

FINAL REPORT

**MONITORING OF CORAL REEF COMMUNITIES FROM NATURAL
RESERVES IN PUERTO RICO, 2006 : ISLA DESECHEO, RINCON,
MAYAGUEZ BAY, GUANICA, PONCE AND ISLA CAJA DE MUERTO**

by:

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December, 2006

Executive Summary

A total of 12 coral reef stations from six Natural Reserves were included as part of the 2006 Puerto Rico - U.S. National Coral Reef Monitoring Program (NOAA/DNER). The sessile-benthic community structure 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 reductions of live coral cover. The maximum decline of live coral cover between the 2005 and the 2006 monitoring surveys was of 59.1 % at Derrumbadero Reef. In all cases, the decline of (total) live coral cover at the community level was driven by mortality of Boulder Star Coral, *Montastrea annularis* (complex), a highly dominant species in terms of reef substrate cover and the principal reef building species. In most cases, a proportional increase of cover by turf algae was measured. The Tres Palmas Reef system did not exhibit any major structural changes, nor statistically significant variations of percent substrate cover by live corals at any of the three depths surveyed between the initial baseline characterization and subsequent 2005 and 2006 monitoring surveys. The fringing shoreline reef at Tres Palmas is largely an Elkhorn Coral (*Acropora palmata*) biotope, and is dominated by encrusting Great Star Coral (*Montastrea cavernosa*) at the patch reef formations of the mid-shelf (10 m depth).

Tourmaline Reef exhibited significant declines of cover by Boulder Star Coral at 10 and 20 meter depths, but differences of substrate cover by sessile-benthic components were not statistically significant at the 30 meter depth, which was the deepest station examined. The decline of live coral cover from the 30 meter depth station at Puerto Canoas Reef in Isla Desecheo was less pronounced than at shallower stations examined (e.g. 20 and 10 m), but still substantial (ca. 23 %), consistent throughout all transects and statistically significant.

The sharp decline of live coral cover at many of the reefs included in this monitoring program is associated with a massive regional coral bleaching event that affected the US Virgin Islands and Puerto Rico between September and late October, 2005. The massive bleaching of corals coincided with an extended period of elevated sea surface temperatures (SST). As much as 14 Degree Heating Weeks (DHW), an indicator of thermal stress acting upon shallow reef communities were measured from daily temperature records produced by a NOAA/NESDIS satellite infrared radiometer. During

our 2006 coral monitoring survey, approximately 6 to 9 months after the bleaching event, a relatively high proportion of live corals, particularly *Montastrea annularis* were observed to still retain partially bleached conditions. The potential recuperation of these corals is uncertain at this point. Lingering effects of the October 2005 bleaching event will need to be evaluated by the next (2007) coral monitoring survey.

A total of 165 species of diurnal, non-cryptic fish species have been identified during the coral reef monitoring program at the reefs surveyed. Fish populations presented in general, stable species richness and taxonomic composition in most cases, but a consistent trend of declining abundance within belt-transects that was statistically significant in seven out of the 12 reef stations surveyed. These included Tourmaline Reef at 10, 20 and 30 meters; Puerto Botes Reef at 15 m; Tres Palmas Reef at 10 m; Derrumbadero Reef at 20 m, and West Reef at 8 m. Variations between surveys were mostly associated with reductions of abundance by numerically dominant populations that exhibit highly aggregated distributions, such as the Masked Goby (*Coryphopterus personatus*) and the Blue Chromis (*Chromis cyanea*). It is uncertain at this point if such reductions of abundance by reef fishes closely associated with coral habitats are related to the massive coral mortality exhibited by reef systems in the monitoring program.

Although in low abundance, large demersal fishes that have been overfished during the last decades have been detected 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*).

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I INTRODUCTION

This work is part of the US National Coral Reef Monitoring Program sponsored by NOAA and administered by the Department of Natural and Environmental Resources (DNER) in Puerto Rico. It includes the fourth annual monitoring cycle of Puerto Botes Reef (Isla Desecheo) at 20 m, and the third monitoring of Tourmaline Reef (Mayaguez Bay) at 10 m, after the initial (baseline) characterizations of 1999. The report also presents the second monitoring observations of Cayo Coral Reef (Guánica), Derrumbadero Reef (Ponce), West Reef of Isla Caja de Muerto (Ponce), Puerto Botes Reef at 15 and 30 m, Tourmaline Reef at 20 and 30 m, and Tres Palmas Reef (Rincón) at 5, 10, and 20 m. The initial (baseline) characterizations of Cayo Coral and West Reef were performed during the summer of 1999, whereas baseline characterizations of the Tres Palmas Reef at 5, 10, and 20 m, Tourmaline Reef at 20 and 30 m, and Puerto Botes/Puerto Canoas Reefs at 15 and 30 m were performed during the summer of 2004.

The Tres Palmas Reef system of Rincón was designated in 2003 as a Marine Reserve with a “no-take zone”, or Marine Protected Area due to the presence of perhaps the most extensive and “healthy” biotope of Elkhorn Coral (*Acropora palmata*) in the island. Tourmaline Reef in outer Mayaguez Bay is a shelf-edge “spur-and-groove” formation which extends across a depth range of 10 – 30 m and presents one of the most diverse coral communities of the Island. Puerto Canoas and Puerto Botes of Isla Desecheo represent reef systems with the highest live coral cover, fish density and fish species richness of Puerto Rico. Cayo Coral and West Reef of Isla Caja de Muerto were included in the Puerto Rico National Coral Reef Monitoring Program because of their location within Natural Reserves where present and/or potentially high recreational impact is expected. These are Natural Reserves where the DNER of the Puerto Rican government has constructed public recreational facilities and receive visitors on a daily basis. Derrumbadero Reef in Ponce has been included in the coral monitoring program because it is one of the best developed coral reef systems in Puerto Rico (García et al, 2005) and is located just offshore of a large-scale coastal maritime development project in Ponce, Las Americas Megaport.

The first monitoring cycle of coral reef communities under the US National Coral Reef Monitoring Program in Puerto Rico was prepared by DNER in 2001 DNER (Nemeth, 2002). It included 18 reefs from seven Natural Reserve sites. In general, the variations

of sessile-benthic community structure among the reefs monitored one year after the baseline characterization by García et al (2001 a, b, c) were statistically insignificant. A similar assessment holds for six reefs surveyed during 2004 at Isla de Vieques by García et al. (2004 b), and for the reefs at Puerto Botes-20 m (Isla Desecheo) and Tourmaline-10 m (Mayaguez Bay), where in most cases live coral cover remained virtually constant four (Vieques reefs) to five (Puerto Botes-20 m, Tourmaline -10 m) years after the initial baseline characterizations (García et al., 2001 d, 2004 a). Field work corresponding to the monitoring cycle of 2005 was completed in late August (2005), about one month prior to the onset of a massive coral bleaching event observed to affect corals of several species throughout the island of Puerto Rico and the US Virgin Islands within a depth range of one (1) to (at least) 40 m. Therefore, the report from the 2005 monitoring cycle did not include an assessment of the bleaching impact upon coral reefs surveyed.

This 2006 coral reef monitoring report includes a detailed account of the decline of live coral and shifts in benthic community structure exhibited by several reefs included within the Puertorrican coral reef monitoring program associated to the massive coral bleaching event. Lingering effects of the bleaching phenomena persist at present, since many coral colonies here reported as live coral are still partially bleached and their eventual recuperation is uncertain at this point.

II Methods

The general location of coral reef monitoring sites in the west and south coasts of Puerto Rico are shown in Figures 1 and 2. A total of five permanent 10-m long transects were surveyed at each reef station. The DGPS referenced station coordinates and depths of the 12 reef stations included in the monitoring program are presented in Table 1. Monitoring surveys were performed during the period between April and July, 2006.

A. Sessile-benthic reef communities

Sessile-benthic reef communities were quantitatively monitored by the continuous intercept chain-link method, as modified from Porter (1972) by CARICOMP (1984). This method provides information on the percent linear cover by sessile-benthic biota and other substrate categories. 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 positioning of the chain was guided by a series of steel nails hammered into available hard (abiotic) substrates at approximately 0.5 m intervals in the reef. Also, a thin nylon reference line was stretched from rod to rod in order to identify the location of transects and guide the divers over the linear transect paths. Individual measurements of substrate categories, as recorded from the number of chain links were sorted, added and divided by the total distance (in chain links) on each transect to calculate the cumulative percent linear cover by each substrate category.

Soft corals, with the exception of encrusting forms (e.g. *Erythropodium caribaeorum*) were counted as number of colonies intercepted per transect, whenever any of their branches crossed the transect reference line. The vertical relief of the reef, or rugosity, was calculated by subtracting 10 m from the total length (links) recorded with the chain at the 10 m marker of the reference line. Underwater videos of each transect were recorded for archival records on Digital-8 format using a Sony TR camcorder and an Ikelite underwater housing. Distance from the bottom was maintained constant using a metal rod fixed to the housing.

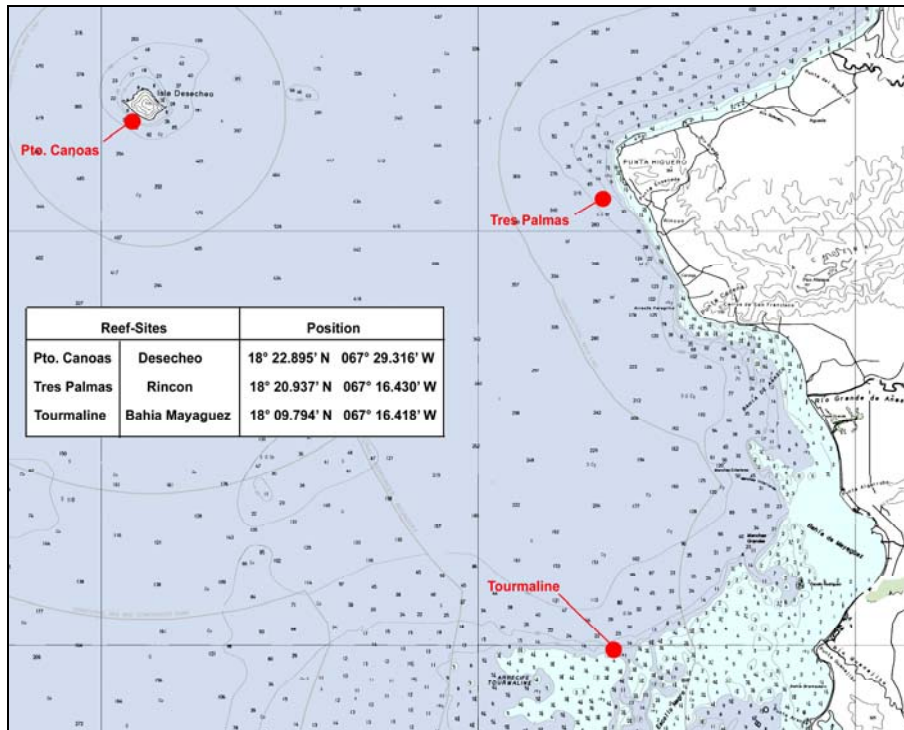


Figure 1. Location of west coast reef sites, Isla Desecheo, Mayaguez and Rincón.

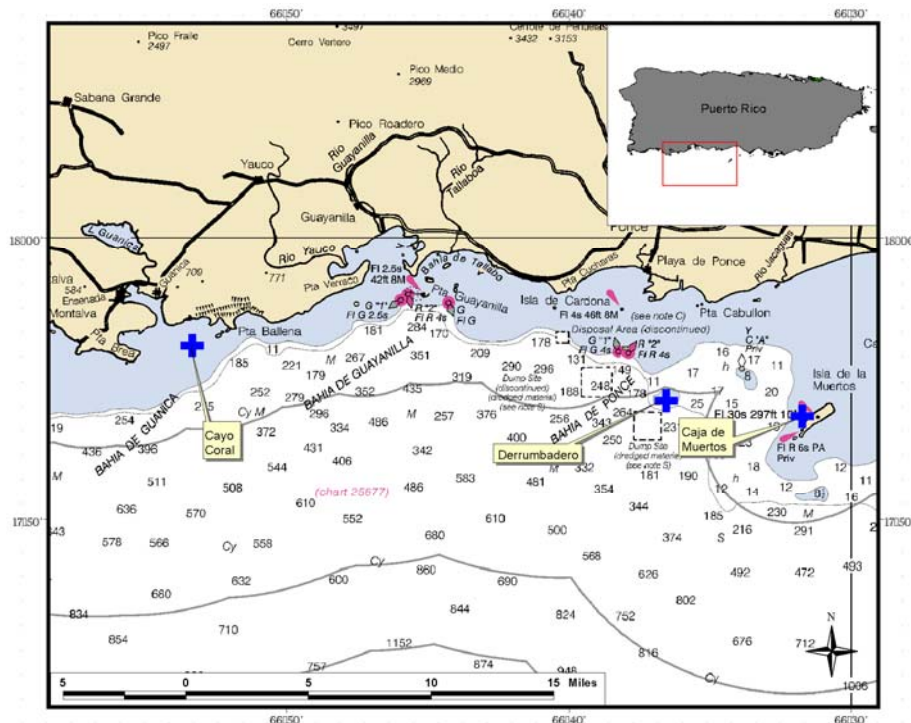


Figure 2. Location of south coast reef sites, Cayo Coral (Guánica), Derrumbadero and West Reef of Isla Caja de Muerto (Ponce)

Table 1. Geographic coordinates and depths of coral reef stations surveyed in 2006

Reef - Site	Depth (m)	Latitude	Longitude
Tres Palmas - Rincón			
Rincón elkhorn reef	2 - 5	18° 21.023' N	067° 15.959' W
Rincón outer shelf	10	18° 20.832' N	067° 16.206' W
Rincón shelf edge	20	18° 20.790' N	067° 16.248' W
Puerto Botes/Canoas - Isla Desecheo			
Desecheo inner shelf - Puerto Botes	15	18° 22.920' N	067° 29.300' W
Desecheo mid shelf - Puerto Botes	20	18°22.900' N	067° 29.315' W
Desecheo shelf edge - Puerto Canoas	30	18°22.706' N	067° 29.199' W
Tourmaline Reef - Mayaguez			
Tourmaline 10m	10	18° 09.788' N	067° 16.424' W
Tourmaline 20m	20	18° 09.910' N	067° 16.512' W
Tourmaline 30m	30	18° 09.985' N	067° 16.581' W
Ponce			
West Reef -Caja de Muerto	7.6	17° 53.701' N	066° 31.703' W
Derrumbadero	20	17° 54.2371' N	066° 36.5161' W
Guánica			
Cayo Coral	7.6	17° 56.173' N	066° 53.303' W

B. Reef Fishes and Motile Megabenthic Invertebrates

Demersal, non-cryptic reef fish populations and motile megabenthic invertebrates were surveyed by five 10-m long by 3-m wide (30 m²) belt-transects centered along the reference line of transects used for sessile-benthic reef community characterizations. Transect width was marked with flagging tape stretched and tied to weights on both ends. Each transect was surveyed during 12 minutes. Fish species observed outside transect areas were reported to supplement taxonomic assessments, but were not included in density determinations. This approach yields a taxonomic account of the diurnal, non-cryptic fish and motile megabenthic (> 3 cm) invertebrate species present and provides estimates of their densities at each reef physiographic zones or depths. A set of five belt-transects for fish and motile megabenthic invertebrates were performed at each reef surveyed.

Large, elusive fish populations, which includes most of the commercially important and many recreationally valuable populations were surveyed using an Active Search Census (ASEC). 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 data. At each reef physiographic zone (or depth strata) the total number of individuals of each particular species observed within a fixed time frame of 20 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 cm) was visually estimated and aided by a measuring rod with adjustable width. Precision of length estimates allows discrimination between small juveniles, juveniles, adult and large adult size classes. One ASEC survey was performed at the same depths in which belt-transects were surveyed from each reef. All data was recorded in plastic paper.

Statistical Analyses

Monitoring data on the percent cover by live corals and fish species richness and abundance within belt transects was analyzed using a Repeated Measurements Analysis of Variance (InfoStat, 2004). The data base for the comparative analyses between surveys for each reef station consisted of five replicates of each parameter for each monitoring year. Specific differences between monitoring years were examined with a LSD Fisher Multiple Mean Comparison Test with an alpha level set at 0.05. Inter-annual monitoring trends of the sessile benthic community for each reef were statistically tested for substrate cover by total live corals (percent) and for the percent cover by Boulder Star Coral, *Montastrea annularis*. The total number of fish species identified within each belt-transect (# spp/transect) was used as the measurement of fish species richness.

III Baseline Characterization and Monitoring of Coral Reef Communities

A. Tres Palmas Reef System – Rincón

1. 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 corals are more abundant on the seaward slope of the hard ground platform which ends in a sandy bottom at a depth of about six meters.

Rainfall runoff with heavy loads of terrestrial sediments was observed to reach the fringing coral reef following a prevailing northerly alongshore current during our 2004 survey (García-Sais et al., 2004 a). Also, there were considerable amounts of garbage (cans, bottles, tires, etc.) in the reef. Many coral colonies were entangled with clothing and towels, apparently lost from immigrants trying to reach the Rincón coastline. The backreef lagoon is a popular place for bathers and divers, some of which were observed fishing with spear guns within the no-take area. During the 2005 monitoring cycle, the field work at this reef had to be postponed several times due to strong wave action. The work was finally completed in December (2005) under considerable surge from waves. The present 2006 survey was performed under conditions of relatively dry weather and flat seas, with good underwater visibility. 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.

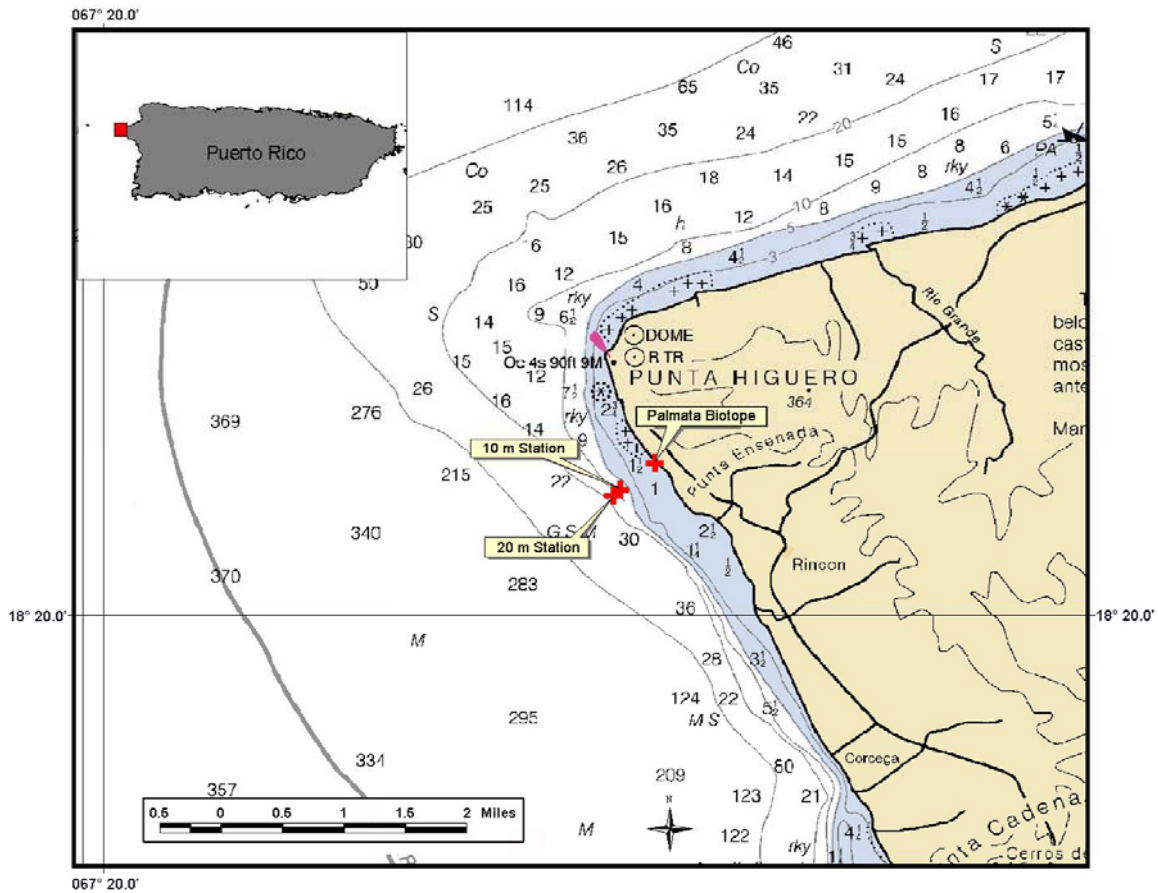


Figure 3. Location of coral reef survey stations off Tres Palmas, Rincón.

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 surveyed are presented in Table 2. Live coral cover averaged 37.02% (range: 14.29 – 53.9%). Elkhorn Coral (*A. palmata*) was the dominant species with a mean substrate cover of 28.8% (range: 0.74 – 52.9%), representing 77.8% of the total live coral cover. Four additional coral species, mostly encrusting types (e.g. *Diploria clivosa*, *D. strigosa*, *P. astreoides* and *Montastrea annularis*) were intersected by linear transects during our survey. A total of 13 species of stony corals were identified from the fringing reef. Hard ground substrate, including dead coral sections not colonized by corals was mostly covered by turf algae (mean cover: 41.39%). Fleshy macroalgae (*Valonia sp.*, *Styopodium sp.*) and red coralline algae were observed outside transect areas. The encrusting zoanthid, *Palythoa caribbea* and the encrusting gorgonian *Erythropodium*

Table 2. Percent reef substrate cover by sessile-benthic categories at the fringing Elkhorn Coral Reef off Tres Palmas, Rincon, June, 2006

Depth: 2 - 5 m Survey Date: June, 2006		TRANSECTS					Mean
		1	2	3	4	5	
Rugosity (m)		3.51	3.48	3.55	1.42	1.91	2.77
SUBSTRATE CATEGORIES							
BENTHIC ALGAE							
Turf Algae		40.59	34.47	35.06	31.32	65.49	41.39
Coralline Algae			0.73		0.35	0.49	0.32
Total Benthic Algae		40.59	35.20	35.06	31.67	65.98	41.71
ABIOTIC							
Reef Overhang		26.52	21.13	14.02		10.96	14.53
Sand					12.43	6.05	3.70
Gap		1.11	1.04		1.54	2.72	1.28
Total Abiotic		27.63	22.17	14.02	13.97	19.73	19.51
ANTHOZOANS		5.41		3.03	0.47		1.78
LIVE CORAL							
<i>Acropora palmata</i>		12.00	40.70	37.64	52.90	0.74	28.80
<i>Diploria clivosa</i>				6.44		7.04	2.70
<i>Diploria strigosa</i>		9.70	1.04	0.52		2.84	2.82
<i>Montastrea annularis</i>		2.22		0.96		2.96	1.23
<i>Porites astreoides</i>		2.52	0.84	2.39	1.06	0.74	1.51
Total Stony Coral		26.37	42.63	47.90	53.90	14.29	37.02
Recently Dead Corals							
<i>Porites astreoides</i>		1.04					0.21
GORGONIANS (# colonies/ transect)		2	0	1	3	1	1.4

Coral Species Outside Transects: *Colpophyllia natans*, *Millepora alcicornis*, *Siderastrea radians*, *Mycetophyllia lamarckiana*, *Isophyllia rigida*, *Agaricia agaricites*, *Porites porites*, *Diploria labyrinthiformis*

caribaeorum were present outside transects. Abiotic categories, associated with reef overhangs, gaps or holes and sand represented 19.51 % of the reef substrate cover. Vertically projected soft corals (gorgonians) were found in very low abundance (mean 1.4 colonies/transect). This was expected in an environment seasonally affected by very strong wave action. The most common species observed out of transects included *Pseudopterogorgia americana*, *Plexaura homomalla*, *Gorgonia ventalina*, *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 fluctuated between 38.62 % and 35.55 % during the monitoring period between 2004 and 2006. The relatively small variation of mean live coral cover between surveys was not statistically significant (ANOVA; $p > 0.05$). The consistent trend of live coral cover at this reef is largely driven by Elkhorn Coral (*Acropora palmata*), which has not shown major variations in ecological health over the survey period (Figure 5). There was no indication of bleaching, recently dead colonies, or sickness among Elkhorn coral colonies (within transects) during the 2006 survey. Only one colony of Mustard Hill Coral, *Porites astreoides* was observed to be recently dead (see Table 2).

It is possible that the sampling variability for this reef may be comparatively higher than for others in the monitoring program due to the high morphological complexity (irregularity) of the Elkhorn coral colonies and the constraints in marking the chain path over such long stretches of live coral. Also, the extremely shallow nature of this coral reef (reef crest zone) and its frequent exposure to strong wave action makes it difficult to provide precise repeated measurements of the reef profile using the chain technique for monitoring evaluations.

