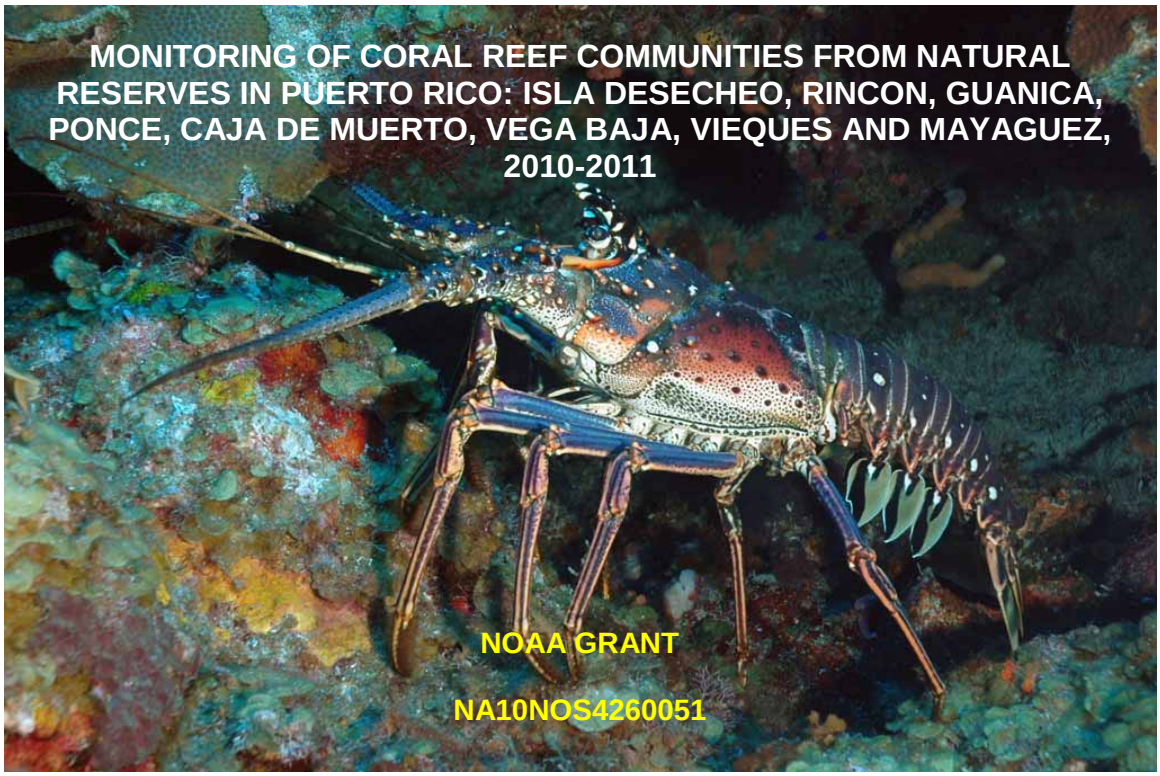
FINAL REPORT



MONITORING OF CORAL REEF COMMUNITIES FROM NATURAL RESERVES IN PUERTO RICO: ISLA DESECHEO, RINCON, GUANICA, PONCE, CAJA DE MUERTO, VEGA BAJA, VIEQUES AND MAYAGUEZ, 2010-2011

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I Executive Summary

A total of 15 reefs from six Natural Reserves (Desecheo, Rincón, Mayaguéz, Guánica, Caja de Muerto, and Ponce) and two new additional sites (Vieques and Vega Baja) were included in the 2011 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 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), and Derrumbadero Reef (Ponce) presented statistically significant differences of live coral cover between annual monitoring surveys. Differences were mostly associated with a sharp decline measured during 2006, after a severe regional coral bleaching event that affected Puerto Rico and the U. S. Virgin Islands during August through October 2005. Statistically significant reductions of live coral cover continued as lingering effects of the regional bleaching mortality until 2007 at Isla Desecheo and Cayo Coral. The decline of (total) live coral cover at the reef community level during 2006 was largely driven by mortality of Boulder Star Coral, *Montastraea 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 and abiotic categories were measured. During the present 2011 monitoring survey live coral cover remained stable at all reefs monitored and coral bleaching at the reef community level was not observed on any reef surveyed. The *Acropora palmata* fringing reef of Tres Palmas in Rincon is still infected by 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 reef substrate cover by *A. palmata* was stable relative to 2009, given favorable conditions for the disease massive coral mortality could ocurr. Baseline surveys at Cayo Aurora in Guanica, Cibuco Reef in Vega Baja and El Seco Reef in Vieques now allow inferences to be made regarding the ecological health of a pristine Elkhorn coral (*Acropora palmata*) biotope, a Boulder Star and Finger Coral dominated reef influenced by estuarine conditions in the north coast, and of a pristine *Montastraea franksi* mesophotic reef that may be the largest continuous coral reef system in Puerto Rico.

Fish populations presented in the 2011 survey a general pattern of stable abundance relative to the 2008 - 2010 levels, except at Tourmaline (20 and 30 m stations) and Derrumbadero Reef (Ponce) at 20 m, where statistically significant increments of abundance relative to other annual surveys were observed. Abundance increments were all associated with population increments of Masked Goby, *Coryphopterus personatus*, a small numerically dominant species that exhibits highly aggregated distributions in the immediate vicinity of live coral heads. Major shifts of reef fish community structure were not observed during 2011, as many of the numerically dominant assemblages remained in place at most reefs monitored, which suggests that predation by Lionfish, *Pterois volitans* has not had any measurable effects on the fish community structure of reefs studied. Although in low abundance, large demersal (top predator) fishes have been observed during ASEC 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 2010-11 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 15 reef stations within six Natural Reserve sites in Puerto Rico (Isla Desecheo, Rincon, Mayaguez, Guánica, Isla Caja de Muertos and Ponce). Initial baseline characterization surveys for these sites were performed during 1999 - 2001 (García-Sais et al., 2001 a, b, c). This report also includes baseline characterizations of El Seco Reef in southeast Vieques, Cibuco Reef in Vega Baja and Aurora Reef in Guanica. Summarized time series data for all reef sites are here presented and analyzed. Detailed monitoring data is included only for the most recent 2010-11 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). 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 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* 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 and 2009-10 monitoring surveys (Garcia et al. 2008, 2009). 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).

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, stable species richness and taxonomic structure, but a trend of fluctuating differences of abundance within belt-transects in seven out of the 15 reef stations surveyed (García-Sais et al., 2007, 2008, 2009). 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*). It is uncertain at this point if such fluctuations of abundance by reef fishes closely associated with coral habitats were related to the severe coral mortality exhibited by reef systems after 2005. The recently stable and/or abundance increment trends exhibited by reef fish populations during recent recent surveys suggests that Linofish (*Pterois volitans*) predation pressure has not had any measurable effects upon the local coral reef fish communities at Natural Reserve sites surveyed. Although in low abundance, large demersal fishes that have been overfished during the last decades have been observed during ASEC surveys in several reefs. These include Yellowfin, Tiger, Jewfish, and Nassau Groupers (*Mycteroperca venenosa, M. tigris, Epinephelus itajara, E. striatus*), and the Cubera, Dog and Mutton Snappers (*Lutjanus cyanopterus, L. jocu, L. analis*).

III Methodology

The location of coral reef sites included in the PR monitoring program is shown in Figures 1 - 2. Table 1 presents the geographic coordinates and depths of reefs monitored.

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°22.706	67°29.199
	Botes	20	18°22.895	67°29.316
	Botes	15	18°22.920	67°29.300
Mayaguez				
	Tourmaline	30	18°09.985	67°16.581
	Tourmaline	20	18°09.910	67°16.512
	Tourmaline	10	18°09.791	67°16.416
Rincon				
	Tres Palmas	20	18°20.790	67°16.248
	Tres Palmas	10	18°20.832	67°16.206
	Tres Palmas	3	18°21.023	67°15.959
Ponce				
	Derrumbadero	20	17°54.240	66°36.515
Guanica				
	Cayo Coral	10	17°56.172	66°53.304
	Cayo Aurora	2 - 5	17° 56.214	66° 52.430
Caja de Muertos				
	West Reef	10	17°53.700	66°31.704
Vega Baja				
	Cibuco Reef	2 - 5	18° 29.350	66° 22.416
Isla de Vieques				
	El Seco	30	18° 08.321	65° 11.828

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 has 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 identified and 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.

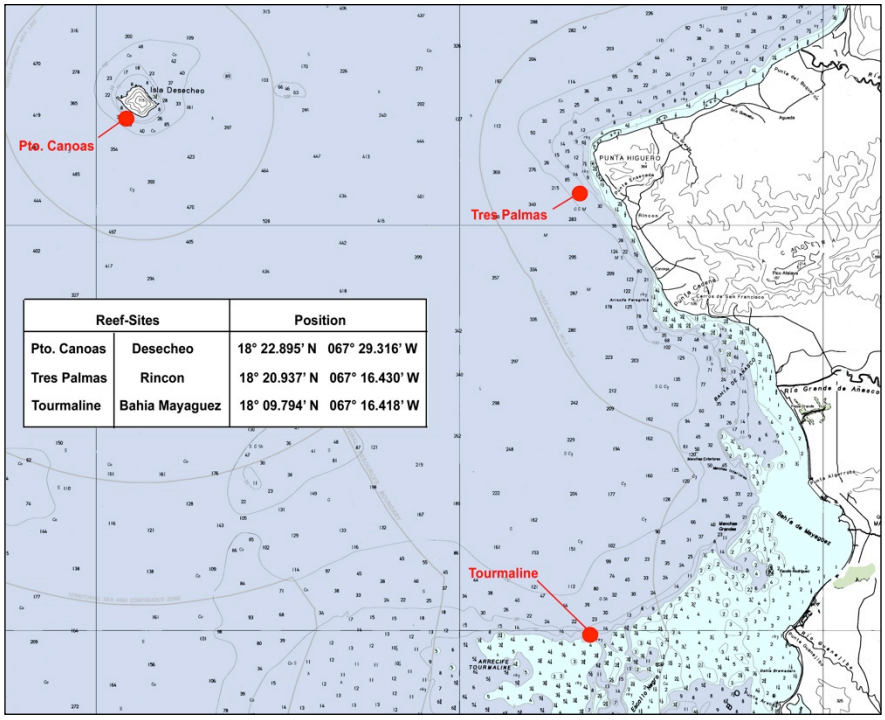


Figure 1. Location of west coast reef sites, Isla Desecheo, Mayaguez and Rincón

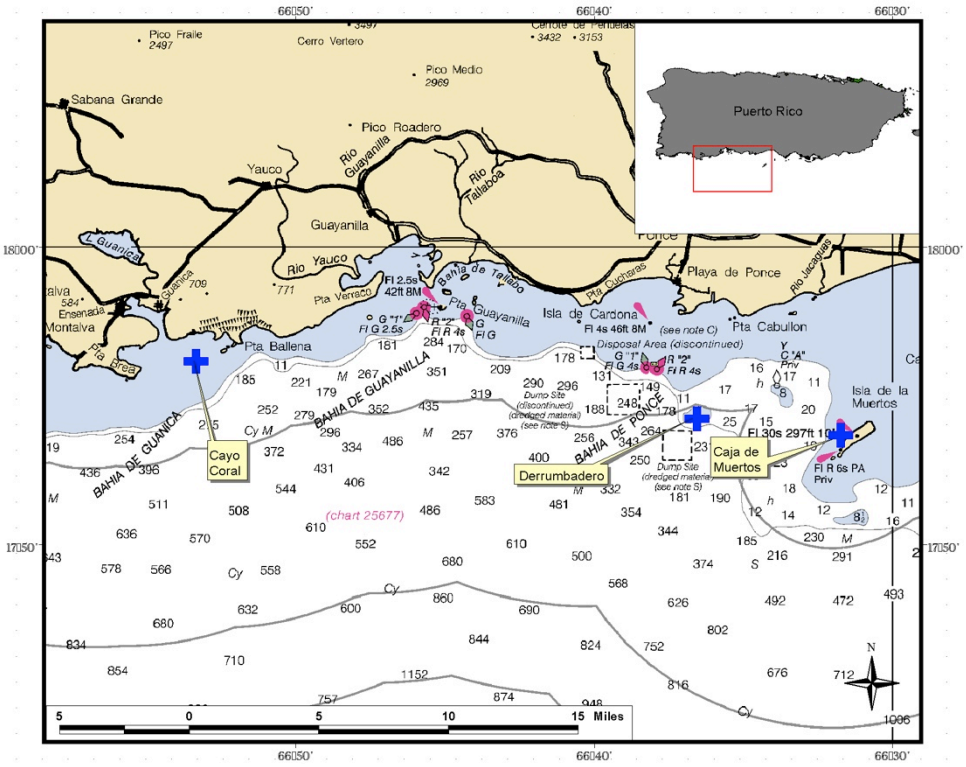


Figure 2. Location of south coast reef sites, Cayo Coral (Guánica), Derrumbadero and West Reef of Isla Caja de Muerto (Ponce)

Results

IV Baseline Characterization and Monitoring of Coral Reef Communities

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.

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

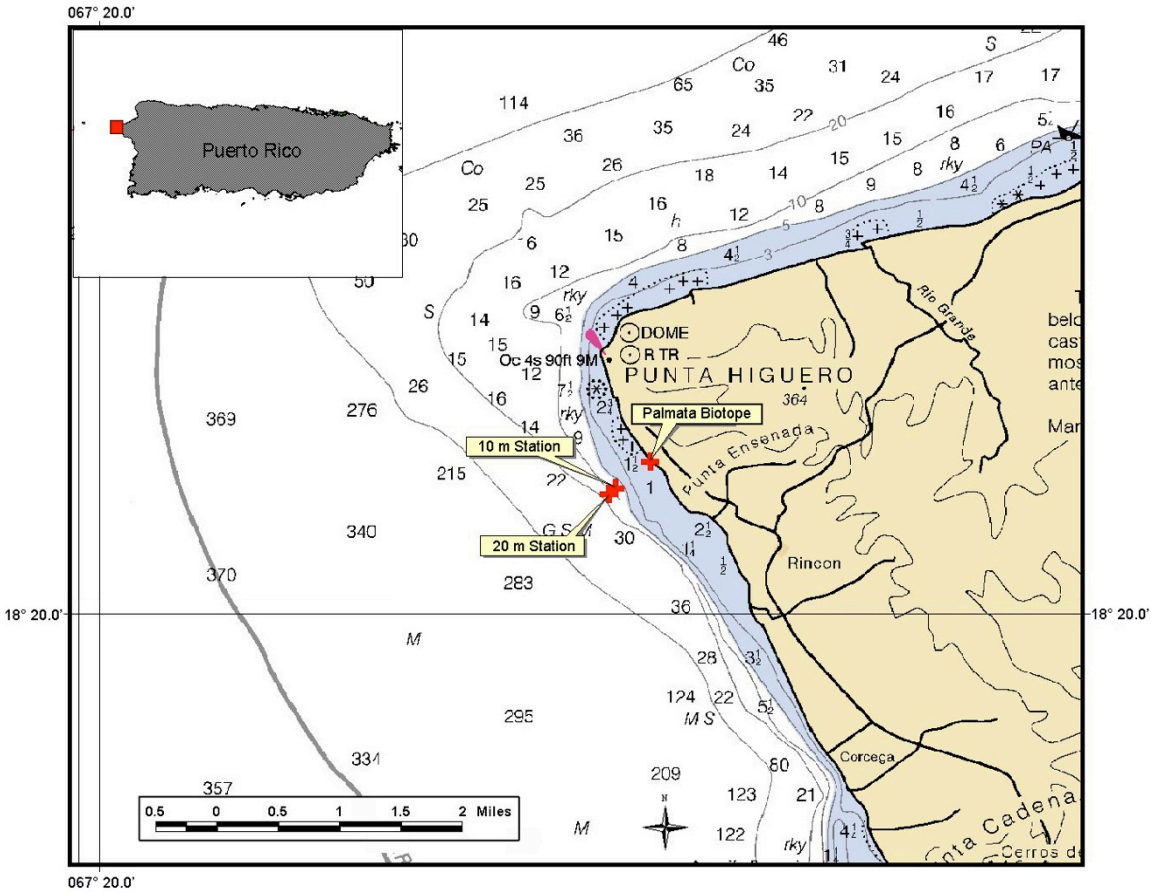


Figure 3. Location of coral reef monitoring stations off Tres Palmas, Rincón.

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 2008-09 survey. 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.

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). The percent of reef substrate cover by sessile-benthic categories along permanent transects during the present 2011 survey are presented in Table 2. Live coral cover averaged 28.7% (range: 12.8 – 56.6 %). Elkhorn Coral (*A. palmata*) was the dominant species with a mean substrate cover of 23.6 % (range: 2.7 – 55.6 %), representing 82.2 % of the total live coral cover. Five additional coral species (e.g. *Diploria strigosa, D. clivosa, P.*

Table 2. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon. September 2011. Depth: 2 - 5 m.

	Transects					
	1	2	3	4	5	**MEAN**
Rugosity (m)	2.6	5.0	1.7	2.2	2.4	**2.8**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	22.9	16.4	22.8	22.0	5.7	**18.0**
Sand				4.1	2.3	**1.3**
Gaps				1.7		**0.3**
Total Abiotic	22.9	16.4	22.8	27.8	7.9	**19.6**
Benthic Algae						
Turf-mixed assemblage	48.5	26.1	43.1	46.7	77.3	**48.3**
Total Benthic Algae	48.5	26.1	43.1	46.7	77.3	**48.3**
Gorgonians		0.9				
Total gorgonians	0.0	0.9	0.0	0.0	0.0	**0.2**
Zoanthids						
Palythoa caribaeorum	15.9					**3.2**
Live Stony Corals						
Acropora palmata	10.6	55.6	24.6	24.4	2.7	**23.6**
Diploria strigosa	2.1	1.0	2.7		7.4	**2.6**
Montastraea cavernosa					3.4	**0.7**
Montastraea annularis			3.4			**0.7**
Porites astreoides			0.6	1.2	1.3	**0.6**
Diploria clivosa			2.7			**0.5**
Total Stony Corals	12.8	56.6	34.0	25.6	14.8	**28.7**

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

astreoides, M. cavernosa and M. annularis were intersected by linear transects during our survey. A total of 17 species of stony corals were identified from the fringing reef. Hard ground substrates, including dead coral sections not colonized by corals were mostly covered by turf algae (mean cover: 48.3 %). Fleshy macroalgae (*Dictyota sp*., *Valonia sp., Stypopodium sp*.) and red coralline algae (*Amphiroa sp*.) were observed outside transect areas. The encrusting zoanthid, *Palythoa caribdea* was present in one transect with a mean cover of 3.2 %. The encrusting gorgonian, *Erythropodium*

caribaeorum was observed outside transects. Abiotic categories, associated with reef overhangs, gaps or holes and sand represented 19.6 % of the reef substrate cover. Vertically projected soft corals (gorgonian) were present but in low abundance within 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 has declined 27.2 % during the last three surveys to a present mean reef substrate cover of 28.7 %. Differences between monitoring surveys were not statistically significant (ANOVA; $p = 0.612$; see Appendix 2) 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). A mild, yet consistent trend of declining cover by live A. palmata has continued until the present 2010-11 survey.

The reduction of reef substrate cover by *A. palmata* may be 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.

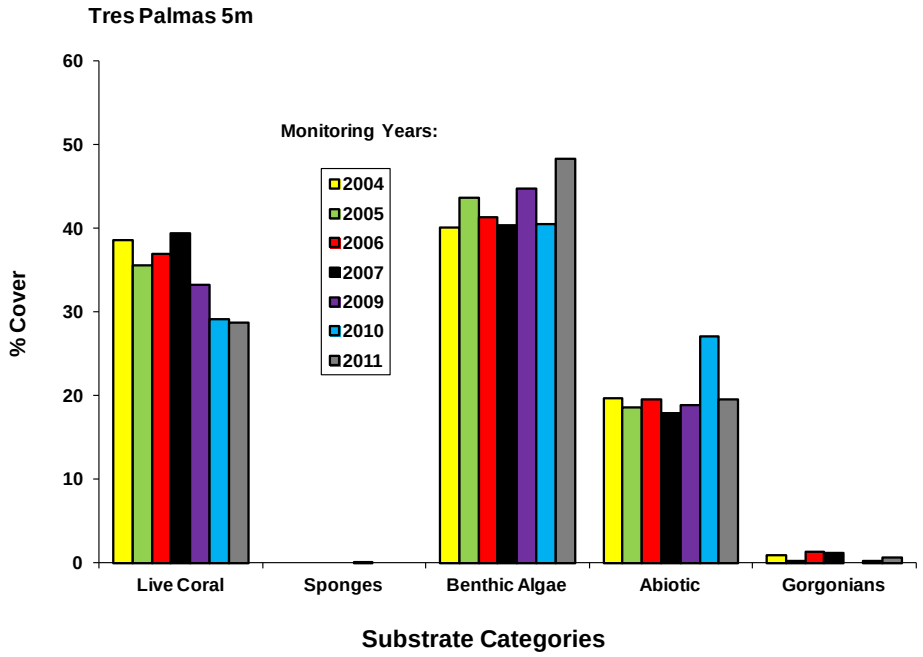


Figure 4. Monitoring trends (2004 – 2011) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon, 2 - 5 m depth.

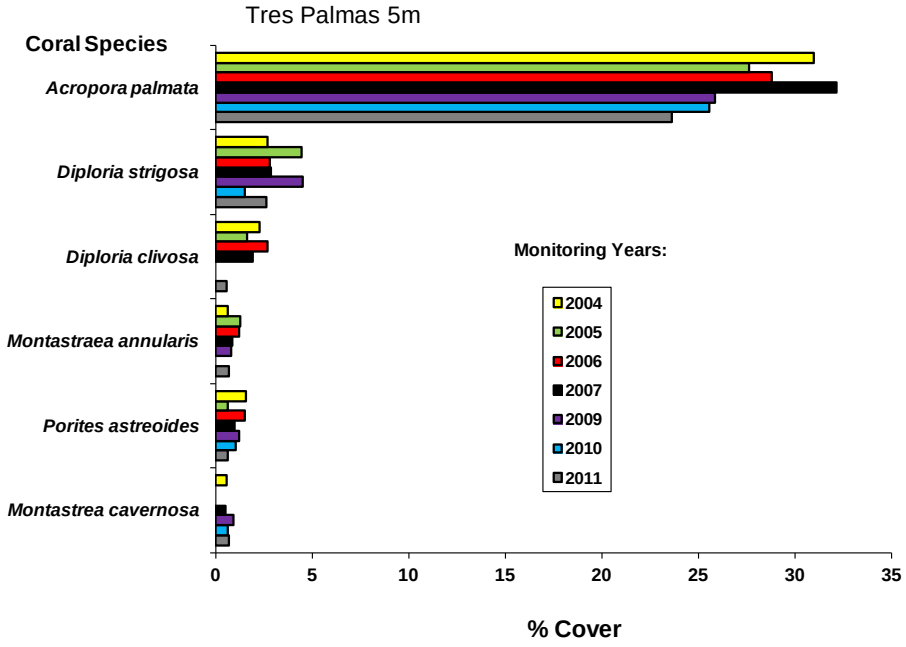


Figure 5. Monitoring trends (2004 – 2011) of mean substrate cover by stony coral species at Tres Palmas Reef, Rincon, 2 - 5 m depth.

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 2010-11 monitoring survey, 49 fish species, including 25 present within belt-transects were identified from the fringing reef. The mean abundance of individuals was 41.8 Ind/30 m^2 (range: 22 - 67 Ind/30 m^2), and the mean number of species per transect was 9.8 (range: 5 - 16). The combined abundance of five species represented 74.2 % of the mean abundance within belt-transects (Table 3). The most abundant species was the Dusky Damselfish (*Stegastes dorsopunicans*) with a mean of 13.8 Ind/30 m^2 followed by the Bluehead Wrasse (*Thalassoma bifasciatum*), Redlip Blenny (*Ophioblennius atlanticus*), Clown Wrasse (*Halichoeres maculipinna*) and Yellowtail Damselfish (*Microspathodon chrysurus*). With the exception of bluehead wrasse, these species were present within all five belt-transects surveyed and along with the Blue Tang, Sargent Major, Ocean Surgeon, Glasseye Sweeper, Bermuda Chub and the Yellowtail and Stoplight Parrotfishes appear to comprise the main resident demersal fish assemblage. 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 (*Acanthurus coeruleus*), which occur in such high densities that influence (increase) abundances within belt-transects during some surveys, particularly during the 2009 and 2010 (Figure 6). During the present 2011 survey, fish abundance was within the 95% confidence interval of surveys performed during the 2004-2008 period (see Appendix 3).

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

Table 3. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef 5m, Rincon. September 2011. Depth: 2-5 m

		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Stegastes dorsopunicans	Dusky Damselfish	10	16	18	13	12	**13.8**
Thalassoma bifasciatum	Bluehead Wrasse	10	0	15	0	0	**5**
Ophioblennius atlanticus	Redlip Blenny	8	5	6	2	3	**4.8**
Halichoeres maculipina	Clown Wrasse	10	5	2	2	0	**3.8**
Microspathodon chrysurus	Yellowtail Damselfish	5	6	2	2	3	**3.6**
Acanthurus coeruleus	Blue Tang	3	0	0	5	3	**2.2**
Abudefduf sexatilis	Sargent Major	3	0	1	0	0	**0.8**
Acanthures bahianus	Ocean Surgeon	3	1	0	0	0	**0.8**
Pempheris schomburgki	Glasseye Sweeper	2	0	0	2	0	**0.8**
Sparisoma aurofrenatum	Redband Parrotfish	4	0	0	0	0	**0.8**
Bodianus rufus	Spanish Hogfish	1	0	0	2	0	**0.6**
Caranx ruber	Bar Jack	1	0	0	2	0	**0.6**
Sparisoma rubripinne	Yellowtail Parrotfish	0	0	1	2	0	**0.6**
Amblycirrhitus pinos	Redspotted Hawkfish	3	0	0	0	0	**0.6**
Haemulon flavolineatum	French Grunt	0	0	0	2	0	**0.4**
Halichoeres bivittatus	Slipery Dick	0	1	0	0	1	**0.4**
Halichoeres garnoti	Yellowhead Wrasse	0	0	0	2	0	**0.4**
Mulloidichthys martinicus	Yellow Goatfish	0	0	0	2	0	**0.4**
Sargocentron vexillarium	Dusky Squirrelfish	0	0	0	1	0	**0.2**
Holocentrus rufus	Longspine Squirrelfish	0	1	0	0	0	**0.2**
Kyphosys sectatrix	Bermuda Chub	1	0	0	0	0	**0.2**
Scarus vetula	Queen Parrotfish	0	0	1	0	0	**0.2**
Sparisoma viride	Stoplight Parrotfish	1	0	0	0	0	**0.2**
Stegastes leucostictus	Beaugregory	1	0	0	0	0	**0.2**
Scarus iserti	Stripped Parrotfish	1	0	0	0	0	**0.2**
	TOTAL INDIVIDUALS	67	35	46	39	22	**41.8**
	TOTAL SPECIES	16	7	8	13	5	**9.8**

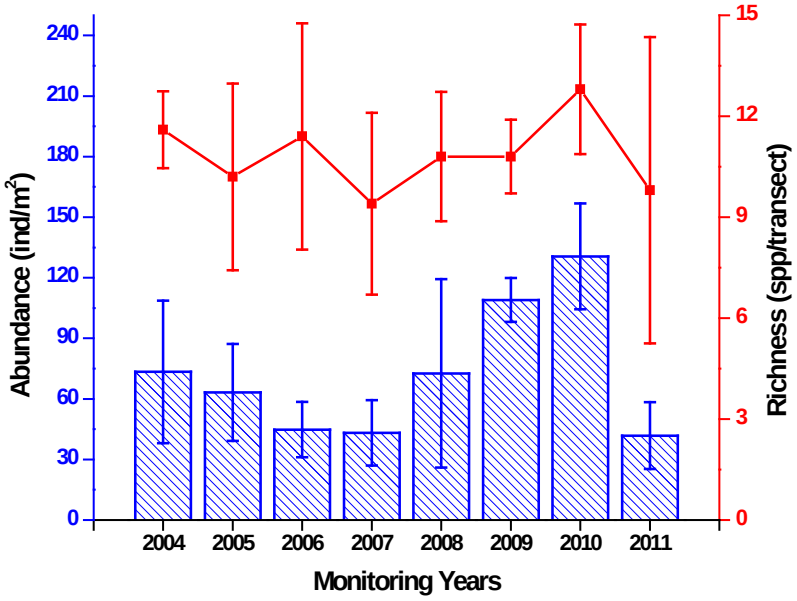


Figure 6. Monitoring trends (2004 – 2011) of fish species richness and abundance at Tres Palmas Reef, Rincon 2-5 m.

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 ASEC survey (Table 4), as well as during previous surveys (García-Sais et al., 2004 a, 2005, 2006, 2007, 2009, 2010), suggesting that this shallow reef functions as a nursery area for these commercially important species. This reef is also the recruitment, nursery and residential habitat of the Yellowtail Damselfish (*Microspathodon chrysurus*), which in its early juvenile stage (known as "Jewel Damselfish") is commercially important as an aquarium trade target species. One Hawksbill Turtle (*Eretmochelys imbricata*) was reported during the 2004 baseline survey (García-Sais et al., 2004a).

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: September 2011

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

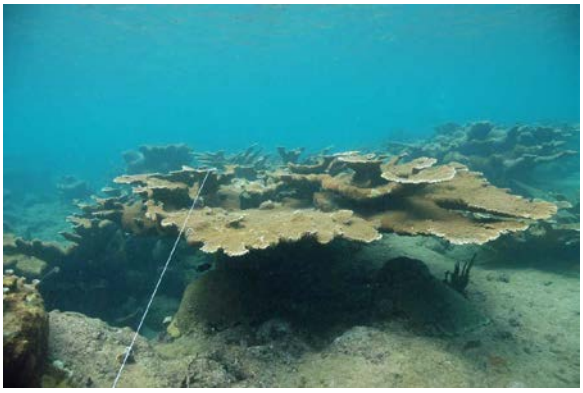
SPECIES	**COMMON NAME**		# - (cm)	
Caranx crysos	Blue Runner	2 – (25)	1 – (30)	
Lutjanus analis	Mutton Snapper	1 – (25)		
Lutjanus synagris	Lane Snapper	4– (10)	1 – (20)	
Lutjanus apodus	Schoolmaster	7 – (10)	5 – (20)	1 – (30)
Ocyurus chrysurus	Yellowtail Snapper	2 – (10)		
Sphyraena barracuda	Great Barracuda	1 – (40)	1 – (50)	

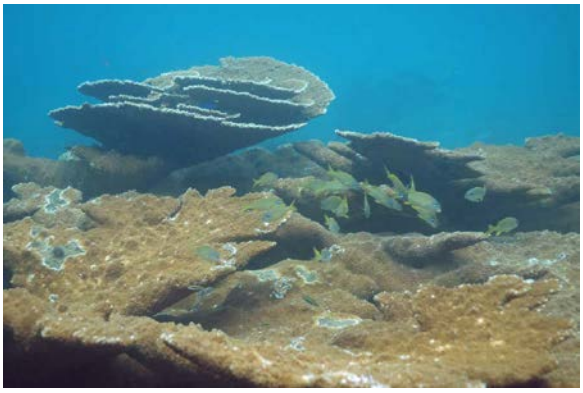
Motile megabenthic invertebrates observed within belt-transects during the 2010-11 monitoring survey are presented in Table 5. The Rock-boring sea urchin was the most abundant with a mean of 3.0 Ind/30 m^2. The Rustic and Caribbean Coral Shell were present in three out of the five transects surveyed. 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).

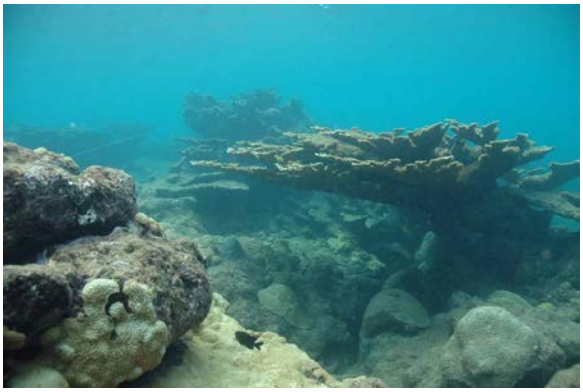
Table 5. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Elkhorn Coral Reef, 5 m, Rincon, September 2011

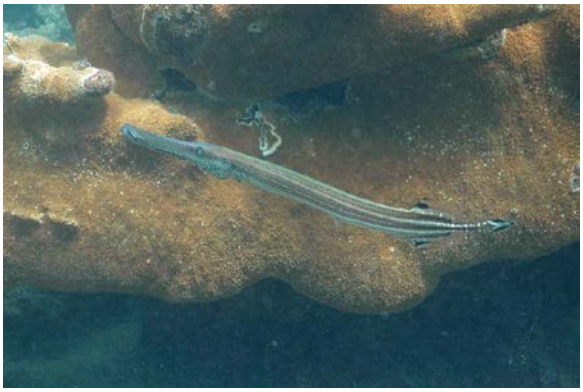
Depth: 2 - 5 m		**TRANSECTS**					**MEAN**
		1	**2**	**3**	**4**	**5**	**ABUNDANCE (IND/30 m2)**
SPECIES	**COMMON NAME**						
Coralliophila caribdea	Caribbean Coral Shell	4	1	5			**2.0**
Thais rustica	Rustic Shell	1		2	1		**0.8**
Echinometra lucunter	Rock boring Urchin	5	3	4	3		**3.0**
	TOTALS	10	4	11	4	0	**5.8**

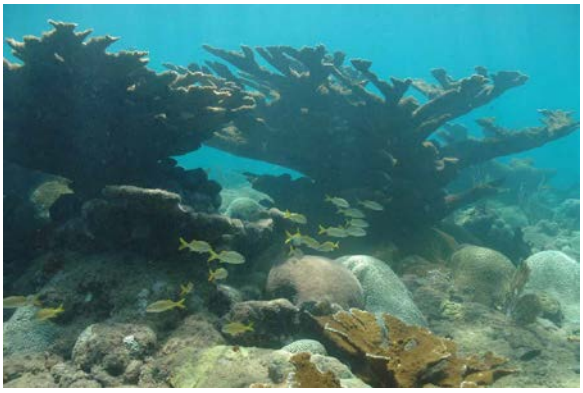
Photo Album 1 (Rincon 5m)
Fringing *Acropora palmata* Reef











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 a mean density of 23.2 col./transect (range: 18 – 28 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 14 species intercepted by line transects. Live stony coral cover averaged 21.7 % (range: 7.6 – 30.4 %). Great Star Coral, *Montastraea cavernosa* and Mustard-Hill Coral, *Porites astreoides* were the dominant species in terms of substrate cover with means of 8.4 and 2.9%, respectively. A total of 11 coral species were represented with less than 2% reef substrate cover. Total abiotic cover averaged 2.1 %. Cyanobacterial films were observed covering reef substrate in three transects with an overall average cover of 1.5 %.

Table 6. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon. July 2011. Depth: 10 m

	TRANSECT					
	1	2	3	4	5	**MEAN**
Rugosity (m)	1.8	2.2	2.2	1.4	1.2	**1.7**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	4.2	2.2		3.4	0.6	**2.1**
Total Abiotic	4.2	2.2	0.0	3.4	0.6	**2.1**
Benthic Algae						
Turf-mixed assemblage	82.6	71.0	63.3	65.0	63.7	**69.1**
Galaxaura sp.	0.6	0.7		0.6	0.4	**0.5**
Dictyota sp.			1.7			**0.3**
Halimeda sp.	0.5					**0.1**
Total Benthic Algae	83.7	71.7	65.0	65.6	64.1	**70.0**
Gorgonians						
Total gorgonians	24	28	24	18	22	**23.2**
Sponges	3.0	0.6	9.3	2.4	3.7	**3.8**
Xestospongia muta	1.2	2.9				**0.8**
Total sponges	4.2	3.5	9.3	2.4	3.7	**4.6**
Cyanobacteria		1.2	5.4		1.1	**1.5**
Live Stony Corals						
Montastraea cavernosa	2.1	8.2	7.1	6.2	18.2	**8.4**
Porites astreoides		3.7	3.2	2.4	5.3	**2.9**
Colpophyllia natans		0.5		9.3		**2.0**
Agaricia agaricites	0.5	3.0	2.8	1.2		**1.5**
Montastraea annularis	3.8	2.2		0.6		**1.3**
Siderastrea siderea		1.0	1.4	2.0	2.1	**1.3**
Diploria strigosa		1.9	0.7	1.3	1.3	**1.0**
Dendrogyra cylindrus				4.6		**0.9**
Diploria labyrinthiformis			2.5		1.9	**0.9**
Millepora alcicornis		0.4	1.7		0.9	**0.6**
Madracis decactis	0.5	0.6		0.4	0.6	**0.4**
Meandrina meandrites			0.9			**0.2**
Stephanocoenia intersepta	0.7					**0.1**
Siderastrea radians				0.6		**0.1**
Total Stony Corals	7.6	21.4	20.4	28.6	30.4	**21.7**

Coral Species Outside Transects: *Acropora cervicornis, Favia fragum, Manicina areolata, Isophyllia sinuosa*

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 69.1 % (range: 63.3 – 82.6 %). Fleshy brown (*Dictyota sp*.), red (*Galaxaura sp*.) and calcareous (*Halimeda discoidea*) macroalgae were present within transects with a combined cover of 0.9 %. Encrusting sponges were intersected by all five transects with a mean substrate cover of 4.6 % (range: 2.4 – 9.3 %). The encrusting gorgonian, *Erythropodium caribaeorum* and the encrusting zoanthid, *Palythoa caribbea,* were observed outside transects. Abiotic categories associated with reef overhangs and sand pockets comprised 2.1 % of the reef substrate cover, influenced in part by the essentially flat bathymetry and the prevailing encrusting growth pattern of corals, sponges and turf algae. Reef rugosity, which is an indicator of underwater topographic averaged 1.7 m.

The sessile-benthic community at the patch reef surveyed is typical of high wave energy environments, dominated by encrusting stony corals and 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 in this survey. The reef hard ground was mostly colonized by turf algae, which is the dominant assemblage and a quasi-permanent feature of high-energy reefs of 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 – 2011) at this reef were not statistically significant (ANOVA; $p = 0.612$). Statistical test results are included in this report as Appendix 2.

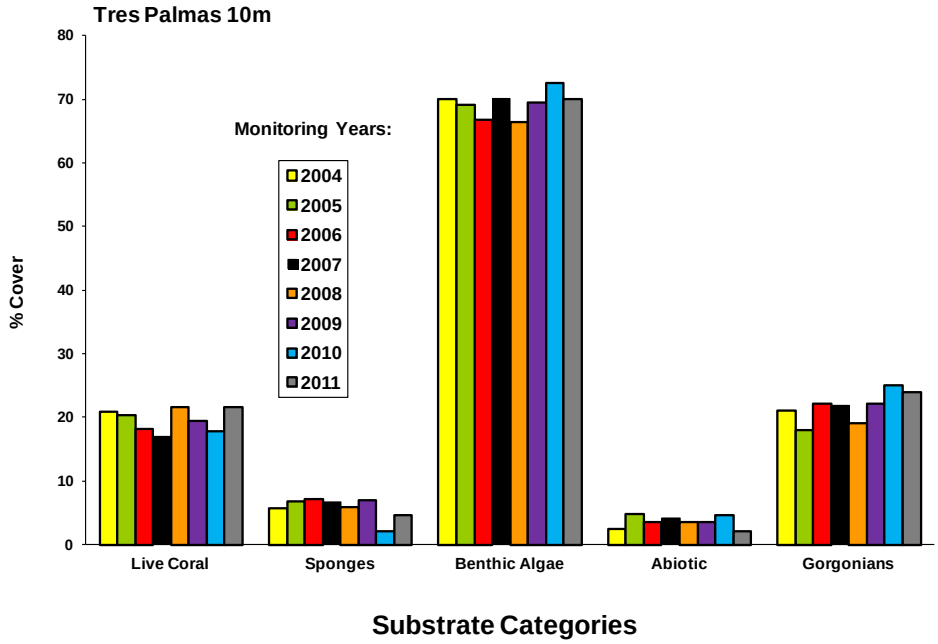


Figure 7. Monitoring trends (2004 – 2011) of mean substrate cover by sessile-benthic categories at Tres Palmas Outer Patch Reef – 10 m.

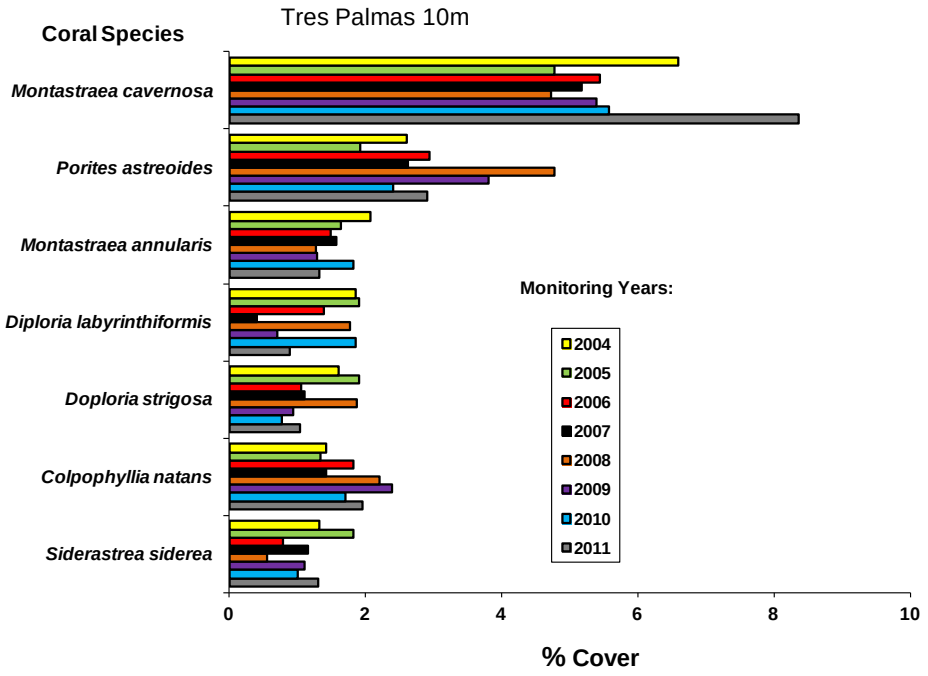


Figure 8. Monitoring trends (2004 – 2011) of mean substrate cover by stony coral species at Tres Palmas Outer Patch Reef – 10 m.

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 104 fish species have been identified from the patch reef formation at the Tres Palmas Reef system of Rincón (Appendix 1). During the 2010-11 survey, abundance of individuals within belt-transects averaged 84.4 Ind/30 m^2 (range: 61 - 104 Ind/30 m^2). The mean number of species per transect was 14.8 (range: 12 - 17).

Two species, the Bluehead Wrasse (*Thalassoma bifasciatum*) and the Bicolor Damselfish (*Stegastes partitus*) were (as in previous surveys) numerically dominant within belt-transects with mean abundances of 31.2 and 26.6 Ind/30 m^2, respectively (Table 7). The combined abundance of these two species represented 68.5 % of the community mean abundance within belt-transects. In addition to the two aforementioned species, the Stoplight and Striped Parrotfishes, Yellowhead and Clown Wrasses, Doctorfish, Coney, Sharknose Goby, Four-eyed Butterflyfish, Caribbean Puffer and Harlequin Bass were present in at least four of the five transects surveyed (Table 7). 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, Yellowtail, Mahogony and Schoolmaster Snappers, in addition to one large Southern Stingray were observed over sandy bottom at the base of the wall during the ASEC survey (Table 8). One large Hawksbill turtle was also present in the reef.

Statistically significant differences of fish abundance and species richness between monitoring surveys have been detected for this reef (Figure 9). These include an abundance peak in 2006, which was higher than all other surveys, and a period of higher richness from 2004 through 2006 (see Appendix 3). These fluctuations appear to be real and probably associated with escape movements by transitional species to deeper, more protected waters during periods of strong wave action and associated surge effect over shallow reefs. Fish species richness and abundance during the present 2011 were within baseline levels and not significantly different to the majority of the previous surveys.

Table 7. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef 10m Rincon, July 2011. Depth: 10m

		TRANSECTS					
		1	2	3	4	5	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	40	37	30	32	17	**31.2**
Stegastes partitus	Bicolor Damselfish	20	25	22	47	19	**26.6**
Sparisoma viride	Stoplight Parrotfish	8	3	4	1	3	**3.8**
Cephalopholis fulva	Coney	2	4	4	2	4	**3.2**
Gobiosoma evelynae	Sharknose Goby	1	2	4	4	2	**2.6**
Halichoeres garnoti	Yellow-head Wrasse	5	2	4	1	0	**2.4**
Scarus iserti	Striped Parrotfish	2	0	3	1	5	**2.2**
Acanthurus chirurgus	Doctorfish	1	4	1	1	2	**1.8**
Halichoeres maculipinna	Clown Wrasse	2	1	1	3	2	**1.8**
Chaetodon capistratus	Four eye Butterflyfish	2	0	4	1	1	**1.6**
Canthigaster rostrata	Caribbean Puffer	0	4	1	1	1	**1.4**
Serranus tigrinus	Harlequin Bass	0	3	1	2	1	**1.4**
Chromis cyanea	Blue Chromis	0	0	0	4	0	**0.8**
Holocentrus rufus	Squirrelfish	0	1	1	0	1	**0.6**
Acanthurus coeruleus	Blue Tang	0	1	1	0	0	**0.4**
Amblycirrhitus pinos	Redspotted Hawkfish	1	0	0	1	0	**0.4**
Scarus taeniopterus	Princess Parrotfish	0	1	0	0	1	**0.4**
Sparisoma aurofrenatum	Redband Parrotfish	1	0	1	0	0	**0.4**
Chaetodon striatus	Banded Butterflyfish	0	0	0	0	1	**0.2**
Coryphopterus glaucofraenum	Bridled Goby	0	0	0	1	0	**0.2**
Coryphopterus lipernes	Peppermint Goby	0	0	0	1	0	**0.2**
Malacoctenus triangulatus	Saddled Blenny	0	0	0	1	0	**0.2**
Platophrys lunatus	Peacock Flounder	0	0	0	0	1	**0.2**
Microspathodon chrysurus	Yellowtail Damselfish	0	0	1	0	0	**0.2**
Ophioblennius atlanticus	Redlip Blenny	0	0	1	0	0	**0.2**
	TOTAL INDIVIDUALS	85	88	84	104	61	**84.4**
	TOTAL SPECIES	12	13	17	17	15	**14.8**

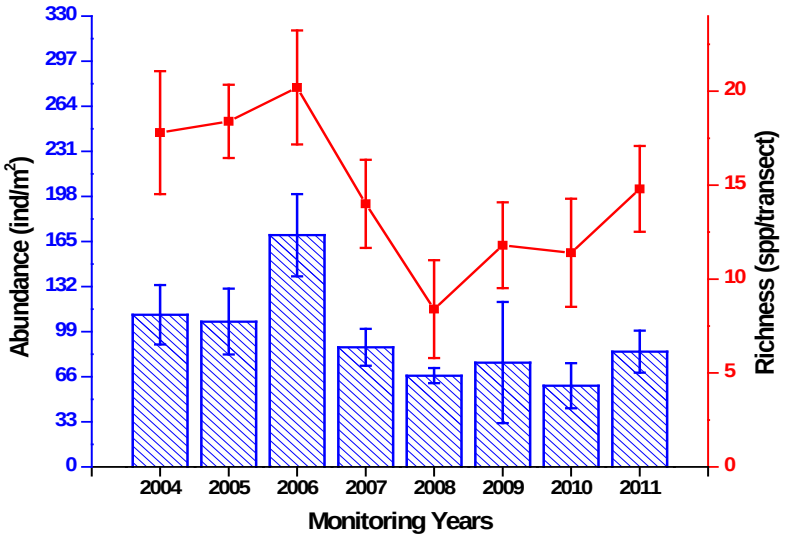


Figure 9. Monitoring trends (2004 – 2011) of fish species richness and abundance at Tres Palmas Outer Shelf Patch Reef, 10 m, Rincon.

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). Mid size adult and juvenile Lane, Mahogany and Yellowtail snappers (*Lutjanus synagris, L. mahogony, Ocyurus chrysurus*) were present as well as a pair of Red Hinds (*Epinephelus guttatus*) (Table 8). Large (adult) commercially important demersal fishes were not observed. The largest demersal predator present was one Southern Stingray (*Dasyatis americana*) at the reef sand interface.

Table 8. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at the Tres Palmas outer patch reef, Rincon, 10 m. Survey Date: July, 2011.

