6**
Lobophora spp.	7.6	5.2	17.1	2.8	18.5	**10.3**
Coralline algae	2.8	3.4	1.4	2.0	0.4	**1.8**
Padina spp.		0.3				**0.1**
Total Benthic Algae	**76.1**	**56.0**	**73.8**	**61.9**	**75.0**	**73.7**
Cyanobacteria	3.8	1.3	5.5		9.4	**4.0**
Sponges						
Agelas citrina	0.4			4.3	0.4	**1.0**
Agelas conifera	1.4	3.0			0.7	**1.0**
Agelas citrinia			2.4			**0.5**
Agelas dispar	2.8					**0.4**
Agelas sceptrum			0.9	1.1		**0.4**
Verongula rigida	1.6					**0.3**
Aplysina insularis			0.4			**0.1**
Total Sponges	**6.2**	**3.0**	**3.7**	**5.4**	**1.1**	**3.7**
Live Stony Corals						
Porites porites				15.7	0.9	**3.3**
Porites astreoides	1.8	4.3	1.3	0.9	0.9	**1.8**
Orbicella annularis	1.9	2.8	1.7	1.9		**1.5**
Agaricia agaricites	2.7		1.3	0.8	1.1	**1.2**
Meandrina sp			2.3	2.1		**0.9**
Eusmilia fastigiata		1.8	2.5			**0.9**
Diploria labyrinthiformis				2.2		**0.4**
Montastraea cavernosa					2.2	**0.4**
Madracis decactis	0.3	0.4			0.4	**0.2**
Millepora alcicornis			0.4			**0.1**
Agaricia fragilis					0.4	**0.1**
Stephanocoenia sp					0.3	**0.1**
Agaricia tenuifolia				0.2		**0.0**
Total Stony Corals	**6.6**	**9.2**	**9.6**	**23.9**	**6.4**	**10.9**

Reef overhangs, largely associated with skeletal buildups of *O. annularis* averaged 6.1 % of the reef substrate cover and contributed substantially to the reef rugosity of 3.4 m. Erect and encrusting sponges, represented by at least seven species within transects presented a mean substrate cover of 3.7 %. Agelas citrina and A. conifera were 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. The assemblage of benthic algae represented the main substrate category at Puerto Botes with a combined mean cover of 73.7 % (Table 18). Cyanobacterial films were present in four out of the five transects with a mean cover of 4.0 %. Erect gorgonians were not intersected by line transects.

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. During the present 2013 monitoring survey, live coral cover has declined furthermore to a historical minimum of 10.9 %. Differences of live coral during the 2000 – 2005 and the 2006 – 2013 monitoring surveys were statistically significant (ANOVA; $p < 0.0001$) reflecting the acute degradation experienced by the reef system after October 2005 (see Appendix 2). A corresponding increment of substrate cover by benthic algae, cyanobacteria, sponges and abiotic categories has been measured (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 present 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 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

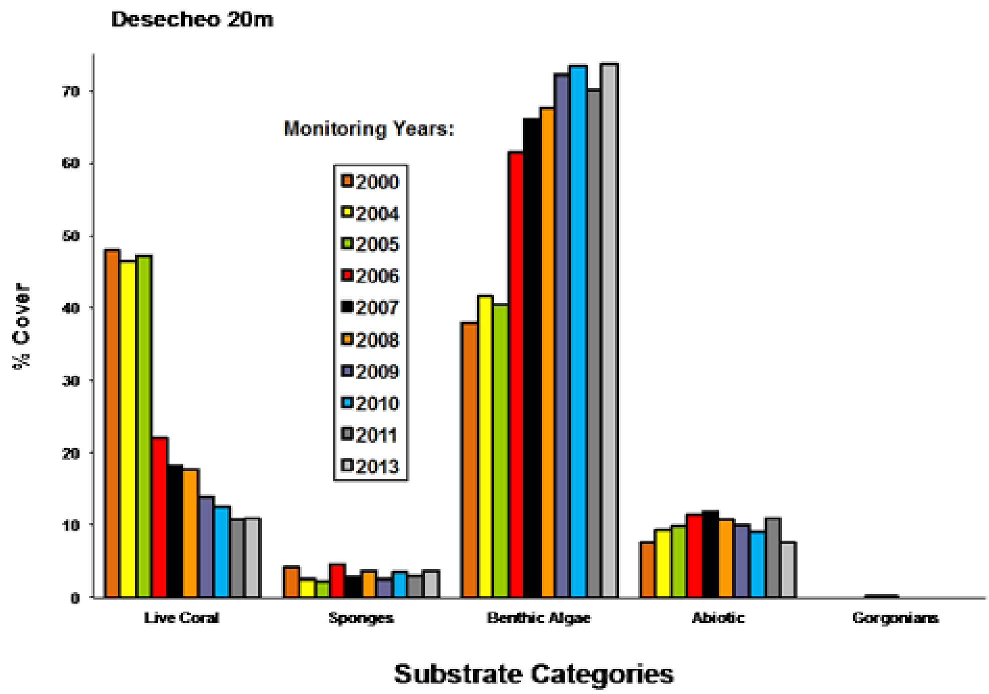


Figure 17. Monitoring trends (2000 - 13) of mean substrate cover by sessile-benthic categories at Puerto Botes Reef, Desecheo Island – 20 m.

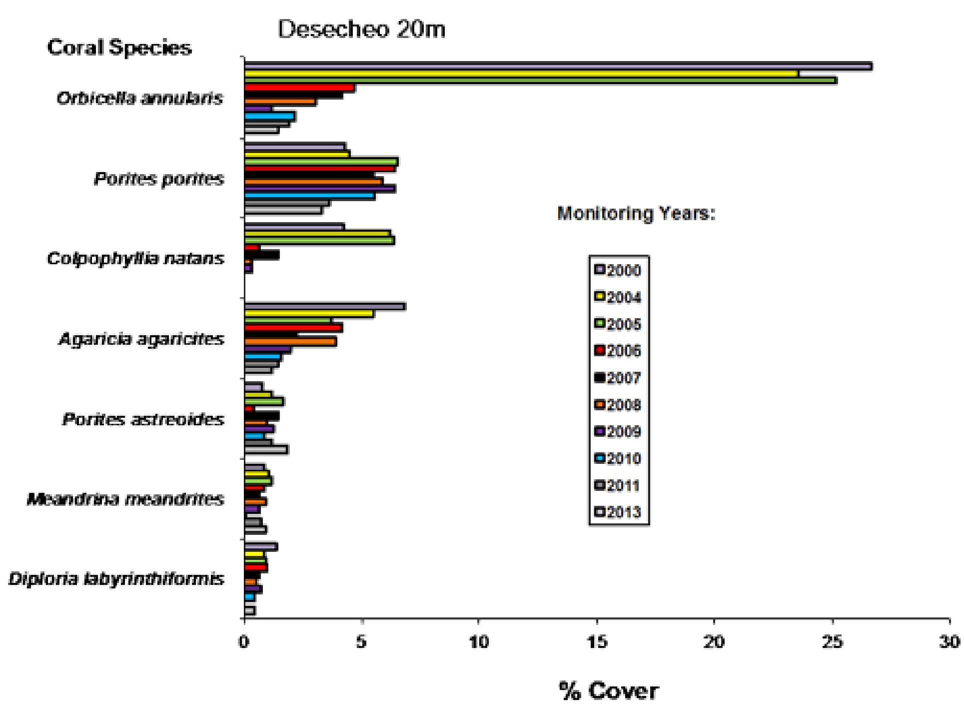


Figure 18. Monitoring trends (2000 – 13) of mean substrate cover by stony coral species at Puerto Botes Reef, Desecheo Island – 20 m.

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. Finger Coral (*Porites porites*), a relatively fast growing branching coral species was one of the few corals that appeared not to be severely affected by the bleaching event and maintained its reef substrate cover stable until 2009, but has declined markedly also since the 2010 survey. 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. From the benthic algal assemblage, the fleshy brown macroalgae (particularly *L. variegata* + *Dictyota sp.*) showed the highest increment between the 2005 and 2013 surveys, from 3.6 % in 2005 to 40.9 % in 2013.

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 43 fish species were identified within belt-transects from the mid-shelf patch reefs off Puerto Botes during 2013 (Table 19). During the 10 surveys, a total of 71 diurnal, non-criptic fishes have been reported from this reef (Appendix 1). Mean abundance of fishes within belt-transects was 246.2 Ind/30 m^2 (range: 191 - 306 Ind/30 m^2). The mean number of species per transect was 23 (range: 19 - 30). The Masked Goby (*Coryphopterus personatus*) was the numerically dominant species within belt-transects during the 2013 survey with a mean abundance of 79.0 Ind/30 m^2. The combined abundance of five species, including the Blue Chromis, Bicolor Damselfish, Bluehead and Creole Wrasses, and Masked Goby represented 81.5 % of the total fish abundance within belt-transects. Six species were present in all five transects and another eight were present in four transects (Table 19).

Table 19. Taxonomic composition and abundance of fishes within belt-transects at Puerto Botes Reef, Isla Desecheo, 20m. Survey Date: June, 2013

Depth: 20m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	100	50	100	15	130	**79.0**
Thalassoma bifasciatum	Bluehead Wrasse	35	53	38	50	14	**38.0**
Chromis cyanea	Blue Chromis	25	75	50	25	0	**35.0**
Clepticus parrae	Creole Wrasse	25	32	42	30	6	**27.0**
Coryphopterus lipernes	Peppermint Goby	16	10	19	44	19	**21.6**
Stegastes partitus	Bicolor Damselfish	6	12	14	0	2	**6.8**
Chromis multilineata	Brown Chromis	22	1	4	3	1	**6.2**
Halichoeres garnoti	Yellow-head Wrasse	0	5	6	0	6	**3.4**
Gramma loreto	Fairy Basslet	2	2	0	8	1	**2.6**
Epinephelus cruentatus	Graysby	0	5	5	2	1	**2.6**
Scarus iserti	Stripped Parrotfish	6	1	3	0	0	**2.0**
Kyphosus bermudensis	Sea Chub	0	1	0	2	6	**1.8**
Halichoeres maculipinna	Clown Wrasse	2	4	0	0	2	**1.6**
Caranx crysos	Bule Runner	0	2	5	0	1	**1.6**
Epinaphelus fulva	Coney	1	2	3	0	2	**1.6**
Gobiosoma evelynae	Sharknose Goby	2	2	0	1	3	**1.6**
Myripristis jacobus	Blackbar Soldierfish	1	2	4	0	0	**1.4**
Microspathodon chrysurus	Yellowtail Damselfish	1	1	2	2	0	**1.2**
Acanthurus coeruleus	Blue Tang	2	0	2	1	0	1.0
Sparisoma viride	Stoplight Parrotfish	1	1	2	0	1	**1.0**
Holocentrus rufus	Squirrelfish	0	1	0	1	2	**0.8**
Muilloides martinicus	Yellowfih Goatfish	0	0	4	0	0	**0.8**
Scarus taeniopterus	Princess Parrotfish	4	0	0	0	0	**0.8**
Haemulon flavolineatum	French Grunt	0	1	1	0	1	**0.6**
Neoniphon marianus	Longspine Squirrelfish	0	1	0	0	2	**0.6**
Bodianus rufus	Spanish Hogfish	1	1	0	0	0	**0.4**
Chaetodon capistratus	Four-eye Butterflyfish	0	2	0	0	0	**0.4**
Equetus lanceolatus	Highhat	1	0	0	0	1	**0.4**
Melichthys niger	Black Durgon	0	2	0	0	0	**0.4**
Ptoris volitans	Lionfish	0	2	0	0	0	**0.4**
Serranus tigrinus	Harlequin Bass	0	0	0	2	0	**0.4**
Sparisoma aurofrenatum	Redband Parrotfish	1	0	0	0	1	**0.4**
Stegastes leucostictus	Beugregory	0	0	0	2	0	**0.4**
Abudefduf sexatilis	Sargent Mayor	1	0	0	0	1	**0.4**
Acanthostracion quadricornis	Scrawled Cowfish	1	0	0	0	0	**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish	1	0	0	0	0	**0.2**
Caranx bartholomei	Yellow Jack	0	1	0	0	0	**0.2**
Canthigaster rostrata	Caribbean Puffer	0	0	0	1	0	**0.2**
Haemulon macrustomus	Smanish Grunt	1	0	0	0	0	**0.2**
Holacanthus tricolor	Rock Beauty	0	0	1	0	0	**0.2**
Mycteroperca vennenosa	Yellowfin Grouper	0	0	1	0	0	**0.2**
Ocyurus crysurus	Yellowtail Snapper	0	1	0	0	0	**0.2**
Coryphopterus glaucophraenum	Briddled Goby	0	0	0	1	0	**0.2**
Sparisoma radians	Bucktooth Parrotfish	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	**258**	**273**	**306**	**191**	**203**	**246.2**
	TOTAL SPECIES	**24**	**30**	**21**	**19**	**21**	**23**

Annual monitoring trends of fish species richness and abundance surveyed within belt-transects are presented in Figure 19. Mean abundance at 246 Ind/30 m^2 is within the range of previous surveys during the 10 year monitoring program. Fish species richness during the 2013 survey (e.g. 23 spp/transect) fell within the low end of the historical range recorded since the baseline survey in 2000 (species richness range: 28 - 21 species per transect). 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 63 % of the total individuals within transects. Pelagic schools of Creole Wrasse (15 – 25 individuals) were observed throughout the water column, making frequent incursions over the reef. These serve as forage for large pelagic predators, such as Cero Mackerels, Black Jacks and Great Barracudas observed during an ASEC survey in this reef (Table 20). Dense swarms of mysid shrimps were present below ledges and on crevices. These small shrimps appear to be important forage for the demersal zooplanktivorous fishes.

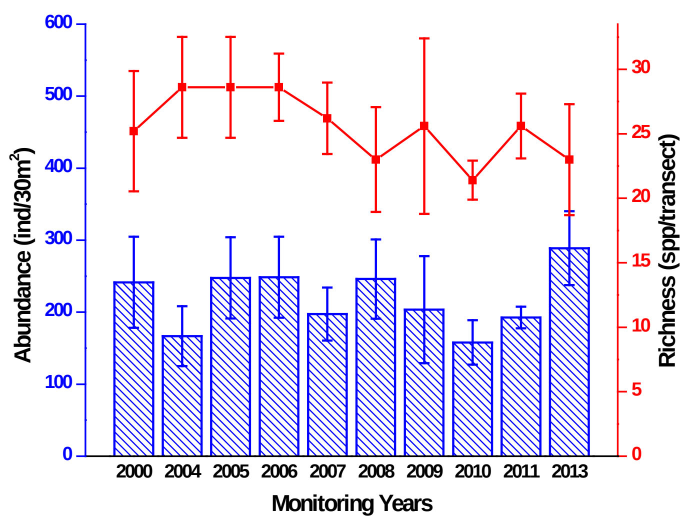


Figure 19. Monitoring trends (2000 – 2013) of fish species richness and abundance at the Mid-Shelf Reef, Puerto Botes, 20 m, Isla Desecheo.

A large variety of small invertebrate feeders were present (30.6 % 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. Mid-size carnivores that are commercially exploited, such as the Yellowtail, Mahogany and Schoolmaster Snappers, Red Hind, Coney and Queen Triggerfish were observed as adults. 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 an average fish abundance at Puerto Botes, suggesting that predation pressure by Lionfish is not having a noticeable effect at the fish community level.

Arrow Crabs and Cleaner Shrimps were the only motile megabenthic invertebrates 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 20. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Puerto Botes, Isla Desecheo, 20 m. Survey Date: September 2013

Depth range : 17 - 20 m   Duration - 30 min.

SPECIES	**COMMON NAME**	# - (cm)		
Caranx hippos	Horse-eye Jack	5 - (60)		
Caranx lugubris	Black Jack	1 - (50)		
Epinephelus guttatus	Red Hind	1 - (20)	2 - (30)	
Lutjanus apodus	Schoolmaster	12 – (20)	7- (30)	4 - (40)
Lutjanus mahogany	Mahogani Snapper	5 - (20)	3 - (25)	
Mycteroperca venenosa	Yellowfin Grouper	1 – (55)		
Ocyurus chrysurus	Yellowtail Snapper	2 – (30)	3 - (40)	2 - (45)
Pterois sp.	Lionfish	1 – (25)		
Scomberomorus regalis	Cero Mackerel	2 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (60)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (20)		

Table 21. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Puerto Botes Mid-shelf Reef. Isla Desecheo 20m, September 2013

Depth: 20 m		**TRANSECTS** 1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Periclimenes pedersoni	Cleaner Shrimp		2	1	1		**0.8**
Stenopus hispidus	Banded coral shrimp	1			1	1	**0.6**
	TOTALS	**1**	**2**	**1**	**2**	**1**	**1.4**

Photo Album 5 (Desecheo 20m)

Mid Shelf 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 10 intersected by line transects were identified during this 2013 monitoring survey at Puerto Botes Inner Reef. Stony corals presented a mean substrate cover of 12.1 % (range: 9.8 – 16.6 %) (Table 22). 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 9.8 %, representative of 81.0 % of the total live coral cover in the reef. 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. Reef overhangs, largely associated with growth of *O. annularis* presented a mean substrate cover of 2.1 % and contributed substantially to the reef rugosity of 3.12 m. Total abiotic cover also included wide sections of sand and averaged 16.8 %. Sponges were represented by at least 15 species along transects and contributed a mean substrate cover of 4.5 %. The dominant assemblage included *Xestospongia muta*, *Haliclona sp*., *Aplysina spp*. and *Agelas spp*. (Table 22).

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 65.9 % (Table 22). Fleshy macroalgae, mostly comprised by *Dictyota sp*., *Lobophora variegata* and *Padina sp*.) were the dominant component of the benthic algae with a mean cover of 33.0 %. 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 15m. Survey Date: September 2013.

Depth: 15 m	Transects					
	1	2	3	4	5	**Mean**
	4.60	3.06	3.80	1.76	2.40	**3.12**
SUBSTRATE CATEGORY						
Abiotic						
Sand	29.8	12.4	9.6	11.9	8.2	**14.3**
Reef Overhang	1.6	3.3		3.6	2.1	**2.1**
Rubble			1.1			**0.2**
Total Abiotic	**31.4**	**15.8**	**10.8**	**15.5**	**10.4**	**16.8**
Benthic Algae						
Turf	25.8	28.9	46.3	29.8	33.5	**32.8**
Dictyota spp.	15.1	33.2	22.0	34.6	29.6	**26.7**
Lobophora spp.	6.1	6.2	4.4	2.5	6.9	**5.0**
Crustose coralline algae		1.7		2.4	2.3	**1.1**
Padina spp.		0.9			0.2	**0.2**
Total Benthic Algae	**47.1**	**70.9**	**72.7**	**69.3**	**72.5**	**65.9**
Sponges						
Xestospongia muta	4.7					**0.9**
Haliclona spp.	2.3	0.5	0.3			**0.6**
Aplysina cauliformis		0.9	0.7	1.0		**0.5**
Agelas citrina			0.6		1.6	**0.4**
Aplysina insularis	1.3	0.2		0.4		**0.4**
Agelas sceptrum		0.8	0.2		0.5	**0.3**
Agelas conifera	1.0			0.4		**0.3**
Aiolochoria crassa yellow		1.3				**0.3**
Agelas dispar				1.7		**0.2**
Ecytoplasia ferox	0.8					**0.2**
Amphimedon compressa		0.3	0.1			**0.1**
Prosuberites laughlini	0.3					**0.1**
Spirastrella coccinea	0.3					**0.1**
Amphimedon compressa black		0.2				**0.0**
Scopalina ruetzleri		0.2				**0.0**
Total Sponges	**10.6**	**4.4**	**2.0**	**3.4**	**2.0**	**4.5**
Cyanobacteria	1.7		0.9	1.2	4.2	**1.6**
Live Stony Corals						
Porites astreoides	3.7	7.7	6.9	4.4	1.2	**4.4**
Orbicella annularis	0.8		8.0	2.4	6.8	**3.4**
Montastraea cavernosa	0.4			1.9	3.4	**1.1**
Siderastrea siderea	4.1	0.3				**0.9**
Agaricia agaricites	0.2	1.0		1.4	0.2	**0.6**
Diploria strigosa	0.5		0.9		0.7	**0.4**
Madracis decactis	0.2	0.8		1.0		**0.4**
Millepora alcicornis			0.8			**0.2**
Leptoseris cucullata		0.5				**0.1**
Porites porites				0.2		**0.0**
Total Stony Corals	**9.8**	**10.3**	**16.6**	**11.4**	**12.2**	**12.1**

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 2004-13. 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 measured. 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; $p = 0.008$; appendix 2). The decline of coral cover during 2007 was observed in four out of the five transects surveyed. After 2007, statistically significant declines of substrate cover by live corals have not been observed. An increasing trend of live coral cover, influenced by increments of cover by *O. annularis* and *P. astreoides* appears to be developing 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. At present, the dominant coral species in terms of reef substrate cover is the Mustard-Hill Coral, *Porites astreoides*, which implies a shift in the sessile-benthic community structure of the reef.

A total of seven 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*, Massive Starlet Coral, *Siderastrea siderea*, Symmetrical Brain Coral, *Diploria strigosa*, Ten-ray Star Coral, *Madracis decactis*, Sunray Lettuce Coral, *Leptoseris cucullata*, Branching Fire Coral, *Millepora alcicornis*, and Finger Coral, *Porites porites*.

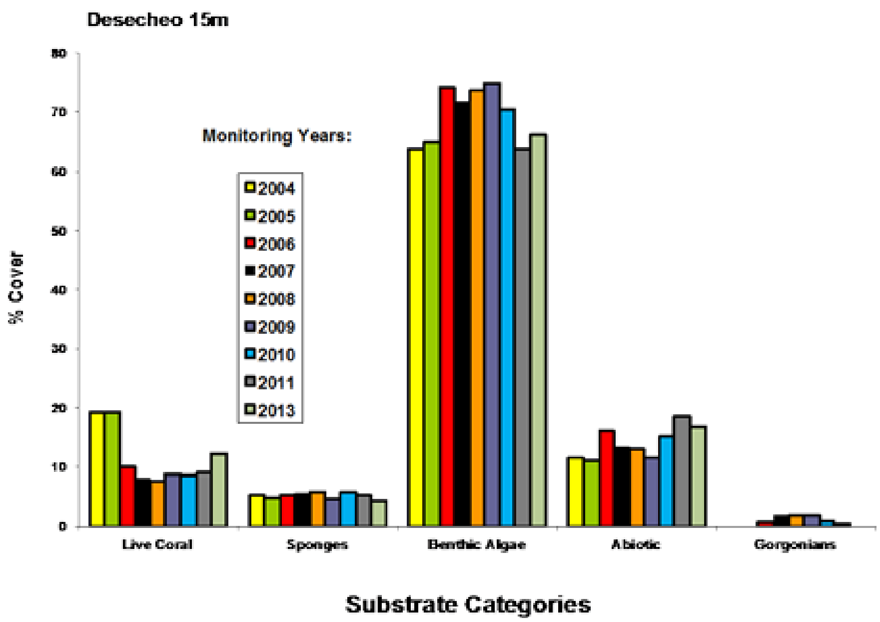


Figure 20. Monitoring trends (2004 -13) of mean substrate cover by sessile-benthic categories at Puerto Botes Inner Shelf Reef, Desecheo Island – 15 m.

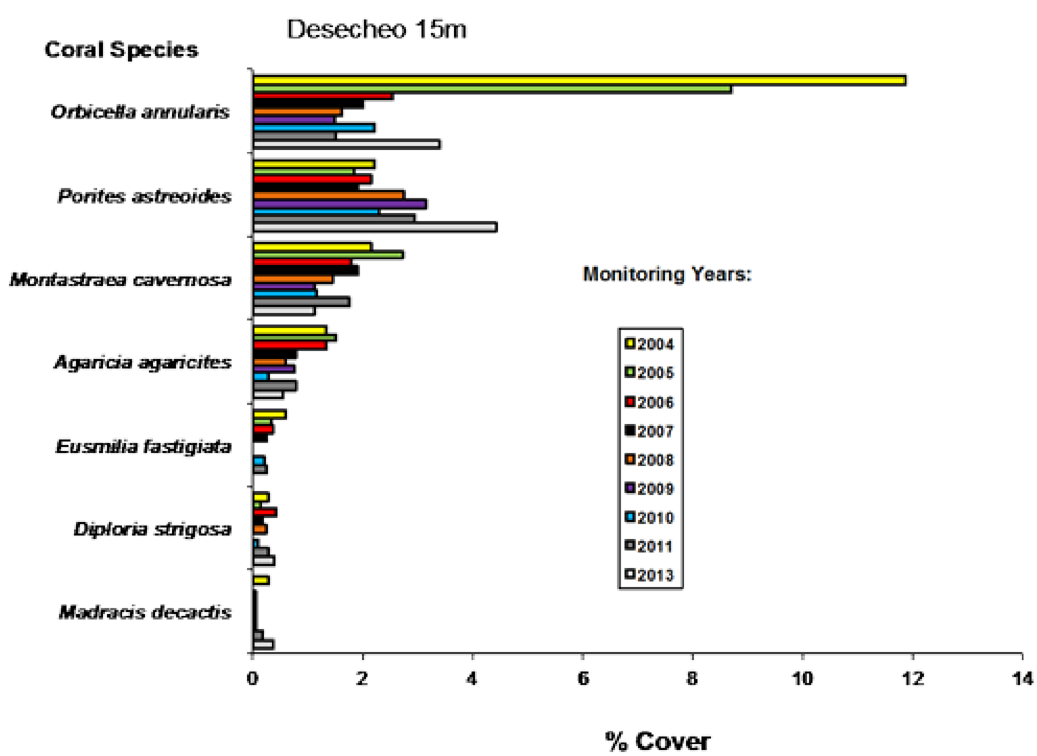


Figure 21. Monitoring trends (2004 -13) of mean substrate cover by stony coral species at Puerto Botes Inner Shelf Reef, Desecheo Island – 15 m.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 37 fish species were identified within belt-transects from the Inner-Shelf Reef off Puerto Botes, Isla Desecheo during June 2013 (Table 23). Mean abundance within belt-transects during the 2013 survey was 143.6 Ind/30 m^2 (range: 87 - 247 Ind/30 m^2). The mean number of species per transect was 21.2 (range: 18 - 25). The Blue Chromis, Bicolor Damselfish, Bluehead Wrasse, Peppermint Goby and Masked Goby were the numerically dominant species with a combined abundance of 95.4 Ind/30 m^2, representing 66.4 % of the total fish abundance. Twelve (12) additional species were present in at least four out of the five transects. These include the Yellowhead Wrasse, Stoplight and Redband Parrotfishes, Yellowtail Damselfish, Blue Tang, Sargassum Triggerfish, Sharknose Goby, Black Durgon, and the Coney. A total of 9 species were represented by only one individual in the five belt-transects surveyed.

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 143.6 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 23. Taxonomic composition and abundance of fishes within belt-transects at the Inner Shelf Reef off Puerto Botes, Isla Desecheo, September 2013

Depth: 15m

		Transects					
		1	2	3	4	5	
		(Individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Chromis cyanea	Blue Chromis	35	20	44	15	75	**37.8**
Stegastes partitus	Bicolor Damselfish	32	33	22	0	25	**22.4**
Thalassoma bifasciatum	Bluehead Wrasse	30	10	22	0	30	**18.4**
Coryphopterus lipernes	Peppermint Goby	0	6	6	14	18	**8.8**
Coryphopterus personatus	Masked Goby	0	0	0	15	25	**8.0**
Scarus iserti	Stripped Parrotfish	7	4	5	2	11	**5.8**
Clepticus parrae	Creole Wrasse	0	0	0	1	25	**5.2**
Myripristis jacobus	Blackbar Soldierfish	5	3	6	7	4	**5.0**
Halichoeres maculipinna	Clown Wrasse	4	5	4	1	8	**4.4**
Chromis multilineata	Brown Chromis	7	0	3	5	0	**3.0**
Gramma loreto	Fairy Basslet	0	2	3	1	7	**2.6**
Halichoeres garnoti	Yellow-head Wrasse	8	1	2	0	2	**2.6**
Sparisoma viride	Stoplight Parrotfish	1	0	1	6	3	**2.2**
Sparisoma aurofrenatum	Redband Parrotfish	0	1	5	3	1	**2.0**
Acanthurus coeruleus	Blue Tang	2	1	2	2	2	**1.8**
Microspathodon chrysurus	Yellowtail Damselfish	0	2	1	4	2	**1.8**
Epinephelus fulva	Coney	1	2	1	4	0	**1.6**
Ocyurus chrysurus	Yellowtail Snapper	0	3	1	0	3	**1.4**
Gobiosoma evelynae	Sharknose Goby	1	1	2	2	0	**1.2**
Melichthys niger	Black Durgon	2	2	1	0	1	**1.2**
Holacanthus tricolor	Rock Beauty	2	2	1	0	0	**1.0**
Acanthostracion polygonia	Honeycomb Cowfish	1	0	1	1	0	**0.6**
Bodianus rufus	Spanish Hogfish	1	0	1	0	1	**0.6**
Epinephelus cruentatus	Graysby	2	1	0	0	0	**0.6**
Holocentrus rufus	Squirrelfish	0	1	1	1	0	**0.6**
Acanthurus chirurgus	Doctorfish	0	0	0	2	0	**0.4**
Haemulon flavolineatum	French Grunt	0	0	0	0	2	**0.4**
Xanthychys rigens	Sargassum Triggerfish	0	1	1	0	0	**0.4**
Acanthemblemaria aspera	Roughead Blenny	0	1	0	0	0	**0.2**
Amblycirrhitus pinnos	Redspotted Hawkfish	0	0	0	1	0	**0.2**
Coryphop. glaucophraenum	Goby	1	0	0	0	0	**0.2**
Lactophrys triqueter	Smooth Trunkfish	0	0	1	0	0	**0.2**
Ptoris volitans	Lionfish	0	0	0	0	1	**0.2**
Neoniphon marianus	Squirrelfish	0	0	1	0	0	**0.2**
Serranus tigrinus	Harlequin Bass	0	1	0	0	0	**0.2**
Sparisoma radians	Bucktooth Parrotfish	0	1	0	0	0	**0.2**
Sparisoma rubripine	Yellowtail Parrotfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	142	104	138	87	247	**143.6**
	TOTAL SPECIES	18	23	25	19	21	**21.2**

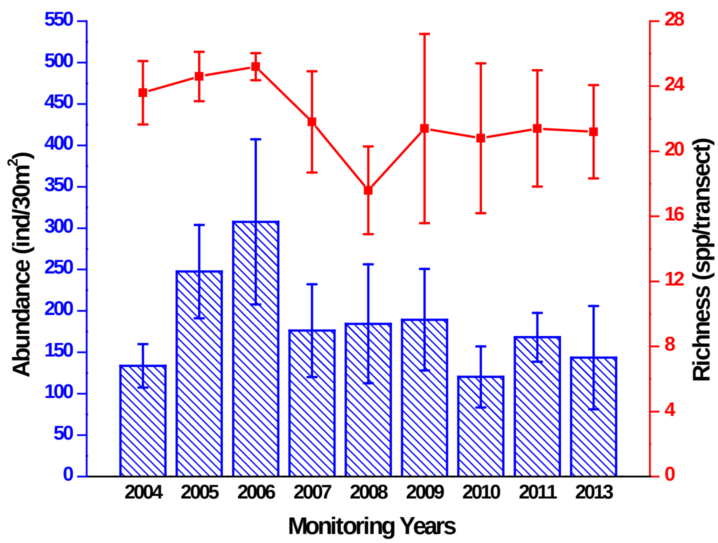


Figure 22. Monitoring trends (2004 – 2013) of fish species richness and abundance at Inner Shelf Reef, Puerto Botes, 15 m depth, Isla Desecheo.

Reef zooplankton feeders, such as the Blue and Brown Chromis, Bicolor Damselfish and Creole Wrasse the comprise the most prominent fish assemblage of this inshore reef 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 that have been observed during the ASEC surveys (Table 24). 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 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. Motile megabenthic invertebrates were represented within belt-transects by arrow crabs and cleaner shrimps (Table 25).

Table 24. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Puerto Botes Inner-shelf Reef, Isla Desecheo, September 2013

Depth range :14-16 m Duration - 30 min.

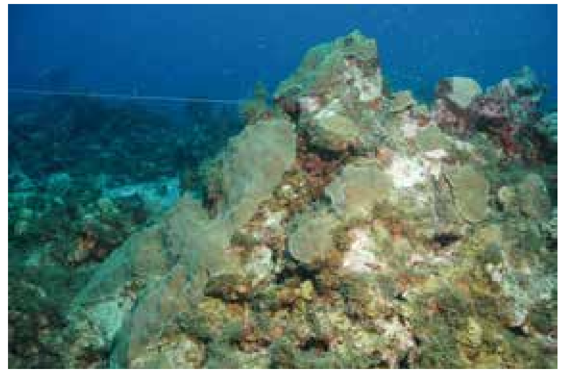
SPECIES	**COMMON NAME**		# - (cm)	
Caranx crysos	Blue Runner	3 - (40)		
Epinephelus guttatus	Red Hind	1 – (33)		
Lutjanus apodus	Schoolmaster	2 - (20)	8 - (25)	2 - (30)
Lutjanus mahogany	Mahogani Snapper	2 - (20)	2 – (25)	1 - (30)
Ocyurus chrysurus	Yellowtail Snapper	8 – (45)		
Scomberomo regalis	Cero Mackerel	1 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (55)		

Table 25. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at the Puerto Botes Inner-Shelf Reef,15 m, Isla Desecheo, September 2013

Depth: 15 m		**TRANSECTS**					
		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			**0.4**
	TOTALS	**1**	**1**	**1**	**1**	**1**	**1.0**

Photo Album 6 (Desecheo 15m)

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).

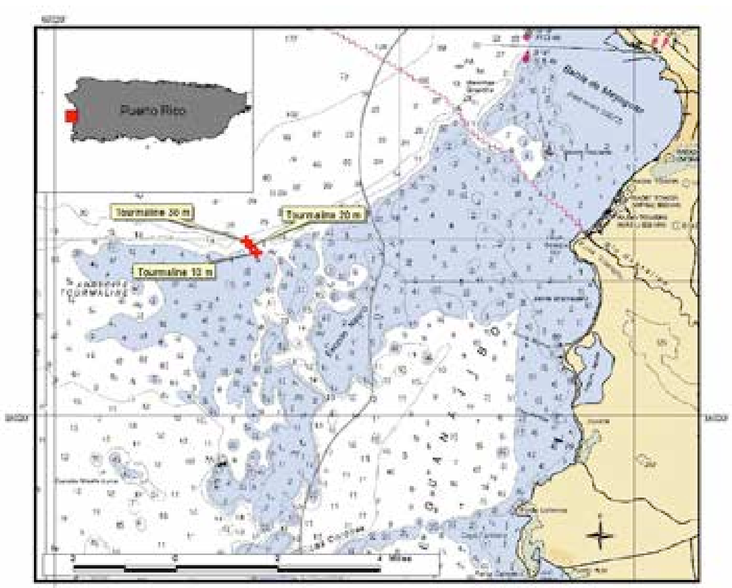


Figure 23. Location of coral reef survey stations at Tourmaline Reef, off Mayaguez Bay.

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, 14 of which were intercepted by line transects during our 2013 survey (Table 26). Stony corals occurred mostly as isolated encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 17.6 % (range: 9.0 – 24.3 %). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant species in terms of substrate cover with a mean of 6.6 % (range: 4.4 – 8.3 %), representing 37.5 % 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. Soft corals (gorgonians) were present in all transects surveyed, but in relatively low densities with an average of 4.8 colonies/transect. The Corky Sea Finger, *Briareum asbestinum* 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 nine species along transects surveyed with an average substrate cover of 4.8 %. Some of the most prevalent along transects included *Agelas conifera, Plakortis angulospiculatus* and *Prosuberites laughlini* (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 7.5 % and contributed substantially to a topographic rugosity of 5.97 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 48.9 % (range : 39.9 – 66.5 %). Turf algae was found

Table 26. Percent substrate cover by sessile-benthic categories at Tourmaline Reef, Mayaguez, 30m. Survey Date: December 2012.

Depth: 30 m	Transects					
	1	2	3	4	5	**Mean**
	5.61	4.60	5.05	7.05	7.53	**5.97**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	4.5	1.5		9.9	21.4	**7.5**
Sand	0.3	12.8	12.3			**5.1**
Total Abiotic	**4.8**	**14.4**	**12.3**	**9.9**	**21.4**	**12.5**
Benthic Algae						
Turf	51.7	45.4	66.5	41.1	39.9	**48.9**
Crustose coralline algae	3.4	4.1	4.1	9.3	4.6	**5.1**
Halimeda spp.			2.5			**0.5**
Sargassum hystrix	1.8					**0.4**
Total Benthic Algae	**56.9**	**49.6**	**73.1**	**50.4**	**44.5**	**54.9**
Gorgonian						
Encrusting gorgonians				16.8	14.4	**6.2**
Briareum asbestinum	8.6	2.2	1.5			**2.5**
Erythropodium caribaeorum	3.4	2.2				**1.1**
Total Gorgonian	**12.0**	**4.4**	**1.5**	**16.8**	**14.4**	**9.8**
Erect Gorgonians (#col/transect)	4.0	2.0	3.0	9.0	6.0	**4.8**
Sponges						
Unid. sponge	1.1			2.1	8.4	**2.3**
Agelas conifera	0.5	4.1				**0.9**
Plakortis angulospiculatus		1.5	1.7			**0.6**
Prosuberites laughlini	0.3	0.2	2.2			**0.5**
Niphates erecta		0.5	0.2			**0.1**
Svenzea zeai		0.6				**0.1**
Halisarca caerulea	0.4					**0.1**
Aplysina cauliformis	0.3					**0.1**
Iotrochota birotulata		0.1				**0.0**
Total Sponge	**2.6**	**7.0**	**4.1**	**2.1**	**8.4**	**4.8**
Live Stony Corals						
Orbicella annularis	5.7	6.4	4.4	8.5	8.3	**6.6**
Agaricia gramahae	8.4	9.1	2.2			**4.0**
Agaricia agaricites	1.1			8.4	3.0	**2.5**
Agaricia lamarcki	1.1	5.0	1.0			**1.4**
Montastraea cavernosa	0.9	1.1	1.0	2.1		**1.0**
Porites astreoides	1.2			2.0		**0.6**
Madracis carmabi		1.1	0.4			**0.3**
Agaricia fragilis		1.2				**0.2**
Mycetophyllia aliciae	1.2					**0.2**
Madracis decactis	1.0					**0.2**
Dichocoenia stokesi	0.8					**0.2**
Madracis pharensis	0.7					**0.1**
Siderastrea siderea		0.4				**0.1**
Stephanocoenia intersepta	0.2					**0.0**
Total Stony Corals	**22.2**	**24.3**	**9.0**	**21.0**	**11.3**	**17.6**

overgrowing rocky substrates, as well as dead coral sections and other hard bottom. The total cover by benthic algae was 54.9 %.

Figure 24 presents 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 between the previous baseline survey (13.5 %) and the present 2013 monitoring survey (13.1 %) has remained within the sampling error margin. Differences of live coral cover between monitoring surveys were small and not statistically significant (ANOVA; $p = 0.429$, Appendix 2). 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 three species of lettuce corals *(Agaricia spp)* now surpass reef substrate cover by stony corals (Figure 25). Since our baseline survey in 2004, many large colonies of *O. annularis* stand 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. After 2007, a gradual and consistent trend of increasing cover by *O. annularis* has been measured, but differences are within sampling variability error (Appendix 2).

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 2013 monitoring survey was 94.8 Ind/30 m^2 (range: 57 - 171 Ind/30 m^2). The mean number of species per transect was 13 (range: 14 - 21). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 46.6 Ind/30 m^2 (range: 25 - 95 Ind/30 m^2), representing 49.2 % 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, Fairy Basslet, Blue Chromis, Tomtate, Princess Parrotfish, Bicolor Damselfish and Black-bar Soldierfish were present on at least four of the five transects surveyed and along with Creole Wrasse comprised the most abundant fish assemblage at the Tourmaline Reef shelf-edge.

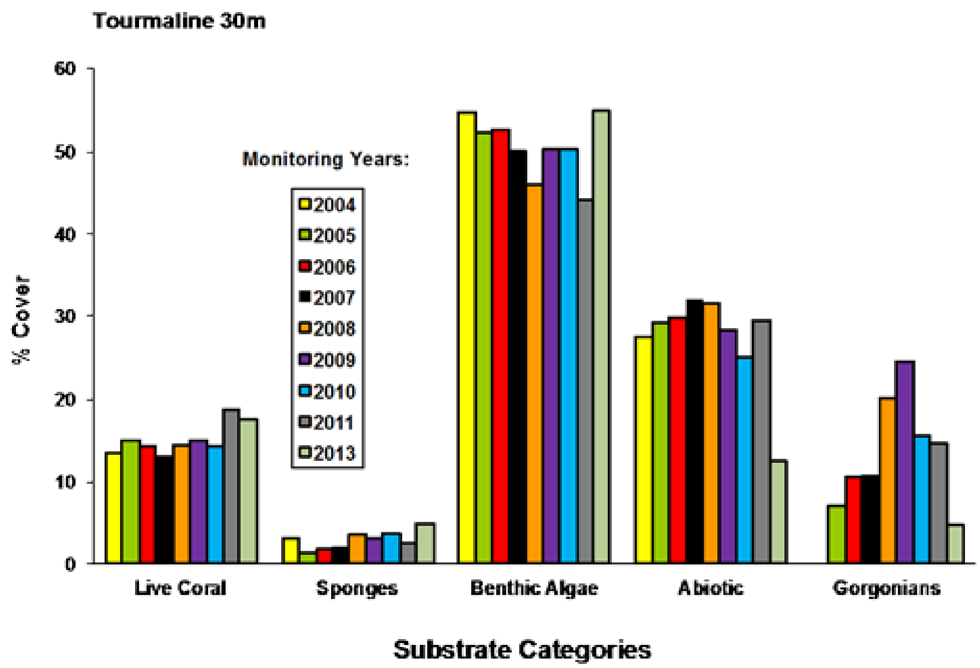


Figure 24. Monitoring trends (2004 – 2013) of mean substrate cover by sessile-benthic categories at Tourmaline Shelf-edge Reef – 30 m, Mayaguez Bay.

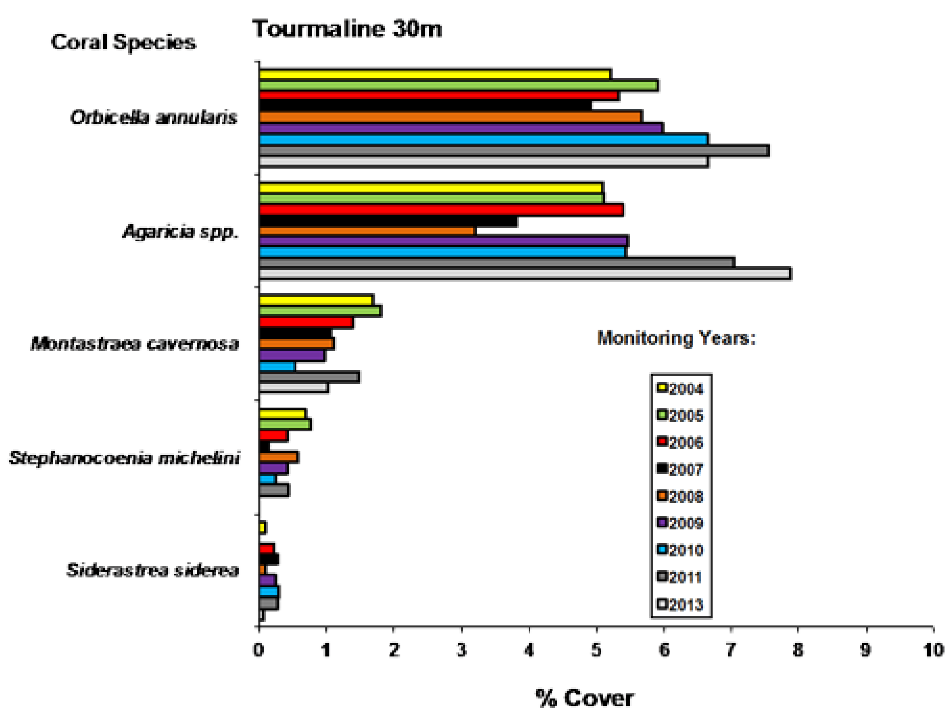


Figure 25. Monitoring trends (2004 – 2013) of mean substrate cover by stony coral species at Tourmaline Reef – 30 m, Mayaguez Bay.

Table 27. Taxonomic composition and abundance of fishes within belt transects at Tourmaline Reef, Mayaguez Bay, 30m. Survey: December 2012

		Transects					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	25	28	30	55	95	**46.6**
Clepticus parrae	Creole Wrasse	50	0	0	0	0	**10.0**
Chromis cyanea	Blue Chromis	5	14	3	10	17	**9.8**
Coryphopterus lipernes	Peppermint Goby	4	2	3	2	22	**6.6**
Gramma loreto	Fairy Basslet	1	3	4	1	8	**3.4**
Myripristis jacobus	Blackbar Soldierfish	9	1	4	2	1	**3.4**
Stegastes partitus	Bicolor Damselfish	5	3	0	0	9	**3.4**
Scarus taeniopterus	Princess Parrotfish	1	0	4	5	6	**3.2**
Haemulon aurolineatum	Tomtate	0	2	3	1	5	**2.2**
Stegastes leucostictus	Beau Gregory	1	1	0	0	3	**1.0**
Chaetodon capistratus	Four-eye Butterflyfish	0	1	0	1	1	**0.6**
Ptoris volitans	Lionfish	0	0	1	1	1	**0.6**
Gobiosoma evelynae	Sharknose Goby	0	1	1	0	0	**0.4**
Halichoeres garnoti	Yellow-head Wrasse	0	0	1	0	1	**0.4**
Epinephelus cruentatus	Graysby	0	0	0	1	1	**0.4**
Neoniphon marianus	Longspine Squirrelfish	1	0	1	0	0	**0.4**
Sparisoma aurofrenatum	Redband Parrotfish	0	0	0	2	0	**0.4**
Thalassoma bifasciatum	Bluehead Wrasse	0	1	0	0	0	**0.2**
Canthigaster rostrata	Caribbean Puffer	0	0	1	0	0	**0.2**
Haemulon flavolineatum	French Grunt	0	1	0	0	0	**0.2**
Chaetodon aculeatus	Longsnout Butterflyfish	0	0	0	1	0	**0.2**
Holacanthus tricolor	Rock Beauty	0	1	0	0	0	**0.2**
Epinephelus guttatus	Red Hind	1	0	0	0	0	**0.2**
Hypoplectrus gummigutta	Golden Hamlet	0	0	1	0	0	**0.2**
Hypoplectrus unicolor	Butter Hamlet	1	0	0	0	0	**0.2**
Synodus intermedius	Sand Diver	0	0	0	1	0	**0.2**
Holocentrus rufus	Squirrelfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	104	59	57	83	171	**94.8**
	TOTAL SPECIES	12	13	13	13	14	**13**

Annual fluctuations of fish species richness and abundance at the Mayaguez 30 m reef are shown in Figure 26. Fish species richness maintained a consistent decline after 2006, reaching a minimum of 13 species per transect in the present 2013 survey. Differences of species richness between annual surveys were statistically significant (ANOVA; $p = 0.006$). The overall reduction in species richness from the baseline survey (23 spp/transect) to the present 2013 survey was of 43.4 %. Differences of fish abundance between monitoring surveys were also statistically significant (ANOVA; $p < 0.001$). Annual variations were mostly driven by the abundance 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. Top demersal and pelagic predators, such as large snappers, groupers and mackerels have been observed at the shelf-edge reef, but in low abundance. Red Hind, Yellowmouth and Nassau Groupers, and several snappers were observed during the2010-11 ASEC survey (García-Sais et al., 2012). Juvenile Nassau Groupers, Mutton,

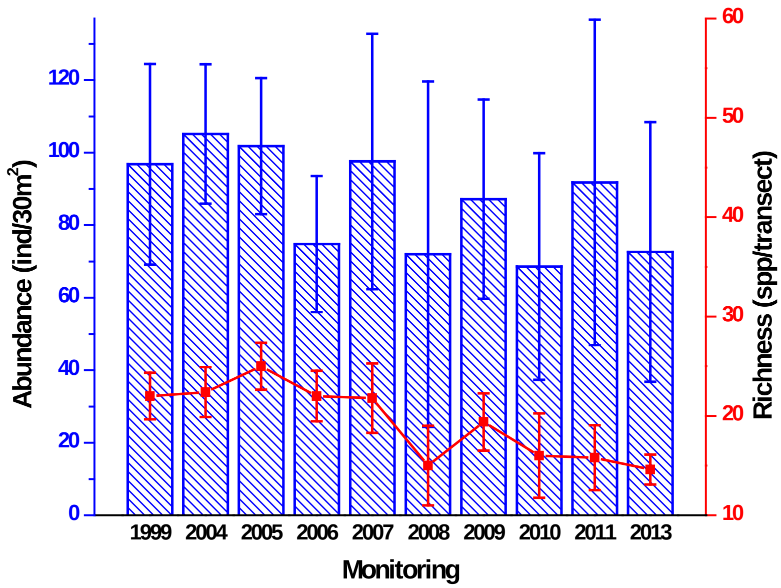


Figure 26. Monitoring trends (2004 – 2010) of fish species richness and abundance at Shelf-edge Reef Tourmaline, 30 m, Mayaguez Bay.

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* were present 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 70% 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 were present, including Hogfish (Table 28), wrasses, gobies, goatfishes and squirrelfishes among others. Lionfishes were present within three belt-transects surveyed in 2012. One cleaner shrimp was the only motile megabenthic invertebrate observed within belt-transects at the Tourmaline shelf-edge reef during this survey (Table 29).

Table 28. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Tourmaline Shelf-edge Reef, December 2012

Depth range : 25 - 32 m   Duration - 30 min.

SPECIES	**COMMON NAME**	**# - (cm)**	**# - (cm)**
Aetobatus narinari	Spotted Eagle Ray	1 – (120)	
Epinephelus guttatus	Red Hind	1 - (30)	2 – (35)
Decapterum macarellus	Mackerel Scad	>100 – (10 – 15)	
Lachnolaimus maximus	Hogfish	1 – (50)	
Lutjanus apodus	Schoolmaster Snapper	3 - (25)	2 – (30)
Sphyraena barracuda	Great barracuda	1 - (70)	

Table 29. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Shelf-edge Reef, 30 m, December 2012

Depth: 30 m

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

Photo Album 7 (Tourmaline 30 m)

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, 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 26.0 % (range: 18.8 – 32.7 %). Large and massive colonies of Boulder Star Coral 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 18.0 % (range: 11.2 – 24.0 %), representing 69.0 % of the total cover by stony corals. Colonies of Boulder Star and Mustard Hill Corals (*Porites astreoides*) were intercepted by all five transects. In addition to the aforementioned species, Massive Starlet Coral (*Siderastrea siderea*) and Great Star Coral (*M. cavernosa*) comprised the main stony coral assemblage at Tourmaline 20 m (Table 30).

Soft corals (gorgonians) were moderately abundant with an average of 7.4 colonies/transect and nine species intercepted by transects (Table 30). *Briareum asbestinum,* and *Pseudoptergorgia acerosa* were the most abundant soft coral species and were present in all transects surveyed.

Table 30. Percent substrate cover by sessile-benthic categories at Tourmaline Reef, Mayaguez. 20 m. Survey Date: December 2012

	Transects					
	1	2	3	4	5	**Mean**
	4.08	3.86	4.57	5.99	4.71	**4.64**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhang	10.3	13.5	3.2	22.6	24.2	**14.8**
Sand				1.9		**0.4**
Total Abiotic	**10.3**	**13.5**	**3.2**	**24.5**	**24.2**	**15.1**
Benthic Algae						
Turf	43.8	38.8	66.9	39.4	36.6	**45.1**
Lobophora spp.	2.3	6.7	2.4	3.8	8.0	**4.6**
Crustose coralline algae	3.8	4.6	2.3		1.2	**2.4**
Dictyota spp.	3.4		2.5	5.6		**2.3**
Total Benthic Algae	**53.3**	**50.1**	**74.1**	**48.8**	**45.8**	**54.4**
Gorgonians						
Erythropodium caribaeorum	0.6	7.3	3.2	0.9	0.5	**2.5**
Briareum asbestinum	1.4	1.3	0.8	0.5	0.3	**0.8**
Total Gorgonians	**2.0**	**8.6**	**3.9**	**1.4**	**0.8**	**3.3**
Erect Gorgonians (#col/transect)	9.0	7.0	8.0	6.0	7.0	**7.4**
Sponges						
Clathria spp.	1.4					**0.3**
Agelas conifera					1.1	**0.2**
Prosuberites laughlini				1.0		**0.2**
Aiolochroia crassa		0.9				**0.2**
Unknown encrusting sponge	0.3					**0.1**
Mycale laevis		0.1				**0.0**
Total Sponges	**1.7**	**1.0**		**1.0**	**1.1**	**1.0**
Live Stony Corals						
Orbicella annularis	24.0	17.5	11.2	20.0	17.3	**18.0**
Siderastrea siderea	1.9		3.3	2.6	2.0	**2.0**
Montastraea cavernosa	5.5		0.4		3.9	**2.0**
Agaricia lamarcki	1.3		1.2		3.3	**1.1**
Porites astreoides	0.1	2.0	0.3	0.9	1.5	**1.0**
Colpophyllia natans		3.1				**0.6**
Madracis decactis		2.5		0.4		**0.6**
Diploria strigosa			1.2			**0.2**
Mycetophyllia danaanae			0.8			**0.2**
Dichocoenia stokesi			0.5			**0.1**
Eusmilia fastigiata		0.4				**0.1**
Meandrina meandrites				0.4		**0.1**
Porites porites		0.3				**0.1**
Agaricia fragilis		0.2				**0.0**
Porites furcata		0.1				**0.0**
Total Stony Corals	**32.7**	**26.2**	**18.8**	**24.3**	**28.1**	**26.0**

Colonies of Bushy Black Coral (*Antipathes caribbeana*) were present at the reef base. Encrusting sponges were represented by at least six species along transects with a mean cover of 1.0 %, and comprised a minor component of the reef benthos. Reef overhangs, associated with live and dead ledges of Boulder Star Coral averaged 14.8 % of the reef substrate cover and contributed markedly to the topographic rugosity of 4.6 m (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 54.4 % (range: 45.8 – 74.1 %). Turf algae, a mixed assemblage of short filamentous red and brown macroalgae contributed a reef substrate cover of 45.1%, representing 82.9% of the total benthic algae. The Encrusting Fan Alga, *Lobophora variegata* (mean cover: 4.6%) 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 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, $p = 0.429$; 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, presenting small fluctuations that appear to be within sampling variability error. Increasing trends of reef substrate cover by benthic algae appears to be associated with colonization of previously abiotic substrates (Figure 27).

Orbicella annularis was the main driver of the declining trend of live coral at Tourmaline Reef between 2004 and 2007 because it was, and still is, the dominant coral species (Figure 28). Other massive coral types, such as Great Star Coral, *M. cavernosa*, and Massive Starlet Coral, *Siderastrea siderea* also showed a declining trend of substrate cover during the monitoring program.