1.2 Reef Fishes and Motile Megabenthic Invertebrates

A total of 65 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 2006 monitoring survey, 42 fish species, including 26 present within belt-transects were identified from the fringing reef. The mean abundance of individuals was

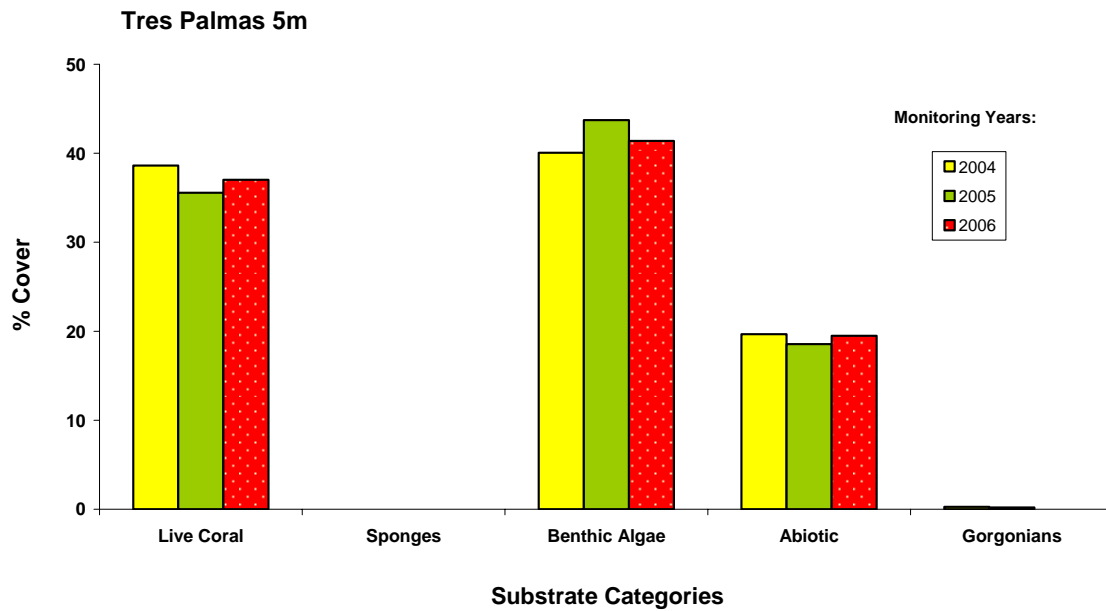


Figure 4. Monitoring trends (2004 – 2006) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon, 5 m depth.

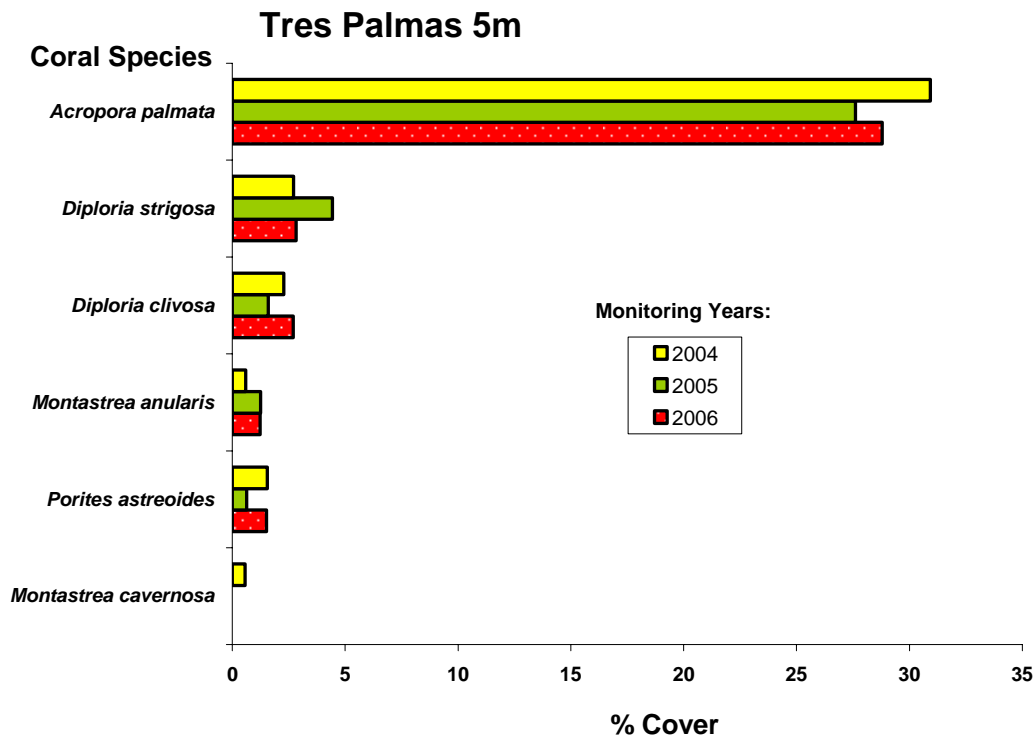


Figure 5. Monitoring trends (2004 – 2006) of mean substrate cover by stony coral species at Tres Palmas Reef, Rincon, 5 m depth.

44.8 Ind/30 m² (range: 26 - 60 Ind/30 m²), and the mean number of species per transect was 11 (range: 6-15). The combined abundance of six species represented 74.6 % of the mean abundance within belt-transects (Table 3). The most abundant species was the Dusky Damselfish (*Stegastes dorsopunicans*) with 12.4 Ind/30 m² followed by the Bluehead Wrasse (*Thalassoma bifasciatum*) and the Redlip Blenny (*Ophioblennius atlanticus*) with means of 5.8 and 5.6 Ind/30 m², respectively. Juveniles of the Yellowtail Damselfish (*Microspathodon chrysurus*) and the Sargeant Fish (*Abudefduf sexatilis*) were present within all five belt-transects surveyed and along with the aforementioned species appear to be the main resident fish assemblage. The Glassy Sweeper (*Pempheris schomburgki*) maintains a large schooling aggregation within a crevice in Transect 1 since the initial baseline survey in 2004. Large schools of Blue Tangs and Yellowtail Goatfishes were observed out of transect areas. Smaller schools of juvenile grunts were also common.

Monitoring trends of fish abundance and species richness are presented in Figure 6. No statistically significant differences of fish species richness or abundance (ANOVA; $p > 0.05$) have been detected during the monitoring period (2004-2006) at this reef. The shallow, high energy environment of the fringing reef appears to be an ideal habitat for opportunistic carnivores, such as Wrasses (*Thalassoma bifasciatum*, *Halichoeres radiatus*, *H. maculipinna*, *H. bivittatus*) and Blennies (*Ophioblennius atlanticus*) which feed on small benthic (infaunal) invertebrates that become exposed upon disturbances of the substrate due to wave action. Also, herbivores (e.g. parrotfishes, doctorfishes, damselfishes) that feed on the turf algae were 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 silversides (*Anchoa spp.*, *Allanetta 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. mahogany*) were observed during the 2006 ASEC survey (Table 4), as well as during previous surveys (García-Sais et al., 2004 a, 2005), suggesting that this shallow reef functions as a nursery area for these commercially important species. One Hawksbill Turtle (*Eretmochelys imbricata*) was reported during the 2004 baseline survey (García-Sais et al., 2004a).

Table 3. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef, 5m, Rincon. June, 2006

Depth: 2-5m Survey Date: June, 2006		TRANSECTS					MEAN
		1	2	3	4	5	
SPECIES	COMMON NAME	(individuals/30 m2)					
<i>Stegastes dorsopunicans</i>	Dusky Damselfish	15	17	16	9	5	12.40
<i>Thalassoma bifasciatum</i>	Bluehead Wrasse	8	7	5	6	3	5.80
<i>Ophioblennius atlanticus</i>	Redlip Blenny	12	6	5	4	1	5.60
<i>Microspathodon chrysurus</i>	Yellowtail Damselfish	3	8	6	6	1	4.80
<i>Abudefduf sexatilis</i>	Sargeant Fish	1	3	2	7	1	2.80
<i>Halichoeres bivittatus</i>	Slippery Dick	1			4	5	2.00
<i>Acanthurus coeruleus</i>	Blue Tang	7				1	1.60
<i>Mulloides martinicus</i>	Yellowtail Goatfish	2	5				1.40
<i>Sparisoma rubripinne</i>	Yellowtail parrotfish		2	1		4	1.40
<i>Halichoeres maculipinna</i>	Clown wrasse		2	3		1	1.20
<i>Haemulon sp.</i>	Juvenile Grunts			5			1.00
<i>Acanthurus chirurgus</i>	Doctorfish	3	1			1	1.00
<i>Halichoeres radiatus</i>	Pudding wife	1		2			0.60
<i>Pempheris schomburgki</i>	Glassy Sweeper	3					0.60
<i>Bodianus rufus</i>	Spanish hogfish			2			0.40
<i>Acanthurus bahianus</i>	Ocean surgeon	1					0.20
<i>Sparisoma viride</i>	Stoplight parrotfish		1				0.20
<i>Caranx ruber</i>	Bar jack		1				0.20
<i>Abudefduf taurus</i>	Night Sargeant	1					0.20
<i>Grama loreto</i>	Fairy Basslet	1					0.20
<i>Haemulon flavolineatum</i>	French Grunt		1				0.20
<i>Priacanthus arenatus</i>	Glasseye	1					0.20
<i>Epinephelus adscensionis</i>	Rock Hind			1			0.20
<i>Lutjanus analis</i>	Mutton snapper					1	0.20
<i>Ocyurus chrysurus</i>	Yellowtail snapper					1	0.20
<i>Cantherhines pullus</i>	Tail-light Filefish					1	0.20
TOTAL INDIVIDUALS		60	54	48	36	26	44.80
TOTAL SPECIES		15	12	11	6	13	11

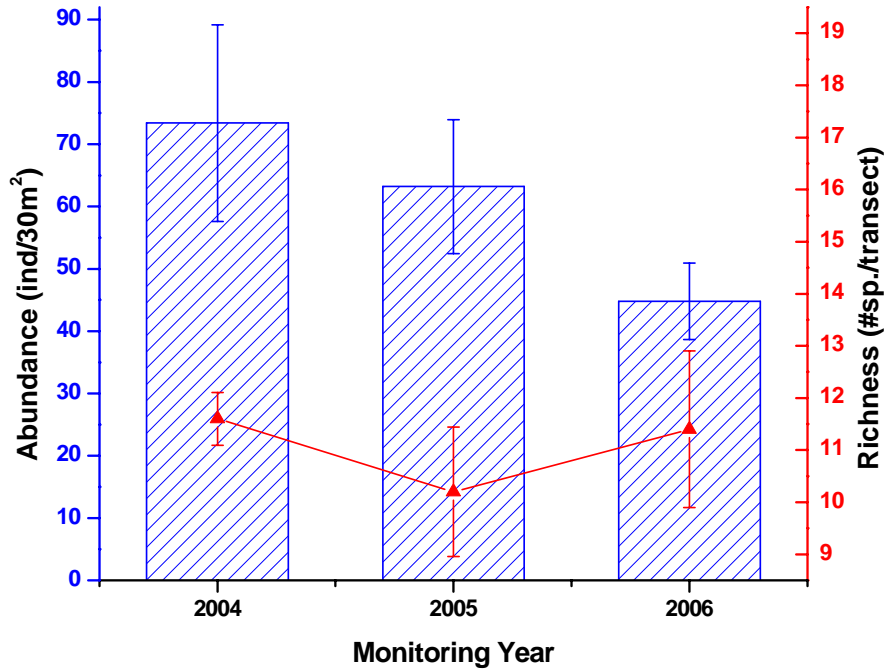


Figure 6. Monitoring trends (2004 – 2006) of fish species richness and abundance at Tres Palmas Elkhorn Coral Reef, 2-5 m depth, Rincon.

Table 4. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at the fringing Elkhorn Coral Reef off Tres Palmas Reef, Rincón, June, 2006

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

SPECIES	COMMON NAME	# - (cm)			
<i>Carangoides crysos</i>	Blue Runner	1 – (35)			
<i>Epinephelus adscensionis</i>	Rock Hind	1 – (30)			
<i>Gramma loreto</i>	Fairy Basslet	2 – (3)	6 – (4)		
<i>Lutjanus analis</i>	Mutton Snapper	3 – (10)	1 – (15)	1 – (25)	
<i>Lutjanus apodus</i>	Schoolmaster	1 – (20)	3 – (25)		
<i>Lutjanus mahogany</i>	Mahogany Snapper	3 – (20)			
<i>Microspathodon chrysurus</i>	Yellowtail Damselfish	51 – (<5)	43 – (10)	7 – (15)	5 – (20)
<i>Ocyurus chrysurus</i>	Yellowtail Snapper	1 – (25)			
Invertebrates					
	Spotted Spiny				
<i>Panulirus guttatus</i>	Lobster	1 – (10)			

Among motile megabenthic invertebrates, White, Rock-boring and Long-spined Sea Urchins (*Tripneustes esculentus*, *Echinometra lucunter*, *Diadema antillarum*), and one juvenile Rock Lobster (*Panulirus guttatus*) were present within belt-transect areas during the 2006 monitoring survey (Table 5).

Table 5. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Elkhorn Coral Reef, 2-5 m depth, Rincon, June, 2006

DATE: June, 2006 Depth: 2 - 5 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m ²)
		1	2	3	4	5	
Taxa	COMMON NAME						
<i>Diadema antillarum</i>	Long-spined Sea Urchin	1					0.2
<i>Tripneustes esculentus</i>	White Sea Urchin				1		0.2
<i>Panulirus guttatus</i>	Spotted Spiny Lobster				1		0.2
<i>Echinometra lucunter</i>	Rock boring Urchin			6	4		2.0
TOTALS		1	0	6	6	0	2.6

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





2. 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 of 22.2 col./transect (range: 14 – 27 col./transect) (Table 6). Some of the most common species include the Sea Fans, *Gorgonia flabellum*, *G. ventalina* and *G. mariae*; Sea Plumes, *Pseudopterogorgia americana*, *P. bipinnata*, *Muriceopsis* sp. and Sea Rods, *Plexaura homomalla*, *Pseudoplexaura* sp., *Eunicea* spp., *Muricea* spp.

Stony corals occurred mostly as encrusting colonies of typically small size and low vertical relief. A total of 19 species of stony corals were identified from the patch reef community during our survey. Stony coral cover averaged 18.56 % (range: 7.62 – 26.84 %). Great Star Coral, *Montastrea cavernosa* was the dominant species in terms of substrate cover with a mean of 5.44 % (range: 2.10 – 10.49 %), representing 29.3 % of the total live coral cover from this reef. Fourteen additional coral species were intersected by linear transects, but nine of them with less than 1 % mean cover. Recently dead coral colonies were not observed within transects. One colony of *Montastrea cavernosa* was observed to be partially bleached during the present 2006 survey (Table 6).

Table 6. Percent reef substrate cover by sessile-benthic categories at the outer shelf patch reef off Tres Palmas, Rincon, June, 2006

Depth: 10 m Survey Date: June, 2006		TRANSECTS					Mean
		1	2	3	4	5	
Rugosity (m)		1.87	2.44	2.11	2.08	2.17	2.13
SUBSTRATE CATEGORIES							
BENTHIC ALGAE							
Turf Algae		60.61	68.55	68.13	60.18	65.08	64.51
Coralline Algae		3.79	0.64	1.73	2.32	2.79	2.26
Total Benthic Algae		64.40	69.19	69.86	62.50	67.87	66.77
ABIOTIC							
Reef Overhang		2.61	2.25	1.07	4.47	3.78	2.84
Sand		3.68					0.74
Total Abiotic		6.29	2.25	1.07	4.47	3.78	3.58
SPONGES		7.74	7.48	7.93	4.30	8.46	7.18
ENCRUSTING GORGONIANS		13.97	1.47		1.90	2.30	3.93
LIVE CORAL							
<i>Montastrea cavernosa</i>		2.10	5.79	10.49	5.79	3.04	5.44
<i>Porites astreoides</i>		0.71	3.54	1.49	1.99	6.98	2.94
<i>Colpophyllia natans</i>				2.33	6.76		1.82
<i>Montastrea annularis</i>		3.79	3.62				1.48
<i>Diploria labyrinthiformis</i>				4.07		2.88	1.39
<i>Dendrogyra cylindrus</i>					6.53		1.31
<i>Diploria strigosa</i>			3.54		1.74		1.06
<i>Siderastrea siderea</i>					1.75	2.20	0.79
<i>Agaricia agaricites</i>			1.37	0.81	0.82		0.60
<i>Siderastrea radians</i>				1.07		1.50	0.52
<i>Meandrina meandrites</i>			1.37	0.93			0.46
<i>Millepora alcicornis</i>		0.47	0.45		0.35	0.69	0.39
<i>Stephanocoenia michelini</i>					1.05		0.21
<i>Madracis decactis</i>		0.47					0.09
<i>Porites porites</i>						0.35	0.07
Total Stony Coral		7.62	19.60	21.14	26.84	17.62	18.56
Partially Bleached (PB) Corals							
<i>Montastrea cavernosa</i>		0.67					0.13
GORGONIANS (# col./transect)		27	26	18	14	26	22.2

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

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 64.51 % (range: 60.18 – 68.55 %). Red coralline algae, mostly the Y-Twig Alga, *Amphiroa* sp. was present in all transects with a mean substrate cover of 2.26 %. Fleshy brown (*Dictyota* sp.), red (*Galaxaura* sp.) and calcareous (*Halimeda discoidea*) macroalgae were present outside transects. Encrusting sponges were intersected by all five transects with a mean substrate cover of 7.18 % (range: 4.30 – 8.46 %). The encrusting gorgonian *Erythropodium caribaeorum* was present in four out of the five transects with a mean substrate cover of 3.93 %. *Palythoa caribbea*, an encrusting zoanthid was observed outside transects. Abiotic categories associated with reef overhangs and sand pockets comprised only 3.58 % of the reef substrate cover, influenced in part by the essentially flat bathymetry and the prevailing encrusting growth pattern of corals and sponges. Reef rugosity, which is an indicator of underwater topographic relief was only 2.13 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 in the north coast of Puerto Rico (García-Sais et al., 2003).

The monitoring time series for sessile-benthic communities at the Tres Palmas outer-shelf patch reefs consists of the baseline characterization of 2004 (García-Sais et al., 2004 a), the 2005 survey (García-Sais et al. 2005), and the present 2006 survey. Variation of reef substrate cover by live corals between monitoring surveys was not statistically significant (ANOVA; $p > 0.05$). Mean percent substrate cover by live stony corals, sponges and benthic algae varied by less than 2.5 % between the previous (2005) and the present (2006) monitoring survey (Figures 7 and 8). The largest variation of substrate cover by sessile-benthic categories was a 3.4 % increment of substrate cover by the encrusting gorgonian, *Erythropodium caribbaeorum*.

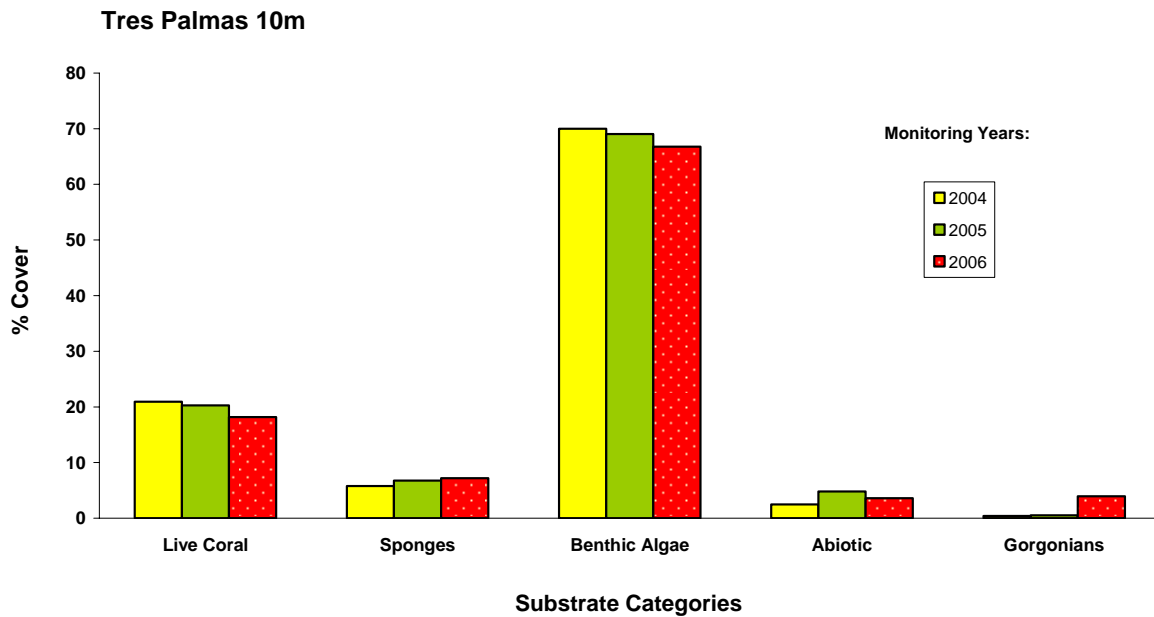


Figure 7. Monitoring trends of mean substrate cover by sessile-benthic categories at Tres Palmas Outer Patch Reef – 10 m.

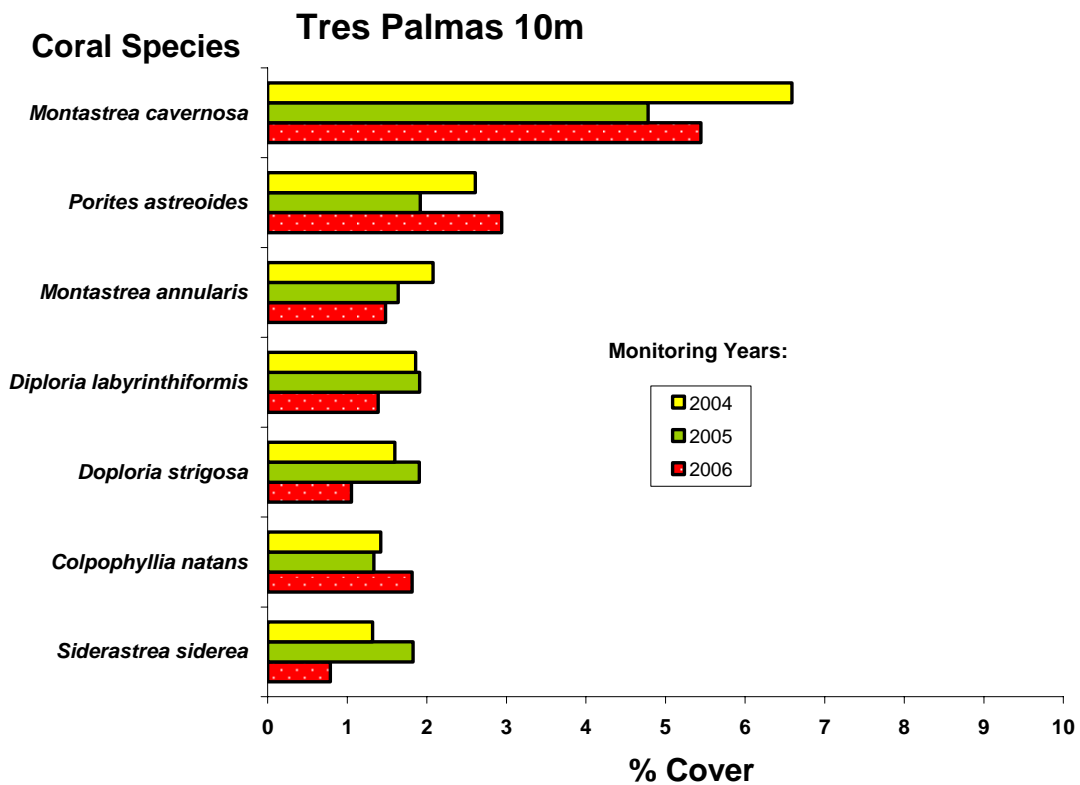


Figure 8. Monitoring trends of mean substrate cover by stony coral species at Tres Palmas Outer Patch Reef – 10 m

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 109 fish species have been identified from the patch reef formation at the Tres Palmas Reef system of Rincón (Appendix 1). During the 2006 survey, mean abundance of individuals within belt-transects was 169.6 Ind/30 m² (range: 141-208 Ind/30 m²). The mean number of species per transect was 20.2 (range: 17-25). Fish species richness increased by 8.9 % and mean abundance increased by 37.3 % compared to the 2005 survey (Figure 9). The increment of abundance during 2006, compared to the two previous surveys of 2004 and 2005 was statistically significant (ANOVA; $p = 0.0034$).

Two species, the Bicolor Damselfish (*Stegastes partitus*) and the Bluehead Wrasse (*Thalassoma bifasciatum*) were numerically dominant within belt-transects with mean abundances of 90.2 and 34.6 Ind/30 m², respectively (Table 7). The combined abundance of these two species represented 73.5 % of the community mean abundance within belt-transects. In addition to the two aforementioned species, the Sharknose Goby, Bucktooth and Redband Parrotfishes, Harlequin Bass, Blue Tang and the Coney were present within all five transects surveyed. Given their prevalence in previous surveys they appear to be part of the resident fish assemblage at this reef. Other fish species, such as the Fairy Basslet, Queen Angelfish, Rock Beauty, Lane and Schoolmaster Snappers were observed at the vertical wall habitat during the ASEC survey (Table 8). Only juvenile snappers were present. Angelfishes and grunts included both juveniles and adults.

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 the Great Barracuda was observed on top of the reef. Cero Mackerels and several species of jacks have been previously reported from this reef (García-Sais et al., 2005). Large (adult) commercially important demersal fishes (snappers, groupers, hogfishes) were not observed.