Depth range : 9 – 12 m Duration – 30 min.

SPECIES	**COMMON NAME**	# - (cm)		
Caranx crysos	Blue Runner	1 – (30)		
Epinephelus guttatus	Red Hind	1 – (25)	1 – (35)	
Lutjanus mahogony	Mahogany Snapper	3 – (20)	2 – (25)	1 – (25)
Lutjanus synagris	Lane Snapper	4 – (25)	1 – (30)	
Ocyurus chrysurus	Yellowtail Snapper	2 – (25)		
Eretmochelys imbricata	Hawksbill Turtle	1 – (90)		

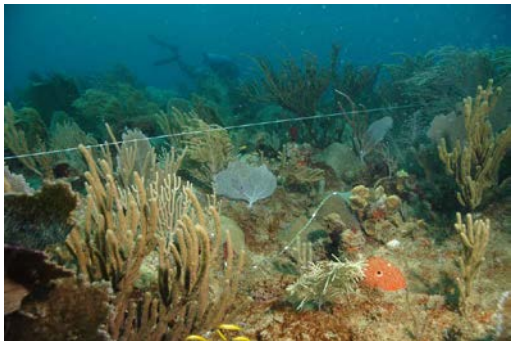
Among motile megabenthic invertebrates, several spiny Lobsters (*Panulirus argus*) Slate-pencil Urchins (*Eucidaris tribuloides*), Cleaner Shrimps (*Periclimenes sp*., *Stenopus hispidus*), Arrow and Hermit Crabs (*Stenorhynchus seticornis, Paguridae*) and Sponge Brittle Stars have been previously reported from this reef (Garcia-Sais et al., 2006). Cleaner Shrimps, Long-spined Urchins and one Hermit Crab were observed within belt-transects during the present 2011 survey (Table 9).

Table 9. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Reef, Rincon, 10m, July, 2011

		TRANSECTS					
Depth: 10 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Paguristes sp.	Hermit Crab				1		**0.2**
Periclimenes pedersoni	Cleaner Shrimp			1			**0.2**
Diadema antillarum	Long-spined Urchin			1			**0.2**
	TOTALS	0	0	2	1	0	**0.6**

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) were identified from the shelf-edge reef off Tres Palmas, 15 of which were intercepted by line transects during the 2011 survey (Table 10). Stony corals occurred mostly as encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 23.4 % (range: 14.6 – 28.7 %). Boulder Star Coral, *Montastraea annularis* complex was the dominant species in terms of substrate cover with a mean of 10.0 % (range: 2.0 – 20.5 %), representing 42.7 % of the total cover by stony corals (Table 10). Colonies of *M. annularis* and Maze Coral (*Meandrina meandrites*) were present in all five transects. Also present in four out of the five transects were colonies of Great Star Coral, *M. cavernosa* and Lettuce Coral, *Agaricia agaricites*. Erect soft corals (gorgonians) were moderately abundant, with an average of 12.4 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. July 2011. Depth: 20 m

	TRANSECT					
	1	2	3	4	5	**MEAN**
Rugosity (m)	2.55	3.31	3.58	2.30	2.35	**2.8**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs			16.71	11.23	6.07	**6.8**
Total Abiotic	0.00	0.00	16.71	11.23	6.07	**6.8**
Benthic Algae						
Turf-mixed assemblage	65.47	61.16	42.32	53.62	56.92	**55.9**
Lobophora variegata	1.12	2.78	5.01	3.58	3.97	**3.3**
Dictyota sp.		1.73		2.60	2.51	**1.4**
Amphiroa sp.		1.73		1.95	0.34	**0.8**
Total Benthic Algae	66.59	67.40	47.33	61.75	63.74	**61.4**
Erect Gorgonians	14	12	18	11	7	**12.4**
Encrusting Gorgonians						
Erythropodium caribaeorum	1.57		1.99	1.72		**1.1**
Sponges	16.59	2.40	3.58	3.91	5.10	**6.3**
Xestospongia muta			6.16			**1.2**
Total sponges	16.59	2.40	9.74	3.91	5.10	**7.6**
Cyanobacteria		2.40	3.50		0.91	**1.4**
Live Stony Corals						
Montastraea annularis	1.99	8.64	20.53	7.49	11.17	**10.0**
Agaricia agaricites	5.82	2.33		2.03	1.82	**2.4**
Porites astreoides		4.30		4.48	2.43	**2.2**
Meandrina meandrites	1.12	1.80	4.38	1.83	0.46	**1.9**
Montastraea cavernosa	1.57	2.03	2.24	1.38		**1.4**
Siderastrea siderea	1.80	4.43			0.68	**1.4**
Colpophyllia natans		4.06			1.71	**1.2**
Diploria strigosa	1.12				3.64	**1.0**
Leptoseris cucullata			0.58	0.34	1.71	**0.5**
Agaricia grahamae				1.95		**0.4**
Madracis decactis				1.38	0.57	**0.4**
Porites colonensis			0.67	0.57		**0.2**
Madracis sp.	0.79					**0.2**
Millepora alcicornis	0.34	0.21				**0.1**
Agaricia lamarcki			0.34			**0.1**
Total Stony Corals	14.55	27.80	28.74	21.45	24.19	**23.4**

Coral Species Outside Transects: *Acropora cervicornis, Favia fragum, Isophyllastrea rigida, Manicina areolata, Porites porites*

Encrusting and erect sponges, including several large Basket Sponges, *Xestospongia muta* were present in all transects with an average cover of 7.6 %. Reef overhangs averaged 6.8 % and contributed to a topographic rugosity of 2.8 m. 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 55.9 % (range: 42.3 – 65.5 %). 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 4.7 % to the reef substrate cover. Isolated tufts of red coralline alga (*Amphiroa sp*, *Galaxaura sp*.) and other green filamentous algae were also present. The total reef substrate cover by benthic algae was 61.4 %. Patches of reddish, slimy mats of benthic cyanobacteria were observed, mostly covering sandy sediments with a mean cover of 1.4 %.

Figure 10 presents the variation between monitoring surveys of percent cover by sessile-benthic components at the Tres Palmas shelf-edge reef in Rincón, including the baseline characterization of 2004 and the annual monitoring surveys up to present (2011). A mild, but consistent trend of declining mean coral cover between monitoring surveys until 2008 is suggested by the data. This pattern ended during 2009 with a minor increment of live coral cover. A mild decline of live coral cover reported during the present 2011 survey was not statistically significant (Figure 10, Appendix 2). The variability in both magnitude and direction of live coral cover within transects was high enough to render the differences between monitoring years statistically insignificant. The increasing trend of live coral cover was influenced by an apparent recuperation of Boulder Star Coral, *Montastraea annularis* (complex) from its acute degradation after the 2005 coral bleaching event (Figure 11). Lettuce Coral, *Agaricia agaricites* has shown increasing trend of reef substrate cover during the last two surveys.

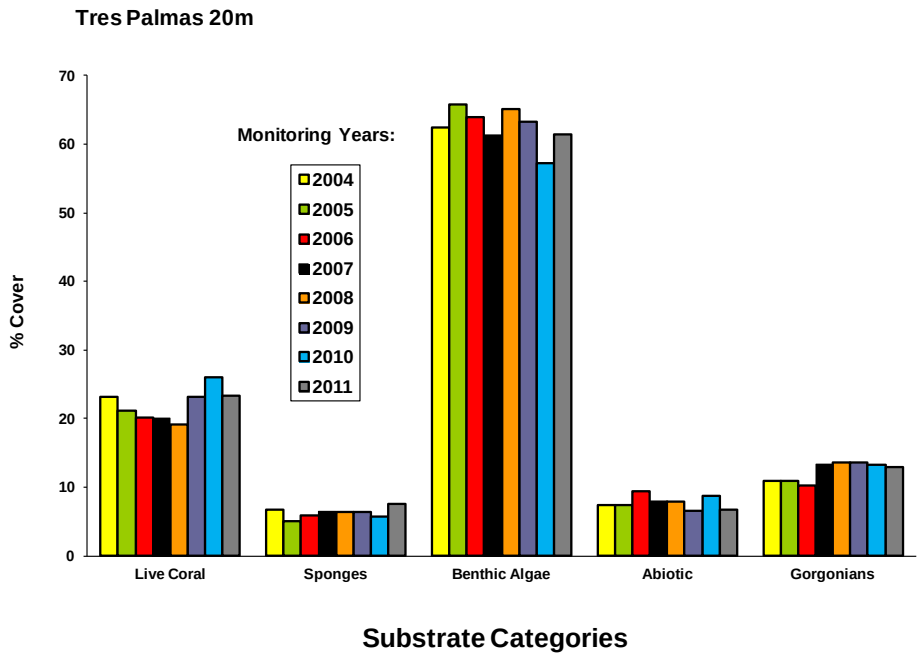


Figure 10. Monitoring trends (2004 – 2011) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef – 20 m.

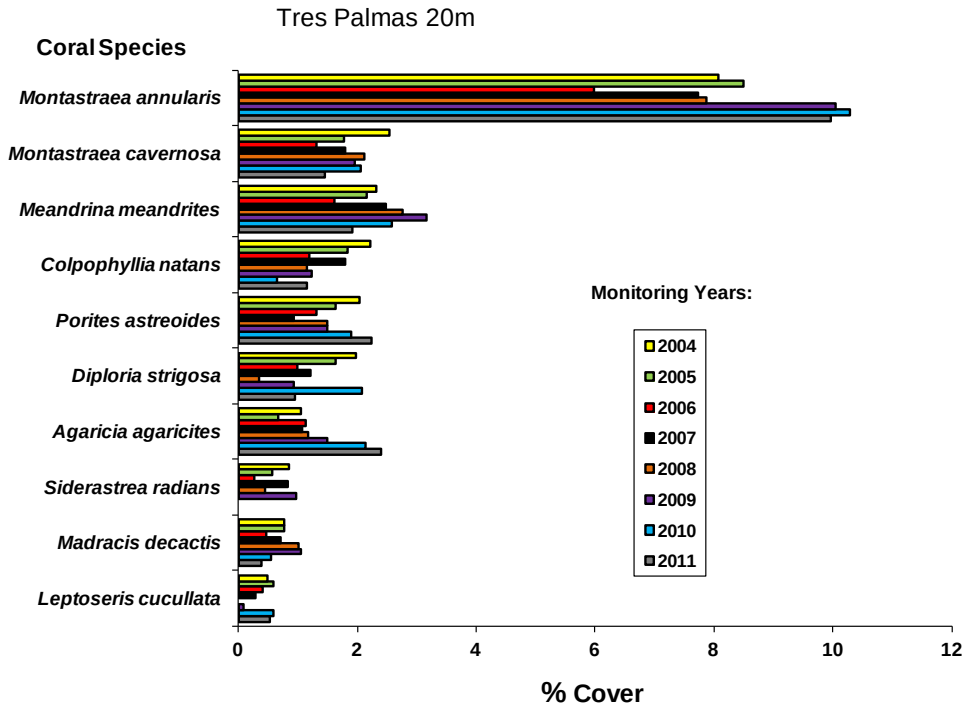


Figure 11. Monitoring trends (2004 – 2011) of mean substrate cover by stony coral species at Tres Palmas Reef – 20 m.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 87 fish species have been identified from the shelf-edge reef off Tres Palmas (Appendix 1). Table 11 lists the 42 fish species observed within belt-transects during the 2011 survey in decreasing order of abundance. Mean abundance within belt-transects was 175.8 Ind/30 m^2 (range: 91 – 241 Ind/30 m^2). The mean number of species per transect was 21.8 (range: 16– 26). An assemblage consisting of six species represented 81.2 % of the total fish individuals within belt-transects (Table 11). The Masked Goby, Peppermint Goby, Blue Chromis, Bicolor Damselfish, Bluehead and Creole Wrasse comprised the numerically dominant assemblage. In addition, The Beau Gregory, Sharknose Goby, Yellowhead Wrasse and Striped Parrotfish were present in at least four of the five transects surveyed.

Annual fluctuations of fish abundance and species richness from the baseline survey in 2004 to the present are presented in Figure 12. Fish species richness within belt-transects has varied from a maximum annual mean of 26 spp/ transect during the baseline survey of 2004 to a minimum of 20.6 spp/ transect in 2010. These variations are still within 95% confidence intervals due to the naturally high variability within transects. Fish abundance presented statistically significant differences between survey years (ANOVA; $p = 0.003$). Mean fish abundance decreased 64.4 % from the baseline (531.4 Ind/30 m^2) in 2004 to a minimum abundance of 175.8 Ind/30 m^2 during 2011. The main species that has contributed to the variability of fish abundance between monitoring surveys is the Masked Goby, *Coryphopterus personatus*. This is a small zooplanktivorous 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. It is possible that under conditions of moderate wave action and surge swarms retrieve to cryptic reef habitas and go undetected by visual surveys. 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 well balanced in terms of trophic structure, except for the

Table 11. Taxonomic composition and abundance of fishes within belt-transects at the shelf-edge reef off Tres Palmas, Rincón. July, 2011. Depth: 20m

		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	30	24	64	40	8	**33.2**
Clepticus parrae	Creole wrasse	0	65	30	0	20	**23.0**
Coryphopterus lipernes	Peppermint goby	13	25	25	25	21	**21.8**
Thalassoma bifasciatum	Bluehead Wrasse	6	40	12	29	13	**20.0**
Chromis cyanea	Blue Chromis	1	22	20	0	50	**18.6**
Stegastes partitus	Bicolor Damselfish	13	28	15	9	24	**17.8**
Chromis multilineata	Brown chromis	0	5	14	0	10	**5.8**
Halichoeres garnoti	Yellow-head Wrasse	9	3	6	2	4	**4.8**
Sparisoma viride	Stoplight Parrotfish	3	0	3	2	11	**3.8**
Gobiosoma evelynae	Sharknose Goby	1	2	4	3	4	**2.8**
Stegastes leucostictus	Beau Gregory	5	4	2	2	1	**2.8**
Cephalopholis cruentatus	Graysby	4	1	4	1	2	**2.4**
Myripristis jacobus	Blackbar Soldierfish	0	0	7	3	2	**2.4**
Canthigaster rostrata	Caribbean Puffer	1	3	3	2	1	**2.0**
Scarus taeniopterus	Princess Parrotfish	1	0	4	0	4	**1.8**
Acanthurus chirurgus	Doctorfish	0	4	1	1	2	**1.6**
Haemulon flavolineatum	French grunt	0	3	1	1	1	**1.2**
Haemulon melanorum	Cottonwick	0	5	0	0	0	**1.0**
Melichthys niger	Black Durgon	0	0	4	1	0	**1.0**
Neoniphon marianus	Longspine squirrelfish	0	2	2	0	0	**0.8**
Sparisoma aurofrenatum	Redband Parrotfish	0	0	1	2	1	**0.8**
Cephalopholis fulva	Coney	1	0	0	2	0	**0.6**
Chaetodon capistratus	Four-eye Butterflyfish	0	0	0	2	1	**0.6**
Amblycirrhitus pinos	Redspotted Hawkfish	0	0	0	1	1	**0.4**
Caranx crysos	Blue runner	0	0	0	0	2	**0.4**
Chaetodon sedentarius	Reef Butterflyfish	0	0	2	0	0	**0.4**
Holacanthus tricolor	Rock beauty	0	1	0	1	0	**0.4**
Serranus tigrinus	Harlequin Bass	1	0	0	0	1	**0.4**
Pseudupeneus maculatus	Spotted Goatfish	1	0	1	0	0	**0.4**
Coryphopterus glaucofraenum	Bridled Goby	0	0	0	1	1	**0.4**
Acanthurus coeruleus	Blue Tang	0	0	0	0	1	**0.2**
Acanthurus bahianus	Ocean Surgeon	0	0	1	0	0	**0.2**
Bodianus rufus	Spanish Hogfish	0	1	0	0	0	**0.2**

Table 11. Continued

Epinephelus guttatus	Red hind	0	0	1	0	0	**0.2**
Chaetodon striatus	Banded Butterflyfish	0	0	1	0	0	**0.2**
Gymnothorax moringa	Golden moray	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 nigricans	Black Hamlet	0	0	0	0	1	**0.2**
Hypoplectrus unicolor	Butter hamlet	0	1	0	0	0	**0.2**
Pomacanthus arcuatus	Gray Angelfish	0	1	0	0	0	**0.2**
Pomacanthus paru	French Angelfish	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	91	241	229	131	187	**175.8**
	TOTAL SPECIES	16	21	26	21	25	**21.8**

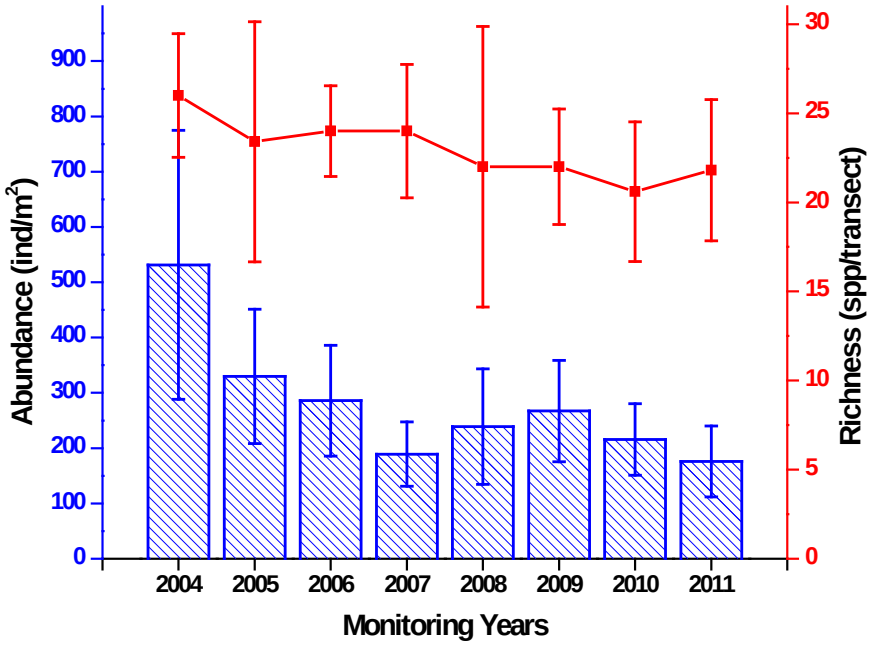


Figure 12. Monitoring trends (2004 – 2011) of fish species richness and abundance at Tres Palmas Shelf Edge Reef, Rincon, 20 m

absence of large demersal predators, such as large snappers and groupers. However, this is the present condition of most insular coral reefs. 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 an ASEC survey in this reef (Table 12). The Blue, Brown and Sunshine Chromis are also important zooplanktivores that were common over coral heads closer to the reef. A large variety of small invertebrate feeders were present, including wrasses, hamlets, gobies, and squirrelfishes, among others. 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.

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 (*Gramma loreto*), Queen and French Angelfishes (*Holacanthus ciliaris, Pomacanthus paru*), Rock Beauty (*Holacanthus tricolor*), Blue Chromis (*Chromis cyanea*) and Swissguard Basslet (*Liopropoma rubre*). A total of 10 lionfishes within the 20 – 30 cm total length were observed during the ASEC survey at this reef (Table 12).

Motile megabenthic invertebrates, such as Arrow Crabs, *Stenorhynchus seticornis,* Cleaner Shrimps *Periclimenes pedersoni* and *Stenopus hispidus*, Common Octopus, *Octopus vulgaris*, and Spiny Lobsters, *Panulirus argus* have been previously reported within belt-transects during previous surveys at this reef. Cleaner shrimps and one arrow crab were observed withion belt-transects during 2011 (Table 13). One adult Spiny lobster (*P. argus*) was present outside transects.

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, July, 2011

Depth: 18 - 22 m Duration - 30 min.

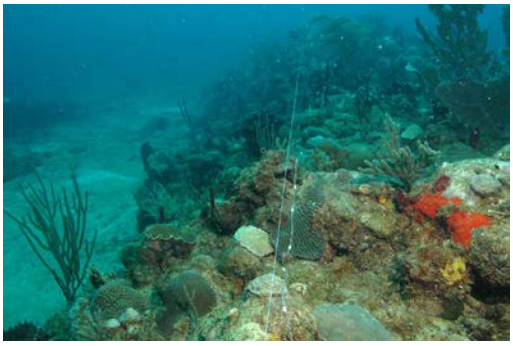
SPECIES	**COMMON NAME**	# - (cm)		
Epinephelus guttatus	Red Hind	1 – (20)	1 – (35)	
Lutjanus apodus	Schoolmaster	3 - (20)	1 – (30)	
Lutjanus mahogony	Mahogany Snapper	10 - (20)	3 - (25)	
Lutjanus synagris	Lane Snapper	1 – (20)	2 – (25)	
Pterois volitans	Lionfish	4 – (20)	4 – (22)	2 – (25)
Scomberomorus regalis	Cero Mackerel	2 - (40)		
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, July, 2011

Depth: 20 m		**TRANSECTS**					**MEAN ABUNDANCE (IND/30 m2)**
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						
Stenorhynchus seticornis	Arrow Crab				1		**0.2**
Periclimenes pedersoni	Cleaner Shrimp	1		2			**0.6**
	TOTALS	1	0	2	1	0	**0.8**

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, Garcia-Sais 2010). 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 (*Montastraea 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.

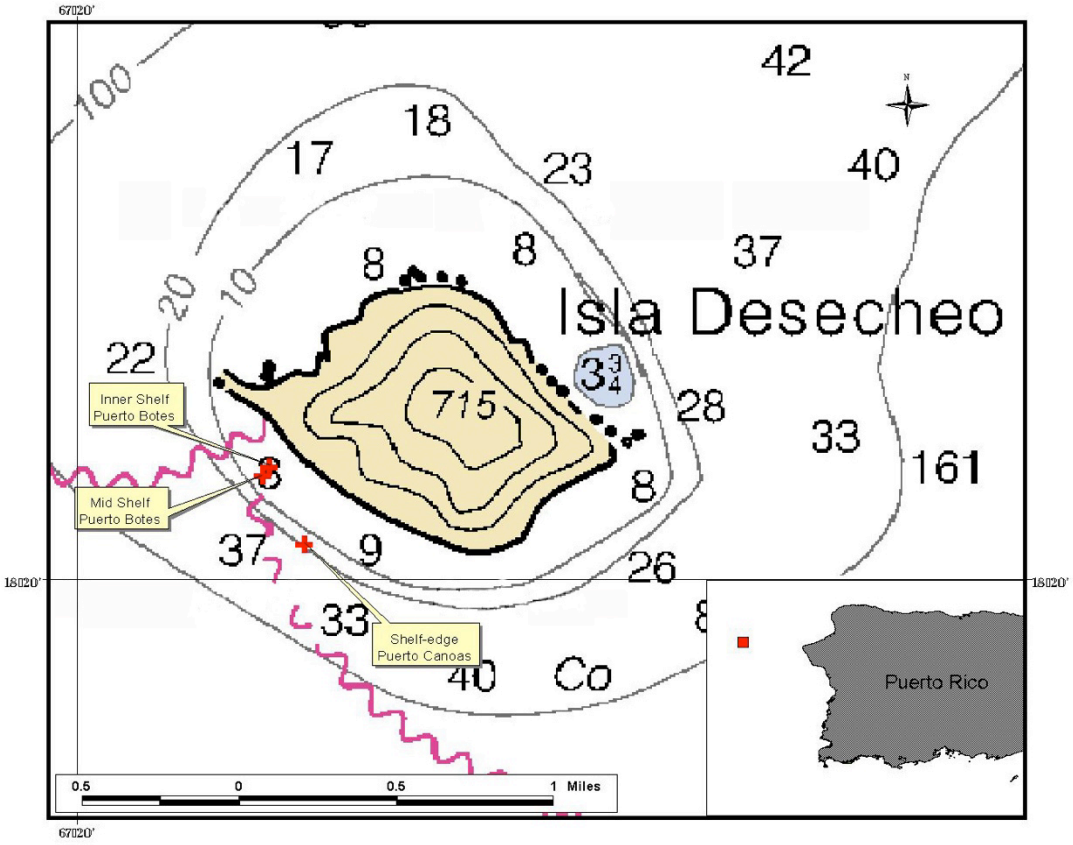


Figure 13. Location of coral reef survey stations at Puerto Canoas/Botes, Isla Desecheo.

Stony corals dominated reef substrate cover along surveyed transects with a mean of 24.7% (range: 18.6 – 31.1 %). Boulder Star Coral (*Montastraea annularis* complex), with a mean cover of 13.2 % represented 53.4 % of the total stony coral cover. In addition to *M. annularis*, Lettuce Coral (*Agaricia agaricites*) and Mustard-Hill Coral (*Porites astreoides*) were present in all five transects at the shelf-edge reef of Puerto Canoas (Table 14). A total of 16 species of stony corals were identified, including 10 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 13.3 % and contributed to a mean reef substrate rugosity of 3.0 m. Encrusting and erect sponges were common, with a mean cover of 10.4 % (range: 5.6 – 14.5 %).

Table 14. Percent substrate cover by sessile-benthic categories at the shelf-edge Reef Puerto Canoas, Isla Desecheo during September 2011.

Depth: 30 m

	Transects					
	1	2	3	4	5	**MEAN**
Rugosity (m)	1.65	1.23	5.07	3.55	3.39	**3.0**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	8.50	4.39	29.00	20.37	3.66	**13.2**
Gaps			0.37			**0.1**
Total Abiotic	8.50	4.39	29.37	20.37	3.66	**13.3**
Benthic Algae						
Lobophora variegata	10.99		16.06	35.65	17.33	**16.0**
Lobophora and Dictyota	24.03	27.09			18.82	**14.0**
Turf-mixed assemblage	15.02	4.55	18.98	8.41	8.96	**11.2**
Coralline algae	2.92	6.86			1.87	**2.3**
Dictyota sp.				2.36		**0.5**
Wrangelia bicuspidata			0.93			**0.2**
Total Benthic Algae	52.96	38.50	35.97	46.42	46.98	**44.2**
Sponges	5.58	14.53	13.01	9.37	9.71	**10.4**
Cyanobacteria	8.84	7.40	3.05	3.32	14.34	**7.4**
Live Stony Corals						
Montastraea annularis	7.12	18.98	11.28	11.22	17.25	**13.2**
Agaricia agaricites	5.06	4.01	1.66	4.06	4.31	**3.8**
Porites astreoides	2.15	5.88	2.06	1.35	3.81	**3.1**
Colpophyllia natans	7.90	5.53				**2.7**
Agaricia tenuifolia			2.92			**0.6**
Meandrina meandrites				2.29		**0.5**
Porites porites	1.93					**0.4**
Agaricia grahamae			0.65	1.03		**0.3**
Eusmilia fastigiata		0.71				**0.1**
Madracis decactis				0.52		**0.1**
Total Stony Corals	24.16	35.11	18.57	20.47	25.37	**24.7**

Coral Species Outside Transects: *Agaricia sp., Diploria labyrinthiformis, Isophyllastrea rigida, Montastraea cavernosa, Mycetophyllia lamarki, Stylaster roseus*

Benthic macroalgae, comprised by an assemblage of turf, fleshy and calcareous types presented a combined substrate cover of 44.2 % along permanent transects. *Lobophora variegata, Dictyota sp.* and *Wrangelia bicuspidata* 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 all five transects with a mean substrate cover of 7.4 %.

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 (48.1 %) and the 2006 (37.5 %) survey (ANOVA; $p < 0.0001$). The decline of mean live coral cover was largely associated with the dominant reef building species, *Montastraea 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), *M 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, when a statistically significant difference between live coral cover during 2010 and 2006 emerged (ANOVA; $p< 0.05$; see Appendix 2). A corresponding increment of substrate cover by benthic algae, cyanobacteria, sponges and abiotic categories was also measured (Figure 14). During 2011 a small, statistically insignificant increment of live coral was measured.

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 90 fish species have been identified during the monitoring program (2004-11) at the shelf-edge reef off Puerto Canoas, Isla Desecheo (Appendix 1). Mean abundance of fishes within belt-transects during 2011 was 270.6 Ind/30 m^2 (range: 88 – 495 Ind/30 m^2). The mean number of species per transect was 23.6 (range: 17 – 27) (Table 15). An assemblage of seven species, including the Creole Wrasse, Masked and Peppermint Goby, Blue and Brown Chromis, Bermuda Chub, and Fairy Basslet represented 76.0 % of the total fish abundance within belt-transects. A total of 9 species were present within all five belt-transects surveyed. The Creole Wrasse, *Clepticus parrae* was the

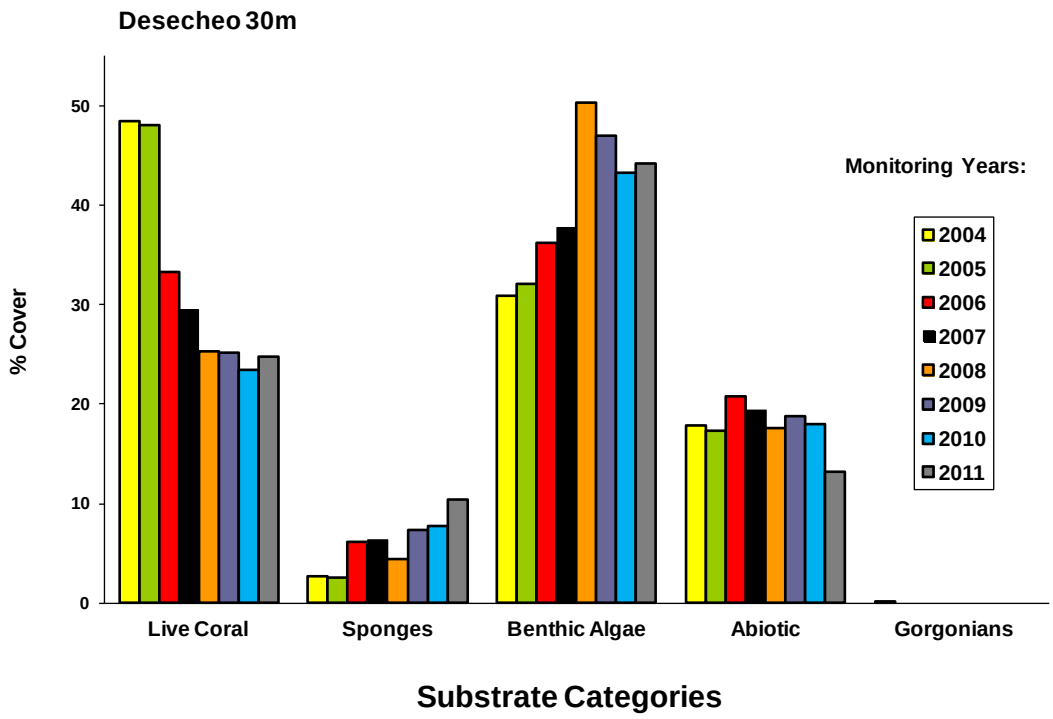


Figure 14. Monitoring trends (2004 – 2011) of substrate cover by sessile-benthic categories at Puerto Canoas Reef, Desecheo Island – 30 m.

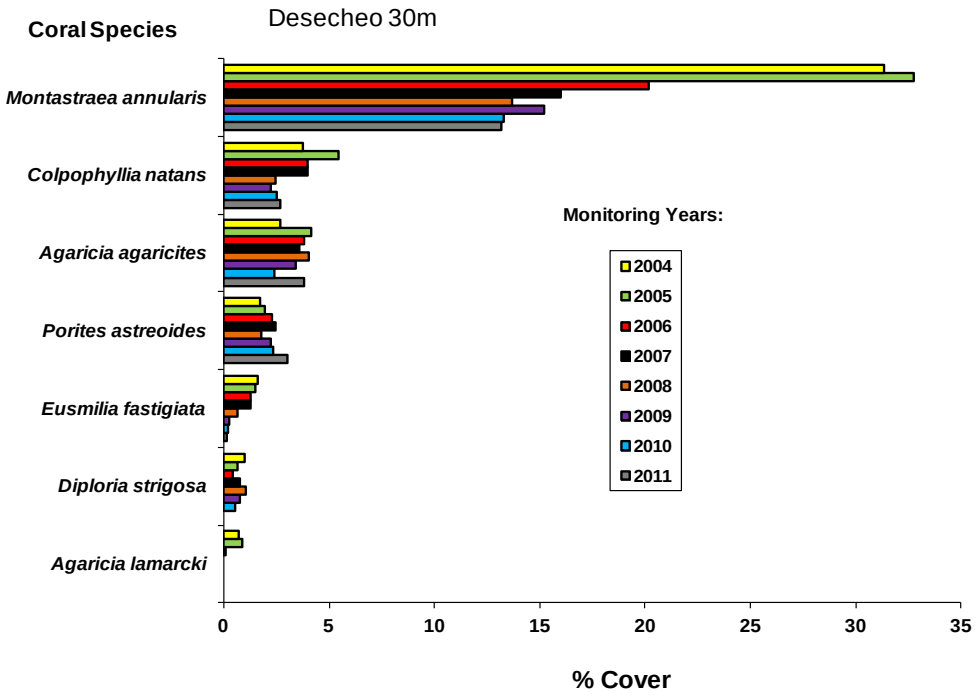


Figure 15. Monitoring trends (2004-2011) of mean substrate cover by stony coral species at Puerto Canoas Reef, Desecheo Island – 30 m.

Table 15. Taxonomic composition and abundance of fishes within belt-transects at Puerto Canoas Reef 30 m, Isla Desecheo. June, 2011. Depth: 30m

		TRANSECTS					
		1	2	3	4	5	
SPECIES	**COMMON NAME**	(Individuals/30 m2)					**MEAN**
Clepticus parrae	Creole Wrasse	200	40	65	0	15	**64.0**
Coryphopterus personatus	Masked Goby	30	10	20	20	100	**36.0**
Chromis cyanea	Blue Chromis	10	30	37	20	45	**28.4**
Kyphosus bermudensis	Sea Chub	50	12	62	2	0	**25.2**
Gramma loreto	Fairy Basslet	25	23	30	3	24	**21.0**
Chromis multilineata	Brown Chromis	50	4	14	8	6	**16.4**
Coryphopterus lipernes	Peppermint Goby	20	22	11	5	16	**14.8**
Caranx ruber	Bar Jack	50	0	0	0	0	**10.0**
Halichoeres garnoti	Yellow-head Wrasse	5	5	9	8	2	**5.8**
Mulloidichthys martinicus	Yellow Goatfish	0	0	0	0	28	**5.6**
Stegastes partitus	Bicolor Damselfish	4	4	15	0	5	**5.6**
Thalassoma bifasciatum	Bluehead Wrasse	2	6	8	0	11	**5.4**
Scarus iserti	Stripped Parrotfish	5	2	7	5	2	**4.2**
Caranx latus	Horse-eye Jack	15	0	0	0	0	**3.0**
Gobiosoma evelynae	Sharknose Goby	5	2	2	0	6	**3.0**
Halichoeres maculipinna	Clown Wrasse	5	5	5	0	0	**3.0**
Sparisoma aurofrenatum	Redband Parrotfish	6	1	4	1	1	**2.6**
Lutjanus apodus	Schoolmaster Snapper	0	1	0	5	6	**2.4**
Epinephelus cruentatus	Graysby	2	2	4	0	3	**2.2**
Acanthurus coeruleus	Blue Tang	1	1	1	3	0	**1.2**
Melichthys niger	Black Durgon	0	4	0	2	0	**1.2**
Sparisoma viride	Stoplight Parrotfish	3	0	1	1	1	**1.2**
Coryphopterus glaucophraenum	Briddled Goby	1	1	1	1	1	**1.0**
Paranthias fucifer	Creolefish	0	1	0	2	2	**1.0**
Pterois volitans	Lionfish	2	2	1	0	0	**1.0**
Stegastes planifrons	Threespot Damselfish	2	2	0	0	1	**1.0**
Microspathodon chrysurus	Yellowtail Damselfish	0	0	1	1	1	**0.6**
Bodianus rufus	Spanish Hogfish	1	1	0	0	0	**0.4**
Canthigaster rostrata	Caribbean Puffer	0	0	1	0	1	**0.4**
Chaetodon striatus	Banded Butterflyfish	0	0	1	0	1	**0.4**
Chaetodon capistratus	Four-eye Butterflyfish	0	2	0	0	0	**0.4**
Neoniphon marianus	Longspine Squirrelfish	0	1	0	0	1	**0.4**
Sparisoma rubripinne	Yellowtail Parrotfish	0	0	1	0	1	**0.4**
Anisotremus suranimense	Black Margate	0	0	1	0	0	**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish	0	0	0	0	1	**0.2**
Epinephelus striatus	Nassau Grouper	1	0	0	0	0	**0.2**
Epinephelus fulva	Coney	0	0	1	0	0	**0.2**
Holacanthus tricolor	Rock Beauty	0	0	0	1	0	**0.2**
Holocentrus adcencionis	Squirrelfish	0	1	0	0	0	**0.2**
Lactophrys triqueter	Smooth Trunkfish	0	1	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**495**	**186**	**303**	**88**	**281**	**270.6**
	TOTAL SPECIES	**24**	**27**	**25**	**17**	**25**	**23.6**

numerically dominant species with a mean abundance of 64.0 Ind/30 m^2 (range: 0 – 200 Ind/30 m^2), representing 23.7 % of the total (Table 15). Most of the Creole Wrasses within transect areas were early recruitment juveniles forming swarms in protected areas on the reef, sometimes in mixed aggregations with Blue Chromis (*Chromis cyanea*). Large streaming schools of adult Creole Wrasse were observed throughout the water column, making frequent incursions over the reef. These are zooplanktivores that serve 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 in the reef.

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 and represented one of the reefs with highest fish abundance studied in Puerto Rico. During 2009 a declining trend of fish abundance was observed until the 2010. Lower species richness and abundance were detected between the 2010 survey and all other surveys previous to 2009 (Figure 16). A mild increment of mean abundance was observed for the present 2011 survey, but abundance remained significantly lower than that of the 2004 – 2008 period (ANOVA; $p < 0.05$; see Appendix 3). The largest decline was associated with Masked Goby, but Fairy Basslet and Blue Chromis also presented lower abundances during 2010 and 2011, relative to 2008 and previous surveys. Such declines of abundance may be associated to a new predation pressure imposed by Lionfishes (*Pterois volitans*) in this reef. Seven adult lionfish were observed in the vicinity of our belt-transects during this 2011 survey. The predation potential of this invasive species may impose shifts in community structure directly related with its prey and still unknown cascading effects.

The shelf-edge reef off Puerto Canoas presents an unusually well balanced fish community in terms of trophic structure, including the presence of large demersal and

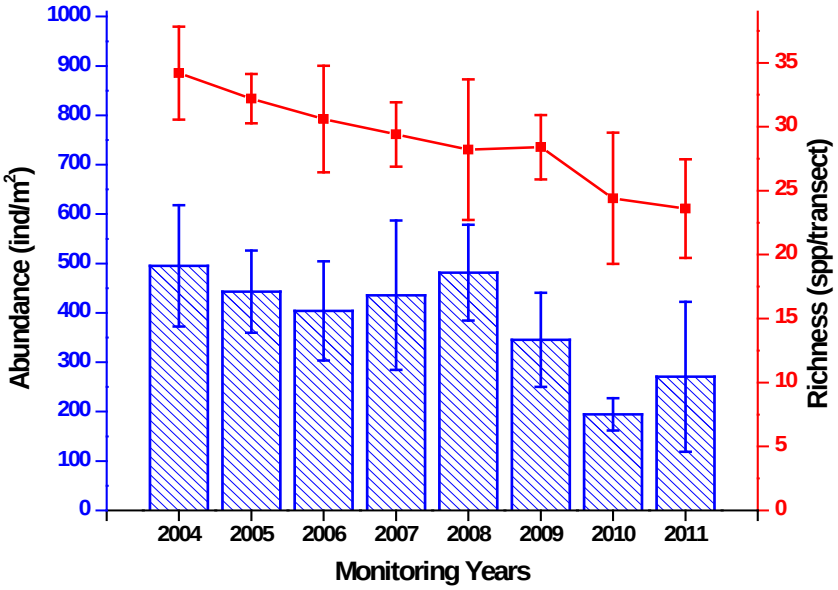


Figure 16. Monitoring trends (2004 – 2011) of fish species richness and abundance at Puerto Canoas Reef, Isla Desecheo, 30m

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. August, 2011. Depth range : 25 - 30

SPECIES	**COMMON NAME**		# - (cm)	
Caranx lugubris	Black Jack	3 - (50)	3 - (60)	
Dasyatis americana	Southern Stingray	1 – (90)		
Epinephelus guttatus	Red Hind	1 – (25)	2 - (30)	
Epinephelus striatus	Nassau Grouper	1 - (40)	1 - (60)	
Etelis bippinulata	Rainbow Runner	>1000 (15)		
Lutjanus apodus	Schoolmaster	30 - (25)	66 - (30)	5 - (40)
Lutjanus mahogany	Mahogani Snapper	2 - (25)	5 - (30)	
Mycteroperca venenosa	Yellowfin Grouper	1 - (50)	1 - (60)	
M. interstitialis	Yellowmouth Grouper	1 – (40)		
Ocyurus chrysurus	Yellowtail Snapper	2 - (30)	2 – (40)	
Pterois volitans	Lionfish	4 – (25)	3 – (30)	
Scomberomorus regalis	Cero Mackerel	2 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (70)		
Invertebrates				
Panulirus argus	Spiny Lobster	2 - (20)	1 – (25)	
Strombus gigas	Queen Conch	8 - (25)		
Sea Turtles				
Eretmochelys imbricata	Hawksbill Turtle	1 – (70)		

pelagic predators, such as Nassau and Yellowfin Groupers, Barracudas, Cero Mackerels, Blue Runners, and Black Jacks (Table 16). During the 2011 an exceptionally large school of juvenile Rainbow Runners (*Elagatis bippinulata*) were observed under a sargassum mat over the reef. Yellowtail, Mahogany, Dog and Schoolmaster Snappers, Red Hind, Coney, Queen Triggerfish and the Caribbean Reef Shark (*Carcharhinus perezi*) have been previously observed in full adult sizes at this reef (García-Sais et al., 2004-10). A large variety of small invertebrate feeders were present, including wrasses, gobies, goatfishes and squirrelfishes, among others. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous assemblage. 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.

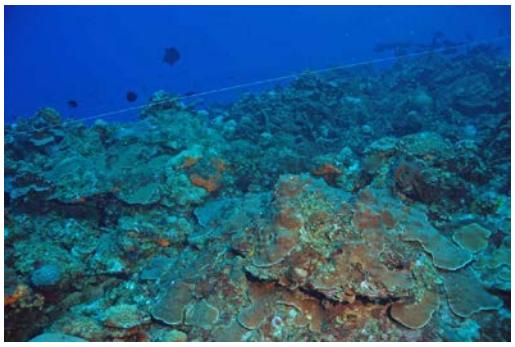
Arrow Crabs, Cleaner Shrimps and one Spiny Lobster were the motile megabenthic invertebrates observed within belt-transects during the 2011 survey (Table 17). Several Queen Conch and one additional adult Spiny Lobster were observed outside transects during the ASEC survey.

Table 17. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Puerto Canoas Shelf-edge Reef, Isla Desecheo 30m, August 2011

Depth: 25 – 30 m		TRANSECTS					**MEAN ABUNDANCE (IND/30 m2)**
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						
Stenorhynchus seticornis	Arrow crab			1			**0.4**
Stenopus hispidus	Cleaner shrimp		2				**0.2**
Periclimenes pedersoni	Cleaner Shrimp	1	1			2	**0.8**
Panulirus argus	Banded Coral Spiny Lobster					1	**0.2**
	TOTALS	**2**	**2**	**2**	**0**	**2**	**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). Digital photos of the mid shelf patch reef at Puerto Botes are shown as Photo Album 5.

A total of 23 stony corals, including 10 intersected by line transects were identified during this survey. Finger Coral, *Porites porites* was the species of highest mean percent substrate cover with a mean of 3.7 % (range: 0 – 14.4). It was present as a large single colony and two smaller colonies in three of the five transects surveyed. Boulder Star Coral, *Montastraea annularis* (complex), Lettuce Coral, *Agaricia agaricites*, and Mustard Hill Coral, *P. astreoides* comprised (with Finger Coral) the most prominent coral assemblage along transects representing 77.6 % of the total cover by live corals at Puerto Botes (Table 18). Recently dead corals, indicative of continued reef degradation have been observed at this reef since the massive bleaching event of 2005-06. The most affected coral was *M. annularis*, but the declining trend included other species as well. During the present 2011 survey, a marked decline of live cover by the branching Finger Coral, *P. porites* was noted

Reef overhangs, largely associated with skeletal buildups of *M. annularis* averaged 8.1 % of the reef substrate cover and contributed substantially to the reef rugosity of 3.7 m. Erect and encrusting sponges were present in four out of the five transects with a mean substrate cover of 3.0 %. Reef hard-ground substrates not colonized by stony corals or sponges were mostly overgrown by a combination of turf algae (47.9 %) and fleshy macroalgae, mostly the encrusting fan alga, *Lobophora variegata.* The assemblage of

Table 18. Percent substrate cover by sessile-benthic categories at Desecheo Reef. July 2011. Depth: 20 m

	TRANSECTS					
	1	2	3	4	5	**MEAN**
Rugosity (m)	4.56	2.85	4.23	2.06	4.73	**3.7**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	14.4	12.7	9.0	4.5		**8.1**
Gaps		5.5	0.8		1.0	**1.4**
Sand				5.8	1.2	**1.4**
Total Abiotic	14.4	18.2	9.8	10.3	2.2	**11.0**
Benthic Algae						
Turf-mixed assemblage	50.8	47.2	47.2	35.4	59.0	**47.9**
Amphiroa sp.				6.4	0.6	**1.4**
Lobophora and Dictyota	21.6	18.9	9.4	7.1	6.5	**12.7**
Lobophora variegata	1.9	4.3	9.7	5.8	8.0	**5.9**
Dictyota sp.	3.7	2.0	5.6			**2.2**
Total Benthic Algae	78.0	72.4	71.9	54.8	74.1	**70.2**
Sponges		3.0	4.9	5.2	1.9	**3.0**
Cyanobacteria	2.5	4.1	2.2	4.7	11.9	**5.1**
Live Stony Corals						
Porites porites			3.2	14.4	0.8	**3.7**
Montastraea annularis	2.7	0.9	1.2	2.9	1.9	**1.9**
Agaricia agaricites	0.7		1.1	2.3	3.3	**1.5**
Porites astreoides		1.6		4.3		**1.2**
Montastraea cavernosa			0.9		3.1	**0.8**
Meandrina meandrites			1.5	1.2	0.9	**0.7**
Agaricia tenuifolia	1.7		1.6			**0.7**
Millepora alcicornis			0.7			**0.1**
Eusmilia fastigiata			0.6			**0.1**
Leptoseris cucullata	0.5					**0.1**
Total Stony Corals	5.6	2.4	10.7	25.1	9.9	**10.7**

Coral Species Outside Transects: *Agaricia sp., D. strigosa, Dendrogyra cylindrus, Millepora complanata*, *Mycetophyllia ferox, M. lamarki, M. aliciae, Siderastrea siderea, Scolymia cubensis, Stylaster roseus*

benthic algae represented the main substrate category at Puerto Botes with a combined mean cover of 70.2 % (Table 18). Cyanobacterial films were present on all five transects with a mean cover of 5.1 %. 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 48.01 %. Differences of live coral cover were minimal and statistically insignificant until the 2006 monitoring survey when live coral cover declined sharply to a mean of 22.35 %, a loss of 53.4% from the mean live coral cover in 2005. After 2006, live coral cover has continued its declining trend to a historical minimum of 10.7 %. Differences of live coral during the 2000 – 2005 and the 2006 – 2011 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 observed (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 2011 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, *M. 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 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 between surveys until present, when it declined from 5.6 % in 2010 to 3.7 % in the 2011 survey. Due to the marked decline of

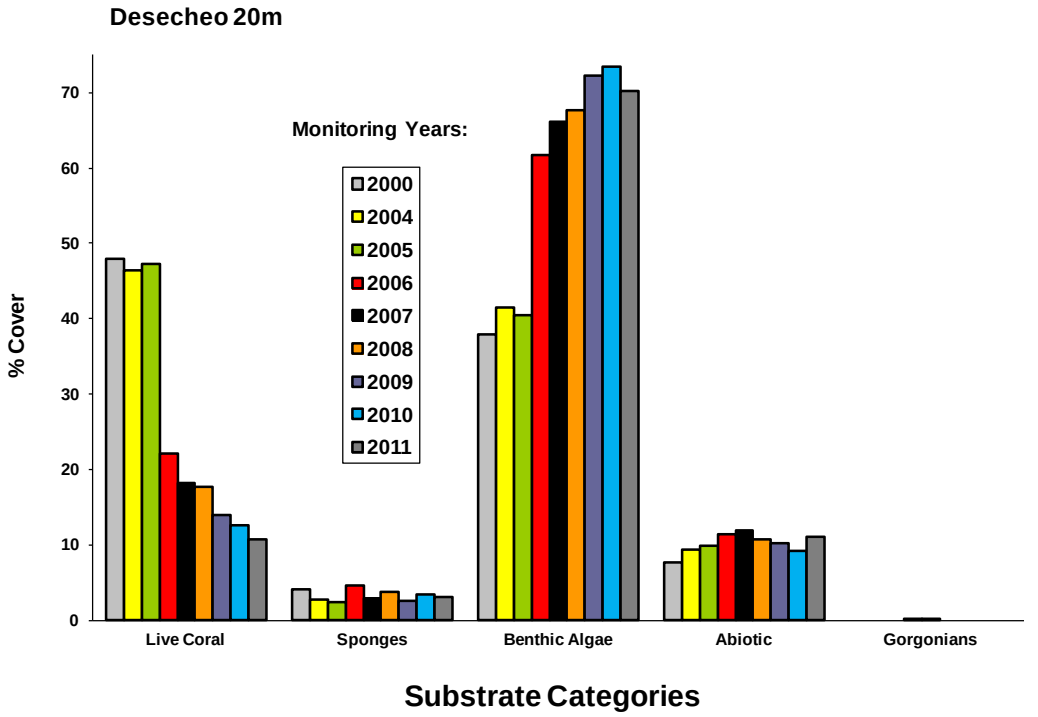


Figure 17. Monitoring trends (2000 – 11) of mean substrate cover by sessile-benthic categories at Puerto Botes Reef, Desecheo Island – 20 m.