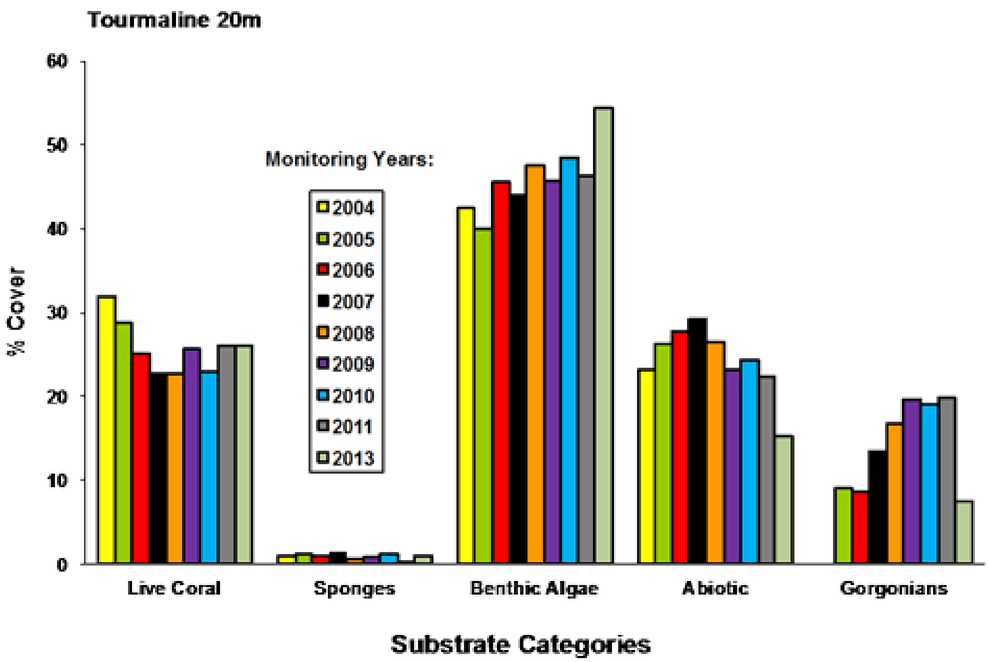


Figure 27. Monitoring trends (2004 – 2013) of mean substrate cover by sessile-benthic categories at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

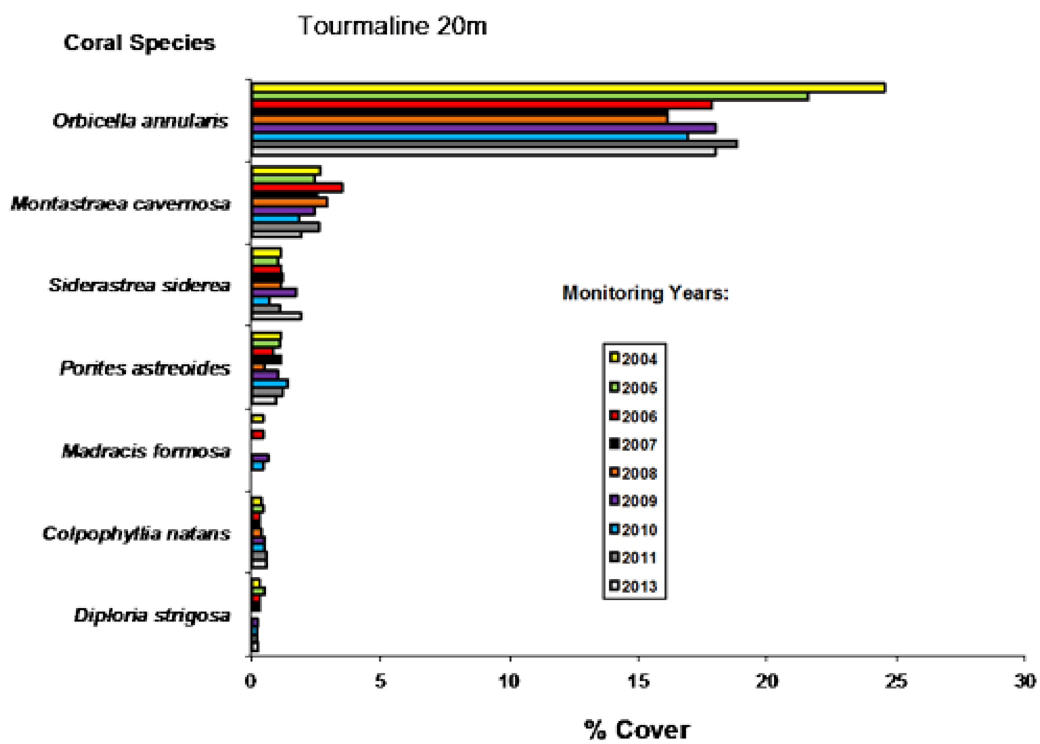


Figure 28. Monitoring trends (2004 – 2013) of mean substrate cover by stony coral species at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

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 2013 was 111.0 Ind/30 m^2 (range: 91 - 156 Ind/30 m^2). The mean number of species per transect was 17.2 (range: 15 - 19). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 31.0 Ind/30 m^2 (range: 15 – 45 Ind/30 m^2), representing 27.9 % 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, Striped and Princess Parrotfishes, Fairy Basslet and Peppermint Goby, 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.

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. 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 sharp have been observed in highly degraded reefs, such as Desecheo 20 and 30 m, which suggests that recruitment dynamicas play an important role.

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. Tourmaline outer reef has been identified as a Red Hind

Table 31. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, Mayaguez Bay, 20 m. Survey Date: December 2012

Depth: 20m		TRANSECTS					
		1	2	3	4	5	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	35	30	30	45	15	**31.0**
Clepticus parrae	Creole Wrasse	32	35	0	35	0	**20.4**
Chromis cyanea	Blue Chromis	6	9	5	12	22	**10.8**
Scarus iserti	Stripped Parrotfish	1	0	8	32	5	**9.2**
Gramma loreto	Fairy Basslet	10	5	5	8	8	**7.2**
Coryphopterus lipernes	Peppermint Goby	7	5	8	6	5	**6.2**
Scarus taeniopterus	Princess Parrotfish	3	0	15	5	0	**4.6**
Halichoeres garnoti	Yellow-head Wrasse	0	1	4	3	7	**3.0**
Myripristis jacobus	Blackbar Soldierfish	0	0	2	2	10	**2.8**
Sparisoma aurofrenatum	Redband Parrotfish	3	0	3	0	5	**2.2**
Stegastes leucostictus	Beau Gregory	2	4	2	1	2	**2.2**
Stegastes partitus	Bicolor Damselfish	0	2	1	3	4	**2.0**
Canthigaster rostrata	Caribbean Puffer	3	1	1	1	3	**1.8**
Acanthurus bahianus	Ocean Surgeon	3	1	1	0	0	**1.0**
Cephalopholis cruentatus	Graysby	1	0	0	1	2	**0.8**
Caranx ruber	Bar Jack	2	0	1	0	0	**0.6**
Haemulon flavolineatum	French Grunt	0	2	0	0	1	**0.6**
Holocentrus rufus	Squirrelfish	0	1	1	1	0	**0.6**
Gobiosoma evelynae	Sharknose Goby	2	0	0	0	0	**0.4**
Acanthurus coeruleus	Blue Tang	1	0	1	0	0	**0.4**
Hypoplectrus indigo	Indigo Hamlet	0	1	1	0	0	**0.4**
Anisotremus virginicus	Porkfish	0	0	0	1	0	**0.2**
Aulostomus maculatus	Trumpetfish	1	0	0	0	0	**0.2**
Equetus punctatus	Spotted Drum	0	0	1	0	0	**0.2**
Hypoplectrus sciurus	Yellowtail Hamlet	0	0	0	0	1	**0.2**
Hypoplectrus unicolor	Butter Hamlet	1	0	0	0	0	**0.2**
Lachnolaimus maximus	Hogfish	0	1	0	0	0	**0.2**
Lipropoma rubre	Swiss Guard Basslet	0	0	0	0	1	**0.2**
Ocyurus chrysurus	Yellowtail Snapper	0	1	0	0	0	**0.2**
Boadianus rufus	Spanish Hoggfish	0	0	0	0	1	**0.2**
Chaetodon acuelatus	Longsnout Butterflyfish	0	0	0	0	1	**0.2**
Heteropriacantus cruentatus	Glasseye Snapper	0	0	0	0	1	**0.2**
Mycteroperca venenosa	Yellowfin Grouper	0	1	0	0	0	**0.2**
Neoniphon marianus	Longjaw Squirrelfish	0	0	0	0	1	**0.2**
Pterois volitans	Lionfish	0	0	1	0	0	**0.2**
	TOTAL INDIVIDUALS	**113**	**100**	**91**	**156**	**95**	**111.0**
	TOTAL SPECIES	**17**	**16**	**19**	**15**	**19**	**17.2**

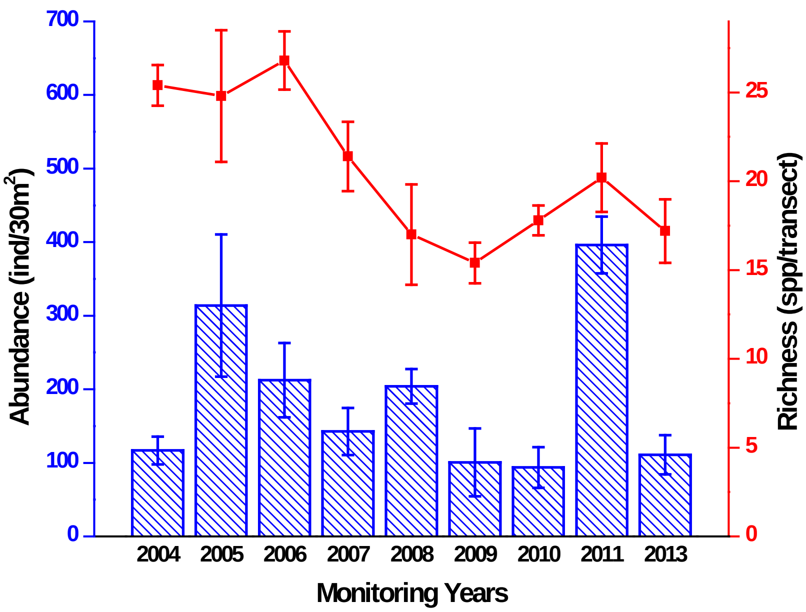


Figure 29. Monitoring trends (2004 – 2010) of fish species richness and abundance at outer shelf reef Tourmaline, 20 m, Mayaguez.

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 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 seven species and doctorfishes (*Acanthurus spp*.), represented by three species comprised the main herbivorous fish assemblage. Among large invertebrate and small demersal fish predators, Red Hinds, Schoolmaster and Yellowtail Snappers, Great Barracuda and Cero Mackerels were observed during the 2013 and previous ASEC surveys (Table 32). Nassau Groupers and

Cubera and Dog Snappers have been identified from previous ASEC surveys at this reef (García-Sais et al, 2005).

One Arrow Crab and one Banded Coral Shrimp were the only motile megabenthic invertebrates observed within belt-transects during 2013. One Spiny Lobster was observed outside transects.

Table 32. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Tourmaline 20 m. December 2012

Depth range : 17 - 21 m   Duration - 30 min.

SPECIES	**COMMON NAME**		# - (cm)
Epinephelus guttatus	Red Hind	2 - (30)	2– (35)
Lutjanus apodus	Schoolmaster	5 - (20)	6 – (25)
Lutjanus mahogany	Mahogany Snapper	3 - (15)	1 – (25)
Ocyurus chrysurus	Yellowtail Snapper	1 - (15)	2 - (25)
Scomberomorus regalis	Cero Mackerel	1 - (40)	
Sphyraena barracuda	Great Barracuda	1 - (60)	
Invertebrates			
Panulirus argus	Spiny Lobster	1 – (40)	

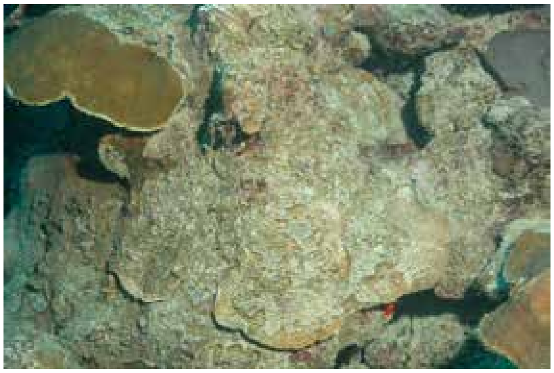
Table 33. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline 20 m, Mayaguez, December 2012

Depth: 20 m

		TRANSECTS					**MEAN ABUNDANCE (IND/30 m^2)**
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Stenopus hispidus	Banded Coral Shrimp				1		**0.2**
Stenorhynchus seticornis	Arrow Crab					1	**0.2**
	TOTALS	**0**	**0**	**0**	**1**	**1**	**0.4**

Photo Album 8 (Tourmaline 20 m)

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 nineth time during December 2013. 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, 16 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 38.5 % (range: 29.0 – 71.5 %). Boulder Star Coral, *O. annularis* and Yellow Pencil Coral, *Madracis mirabilis* were the dominant coral species in terms of substrate cover with means of 10.3 and 9.9 %, 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 survey (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 71.5 % in that transect, which is the highest in the monitoring program. Boulder Star Coral (*O. annularis* complex), Finger Coral (*P. porites*), Mustard Hill Coral (*Porites astreoides*), and Lettuce Coral (*Agaricia agaricites*) were intercepted by all five transects in the present 2013 monitoring survey and comprised in addition to *M. mirabilis* the main stony coral assemblage at this reef. A total of nine coral species were represented with less than 1% substrate cover.

Table 34. Percent substrate cover by sessile-benthic categories at Tourmaline Reef, Mayaguez. 10m. Survey Date: December 2012.

	Transects					
	1	2	3	4	5	**Mean**
	2.84	4.01	3.20	1.80	1.97	**2.8**
SUBSTRATE CATEGORY						
Benthic Algae						
Turf	50.9	14.4	50.5	54.9	48.4	**43.8**
Dictyota spp.	8.8	9.7	4.8	1.3	7.4	**6.4**
Crustose coralline algae	2.3	3.1	0.1	3.0	3.7	**2.4**
Total Benthic Algae	**62.1**	**27.2**	**55.4**	**59.2**	**59.5**	**52.7**
Cyanobacteria			0.2			**0.0**
Encrusting Gorgonians						
Erythropodium caribaeorum	6.3		5.7	1.2		**2.6**
Briareum asbestinum	0.8	0.1	1.4	8.4		**2.1**
Encrusting gorgonians					6.8	**1.4**
Total Gorgonian	**0.8**	**0.1**	**1.4**	**8.4**	**6.8**	**4.8**
Erect Gorgonians						
(#col/transect)	26.0	20.0	16.0	21.0	24.0	**21.4**
Sponges						
Unid. sponge					4.7	**0.9**
Scopalina reutzleri			2.5			**0.5**
red encrusting sponge		0.7	1.6			**0.5**
Amphimedon compressa				0.6		**0.1**
black encrusting sponge	0.5					**0.1**
Monanchora arbuscula		0.4				**0.1**
Clathria spp.			0.3			**0.1**
Aplysina lacunosa		0.1				**0.0**
Total Sponge	**0.5**	**1.2**	**4.5**	**0.6**	**0.0**	**1.4**
Live Stony Corals						
Orbicella annularis	7.1	16.3	11.0	8.1	8.9	**10.3**
Madracis mirabilis		49.7				**9.9**
Porites astreoides	8.9	2.8	7.5	7.2	6.3	**6.6**
Agaricia agaricites	2.8	0.4	1.4	7.5	6.3	**3.7**
Porites porites	4.9	0.6	3.1	1.1	2.0	**2.3**
Dendrogyra cylindrus	3.7		1.4	3.6		**1.7**
Colpophyllia natans			4.7		0.9	**1.1**
Meandrina meandrites		1.0	1.1	0.8	1.2	**0.8**
Agaricia lamarcki	1.5		0.3	0.9		**0.6**
Montastraea cavernosa		0.8	1.1		0.5	**0.5**
Diploria labyrinthiformis					2.0	**0.4**
Millepora alcicornis	0.2				0.9	**0.2**
Agaricia humilis	0.7					**0.1**
Leptoseris cucullata			0.6			**0.1**
Acropora cervicornis			0.5			**0.1**
Siderastrea siderea			0.2			**0.0**
Total Stony Corals	**29.9**	**71.5**	**32.9**	**29.2**	**29.0**	**38.5**

Erect soft corals (gorgonians) were highly abundant with an average of 21.4 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 4.8 %. Sponges were represented by at least eight species along transects with a combined mean cover of 1.4 %, and represented minor components of the reef benthos. Reef overhangs, associated with coral ledges of Boulder Star Coral contributed markedly to the topographic rugosity of 2.8 m.

Turf algae, comprised by a mixed assemblage of short filamentous red and brown macroalgae presented an average substrate cover of 43.8 % (range: 14.4 – 54.9 %), representing 83.1% 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 52.7 %. Cyanobacterial films were observed in one transect with low substrate cover (< 1.0%).

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 eigth annual monitoring surveys (2004-13). During the 2006 monitoring survey, mean live coral cover declined 22.6%, from 44.26% in 2005 to 34.25%. 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 10.5 – 9.0% cover until the present 2013 survey, perhaps due to the lack of hard ground space to grow. Between 1999 and 2010, *M. mirabilis* more than doubled its substrate cover in transect 2 from 27.4% to 55.3 % (Figure 31). Such growth has influenced a partial 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. During 2009 and 2010, this species suffered from what appears to be an infectious disease and exhibited substantial colony degradation and loss of substrate cover back to its baseline mean of 5.3%. During this 2013 survey, colonies showed some recuperation and increased cover to an average of 6.8 %.

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 2013 survey was 72.6 Ind/30 m^2 (range: 36 - 120 Ind/30 m^2). A total of 27 species were observed within belt-transects and the mean number of species per transect was 14.6 (range: 13 - 17). The Blue Chromis (*Chromis cyanea*), Creole Wrasse (*Clepticus parrae*), Bicolor Damselfish (*Stegastes partitus*), Princess and Stoplight Parrotfishes (*Scarus taeniopterus, S, viride*), and Bluehead Wrasse (*Thalassoma bifasciatum*) were the numerically dominant species with a combined mean abundance of 56.7 Ind/30 m^2, representing 78.1 % 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 Beau Gregory, French Grunt, Caribbean Puffer, and Graysbe.

Small demersal and pelagic schooling zooplanktivores, including the Blue Chromis, Creole Wrasse and Bicolor Damselfish dominated the Tourmaline 10m reef community structure in terms of trophic categories, representing approximately 53 % of the total individuals within belt-transects. Small, opportunistic micro-invertebrate predators

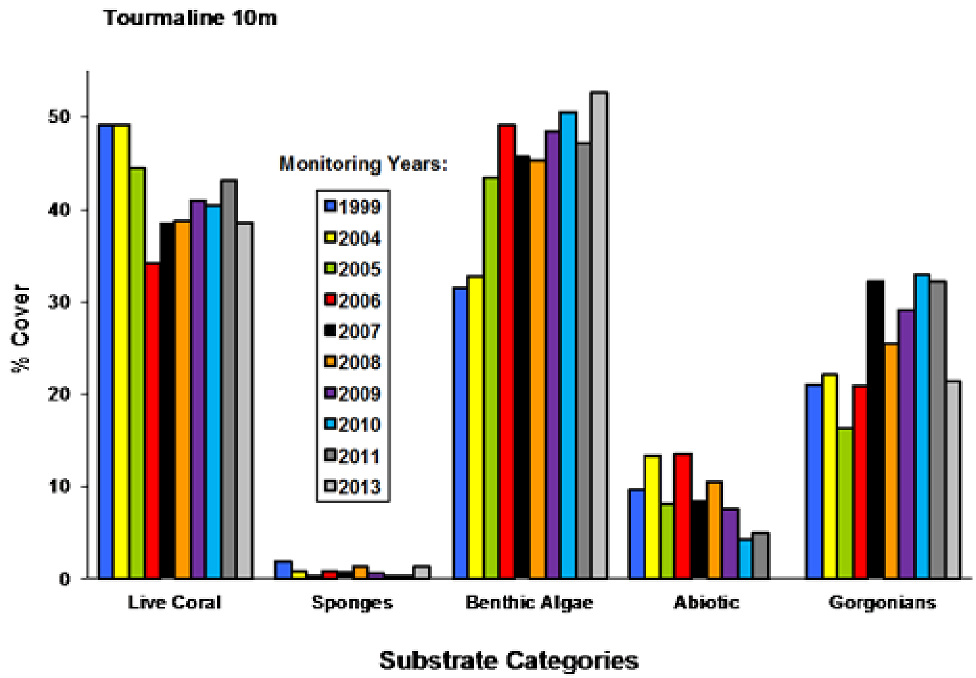


Figure 30. Monitoring trends (1999 – 2013) of mean substrate cover by sessile-benthic categories at Tourmaline Reef – 10 m, Mayaguez.

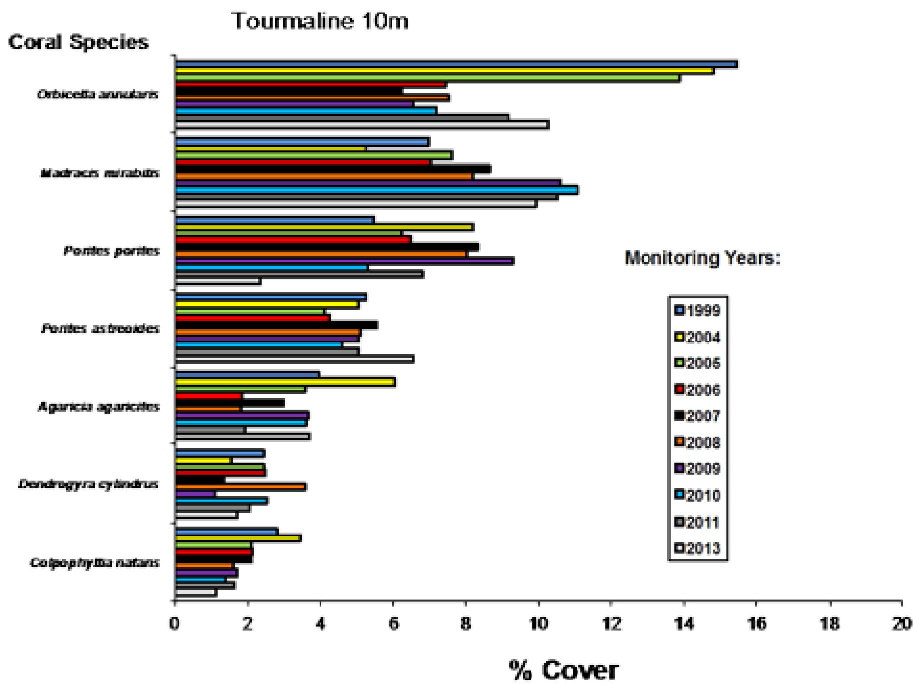


Figure 31. Monitoring trends (1999 – 2013) of mean cover by stony coral species at Tourmaline Reef – 10 m, Mayaguez.

Table 35. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, 10 m, Mayaguez Bay. December 2012

Depth: 10m		Transects					
		1	**2**	**3**	**4**	**5**	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Chromis cyanea	Blue Chromis	5	20	35	22	4	**17.2**
Clepticus parrae	Creole Wrasse	0	6	5	60	0	**14.2**
Stegastes partitus	Bicolor Damselfish	8	16	7	4	7	**8.4**
Scarus taeniopterus	Princess Parrotfish	9	8	9	4	2	**6.4**
Thalassoma bifasciatum	Bluehead Wrasse	2	12	5	3		**5.5**
Sparisoma viride	Stoplight Parrotfish	1	5	8	9	2	**5.0**
Stegastes leucostictus	Beau Gregory	3	0	3	3	3	**2.4**
Haemulon flavolineatum	French Grunt	1	3	3	4	0	**2.2**
Scarus iserti	Stripped Parrotfish	2	0	0	0	7	**1.8**
Halichoeres garnoti	Yellow-head Wrasse	1	0	3	0	3	**1.4**
Myripristis jacobus	Blackbar Soldierfish	0	0	4	3	0	**1.4**
Canthigaster rostrata	Caribbean Puffer	2	2	0	1	1	**1.2**
Chaetodon capistratus	Four-eye Butterflyfish	0	2	0	3	0	**1.0**
Cephalopholis cruentatus	Graysby	1	1	0	1	1	**0.8**
Holacanthus tricolor	Rock Beauty	0	2	0	1	0	**0.6**
Acanthurus chirurgus	Doctorfish	1	0	1	1	0	**0.6**
Sparisoma aurofrenatum	Redband Parrotfish	0	0	0	0	2	**0.4**
Chaetodon striatus	Banded Butterflyfish	0	0	0	1	1	**0.4**
Coryphopterus lipernes	Peppermint Goby	1	0	1	0	0	**0.4**
Holocentrus rufus	Squirrelfish	0	1	1	0	0	**0.4**
Serranus tigrinus	Harlequin Bass	0	1	1	0	0	**0.4**
Hypoplectrus nigricans	Black Hamlet	1	0	0	0	1	**0.4**
Pomacanthus paru	French Angelfish	0	0	2	0	0	**0.4**
Stegastes variabilis	Cocoa Damselfish	0	0	1	0	0	**0.2**
Acanthurus bahianus	Ocean Surgeon	0	0	0	0	1	**0.2**
Acanthurus coeruleus	Blue Tang	0	0	1	0	0	**0.2**
Stegastes dorsopunicans	Dusky Damselfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	38	79	90	120	36	**72.6**
	TOTAL SPECIES	14	13	17	15	14	**14.6**

(wrasses, gobies) were also prominent trophic groups. Herbivores were represented by four species of parrotfishes, three species of damselfishes and three species of doctorfishes comprised approximately 24 % 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 ASEC surveys at this reef (Table 36). Schools of Mackerel Scad, *Decapterus macarellus* and Ballyhoo, *Hemiramphus ballyhoo* were present near the surface over the reef. These serve as forage for pelagic predators, such as Cero Mackerels, Great Barracuda and Blue Runners.

Annual monitoring trends of fish species richness and abundance are presented in Figure 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*) and the 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 low abundance of Red Hinds noted during our monitoring surveys is indicative

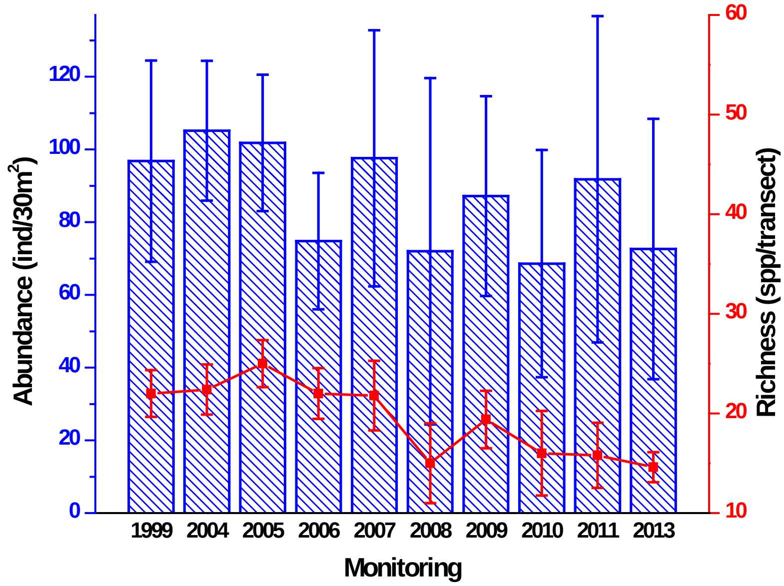


Figure 32. Monitoring trends (2004 – 2013) of fish species richness and abundance at Outer Shelf Reef Tourmaline, 10 m, Mayaguez.

that this fish population has not recovered from the intense fishing effort that it received during the previous decade.

Arrow Crabs and Cleaner Shrimps were the only megabenthic invertebrates observed within belt-transects during the 2013 monitoring survey (Table 37). Spiny and Spotted Lobsters, *Panulirus argus*, *P. guttatus*, have been previously reported observed outside transects during the ASEC surveys.

Table 36. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Tourmaline Reef 10 m, Mayaguez Bay. December 2012

Duration - 30 min.   Depth range : 10 - 13 m

SPECIES	**COMMON NAME**		# - (cm)
Epinephelus guttatus	Red Hind	1 - (15)	2 – (25)
Epinephelus striatus	Nassau Grouper	1 – (50)	
Lutjanus synagris	Lane Snapper	2 - (15)	3 - (20)
Ocyurus chrysurus	Yellowtail Snapper	3 - (15)	3– (20)
Pterois sp.	Lionfish	2 – (25)	2 – (30)
Scomberomorus regalis	Cero Mackerel	1 - (40)	
Sphyraena barracuda	Great Barracuda	1 - (60)	

Table 37. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Reef, 10 m, December 2012

Depth: 10 m

TAXA	**COMMON NAME**	**TRANSECTS** 1	2	3	4	5	**MEAN ABUNDANCE (IND/30 m2)**
Stenorhynchus seticornis	Arow Crab		1	1		1	**0.6**
Stenophus hispidus	Banded Coral Shrimp					1	**0.2**
	TOTALS	**0**	**1**	**1**	**0**	**2**	**0.8**

Photo Album 9 (Tourmaline 10 m)
















D. Guánica Natural Reserve

1.0 Cayo Coral

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

Cayo Coral is an emergent reef located to the west of Cayos de Caña Gorda, between Punta Ballena and the mouth of Guánica Bay (Figure 33). 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.

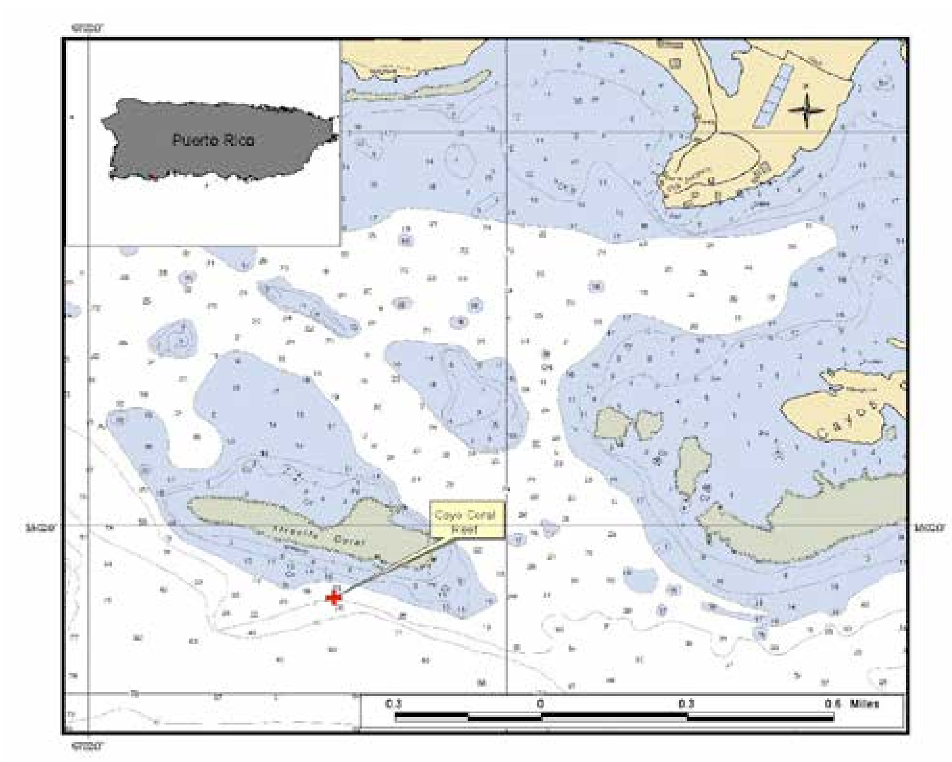


Figure 33. Location of coral reef survey stations at Cayo Coral Reef, Guánica.

1.1 Sessile**-benthic Reef Community**

A total of 17 stony corals, including 10 intersected by permanent line transects were identified from Cayo Coral Reef during the 2013 survey (Table 38). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 13.8 % (range: 4.7 – 26.7%). Boulder Star Coral, *Orbicella annularis* (complex) was the main species in terms of substrate cover with a mean of 4.8% (range: 1.7 – 12,6 %), representing 34.8 % of the total cover by stony corals (Table 38). Symmetrical Brain Coral, *Diploria strigosa*, Great Star Coral, *M. cavernosa*, and Massive Starlet Coral, *Siderastrea siderea* along with Boulder Star Coral and Boulder Brain Coral, *Colpophyllia natans* comprised the main coral assemblage of the reef at a depth of 7-10m.

Soft corals (gorgonians) were moderately abundant with an average of 15.8 colonies/transect. A total of 24 species of gorgonians are known to occur at this reef (García-Sais et al. 2007). Some of the numerically dominant species present included the Corky Sea Finger, *Briareum asbestinum*, Sea Rods, *Plexaura homomalla*, *Pseudoplexaura spp*., *Eunicea 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. Small sponges and patches of colonial zoanthids (*Palythoa sp*) represented minor components of the reef benthos. Reef overhangs associated with mostly dead massive Boulder Star Coral colonies averaged a substrate cover of 2.7 % and contributed substantially to the mean rugosity of 2.7 m.

Benthic algae, comprised mostly by turf algae was the most prominent sessile-benthic category in terms of substrate cover with a mean of 64.1 % (range: 56.0 – 72.8 %). Turf algae was found colonizing hard ground substrates, particularly dead coral colonies. Some dead coral colonies were also colonized by a reddish film of blue-green algae, or cyanobacteria, which presented a mean cover of 9.9 % in transects surveyed. 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.

Table 38. Percent substrate cover by sessile-benthic categories at Cayo Coral, Guanica. 8 m
Survey Date: December 2012.

	Transects					
	1	2	3	4	5	**Mean**
	0.85	3.55	2.50	2.40	4.27	**2.71**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang			1.7	7.2	4.5	**2.7**
Sand	7			6.1	0.0	**2.6**
Total Abiotic	**7**		**1.7**	**13.3**	**4.5**	**5.3**
Benthic Algae						
Turf	60.8	71	53.2	56.9	60.2	**60.4**
Fleshy macroalgae	2.6	1	2.2		5.6	**2.3**
Crustose coralline algae		0.8	0.6	3.2	2.4	**1.4**
Total Benthic Algae	**63.4**	**72.8**	**56.0**	**60.1**	**68.1**	**64.1**
Cyanobacteria	13.3	6.7	7.3	15.8	6.6	**9.9**
Gorgonian						
Encrusting gorgonian	1.4	4.2	2.7	2.7	1.9	**2.6**
Total Gorgonian	**1.4**	**4.2**	**2.7**	**2.7**	**1.9**	**2.6**
Erect Gorgonians (#colonies/transect)	14.0	24.0	18.0	11.0	12.0	**15.8**
Sponges	5.7	1	3.9	1.4	3.5	**3.1**
Total Sponge	**5.7**	**1.0**	**3.9**	**1.4**	**3.5**	**3.1**
Live Stony Corals						
Orbicella annularis	3.5	1.7	3.4	3	12.6	**4.8**
Diploria strigosa	1.3	1.2	8.5	0.7	0.0	**2.3**
Montastraea cavernosa	1.3	3.2	1.6	1	0.9	**1.6**
Siderastrea siderea	1.5	4.6			0.3	**1.3**
Colpophyllia natans			5.6		0.0	**1.1**
Porites astreoides	1	2.3	0.6		1.7	**1.1**
Meandrina meandrites			4.3			**0.9**
Porites porites			2.7		0.0	**0.5**
Unknown coral	0.6					**0.1**
Siderastrea radians		0.2				**0.0**
Total Stony Corals	**9.2**	**13.2**	**26.7**	**4.7**	**15.4**	**13.8**

Figure 34 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 2005-13. 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 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 34). 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 (2013). 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 35).

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 99 fish species have been identified from Cayo Coral during monitoring surveys (Appendix 1). Mean abundance within belt-transects during December 2012 was 26.8 Ind/30 m^2 (range: 17 - 44 Ind/30 m^2). The mean number of species per transect was 14.2 (range: 11 - 19). Bluehead Wrasse (*Thalassoma bifasciatum*), Dusky Damselfish (*Stegastes partitus*), Beaugregory (*Stegastes leucostictus*), and the Stoplight, Striped and Redband Parrotfishes (*Sparisoma viride, S. aurofrenatum, Scarus iserti*) were the numerically dominant species with a combined mean abundance of 15.8 Ind/30 m^2, representing 59.0 % 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 Yellowtail Damselfish, Yellowhead Wrasse and Blue Chromis comprised the main reef fish assemblage at Cayo Coral during the 2013 monitoring survey.

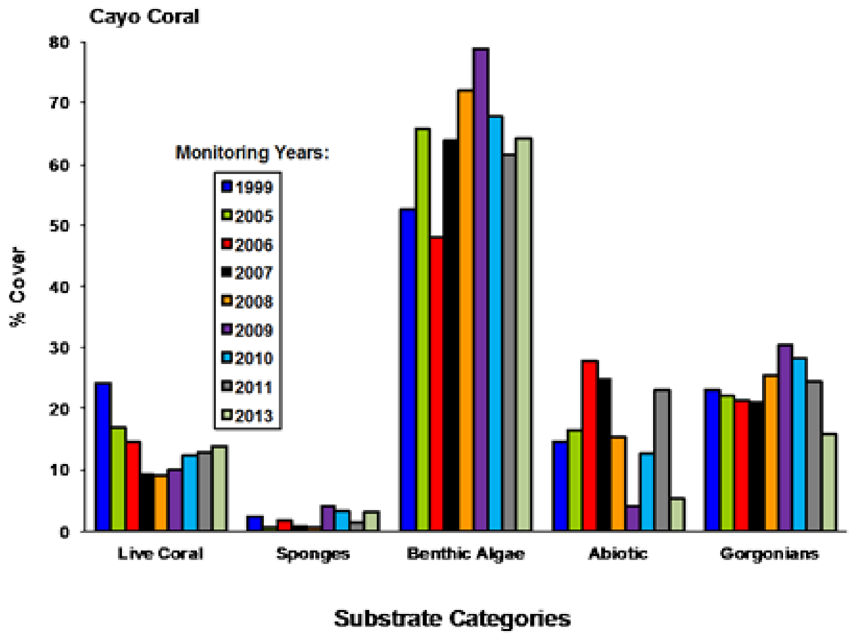


Figure 34. Monitoring trends (1999 – 2013) of mean substrate cover by sessile-benthic categories at Cayo Coral – 8 m, Guánica.

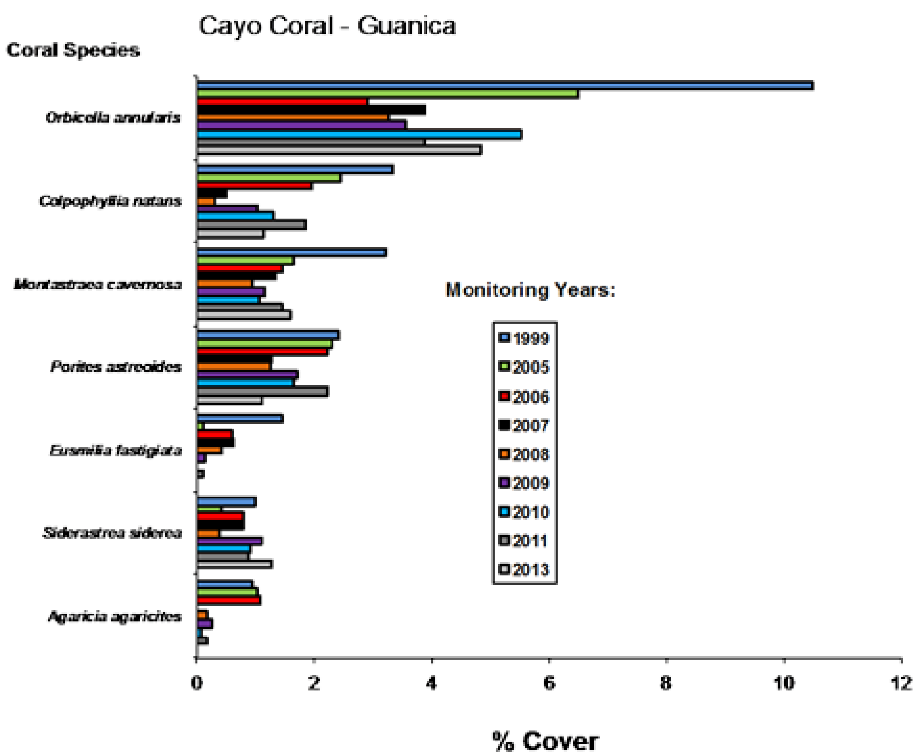


Figure 35. Monitoring trends (1999 – 2013) of mean substrate cover by stony coral species at Cayo Coral – 8 m, Guánica

Table 39. Taxonomic composition and abundance of fishes within belt-transects at Cayo Coral, Guanica, 10 m. December 2012

Depth: 7-8 m

		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(Individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	1	14	6	7	2	**6.0**
Stegastes dorsopunicans	Dusky Damselfish	4	1	2	3	3	**2.6**
Stegastes leucostictus	Beau Gregory	3	2	4	1	1	**2.2**
Scarus iserti	Stripped Parrotfish	0	5	1	1	3	**2.0**
Sparisoma viride	Stoplight Parrotfish	1	5	1	0	2	**1.8**
Sparisoma aurofrenatum	Redband Parrotfish	1	0	2	1	2	**1.2**
Microspathodon chrysurus	Yellowtail Damselfish	1	1	2	1	0	**1.0**
Chromis cyanea	Blue Chromis	1	4	0	0	0	**1.0**
Acanthurus bahianus	Ocean Surgeon	1	0	0	2	1	**0.8**
Halichoeres garnoti	Yellow-head Wrasse	0	1	0	0	3	**0.8**
Cephalopholis cruentatus	Graysby	0	1	1	1	0	**0.6**
Holocentrus rufus	Squirrelfish	0	1	1	0	1	**0.6**
Stegastes partitus	Bicolor Damselfish	1	1	1	0	0	**0.6**
Canthigaster rostrata	Caribbean Puffer	0	1	0	0	2	**0.6**
Chaetodon capistratus	Four-eye Butterflyfish	0	1	0	0	2	**0.6**
Abudefduf sexatilis	Sergeant Major	0	0	3	0	0	**0.6**
Haemulon flavolineatum	French Grunt	0	0	1	1	0	**0.4**
Serranus tigrinus	Harlequin Bass	1	1	0	0	0	**0.4**
Caranx ruber	Bar jack	0	1	0	1	0	**0.4**
Acanthurus coeruleus	Blue Tang	0	0	1	0	0	**0.2**
Aulostomus maculatus	Trumpetfish	0	1	0	0	0	**0.2**
Gobiosoma evelynae	Sharknose Goby	0	1	0	0	0	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	1	0	0	0	0	**0.2**
Coryphopterus glaucofraenum	Bridled Goby	0	1	0	0	0	**0.2**
Mulloides martinicus	Yellowtail Goatfish	1	0	0	0	0	**0.2**
Scomberomorus regalis	Cero	0	0	0	0	1	**0.2**
Haemulon plumieri	White Grunt	0	0	1	0	0	**0.2**
Hypoplectrus nigricans	Black Hamlet	0	0	0	0	1	**0.2**
Hypoplectrus indigo	Indigo Hamlet	0	0	0	0	1	**0.2**
Lactophrys triqueter	Smooth Trunkfish	0	0	1	0	0	**0.2**
Sargocentron vexillarium	Dusky Squirrelfish	0	0	0	1	0	**0.2**
Odontoscion dentex	Reef Croaker	0	1	0	0	0	**0.2**
	TOTAL INDIVIDUALS	17	44	28	20	25	**26.8**
	TOTAL SPECIES	12	19	15	11	14	**14.2**

Figure 36 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 present 2013 survey when fish abundance and species richness both declined. Such wide range variations of fish community structure appear to be normal in shallow reef systems that are strongly influenced by wave action and the associated surge and substrate abrasion effects.

In contrast to shelf-edge and oceanic coral reef sites, the fish community structure of Cayo Coral apperars to be strongly driven by herbivores, including three species of parrotfishes, three species of damselfishes and two species of doctorfishes that comprised 44.0 % of the total fish individuals within belt-transects. Small, opportunistic micro-invertebrate predators (wrasses, gobies, puffers) were also prominent with 40% 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 observed during previous ASEC surveys at Cayo Coral (Garcia-Sais et al., 2006). 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 observed during the 2013 (and previous) ASEC surveys (Table 40). Several Bottlenose dolphins were reported from Cayo Coral during the 2010 survey.

Motile megabenthic invertebrates observed within belt-transects included the Flamingo Tongue, a predator of soft coral polyps and the Arrow Crab (Table 41).

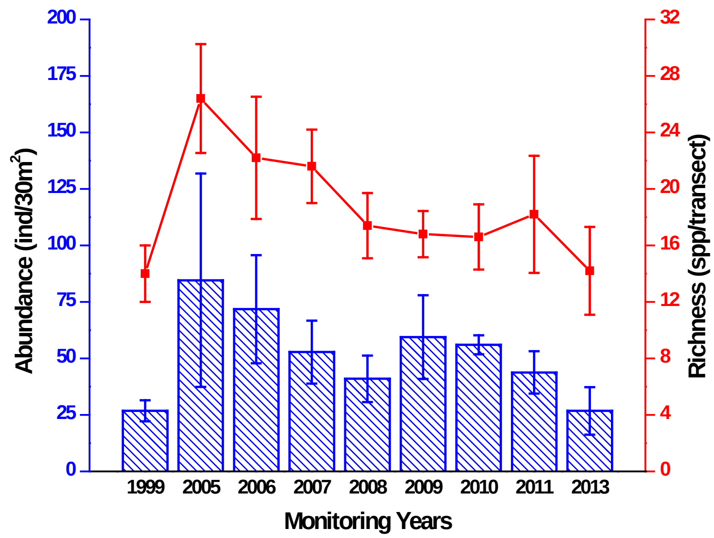


Figure 36. Monitoring trends (1999 – 2013) of fish species richness and abundance at Cayo Coral Reef, 8 m, Guanica Natural Reserve

Table 40. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Cayo Coral. Guánica. December 2012

Depth range : 8 - 10 m Duration - 30 min.

SPECIES	**COMMON NAME**	# - (cm)		
Epinephelus guttatus	Red Hind	1 - (30)		
Lutjanus apodus	Schoolmaster	3 - (20)	1 - (30)	
Lutjanus synagris	Lane Snapper	4 - (15)	2 – (20)	1 – (25)
Scomberomorus regalis	Cero Mackerel	2 – (40)	1 – (50)	
Sphyraena barracuda	Great Barracuda	1 - (50)		

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

Depth: 8 -10 m **TAXA**	**COMMON NAME**	**TRANSECTS** **1**	 **2**	 **3**	 **4**	 **5**	**MEAN ABUNDANCE (IND/30 m2)**
Cyphoma gibbosum	Flamingo Tongue		2		1	1	**0.8**
Stenorhinchus seticornis	Arrow Crab	1				1	**0.4**
	TOTALS	1	2	0	1	2	**1.2**

Photo Album 10 (Guanica 10 m)
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). Permanent transects installed during the baseline survey of 2011 were not found during this monitoring survey, perhaps due to mechanical dislodging by wave action. Thus, this 2013 survey now stands as the baseline for Cayo Aurora. Nevertheless, data recorded during the 2011 survey is presented as supplemental information. 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 37). Panoramic views of Cayo Aurora are shown in Photo Album 11.

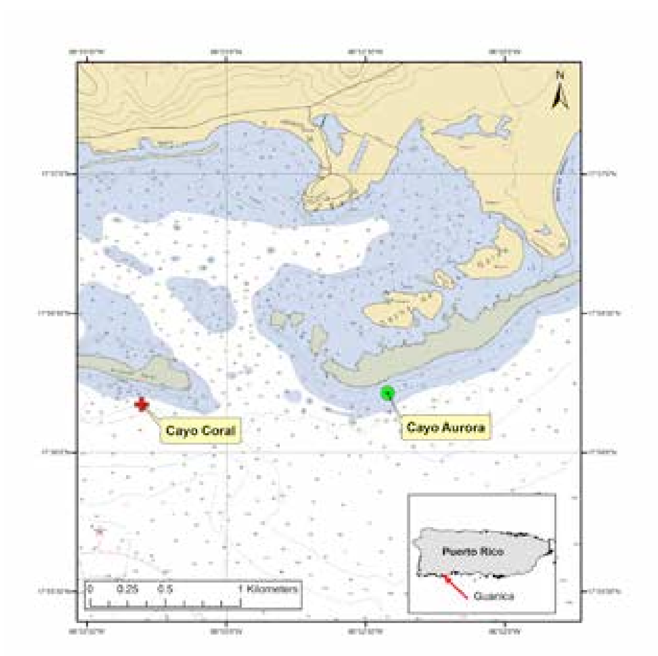


Figure 37. Location of coral reef monitoring station in Cayo Aurora, Guanica

2.1 Sessile-benthic Reef Community

A total of 15 stony corals, including 5 intersected by transects were identified from Cayo Aurora during the 2013 survey (Table 42). Substrate cover by stony corals along transects averaged 34.6 % (range: 20.9 – 55.9 %). Elkhorn Coral, *Acropora palmata* was the main species in terms of substrate cover with a mean of 32.8% (range: 19.5 – 55.9 %), representing 94.8 % of the total cover by stony corals (Table 42). Mustard Hill Coral, *Porites astreoides*, Staghorn Coral, *Acropora cervicornis*, Symmetrical Brain Coral, *Diploria strigosa* and Fire Coral, *Millepora alcicornis* comprised along with Elkhorn Coral the main coral assemblage of the reef at depths of 2 - 5 m. 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 0.6 colonies/transect. Also, the encrusting gorgonian, *Erythropodium caribaeorum* was observed out of transects. Sponges, particularly encrusting forms, such as *Anthosigmella varians* and *Cliona sp*. were present in four out of the five transects surveyed with a mean substrate cover of 3.0 % (Table 42). Encrusting zoanthids (mostly *Palythoa sp*.) were also present outside transects. A mixed assemblage of short filamentous algae, or turf algae were the dominant category in terms of reef substrate cover at Cayo Aurora with average mean of 47.7 % (range: 31.6 – 60.8 %), representing 97.5% of the total cover by benthic algae (Table 42). Abiotic cover, which averaged 10.7 % was mostly associated with the large overhangs created by Elkhorn Coral branches and gaps.

Figure 38 shows the mean cover by substrate categories at Cayo Aurora during the 2011 and 2013 surveys. Although transects were analyzed from diferent reef locations differences between surveys were not statistically different. Elkhorn Coral represented more than 89% of the total cover by corals in both surveys (Figure 39).

Table 42. Percent substrate cover by sessile-benthic categories at Cayo Aurora, Guanica. December 2012

	Transects					
	1	2	3	4	5	**Mean**
	2.88	2.21	2.73	4.11	1.65	**2.71**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	14.7	3.8	12.8	17.6	3.6	**10.5**
Gaps	0.8					**0.2**
Total Abiotic	15.5	3.8	12.8	17.6	3.6	**10.7**
Benthic Algae						
Turf	52.3	60.8	42.5	51.3	31.6	**47.7**
Crustose coralline algae		1.5			4.6	**1.2**
Total Benthic Algae	52.3	62.3	42.5	51.3	36.2	**48.9**
Erect Gorgonians (#col/transect)	0	0	0	3	0	**0.6**
Sponges						
Unid. Sponge	11.1	1.9	1.1	0.7		**3.0**
Total Sponge	11.1	1.9	1.1	0.7		**3.0**
Live Stony Corals						
Acropora palmata	19.5	21	43.1	24.7	55.9	**32.8**
Porites astreoides	0.4	0.8	0.6	1.8		**0.7**
Acropora cervicornis				3		**0.6**
Diploria strigosa	1					**0.2**
Millepora alcicornis				1		**0.2**
Total Stony Corals	20.9	21.8	43.7	30.5	55.9	**34.6**

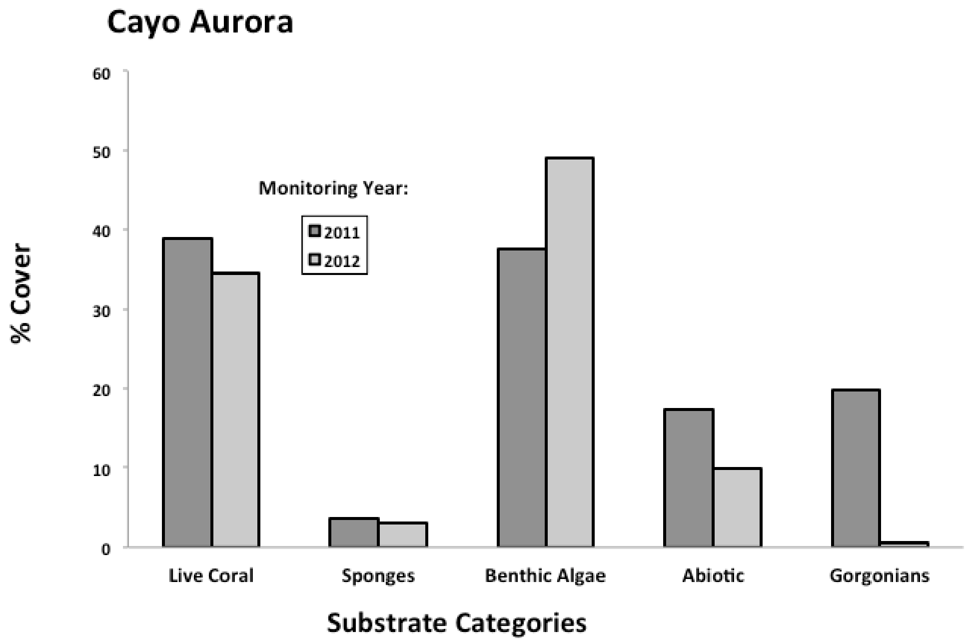


Figure 38. Monitoring trends (2011 – 2013) of mean substrate cover by sessile-benthic categories at Cayo Aurora– 3 m, Guánica.

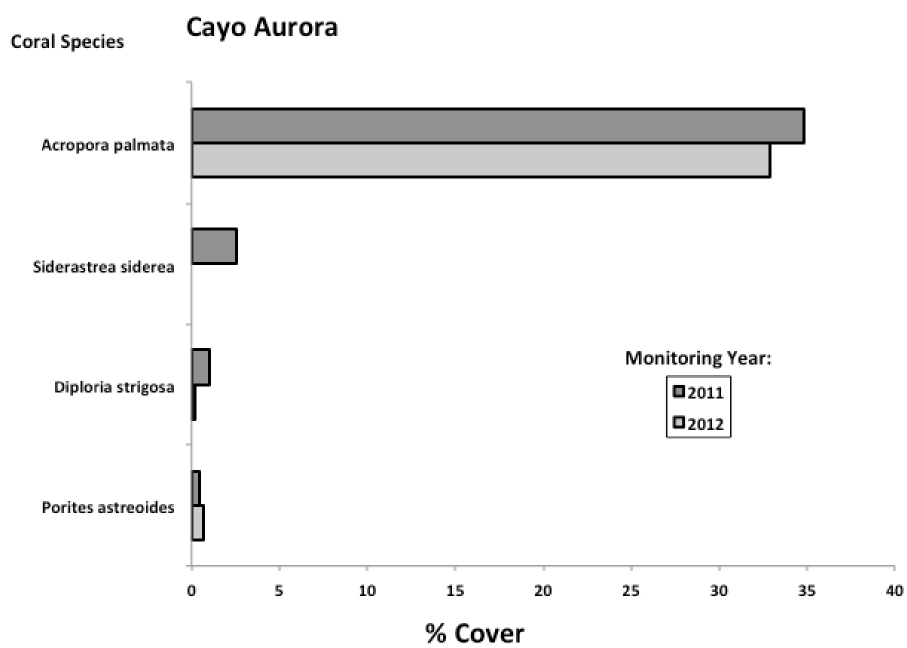


Figure 39. Monitoring trends (2011 – 2013) of mean substrate cover by stony coral species at Cayo Aurora – 3 m, Guánica

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 28 present within belt-transects during this baseline survey. The mean abundance of individuals was 79.2 Ind/30 m^2 (range: 67.0 – 93.0 Ind/30 m^2), and the mean number of species per transect was 14.0 (range: 10 - 19). The combined abundance of seven species represented 74.5 % of the mean abundance within belt-transects (Table 43). The most abundant species was the Bluehead Wrasse (*Thalassoma bifasciatum*) with a mean of 15.4 Ind/30 m^2 followed by the Dusky and Yellowtail Damselfishes (*Stegastes adustus*, *Microspathodon chrysurus*). The Redlip Blenny (*Ophioblennius atlanticus*), Yellowhead Wrasse (*Halichoeres garnoti*), Bicolor Damselfish (*Stegastes partitus*), and Dusky Damselfish (*Holocentrus rufus*) were present in at least four out of the five transects surveyed and along with Clown Wrasse (*Halichoeres maculipinna*) and Brown Chromis (*Chromis multilineata*) appear to comprise the main resident demersal fish assemblage. Large 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.