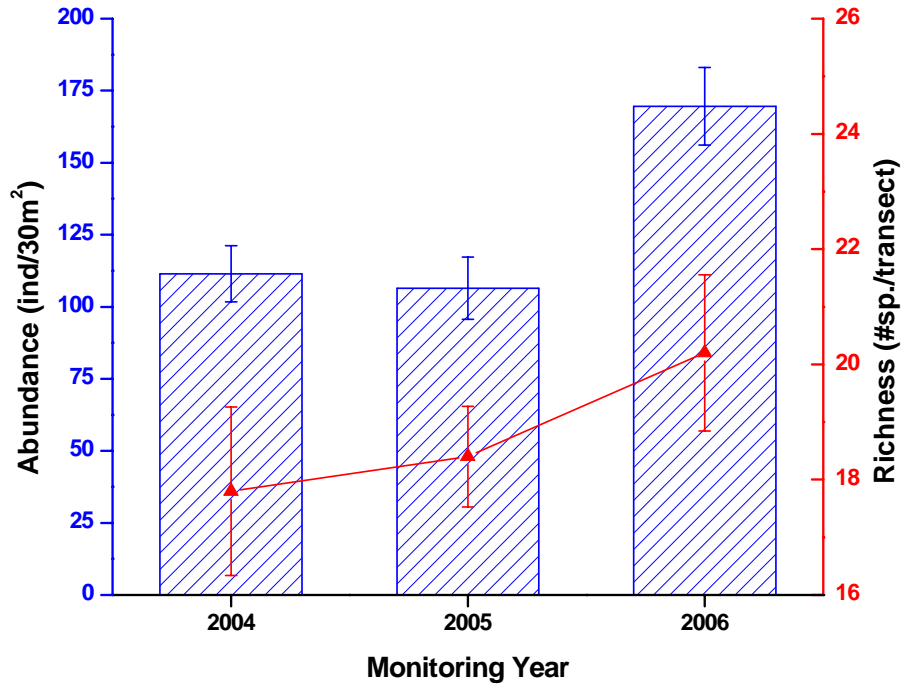


Figure 9. Monitoring trends (2004 – 2006) of fish species richness and abundance at Tres Palmas Outer Shelf Patch Reef, 12-15 m depth, Rincon.

Among motile megabenthic invertebrates, several Slate-pencil Urchins (*Eucidaris tribuloides*), Cleaner Shrimps (*Periclimenes sp.*, *Stenopus hispidus*), Arrow and Hermit Crabs (*Stenorhynchus seticornis*, *Paguridae*) and Sponge Brittle Stars were present within belt-transects (Table 9).

Table 7. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef, Rincon. Depth: 10 m. June, 2006

Depth: 10m Survey Date: June, 2006		TRANSECTS					MEAN
SPECIES	COMMON NAME	1	2	3	4	5	
		(Individuals/30 m ²)					
<i>Stegastes partitus</i>	Bicolor Damselfish	84	75	93	104	95	90.2
<i>Thalassoma bifasciatum</i>	Bluehead Wrasse	20	47	34	52	19	34.4
<i>Chromis cyanea</i>	Blue Chromis		42	3	2		9.4
<i>Sparisoma radians</i>	Bucktooth Parrotfish	7	5	4	4	3	4.6
<i>Gobiosoma evelynae</i>	Sharknose Goby	4	1	3	8	2	3.6
<i>Halichoeres garnoti</i>	Yellow-head Wrasse	7	3	2	2		2.8
<i>Cephalopholis fulva</i>	Coney	2	3	2	4	2	2.6
<i>Anisotremus surinamensis</i>	Black margate		11				2.2
<i>Halichoeres maculipinna</i>	Clown wrasse	4	3		3	1	2.2
<i>Chaetodon capistratus</i>	Foureye Butterflyfish	2		2	2	2	1.6
<i>Sparisoma aurofrenatum</i>	Redband Parrotfish	2	1	1	2	2	1.6
<i>Acanthurus coeruleus</i>	BlueTang	1	1	1	2	2	1.4
<i>Acanthurus bahianus</i>	Ocean Surgeon	1	2	2	1		1.2
<i>Malacoctenus triangulatus</i>	Saddled blenny	1			2	3	1.2
<i>Scarus taeniopterus</i>	Princess parrotfish	5			1		1.2
<i>Acanthurus chirurgus</i>	Doctorfish		1	1		3	1.0
<i>Serranus tigrinus</i>	Harlequin bass	1	1	1	1	1	1.0
<i>Scarus iserti</i>	Stripped parrotfish	1	1			2	0.8
<i>Amblycirrhitus pinos</i>	Redspotted Hawkfish	2				1	0.6
<i>Canthigaster rostrata</i>	Caribbean Puffer	1		1		1	0.6
<i>Sparisoma viride</i>	Stoplight parrotfish		2		1		0.6
<i>Holocentrus rufus</i>	Squirrelfish		1			1	0.4
<i>Sphoeroides greeleyi</i>	Green Puffer	1	1				0.4
<i>Stegastes leucostictus</i>	Beau Gregory			1	1		0.4
<i>Ophioblennius atlanticus</i>	Yellowhead jawfish				2		0.4
<i>Anisotremus virginicus</i>	Porkfish		1				0.2
<i>Bodianus rufus</i>	Spanish Hogfish			1			0.2
<i>Chromis multilineata</i>	Brown chromis		1				0.2
<i>Clepticus parrae</i>	Creole wrasse		1				0.2
<i>Flammeo marianus</i>	Longspine squirrelfish		1				0.2
<i>Haemulon flavolineatum</i>	French grunt			1			0.2
<i>Myripristis jacobus</i>	Blackbar soldierfish			1			0.2
<i>Cantherhines pullus</i>	Tail-light triggerfish			1			0.2
<i>Chaetodon striatus</i>	Banded butterflyfish	1					0.2
<i>Epinephelus guttatus</i>	Red hind			1			0.2
<i>Halichoeres radiatus</i>	Puddinwife		1				0.2
<i>Halichoeres sp.</i>	wrasse			1			0.2
<i>Haemulon plumieri</i>	White grunt		1				0.2
<i>Holocentrus adsencionis</i>	Longjaw squirrelfish		1				0.2
<i>Microspathodon chrysurus</i>	Yellowtail damselfish					1	0.2
<i>Stegastes variabilis</i>	Cocoa damselfish				1		0.2
	TOTAL INDIVIDUALS	147	208	157	195	141	169.6
	TOTAL SPECIES	19	25	21	19	17	20.2

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 system, 10 m depth, June, 2006.

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

SPECIES	COMMON NAME	# - (cm)			
<i>Epinephelus guttatus</i>	Red Hind	2 – (30)			
<i>Lutjanus apodus</i>	Schoolmaster	1 – (25)			
<i>Lutjanus synagris</i>	Lane Snapper	1 – (20)	1 – (25)		
<i>Sphyræna barracuda</i>	Great Barracuda	1 – (70)			
<i>Holacanthus ciliaris</i>	Queen Angel	1 – (30)			
<i>Grama loreto</i>	Fairy Basslet	17 – (3)	12 – (4)	6 – (5)	2 – (6)
<i>Holacanthus tricolor</i>	Rock Beauty	1 – (15)			
<i>Pomacanthus paru</i>	French Angel	2 – (35)			
Invertebrates					
<i>Panulirus argus</i>	Spiny Lobster	2 – (12)			

Table 9. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Reef, Rincon, 10m depth, June, 2006

DATE: June 2006	Depth: 10 m	TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	2	3	4	5	
TAXA	COMMON NAME						
<i>Ophiothrix suensoni</i>	Sponge Brittle Star		5				1.0
<i>Periclimenes pedersoni</i>	Cleaner Shrimp		1			2	0.6
<i>Paguridae</i>	Hermit Crab		1				0.2
<i>Stenorhynchus seticornis</i>	Arrow Crab		2			1	0.6
<i>Stenopus hispidus</i>	Banded coral Shrimp					1	0.2
<i>Eucidaris tribuloides</i>	Slate-pencil Urchin					1	0.2
TOTALS		0	9	0	0	5	2.8

Photo Album 2 (Rincon 15m)
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 was substantial sediment transport down the shelf-edge and most of the rocky substrate was 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, 13 of which were intercepted by line transects during our survey (Table 10). Stony corals occurred mostly as encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 20.13 % (range: 9.30 – 28.24 %). Boulder Star Coral, *Montastrea annularis* complex was the dominant species in terms of substrate cover with a mean of 5.99 % (range: 0.9 – 15.97 %), representing 29.8 % of the total cover by stony corals (Table 10). Colonies of *Montastrea annularis* and *M. cavernosa* were present in all five transects. Also present in four out of the five transects were colonies of Maze Coral, *Meandrina meandrites*, Mustard-Hill Coral, *Porites astreoides*, Lettuce Coral, *Agaricia agaricites*, and Ten-Ray Star Coral, *Madracis decactis*. Soft corals (gorgonians) were moderately abundant, with an average of 10.2 colonies/transect. The deep water Sea Fan, *Iciligorgia schrammi* was common at the shelf-edge, particularly at the edge of rock walls and crevices.

Encrusting and erect sponges, including several large Basket Sponges, *Xestospongia muta* were present in all transects with an average cover of 5.95 %. Reef overhangs averaged 9.36 % and contributed to a topographic rugosity of 2.34 m. Turf algae, comprised by an assemblage of short filamentous red and brown macroalgae was the

Table 10. Percent reef substrate cover by sessile-benthic categories at the Shelf-edge Reef off Tres Palmas, Rincon, June, 2006

		TRANSECTS					Mean
		1	2	3	4	5	
Survey Date: June, 2006							
Depth: 20.0 m							
Rugosity (m)		2.37	2.79	2.96	1.99	1.59	2.34
SUBSTRATE CATEGORIES							
BENTHIC ALGAE							
Turf Algae		58.45	24.00	22.84	46.17	36.21	37.53
Fleshy Algae		17.30	32.68	26.31	24.83	23.19	24.86
Filamentous Algae			1.80			5.00	1.36
Coralline Algae						0.61	0.12
Total Benthic Algae							63.88
ABIOTIC							
Reef Overhangs		8.33	8.37	14.97	8.08	7.07	9.36
SPONGES		6.14	4.30	6.33	3.17	9.83	5.95
ENCrustING GORGONIAN		0.46		2.31		0.24	0.60
LIVE CORAL							
<i>Montastrea annularis</i>		1.59	0.9	15.97	4.92	6.55	5.99
<i>Meandrina meandrites</i>			0.39	3.01	3.83	0.85	1.62
<i>Porites astreoides</i>		0.23	0.28		4.83	1.21	1.31
<i>Montastrea cavernosa</i>		2.43	0.46	1.63	1.41	0.61	1.31
<i>Colpophyllia natans</i>			0.68	3.47		1.82	1.19
<i>Agaricia agaricites</i>		2.43	0.10		1.08	2.07	1.14
<i>Diploria strigosa</i>		0.91	0.21			3.79	0.98
<i>Madracis decactis</i>		0.89	0.04		1.17	0.24	0.47
<i>Leptosetis cucullata</i>				1.30		0.73	0.41
<i>Dichocoenia stokesi</i>				1.54			0.31
<i>Siderastrea radians</i>		0.89	0.49				0.28
<i>Agaricia grahamae</i>					0.47		0.09
<i>Millepora alcicornis</i>			0.22				0.04
(P B) <i>Siderastrea radians</i>			6.61				1.32
Total Live Stony Coral		9.30	28.62	26.93	17.75	17.84	20.13
Recently Dead Corals							
<i>Colpophyllia natans</i>				0.62			0.12
<i>Montastrea annularis</i>					1.75		0.35
GORGONIANS (# Colonies/transect)		10	7	7	16	11	10.2

Coral Species Outside Transects: *Acropora cervicornis*, *Favia fragum*, *Porites porites*, *Isophyllastrea rigida*, *Manicina areolata*, *Siderastrea siderea*, *Millepora alcicornis*, *Stylaster roseus*

dominant sessile-benthic component in terms of substrate cover with an average of 37.53 % (range : 24.0 – 58.46 %). Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard ground. Fleshy brown and red macroalgae, particularly *Lobophora sp.* and *Amphiroa sp.* were also common in the reef, contributing an additional 24.86 % to the reef substrate cover. Isolated tufts of red coralline alga (*Amphiroa sp.*) and other green filamentous algae were also present. The total reef substrate cover by benthic algae was 63.88 %.

Figure 10 presents the variation of percent cover by sessile-benthic components at the Tres Palmas shelf-edge reef in Rincón between monitoring surveys, including the baseline characterization of 2004 and the monitoring surveys of 2005 and 2006. Mean live coral cover declined by 2.94 % since the baseline characterization in 2004, but differences are not statistically significant (ANOVA, $p > 0.05$). A general trend of declining mean coral cover between the monitoring surveys of 2005 and 2006 is suggested by the data, particularly for the dominant coral species, *Montastrea annularis* complex (Figure 11). Still, the variability in both magnitude and direction of live coral cover within transects is high enough to render the differences between monitoring years statistically insignificant, even for *M. annularis* ($p = 0.53$).

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 76 fish species have been identified during the three surveys (2004-06) from the shelf-edge reef off Tres Palmas (Appendix 1). Table 11 lists the 43 species present within belt-transects during the most recent 2006 survey in decreasing order of abundance. Mean abundance within belt-transects was 285.8 Ind/30 m² (range: 134 – 389 Ind/30 m²). The mean number of species per transect was 24 (range: 20– 27). Fish species richness increased by 4.0 % and mean abundance decreased by 13.4 % compared to the 2005 survey (Figure 12). Differences in fish species richness and abundance between monitoring years were not statistically significant (ANOVA; $p > 0.05$). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species during the 2006 survey with a mean abundance of 121.8 Ind/30 m² (range: 14 – 210 Ind/30 m²), representing 42.6 % of the total abundance within belt-transects (Table 11). The Masked Goby is a small carnivorous fish (< 2.0 cm) that forms swarms of

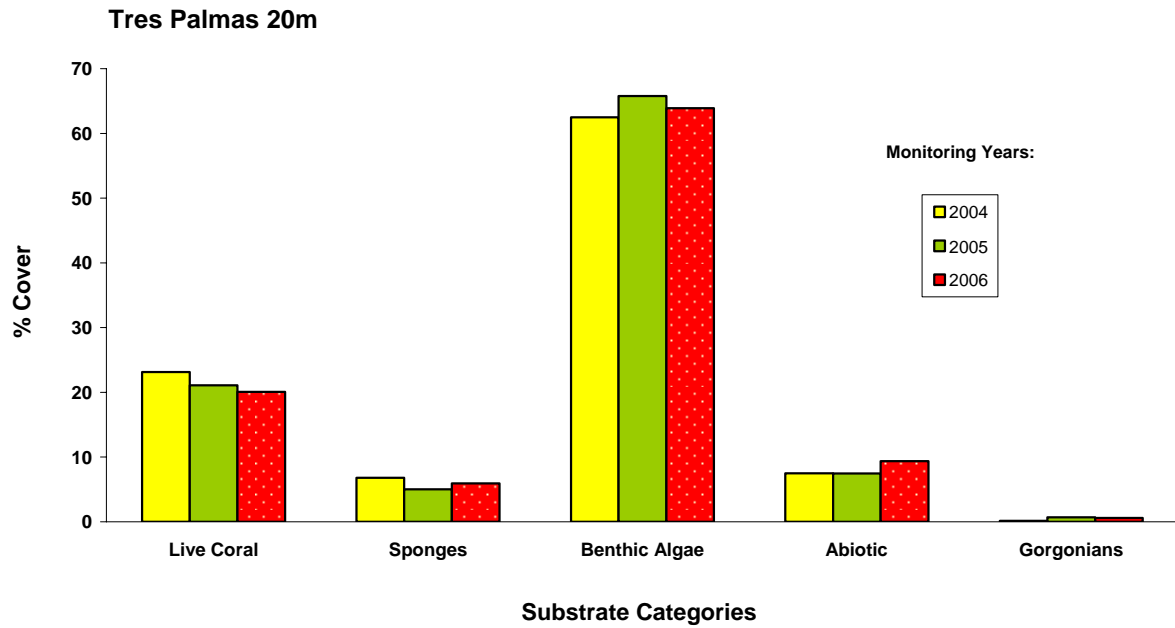


Figure 8. Monitoring trends of mean substrate cover by sessile-benthic categories at Tres Palmas Reef – 20 m.

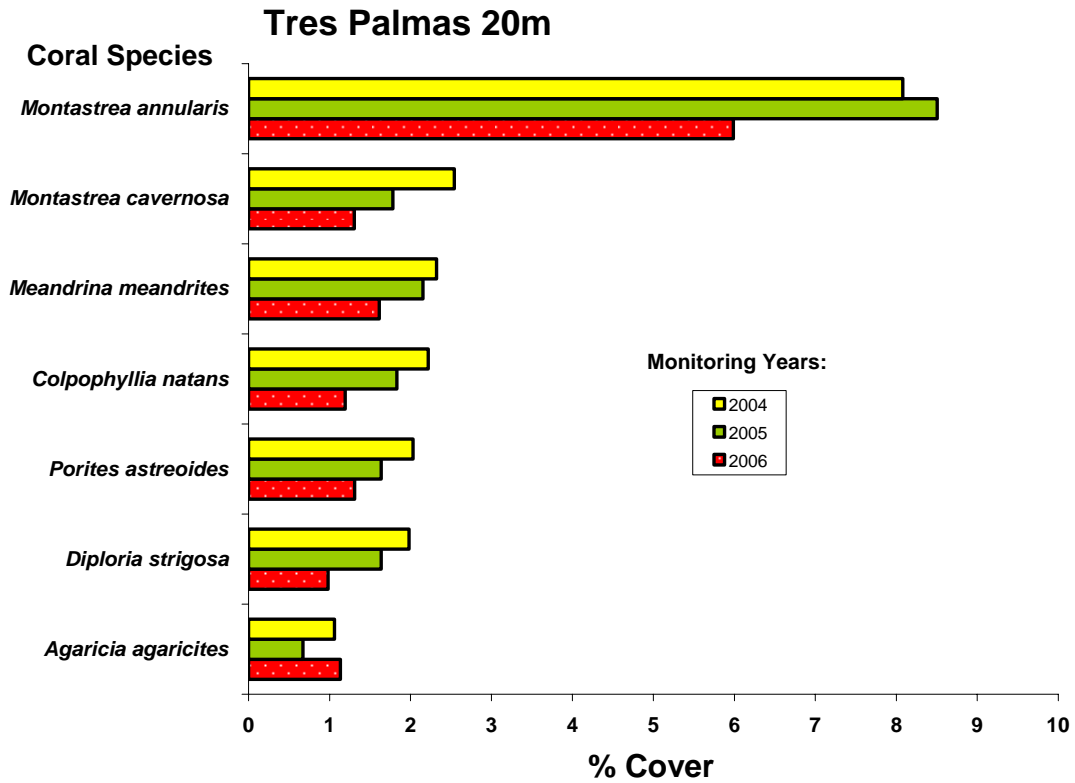


Figure 9. Monitoring trends of mean substrate cover by stony coral species at Tres Palmas Reef – 20 m.

Table 11. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef, Rincon. June, 2006

Depth: 20 m		TRANSECTS					MEAN
SPECIES	COMMON NAME	1	2	3	4	5	
		(Individuals/30 m ²)					
<i>Coryphopterus personatus</i>	Masked goby	100	180	14	210	105	121.8
<i>Stegastes partitus</i>	Bicolor Damselfish	52	23	33	61	62	46.2
<i>Chromis cyanea</i>	Blue Chromis	42	15	15	34	12	23.6
<i>Coryphopterus lipernes</i>	Peppermint Goby	33	26	22	14	12	21.4
<i>Thalassoma bifasciatum</i>	Bluehead Wrasse	26	14	5	12	8	13.0
<i>Clepticus parrae</i>	Creole Wrasse	3	2	8	28	22	12.6
<i>Gramma loreto</i>	Royal Gramma	30					6.0
<i>Halichoeres garnoti</i>	Yellow-head Wrasse	12	3	1	4	3	4.6
<i>Mulloides martinicus</i>	Yellowtail Goatfish	18					3.6
<i>Stegastes leucostictus</i>	Beau Gregory	2	6	3	2	3	3.2
<i>Chromis multilineata</i>	Brown Chromis	6	2	2	1	4	3.0
<i>Gobiosoma evelynae</i>	Sharknose Goby		2	7	2	2	2.6
<i>Haemulon flavolineatum</i>	French Grunt	12				1	2.6
<i>Sparisoma radians</i>	Bucktooth Parrotfish		3	5	2	1	2.2
<i>Cephalopholis cruentatus</i>	Graysby		2	2	3	2	1.8
<i>Canthigaster rostrata</i>	Caribbean Puffer	2		2	2	2	1.6
<i>Chaetodon capistratus</i>	Foureye Butterflyfish	2	1	2		2	1.4
<i>Flammeo marianus</i>	Longspine Squirrelfish	2	2	1	1	1	1.4
<i>Myripristis jacobus</i>	Blackbar Soldierfish		1	2	2	1	1.2
<i>Sparisoma aurofrenatum</i>	Redband Parrotfish	2		1		3	1.2
<i>Chromis insulata</i>	Sunshine Chromis	6					1.2
<i>Acanthurus bahianus</i>	Ocean Surgeon	1	1	1		2	1.0
<i>Bodianus rufus</i>	Spanish Hogfish	1		1	1	2	1.0
<i>Scarus iserti</i>	Stripped Parrotfish	1		2	2		1.0
<i>Amblycirrhites pinos</i>	Redspotted Hawkfish	1		1	1		0.6
<i>Holocentrus rufus</i>	Squirrelfish			1	2		0.6
<i>Hypoplectrus puella</i>	Barred Hamlet	1	2				0.6
<i>Serranus tigrinus</i>	Harlequin Bass	1				2	0.6
<i>Acanthurus chirurgus</i>	Doctorfish	1			1		0.4
<i>Apogon sp.</i>	Cardinalfish					2	0.4
<i>Anisotremus virginicus</i>	Porkfish	1				1	0.4
<i>Carangoides ruber</i>	Horse-eye Jack		2				0.4
<i>Coryphopterus sp.</i>	Goby		1	1			0.4
<i>Holacanthus ciliaris</i>	Queen Angelfish	1			1		0.4
<i>Acanthurus coeruleus</i>	BlueTang				1		0.2
<i>Cephalopholis fulva</i>	Coney					1	0.2
<i>Holacanthus tricolor</i>	Rock Beauty		1				0.2
<i>Hypoplectrus unicolor</i>	Butter Hamlet	1					0.2
<i>Melychthis niger</i>	Black Durgon			1			0.2
<i>Paranthias furcifer</i>	Creole Fish	1					0.2
<i>Synodus intermedius</i>	Sand Diver				1		0.2
<i>Sparisoma chrysopterum</i>	Redtail Parrotfish			1			0.2
	TOTAL INDIVIDUALS	361	289	134	389	256	285.8
	TOTAL SPECIES	27	20	25	24	24	24

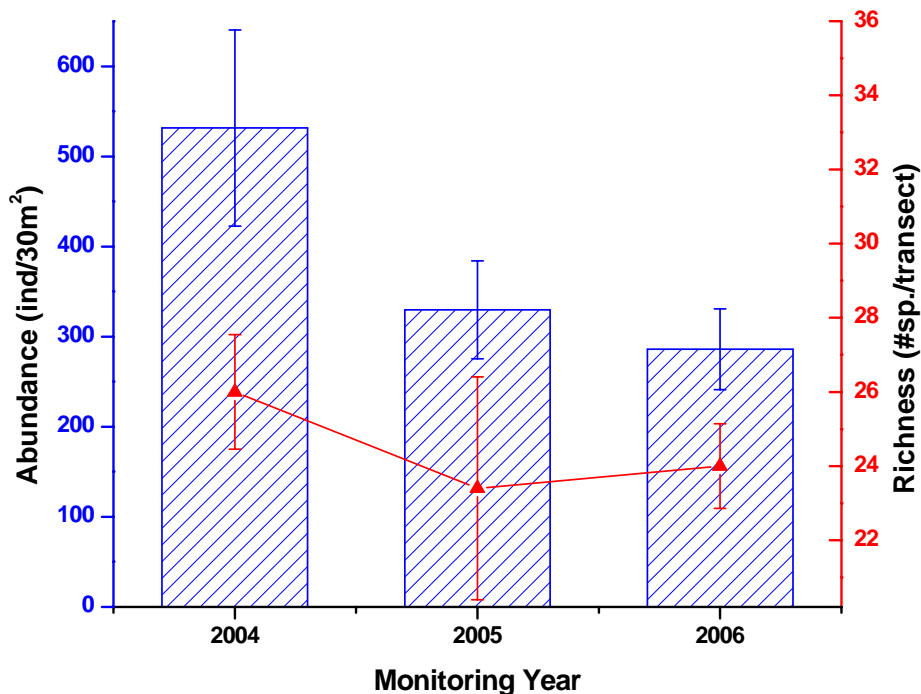


Figure 12. Monitoring trends (2004 – 2006) of fish species richness and abundance at Tres Palmas Shelf Edge Reef, 20 m depth, Rincon.

hundreds of individuals below large coral ledges and near the sand-coral interface of the spur and groove reef formation. In many instances, swarms of Masked Goby coincided with swarms of mysid shrimps on the reef. It is possible that gobies were feeding on them. The Bicolor Damselfish, Blue and Brown Chromis, Masked, Peppermint and Sharknose Gobies, Bluehead and Yellowhead Wrasse, Creole Wrasse, Longspine Squirelfish and Beaugregory were present within all five transects surveyed. Their combined abundance represented 87.8 % of the total fish abundance within belt-transects.

The fish community associated with the Tres Palmas shelf-edge reef appears to be well balanced in terms of trophic structure, except for the absence of large demersal predators, such as large snappers and groupers. However, this is the present condition for most insular coral reefs. Large schools of Creole Wrasse, *Clepticus parrae* and 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,

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 (3 spp), hamlets (2 spp), gobies (3 spp), and squirrelfishes (3 spp), 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 (5 spp), doctorfishes (3 spp) and damselfishes (3 spp) 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 Angelfish (*Holacanthus ciliaris*), Rock Beauty (*Holacanthus tricolor*), Blue Chromis (*Chromis cyanea*) and Peppermint Bass (*Liopropoma rubre*).