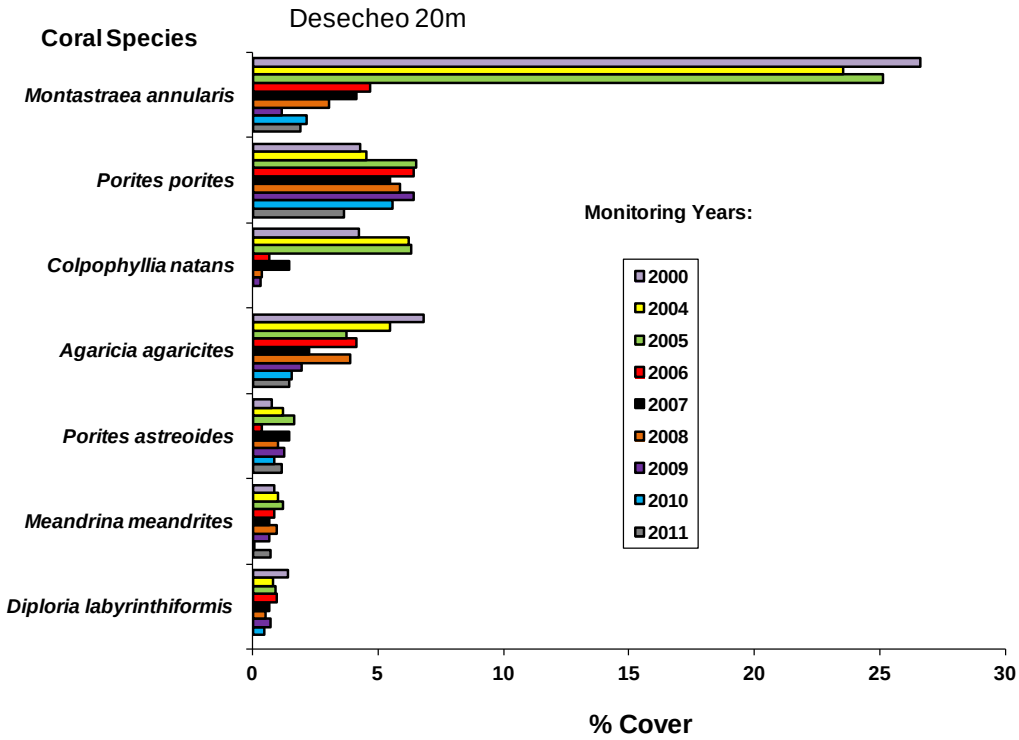


Figure 18. Monitoring trends (2000 – 11) of mean substrate cover by stony coral species at Puerto Botes Reef, Desecheo Island – 20 m.

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*) showed the highest increment between the 2005 and 2011 surveys, from 3.6 % in 2005 to 37.7 % in 2010. During 2011, *Lobophora* was found growing intermixed with the Y-twig Alga, *Dictyota sp*., but declined in cover to less than 20%.

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 45 fish species were identified within belt-transects from the mid-shelf patch reefs off Puerto Botes, Isla Desecheo during 2011 (Table 19). During the monitoring program, a total of 77 diurnal, non-criptic fishes have been reported from this reef (Appendix 1). Mean abundance of fishes within belt-transects was 192.6 Ind/30 m^2 (range: 182 - 218 Ind/30 m^2). The mean number of species per transect was 25.6 (range: 24 - 30). As in previous surveys, the Blue Chromis (*Chromis cyanea*) was the numerically dominant species within belt-transects during the 2011 with a mean abundance of 52.8 Ind/30 m^2. The combined abundance of seven species, including the Blue Chromis, Bicolor Damselfish, Bluehead and Yellowhead Wrasses, and the Sharknose and Peppermint Goby represented 78.5 % of the total fish abundance within belt-transects. Eight species were present in all five transects and another nine were present in four transects (Table 19).

Annual monitoring trends of fish species richness and abundance surveyed within belt-transects are presented in Figure 19. During the monitoring program, the mean number of fish species within transects (species richness) has fluctuated between 23.0 and 29.0, and mean abundance has varied between 166.8 Ind/30 m^2 and 248.6 Ind/30 m^2. The 2011 mean fish abundance and species richness fell within that range. Differences between surveys were not statistically significant (ANOVA; $p > 0.05$, see Appendix 3).

Table 19. Taxonomic composition and abundance of fishes within belt-transects at Puerto Botes Reef 20m, Isla Desecheo, July 2011

		TRANSECTS					
		1	2	3	4	5	
SPECIES	**COMMON NAME**	**Individuals/30m^2**					**MEAN**
Chromis cyanea	Blue Chromis	60	50	36	56	62	**52.8**
Clepticus parrae	Creole Wrasse	30	33	64	0	7	**26.8**
Stegastes partitus	Bicolor Damselfish	23	8	7	50	22	**22.0**
Thalassoma bifasciatum	Bluehead Wrasse	10	15	36	16	19	**19.2**
Gobiosoma evelynae	Sharknose Goby	12	11	11	9	13	**11.2**
Halichoeres garnoti	Yellow-head Wrasse	8	7	13	12	9	**9.8**
Coryphopterus lipernes	Peppermint Goby	4	5	9	16	13	**9.4**
Chromis multilineata	Brown Chromis	6	25	5	2	0	**7.6**
Halichoeres maculipinna	Clown Wrasse	5	5	4	4	3	**4.2**
Sparisoma aurofrenatum	Redband Parrotfish	11	0	5	0	0	**3.2**
Sparisoma radians	Bucktooth Parrotfish	6	0	4	1	0	**2.2**
Coryphopterus personatus	Masked Goby	0	1	0	0	8	**1.8**
Epinaphelus fulva	Coney	4	1	2	1	0	**1.6**
Acanthurus coeruleus	Blue Tang	1	1	1	1	2	**1.2**
Epinephelus cruentatus	Graysby	1	1	0	2	2	**1.2**
Gramma loreto	Fairy Basslet	1	1	2	0	2	**1.2**
Microspathodon chrysurus	Yellowtail Damselfish	1	3	0	1	1	**1.2**
Sparisoma viride	Stoplight Parrotfish	0	0	0	2	4	**1.2**
Amblycirrhitus pinos	Redspotted Hawkfish	1	1	1	0	2	**1.0**
Holocentrus rufus	Squirrelfish	3	0	1	0	1	**1.0**
Kyphosus bermudensis	Sea Chub	0	2	1	1	1	**1.0**
Melichthys niger	Black Durgon	2	0	2	1	0	**1.0**
Myripristis jacobus	Blackbar Soldierfish	0	3	1	1	0	**1.0**
Scarus taeniopterus	Princess Parrotfish	1	1	2	1	0	**1.0**
Ptoris volitans	Lionfish	0	3	2	0	0	**1.0**
Coryphopterus glaucophraenum	Briddled Goby	1	0	1	0	2	**0.8**
Bodianus rufus	Spanish Hogfish	0	1	1	0	1	**0.6**
Chaetodon capistratus	Four-eye Butterflyfish	1	0	1	1	0	**0.6**
Neoniphon marianus	Longspine Squirrelfish	0	2	0	0	1	**0.6**
Haemulon flavolineatum	French Grunt	0	0	1	0	2	**0.6**
Holacanthus tricolor	Rock Beauty	0	1	0	1	1	**0.6**
Scarus iserti	Stripped Parrotfish	0	0	0	1	2	**0.6**
Pomacanthus paru	French Angelfish	0	2	0	0	0	**0.4**
Ocyurus crysurus	Yellowtail Snapper	1	0	1	0	0	**0.4**
Serranus tigrinus	Harlequin Bass	0	0	0	2	0	**0.4**
Scarus iserti	Stripped Parrotfish	0	2	0	0	0	**0.4**
Acanthurs bahianus	Ocean Surgeon	0	0	1	0	0	**0.2**
Acanthostracion quadricornis	Scrawled Cowfish	0	0	0	1	0	**0.2**

Table 19. Continued

Canthigaster rostrata	Caribbean Puffer	0	0	0	1	0	**0.2**
Caranx crysos	Bule Runner	0	0	0	0	1	**0.2**
Haemulon macrustomus	Smanish Grunt	1	0	0	0	0	**0.2**
Lactophrys triqueter	Smooth Trunkfish	0	0	0	0	1	**0.2**
Hypleurochilus bermudensis	Barred Blenny	0	0	1	0	0	**0.2**
Sparisoma rubripinne	Yellowtail Parrotfish	0	0	1	0	0	**0.2**
Scomberomorus regalis	Cero	0	0	1	0	0	**0.2**
	TOTAL INDIVIDUALS	**194**	**185**	**218**	**184**	**182**	**192.6**
	TOTAL SPECIES	**24**	**25**	**30**	**24**	**25**	**25.6**

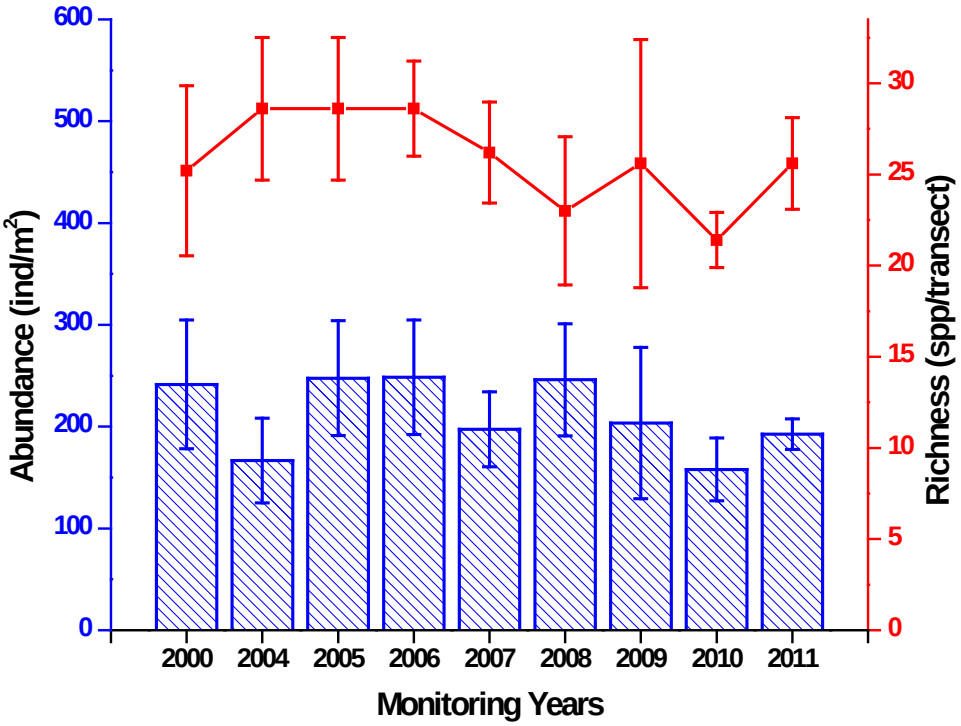


Figure 19. Monitoring trends (2000 – 2011) of fish species richness and abundance at the Mid-Shelf Reef, Puerto Botes, 20 m, Isla Desecheo.

The mid-shelf reef off Puerto Botes presented a well-balanced fish community in terms of trophic structure, except for the absence of large demersal predators, which were observed to be present in deeper sections of the shelf-edge off Puerto Canoas Reef, adjacent to Puerto Botes. Pelagic schools of Creole Wrasse (15 – 25 individuals) were observed throughout the water column, making frequent incursions over the reef. These are zooplanktivores that serve as forage for large pelagic predators, such as Cero

Mackerels, Black Jacks and Barracudas observed during an ASEC survey in this reef (Table 20). 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. These small shrimps appear to be important forage for the demersal zooplanktivorous fishes. 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. A large variety of small invertebrate feeders were present, including wrasses, gobies, goatfishes and squirrelfishes, among others. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous assemblage. 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 some of the lowest fish abundance and species richness reported during the monitoring program at Puerto Botes.

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. July, 2011

Depth : 17 - 20 m Duration - 30 min.

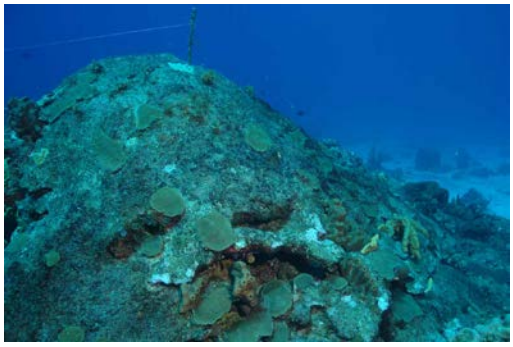
SPECIES	**COMMON NAME**		# - (cm)	
Carangoides hippos	Horse-eye Jack	5 – (40)		
Caranx lugubris	Black Jack	1 - (40)	2 – (50)	
Epinephelus guttatus	Red Hind	2 – (30)		
Lutjanus apodus	Schoolmaster	32 - (25)	7- (30)	5- (40)
Lutjanus mahogany	Mahogani Snapper	3 - (20)	4 – (25)	
Mycteroperca venenosa	Yellowfin Grouper	1 - (70)		
Ocyurus chrysurus	Yellowtail Snapper	2 – (30)	2 – (40)	
Pterois volitans	Lionfish	2 – (25)	1 – (30)	
Scomberomorus regalis	Cero Mackerel	2 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (70)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (20)		

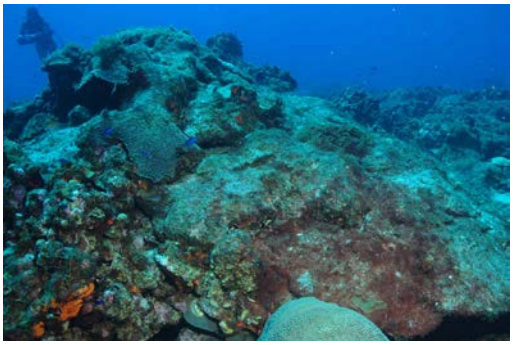
Table 21. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Puerto Botes Mid-shelf Reef. Isla Desecheo 20m, July 2011

		TRANSECTS					
Depth: 20 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Periclimenes pedersoni	Cleaner Shrimp		2	1			**0.6**
Stenorhynchus seticornis	Arrow Crab				1	1	**0.4**
Stenopus hispidus	Banded coral shrimp	1			2		**0.6**
	TOTALS	**1**	**2**	**1**	**3**	**1**	**1.6**

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 12 intersected by line transects were identified during this 2011 monitoring survey at Puerto Botes Inner Reef. Stony corals presented a mean substrate cover of 8.9 % (range: 7.6 – 10.2 %) (Table 22). Mustard-Hill Coral, *Porites astreoides*, Great Star Coral, *Montastraea cavernosa*, and Boulder Star Coral, *Montastraea annularis* (complex) comprised the main coral assemblage with a combined reef substrate cover of 6.3 %, representative of 70.8 % 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 *M. annularis* presented a mean substrate cover of 6.6 % and contributed substantially to the reef rugosity of 3.4 m. Total abiotic cover also included sections of sand and averaged 18.5 %. Sponges were present at all transects with a mean substrate cover of 5.3 % (Table 22).

Benthic algae, represented by a mixed assemblage of turf, fleshy (brown and red), and red-coralline macroalgae were the main sessile-benthic reef component in terms of substrate cover with a combined mean of 64.0 % (Table 22). Fleshy macroalgae, mostly comprised by *Lobophora variegata and Dictyota sp*. were the dominant component of the benthic algae with a mean cover of 37.2 %. 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 Desecheo Reef, 15 m. . July 2011

Depth: 15 m	TRANSECT					
	1	2	3	4	5	**MEAN**
Rugosity (m)	3.6	3.8	3.2	2.4	4.1	**3.4**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	12.4	7.9	8.9	0.9	2.8	**6.6**
Sand	16.2	9.3	15.4	15.5	3.1	**11.9**
Total Abiotic	28.6	17.2	24.3	16.4	5.9	**18.5**
Benthic Algae						
Lobophora and Dictyota	8.0	37.3	38.4	36.7	24.6	**29.0**
Turf-mixed assemblage	23.4	18.8	15.1	23.8	47.1	**25.6**
Dictyota sp.	24.3	12.8	4.1			**8.2**
Amphiroa sp.	0.5			5.0		**1.1**
Total Benthic Algae	56.2	68.9	57.5	65.5	71.7	**64.0**
Gorgonians						
Sponges	6.1	3.7	1.7	3.6	11.5	**5.3**
Cyanobacteria	0.5		7.9	7.0	1.2	**3.3**
Live Stony Corals						
Porites astreoides	2.5	7.3	3.7	1.3		**3.0**
Montastraea cavernosa	2.1	1.0	1.8	1.4	2.6	**1.8**
Montastraea annularis			1.5	2.1	4.1	**1.5**
Agaricia agaricites		0.8		1.7	1.5	**0.8**
Siderastrea siderea	2.0		1.6			**0.7**
Diploria strigosa					1.4	**0.3**
Eusmilia fastigiata				1.3		**0.3**
Madracis decactis	0.7	0.2				**0.2**
Diploria labyrinthiformis	0.9					**0.2**
Millepora alcicornis	0.4					**0.1**
Leptoseris cucullata		0.4				**0.1**
Porites porites		0.4				**0.1**
Total Stony Corals	8.6	10.2	8.6	7.6	9.7	**8.9**

Coral Species Outside Transects: *Acropora cervicornis, Agaricia tenuifolia, Colpophyllia natans, Diploria clivosa, Leptoseris cucullata, Siderastrea radians, Stylaster roseus,*

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 2004-11. 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; $p < 0.0001$, see Appendix 2). The decline of coral cover during 2007 was observed in four out of the five transects surveyed. After 2007, live coral cover at Puerto Botes Reef 15m has remained within sampling variability error.

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, *Montastraea 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 *M. annularis* in recent surveys. 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 nine 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 Corals *Agaricia agaricites*, Starlet Coral, *Siderastrea siderea*, Flower Coral, *Eusmilia fastigiata* and Symetrical Brain Coral, *Diploria strigosa*.

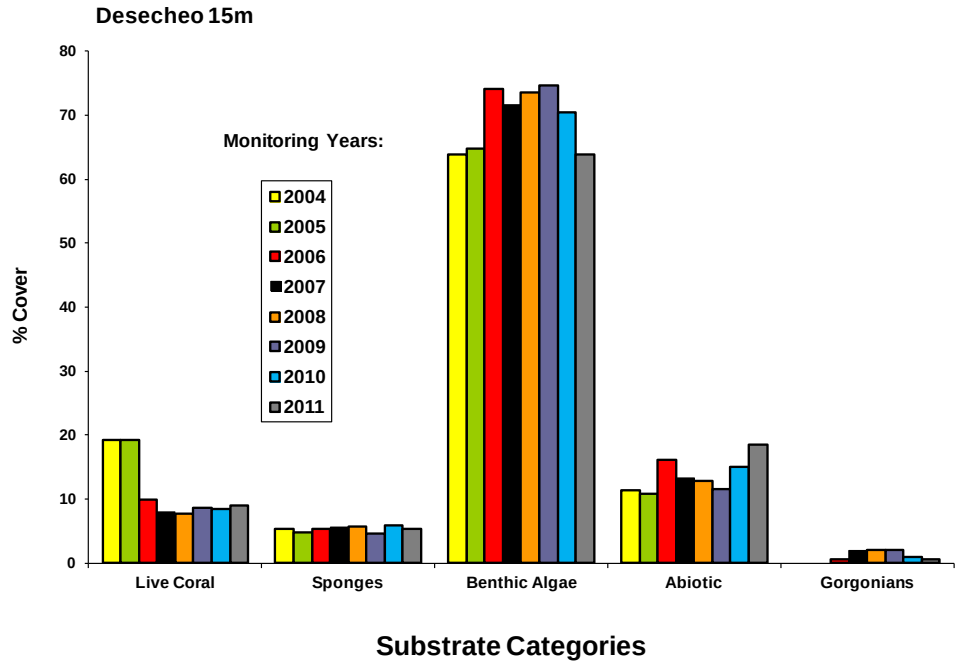


Figure 20. Monitoring trends (2004 -2011) of mean substrate cover by sessile-benthic categories at Puerto Botes Inner Shelf Reef, Desecheo Island – 15 m.

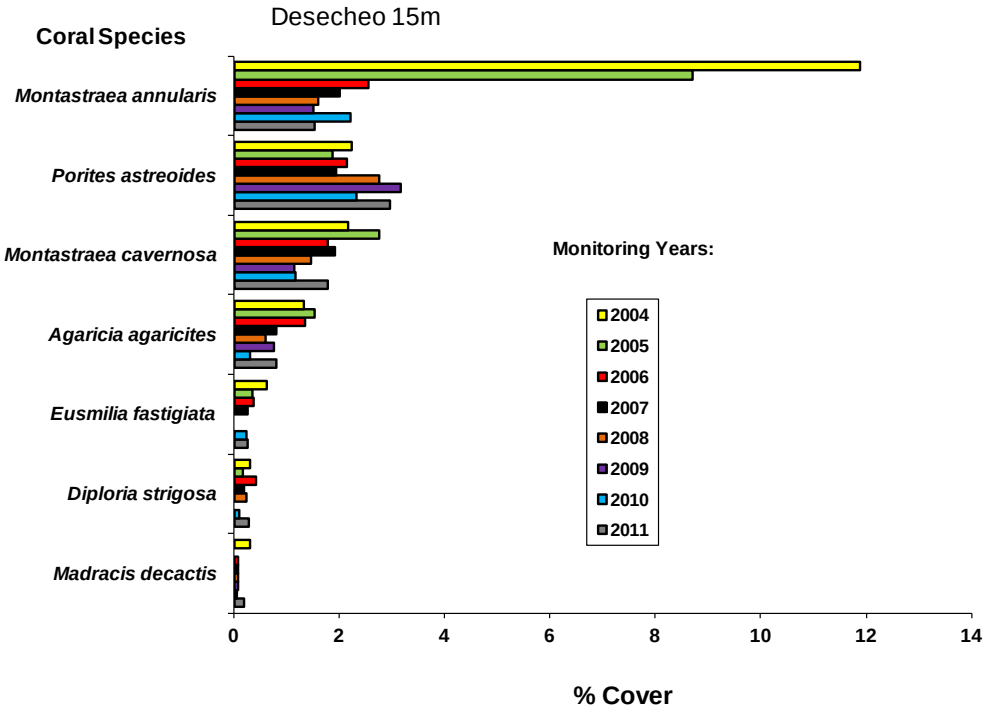


Figure 21. Monitoring trends (2004 -2011) of mean substrate cover by stony coral species at Puerto Botes Inner Shelf Reef, Desecheo Island – 15 m.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 38 fish species were identified within belt-transects from the Inner-Shelf Reef off Puerto Botes, Isla Desecheo during 2011 (Table 23). Mean abundance within belt-transects during the 2011 survey was 168.2 Ind/30 m^2 (range: 134 - 202 Ind/30 m^2). The mean number of species per transect was 21.4 (range: 19 - 27). The Blue Chromis, Bicolor Damselfish, and Bluehead Wrasse were the numerically dominant species with a combined abundance of 109.0 Ind/30 m^2, representing 64.8 % of the total fish abundance. Eleven additional species were present in at least four out of the five transects. These include the Yellowhead and Clown Wrasses, Sharknose and Bridled Goby, Yellowtail Damselfish, Blue Tang, Coney, Bucktooth, Princess, Stripped and Redband Parrotfishes. A total of seven 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 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 monitoring program at this reef. A statistically significant decline of fish species richness and abundance was observed during the 2008 (spp. richness) and 2010 (abundance) surveys relative to previous surveys (ANOVA; $p < 0.05$, see Appendix 3). Differences of fish abundance were 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 real patterns. Nevertheless, the marked decline of live coral may have influenced the reduction in numbers of schooling chromis from the reef. As live coral disappeared, reef substrate was colonized by turf and fleshy algae, which in turn became an appropriate habitat for herbivorous damselfishes. These species are territorial and very aggressive and can drive away the schooling chromis species. Also, the minimum fish abundance record of the 2010 survey coincided with the establishment of the Lionfish (*Pterois volitans*) in this reef. This invasive species is regarded as a voracious predator of small fishes and could have influenced the abundance of small fishes in the reef.

Table 23. Taxonomic composition and abundance of fishes within belt-transects at the Inner Shelf Reef off Puerto Botes, 15 m Isla Desecheo, July, 2011

Depth: 15m

		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**	**Individuals/30m^2**					**MEAN**
Chromis cyanea	Blue Chromis	22	62	35	41	44	**40.8**
Stegastes partitus	Bicolor Damselfish	56	44	45	28	0	**34.6**
Thalassoma bifasciatum	Bluehead Wrasse	50	15	15	45	43	**33.6**
Halichoeres garnoti	Yellow-head Wrasse	15	9	10	17	9	**12.0**
Gobiosoma evelynae	Sharknose Goby	22	7	3	2	0	**6.8**
Mulloides martinicus	Yellowtail Goatfish	0	25	0	0	0	**5.0**
Epinephelus fulva	Coney	6	4	7	2	2	**4.2**
Sparisoma radians	Bucktooth Parrotfish	6	5	1	1	0	**2.6**
Halichoeres maculipinna	Clown Wrasse	4	1	5	1	1	**2.4**
Scarus taeniopterus	Princess Parrotfish	2	1	3	1	5	**2.4**
Scarus iserti	Stripped Parrotfish	0	8	2	1	0	**2.2**
Acanthurus coeruleus	Blue Tang	1	4	2	1	2	**2.0**
Microspathodon chrysurus	Yellowtail Damselfish	1	1	3	1	4	**2.0**
Chromis multilineata	Brown Chromis	0	4	4	1	0	**1.8**
Lutjanus apodus	Schoolmaster	0	2	7	0	0	**1.8**
Sparisoma aurofrenatum	Redband Parrotfish	3	1	2	1	2	**1.8**
Clepticus parrae	Creole Wrasse	0	0	2	0	5	**1.4**
Myripristis jacobus	Blackbar Soldierfish	0	2	3	0	2	**1.4**
Amblycirrhitus pinnos	Redspotted Hawkfish	0	1	0	1	4	**1.2**
Holocentrus rufus	Squirrelfish	1	1	0	1	3	**1.2**
Coryphopterus lipernes	Peppermint Goby	0	1	2	0	2	**1.0**
Coryphopterus glaucophraenum	Goby	1	1	1	1	0	**0.8**
Bodianus rufus	Spanish Hogfish	0	1	2	0	0	**0.6**
Epinephelus cruentatus	Graysby	0	0	0	1	1	**0.4**
Chaetodon capistratus	Four-eye Butterflyfish	0	2	0	0	0	**0.4**
Chaetodon striatus	Banded Butterflyfish	0	0	2	0	0	**0.4**
Gramma loreto	Fairy Basslet	0	0	0	0	2	**0.4**
Acanthostracion polygonia	Honeycomb Cowfish	1	0	1	0	0	**0.4**
Lactophrys triqueter	Smooth Trunkfish	0	0	1	0	1	**0.4**
Sparisoma viride	Stoplight Parrotfish	0	0	1	0	1	**0.4**
Sparisoma rubripine	Yellowtail Parrotfish	1	0	1	0	0	**0.4**
Acanthurus bahianus	Ocean Surgeon	0	0	1	0	0	**0.2**
Halichoeres poegy	Blackear Wrasse	1	0	0	0	0	**0.2**
Holacanthus tricolor	Rock Beauty	0	0	1	0	0	**0.2**
Acanthurus chirurgus	Doctorfish	0	0	0	0	1	**0.2**
Melichthys niger	Black Durgon	1	0	0	0	0	**0.2**
Serranus tigrinus	Harlequin Bass	1	0	0	0	0	**0.2**
Acanthemblemaria aspera	Roughead Blenny	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	195	202	162	148	134	**168.2**
	TOTAL SPECIES	19	23	27	19	19	**21.4**

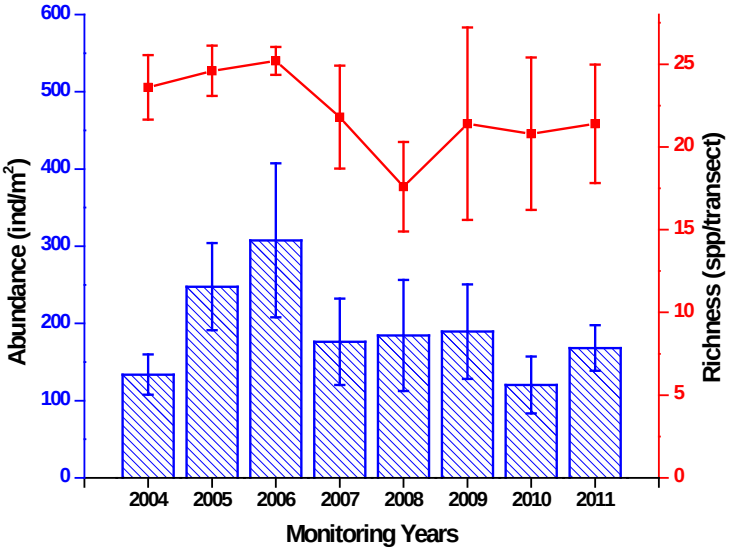


Figure 22. Monitoring trends (2004 – 2011) of fish species richness and abundance at Inner Shelf Reef, Puerto Botes, 15 m depth, Isla Desecheo.

Reef zooplankton feeders, such as the Bicolor Damselfish, Creole Wrasse and the Blue and Brown Chromis 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 observed and previously reported 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 were 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.

A specious assemblage of small invertebrate feeders was also present, including wrasses, gobies, goatfishes and squirrelfishes, among others. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous assemblage. Commercially important species for the aquarium trade market were mostly represented by Blue Chromis and Fairy Basslet (*Gramma loreto*) or Royal Gramma, as it is known in the aquarium trade. Fairy Basslets were present at the Inner Reef, but in much lower abundance than in deeper sections of the reef. The Queen Angelfish (*Holacanthus ciliaris*) and Rock Beauty (*Holacanthus tricolor*) have been previously reported. Motile megabenthic invertebrates were represented within belt-transects by sponge stars, 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, July, 2011

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

SPECIES	**COMMON NAME**		# - (cm)	
Caranx crysos	Blue Runner	2 - (30)	1 – (40)	
Elagatis bippinulatus	Rainbow Runner	3 – (50)		
Epinephelus guttatus	Red Hind	1 – (30)		
Lutjanus apodus	Schoolmaster	42 - (25)	5 - (30)	1 - (40)
Lutjanus mahogany	Mahogani Snapper	3 - (20)	4 – (25)	1 - (30)
Ocyurus chrysurus	Yellowtail Snapper	8 – (40)		
Scomberomorus regalis	Cero Mackerel	1 - (40)	1 - (50)	
Sphyraena barracuda	Great Barracuda	1 - (60)		

Table 25. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at the Puerto Botes Inner-Shelf Reef, 15 m, Isla Desecheo, July, 2011

		TRANSECTS					
Depth: 15 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Stenorhynchus seticornis	Arrow Crab	1			1	1	**0.6**
Periclimenes pedersoni	Cleaner Shrimp	1	1				**0.4**
Ophiothrix suensoni	Sponge Brittle Star	1		3			**0.8**
	TOTALS	**3**	**1**	**3**	**1**	**1**	**1.8**

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).

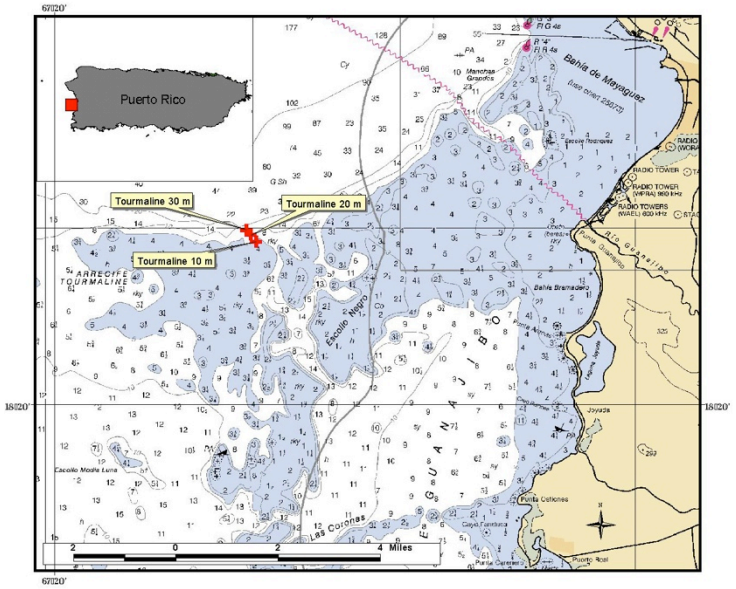


Figure 23. Location of coral reef survey stations at Tourmaline Reef, off Mayaguez Bay.

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 were identified from the shelf-edge off Tourmaline Reef, 12 of which were intercepted by line transects during our survey (Table 26). Stony corals occurred mostly as isolated encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 18.8 % (range: 12.3 – 25.6 %). Boulder Star Coral, *Montastraea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 7.5 % (range: 5.4 – 10.6 %), representing 39.9 % 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*, and Lettuce Coral, *A. agaricites* were also prominent at the shelf-edge. These species are difficult to discern in the generally poorly illuminated condition of the reef at 30m and are here reported as one group of species (e.g. *Agaricia spp*). Vertically projected soft corals (erect gorgonians) were highly abundant, with an average of 15.4 colonies/transect. The Corky Sea Finger, *Briareum asbestinum* and the Sea Plume, *Pseudopterogorgia acerosa* were some of the most common species observed. Encrusting gorgonians, particularly *Erythropodium caribaeorum* were present in all five transects with a combined abundance of 4.4 %. Colonies of Bushy Black Coral (*Antipathes caribeana*) and Wire Coral (*Stichopathes lutkeni*) were observed close to the deepest end of the reef at 32 m.

Encrusting and erect sponges, including several large Basket Sponges, *Xestospongia muta* were present in all transects with an average cover of 2.6 %. The Blue Bell Tunicate, *Clavelina puertosecensis* was very common throughout the shelf-edge reef. Reef overhangs, associated with substrate depressions and coral ledges averaged 26.5 % and contributed substantially to a topographic rugosity of 5.2 m.

Table 26. Percent substrate cover by sessile-benthic categories at Tourmaline Reef, Mayaguez. June 2011

Depth: 30 m

	1	2	3	4	5	MEAN
Rugosity (m)	6.51	4.34	6.00	5.13	3.93	**5.2**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	9.8	30.8	37.1	29.6	25.0	**26.5**
Gap	0.3					**0.1**
Silt	2.6	6.4	2.1		4.0	**3.0**
Total Abiotic	12.7	37.2	39.2	29.6	28.9	**29.5**
Benthic Algae						
Turf-mixed assemblage	46.2	37.1	42.7	50.8	42.3	**43.8**
Dictyota sp.				1.1		**0.2**
Total Benthic Algae	46.2	37.1	42.7	52.0	42.3	**44.0**
Encrusting Gorgonians						**0.0**
Erythropodium caribaeorum	13.3	0.6	3.9	2.9	0.9	**4.3**
Briareum asbestinum		0.4				**0.1**
Total encrusting gorgonians	13.3	1.0	3.9	2.9	0.9	**4.4**
Sponges	6.7	2.4		3.2	0.4	**2.6**
Cyanobacteria	0.6				1.8	**0.5**
Live Stony Corals						
Montastraea annularis	5.4	6.0	8.7	7.0	10.6	**7.5**
Agaricia spp.	6.3	10.3	3.0	4.8	10.7	**7.0**
Montastraea cavernosa	1.4	0.4	2.1		3.5	**1.5**
Madracis formosa	0.8	2.9				**0.7**
Porites astreoides	2.1	0.4		0.4		**0.6**
Stephanocoenia intersepta		1.0	0.4		0.8	**0.4**
Mycetophyllia sp.	2.1					**0.4**
Siderastrea siderea	1.4					**0.3**
Porites colonensis		1.0				**0.2**
Siderastrea radians		0.3				**0.1**
Total Stony Corals	19.4	22.2	14.3	12.3	25.6	**18.8**
Total Erect Gorgonians (# col/transect)	18	10	15	16	18	**15.4**

Coral Species Outside Transects: *Antipathes caribbeana, Stichopathes lutkeni, Scolymia cubensis, Millepora alcicornis, Meandrina meandrites, Mycetophyllia lamarkiana, M. aliciae, Porites porites, Madracis decactis*

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 43.8 % (range: 37.1 – 50.8%). Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard bottom. The total cover by benthic algae was 44.0 %. Cyanobacterial films were present in two transects with a mean reef substrate cover of 0.5 %.

Figure 24 presents the annual fluctuations of mean percent cover by sessile-benthic categories from the shelf-edge of Tourmaline Reef at 30 m depth. Live coral cover exhibited a mild trend of degradation during 2006 and 2007 after the 2005 regional coral bleaching event and since then has maintained a slow but consistent trend of increasing substrate cover until present. Differences of live coral cover between monitoring surveys are still within sampling variability error (ANOVA; $p = 0.150$, see Appendix 2), but the trend appears to be indicative of a partial recuperation from the degraded baseline conditions in which it was initially characterized. Boulder Star Coral, *Montastraea annularis* maintained its status as the dominant coral species in terms of reef substrate cover at 30 m (Figure 25). Since our baseline survey in 2004, many large colonies of *M. 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 *M. annularis* during the 2006 monitoring survey, widespread mortality associated with bleaching has not been observed at this reef.

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 110 fish species have been identified from Tourmaline Reef at depths of 25-30 m (Appendix 1), including 38 within belt-transects during the 2011 monitoring survey. Mean abundance was 518.6 Ind/30 m^2 (range: 431 - 687 Ind/30 m^2). The mean number of species per transect was 21.8 (range: 15 - 25). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 362.0 Ind/30 m^2 (range: 280 - 500 Ind/30 m^2), representing 69.8 % of the total abundance within belt-transects (Table 27). The Masked Goby is a small carnivorous fish (< 2.0 cm) that aggregates in swarms below coral ledges and crevices near the sand-coral

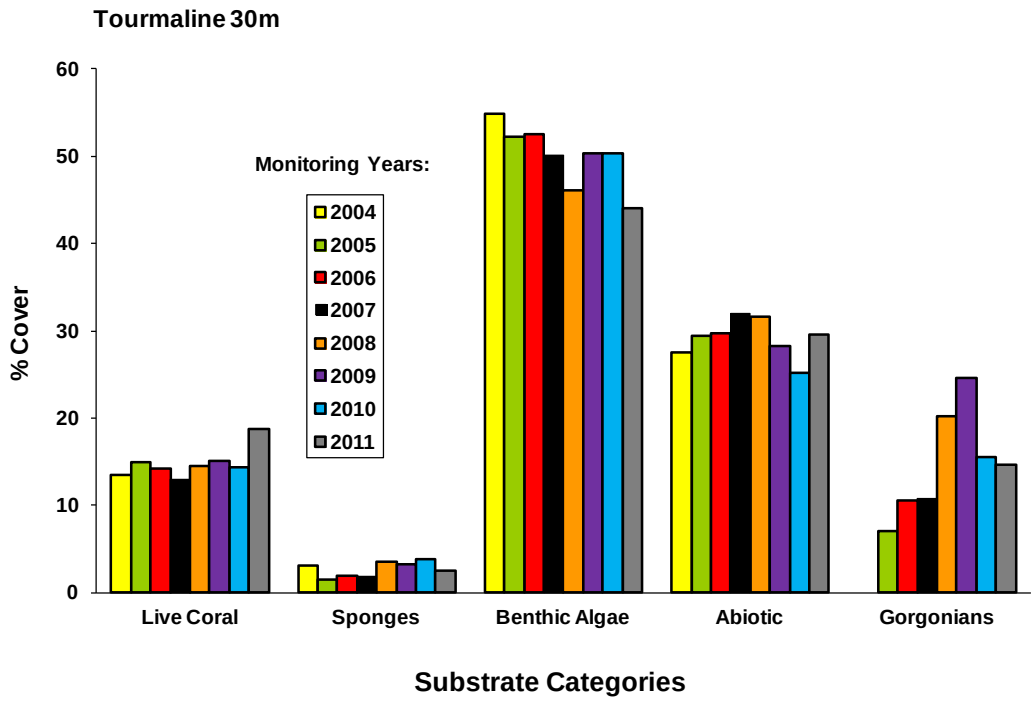


Figure 24. Monitoring trends (2004 – 2011) of mean substrate cover by sessile-benthic categories at Tourmaline Shelf-edge Reef – 30 m, Mayaguez Bay.

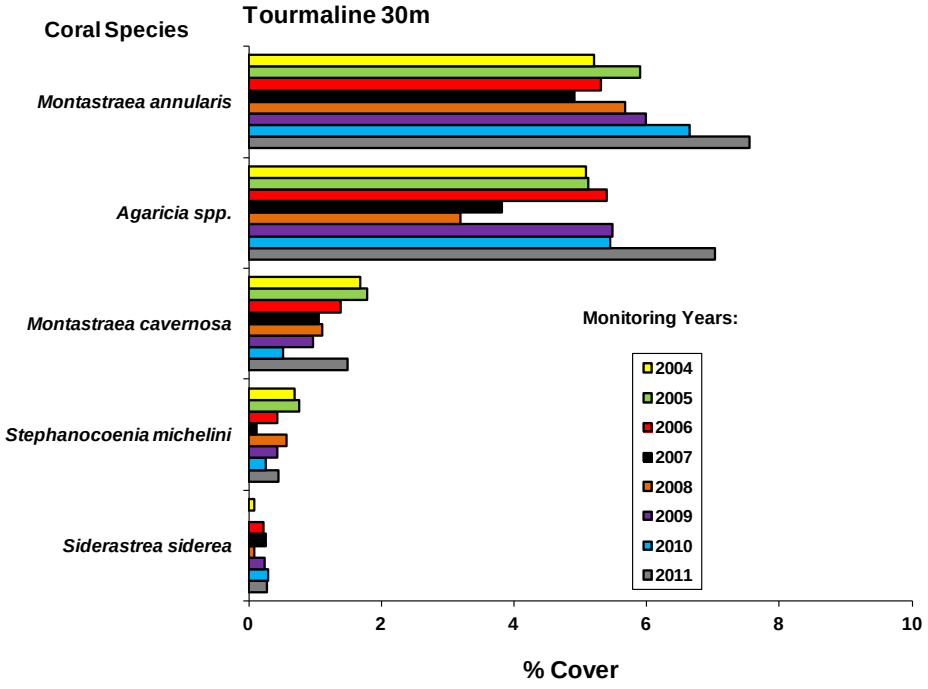


Figure 25. Monitoring trends (2004 – 2011) of mean substrate cover by stony coral species at Tourmaline Reef – 30 m, Mayaguez Bay.

Table 27. Taxonomic composition and abundance of fishes within belt-transects at the Tourmaline Shelf-Edge Reef, 30 m. Mayaguez, July 2011

Depth: 30m		Transects 1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	500	350	360	320	280	**362.0**
Clepticus parrae	Creole Wrasse	105	25	120	32	60	**68.4**
Coryphopterus lipernes	Peppermint Goby	8	25	35	17	56	**28.2**
Chromis cyanea	Blue Chromis	15	0	23	9	17	**12.8**
Gramma loreto	Fairy Basslet	7	6	8	14	1	**7.2**
Chromis insolata	Sunshine Chromis	5	10	6	5	0	**5.2**
Myripristis jacobus	Blackbar Soldierfish	5	6	3	2	1	**3.4**
Stegastes partitus	Bicolor Damselfish	7	2	5	2	1	**3.4**
Scarus iserti	Stripped Parrotfish	0	1	3	7	4	**3.0**
Ocyurus chrysurus	Yellowtail Snapper	12	0	0	0	0	**2.4**
Stegastes leucostictus	Beau Gregory	2	2	2	4	2	**2.4**
Gobiosoma evelynae	Sharknose Goby	0	5	2	2	0	**1.8**
Halichoeres garnoti	Yellow-head Wrasse	3	2	1	2	1	**1.8**
Thalassoma bifasciatum	Bluehead Wrasse	0	1	3	2	3	**1.8**
Canthigaster rostrata	Caribbean Puffer	1	1	3	1	2	**1.6**
Epinephelus cruentatus	Graysby	2	3	1	2	0	**1.6**
Lutjanus synagris	Lane Snapper	0	0	4	4	0	**1.6**
Chaetodon capistratus	Four-eye Butterflyfish	0	3	2	2	0	**1.4**
Neoniphon marianus	Longspine Squirrelfish	0	2	1	1	0	**0.8**
Haemulon aurolineatum	Tomtate	2	1	1	0	0	**0.8**
Hypoplectrus puella	Barred Hamlet	1	0	1	1	1	**0.8**
Mulloides martinicus	Yellowtail Goatfish	3	1	0	0	0	**0.8**
Coryphopterus glaucofraenum	Briddled Goby	0	3	0	0	0	**0.6**
Haemulon flavolineatum	French Grunt	1	1	1	0	0	**0.6**
Sparisoma viride	Stoplight Parrotfish	0	1	0	2	0	**0.6**
Liopropoma rubre	Swiss Guard Basslet	0	1	0	1	1	**0.6**
Chaetodon aculeatus	Longsnout Butterflyfish	0	2	0	0	0	**0.4**
Holacanthus tricolor	Rock Beauty	1	1	0	0	0	**0.4**
Sparisoma aurofrenatum	Redband Parrotfish	0	0	1	1	0	**0.4**
Acanthurus coeruleus	Blue Tang	0	0	0	0	1	**0.2**
Caranx crysos	Blue Runner	1	0	0	0	0	**0.2**
Caranx ruber	Bar Jack	1	0	0	0	0	**0.2**
Epinephelus fulva	Coney	1	0	0	0	0	**0.2**
Hypoplectrus unicolor	Butter Hamlet	1	0	0	0	0	**0.2**
Pomacanthus arcuatus	Grey Angelfish	1	0	0	0	0	**0.2**

Table 27. Continued

Pseudupeneus maculatus	Spotted Goatfish	1	0	0	0	0	**0.2**
Serranus baldwini	Lantern Bass	0	1	0	0	0	**0.2**
Sparisoma radians	Bucktooth Parrotfish	1	0	0	0	0	**0.2**
	TOTAL INDIVIDUALS	687	456	586	433	431	**518.6**
	TOTAL SPECIES	25	25	22	22	15	**21.8**

interface. A total of 14 species were present in at least four transects and appear to be the main residential assemblage of the Tourmaline shelf-edge reef at 30 m. These include the Masked and Peppermint Gobies, Creole Wrasse, Yellowhead and Bluehead Wrasses, Graysbe, Fairy Basslet, Beaugregory and Bicolor Damselfishes, Blue and Sunshine Chromis, Caribbean Puffer, Striped Parrotfish, and Black-bar Soldierfish

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 16.2 species per transect in the 2008 survey. Differences of species richness between annual surveys were statistically significant (ANOVA; $p = 0.018$). After a trend of declining species richness that started on 2008 and extended until 2010, a partial recuperation from baseline levels was observed during the present 2011 survey. Differences of fish abundance between monitoring surveys were also statistically significant (ANOVA; $p < 0.001$). Annual fluctuations are large and mostly driven by the abundance variability 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. During 2011, peak abundances of Masked Goby were recorded at Tourmaline 30 m.