The fish community at Cayo Aurora was comprised by a prominent assemblage of herbivores, represented by a total of five species of parrotfishes (Scaridae), three species of doctorfishes (Acanthuridae), at least five species of damselfishes (Pomacentridae) that comprised approximately 40 % of the total individuals within belt-transects. A diverse assemblage of small opportunistic invertebrate feeders, such as the wrasses (Labridae – 5 spp.), squirrelfishes (Holocentridae – 3 spp), blennies (Blenniidae – 3 spp), grunts (Haemulidae – 2 spp.) and small groupers (Serranidae – 2 spp) was also prominent in the reef. Piscivores were best represented by snappers (Lutjanidae), barracuda (Sphyraenidae) and Jacks (Carangidae), included in an ASEC survey during this survey (Table 44).

Motile megabenthic invertebrates were represented within belt-transects by Long-spined and Boring Sea Urchins, and Fire Worms (*Hermodice carunculata*) (Table 45). One juvenile Spiny Lobster (*Panulirus argus*) was observed outside transects.

Table 43. Taxonomic composition and abundance of fishes within belt-transects at the fringing Elkhorn Coral Reef Cayo Aurora, Guanica. December 2012

Depth: 3 - 5m		Transects					
		1	**2**	**3**	**4**	**5**	
		Individuals/30m2					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	24	25	10	10	8	15.4
Stegastes adustus	Dusky Damselfish	15	12	12	10	12	12.2
Microspathodon chrysurus	Yellowtail Damselfish	6	12	3	7	16	8.8
Halichoeres garnoti	Yellowhead Wrasse	4	1	31	1	0	7.4
Halichoeres maculipinna	Clown Wrasse	6	4	3	11	3	5.4
Stegastes partitus	Bicolor Damselfish	3	12	3	7	0	5.0
Chromis multilineata	Brown Chromis	0	10	0	8	6	4.8
Sargocentron vexillarium	Dusky Squirrelfish	5	1	0	1	12	3.8
Abudefduf sexatilis	Sargent Major	4	0	0	0	12	3.2
Acanthurus chirurgus	Doctorfish	0	8	3	3	0	2.8
Ophioblennius atlanticus	Redlip Blenny	3	4	1	3	2	2.6
Sparisoma viride	Stoplight Parrotfish	1	0	1	3	4	1.8
Haemulon flavolineatum	French Grunt	0	1	0	0	4	1.0
Haemulon melanorum	Cottonwick	0	0	0	0	4	0.8
Acanthurus coeruleus	Blue Tang	1	0	2	0	1	0.8
Sparisoma aurofrenatum	Redband Parrotfish	0	1	0	0	2	0.6
Chaetodon capistratus	Four-eye Butterflyfish	0	0	0	2	0	0.4
Malacoctenus triangulatus	Saddled blenny	1	0	0	0	1	0.4
Aulostomus maculatus	Trumpetfish	0	0	0	1	0	0.2
Heteropricantus cruentatus	Glasseye Snapper	0	0	0	0	1	0.2
Holocentrus rufus	Squirrelfish	0	0	0	0	1	0.2
Lutjanus apodus	Schoolmaster Snapper	0	0	0	0	1	0.2
Scarus iserti	Striped Parrotfish	0	1	0	0	0	0.2
Sparisoma rubripinne	Yellowtail parrotfish	0	0	0	0	1	0.2
Bodianus rufus	Spanish Hogfish	0	0	0	0	1	0.2
Cantherhines pullus	Orangespotted Filefish	1	0	0	0	0	0.2
Lactophrys triqueter	Smooth Trunkfish	1	0	0	0	0	0.2
Sphyraena barracuda	Great Barracuda	0	1	0	0	0	0.2
	TOTAL INDIVIDUALS	75	93	69	67	92	79.2
	TOTAL SPECIES	14	14	10	13	19	14

Table 44. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Cayo Aurora, Guanica, December 2102.

Depth: 2 –5 m, Duration - 30 min.

SPECIES	**COMMON NAME**	# - (cm)		
Carangoides crysos	Blue Runner	4 - (25)	1 – (30)	
Lutjanus apodus	Schoolmaster	3 – (15)	3 – (20)	
Lutjanus griseus	Mangrove Snapper	2 – (25)		
Ocyurus chrysurus	Yellowtail Snapper	3 – (15)	3 – (20)	1 – (25)
Sphyraena barracuda	Great Barracuda	1 - (40)		

Table 45. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Aurora, Guanica, December 2102.

Depth: 2 - 5 m

TAXA	**COMMON NAME**	**TRANSECTS** 1	2	3	4	5	**MEAN ABUNDANCE (IND/30 m2)**
Echinometra lucunter	Rock-boring Urchin	1	1	3	2	4	**2.2**
Diadema antillarum	Long-spined urchin				1		**0.2**
Hermodice carunculata	Fire Worm		1				**0.2**
	TOTALS	**1**	**2**	**3**	**3**	**4**	**2.6**

Photo Album 11 (Guanica 3 m)
Cayo Aurora
















3.0 Guanica Shelf-Edge

The insular shelf off Guanica extends offshore approximately 4.3 nautical miles (Figure 33). At the shelf's edge there is a well developed spur and groove coral reef formation that appears to be part of a much largar reef system associated with the shelf-edge of the southwest coast of Puerto Rico, from Guanica to La Parguera, Lajas. Spurs run north-south and rise up to 3-4 meters from well defined sand channels ranging in width from 2 – 4 meters. Five permanent transects were installed on top of the spurs near the shelf-edge at depths of 18 – 20 meters during April 2013. 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

Figure 40 shows the mean substrate cover by major benthic categories at the Guanica shelf-edge reef (c.a. "Guanica Deep"). A total of 14 species of stony corals were intercepted by line transects during the 2013 survey with a mean substrate cover of 15.8 % (range: 10.2 – 20.8 %). An assemblage of three Lettuce Coral species, *Agaricia agaricites*, *A. fragilis* and *A. humilis* was the main taxonomic component with a combined cover of 9.7 %, representing 61.4 % of the total cover by stony corals at the shelf-edge reef (Table 46, Figure 41). Both *A. agaricites* and *A. humilis* were present from all five transects surveyed. Soft corals or gorgonians were also prominent at the shelf-edge reef with a mean combined density of 16 colonies per transect. Some of the most prominent species included *Briareum asbestinum*, *Gorgonia ventalina, Pterogorgia guadalupensis*, and *Eunicea spp*. At least 17 sponge species were intercepted by transects with a combined reef substrate cover of 4.1 % (range: 1.9 – 6.2%). *Agelas spp* comprised the main taxonomic assemblage in terms of substrate cover with a combined contribution of 2.0 %, representing 48.8 % of the total cover by sponges (Table 46).

Benthic algae were the dominant category at the Guanica shelf-edge in terms of reef substrate cover with a combined mean of 72.3 % (range: 66.5 – 80.5 %). Both turf (mixed assemblage) and brown fleshy algae (e.g. *Lobophora variegata, Dictyota spp*.) were important taxonomic components of the benthic algae assemblage with combined means of 36.4 and 32.4 %, respectively (Table 46). Crustose coraline algae and red coraline algae (*Jania spp*) were also common at the reef benthos. Abiotic cover included sand pockets and reef overhangs with a mean cover of 3.2 %.

Table 46. Percent substrate cover by sessile-benthic categories at Guanica's shelf-edge. (Guanica Deep). April 2013

	Transects					
Depth: 18 - 20m	1	2	3	4	5	**Mean**
	4.32	2.14	1.76	2.10	3.58	**2.78**
SUBSTRATE CATEGORY						
Abiotic						
Sand	2.9		2.1	5.0		**2.0**
Reef Overhang		1.2		1.5	3.4	**1.2**
Total Abiotic	**2.9**	**1.2**	**2.1**	**6.5**	**3.4**	**3.2**
Benthic Algae						
Turf	31.8	48.7	36.7	39.2	25.5	**36.4**
Lobophora spp.	24.5	23.2	40.2	23.5	37.2	**29.7**
Dictyota spp.	2.6	2.0	2.0	4.7	1.8	**2.6**
Halimeda spp.	9.8					**2.0**
Crustose coralline algae	1.0	1.2	1.5		2.1	**1.1**
Jania spp.		0.9		0.3		**0.3**
Macroalgae	0.3			0.6		**0.2**
Padina spp.	0.3					**0.1**
Total Benthic Algae	**70.3**	**75.9**	**80.5**	**68.4**	**66.5**	**72.3**
Cyanobacteria	2.3		0.6		2.0	**1.0**
Gorgonian						
Briareum asbestinum	0.9	5.5	2.5	2.7	3.6	**3.0**
Eunicea calyculata				0.5		**0.1**
Eunicea tourneforti				0.2		**0.0**
Gorgonia ventalina		0.2				**0.0**
Pterogorgia guadalupensis	0.1					**0.0**
Total Gorgonian	**1.0**	**5.8**	**2.5**	**3.4**	**3.6**	**3.2**
Erect Gorgonians (#col/transect)	25.0	17.0	18.0	13.0	7.0	**16.0**
Sponge						
Agelas dispar		1.2	0.8	2.1		**0.8**
Agelas sceptrum	0.9	0.5	1.0		0.9	**0.6**
Agelas spp.	0.7		0.7	1.2	0.2	**0.6**
Aiolochoria crassa yellow	0.3	1.0	0.5	0.2		**0.4**
Aplysina cauliformis	1.6					**0.3**
Aplysina fistularis	0.3	0.8		0.2		**0.3**
Cliona caribbea	0.8	0.2				**0.2**
Ecytoplasia ferox	1.0					**0.2**
Halisarca spp.			0.8			**0.2**
Iotrochota birutulata	0.5		0.2		0.1	**0.2**
Monanchora arbuscula	0.2	0.1		0.2		**0.1**
Niphates digitalis				0.3		**0.1**
Niphates erecta					0.3	**0.1**
Petrosia pellasarca				0.2		**0.0**
Scopalina ruetzleri					0.2	**0.0**
Unknown sponge				0.1		**0.0**
Topsentia spp.					0.1	**0.0**
Total Sponges	**6.2**	**3.8**	**4.0**	**4.6**	**1.9**	**4.1**

Table 46. continued

Live Stony Corals						
Agaricia agaricites	8.9	4.8	2.5	2.3	7.5	**5.2**
Agaricia fragilis		4.3		5.8	1.3	**2.3**
Agaricia humilis	3.1	1.7	1.7	3.6	0.9	**2.2**
Diploria strigosa	2.1				5.2	**1.4**
Eusmilia fastigiata				2.0	4.2	**1.2**
Madracis decactis	0.8	1.4		1.7	0.4	**0.9**
Meandrina meandrites	0.4		1.5	1.7		**0.7**
Orbicella annularis	1.5		2.3		1.0	**0.5**
Montastraea cavernosa	0.6		1.0			**0.3**
Porites astreoides		0.9				**0.2**
Porites porites			0.7		0.2	**0.2**
Siderastrea siderea			0.5			**0.1**
Stephanocoenia intersepta		0.2				**0.0**
Millepora alcicornis			0.1			**0.0**
Total Stony Corals	**17.3**	**13.4**	**10.2**	**17.1**	**20.8**	**15.8**

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 47 fish species were identified from Guanica's shelf-edge including 31 within belt-transects at a depths of 18 - 20 meters (Table 47). The mean abundance of individuals was 81.0 Ind/30 m^2 (range: 45.0 – 123.0 Ind/30 m^2), and the mean number of species per transect was 18.2 (range: 17 - 19). The combined abundance of four species represented 67.8 % of the mean abundance within belt-transects. The most abundant species was the Blue Chromis (*Chromis cyanea*) with a mean of 22.0 Ind/30 m^2 followed by the Bicolor Damselfish (*Stegastes partitus)*, Bluehead Wrasse *(Thalassoma bifasciatum)* and Sharknose Goby (*Gobiosoma evelynae*). The Peppermint Goby, French Grunt, Yellowhead Wrasse, Beaugregory, Longspine Squirrelfish and a goby (*Coryphopterus sp*.) were present in at least four out of the five transects surveyed. A total of seven fish species were only represented by one individual within transects.

The fish community at Guanica's shelf-edge was comprised by a prominent assemblage of herbivores, represented by a total of four species of parrotfishes (Scaridae), two species of doctorfishes (Acanthuridae), four species of damselfishes (Pomacentridae), and by a diverse assemblage of small opportunistic invertebrate feeders, such as the wrasses (Labridae), squirrelfishes (Holocentridae), grunts (Haemulidae) and small groupers (Serranidae). Piscivores were represented by Great Barracuda, Cero and one large Cubera Snapper (Table 48).

Table 47. Taxonomic composition and abundance of fishes within belt-transects at the fringing Elkhorn Coral Reef Cayo Aurora, Guanica. April 2013

Depth : 18 - 20 m

SPECIES	COMMON NAME	Transects 1	2	3	4	5	MEAN
		Individuals/30m2					
Chromis cyanea	Blue Chromis	3	5	56	26	20	22.0
Stegastes partitus	Bicolor Damselfish	14	18	17	18	7	14.8
Thalassoma bifasciatum	Bluehead wrasse	9	13	15	14	8	11.8
Gobiosoma evelynae	Sharknose Goby		2	8	7	8	5.0
Haemulon flavolineatum	French Grunt	1	1	3	4	7	3.2
Halichoeres garnoti	Yellowhead Wrasse	1	5	2	5	3	3.2
Coryphopterus lipernes	Peppermint Goby		2	2	5	5	2.8
Scarus taeniopterus	Princess Parrotfish		4	4		1	1.8
Acanthurus bahianus	Ocean Surgeon	2	3	3			1.6
Melichthys niger	Black Durgon		2		1	5	1.6
Scarus iserti	Striped Parrotfish	3	1	2			1.2
Sparisoma radians	Bucktooth Parrotfish	1	3		2		1.2
Coryphopterus sp.	Goby	1		1	2	2	1.2
Holocentrus marianus	Longspine Squirrelfish		1	1	2	2	1.2
Stegastes leucostictus	Beaugregory	1		3	1	1	1.2
Cephalopholis cruentatus	Graysbe	1	1	1	1	1	1.0
Chaetodon capistratus	Four-eye Butterflyfish	1	2	1			0.8
Sparisoma aurofrenatum	Redband Parrotfish	2		1	1		0.8
Acanthurus coeruleus	Blue tang	1			2		0.6
Myripristis jacobus	Black-bar Soldierfish			1		2	0.6
Canthigaster rostrata	Caribbean Puffer	1			1	1	0.6
Holocentrus rufus	Squirrelfish			1	1	1	0.6
Cantherhines pullus	Orangespotted Filefish		2				0.4
Serranus tigrinus	Harlequin Bass	1	1				0.4
Chromis multilineata	Brown Chromis					1	0.2
Epinephelus guttatus	Red Hind	1					0.2
Holacanthus tricolor	Rock Beauty	1					0.2
Microspathodon chrysurus	Yellowtail damselfish		1				0.2
Pseudupeneus maculatus	Yellowspotted Goatfish			1			0.2
Pterois sp.	Lionfish					1	0.2
Sparisoma viride	Stoplight parrotfish		1				0.2
	TOTAL INDIVIDUALS	45	68	123	93	76	81.0
	TOTAL SPECIES	18	19	19	17	18	18.2

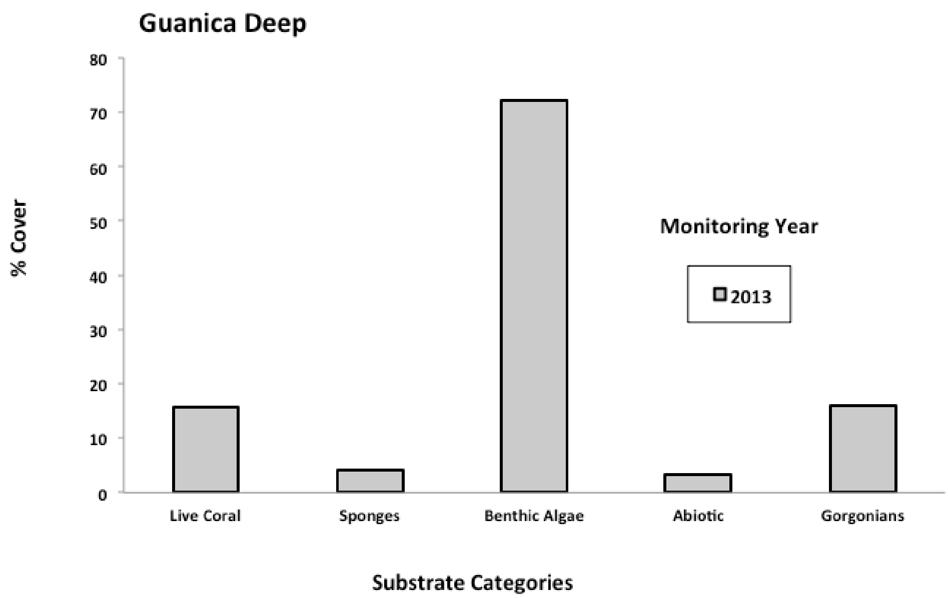


Figure 40. Mean substrate cover by sessile-benthic categories during the baseline survey at Guanica's shelf-edge (Guanica Deep). April 2013

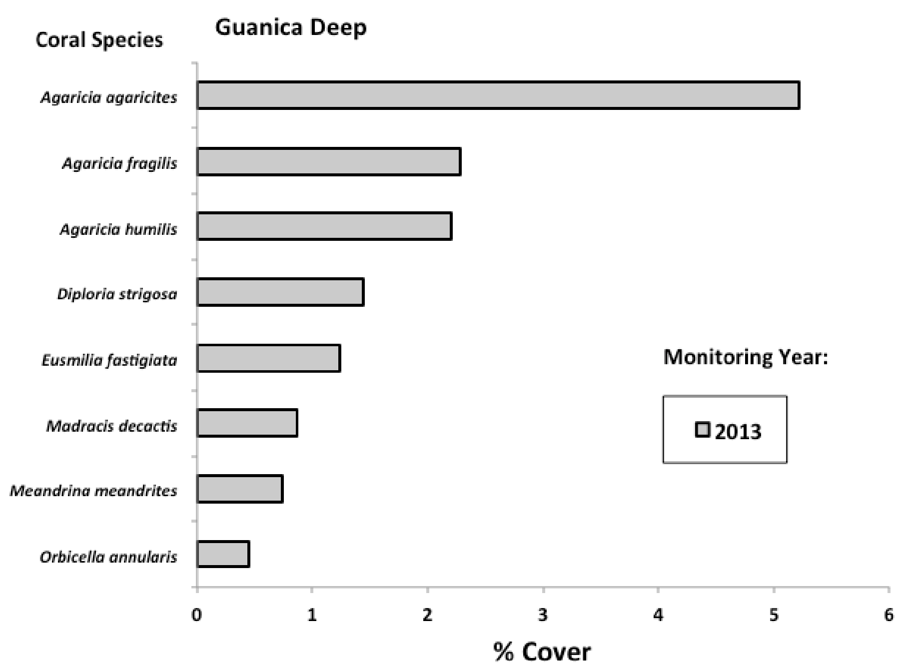


Figure 41. Mean substrate cover by stony coral species during the baseline survey at Guanica's shelf-edge (Guanica Deep). April 2013

The high relative abundance of herbivores relative to other fish trophic groups, particularly zooplanktiovores stands as one of the main differences between insular shelf and oceanic (island) reef systems in terms of fish community structure (Esteves, 2014).

Motile megabenthic invertebrates were represented within belt-transects by Cleaner Shrimps, Flamingo Tongues, one Slipper Lobster, and one Spiny Lobster observed outside transects (Table 49).

Table 48. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Guanica's shelf-edge, April 2013.

Depth: 2 –5 m, Duration - 30 min.

SPECIES	**COMMON NAME**		# - (cm)
Lutjanus apodus	Schoolmaster	3 – (20)	1 – (30)
Lutjanus cyanopterus	Cubera Snapper	2 – (55)	
Ocyurus chrysurus	Yellowtail Snapper	2 – (25)	1 – (35)
Scomberomorus regalis	Cero	1 – (40)	
Sphyraena barracuda	Great Barracuda	1 - (50)	

Table 49. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at at Guanica's shelf-edge, April 2013.

Depth: 2 - 5 m

		TRANSECTS					**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Cyphoma gibbosum	Flamingo Tongue		4	2	2		**1.6**
Periclimenes pedersoni	Cleaner Shrimp	2			1		**0.4**
Scillarides sp.	Slipper Lobster			1			**0.2**
	TOTALS	**2**	**4**	**3**	**3**	**0**	**2.2**

Photo Album 12

Guanica 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 42). 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.

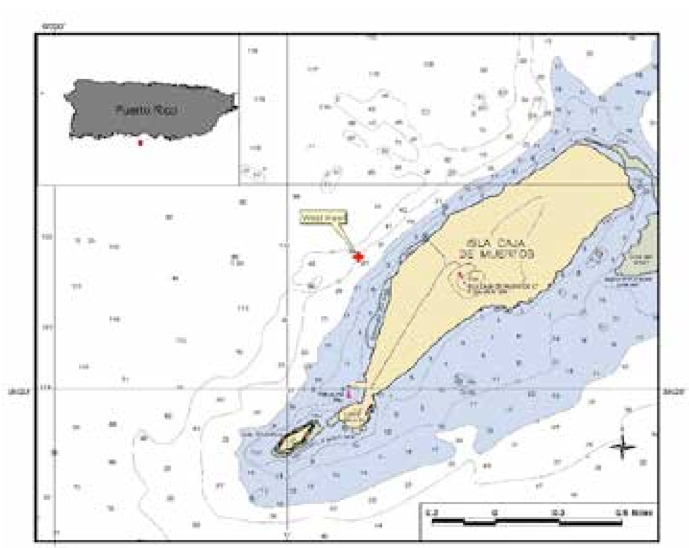


Figure 42. Location of coral reef monitoring stations at West Reef, Isla Caja de Muerto, Ponce.

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 54.2 % (range: 50.1 – 59.4 %) along permanent transects and was observed colonizing dead coral colonies and other hard ground substrates in the reef (Table 50). Fleshy brown (*Dictyota sp*.) and calcareous (*Halimeda tuna, H. opuntia*) macroalgae represented minor components 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 present 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).

A total of 20 stony coral species, including nine within transect were identified from West Reef in the 2013 survey (Table 50). Live stony corals presented a mean substrate cover of 9.7 % (range: 4.2 – 14.5 %). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant coral species with a mean substrate cover of 3.7 % (range: 0.5 – 10.0 %), representing 38.1 % of the total substrate cover by live stony corals. Great Star Coral (*M. cavernosa*), Mustard-Hill Coral (*Porites astreoides*), and the Greater Starlet Coral, *Siderastrea siderea* were present in at least three 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 17.4 colonies/transect and included colonies of very large size. Some of the most abundant species included the Slimy Sea Plumes (*Pseudopterogorgia americana, Pseudopterogorgia spp.*), Porous Sea Rods (*Pseudoplexaura spp*.), Corky Sea Finger (*Briareum asbestinum*), Common Sea Fan (*Gorgonia ventalina*), Knobby Sea Rods (*Eunicea spp*.) and the Encrusting Gorgonian (*Erythropodium caribaeorum*). Sponges, represented along transects by 14 species were present with a mean substrate cover of 3.7 %. Abiotic categories combined for a mean substrate cover of 26.3 %. The high rugosity measured at 5.7 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. 10 m Survey Date: February 2013.

	Transects					
	1	2	3	4	5	**Mean**
	2.91	6.30	6.98	5.55	6.60	**5.7**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhang	11.5	8.7	11.9	14.1	14.4	**12.1**
Rubble	25.2	10.3	7.4	3.6	8.7	**11.0**
Sand	2.0		6.3	7.5		**3.1**
Total Abiotic	**38.6**	**19.0**	**25.6**	**25.2**	**23.1**	**26.3**
Benthic Algae						
Turf	50.1	55.7	52.0	53.9	59.4	**54.2**
Filamentous algal mat		8.4	4.0	3.6		**3.2**
Dictyota spp.			0.8	3.3	1.2	**1.1**
Halimeda spp.		0.5				**0.1**
Total Benthic Algae	**50.1**	**64.6**	**56.8**	**60.8**	**60.6**	**58.6**
Gorgonians						
Erythropodium caribaeorum			0.7	2.7		**0.7**
Briareum asbestinum			0.8	2.3		**0.6**
Antillogorgia americana			0.6		0.3	**0.2**
Gorgonia ventalina		0.1			0.3	**0.1**
Plexaura kukenthali	0.1					**0.0**
Total Gorgonians	**0.1**	**0.1**	**2.1**	**5.0**	**0.5**	**1.5**
Erect Gorgonians (#colonies/transect)	15.0	5.0	16.0	19.0	32.0	**17.4**
Sponges						
Xestospongia muta	0.5		3.9			**0.9**
Agelas conifera	3.4					**0.7**
Aiolochoria crassa	1.3	0.7		0.4		**0.5**
Chondrilla caribensis	1.1				0.2	**0.3**
Svenzea zeai					1.1	**0.2**
Cliona caribbaea			1.0			**0.2**
Verongula rigida			0.5		0.4	**0.2**
Aplysina fistularis		0.9				**0.2**
Cliona varians					0.7	**0.1**
Aplysina cauliformis	0.7					**0.1**
Ectyoplasia ferox			0.5			**0.1**
Unknown sponge			0.5			**0.1**
Monanchora arbuscula		0.3		0.2		**0.1**
Cinachyrella kuekenthali					0.4	**0.1**
Total Sponges	**6.9**	**1.8**	**6.3**	**0.5**	**2.8**	**3.7**
Live Stony Corals						
Orbicella annularis	1.4	10.0	3.0	0.5	3.6	**3.7**
Montastrea cavernosa		2.6	0.3	3.8	3.1	**2.0**
Porites astreoides	1.2		2.2	0.7	4.6	**1.7**
Siderastrea siderea		1.4	3.4	0.6		**1.1**
Stephanocoenia intersepta	1.6	0.3			0.3	**0.4**
Agaricia lamarcki				1.4		**0.3**
Meandrina meandrites				1.4		**0.3**
Agaricia agaricites				0.2	0.7	**0.2**
Agaricia humilis		0.3				**0.1**
Total Stony Corals	**4.2**	**14.5**	**8.9**	**8.5**	**12.2**	**9.7**

Figure 43 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 2005-13. 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. 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 slowly recuperating, but has exhibited a gradual decreasing, yet statistically insignificant trend during the last two surveys.

Variations of the mean substrate cover by coral species are shown in Figure 44. Boulder Star Coral, *Orbicella annularis* exhibited a decline of 16 % between the baseline survey of 1999 and the 2005 survey, but then dropped 58.0 % between 2005 and 2006, driving the overall decline of live coral cover at West Reef. During the 2007 survey, *O. annularis* declined again 7.4 % from its cover in 2006, and then stabilized during the 2008 survey (Figure 44). Sharp reductions of substrate cover by live corals were also measured until 2007 for *Agaricia agaricites, Colpophyllia natans* and *Stephanocoenia michelini*. Mild increments of substrate cover by *O. annularis*, *P. astreoides* and *Siderastrea radians* were measured in the 2009 and 2010 surveys, but are presently back to the 2008 values. Such recent trends are statistically insignificant.

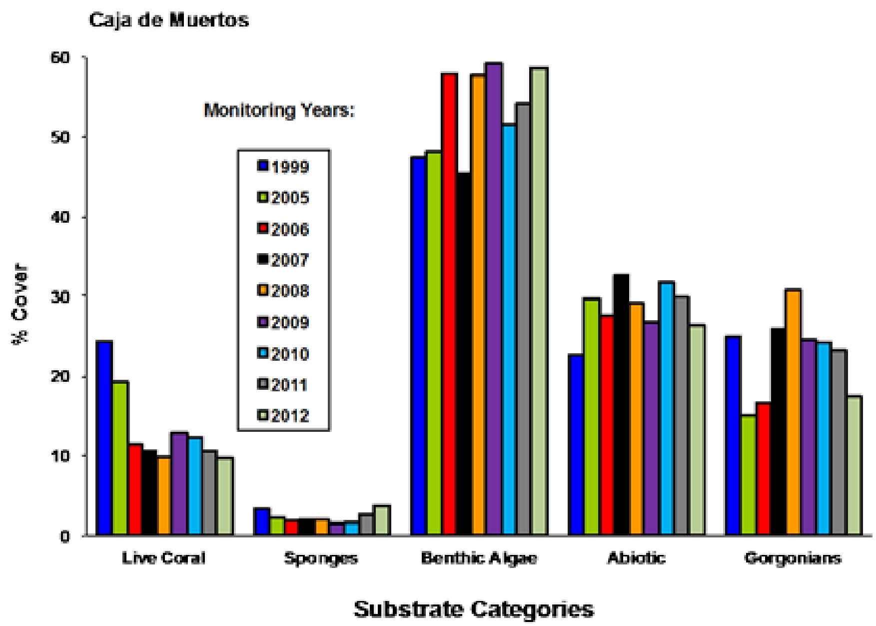


Figure 43. Monitoring trends (1999 - 2013) of mean substrate cover by sessile-benthic categories at West Reef, Isla Caja de Muerto, Ponce.

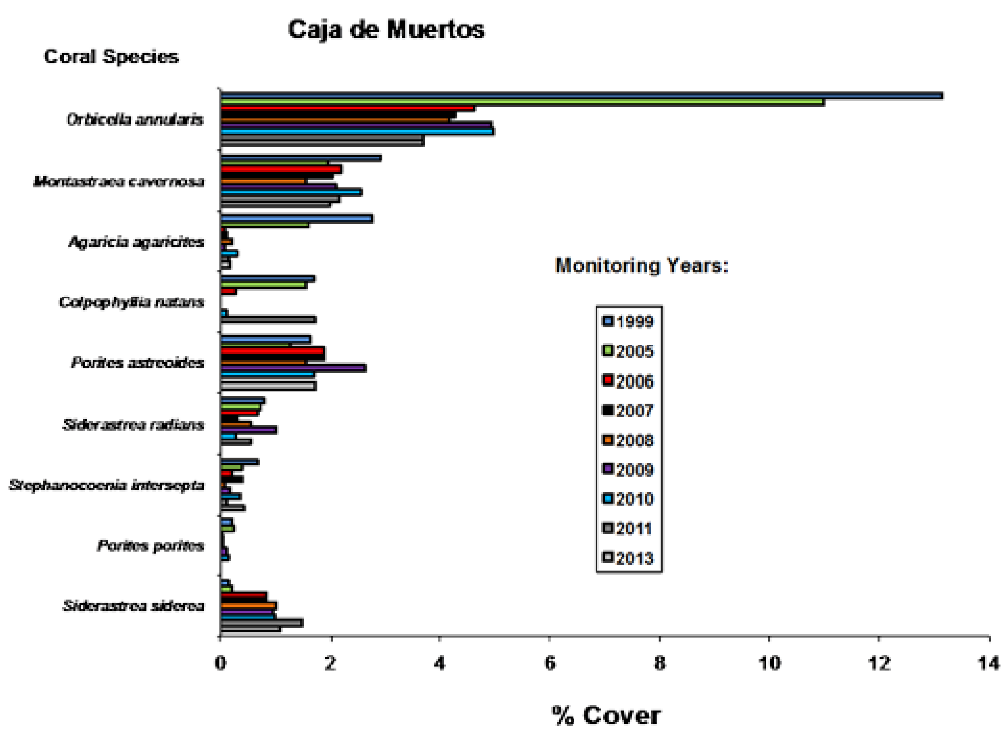


Figure 44. Monitoring trends (1999 – 2013) of mean substrate cover by stony coral species at West Reef, Isla Caja de Muerto, Ponce.

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 2013 was 57.6 Ind/30 m^2 (range: 45 - 71 Ind/30 m^2). The mean number of species per transect was 15.2 (range: 12- 22). The Masked Goby (*Coryphopterus personatus*) was the numerically dominant species with a mean abundance of 19.2 Ind/30 m^2 (range: 5 - 45 Ind/30 m^2), representing 33.3 % 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 Striped, Princess and Redband Parrotfishes, Bluehead Wrasse, Blue and Brown Chromis, Bicolor, Dusky and Bicolor Damselfishes 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).

Figure 45 shows the annual trends of fish abundance and species richness during monitoring surveys at West Reef. Statistically significant differences of fish abundance (ANOVA; $p < 0.001$) 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 2009, 2010 and the present 2013 surveys. Differences in 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 present 2013 relative to other surveys.

The fish community structure at West Reef is strongly represented by zooplankton feeders, including the Masked Goby, 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 the ASEC survey at this reef (Table 52).

Table 51. Taxonomic composition and abundance of fishes within belt-transects at West Reef, Isla Caja de Muerto, 6.5 m, Ponce. Survey Date: February 2013.

Depth: 20m

		TRANSECTS					
		1	2	3	4	5	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						MEAN
Coryphopterus personatus	Masked Goby	15	17	14	5	45	**19.2**
Scarus iserti	Stripped Parrotfish	6	1	7	3	7	**4.8**
Thalassoma bifasciatum	Bluehead Wrasse	5	10	5	2	0	**4.4**
Chromis cyanea	Blue Chromis	6	3	4	6	0	**3.8**
Stegastes partitus	Bicolor Damselfish	2	6	5	1	2	**3.2**
Sparisoma aurofrenatum	Redband Parrotfish	4	0	4	4	2	**2.8**
Scarus taeniopterus	Princess Parrotfish	9	3	0	0	1	**2.6**
Abudefduf sexatilis	Sargent Major	0	0	6	5	0	2.2
Chromis multilineata	Brown Chromis	0	1	7	0	0	**1.6**
Stegastes adustus	Dusky Damselfish	0	4	2	2	0	**1.6**
Gobiosoma evelynae	Sharknose Goby	0	0	0	6	1	**1.4**
Myripristis jacobus	Blackbar Soldierfish	1	0	2	4	0	**1.4**
Acanthurus coeruleus	Blue Tang	2	1	0	2	1	**1.2**
Canthigaster rostrata	Caribbean Puffer	0	2	1	0	2	**1.0**
Stegastes variabilis	Cocoa Damselfish	0	0	1	2	1	**0.8**
Stegastes leucostictus	Beau Gregory	2	0	1	0	1	**0.8**
Chaetodon capistratus	Four-eye Butterflyfish	1	1	1	0	0	**0.6**
Haemulon flavolineatum	French Grunt	0	0	3	0	0	**0.6**
Haemulon aurolineatum	Tomtate	0	0	2	0	0	**0.4**
Hypoplectrus unicolor	Butter Hamlet	0	0	0	1	1	**0.4**
Aulostomus maculatus	Trumpetfish	0	0	1	0	0	**0.2**
Caranx crysos	Blue runner	0	1	0	0	0	**0.2**
Cephalopholis cruentatus	Graysby	0	0	0	0	1	**0.2**
Haemulon album	White Margate	0	0	1	0	0	**0.2**
Haemulon sciurus	Bluestriped Grunt	0	0	1	0	0	**0.2**
Halichoeres garnoti	Yellow-head Wrasse	1	0	0	0	0	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	0	0	0	1	**0.2**
Holocentrus rufus	Squirrelfish	0	0	1	0	0	**0.2**
Hypoplectrus nigricans	Black Hamlet	0	0	1	0	0	**0.2**
H. cruentatus	Glasseye Snapper	1	0	0	0	0	**0.2**
Pseudupeneus maculatus	Spotted Goatfish	0	0	0	1	0	**0.2**
Scarus vetula	Queen Parrotfish	0	0	0	0	1	**0.2**
Serranus tigrinus	Harlequin Bass	0	0	1	0	0	**0.2**
Sparisoma viride	Stoplight Parrotfish	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	55	50	71	45	67	**57.6**
	TOTAL SPECIES	13	12	22	15	14	**15.2**

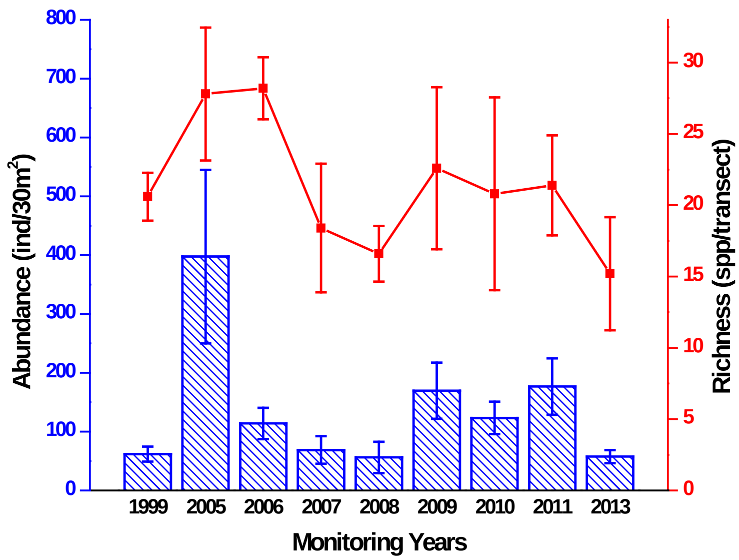


Figure 45. Monitoring trends (1999 – 2013) of fish species richness and abundance at West Reef, Isla Caja de Muerto, Ponce

A specious assemblage of herbivores, particularly parrotfishes, and small invertebrate feeders were also present, including wrasses, gobies, puffers, goatfishes and squirrelfishes, among others. Mid-size carnivores that are commercially exploited, such as the Yellowtail, Mahogany, Lane, Grey and Schoolmaster Snappers, Red Hind, and Coney were observed during the ASEC survey (Table 52). 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 ASEC surveys. The aggregation of these Lane Snappers at West Reef is most impressive and represents a highly valuable resource.

Juvenile and some adult Yellowtail Snappers (*Ocyurus chrysurus*) 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 (*L. apodus*) were mostly observed as juvenile/adult stages swimming in and out of caves and crevices within the fore-reef slope. Juvenile and young adult Mutton Snappers (*L. analis*) were observed foraging along with the large Lane Snapper aggregation during the 2006 ASEC survey (García-Sais et al., 2006).

Motile megabenthic invertebrates were represented within belt-transects by the Flamingo Tongue gastropod present on soft corals, the Arrow Crab, and the Fire Worm (Table 53). Juvenile and adult spiny lobsters, *Panulirus argus*, and adult Queen Conch, *Strombus gigas* have been reported in previous surveys.

Table 52. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at West Reef, Isla Caja de Muerto, February 2013.

Depth range : 7–15m	Duration - 30 min.			
SPECIES	**COMMON NAME**		# - (cm)	
Epinephelus guttatus	Red Hind	1 - (30)		
Lutjanus apodus	Schoolmaster	4 – (15)	4 – (20)	2 – (30)
Lutjanus mahogany	Mahogani Snapper	3 - (15)	2- (30)	
Lutjanus synagris	Lane Snapper	260 – (10-15)	70 – (25)	13 – (30)
Ocyurus chrysurus	Yellowtail Snapper	40 – (10 - 15)	5 – (25)	2 – (30)
Scomberomorus regalis	Cero Mackerel	2 - (40)		
Sphyraena barracuda	Great Barracuda	1 - (60)	1 – (70)	

Table 53. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at West Reef, Caja de Muerto. February 2013.

Depth: 6 - 7 m		**TRANSECTS**					**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Cyphoma gibbosum	Flamingo tongue			2		1	**0.6**
Hermodice carunculata	Fire Worm	1					**0.2**
Stenorhynchus seticornis	Arrow Crab		1			1	**0.4**
	TOTALS	**1**	**1**	**1**	**0**	**1**	**1.2**

Photo Album 13 (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 46). 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 14 intersected by line transects were identified from Derrumbadero Reef at a depth of 20 m during 2013 (Table 54). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 11.3 % (range: 7.6 – 13.4 %). Boulder Star Coral, *Orbicella annularis* (complex) was the dominant species in terms of substrate cover with a mean of 5.4 % (range: 3.7 – 8.6.0 %), representing 47.8 % of the total cover by stony corals. Mustard-Hill Coral (*Porites astreoides*) and Great Star Coral (*M. cavernosa*) ranked second and third in terms of substrate cover by stony corals. Boulder Star and Great Star Corals, Mustard-Hill Coral and Lettuce Coral (*Agaricia agaricites*) were present in at least three transects and comprised the main stony coral assemblage at Derrumbadero Reef (Table 54).

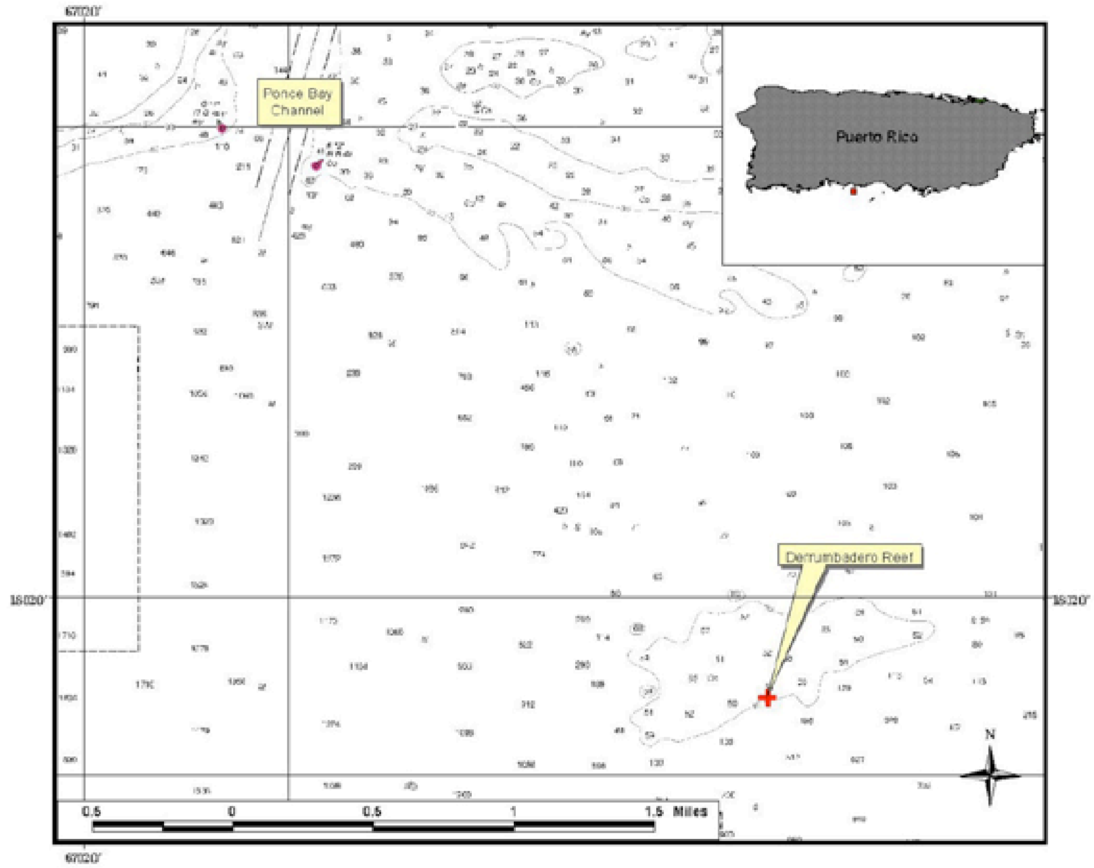


Figure 46. Location of the coral reef monitoring station at Derrumbadero Reef, Ponce.

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 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).

Table 54. Percent substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce, 20 m. Survey Date: September 2013

	Transects					
	1	2	3	4	5	**Mean**
	3.34	0.28	6.07	3.65	2.33	**3.13**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhang	13.1	12.4	12.0	10.1	3.3	**10.2**
Sand			1.7			**0.3**
Rubble	1.5					0.3
Total Abiotic	**14.6**	**12.4**	**13.7**	**10.1**	**3.3**	**10.8**
Benthic Algae						
Turf	33.7	27.5	38.6	42.5	34.3	**35.3**
Lobophora spp.	26.7	27.2	22.6	27.2	40.5	**28.8**
Dictyota spp.	3.3	5.7	7.1	3.5	1.6	**4.2**
Crustose coralline algae	0.8	1.4	1.0	2.2	4.1	**1.9**
Total Benthic Algae	**64.4**	**61.9**	**69.2**	**75.3**	**80.5**	**70.2**
Cyanobacteria		0.5	1.4			**0.4**
Gorgonians						
Erythropodium caribaeorum	1.8	6.5	0.8	0.5	0.9	**2.1**
Briareum asbestinum	0.5	5.4	0.6			**1.3**
Gorgonia ventalina		0.5				**0.1**
Antillogorgia americana	0.4					**0.1**
Eunicea colombiana				0.3		**0.1**
Pseudopterogorgia flagellosa		0.3				**0.1**
Eunicea flexuosa				0.2		**0.0**
Total Gorgonians	**2.7**	**12.8**	**1.4**	**1.0**	**0.9**	**3.8**
Erect Gorgonians (#col/transect)	10.0	23.0	19.0	27.0	12.0	**18.2**
Sponges						
Agelas conifera	1.7	0.4				**0.4**
Agelas dispar	1.4		0.5			**0.4**
Monanchora arbuscula				0.5	1.1	**0.3**
Aplysina fistularis		0.7		0.9		**0.3**
Petrosia pellasarca	0.8			0.4		**0.2**
Agelas citrina	0.2		0.3	0.2	0.6	**0.2**
Ectyoplasia ferox		1.2				**0.2**
Niphates digitalis	0.3	0.7				**0.2**
Agelas dispar				0.9		**0.2**
Agelas clathrodes		0.4	0.3		0.2	**0.2**
Agelas spp.	0.5	0.3				**0.2**
Scopalina ruetzleri	0.1	0.7				**0.2**
Chondrilla caribbaea				0.7		**0.1**
Callyspongia vaginalis				0.4		**0.1**
Amphimedon compressa		0.4				**0.1**
Aiolochoria crassa			0.3			**0.1**
Unknown sponge			0.2			**0.0**
Desmapsamma anchorata	0.1					**0.0**
Total Sponges	**5.1**	**4.8**	**1.6**	**4.1**	**1.9**	**3.5**

Table 54. continued

Live Stony Corals						
Orbicella annularis	8.6	3.7	4.9	5.0	4.9	**5.4**
Porites astreoides	3.4	1.1	3.1	1.9	1.9	**2.3**
Montastraea cavernosa			2.4	1.9	2.0	**1.3**
Diploria labyrinthiformis		1.4			0.8	**0.5**
Agaricia grahamae					1.7	**0.3**
Agaricia agaricites			0.6	0.6	0.5	**0.3**
Siderastrea siderea	1.2				0.3	**0.3**
Agaricia lamarcki			1.4			**0.3**
Meandrina meandrites					1.2	**0.2**
Agaricia humilis		0.8				**0.2**
Eusmilia fastigiata		0.7				**0.1**
Stephanocoenia intersepta			0.2			**0.0**
Total Stony Corals	**13.1**	**7.6**	**12.6**	**9.5**	**13.4**	**11.3**

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 70.2 % (range: 61.9 – 80.5 %). 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).

Figure 47 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 2005-13. 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, but the increasing cover trend has reverted during the last two monitoring surveys (Figure 47).

Monitoring trends of mean substrate cover by coral species at Derrumbadero Reef are shown in Figure 48. 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. Yet, the increasing cover trend by *O. annularis* has reversed again back to the post 2006 condition. Such small fluctuations of live coral cover by *O. annularis* after the 2006 massive mortality were not statistically significant and may be artifacts of sampling variability (Appendix 2).

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 86 fish species have been identified from Derrumbadero Reef during monitoring surveys (Appendix 1), including 29 within belt-transects during 2013 (Table 55). Mean abundance within belt-transects during 2013 was 65.2 Ind/30 m^2 (range: 22 - 176 Ind/30 m^2). The mean number of species per transect was 13.6 (range: 10 - 18). The Creole Wrasse, Bicolor Damselfish, Blue Chromis, and the Princess and Redband Parrotfishes were the numerically dominant species with a combined mean abundance of 51.6 Ind/30 m^2 representing 79.1 % of the total abundance within belt-transects (Table 55). In addition to the aforementioned species, the Peppermint and Sharknose Gobies, Blue Tang, Four-eye Butterflyfish, Squirrelfish and Beaugregory were present in at least three of the five transects surveyed and were part of the numerically dominant fish assemblage at Derrumbadero Reef.

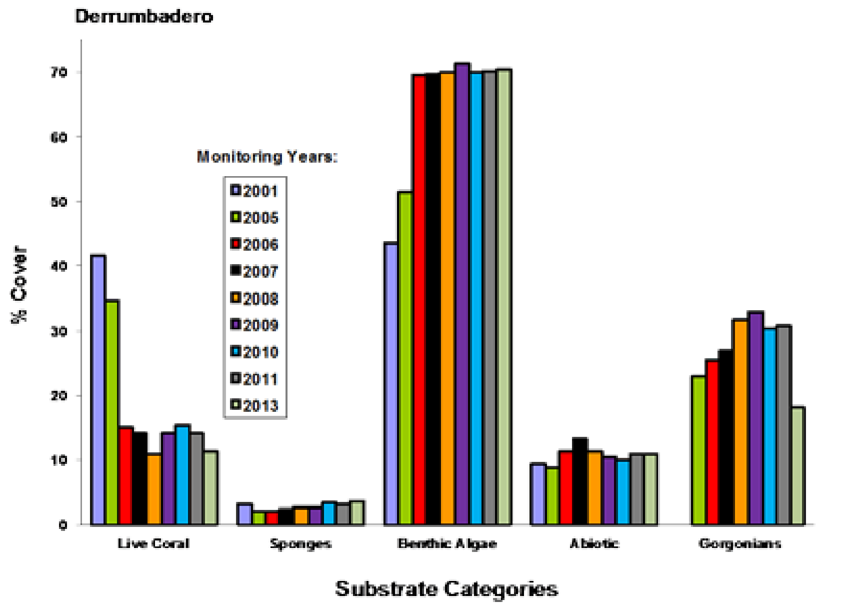


Figure 47. Monitoring trends (2001 – 2013) of mean substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce.

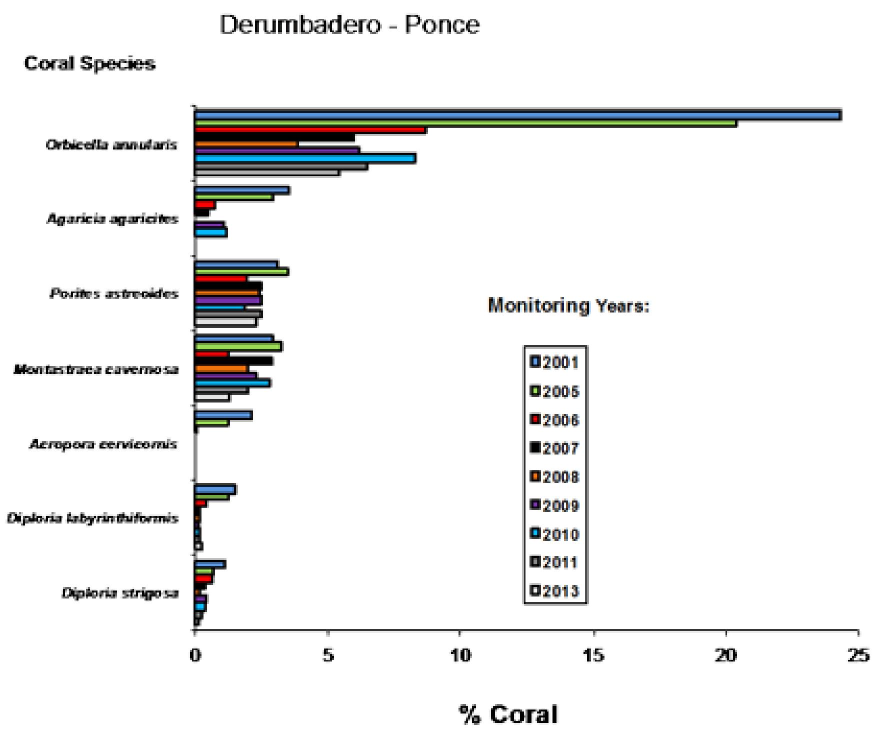


Figure 48. Monitoring trends (2001 – 2013) of mean substrate cover by coral species at Derrumbadero Reef, Ponce

Table 55. Taxonomic composition and abundance of fishes within belt-transects at Derrumbadero Reef, 20 m, Ponce. September 2013

Depth: 20m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Clepticus parrae	Creole Wrasse	150	0	0	0	2	30.4
Stegastes partitus	Bicolor Damselfish	10	14	8	4	12	9.6
Chromis cyanea	Blue Chromis	5	12	2	0	10	5.8
Scarus taeniopterus	Princess Parrotfish	2	3	3	7	1	3.2
Sparisoma viride	Stoplight Parrotfish	4	2	1	3	3	2.6
Acanthurus coeruleus	Blue Tang	0	2	3	1	0	1.2
Chaetodon capistratus	Four-eye Butterflyfish	1	2	0	3	0	1.2
Holocentrus rufus	Squirrelfish	0	1	1	2	1	1.0
Melichthys niger	Black Durgon	0	0	0	0	5	1.0
Sparisoma aurofrenatum	Redband Parrotfish	0	0	0	5	0	1.0
Acanthurus bahianus	Ocean Surgeon	1	0	1	1	1	0.8
Stegastes leucostictus	Beau Gregory	0	2	1	0	1	0.8
Gobiosoma evelynae	Sharknose Goby	0	0	0	2	1	0.6
Halichoeres garnoti	Yellow-head Wrasse	1	0	0	2	0	0.6
Ocyurus chrysurus	Yellowtail Snapper	0	0	1	2	0	0.6
Amblycirrhitus pinos	Redspotted Hawkfish	0	0	0	1	1	0.4
Chaetodon ocellatus	Spotfin Butterflyfish	0	2	0	0	0	0.4
Haemulon flavolineatum	French Grunt	0	0	0	1	1	0.4
Hypoplectrus unicolor	Butter Hamlet	1	0	0	0	1	0.4
Myripristis jacobus	Blackbar Soldierfish	0	0	0	1	1	0.4
Neoniphon marianus	Longspine Squirrelfish	1	0	0	1	0	0.4
Thalassoma bifasciatum	Bluehead Wrasse	0	0	0	0	2	0.4
Anisotremus virginicus	Porkfish	0	0	0	0	1	0.2
Aulostomus maculatus	Trumpetfish	0	0	0	0	1	0.2
Caranx crysos	Blue runner	0	1	0	0	0	0.2
Coryphopterus lipernes	Peppermint Goby	0	0	0	1	0	0.2
Haemulon album	White Margate	0	1	0	0	0	0.2
Lactophrys triqueter	Honeycomb Cowfish	0	1	0	0	0	0.2
Lutjanus analis	Mutton Snapper	0	0	0	0	1	0.2
Serranus tigrinus	Harlequin bass	0	1	0	0	0	0.2
Stegastes adustus	Dusky Damselfish	0	0	1	0	0	0.2
Sphyraena barracuda	Great Barracuda	0	1	0	0	0	0.2
	TOTAL INDIVIDUALS	176	45	22	37	46	65.2
	TOTAL SPECIES	10	14	10	16	18	13.6

Figure 49 presents the temporal trends of fish abundance and species richness within belt-transects during the baseline characterization of 2001 and subsequent monitoring surveys of 2005-13. 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 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 piscivorous 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 an ASEC survey in this reef (Table 56). 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.

The Cleaner Shrimp and Arrow Crabs represented megabenthic invertebrates within belt transects during the 2013 survey (Table 57). Two spiny lobsters were observed outside transects.