The Arrow Crab, *Stenorhynchus seticornis*, the cleaner shrimp, *Periclimenes sp.* and Spiny Lobster, *Panulirus argus* were the motile megabenthic invertebrates observed within belt-transects (Table 13).

Table 12. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at the shelf-edge off Tres Palmas Reef, Rincón, June, 2006

Depth range : 18 - 22 m

Duration - 30 min.

SPECIES	COMMON NAME	# - (cm)		
<i>Chromis cyanea</i>	Blue chromis	74 – (< 2)	42 – (3-4)	9 – (> 4)
<i>Carangoides crysos</i>	Blue Runner	1 – (50)		
<i>Chaetodon sedentarius</i>	Reef Butterflyfish	1 - (8)		
<i>Dasyatis americana</i>	Southern Stingray	1 – (60)		
<i>Epinephelus guttatus</i>	Red Hind	1 - (30)		
<i>Gramma loreto</i>	Fairy Basslet	4 - (< 3)	23 - (4)	7 - (6)
<i>Holacanthus ciliaris</i>	Queen Angel	1 - (15)	1 - (35)	
<i>Holacanthus tricolor</i>	Rock Beauty	1 - (15)	1 - (20)	1 - (25)
<i>Lutjanus apodus</i>	Schoolmaster	1 - (25)		
<i>Lutjanus synagris</i>	Lane Snapper	2 - (20)		
<i>Ocyurus chrysurus</i>	Yellowtail Snapper	3 – (25)	1 - (30)	
<i>Opistognathus aurifrons</i>	Yellowhead Jawfish	2 – (6)	4 - (10)	
<i>Scomberomorus regalis</i>	Cero Mackerel	1 - (25)	4 - (30)	1 – (50)
<i>Sphyrnaea barracuda</i>	Great Barracuda	1 - (65)		
Invertebrates				
<i>Panulirus argus</i>	Spiny Lobster	1 - (12)		

Table 13. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Shelf-edge Reef, Rincon, June, 2006

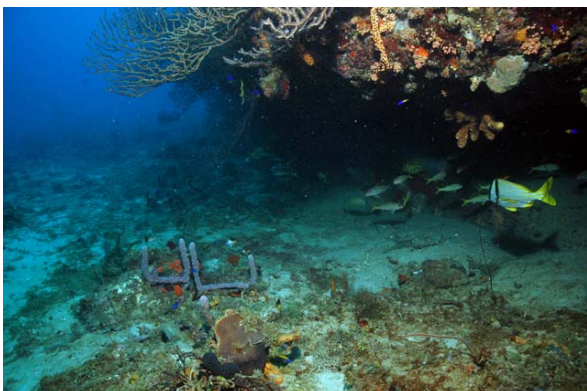
DATE: June 2006

Depth: 20 m

SPECIES	COMMON NAME	TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	2	3	4	5	
<i>Stenorhynchus seticornis</i>	Arrow Crab				2		0.4
<i>Panulirus argus</i>	Spiny Lobster				1		0.2
TOTALS		0	0	0	3	0	0.6

Photo Album 3 (Rincon 20m)
Shelf edge Reef





B. Puerto Canoas /Puerto Botes Reefs - Isla Desecheo

Isla Desecheo is an oceanic island in the 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). 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. 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 (*Montastrea annularis*). 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 27 – 30 m, bordering the edge of two of the larger massive coral promontories. Panoramic views of the shelf edge reef at Puerto Canoas are presented as Photo Album 4.

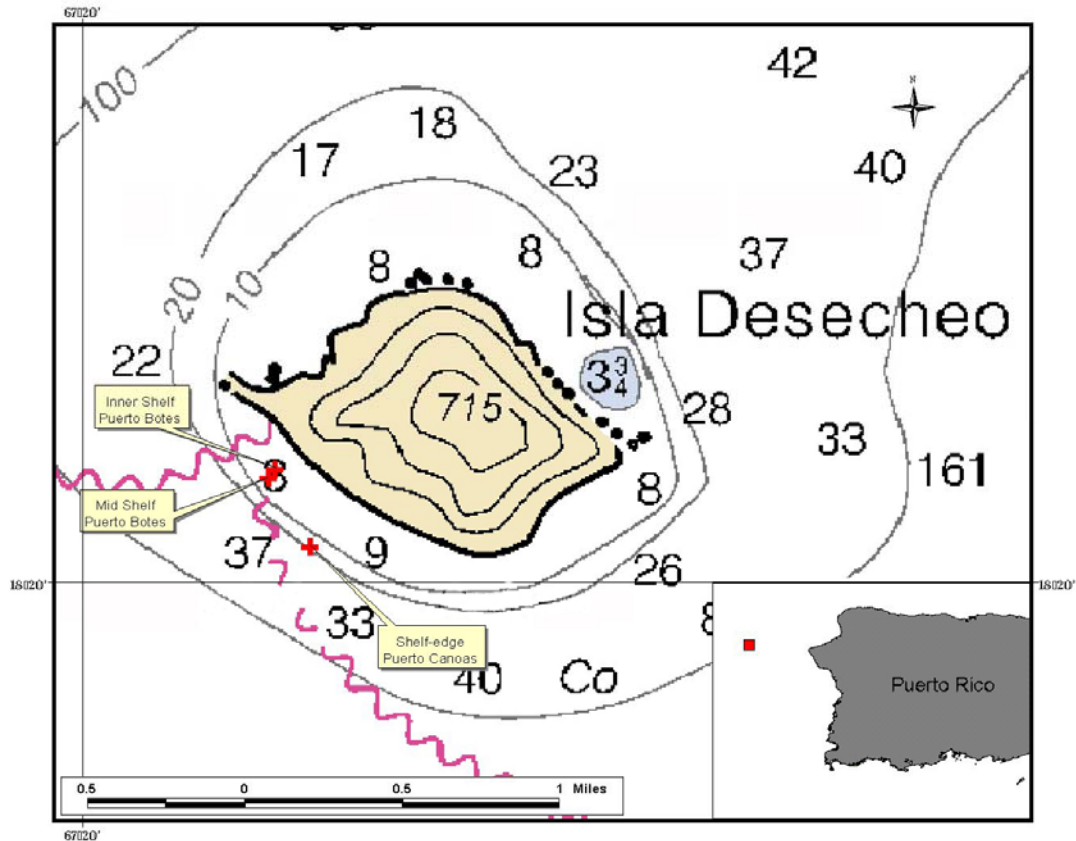


Figure 13. Location of coral reef survey stations at Puerto Canoas/Botes, Isla Desecheo.

Stony corals dominated reef substrate cover along surveyed transects with a mean of 37.50% (range: 25.25 – 49.81 %). Boulder Star Coral (*Montastrea annularis*), with a mean cover of 24.44 % (5.7 % partially bleached condition) represented 65.2 % 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 17 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 20.82 % and contributed to a mean reef substrate rugosity of 4.26. Encrusting and erect sponges were common, with a mean cover of 6.12 % (range: 1.02 – 8.26 %).

Table 14. Percent reef substrate cover by sessile-benthic categories at the Shelf-edge
Reef off Puerto Canoas, Isla Desecheo, June, 2006

Survey Date: June, 2006 Survey Depth: 30 m		Transects					Mean
		1	2	3	4	5	
Rugosity (m)		3.7	4.31	4.63	5.16	3.49	4.26
SUBSTRATE CATEGORIES							
BENTHIC ALGAE							
Turf Algae		19.64	13.68	14.34	15.96	12.01	15.13
Fleshy Algae		13.14	30.91	8.38	15.77	24.54	18.54
Total Benthic Algae		32.78	44.59	22.72	31.73	36.55	33.67
CYANOBACTERIA		1.53	3.35	2.12	4.02	1.70	2.55
ABIOTIC							
Gaps						1.04	0.21
Reef Overhangs		19.93	14.96	26.48	27.44	14.23	20.61
Total Abiotic							20.82
SPONGES							
Encrusting			0.39	9.63			2.00
Erect		1.02	7.87		5.41	6.30	4.12
Total Sponges							6.13
LIVE CORAL							
<i>Montastrea annularis</i>		18.55	27.03	21.43	22.43	32.78	24.44
<i>Colpophyllia natans</i>		15.11	3.94		0.84		3.98
<i>Agaricia agaricites</i>		6.89	2.46	3.08	5.02	1.67	3.82
<i>Porites astreoides</i>		0.62	3.54	0.77	2.77	3.65	2.27
<i>Eusmilia fastigiata</i>		4.01	2.17		0.19		1.27
<i>Meandrina meandrites</i>		2.06			1.49		0.71
<i>Diploria strigosa</i>						2.19	0.44
<i>Porites porites</i>		2.06					0.41
<i>Agaricia grahamae</i>		0.51					0.10
<i>Scolymia cubensis</i>					0.28		0.06
Total Stony Coral		49.81	39.14	25.25	32.74	40.29	37.50
Recently Dead Corals							
<i>Montastrea annularis</i>				18.87	5.41		4.86
PB <i>Montastrea annularis</i>		5.55	10.33	5.1	6.99	0.52	5.70
GORGONIANS (# col/ transect)		0	0	0	0	0	0

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

Benthic macroalgae, comprised by an assemblage of turf and fleshy macroalgae presented a combined substrate cover of 33.67 % along permanent transects. *Lobophora variegata*, *Padina sp.* and *Ventricaria ventricosa* were some of the most common fleshy macroalgae present. Turf algae included an unidentified variety of short filamentous red and brown macroalgae. A slimy red cyanobacterial film was present in all five transects with a mean substrate cover of 2.55 %.

Figure 13 presents the 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 all within 1 %. A sharp, statistically significant decline of mean live coral cover between the 2005 (48.07 %) and the 2006 (37.50 %) monitoring surveys was observed (ANOVA; $p = 0.029$). The reduction of live coral cover was evidenced from all five transects surveyed. A corresponding increment of substrate cover by benthic algae, sponges and abiotic categories was measured (Figure 13). The decline of mean live coral cover was largely associated with the dominant reef building species, *Montastrea annularis*, which varied from a mean cover of 32.7 % in 2005 to 24.44 % in 2006 (Figure 14). At the time of the 2006 monitoring survey (mid June), *M annularis* still showed partially bleached conditions representing 5.70 % of its mean reef substrate cover, equivalent to 23.4 % of the remaining live coral tissue within surveyed transects at 30 m.

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 89 fish species have been identified during the three surveys (2004-06) from the shelf-edge reef off Puerto Canoas, Isla Desecheo (Appendix 1). Mean abundance of fishes within belt-transects during June, 2006 was 404.0 Ind/30 m² (range: 327 – 600 Ind/30 m²). The mean number of species per transect was 30.7 (range: 26 – 35) (Table 15). Compared to the 2005 survey, both mean fish abundance and species richness declined by 9.0 % and 4.5 %, respectively (Figure 15). Variations of mean fish abundance and species richness between the 2005 and the present 2006 survey were not statistically significant (ANOVA; $p > 0.05$).

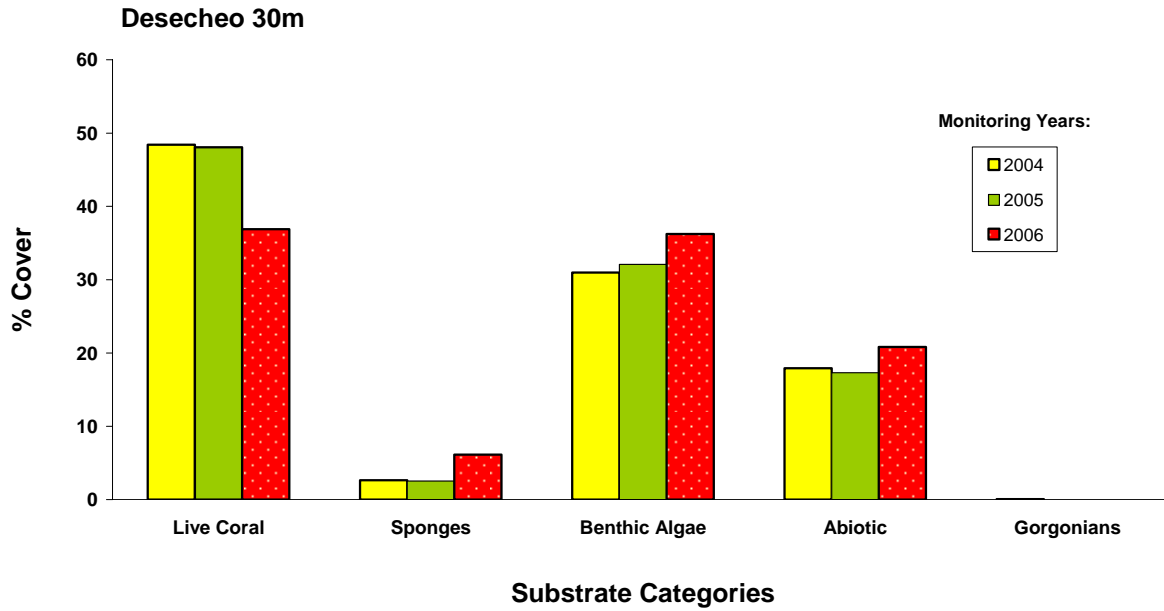


Figure 13. Monitoring trends (2004 – 06) of substrate cover by sessile-benthic categories at Puerto Canoas Reef – 30 m.

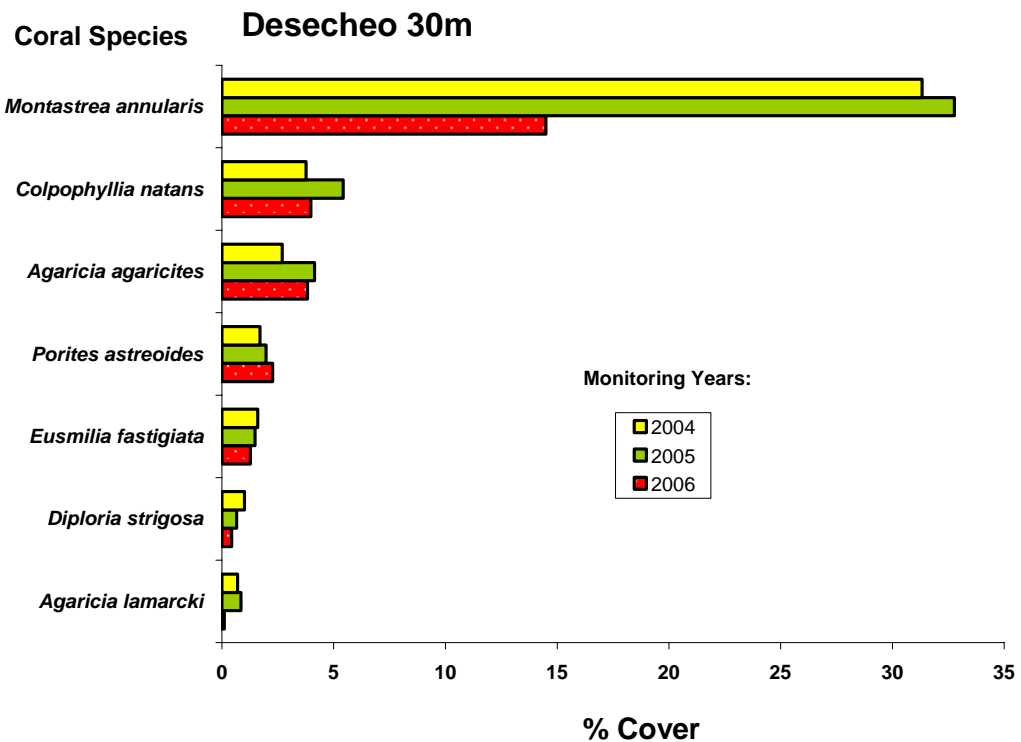


Figure 14. Monitoring trends (2004-06) of mean substrate cover by stony coral species at Puerto Canoas Reef – 30 m.

The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 130.3 Ind/30 m² (range: 70 – 260 Ind/30 m²), representing 32.2 % of the total fish abundance within belt-transects (Table 15). A total of 15 species were present within all six belt-transects surveyed. The combined abundance of Masked and Peppermint Gobies, Creole Wrasse, Blue and Brown Chromis, Fairy Basslet, and Bicolor Damselfish represented 90.4 % of the total fish abundance at Puerto Canoas Reef. Large streaming schools of 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, Rainbow 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.

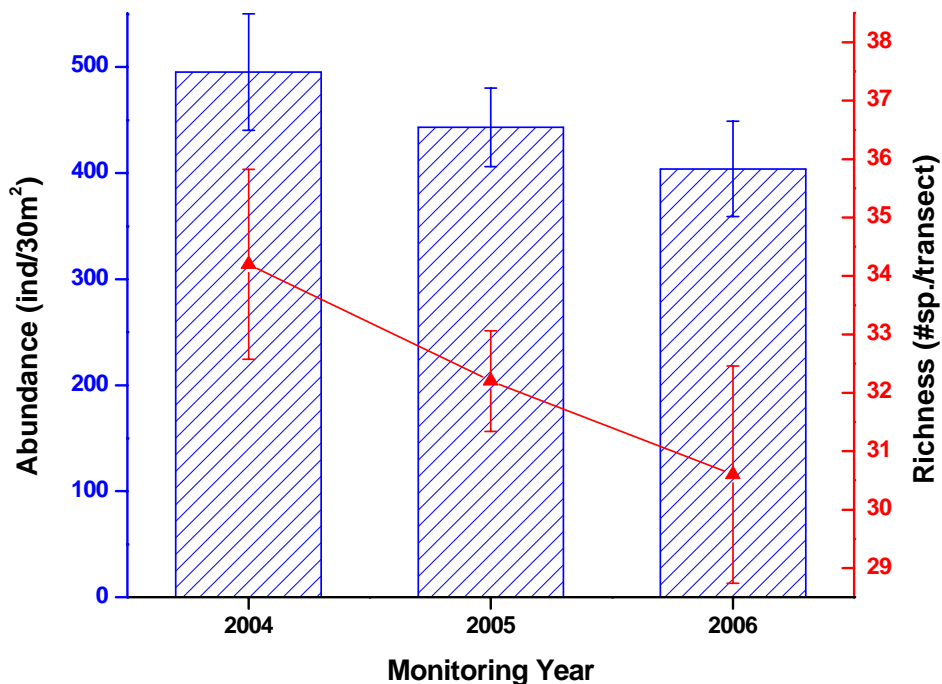


Figure 15. Monitoring trends (2004 – 2006) of fish species richness and abundance at Shelf-edge Reef Puerto Canoas, 30 m depth, Isla Desecheo.

Table 15. Taxonomic composition and abundance of fishes within belt-transects at Puerto Canoas Reef, Isla Desecheo. June, 2006

Depth: 30m Survey Date: June, 2006		TRANSECTS						MEAN
		1	2	3	4	5	6	
SPECIES	COMMON NAME	(Individuals/30 m ²)						
<i>Coryphopterus personatus</i>	Masked goby	70	140	112	80	120	260	130.3
<i>Chromis cyanea</i>	Blue Chromis	60	86	35	54	76	102	68.8
<i>Clepticus parrae</i>	Creole wrasse	130	57	36	17	72	52	60.7
<i>Chromis multilineata</i>	Brown Chromis	22	130	17	6	16	10	33.5
<i>Gramma loreto</i>	Fairy Basslet	12	40	27	23	42	39	30.5
<i>Coryphopterus lipernes</i>	Peppermint goby	17	23	31	32	17	20	23.3
<i>Stegastes partitus</i>	Bicolor Damselfish	9	9	11	22	25	32	18.0
<i>Thalassoma bifasciatum</i>	Bluehead Wrasse	6	5	10	9	8	6	7.3
<i>Gobiosoma evelynae</i>	Sharknose Goby	3	11	6	7	5	11	7.2
<i>Halichoeres garnoti</i>	Yellow-head Wrasse	8	5	5	5	5	5	5.5
<i>Decapterus macarellus</i>	Mackerel scad						30	5.0
<i>Caranx lugubris</i>	Black jack		18	1				3.2
<i>Mulloides martinicus</i>	Yellowtail goatfish	2	11			3		2.7
<i>Kyphosus bermudensis.</i>	Sea Chub	6	4	5				2.5
<i>Paranthias furcifer</i>	Creole fish	3	2	3	2	3	2	2.5
<i>Sparisoma radians</i>	Bucktooth Parrotfish	4	3	6		1		2.3
<i>Chromis insolata</i>	Sunshine chromis					6	8	2.3
<i>Cephalopholis cruentatus</i>	Graysby	1	2	3	1	3	3	2.2
<i>Scarus iserti</i>	Stripped Parrotfish	3	3	1	2	1	1	1.8
<i>Amblycirrhitus pinos</i>	Redspotted Hawkfish	1	1	2	3	1	2	1.7
<i>Acanthurus coeruleus</i>	BlueTang	1	2	2	1	1	1	1.3
<i>Bodianus rufus</i>	Spanish Hogfish	1		4	1		1	1.2
<i>Chaetodon capistratus</i>	Foureye Butterflyfish	2	1	1		1	2	1.2
<i>Melichthys niger</i>	Black Durgon		1	2	2		2	1.2
<i>Flammeo marianus</i>	Longspine Squirrelfish	1	1		2	1	1	1.0
<i>Halichoeres maculipinna</i>	Clown Wrasse	1		3	1		1	1.0
<i>Caranx latus</i>	Horse-eye jack	5						0.8
<i>Sparisoma aurofrenatum</i>	Redband Parrotfish	2	1		1	1		0.8
<i>Sparisoma rubripinne</i>	Yellowtail parrotfish				4	1		0.8
<i>Sparisoma viride</i>	Stoplight Parrotfish	1	1		3			0.8
<i>Coryphopterus glaucofraenum</i>	Bridled Goby		1		1	1	1	0.7
<i>Lutjanus apodus</i>	Schoolmaster snapper	1	1			1		0.5
<i>Microspathodon chrysurus</i>	Yellowtail Damselfish	1			1	1		0.5
<i>Canthigaster rostrata</i>	Caribbean puffer		1			1	1	0.5
<i>Holacanthus tricolor</i>	Rock Beauty		1			1	1	0.5
<i>Lactophrys triqueter</i>	Smooth Trunkfish		1			1	1	0.5
<i>Stegastes planifrons</i>	Yellow-eye damselfish	1				1	1	0.5
<i>Acanthurus chirurgus</i>	Doctorfish		1		1			0.3
<i>Carangoides ruber</i>	Bar jack		2					0.3
<i>Chaetodon aculeatus</i>	Longsnout butterflyfish		1			1		0.3
<i>Sparisoma chrysopterum</i>	Redtail Parrotfish			1		1		0.3
<i>Scarus vetula</i>	Queen Parrotfish	1	1					0.3

Table 15. Continued								
<i>Scarus vetula</i>	Queen Parrotfish	1	1					0.3
<i>Cantherhines surinamensis</i>	Ocean Triggerfish				1	1		0.3
<i>Cephalopholis fulva</i>	Coney					1	1	0.3
<i>Equetus punctatus</i>	Spotted Drum		1				1	0.3
<i>Myripristis jacobus</i>	Blackbar Soldierfish				1		1	0.3
<i>Acanthostracion quadricornis</i>	Honeycomb trunkfish		1					0.2
<i>Aulostomus maculatus</i>	Trumpetfish					1		0.2
<i>Balistes vetula</i>	Queen triggerfish			1				0.2
<i>Gobiosoma sacrum</i>	Leopard Goby				1			0.2
<i>Diodon holacanthus</i>	Balloonfish		1					0.2
<i>Gymnothorax funebris</i>	Green moray		1					0.2
<i>Holacanthus ciliaris</i>	Queen Angelfish				1			0.2
<i>Holocentrus rufus</i>	Squirrelfish					1		0.2
<i>Liopropoma rubre</i>	Peppermint Bass					1		0.2
<i>Acanthurus bahianus</i>	Ocean surgeon							0.0
TOTAL INDIVIDUALS		375	569	327	327	422	600	404.0
TOTAL SPECIES		28	35	26	29	35	31	30.7

The shelf-edge reef off Puerto Canoas presented an unusually well balanced fish community in terms of trophic structure, including the presence of large demersal and pelagic predators, such as Dog Snappers, Nassau and Yellowfin Groupers, Barracudas, Cero Mackerels, Blue Runners, Rainbow Runners and Black Jacks (Table 16). Yellowtail, Mahogany and Schoolmaster Snappers, Red Hind, Coney and Queen Triggerfish were observed in full adult sizes. The Caribbean Reef Shark (*Carcharhinus perezii*) was reported in a previous survey of this reef (García-Sais et al., 2004). 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. The Arrow Crab, *Stenorhynchus seticornis* and the cleaner shrimps, *Periclimenes sp.* and *Stenopus hispidus* were the motile megabenthic invertebrates observed within belt-transects (Table 17). One Spiny Lobster, *Panulirus argus*, the Clinging Crab, *Mithrax spinosissimus*, and the Queen Conch (*Strombus gigas*) were observed outside transects during the ASEC survey.