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 and Nassau Groupers, one large Hogfish, and several snappers were observed during the 2011 ASEC survey (Table 28). Juvenile Nassau and Yellowmouth Groupers were previously reported from this reef (García-Sais et al., 2004, 2005), as well as large pelagics, such as Cero Mackerel and Great Barracuda (García-Sais et al., 2004, 2005).

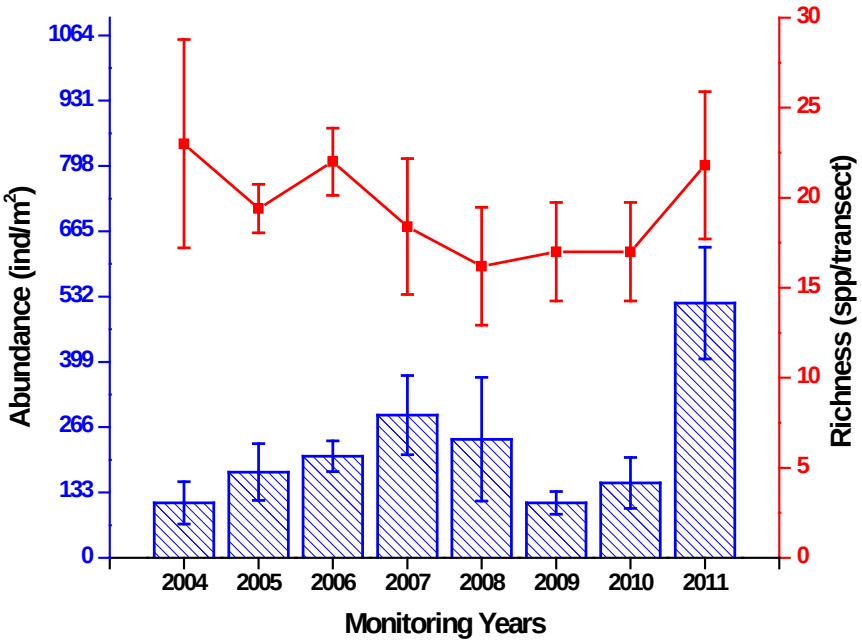


Figure 26. Monitoring trends (2004 – 2011) of fish species richness and abundance at Shelf-edge Reef Tourmaline, 30 m, Mayaguez Bay.

Schools of Mackerel Scad, *Decapterus macarellus* were present in mid-water over the reef. These are zooplanktivores that serve as forage for pelagic predators, such as Almaco Jack, Cero Mackerels and Barracudas. The Blue Chromis is also an important zooplanktivore that was common over coral heads closer to the reef. A large variety of small invertebrate feeders were present, including wrasses, gobies, goatfishes and squirrelfishes among others. Two Lionfishes were observed on the reef during our survey.

Banded-Coral and Cleaner Shrimps were observed within belt-transects at the Tourmaline shelf-edge Reef during this survey (Table 29). Arrow Crabs (*Stenorhynchus seticornis)* and two Spiny Lobsters (*Panulirus argus*) were observed outside transects during the ASEC survey (Table 28).

Table 28. Size-frequency distribution of large and/or commercially important reef fishes observed during an ASEC survey at Tourmaline Shelf-edge Reef, 30 m. June, 2011

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

SPECIES	**COMMON NAME**	**# - (cm)**	**# - (cm)**
Epinephelus guttatus	Red Hind	2 - (35)	
Epinephelus striatus	Nassau Grouper	1 - (40)	
Decapterum macarellus	Mackerel Scad	>100 – (10 – 15)	
Lutjanus apodus	Schoolmaster Snapper	1 - (25)	1 – (30)
Lutjanus mahogony	Mahogany Snapper	2 - (25)	
Lachnolaimus maximus	Hogfish	1 - (65)	
Ocyurus chrysurus	Yellowtail Snapper	2 - (25)	
Scomberomorus regalis	Cero Mackerel	2 - (50)	
Sphyraena barracuda	Great barracuda	1 - (50)	

Table 29. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Shelf-edge Reef, 30 m, Mayaguez. June, 2011

Depth: 30 m		**TRANSECTS**					**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Periclimenes pedersoni	Cleaner Shrimp	4	2				**1.2**
Stenopus hispidus	Banded Coral Shrimp		1	1			**0.4**
	TOTALS	**4**	**3**	**1**	**0**	**0**	**1.6**

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, 13 of which were intercepted by line transects during our survey (Table 30). Stony corals occurred as massive (*Montastraea 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 26.1 % (range: 23.2 – 28.5 %). 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 18.8 % (range: 15.6 – 22.2 %), representing 72.0 % of the total cover by stony corals. Colonies of Boulder Star Coral were intercepted by all five transects. Mustard Hill Coral (*Porites astreoides*), Great Star Coral and Greater Starlet Coral along with Boulder Star Coral comprised the main stony coral assemblage at 20 m.

Vertically projected soft corals (gorgonians) were highly abundant and intercepted by all transects with a mean abundance of 19.8 col/transect. *Briareum asbestinum,* and *Pseudoptergorgia sp.* were the most abundant species. Sponges were present at the reef, but were not common and only intercepted by one transect for a mean cover of 0.3 %.

Table 30. Percent substrate cover by sessile-benthic categories at Tourmaline Reef, 20 m Mayaguez. June 2011

Depth: 20 m	1	2	3	4	5	**MEAN**
Rugosity (m)	3.51	4.82	4.10	6.01	4.56	**4.60**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	11.3	21.6	14.3	27.1	32.2	**21.3**
Gaps			0.5		1.3	**0.4**
Sand				3.0		**0.6**
Total Abiotic	11.3	21.6	14.8	30.2	33.5	**22.2**
Benthic Algae						
Turf-mixed assemblage	26.9	31.2	19.1	22.6	14.8	**22.9**
Lobophora variegata	27.1	15.3	29.2	15.7	23.7	**22.2**
Coralline algae	1.9		1.2			**0.6**
Dictyota sp.				1.3	1.7	**0.6**
Total Benthic Algae	55.9	46.5	49.5	39.6	40.2	**46.3**
Encrusting Gorgonians						
Erythropodium caribaeorum	4.4	3.6	6.7	3.8	1.9	**4.1**
Briareum asbestinum		2.0				**0.4**
Total Encrusting Gorgonians	4.4	5.7	6.7	3.8	1.9	**4.5**
Sponges					1.4	**0.3**
Cyanobacteria		0.5	2.0	0.8		**0.6**
Live Stony Corals						
Montastraea annularis	21.6	18.7	15.6	22.2	16.1	**18.8**
Montastraea cavernosa	2.2		7.4		3.7	**2.7**
Porites astreoides		1.6	1.9	0.9	1.6	**1.2**
Siderastrea siderea	2.3			1.4	1.7	**1.1**
Colpophyllia natans		2.9				**0.6**
Meandrina meandrites		1.6		0.6		**0.4**
Madracis decactis		0.9		0.4		**0.3**
Agaricia lamarcki	0.8		0.5			**0.3**
Madracis auretenra	1.3					**0.3**
Diploria labyrinthiformis			1.1			**0.2**
Millepora alcicornis	0.3		0.3			**0.1**
Mycetophyllia			0.3			**0.1**
juvenile coral				0.2		**0.03**
Total Stony Corals	28.5	25.8	27.1	25.7	23.2	**26.1**
Gorgonians (# col.)	18	15	18	24	24	**19.8**

Coral Species Outside Transects : *Eusmilia fastigiata, Acropora cervicornis, Diploria strigosa, Antipathes sp, Leptoseris cucullata*, *Stephanocoenia michelini, Scolymia cubensis, Millepora sp.*

Colonies of Bushy Black Coral (*Antipathes caribbeana*) were present at the reef base. Reef overhangs, associated with live and dead ledges of Boulder Star Coral averaged 21.3 % of the reef substrate cover and contributed markedly to the topographic rugosity of 4.6 m.

Benthic algae, comprised by turf, fleshy and coralline macroalgae were the dominant sessile-benthic component in terms of substrate cover at the outer shelf reef with a combined average of 46.3 % (range: 39.6– 55.9 %). Turf algae, a mixed assemblage of short filamentous red and brown macroalgae contributed a reef substrate cover of 22.9%, representing 49.5% of the total benthic algae. The Encrusting Fan Alga, *Lobophora variegata* (mean cover: 22.2%) was the other main component of the fleshy algal assemblage. Cyanobacterial films were intercepted by three transects with a mean surface cover of 0.6 %.

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, $p = 0.149$; Appendix 2). Live coral declined 9.5 % between 2004 and 2005, then declined 12.9 % between 2005 and 2006, and 9.0 % between 2006 and 2007. During the last four years live coral cover stabilized at 23 - 26%, presenting small fluctuations that appear to be within sampling variability error.

Montastraea 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 Greater Starlet Coral, *Siderastrea siderea* also showed a declining trend of substrate cover during the monitoring program. Mild increments of cover have been measured for Mustard Hill Coral, *Porites astreoides* and more recently for Boulder Star Coral, but these are within sampling variability error.

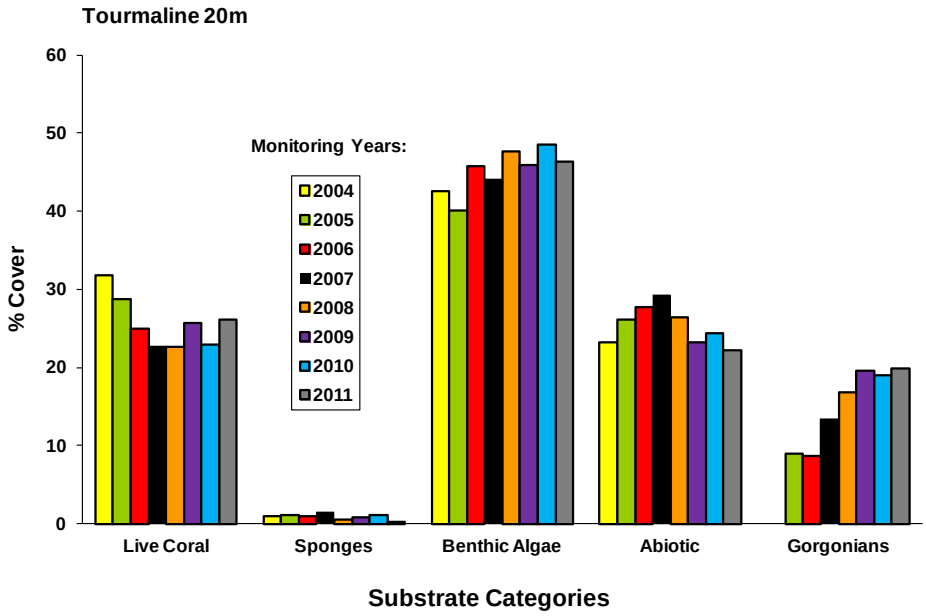


Figure 27. Monitoring trends (2004 – 2011) of mean substrate cover by sessile-benthic categories at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

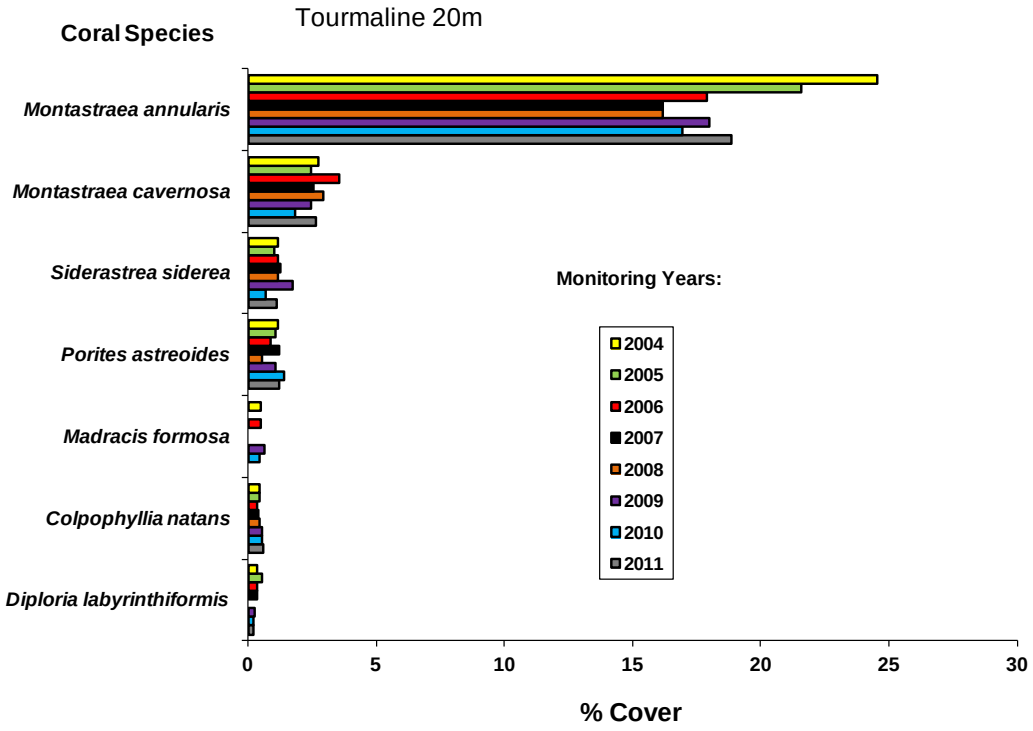


Figure 28. Monitoring trends (2004 – 2011) of mean substrate cover by stony coral species at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

2.2 Fishes and Motile Megabenthic Invertebrates-

A total of 99 fish species have been identified from Tourmaline outer shelf reef at 20 m (Appendix 1). Mean abundance within belt-transects during 2011 was 396.2 Ind/30 m^2 (range: 338 - 434 Ind/30 m^2). The mean number of species per transect was 20.2 (range: 18 - 23). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 298.0 Ind/30 m^2 (range: 250 – 350 Ind/30 m^2), representing 75.2 % of the total abundance within belt-transects (Table 31).

The Masked Goby is a small zooplanktivorous fish (< 2.0 cm) that was observed swarming below coral ledges and crevices near the sand-coral interface. In addition to the Masked Goby, another 14 fish species were present in four out of the five transets surveyed and appear to comprise the main small demersal fish assemblage of the reef. Among these, the Blue Chromis, Peppermint Goby, Fairy Basslet, Bluehead, Creole and Yellowhead Wrasses, and the Stoplight Parrotfish were the most prominent in terms of numerical abundance.

Annual variations of fish abundance and species richness are presented in Figure 29. Differences of fish species richness and abundance between annual monitoring surveys were both statistically significant (ANOVA; $p < 0.0001$, Appendix 3). Fish species richness was highest during the baseline and subsequent monitoring surveys until 2006, then consistently declined to a minimum in 2009. During the last two years, an increasing pattern has emerged, but still below the richness observed during the initial 2004 – 2006 period (Figure 29). The temporal abundance pattern is characterized by marked fluctuations that include very low values in 2004, 2009 and 2010, and peak values in 2005 and during the present 2011 survey (Figure 29). 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 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 Outer Shelf Reef 20 m, Mayaguez, June, 2011

Depth: 20m

		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	320	350	260	310	250	**298.0**
Chromis cyanea	Blue Chromis	16	15	34	30	0	**19.0**
Coryphopterus lipernes	Peppermint Goby	12	5	17	14	20	**13.6**
Gramma loreto	Fairy Basslet	6	6	12	15	12	**10.2**
Clepticus parrae	Creole Wrasse	0	10	30	6	0	**9.2**
Thalassoma bifasciatum	Bluehead Wrasse	13	10	2	16	0	**8.2**
Halichoeres garnoti	Yellow-head Wrasse	3	5	3	6	3	**4.0**
Scarus iserti	Stripped Parrotfish	0	13	0	0	6	**3.8**
Sparisoma viride	Stoplight Parrotfish	2	3	1	9	4	**3.8**
Myripristis jacobus	Blackbar Soldierfish	0	0	5	4	6	**3.0**
Chaetodon capistratus	Four-eye Butterflyfish	0	2	2	2	6	**2.4**
Stegastes leucostictus	Beau Gregory	2	2	2	3	3	**2.4**
Canthigaster rostrata	Caribbean Puffer	1	3	0	1	6	**2.2**
Gobiosoma evelynae	Sharknose Goby	2	0	3	4	2	**2.2**
Stegastes partitus	Bicolor Damselfish	2	2	1	2	4	**2.2**
Ocyurus chrysurus	Yellowtail Snapper	10	0	0	0	0	**2.0**
Scarus taeniopterus	Princess Parrotfish	0	0	4	2	3	**1.8**
Acanthurus coeruleus	Blue Tang	0	1	4	0	2	**1.4**
Cephalopholis cruentatus	Graysby	1	1	2	0	3	**1.4**
Coryphopterus glaucofraenum	Briddled Goby	0	1	1	0	1	**0.6**
Holacanthus tricolor	Rock Beauty	0	1	1	1	0	**0.6**
Equetus punctatus	Spotted Drum	0	1	0	1	0	**0.4**
Flammeo marianus	Longspine Squirrelfish	0	1	0	0	1	**0.4**
Holocentrus rufus	Squirrelfish	0	1	0	0	1	**0.4**
Mulloides martinicus	Yellowtail Goatfish	0	1	0	0	1	**0.4**
Sparisoma aurofrenatum	Redband Parrotfish	1	0	0	1	0	**0.4**
Acanthurus bahianus	Ocean Surgeon	0	0	1	0	0	**0.2**
Anisotremus virginicus	Porkfish	0	0	0	0	1	**0.2**
Aulostomus maculatus	Trumpetfish	0	0	0	0	1	**0.2**
Haemulon flavolineatum	French Grunt	0	0	1	0	0	**0.2**
Hypoplectrus nigricans	Black Hamlet	0	0	0	1	0	**0.2**
Hypoplectrus unicolor	Butter Hamlet	1	0	0	0	0	**0.2**
Lachnolaimus maximus	Hogfish	1	0	0	0	0	**0.2**
Liopropoma rubre	Swiss Guard Basslet	1	0	0	0	0	**0.2**

Table 31. Continued

Caranx crysos	Blue Runner	0	0	0	0	1	**0.2**
Pseudupeneus maculatus	Spotted Goatfish	0	0	0	0	1	**0.2**
Synodus intermedius	Sand Diver	1	0	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**395**	**434**	**386**	**428**	**338**	**396.2**
	TOTAL SPECIES	**18**	**21**	**20**	**19**	**23**	**20.2**

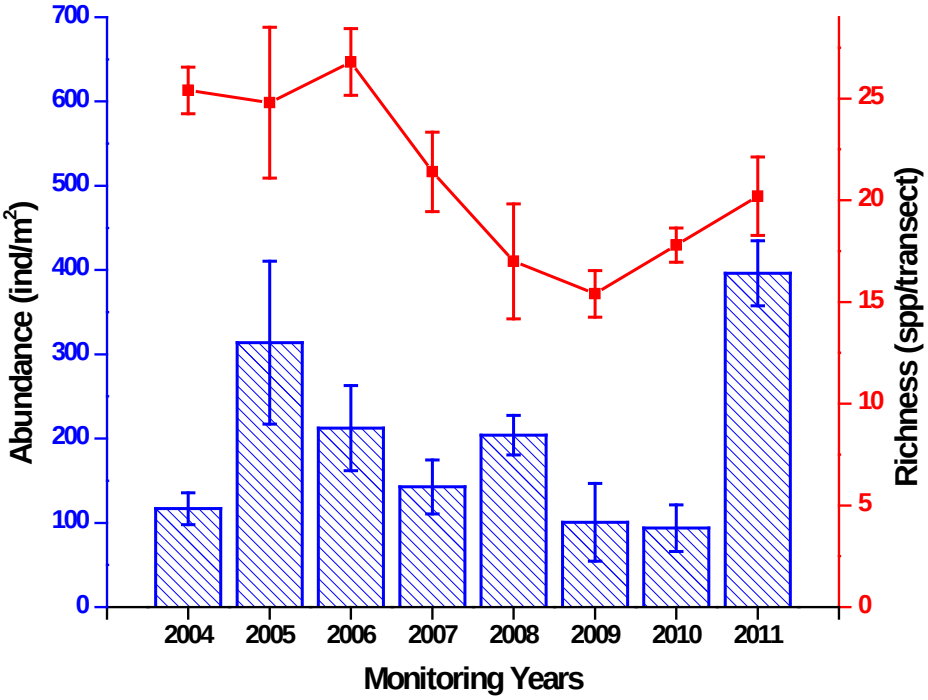


Figure 29. Monitoring trends (2004 – 2011) of fish species richness and abundance at outer shelf reef Tourmaline, 20 m, Mayaguez.

spawning aggregation site and since 1993 has been seasonally closed to fishing (December – February). The intense fishing effort over the last 20-30 years, however, has decimated the populations of commercially important fishes, conch and lobster. Clear signs of recuperation of the Red Hind population are still not evident.

Small zooplanktivorous fishes, such as the Masked Goby, Blue Chromis, Bicolor Damselfish and micro-invertebrate predators, including wrasses, gobies, basslets,

hamlets, and squirrelfishes numerically dominate the reef fish community. Parrotfishes (*Scarus spp., Sparisoma spp*.), represented by four species and doctorfishes (*Acanthurus spp*.), represented by three species comprised the main herbivorous fish assemblage. Among large invertebrate and small demersal fish predators, Nassau Grouper, Red Hinds, Schoolmaster Snapper, Great Barracuda and Cero Mackerels were observed during an ASEC survey (Table 32). Also, several juvenile and adult Schoolmaster, Mahogany and Yellowtail Snappers were observed close to the reef-sand interface. Schools of Mackerel Scad, *Decapterus macarellus* were present in mid-water over the reef. These are zooplanktivores that serve as forage for pelagic predators, such as Cero Mackerels and Barracudas. Cubera and Dog Snappers have been identified from previous ASEC surveys at this reef (García-Sais et al, 2005). One adult Hawsbill Turtle was also observed during the ASEC survey. Cleaner Shrimps and one octopus were the only motile megabenthic invertebrates observed within belt-transects during 2011 (Table 33).

Table 32. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Tourmaline Outer Shelf Reef, 20 m. June 2011

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

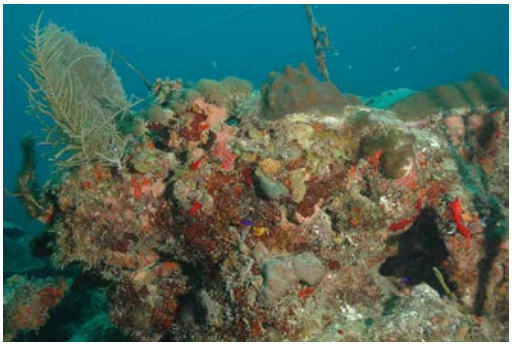
SPECIES	**COMMON NAME**		# - (cm)
Dasyatis americana	Southern Stingray	1 – (90)	
Epinephelus guttatus	Red Hind	1 - (30)	1 – (35)
Epinephelus striatus	Nassau Grouper	1 - (40)	
Lachnolaimus maximus	Hogfish	1 – (40)	
Lutjanus apodus	Schoolmaster	3 - (20)	4 – (30)
Lutjanus mahogany	Mahogany Snapper	2 - (20)	
Ocyurus chrysurus	Yellowtail Snapper	2 - (25)	
Scomberomorus regalis	Cero Mackerel	1 – (50)	
Sphyraena barracuda	Great Barracuda	1 – (50)	
Aetobatus narinan	Spotted Eagle Ray	1 – (175)	
Invertebrates			
Octopus vulgaris	Common Octopus	1 – (30)	
Reptiles			
Eretmochelys imbricata	Hawksbill Turtle	1 – (80)	

Table 33. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Shelf-edge Reef, 20 m, Mayaguez. June, 2011

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

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 during June, 2011. Panoramic views of Tourmaline outer shelf reef at a depth of 10 m are presented in Photo Album 9.

A total of 25 stony coral species were identified from the Outer Shelf Reef at a depth of 10 m, 19 of which were intercepted by line transects during this survey (Table 34). Stony corals occurred as massive (*Montastraea 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 43.2 % (range: 23.6 – 73.3 %). Yellow Pencil Coral, *Madracis auretenra (mirabilis)* was the dominant coral species in terms of substrate cover with a mean of 10.5 %. This species exhibits branching growth over the reef hard bottom and has kept an increasing pattern of substrate cover over the years at this reef, reaching its maximum cover during the 2010 survey. 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 73.3 % in that transect, which is the highest in the monitoring program. Boulder Star Coral (*M. annularis* complex), Finger Coral (*P. porites*), Mustard Hill Coral (*Porites astreoides*), and Lettuce Corals (*Agaricia spp.*) were intercepted by at least four of the five transects in the 2011 monitoring survey and comprised in addition to *M. mirabilis* the main stony coral assemblage at this reef.

Erect soft corals (gorgonians) were highly abundant with an average of 32.2 colonies/transect and along with stony corals were the most visually prominent

Table 34. Percent substrate cover by sessile-benthic categories at Tourmaline reef, Mayaguez, 10 m, June 2011

Depth: 10 m	TRANSECTS					
	1	2	3	4	5	**MEAN**
Rugosity (m)	3.00	5.04	2.63	2.94	3.52	**3.43**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs		14.0	1.1	4.6	4.7	**4.9**
Total Abiotic	0.0	14.0	1.1	4.6	4.7	**4.9**
Benthic Algae						
Turf-mixed assemblage	59.9	56.7	47.2	21.6	47.4	**46.5**
Halimeda tuna		0.6	1.7			**0.4**
Dictyota sp.	0.4				0.7	**0.2**
Total Benthic Algae	60.4	57.2	48.9	21.6	48.1	**47.2**
Encrusting Gorgonians		0.9				**0.2**
Briareum asbestinum		2.5				**0.5**
Erythropodium caribaeorum	8.5	0.4	2.9		2.2	**2.8**
Total Encrusting Gorgonians	8.5	3.8	2.9	0.0	2.2	**3.5**
Erect Gorgonians	36	31	25	35	34	**32.2**
Sponges			0.9	0.7		**0.3**
Zoanthids		1.4			2.4	**0.8**
Cyanobacteria			1.1			**0.2**
Live Stony Corals						
Madracis auretenra				52.5		**10.5**
Montastraea annularis	8.5	7.1	11.5	13.3	5.4	**9.1**
Porites porites	4.5		5.2	2.4	21.9	**6.8**
Porites astreoides	5.9	2.5	8.8	2.3	5.6	**5.0**
Dendrogyra cylindrus		4.9			5.4	**2.1**
Agaricia grahamae	1.2	4.2	3.8		1.0	**2.0**
Agaricia agaricites	5.9	2.8			0.9	**1.9**
Colpophyllia natans	0.9		7.4			**1.6**
Meandrina meandrites	1.1	0.8	2.9	1.3	1.0	**1.4**
Montastraea cavernosa	0.3	1.1	1.9			**0.7**
Diploria labyrinthiformis	2.3					**0.5**
Acropora cervicornis			2.2			**0.4**
Agaricia lamarcki		0.3			0.8	**0.2**
Porites divaricata				0.7	0.4	**0.2**
Porites colonensis				0.9		**0.2**
Diploria strigosa	0.7					**0.1**
Millepora alcicornis			0.6			**0.1**
Eusmilia fastigiata			0.5			**0.1**
Millepora complanata			0.5			**0.1**
Total Stony Corals	31.1	23.6	45.2	73.3	42.6	**43.2**

Coral species outside transects: *Acropora cervicornis*, *Manicina areolata, Mycetophyllia lamarckiana, Mycetophyllia sp., Millepora squarrosa, Porites divaricata*

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, particularly *Erythropodium caribaeorum* were present with an average substrate cover of 3.5 %. Sponges and zoanthids (*Palythoa caribdea*) were also present along transects, but represented minor components of the reef benthos (substrate cover < 1 %). Reef overhangs, associated with coral ledges of Boulder Star Coral averaged 4.9 % and contributed markedly to the topographic rugosity of 3.4 m. Turf algae, comprised by a mixed assemblage of short filamentous red and brown macroalgae presented an average substrate cover of 46.5 % (range: 21.6 – 59.9 %). Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard ground. Cyanobacterial films were only present in one transect with low substrate cover (1.1%).

Figure 30 presents the monitoring trends of reef substrate cover by sessile-benthic categories from Tourmaline outer shelf reef at 10 m. 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; $p = 0.883$), perhaps due to the high variability associated with the magnitude (not direction) of the variations within transects (see Appendix 2). At the population level, a statistically significant decline of live coral cover (ANOVA; $p = 0.028$) was found for *Montastraea 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 *M. annularis* declined 46 % between 2005 and 2006 (Figure 31), and was the main driver of the overall decline of live coral for this reef. The loss of reef substrate by *M. annularis* was aggressively colonized by the branching and fast growing Yellow Pencil Coral, *M. auretenra (mirabilis),* which is now the dominant coral in terms of substrate cover at Tourmaline 10 m. The trend of increasing reef substrate cover by *M. auretenra* has stabilized since the 2010 survey perhaps due to the lack of hard ground space to grow. Between 1999 and 2011, *M. auretenra* more than doubled its substrate cover in transect 2 from 27.4% to 52.5 %. Such growth growth has influenced a partial

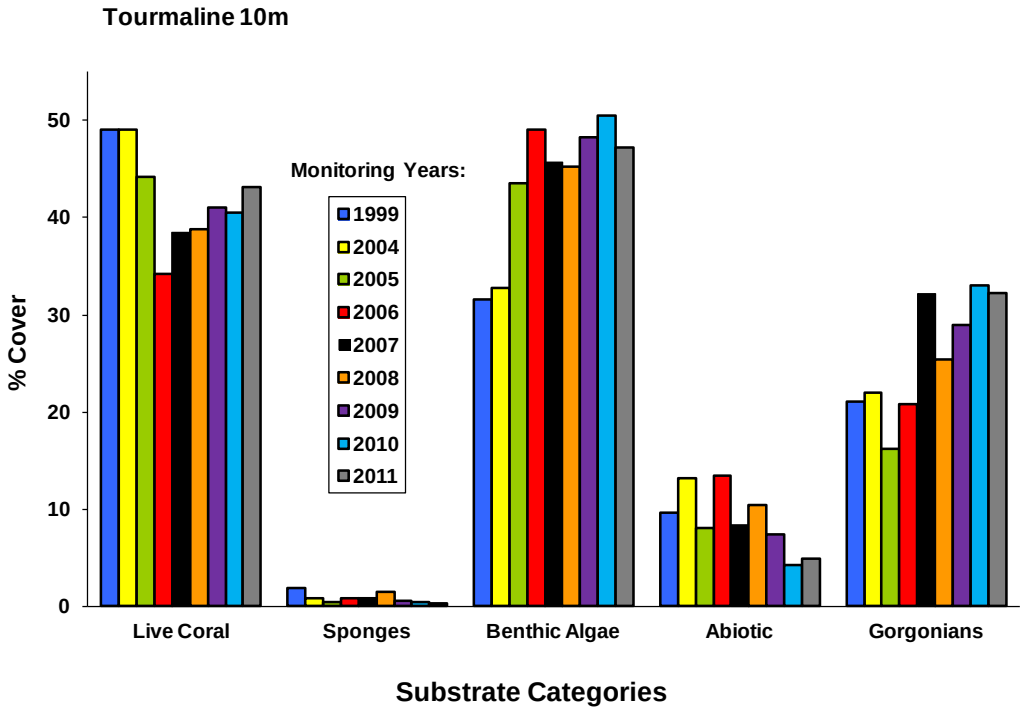


Figure 30. Monitoring trends (1999 – 2011) of mean substrate cover by sessile-benthic categories at Tourmaline Reef – 10 m, Mayaguez.

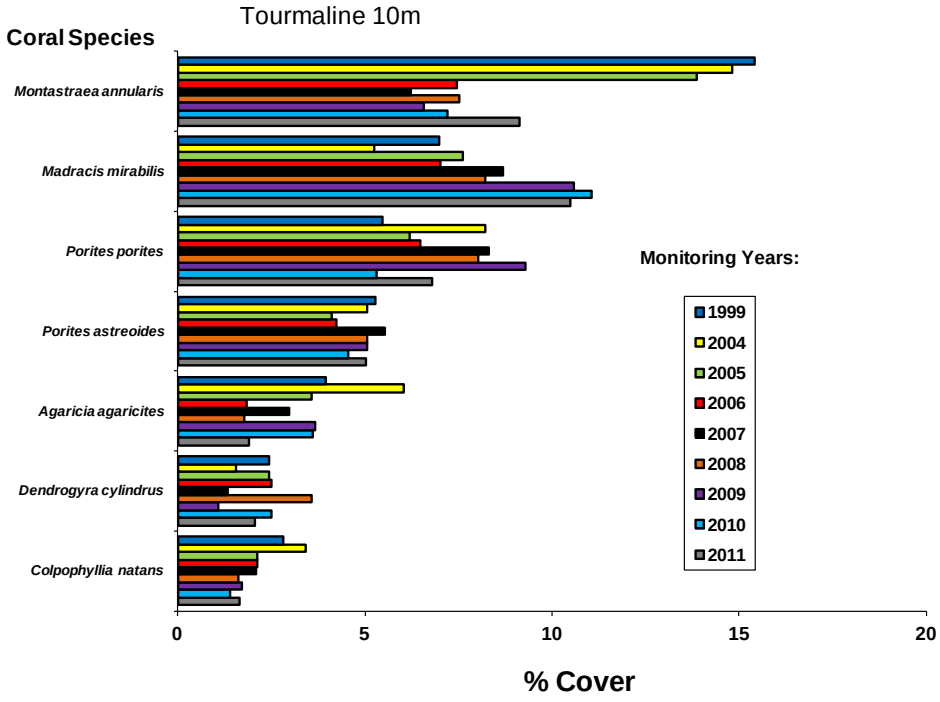


Figure 31. Monitoring trends (1999 – 2011) of mean cover by stony coral species at Tourmaline Reef – 10 m, Mayaguez.

recuperation of live coral cover at Tourmaline 10 m. Finger Coral, *Porites porites* also displayed a very active growth pattern after the 2005-bleaching event, increasing cover from a baseline mean of 5.3 % to a peak of 9.3 % in 2009. After 2009 (last year), this species has suffered from what appears to be an infectious disease and exhibited substantial colony degradation and loss of substrate cover close to its baseline mean of 5.3%. Conversely, a trend of increasing substrate cover of Boulder Star Coral, *M. annularis* has been observed (Figure 31).

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 91 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 2011 survey was 91.8 Ind/30 m^2 (range: 35 - 157 Ind/30 m^2). A total of 34 species were observed within belt-transects and the mean number of species per transect was 16 (range: 13 - 21). The Bluehead Wrasse (*Thalassoma bifasciatum*), Blue Chromis (*Chromis cyanea*), Bicolor Damselfish (*Stegastes partitus*) and the Striped Parrotfish (*Scarus iserti*) were the numerically dominant species with a combined mean abundance of 62.4 Ind/30 m^2, representing 68.0 % 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 Creole and Yellowhead Wrasse, Stoplight Parrotfishes and Beaugregory. A total of 11 species were represented by only one individual within belt-transects.

Small, opportunistic micro-invertebrate predators (wrasses, gobies), demersal and pelagic schooling zooplanktivores (Blue Chromis, Creole Fish, Bicolor Damselfish,) and herbivores (*Scarus spp*., *Sparisoma spp*., *Acanthurus spp*.) numerically dominated the reef fish community. 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.

Table 35. Taxonomic composition and abundance of fishes within belt-transects at the Tourmaline Outer Shelf Reef, 10 m, Mayaguez, June 2011

Depth: 10m

		TRANSECTS					
		1	2	3	4	5	
		Individuals/30m^2					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	0	30	25	36	16	**21.4**
Chromis cyanea	Blue Chromis	0	33	17	50	0	**20.0**
Stegastes partitus	Bicolor Damselfish	4	1	13	29	13	**12.0**
Scarus iserti	Stripped Parrotfish	3	11	2	11	18	**9.0**
Coryphopterus personatus	Masked Goby	2	0	3	15	0	**4.0**
Halichoeres garnoti	Yellow-head Wrasse	2	3	8	0	7	**4.0**
Sparisoma viride	Stoplight Parrotfish	6	3	4	4	3	**4.0**
Stegastes leucostictus	Beau Gregory	5	4	1	2	7	**3.8**
Sparisoma aurofrenatum	Redband Parrotfish	4	1	2	0	0	**1.4**
Haemulon flavolineatum	French Grunt	0	3	1	2	0	**1.2**
Canthigaster rostrata	Caribbean Puffer	2	0	1	0	1	**0.8**
Chaetodon capistratus	Four-eye Butterflyfish	0	0	0	2	2	**0.8**
Gobiosoma evelynae	Sharknose Goby	1	3	0	0	0	**0.8**
Holacanthus tricolor	Rock Beauty	0	1	2	1	0	**0.8**
Myripristis jacobus	Blackbar Soldierfish	0	4	0	0	0	**0.8**
Scarus taeniopterus	Princess Parrotfish	2	0	0	0	2	**0.8**
Acanthurus bahianus	Ocean Surgeon	0	0	1	1	1	**0.6**
Coryphopterus lipernes	Peppermint Goby	0	1	1	0	1	**0.6**
Flammeo marianus	Longspine Squirrelfish	0	0	0	2	1	**0.6**
Gramma loreto	Fairy Basslet	0	3	0	0	0	**0.6**
Pomacanthus arcuatus	Grey Angelfish	0	2	1	0	0	**0.6**
Holocentrus rufus	Squirrelfish	1	1	0	0	0	**0.4**
Ophioblennius atlanticus	Redlip Blenny	0	2	0	0	0	**0.4**
Serranus tigrinus	Harlequin Bass	1	0	0	1	0	**0.4**
Acanthurus chirurgus	Doctorfish	0	0	1	0	0	**0.2**
Acanthurus coeruleus	Blue Tang	0	0	1	0	0	**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish	1	0	0	0	0	**0.2**
Caranx crysos	Blue Runner	1	0	0	0	0	**0.2**
Cephalopholis cruentatus	Graysby	0	0	1	0	0	**0.2**
Holocanthus ciliaris	Queen Angelfish	0	0	0	1	0	**0.2**
Hypoplectrus nigricans	Black Hamlet	0	0	0	0	1	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	0	1	0	0	**0.2**
Mycrospathodon chrysurus	Yellowtail Damselfish	0	0	1	0	0	**0.2**
Pomacanthus paru	French Angelfish	0	0	1	0	0	**0.2**
	TOTAL INDIVIDUALS	35	106	88	157	73	**91.8**
	TOTAL SPECIES	14	17	21	14	13	**15.8**

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 of abundance between annual surveys were not statistically significant (ANOVA; $p = 0.517$). 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, the 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 previous surveys. The pattern of lower fish species richness has prevailed until the present survey.

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

Motile megabenthic invertebrates were not observed within belt-transects during the 20011 monitoring survey (Table 37). Spiny and Spotted Lobsters, *Panulirus argus*, *P. guttatus*, cleaner shrimps and arrow crabs have been previously reported observed outside transects during the ASEC surveys.

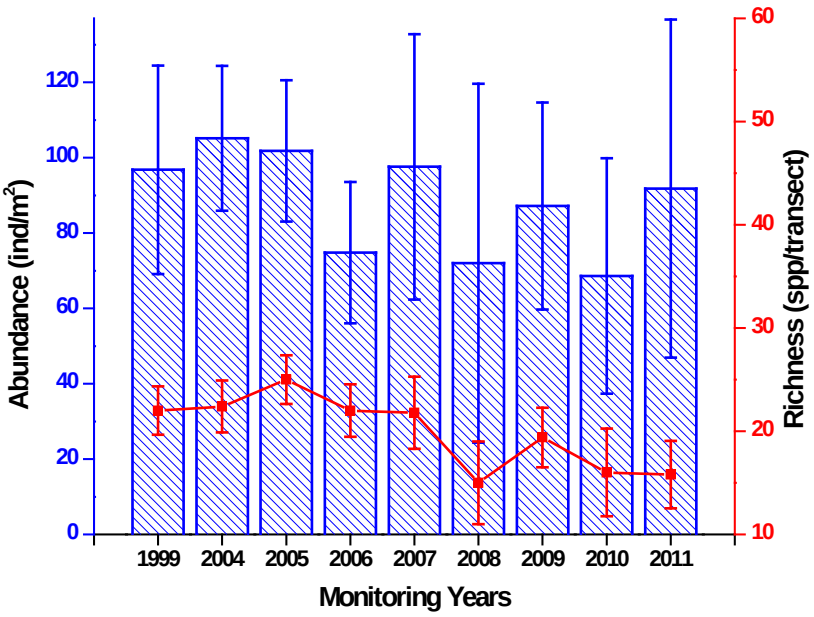


Figure 32. Monitoring trends (2004 – 2011) of fish species richness and abundance at Outer Shelf Reef Tourmaline, 10 m, Mayaguez.

Table 36. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Tourmaline Outer Shelf Reef, 10 m, June 2011

Duration - 30 min. Depth: 10 - 13 m

SPECIES	**COMMON NAME**	# - (cm)		
Epinephelus guttatus	Red Hind	1 - (25)		
Lutjanus synagris	Lane Snapper	3 - (15)	5 - (20)	1 – (25)
Ocyurus chrysurus	Yellowtail Snapper	2 - (15)	3– (20)	
Scomberomorus regalis	Cero Mackerel	1 - (40)		
Sphyraena barracuda	Great Barracuda	1 - (50)		

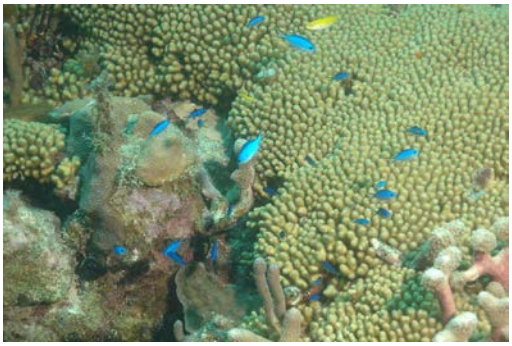
Table 37. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Outer-shelf Reef, 10 m, June 2011

Depth: 10 m

TAXA	**COMMON NAME**	**TRANSECTS 1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
None observed							
	TOTALS	**0**	**0**	**0**	**0**	**0**	**0.0**

Photo Album 9 (Tourmaline 10 m)

OuterShelf Reef



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.

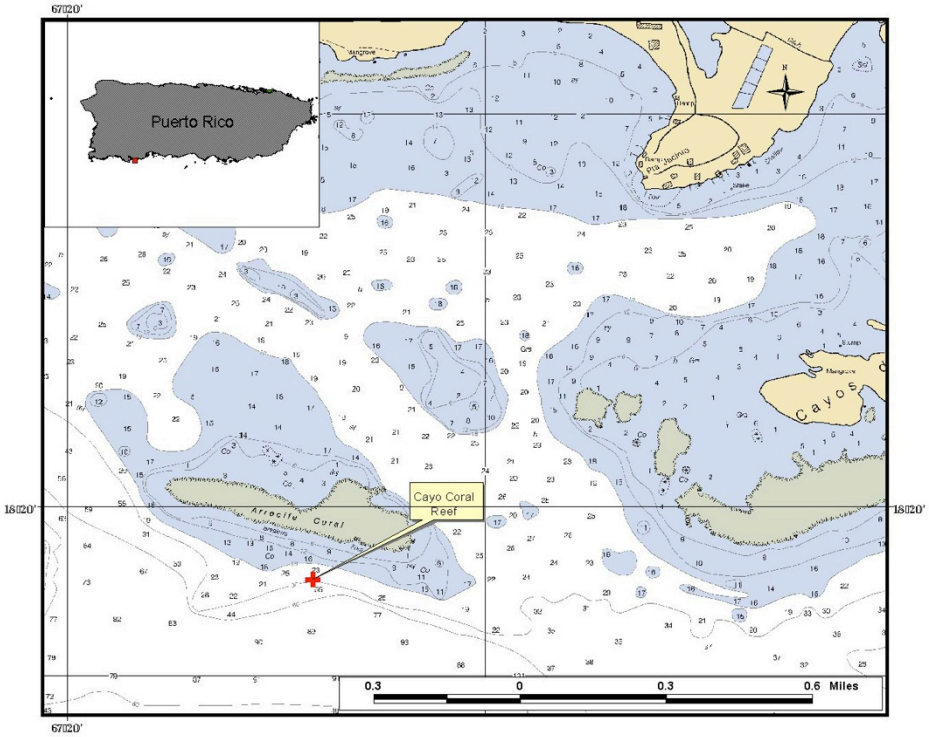


Figure 33. Location of coral reef survey stations at Cayo Coral Reef, Guánica.

1.1 Sessile-benthic Reef Community

A total of 17 stony corals, including 13 intersected by permanent line transects were identified from Cayo Coral Reef during the 2011 survey (Table 38). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 12.7 % (range: 5.2 – 20.8 %). Boulder Star Coral, *Montastraea annularis* (complex) was the main species in terms of substrate cover with a mean of 3.9% (range: 1.7 – 6.1 %), representing 30.7 % of the total cover by stony corals (Table 38). Mustard-Hill Coral, *Porites astreoides* and Great Star Coral, *M. cavernosa* were intercepted by all transects, and 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 highly abundant with an average of 29.4 colonies/transect. At least 24 species of gorgonians are known to ocurr at this reef (García-Sais et al. 2007, 2008, 2009, 2010). Some of the visually 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 caribbea*) represented minor components of the reef benthos. Reef overhangs associated with mostly dead massive Boulder Star Coral colonies averaged a substrate cover of 14.6 % and contributed substantially to the mean rugosity of 3.9 m.

Benthic algae, comprised mostly by turf algae was the most prominent sessile-benthic category in terms of substrate cover with a mean of 61.7 % (range: 54.4 – 70.9 %). Turf algae was found colonizing hard ground substrates, particularly dead coral colonies.

Table 38. Percent substrate cover by sessile-benthic categories at Cayo Coral Reef, Guanica, 10 m. July 2011

Depth: 10 m	TRANSECTS					
	1	2	3	4	5	**MEAN**
Rugosity (m)	2.23	4.83	3.55	4.17	4.69	**3.89**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	14.9	19.7	10.6	18.0	9.9	**14.6**
Silt	1.2		10.2	12.9		**4.8**
Rubble	1.0			8.3	7.9	**3.4**
Total Abiotic	17.1	20.2	20.8	39.2	17.8	**23.0**
Benthic Algae						
Turf-mixed assemblage	65.3	60.8	54.4	46.8	70.4	**59.5**
Dictyota sp.	1.7			8.5		**2.0**
Halimeda discoidea					0.5	**0.1**
Total Benthic Algae	67.1	60.8	54.4	55.3	70.9	**61.7**
Encrusting Gorgonians						
Erythropodium caribaeorum	0.4	0.5		0.4		**0.3**
Total Encrusting Gorgonians	0.4	0.5	0.0	0.4	0.0	**0.3**
Sponges	3.4		2.9			**1.3**
Xestospongia muta	0.8					**0.2**
Total sponges	4.2	0.0	2.9	0.0	0.0	**1.4**
Anemone		0.5				**0.1**
Zoanthids		2.3	1.0		0.9	**0.8**
Live Stony Corals						
Montastraea annularis	3.4	5.4	2.9	1.7	6.1	**3.9**
Porites astreoides	1.0	2.5	2.6	2.0	3.0	**2.2**
Colpophyllia natans			8.6	0.6		**1.8**
Montastraea cavernosa	3.4	1.4	0.6	0.9	0.9	**1.4**
Siderastrea siderea		3.8	0.6			**0.9**
Porites divaricata			2.6			**0.5**
Diploria strigosa	1.4	1.0				**0.5**
Meandrina meandrites			2.0			**0.4**
Porites porites	0.6	1.0				**0.3**
Siderastrea radians	1.5					**0.3**
Madracis decactis			0.9			**0.2**
Agaricia agaricites		0.2			0.6	**0.2**
Eusmilia fastigiata		0.6				**0.1**
Total Stony Corals	11.3	15.8	20.8	5.2	10.5	**12.7**

Coral Species Outside Transects: *Acropora cervicornis, Agaricia lamarcki, Diploria labyrinthiformis, Leptoseris cucullata, Madracis decactis, Porites astreoides, P. porites*

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 2005-11. 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. After 2008, the declining trend of live coral cover has reversed to a pattern of mild annual increments.

Variations of the mean substrate cover by coral species during monitoring surveys are shown in Figure 35. A drastic decline of the percent substrate cover by Boulder Star Coral, *Montastraea annularis* (complex) is evident from the monitoring data. The variations of cover by *M. annularis* between monitoring years were statistically significant (ANOVA; $p = 0.045$). Boulder Star Coral declined its mean substrate cover by approximately 40 % between 1999 and 2005 (from 10.49 % to 6.5%), and suffered another reduction of 55% between 2005 and 2006 (from 6.5 % to 2.9 %). Other scleractinian coral species that have shown marked declines of substrate cover since our baseline survey at Cayo Coral include *Colpophyllia natans, M. cavernosa, P. astreoides* and *Agaricia spp*.