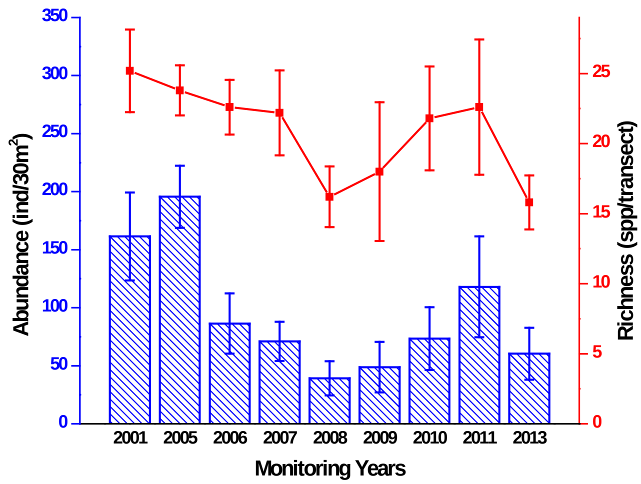


Figure 49. Monitoring trends (1999 – 2013) of fish species richness and abundance at Derrumbadero Reef, Ponce

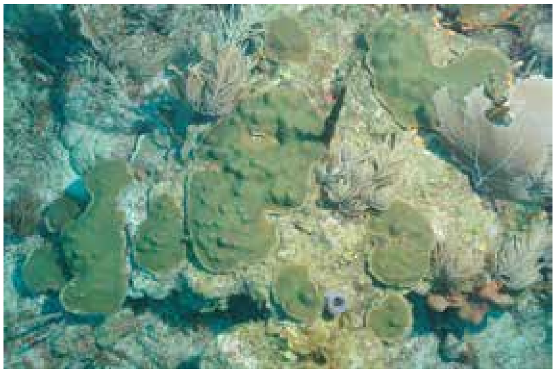
Table 56. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Derrumbadero Reef, Ponce. September 2013. Depth: 18 – 22 m

SPECIES	**COMMON NAME**		# - (cm)	
Epinephelus guttatus	Red Hind	2 – (30)		
Lutjanus apodus	Schoolmaster	3 - (20)	3 – (30)	1 – (40)
Lutjanus mahogany	Mahogani Snapper	1 - (20)	3 – (25)	
Ocyurus chrysurus	Yellowtail Snapper	4 – (20)	2 - (30)	
Scomberomorus regalis	Cero Mackerel	1- (45)		
Sphyraena barracuda	Great Barracuda	1- (60)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (25)	1 – (30)	

Table 57. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Derrumbadero Reef, 20 m, Ponce, September 2013

Depth: 20 m		**TRANSECTS**					**MEAN**
TAXA	DEPTH (m) COMMON NAME	**1**	**2**	**3**	**4**	**5**	**ABUNDANCE (IND/30 m2)**
Periclimenes pedersoni	Cleaner Shrimp	2			1		**0.6**
Stenorhynchus seticornis	Arrow Crab	1	1			1	**0.6**
	TOTALS	**3**	**1**	**0**	**2**	**1**	**1.2**

Photo Album 14 (Ponce)
Derrumbadero Reef








G. Vieques

1.0 El Seco Reef-Vieques

"El Seco" is a submerged promontory, or ridge that rises from a deep outer shelf basin at the southeastern tip of the Vieques shelf, approximately 6 km from Punta del Este. The promontory with an elliptical shape runs along a north-south axis and rises from the basin at depths of 33 – 36 m to a mostly flat hard ground reef top at depths of 23 – 28 m (Figure 50). Depth increases towards the shelf-edge to the east and south of the ridge, and decreases towards the north, where an extensive mesophotic coral reef system consisting of several benthic habitats was discovered (Garcia-Sais et al. 2011). The coral reef system ends as patch reef spurs separated by coralline sand pools at depths between 40 – 45 m. Exceptionally clear waters prevail at "El Seco" with underwater visibility generally exceeding the 30 - 40 m range.

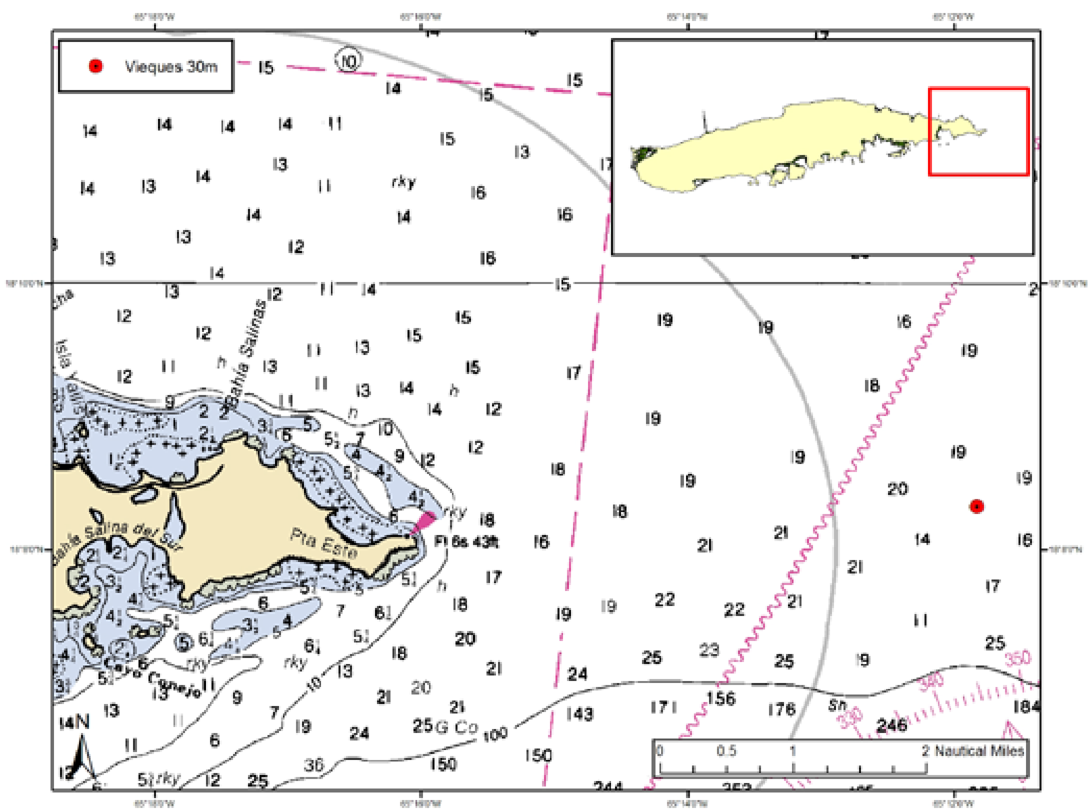


Figure 50. Location of the coral reef monitoring station at El Seco Reef, Vieques.

The coral reef bank habitat at El Seco is an impressive continuous formation of scleractinian corals growing at depths of 33 – 41 m (110 – 135') throughout the northern and northeastern sections of the study area. The coral reef bank is largely (almost a biotope) of Boulder Star Coral, *Orbicella franksi* growing as laminar planks of up to 1 m of diameter, supported by pedestals of unknown origin and variable heights. Even though its entire areal extension has not been mapped, the coral reef formation off southeast Vieques represents the largest continuous coral reef benthic habitat reported for Puerto Rico (Garcia-Sais et al. 2011). Panoramic views of the coral reef system of El Seco are presented as Photo Album 15.

1.1 Sessile-Benthic Reef Community

Substrate cover data by sessile-benthic categories from transects surveyed at the coral reef bank habitat are presented in Table 58. The combined assemblage of benthic algae, comprised by turf algae, fleshy brown algae (*Lobophora sp*.), calcareous green algae (*Halimeda sp*.) and coralline red algae was the dominant category in terms of percent cover with a mean of 51.9 % (range: 41.2 – 58.9 %). Turf algae, a mixed array of short filamentous algae were the main component of the benthic algae with an average cover of 32.8 %, representing 63.2 % of the total cover by benthic macroalgae. The encrusting fan alga, *Lobophora variegata* and encrusting red coralline algae were present in all transects with a mean cover of 7.0 % and 12.0 %, respectively (Table 58).

Table 58. Percent substrate cover by sessile-benthic categories at El Seco Reef, Vieques. October 2013

	Transects					
	1	2	3	4	5	**Mean**
SUBSTRATE CATEGORY						
Abiotic						
Sand	1.7	6.8	9.2	2.8	6.5	**5.4**
Recently dead coral				1.2		**0.2**
Total Abiotic	**0.0**	**0.0**	**0.0**	**4.1**	**0.0**	**5.6**
Benthic Algae						
Turf	35.9	38.1	27.7	21.8	40.5	**32.8**
Crustose coralline algae	14.1	8.5	12.9	11.3	13.4	**12.0**
Lobophora spp.	8.6	6.1	8.2	8.1	4.1	**7.0**
Halimeda spp.	0.4					**0.1**
Total Benthic Algae	**58.9**	**6**	**48.8**	**41.2**	**58.0**	**51.9**

Table 58. continued						
Cyanobacteria	**2.4**	**6.0**	**5.2**	**2.8**	**1.7**	**3.6**
Gorgonian						
Erythropodium caribaeorum	0.4			0.4	0.4	**0.2**
Briareum asbestinum				0.4		**0.1**
Total Gorgonian	**0.4**	**0.0**	**0.0**	**0.8**	**0.4**	**0.3**
Sponge						
Cliona sp.				3.7		**0.7**
Unid. Sponge			1.2	0.4		**0.3**
Petrosia pellasarca					0.4	**0.1**
Total Sponge	**0.0**	**0.0**	**1.2**	**4.1**	**0.4**	**1.1**
Live Stony Corals						
Orbicella annularis	32.2	29.4	32.8	44.2	28.6	**33.4**
Porites astreoides	2.0	1.2	1.2	0.8	0.8	**1.2**
Agaricia lamarcki	0.4	1.6	0.4		1.6	**0.8**
Diploria labyrinthiformis	2.0		0.8			**0.6**
Agaricia fragilis		0.4			0.8	**0.2**
Agaricia grahamae				0.8	0.4	**0.2**
Siderastrea siderea		0.4			0.4	**0.2**
Porites porites				0.8		**0.2**
Unknown coral			0.4	0.4		**0.2**
Agaricia agaricites					0.4	**0.1**
Montastraea cavernosa		0.4				**0.1**
Total Stony Corals	**36.6**	**33.4**	**35.6**	**47.1**	**33.1**	**37.1**

Most of the substrate cover by benthic algae was associated with vertical surfaces of the coral colony's pedestal and the area underneath the table shaped colonies from which pedestals rise. Otherwise, there was very limited algal cover associated with overgrowth of relict or recently dead coral at this habitat.

Live scleractinian coral was the dominant sessile-invertebrate taxa in terms of substrate cover at the coral reef bank with an average of 37.1 % (range: 33.1 – 47.1). Coral cover was observed to be virtually a biotope of Boulder Star Coral, *Orbicella franksi* growing in table shaped colonies side by side, sometimes slightly overlapping and producing an impressive continuous live mesophotic coral system resembling that described by Smith et al. (2010) for the MCD Hind Bank in St. Thomas, USVI. Mean substrate cover by *M. franksi* was 33.4 % (range: 28.6 – 44.2 %), representing 90.0 % of the total cover by live corals at El Seco Reef (Table 58). Another 10 scleractinian corals were intercepted by transects. Mustard-hill coral, *Porites astreoides* with a mean cover of 1.2 %, and Whitestar Sheet Coral, *Agaricia lamarcki* with 0.8 % were present in at least four out of the five transects surveyed. Other scleractinian corals that were shown to form part of the predominant coral assemblage at El Seco Reef include the Lettuce Corals, *A. agaricites*, *A. grahamae*, *A. fragilis,* Grooved Brain Coral*, Diploria labyrinthiformis and* Massive Starlet Coral*, Siderastrea siderea* (Table 58).

Octocorals (gorgonians) were present in low abundance at the coral reef bank, their average substrate cover was measured for encrusting types as 0.3 %, with erect colonies only observed outside transects surveyed. Likewise, sponges were observed in very low cover with a mean of 1.1 % and only two species identified within transects (Table 58).

This was the first monitoring survey of the sessile-benthic community at El Seco Reef. No statistically significant differences have been detected since its quantitative baseline characterization in 2011 (Figure 51). The temporal variation of cover by the dominant coral species, *Montastraea franksi* was in the order of only 8% (Figure 52), which is well within the range of sampling variability error.

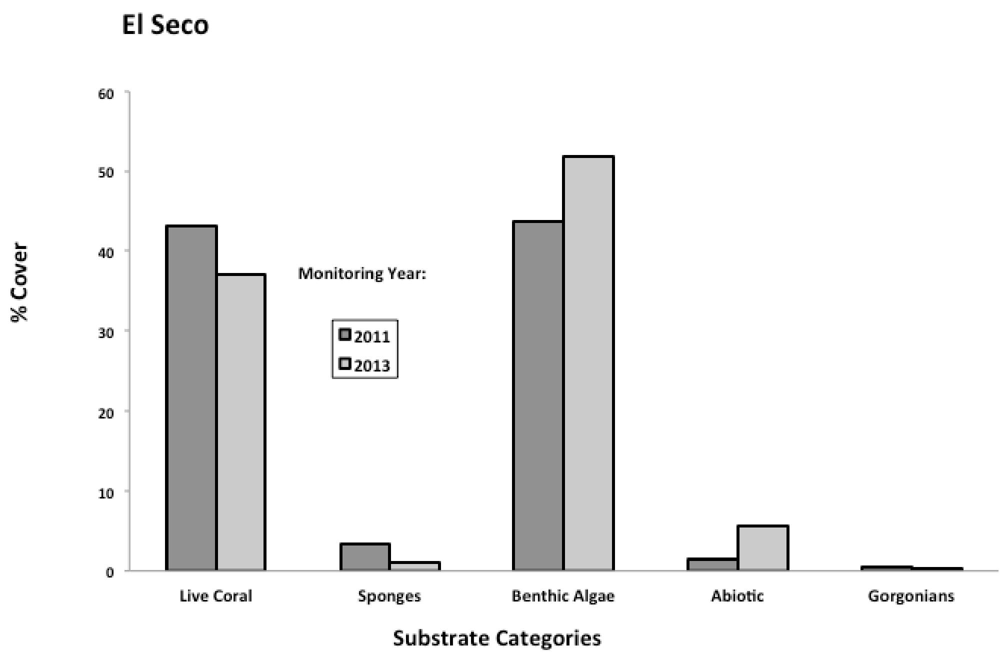


Figure 51. Monitoring trends (2011 – 2013) of mean substrate cover by sessile-benthic categories at El Seco Reef, Vieques.

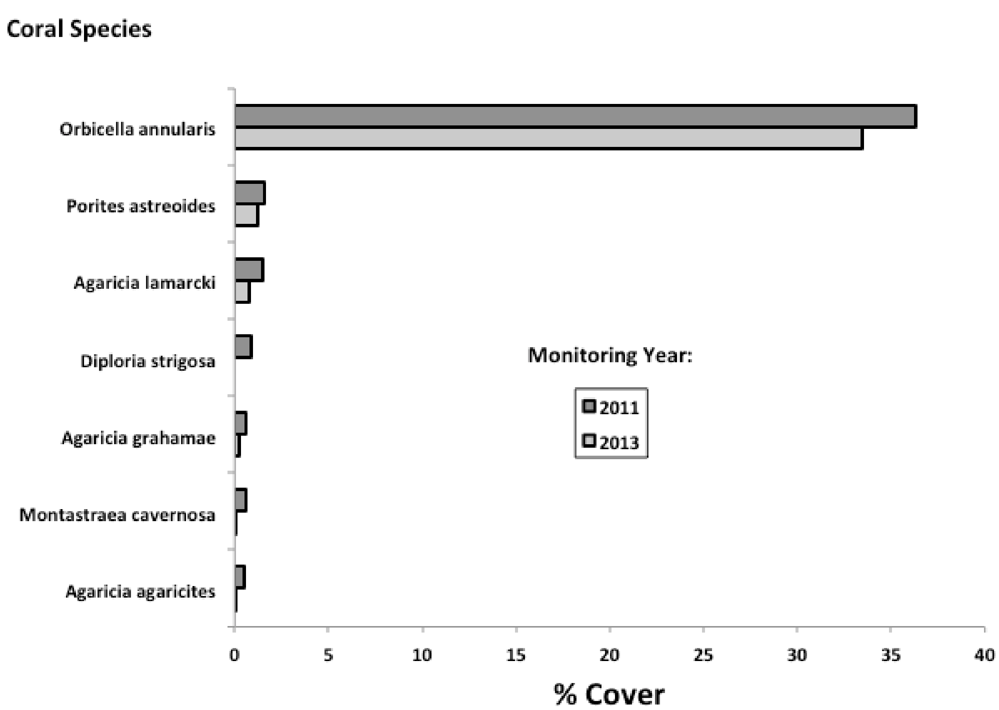


Figure 52. Monitoring trends (2011 – 2013) of mean substrate cover by coral species at El Seco Reef, Vieques

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 82 fish species, including 41 within belt-transects were identified from mesophotic depths (34 – 40 m) at the coral reef bank in October 2013 (Table 59). A complete list of fish species observed from the different benthic habitats is included as Appendix 1. Mean abundance within belt-transects was 95.0 Ind/30m^2 (range: 49 - 196 Ind/30m^2). Mean species richness was 13.4 spp/30m^2 (range: 10 – 17 spp/30m^2). Fish species composition and abundance estimates from this reef must be evaluated with caution due to the high rugosity and labyrinth dimensions that constrain visual access of the reef seascape and full microhabitats range to divers.

The Masked Goby, *Coryphopterus personatus* a species with highly aggregated distributions that forms swarms of dozens, sometimes hundreds of individuals beneath ledges and crevices in the reef accounted for 66.7 % of the total mean abundance within belt-transects (Table 59). Five additional species were present in at least four out of the five transects surveyed and along with Masked Goby comprised the numerically dominant small demersal fish assemblage of the coral bank habitat of El Seco reef system. These include the Blue Chromis, Bicolor Damselfish, Yellowhead Wrasse, Peppermint Goby and Four-eye Butterflyfish. A total of 10 species were only observed in one out of the ten transects surveyed.

The bank coral reef was observed to function as the residential habitat of several commercially important medium and large demersal reef fish predators, such as Red Hind, *Epinephelus guttatus*, Hogfish, *Lachnolaimus maximus,* Schoolmaster, Dog and Cubera snappers, *Lutjanus apodus, L. jocu, L. cyanopterus*, Tiger and Yellowfin Groupers, *Mycteroperca tigris* and Nurse Shark, *Ginglymostoma cirratum* (Table 60). Of these, the Cubera Snapper appeared to be the most abundant. Large adult cubera snappers were observed to be common and frequently sighted outside transects at the coral reef bank. The largest demersal predator of the reef at size distributions ranging between 150–250 cm appears to be the Nurse Shark, which appear to be common in the reef and were typically attracted to divers during our surveys of the reef bank.

The pelagic fish community at the bank reef was depauperate, compared to other mesophotic reefs studies, such as Bajo de Sico, Isla Desecheo and Abrir la Sierra

Table 59 . Taxonomic composition and abundance of fishes within belt-transects at the El Seco Reef, Vieques. October 2013

Depth: 35m

		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**Common Name**						**MEAN**
Coryphopterus personatus	Masked Goby	150	27	50	30	60	63.4
Chromis cyanea	Blue Chromis	5	2	10	2	3	4.4
Coryphopterus lipernes	Peppermint Goby	5	0	12	3	1	4.2
Scarus taeniopterus	Princess Parrotfish	7	0	10	2	0	3.8
Chaetodon capistratus	Four-eye Butterflyfish	7	2	2	0	2	2.6
Stegastes partitus	Bicolor Damselfish	4	3	2	1	1	2.2
Halichoeres garnoti	Yellowhead Wrasse	1	1	1	7	1	2.2
Gramma loreto	Royal Gramma	1	5	1	0	3	2.0
Lutjanus apodus	Schoolmaster	8	0	0	0	0	1.6
Scarus iserti	Striped Parrotfish	0	3	0	0	2	1.0
Acanthurus bahianus	Doctorfish	0	0	3	1	0	0.8
Thalassoma bifasciatum	Bluehead Wrasse	0	2	0	1	1	0.8
Canthigaster rostrata	Sharpnose Puffer	0	4	0	0	0	0.8
Bodianus rufus	Spanish Hogfish	2	0	1	0	0	0.6
Epinephelus cruentatus	Graysby	1	1	0	0	1	0.6
Epinephelus fulva	Coney	0	1	0	1	0	0.4
Hypoplectrus chlorurus	Yellowtail Hamlet	0	0	1	0	1	0.4
Ocyurus chrysurus	Yellowtail Snapper	2	0	0	0	0	0.4
Holocentrus rufus	Squirrelfish	0	0	0	1	1	0.4
Pomacanthus arcuatus	Grey Angelfish	2	0	0	0	0	0.4
Chaetodon aculeatus	Longsnout Butterflyfish	0	0	0	0	1	0.2
Sparisoma aurofrenatum	Redband Parrotfish	0	0	0	0	1	0.2
Sparisoma viride	Stoplight Parrotfish	0	0	0	0	1	0.2
Epinephelus guttatus	Red Hind	0	0	0	0	1	0.2
Stegastes leucostictus	Beaugregory	0	0	1	0	0	0.2
Holacanthus tricolor	Rock Beauty	0	0	1	0	0	0.2
Pseudupeneus maculatus	Spotted Goatfish	0	0	1	0	0	0.2
Haemulon macrostomum	Spanish Grunt	0	0	0	0	1	0.2
Lachnolaimus maximus	Hogfish	0	1	0	0	0	0.2
Amblycirrhitus pinos	Redspotted Hawkfish	1	0	0	0	0	0.2
	TOTAL INDIVIDUALS	**196**	**52**	**96**	**49**	**82**	**95.0**
	TOTAL SPECIES	**14**	**12**	**14**	**10**	**17**	**13.4**

Table 60. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at El Seco Reef, 30 - 35 m, Vieques, October 2013.

SPECIES	**COMMON NAME**	# - (cm)	
Epinephelus guttatus	Red Hind	3 – (30)	1 – (40)
Ginglymostoma cirratum	Nurse Shark	1 – (250)	
Lachnolaimus maximus	Hogfish	1 – (45)	
Lutjanus apodus	Schoolmaster	4 - (30)	5 – (40)
Lutjanus cyanopterus	Cubera Snapper	2 - (50)	1 – (60)
Lutjanus jocu	Dog Snapper	1 - (45)	
Lutjanus analis	Mutton Snapper	2 – (50)	
Mycteroperca tigris	Tiger Grouper	1 – (50)	
Mycteroperca venenosa	Yellowfin Grouper	1 – (45)	
Scomberomorus regalis	Cero	1 – (50)	
Sphyraena barracuda	Great Barracuda	1 - (70)	

(Garcia-Sais et al., 2005, 2007, 2010). In addition to ballyhoo and flying-fishes (Exocoetidae) only small schools of mackerel scad, *Decapterus macarelus* and creole wrasse, *Clepticus parrae* were observed in mid-water to serve as potential forage species for the larger pelagic predators, such as great barracuda and Cero Mackerel. Several large hawksbill turtles, *Eretmochelys imbricata* were present at the bank reef during the baseline survey in 2011. No megabenthic invertebrates were observed within belt-transects.

Figure 53 shows the annual variations of fish abundance and species richness at El Seco Reef. Such differences were relatively small and within sampling variability error.

Table 61. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at El Secop Reef, 35 m, Vieques, October 2013.

Depth: 35 m TAXA	DEPTH (m) COMMON NAME	**TRANSECTS** **1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
No megabenthic invertebrates							
	TOTALS	**0**	**0**	**0**	**0**	**0**	**0**

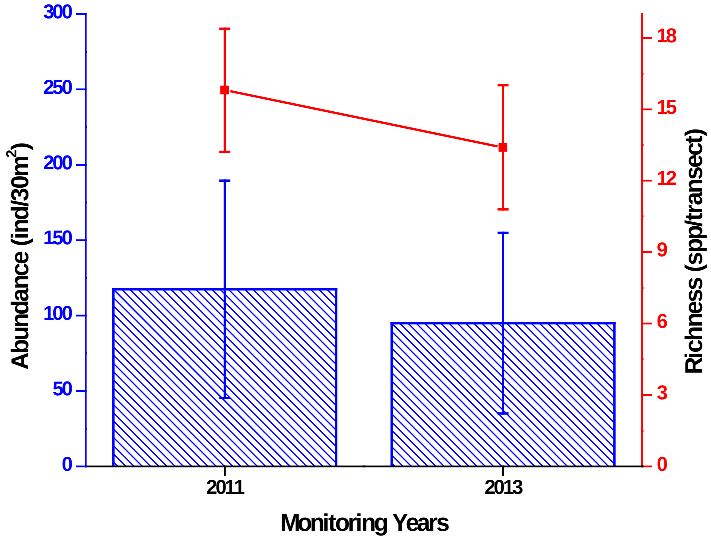
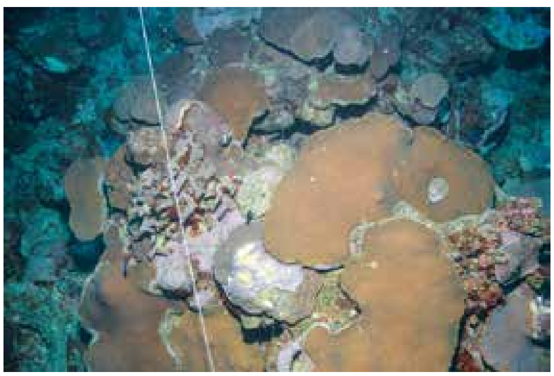
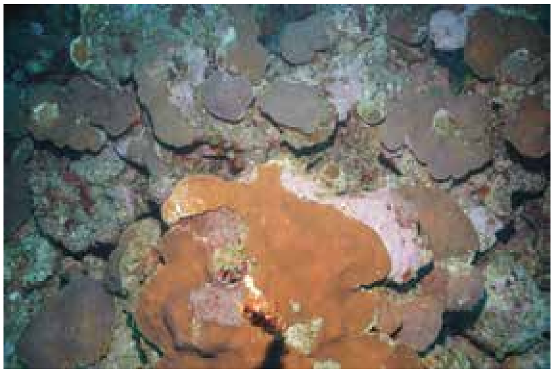
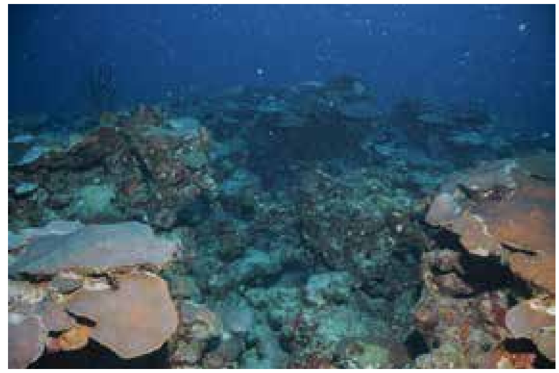
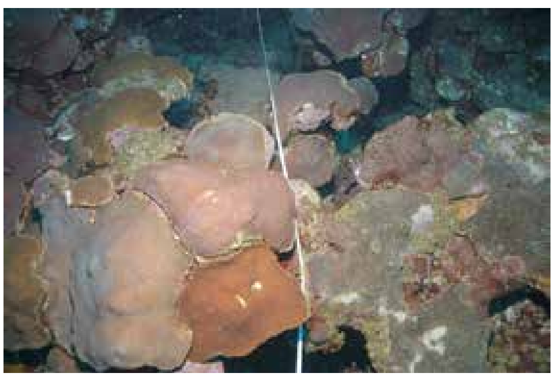
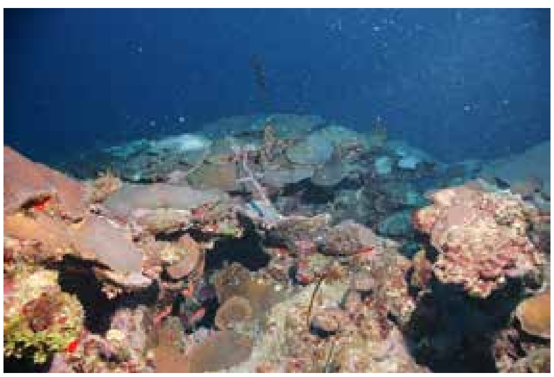


Figure 53. Monitoring trends (2011 – 2013) of fish species richness and abundance at El Seco Reef, Vieques

Photo Album 15
El Seco Reef



2.0 Boya Esperanza Reef - Vieques

Boya Esperanza Reef is a submerged patch reef sitting at the edge of a hard-ground platform located about 0.8 nautical miles off Puerto Esperanza, on the south coast of Vieques (Figure 54). A green navigation buoy marks the eastern boundary of the reef and the entrance channel to Puerto Esperanza. The reef has a highly irregular bathymetry, with large coral outcrops rising more than five meters from the base of the reef platform and reaching to about 2 meters from the surface. Extensive coralline sand pools (deposits) are found at the base of the reef on its northern boundary. Large crevices are found at the interface of the sandy bottom and the rock/coral outcrops. Our surveys were performed on the southern section of the reef, at a depth of 9-10 meters. Transects were established in a north-south direction on top of large coral outcrops of Boulder Star Coral. This is the second monitoring survey of Boya Esperanza Reef. The baseline survey was performed during 2000 (Garcia-Sais et al. 2001), and the first monitoring survey was done in 2004 (Garcia-Sais et al. 2004). Panoramic images of the reef are included as Photo Album 16.

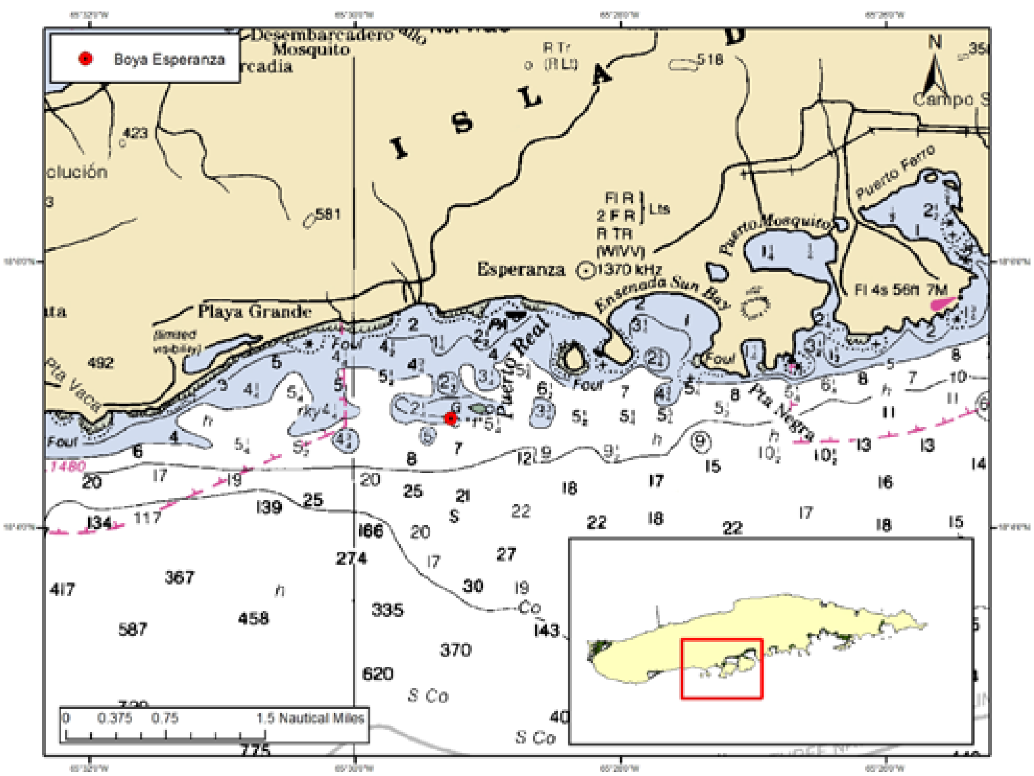


Figure 54. Location of the coral reef monitoring station at Boya esperanza, Vieques.

2.1 Sessile-Benthic Reef Community

A total of 21 species of stony corals were identified at Boya Esperanza Reef during the three surveys performed, 11 of which were intercepted by linear transects in the present 2013 survey. Live stony corals averaged a surface cover of 10.4 % (range: 3.3 – 16.2 %) along linear transects (Table 62). Surface cover by Boulder Star Coral represented 46.2 % of the total cover by stony corals. Soft corals (gorgonians) were highly abundant, with a mean density of 25 colonies intercepted per transect. An assemblage of at least 12 sponge species were intercepted by transects with a combined mean substrate cover of 2.2 %. Zoanthids, ascidians and encrusting gorgonians were observed outside transects, but represented only minor components of the benthic reef community. Turf algae was the dominant biological component in terms of coral cover with a mean of 73.6 %, representing 94.0 % of the total cover by benthic algae. Brown fleshy (*Lobophora sp, Dictyota sp*), calcareous (*Halimeda sp*.) and crustose coralline algae were also part of the benthic algae assemblage at Boya Esperanza (Table 62).

Figure 55 presents the monitoring trends of mean substrate cover by sessile-benthic categories at Boya Esperanza measured during the baseline (2000) and the monitoring surveys of 2004 and 2013. Differences of live coral cover between the baseline survey and the first monitoring survey were insignificant, with mean coral cover varying by less than 2.5 %. All other reef benthic categories remained virtually constant between surveys. A pronounced, statistically significant ($p < 0.022$) difference of live coral cover was measured during this 2003 survey (Appendix 2). Live coral cover declined more than 3 fold, from 33.6 % in 2004 to 10.4 % in 2013, a net loss of 23.2 % of live coral. Such reduction of live coral cover stands as one of the most drastic measured during the Puerto Rico coral monitoring program and is consistent with the sharp reductions evidenced by most reefs after the late 2005 regional coral bleaching event that affected

Table 62. Percent substrate cover by sessile-benthic categories at Boya Esperanza Reef, Vieques. October 2013

	Transects					
	1	2	3	4	5	**Mean**
	1.77	2.52	4.62	1.35	2.59	**2.57**
SUBSTRATE CATEGORY						
Abiotic						
Sand	4.9	1.9	0.6	2.8	4.3	**2.9**
Reef overhang	3.1	2.2	1.6	1.2	6.3	**2.9**
Rubble		1.3			2.2	**0.7**
Total Abiotic	**8.0**	**5.4**	**2.2**	**4.1**	**12.9**	**6.5**
Benthic Algae						
Turf	69.4	84.1	78.7	77.6	58.3	**73.6**
Dictyota spp.	0.4	0.1	3.4	2.1	4.8	**2.1**
Halimeda spp.	2.4	2.4		2.5	2.4	**1.9**
Crustose coralline algae		1.0			0.6	**0.3**
Lobophora spp.					1.6	**0.3**
Total Benthic Algae	**72.2**	**87.6**	**82.1**	**82.1**	**67.6**	**78.3**
Cyanobacteria			2.1	2.2	0.9	**1.0**
Gorgonian						
Plexaura homomalla	1.0	0.4			1.2	**0.5**
Pseudopterogorgia flagellosa	0.2		0.4	0.2	0.4	**0.3**
Briareum asbestinum	0.5					**0.1**
Gorgonia ventalina			0.3			**0.1**
Eunicea flexuosa				0.1		**0.0**
Total Gorgonian	**1.7**	**0.4**	**0.7**	**0.4**	**1.7**	**1.0**
Erect Gorgonians						
(#col/transect)	32.0	13.0	29.0	21.0	30.0	**25.0**
Sponge						
Chondrilla caribbaea	1.9					**0.4**
Mycale laevis	0.4	0.2		0.6	0.3	**0.3**
Agelas citrina			0.7	0.6		**0.3**
Spheciospongia vesparium				1.2		**0.2**
Haliclona spp.				1.1		**0.2**
Topsentia spp.				1.0		**0.2**
Dictyonella funicularis		0.4			0.3	**0.1**
Aplysina cauliformis				0.7		**0.1**
Niphates erecta				0.7		**0.1**
Niphates digitalis				0.4		**0.1**
Agelas spp.	0.4					**0.1**
Unknown sponge			0.2			**0.0**
Total Sponge	**2.6**	**0.6**	**0.9**	**6.4**	**0.7**	**2.2**
Live Stony Corals						
Orbicella annularis	5.1	0.6	5.8	0.5	11.9	**4.8**
Siderastrea siderea	4.5	0.5	0.3	1.1	1.1	**1.5**
Porites astreoides	1.7	2.6	1.8			**1.2**
Table 62. continued						
Millepora alcicornis		0.3	2.5	0.6	0.6	**0.8**
Diploria strigosa	1.0	0.3	1.6		0.7	**0.7**
Stephanocoenia intersepta				0.4	1.1	**0.3**
Porites furcata	0.2			0.1	0.9	**0.3**
Agaricia agaricites		0.6		0.6		**0.2**
Diploria labyrinthiformis	1.2					**0.2**
Montastraea cavernosa		1.0				**0.2**
Isophyllastrea rigida	0.7					**0.1**
Total Stony Corals	**14.4**	**6.0**	**12.1**	**3.3**	**16.2**	**10.4**

Puerto Rico and the U. S. Virgin Islands. A corresponding increment of benthic algae (21.8 %) and sponges (2.1 %) was measured during the present 2013 survey. A slight increment of erect gorgonians, from 20 col/transect to 25 col/transect was also observed.

As was the case for most reef systems included in the PR monitoring program, the sharp decline of total live coral was associated with the acute mortality of Boulder Star Coral, *Orbicella annularis* which presented a reduction of almost 6 fold, from 28.3 % in 2004 to 4.8 % in 2013 (Figure 56). Since reef substrate cover by *O. annularis* represented 84.2 % of the total cover by live corals at Boya Esperanza in 2004, its acute mortality had very pronounced implications of coral cover loss at this reef. Great Star Coral, *Montastraea cavernosa* also declined from 2.2 % to 0.2 %. Other corals with cover above 1% during 2004, such as Massive Starlet, *Siderastrea siderea* and Mustard Hill Coral, *Porites astreoides* did not exhibit any significant variations of reef substrate cover during this period.

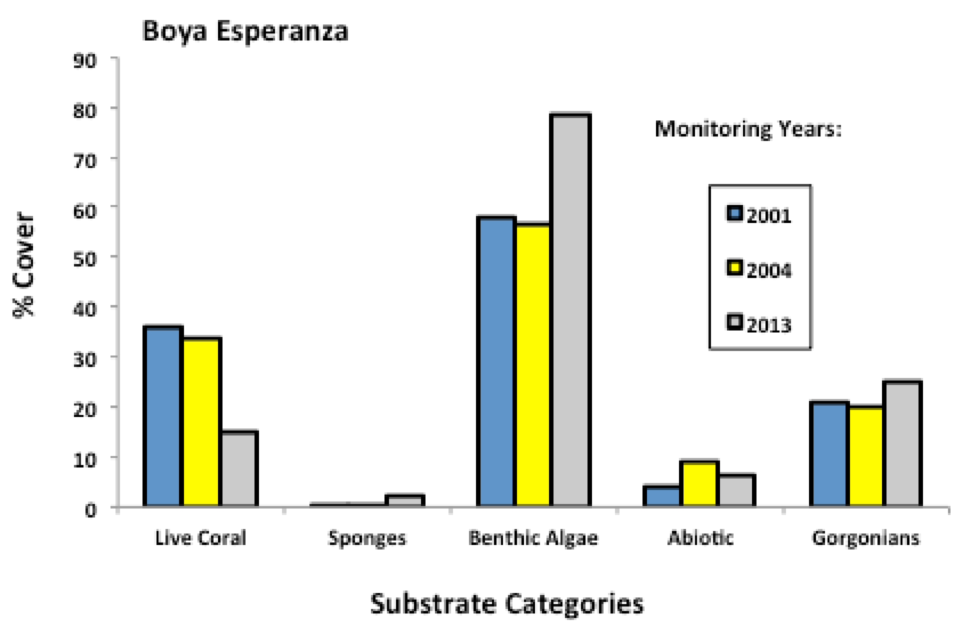


Figure 55. Monitoring trends (2011 – 2013) of mean substrate cover by sessile-benthic categories at Boya Esperanza Reef, Vieques.

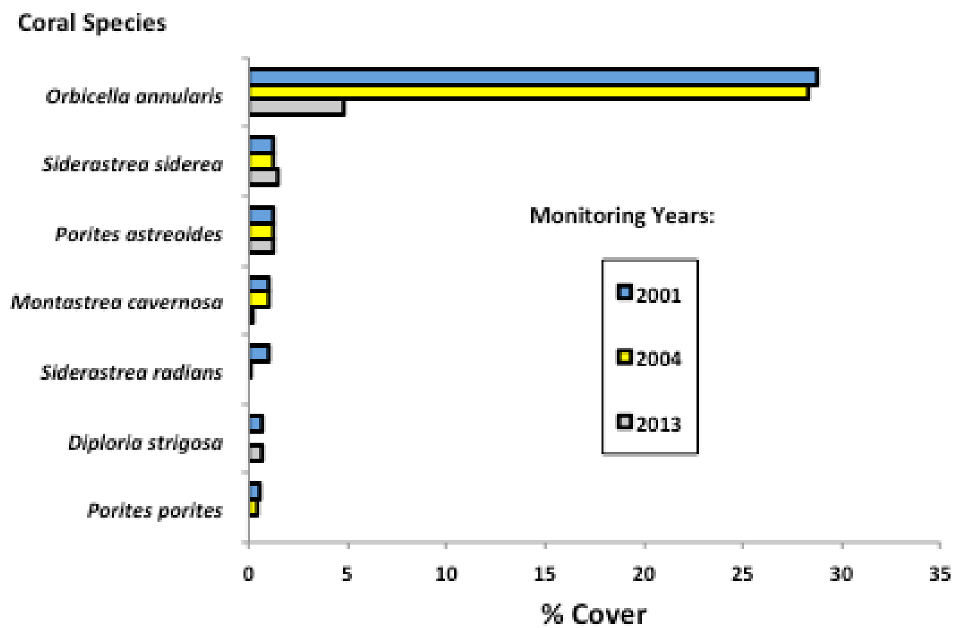


Figure 56. Monitoring trends (2011 – 2013) of mean substrate cover by coral species at Boya Esperanza Reef, Vieques

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 63 reef fishes were identified from Boya Esperanza Reef, 49 of which were observed within belt-transect areas (Table 63). The mean abundance of fishes was 75.0 Ind/30 m^2 and the mean number of species per transect was 18.6. The numerically and Brown Chromis (*Chromis cyanea, C. multilineata*), and the Bicolor Damselfish (*Stegastes partitus*). The combined abundance of these four species represented 55.5 % of the total fish abundance. Other seven species were present in at least three out of the five transects surveyed, including the Yellowhead, Clown and Creole Wrasses, Redband and Stoplight Parrotfishes, Caribbean Puffer, Dusky Damselfish and Blue Tang. The Boya Esperanza fish community structure exhibited a very well balanced composition of trophic groups. Small benthic invertebrate feeders, represented by Wrasses, Squirrelfishes, Puffers, Hamlets, Gobies and Blennies comprised approximately 37.6 % of the total fishes within transects. Zooplanktivores, largely represented by *Chromis spp*, Bicolor Damselfish and Creole Wrasse comprised 35.8 %. Herbivores were represented by six species of parrotfishes (Scaridae), three species of doctorfishes (Acanthuridae) and six species of Damselfishes (Pomacentridae) among others. Their combined assemblage represented

24.5 % of the total fish individuals within transects, but because of their larger size they probably represent a dominant trophic group within the community structure at Boya Esperanza. Piscivores and species of commercial value included Great Barracuda, Jacks, Yellowtail, Lane and Gray Snappers, and the Cero were also present (Table 64). dominant assemblage included the Bluehead Wrasse (*Thalassoma bifasciatum*), Blue

Monitoring trends of fish abundance and species richness is shown in Figure 57. Difference between surveys were within sampling variability error. Fish abundance increased almost one fold between the baseline and the 2001 survey, but stabilized back again to the 66 Ind/30m^2 during the present 2013 survey. Species richness has varied from 20 – 26 species per transect between the three surveys, and such differences were not statistically significant (see Appendix 3 and 4).

Motile megabenthic invertebrates were represented within belt-transects by one Long-Rock-boring Sea Urchin and Flamingo Tongue. One Spiny Lobster (*Panulirus argus*) and several juvenile Queen Conch (*Strombus gigas*) were observed outside transects.

Table 63. Taxonomic composition and abundance of fishes within belt-transects at Boya Esperanza Reef, Vieques. October 2013

		BELT-TRANSECTS					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	25	27	19	16	5	**18.4**
Chromis multilineata	Brown Chromis	10	11	20	8	0	**9.8**
Chromis cyanea	Blue Chromis	17	7	13	2	3	**8.4**
Stegastes partitus	Bicolor Damselfish	12	0	5	3	5	**5.0**
Acanthurus coeruleus	Blue Tang	3	1	7	0	7	**3.6**
Sparisoma aurofrenatum	Redband Parrotfish	3	4	5	1	1	**2.8**
Clepticus parrae	Creole Wrasse	0	9	3	1	0	**2.6**
Sparisoma viride	Stoplight Parrotfish	3	0	4	1	4	**2.4**
Scarus iserti	Stripped Parrotfish	9	0	0	1	0	**2.0**
Canthigaster rostrata	Caribbean Puffer	1	3	2	1	1	**1.6**
Microspathodon chrysurus	Yellowtail Damselfish	0	2	4	0	2	**1.6**
Halichoeres garnoti	Yellow-head Wrasse	0	3	4	0	0	**1.4**
Acanthurus chirurgus	Doctorfish	1	1	2	2	1	**1.4**
Halichoeres maculipinna	Clown Wrasse	2	1	0	0	3	**1.2**
Stegastes dorsopunicans	Dusky Damselfish	0	3	1	2	0	**1.2**
Holocentrus rufus	Squirrelfish	1	2	2	0	1	**1.2**
Scarus taeniopterus	Princess Parrotfish	0	5	0	0	1	**1.2**

Stegastes planifrons	Yellow-eye Damselfish	1	0	3	1	1	**1.2**
Haemulon flavolineatum	French Grunt	0	0	4	1	0	**1.0**
Sparisoma radians	Bucktooth Parrotfish	0	2	0	3	0	**1.0**
Cephalopholis cruentatus	Graysby	1	0	1	0	2	**0.8**
Chaetodon capistratus	Four eye Butterflyfish	0	0	2	1	0	**0.6**
Pseudupeneus maculatus	Spotted Goatfish	0	3	0	0	0	**0.6**
Gramma loreto	Royal Gramma	0	3	0	0	0	**0.6**
Flammeo marianus		0	1	1	0	1	**0.6**
Gobiosoma evelynae	Sharknose Goby	0	0	2	0	0	**0.4**
Abudefduf sexatilis	Sargent Major	0	1	1	0	0	**0.4**
Serranus tigrinus	Harlequin Bass	1	0	0	1	0	**0.4**
Pomacanthus arcuatus	Gray Angelfish	0	0	2	0	0	**0.4**
Ophioblennius atlanticus	Redlip Blenny	1	0	0	0	0	**0.2**
Haemulon macrostomum	Spanish Grunt	0	1	0	0	0	**0.2**
Holacanthus tricolor	Rock Beauty	1	0	0	0	0	**0.2**
	Bluestriped Grunt	0	0	0	1	0	**0.2**
Cantherhines pullus	Tail-light Filefish	1	0	0	0	0	**0.2**
Hypoplectrus nigricans	Black Hamlet	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**93**	**90**	**107**	**46**	**39**	**75.0**
	TOTAL SPECIES	**18**	**20**	**22**	**17**	**16**	**18.6**

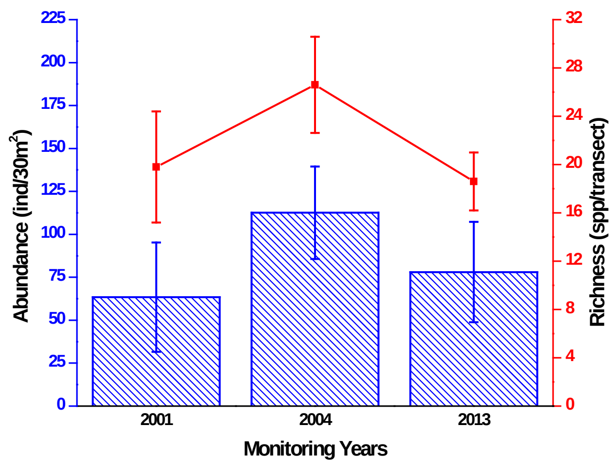


Figure 57. Monitoring trends (2011 – 2013) of fish species richness and abundance at Boya Esperanza Reef, Vieques

Table 64. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Boya Esperanza Reef, Vieques, October 2013.

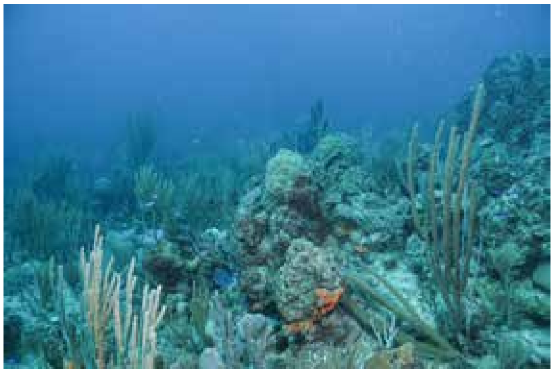
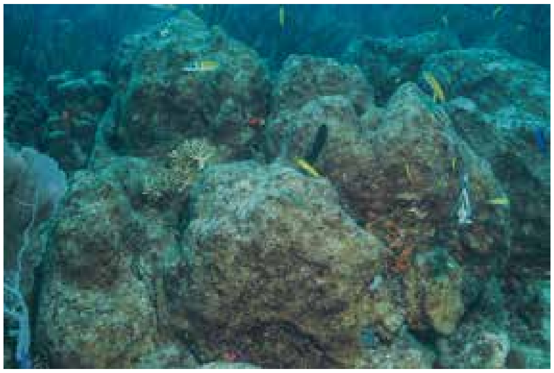
SPECIES	**COMMON NAME**		# - (cm)	
Carangoides crysos	Blue Runner	2 – (30)		
Epinephelus guttatus	Red Hind	1 – (30)		
Lutjanus apodus	Schoolmaster	4 - (20)	2 – (25)	1 – (30)
Lutjanus synagris	Lane Snapper	1 – (20)		
Ocyurus chrysurus	Yellowtail Snapper	6 – (15)	3 – (20)	4 – (25)
Scomberomorus regalis	Cero	1 – (50)		
Sphyraena barracuda	Great Barracuda	1 - (70)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 – (20)		
Strombus gigas	Queen Conch	3 - (15)		

Table 65. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Boya Esperanza Reef. October 2013

Depth: 9.1 m		**TRANSECTS**					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
Echinometra lucunter	Rock Boring Urchin	1	0	1	0	0	**0.4**
Cyphoma gibbosum	Flamingo Tongue					1	**0.2**
	TOTALS	**1**	**0**	**1**	**0**	**1**	**0.6**

Photo Album 16
Boya Esperanza Reef - Vieques



3.0 Canjilones Reef - Vieques

Canjilones is a diffuse “spur-and-groove” coral reef system located at the base of the southern edge of a rather long and narrow rocky ridge that runs along an east-west axis off Punta Arenas, on the southwest coast of Vieques (Figure 58). The ridge presents an almost flat, hard-ground terrace with sparse gorgonians and coral heads at depths of 9-11 meters and slopes down to a depth of 15 meters where the spur-and-groove coral reef formation has developed. The spurs rise only about 2-3 meters from the narrow sandy channels that separate them at the base. Our permanent transects were established along five consecutive spurs at a depth of 15.2 meters. Panoramic pictures of Canjilones Reef are included as Photo Album 17.

The quantitative baseline characterization of Canjilones Reef was executed on 2000 (Garcia-Sais et al. 2001) and its first monitoring survey performed on October 2004 (Garcia-Sais et al. 2004). This is the second monitoring survey of Canjilones Reef completed on October 2013.

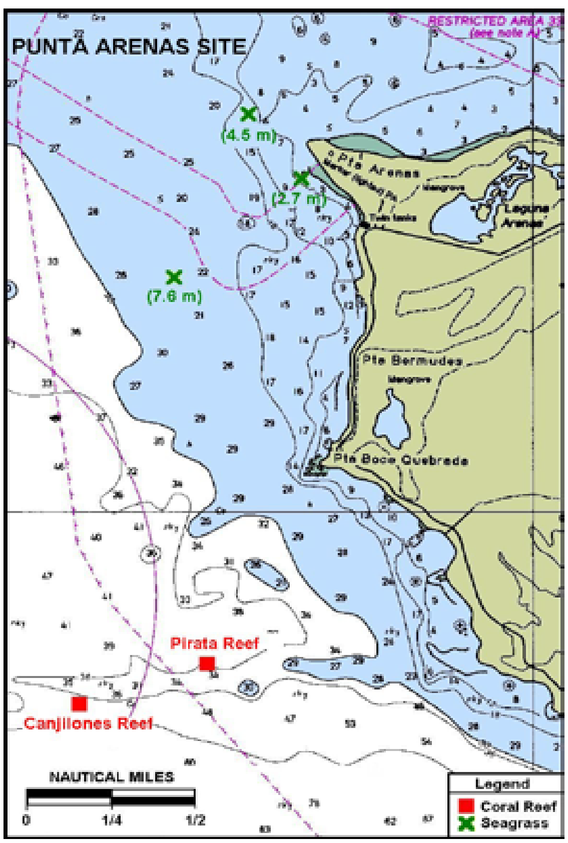


Figure 58. Location map of Canjilones Reef along the western coast of Vieques.

3.1 Sessile-Benthic Community

The sessile-benthic community at Canjilones Reef was characterized by a high density and species rich assemblage of (erect) soft corals, or gorgonians with a mean of 23.6 colonies per transect (Table 66). Some of the most abundant taxa included Sea Rods (*Plexaura flexuosa, P. homomalla, Pseudoplexaura spp*.), knobby Sea Rods (*Eunicea spp*) and Sea Fans (*Gorgonia ventalina, Pseudopterogorgia spp., P. americana, Muricea sp*). The encrusting gorgonian, *Erythropodium caribaeorum* was present along transects with a mean cover of 1.0 %. Erect and encrusting sponges were present in all five transects surveyed with a mean cover of 4.8 %. Reef substrate cover was dominated by an assemblage of benthic algae with a combined mean of 69.1 % (range: 64.8 – 71.4 %). Turf algae were the main component of the benthic algae with an average cover of 58.3%, representing 84.4% of the total. Fleshy brown macroalgae (*Dictyota sp., Lobophora variegata*) and crustose coralline algae were the other main components of the benthic algae assemblage. Cyanobacterial films were present along three transect with a mean cover of 1.9%.

A total of 24 species of stony corals were identified from Canjilones Reef, including 10 intercepted by line transects with a combined mean cover of 16.2 % (range 12.4 – 20.4). Boulder Star Coral, *Orbicella annularis* was the main coral species with a mean of 10.4 %, representing 64.2 % of the total surface cover by stony corals (Table 66). Mustard-Hill Coral (*Porites astreoides*), Massive Starlet Coral (*Siderastrea siderea*), Great Star Coral (*Montastrea cavernosa*) and Lettuce Corals (*Agaricia spp*) were also common. Five coral species were only intercepted by one transect.

Figure 59 presents the time series measurements of substrate cover by sessile-benthic categories during the baseline and two monitoring surveys at Canjilones Reef. Live coral cover, as well as the other main reef substrate categories remained virtually constant between the baseline survey and the 2004 survey. A sharp, statistically significant decline of live coral cover was measured during the present 2013 survey (ANOVA; $p = 0.008$; see Appendix 2). Live coral cover declined 33.8 %, from a mean of 24.5 % in 2004 to a mean of 16.2 % in 2013. As for other reefs in the monitoring program, such decline was largely associated with the reduction of reef substrate cover by Boulder Star Coral, *Orbicella annularis* that varied from a mean of 17.9 % in 2004 to a mean of 10.4 % in 2013, a decline of 41.8 % (Figure 60).