Table 16. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Puerto Canoas Reef, Isla Desecheo, June, 2006

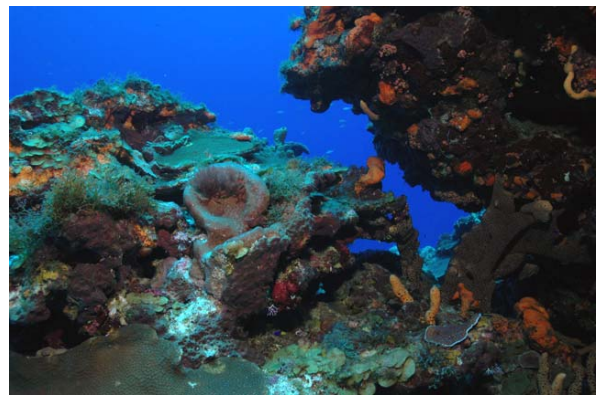
Depth range : 25 - 30 m
Duration - 30 min.

SPECIES	COMMON NAME	# - (cm)		
<i>Carangoides crysos</i>	Blue Runner	4 – (30)	2 - (40)	2 - (50)
<i>Caranx hippos</i>	Horse-eye Jack	4 – (30)	6 - (40)	
<i>Caranx lugubris</i>	Black Jack	1 - (50)	1 - (70)	
<i>Chaetodon aculeatus</i>	Longsnout Butterflyfish	3 - (5)	5 - (7)	
<i>Dasyatis americana</i>	Southern Stingray	1 - (120)		
<i>Elagatis bipinnulata</i>	Rainbow Runner	2 – (50)		
<i>Epinephelus guttatus</i>	Red Hind	2 - (30)	1 - (40)	
<i>Epinephelus striatus</i>	Nassau Grouper	1 - (50)	1 - (60)	1 - (75)
<i>Gramma loreto</i>	Fairy Basslet	40 - (<3)	11 - (4-5)	3 -(>5)
<i>Holacanthus ciliaris</i>	Queen Angel	1 - (40)		
<i>Holacanthus tricolor</i>	Rock Beauty	2 - (20)	2 - (25)	1 - (15)
<i>Lactophrys trigonus</i>	Buffalo Trunkfish	1 - (35)		
<i>Lutjanus apodus</i>	Schoolmaster	11 - (30)	6 - (40)	1 - (50)
<i>Lutjanus jocu</i>	Dog Snapper	1 - (40)		
<i>Lutjanus mahogany</i>	Mahogani Snapper	1 - (25)		
<i>Mycteroperca venenosa</i>	Yellowfin Grouper	1 - (45)		
<i>Ocyurus chrysurus</i>	Yellowtail Snapper	1 - (35)		
<i>Scomberomorus regalis</i>	Cero Mackerel	2 - (40)	2 - (60)	
<i>Sphyraena barracuda</i>	Great Barracuda	1 - (60)		
Invertebrates				
<i>Panulirus argus</i>	Spiny Lobster	1 - (15)		
<i>Strombus gigas</i>	Queen Conch	2 - (25)		
<i>Mithrax spinosissimus</i>	Channel Clinging Crab	1 – (15)		
Sea Turtles				
<i>Eretmochelys imbricata</i>	Hawksbill Turtle	2 – (70)		

Table 17. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at the shelf-edge of Puerto Canoas Reef, Isla Desecheo, June, 2006

SPECIES	COMMON NAME	TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	2	3	4	5	
<i>Stenorhynchus seticornis</i>	Arrow crab		2	1	1	1	1.0
<i>Periclimenes sp.</i>	Cleaner Shrimp	1	1		1		0.6
<i>Stenopus hispidus</i>	Banded Coral Shrimp					1	0.2
TOTALS		1	3	1	2	2	1.8

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 northwest coast of Isla Desecheo. The coral reef system is exuberant, with large stony corals growing close together and forming large promontories that provide very high topographic relief. At some points, sand channels cut through the sloping terrace of the reef towards the shelf-edge. Permanent transects were installed over two adjacent patch reef promontories separated by a narrow sand channel. The five transects lie close to the border of each patch reef at depths between 17 -19 m. The initial baseline characterization was performed in June, 2000 (García-Sais et al., 2001). This is the fourth monitoring survey of the mid-shelf patch reefs at Puerto Botes. Panoramic views of the mid shelf patch reef at Puerto Botes are presented as Photo Album 5.

A total of 24 stony corals, including 12 intersected by line transects were identified during this survey. Finger Coral, *Porites porites* was the species of highest percent substrate cover with a mean of 6.42 % (range: 0 – 29.63). Boulder Star Coral, *Montastrea annularis* (complex), Lettuce Coral, *Agaricia agaricites*, and Great Star Coral *M. cavernosa* comprised (with Finger Coral) the most prominent coral assemblage along transects representing 83.5 % of the total cover by live corals at Puerto Botes (Table 18). Reef overhangs, largely associated with skeletal buildups of *M. annularis* averaged 11.17 % of the reef substrate cover and contributed substantially to the reef rugosity of 3.96 m. Erect and encrusting sponges were present with a mean substrate cover of 4.54 %. Reef hard-ground substrates not colonized by stony corals or sponges were mostly overgrown by a dense algal turf (mean cover: 46.06 %), comprised of a mixed assemblage of red coralline and brown macroalgae. Fleshy brown (*Lobophora sp.*, *Dictyota sp.*, *Padina sp.*) and calcareous macroalgae contributed an additional 15.48 % to the total benthic algal cover at Puerto Botes (Table 18).

Table 18. Percent reef substrate cover by sessile-benthic categories at the Mid-shelf Reef off Puerto Canoas, Isla Desecheo, June, 2006

Survey Date: June, 2006

TRANSECTS

Depth: 20 m

	1	2	3	4	5	Mean
Rugosity (m)	2.92	5.48	4.28	2.69	4.41	3.96
SUBSTRATE CATEGORIES						
BENTHIC ALGAE						
Turf Algae	60.76	50.19	45.62	22.30	51.42	46.06
Fleshy Algae	13.85	15.31	17.94	14.58	13.12	14.96
Coralline Algae	0.65			0.89	0.29	0.37
Blue-green Algae		1.27				0.25
Total Benthic Algae	75.27	66.78	63.56	37.77	64.83	61.64
ABIOTIC						
Reef Overhangs	6.19	15.63	13.59	8.90	11.52	11.17
Gap				1.02	0.49	0.30
Total Abiotic	6.19	15.63	13.59	9.92	12.01	11.47
SPONGES						
Erect		8.72	3.22	7.96	2.15	4.41
Encrusting	0.65					0.13
LIVE CORAL						
<i>Porites porites</i>		1.29		29.63	1.17	6.42
<i>Montastrea annularis</i>	5.03	2.97	8.48	3.47	3.54	4.70
<i>Agaricia agaricites</i>	2.63	2.45	4.27	2.68	8.67	4.14
<i>Montastrea cavernosa</i>	8.83		2.47		5.76	3.41
<i>Diploria labyrinthiformis</i>				4.81		0.96
<i>Meandrina meandrites</i>	1.09		1.18	0.78	1.18	0.85
<i>Colpophyllia natans</i>		0.55		2.77		0.66
<i>Eusmilia fastigiata</i>		0.45	1.58		0.49	0.50
<i>Porites astreoides</i>		1.10	0.69			0.36
<i>Millepora alcicornis</i>	0.33		0.99			0.26
<i>Siderastrea radians</i>				0.33		0.07
<i>Madracis decactis</i>					0.20	0.04
Total Stony Coral	17.91	8.82	19.66	44.47	21.01	22.37
Recently Dead Corals						
<i>Montastrea annularis</i>	4.69	1.65	4.07	0.38	3.77	2.91
<i>Colpophyllia natans</i>		2.86		0.28		0.63
<i>Montastrea cavernosa</i>					0.24	0.05
unidentified coral					1.13	0.23
GORGONIANS (# col/ transect)	0	0	0	0	1	0.2

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

From the initial baseline characterization in 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 %. During the present 2006 monitoring survey, live coral cover declined sharply to a mean of 22.35 %, a loss of 53.4% from the mean live coral cover in 2005. Such decline of live coral cover was statistically significant (ANOVA; $p = 0.0032$). A corresponding increment of substrate cover by benthic algae, sponges and abiotic categories was observed (Figure 16). The sharp downfall of live coral at Puerto Botes Reef appears to have been triggered by the massive coral bleaching event reported for Puerto Rico and the USVI that started during late September through October 2005 (J. Miller, personal communication). 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, *Montastrea annularis* (complex). This species declined in substrate cover from a mean of 25.15% in 2005 to a mean of 4.70 % in 2006, a statistically significant reduction (ANOVA; $p = 0.015$) of more than 80 % from its condition in 2005 (Figure 17). 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 drastic decline recorded during this 2006 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. Due to the marked decline of Boulder Star Coral, Finger Coral now stands as the main coral species in terms of live coral cover, which represents a taxonomic shift in the sessile-benthic community structure of the reef.

Benthic algae, seemingly the fastest growing component of the sessile-benthos at Puerto Botes Reef increased its substrate cover by 34.6 % between the 2005 and the 2006 monitoring surveys (Figure 16), colonizing recently dead coral sections. From the benthic algal assemblage, the fleshy brown macroalgae showed the highest increment between surveys, from 3.6 % in 2005 to 15.0 % in 2006. Increments of reef substrate cover by sponges were observed in four out of the five transects surveyed, for an overall increase in mean substrate cover of 48.2 %, from 2.35 % in 2005 to 4.54 % in 2006.

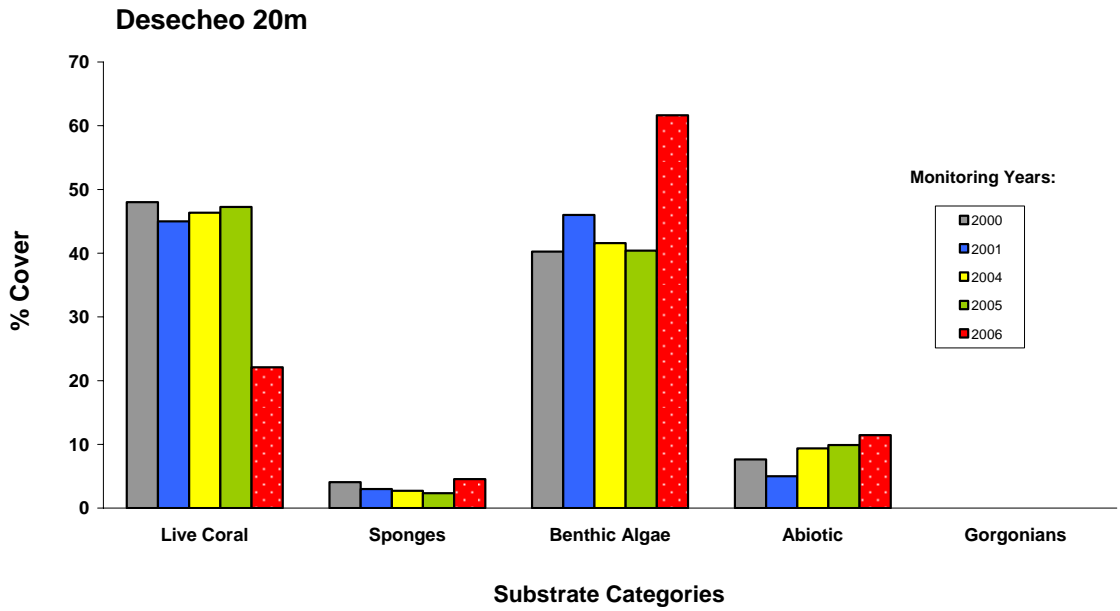


Figure 16. Monitoring trends (2000 – 06) of mean substrate cover by sessile-benthic categories at Puerto Botes Reef – 20 m.

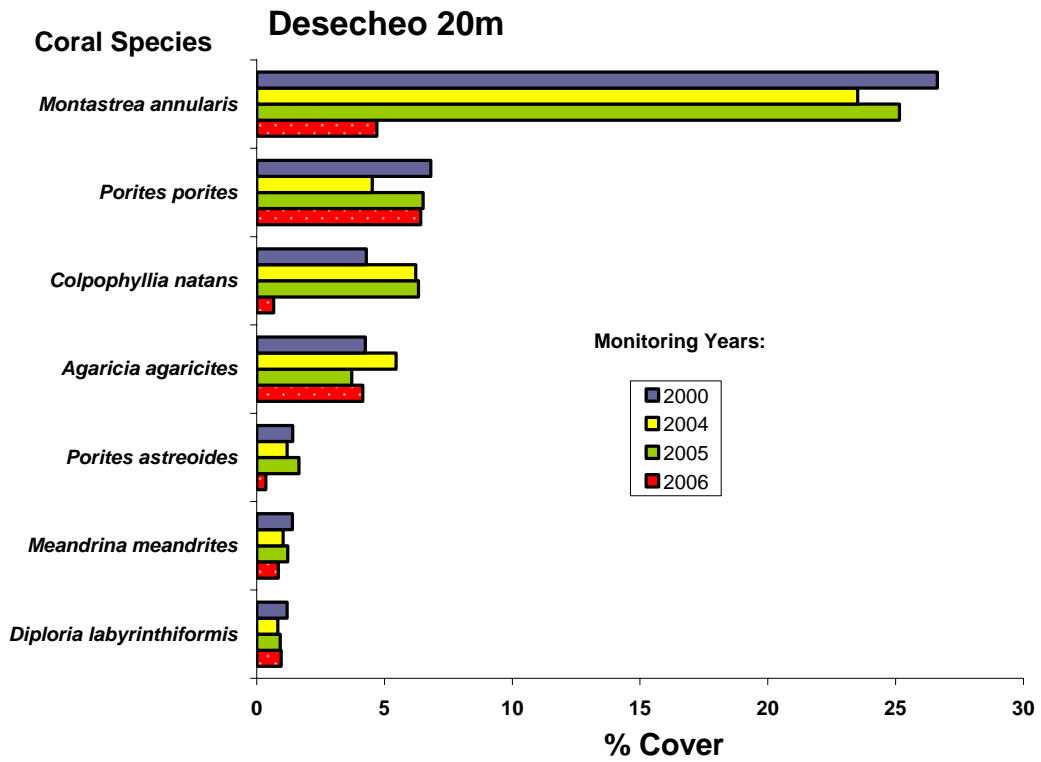


Figure 17. Monitoring trends (2000 – 06) of mean substrate cover by stony coral species at Puerto Botes Reef – 20 m.

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 44 fish species were identified within belt-transects from the mid-shelf patch reefs off Puerto Botes, Isla Desecheo during June, 2006 (Table 19). During the five surveys, a total of 79 fishes have been reported from this reef (Appendix 1). Mean abundance of fishes within belt-transects was 248.6 Ind/30 m² (range: 177 - 293 Ind/30 m²). The mean number of species per transect was 28.6 (range: 26 - 33). The Blue Chromis (*Chromis cyanea*) and the Bicolor Damselfish (*Stegastes partitus*) were the numerically dominant species within belt-transects during the 2006 survey with mean abundances of 74.4 and 44.6 Ind/30 m², respectively. The combined abundance of seven species, including the Blue and Brown Chromis, Bluehead Wrasse, Sharknose, Peppermint and Masked Gobies, Bicolor Damselfish and Fairy Basslet represented 83.1 % of the total fish abundance within belt-transects. A total of 10 species were present in all five transects and other 11 species were present in four transects surveyed (Table 19).

Annual monitoring trends of fish species richness and abundance surveyed within belt-transects are presented in Figure 18. The mean number of fish species within transects (species richness) has fluctuated between 25.2 and 29.0, and mean abundance has varied between 166.8 Ind/30 m² and 248.6 Ind/30 m² during the four year monitoring period at this reef. Differences of species richness and abundance between surveys were not statistically significant (ANOVA; $p > 0.05$).

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.

Motile megabenthic invertebrates within belt-transects included Sponge Brittle Stars (*Ophiothrix suensoni*), Arrow Crab (*Stenorhynchus seticornis*), Banded Coral Shrimp (*Stenopus hispidus*) and Long-Spined Urchin (*Diadema antillarum*) (Table 21). The Spiny and Spotted Spiny Lobsters (*Panulirus argus*, *P. guttatus*) was present outside transect areas.

Table 19. Taxonomic composition and abundance of fishes within belt-transects at Puerto Botes Reef, Isla Desecheo. June, 2006.

Depth: 20m Survey Date: June, 2006		TRANSECTS					MEAN
		1	2	3	4	5	
SPECIES	COMMON NAME						
<i>Chromis cyanea</i>	Blue Chromis	46	82	80	86	78	74.4
<i>Stegastes partitus</i>	Bicolor Damselfish	42	40	48	45	48	44.6
<i>Chromis multilineata</i>	Brown Chromis		6	23	20	95	28.8
<i>Coryphopterus personatus</i>	Masked goby			66	37		20.6
<i>Thalassoma bifasciatum</i>	Bluehead Wrasse	19	13	20	7	9	13.6
<i>Gobiosoma evelynae</i>	Sharknose Goby	15	10	5	10	10	10.0
<i>Coryphopterus lipernes</i>	Peppermint goby	13	6	6	10	9	8.8
<i>Gramma loreto</i>	Fairy Basslet		12	8		9	5.8
<i>Halichoeres garnoti</i>	Yellow-head Wrasse	1	7	5	7	6	5.2
<i>Sparisoma radians</i>	Bucktooth Parrotfish	5		4	5	3	3.4
<i>Scarus taeniopterus</i>	Princess Parrotfish	3		4	2	1	2.0
<i>Sparisoma aurofrenatum</i>	Redband Parrotfish	3	1	2	2	2	2.0
<i>Amblycirrhitus pinos</i>	Redspotted Hawkfish	2			2	5	1.8
<i>Cephalopholis fulva</i>	Coney	4	1	3	1		1.8
<i>Clepticus parrae</i>	Creole wrasse					9	1.8
<i>Microspathodon chrysurus</i>	Yellowtail Damselfish	2	1	2	2	2	1.8
<i>Mulloides martinicus</i>	Yellowtail goatfish		8			1	1.8
<i>Acanthurus coeruleus</i>	BlueTang	1	1	2	2	2	1.6
<i>Cephalopholis cruentatus</i>	Graysby		2	2	1	3	1.6
<i>Haemulon flavolineatum</i>	French grunt	2	2		1	2	1.4
<i>Halichoeres maculipinna</i>	Clown Wrasse	3		1	1	2	1.4
<i>Sparisoma viride</i>	Stoplight Parrotfish	2	1	1	2	1	1.4
<i>Acanthurus chirurgus</i>	Doctorfish	2	1	1	1		1.0
<i>Bodianus rufus</i>	Spanish Hogfish	2	1		1	1	1.0
<i>Myripristis jacobus</i>	Blackbar Soldierfish		2			3	1.0
<i>Malacoctenus triangulatus</i>	Saddled blenny	1	2	1		1	1.0
<i>Flammeo marianus</i>	Longspine Squirrelfish		1	1	1	1	0.8
<i>Scarus iserti</i>	Stripped Parrotfish	2	1			1	0.8
<i>Lutjanus apodus</i>	Schoolmaster snapper		3			1	0.8
<i>Acanthurus bahianus</i>	Ocean surgeon	2				1	0.6
<i>Canthigaster rostrata</i>	Caribbean puffer			1	1	1	0.6
<i>Chaetodon capistratus</i>	Foureye Butterflyfish		1		1	1	0.6
<i>Coryphopterus sp1.</i>	Goby			1	1	1	0.6
<i>Halichoeres radiatus</i>	Puddinwife		1	2			0.6
<i>Lactophrys triqueter</i>	Smooth Trunkfish		1		1	1	0.6
<i>Melichthys niger</i>	Black Durgon	1		1	1		0.6
<i>Stegastes planifrons</i>	Yellow-eye damselfish	1			1	1	0.6
<i>Holacanthus tricolor</i>	Rock Beauty	1		1			0.4
<i>Kyphosus bermudensis</i>	Sea Chub		1	1			0.4
<i>Holocentrus rufus</i>	Squirrelfish	1					0.2
<i>Serranus tigrinus</i>	Harlequin Bass			1			0.2

Table 19. Continued							
<i>Acanthostracion quadricornis</i>	Honeycomb trunkfish		1				0.2
<i>Liopropoma sp</i>	Peppermint Bass	1					0.2
<i>Ophioblennius atlanticus</i>	Yellowhead Jawfish					1	0.2
TOTAL INDIVIDUALS		177	209	293	252	312	248.6
TOTAL SPECIES		26	28	28	28	33	28.6

Table 20. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Puerto Botes Reef, Isla Desecheo, 20 m depth, June, 2006

Depth range : 26 - 30 m
Duration - 30 min.

SPECIES	COMMON NAME	# - (cm)			
<i>Carangoides crysos</i>	Blue Runner	1 – (30)			
<i>Caranx lugubris</i>	Black Jack	1 - (30)			
<i>Balistes vetula</i>	Queen Triggerfish	1 - (35)			
<i>Dasyatis americana</i>	Southern Stingray	1 – (80)			
<i>Epinephelus striatus</i>	Nassau Grouper	1 – (70)			
<i>Gramma loreto</i>	Fairy Basslet	6 - (3)	10 - (5)	6 -(7)	
<i>Holacanthus ciliaris</i>	Queen Angel	1 - (35)			
<i>Holacanthus tricolor</i>	Rock Beauty	1 - (15)	2 - (25)		
<i>Lutjanus apodus</i>	Schoolmaster	2 – (20)	18 - (25)	14 - (30)	5 – (40)
<i>Lutjanus mahogany</i>	Mahogani Snapper	4 - (25)	2 - (30)		
<i>Ocyurus chrysurus</i>	Yellowtail Snapper	2 – (30)	3 - (40)		
<i>Scomberomorus regalis</i>	Cero Mackerel	1 - (45)			
<i>Sphyraena barracuda</i>	Great Barracuda	1 - (80)			
Invertebrates					
<i>Panulirus guttatus</i>	Spotted Spiny Lobster	1 - (10)			
<i>Panulirus argus</i>	Spiny Lobster	1 - (15)			

Table 21. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Puerto Botes Mid-shelf Reef. Isla Desecheo, June 2006

DATE: June 2006 Depth: 20 m	TRANSECTS					MEAN ABUNDANCE (IND/30 m ²)
	1	2	3	4	5	
TAXA	COMMON NAME					
<i>Ophiothrix suensoni</i>	Sponge Brittle Star					2.4
<i>Diadema antillarum</i>	Long-Spined Sea Urchin					0.2
<i>Stenorhynchus seticornis</i>	Arrow crab					0.2
<i>Stenopus hispidus</i>	Banded coral shrimp					0.4
TOTALS						3.2

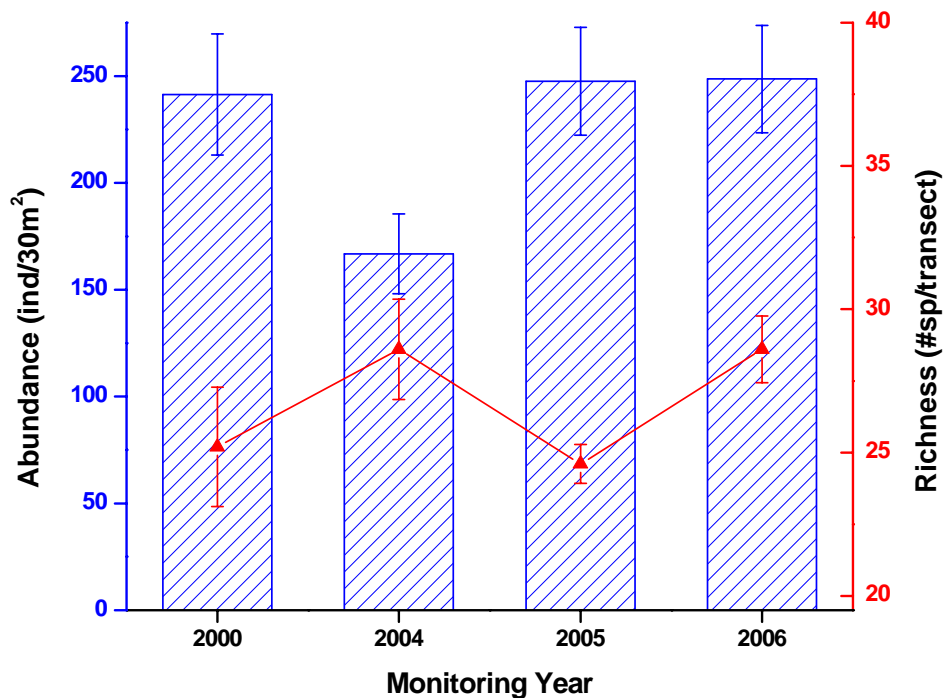
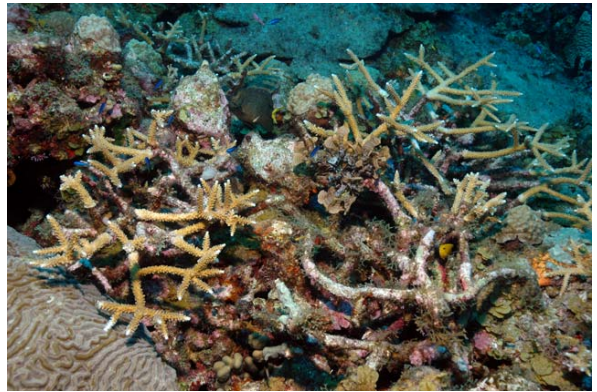


Figure 18. Monitoring trends (2000 – 2006) of fish species richness and abundance at Mid Shelf Reef Puerto Botes, 20 m depth, Isla Desecheo.