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 95 fish species have been identified from Cayo Coral during monitoring surveys (Appendix 1). Mean abundance within belt-transects during 2011 was 43.8 Ind/30 m^2 (range: 30 - 54 Ind/30 m^2). The mean number of species per transect was 18 (range: 15 - 25). Bluehead Wrasse (*Thalassoma bifasciatum*), Dusky Damselfish (*Stegastes partitus*), Sharknose Goby (*Gobiosoma evelynae*), Four-eye Butterflyfish (*Chaetodon capistratus*) and Striped Parrotfishes (*Sparisoma aurofrenatum)* were the numerically dominant species with a combined mean abundance of 21.6 Ind/30 m^2, representing 49.3 % of the total abundance within belt-transects (Table 39). All of the aforementioned species were present in at least four transects and along with the Yellowtail and Bicolor Damselfishes, Blue Chromis, Stoplight Parrotfish and Masked Goby comprised the main reef fish assemblage at Cayo Coral.

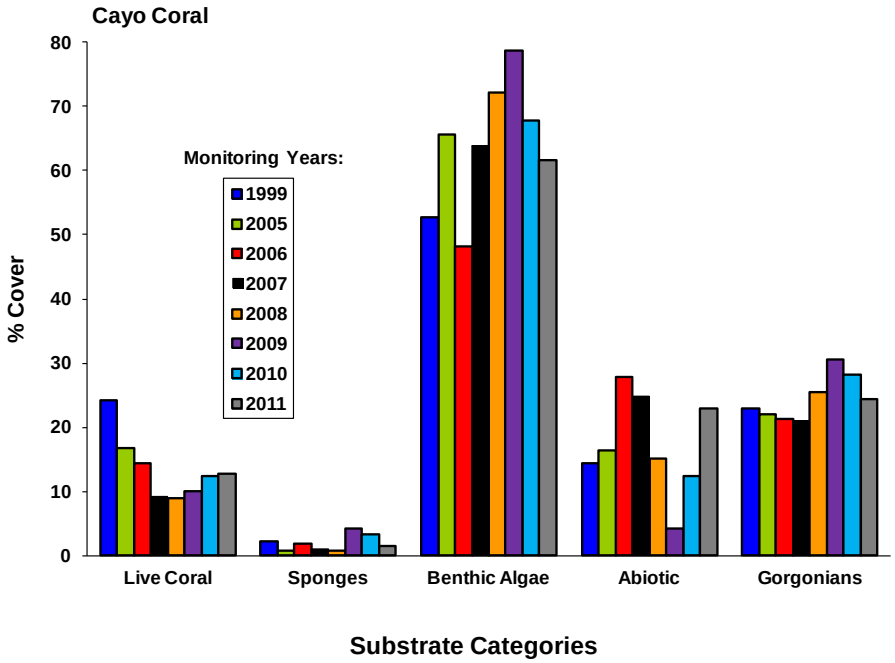


Figure 34. Monitoring trends (1999 – 2011) of mean substrate cover by sessile-benthic categories at Cayo Coral – 8 m, Guánica.

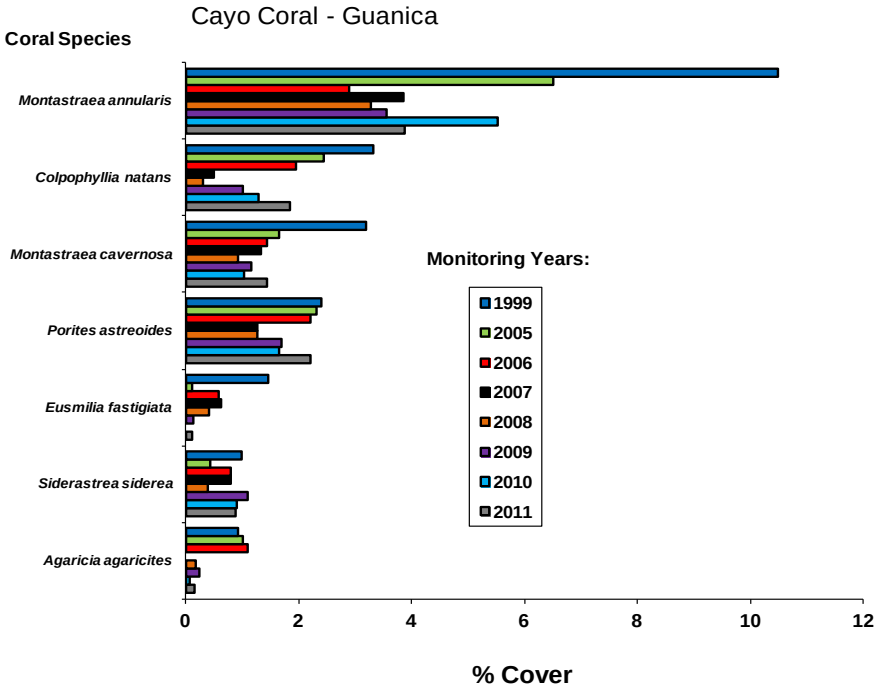


Figure 35. Monitoring trends (1999 – 2011) of mean substrate cover by stony coral species at Cayo Coral – 8 m, Guánica

Table 39. Taxonomic composition and abundance of fishes within belt-transects at Cayo Coral-Guánica, 7 m, July 2011

		TRANSECTS					
Depth: 8 - 10 m		1	2	3	4	5	
		(individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	0	6	7	16	5	**6.8**
Stegastes dorsopunicans	Dusky Damselfish	7	5	6	7	4	**5.8**
Gobiosoma evelynae	Sharknose Goby	1	5	9	2	6	**4.6**
Chaetodon capistratus	Four-eye Butterflyfish	2	1	1	5	2	**2.2**
Scarus iserti	Stripped Parrotfish	0	0	3	3	5	**2.2**
Microspathodon chrysurus	Yellowtail Damselfish	3	1	3	2	1	**2.0**
Chromis cyanea	Blue Chromis	4	0	1	1	3	**1.8**
Sparisoma viride	Stoplight Parrotfish	1	1	4	1	2	**1.8**
Stegastes leucostictus	Beau Gregory	2	1	1	2	3	**1.8**
Stegastes partitus	Bicolor Damselfish	2	1	0	1	5	**1.8**
Coryphopterus personatus	Masked Goby	7	0	0	0	0	**1.4**
Acanthurus bahianus	Ocean Surgeon	1	0	1	0	3	**1.0**
Sparisoma aurofrenatum	Redband Parrotfish	2	1	1	0	1	**1.0**
Canthigaster rostrata	Caribbean Puffer	1	0	1	2	0	**0.8**
Halichoeres garnoti	Yellow-head Wrasse	0	0	1	3	0	**0.8**
Holocentrus rufus	Squirrelfish	1	1	2	0	0	**0.8**
Acanthurus coeruleus	Blue Tang	0	0	1	0	2	**0.6**
Cephalopholis cruentatus	Graysby	1	1	1	0	0	**0.6**
Coryphopterus lipernes	Peppermint Goby	0	0	2	1	0	**0.6**
Haemulon flavolineatum	French Grunt	0	0	2	0	1	**0.6**
Sparisoma rubripinne	Yellowtail Parrotfish	0	3	0	0	0	**0.6**
Abudefduf sexatilis	Sergeant Major	0	0	1	0	1	**0.4**
Chaetodon striatus	Banded Butterflyfish	1	0	0	0	1	**0.4**
Coryphopterus glaucofraenum	Bridled Goby	0	1	0	1	0	**0.4**
Serranus tigrinus	Harlequin Bass	0	0	1	0	1	**0.4**
Scomberomorus regalis		2	0	0	0	0	**0.4**
Aulostomus maculatus	Trumpetfish	0	0	1	0	0	**0.2**
Bodianus rufus	Spanish Hogfish	0	0	0	0	1	**0.2**
Gramma loreto	Fairy Basslet	0	0	1	0	0	**0.2**
Equetus lanceolatus	Jacknife	0	0	1	0	0	**0.2**
Holacanthus ciliaris	Queen Angelfish	0	0	1	0	0	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	1	0	0	0	**0.2**
Hypoplectrus puella	Barred Hamlet	0	0	1	0	0	**0.2**
Neoniphon marianus	Longspine Squirrelfish	0	0	0	0	1	**0.2**
Mulloides martinicus	Yellowtail Goatfish	1	0	0	0	0	**0.2**
Pterois volitans	Lionfish	0	1	0	0	0	**0.2**

Table 36. Continued

Scarus taeniopterus	Princess Parrotfish	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	39	30	54	48	48	**43.8**
	TOTAL SPECIES	17	15	25	15	19	**18.2**

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). Both species richness and abundance were significantly lower during the baseline survey of 1999 than in subsequent monitoring surveys. Such difference was influenced 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.

Small, opportunistic micro-invertebrate predators (wrasses, gobies, puffers), demersal and pelagic schooling zooplanktivores (Blue Chromis, Creole Wrasse, Bicolor Damselfish,) and herbivores (*Scarus spp., Sparisoma spp*., *Acanthurus spp*.) comprised the most prominent assemblage of the reef fish community. Among large invertebrate and small demersal fish predators, small growing groupers such Graysbys and Coneys were common. Juvenile Jewfish and Yellowfin Groupers, 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 common at Cayo Coral and serve as forage for several pelagic predators, particularly Cero Mackerels and Great Barracudas observed during the 2011 (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 one Arrow Crab (Table 41).

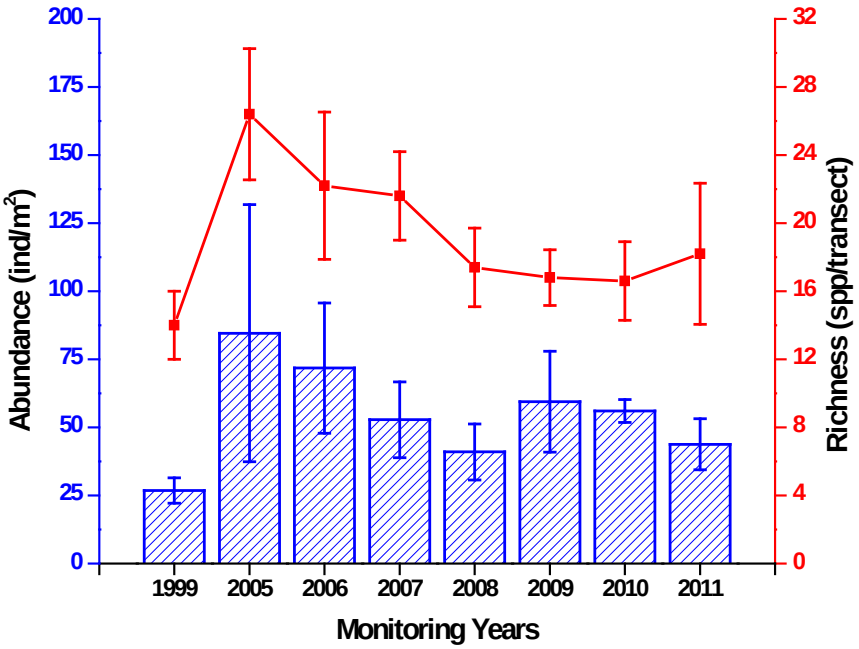


Figure 36. Monitoring trends (1999 – 2011) of fish species richness and abundance at Cayo Coral Reef, 8 m, Guanica Natural Reserve

Table 40. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Cayo Coral. Guánica. July 2011

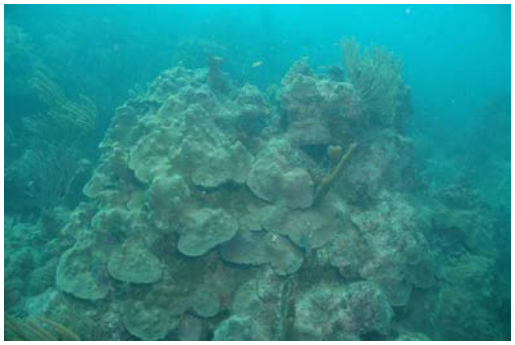
Depth range : 8 - 10 m Duration - 30 min.

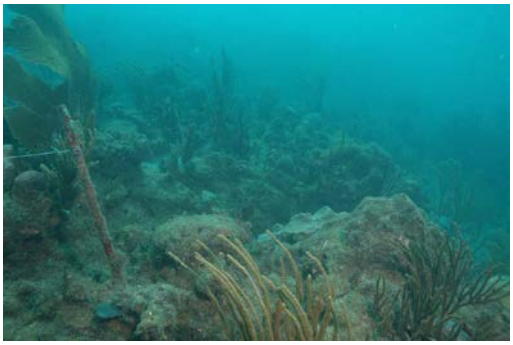
SPECIES	**COMMON NAME**		# - (cm)
Epinephelus guttatus	Red Hind	2 - (20)	1 - (30)
Epinephelus adsensionis	Rock Hind	1 – (20)	
Lutjanus apodus	Schoolmaster	3 - (20)	2 - (25)
Lutjanus mahogany	Mahogany Snapper	3 - (20)	1 – (25)
Lutjanus synagris	Lane Snapper	2 - (15)	2 – (20)
Ocyurus chrysurus	Yellowtail Snapper	4 - (20)	1 – (20)
Scomberomorus regalis	Cero Mackerel	2 – (50)	
Sphyraena barracuda	Great Barracuda	1 - (50)	
Pterois volitans	Lionfish	3 – (20)	1 – (25)
Invertebrates			
Panulirus argus	Spiny Lobster	2 - (15)	1 – (20)

Table 41. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Coral 8 m, Guánica. July 2011

Depth: 8 -10 m		TRANSECTS					MEAN
		1	2	3	4	5	ABUNDANCE
TAXA	COMMON NAME						(IND/30 m2)
Cyphoma gibbosum	Flamingo Tongue	2	2	1	3	1	**1.8**
Stenorhynchus seticornis	Arrow Crab			1			**0.2**
	TOTALS	2	2	2	3	1	**2.0**

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 Cana Gorda, a fringing coral reef system that extends southwesterly from Punta Ballena in the east towards Punta Jacinto in the west. The reef is approximately 2.3 km long and at least 1 km wide. It is separated from Cayo Coral by a deep submarine canyon that cuts through the insular shelf and extends easterly towards the shelf-edge. A georeferenced map of benthic habitats and qualitative characterization of marine communities associated with the main benthic habitats at Cayo Aurora was prepared by Garcia-Sais et al. (2005). The fore reef of Cayo Aurora is characterized by a gently sloping terrace where Elkhorn Coral, *Acropora palmata* represents the main benthic habitat, creating a biotope intermixed with sparsely distributed massive and encrusting corals and gorgonians at depths between 2 – 5 m (Garcia-Sais et al, 2005). Transects 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 weel defined *A. palmata* zone (Figure 37). Panoramic views of Cayo Aurora are shown in Photo Album 11.

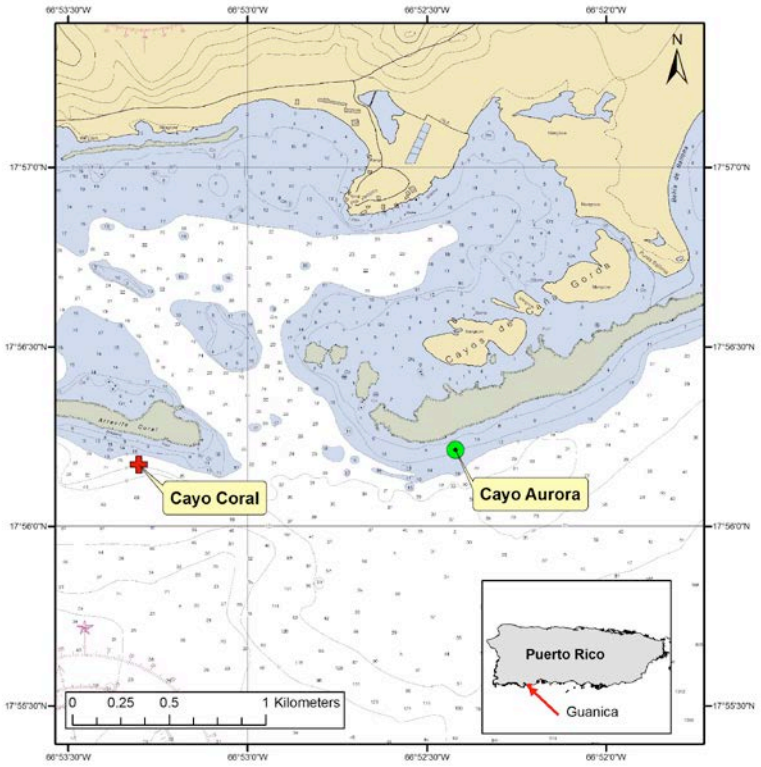


Figure 37. Location of coral reef monitoring station in Cayo Aurora, Guanica

2.1 Sessile-benthic Reef Community

A total of 15 stony corals, including 4 intersected by transects were identified from Cayo Aurora during the 2011 baseline survey (Table 42). Substrate cover by stony corals along transects averaged 38.8 % (range: 25.8 – 77.0 %). Elkhorn Coral, *Acropora palmata* was the main species in terms of substrate cover with a mean of 34.8% (range: 22.0 – 77.0 %), representing 89.7 % of the total cover by stony corals (Table 42). Massive Starlet Coral, *Siderastrea siderea*, Symmetrical Brain Coral, *Diploria strigosa* and Mustard Hill Coral, *Porites astreoides* comprised along with Elkhorn Coral the main coral assemblage of the reef at depths of 2 - 5 m. Elkhorm 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 2.2 colonies/transect. Also, the encrusting gorgonian, *Erythropodium caribbaeourm* was present in two transets with a mean cover of 0.7 %. Sponges, particularly encrusting forms, such as *Anthosigmella varians* were present in four out of the five transects surveyed with a mean reef substrate cover of 3.6 %. Encrusting zonathids (mostly *Palythoa sp*.) were also present in three transects with an average cover of 2.1 % (Table 42).

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 34.8 % (range: 16.0 – 53.0 %), representing almost 99% of the total cover by benthic algae (Table 42). Abiotic cover, which averaged 17.4 % was mostly associated with the large overhangs created by Elkhorn Coral branches and gaps.

Table 42. Percent substrate cover by sessile-benthic categories at Cayo Aurora, Guanica. July 2011

Depth: 2 - 5 m	TRANSECT					
	1	2	3	4	5	**MEAN**
Rugosity (m)	5.2	7.3	8.8	6.6	2.4	**6.1**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	14.8	16.3	26.2	19.9	7.0	**16.8**
Gaps	2.8					**0.6**
Total Abiotic	17.6	16.3	26.2	19.9	7.0	**17.4**
Benthic Algae						
Turf-mixed assemblage	44.5	53.0	34.5	37.1	16.0	**37.0**
Coralline algae	0.9			1.3		**0.4**
Total Benthic Algae	45.5	53.0	34.5	38.4	16.0	**37.5**
Encrusting Gorgonians						
Erythropodium caribaeorum			1.5	1.8		**0.7**
Total Encrusting Gorgonians	0.0	0.0	1.5	1.8	0.0	**0.7**
Erect Gorgonians (# colonies/transect)	1	0	7	3	0	**2.2**
Sponges			1.5			**0.3**
Anthosigmella varians	3.8	1.6	9.0	2.1		**3.3**
Total Sponges	3.8	1.6	10.5	2.1	0.0	**3.6**
Zoanthids *Palythoa caribaeorum*	4.3		1.5	4.7		**2.1**
Live Stony Corals						
Acropora palmata	26.8	27.7	20.6	22.0	77.0	**34.8**
Siderastrea siderea	1.1	0.8	1.5	9.5		**2.6**
Diploria strigosa			3.0	2.0		**1.0**
Porites astreoides	0.9	0.6	0.7			**0.4**
Total Stony Corals	28.8	29.1	25.8	33.5	77.0	**38.8**

Stony corals outside transects: *Acropora cervicornis, Porites porites, Dendrogira cylindrus, Montastraea annularis, M. cavernosa, Favia fragum, Siderastrea radians, Diploria clivosa, D. labyrinthiformis, Colpophyllia natans, Agaricia sp*.

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 during the 2011 baseline survey (Appendix 1), including 35 present within belt-transects. The mean abundance of individuals was 67.2 Ind/30 m^2 (range: 27 - 112 Ind/30 m^2), and the mean number of species per transect was 15.2 (range: 12 - 18). The combined abundance of seven species represented 77.1 % of the mean abundance within belt-transects (Table 43). The most abundant species was the Bluehead Wrasse (*Thalassoma bifasciatum*) with a mean of 14.0 Ind/30 m^2 followed by the Bicolor, Dusky and Yellowtail Damselfishes, *Stegastes partitus*, *S. adustus*, *Microspathodon chrysurus*). The Redlip Blenny (*Ophioblennius atlanticus*), Four-eye Butterflyfish and Redband Parrotfish were present in 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 outside transect areas.

The fish community at Cayo Aurora was comprised by a prominent assemblage of hervibores, represented by a total of five species of parrotfishes (Scaridae), three species of doctorfishes (Acanthuridae), and at least three species of damselfishes (Pomacentridae), and by a diverse assemblage of small opportunistic invertebrate feeders, such as the wrasses (Labridae – 5 spp.), squirrelfishes (Holocentridae – 3 spp), blennies (Blennide – 3 spp) and small groupers (Serranidae – 2 spp). Piscivorous species were best represented by snappers (Lutjanidae), barracuda (Sphyraenidae) and Jacks (Carangidae), included in an ASEC survey during this baseline characterization of the reef.

Motile megabenthic invertebrates were represented within belt-transects by Boring Sea Urchins (*Echinometra lucunter*) 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. July 2011

Depth: 2 – 5 m

		Transects					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**	Individuals/30m^2					**MEAN**
Thalassoma bifasciatum	Bluehead wrasse	14	2	10	44	0	**14.0**
Stegastes partitus	Bicolor Damselfish	7	2	14	17	4	**8.8**
Stegastes adustus	Dusky Damselfish	6	5	5	10	16	**8.4**
Microspathodon chrysurus	Yellowtail damselfish	5	5	2	7	14	**6.6**
Haemulon flavolineatum	French Grunt	0	3	1	0	22	**5.2**
Ophioblennius atlanticus	Redlip blenny	4	1	7	8	4	**4.8**
Abudefduf sexatilis	Sargent Major	6	0	0	0	14	**4.0**
Chromis multilineata	Brown Chromis	0	0	0	13	0	**2.6**
Chaetodon capistratus	Four-eye Butterflyfish	3	1	2	0	3	**1.8**
Sargocentron vexillarium	Dusky Squirrelfish	0	0	0	0	6	**1.2**
Acanthurus chirurgus	Doctorfish	0	0	2	3	0	**1.0**
Sparisoma aurofrenatum	Redband Parrotfish	1	1	1	1	1	**1.0**
Scarus iserti	Striped Parrotfish	0	0	2	2	0	**0.8**
Sparisoma radians	Bucktooth parrotfish	3	1	0	0	0	**0.8**
Aulostomus maculatus	Trumpetfish	0	1	1	0	1	**0.6**
Acanthurus coeruleus	Blue tang	0	0	1	2	0	**0.6**
Halichoeres maculipinna	Clown wrasse	0	1	1	1	0	**0.6**
Halichoeres radiatus	Pudding wife	0	1	1	1	0	**0.6**
Epinephelus cruentatus	Graysby	0	0	0	1	1	**0.4**
Heteropricantus cruentatus	Bigeye	0	1	0	0	1	**0.4**
Anisotremus virginicus	Porkfish	0	0	1	0	0	**0.2**
Canthigaster rostrata	Caribbean puffer	0	0	0	1	0	**0.2**
Caranx ruber	Bar jack	0	0	0	0	1	**0.2**
Haemulon melanorum	Cottonwick	0	0	0	1	0	**0.2**
Halichoeres garnoti	Yellowhead Wrasse	1	0	0	0	0	**0.2**
Haemulon carbonarium	Cesar Grunt	1	0	0	0	0	**0.2**
Halichoeres bivittatus	Slippery dick	1	0	0	0	0	**0.2**
Holocentrus adcensionis	Longjaw squirrelfish	0	1	0	0	0	**0.2**
Holocentrus rufus	Squirrelfish	0	0	0	0	1	**0.2**
Lutjanus mahogany	Mahogany Snapper	0	0	1	0	0	**0.2**
Malacoctenus triangulatus	Saddled blenny	0	0	1	0	0	**0.2**
Neoniphon marianus	Longspine Squirrelfish	0	0	1	0	0	**0.2**
Sparisoma rubripinne	Yellowtail parrotfish	0	0	0	0	1	**0.2**
Sparisoma viride	Stoplight parrotfish	0	1	0	0	0	**0.2**
Stegastes planifrons	Three-spot Damselfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	52	27	54	112	91	**67.2**
	TOTAL SPECIES	12	15	18	15	16	**15.2**

Table 44. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Cayo Aurora, Guanica, July 2011.

Depth: 2 –5 m, Duration - 30 min.

SPECIES	**COMMON NAME**		# - (cm)	
Carangoides crysos	Blue Runner	2 - (30)		
Lutjanus apodus	Schoolmaster	5 – (20)	3 – (25)	2 – (30)
Lutjanus griseus	Mangrove Snapper	1 – (25)		
Ocyurus chrysurus	Yellowtail Snapper	3 – (15)	1 – (20)	
Sphyraena barracuda	Great Barracuda	1 - (50)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (20)		

Table 45. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Aurora, Guanica, July 2011.

Depth: 2 - 5 m		**TRANSECTS**					**MEAN ABUNDANCE**
		1	**2**	**3**	**4**	**5**	**(IND/30 m2)**
TAXA	**COMMON NAME**						
Echinometra lucunter	Rock-boring Urchin			1	2	8	**2.2**
Hermodice carunculata	Fire Worm		1				**0.2**
	TOTALS	**0**	**1**	**1**	**2**	**8**	**2.4**

Photo Album 11 (Guanica 5 m)
Cayo Aurora

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 (Figure 2). 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 38). 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 face 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 12.

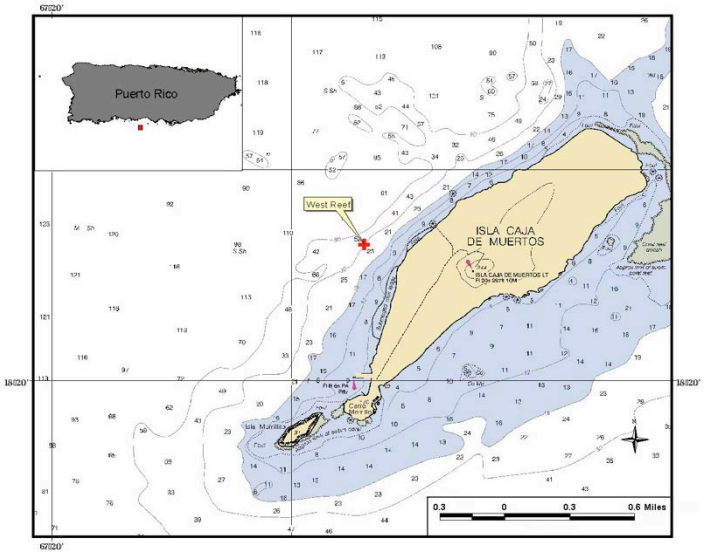


Figure 38. Location of coral reef survey stations at West Reef, Isla Caja de Muerto, Ponce.

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 53.0 % (range: 44.1 – 69.0 %) along permanent transects and was observed colonizing dead coral colonies and other hard ground substrates in the reef (Table 46). Fleshy brown (*Lobophora variegata*, *Dictyota sp*.) and calcareous (*Halimeda tune, 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 since 2008 have declined to a mean of 2.7 % during the present 2011 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 21 stony coral species, icluding 11 within transect were identified from West Reef in the 2011 survey (Table 46). Live stony corals presented a mean substrate cover of 10.7 % (range: 3.3 – 14.8 %). Boulder Star Coral, *Montastraea annularis* (complex) was the dominant coral species with a mean substrate cover of 3.7 % (range: 0.9 – 8.4 %), representing 34.6 % of the total substrate cover by live stony corals. Great Star Coral (*M. cavernosa*), Mustard-Hill Coral (*Porites astreoides*), and the Massive Starlet Coral, *Siderastrea siderea* were present in at least four out of the five transects surveyed, and along with Boulder Star Coral comprised the main coral assemblage of the West Reef (Table 46).

Soft corals (gorgonians) presented a mean density of 23.2 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 were present in all five transects with a mean substrate cover of 2.5 %. Abiotic categories combined for a mean substrate cover of 29.8 %. Coral rubble and sand accumulated within crevices, holes and gaps of

Table 46. Percent substrate cover by sessile-benthic categories at Caja de Muerto Reef, Ponce. July, 2011

	Transects					
	1	2	3	4	5	**MEAN**
Rugosity (m)	3.79	5.68	6.61	5.17	6.35	**5.52**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	8.6	16.0	23.7	22.3	26.8	**19.5**
Silt	8.2	11.6	6.0	3.7	6.4	**7.2**
Rubble		3.1	6.4	5.6		**3.0**
Total Abiotic	16.8	30.7	36.0	32.5	33.1	**29.8**
Benthic Algae						
Turf-mixed assemblage	69.0	51.7	44.1	46.2	54.3	**53.0**
Halimeda sp.				5.7		**1.1**
Total Benthic Algae	69.0	51.7	44.1	51.9	54.3	**54.2**
Encrusting Gorgonians						
Erythropodium caribaeorum	0.5					**0.1**
Total Encrusting Gorgonians	0.5	0.0	0.0	0.0	0.0	**0.1**
Erect Gorgonians (# colonies/transect)	26	16	20	25	29	**23.2**
Sponges	5.4	0.6	1.5	0.5	0.8	**1.8**
Xestospongia muta			3.6			**0.7**
Total Sponges	5.9	0.6	5.1	0.5	0.8	**2.5**
Cyanobacteria	5.1	2.2	1.4	3.6	1.0	**2.7**
Live Stony Corals						
Montastraea annularis	0.9	8.4	5.0	2.6	1.5	**3.7**
Montastraea cavernosa		3.4	0.9	3.4	3.1	**2.2**
Porites astreoides		1.3	2.1	0.7	4.6	**1.7**
Siderastrea siderea	0.9	1.2	2.7	2.2	0.4	**1.5**
Siderastrea radians	1.0	0.5	1.2			**0.5**
Meandrina meandrites				1.3		**0.3**
Dendrogyra cylindrus			1.3			**0.3**
Millepora alcicornis	0.4		0.3	0.3	0.3	**0.2**
Agaricia agaricites				0.4	0.3	**0.1**
Stephanocoenia intersepta					0.5	**0.1**
Madracis decactis				0.5		**0.1**
Total Stony Corals	3.3	14.8	13.4	11.4	10.7	**10.7**

Coral Species Outside Transects: *Agaricia lamarki*, *A. grahamae*, *Colpophyllia natans*, *Diploria strigosa, Isophyllia sinuosa, Dichocoenia stokesii, Millepora sp., Mycetophyllia lamarckiana, Leptoseris cucullata, Porites porites*

the highly irregular bottom topography. The high rugosity measured at 5.5 m was strongly influenced by large dead coral heads (mostly *Montastraea annularis*).

Figure 39 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 2005-11. 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. 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 *Montastraea 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 has stabilized since the 2008 monitoring survey and the small annual fluctuations appear to be within the sampling variability range. Soft corals (gorgonians) increased markedly after 2006 (Figure 39) suggesting that the massive mortality of stony corals after the 2005 bleaching event may have allowed an increse of recruitment by soft corals at West Reef.

Variations of the mean substrate cover by coral species are shown in Figure 40. Boulder Star Coral, *Montastraea annularis* exhibited a decline of 16 % between the baseline survey of 1999 and the 2005 survey, then droped 58.0 % between 2005 and 2006, driving the overall decline of live coral cover at West Reef. During the 2007 survey, *M. annularis* declined again 7.4 % from its cover in 2006, and then stabilized during the 2008 survey (Figure 40). 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 *M. annularis*, were measured in the 2009 survey, but apper to be an artifact of sampling variability influenced by the low sample size (low coral cover).

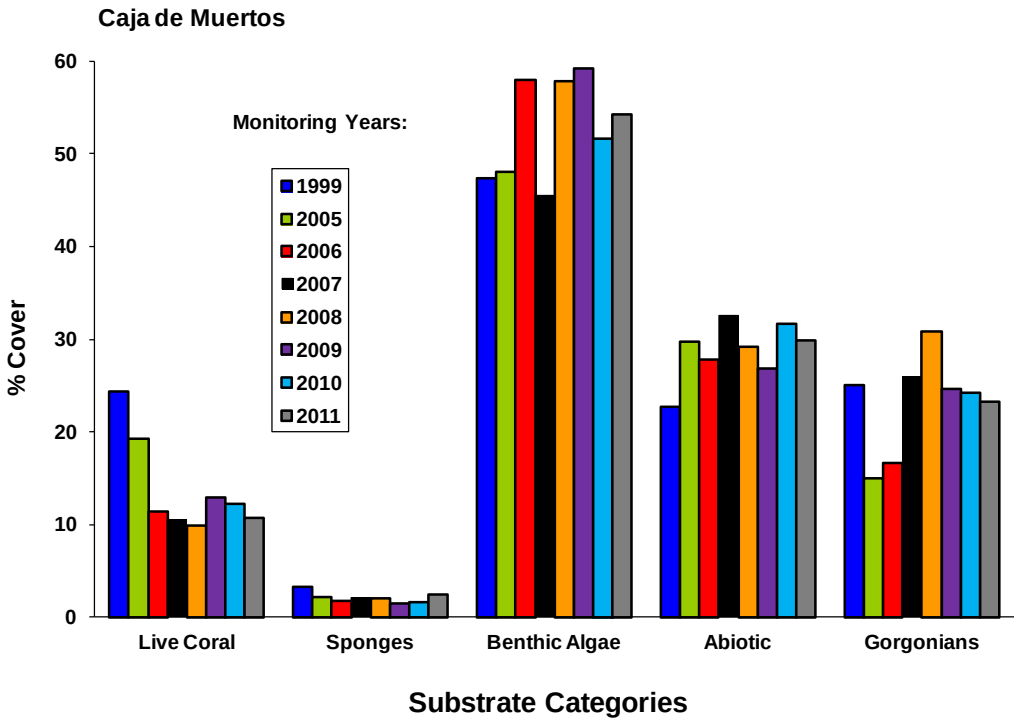


Figure 39. Monitoring trends (1999 - 2011) of mean substrate cover by sessile-benthic categories at West Reef, Isla Caja de Muerto, Ponce.

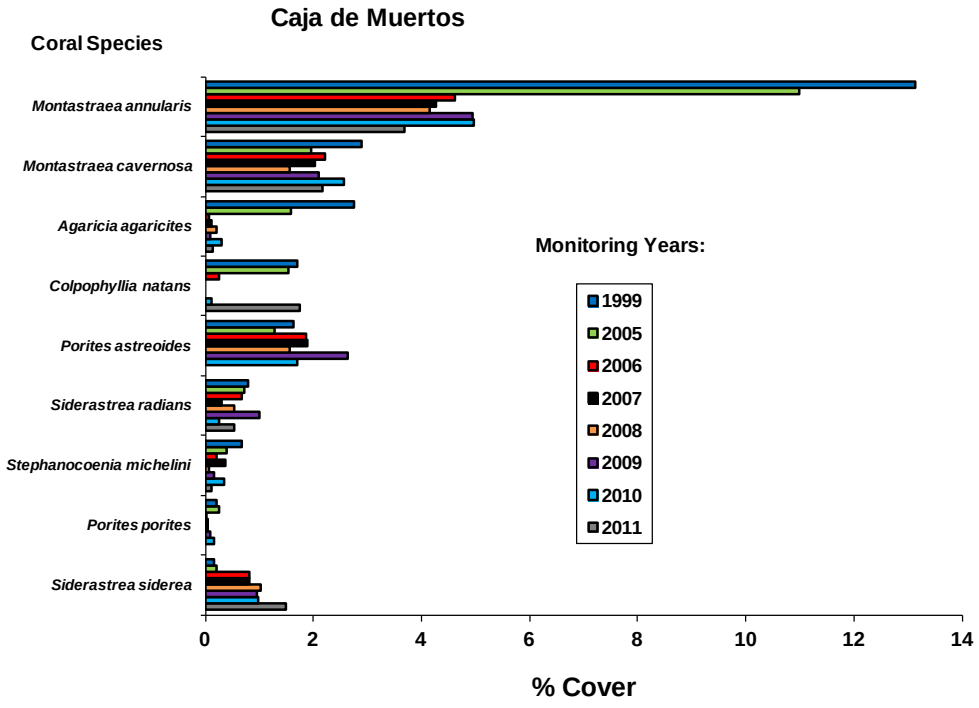


Figure 40. Monitoring trends (1999 – 2011) of mean substrate cover by stony coral species at West Reef, Isla Caja de Muerto, Ponce.

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 78 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 2011 was 176.6 Ind/30 m^2 (range: 117 - 227 Ind/30 m^2). The mean number of species per transect was 21.4 (range: 16- 25). The Masked Goby (*Coryphopterus personatus*) was the numerically dominant species with a mean abundance of 113.0 Ind/30 m^2 (range: 65 - 150 Ind/30 m^2), representing 64.0 % of the total abundance within belt-transects (Table 47). The Masked Goby was present in swarms of 15 – 100 individuals close to the reef substrate, below ledges, in front of crevices and other protective microhabitats of the reef. The Bluehead Wrasse, Bicolor, Yellow-eye and Dusky Damselfishes, Striped and Redband Parrotfishes, Black-bar Souldierfish, Four-eye Butterflyfish, Doctorfish, Blue Tang and the Caribbean Puffer 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 47).

Figure 41 shows the annual trends of fish abundance and species richness during monitoring surveys at West Reef. Statisticaly significant differences of fish abundance (ANOVA; $p < 0.001$, Appendix 3) were found. These differences were driven by abundance fluctuations of the Masked Goby, a numerically dominant species within belt transects. Abundances were relatively lower during the baseline survey and then again during the period of 2006-08 relative to the 2009 - 2011 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 and 2008 relative to previous 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. Some of these species were not prominent within belt-transects, but were observed forming large schooling aggregations in the water column over the reef. These species are known to serve as forage for a diverse assemblage of top pelagic and demersal predators, including barracudas, jacks, and large groupers and snappers observed during this and/or previous ASEC surveys at this reef (Table 48).

Table 47. Taxonomic composition and abundance of fishes within belt-transects at West Reef Caja de Muertos, Ponce. April, 2011

Depth: 8 – 10 m

		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(individuals/30 m2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	150	65	125	145	80	**113.0**
Thalassoma bifasciatum	Bluehead Wrasse	18	45	4	17	0	**16.8**
Scarus iserti	Stripped Parrotfish	12	4	3	13	3	**7.0**
Stegastes partitus	Bicolor Damselfish	10	6	10	8	0	**6.8**
Stegastes planifrons	Yellow-eye Damselfish	7	4	2	4	3	**4.0**
Sparisoma aurofrenatum	Redband Parrotfish	3	1	5	1	3	**2.6**
Stegastes dorsopunicans	Dusky Damselfish	1	7	1	4	0	**2.6**
Gobiosoma evelynae	Sharknose Goby	0	0	0	8	2	**2.0**
Myripristis jacobus	Blackbar Soldierfish	2	1	5	1	0	**1.8**
Chaetodon capistratus	Four-eye Butterflyfish	2	1	2	2	1	**1.6**
Stegastes leucostictus	Beau Gregory	1	0	0	3	4	**1.6**
Acanthurus chirurgus	Doctorfish	1	2	1	1	2	**1.4**
Canthigaster rostrata	Caribbean Puffer	2	1	1	2	1	**1.4**
Haemulon aurolineatum	Tomtate	0	0	5	0	1	**1.2**
Acanthurus coeruleus	Blue Tang	0	1	1	1	1	**0.8**
Cephalopholis cruentatus	Graysby	3	0	0	1	0	**0.8**
Coryphopterus lipernes	Peppermint Goby	0	0	0	1	3	**0.8**
Haemulon flavolineatum	French Grunt	1	0	1	2	0	**0.8**
Bodianus rufus	Spanish Hogfish	0	0	0	3	0	**0.6**
Chromis cyanea	Blue Chromis	0	2	0	1	0	**0.6**
Halichoeres garnoti	Yellow-head Wrasse	2	1	0	0	0	**0.6**
Lutjanus apodus	Schoolmaster	0	0	0	3	0	**0.6**
Lutjanus mahogoni	Mahogani Snapper	0	0	3	0	0	**0.6**
Scarus taeniopterus	Princess Parrotfish	0	0	0	1	2	**0.6**
Holocentrus rufus	Squirrelfish	1	1	0	0	0	**0.4**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	0	0	1	1	**0.4**
Hypoplectrus puella	Barred Hamlet	1	0	0	0	1	**0.4**
Pseudupeneus maculatus	Spotted Goatfish	0	1	1	0	0	**0.4**
Synodus intermedius	Sand Diver	0	0	1	0	1	**0.4**
Acanthurus bahianus	Ocean Surgeon	1	0	0	0	0	**0.2**
Anisotremus virginicus	Porkfish	0	0	1	0	0	**0.2**
Aulostomus maculatus	Trumpetfish	1	0	0	0	0	**0.2**
Carangoides ruber	Bar Jack	0	0	0	1	0	**0.2**
Chaetodon striatus	Banded Butterflyfish	0	0	0	0	1	**0.2**
Pterois volitans	Lionfish	0	0	0	1	0	**0.2**

Table 47. Continued

Gymnothorax moringa	Golden moray	1	0	0	0	0	**0.2**
Haemulon macrostomum	Spanish Grunt	0	0	1	0	0	**0.2**
Pomacanthus arcuatus	Gray Angelfish	0	0	0	0	1	**0.2**
Pomacanthus paru	French Angelfish	0	0	0	1	0	**0.2**
Lutjanus griseous	Gray Snapper	0	0	0	0	1	**0.2**
Microspathodon chrysurus	Yellowtail Damselfish	0	0	0	0	1	**0.2**
Serranus tigrinus	Harlequin Bass	1	0	0	0	0	**0.2**
Sparisoma radians	Bucktooth Parrotfish	0	0	0	0	1	**0.2**
Sparisoma viride	Stoplight Parrotfish	0	0	0	0	1	**0.2**
Heteropricantus cruentatus	Glasseye Snapper	0	0	1	0	1	**0.4**
Hypoplectrus sp	Hamlet Hybrid	0	0	1	0	0	**0.2**
Diodon histrix	Porcupinefish	0	0	0	1	0	**0.2**
Sargocentron vexillarium	Dusky Squirrelfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	221	143	175	227	117	**176.6**
	TOTAL SPECIES	21	16	21	25	24	**21.4**

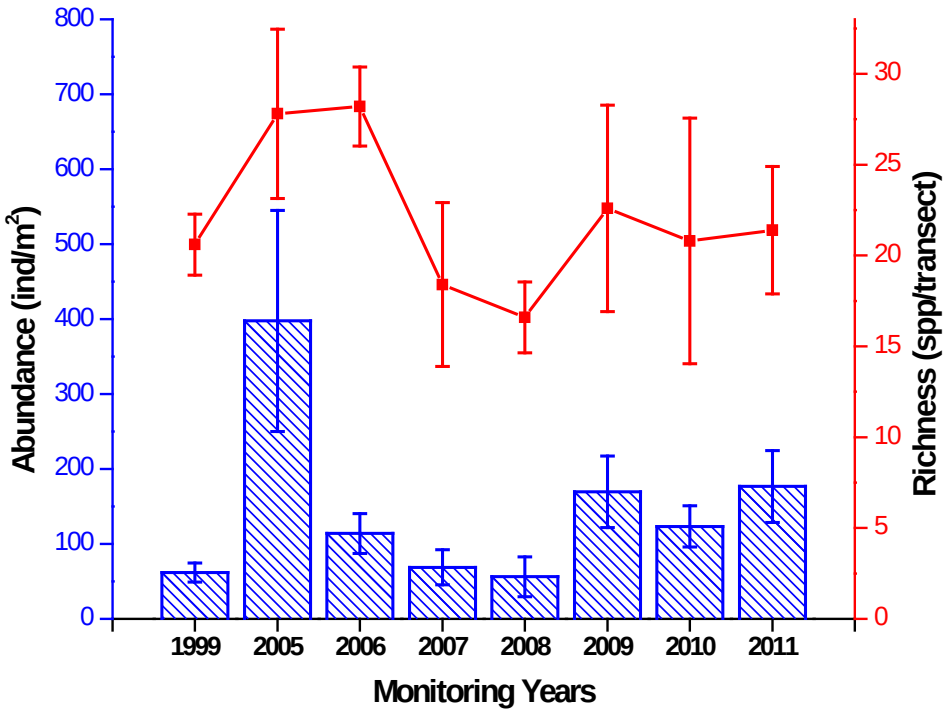


Figure 41. Monitoring trends (1999 – 2011) of fish species richness and abundance at West Reef, Isla Caja de Muerto, Ponce

A specious assemblage of small invertebrate feeders was 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 48). Two Linfishes were also observed outside transects. 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 and 2010 ASEC surveys. The aggregation of these Lane Snappers at West Reef is 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*) have been observed foraging along with the large Lane Snapper aggregations during the 2011 and previous ASEC surveys (García-Sais et al., 2006). Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous fish assemblage of West Reef. One Hawksbill Turtle (*Eretmochelys imbricata*) was observed basking at the surface over West Reef.

Motile megabenthic invertebrates were represented within belt-transects by Arrow Crabs, Flamingo Tongues, Cleaner Shrimps and one Giant Basket Star (Table 49). Three spiny lobsters, *Panulirus argus* and several adult Queen and Milk Conch, *Strombus gigas, S. costatus* were observed outside transects.

Table 48. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at West Reef, Isla Caja de Muerto, July 2011.

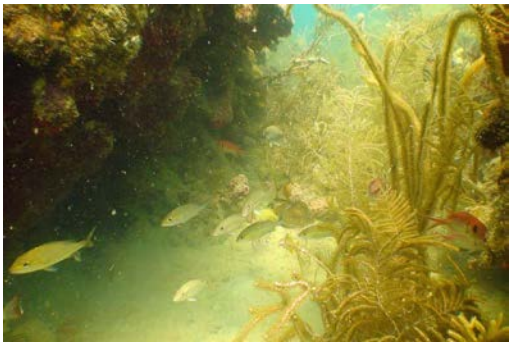
Depth range : 7 – 15 m Duration - 30 min.

SPECIES	**COMMON NAME**	# - (cm)		
Dasyatis americana	Southern Stingray	1 – (70)		
Epinephelus guttatus	Red Hind	2 - (25)		
Lutjanus apodus	Schoolmaster	5 – (15)	6 – (20)	4 – (30)
Lutjanus mahogany	Mahogani Snapper	5 - (20)		
Lutjanus synagris	Lane Snapper	100 – (15-20)	60 – (25)	20 – (30)
Lutjanus analis	Mutton Snapper	1 - (35)		
Lutjanus griseus	Grey Snapper	2 – (25), 2 – (30)		
Ocyurus chrysurus	Yellowtail Snapper	20 – (10 - 15)	10 – (25)	5 – (30)
Pterois volitans	Lionfish	2 – (25)		
Sphyraena barracuda	Great Barracuda	1 - (60)		
Invertebrates				
Strombus gigas	Queen Conch	4 – (25-30)		
Strombus costatus	Milk Conch	12 – (8 – 12)		
Panulirus argus	Spiny Lobster	3 - (12 - 18)		
Other				
Eretmochelys imbricata	Hawksbill Turtle	(1 – (60)		

Table 49. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at West Reef, Caja de Muerto. March 2011.

Depth: 6 - 7 m		**TRANSECTS**					**MEAN ABUNDANCE**
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**(IND/30 m2)**
Periclimenes pedersoni	Cleaner Shrimp		2				**0.4**
Astrophyton muricatum	Giant Basket Star	1					**0.2**
Ciphoma gibbosum	Flamingo Tongue	1				1	**0.4**
Stenorhynchus seticornis	Arrow Crab	1	1	1		1	**0.8**
	TOTALS	**3**	**3**	**1**	**0**	**2**	**1.8**

Photo Album 12 (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 42). 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 12.

1.0 Sessile-Benthic Reef Community

A total of 22 stony corals, including 12 intersected by line transects were identified from Derrumbadero Reef at a depth of 20 m during 2011 (Table 50). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 14.2 % (range: 5.4 – 19.7 %). Boulder Star Coral, *Montastraea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 6.5 % (range: 1.0 – 9.6 %), representing 45.8 % 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, Mustard-Hill and Lettuce Coral (*Agaricia agaricites*) were present in all five transects and along with Great Star Coral comprised the main stony coral assemblage at Derrumbadero Reef (Table 50). Six additional coral species were represented by only one colony within transects surveyed.