Table 66. Percent substrate cover by sessile-benthic categories at Canjilones Reef, Vieques. October 2013

	Transects					
	1	**2**	**3**	**4**	**5**	**Mean**
Rugosity	2.08	3.08	1.76	1.98	1.41	**2.06**
SUBSTRATE CATEGORY						
Abiotic						
Sand	2.8	1.4	1.2	2.2	10.7	**3.7**
Reef overhang	4.1	2.1	4.0	3.7	1.8	**3.2**
Total Abiotic	**6.8**	**3.5**	**5.2**	**6.0**	**12.5**	**6.8**
Benthic Algae						
Turf	62.1	67.0	55.7	66.0	40.5	**58.3**
Macroalgae	4.6	2.2	9.8	3.7	13.7	**6.8**
Crustose coralline algae	0.9	0.7	1.8	1.6	5.9	**2.2**
Lobophora spp.	1.4	1.2	1.9	0.0	4.7	**1.8**
Total Benthic Algae	**69.1**	**71.2**	**69.2**	**71.4**	**64.8**	**69.1**
Cyanobacteria		1.1		6.0	2.3	**1.9**
Gorgonians						
Erythropodium caribaeorum	1.4	2.7	0.8			**1.0**
Unknown gorgonian				0.7		**0.1**
Total Gorgonian	1.4	2.7	0.8	0.7		**1.1**
Erect Gorgonians (#col/transect)	30.0	23.0	18.0	23.0	24.0	**23.6**
Sponges	5.6	9.1	4.4	2.3	2.8	**4.8**
	5.6	**9.1**	**4.4**	**2.3**	**2.8**	**4.8**
Live Stony Corals						
Orbicella annularis	12.7	6.2	15.2	9.9	8.0	**10.4**
Porites astreoides	3.5	2.8	1.1		1.1	**1.7**
Siderastrea siderea					6.3	**1.3**
Montastraea cavernosa		1.6		3.7	0.6	**1.2**
Porites porites		0.5	2.9			**0.7**
Agaricia agaricites	0.9	1.3				**0.4**
Diploria strigosa					1.0	**0.2**
Agaricia grahamae			0.7			**0.1**
Unknown coral					0.6	**0.1**
Agaricia spp.			0.5			**0.1**
Total Stony Corals	**17.1**	**12.4**	**20.4**	**13.7**	**17.5**	**16.2**

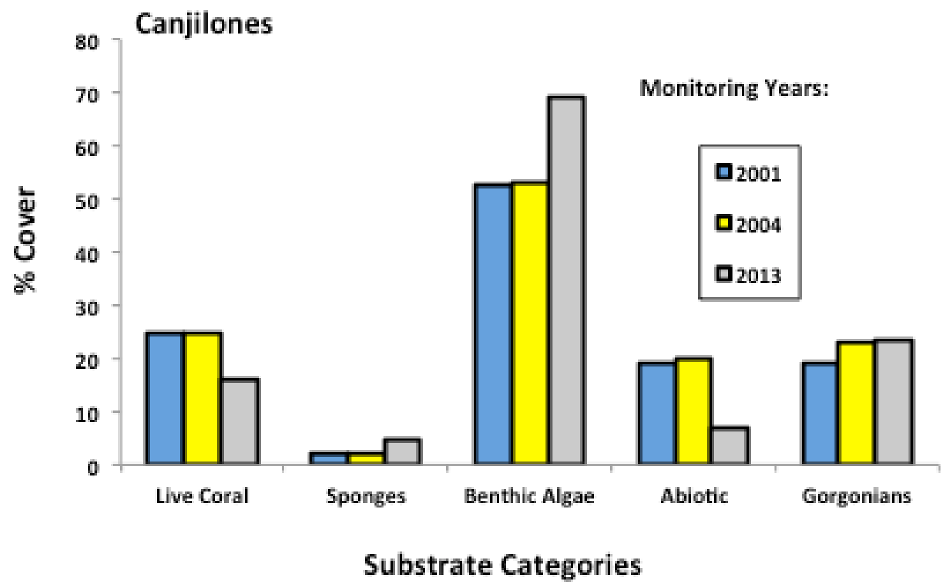


Figure 59. Monitoring trends (2001 – 2013) of mean substrate cover by sessile-benthic categories at Canjilones Reef, Vieques.

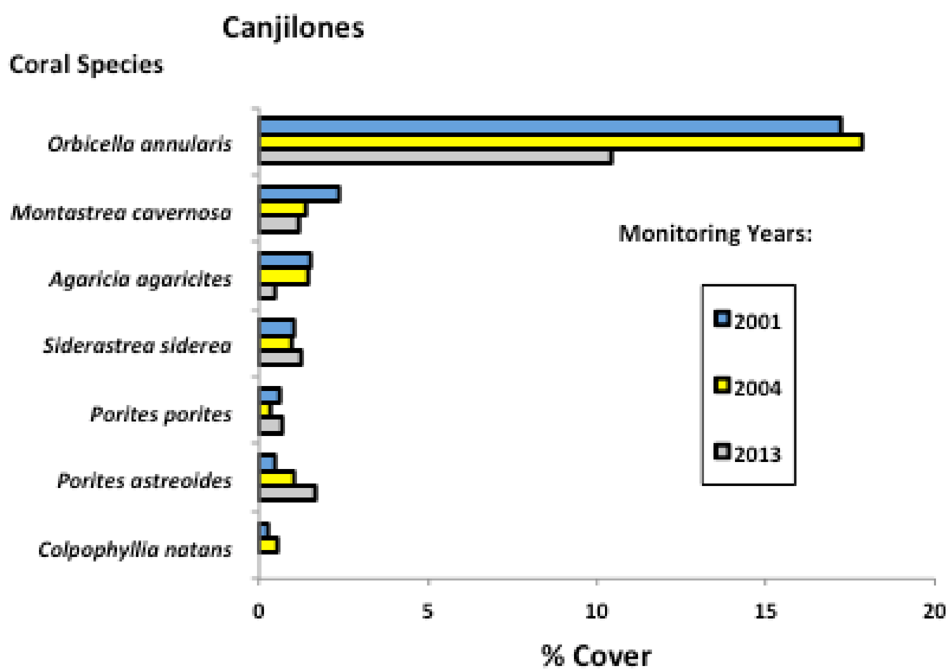


Figure 60. Monitoring trends (2001 – 2013) of mean substrate cover by coral species at Canjilones Reef, Vieques

It is important to note that although Boya Esperanza and Canjilones reefs are within the same southern Vieques shelf section and less than 10 nautical miles apart, variations of live coral cover were much less pronounced at Canjilones. Differences may be related with depth and suggest that light and/or UV radiation may have been acting synergistically with high sea surface temperatures to produce the massive regional coral bleaching event that affected coral reefs in Puerto Rico and the US Virgin Islands during late 2005, and that appear to be responsible for the sharp declined of live coral cover measured at Canjilones Reef.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 64 species of reef fishes have been identified during baseline and monitoring surveys at Canjilones Reef, including 29 species within transects during the 2003 survey (Table 67). The mean abundance of fishes within belt-transects was 38.8 Ind/30m^2 (range: 21 – 54 Ind/30m^2) and the mean number of species present per transect was 15. The most abundant species included the Princess, Striped and Redband Parrotfishes (*Scarus Taeniopterus, S. iserti*, Sparisoma aurofrenatum), Bicolor Damselfish (*Stegastes partitus*), Masked Goby (*Coryphopterus personatus*), Caribbean Puffer (*Canthigaster rostrata*), Blue Chromis (*Chromis cyanea*), and Bluehead Wrasse (*Thalassoma bifasciatum*). Other five species were present in at least three transects, including the Stoplight Parrotfishe, Beaugregory, French Grunt, Four-eye Butterflyfish and Doctorfish. Species of commercial value included the Red Hind (*Epinephelus guttatus*), Hogfish (*Lachnolaimus maximus*) and the Coney (*Cephalopholis fulva*). Large predators, such as the Great Barracuda and the Nurse Sharks were observed during the baseline survey. No motile megabenthic invertebrates were recorded within belt-transects. One Spiny Lobster was observed outside transect areas.

The herbivore fish component, represented within belt-transects at least by five species of parrotfishes (Scaridae), three species of herbivorous damselfishes (*Stegastes spp*) and two species of doctorfishes (*Acanthuridae*) was the most prominent trophic group assemblage at Canjilones Reef. The combined abundance of these taxa represented 49.3 % of the total ref fish abundance. This supports the findings by Esteves (2014) in that the strong herbivore trophic group component is one of the most consistent trends of fish community structure in coastal reefs, in contrast to the zooplanktivores driven structure of oceanic and shelf-edge reefs far from land.

Table 67. Taxonomic composition and abundance of fishes within belt-transects at Canjilones Reef, Vieques, October 2013.

		BELT-TRANSECTS					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Scarus taeniopterus	Princess Parrotfish	3	3	13	8	8	**7.0**
Stegastes partitus	Bicolor Damselfish	11	1	2	5	8	**5.4**
Coryphopterus personatus	Masked Goby	3	1	5	6	5	**4.0**
Thalassoma bifasciatum	Bluehead Wrasse	3	0	0	5	8	**3.2**
Chromis cyanea	Blue Chromis	5	0	2	3	2	**2.4**
Canthigaster rostrata	Caribbean Puffer	3	2	4	1	2	**2.4**
Scarus iserti	Stripped Parrotfish	2	4	1	1	0	**1.6**
Sparisoma aurofrenatum	Redband Parrotifish	2	0	1	1	3	**1.4**
Segastes leucostictus	Beaugregory	2	0	1	1	2	**1.2**
Sparisoma viride	Stoplight Parrotfish	2	2	0	0	2	**1.2**
Acanthurus chirurgus	Doctorfish	1	1	0	2	2	**1.2**
Gramma loreto	Fairy Basset	0	0	5	1	0	**1.2**
Chaetodon capistratus	Foureye Butterflyfish	0	1	2	1	0	**0.8**
Gobiosoma evelynae	Sharknose Goby	0	0	1	0	2	**0.6**
Sparisoma radians	Bucktootth Parrotfish	0	0	0	0	3	**0.6**
Haemulon flavolineatum	French Grunt	1	1	1	0	0	**0.6**
Acanthurus coeruleus	BlueTang	0	0	0	1	2	**0.6**
Holocentrus rufus	Squirrelfish	0	1	0	0	2	**0.6**
Halichoeres garnoti	Yellow-head Wrasse	1	0	0	0	1	**0.4**
Serranus tigrinus	Harlequin Bass	0	0	0	1	1	**0.4**
Stegastes dorsopunicans	Dusky Damselfish	0	1	1	0	0	**0.4**
Ocyurus chrysurus	Yellowtail Snapper	0	1	0	0	0	**0.2**
Cephalopholis cruentatus	Graysby	0	0	0	0	1	**0.2**
Cantherhines pullus	Tail-light Filefish	0	0	1	0	0	**0.2**
Holacanthus tricolor	Rock Beauty	0	0	0	1	0	**0.2**
Hypoplectrus puella	Barred Hamlet	0	1	0	0	0	**0.2**
Mulloides martinicus	Yellowtail Goatfish	0	0	1	0	0	**0.2**
Pseudupeneus maculatus	Spotted Goatfish	0	1	0	0	0	**0.2**
Amblychirritus pinos	Redspoted Hawkfish	1	0	0	0	0	**0.2**
	TOTAL INDIVIDUALS	40	21	41	38	54	**38.8**
	TOTAL SPECIES	14	14	15	15	17	**15**

Table 68. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Canjilones Reef, Vieques, October 2013.

SPECIES	**COMMON NAME**	# - (cm)	
Epinephelus guttatus	Red Hind	1 – (35)	
Lutjanus apodus	Schoolmaster	2 - (20)	1 – (25)
Ocyurus chrysurus	Yellowtail Snapper	3 – (15)	2 – (20)
Sphyraena barracuda	Great Barracuda	1 - (50)	
Invertebrates			
Panulirus argus	Spiny Lobster	1 – (15)	

Figure 61 presents the variations of fish species richness and abundance between monitoring surveys. Significantly higher richness (ANOVA; $p < 0.001$) and abundance (ANOVA; $p = 0.022$) were observed during the 2004 survey relative to the baseline and the present 2013 survey (see Appendix 3 and 4). Higher abundance was mostly associated with increased abundance during 2004 of Masked Goby and Blue Chromis, both of which are schooling species with highly aggregated distributions. Such fluctuations are probably associated to density independent factors, including recruitment pulses and are common features of the inter-annual variations dynamics of fish community structure in Caribbean reefs (Esteves 2013). The higher species richness measured during the 2004 relative to other surveys was driven by the presence of 16 species represented by only one individual within belt-transects. This could have been influenced by the clear and calm conditions that prevailed during the 2004 survey (Garcia-Sais et al., 2004).

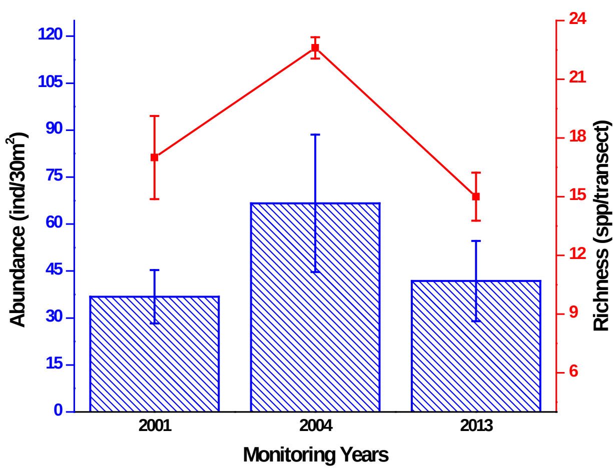
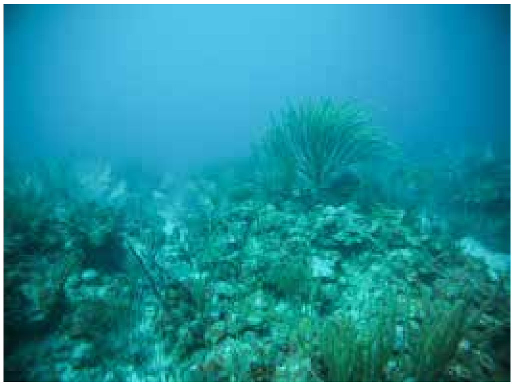
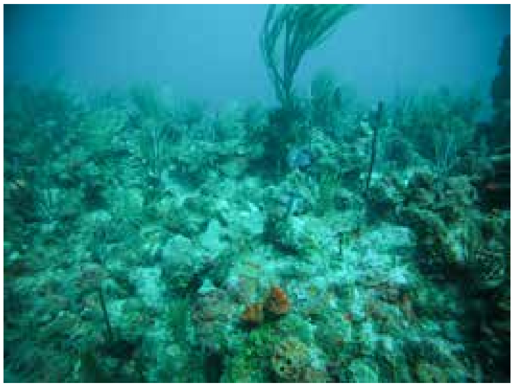


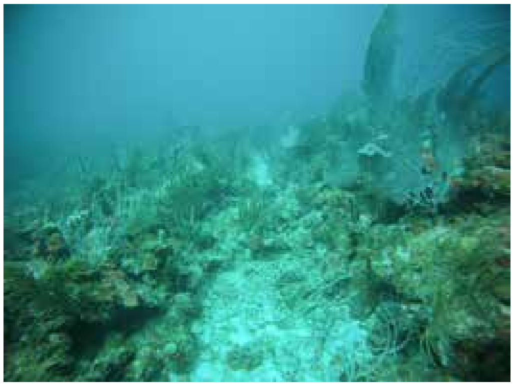
Figure 61. Monitoring trends (2011 – 2013) of fish species richness and abundance at Canjilones Reef, Vieques

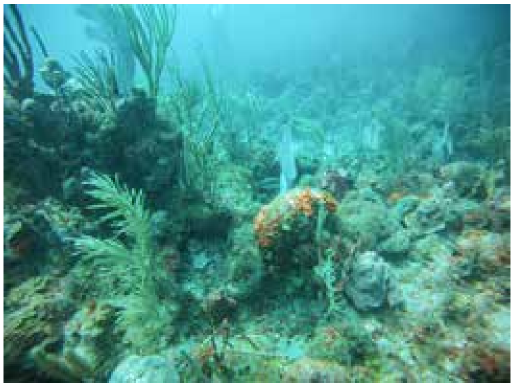
Photo Album 17
Canjilones Reef - Vieques









H. 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 62). 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 2013 baseline survey was performed on top of low relief patch reefs at a depth of 4 meters within the *A. palmata* biotope. Panoramic views of Gallardo Reef are shown in Photo Album 18.

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 27.5 % (range: 15.6 – 43.9 %), representing 95.5 % of the total cover by corals along transects (Table 69). Mean substrate cover by reef sessile-benthic categories are shown in Figure 63. 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. Five other stony coral species (*Millepora alcicornis, Agaricia spp., Porites spp*.) were intercepted by transects during the baseline survey, but were present with very low reef substrate cover (Figure 64). Soft corals (gorgonians) were uncommon and absent along transects. The encrusting gorgonian, *Erythropodium caribaeorum* was present along two transects with a mean cover of 1.8 %. Colonial zoanthids (*Palythoa* sp.) and sponges were observed outside transects, but were not prominent within the Elkhorn Coral biotope at Gallardo Reef.

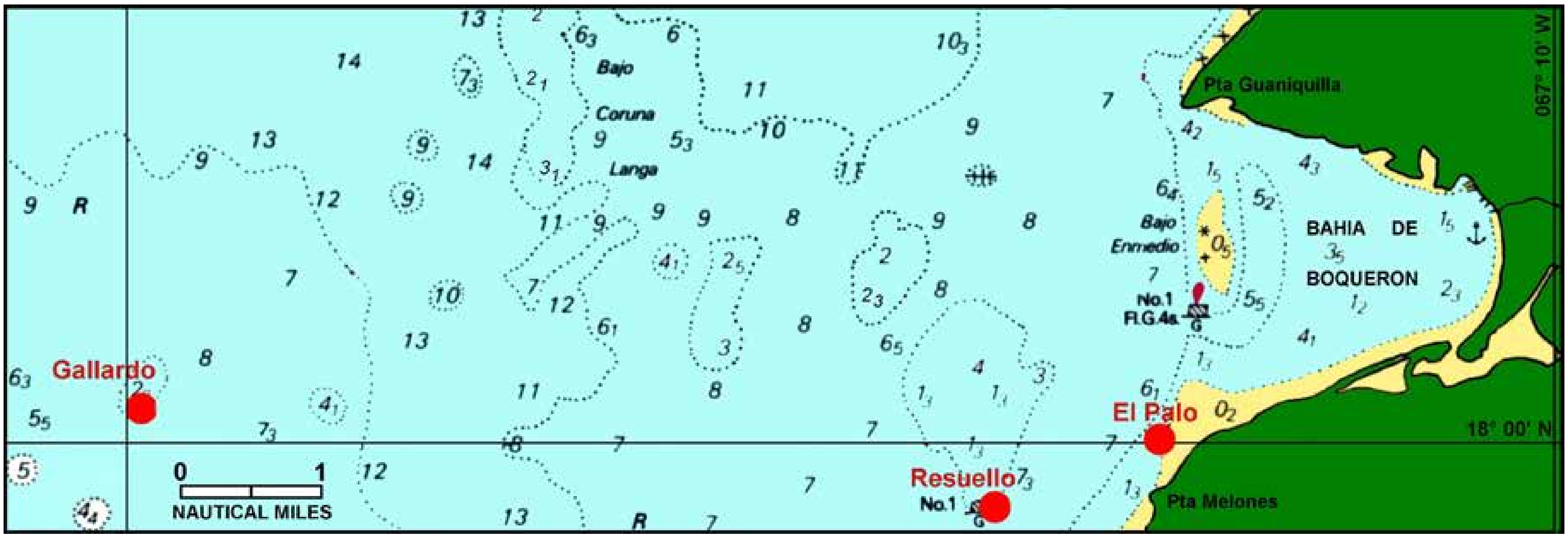


Figure 62. Location of reefs surveyed within the Boqueron (Cabo Rojo) Natural Reserve.

Large sections of the hard ground not colonized by Elkhorn Coral were covered by encrusting growth of red crustose coralline algae (probably *Porolithon sp*).

This alga was particularly observed overgrowing dead sections and relict fragments of Elkhorn Coral. It was the dominant component of the reef sessile-benthos in terms of substrate cover with a mean of 45.1 % (range: 27.8 – 58.0), representing 89.7 % of the total cover by the benthic algal assemblage (Table 69). Turf algae, growing mostly intermixed with calcareous green (*Halimeda opuntia*) and red macroalgae (*Galaxaura* sp., *Jania* sp.) were also present along transects. Cyanobacterial films were also present, but with a very low cover of 0.1 %. Abiotic substrates, particularly reef overhangs produced by Elkhorn Coral growth were also prominent in terms of reef substrate cover with a mean of 18.9 %. Such overhangs contributed to a mean substrate rugosity of 6.7 m.

1.2 Fishes and Motile megabenthic Invertebrates

The taxonomic composition and abundance of fishes within belt-transects surveyed at Gallardo Reef during November 2012 are presented in Table 70. A total of 56 species were identified, including 23 within belt-transects. The mean number of species per transect was 10.6 (range : 10 – 11) and the mean density of fishes was 56.8 Individuals/30 m^2 (range : 40 – 70 Individuals/30 m^2). Five species represented 77.1 % of the total individuals within transect areas. The main fish assemblage included the Bluehead Wrasse (*Thalassoma bifasciatum*), Yellowtail Damselfish (*Microspathodon chrysurus*), Redlip Blenny (*Ophioblennius atlanticus*), Stoplight Parrotfish (*Sparisoma viride*) and the Dusky Damselfish (*Stegastes adustus*). The Striped Parrotfish (*Scarus iserti*), Blue Tang (*Acanthurus coeruleus*) and Redband Parrotfish (*Sparisoma aurofrenatum*) were present in al least three out of the five transects surveyed and appear to be part of the resident fish assemblage at Gallardo Reef.

Table 69. Percent substrate cover by sessile-benthic categories at Gallardo Reef, Cabo Rojo. November 2012

	Transects					
	1	2	3	4	5	**Mean**
	5.04	7.57	8.04	8.07	4.83	**6.71**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhang	9.5	19.0	20.7	22.1	20.8	**18.4**
Gaps					2.5	**0.5**
Total Abiotic	**9.0**	**19.0**	**20.7**	**22.1**	**23.3**	**18.9**
Benthic Algae						
Crustose coralline algae	58.0	38.4	49.9	51.6	27.8	**45.1**
Turf	0.3	9.1	1.3	0.3	4.7	**3.1**
Dictyota spp.	3.7		2.9	0.2		**1.3**
Halimeda spp.		0.2	1.2	0.2		**0.3**
Jania spp.		1.2				**0.2**
Galaxaura spp.		0.6				**0.1**
Total Benthic Algae	**62.0**	**49.5**	**55.3**	**52.3**	**32.5**	**50.3**
Cyanobacteria				0.7		**0.1**
Gorgonian						
Erythropodium caribaeorum	8.8	0.3				**1.8**
Total Gorgonian	**8.8**	**0.3**				**1.8**
Erect Gorgonians (#col/transect)	0.0	0.0	0.0	0.0	0.0	**0.0**
Live Stony Corals						
Acropora palmata	15.6	30.4	22.8	24.9	43.9	**27.5**
Millepora alcicornis	3.0	0.8				**0.8**
Agaricia fragilis			1.0			**0.2**
Porites furcata	0.8					**0.2**
Porites porites			0.3			**0.1**
Agaricia fragilis	0.3					**0.1**
Total Stony Corals	**19.7**	**31.2**	**24.0**	**24.9**	**43.9**	**28.8**

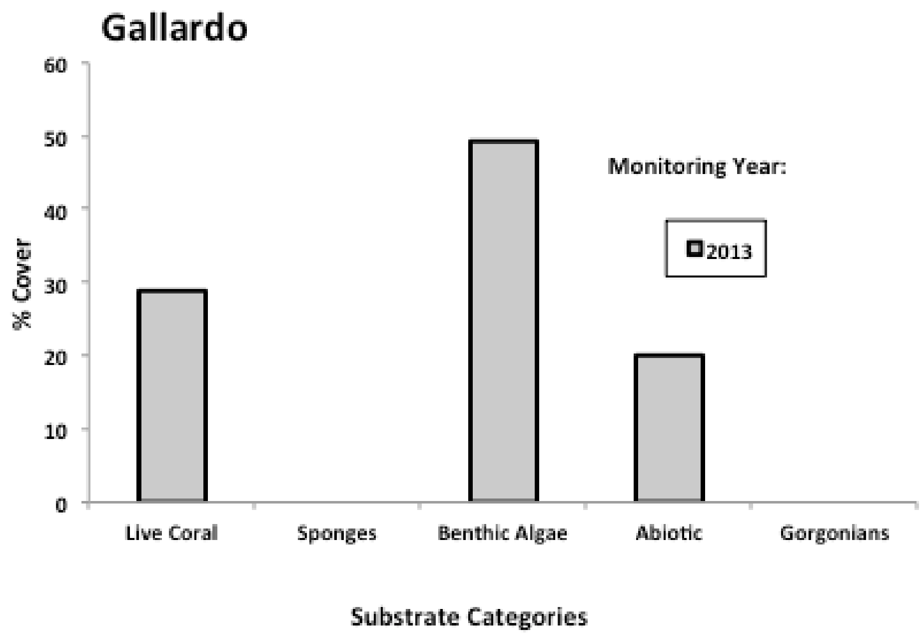


Figure 63. Mean substrate cover by sessile-benthic categories at Gallardo Reef, Cabo Rojo. Baseline survey: November 2012.

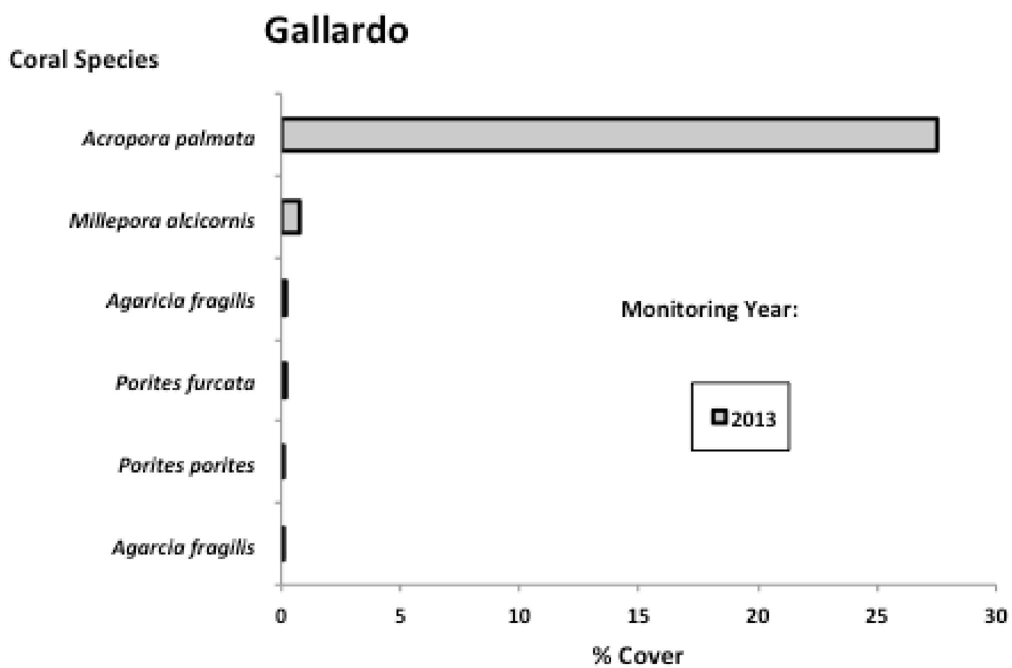


Figure 64. Mean substrate cover by stony coral spp. categories at Gallardo Reef, Cabo Rojo. Baseline survey: November 2012.

With a total of six species present within belt-transects, the parrotfish family (Scaridae) was the most specious taxonomic group, and combined with doctorfishes (Acanthuridae) and "farmer damselfishes" (e.g. *Stegastes adustus, M. chrysurus* - Pomacentridae) constituted the principal herbivorous fish assemblage. The combined abundance of herbivores represented (at least) 44.0% of the total individuals within belt-transect areas. Opportunistic carnivoreswhich feed on small benthic invertebrates, such as wrasses (Labridae), puffers (Tetraodontidae), gobies (Gobiidae) and hamlets (*Hypoplectrus* spp.- Serranidae) were prominent at this reef with nine species representing about 51.4% of the total individuals. The zooplanktivorous fish assemblage comprised by the Blue and Brown Chromis (*Chromis cyanea, C. multilineata*), and the Creole Wrasse (*Clepticus parrae*) were present outside transects and represented a minor component of the fish community structure. Also present outside transects in large schools was the Mackerel Scad, *Decapterus macarellus*. These zooplanktivores fishes are mostly pelagic, and thus available as important forage species for larger pelagic predators, such as the Great Barracuda and the Bar Jack, both present at Gallardo Reef during our survey. 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 during the ASEC survey (Table 71).

Corallivorous snails (*Coralliophila sp*.) and one Long-spined Urchin were observed within belt-transect areas at Gallardo Reef (Table 72). One Spiny Lobster, *Panulirus argus* was present outside transects.

Table 70. Taxonomic composition and abundance of fishes within belt-transects at Gallardo Reef, Cabo Rojo, November 2012

Depth: 4m

		TRANSECTS					
		1	2	3	4	5	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	28	10	26	21	34	**23.8**
Microspathodon chrysurus	Yellowtail Damselfish	8	10	6	8	11	**8.6**
Ophioblennius atlanticus	Redlip Blenny	4	5	2	5	3	**3.8**
Sparisoma viride	Stoplight Parrotfish	5	2	3	2	7	**3.8**
Stegastes adustus	Dusky Damselfish	0	6	0	8	5	**3.8**
Scarus taeniopterus	Princess Parrotfish	9	0	5	0	0	**2.8**
Scarus iserti	Stripped Parrotfish	0	2	3	4	2	**2.2**
Acanthurus coeruleus	Blue Tang	5	0	3	1	1	**2.0**
Chromis cyanea	Blue Chromis	4	0	0	2	0	**1.2**
Sparisoma radians	Bucktooth Parrotfish	3	0	2	0	0	**1.0**
Sparisoma aurofrenatum	Redband Parrotfish	1	0	1	0	1	**0.6**
Aulostomus maculatus	Trumpetfish	0	0	0	2	0	**0.4**
Canthigaster rostrata	Caribbean Puffer	2	0	0	0	0	**0.4**
Chaetodon capistratus	Four-eye Butterflyfish	0	0	0	0	2	**0.4**
Holocentrus rufus	Squirrelfish	1	1	0	0	0	**0.4**
Bodianus rufus	Spanish Hogfish	0	0	1	0	0	**0.2**
Cephalopholis fulva	Coney	0	0	0	0	1	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	1	0	0	0	**0.2**
Hypoplectrus puella	Barred Hamlet	0	0	0	1	0	**0.2**
Hypoplectrus unicolor	Butter Hamlet	0	1	0	0	0	**0.2**
Myripristis jacobus	Blackbar Soldierfish	0	1	0	0	0	**0.2**
Ocyurus chrysurus	Yellowtail Snapper	0	0	0	1	0	**0.2**
Sparisoma rubripinne	Yellowtail Parrotfish	0	1	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**70**	**40**	**52**	**55**	**67**	**56.8**
	TOTAL SPECIES	**11**	**11**	**10**	**11**	**10**	**10.6**

Table 71. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Gallardo Reef, Cabo Rojo, November 2012.

SPECIES	**COMMON NAME**		# - (cm)	
Carangoides crysos	Blue Runner	9 – (10)	1 – (25)	
Epinephelus guttatus	Red Hind	1 - (40)		
Lutjanus apodus	Schoolmaster	6 - (15)	1 – (25)	
Ocyurus chrysurus	Yellowtail Snapper	12 - (15)	3 – (20)	2 – (25)
Sphyraena barracuda	Great Barracuda	1 - (60)		
Scomberomorus regalis	Cero	1 - (50)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 – (15)		

Table 72 Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Gallardo Reef. November 2012.

Depth: 4.0 m		**TRANSECTS**					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
Diadema antillarum	Long-spined Urchin	0	0	0	1	0	**0.2**
Coralliphila spp	Gastropods	14	2	6	7	4	**6.6**
	TOTALS	**14**	**2**	**6**	**8**	**4**	**6.8**

Photo Album 18

Gallardo Reef – Cabo Rojo






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 62). 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 2013 survey is the first monitoring effort of Resuellos Reef, 13 years after the original baseline assessment. Transects were installed following the 8.0 meter depth contour along the reef slope. Panoramic views of Resuellos Reef are presented in Photo Album 19.

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 23 erect col/transect and a reef substrate cover of 21.7 % (range: 10.5 – 39.7 %) (Table 73). Some of the most abundant included *Briareum asbestinum*, *Antilligorgia americana*, *Gorgonia ventalina* and *Eunicea spp*. The encrusting gorgonian, *Erythropodium caribaeorum* was present in all five transects surveyed with a mean linear cover of 16.7 % (range: 7.3 – 33.6 %). Stony corals, represented by at least 20 species, including seven along transects contributed a mean linear cover of 13.3 % (range: 8.9 – 22.1%). Boulder Brain Coral, *Orbicella annularis* was the

Table 73. Percent substrate cover by sessile-benthic categories at Resuellos Reef, Cabo Rojo. November 2012

	Transects					
	1	2	3	4	5	**Mean**
	6.10	3.79	6.62	3.96	3.97	**4.89**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhang	11.1	8.8	26.5	14.5	4.0	**13.0**
Dead coral	0.8					**0.2**
Total Abiotic	**11.8**	**8.8**	**26.5**	**14.5**	**4.0**	**13.1**
Benthic Algae						
Turf	41.1	36.3	43.5	38.9	57.9	**43.5**
Crustose Coralline algae		1.1				**0.2**
Sargassum hystrix	0.8					**0.2**
Total Benthic Algae	**41.9**	**37.5**	**43.5**	**38.9**	**57.9**	**43.9**
Gorgonians						
Erythropodium caribaeorum	21.0	33.6	7.3	11.0	10.4	**16.7**
Briareum asbestinum	1.6	4.6	1.1	6.6	3.9	**3.6**
Antilligorgia americana	1.6	0.8	1.7	0.2	1.0	**1.1**
Gorgonia ventalina	0.8		0.3			**0.2**
Plexaurella nutans		0.5				**0.1**
Pseudoplexaura flagellosa	0.3					**0.1**
Eunicea flexuosa	0.2					**0.0**
Eunicea succinea			0.1			**0.0**
Plexaura kukenthali		0.2				**0.0**
Total Gorgonians	**25.3**	**39.7**	**10.5**	**17.9**	**15.3**	**21.7**
Erect Gorgonians						
(#colonies/transect)	26.0	20.0	15.0	26.0	28.0	**23.0**
Sponges						
Cliona caribbaea	5.2		0.7		6.7	**2.5**
Mycale laevis		1.5	0.2	2.5	0.7	**1.0**
Unknown encrusting red sponge			0.5	2.5	0.5	**0.7**
Aplysina cauliformis	0.2		1.4	1.0	0.4	**0.6**
Ircinia brown	0.2				1.8	**0.4**
Smenospongia conulosa	1.7					**0.3**
Callyspongia vaginalis			1.7			**0.3**
Unknown orange sponge					1.5	**0.3**
Niphates erecta		0.5	0.3		0.6	**0.3**
Aplysina lacunosa				0.6	0.5	**0.2**
Dysidea janiae		1.0				**0.2**
Agelas citrina	1.0					**0.2**
Monanchora arbuscula	0.3		0.7			**0.2**
Plakortis halichondriodes		0.3	0.6			**0.2**
Black unknown sponge		0.6				**0.1**
Niphates caycedoi		0.5				**0.1**
Iotrochota birotulata		0.3	0.1			**0.1**
Neopetrosia proxima	0.3					**0.1**
Total Sponges	**8.8**	**5.1**	**6.1**	**6.6**	**12.7**	**7.9**
Live Stony Corals						
Orbicella annularis	8.4	0.8	8.1	1.9	5.9	**5.0**
Siderastrea siderea	1.5	1.4	3.6	6.8	2.5	**3.2**
Porites astreoides		2.1	0.3	5.3	0.5	**1.6**
Stephanocoenia intersepta		4.6		1.0		**1.1**
Montastraea cavernosa	1.2		1.5	1.1	0.8	**0.9**
Meandrina meandrites	1.1			2.9		**0.8**
Eusmilia fastigiata				3.0	0.3	**0.7**
Total Stony Corals	**12.2**	**8.9**	**13.5**	**22.1**	**10.0**	**13.3**

dominant coral species with a mean cover of 5.0 %, representing 37.6 % of the total cover by stony corals. Massive Starlet Coral (*Siderastrea siderea*), Mustard-Hill Coral (*Porites astreoides*) and Great Star Coral (*Montastrea cavernosa*) 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 73).

Sponges were also prominent components of the sessile-benthic community with at least 18 species intercepted by line transects and a mean linear cover of 7.9 % (Table 73). They were present as erect and encrusting colonies. *Cliona caribbaea, Mycaele laevis, Aplysina cauliformis, Niphates erecta* and an unidentified red sponge were present in at least three transects and comprised the main taxonomic assemblage. Reef overhangs, largely associated with massive and laminar coral growth were the main contributor of abiotic cover with a mean of 13.0 %. Otherwise, this reef was fully colonized by biotic components.

Figure 65 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 2013 monitoring survey. It is truly remarkable that after 13 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 13.3 % in November 2012. The 26.5 % difference was statistically insignificant (ANOVA; $p = 0.368$; 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 a present absence (0 %) along transects. Interestingly, 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 66).

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 previaling crystal clear waters.

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 51 fish species have been identified at Resuellos Reef, 28 of which were present within belt-transect during the 2013 survey (Table 74). The mean number of species per transect was 11.4 (range 9 – 16), and the mean density of fishes was 28.8 Individuals/30 m^2 (range: 20 - 41 Individuals/30 m^2). Seven species represented 61.1 % of the total individuals within transect areas. The numerically dominant fish assemblage included the Schoolmaster Snapper (*Lutjanus apodus*), Bluehead Wrasse (*Thalassoma bifasciatum*), the Striped, Redband and Stoplight Parrotfishes (*Scarus iserti, Sparisoma aurofrenatum, S. viride*), the Sharknose goby (*Elacatinus sp*) and the Masked Goby (*Coryphopterus personatus*).

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, the Blue Chromis (*Chromis cyanea*) and the Bicolor Damselfish (*Stegastes partitus*), but these species were not observed in high relative abundance.

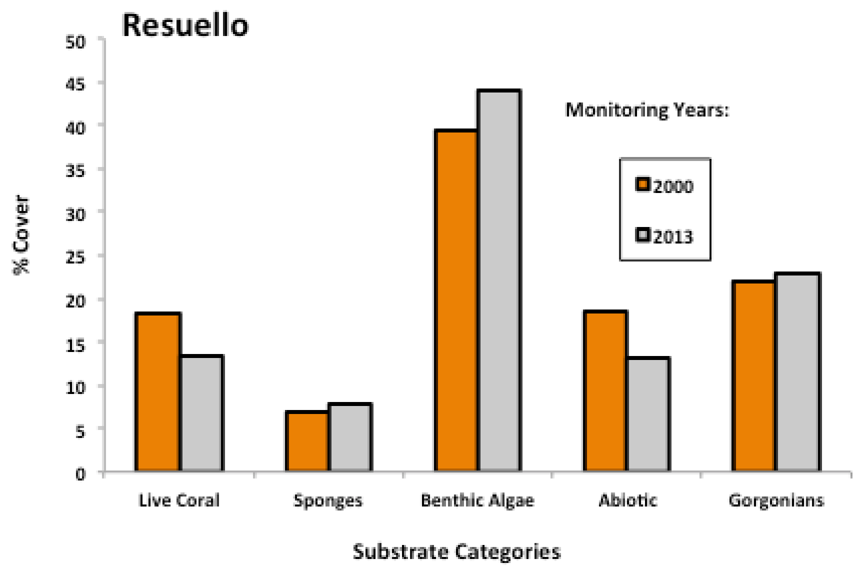


Figure 65. Monitoring trends (2000 – 2013) of mean substrate cover by sessile-benthic categories at Resuellos Reef, Cabo Rojo

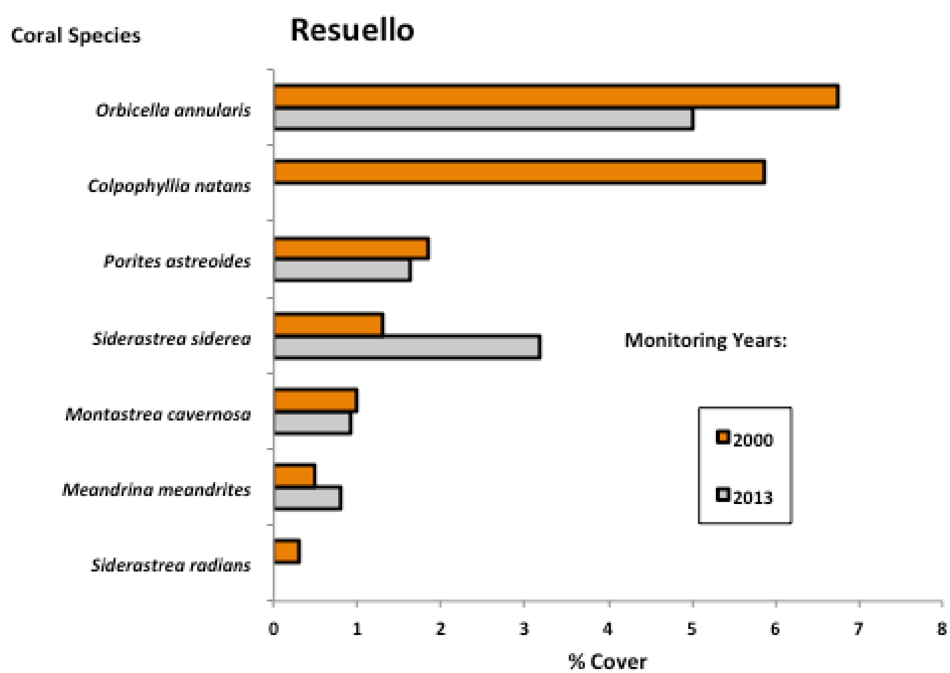


Figure 60. Monitoring trends (2000 – 2013) of mean substrate cover by coral species at Resuellos Reef, Cabo Rojo

Table 74. Taxonomic composition and abundance of fishes within belt-transects at Resuellos Reef, Cabo Rojo, November 2012

Depth: 8m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(individuals/30 m2)					
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**

Predators of larger reef invertebrates and small demersal fishes included several species of snappers (Lutjanidae), grunts (Haemulidae), groupers (Serranidae) and hogfishes (Labridae). Within this group, several species of high commercial value included the Red Hind and Nassau groupers (*Epinephelus guttatus, E. striatus*), the Dog, Mahogany, Schoolmaster and Yellowtail snappers (*Lutjanus jocu, L. mahogany, L. apodus* and *Ocyurus chrysurus)* and the Hogfish (*Lachnolaimus maximus*) observed during the 2000 baseline survey (Garcia-Sais et al., 2001). 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 (Table 75). An Arrow Crab and one Spiny Lobster, *Panulirus argus* were observed within belt-transects (Table 76).

Variations of fish abundance and species richness between the baseline 2000 and the present 2013 monitoring survey are shown in Figure 67. Variations in abundance were negligible (Appendix 3). Fish species richness declined during the present survey relative to the baseline, but the difference was statistically marginal at an alpha level of 0.05 (ANOVA; p = 0.055; 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.

Table 75. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Resuellos Reef, Cabo Rojo. November 2012.

SPECIES	**COMMON NAME**		# - (cm)
Carangoides crysos	Blue Runner	9 - (10)	1 - (25)
Epinephelus guttatus	Red Hind	1 - (20)	
Lutjanus apodus	Schoolmaster	2 - (25)	1 - (30)
Lutjanus analis	Mutton Snapper	1 - (50)	
Lutjanus synagris	Lane Snapper	1 - (25)	
Ocyurus chrysurus	Yellowtail Snapper	6 - (15)	1 - (25)
Pterois sp.	Lionfish	2 - (25)	
Sphyraena barracuda	Great Barracuda	1 - (60)	
Scomberomorus regalis	Cero	1 - (50)	
Invertebrates			
Panulirus argus	Spiny Lobster	1 - (15)	

Table 76. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Resuellos Reef. Cabo Rojo. November 2012.

Depth: 4.0 m SPECIES	COMMON NAME	TRANSECTS 1	2	3	4	5	MEAN ABUNDANCE (IND/30 m2)
Panulirus argus	Spiny Lobster	0	0	1	0	0	**0.2**
Stenorhynchus seticornis	Arrow Crab	0	0	0	1	0	**0.2**
	TOTALS	**0**	**0**	**1**	**1**	**0**	**0.4**

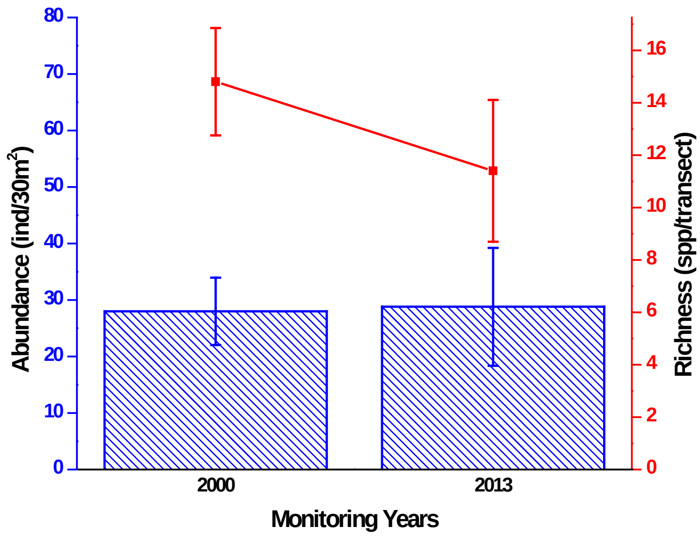


Figure 67. Monitoring trends (2000 – 2013) of fish species richness and abundance at Resuellos Reef, Cabo Rojo

Photo Album 19
Resuellos Reef, Cabo Rojo



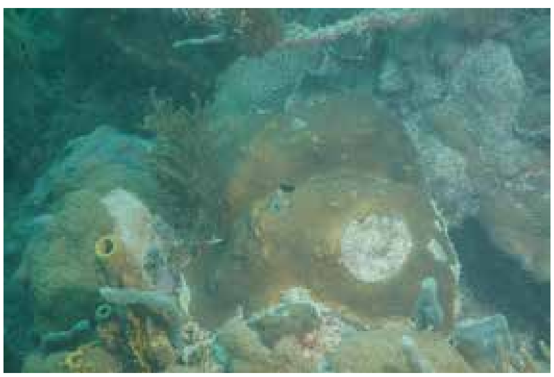













3.0 El Palo Reef – Cabo Rojo

El Palo Reef is a small fringing reef located due north of Punta Melones, at the entrance of Boquerón Bay (Figure 62). 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 first monitoring survey of the reef after 13 years of the initial assessment. Two of the five transects initially installed were not found and new transects had to be constructed. Thus, the comparative analysis is biased due to the transect modifications. Panoramic views of El Palo Reef are exhibited in Photo Album 20.

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 45.8 %, representing 87.6 % of the total cover by benthic algae (Table 77). 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 = 21.8 colonies/transect) and of variable sizes, including very large ones. Their combined mean abundance along transects was 7.2 %. Some of the most abundant included *Briareum asbestinum, Antillogorgia americana, Gorgonia ventalina* and *Eunicea spp*. The encrusting gorgonian, *Erythropodium caribaeorum* was present at all transects with a mean linear cover of 3.2 %. A total of 16 sponge species were intercepted

Table 77. Percent substrate cover by sessile-benthic categories at El Palo Reef, Cabo Rojo. November 2012

	Transects					
	1	2	3	4	5	**Mean**
	2.68	2.57	3.76	0.69	6.20	**2.8**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhang		8.2	11.9	23.7	16.4	**12.0**
Sand	6.0	12.1	2.3	7.9	7.9	**7.1**
Total Abiotic	**6.0**	**20.3**	**14.3**	**31.6**	**24.3**	**19.1**
Benthic Algae						
Turf	52.6	51.8	47.7	34.8	42.5	**45.8**
Halimeda spp.	11.7		7.8	4.5	7.8	**6.3**
Total Benthic Algae	**64.3**	**51.8**	**55.5**	**39.3**	**50.3**	**52.3**
Gorgonian						
Briareum asbestinum	2.5	6.6	3.2		2.6	**3.7**
Erythropodium caribaeorum	0.3	4.7	4.7	5.5	1.3	**3.2**
Antillogorgia americana	1.5	0.9	0.4		0.7	**0.7**
Gorgonia ventalina					1.0	**0.2**
Muricea pinnata	0.3					**0.1**
Eunicea flexuosa			0.4			**0.1**
Eunicea succinea			0.2			**0.0**
Total Gorgonian	**4.7**	**12.1**	**8.8**	**5.5**	**5.5**	**7.2**
Erect Gorgonians (#col/transect)	15.0	30.0	17.0	20.0	27.0	**21.8**
Sponges						
Verongula rigida			0.7	0.3	3.9	**1.0**
Mycale laevis	0.6		0.6		1.8	**0.6**
Aplysina cauliformis	1.3	0.8				**0.4**
Aplysina fulva	0.2	1.1				**0.3**
Niphates erecta	0.4		0.7			**0.2**
Cliona caribbaea	1.1					**0.2**
Ircinia strobilina			0.9			**0.2**
Unknown encrusting sponge	0.3	0.6				**0.2**
Cinachyrella kuekenthali			0.5		0.3	**0.2**
Brown encrusting sponge	0.7					**0.1**
Ircinia brown			0.6			**0.1**
Smenospongia conulosa				0.3		**0.1**
Callyspongia fallax	0.2					**0.04**
Mycale laxissima	0.2					**0.04**
Ircinia campana					0.2	**0.03**
Agelas conifera					0.9	**0.02**
Total Sponges	**5.2**	**2.4**	**4.0**	**0.6**	**7.1**	**3.7**
Live Stony Corals						
Orbicella annularis	1.6	0.8	5.3	19.8	2.7	**7.8**
Siderastrea siderea	4.0	5.2	4.0	1.6	4.8	**3.7**
Porites astreoides	2.0	3.6	4.3	0.4	1.6	**2.4**
Montastraea cavernosa			0.7	1.6	3.5	**1.2**
Stephanocoenia intersepta		3.1				**0.6**
Agaricia humilis	3.0	0.8				**0.6**
Diploria strigosa			2.3			**0.4**
Millepora alcicornis	2.0					**0.4**
Porites porites			1.5		0.9	**0.3**
Madracis decactis					0.9	**0.2**
Agaricia agaricites			0.6			**0.1**
Total Stony Corals	**12.5**	**13.5**	**18.7**	**23.4**	**14.4**	**17.7**

by transects with a combined mean cover of 3.7 %. *Verongula rigida* and *Mycale laevis* were present along three of the five transects surveyed (Table 77).

Abiotic substrates, largely represented by reef overhangs were prominent at El Palo Reef and presented a combined linear cover of 19.1 %. 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 and unconsolidated sediments, including coral rubble, sand and silt were deposited in between the hard bottom sections. The mean substrate rugosity (2.8 m) was influenced by the presence of large (mostly dead), massive coral colonies.

A total of 18 species of stony corals, including 11 intercepted by line transects during the 2013 survey are reported for El Palo Reef. The combined mean live coral cover during the present 2013 survey was 17.7 % (range: 12.5 – 23.4%). Boulder Star Cora (*Orbicella annularis)* was the dominant species in terms of reef substrate cover with 7.8%, representing 44.1 % of the total cover by stony corals. Massive Starlet Coral (*Siderastrea siderea*), Mustard-Hill Coral (*Porites astreoides*) and Great Star Coral (*Montastrea cavernosa*) were intercepted by at least three transects 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 68 shows the variations of mean substrate cover by reef sessile-benthic categories during the baseline and 2013 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. Live coral cover showed an increment of substrate cover from the initial baseline survey, from 11.4 % to 17.7 %, an increment of 35.6 %. Although this is probably an artifact of the new transects, the fact is that there are still areas of optimal coral growth in the same or better condition than those existing during the 2000 baseline survey. Indeed, from the data of the three original transects it is suggested that 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 again 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, Mustard-Hill Coral (*Porites astreoides*) and Massive Starlet Coral (*Siderastrea siderea*) also exhibited similar or increased cover during 2013. Differences of cover by Great Star Coral (*Montastrea cavernosa*) were small and statistically insignificant (Figure 69).

3.2 Fishes and Motile Megabenthic Invertebrates

The taxonomic composition and abundance of fishes surveyed within belt-transects at El Palo Reef during the 2013 monitoring survey are presented in Table 78. A total of 43 species were identified, including 23 within belt-transects. The mean number of species per transect was eight (range: 4 – 10) and the mean density of fishes was 18.2 Ind/30 m^2 (range: 4 – 24 Ind/30 m^2). Five species, with a combined abundance of 12.5 Ind/30 m^2 represented 68.7 % of the total abundance within transect areas. The main fish assemblage included the Blue-head Wrasse (*Thalassoma bifasciatum*), Redband Parrotfish and Striped (*Sparisoma aurofrenatum, Scarus iserti*), Dusky Damselfish (*Stegastes dorsopunicans*), Threespot Damselfish (Stegastes planifrons). With a total of three species present, the parrotfish family (Scaridae) was the most specious

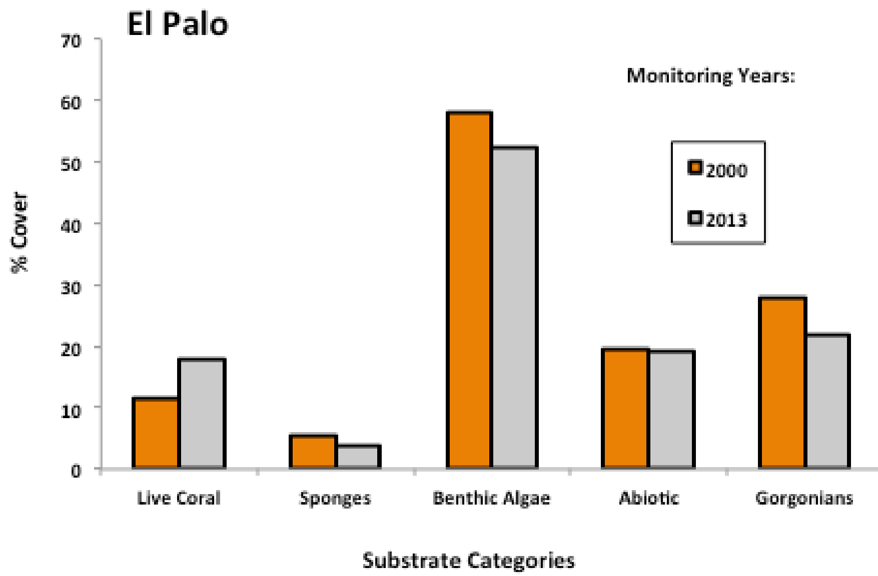


Figure 68. Monitoring trends (2000 – 2013) of mean substrate cover by sessile-benthic categories at El Palo Reef, Cabo Rojo

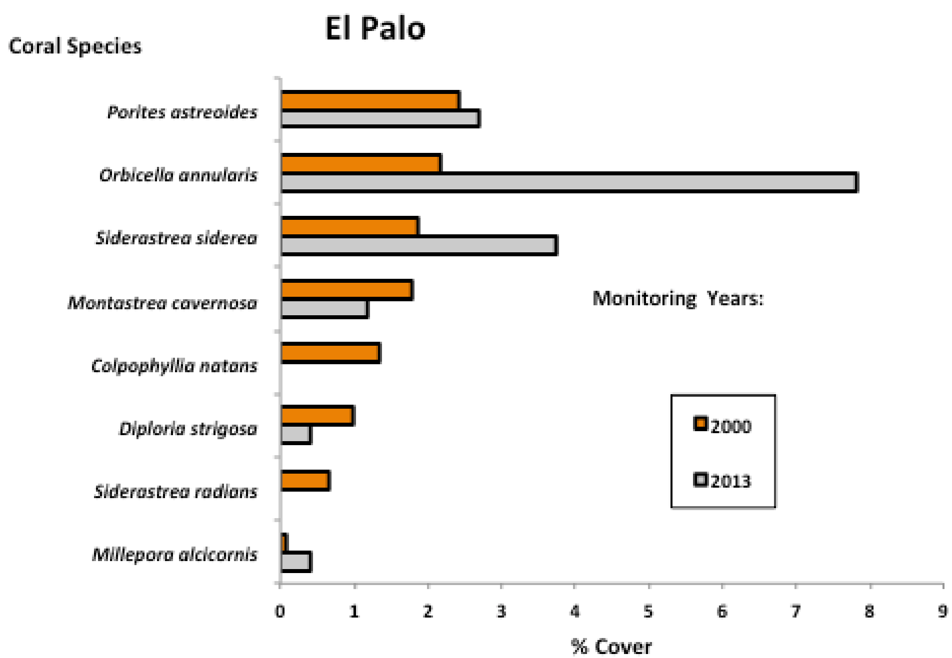


Figure 69. Monitoring trends (2000 – 2013) of mean substrate cover by coral species at El Palo Reef, Cabo Rojo

Table 78. Taxonomic composition and abundance of fishes within belt-transects at El Palo Cabo Rojo, November 2012

Depth: 5 m

		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(individuals/30m2)					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	8	0	5	0	9	**3.5**
Sparisoma aurofrenatum	Redband Parrotfish	4	6	2	0	5	**3.3**
Stegastes dorsopunicans	Dusky Damselfish	1	0	7	1	3	**2.4**
Scarus iserti	Stripped Parrotfish	2	3	4	0	1	**2.0**
Stegastes planifrons	Threespot Damselfish	0	0	3	1	1	**1.3**
Acanthurus bahianus	Ocean Surgeon	0	2	0	0	0	**0.5**
Canthigaster rostrata	Caribbean Puffer	1	1	0	1	0	**0.5**
Elacatinus evelynae	Sharknose Goby	2	0	0	0	0	**0.4**
Chaetodon capistratus	Four-eye Butterflyfish	1	0	0	1	0	**0.4**
Haemulon sciurus	Bluestriped Grunt	1	1	0	0	0	**0.4**
Sparisoma viride	Stoplight Parrotfish	0	0	0	0	2	**0.4**
Acanthurus coeruleus	Blue Tang	0	0	0	0	1	**0.3**
Chaetodon striatus	Banded Butterflyfish	0	1	0	0	0	**0.3**
Coryphopterus personatus	Masked Goby	0	0	1	0	0	**0.3**
Haemulon flavolineatum	French Grunt	0	1	0	0	0	**0.3**
Holocentrus rufus	Squirrelfish	0	1	0	0	0	**0.3**
Hypoplectrus nigricans	Black Hamlet	0	1	0	0	0	**0.3**
Hypoplectrus sciurus	Yellowtail Hamlet	0	0	1	0	0	**0.3**
Lachnolaimus maximus	Hogfish	1	0	0	0	0	**0.2**
Myripristis jacobus	Blackbar Soldierfish	1	0	0	0	0	**0.2**
Lutjanus apodus	Schoolmaster Snapper	0	1	0	0	0	**0.2**
Lutjanus griseus	Grey Snapper	0	0	1	0	0	**0.2**
Pomacanthus paru	French Angelfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**22**	**18**	**24**	**4**	**23**	**18.2**
	TOTAL SPECIES	**10**	**10**	**8**	**4**	**8**	**8**

taxonomic group, and combined with doctorfishes(Acanthuridae) and damselfishes (Pomacentridae) constituted the main herbivorous fish assemblage. The combined abundance of herbivores represented approximately 56.0 % 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 15% 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). Pelagic predators included the Houndfish, (*Tylosurus crocodilus*) and the Bar Jack (*Carangoides ruber*). One juvenile Hogfish and one Mutton Snapper were observed during the ASEC survey during 2013 (Table 79). One Spider Crab and one Arrow Crab were observed within belt-transects at El Palo Reef during the 2013 survey (Table 80).