Photo Album 5 (Desecheo 20m)
Mid Shelf Reef





2.0 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 which is 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 22 stony corals, including 14 intersected by line transects were identified during this 2006 monitoring survey at Puerto Botes Inner Reef. Stony corals presented a mean substrate cover of 9.86 % (range: 4.61 – 17.36 %) (Table 22). Boulder Star Coral, *Montastrea annularis* (complex), Mustard-Hill Coral, *Porites astreoides*, Great Star Coral, *Montastrea cavernosa*, and *Agaricia agaricites* comprised the main coral assemblage with a combined reef substrate cover of 7.81 %, representative of 79.3 % 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. Soft corals were present, but in low abundance (mean: 0.6 colonies /transect). Reef overhangs, largely associated with growth of *M. annularis* averaged a substrate cover of 9.89 % and contributed substantially to the reef rugosity of 3.70 m. Total abiotic cover also included sections of sand and averaged 6.18 %. Sponges were present at all transects with a mean substrate cover of 5.36 % (Table 22).

Benthic algae, comprised of a mixed assemblage of fleshy (brown and red), red coralline and turf algae represented the main sessile-benthic reef component in terms of substrate cover with a combined mean of 74.13 % (Table 22). Fleshy brown (*Lobophora* sp., *Dictyota* sp., *Padina* sp.) and turf macroalgae, a mixed assemblage of red coralline (*Amphiroa* sp.) and short filamentous brown macroalgae were the principal components of the benthic algae. Both turf and fleshy macroalgae were observed overgrowing recently dead sections of coral colonies in the reef.

Table 22. Percent reef substrate cover by sessile-benthic categories at the Inner-shelf Reef off Puerto Canoas, Isla Desecheo, June, 2006

Depth: 15 – 17 m Survey Date: June, 2006		TRANSECTS					Mean
		1	2	3	4	5	
Rugosity (m)		3.44	3.35	3.54	3.68	4.47	3.70
SUBSTRATE CATEGORIES							
BENTHIC ALGAE							
Turf Algae		62.88	28.91	40.09	14.13	41.75	37.55
Fleshy Algae		27.46	42.32	35.72	55.23	20.75	36.30
Coralline Algae					0.93	0.49	0.28
Total Benthic Algae		90.34	71.24	75.81	70.29	62.98	74.13
ABIOTIC							
Reef Overhang		9.45	9.29	9.76	11.12	9.82	9.89
Sand		12.28	9.89	3.11	5.63		6.18
Total Abiotic		21.73	19.18	12.87	16.75	9.82	16.07
SPONGES		4.69	1.50	2.81	8.34	9.47	5.36
LIVE STONY CORAL							
<i>Montastrea annularis</i>		1.56	1.27	3.99		5.95	2.55
<i>Porites astreoides</i>		2.08	4.94	2.29	0.93	0.49	2.15
<i>Montastrea cavernosa</i>		3.05		1.99	1.55	2.35	1.79
<i>Agaricia agaricites</i>					0.31	6.36	1.33
<i>Diploria strigosa</i>		0.84				1.27	0.42
<i>Eusmilia fastigiata</i>					1.83		0.37
<i>Siderastrea radians</i>		0.63	0.53				0.23
<i>Siderastrea siderea</i>		1.15					0.23
<i>Diploria labyrinthiformis</i>		0.52	0.53				0.21
<i>Meandrina meandrites</i>						0.97	0.19
<i>Colpophyllia natans</i>			0.84				0.17
<i>Stephanocoenia michelini</i>		0.45					0.09
<i>Mycetophyllia lamarckiana</i>		0.42					0.08
<i>Madracis decactis</i>				0.31			0.06
Total Live Stony Coral		10.71	8.09	8.51	4.61	17.36	9.86
Recently Dead Corals							
<i>Montastrea annularis</i>		0.92	1.45	2.23	0.56	0.45	1.12
GORGONIANS (# col/ transect)		3	0	0	0	0	0.6

Coral Species Outside Transects: *Porites porites*, *Diploria clivosa*, *Stylaster roseus*, *Siderastrea siderea*, *Madracis decactis*, *Leptoseris cucullata*, *Acropora cervicornis*, *Millepora alcicornis*

Figure 19 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 -06. 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). During the 2006 monitoring event a reduction 49.4 % of mean live coral cover was measured, from 19.49 % in 2005 to 9.86 % in 2006. Corresponding increments of substrate cover by benthic algae and abiotic categories were also measured. Differences of total live coral cover between surveys were not statistically significant (ANOVA; $p = 0.118$), although a consistent decline (of coral cover) was observed from all five transects. It appears that high variability in the magnitude (not direction) of the temporal differences of percent live coral cover between transects influenced the error measurement of the parametric (repeated measurements) ANOVA.

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, *Montastrea annularis* (complex), which declined in reef substrate cover from a mean of 11.5 % in 2005 to a mean of only 2.55 % in 2006 (Figure 20). The reduction of percent cover for Boulder Star Coral between the 2005 and the 2006 surveys was statistically significant (ANOVA; $p = 0.027$). Before the massive bleaching event of October 2005, Boulder Star Coral used to represent 58.5 % of the total coral cover at this reef and was present from all transects surveyed. During the summer 2006 survey, live colonies of Boulder Star Coral disappeared from transect four (4), and presented substrate cover below 2% in two out of the four transects in which it was present. Other species that comprise the main coral assemblage of the inner shelf reef at Puerto Botes, such as Mustard-Hill Coral, *Porites astreoides*, Great Star Coral, *Montastrea cavernosa*, Lettuce Coral, *Agaricia agaricites*, and Flower Coral, *Eusmilia fastigiata* did not show any statistically significant differences in substrate cover between surveys.

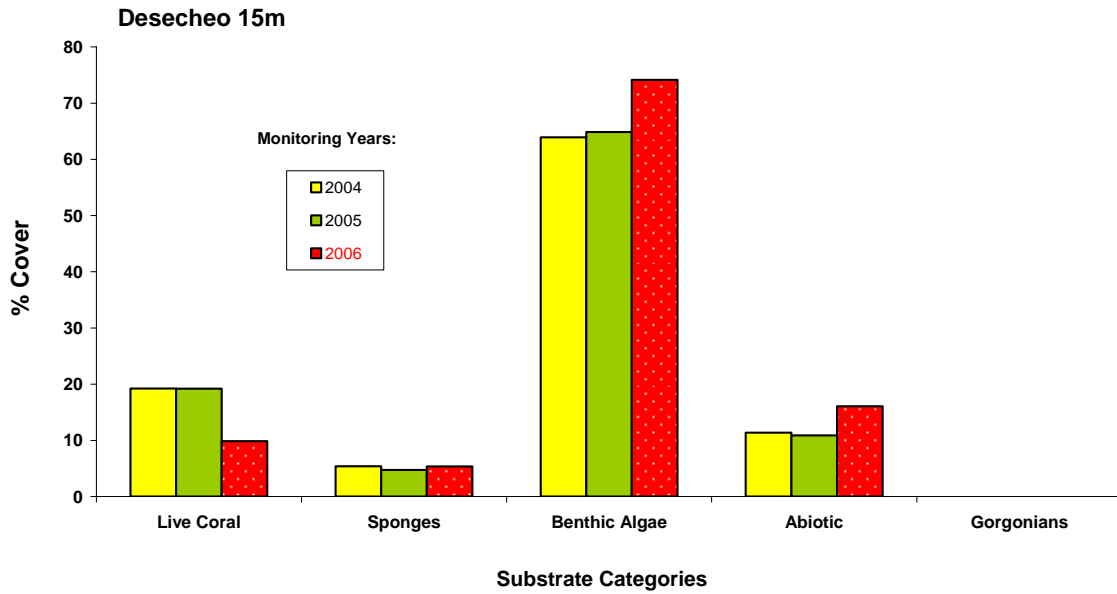


Figure 19. Monitoring trends (2004 -06) of mean substrate cover by sessile-benthic categories at Puerto Botes Reef – 15 m.

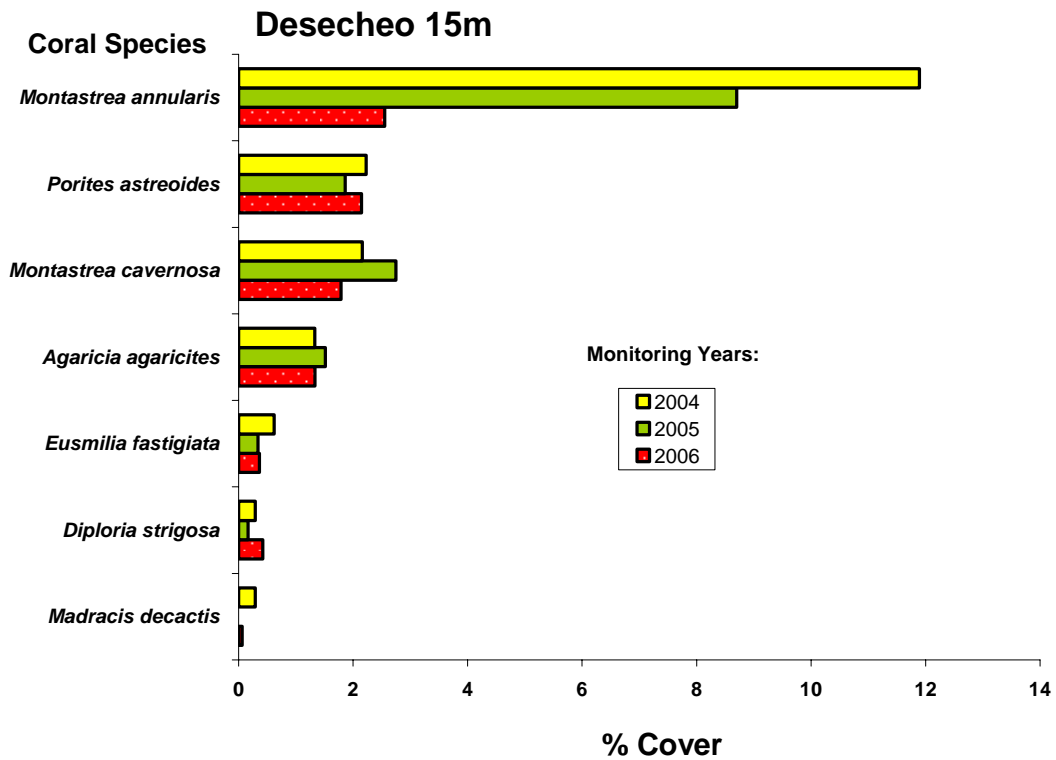


Figure 20. Monitoring trends (2004 -06) of mean substrate cover by stony coral species at Puerto Botes Inner Shelf Reef – 15 m.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 44 fish species were identified within belt-transects from the Inner-Shelf Reef off Puerto Botes, Isla Desecheo during June, 2006. The complete list of species reported from this reef is shown in Appendix 1. Mean abundance of fishes within belt-transects during the 2006 survey was 307.6 Ind/30 m² (range: 185 - 445 Ind/30 m²). The mean number of species per transect was 25.2 (range: 24 - 26). The Blue Chromis was the numerically dominant species with a mean abundance of 113.0 Ind/30 m² (range: 62 - 225 Ind/30 m²), representing 36.7 % of the total abundance within belt-transects (Table 23). The combined abundance of six species, including the Blue and Brown Chromis, Creole Wrasse, Bicolor Damselfish, Bluehead and Yellowhead Wrasses, and the Bicolor Damselfish represented 86.0 % of the total abundance within belt-transects. A total of 13 species were present in all five transects surveyed and other two species were present in four transects (Table 23).

Annual monitoring trends of fish species richness and abundance surveyed within belt-transects are presented in Figure 21. The mean number of fish species within transects (species richness) has fluctuated between 23.6 and 25.2, and mean abundance has varied between 133.8 Ind/30 m² and 307.6 Ind/30 m² during the three year monitoring period at this reef. Differences of species richness between surveys were not statistically significant (ANOVA; $p = 0.275$), but higher fish abundances have been recorded during the most recent 2005 and 2006 surveys, as compared to the initial baseline survey of 2004 (ANOVA; $p = 0.005$).

Reef zooplankton feeders, such as the Blue and Brown Chromis, the Creole Wrasse and the Bicolor Damselfish comprised the most prominent fish assemblage of this inshore reef in terms of abundance. Also, open water zooplanktivores, such as the Mackerel Scad (*Decapterus macarellus*) were present outside transects in large aggregations. This is consistent with fish surveys from the mid-shelf and shelf-edge reefs of Isla Desecheo (see previous sections). The relatively high abundance of zooplanktivorous fish populations is quite interesting because Rodriguez (2004) sampled the macrozooplankton of Puerto Botes/Puerto Desecheo Reefs six times during a year and found that zooplankton populations are depauperate and unproductive with exception of fish eggs. At least three preliminary hypothesis, or an 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 were also present, including wrasses, gobies, goatfishes and squirrelfishes, among others. Mid-size carnivores that are commercially exploited, such as the Yellowtail and Schoolmaster Snappers, Red Hind and Coney were observed in low abundance and small sizes. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous assemblage. Commercially important species for the aquarium trade market were mostly represented by the populations of 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. A few specimens of the Queen Angelfish (*Holocanthus ciliaris*) and Rock Beauty (*Holocanthus tricolor*) were also present. One large Cero Mackerel and one Great Barracuda were present observed during our ASEC survey (Table 24). Motile megabenthic invertebrates were represented within belt-transects by Coral Crabs, Arrow Crabs (*Stenorhynchus seticornis*), Spotted and Spiny Lobsters (*Panulirus guttatus*, *P. argus*), Long-spined Sea Urchins (*Diadema antillarum*) and Brittle Stars (Ophiuroids) (Table 25).

Table 23. Taxonomic composition and abundance of fishes within belt-transects at Puerto Botes Inner Shelf Reef, Isla Desecheo. June, 2006

Depth: 15m Survey Date: June, 2006		TRANSECTS					MEAN
		1	2	3	4	5	
SPECIES	COMMON NAME						
<i>Chromis cyanea</i>	Blue Chromis	86	225	126	62	66	113.0
<i>Clepticus parrae</i>	Creole wrasse	56	58	90	5	57	53.2
<i>Stegastes partitus</i>	Bicolor Damselfish	59	42	39	36	36	42.4
<i>Chromis multilineata</i>	Brown Chromis	9	25	39	6	55	26.8
<i>Thalassoma bifasciatum</i>	Bluehead Wrasse	18	47	15	18	13	22.2
<i>Halichoeres garnoti</i>	Yellow-head Wrasse	7	7	8	11	1	6.8
<i>Crioptomus roseus</i>	Parrotfish	2	1	4	15	5	5.4
<i>Sparisoma radians</i>	Bucktooth Parrotfish	6	6	5	5	3	5.0
<i>Cephalopholis fulva</i>	Coney	6	5	7	3	3	4.8
<i>Gobiosoma evelynae</i>	Sharknose Goby	6	5	6	2	2	4.2
<i>Sparisoma aurofrenatum</i>	Redband Parrotfish	2	2	3	3	2	2.4
<i>Acanthurus coeruleus</i>	BlueTang	2	2	3	1		1.6
<i>Cephalopholis cruentatus</i>	Graysby	2	2		3		1.4
<i>Halichoeres maculipinna</i>	Clown Wrasse	1	2	1	3		1.4
<i>Microspathodon chrysurus</i>	Yellowtail Damselfish	2	1	2	1	1	1.4
<i>Scarus taeniopterus</i>	Princess Parrotfish	7					1.4
<i>Sparisoma viride</i>	Stoptlight Parrotfish	1	1	2	1	2	1.4
<i>Amblycirrhitus pinos</i>	Redspotted Hawkfish		1		1	3	1.0
<i>Myripristis jacobus</i>	Blackbar Soldierfish			3		2	1.0
<i>Chaetodon capistratus</i>	Foureye Butterflyfish	1		1		2	0.8
<i>Holocentrus rufus</i>	Squirrelfish		2	1		1	0.8
<i>Scarus iserti</i>	Stripped Parrotfish	1			2	1	0.8
<i>Xanthichthys ringens</i>	Sargassum triggerfish	1	2		1		0.8
<i>Acanthurus bahianus</i>	Ocean surgeon		1	1	1		0.6
<i>Halichoeres radiatus</i>	Puddinwife	3					0.6
<i>Holacanthus tricolor</i>	Rock Beauty				2	1	0.6
<i>Lactophrys triqueter</i>	Smooth Trunkfish			1	1	1	0.6
<i>Melichthys nigrer</i>	Black Durgon		1	1		1	0.6
<i>Acanthurus chirurgus</i>	Doctorfish	1	1				0.4
<i>Canthigaster rostrata</i>	Caribbean puffer			2			0.4
<i>Chaetodon striatus</i>	Banded Butterflyfish		2				0.4
<i>Scarus vetula</i>	Queen Parrotfish		1	1			0.4
<i>Stegastes dorsopunicans</i>	Dusky damselfish		2				0.4
<i>Bodianus rufus</i>	Spanish Hogfish	1					0.2
<i>Coryphopterus personatus</i>	Masked goby					1	0.2
<i>Coryphopterus sp1.</i>	Goby			1			0.2
<i>Equetus punctatus</i>	Jacknifefish					1	0.2
<i>Flammeo marianus</i>	Longspine Squirrelfish		1				0.2
<i>Gramma loreto</i>	Fairy Basslet				1		0.2
<i>Haemulon flavolineatum</i>	French Grunt					1	0.2
<i>Kyphosus bermudensis</i>	Sea Chub					1	0.2
<i>Malacoctenus sp.</i>	Blenny			1			0.2
<i>Muraenidae</i>	Moray sp.	1					0.2

Table 23. Continued							
<i>Serranus tigrinus</i>	Harlequin Bass	1					0.2
<i>Stegastes variabilis</i>	Cocoa damselfish		1				0.2
<i>Cantherhines macrocerus</i>	Whitespotted Filefish			1			0.2
TOTAL INDIVIDUALS		282	445	364	185	262	307.6
TOTAL SPECIES		25	26	26	24	25	25.2

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, June, 2006

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

SPECIES	COMMON NAME	# - (cm)		
<i>Chromis cyanea</i>	Blue chromis	16 - (<3)	80 - (3-5)	5 - (>5)
<i>Dasyatis americana</i>	Southern Stingray	1 - (70)		
<i>Decapterus macarellus</i>	Mackerel Scad	40 - (12)		
<i>Epinephelus guttatus</i>	Red Hind	1 - (30)		
<i>Gramma loreto</i>	Fairy Basslet	12 - (3)	15 - (5)	6 - (7)
<i>Ginglymostoma cirratum</i>	Nurse Shark	1 - (90)		
<i>Holacanthus ciliaris</i>	Queen Angel	1 - (35)		
<i>Holacanthus tricolor</i>	Rock Beauty	1 - (20)		
<i>Lutjanus apodus</i>	Schoolmaster	6 - (25)	12 - (35)	4 - (50)
<i>Lutjanus mahogany</i>	Mahogani Snapper	1 - (30)		
<i>Ocyurus chrysurus</i>	Yellowtail Snapper	1 - (35)	1 - (50)	
<i>Scomberomorus regalis</i>	Cero Mackerel	1 - (50)		
<i>Sphyaena barracuda</i>	Great Barracuda	1 - (70)		
Invertebrates				
<i>Panulirus guttatus</i>	Spotted Spiny Lobster	1 - (8)		
<i>Panulirus argus</i>	Spiny Lobster	1 - (20)		

Table 25. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at the Puerto Botes Inner-Shelf Reef, Isla Desecheo, June, 2006

TAXA	COMMON NAME	TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	2	3	4	5	
<i>Percnon gibbesi</i>	Nimble Spray Crab			1			0.2
<i>Stenorhynchus seticornis</i>	Arrow Crab	4	2				1.2
<i>Diadema antillarum</i>	Long-Spined Sea Urchin		1				0.2
TOTALS		4	3	1	0	0	1.6

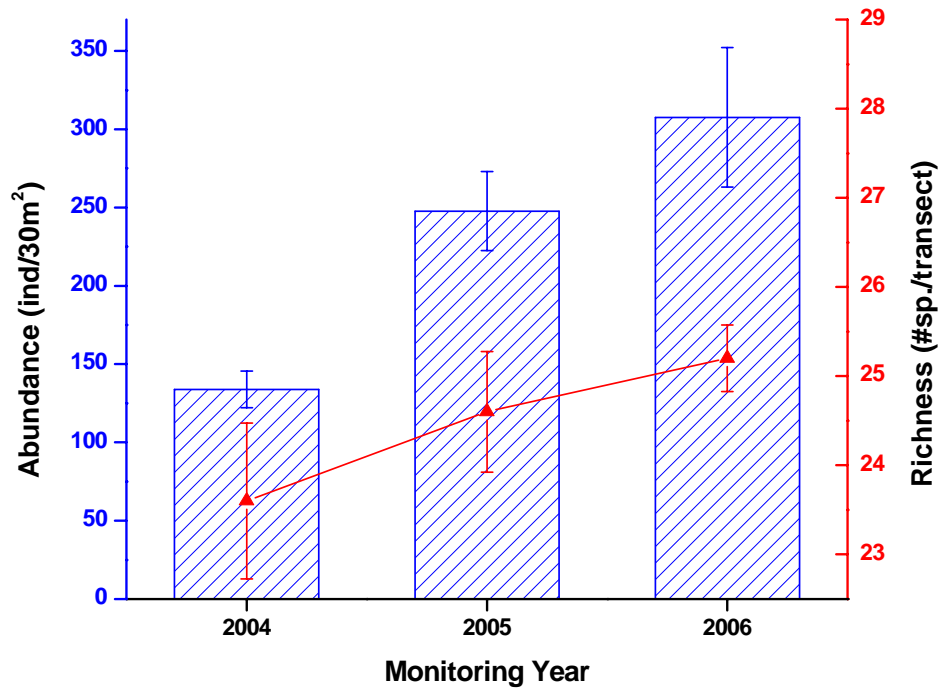


Figure 21. Monitoring trends (2004 – 2006) of fish species richness and abundance at Inner Shelf Reef Puerto Botes, 15 m depth, Isla Desecheo.

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 22).

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).

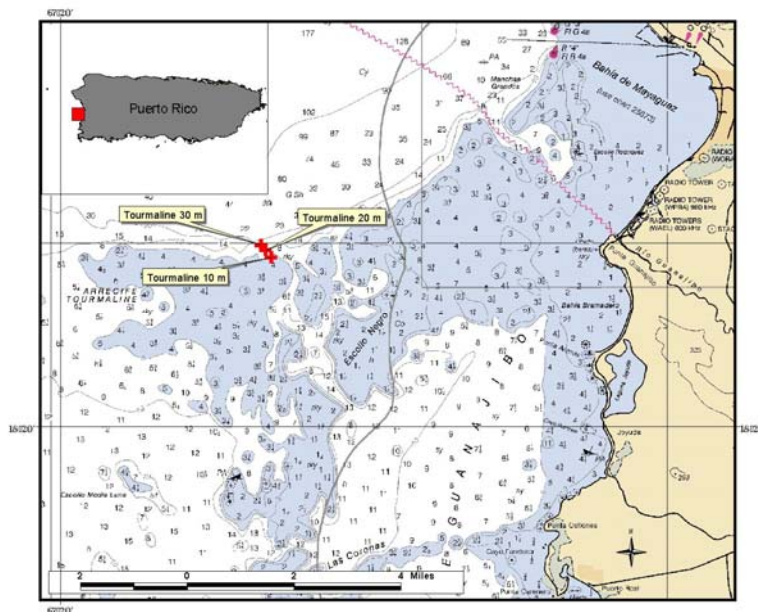


Figure 22. Location of coral reef survey stations at Tourmaline Reef, off Mayaguez Bay.

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 24 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 14.23 % (range: 8.65 – 18.48 %). Boulder Star Coral, *Montastrea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 5.32 % (range: 3.14 – 8.93 %), representing 37.4 % of the total cover by stony corals. Isolated colonies of Lamarck's Sheet Coral, *Agaricia lamarcki*, Graham's Sheet Coral, *A. grahamae* and Great Star Coral, *Montastrea cavernosa* were also prominent at the shelf-edge. Soft corals (gorgonians) were moderately abundant, with an average of 10.6 colonies/transect. The encrusting gorgonian, *Erythropodium caribaeorum* was intercepted by all five transects and presented a mean substrate cover of 1.6 %. Colonies of Bushy Black Coral (*Antipathes* sp.) and Wire Coral (*Stichopathes lutkeni*) were present close to the deepest end of the reef at 32 m.

Encrusting and erect sponges, including several large Basket Sponges, *Xestospongia muta* were present in all transects with an average cover of 1.86 %. The Blue Bell Tunicate, *Clavelina puertosecensis* was very common throughout the shelf-edge reef. Reef overhangs, associated with substrate depressions and coral ledges averaged 29.76 % and contributed substantially to a topographic rugosity of 5.51 m.

Turf algae, comprised by an assemblage of short filamentous red and brown macroalgae was the dominant sessile-benthic component in terms of substrate cover at the shelf-edge reef with an average of 49.41 % (range : 43.70 – 55.77 %). Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard bottom. The total cover by benthic algae was 50.31 %. Cyanobacterial films were present in three out of five transects with a mean reef substrate cover of 2.26 %.