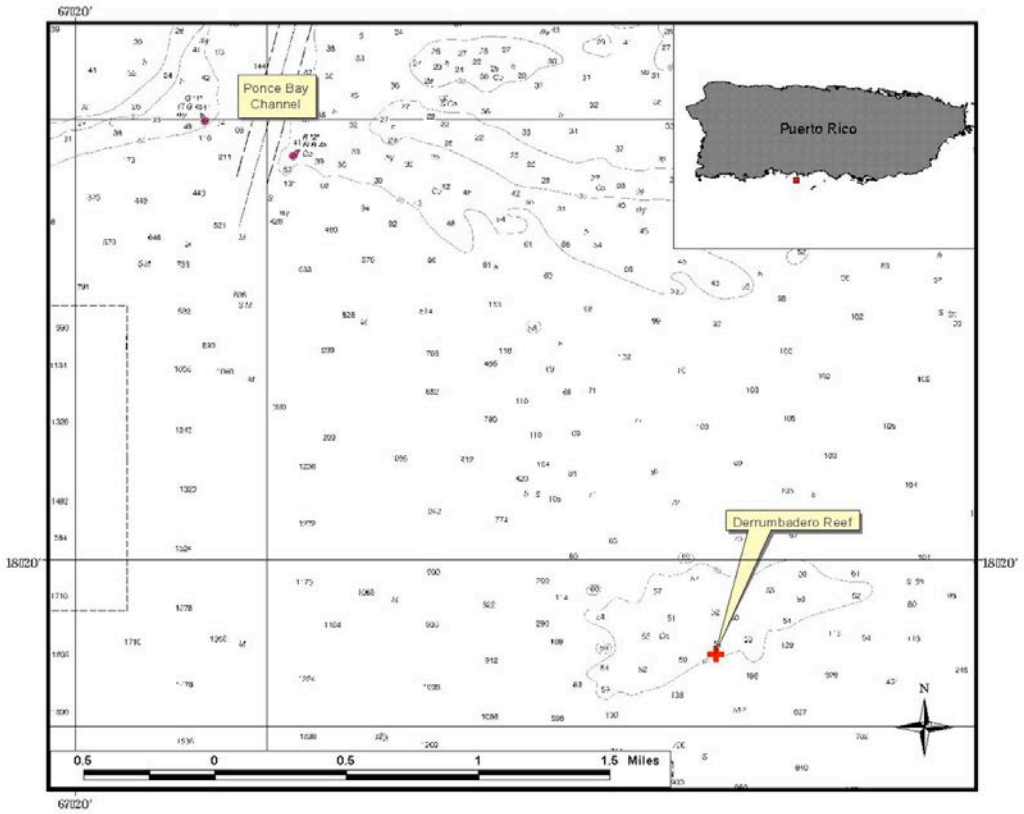


Figure 42. Location of the coral reef monitoring station at Derrumbadero Reef, Ponce.

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 highly abundant (mean: 30.8 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.

Turf algae comprised by an assemblage of brown and red algae were the most prominent sessile-benthic category in terms of substrate cover at Derrumbadero Reef with a mean of 41.8 % (range: 30.7 – 53.0 %). Sponges were also present in all five transects with a mean substrate cover of 3.2 %. Abiotic categories were mostly contributed by reef overhangs associated to the mounds and ledges of Boulder Star Coral (*M. annularis*), which added to a reef mean rugosity of 2.8 m (Table 50).

Table 50. Percent substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce. Depth: 20 m. July 2011.

	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	3.59	3.58	2.73	3.00	3.54	**3.29**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	18.6	16.2	1.3	3.5	10.6	**10.0**
Rubble	1.8				0.9	
Sand			1.1			**0.2**
Total Abiotic	20.3	16.2	2.4	3.5	11.6	**10.8**
Benthic Algae						
Turf-mixed assemblage	32.8	46.5	53.0	46.3	30.7	**41.8**
Lobophora variegata	18.9	20.1	17.1	20.3	35.1	**22.3**
Dictyota sp.	10.8	3.3	3.5	2.2	2.5	**4.5**
Coralline algae			3.2	3.0		**1.2**
Halimeda discoidea		1.0				**0.2**
Total Benthic Algae	62.4	70.9	76.8	71.8	68.3	**70.0**
Encrusting Gorgonians						
Erythropodium caribaeorum		5.0	0.6			**1.1**
Total Encrusting Gorgonians	0.3	5.0	0.6	0.0	0.0	**1.2**
Erect Gorgonians (#colonies/transect)	27	39	31	37	20	**30.8**
Sponges	2.6	2.5	4.6	5.0	1.3	**3.2**
Cyanobacteria	1.6				1.6	**0.6**
Live Stony Corals						
Montastraea annularis	8.9	1.0	7.4	5.7	9.6	**6.5**
Porites astreoides	2.4	2.5	2.8	2.7	2.3	**2.5**
Montastraea cavernosa			2.7	4.2	3.1	**2.0**
Agaricia agaricites	0.5	0.6	1.4	4.0	1.5	**1.6**
Colpophyllia natans				2.2		**0.4**
Meandrina meandrites				0.6	0.9	**0.3**
Diploria strigosa			1.3			**0.3**
Diploria labyrinthiformis		0.8				**0.2**
Madracis decactis	0.6					**0.1**
Millepora alcicornis				0.4		**0.1**
Agaricia grahamae	0.4					**0.1**
Eusmilia fastigiata		0.4				**0.1**
Total Stony Corals	12.8	5.4	15.5	19.7	17.4	**14.2**

Coral Species Outside Transects*: Acropora cervicornis, Agaricia grahamae, A. lamarcki, Dichocoenia stokesi, Isophyllia sinuosa, Leptoseris cucullata, Madracis mirabilis, Meandrina meandrites, Mycetophyllia lamarckiana, Stephanocoenia michelini*

Figure 43 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 2005-11. Differences of mean total percent cover by stony corals between monitoring surveys were statistically significant (ANOVA; $p < 0.001$; 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 appeared 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), yet consistent increment of live coral cover was measured during the 2009 and 2010 surveys (Figure 43). No significant change of live coral cover was measured in 2011 relative to the previous 2009 and 2010 monitoring surveys (see Appendix 2).

Monitoring trends of mean substrate cover by coral species at Derrumbadero Reef are shown in Figure 44. 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 cervicornis*. During the 2009 and 2010 surveys, a mild increment of live cover by *M. annularis* was measured at Derrumbadero Reef, but no significant change was measured during 2011 relative to previous two annual surveys.

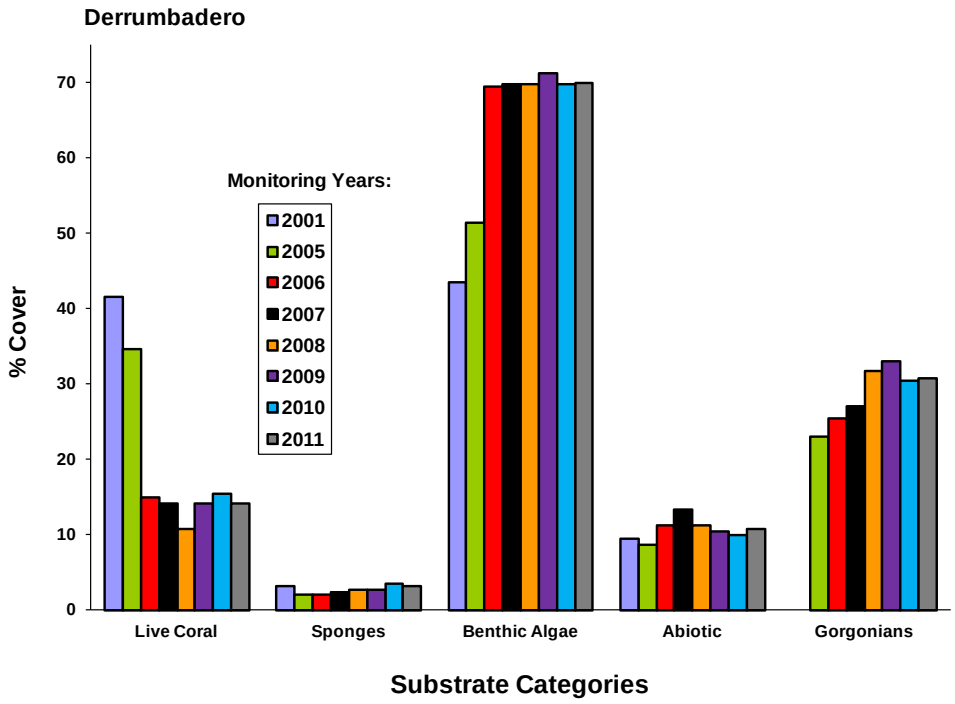


Figure 43. Monitoring trends (2001 – 2011) of mean substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce.

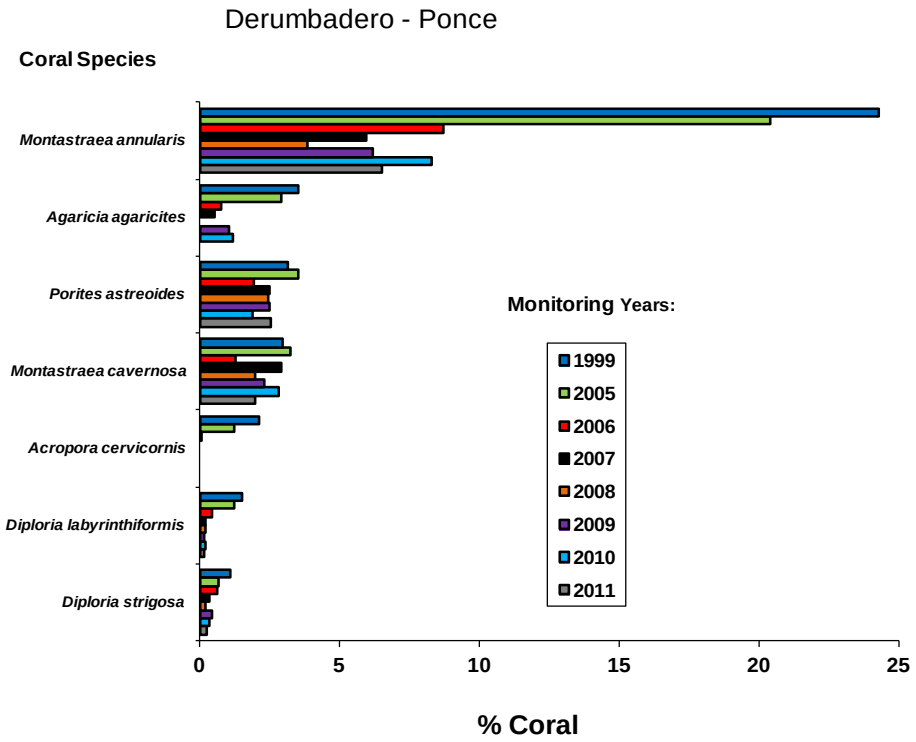


Figure 44. Monitoring trends (2001 – 2011) of mean substrate cover by coral species at Derrumbadero Reef, Ponce.

Soft corals (gorgonian) were not adversely affected by the environmental conditions affecting scleractinian corals after 2005 in Derrumbadero Reef. They have shown an increment from 23 to 30 col/transect between the 2006 and the 2011 surveys.

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 90 fish species have been identified from Derrumbadero Reef during monitoring surveys (Appendix 1), including 46 within belt-transects during 2011. Mean abundance within belt-transects during 2011 was 118.0 Ind/30 m^2 (range: 66 - 170 Ind/30 m^2). The mean number of species per transect was 22.6 (range: 16 - 29). The Masked Goby, Blue Chromis, Bluehead Wrasse, Peppermint Goby and the Bicolor Damselfish were the numerically dominant species with a combined mean abundance of 76.0 Ind/30 m^2 representing 64.4 % of the total abundance within belt-transects (Table 51). In addition to the aforementioned species, the Yellowhead Wrasse, Princess, Striped, Bucktooth and Redband Parrotfishes, Sharknose Goby, Beaugregory, Squirrelfish, Doctorfish and Blue Tang were present in at least four of the five transects surveys and were part of the resident fish assemblage at Derumbadero Reef. A total of 14 species were represented by only one individual within belt-transects (Table 51).

Figure 44 presents the temporal trends of fish abundance and species richness within belt-transects during the baseline characterization of 2001 and subsequent monitoring surveys of 2005-11. Statistically significant declines of fish abundance and species richness (ANOVA; $p < 0.001$, Appendix 3) were detected. Higher fish abundance was observed during the 2001 and 2005 surveys compared to the 2006 - 11 surveys. Differences were largely associated to a marked abundance decline by Masked Goby, *Coryphopterus personatus*, a species that was numerically dominant during the baseline (2001) and 2005 surveys. This is a small zooplanktivorous species that forms dense swarms below coral ledges. Its mean abundance within belt-transects declined more than 10 fold between the 2001-05 and the 2006-11 monitoring surveys. It is uncertain if the decline in abundance of the Masked Goby, and perhaps other reef fishes is correlated with the abrupt decline of live coral cover in Derrumbadero and other reef systems in the monitoring program. However, a marked drop of fish species richness (# species per transect) was also observed in the 2006 survey, coincident with the massive coral mortality associated with the 2005 regional bleaching event. The large-scale loss

Table 51. Taxonomic composition and abundance of fishes within belt-transects at Derrumbadero Reef, Ponce. July 2011

Depth: 20m

		TRANSECTS					
		1	2	3	4	5	
		(Individuals/30 m^2)					
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	46	22	73	4	31	**35.2**
Chromis cyanea	Blue Chromis	10	8	38	1	14	**14.2**
Thalassoma bifasciatum	Bluehead Wrasse	8	2	18	12	5	**9.0**
Coryphopterus lipernes	Peppermint Goby	13	2	5	7	17	**8.8**
Stegastes partitus	Bicolor Damselfish	12	9	3	7	13	**8.8**
Scarus iserti	Stripped Parrotfish	0	12	8	7	5	**6.4**
Gobiosoma evelynae	Sharknose Goby	10	3	1	4	8	**5.2**
Scarus taeniopterus	Princess Parrotfish	8	5	2	3	1	**3.8**
Clepticus parrae	Creole Wrasse	5	0	0	0	12	**3.4**
Sparisoma aurofrenatum	Redband Parrotfish	2	7	1	2	2	**2.8**
Halichoeres garnoti	Yellow-head Wrasse	2	1	3	2	1	**1.8**
Holocentrus rufus	Squirrelfish	1	3	1	3	1	**1.8**
Myripristis jacobus	Blackbar Soldierfish	5	0	0	0	4	**1.8**
Acanthurus chirurgus	Doctorfish	1	1	0	1	3	**1.2**
Stegastes leucostictus	Beau Gregory	1	1	2	1	1	**1.2**
Sparisoma radians	Bucktooth Parrotfish	1	0	2	2	0	**1.0**
Sparisoma viride	Stoplight Parrotfish	0	0	1	2	2	**1.0**
Acanthurus coeruleus	Blue Tang	0	1	1	1	1	**0.8**
Chaetodon capistratus	Four-eye Butterflyfish	1	0	2	1	0	**0.8**
Acanthurus bahianus	Ocean Surgeon	0	0	3	0	0	**0.6**
Caranx crysos	Blue runner	0	0	0	3	0	**0.6**
Cephalopholis cruentatus	Graysby	1	0	0	0	2	**0.6**
Haemulon flavolineatum	French Grunt	1	0	0	0	2	**0.6**
Melichthys niger	Black Durgon	0	0	0	0	3	**0.6**
Canthigaster rostrata	Caribbean Puffer	0	0	0	0	2	**0.4**
Chaetodon aculeatus	Longsnout Butterflyfish	1	0	1	0	0	**0.4**
Chromis multilineata	Brown Chromis	2	0	0	0	0	**0.4**
Neoniphon marianus	Longspine Squirrelfish	0	0	1	0	1	**0.4**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	0	2	0	0	**0.4**
Hypoplectrus puella	Barred Hamlet	0	0	1	1	0	**0.4**
Hypoplectrus unicolor	Butter Hamlet	1	0	0	0	1	**0.4**
Pomacanthus paru	French Angelfish	0	2	0	0	0	**0.4**
Anisotremus virginicus	Porkfish	0	0	0	0	1	**0.2**
Aulostomus maculatus	Trumpetfish	1	0	0	0	0	**0.2**
Carangoides ruber	Bar Jack	0	0	0	0	1	**0.2**

Table 51. Continued

Chaetodon striatus	Banded Butterflyfish	0	0	1	0	0	**0.2**
Coryphopterus glaucofraenum	Bridled Goby	1	0	0	0	0	**0.2**
Equetus lanceolatus	Jacknife	0	0	0	0	1	**0.2**
Gymnothorax moringa	Golden moray	0	0	0	1	0	**0.2**
Haemulon sciurus	Bluestriped Grunt	0	0	0	0	1	**0.2**
Hypoplectrus nigricans	Black Hamlet	0	0	0	1	0	**0.2**
Mulloides martinicus	Yellowtail Goatfish	1	0	0	0	0	**0.2**
Lutjanus apodus	Schoolmaster Snapper	0	0	0	0	1	**0.2**
Ophioblennius atlanticus	Redlip Blenny	0	0	0	0	1	**0.2**
Ocyurus chrysurus	Yellowtail Snapper	1	0	0	0	0	**0.2**
Sphyraena barracuda	Great Barracuda	0	1	0	0	0	**0.2**
	TOTAL INDIVIDUALS	136	80	170	66	138	**118.0**
	TOTAL SPECIES	25	16	22	21	29	**22.6**

of habitat quality associated with decreased live coral cover may have affected the reef fish community structure as it affects microhabitat availability and food webs (Paddack et al. 2009). Conversely, with the gradual improvement of live coral cover at Derrumbadero an increasing trend of both fish species richness and abundance has emerged during the last three years of the monitoring program (e.g. 2009 and 2011, Figure 44).

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 52). 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.

Arrow Crabs and Cleaner Shrimps represented megabenthic invertebrates within belt transects during the 2011 survey (Table 53). One spiny lobster was observed outside transects.

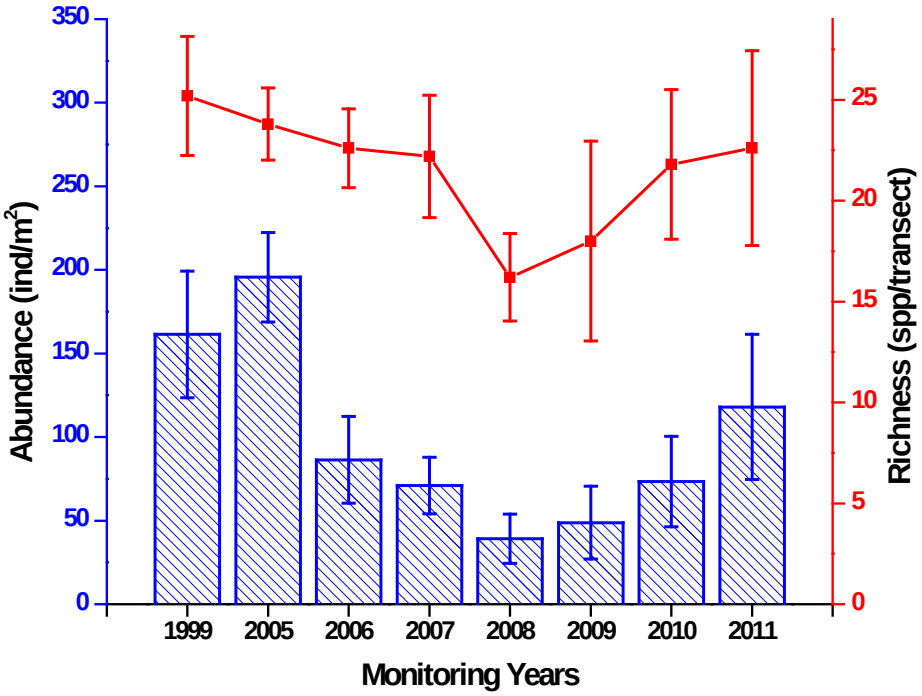


Figure 44. Monitoring trends (1999 – 2011) of fish species richness and abundance at Derrumbadero Reef, Ponce

Table 52. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Derrumbadero Reef, Ponce. July 2011

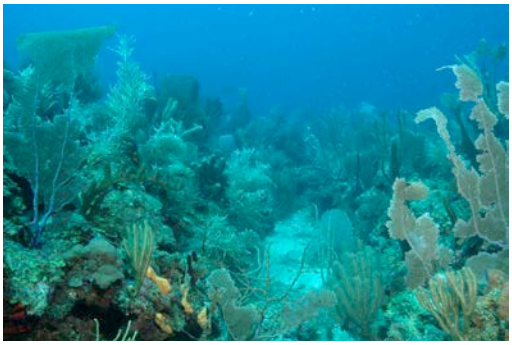
Duration - 30 min. Depth: 18 - 22 m

SPECIES	**COMMON NAME**		# - (cm)
Balistes vetula	Queen Triggerfish	2 – (35)	
Epinephelus guttatus	Red Hind	2 – (30)	
Lachnolaimus maximus	Hogfish	1 – (40)	
Lutjanus apodus	Schoolmaster	3 - (25)	4 – (30)
Lutjanus mahogany	Mahogani Snapper	2 - (25)	
Lutjanus synagris	Lane Snapper	4 - (20)	1 – (25)
Ocyurus chrysurus	Yellowtail Snapper	3 – (20)	2 - (25)
Scomberomorus regalis	Cero Mackerel	2- (40)	
Sphyraena barracuda	Great Barracuda	1- (50)	
Invertebrates			
Panulirus argus	Spiny Lobster	1 - (20)	

Table 53. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Derrumbadero Reef, 20 m, Ponce, July 2011

Depth: 20 m		**TRANSECTS**					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	DEPTH (m) COMMON NAME						
Periclimenes pedersoni	Cleaner Shrimp		1		1		**0.4**
Stenorhynchus seticornis	Arrow Crab		1			1	**0.4**
	TOTALS	**0**	**2**	**0**	**1**	**1**	**0.8**

Photo Album 13 (Ponce)
Derrumbadero Reef



G. 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 45). 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.

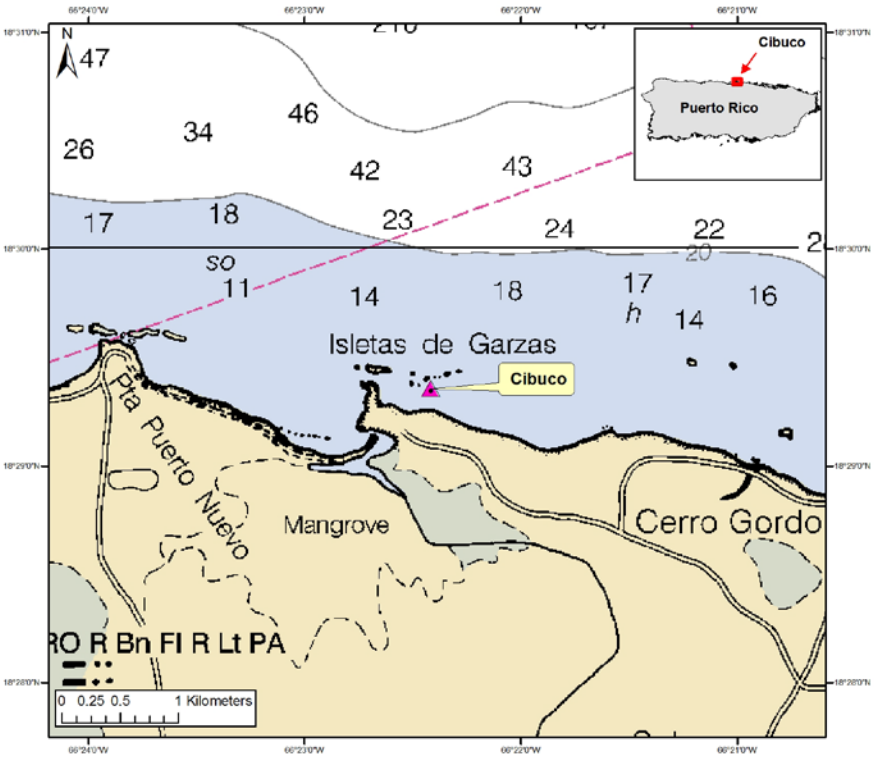


Figure 45. Location of Cibuco Reef at Isletas de Garza off Vega Baja in the north coast of Puerto Rico.

Extensive thickets of Finger Coral, *Porites porites* have grown over sections of the eolianite structures at depths between 2 – 5 m. There were several sections where Finger Coral thickets surpass 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". Five permanent transects were installed on three sections of one of the Isletas de Garza (Figure 45). Panoramic view of the reef are shown in Photo Album 14.

1.0 Sessile-Benthic Reef Community

A total of 17 species of stony corals, including 10 intersected by transects were identified from Cibuco Reef during the 2011 baseline survey (Table 54). Substrate cover by stony corals along transects averaged 47.3 % (range: 31.3 – 55.2 %). Boulder Star Coral, *Montastraea annularis* (complex) was the main species in terms of substrate cover with a mean of 18.7% (range: 6.8 – 28.2 %), representing 39.5 % of the total cover by stony corals (Table 54). Finger Coral, *Porites porites*, Symmetrical Brain Coral, *Diploria strigosa* and Mustard Hill Coral, *Porites astreoides* comprised along with Boulder Star Coral the main coral assemblage of the reef at depths of 2 - 5 m. Boulder Barin Coral was observed growing mostly as encrusting colonies of small to moderate size, not forming massive boulders with overhangs as in more protected environments. Recently dead colonies and sections of live *M. annularis* colonies were observed, evidencing considerable tissue mortality during recent years. 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. 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

Table 54. Percent substrate cover by sessile-benthic categories at Cibuco Reef, Vega Baja. October 2011

Depth: 2-5 m	1	2	3	4	5	**MEAN**
Rugosity (m)	4.49	6.82	3.72	6.66	7.10	**5.8**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	4.83	5.02	3.08	4.65	1.24	**3.8**
Gaps		1.67	2.57			**0.8**
Sand	8.75					**1.8**
Total Abiotic	13.58	6.69	5.65	4.65	1.24	**6.4**
Benthic Algae						
Turf-mixed assemblage	35.68	53.98	41.91	35.95	39.47	**41.4**
Coralline algae			4.74		1.99	**1.3**
Dictyota sp.				4.20		**0.8**
Total Benthic Algae	35.68	53.98	46.65	40.15	41.46	**43.6**
Encrusting Gorgonians						
Erythropodium caribaeorum					1.32	**0.3**
Total encrusting gorgonians	0.00	0.00	0.00	0.00	1.32	**0.3**
Sponges						
Cliona sp.		3.21			1.17	**0.9**
Total sponges	0.00	3.21	0.00	0.00	1.17	**0.9**
Zoanthids						
Palythoa caribaeorum		4.70	2.05		0.66	**1.5**
Zoanthus sociatus					0.49	**0.1**
Total Zoanthids	0.00	4.70	2.05	0.00	1.15	**1.6**
Live Stony Corals						
Montastraea annularis	28.16	6.84	22.59	20.47	15.67	**18.7**
Porites porites		1.00	6.71	32.52	20.18	**12.1**
Diploria strigosa		13.56	13.56	1.94	4.94	**6.8**
Montastraea cavernosa	15.73	5.95	0.92		4.27	**5.4**
Porites astreoides	3.52	2.32	0.92	0.25	4.04	**2.2**
Siderastrea siderea	3.31				4.20	**1.5**
Diploria clivosa		1.25				**0.3**
Millepora alcicornis			1.03			**0.2**
Mycetophyllia sp.		0.42				**0.1**
Agaricia agaricites					0.41	**0.1**
Total Stony Corals	50.72	31.34	45.73	55.18	53.71	**47.3**

Stony Corals Outside Transects: *Stylaster roseus, Eusmilia fastigiata, Acropora palmata, Siderastrea radians, Meandrina meandrites, M. complanata, Mycetophyllia sp.*

gorgonians were present, but represented minor components of the reef benthic community (Table 54). Abiotic substrates, particularly ref overhangs were encountered in all five transects with a mean cover of 6.4 %. Sandy substrate averaged a cover of 1.8%, 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 41.4 % (range: 35.7 – 54.0 %), representing 95 % of the total cover by benthic macroalgae (Table 54).

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 31 fish species were identified from Cibuco Reef within a depth range of 2 – 5 meters during the 2011 baseline survey (Appendix 1), including 30 present within belt-transects. The mean abundance of individuals was 54.4 Ind/30 m^2 (range: 30 - 95 Ind/30 m^2), and the mean number of species per transect was 13.6 (range: 13 - 16). The combined abundance of three species represented 63.2 % of the mean abundance within belt-transects (Table 55). The most abundant species was the Bluehead Wrasse (*Thalassoma bifasciatum*) with a mean of 22.4 Ind/30 m^2 followed by the Dusky and Yellowtail Damselfishes. Five additional species were present in at least four out of the five transects and appear to comprise the main resident demersal fish assemblage. These include the Blue Tang, Schoolmaster Snapper, French Grunt, Coney, and Squirelfish.

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

Table 55. Taxonomic composition and abundance of fishes within belt-transects at Cibuco 3m Vega Baja. October 2011

Depth: 2-5m

		Transects					
		1	2	3	4	5	
		Ind/30 m^2					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	8	7	40	7	50	**22.4**
Stegastes dorsopunicans	Dusky Damselfish	8	8	9	2	8	**7.0**
Microspathodon chrysurus	Yellowtail Damselfish	0	5	6	6	8	**5.0**
Acanthurus coeruleus	Blue Tang	0	1	2	4	4	**2.2**
Lutjanus apodus	Schoolmaster Snapper	0	1	1	4	5	**2.2**
Haemulon flavolineatum	French Grunt	1	1	2	1	5	**2.0**
Epinephelus fulva	Coney	1	3	2	3	0	**1.8**
Acanthures bahianus	Ocean Surgeon	2	1	0	0	3	**1.2**
Holocentrus adcensionis	Squirrelfish	1	1	1	2	1	**1.2**
Bodianus rufus	Spanish Hogfish	0	1	1	0	3	**1.0**
Anisotremus virginicus	Porkfish	1	1	0	0	3	**1.0**
Abudefduf sexatilis	Sargent Major	0	1	3	0	0	**0.8**
Haemulon macrostomum	Spanish Grunt	0	1	0	0	2	**0.6**
Kyphosys sectatrix	Bermuda Chub	0	1	2	0	0	**0.6**
Pempheris schomburgki	Glasseye Sweeper	0	3	0	0	0	**0.6**
Sparisoma viride	Stoplight Parrotfish	0	0	1	2	0	**0.6**
Haemulon parra	Sailors Choice	3	0	0	0	0	**0.6**
Amblycirrhitus pinos	Redspotted Hawkfish	0	0	2	0	0	**0.4**
Chaetodon striatus	Banded Butterflyfish	1	1	0	0	0	**0.4**
Gobiosoma evelynae	Sharknose Goby	2	0	0	0	0	**0.4**
Lutjanus mahogany	Mahogany Snapper	0	0	0	2	0	**0.4**
Haemulon aurolineatum	Tomtate	0	0	0	2	0	**0.4**
Halichoeres maculipina	Clown Wrasse	0	0	0	1	0	**0.2**
Scarus iserti	Stripped Parrotfish	0	0	1	0	0	**0.2**
Stegastes leucostictus	Beaugregory	1	0	0	0	0	**0.2**
Canterhines macrocerus	Whitespoted Filefish	1	0	0	0	0	**0.2**
Canthigaster rostrata	Sharpnose puffer	0	0	0	1	0	**0.2**
Halichoeres bivittatus	Slipery Dick	0	0	0	0	1	**0.2**
Epinephelus cruentatus	Graysby	0	0	0	0	1	**0.2**
Pseudopeneus maculatus	Spotted Goatfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	30	37	73	37	95	**54.4**
	TOTAL SPECIES	11	16	14	13	14	**13.6**

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), included in an ASEC survey during this baseline characterization of the reef (Table 56). 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.

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 57). One Spiny Lobster (*Panulirus argus*) was observed outside transects.

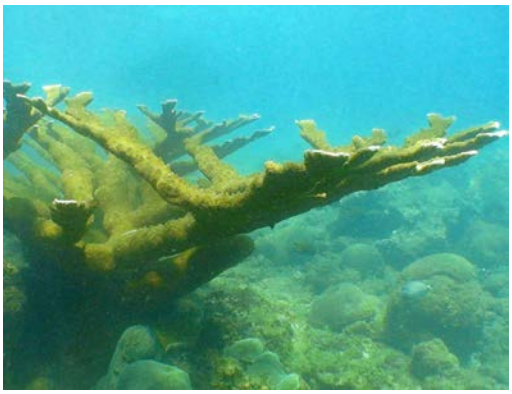
Table 56. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Cibuco Reef, 2 - 5 m, Vega Baja, October 2011.

SPECIES	**COMMON NAME**	# - (cm)		
Cranx crysos	Blue Runner	2 – (30)		
Lutjanus apodus	Schoolmaster	5 - (15)	7 – (20)	3 – (25)
Lutjanus griseus	Grey Snapper	6 - (15)	4 – (20)	1 – (25)
Lutjanus synagris	Lane Snapper	3 - (15)		
Lutjanus analis	Mutton Snapper	2 – (10)		
Sphyraena barracuda	Great Barracuda	1- (50)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (20)		

Table 57. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cibuco Reef, 2-5 m, Vega Baja, October 2011

Depth: 2 - 5 m		**TRANSECTS**					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	DEPTH (m) COMMON NAME						
Diadema antillarum	Long-spined Urchin	5	9	9	4	12	**7.8**
	TOTALS	**5**	**9**	**9**	**4**	**12**	**7.8**

Photo Album 14
Cibuco Reef



H. El Seco Reef, Southeast 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 1). Depth increases towards the shelf-edge to the east and south of the ridge, and decreases towards the north, where an extensive mesophotic coral reef system consisting of several benthic habitats was discovered (Garcia-Sais et al. 2011). The coral reef system ends as patch reef spurs separated by coralline sand pools at depths between 40 – 45 m. Exceptionally clear waters prevail at "El Seco" with underwater visibility generally exceeding the 30 - 40 m range.

The coral 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, *Montastraea 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.

1.0 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, calcareous green algae and coralline red algae was the dominant category in terms of percent cover with a mean of 43.7 % (range: 39.0 – 47.7 %). Turf algae, a mixed array of short filamentous algae were the main component of the benthic algae with an average cover of 29.5 %, representing 67.5 % 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 9.5 % and 4.6 %, respectively (Table 58). Most of the substrate cover by

Table 58. Percent substrate cover by sessile-benthic categories at El Seco Reef, Vieques. October 2011

	TRANSECTS					
Substrate categories	**1**	**2**	**3**	**4**	**5**	**% Cover Mean**
Abiotic						
Sand	2.3	0.3	0.3	3.0	1.0	**1.4**
Total Abiotic	2.3	0.3	0.3	3.0	1.0	**1.4**
Benthic Algae						
Turf Algae	27.7	24.0	29.0	32.3	34.7	**29.5**
Lobophora variegata	14.0	13.0	5.7	9.0	5.7	**9.5**
Coralline algae	6.0	2.7	4.3	5.0	5.0	**4.6**
Calcareous algae						
Halimeda sp.				0.3	0.3	**0.1**
Total Benthic Algae	47.7	39.7	39.0	46.7	45.7	**43.7**
Sponges	1.0	2.3	5.0	4.0	4.7	**3.4**
Encrusting Gorgonians	0.0	1.3	0.0	0.0	0.0	**0.3**
Erect Gorgonians						**0.2**
Cyanobacteria	8.7	5.0	5.3	6.3	6.0	**6.3**
Hydrocorals						
Millepora alcicornis		0.3			0.3	**0.1**
Scleractinian Corals						
Montastraea franksi	34.0	40.3	44.3	31.0	31.7	**36.3**
Porites astreoides	2.0	2.0	1.3	2.3	0.3	**1.6**
Agaricia lamarcki	0.7	1.7	2.3	2.3	0.7	**1.5**
Diploria strigosa				0.7	3.7	**0.9**
Montastraea cavernosa		1.7		0.3	1.0	**0.6**
Agaricia grahamae	0.7		0.3	1.0	1.0	**0.6**
Agaricia agaricites		0.3	0.7	1.0	0.7	**0.5**
unident coral	0.3	0.7			1.0	**0.4**
Siderastrea siderea		0.3	0.7		0.3	**0.3**
Porites furcata		0.7				**0.1**
Scolymia intersepta					0.3	**0.1**
Scolymia cubensis					0.3	**0.1**
Madracis decactis				0.3		**0.1**
Agaricia fragilis				0.33		**0.07**
Total Stony Corals	37.7	48.0	49.7	39.3	41.3	**43.1**

Coral Species Outside Transects:

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 43.1 % (range: 37.7 – 49.7). Coral cover was observed to be virtually a biotope of boulder star coral, *Montastraea annularis* 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. annularis* was 36.3 % (range: 31.0 – 44.3 %), representing 84.0 % of the total cover by live corals at El Seco Reef (Table 58). Another 13 scleractinian corals and one hydrocoral were intercepted by transects. Mustard-hill coral, *Porites astreoides* with a mean cover of 1.6 %, and whitestar sheet coral, *Agaricia lamarcki* with 1.5 % were present in all transects surveyed. Other scleractinian corals that were shown to form part of the predominant coral assemblage include the Lettuce Coral, *A. agaricites*, Symmetrical Brain Coral, *Diploria strigosa* and Dimpled Sheet Coral, *A. grahamae* (Table 58). Bleached corals were not observed during our survey at the coral reef bank in southeast Vieques.

Octocorals (gorgonians) were observed in very low abundance at the coral reef bank, their average substrate cover was measured as 0.4 %, with presence of erect colonies in only 2 of the five transects surveyed (Table 58).

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 82 fish species, including 47 within belt-transects were identified from mesophotic depths (34 – 40 m) at the coral reef bank (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 117.4 Ind/30m^2 (range: 31 - 216 Ind/30m^2). Mean species richness was 15.8 spp/30m^2 (range: 13 – 19 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.

Two fish species with highly aggregated or patchy distributions, creole wrasse, *Clepticus parrae* and masked goby, *Coryphopterus personatus* accounted for 72.4 % of the total mean abundance within belt-transects (Table 59). Six additional species were present in at least four out of the five transects surveyed and along with Creole Wrasse and Masked Goby comprise the dominant small demersal fish component of the coral bank habitat of El Seco reef system. These include the Blue Chromis, Bicolor Damselfish, Bluehead and Yellowhead Wrasses, Fairly Basslet and Princess Parrotfish. A total of 17 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 grouper, *Mycteroperca tigris* and nurse shark, *Ginglymostoma cirratum* included in an ASEC survey at this reef (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 survey 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 (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. Among these, divers observed cero mackerels, *Scomberomorus regalis*, great barracuda, *Sphyraena barracuda*, and sailfish, *Istiophorus albicans*. It is highly expected that other typical components of the large migratory pelagic predators of mesophotic reefs including dolphinfish, *Coryphaena*

Table 59 . Taxonomic composition and abundance of fishes within belt-transects at the El Seco Reef, Vieques. July, 2011

Depth: 35m

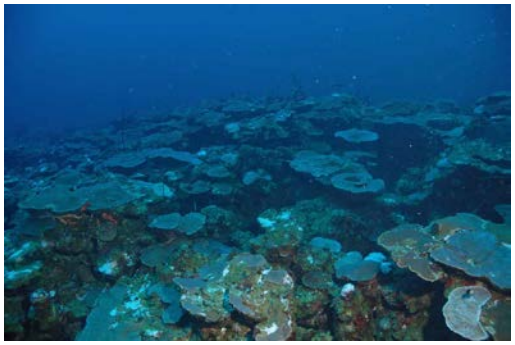
		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		(Individuals/30 m^2)					
SPECIES	**Common Name**						**MEAN**
Clepticus parrae	Creole Wrasse	154	75	28	1	0	51.6
Coryphopterus personatus	Masked Goby	25	37	36	64	5	33.4
Chromis cyanea	Blue Chromis	12	10	1	3	1	5.4
Stegastes partitus	Bicolor Damselfish	6	5	8	2	5	5.2
Thalassoma bifasciatum	Bluehead Wrasse	5	13	1	1	2	4.4
Gramma loreto	Royal Gramma	1	7	1	4	6	3.8
Scarus taeniopterus	Princess Parrotfish	0	1	4	2	1	1.6
Halichoeres garnoti	Yellowhead Wrasse	1	1	1	2	2	1.4
Decapterus macarelus	Mackerel Scad	5	0	0	0	0	1.0
Acanthurus bahianus	Doctorfish	0	0	1	1	2	0.8
Canthigaster rostrata	Sharpnose Puffer	0	1	2	1	0	0.8
Bodianus rufus	Spanish Hogfish	0	2	0	1	0	0.6
Chaetodon aculeatus	Longsnout Butterflyfis	1	0	0	1	1	0.6
Coryphopterus lipernes	Peppermint Goby	0	0	0	0	3	0.6
Gobiosoma evelynae	Sharknose Goby	0	1	0	2	0	0.6
Sparisoma aurofrenatum	Redband Parrotfish	0	2	1	0	0	0.6
Sparisoma viride	Stoplight Parrotfish	1	0	0	2	0	0.6
Chaetodon capistratus	Four-eye Butterflyfish	0	1	0	0	1	0.4
Epinephelus cruentatus	Graysby	0	1	1	0	0	0.4
Epinephelus guttatus	Red Hind	0	1	0	1	0	0.4
Hypoplectrus chlorurus	Yellowtail Hamlet	0	1	0	1	0	0.4
Myripristis jacobus	Blackbar Soldierfish	2	0	0	0	0	0.4
Stegastes leucostictus	Beaugregory	0	0	1	0	1	0.4
Chromis insolata	Sunshine Chromis	1	0	0	0	0	0.2
Chromis multilineata	Brown Chromis	0	1	0	0	0	0.2
Haemulon flavolineatum	French Grunt	0	0	1	0	0	0.2
Holacanthus tricolor	Rock Beauty	0	0	0	1	0	0.2
Lutjanus cyanopterus	Cubera Snapper	0	1	0	0	0	0.2
Neoniphon marianus	Longjaw Squirrelfish	1	0	0	0	0	0.2
Pomacanthus arcuatus	Grey Angelfish	0	1	0	0	0	0.2
Scarus iserti	Striped Parrotfish	1	0	0	0	0	0.2
Scarus vetula	Queen Parrotfish	0	0	0	0	1	0.2
Sparisoma radians	Bucktooth Parrotfish	0	0	0	1	0	0.2
	TOTAL INDIVIDUALS	**216**	**162**	**87**	**91**	**31**	**117.4**
	TOTAL SPECIES	**15**	**19**	**14**	**18**	**13**	**15.8**

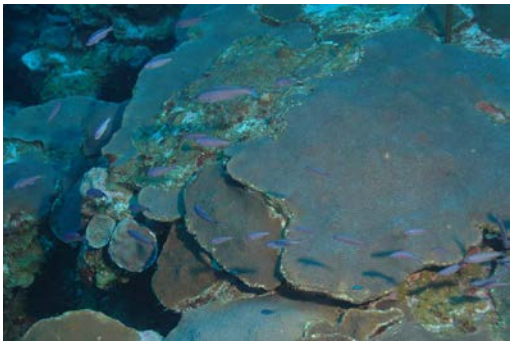
Table 60. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at El Seco Reef, 30 - 35 m, Vieques, October 2011.

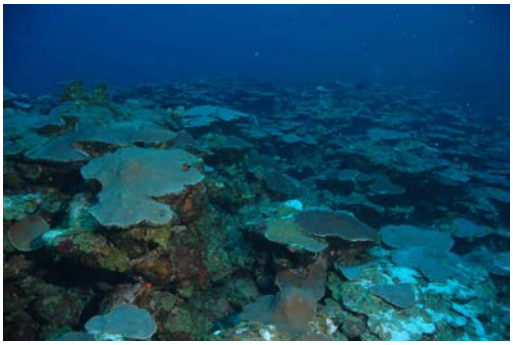
SPECIES	**COMMON NAME**		# - (cm)	
Cranx crysos	Blue Runner	2 – (30)		
Epinephelus guttatus	Red Hind	1 – (30)	2 – (40)	
Ginglymostoma cirratum	Nurse Shark	1 – (180)	1 – (250)	
Lachnolaimus maximus	Hogfish	2 – (25)	1 – (40)	
Lutjanus apodus	Schoolmaster	2 - (30)	3 – (35)	1 – (40)
Lutjanus cyanopterus	Cubera Snapper	6 - (15)	4 – (20)	1 – (25)
Lutjanus jocu	Dog Snapper	3 - (15)		
Lutjanus analis	Mutton Snapper	2 – (10)		
Mycteroperca tigris	Tiger Grouper	2 – (50)	1 – (60)	
Mycteroperca venenosa	Yellowfin Grouper	1 – (35)	1 – (40)	
Ocyurus chrysurus	Yellowtail Snapper	1 – (20)	2 – (30)	
Sphyraena barracuda	Great Barracuda	1- (50)		
Istiophorus albicans	Sailfish	1 - (150)		

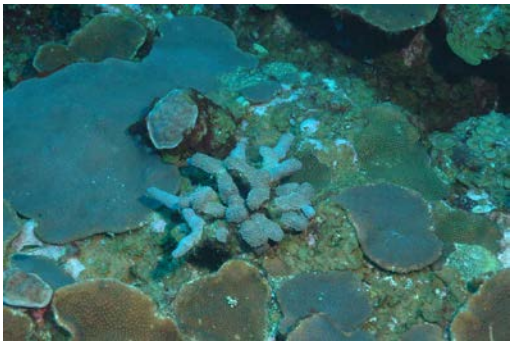
hippurus, wahoo, *Acanthocybium solandri*, marlins (Istiophoridae) and tunas (Scombridae) also forage at this reef. Several large hawksbill turtles, *Eretmochelys imbricata* were present at the bank reef. No megabenthic invertebrates were observed within belt-transects.

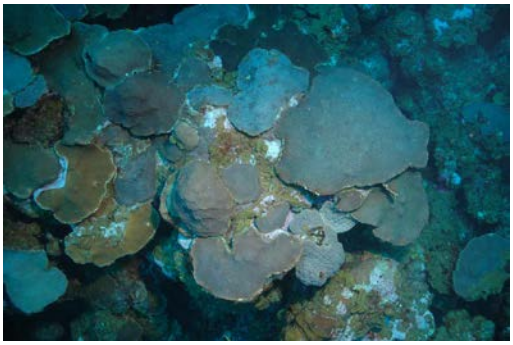
Photo Album 15
El Seco Reef











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), and Derrumbadero Reef (Ponce) presented statistically significant differences of live coral cover between annual surveys during the monitoring program 2001 - 2011.

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, *Montastraea 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 and abiotic categories were measured.

4. During the present 2011 monitoring survey live coral cover remained stable at all reefs monitored and coral bleaching at the reef community level was not observed on any reef surveyed.

5. The *Acropora palmata* fringing reef of Tres Palmas in Rincon is infected by 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 reef substrate cover by *A. palmata* remained stable relative to 2010, given favorable conditions for the disease massive coral mortality can be expected.

6. Baseline surveys at Cayo Aurora in Guanica, Cibuco Reef in Vega Baja and El Seco Reef in Vieques now allow inferences to be made regarding the ecological health of a pristine Elkhorn coral (*Acropora palmata*) biotope, a Boulder Star and Finger Coral dominated reef influenced by estuarine conditions in the north coast, and of a pristine *Montastraea franksi* mesophotic reef that may be the largest continuous coral reef system in Puerto Rico.

7. Fish populations presented in the 2011 survey a general pattern of stable abundance relative to the 2008 - 2010 levels, except at Tourmaline (20 and 30 m stations) and Derrumbadero Reef (Ponce) at 20 m, where statistically significant increments of abundance were observed. Abundance increments were all associated with population increments of Masked Goby, *Coryphopterus personatus*, a numerically dominant species that exhibits highly aggregated distributions in the immediate vicinity of live coral heads.

8. Major shifts of reef fish community structure were not observed during 2011, as many of the numerically dominant assemblages remained in place at most reefs monitored, which suggests that predation by Lionfish, *Pterois volitans* has not had any measurable effects on the fish community structure of reefs studied.

9. Although in low abundance, large demersal (top predator) fishes were detected during ASEC surveys in several reefs. 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*).