Differences of fish abundance and species richness between the 2000 baseline and the 2013 surveys are shown in Figure 70. 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.

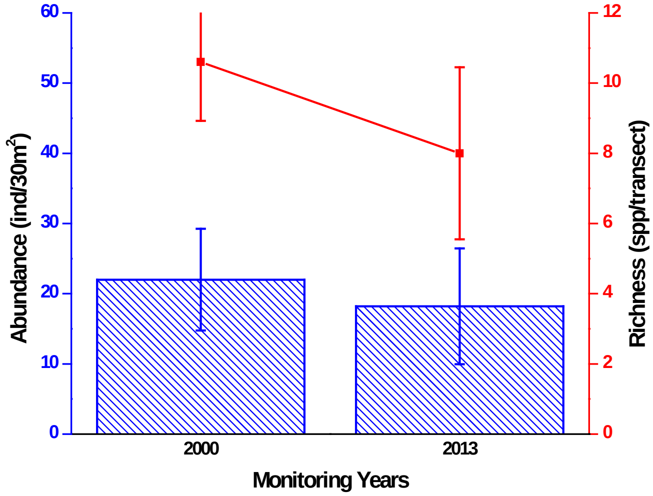


Figure 70. Monitoring trends (2000 – 2013) of fish species richness and abundance at El Palo Reef, Cabo Rojo

Table 79. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at El Palo Reef, Cabo Rojo, November 2012

Depth range : 8 - 10 m Duration - 30 min.

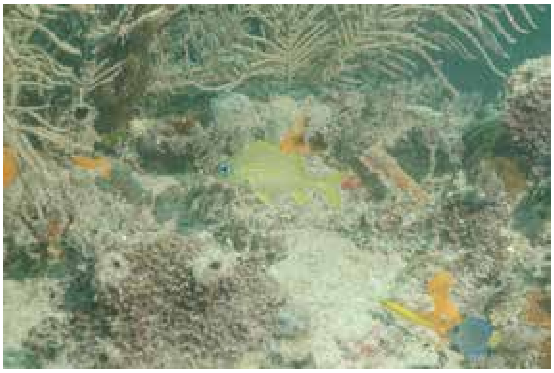
SPECIES	**COMMON NAME**	# - (cm)		
Epinephelus guttatus	Red Hind	1 - (30)		
Lutjanus apodus	Schoolmaster	3 - (20)	1 - (30)	
Lutjanus synagris	Lane Snapper	4 - (15)	2 – (20)	1 – (25)
Scomberomorus regalis	Cero Mackerel	2 – (40)	1 – (50)	
Sphyraena barracuda	Great Barracuda	1 - (50)		

Table 80. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at El Palo Reef, Cabo Rojo, November 2012

Depth: 8 -10 m		TRANSECTS					
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
Mithrax spinosissimus	Spider crab				1		**0.2**
Stenorhynchus seticornis	Arrow Crab			1			**0.2**
	TOTALS	0	0	1	1	0	**0.4**

Photo Album 20

El Palo Reef – Cabo Rojo






I. Guayama

1.0 Guayama Shelf-Edge Reef - Guayama

A well-defined spur and groove coral reef system fringes the shelf-edge at approximately 4.0 nautical miles off the Guayama coast (Figure 71). Spurs, oriented perpendicular to the shelf-edge were relatively low in height, rising not more than 1.5 meters from the base and narrow, separated by sand channels not more than 1-2 meters apart. The coral reef formation appeared to be fairly extensive along the south-north axis, with spurs longer than the prevailing 40 m horizontal visibility at the shelf-edge. Five permanent transects were installed on hard ground along the middle section of consecutive spurs within a depth range of 18 – 20 m during January 2013. This assessment represents the baseline characterization of the Guayama Shelf-Edge Reef. Panoramic views of the Guayama shelf-edge reef are presented in Photo Album 21.

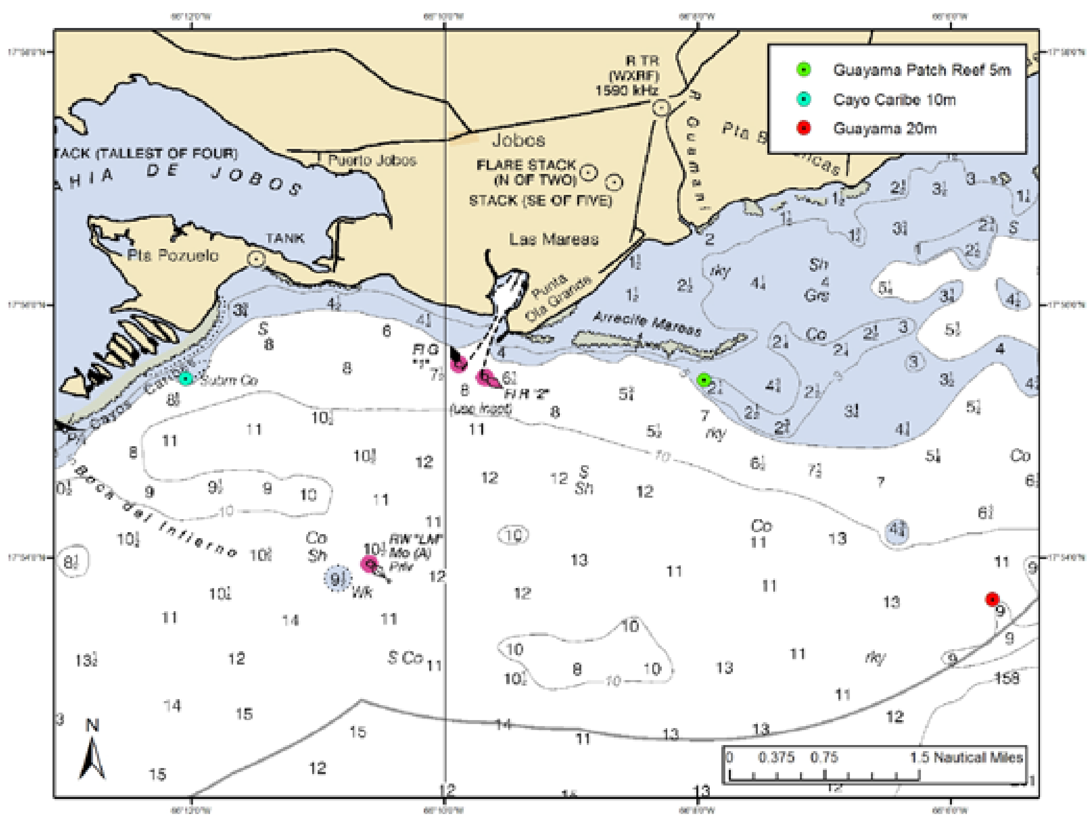


Figure 71. Location map of Guayama Stations along the south coast of Puerto Rico.

1.1 Sessile-benthic Reef Community

Turf algae growing intermixed with brown fleshy macroalgae was the dominant feature of the Guayama shelf-edge reef in terms of substrate cover with a mean cover of 62.0 %, representing 93.9% of the total cover by benthic algae (Table 81). The combined cover by benthic algae averaged 66.0 % (range: 58.9 – 74.5 %). Brown fleshy macroalgae was mostly a mixture of *Lobophora variegata* and *Dictyota sp*. Crustose coralline algae were present in all five transects with a mean cover of 1.6 %. Figure 72 summarizes the mean substrate cover by reef sessile-benthic categories during the 2013 baseline survey.

Stony corals were represented by at least 19 species, including 12 intercepted by transects during this 2013 baseline survey. The combined mean substrate cover by stony corals was 25.2 % (range: 18.4 – 33.7%). An assemblage of six stony corals were present in at least three out of the five transects surveyed with a combined cover of 21.7 %, representing 86.1 % of the total cover by live stony corals (Table 81). The dominant stony coral assemblage included Great Star Coral (*Montastrea cavernosa*), Massive Starlet Coral (*Siderastrea siderea*), Mustard-Hill Coral (*Porites astreoides*), Great Star Coral (*Orbicella annularis*), Lettuce Coral (*Agaricia agaricites*) and Symmetrical Brain Coral (*Diploria strigosa*) (Figure 73). Corals were observed growing mostly as isolated mound shaped colonies of small to moderate size, not contributing much to the reef topographic relief. Reef rugosity averaged 1.2 m. Erect soft corals (gorgonians) were present but not abundant with a mean density of 0.2 col/transect. The encrusting gorgonian, *Erythropodium caribaeorum* was present in one transect with a mean linear cover of 0.1 %. Sponges were present from all transects with a mean linear cover of 5.7 % (Table 81).

Table 81. Percent substrate cover by sessile-benthic categories at Guayama Shelf-Edge Reef**,** Guayama, January 2013

	Transects					
	1	2	3	4	5	**Mean**
	0.75	1.28	1.06	0.95	1.48	**1.10**
SUBSTRATE CATEGORY						
Abiotic						
Sand	9.6					**1.9**
Reef overhang		1.9	2	0.5		**0.9**
Total Abiotic	**9.6**	**1.9**	**2**	**0.5**		
Benthic Algae						
Turf	54.4	73	62.2	63.2	57.2	**62.0**
Fleshy macroalgae	9.6			2.2		**2.4**
Crustose coralline algae	1	1.5	3	1	1.7	**1.6**
Total Benthic Algae	**65.0**	**74.5**	**65.2**	**66.4**	**58.9**	**66.0**
Gorgonian						
Encrusting gorgonians			0.5			**0.1**
Total Gorgonian			**0.5**			**0.1**
Erect Gorgonians (#col/transect)		1.0				**0.2**
Sponges	4.3	5.3	4.1	7.2	7.4	**5.7**
Total Sponge	**4.3**	**5.3**	**4.1**	**7.2**	**7.4**	**5.7**
Live Stony Corals						
Montastraea cavernosa	3	8.7	7	6	7.7	**6.5**
Siderastrea siderea	4.6	3.2		2.7	7.2	**3.5**
Porites astreoides	0.5	1.4	6.6	6.8	2.1	**3.5**
Orbicella annularis	2.6	4	7.7			**2.9**
Agaricia agaricites	5.6		0.8	0.6	7.2	**2.8**
Diploria strigosa			3	8.3	1.2	**2.5**
Colpophyllia natans			1.9		7.7	**1.9**
Dichocoenia stokesi	4.7					**0.9**
Meandrina meandrites				1.5		**0.3**
Porites porites		0.6				**0.1**
Agaricia lamarcki					0.6	**0.1**
Siderastrea radians		0.5				**0.1**
Total Stony Corals	**21.0**	**18.4**	**27.0**	**25.9**	**33.7**	**25.2**

1.2 Fishes and Motile Megabenthic Invertebrates

The taxonomic composition and abundance of fishes surveyed within belt-transects at Guayama Shelf-edge Reef during the 2013 baseline survey are presented in Table 82. A total of 52 species were identified, including 29 within belt-transects. The mean number of species per transect was 15.4 (range: 11 – 19) and the mean density of fishes was 54.6 Ind/30 m^2 (range: 45 – 61 Ind/30 m^2). Seven species, with a combined abundance of 51.8 Ind/30 m^2 represented 94.9 % of the total abundance within transect areas. The main fish assemblage included the Blue Chromis (*Chromis cyanea*), Bicolor Damselfish (*Stegastes partitus*), Peppermint and Masked Gobies (*Coryphopterus lipernes, C. personatus*), Striped Parrotfish (*Scarus iserti*) and the Creole and Blue-head Wrasse (*Clepticus parrae*, *Thalassoma bifasciatum*). Species also present in at least four of the five transects surveyed were the Sharknose Gobi, Beau Gregory, Ocean surgeon, French Grunt and Harlequin Bass (Table 82). Seven fish species were only represented by one individual within belt-transects.

The fish community structure of Guayama's Shelf-edge Reef was largely comprised of small benthic invertebrate and demersal zooplankton feeders that represented 57.8 % of the fish individuals within belt-transects (Table 82). These included four gobies (Gobiidae), three wrasses Labridae), two squirrelfishes (Holocentridae), one goatfish (Mullidae), one puffer (Tetraodontidae), one damselfish (Pomacentridae), one grunt (Haemulidae), one porgy (Sparidae) and two bass/small groupers (Serranidae). Abundance of pelagic zooplanktivores, represented by the Creole Wrasse (Labridae) and two *Chromis spp*. (Pomacentridae) comprised another 25.4 % of the total individuals. Herbivores were represented by three parrotfishes (Scaridae), two doctorfishes (Acanthuridae) and one damselfish (Pomacentridae) with a combined abundance of 9.8 Ind/30 m^2, or 13.9 % of the total fish abundance within belt-transects (Table 82).

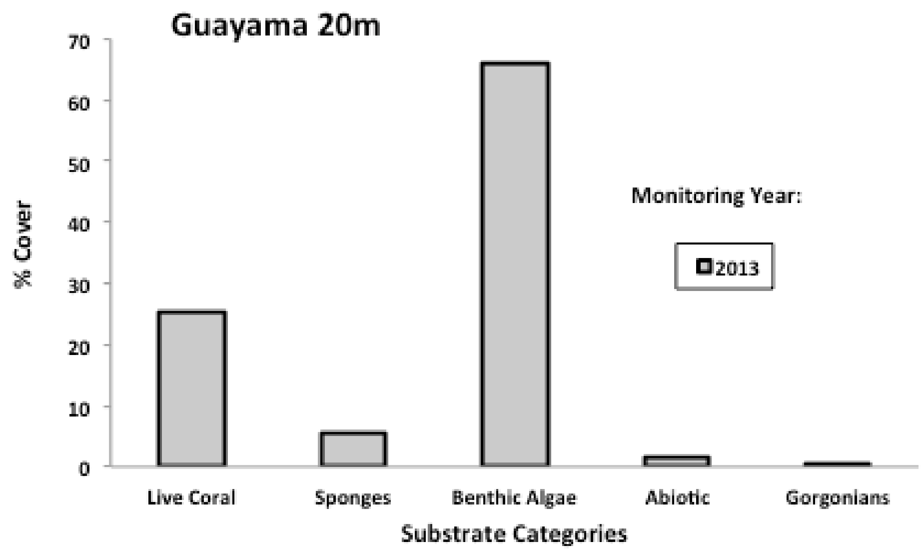


Figure 72. Mean substrate cover by sessile-benthic categories during the baseline (2013) survey at Guayama Shelf-Edge Reef, Guayama.

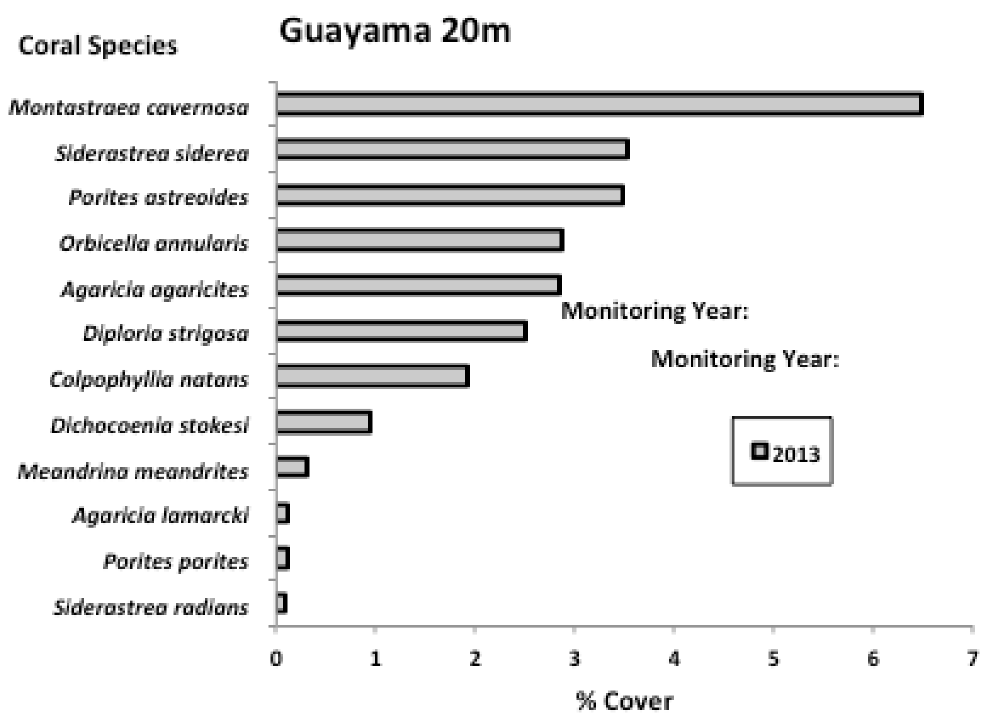


Figure 73. Mean substrate cover by stony coral species during the baseline (2013) survey at Guayama Shelf-Edge Reef, Guayama

Table 82. Taxonomic composition and abundance of fishes within belt-transects at Guayama Shelf-Edge Reef, Guayama, January 2013

Depth: 20m		TRANSECTS					
17˚55.417		**1**	**2**	**3**	**4**	**5**	
66˚12.041		(Individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Chromis cyanea	Blue Chromis	10	6	18	4	19	**11.4**
Stegastes partitus	Bicolor Damselfish	13	8	17	5	7	**10.0**
Coryphopterus lipernes	Peppermint Goby	5	8	9	13	8	**8.6**
Coryphopterus personatus	Masked Goby	5	12	0	0	16	**6.6**
Scarus iserti	Stripped Parrotfish	6	2	15	4	1	**5.6**
Clepticus parrae	Creole Wrasse	10	10	0	5	0	**5.0**
Thalassoma bifasciatum	Bluehead Wrasse	0	1	12	0	10	**4.6**
Gobiosoma evelynae	Sharknose Goby	2	3	0	3	3	**2.2**
Stegastes leucostictus	Beau Gregory	1	1	2	2	2	**1.6**
Acanthurus bahianus	Ocean Surgeon	1	1	0	1	2	**1.0**
Canthigaster rostrata	Caribbean Puffer	3	1	1	0	0	**1.0**
Haemulon flavolineatum	French Grunt	1	1	0	2	1	**1.0**
Halichoeres garnoti	Yellow-head Wrasse	0	1	0	2	2	**1.0**
Serranus tigrinus	Harlequin Bass	2	0	1	1	1	**1.0**
Pomacanthus paru	French Angelfish	1	2	0	0	1	**0.8**
Cephalopholis cruentatus	Graysby	1	2	0	0	0	**0.6**
Sparisoma viride	Stoplight Parrotfish	1	1	0	1	0	**0.6**
Chaetodon capistratus	Four-eye Butterflyfish	0	0	0	0	2	**0.4**
Chaetodon striatus	Banded Butterflyfish	0	0	0	2	0	**0.4**
Chromis multilineata	Brown Chromis	0	0	2	0	0	**0.4**
Coryphopterus glaucofraenum	Briddled Goby	0	0	0	2	0	**0.4**
Neoniphon marianus	Longjaw Squirrelfish	0	1	0	1	0	**0.4**
Acanthurus coeruleus	Blue Tang	0	0	0	1	0	**0.2**
Calamus calamus	Porgy	0	0	1	0	0	**0.2**
Holacanthus tricolor	Rock Beauty	0	0	0	0	1	**0.2**
Holocentrus rufus	Squirrelfish	0	1	0	0	0	**0.2**
Hypoplectrus unicolor	Butter Hamlet	0	0	1	0	0	**0.2**
Pseudupeneus maculatus	Spotted Goatfish	1	0	0	0	0	**0.2**
Sparisoma aurofrenatum	Redband Parrotfish	0	1	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**53**	**57**	**61**	**45**	**57**	**54.6**
	TOTAL SPECIES	**16**	**19**	**11**	**16**	**15**	**15.4**

Predators of larger reef invertebrates, small demersal and/or pelagic fishes included a small assemblage of groupers (Red Hind), snappers (Schoolmaster, Yellowtail), Great Barracuda, Cero Mackerel and one Lionfish observed during the ASEC survey (Table 83). One Cleaner Shrimp and one Arrow Crab were observed within belt-transects at Guayama Shelf-Edge Reef during the 2013 survey (Table 84).

Table 83. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Guayama Shelf-edge Reef**,** Guayama, January 2013

Depth: 20 m Duration - 30 min.

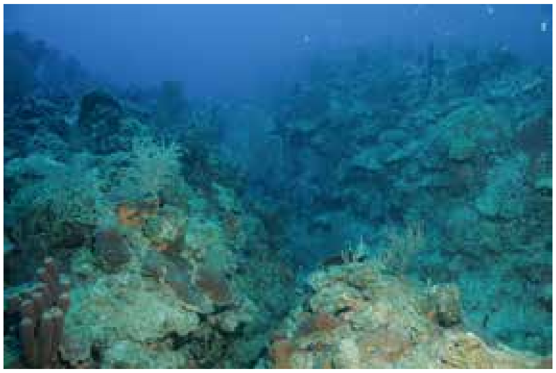
SPECIES	**COMMON NAME**	# - (cm)	
Epinephelus guttatus	Red Hind	1 - (25)	
Lachnolaimus maximus	Hogfish	1 – (35)	
Lutjanus apodus	Schoolmaster	3 - (20)	1 - (25)
Ocyurus chrysurus	Yellowtail Snapper	3 - (20)	1 – (25)
Pterois sp.	Lionfish	1 – (15)	
Scomberomorus regalis	Cero Mackerel	2 – (40)	
Sphyraena barracuda	Great Barracuda	1 - (50)	

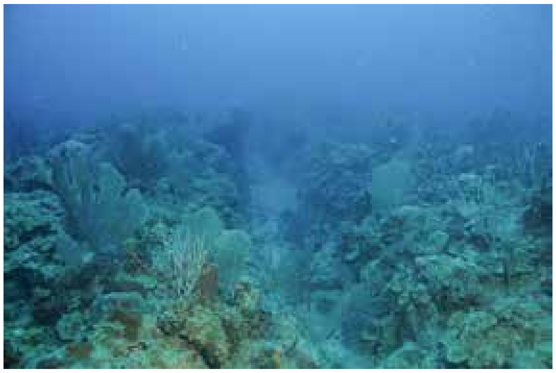
Table 84. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Guayama Shelf-edge Reef**,** Guayama, January 2013

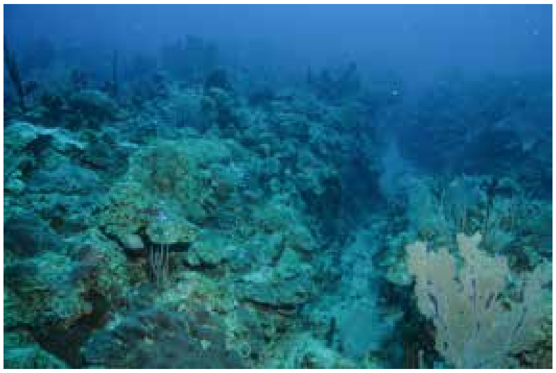
Depth: 20 m

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

Photo Album 21
Guayama Shelf-Edge Reef

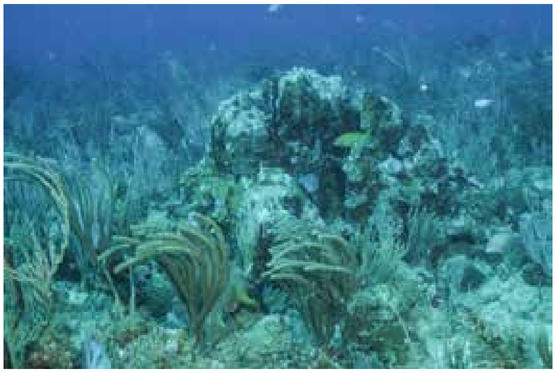










2.0 Cayo Caribe – Guayama

Coral reefs have developed at the windward side of a chain of emergent keys at the entrance of Jobos Bay. These reefs are divided onto four main clusters of keys known (from east to west) as: Cayos Caribe, Cayos de Barca, Cayos de Pájaros and Cayo Morrillo (Figure 71). Our baseline monitoring survey was performed on the fore reef of Cayos Caribe during January 2013.

Reef physiography at Cayos Caribe consists of an extensive reef flat with fringing red mangrove at its landward margin. A series of sand channels cut through the entire mangrove fringe leading to a sandy backreef lagoon with seagrass. The reef crest extends down to a depth of 2-3 meters with an irregular, highly rugose topography. A diffuse spur and groove reef formation characterizes the fore reef slope down to a narrow terrace at about 10 – 12 meters of depth where most of the coral growth was found. The deeper reef slope section is a steep drop-off wall reaching down to the base of the reef at about 16 m. A set of five permanent transects was constructed over hard bottom within the reef terrace at depths of 9 -12 m (Figure 71). Panoramic views of the Cayos Caribe Reef survey area are presented as Photo Album 22.

2.1 Sessile-benthic Community

A dense benthic algal turf growing intermixed with brown fleshy macroalgae was the dominant feature of Cayo Caribes Reef in terms of substrate cover. The combined cover by benthic algae averaged 74.5 % (range: 69.7 – 87.0 %). Turf algae were the main component of the mixed assemblage with a mean cover of 45.9 %, representing 61.6% of the total (Table 85). Brown fleshy macroalgae was mostly a mixture of *Lobophora variegata* and *Dictyota sp*. Crustose coralline algae were present in two transects with a mean cover of 1.3 %. Figure 74 presents the mean substrate cover by reef sessile-benthic categories during the 2013 baseline survey.

Stony corals were represented by at least 18 species, including nine intercepted by transects during this 2013 baseline survey. The combined mean substrate cover by stony corals was 21.0 % (range: 12.1 – 29.3%). Boulder Star Coral, *Orbicella annularis* was the dominant coral species with a mean cover of 12.4 % (range: 5.7 – 22.8%),

Table 84. Percent substrate cover by sessile-benthic categories at Cayos Caribe Reef**,** Guayama, January 2013

	Transects					
	1	2	3	4	5	**Mean**
	1.11	1.72	1.13	0.77	1.28	**1.20**
SUBSTRATE CATEGORY						
Abiotic						
Sand		9.7	4.4		1.2	**3.1**
Reef overhang		6.7			4.5	**2.2**
Total Abiotic		**16.4**	**4.4**		**5.7**	**5.3**
Benthic Algae						
Turf	57.1	38.5	49.7	38.5	45.5	**45.9**
Fleshy macroalgae	29.9	30.9	14.5	32.8	28.8	**27.4**
Crustose coralline algae			5.5	0.8		**1.3**
Total Benthic Algae	**87.0**	**69.4**	**69.7**	**72.1**	**74.3**	**74.5**
Gorgonian						
Encrusting gorgonians			0.6			**0.1**
Total Gorgonian			**0.6**			**0.1**
Erect Gorgonians	7	12	9	13	10	**10**
Sponges	0.9	2.2	0.5	1.7	2.1	**1.5**
Total Sponges	**0.9**	**2.2**	**0.5**	**1.7**	**2.1**	**1.5**
Live Stony Corals						
Orbicella annularis	7.7	5.7	14.1	22.8	11.5	**12.4**
Montastraea cavernosa	0.8	0	0	0.7	11.9	**2.7**
Porites astreoides	0	1.2	8.6	0.7	0	**2.1**
Siderastrea siderea	1.4	1	1	1.3	2.9	**1.5**
Agaricia agaricites	1.1	3.7	0	0	0	**1.0**
Porites porites	1.1	0.5	0.8	0.9	1.2	**0.9**
Stephanocoenia intersepta	0	0	0	0	1.1	**0.2**
Diploria labyrinthiformis	0	0	0	0	0.7	**0.1**
Diploria strigosa	0	0	0.4	0	0	**0.1**
Total Stony Corals	**12.1**	**12.1**	**24.9**	**26.4**	**29.3**	**21.0**

representing 59.0 % of the total cover by stony corals (Table 85). It was present in all transects surveyed. Great Star Coral (*Montastrea cavernosa*), Mustard-Hill Coral (*Porites astreoides*), Massive Starlet Coral (*Siderastrea siderea*) and Lettuce Coral (*Agaricia agaricites*) were present in at least three transects and along with Boulder Star Coral comprised the main coral assemblage in terms of reef substrate cover (Figure 75). Several colonies of ESA listed corals, *Agaricia lamarcki*, *Acropora cervicornis*, and *Dichocoenia stokesi* were observed out of transects. Corals were observed growing mostly as isolated mound shaped or encrusting colonies of small to moderate size, not contributing much to the reef topographic relief. There was also encrusting coral growth over vertical hard bottom surfaces and within crevices, suggesting that coral growth has adapted to conditions of strong wave action. Reef rugosity averaged 1.2 m. Erect soft corals (gorgonians) were moderately abundant with a mean density of 10 col/transect. The encrusting gorgonian *Erythropodium caribaeorum* was present in one transect with a mean linear cover of 0.1 %. Sponges were present from all transects with a mean linear cover of 1.5 % (Table 85).

Previous quantitative characterizations of Cayos Caribe's fore reef within the 10 +/- 2 meters were performed by Garcia-Sais and Castro (1995) and Garcia-Sais et al (2003). Both of these assessments were produced following a similar five 10m long permanent set of transects and applying the continuous intercept substrate categories quantification approach, with transects non-randomly located in areas of optimal coral growth for prospective monitoring. Live coral cover from these previous assessments was reported to be constant between surveys at 19.5 % reef substrate cover (Garcia-Sais et al., 2003), with the dominant species, Boulder Star Coral (*Orbicella annularis*) representing 48.7 % of the total live coral cover. It is important to note that these previous characterizations and monitoring were completed previous to the late 2005 regional coral bleaching event.

The present baseline survey was performed in a different section of the same reef, within the same reef physiographic zone and at the same depth. Total live coral cover varied less than 8 % between surveys, increasing from 19.5 to 21.4 %. Likewise, reef substrate cover by the dominant coral species, *O. annularis* was measured at a 24% higher cover during the present survey (from 9.5 to 12.4%). While these differences are not statistically significant, it is relevant to note that this reef appears to have been

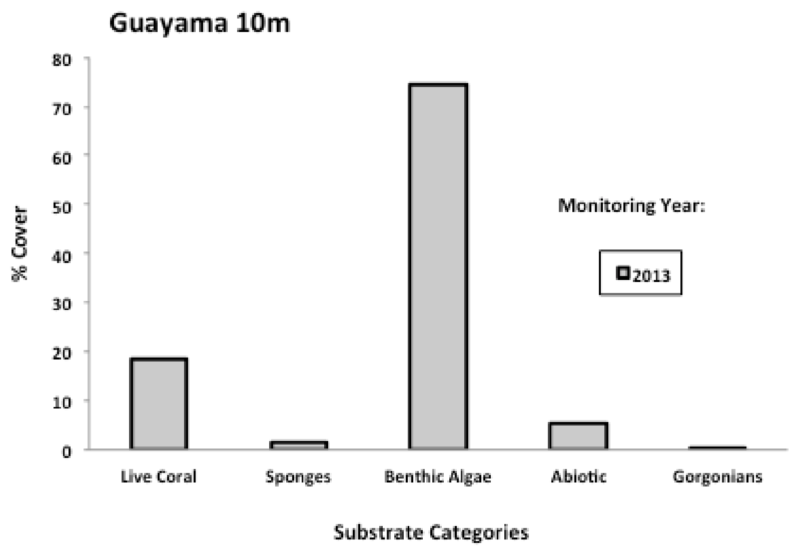


Figure 74. Mean substrate cover by sessile-benthic categories during the baseline (2013) survey at Cayo Caribes Reef, Guayama.

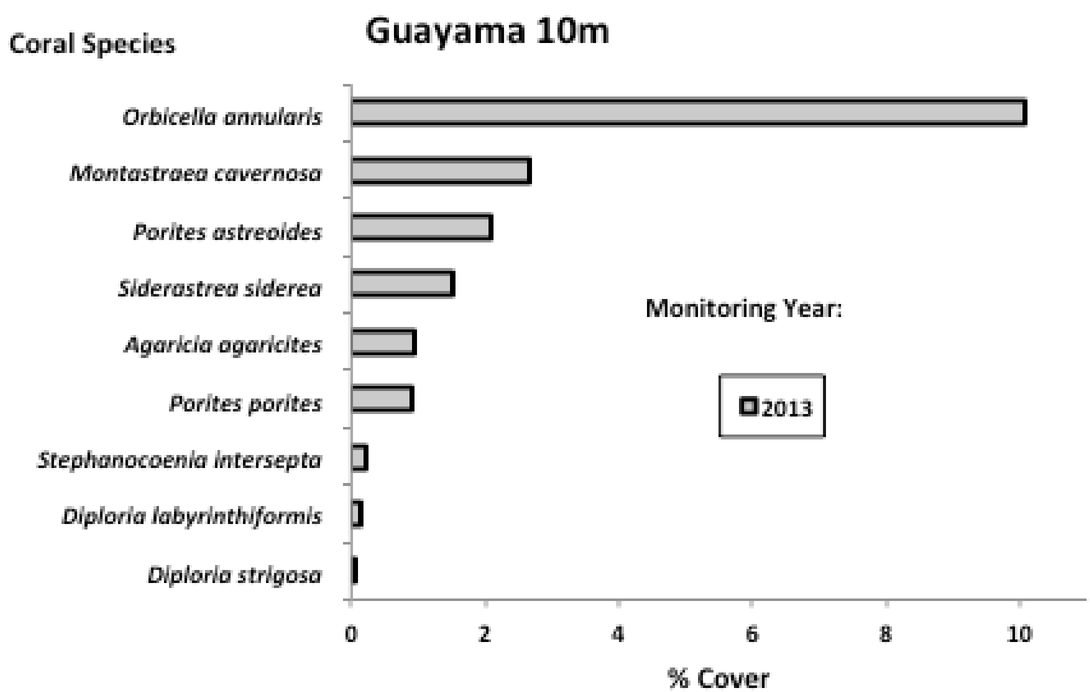


Figure 75. Mean substrate cover by stony coral species during the baseline (2013) survey at Cayo Caribes Reef, Guayama.

resilient to the 2005 regional coral bleaching event. Moreover, the dominant coral species, *O. annularis*, which was observed to be one of the most vulnerable coral species to the bleaching event (if not the most) in Puerto Rico did not show any measurable differences of live cover at this reef. This observation is consistent with the pattern of higher mortality of *O. annularis* at shelf-edge and oceanic reefs with excellent water clarity, and resilience at turbid coastal reefs, supporting the theory here suggested that UV radiation was an important factor for the coral bleaching event, and that increased water turbidity acting on shallow coastal reefs might have influenced to minimize driving factors of the 2005 coral bleaching phenomena.

2.2 Reef Fishes and Motile Megabenthic Invertebrates

The taxonomic composition and abundance of fishes surveyed within belt-transects at Cayo Caribes Reef during the 2013 baseline survey are presented on Table 86. A total of 41 species were identified, including 23 within belt-transects. The mean number of species per transect was 7.8 (range: 5 – 14) and the mean density of fishes was 14.4 Ind/30 m^2 (range: 10 – 26 Ind/30 m^2). Seven species, with a combined abundance of 9.0 Ind/30 m^2 represented 62.5 % of the total abundance within transect areas. The main fish assemblage included the Dusky Damselfish, Beau Gregory and Bicolor Damselfish (*Stegastes adustus, S. leucostictus, S. partitus*), Blue-head Wrasse (*Thalassoma bifasciatum*), Sharknose Goby (*Elacatinus evelynae*) and Striped Parrotfish (*Scarus iserti*). Other species in at two transects included the Yellowtail Snapper (*Ocyurus chrysurus*), Squirrelfish (*Holocentrus rufus*) and the Redband Parrotfish (*Sparisoma aurofrenatum*). Eleven fish species were represented by only one individual within belt-transects (Table 86).

The fish community structure of Cayo Caribes Reef was largely comprised of herbivores that represented 52.8 % of the fish individuals within belt-transects (Table 86). These included three parrotfishes (Scaridae), three damselfishes (Pomacentridae) and two doctorfishes (Acanthuridae). Small invertebrate feeders, including three gobies (Gobiidae), one wrasse Labridae), two squirrelfishes (Holocentridae), one grunt (Haemulidae), one porgy (Sparidae) one bass (Serranidae) and one blenny (Blenniidae) had a combined abundance of 4.6 Ind/30 m^2, representative of 31.9 % of the total fish abundance within transects. Demersal and pelagic zooplanktivores were represented by

Table 86. Taxonomic composition and abundance of fishes within belt-transects at Cayo Caribes Reef, Guayama, January 2013

SPECIES	COMMON NAME	1	2	3	4	5	MEAN
		(Individuals/30 m2)					
Stegastes adustus	Dusky Damselfish	4	5	4	3	4	**4.0**
Stegastes leucostictus	Beau Gregory	1	3	1	1	0	**1.2**
Thalassoma bifasciatum	Bluehead Wrasse	0	0	2	0	3	**1.0**
Gobiosoma evelynae	Sharknose Goby	1	1	3	0	0	**1.0**
Stegastes partitus	Bicolor Damselfish	0	3	0	1	1	**1.0**
Scarus iserti	Stripped Parrotfish	0	0	4	0	0	**0.8**
Amblycirrhitus pinos	Redspotted Hawkfish	3	0	0	0	0	**0.6**
Haemulon flavolineatum	French Grunt	0	0	3	0	0	**0.6**
Ocyurus chrysurus	Yellowtail Snapper	0	0	1	2	0	**0.6**
Holocentrus rufus	Squirrelfish	1	0	1	1	0	**0.6**
Odontoscion dentex	Reef Croaker	0	0	2	0	0	**0.4**
Sparisoma aurofrenatum	Redband Parrotfish	0	0	1	0	1	**0.4**
Acanthurus coeruleus	Blue Tang	0	0	1	0	0	**0.2**
Calamus calamus	Porgy	0	0	0	1	0	**0.2**
Cephalopholis cruentatus	Graysby	0	0	0	0	1	**0.2**
Coryphopterus glaucofraenum	Briddled Goby	0	0	0	1	0	**0.2**
Coryphopterus lipernes	Peppermint Goby	0	1	0	0	0	**0.2**
Hypoplectrus unicolor	Butter Hamlet	0	0	1	0	0	**0.2**
Myripristis jacobus	Blackbar Soldierfish	0	0	1	0	0	**0.2**
Ophioblennius atlanticus	Redlip Blenny	0	0	0	0	1	**0.2**
Pterois volitans	Lionfish	0	0	1	0	0	**0.2**
Serranus tigrinus	Harlequin Bass	0	0	0	1	0	**0.2**
Sparisoma viride	Stoplight Parrotfish	0	1	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**10**	**14**	**26**	**11**	**11**	**14.4**
	TOTAL SPECIES	**5**	**6**	**14**	**8**	**6**	**7.8**

very few species within transects (e.g. Bicolor Damselfish) and comprised a minor component of the fish community structure at Cayo Caribes. Predators of larger reef invertebrates, small demersal and/or pelagic fishes included the Graysbe (Serranidae), Yellowtail, Lane and Schoolmaster Snappers (Lutjanidae), Reef Croaker (*Odontoscion dentex*) and Lionfish (Table 87). Two Fire Worms and one juvenile Spiny Lobster were present within transects Reef during the 2013 survey (Table 88).

Table 87. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Cayo Caribes Reef**,** Guayama, January 2013

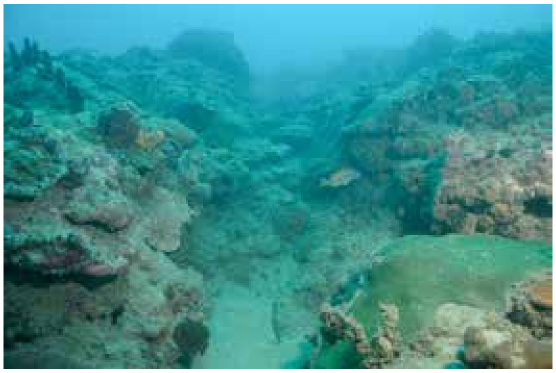
Depth: 10 m Duration - 30 min.

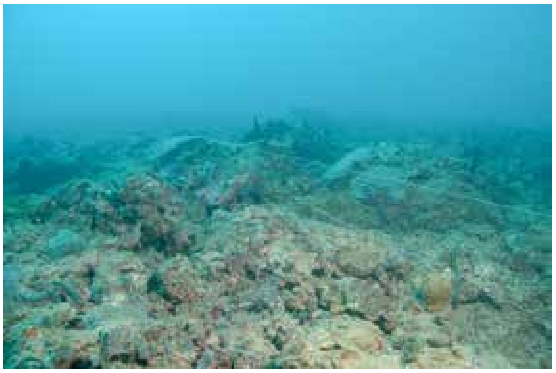
SPECIES	**COMMON NAME**		# - (cm)	
Lutjanus apodus	Schoolmaster	1 - (15)	3 - (20)	1 – (25)
Lutjanus synagris	Lane Snapper	1 - (20)		
Ocyurus chrysurus	Yellowtail Snapper	2 - (15)		
Pterois sp.	Lionfish	1 - (10)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (8)		

Table 88. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Caribes Reef**,** Guayama, January 2013

Depth: 10 m		**TRANSECTS**					**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Hermodice carunculata	Fire Worm	1				1	**0.4**
Panulirus argus	Spiny Lobster	1					**0.2**
	TOTALS	2	0	0	0	1	**0.6**

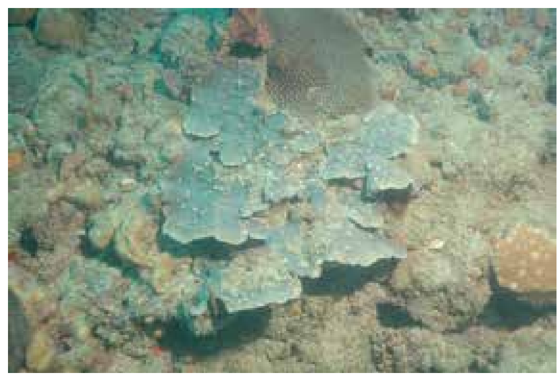
Photo Album 22
Cayo Caribes - Guayama

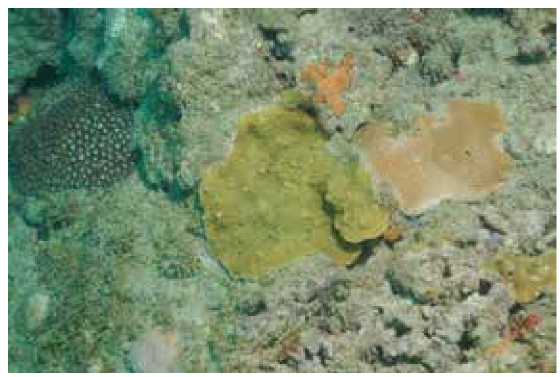











3.0 Guayama Patch Reef 5m

Guayama's Patch Reef lies to the eastern section of the Guayama Reef platform (Figure 71). It is barely emergent at low tide, so it is a zone of strong breakers. The reef top is a shallow hard ground platform with channels cutting through it and with sections of discontinuous sets of coral heads that reach almost to the surface creating a highly irregular reef system. Along the west side, where five permanent transects were installed during our baseline survey (January 2013) the reef slopes down in a series of steps, or narrow terraces to a depth of 10 m. These terraces provide attachment substrate for Boulder Star Coral and other massive corals at depths shallower than 5 meters. The upper section of the reef, or reef top, was largely colonized by fire coral (*Millepora spp*) and zoanthids (*Palythoa sp*). Dead standing and relict colonies and fragments of Elkhorn Coral, *Acropora palmata* were present. Panoramic views of the Guayama Patch Reef are included as Photo Album 23.

3.1 Sessile-benthic Reef Community

Transect data on the percent substrate cover by sessile-benthic categories at the Guayama Patch Reef are shown in Table 89. Benthic algae were the dominant category in terms of reef substrate cover with a combined mean of 65.3 % (Figure 76). Turf algae, an assemblage of short articulated brown and red filamentous algae were the main taxonomic component of the benthic algae with a mean cover of 59.2 %, representative of 90.6 % of the total. Crustose coralline algae (Rhodophyta) and fleshy brown macroalgae (mostly *Dictyota sp*) were also present along transects. Red cyanobacterial films were present in four out of the five transects surveyed and were sometimes observed to occur intermixed with fleshy macroalgae and turf algae.

Tall, mound-shaped colonies of Boulder Star Coral, *Orbicella annularis* were the most prominent feature of Guayama Patch Reef. Live coral cover by *O. annularis* averaged 16.5 % (range: 9.9 – 24.3%) along transects and represented 88.2 % of the total coral cover within a depth range of seven to nine meters (Figure 77). Six other stony coral species were intercepted by transects. Mustard-Hill, Boulder Brain and Lettuce Corals were intercepted by at least two transects, all with mean reef substrate cover below 1%

Table 89. Percent substrate cover by sessile-benthic categories at Guayama Patch Reef Reef**,** Guayama, January 2013

	Transects					
	1	2	3	4	5	**Mean**
	5.74	5.64	5.75	2.08	2.50	**4.34**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhang	5.3	5.4	16.9		2.8	**6.1**
Sand		2.4				**0.5**
Total Abiotic	**5.3**	**7.8**	**16.9**		**2.8**	**5.5**
Benthic Algae						
Turf	52.5	53.8	51	76.4	62.5	**59.2**
Crustose coralline algae	5.1	4	1.4	1.1	4.4	**3.2**
Fleshy macroalgae	1.4	4.7	2.8	2.5	3	**2.9**
Total Benthic Algae	**59.0**	**62.5**	**55.2**	**80.0**	**69.9**	**65.3**
Cyanobacteria	1.1	0.9	2.6		1.1	**1.1**
Gorgonian						
Encrusting gorgonians	2.6	1.6	10.5	1.2	12.3	**5.6**
Total Gorgonian	**2.6**	**1.6**	**10.5**	**1.2**	**12.3**	**5.6**
Erect Gorgonians	3	1	3	5	3	**3.0**
Sponges	5.1	2.1				**1.4**
Total Sponge	**5.1**	**2.1**				**1.4**
Live Stony Corals						
Orbicella annularis	24.3	19.4	12.4	16.6	9.9	**16.5**
Siderastrea siderea		2.9				**0.6**
Porites astreoides	1.2		0.6		0.9	**0.5**
Colpophyllia natans	1.2		1.2			**0.5**
Agaricia sp.				0.8	0.7	**0.3**
Porites porites					1.1	**0.2**
Montastraea cavernosa	0.4					**0.1**
Total Stony Corals	**27.1**	**22.3**	**14.2**	**17.4**	**12.6**	**18.7**

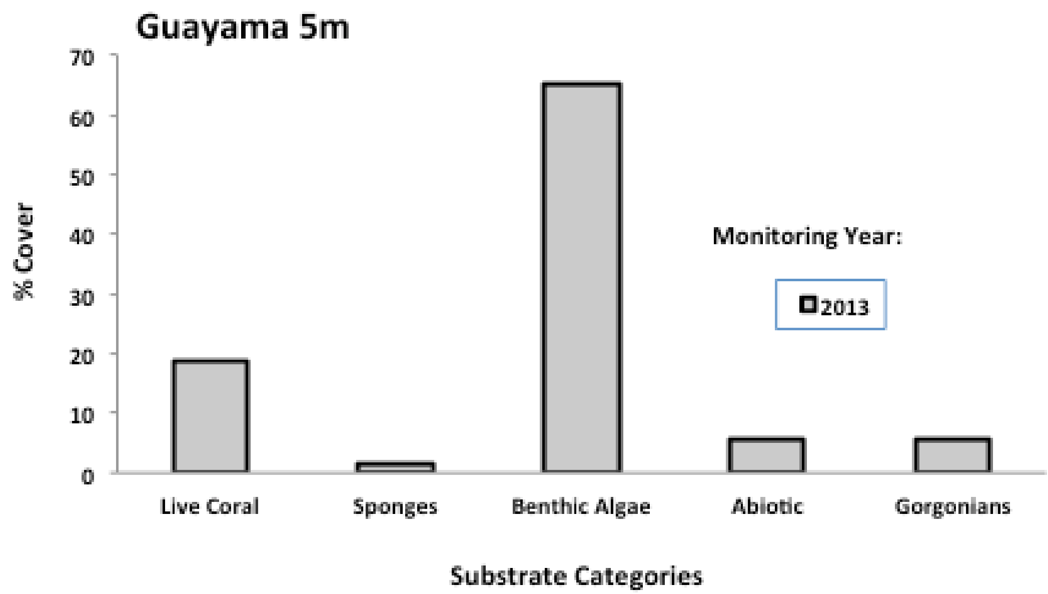


Figure 76. Mean substrate cover by sessile-benthic categories during the baseline (2013) survey at Guayama Patch Reef, Guayama.

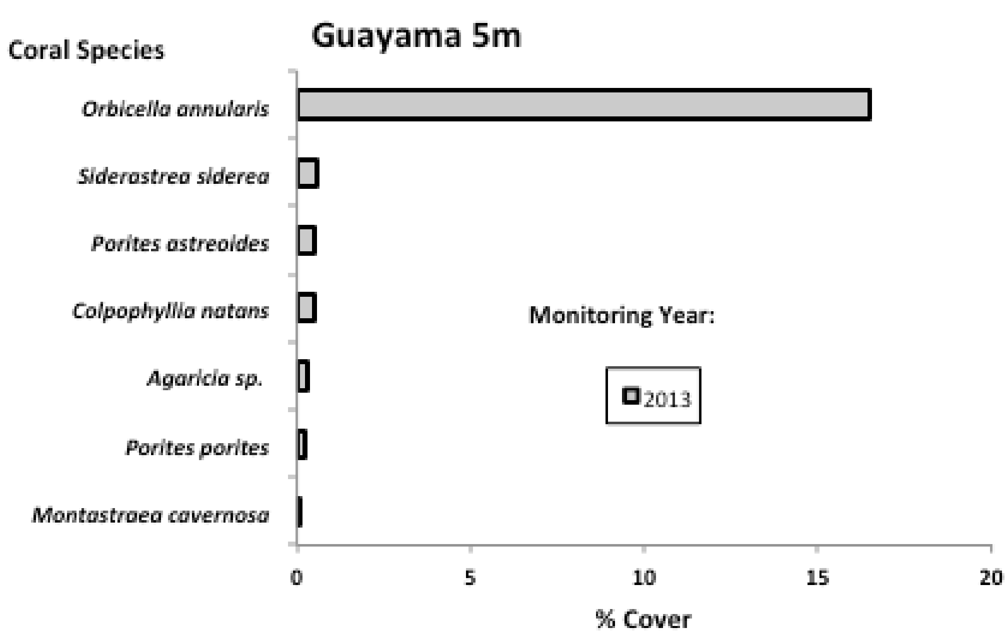


Figure 77. Mean substrate cover by stony coral species during the baseline (2013) survey at Guayama Patch Reef, Guayama.

(Table 89). Erect soft coral colonies were present in low abundance (mean: 3.0 col/transect). Sponges were present only in two transects with a mean substrate cover of 1.4 %. Abiotic substrates presented a mean cover of 5.5 % mostly associated with reef overhangs.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 48 fish species were identified during the 2013 baseline survey at Guayama's Patch Reef, including 38 species within belt-transects (Table 90). Mean fish abundance was 52.4 Ind/30m^2 (range: 34 – 77 Ind/30m^2). The mean number of species per transect averaged 17.6 (range: 14 – 19). Five species, with a combined abundance of 29.8 Ind/30m^2 represented 56.9 % of the total individuals within transects. The numerically dominant taxa included the Blue Tang (*Acanthurus coeruleus*), Dusky Damselfish (*Stegastes dorsopunicans*), Masked Goby (*Coryphopterus personatus*), Bluehead Wrasse (*Thalassoma bifasciatum*) and Mackerel Scad (*Decapterus macarellus*). The Blue Tang and Mackerel Scad are schooling species that penetrated transect areas with many individuals, whereas the other species in the aforementioned numerically dominant assemblage was comprised by demersal, territorial species. In addition to the numerically prominent species, the Stoplight Parrotfish, Caribbean Puffer and Yellow-head Wrasse were present in all transects surveyed, while the Yellowtail and Bicolor Damselfish and Blue Chromis were present in four transects. Nine species were only represented by one individual within transects (Table 90).