Table 26. Percent reef substrate cover by sessile-benthic categories at Tourmarine Shelf-edge Reef, Mayaguez Bay, May, 2006

Depth: 30 m
Survey Date: May, 2006

		Transects					
		1	2	3	4	5	Mean
	Rugosity (m)	4.76	4.34	7.82	5.61	5.01	5.51
Substrate Categories							
BENTHIC ALGAE							
	Turf Algae	48.10	47.00	52.47	55.77	43.70	49.41
	Fleshy Algae	1.56		1.91	0.54	0.47	0.90
	Total Benthic Algae	49.66	47.00	54.38	56.31	43.87	50.24
	CYANOBACTERIA		0.98		2.44	7.86	2.26
ABIOTIC							
	Reef Overhang	29.40	25.94	30.75	28.01	26.38	28.10
	Sand		2.65		1.53	1.13	1.06
	Gap	0.95	1.74			0.28	0.60
	Total Abiotic	30.36	30.34	30.75	29.55	27.79	29.76
	SPONGES	3.12	2.16	1.35	1.35	1.33	1.86
	ENCRUSTING GORGONIAN	3.79	1.05	0.95	1.73	0.47	1.60
Coral Species							
	<i>Montastrea annularis</i>	4.67	6.14	3.70	3.14	8.93	5.32
	<i>Agaricia lamarcki</i>	1.69	5.51	1.96	2.63	2.47	2.85
	<i>Agaricia agaricites</i>	1.42	2.23	0.56	1.79	2.00	1.60
	<i>Montastrea cavernosa</i>		1.08	3.25		2.60	1.39
	<i>Agaricia grahamae</i>	0.95	1.95	1.58	0.27	1.50	1.25
	<i>Porites astreoides</i>	2.17					0.43
	<i>Stephanocoenia michelini</i>	1.34		0.79			0.42
	<i>Madracis sp.</i>		1.60	0.24			0.37
	<i>Siderastrea siderea</i>				0.36	0.75	0.22
	<i>Mycetophyllia sp.</i>	0.86					0.17
	<i>Siderastrea radians</i>				0.45	0.19	0.13
	<i>Diploria strigosa</i>			0.47			0.09
	Total Stony Coral	13.08	18.48	12.57	8.65	18.39	14.23
	Partially Bleached Corals						
	<i>Montastrea annularis</i>	1.28					0.26
	<i>Montastrea cavernosa</i>					0.66	0.13
	GORGONIANS (# col/ transect)	6	13	9	10	15	10.6

Coral Species Outside Transects: *Stephanocoenia michelini*, *Siderastrea siderea*, *Diploria strigosa*, *Antipathes sp.*, *Stichopathes lutkeni*, *Scolymia cubensis*, *Millepora alcicornis*, *Meandrina meandrites*, *Mycetophyllia lamarkiana*, *M. aliciae*, *Porites porites*, *Madracis decactis*

Figure 23 presents the variations of mean percent cover by sessile-benthic categories from the shelf-edge of Tourmaline Reef at 30 m depth. Differences of the mean percent cover by stony corals, sponges, and benthic algae between monitoring surveys were very small and not statistically significant (ANOVA; $p > 0.05$). Boulder Star Coral, *Montastrea annularis* maintained its status as the dominant coral species in terms of reef substrate cover (Figure 24). Although one of its colonies was observed to be partially bleached, it did not present widespread mortality at 30 m depth. Its decline of substrate cover between the 2005 and the present 2006 survey was of 0.6 %. Such small difference was not statistically significant (ANOVA; $p > 0.05$). Partial coral bleaching was also observed for Great Star Coral, *M. cavernosa*.

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 108 fish species have been identified from Tourmaline Reef at depths of 25-30 m (Appendix 1). Mean abundance within belt-transects during the 2006 monitoring survey was 206.8 Ind/30 m² (range: 175 - 251 Ind/30 m²). The mean number of species per transect was 22 (range: 20 - 25). Fish species richness increased during the 2006 survey by 11.8 % relative to the 2005 survey, and remained within 5 % of the 2004 baseline. Differences of fish species richness between surveys were not statistically significant (ANOVA; $p > 0.05$). Mean abundance increased during the 2006 survey by 46 % compared to the 2004 baseline survey, and also increased by 15.6 % compared to the 2005 monitoring survey (Figure 25). There was a statistically significant difference between the mean abundance of 2004 and the abundance in the subsequent 2005 and 2006 monitoring surveys (ANOVA; $p = 0.005$). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 135.0 Ind/30 m² (range: 120 - 145 Ind/30 m²), representing 65.3 % 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 interface. The Fairy Basslet, Peppermint Goby, Black-bar Soldierfish, Beaugregory, Bicolor Damselfish and Striped Parrotfish were present on the five transects surveyed and comprised, along with the Masked Goby, Blue Chromis and Creole Wrasse the most abundant fish assemblage at the shelf-edge reef.

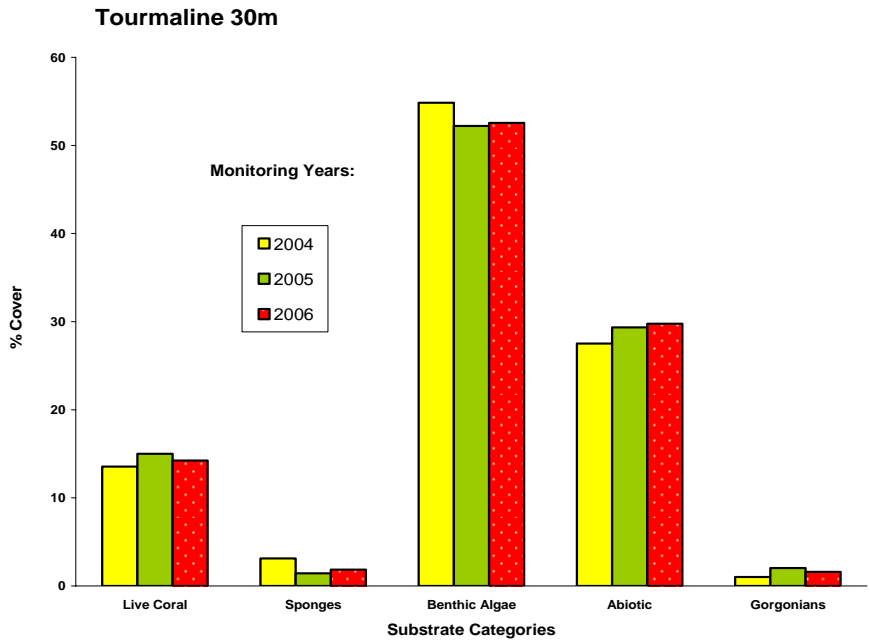


Figure 23. Monitoring trends (2004 – 2006) of mean substrate cover by sessile-benthic categories at Tourmaline Shelf-edge Reef – 30 m, Mayaguez Bay.

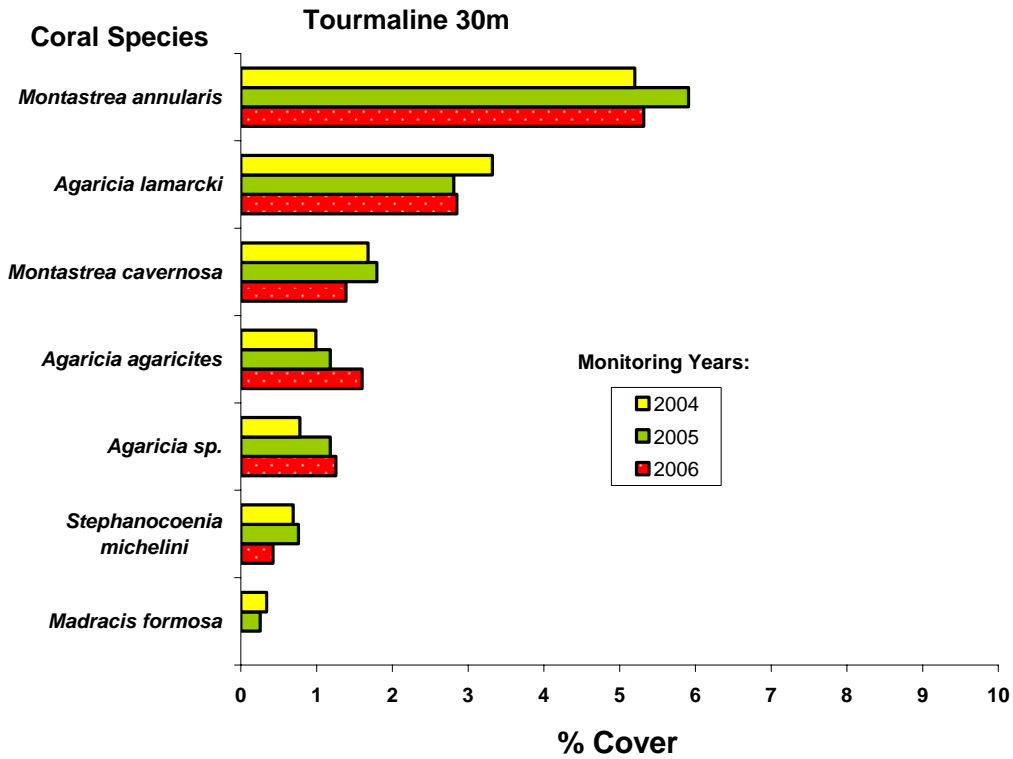


Figure 24. Monitoring trends (2004 – 2006) of mean substrate cover by stony coral species at Tourmaline Reef – 30 m, Mayaguez Bay.

Table 27. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, Mayaguez Bay- 30 m depth. May, 2006

Depth: 30 m Survey Date: May, 2006		TRANSECTS					MEAN
		1	2	3	4	5	
SPECIES	COMMON NAME	(Individuals/m ²)					
<i>Coryphopterus personatus</i>	Masked Goby	120	140	130	140	145	135.0
<i>Chromis insolata</i>	Sunshinefish			1		64	13.0
<i>Gramma loreto</i>	Fairy Basslet	5	11	10	18	2	9.2
<i>Chromis cyanea</i>	Blue Chromis	7	5		5	10	5.4
<i>Coryphopterus lipernes</i>	Peppermint Goby	6	8	4	5	2	5.0
<i>Myripristis jacobus</i>	Blackbar Soldierfish	4	12	5	1	1	4.6
<i>Clepticus parrae</i>	Creole Fish			1	16	4	4.2
<i>Stegastes leucostictus</i>	Beaugregory	3	3	4	3	3	3.2
<i>Stegastes partitus</i>	Bicolor Damselfish	4	2	4	3	2	3.0
<i>Scarus iserti</i>	Stripped Parrotfish	2	5	1	3	3	2.8
<i>Gobiosoma evelynae</i>	Sharknose Goby		3	4		5	2.4
<i>Haemulon aurolineatum</i>	Tomtate	3	1	1	4	1	2.0
<i>Halichoeres garnoti</i>	Yellow-head Wrasse	5	1	1	2	1	2.0
<i>Flammeo marianus</i>	Lonspine Squirelfish	3	2	1	2		1.6
<i>Sparisoma aurofrenatum</i>	Redband Parrotfish	1	3		2		1.2
<i>Canthigaster rostrata</i>	Caribbean Puffer	1	2		2		1.0
<i>Cephalopholis cruentatus</i>	Graysby		1	3		1	1.0
<i>Acanthurus bahianus</i>	Ocean Surgeon				2	2	0.8
<i>Hypoplectrus puella</i>	Barred Hamlet	1	1		1	1	0.8
<i>Chaetodon aculeatus</i>	Longsnout Butterflyfish		2		1		0.6
<i>Gobiosoma saucrum</i>	Leopard Goby	2	1				0.6
<i>Mulloides martinicus</i>	Yellowtail Goatfish				3		0.6
<i>Thalassoma bifasciatum</i>	Bluehead Wrasse		3				0.6
<i>Acanthurus coeruleus</i>	BlueTang	1			1		0.4
<i>Chaetodon capistratus</i>	Foureye Butterflyfish			2			0.4
<i>Chaetodon sedentarius</i>	Reef Butterflyfish	2					0.4
<i>Haemulon flavolineatum</i>	French Grunt		2				0.4
<i>Holocentrus rufus</i>	Squirrelfish		1	1			0.4
<i>Liopropoma rubre</i>	Peppermint Bass		1	1			0.4
<i>Ocyurus chrysurus</i>	Yellowtail Snapper	1		1			0.4
<i>Pseudupeneus maculatus</i>	Yellowtail Goatfish				1	1	0.4
<i>Synodus intermedius</i>	Lizardfish	1				1	0.4
<i>Acanthurus chirurgus</i>	Doctorfish					1	0.2
<i>Amblicirrhitis pinnos</i>	Redspotted Hawkfish					1	0.2
<i>Aulostomus maculatus</i>	Trumpetfish	1					0.2
<i>Cephalopholis fulva</i>	Coney		1				0.2
<i>Chaetodon ocellatus</i>	Spotfin Butterflyfish			1			0.2
<i>Epinephelus guttatus</i>	Red Hind			1			0.2
<i>Hypoplectrus niger</i>	Black Hamlet	1					0.2
<i>Lachnolaimus maximus</i>	Hogfish			1			0.2
<i>Lutjanus synagris</i>	Lane Snapper	1					0.2

Table 27. Continued							
<i>Pomacanthus arcuatus</i>	Gray Angelfish		1				0.2
<i>Priacanthus cruentatus</i>	Glasseye Snapper				1		0.2
<i>Scarus vetula</i>	Queen Parrotfish			1			0.2
<i>Sparisoma radians</i>	Bucktooth Parrotfish		1				0.2
TOTAL INDIVIDUALS		175	213	179	216	251	206.8
TOTAL SPECIES		22	25	22	21	20	22.0

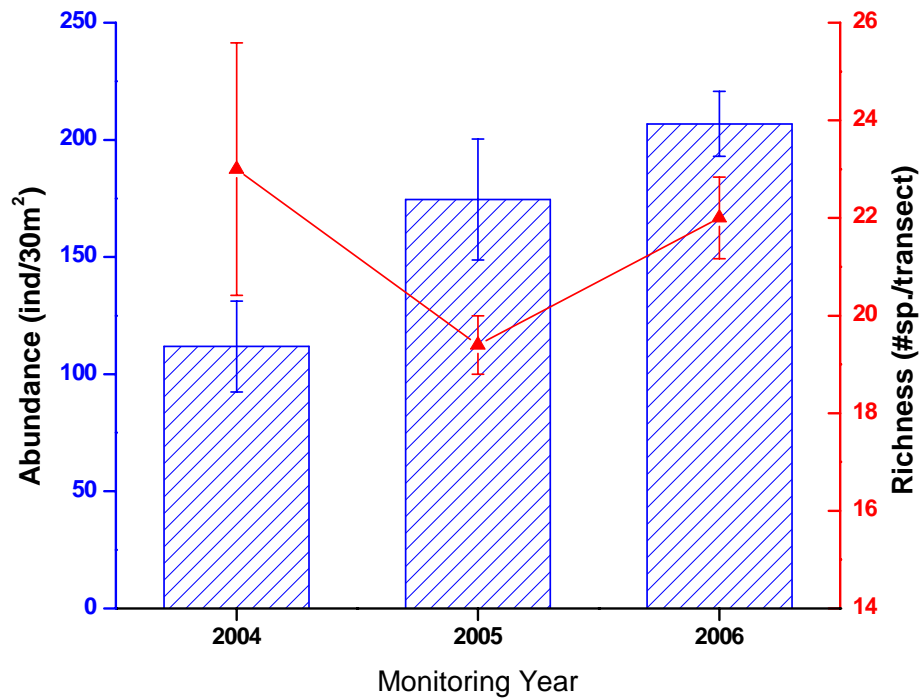


Figure 25. Monitoring trends (2004 – 2006) of fish species richness and abundance at Shelf edge Reef Tourmaline, 30 m depth, Mayaguez Bay.

The fish community associated with Tourmaline shelf-edge reef was characterized by rather low abundance of individuals, considering that one small species (Masked Goby) accounted for 65 % of the total individuals within belt-transects. Top demersal and pelagic predators, such as large snappers, groupers and mackerels were present, but not abundant. Single specimens of adult Red Hind, Yellowfin and Nassau Groupers, along with a Hogfish and several snappers were observed during the 2006 ASEC survey (Table 28). Juvenile Nassau Groupers, Mutton, Schoolmaster and Yellowtail Snappers were previously reported from this reef (García-Sais et al., 2004, 2005), as well as the large pelagics, such as Cero Mackerel and Great Barracuda (García-Sais et al., 2004, 2005). Schools of Mackerel Scad, *Decapterus macarellus* were present at mid-water over the reef. These are zooplanktivores that serve as forage for pelagic predators, such as 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.

Motile megabenthic invertebrates surveyed within belt-transects at the Tourmaline shelf-edge reef during this survey are listed in Table 29. The Cleaner Shrimp (*Periclimenes pedersoni*) and the Arrow Crab (*Stenorhynchus seticornis*) were present within belt-transects. One small Spiny Lobster (*Panulirus argus*) was observed outside transects during the ASEC survey (Table 28).

Table 28. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Tourmaline Shelf-edge Reef, June, 2006

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

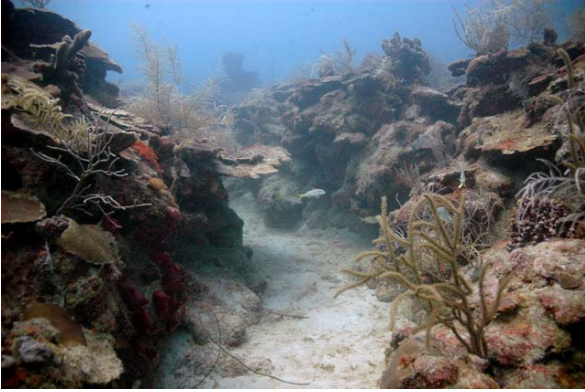
SPECIES	COMMON NAME	# - (cm)
<i>Caranx latus</i>	Horse-eye Jack	1 - (30)
<i>Epinephelus guttatus</i>	Red Hind	1 - (30)
<i>Epinephelus striatus</i>	Nassau Grouper	1 - (60)
<i>Holacanthus ciliaris</i>	French Angelfish	1 - (50)
<i>Lachnolaimus maximus</i>	Hogfish	1 - (40)
<i>Lutjanus apodus</i>	Schoolmaster Snapper	1 - (40)
<i>Mycteroperca venenosa</i>	Yellowfin Grouper	1 - (50)
<i>Ocyurus chrysurus</i>	Yellowtail Snapper	1 - (40)
<i>Scomberomorus regalis</i>	Cero Mackerel	1 - (50)
Invertebrates		
<i>Panulirus argus</i>	Spiny Lobster	1 - (15)

Table 29. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Shelf-edge Reef, 30 m depth, Mayaguez. June, 2006

DATE: June, 2006
Depth: 30 m

TAXA	COMMON NAME	TRANSECTS					MEAN ABUNDANCE (IND/30 m²)
		1	2	3	4	5	
<i>Stenorhynchus seticornis</i>	Arrow Crab		1				0.2
<i>Periclimenes sp.</i>	Cleaner Shrimp			1		2	0.6
TOTALS		0	1	1	0	2	0.8

Photo Album 7 (Tourmaline 30 m)
Shelf edge Reef





2.0 Tourmaline Outer Shelf Reef – 20 m

2.1 Sessile-Benthic Reef Community

The 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 20 stony corals and two black coral species (*Stichopathes lutkeni*, *Antipathes* sp.) were identified from the outer shelf reef, 14 of which were intercepted by line transects during our survey (Table 30). Stony corals occurred as massive (*Montastrea annularis* (complex), *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 25.05 % (range: 18.76 – 31.26 %). 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 17.87 % (range: 12.59 – 26.33 %), representing 71.4 % of the total cover by stony corals. Colonies of Boulder Star Coral and Great Star Coral (*M. cavernosa*) were intercepted by all five transects, and along with Mustard Hill Coral (*P. astreoides*) and Massive Starlet Coral (*Siderastrea siderea*) comprised the main stony coral assemblage.

Soft corals (gorgonians) were moderately abundant, with an average of 8.6 colonies/transect. Colonies of Bushy Black Coral (*Antipathes caribbeana*) were present at the reef base. Encrusting sponges and gorgonians (*Erythropodium caribaeorum*) were present, but represented minor components of the reef benthos (substrate cover < 2 %). Reef overhangs, associated with coral ledges of Boulder Star Coral averaged

Table 30. Percent reef substrate cover by sessile-benthic categories at Tourmarine Shelf-Reef, Mayaguez Bay, May, 2006

Survey Depth: 20 m Date: May, 2006		TRANSECTS					Mean
		1	2	3	4	5	
	Rugosity (m)	1.90	6.34	5.85	6.23	6.68	5.40
SUBSTRATE CATEGORIES							
BENTHIC ALGAE							
	Turf Algae	46.76	30.95	30.39	31.26	30.94	34.06
	Fleshy Algae	12.28	16.27	14.12	4.32	11.21	11.64
	Total Benthic Algae	59.04	47.22	44.51	35.57	42.15	45.70
ABIOTIC							
	Reef Overhang	15.14	27.77	26.67	25.65	35.13	26.07
	Sand				2.17		0.43
	Gap		0.60			0.68	0.26
	Total Abiotic	15.14	28.37	26.67	27.82	35.81	26.76
SPONGES							
		0.25		0.44	4.32		1.00
ENCRUSTING GORGONIANS							
	Recently Dead Coral (% of turf)			2.84	6.78	0.84	2.09
	Partially Bleached Coral (% of coral)	9.92	5.87	6.49	16.83	5.64	8.95
Coral Species							
	<i>Montastrea annularis</i>	17.33	18.35	14.75	26.33	12.59	17.87
	<i>Montastrea cavernosa</i>	10.64	0.69	12.98	1.23	3.12	5.73
	<i>Siderastrea siderea</i>	2.02		0.62	1.82	1.35	1.16
	<i>Porites astreoides</i>		0.34	2.14	0.69	1.18	0.87
	<i>Madracis decactis</i>		1.96		0.52		0.50
	<i>Diploria labyrinthiformis</i>			1.69			0.34
	<i>Colpophyllia natans</i>		1.12			0.51	0.33
	<i>Mycetophyllia ferox</i>			0.89			0.18
	<i>Meandrina meandrites</i>				0.69		0.14
	<i>Dichocoenia stokesii</i>			0.53			0.11
	<i>Millepora complanata</i>	0.12					0.02
	Total Stony Coral	25.48	22.51	27.11	31.26	18.76	25.03
	PB <i>Montastrea cavernosa</i>	4.50		6.49			2.20
	PB <i>Siderastrea siderea</i>	1.18					0.24
	PB <i>Montastrea annularis</i>		5.87				1.17
GORGONIANS (# col/ transect)							
		6	6	10	10	11	8.6

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

26.07 %, representing 97 % of the total abiotic cover and contributing markedly to the topographic rugosity of 5.76 m.

Turf algae, comprised by a mixed assemblage of short filamentous red and brown macroalgae was the dominant sessile-benthic component in terms of substrate cover at the outer shelf reef with an average of 34.06 % (range: 30.39 – 46.76 %). Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard ground. Fleshy algae, mostly *Lobophora variegata* contributed with a mean cover of 11.64 % to the total cover by benthic macroalgae of 45.7 %.

Figure 26 presents the variations of mean percent cover by sessile-benthic categories from Tourmaline outer shelf reef at 20 m depth. Reef substrate cover by live corals has been declining since the baseline characterization in 2004, when the mean cover was measured as 31.79 %. A reduction of 11 % was measured in 2005, when live coral declined to 28.74%. The recently measured cover by live corals of 25.03 % represents an overall decline from the 2004 baseline of 21.3 % and was statistically significant (ANOVA; $p = 0.001$). Reductions of live coral cover between the 2004 baseline and the present 2006 monitoring survey were evidenced for all five transects. The main driver of the declining trend of live coral decline at Tourmaline Reef was Boulder Star Coral, *Montastrea annularis*, which presented a 27 % reduction of substrate cover between 2004 and 2006 (Figure 27). Other components of the stony coral assemblage at a depth of 20 m in Tourmaline Reef, such as Great Star Coral, *M. cavernosa*, Greater Starlet Coral, *Siderastrea siderea* and Mustard Hill Coral, *Porites astreoides* have not shown significant reductions of substrate cover. Increasing trends of reef substrate cover by abiotic and benthic algal components is suggested from the monitoring data.

3.2 Fishes and Motile Megabenthic Invertebrates-

A total of 97 fish species have been identified from Tourmaline outer shelf reef (Appendix 1). Mean abundance within belt-transects during 2006 was 212.4 Ind/30 m² (range: 131 - 256 Ind/30 m²). The mean number of species per transect was 26.8 (range: 25 - 29). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 133.2 Ind/30 m² (range: 56 – 180 Ind/30 m²), representing 62.7 % of the total abundance within belt-transects (Table 31).