10. 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				

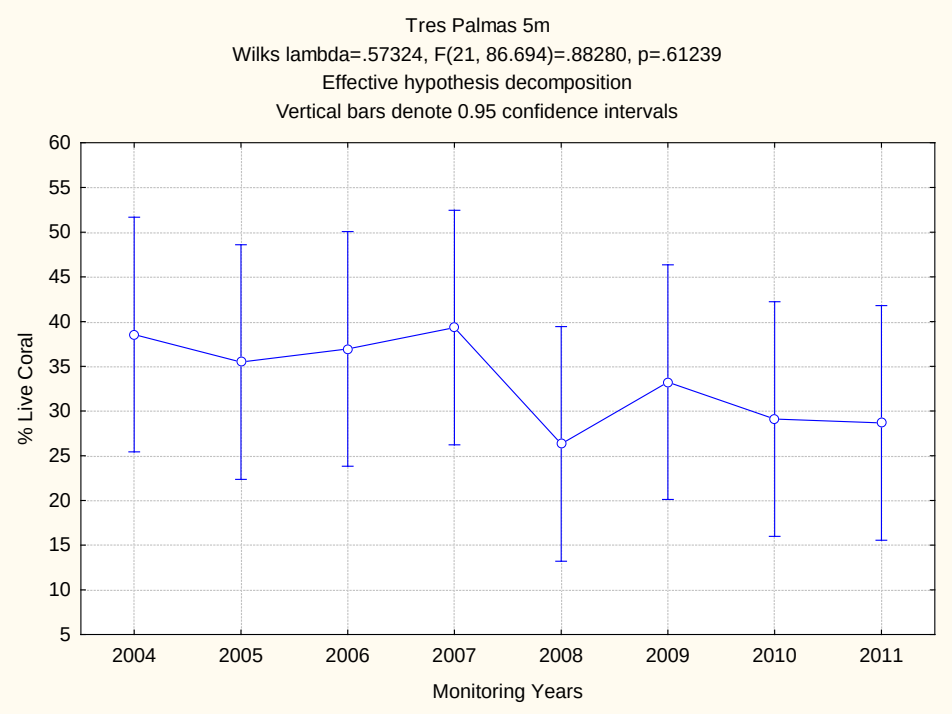
Species Name	Common Name	M30	M20	M10	D30	D20	D15	R5	R10	R20	CDM	Gua	Der	Auro	Cibu	Seco
Hypoplectrus chlorurus	Yellowtail Hamlet								x	x	x	x	x			x
Hypoplectrus guttavarius	Shy Hamlet	x	x	x					x		x	x	x			
Hypoplectrus indico	Indigo Hamlet	x	x	x							x	x	x			
Hypoplectrus nigricans	Black Hamlet	x	x	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
Liopropoma 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

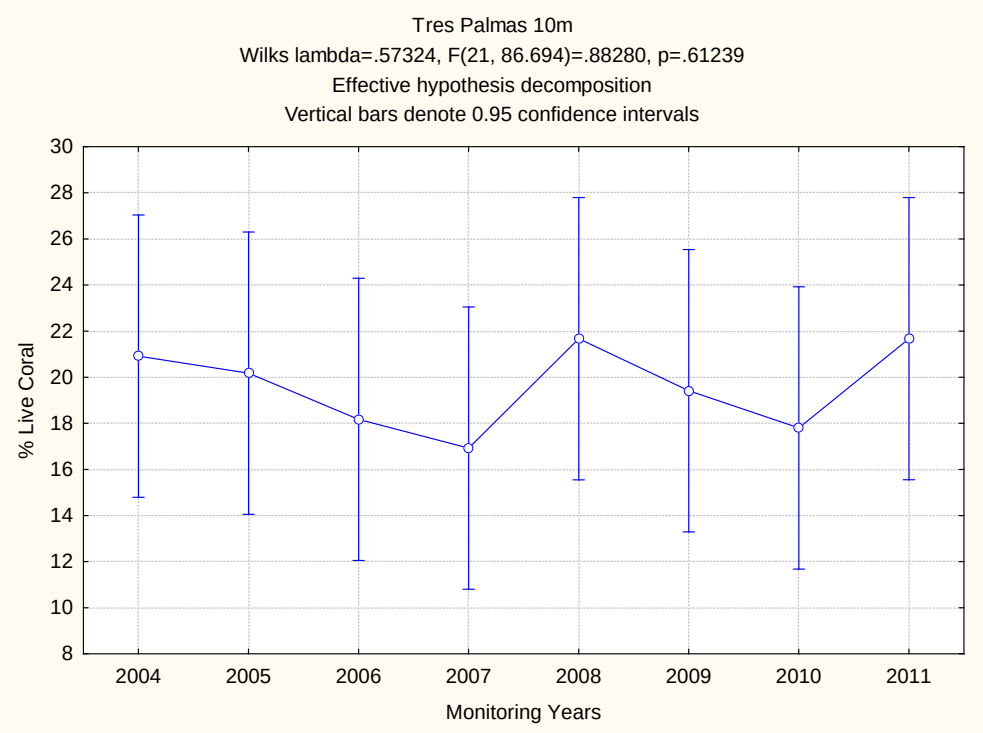
Species Name	Common Name	M30	M20	M10	D30	D20	D15	R5	R10	R20	CDM	Gua	Der	Auro	Cibu	Seco
Mlacoctenus gelli	Dusky blenny							x								
Mulloides martinicus	Yellowtail Goatfish	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Muraena robusta	Stout Moray						x				x					
Mycteroperca tigris	Tiger Grouper												x			x
Mycteroperca 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

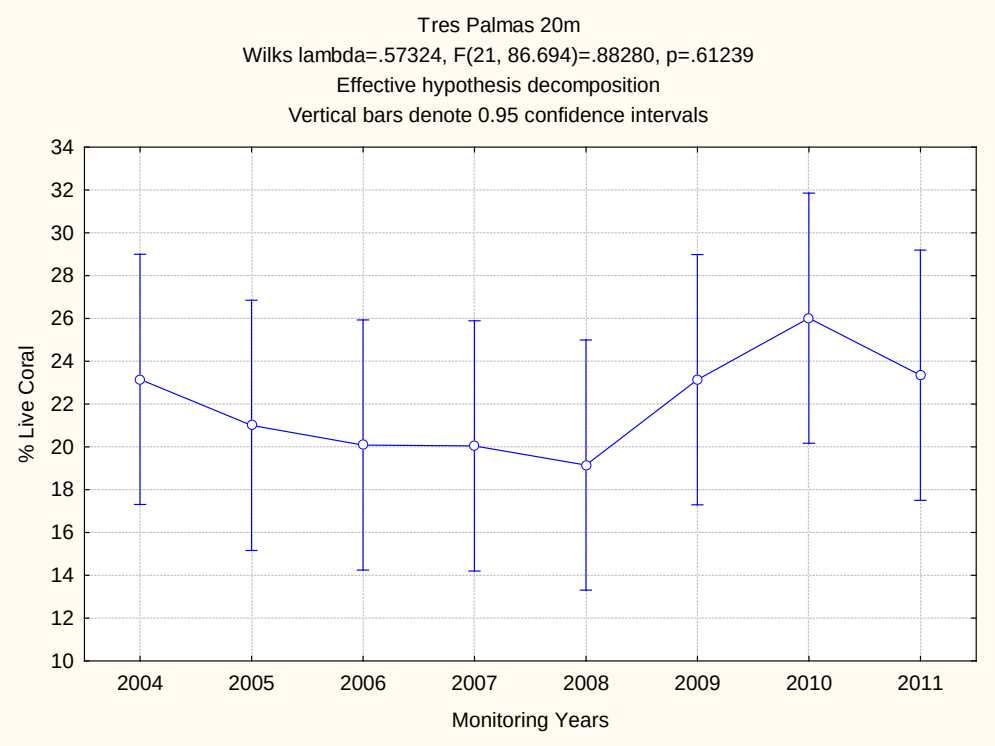
Species Name	Common Name	M30	M20	M10	D30	D20	D15	R5	R10	R20	CDM	Gua	Der	Auro	Cibu	Seco
Scomberomorus regalis	Cero Mackerel	x	x	x	x	x		x	x	x		x	x			
Scorpaena plumieri	Spotted Scorpionfish						x				x		x			
Seriola rivoliana	Almaco Jack										x					
Serranus baldwini	Lantern Bass				x											
Serranus 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		

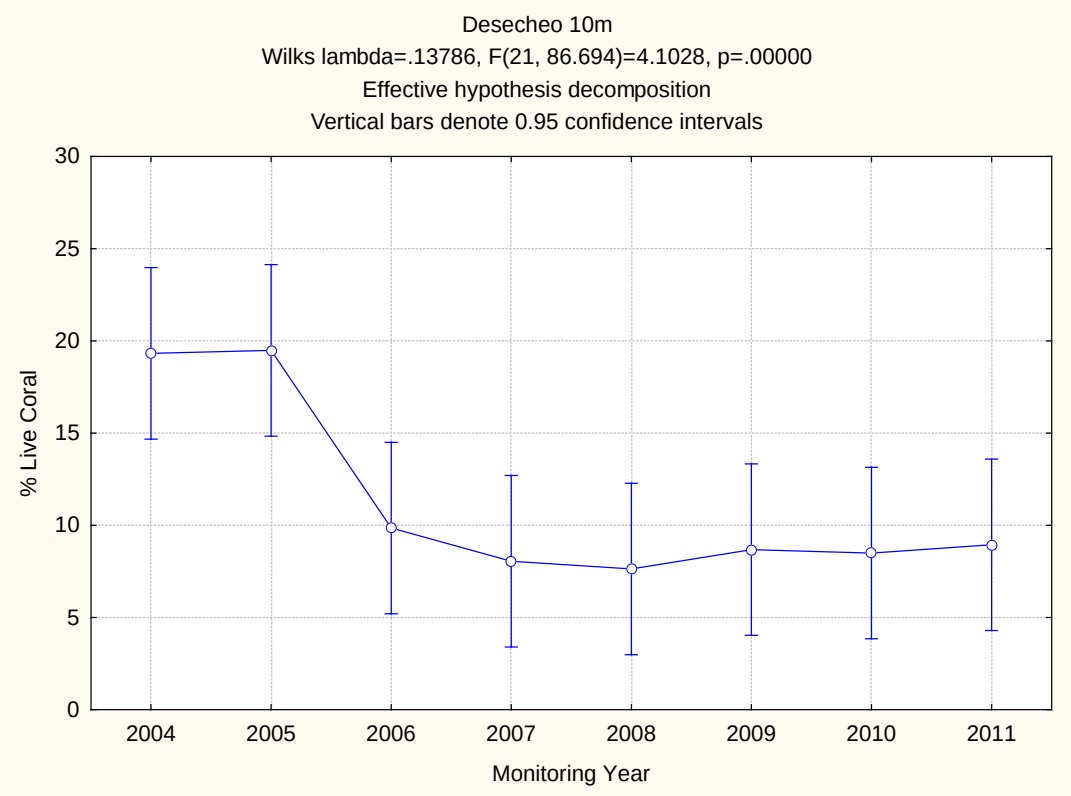
Species Name	Common Name	M30	M20	M10	D30	D20	D15	R5	R10	R20	CDM	Gua	Der	Auro	Cibu	Seco
Synodus intermedius	Sand Diver	x	x	x			x	x	x	x	x		x			
Thalasoma bifaciatum	Bluehead wrass	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Urolophus jamaicensis	Yellowspotted Stingray															
Xanthichthyis ringens	Sargassum Triggerfish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

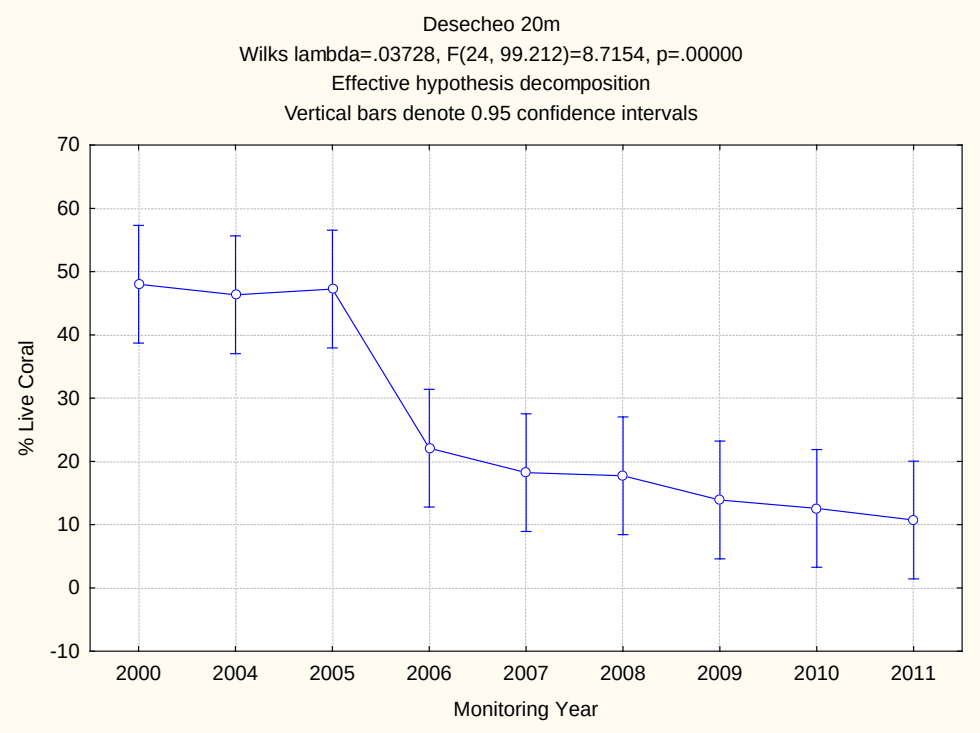
Appendix 2. Analysis of variance (ANOVA) procedure testing differences of live coral cover in annual monitoring surveys through 2009.

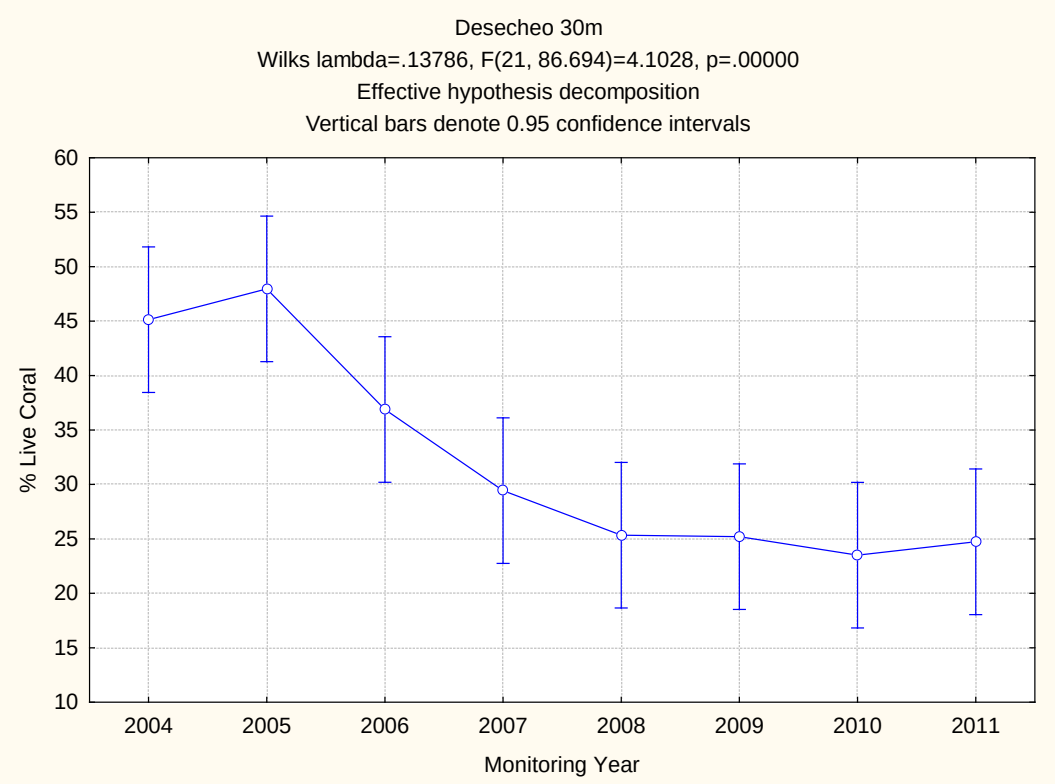


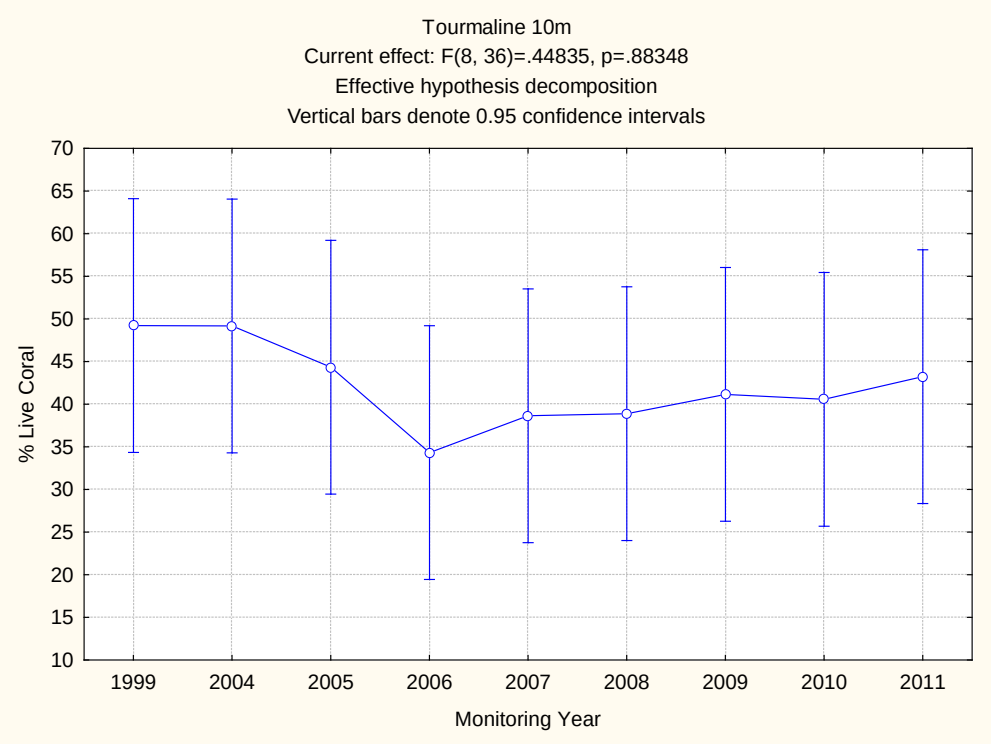


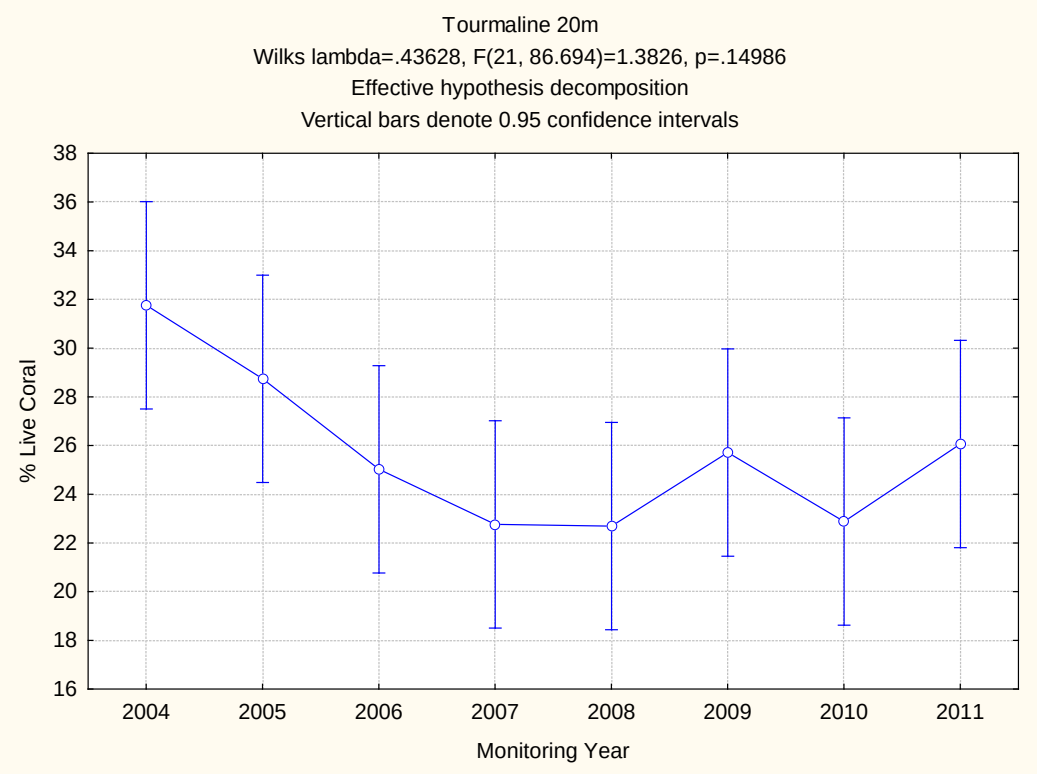

Tres Palmas 20m
Wilks lambda=.57324, F(21, 86.694)=.88280, p=.61239
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
34
32
30
28
26
24
22
20
18
16
14
12
10
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

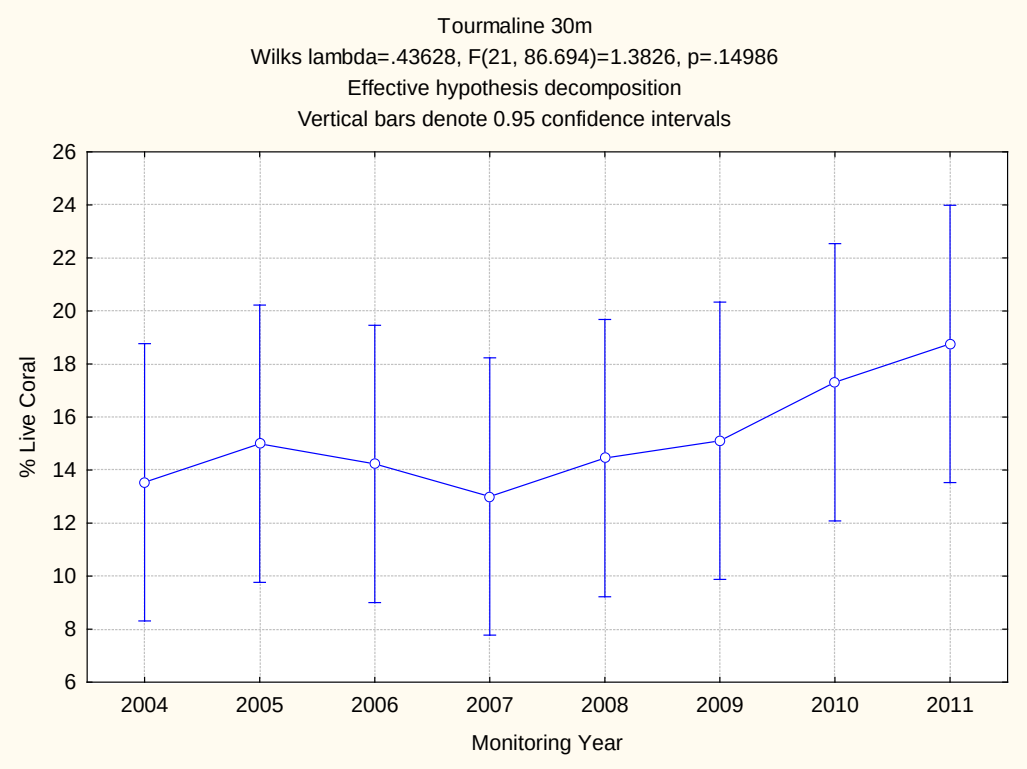

Desecheo 10m
Wilks lambda=.13786, F(21, 86.694)=4.1028, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
30
25
20
15
10
5
0
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Year

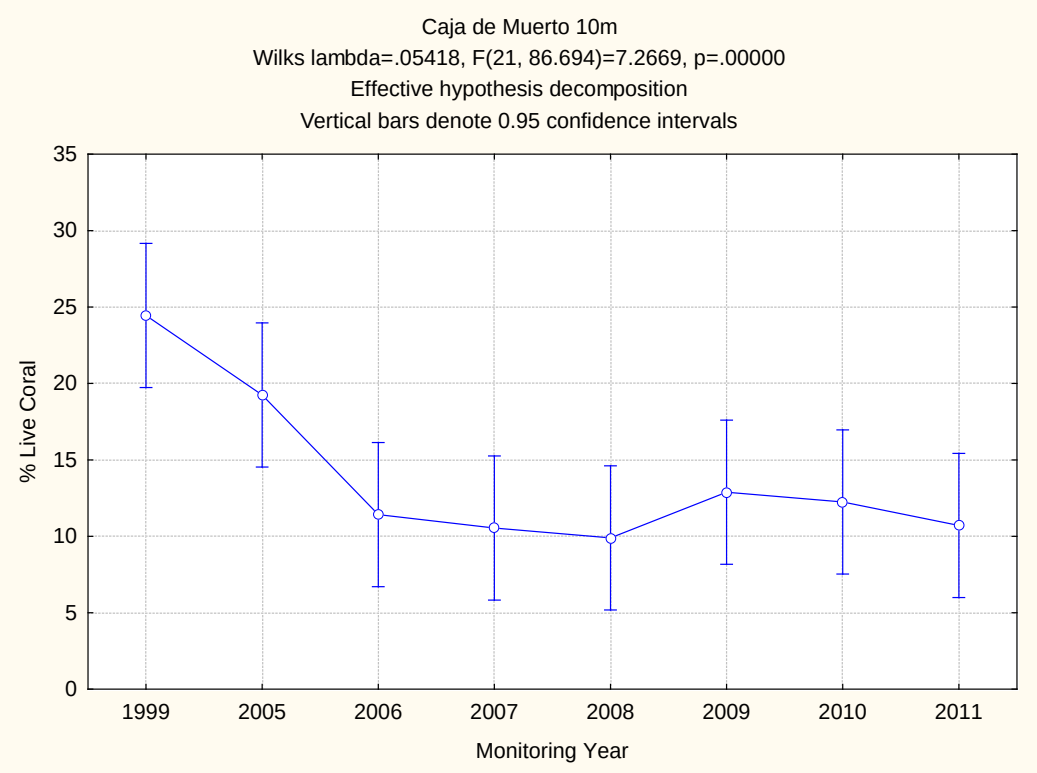

Desecheo 20m
Wilks lambda=.03728, F(24, 99.212)=8.7154, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
70
60
50
40
30
20
10
0
-10
2000
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Year

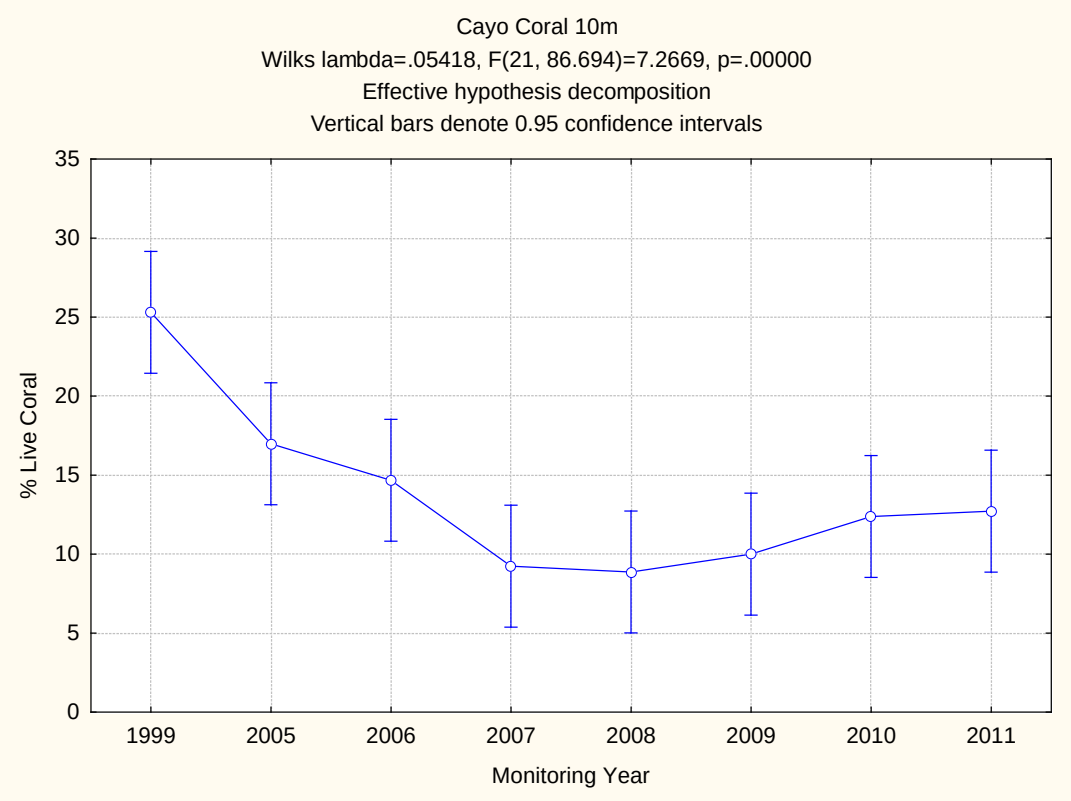

Desecheo 30m
Wilks lambda=.13786, F(21, 86.694)=4.1028, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
60
55
50
45
40
35
30
25
20
15
10
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Year

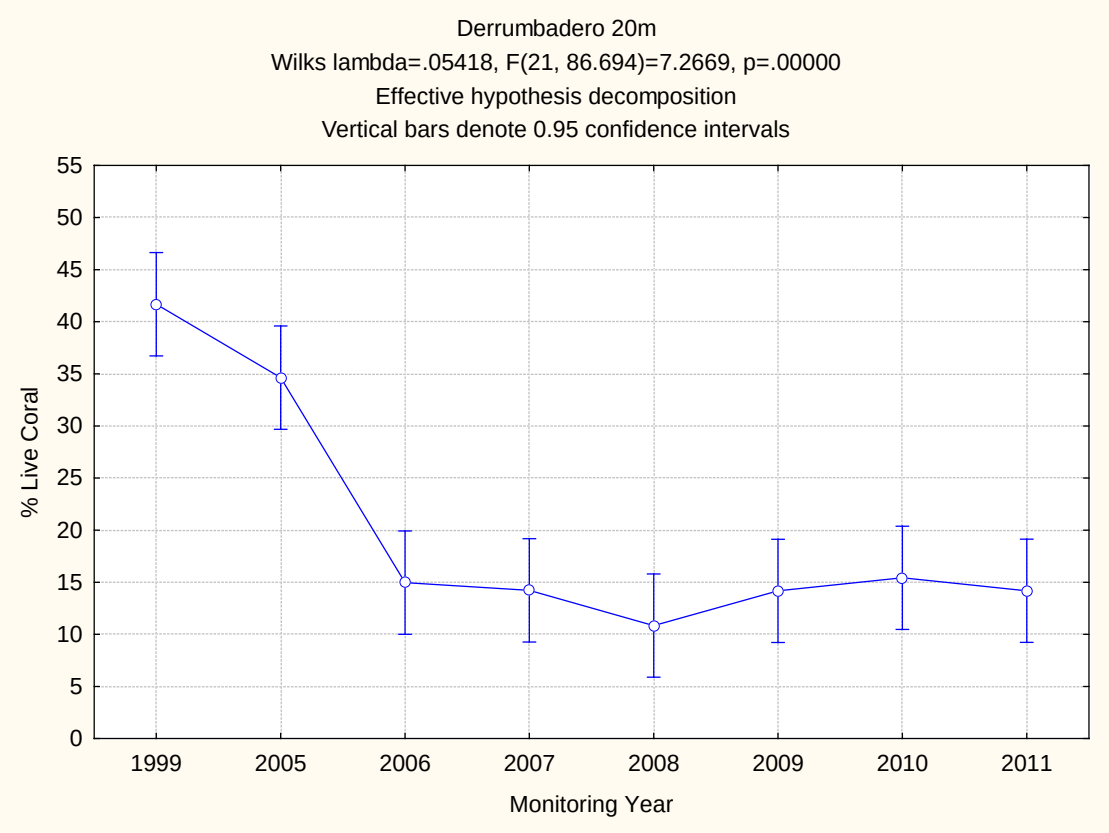

Tourmaline 10m
Current effect: F(8, 36)=.44835, p=.88348
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
70
65
60
55
50
45
40
35
30
25
20
15
10
1999
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Year


Tourmaline 20m
Wilks lambda=.43628, F(21, 86.694)=1.3826, p=.14986
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
Monitoring Year

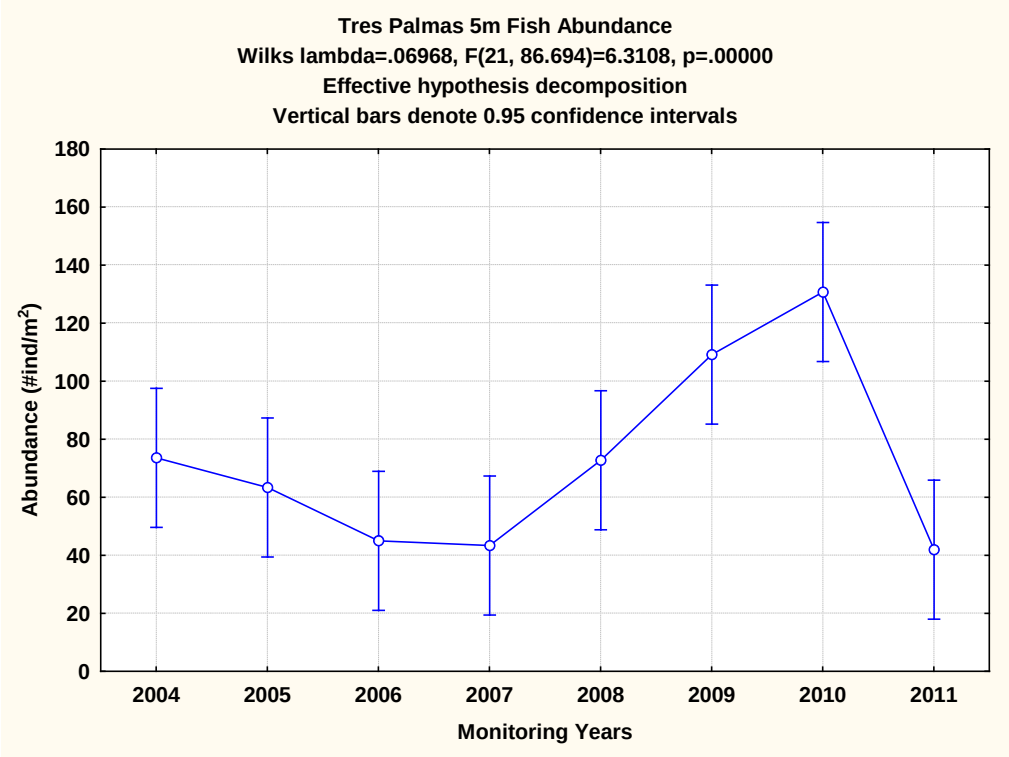

Tourmaline 30m
Wilks lambda=.43628, F(21, 86.694)=1.3826, p=.14986
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
26
24
22
20
18
16
14
12
10
8
6
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Year

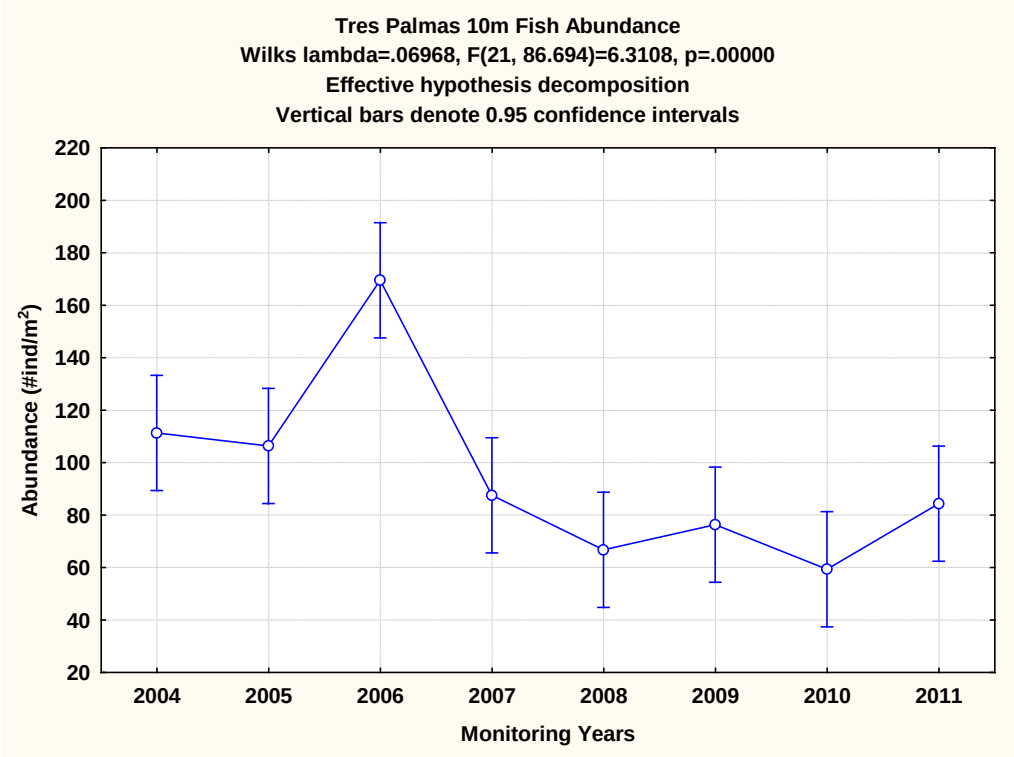

Caja de Muerto 10m
Wilks lambda=.05418, F(21, 86.694)=7.2669, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
35
30
25
20
15
10
5
0
1999
2005
2006
2007
2008
2009
2010
2011
Monitoring Year

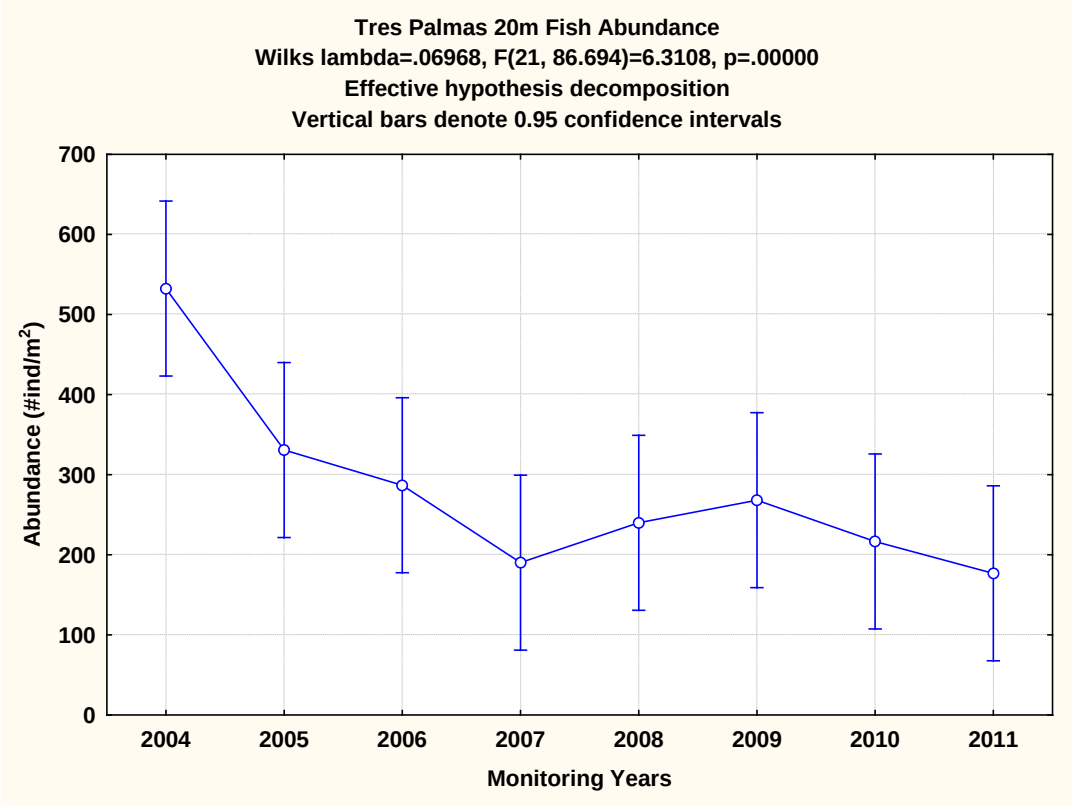

Cayo Coral 10m
Wilks lambda=.05418, F(21, 86.694)=7.2669, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
0
5
10
15
20
25
30
35
1999
2005
2006
2007
2008
2009
2010
2011
Monitoring Year

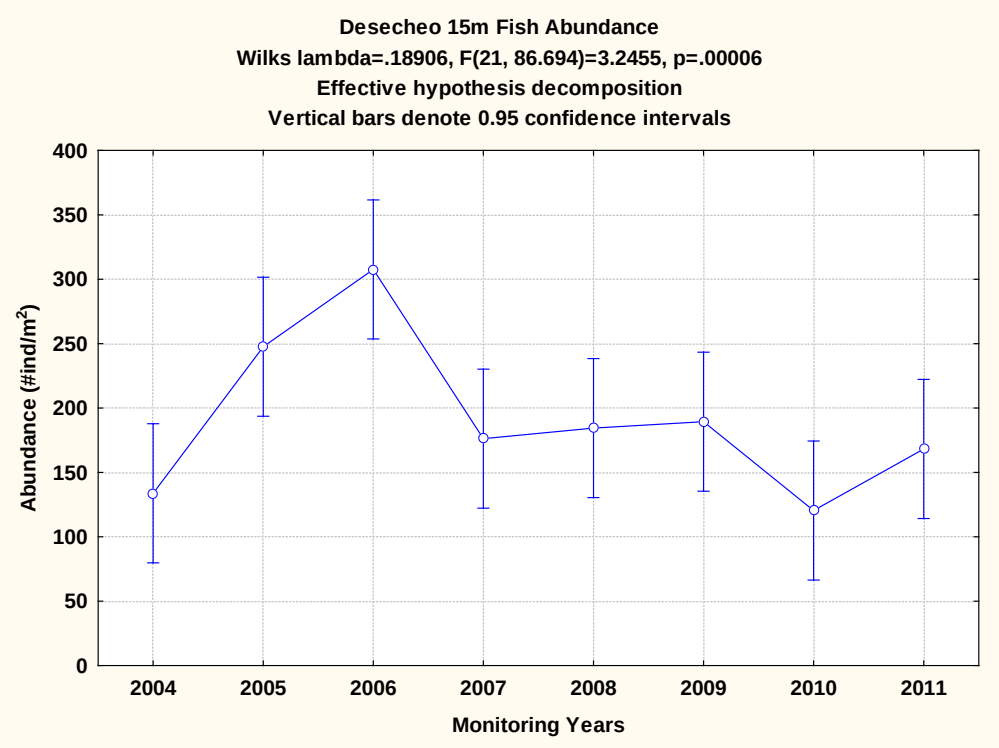

Derrumbadero 20m
Wilks lambda=.05418, F(21, 86.694)=7.2669, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Live Coral
0
5
10
15
20
25
30
35
40
45
50
55
1999
2005
2006
2007
2008
2009
2010
2011
Monitoring Year

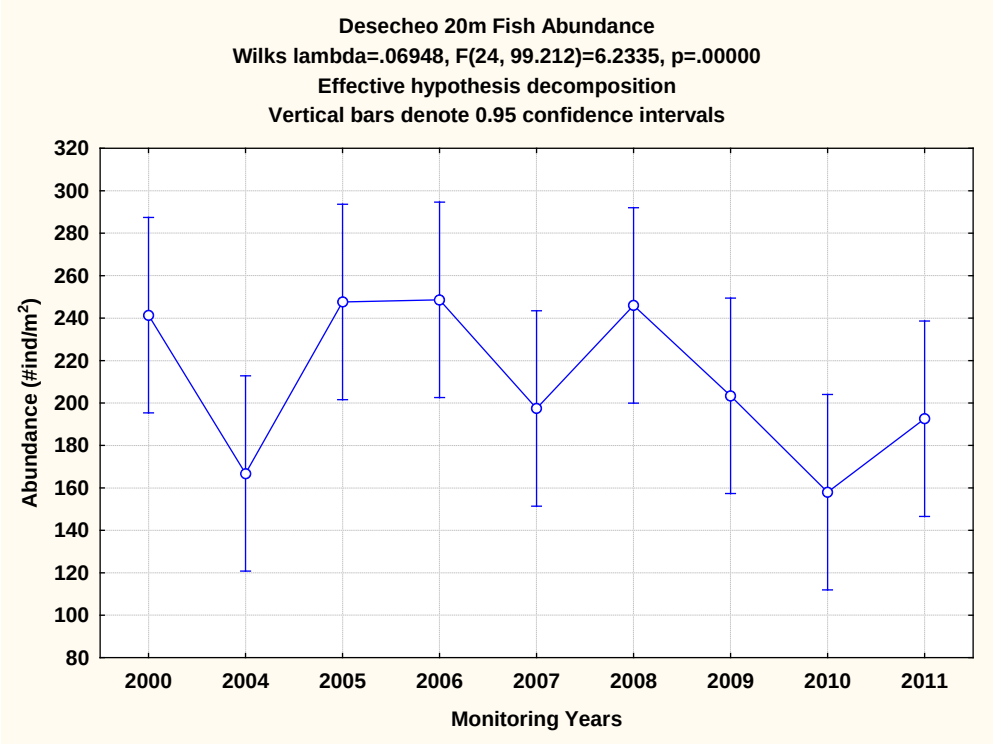
Appendix 3. Analysis of variance (ANOVA) procedure testing difference of fish species abundance (spp/transect) between monitoring surveys.