In terms of trophic structure, herbivores (41.6 %) and small invertebrate feeders (37.8 %) comprised almost 80% of all individuals within belt-transects. Parrotfishes (Scaridae) with five species, damselfishes (Pomacentridae) with two species and Doctorfishes (Acanthuridae) with one species comprised the main herbivorous assemblage. The invertebrate trophic group was conformed by at least 19 species, distributed into 10 families, of which the Wrasses (Labridae) and Gobies (Gobiidae) were the most prominent in terms of number of individuals. Pelagic and demersal zooplanktivores, represented by *Chromis spp*., Sargent Major and the Bicolor Damselfish represented a minor component of the Guayama Patch Ref community structure along with a few piscivores, such as *Lutjanus spp*, *Pterois sp*., *S. barracuda* observed out of transects

Table 89. Taxonomic composition and abundance of fishes within belt-transects at Guayama Reef, Guayama, January 2013

Depth: 15ft 17˚55.669 66˚02.665		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Acanthurus coeruleus	Blue Tang	1	1	40		2	**8.8**
Stegastes dorsopunicans	Dusky Damselfish	7	4	7	5	9	**6.4**
Coryphopterus personatus	Masked Goby	14	9	1		5	**5.8**
Thalassoma bifasciatum	Bluehead Wrasse	7	12	1	4		**4.8**
Decapterus macarellus	Mackerel Scad	20					**4.0**
Sparisoma viride	Stoplight Parrotfish	3	2	4	1	1	**2.2**
Abudefduf sexatilis	Sargent Major			1	6	2	**1.8**
Chromis cyanea	Blue Chromis	2	1	5		1	**1.8**
Canthigaster rostrata	Caribbean Puffer	2	1	2	2	1	**1.6**
Halichoeres garnoti	Yellow-head Wrasse	1	3	1	1	2	**1.6**
Microspathodon chrysurus	Yellowtail Damselfish	1	1		3	3	**1.6**
Chromis multilineata	Brown Chromis		1	5			**1.2**
Scarus taeniopterus	Princess Parrotfish			1	5		**1.2**
Haemulon flavolineatum	French Grunt				1	3	**0.8**
Stegastes partitus	Bicolor Damselfish	1	1	1		1	**0.8**
Bodianus rufus	Spanish Hogfish	1	1	1			**0.6**
Priacanthus arenatus	Glass-eye			1	1	1	**0.6**
Stegastes adustus	Three-spot Damselfish	2	1				**0.6**
Anisotremus virginicus	Porkfish			1		1	**0.4**
Aulostomus maculatus	Trumpetfish	1				1	**0.4**
Chaetodon capistratus	Four-eye Butterflyfish	2					**0.4**
Gobiosoma evelynae	Sharknose Goby	2					**0.4**
Gramma loreto	Fairy Basslet	1				1	**0.4**
Haemulon aurolineatum	Tomtate	1		1			**0.4**
Myripristis jacobus	Black-bar Soldierfish			2			**0.4**
Ocyurus chrysurus	Yellowtail Snapper				1	1	**0.4**
Scarus iserti	Stripped Parrotfish					2	**0.4**
Serranus tigrinus	Harlequin Bass		1	1			**0.4**
Sparisoma aurofrenatum	Redband Parrotfish				2		**0.4**
Coryphopterus lipernes	Peppermint Goby	1					**0.2**
Haemulon sp.	Grunt		1				**0.2**
Haemulon album	White Margate		1				**0.2**
Haemulon sciurus	Bluestriped Grunt				1		**0.2**
Holocentrus rufus	Squirrelfish		1				**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet		1				**0.2**
Neoniphon marianus	Longjaw Squirrelfish				1		**0.2**
Odontoscion dentex	Reef Croaker			1			**0.2**
Sparisoma rubripinne	Yellowtail Parrotfish					1	**0.2**
	TOTAL INDIVIDUALS	**70**	**43**	**77**	**34**	**38**	**52.4**
	TOTAL SPECIES	**19**	**18**	**19**	**14**	**18**	**17.6**

during the ASEC survey (Table 90). Motile megabenthic invertebrates were represented by two Flamingo Tongue gastropods and one Arrow Crab (Table 92)

Table 91. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Guayama Patch Reef**,** Guayama, January 2013

Depth: 5 m Duration - 30 min.

SPECIES	**COMMON NAME**	# - (cm)	
Lutjanus apodus	Schoolmaster	2 - (20)	1 - (30)
Lutjanus jocu	Dog Snapper	1 – (35)	
Ocyurus chrysurus	Yellowtail Snapper	2 - (20)	
Pterois sp.	Lionfish	1 - (15)	
Sphyraena barracuda	Great Barracuda	1 - (50)	

Table 92. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Guayama Patch Reef**,** Guayama, January 2013

Depth: 5 m

TAXA	**COMMON NAME**	**TRANSECTS** 1	2	3	4	5	**MEAN ABUNDANCE (IND/30 m2)**
Ciphoma gibbosum	Flamingo Tongue					2	**0.4**
Stenorhynchus seticornis	Arrow Crab	1					**0.2**
	TOTALS	1	0	0	0	2	**0.6**

Photo Album 23

Guayama Patch Reef











J. Cibuco Reef

At approximately 0.5 km off the Vega Baja coastline lie a small group of emergent reefs known as Isletas de Garza (Figure 78). These appear to be the remains of cemented sand dunes or eolianites that run roughly paralel to the coastline. Due west of the isletas lies the mouth of Rio Cibuco, which discharges into a small embayment partially closed by an extensive sand bar. The reef community associated with the Isletas de Garza receives strong wave action from north Atlantic swells during the Winter (October – April) and are subjected to estuarine conditions during the rainy season. Despite such environmentally rough conditions an impressive coral reef system has been able to develop along the leeward section of the Isletas, and since it lies within the Cibuco River plume we have named this system as Cibuco Reef. The baseline characterization of Cibuco Reef was performed during October 2011 (Garcia-Sais et al., 2012). This June 2014 is the first monitoring event of the Cibuco Reef. Unfortunately, transects previously installed were apparently removed or dislodged by heavy wave action and new transects were constructed in essentially similar reef areas as during the baseline survey.

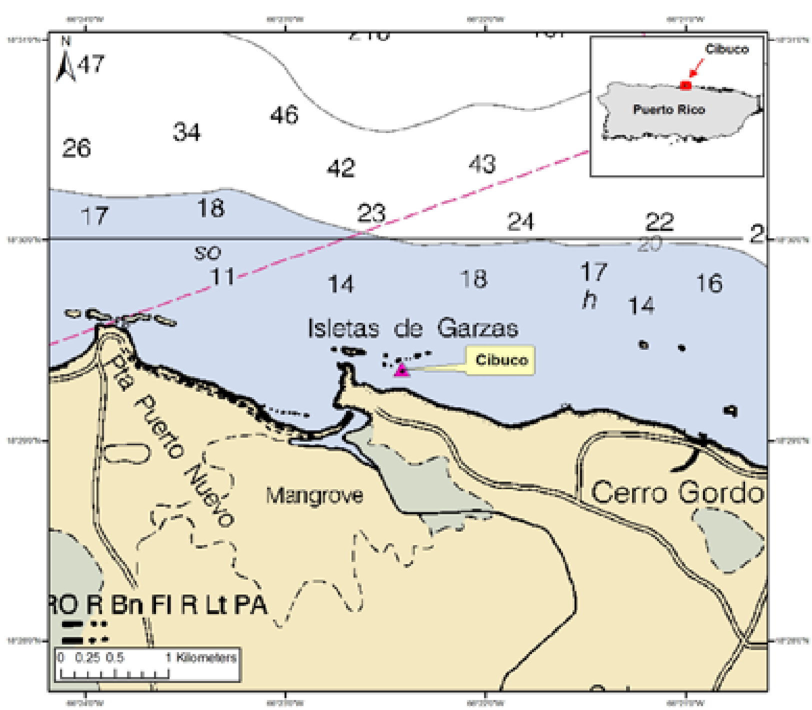


Figure 78. Location of Cibuco Reef at Isletas de Garza off Vega Baja in the north coast of Puerto Rico.

Extensive thickets of Branched Finger Coral, *Porites furcata* have grown over sections of the eolianite structures at depths between 2 – 5 m. There were several sections where Finger Coral thickets surpassed linear sections of 10 m. In addition, both branching and encrusting colonies of Elkhorn Coral, *Acropora palmata* were present in very shallow sections of the reef crest. Encrusting colonies of Symmetrical Brain Coral, *Diploria strigosa* were prominent throughout the reef and grew close together in some areas creating a mossaic of round encrusting colonies over the reef "floor". Panoramic views of the reef are shown in Photo Album 24.

1.0 Sessile-Benthic Reef Community

A total of 17 species of stony corals, including eigth intersected by transects were identified from Cibuco Reef during the 2013 survey (Table 93). Substrate cover by stony corals along transects averaged 44.3 % (range: 28.7 – 61.6 %). Branched Finger Coral, *Porites furcata* was the main species in terms of substrate cover with a mean of 22.6 % (range: 0 – 60.0 %), representing 51.0 % of the total cover by stony corals (Table 93). Boulder Star Coral, *Orbicella annularis* (complex), Symmetrical Brain Coral, *Diploria strigosa,* Great Star Coral, *Montastraea cavernosa* and Mustard Hill Coral, *Porites astreoides* comprised along with Branched Finger Coral the main coral assemblage of the reef at depths of 2 - 5 m. Extensive thickets of Finger Coral growing as carpets were highly prominent at Cibuco Reef. These were observed overlying the eolianite rock at depths between 2 – 5 m. Thickets were at least 40 cm thick and exhibited continuous linear extensions of more than 10 m (3-4 m wide) in various sections of the reef. Boulder Brain Coral was observed growing mostly as encrusting colonies of small to moderate size, but several massive boulders with overhangs were also present. Recently dead colonies and sections of live *M. annularis* colonies were observed, evidencing considerable tissue mortality during recent years. Symmetrical Brain Coral and Mustard-Hill Coral were found growing as round and mound colonies encrusted over the rocky substrate forming a "floor" of coral massaics in sections of the reef. Also, encrusting colonies of Elkhorn Coral, *Acropora palmata* were present in the shallowest sections (less than one meter) of the reef crest. Other encrusting biota, such as zoanthids, sponges and encrusting gorgonians were present, but represented minor components of the reef benthic community (Table 93).

Table 93. Percent substrate cover by sessile-benthic categories at Cibuco Reef, Vega Baja. June 2014

Depth: 2-5 m

	1	2	3	4	5	Mean
Rugosity (m)	2.00	3.30	3.70	3.21	3.52	**3.15**
SUBSTRATE CATEGORY						
Abiotic						
Reef overhangs	10.15	8.21	10.25	19.07	6.85	**10.9**
Sand	3.97			5.30		**1.9**
Total abiotic	14.12	8.21	10.25	24.36	6.85	**12.8**
Benthic Algae						
Turf-mixed assemblage	43.52	30.21	35.29	44.28	48.51	**40.4**
Coralline algae	2.33				5.14	**1.5**
Jania sp.				1.17		**0.2**
Dictyota sp.				0.53		**0.1**
Total benthic algae	45.86	30.21	35.29	45.97	50.64	**41.6**
Octocorals						
Gorgonia mariae	0.35					**0.1**
Total octocorals	0.35					**0.1**
Octocoral colonies	2			1		
Zoanthids						
Palythoa caribaeorum					1.28	**0.3**
Total zoanthids					1.28	**0.3**
Sponges						
Cliona caribbaea			1.07		2.28	**0.7**
Haliclona sp.				0.95		**0.2**
Total sponges			1.07	0.95	2.28	**0.9**
Stony Corals						
Porites furcata	14.94	60.00	29.69		8.27	**22.6**
Montastraea annularis	18.09		22.37	24.47	20.54	**17.1**
Diploria strigosa	3.73	1.58	1.33		12.27	**3.8**
Montastraea cavernosa				3.92		**0.8**
Porites astreoides	0.82				0.57	**0.3**
Diploria clivosa	0.93					**0.2**
Agaricia agaricites				0.32	0.29	**0.1**
Agaricia fragilis	0.23					
Total Stony Corals	38.74	61.58	53.40	28.71	38.94	**44.3**

Abiotic substrates, particularly reef overhangs were encountered in all five transects with a mean cover of 12.8 %. Sandy substrate averaged a cover of 1.9%, but was the main substrate type in between the rocky structures forming Cibuco Reef.

Turf algae, a mixed assemblage of short filamentous macroalgae that is highly resilent to wave action covered most of the substrate not colonized by corals. Turf algae were present in all five transets with an average cover of 40.4 % (range: 30.2 – 48.5 %), representing 97.1 % of the total cover by benthic macroalgae (Table 93).

Variations of live coral cover between the baseline (2011) and the present (2013) monitoring survey were not statistically significant (ANOVA; $p > 0.05$). Live coral cover varied by less than 3% between surveys and there was no evidence of bleaching and/or recent coral mortality between surveys (Figure 79). The variations of reef substrate cover by the main coral species (Figure 80) respond to the relocation of permanent transects during this survey.

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 37 fish species have been identified from Cibuco Reef within a depth range of 2 – 5 meters during the 2011 and 2013 surveys (Appendix 1), including 20 present within belt-transects during the 2013 survey. The mean abundance of individuals was 28.6 Ind/30 m^2 (range: 25 - 30 Ind/30 m^2), and the mean number of species per transect was eight (range: 13 - 16). The combined abundance of three species represented 79.0 % of the mean abundance within belt-transects (Table 94). The most abundant species was the Bluehead Wrasse (*Thalassoma bifasciatum*) with a mean of 13.2 Ind/30 m^2 followed by the Dusky Damselfish (*Stegastes dorsopunicans*) and the Coney (*Epinephelus fulva*).

The fish community at Cibuco Reef was comprised by a prominent assemblage of opportunistic small invertebrate feeders, such as the wrasses (Labridae – 4 spp.), squirrelfishes (Holocentridae – 2 spp), juvenile snappers (Lutjanidae – 4 spp), groupers (Serranidae – 2 spp) and grunts (Haemulidae - 4 spp), among others. The herbivorous component was also well represented by parrotfishes (Scaridae – 4 spp), damselfishes (Pomacentridae – 3 spp), and doctorfishes (Acanthuridae – 3 spp). The

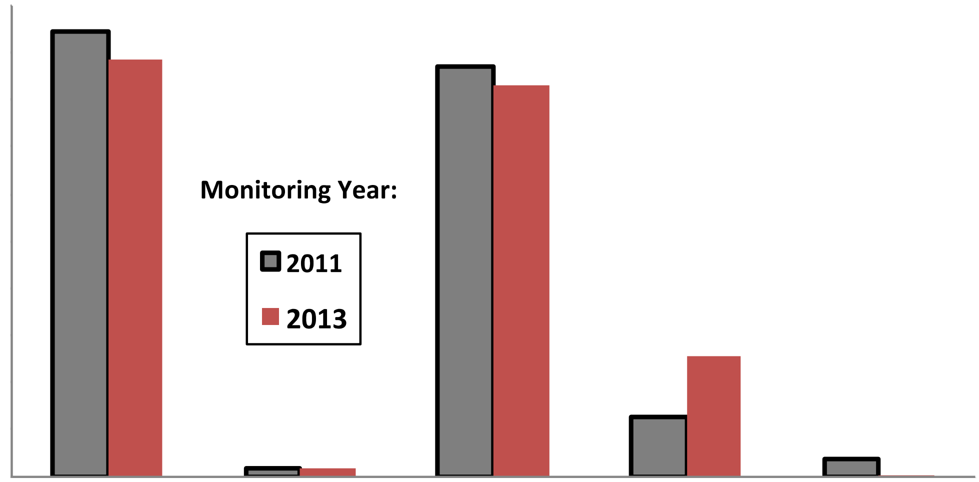


Figure 79. Monitoring trends (2011 – 2013) of mean substrate cover by sessile-benthic categories at Cibuco Reef, Vega Baja

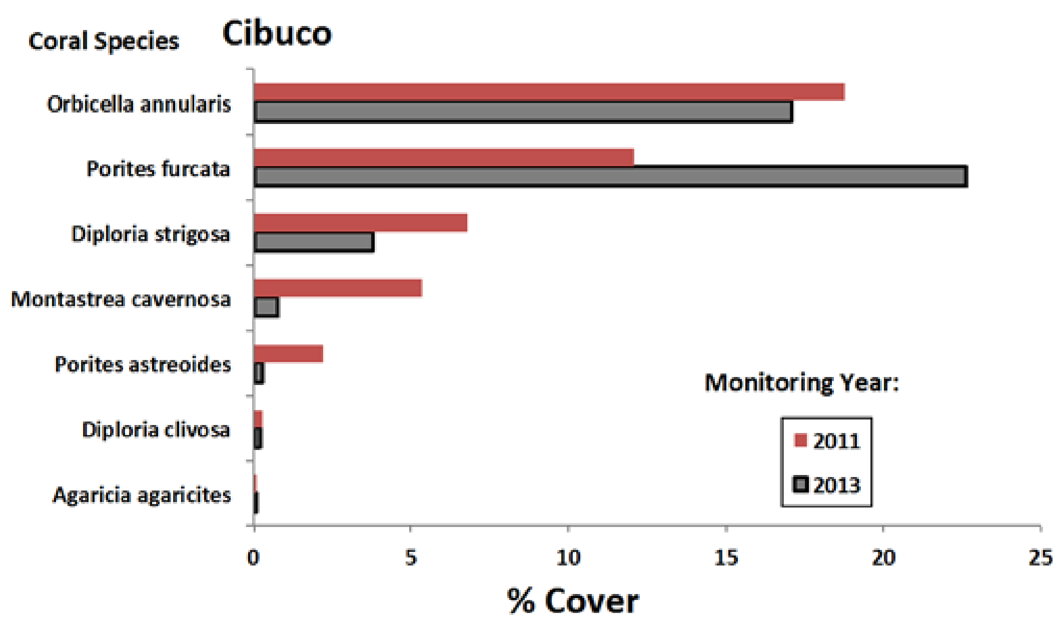


Figure 80. Monitoring trends (2011 – 2013) of mean substrate cover by coral species at at Cibuco Reef, Vega Baja

Table 94. Taxonomic composition and abundance of fishes within belt-transects at Cibuco 3m Vega Baja. June, 2014

Depth: 2-5m		Transects					
		1	**2**	**3**	**4**	**5**	
		Ind/30 m^2					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	11	11	17	19	8	**13.2**
Stegastes dorsopunicans	Dusky Damselfish	4	5	5	7	10	**6.2**
Epinephelus fulva	Coney	3	5	1	3	4	**3.2**
Abudefduf sexatilis	Sargent Major	2	2				**0.8**
Microspathodon chrysurus	Yellowtail Damselfish	2		1			**0.6**
Acanthurus coeruleus	Blue Tang	1		2			**0.6**
Haemulon flavolineatum	French Grunt	1		2			**0.6**
Lutjanius griseus	Grey Snapper		1		1		**0.4**
Gerres cinereus	Yellowfin Mojarra	1				1	**0.4**
Holocentrus adcensionis	Longspine Squirrelfish		1		1		**0.4**
Ophioblennius atlanticus	Redlip Blenny				1	1	**0.4**
Haemulon chrysargireum	Smallmouth Grunt		1				**0.2**
Acanthures bahianus	Ocean Surgeon				1		**0.2**
Miripristis jacobs	Black-bar Soldierfish	1					**0.2**
Cantherhines pullus	Tail-light Filefish	1					**0.2**
Anisotremus virginicus	Porkfish			1			**0.2**
Kyphosys sp.	Bermuda Chub				1		**0.2**
Pempheris schomburgki	Glasseye Sweeper		1				**0.2**
Sparisoma rubripinne	Yellowtail Parrotfish			1			**0.2**
Epinephelus cruentatus	Graysby					1	**0.2**
	TOTAL INDIVIDUALS	**27**	**27**	**30**	**34**	**25**	**28.6**
	TOTAL SPECIES	**10**	**8**	**8**	**8**	**6**	**8**

zooplanktivorous component was best represented by estuarine species, such as anchovies (Engraulidae) observed in large aggregations in the vicinity of the reef over sandy bottom. Piscivorous species were represented by jacks (Carangidae) and Great Barracuda (Sphyraenidae). Piscivorous species were observed feeding on the school of anchovies in the vicinity of the reef. The Yellowfin Mojarra (*Gerres cinereus*) and other species of mojarras (*Eucinostomus spp*) were observed to be abundant over the sandy bottom surrounding the reef. Cibuco Reef appears to be an important recruitment habitat for the Coney (*Epinephelus fulva*) and also for juvenile snappers (*Lutjanus analis, L. synagris, L. griseus*) and grunts (Haemulidae), observed in very small sizes at the reef and in the adjacent seagrass habitats (Table 95).

The Long-spined urchin, *Diadema antillarum* was the most prominent motile megabenthic invertebrate present within belt-transects with a mean abundance of 7.8 Ind/30 m^2 (Table 96). One Spiny Lobster (*Panulirus argus*) and one Fire Worm (*Hermodice carunculata*) were observed outside transects. Several Flamingo Tongues (Gastropoda: *Ciphoma gibbosum*) were observed on soft corals. The adjacent sseagrass habitat at the backreef of Cibuco Reef was observed to function as nursery habitat for juvenile Queen Conch (*Strombus gigas*).

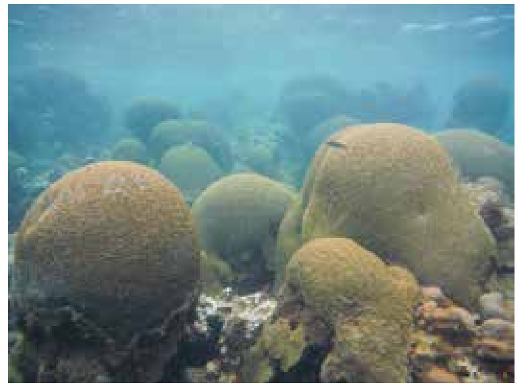
Table 95. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Cibuco Reef, 2 - 5 m, Vega Baja, June 2014.

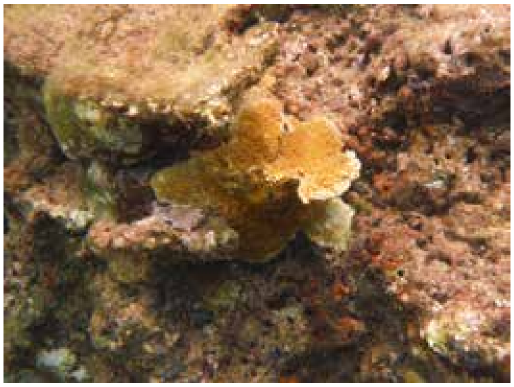
SPECIES	**COMMON NAME**		# - (cm)	
Cranx crysos	Blue Runner	4 – (25)	2 – (30)	
Lutjanus apodus	Schoolmaster	3 - (10)	5– (15)	5 – (20)
Lutjanus griseus	Grey Snapper	4 - (15)	6 – (20)	2 – (25)
Lutjanus synagris	Lane Snapper	2 - (15)	2 – (20)	
Lutjanus analis	Mutton Snapper	3 – (10)		
Sphyraena barracuda	Great Barracuda	1- (50)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (20)		

Table 96. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cibuco Reef, 2-5 m, Vega Baja, June 2014

Depth: 2 - 5 m		**TRANSECTS**					
	DEPTH (m)	**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	COMMON NAME						
Diadema antillarum	Long-spined Urchin	2	2	3	0	3	**2.0**
	TOTALS	**2**	**2**	**3**	**0**	**3**	**2.0**

Photo Album 24
Cibuco 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), and the Canjilones and Boya Esperanza Reefs (Vieques) presented statistically significant differences of live coral cover between annual surveys during the monitoring program 2001 - 2013.
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 new 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) 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 2013 monitoring survey a mild yet consistent recuperation of live coral cover, in most cases driven by growth of *Orbicella annularis* has been measured in some reefs (e.g. Cayo Coral, Desecheo 30m and 15 m, Tourmaline 30m, 20m and 10m), whereas recuperation has not been observed in others (e.g. Desecheo 20, Derrumbadero, Caja de Muerto).

8. 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 very high (>80%) and although active growth by *A. palmata* is evident, given favorable conditions for the disease massive coral mortality can be expected.

9. From the present (2013) 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.

10. 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*.

11. 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).

12. A statistically significant reduction of fish species richness has emerged from the monitoring data for many reef systems in the monitoring program. Although elucidation of a taxonomic structural pattern will require further observations and analyses the substantial loss of live coral and the introduction and establishment of the Lionfish (*Pterois sp*.) stand as possible drivers of such trend.

13. Although in low abundance, large demersal (top predator) fishes have been observed during ASEC 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*).

14. 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.

15. 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 M: Mayaguez; R: Rincon; D Isla Desecheo; CDM: Caja de Muerto; Der: Derrumbadero-Ponce; Gua: Cayo Coral-Guanica; Auro: Aurora Reef; Cibu: Cibuco Reef; Seco: El Seco Reef.

Total Species Database **REEF SITES**

Species Name	**Common Name**	**M30**	**M20**	**M10**	**D30**	**D20**	**D15**	**R5**	**R10**	**R20**	**CDM**	**Gua**	**Der**	**Auro**	**Cibu**	**Seco**
Abudefduf sexatilis	Sergeant Major	x	x	x		x		x	x	x	x	x		x	x	
Abudefduf taurus	Night Sergeant							x	x							
Acanthemblemaria aspera	Roughhead Blenny															
Acanthemblemaria chaplini	Papillose Blenny			x												
Acanthemblemaria spinosa	Sinyhead blenny															
Acanthostracion plygonia	Scrawled Cowfish															
Acanthostrascion quadricornis	Honeycomb Cowfish				x	x				x		x				
Acanthurus bahianus	Ocean Surgeon	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Acanthurus chirurgus	Doctorfish	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Acanthurus coeruleus	BlueTang	x	x	x	x	x	x	x	x	x	x	x	x		x	x
Alutherus scriptus	Scrawled Filefish	x		x	x	x			x		x	x	x			
Amblicirrhitos pinnos	Redspotted Hawkfish	x	x	x	x	x	x		x	x	x	x	x		x	
Anchoa sp.	Anchovy							x								
Anisotremus surinamensis	Black Margate				x				x	x						x
Anisotremus virginicus	Porkfish	x	x	x				x	x	x	x	x	x	x	x	
Apogon townsendi	Belted Cardinalfish				x	x			x	x						
Aulostomus maculatus	Trumpetfish	x	x	x	x	x	x	x	x	x	x	x	x	x		
Balistes vetula	Queen Triggerfish				x	x	x						x			
Bodianus rufus	Spanish Hogfish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Bothus lunatus	Peacock Flounder	x	x							x						
Calamus calamus	Saucereye Porgy							x				x	x			x

Species Name	Common Name	M30	M20	M10	D30	D20	D15	R5	R10	R20	CDM	Gua	Der	Auro	Cibu	Seco
Calamus pennatula	Pluma				x			x						x		
Cantherhines macrocerus	Whitespotted Filefish				x	x	x	x		x			x		x	
Cantherhines pullus	Orangespotted Filefish	x	x	x				x	x			x				
Canthidermis sufflamen	Ocean	x	x	x	x	x			x			x	x			x
Canthigaster rostrata	Caribbean Puffer	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Caranx bartholomaei	Yellow Jack											x				x
Caranx crysos	Blue Runner	x	x	x	x	x		x	x	x	x	x	x	x		x
Caranx hippos	Horse-eye Jack	x			x			x	x	x						x
Caranx latus	Crevalle Jack				x											x
Caranx lugubris	Black Jack	x	x	x	x	x		x	x			x	x			x
Caranx ruber	Bar Jack	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Carcharhinus limbatus	Caribbean Reef Shark				x											
Chaenopsis ocellata	Bluethroat Pikeblenny											x	x			
Chaetodipterus faber	Atlantic Spadefish	x														x
Chaetodon aculeatus	Longsnout Butterflyfish	x	x	x	x	x			x	x		x	x			x
Chaetodon capistratus	Four-eye Butterflyfish	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Chaetodon ocellatus	Spotfin Butterflyfish	x	x	x								x	x			
Chaetodon sedentarius	Reef Butterflyfish	x				x				x						x
Chaetodon striatus	Banded Butterflyfish	x	x	x		x	x		x	x	x	x	x	x	x	x
Chromis cyanea	Blue Chromis	x	x	x	x	x	x		x	x	x	x	x			x
Chromis insolata	Sunshine Chromis	x			x					x						x
Chromis multilineata	Brown Chromis	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Clepticus parrae	Creole Wrasse	x	x	x	x	x	x		x	x		x	x			x
Coryphopterus glaucofraenum	Bridled Goby	x	x	x	x				x		x	x	x			x
Coryphopterus lipernes	Peppermint Goby	x	x	x	x	x	x		x	x	x	x	x			x
Coryphopterus personatus	Masked goby	x	x	x	x	x	x		x	x	x	x	x			x

Species Name	**Common Name**	**M30**	**M20**	**M10**	**D30**	**D20**	**D15**	**R5**	**R10**	**R20**	**CDM**	**Gua**	**Der**	**Auro**	**Cibu**	**Seco**
Criptoptomus roseus	Bluelip Parrotfish						x									
Ctenogobius saepepallens	Dashed Goby									x					x	
Dasyatis americana	Southern Stingray				x	x		x								
Decapterus macarelus	Mackerel Scad	x	x		x		x			x		x				x
Diodon holacanthus	Balloonfish				x			x	x							
Diodon hystrix	Porcupinefish				x		x									
Echenes naucrates	Sharksucker											x				
Echidna catenata	Chain Moray						x									
Elagatis bipinnulata	Rainbow Runner				x								x			
Epinephelus adsensionis	Rock Hind	x	x					x	x							
Epinephelus cruentatus	Graysby	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Epinephelus fulvus	Coney	x	x	x	x	x	x	x	x	x	x	x	x		x	x
Epinephelus guttatus	Red Hind	x	x	x	x	x	x		x	x	x	x	x	x		x
Epinephelus striatus	Nassau Grouper	x	x		x	x										
Equetus acuminatus	Highhat	x	x	x	x	x	x		x	x	x	x	x			
Equetus lanceolatus	Jackknife Fish	x	x						x	x						
Equetus punctatus	Spotted Drum										x	x	x			
Gerres cinereus	Yellowfin Mojarra	x	x	x				x	x		x	x		x		
Ginglymostoma cirratum	Nurse Shark	x					x									x
Gobiosoma evelynae	Sharknose Goby	x	x	x	x	x	x	x	x	x	x	x	x		x	x
Gobiosoma hoorsti	Yellowline Goby										x					
Gobiosoma saucrum	Leopard Goby	x	x	x	x			x	x		x	x	x			
Gramma loreto	Fairy Basslet	x	x	x	x	x		x	x	x	x	x	x			x
Gymnothorax funebris	Green Moray				x									x		x
Gymnothorax miliaris	Goldentail Moray								x	x						
Gymnothorax moringa	Spotted Moray	x	x	x		x	x		x	x		x	x			

Species Name	Common Name	M30	M20	M10	D30	D20	D15	R5	R10	R20	CDM	Gua	Der	Auro	Cibu	Seco
Haemulon aurolineatum	Tomtate	x	x	x		x			x		x	x		x	x	
Haemulon carbonarium	Caesar's Grunt							x		x				x		
Haemulon chrysargyreum	Smallmouth Grunt	x	x	x				x	x	x	x					
Haemulon flavolineatum	French grunt	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Haemulon macrostomum	Spanish Grunt	x	x	x		x	x	x	x	x	x	x	x		x	
Haemulon melanurum	Cottonwick	x	x	x					x	x				x		
Haemulon parra	Sailors Choice														x	
Haemulon plumieri	White Grunt							x	x		x	x		x		x
Haemulon sciurus	Bluestriped Grunt	x	x	x	x		x	x				x	x			x
Haemulon steindachneri	Latin grunt											x				
Halichoeres bivitatus	Slippery Dick							x	x					x	x	
Halichoeres cyanocephalus	Yellowcheek Wrasse												x			
Halichoeres garnoti	Yellow-head Wrasse	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Halichoeres maculipinna	Clown wrasse	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Halichoeres pictus	Painted wrasse							x								
Halichoeres radiatus	Puddinwife	x	x	x		x	x	x	x		x	x	x	x		x
Heteropriacanthus cruentatus	Bigeye													x		
Hemiramphus ballyhoo	Ballyhoo				x	x	x		x	x				x		
Holacanthus ciliaris	Queen Angelfish	x	x	x	x	x	x		x	x	x	x	x	x		x
Holacanthus tricolor	Rock Beauty	x	x	x	x	x	x		x	x	x	x	x	x		x
Holocentrus adscensionis	Longjaw Squirrelfish					x		x	x			x	x	x	x	
Holocentrus coruscus	Reef Squirrelfish	x	x	x							x	x	x			
Holocentrus marianus	Longjaw Squirrelfish															
Holocentrus rufus	Squirrelfish	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Holocentrus vexillarius	Dusky Squirrelfish							x						x		
Hypoplectrus aberrans	Yellowbelly hamlet	x	x	x								x				

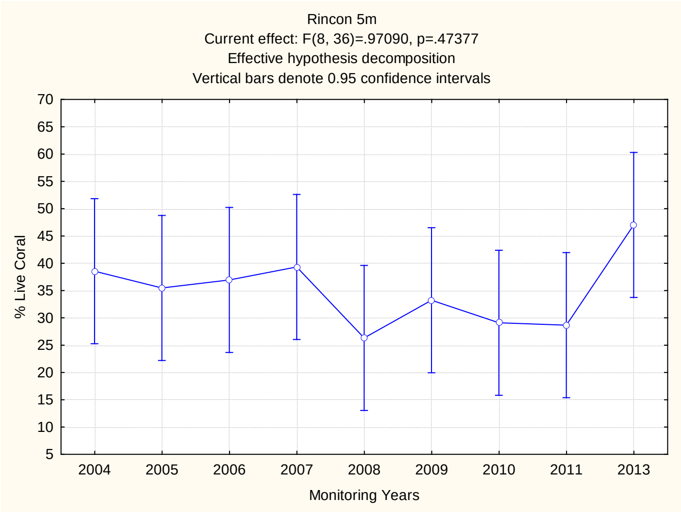
Species Name	Common Name	M30	M20	M10	D30	D20	D15	R5	R10	R20	CDM	Gua	Der	Auro	Cibu	Seco
Hypoplectrus chlorurus	Yellowtail Hamlet								x	x	x	x	x			x
Hypoplectrus guttavarius	Shy Hamlet	x	x	x					x		x	x	x			
Hypoplectrus indico	Indigo Hamlet	x	x	x							x	x	x			
Hypoplectrus nigricans	Black Hamlet	x	x	x	x				x	x	x	x	x			x
Hypoplectrus puella	Barred Hamlet	x	x	x					x	x	x	x	x			x
Hypoplectrus unicolor	Butter Hamlet	x	x	x	x				x	x	x	x	x			x
Istiophorus albicans	Salifish															x
Kyphosus sp.	Bermuda Chub	x	x	x	x	x	x	x	x			x	x		x	x
Lachnolaimus maximus	Hogfish	x											x	x		x
Lactophrys bicaudalis	Spotted Trunkfish	x	x				x									
Lactophrys polygonia	Honeycomb Cowfish	x	x	x	x	x			x			x	x			
Lactophrys trigonus	Trunkfish				x					x						
Lactophrys triqueter	Smooth Trunkfish	x	x		x	x	x	x	x			x	x			x
LiVeroma carmabi	Candy Basslet	x														
Liopropoma rubre	Swissguard Basslet	x	x	x	x	x			x	x		x	x			x
Lutjanus analis	Mutton Snapper							x		x				x		x
Lutjanus apodus	Schoolmaster Snapper	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lutjanus cyanopterus	Cubera Snapper	x	x										x			x
Lutjanus jocu	Dog Snapper	x	x		x											x
Lutjanus mahogani	Mahogani Snapper	x	x	x	x	x			x	x	x	x	x	x	x	
Lutjanus synagris	Lane snapper	x	x	x					x	x	x			x		
Malacanthus plumieri	Sand Tilefish								x	x						
Malacoctenus triangulatus	Saddled Blenny	x	x	x	x	x	x	x	x					x		
Malacoctenus versicolor	Barfin Blenny								x							
Melichthys niger	Black Durgon	x	x	x	x	x	x	x	x	x		x	x			x
Microspatodon chrysurus	Yellowtail damselfish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

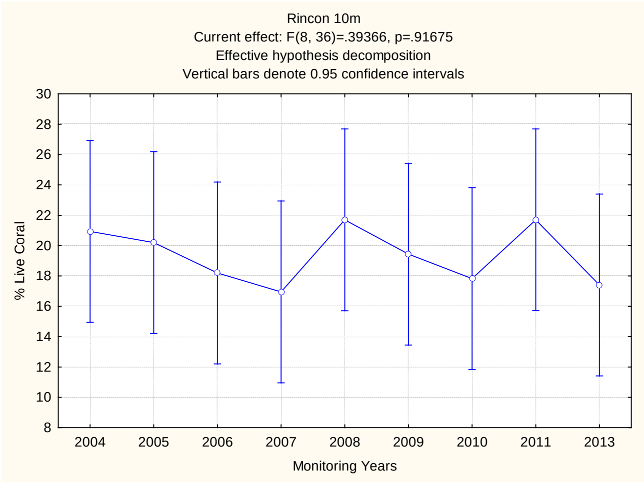
Species Name	**Common Name**	**M30**	**M20**	**M10**	**D30**	**D20**	**D15**	**R5**	**R10**	**R20**	**CDM**	**Gua**	**Der**	**Auro**	**Cibu**	**Seco**
Mlacoctenus gelli	Dusky blenny							x								
Mulloides martinicus	Yellowtail Goatfish	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Muraena robusta	Stout Moray						x				x					
Mycteroperca tigris	Tiger Grouper												x			x
Mycteroperca venenosa	Yellowfin Grouper	x			x							x				x
Myripristis jacobus	Blackbar Soldierfish	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Negaprion brevirostris	Lemon Shark															x
Neoniphon marianus	Longjaw Squirrelfish	x	x	x	x	x	x	x		x	x	x	x	x		x
Ocyurus chrysurus	Yellowtail Snapper	x	x	x	x	x	x		x	x	x	x	x	x		x
Odontoscion dentex	Reef Croaker	x	x	x				x	x		x	x				
Ophioblennius atlanticus	Redlip Blenny	x	x	x		x	x	x	x	x	x			x		
Paranthias fucifer	Creolefish	x	x	x	x	x			x	x		x	x			x
Pempheris schomburgki	Glassy Sweeper	x	x					x							x	
Pomacanthus paru	French Angelfish													x		
Pomacanthus arcuatus	Gray Angelfish	x	x		x	x	x		x	x	x	x	x	x		x
Priacanthus arenatus	Glasseye	x	x	x		x		x	x	x	x	x	x			
Pseudopeneus maculatus	Spotted Goatfish	x	x	x			x	x	x	x	x	x	x	x	x	x
Pterois volitans	Lionfish					x				x						x
Sanopus greenfieldorum	Whitelined Toadfish								x							
Scarus coelestinus	Midnight Parrotfish							x								
Scarus coeruleus	Blue Parrotfish	x	x	x					x		x	x				
Scarus guacamaia	Rainbow Parrotfish													x		
Scarus iserti	Stripped Parrotfish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Scarus taeniopterus	Princess Parrotfish	x	x	x		x	x	x	x	x	x	x	x	x		x
Scarus vetula	Queen Parrotfish	x	x	x	x	x		x	x	x	x	x	x	x		x
Scomberomorus caballa	King Mackerel															x

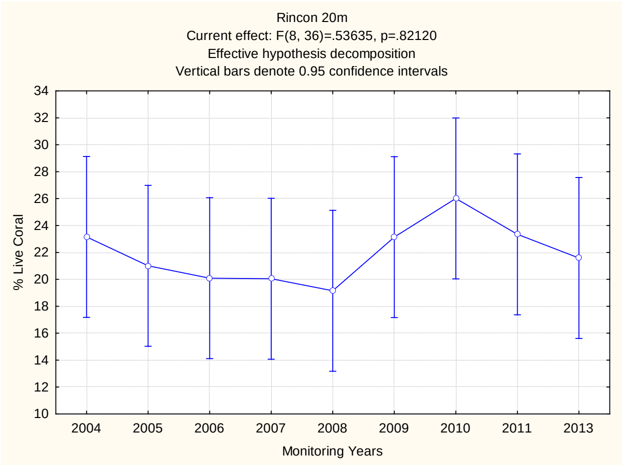
Species Name	**Common Name**	**M30**	**M20**	**M10**	**D30**	**D20**	**D15**	**R5**	**R10**	**R20**	**CDM**	**Gua**	**Der**	**Auro**	**Cibu**	**Seco**
Scomberomorus regalis	Cero Mackerel	x	x	x	x	x		x	x	x		x	x			
Scorpaena plumieri	Spotted Scorpionfish						x				x		x			
Seriola rivoliana	Almaco Jack										x					
Serranus baldwini	Lantern Bass				x											
Serranus chionaraia	Snow Bass								x							
Serranus dewegeri	Vieja															
Serranus tabacarius	Tobacco Fish				x			x								
Serranus tigrinus	Harlequin Bass	x	x	x	x	x	x		x	x	x	x	x	x		x
Sparimoma radians	Bucktootth Parrotfish				x											
Sparisoma atomarium	Greenblotch Parrofish															x
Sparisoma aurofrenatum	Redband Parrotifish	x	x	x	x	x	x	x	x	x	x	x	x			x
Sparisoma chrysopterum	Redtail Parrotfish				x	x				x						
Sparisoma radians	Bucktootth Parrotfish	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Sparisoma rubripinne	Yellowtail Parrotfish				x	x		x	x					x		
Sparisoma viride	Stoplight Parrotfish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Chilomycterus antillarum	Web Burrfish	x	x						x							
Sphoeroides greeleyi	Green Puffer								x							
Sphoeroides testudineus	Checkered Puffer	x	x	x					x							
Sphyraena barracuda	Greate Barracuda	x	x	x	x	x	x	x	x	x			x			x
Stegastes dorsopunicans	Dusky Damselfish	x		x			x	x			x	x		x	x	
Stegastes leucostictus	Beaugregory	x	x	x	x				x	x	x	x	x	x	x	x
Stegastes partitus	Bicolor Damselfish	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Stegastes planifons	Yellow-eye Damselfish	x	x	x	x	x			x	x	x	x	x	x		
Stegastes variabilis	Cocoa Damselfish	x	x	x			x	x	x		x	x	x			
Stephalnolepis setifier	Pygmy Filefish	x		x												
Strongylura timucu	Houndfish													x		

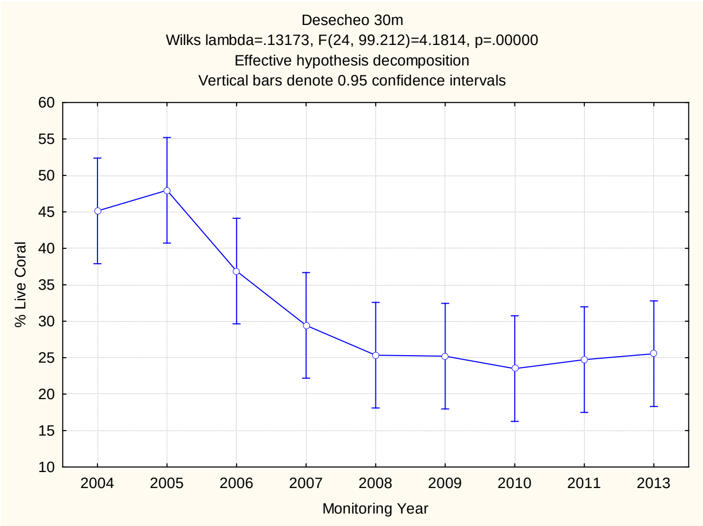
Species Name	Common Name	M30	M20	M10	D30	D20	D15	R5	R10	R20	CDM	Gua	Der	Auro	Cibu	Seco
Synodus intermedius	Sand Diver	x	x	x			x	x	x	x	x		x			
Thalasoma bifaciatum	Bluehead wrass	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Urolophus jamaicensis	Yellowspotted Stingray															
Xanthichthyis ringens	Sargassum Triggerfish						x									
	Total=	**110**	**99**	**91**	**90**	**77**	**67**	**74**	**104**	**87**	**78**	**95**	**90**	**62**	**31**	**82**

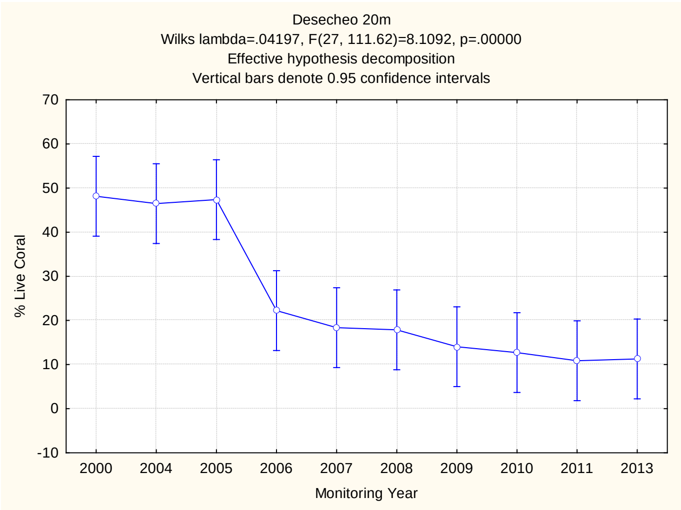
Appendix 2. Analysis of variance (ANOVA) procedure testing differences of live coral cover in annual monitoring surveys through 2013.

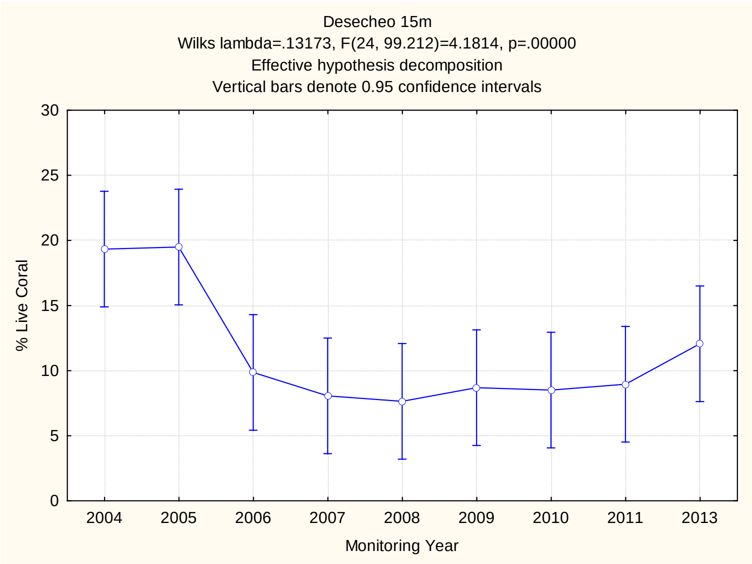


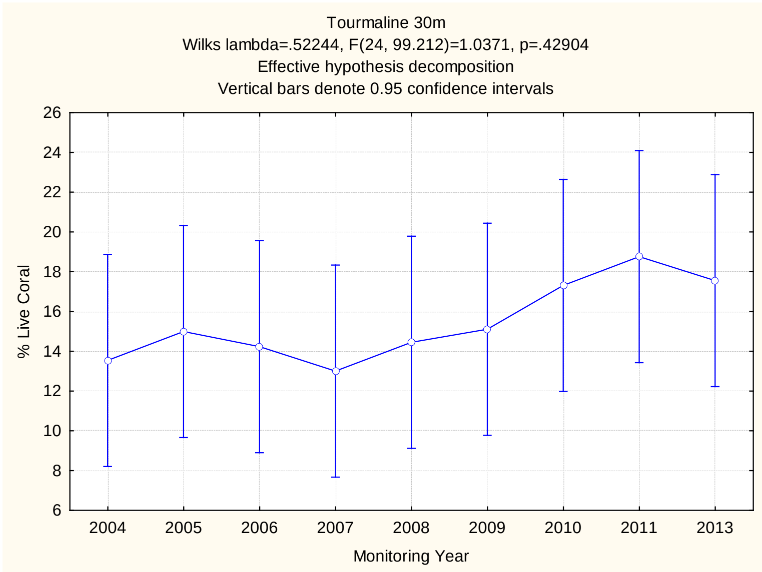


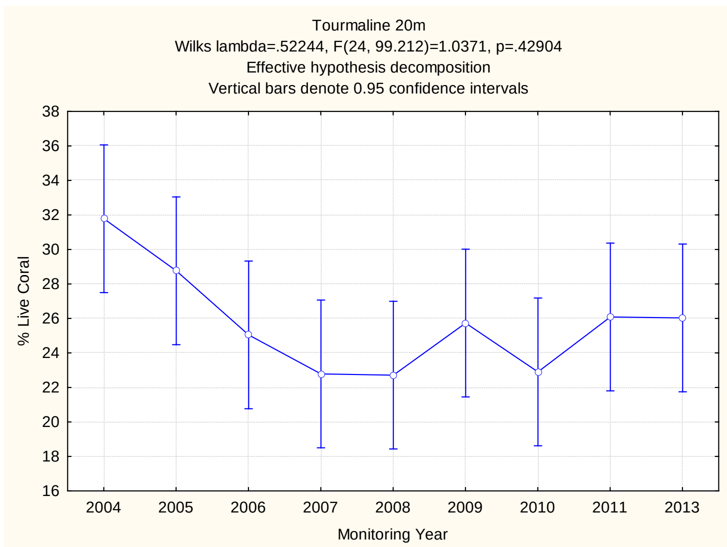


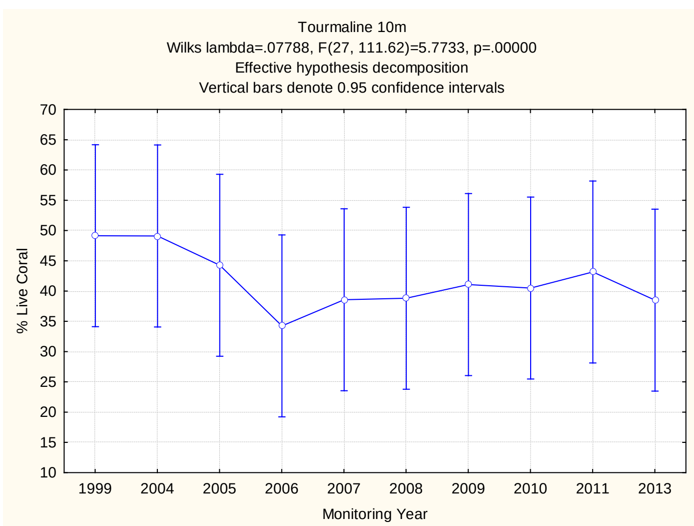

Desecheo 30m
Wilks lambda=.13173, F(24, 99.212)=4.1814, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
Monitoring Year
2004
2005
2006
2007
2008
2009
2010
2011
2013

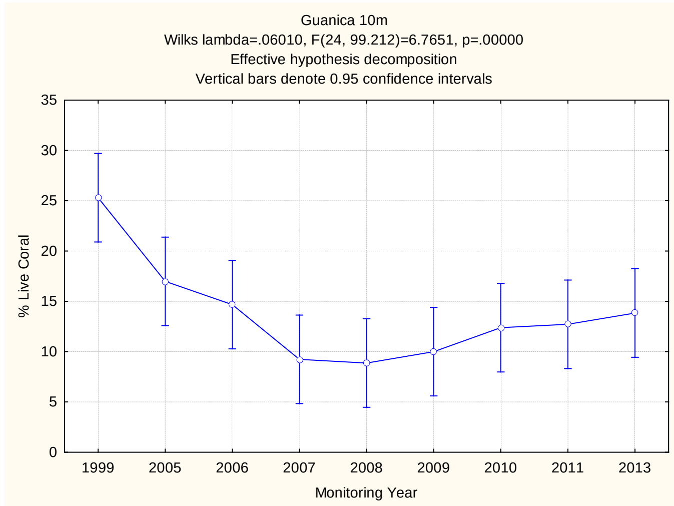

Desecheo 20m
Wilks lambda=.04197, F(27, 111.62)=8.1092, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
Monitoring Year
2000
2004
2005
2006
2007
2008
2009
2010
2011
2013

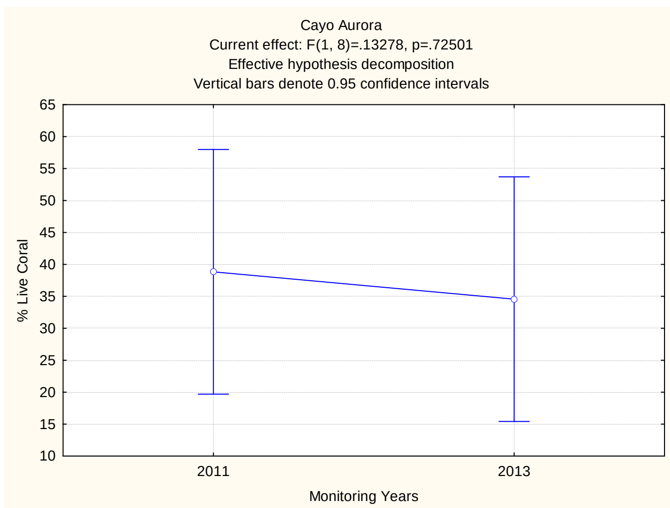

Desecheo 15m
Wilks lambda=.13173, F(24, 99.212)=4.1814, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
Monitoring Year
2004
2005
2006
2007
2008
2009
2010
2011
2013

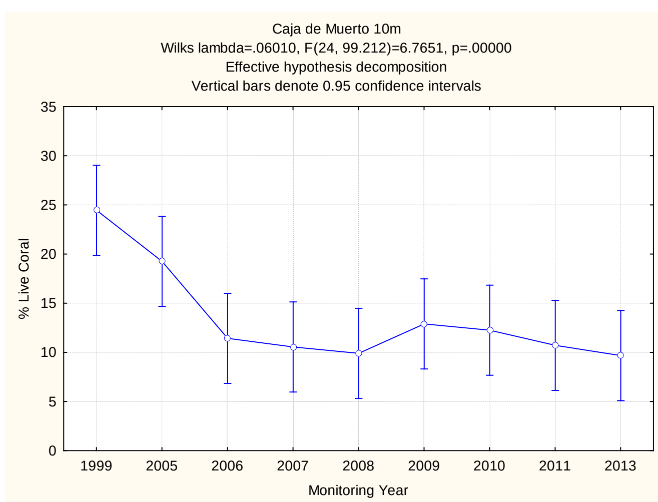

Tourmaline 30m
Wilks lambda=.52244, F(24, 99.212)=1.0371, p=.42904
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
26
24
22
20
18
16
14
12
10
8
6
2004
2005
2006
2007
2008
2009
2010
2011
2013
Monitoring Year

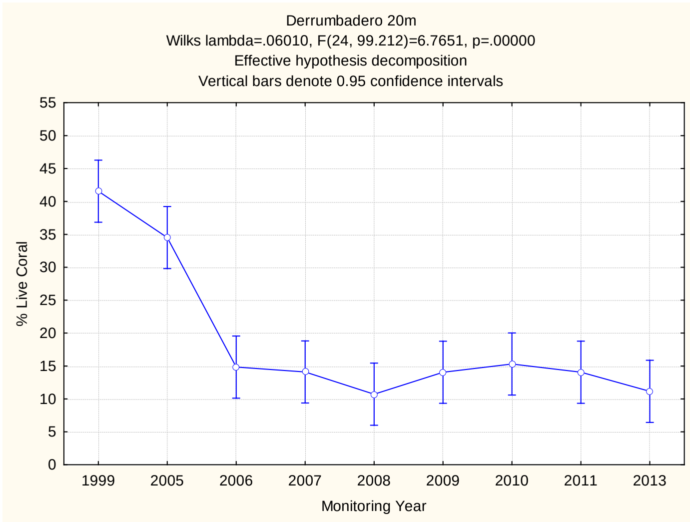

Tourmaline 20m
Wilks lambda=.52244, F(24, 99.212)=1.0371, p=.42904
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
38
36
34
32
30
28
26
24
22
20
18
16
2004
2005
2006
2007
2008
2009
2010
2011
2013
Monitoring Year

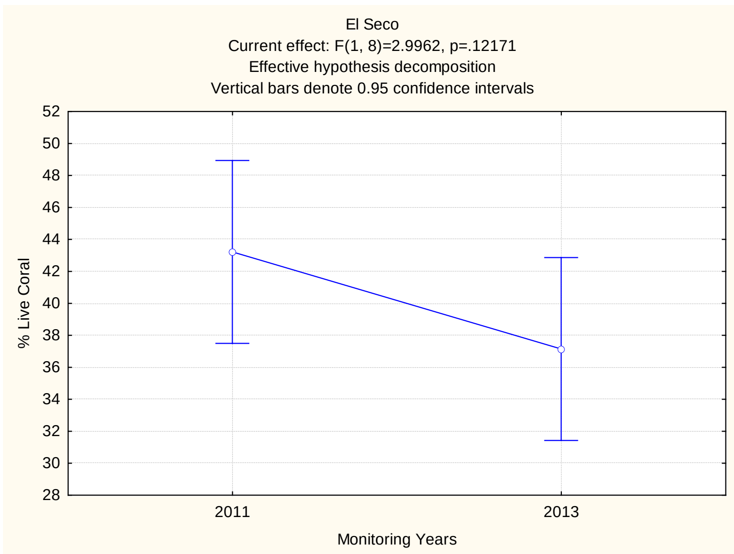

Tourmaline 10m
Wilks lambda=.07788, F(27, 111.62)=5.7733, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
70
65
60
55
50
45
40
35
30
25
20
15
10
1999
2004
2005
2006
2007
2008
2009
2010
2011
2013
Monitoring Year

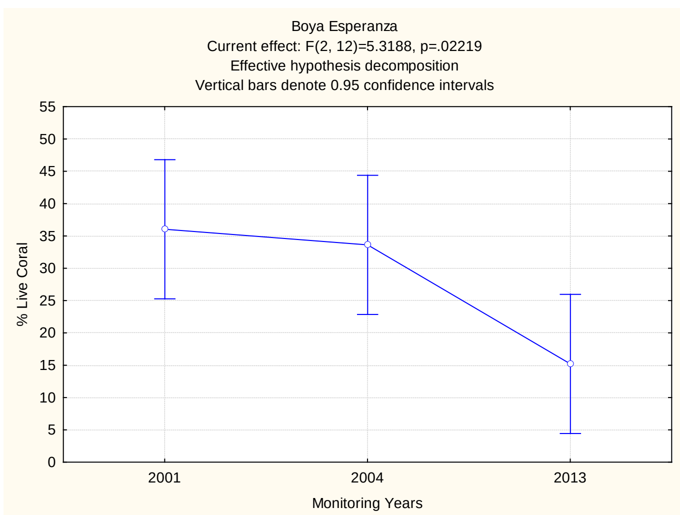

Guanica 10m
Wilks lambda=.06010, F(24, 99.212)=6.7651, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
Monitoring Year
1999
2005
2006
2007
2008
2009
2010
2011
2013

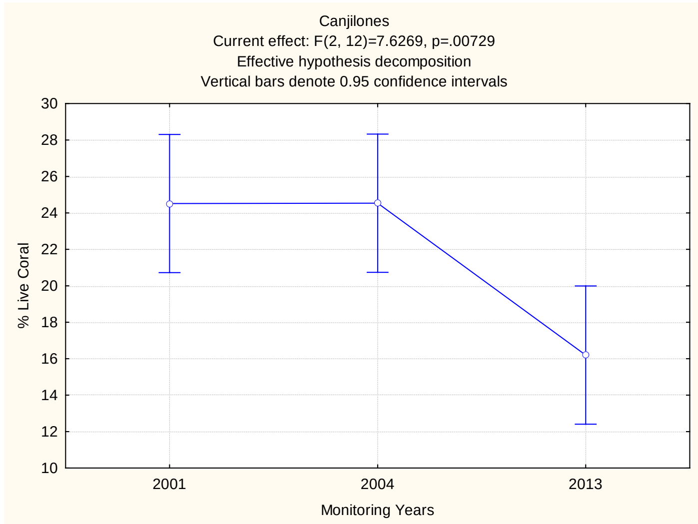

Cayo Aurora
Current effect: F(1, 8)=.13278, p=.72501
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
Monitoring Years
2011
2013

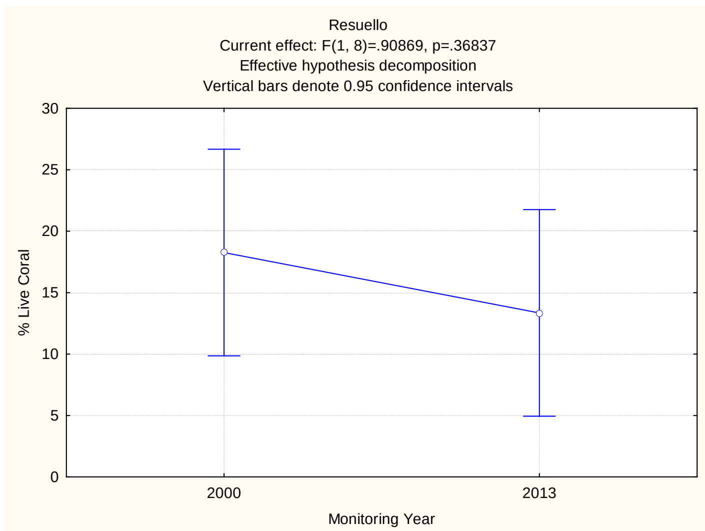

Caja de Muerto 10m
Wilks lambda=.06010, F(24, 99.212)=6.7651, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
Monitoring Year
1999
2005
2006
2007
2008
2009
2010
2011
2013

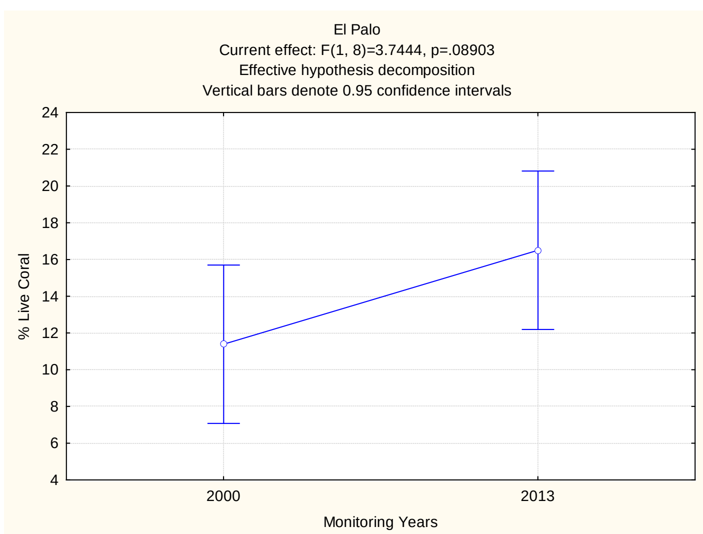

Derrumbadero 20m
Wilks lambda=.06010, F(24, 99.212)=6.7651, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
0
5
10
15
20
25
30
35
40
45
50
55
1999
2005
2006
2007
2008
2009
2010
2011
2013
Monitoring Year


El Seco
Current effect: F(1, 8)=2.9962, p=.12171
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
28
30
32
34
36
38
40
42
44
46
48
50
52
2011
2013
Monitoring Years

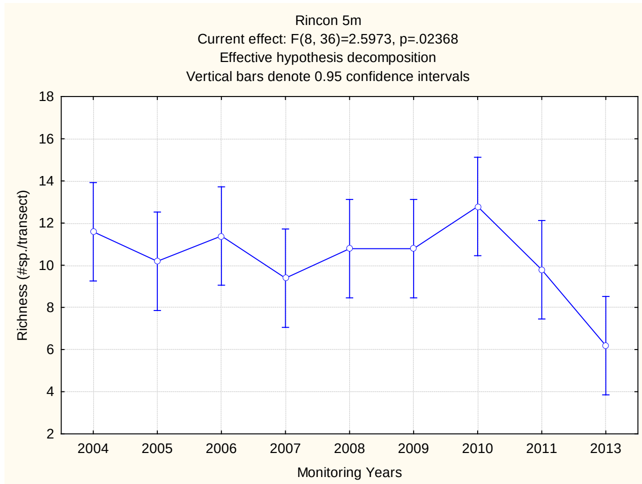

Boya Esperanza
Current effect: F(2, 12)=5.3188, p=.02219
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
0
5
10
15
20
25
30
35
40
45
50
55
2001
2004
2013
Monitoring Years

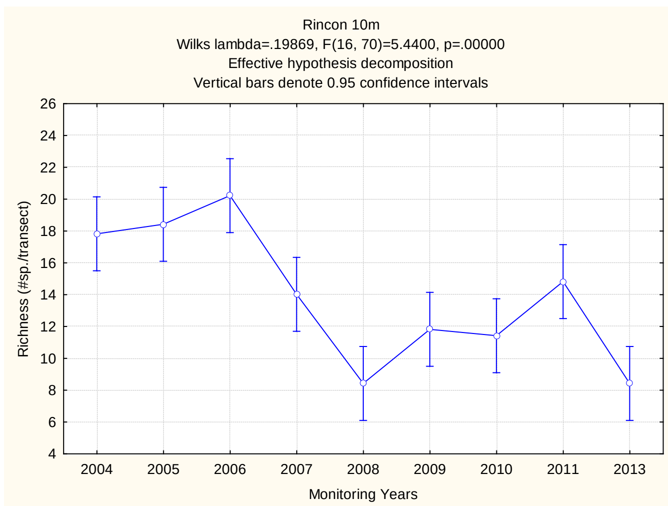

Canjilones
Current effect: F(2, 12)=7.6269, p=.00729
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
30
28
26
24
22
20
18
16
14
12
10
2001
2004
2013
Monitoring Years

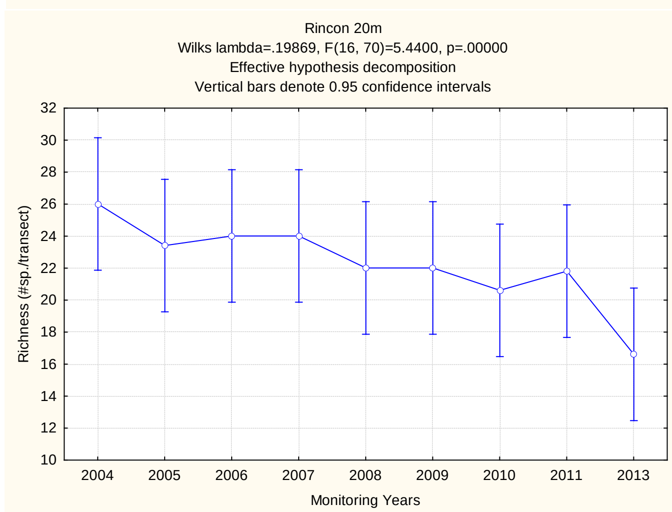

Resuello
Current effect: F(1, 8)=.90869, p=.36837
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
30
25
20
15
10
5
0
2000
2013
Monitoring Year

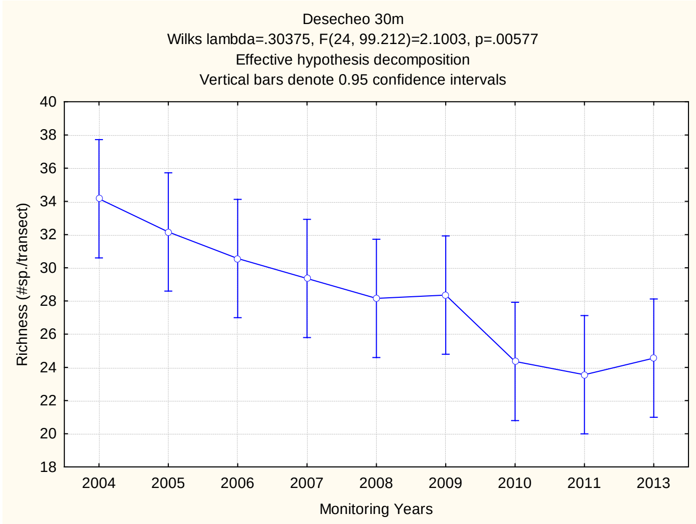

El Palo
Current effect: F(1, 8)=3.7444, p=.08903
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
24
22
20
18
16
14
12
10
8
6
4
2000
2013
Monitoring Years

Appendix 3. Analysis of variance (ANOVA) procedure testing differences of fish species richness in annual monitoring surveys through 2013.

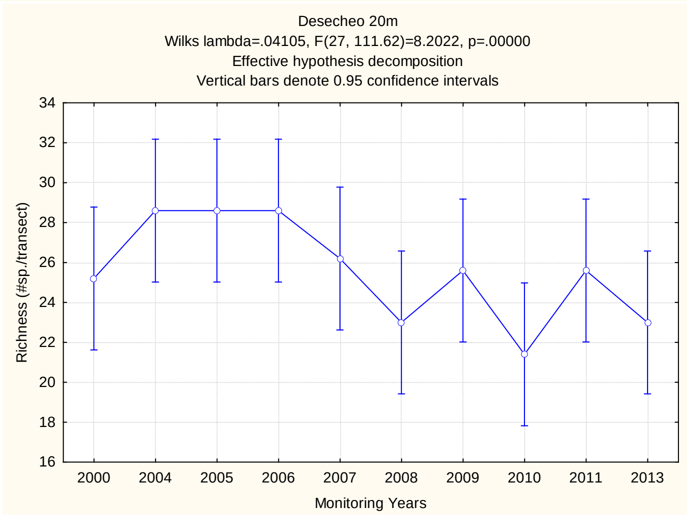




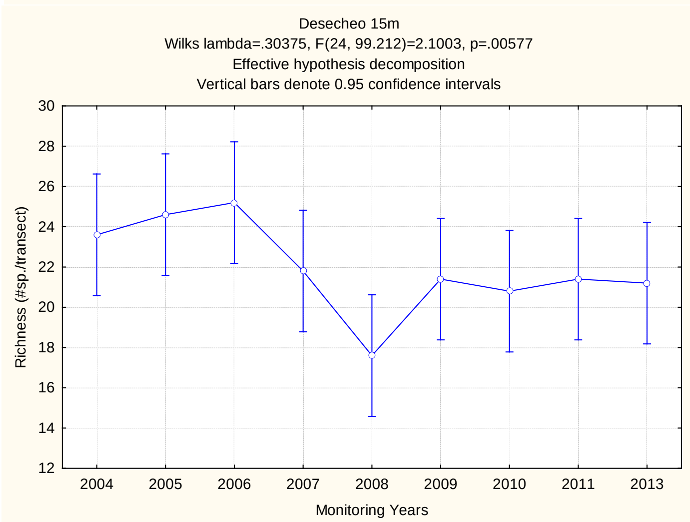




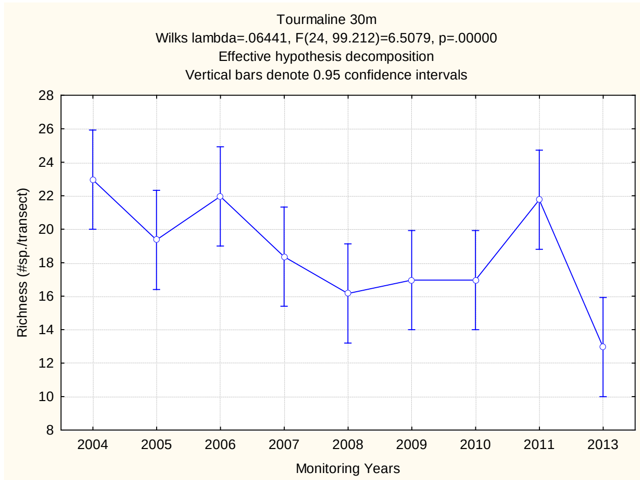
Desecheo 30m
Wilks lambda=.30375, F(24, 99.212)=2.1003, p=.00577
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
Monitoring Years

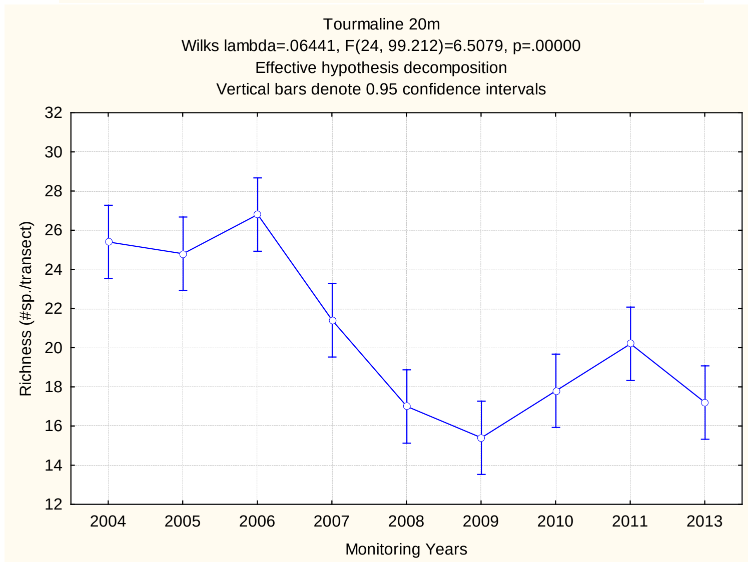


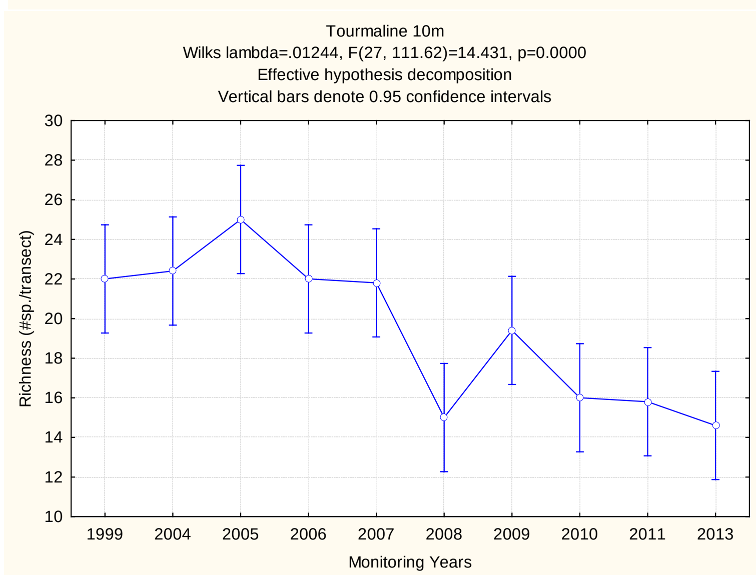
Desecheo 20m
Wilks lambda=.04105, F(27, 111.62)=8.2022, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
Monitoring Years

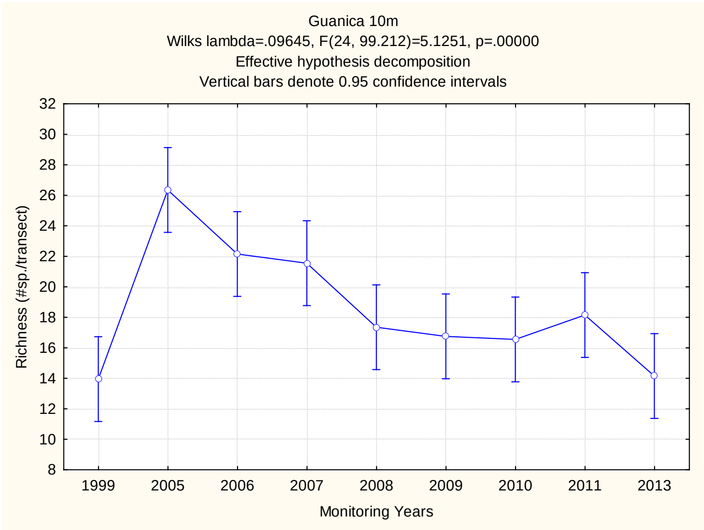


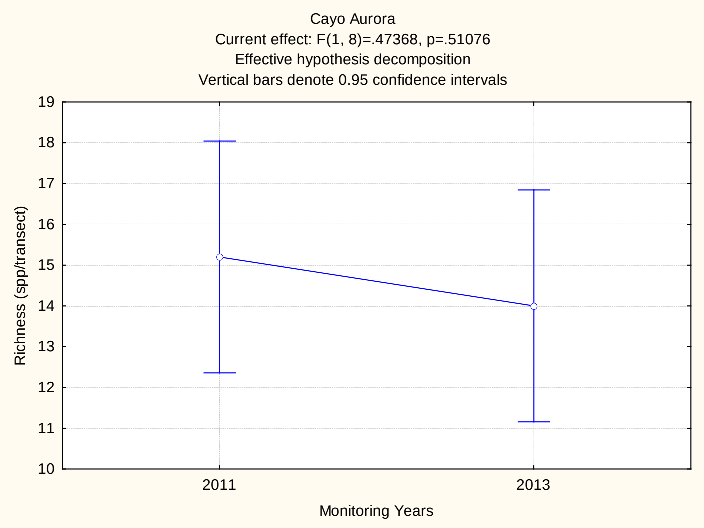
Desecheo 15m
Wilks lambda=.30375, F(24, 99.212)=2.1003, p=.00577
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
Monitoring Years

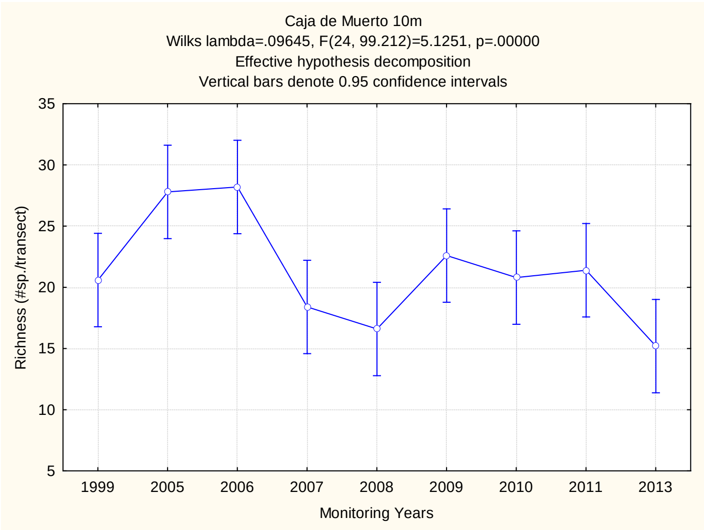

Tourmaline 30m
Wilks lambda=.06441, F(24, 99.212)=6.5079, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
Monitoring Years
2004
2005
2006
2007
2008
2009
2010
2011
2013

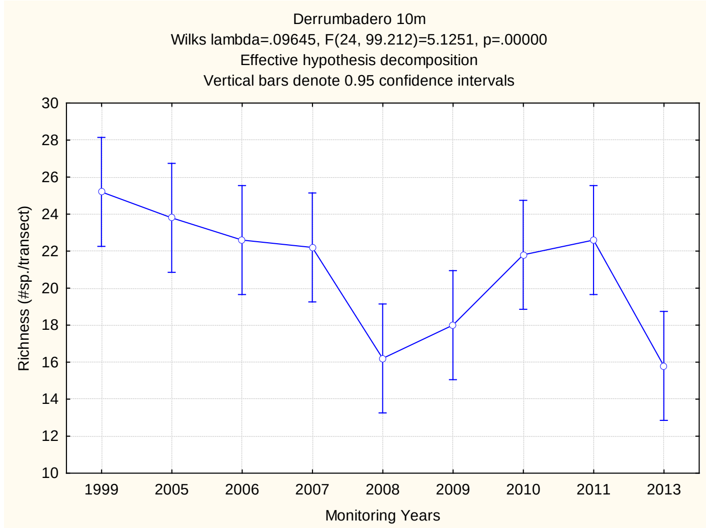

Tourmaline 20m
Wilks lambda=.06441, F(24, 99.212)=6.5079, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
Monitoring Years
2004
2005
2006
2007
2008
2009
2010
2011
2013

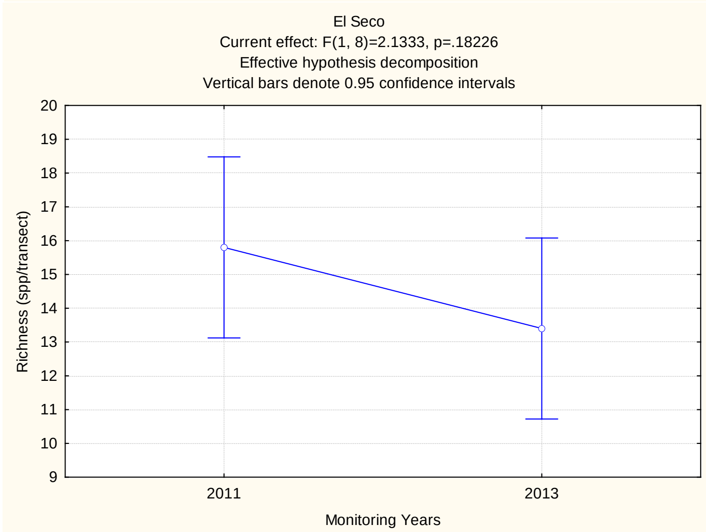

Tourmaline 10m
Wilks lambda=.01244, F(27, 111.62)=14.431, p=0.0000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
Monitoring Years
1999
2004
2005
2006
2007
2008
2009
2010
2011
2013

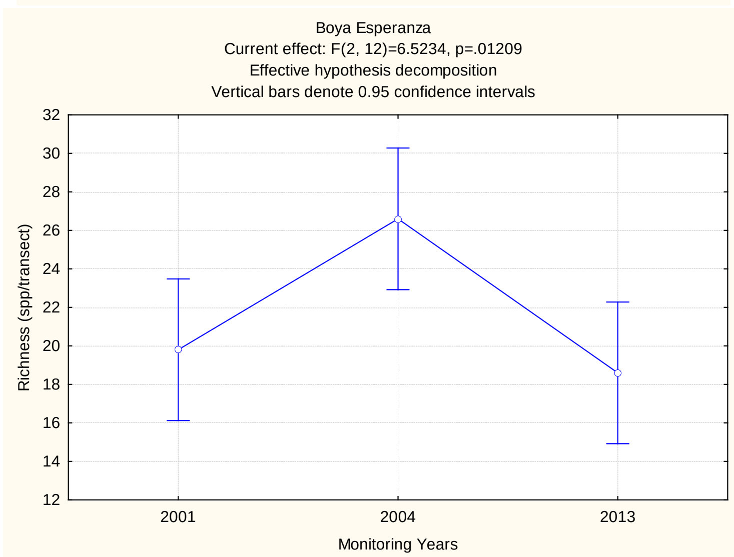

Guanica 10m
Wilks lambda=.09645, F(24, 99.212)=5.1251, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
32
30
28
26
24
22
20
18
16
14
12
10
8
1999
2005
2006
2007
2008
2009
2010
2011
2013
Monitoring Years

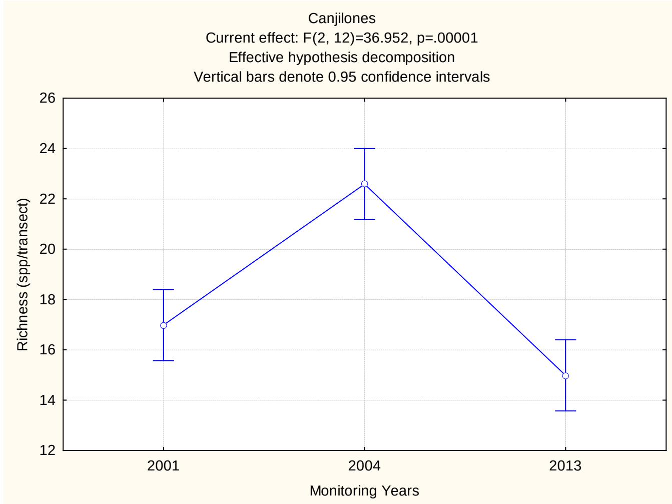

Cayo Aurora
Current effect: F(1, 8)=.47368, p=.51076
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (spp/transect)
19
18
17
16
15
14
13
12
11
10
2011
2013
Monitoring Years

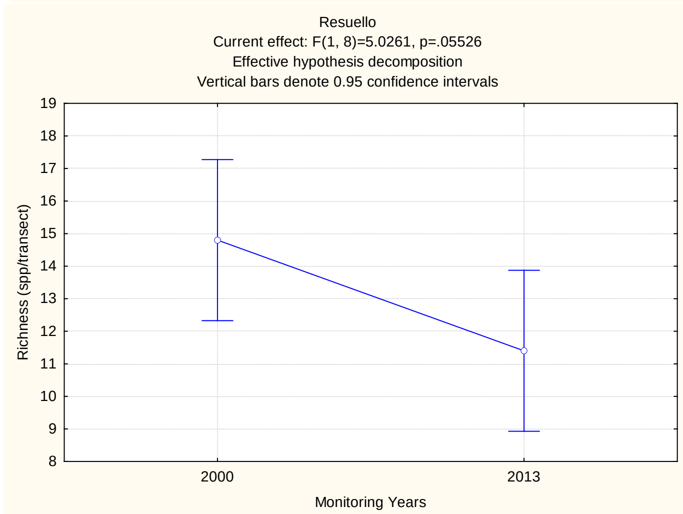

Caja de Muerto 10m
Wilks lambda=.09645, F(24, 99.212)=5.1251, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
35
30
25
20
15
10
5
1999
2005
2006
2007
2008
2009
2010
2011
2013
Monitoring Years

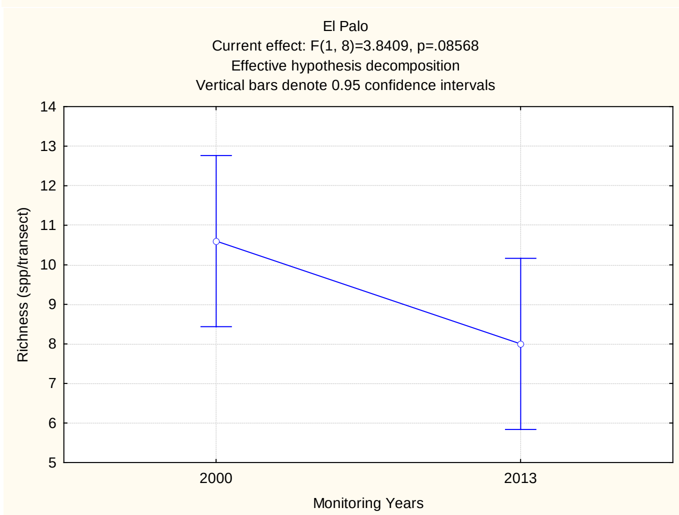

Derrumbadero 10m
Wilks lambda=.09645, F(24, 99.212)=5.1251, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
30
28
26
24
22
20
18
16
14
12
10
1999
2005
2006
2007
2008
2009
2010
2011
2013
Monitoring Years


El Seco
Current effect: F(1, 8)=2.1333, p=.18226
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (spp/transect)
20
19
18
17
16
15
14
13
12
11
10
9
2011
2013
Monitoring Years

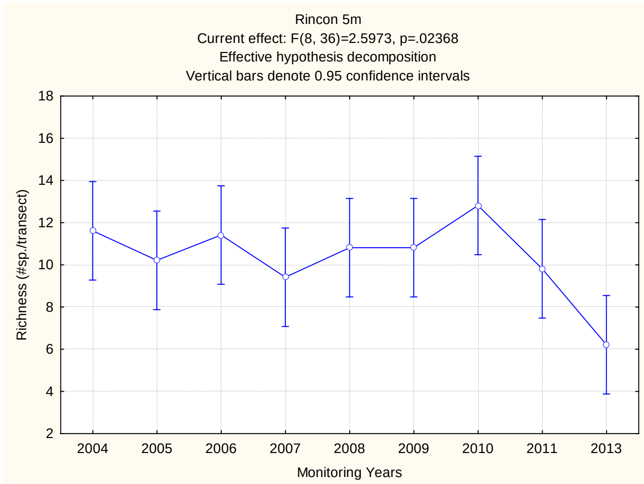

Boya Esperanza
Current effect: F(2, 12)=6.5234, p=.01209
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (spp/transect)
32
30
28
26
24
22
20
18
16
14
12
2001
2004
2013
Monitoring Years

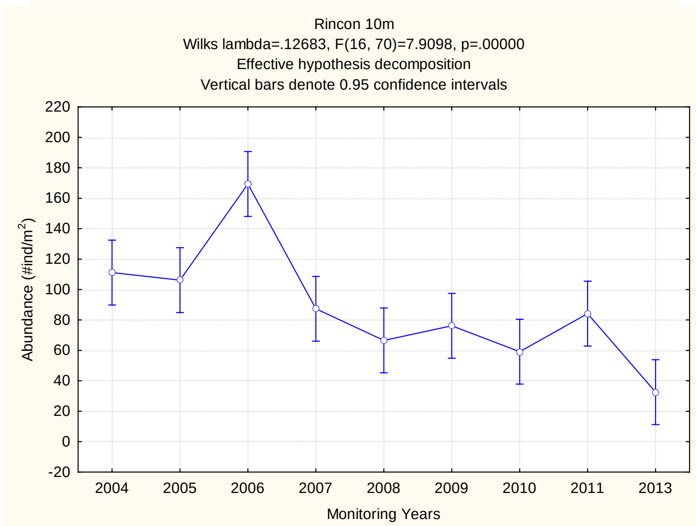

Canjilones
Current effect: F(2, 12)=36.952, p=.00001
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (spp/transect)
26
24
22
20
18
16
14
12
2001
2004
2013
Monitoring Years

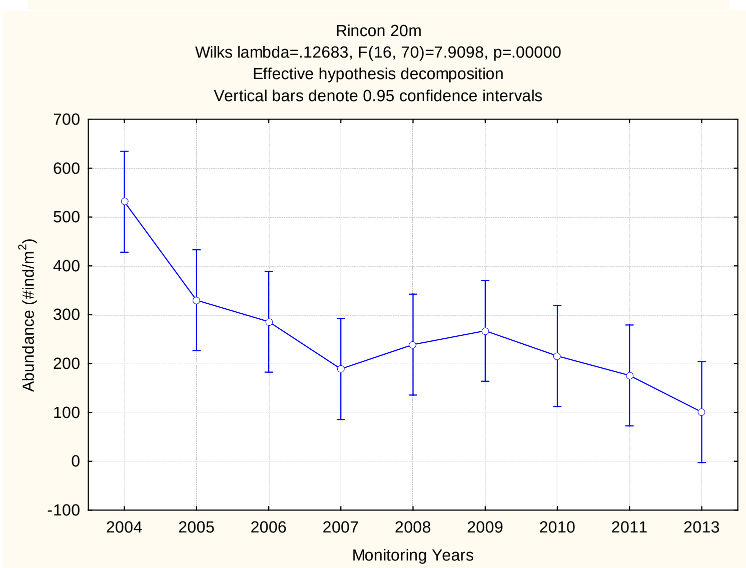

Resuello
Current effect: F(1, 8)=5.0261, p=.05526
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (spp/transect)
19
18
17
16
15
14
13
12
11
10
9
8
2000
2013
Monitoring Years

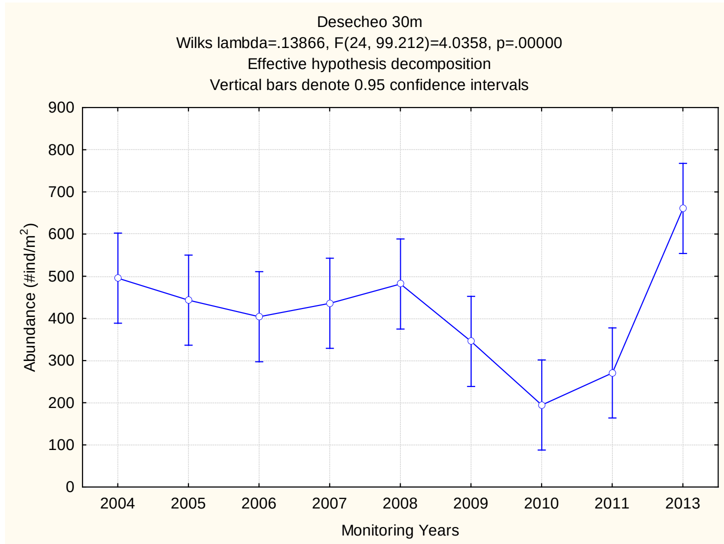

El Palo
Current effect: F(1, 8)=3.8409, p=.08568
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (spp/transect)
14
13
12
11
10
9
8
7
6
5
2000
2013
Monitoring Years

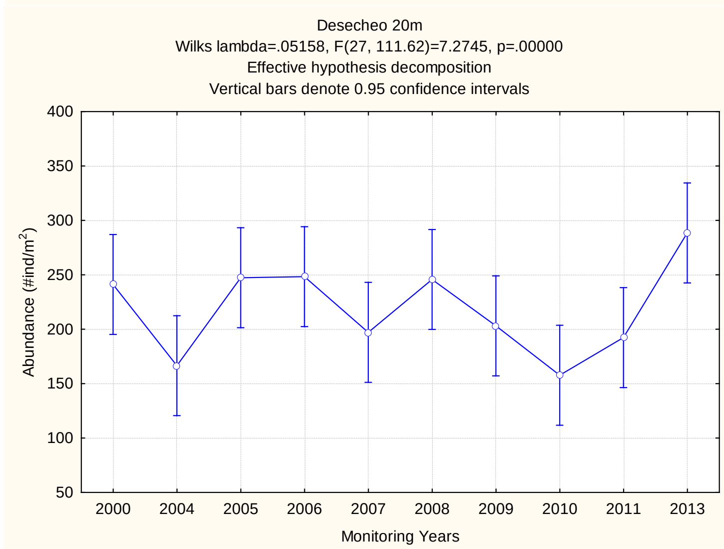
Appendix 4. Analysis of variance (ANOVA) procedure testing differences of total fish abundance in annual monitoring surveys through 2013.

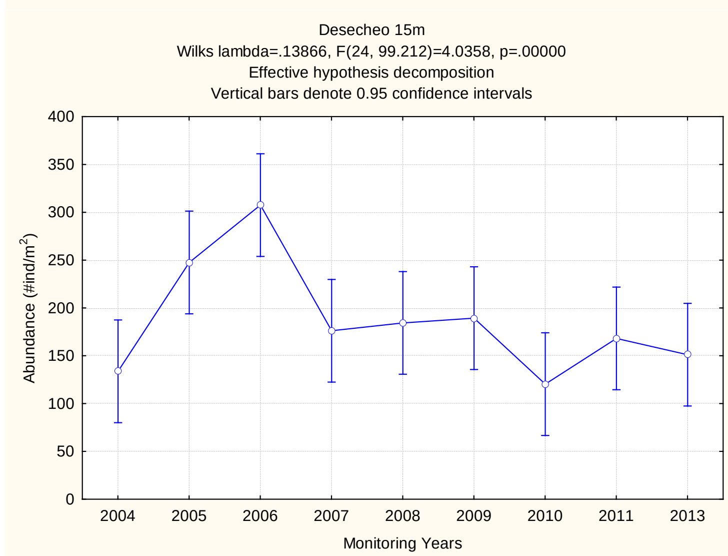


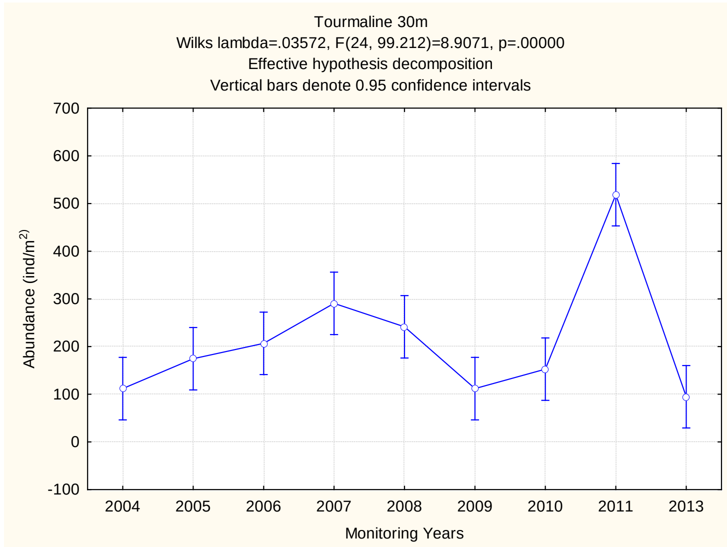


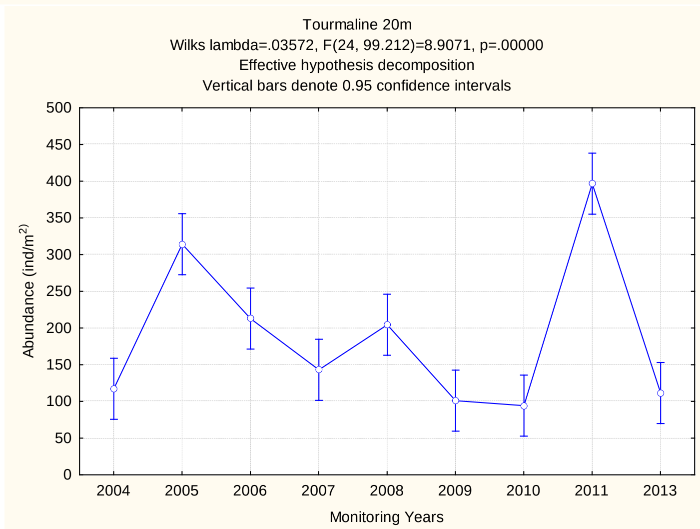


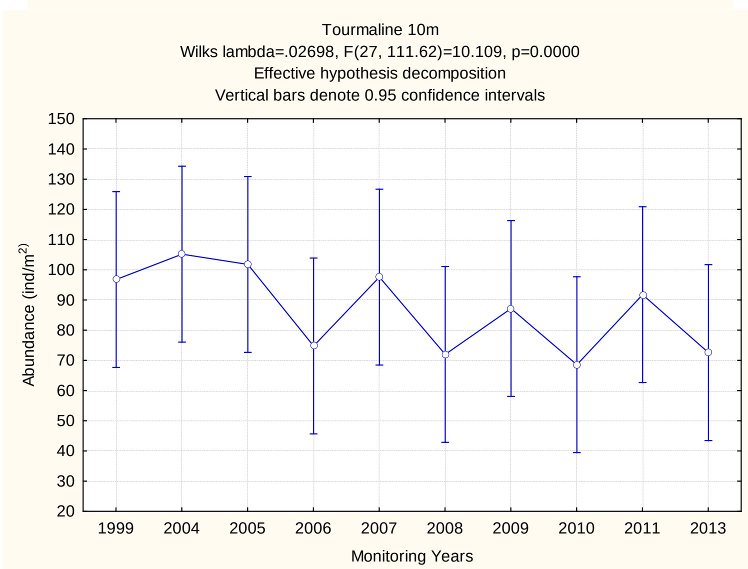

Desecheo 30m
Wilks lambda=.13866, F(24, 99.212)=4.0358, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m²)
0
100
200
300
400
500
600
700
800
900
2004
2005
2006
2007
2008
2009
2010
2011
2013
Monitoring Years

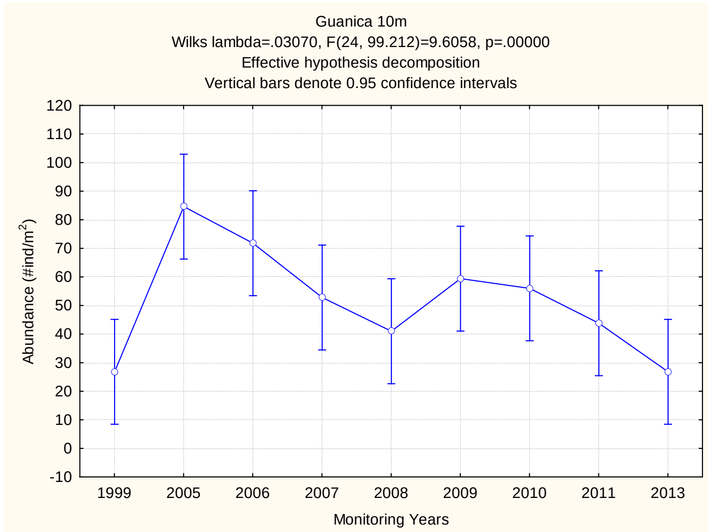

Desecheo 20m
Wilks lambda=.05158, F(27, 111.62)=7.2745, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m²)
50
100
150
200
250
300
350
400
2000
2004
2005
2006
2007
2008
2009
2010
2011
2013
Monitoring Years

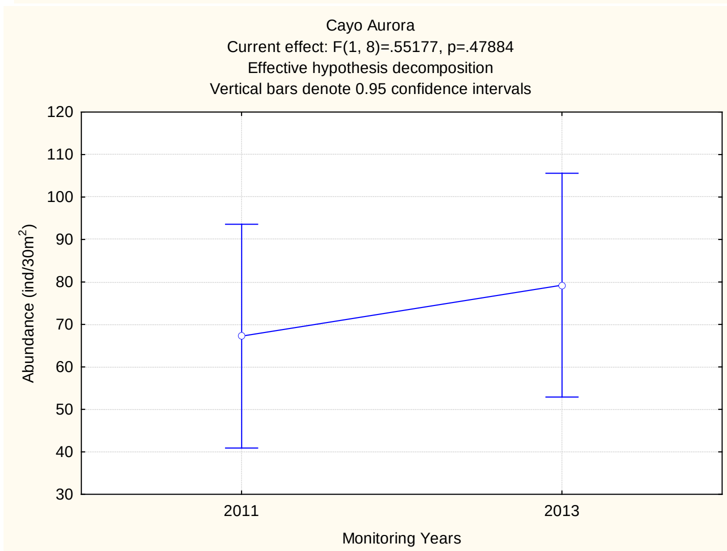

Desecheo 15m
Wilks lambda=.13866, F(24, 99.212)=4.0358, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m²)
0
50
100
150
200
250
300
350
400
2004
2005
2006
2007
2008
2009
2010
2011
2013
Monitoring Years

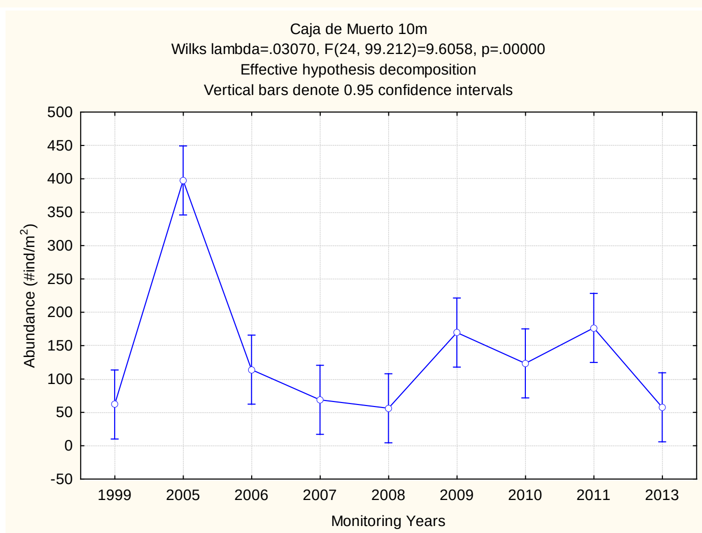

Tourmaline 30m
Wilks lambda=.03572, F(24, 99.212)=8.9071, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/m2)
700
600
500
400
300
200
100
0
-100
2004
2005
2006
2007
2008
2009
2010
2011
2013
Monitoring Years

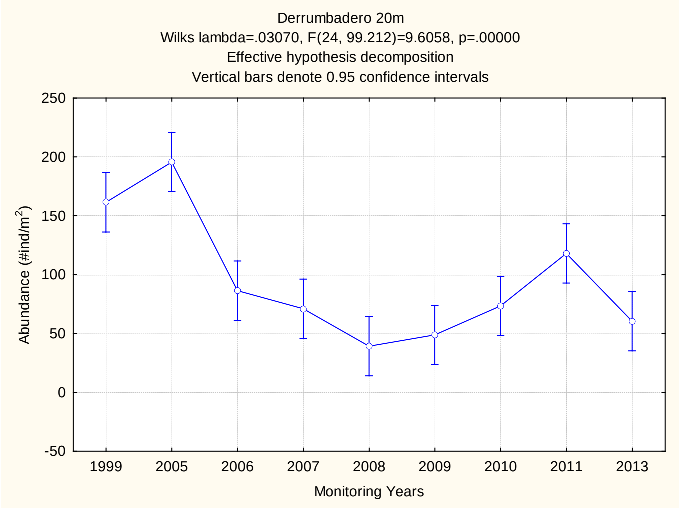

Tourmaline 20m
Wilks lambda=.03572, F(24, 99.212)=8.9071, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/m2)
500
450
400
350
300
250
200
150
100
50
0
2004
2005
2006
2007
2008
2009
2010
2011
2013
Monitoring Years

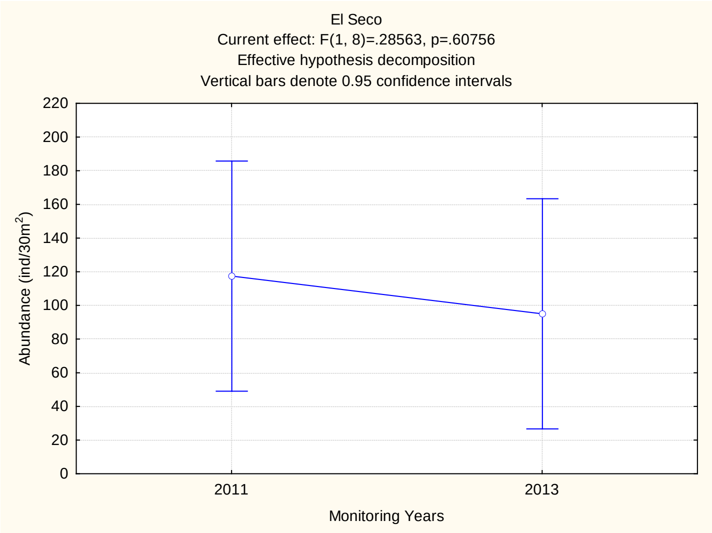

Tourmaline 10m
Wilks lambda=.02698, F(27, 111.62)=10.109, p=0.0000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/m2)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
1999
2004
2005
2006
2007
2008
2009
2010
2011
2013
Monitoring Years

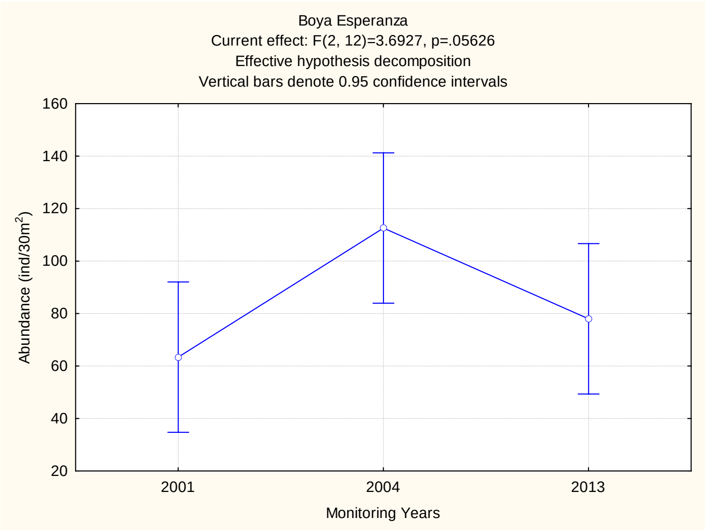

Guanica 10m
Wilks lambda=.03070, F(24, 99.212)=9.6058, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
Monitoring Years
1999
2005
2006
2007
2008
2009
2010
2011
2013

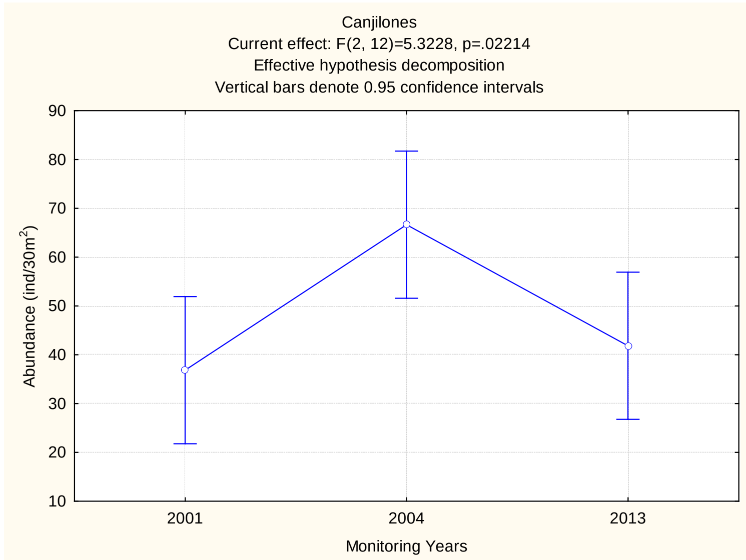

Cayo Aurora
Current effect: F(1, 8)=.55177, p=.47884
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/30m2)
Monitoring Years
2011
2013

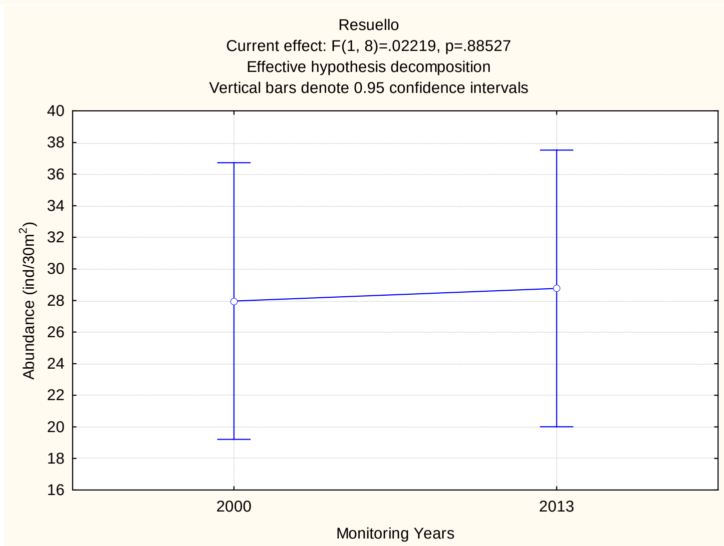

Caja de Muerto 10m
Wilks lambda=.03070, F(24, 99.212)=9.6058, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
Monitoring Years
1999
2005
2006
2007
2008
2009
2010
2011
2013

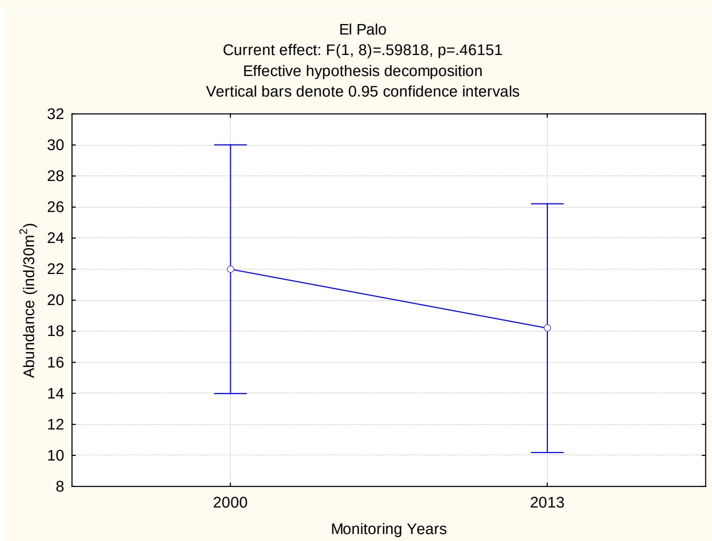

Derrumbadero 20m
Wilks lambda=.03070, F(24, 99.212)=9.6058, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
Monitoring Years
1999
2005
2006
2007
2008
2009
2010
2011
2013


El Seco
Current effect: F(1, 8)=.28563, p=.60756
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/30m2)
Monitoring Years
2011
2013


Boya Esperanza
Current effect: F(2, 12)=3.6927, p=.05626
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/30m2)
Monitoring Years
2001
2004
2013


Canjilones
Current effect: F(2, 12)=5.3228, p=.02214
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/30m2)
90
80
70
60
50
40
30
20
10
2001
2004
2013
Monitoring Years


Resuello
Current effect: F(1, 8)=.02219, p=.88527
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/30m2)
40
38
36
34
32
30
28
26
24
22
20
18
16
2000
2013
Monitoring Years


El Palo
Current effect: F(1, 8)=.59818, p=.46151
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
Monitoring Years