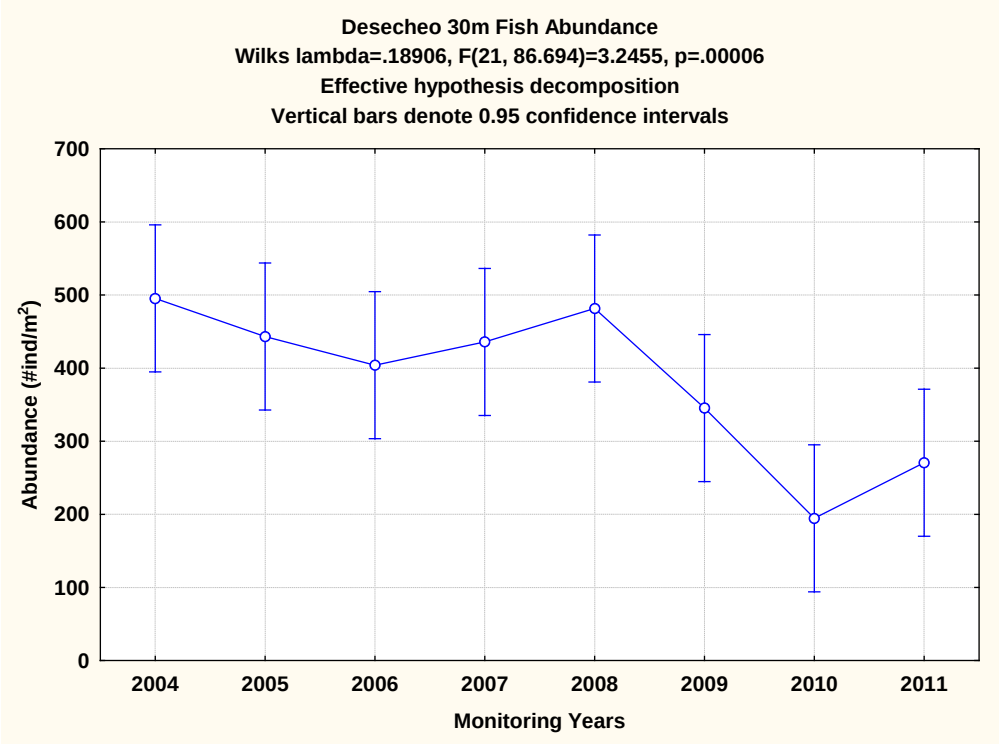


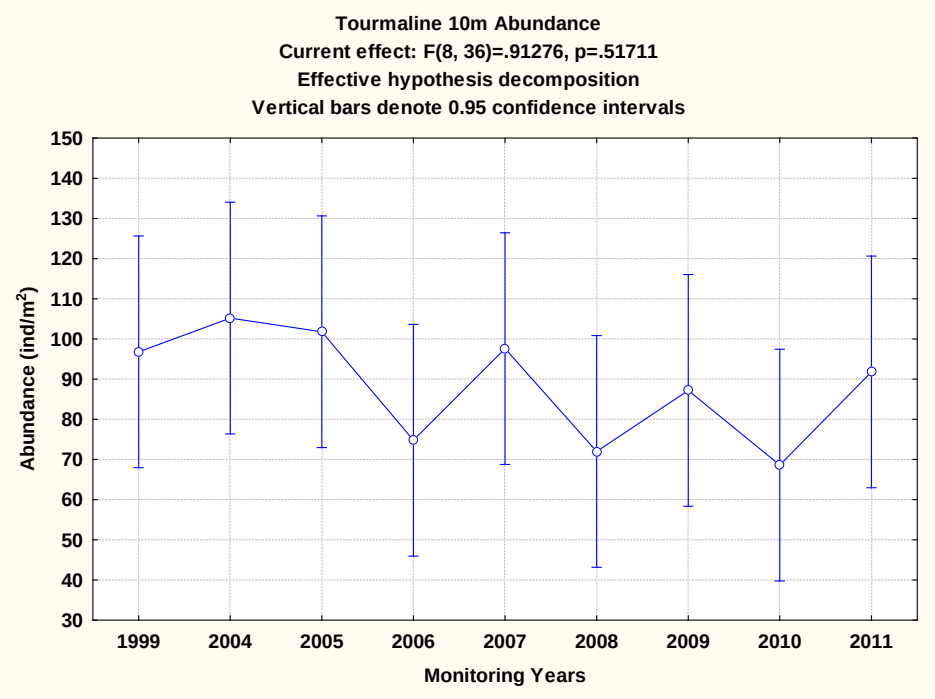


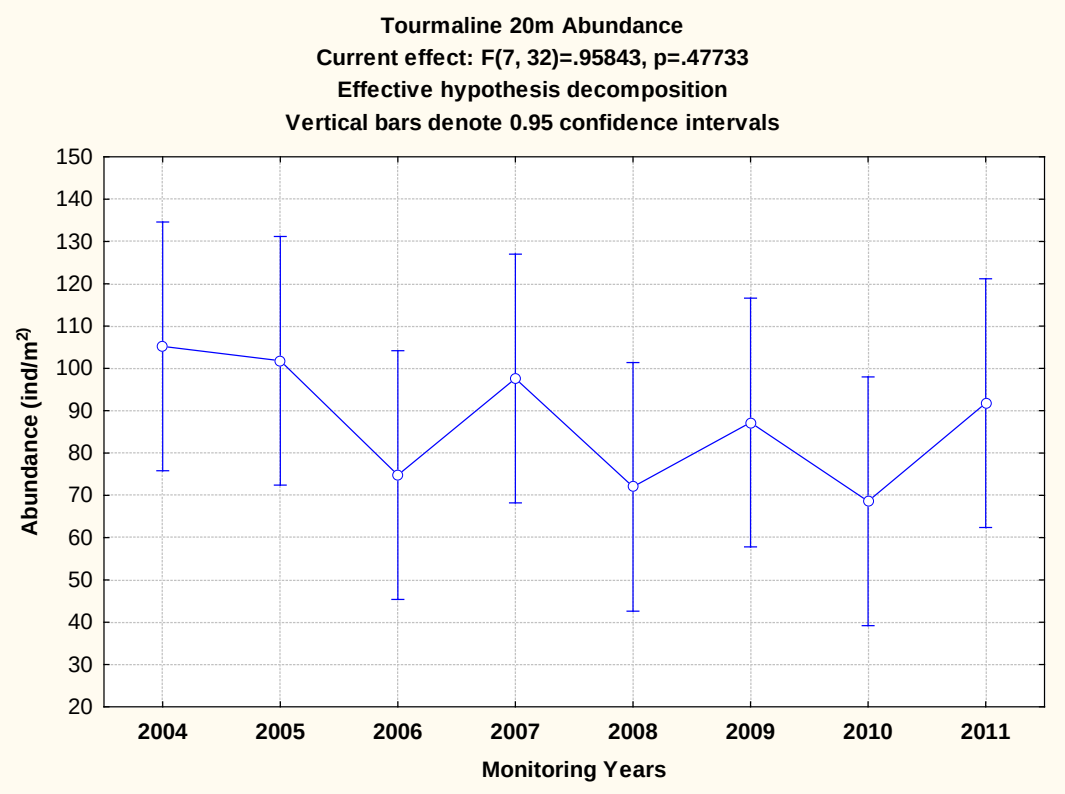

Tres Palmas 20m Fish Abundance
Wilks lambda=.06968, F(21, 86.694)=6.3108, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
700
600
500
400
300
200
100
0
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

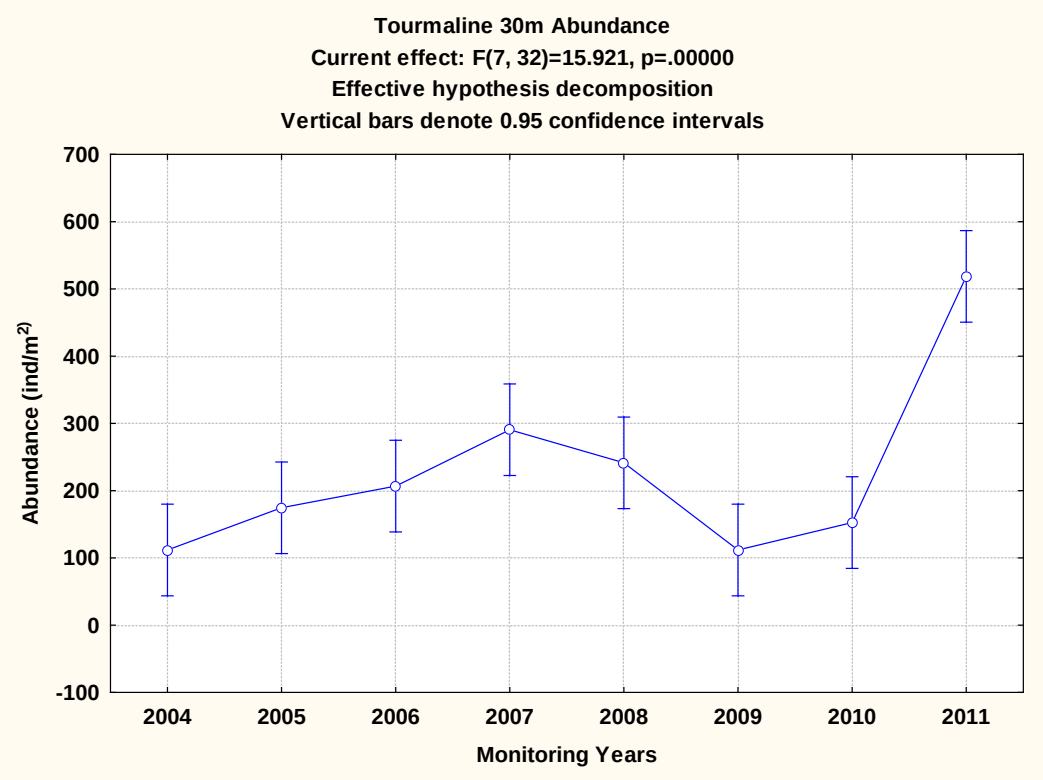

Desecheo 15m Fish Abundance
Wilks lambda=.18906, F(21, 86.694)=3.2455, p=.00006
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
400
350
300
250
200
150
100
50
0
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

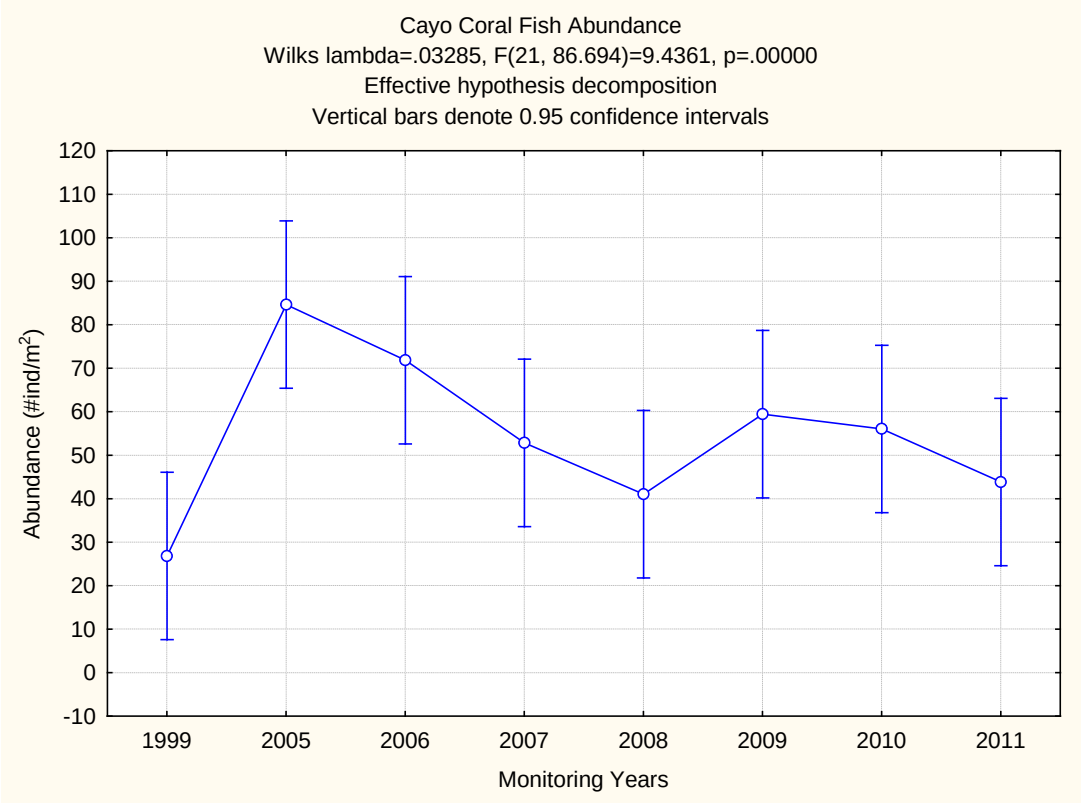

Desecheo 20m Fish Abundance
Wilks lambda=.06948, F(24, 99.212)=6.2335, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
320
300
280
260
240
220
200
180
160
140
120
100
80
2000
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

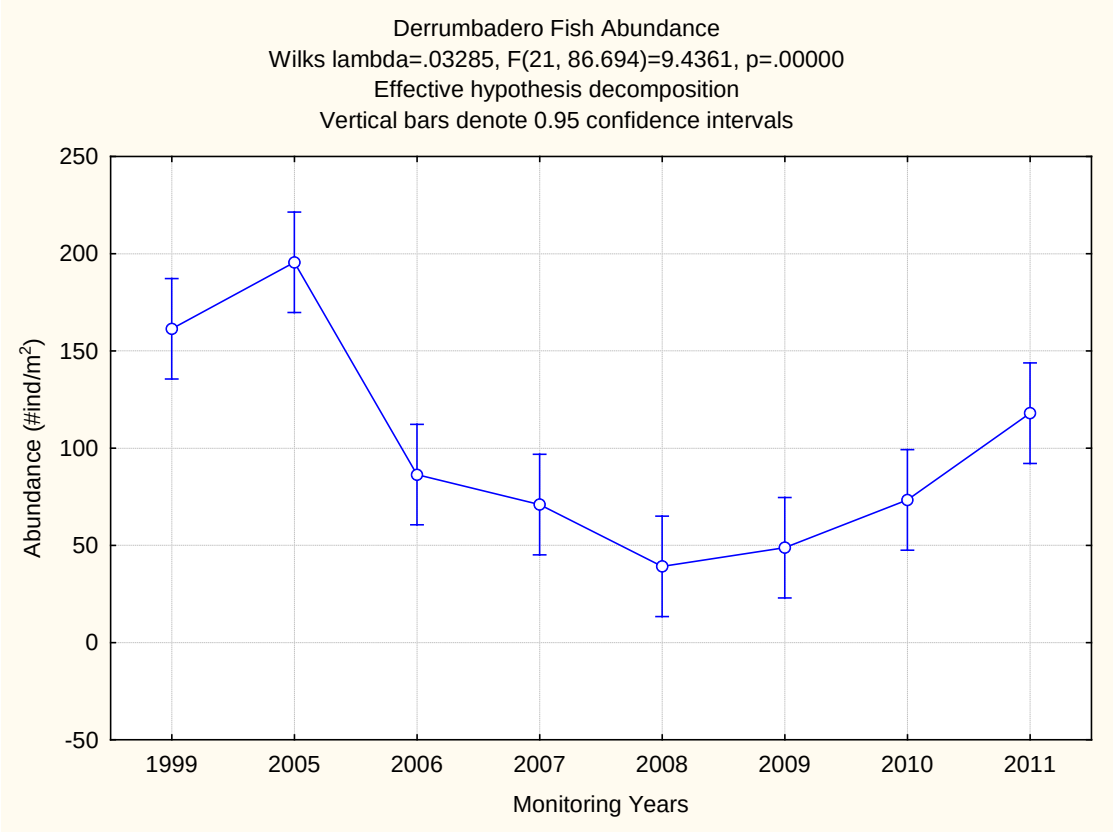

Desecheo 30m Fish Abundance
Wilks lambda=.18906, F(21, 86.694)=3.2455, p=.00006
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
700
600
500
400
300
200
100
0
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

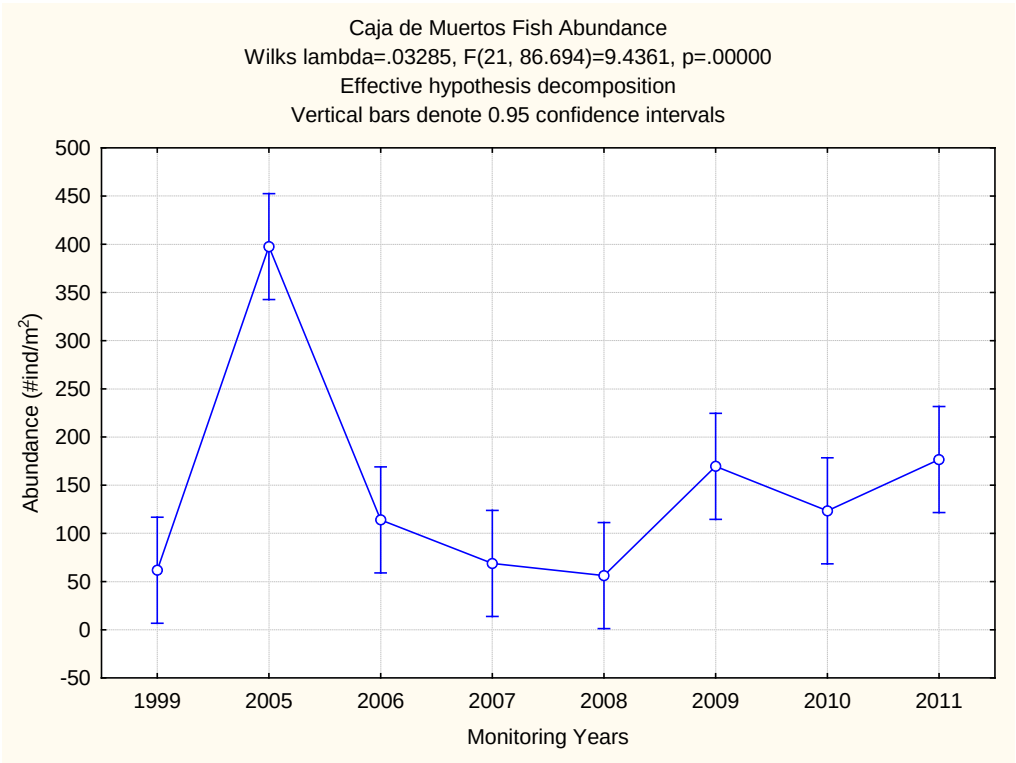

Tourmaline 10m Abundance
Current effect: F(8, 36)=.91276, p=.51711
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/m2)
150
140
130
120
110
100
90
80
70
60
50
40
30
1999
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years


Tourmaline 20m Abundance
Current effect: F(7, 32)=.95843, p=.47733
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
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

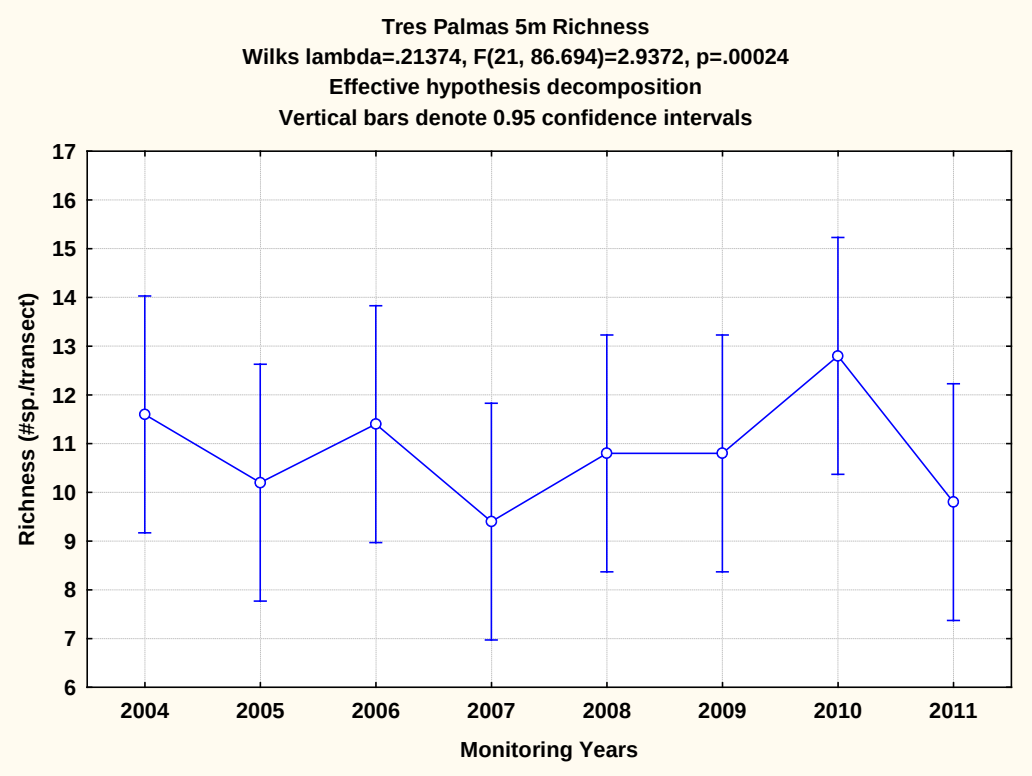

Tourmaline 30m Abundance
Current effect: F(7, 32)=15.921, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/m2)
700
600
500
400
300
200
100
0
-100
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

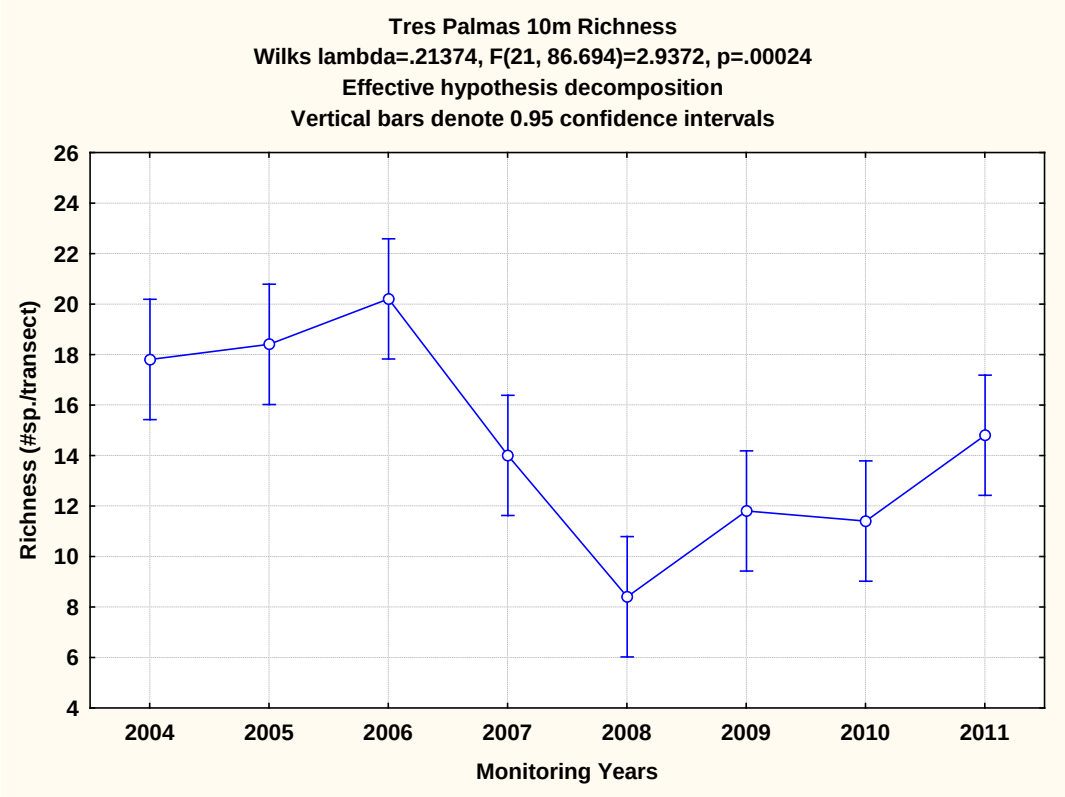

Cayo Coral Fish Abundance
Wilks lambda=.03285, F(21, 86.694)=9.4361, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
1999
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

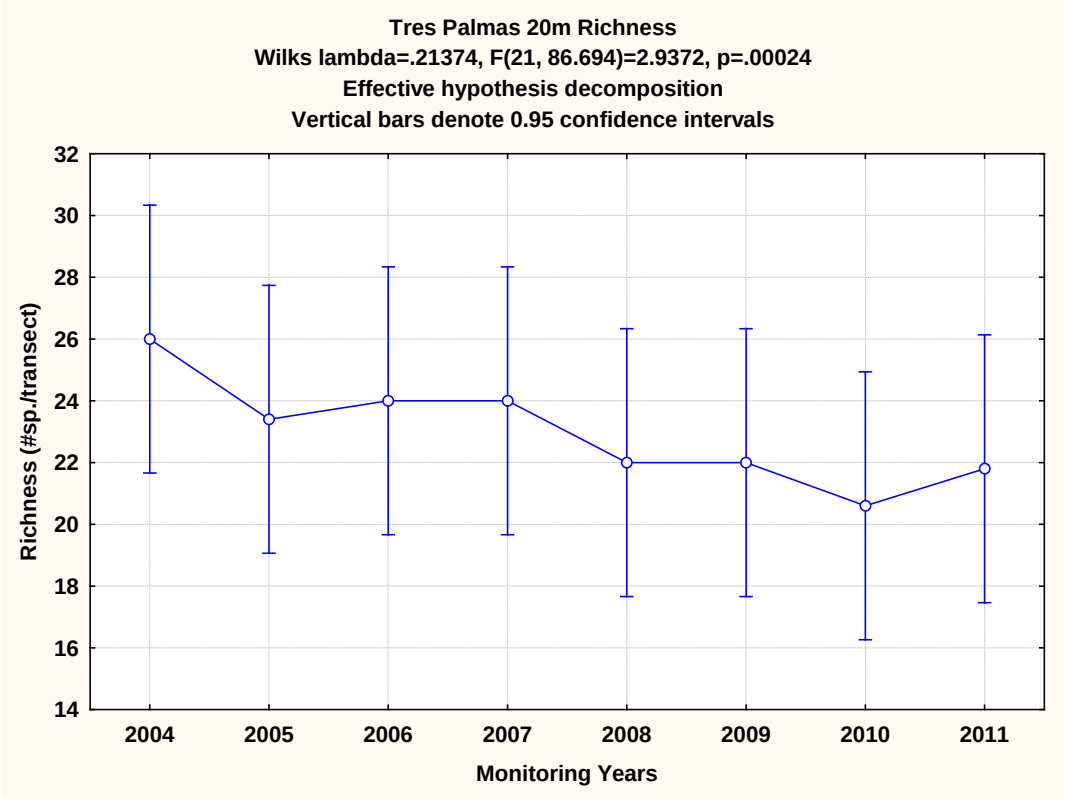

Derrumbadero Fish Abundance
Wilks lambda=.03285, F(21, 86.694)=9.4361, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
250
200
150
100
50
0
-50
1999
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

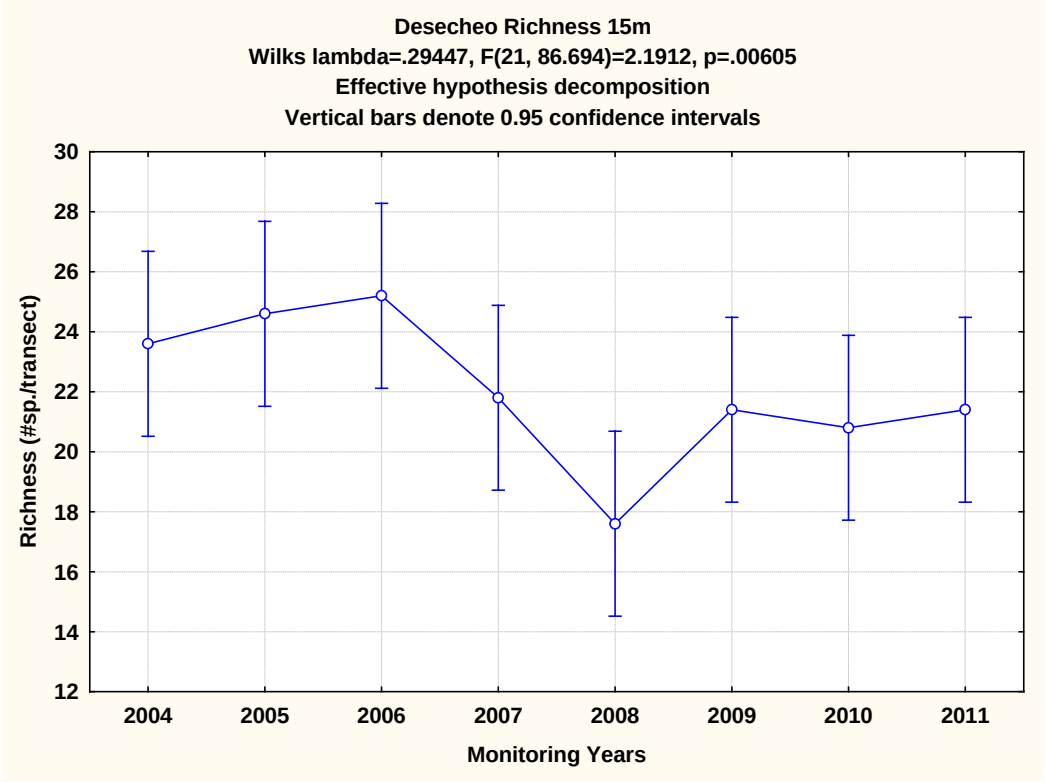

Caja de Muertos Fish Abundance
Wilks lambda=.03285, F(21, 86.694)=9.4361, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
500
450
400
350
300
250
200
150
100
50
0
-50
1999
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

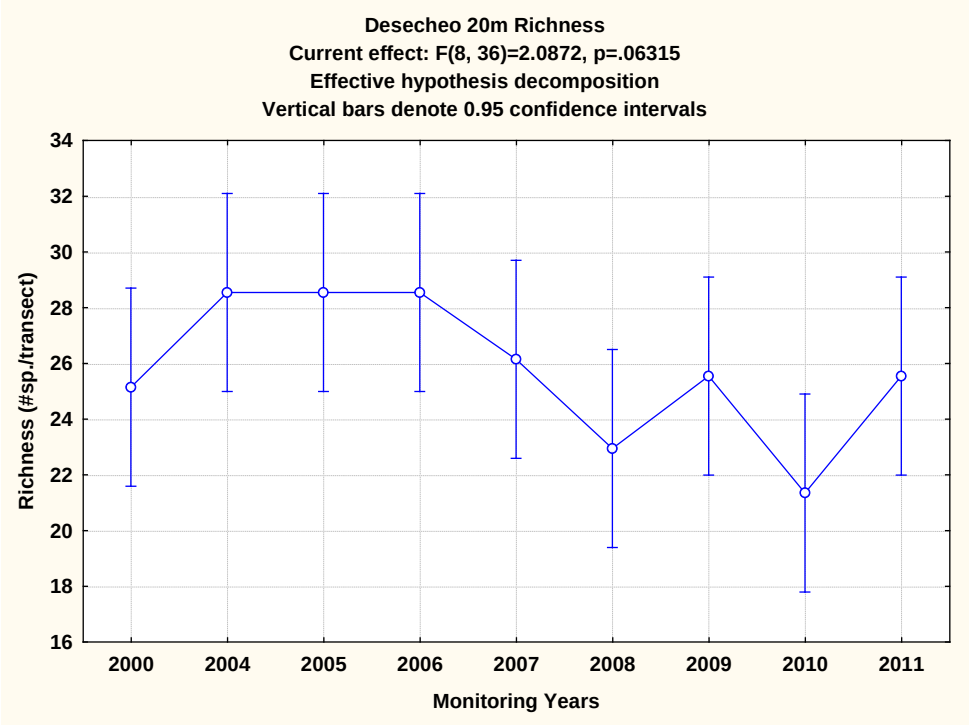
Appendix 4. Analysis of variance (ANOVA) procedure testing difference of fish richness (ind/30m^2) between monitoring surveys.

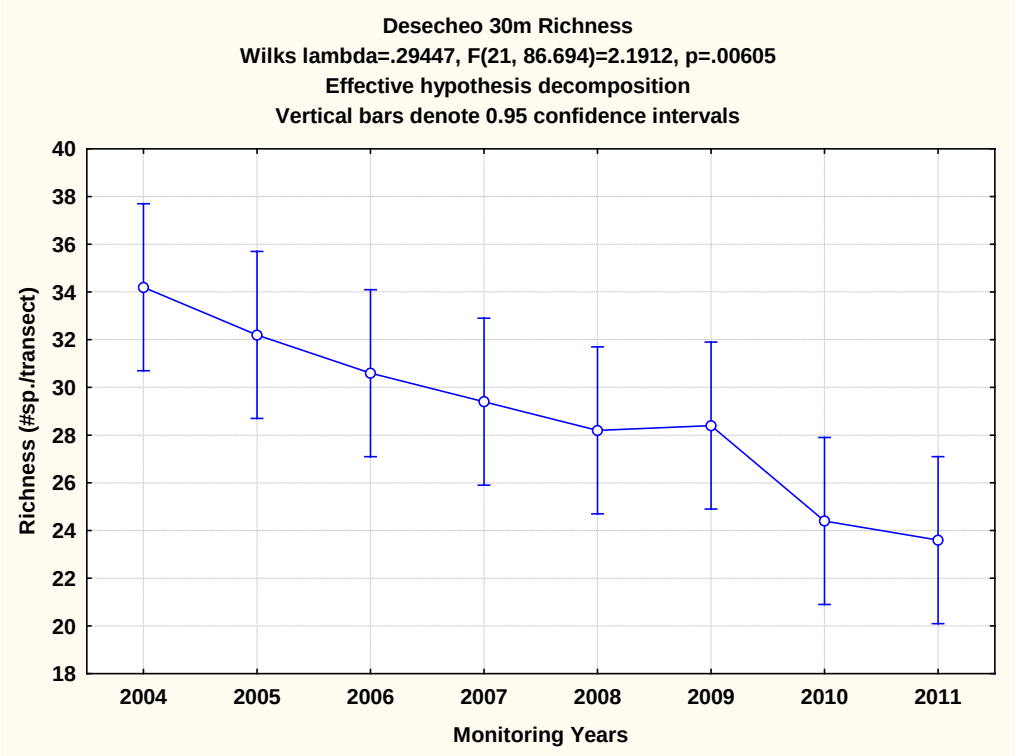


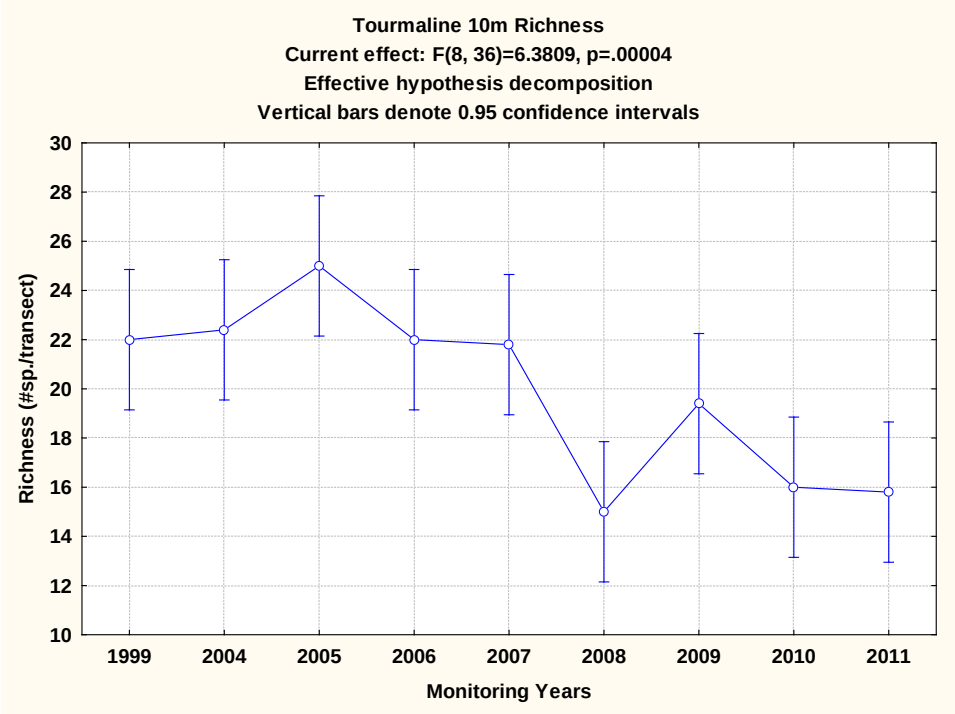


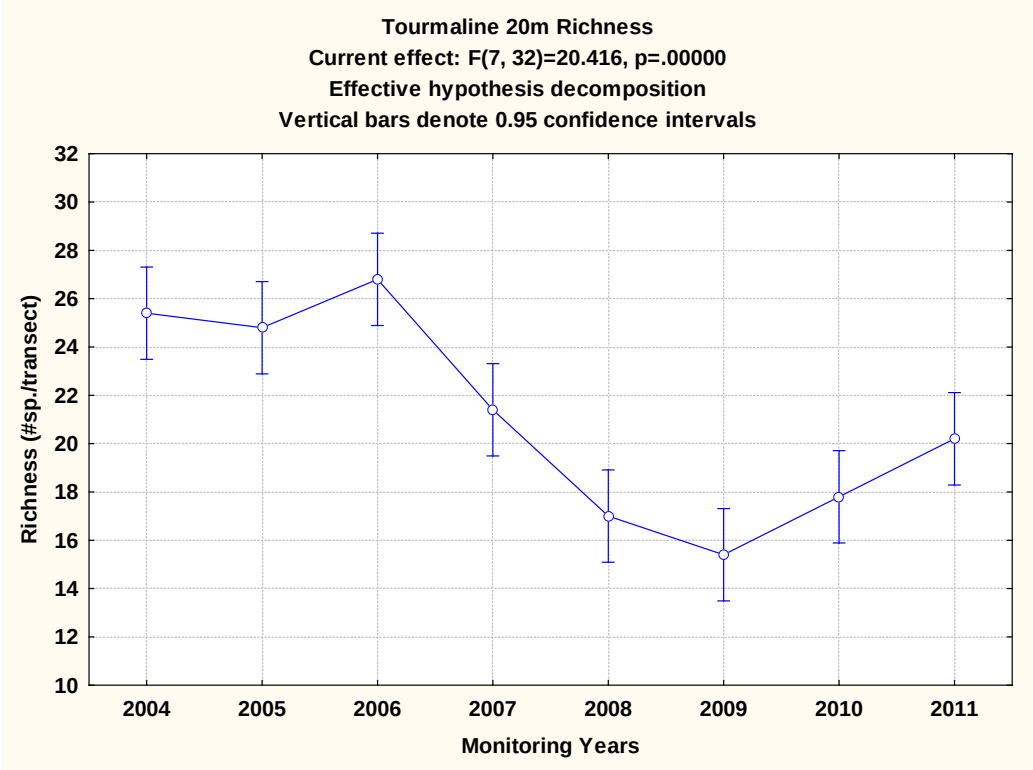

Tres Palmas 20m Richness
Wilks lambda=.21374, F(21, 86.694)=2.9372, p=.00024
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
32
30
28
26
24
22
20
18
16
14
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

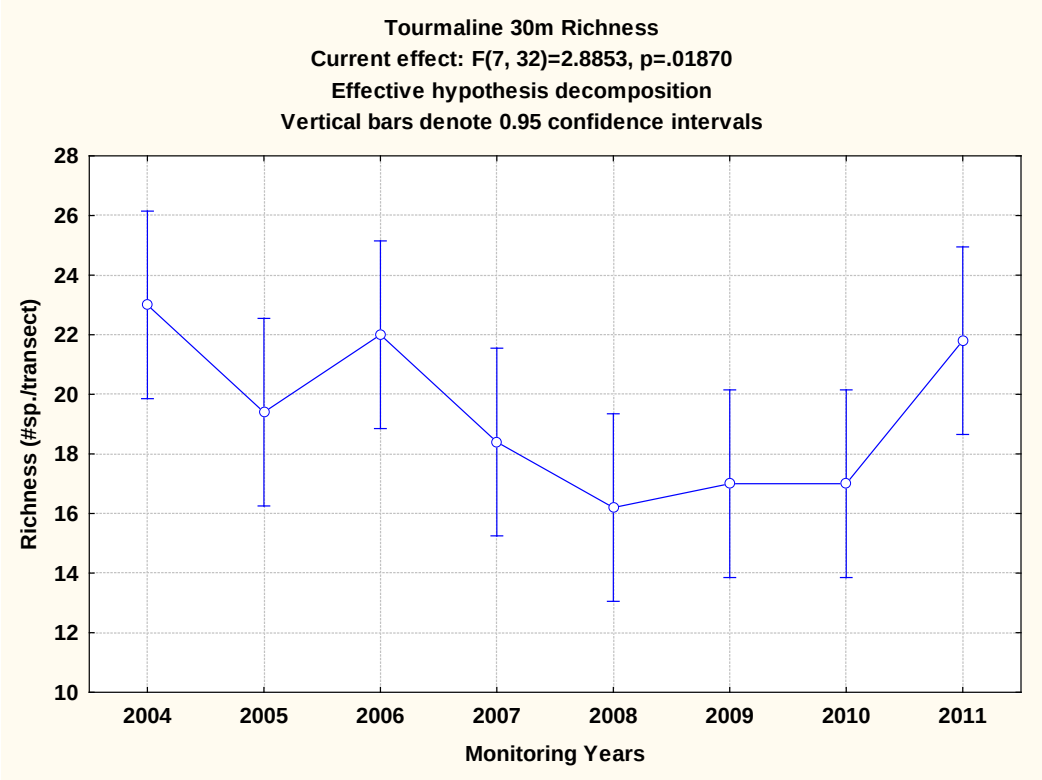

Desecheo Richness 15m
Wilks lambda=.29447, F(21, 86.694)=2.1912, p=.00605
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
30
28
26
24
22
20
18
16
14
12
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

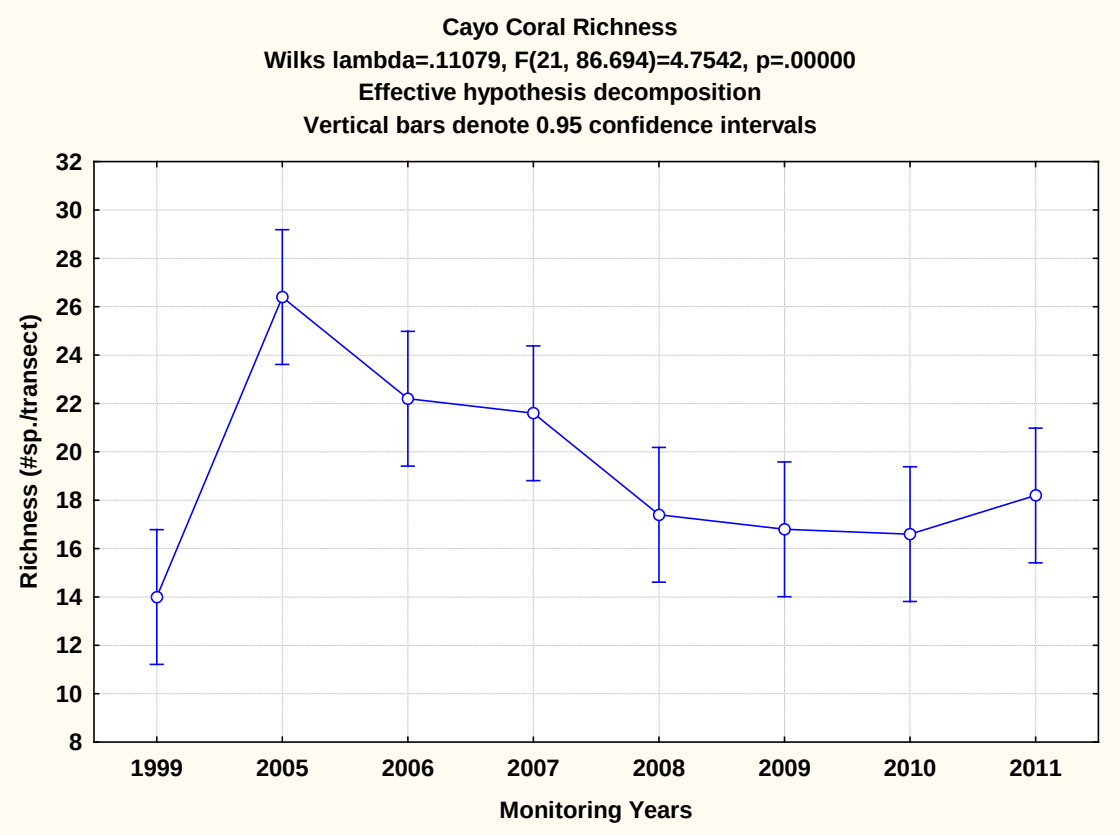

Desecheo 20m Richness
Current effect: F(8, 36)=2.0872, p=.06315
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
34
32
30
28
26
24
22
20
18
16
2000
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

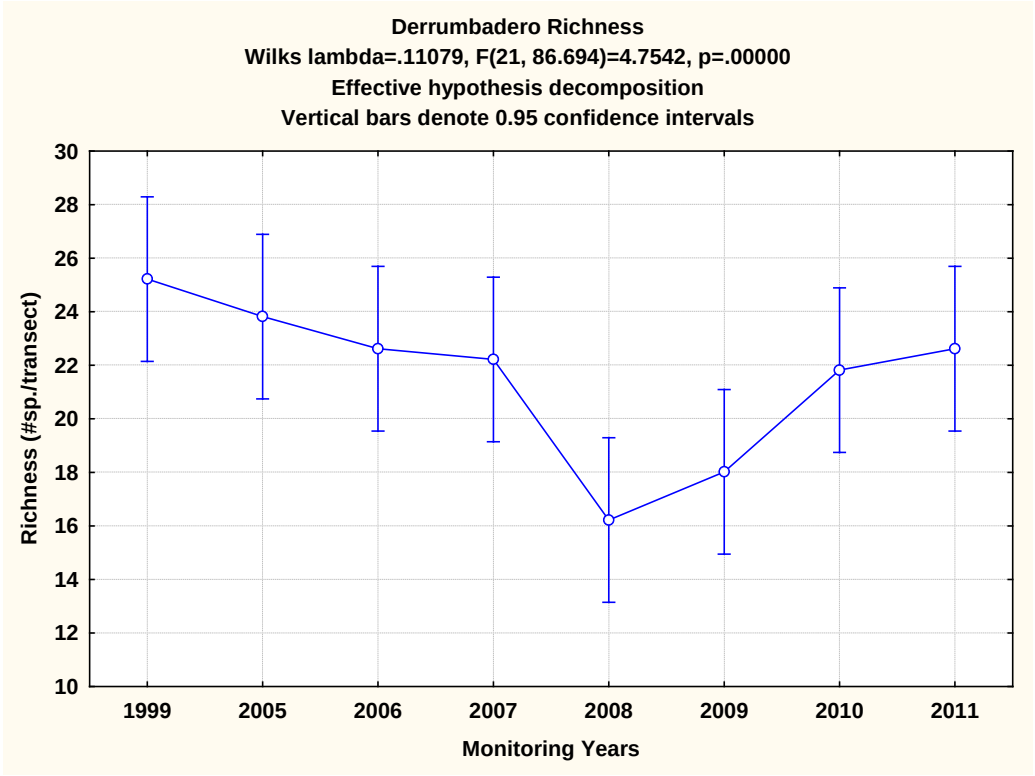

Desecheo 30m Richness
Wilks lambda=.29447, F(21, 86.694)=2.1912, p=.00605
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
40
38
36
34
32
30
28
26
24
22
20
18
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years

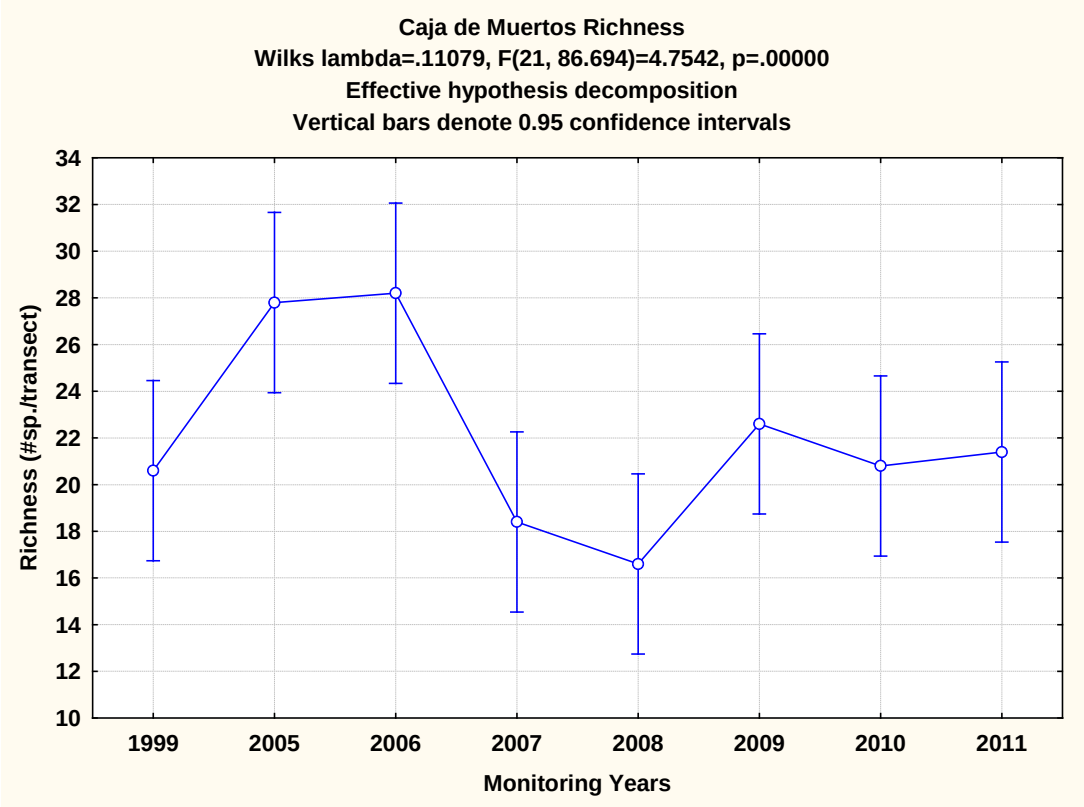

Tourmaline 10m Richness
Current effect: F(8, 36)=6.3809, p=.00004
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
30
28
26
24
22
20
18
16
14
12
10
1999
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years


Tourmaline 20m Richness
Current effect: F(7, 32)=20.416, 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
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years


Tourmaline 30m Richness
Current effect: F(7, 32)=2.8853, p=.01870
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
28
26
24
22
20
18
16
14
12
10
2004
2005
2006
2007
2008
2009
2010
2011
Monitoring Years


Cayo Coral Richness
Wilks lambda=.11079, F(21, 86.694)=4.7542, 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
Monitoring Years


Derrumbadero Richness
Wilks lambda=.11079, F(21, 86.694)=4.7542, 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
Monitoring Years


Caja de Muertos Richness
Wilks lambda=.11079, F(21, 86.694)=4.7542, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
34
32
30
28
26
24
22
20
18
16
14
12
10
1999
2005
2006
2007
2008
2009
2010
2011
Monitoring Years