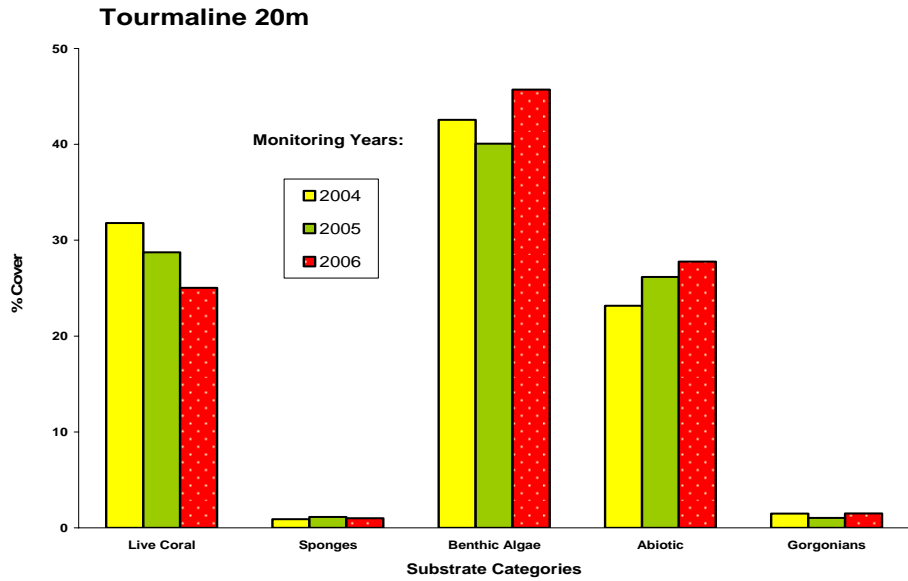


Figure 26. Monitoring trends (2004 – 2006) of mean substrate cover by sessile-benthic categories at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

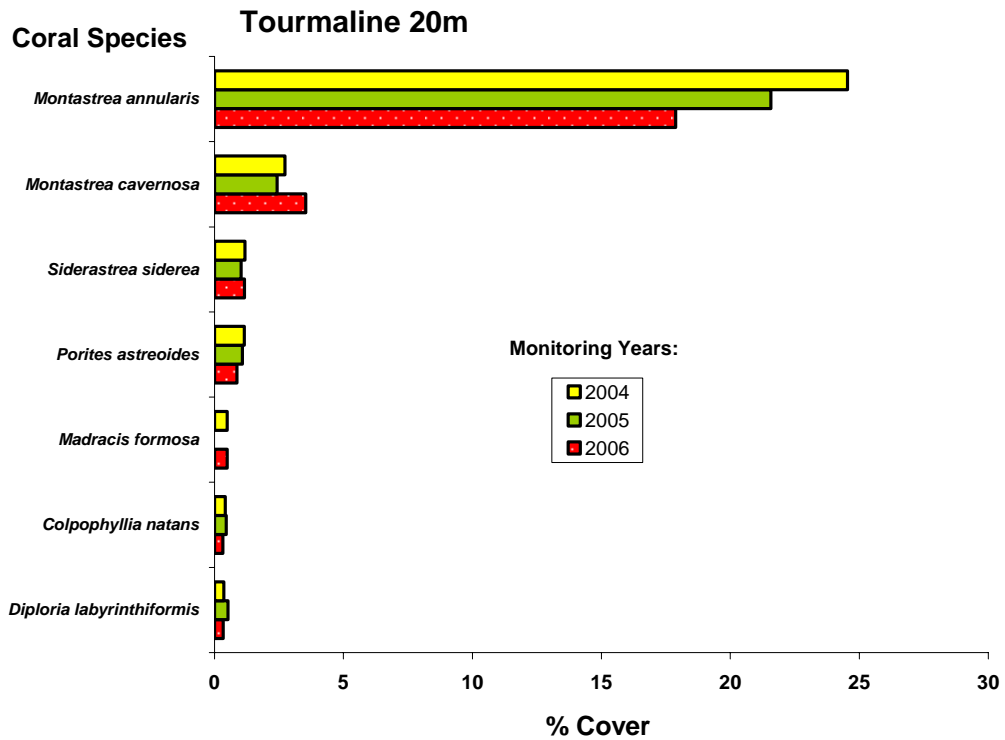


Figure 27. Monitoring trends (2004 – 2006) of mean substrate cover by stony coral species at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

Table 31. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, Mayaguez Bay. May, 2006

Depth: 20 m		TRANSECTS					MEAN
		1	2	3	4	5	
SPECIES	COMMON NAME	(Individuals/m ²)					
<i>Coryphopterus personatus</i>	Masked Goby	56	180	160	140	130	133.2
<i>Chromis cyanea</i>	Blue Chromis	10	6	12	27	1	11.2
<i>Gramma loreto</i>	Fairy Basslet	9	12	15	7	6	9.8
<i>Stegastes partitus</i>	Bicolor Damselfish	9	8	7	5	6	7.0
<i>Thalassoma bifasciatum</i>	Bluehead Wrasse	4	8	8	7	8	7.0
<i>Halichoeres garnoti</i>	Yellow-head Wrasse	6	5	4	1	5	4.2
<i>Canthigaster rostrata</i>	Caribbean Puffer	5	3	1	5	4	3.6
<i>Coryphopterus lipernes</i>	Peppermint Goby	4	2	2	2	8	3.6
<i>Myripristis jacobus</i>	Blackbar Soldierfish	3		2	9	4	3.6
<i>Gobiosoma evelynae</i>	Sharknose Goby	2	1	3	7	4	3.4
<i>Scarus iserti</i>	Stripped Parrotfish		3	4	5	2	2.8
<i>Cephalopholis cruentatus</i>	Graysby	4	3	4	2		2.6
<i>Stegastes leucostictus</i>	Beaugregory	5	3	3	1		2.4
<i>Stegastes planifrons</i>	Yellow-eye Damselfish	1	1	2	2	3	1.8
<i>Sparisoma aurofrenatum</i>	Redband Parrotfish	1	2	3	1		1.4
<i>Acanthurus coeruleus</i>	BlueTang	2	1	1	1		1.0
<i>Coryphopterus glaucofraenum</i>	Bridled Goby	1	1	1	1	1	1.0
<i>Holocentrus rufus</i>	Squirrelfish	1	1	1	1	1	1.0
<i>Scarus taeniopterus</i>	Princess Parrotfish			3	2		1.0
<i>Sparisoma radians</i>	Bucktooth Parrotfish		2			3	1.0
<i>Acanthurus bahianus</i>	Ocean Surgeon	1	1		1	1	0.8
<i>Acanthurus chirurgus</i>	Doctorfish	1	1	1		1	0.8
<i>Holocentrus coruscus</i>	Reef Squirrelfish		2		1	1	0.8
<i>Carangoides ruber</i>	Bar Jack		1		1	1	0.6
<i>Chaetodon aculeatus</i>	Longsnout Butterflyfish	1	1		1		0.6
<i>Flammeo marianus</i>	Lonspine Squirelfish		2	1			0.6
<i>Hypoplectrus puella</i>	Barred Hamlet			1	1	1	0.6
<i>Sparisoma viride</i>	Stoplight Parrotfish		1	1	1		0.6
<i>Aulostomus maculatus</i>	Trumpetfish	1				1	0.4
<i>Chaetodon capistratus</i>	Foureye Butterflyfish	1				1	0.4
<i>Chaetodon ocellatus</i>	Spotfin Butterflyfish		2				0.4
<i>Anisotremus virginicus</i>	Porkfish		1				0.2
<i>Bothus lunatus</i>	Peacock Flounder				1		0.2
<i>Caranx crysos</i>	Blue Runner					1	0.2
<i>Equetus acuminatus</i>	Highhat	1					0.2
<i>Haemulon flavolineatum</i>	French Grunt				1		0.2
<i>Hypoplectrus chlorurus</i>	Yellowtail Hamlet			1			0.2
<i>Hypoplectrus niger</i>	Black Hamlet		1				0.2
<i>Hypoplectrus unicolor</i>	Butter Hamlet					1	0.2
<i>Lutjanus apodus</i>	Schoolmaster Snapper	1					0.2
<i>Malacoctenus triangulatus</i>	Saddled Blenny	1					0.2
<i>Mulloides martinicus</i>	Yellowtail Goatfish					1	0.2
<i>Ocyurus chrysurus</i>	Yellowtail Snapper				1		0.2

Table 31. Continued							
<i>Pempheris schomburgki</i>	Glassy Sweeper	1					0.2
<i>Pomacanthus arcuatus</i>	Gray Angelfish						0.2
<i>Priacanthus cruentatus</i>	Glasseye Snapper	1					0.2
<i>Pseudupeneus maculatus</i>	Yellowtail Goatfish	1					0.2
TOTAL INDIVIDUALS		131	256	243	235	197	212.4
TOTAL SPECIES		25	29	26	28	26	26.8

The Masked Goby is a small zooplanktivorous fish (< 2.0 cm) that was observed hovering in small to moderate aggregations below coral ledges and crevices near the sand-coral interface. The Masked, Bridled, Sharpnose and Peppermint Gobies, Fairy Basslet, Bicolor Damselfish, Bluehead and Yellowhead Wrasses, Blue Chromis, Squirelfish, Caribbean Puffer and the Stoplight, Striped and Redband Parrotfishes were present in at least four of the five transects surveyed, and comprised the most abundant fish assemblage at the outer shelf reef.

Fish abundance decreased by 32 % compared to the previous 2005 survey, but was still 45 % higher than during the 2004 baseline survey (Figure 28). Differences of fish abundance between surveys was statistically significant (ANOVA; $p = 0.0014$). Differences were driven by abundance fluctuations of a numerically dominant species, such as the Masked Goby. Fish species richness has kept essentially constant, between 24.8 – 26.8 species per transect during the study, without any statistically significant differences between surveys (ANOVA; $p > 0.05$).

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 almost 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 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 not yet evident.

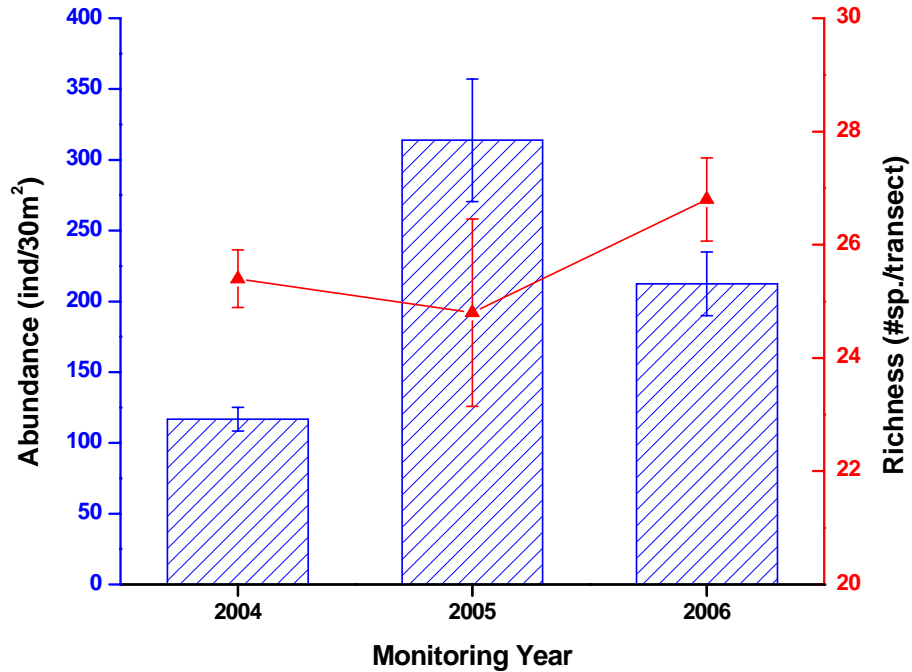


Figure 28. Monitoring trends (2004 – 2006) of fish species richness and abundance at Outer Shelf Reef Tourmaline, 20 m depth, Mayaguez Bay.

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 seven species and doctorfishes (*Acanthurus spp.*), represented by three species comprised the main herbivorous fish assemblage. Among large invertebrate and small demersal fish predators, adult Nassau Grouper, Red Hinds, one large Great Barracuda and several 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. One juvenile Spiny Lobster was observed. Hogfish, Cubera and Dog Snappers have been identified from previous ASEC surveys at this reef (García-Sais et al, 2005). The cleaner Shrimp (*Periclimenes pedersoni*) was the only invertebrate observed within belt-transects during 2006. One small Spiny Lobster, *Panulirus argus* was observed outside transects.

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 depth, May, 2006

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

SPECIES	COMMON NAME	# - (cm)	
<i>Balistes vetula</i>	Queen Triggerfish	1 - (30)	
<i>Epinephelus guttatus</i>	Red Hind	3 - (15)	1 - (25)
<i>Epinephelus striatus</i>	Nassau Grouper	1 - (40)	
<i>Carangoides ruber</i>	Bar Jack	1 - (25)	
<i>Decapterus macarellus</i>	Mackerel Scad	100 - (15)	
<i>Holacanthus tricolor</i>	Rock Beauty	2 - (20)	1 - (25)
<i>Holacanthus ciliaris</i>	French Angelfish	1 - (30)	
<i>Lutjanus apodus</i>	Schoolmaster	1 - (25)	
<i>Lutjanus mahogany</i>	Mahogany Snapper	1 - (25)	
<i>Ocyurus chrysurus</i>	Yellowtail Snapper	5 - (18)	2 - (30)
<i>Scomberomorus regalis</i>	Cero Mackerel	2 - (30)	2 - (50)
<i>Sphyrnaea barracuda</i>	Great Barracuda	1 - (70)	
Invertebrates			
<i>Panulirus argus</i>	Spiny Lobster	1 - (18)	

Table 33. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Outer-shelf Reef, Mayaguez, May, 2006

DATE: May, 2006
Depth: 20 m

TAXA	COMMON NAME	TRANSECTS					MEAN ABUNDANCE (IND/30 m²)
		1	2	3	4	5	
<i>Periclimenes sp.</i>	Cleaner Shrimp		1				0.2
TOTALS		0	1	0	0	0	0.2

Photo Album 8 (Tourmaline 20 m)
OuterShelf Reef





3.0 Tourmaline Outer Shelf Reef – 10 m

3.1 Sessile-benthic Reef Community

At a depth of 10 m, Tourmaline Outer Shelf Reef exhibits a very well defined “spur-and-groove” formation that runs perpendicular to the shelf-edge and ends in a sandy-silt deposit at a depth of 14 m. Spurs are about 2 - 3 m tall, separated by coralline sand and coral rubble deposited at the grooves. Stony corals grow on top of the spurs and along the walls in massive, branching and encrusting colonies. Soft corals are common and a visually prominent feature of the reef benthos. An existing set of five permanent transects established on top of the spurs during the baseline characterization in 1999 by García et al. (2001) was monitored for the third time during July, 2006. Panoramic views of Tourmaline outer shelf reef at a depth of 10 m are presented in Photo Album 9.

A total of 26 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 (*Montastrea 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 34.24 % (range: 18.36 – 53.13 %). Boulder Star Coral, *Montastrea annularis* (complex) and Yellow Pencil Coral, *Madracis mirabilis* were the dominant coral species in terms of substrate cover with means of 7.45 and 7.02 %, respectively. An extraordinarily large colony of Yellow Pencil Coral covered almost four meters along transect two, contributing to a total cover by stony corals of 53.13 % in that transect. Colonies of Boulder Star Coral, Mustard Hill Coral (*Porites astreoides*) and Lettuce Coral (*Agaricia agaricites*) were intercepted by all five transects in the 2006 monitoring survey.

Soft corals (gorgonians) were highly abundant, with an average of 20.8 colonies/transect and along with stony corals were the most visually prominent assemblage of the reef benthos. Encrusting sponges, zoanthids (*Palythoa caribbea*) and gorgonians (*Erythropodium caribaeorum*) were present, but represented minor components of the reef benthos (substrate cover < 3 %). Reef overhangs, associated with coral ledges of Boulder Star Coral averaged 8.10 % and contributed markedly to the topographic

Table 26. Percent reef substrate cover by sessile-benthic categories at Tourmarine Outer Shelf Reef, Mayaguez Bay, May, 2006

Depth: 10 m Survey Date: May, 2006		TRANSECTS					Mean
		1	2	3	4	5	
Rugosity (m)		3.47	4.39	3.72	6.06	4.65	4.46
Substrate Categories							
BENTHIC ALGAE							
Turf Algae		40.46	27.29	42.17	58.41	64.71	46.61
Coralline algae		0.97	0.49	1.46		0.38	0.66
Fleshy Algae		1.05	0.29	3.28	1.06	2.05	1.54
Total Benthic Algae		42.47	28.07	46.90	59.46	67.14	48.81
CYANOBACTERIA							
ABIO TIC			0.49			0.96	0.29
Reef Overhangs		3.64	6.94	11.51	11.52	6.89	8.10
Coral Rubble		15.89	7.64			3.28	5.36
Total Abiotic		19.52	14.58	11.51	11.52	10.17	13.46
SPONGES		0.97	1.37		0.53	0.87	0.75
ANTHOZOANS		0.31			1.43	0.38	0.43
ENCRUSTING GORGONIANS		0.73	2.36	1.46	3.49	2.12	2.03
LIVE CORAL							
<i>Montastrea annularis</i>		7.72	12.99	6.99	4.30	5.26	7.45
<i>Madracis mirabilis</i>		1.56	33.54				7.02
<i>Porites astreoides</i>		2.75	2.64	10.78	3.18	1.84	4.24
<i>Porites divaricata</i>				6.77	4.36	5.12	3.25
<i>Porites porites</i>		14.85	1.25				3.22
<i>Dendrogyra cylindrus</i>		3.27		2.05	7.16		2.50
<i>Colpophyllia natans</i>		2.72		7.90			2.12
<i>Agaricia agaricites</i>		0.52	0.68	1.02	4.55	0.89	1.53
<i>Montastrea cavernosa</i>				1.54		2.66	0.84
<i>Diploria labyrinthiformis</i>			1.18			1.63	0.56
<i>Meandrina meandrites</i>			0.39	2.05			0.49
<i>Agaricia lamarcki</i>		0.63		0.51			0.23
<i>Madracis decactis</i>		0.82					0.16
<i>Stephanocoenia michelini</i>		0.73					0.15
<i>Porites colonensis</i>						0.58	0.12
<i>Eusmilia fastigiata</i>				0.51			0.10
<i>Scolymia cubensis</i>		0.42					0.08
<i>Agaricia grahamae</i>			0.39				0.08
<i>Diploria strigosa</i>						0.38	0.08
Total Stony Coral		36.01	53.13	40.13	23.60	18.36	34.24
GORGONIANS (# col/ transect)		23	22	15	21	23	20.8

Coral species outside transects: *Acropora cervicornis*, *Siderastrea siderea*, *Manicina areolata*, *Mycetophyllia lamarckiana*, *Mycetophyllia sp.*, *Millepora squarrosa*, *Leptoseris cucullata*

rugosity of 4.46 m. Turf algae, comprised by a mixed assemblage of short filamentous red and brown macroalgae presented an average substrate cover of 46.61 % (range: 27.29 – 64.71 %). Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard ground. Cyanobacterial films were present in two transects, but with a relatively low substrate cover in the reef (< 1.0 %).

Figure 29 presents the monitoring trends of reef substrate cover by sessile-benthic categories from Tourmaline outer shelf reef at 10 m depth, including the baseline survey of 1999 and three annual monitoring surveys (2004-06). Live coral remained stable between the baseline survey and 2004. There was a reduction of mean substrate cover by (total) stony corals of approximately 10 % between the 2004 (49.1%) and 2005 (44.3%) survey, but the difference was not statistically significant. Although a decline of live coral cover was measured from all five transects surveyed in 2005, there was substantial variability associated with the magnitude of the variations within transects (García et al., 2005). During this 2006 monitoring survey, mean live coral cover declined again from 44.26% in 2005 to 34.25%, an overall reduction of 22.6%. At the community level, the variation of total live coral cover was not statistically significant (ANOVA; $p = 0.326$), perhaps due to the high variability associated with the magnitude (not direction) of the variations within transects. But at the population level, there was a statistically significant decline of live coral detected for the dominant coral species in terms of reef substrate cover, *Montastrea annularis* (complex) (ANOVA; $p = 0.028$). Reef substrate cover by *M. annularis* declined 46 % between 2006 and 2005 (Figure 30), and was the main driver of the overall decline of live coral for this reef. Conversely, there seems to be a trend of increasing substrate cover for the Yellow Pencil Coral, *Madracis mirabilis*.

This reef is also one of the most complex reefs in the monitoring program because of the high number of substrate transitions and the presence of large, irregular coral colonies (e.g. *Dendrogyra cylindrus*) and extensive zones of fragile branching corals (*M. mirabilis*), where the chain path can not be properly marked for precise repeated measurements of substrate cover.

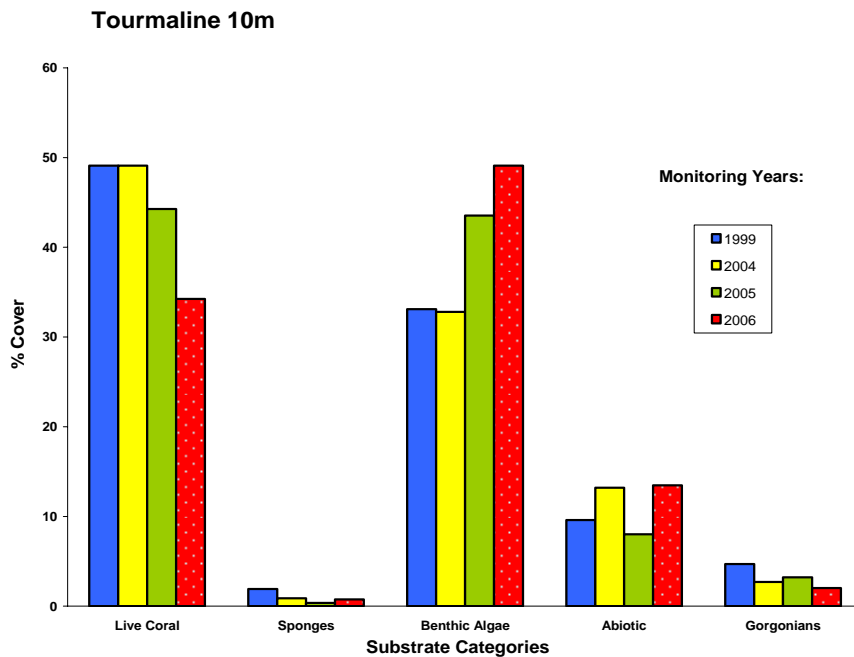


Figure 29. Monitoring trends (1999 – 2006) of mean substrate cover by sessile-benthic categories at Tourmaline Reef – 10 m, Mayaguez.

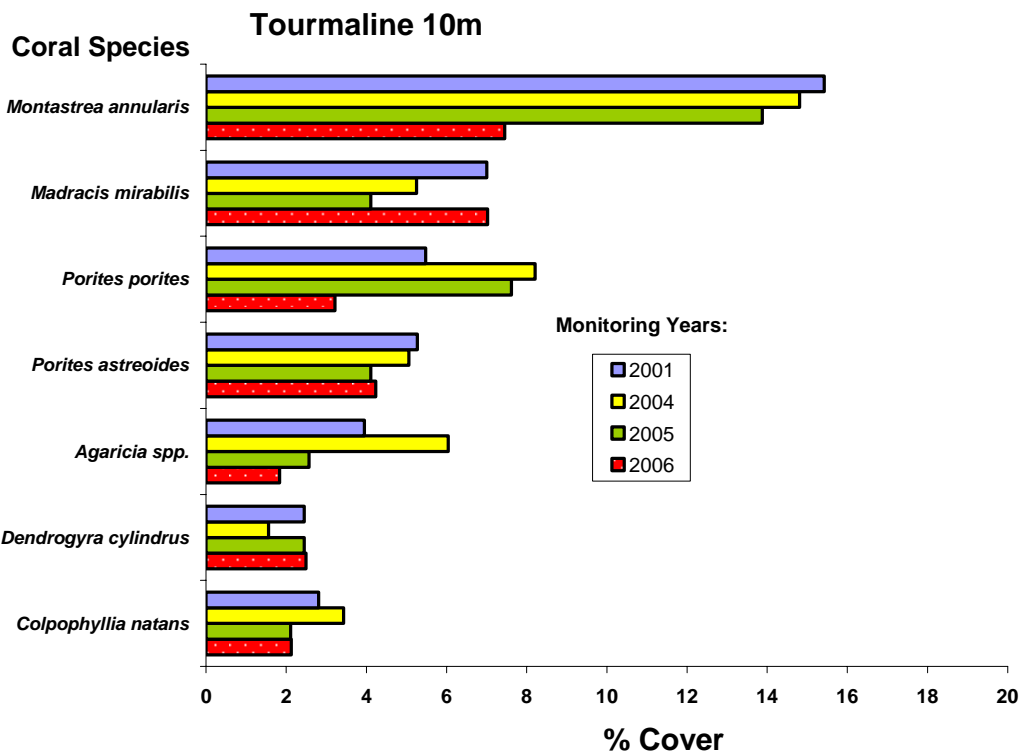


Figure 30. Monitoring trends (1999 – 2006) of mean cover by stony coral species at Tourmaline Reef – 10 m, Mayaguez.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 87 diurnal, non-cryptic fish species have been identified during monitoring surveys from Tourmaline Outer Shelf Reef at a depth of 10 m (Appendix 1). Mean abundance within belt-transects during the 2006 survey was 74.8 Ind/30 m² (range: 51 - 100 Ind/30 m²). The mean number of species per transect was 22 (range: 20 - 26). The Bicolor Damselfish (*Stegastes partitus*) and the Bluehead Wrasse (*Thalassoma bifasciatum*) were the numerically dominant species with a combined mean abundance of 24.6 Ind/30 m², representing 32.9 % of the total abundance within belt-transects (Table 35). A total of eight species were present in all five transects. These included the Yellowhead and Bluehead Wrasses, Sharknose Goby, Beaugregory and Bicolor Damselfishes, Redband Parrotfish, Four-eye Butterflyfish and the Harlequin Bass. The Blue Chromis and Striped Parrotfish were present in four transects and ranked among the top five most abundant species within belt-transects.

Small, opportunistic micro-invertebrate predators (wrasses, gobies), demersal and pelagic schooling zooplanktivores (Bicolor Damselfish, Blue Chromis) and herbivores (*Scarus spp.*, *Sparisoma spp.*, *Acanthurus spp.*) numerically dominated the reef fish community. Among large invertebrate and small demersal fish predators, small growing 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* were present in mid-water over the reef. Pelagic predators included Cero Mackerels, Great Barracuda and Blue Runner.

Monitoring trends of fish species richness and abundance are presented in Figure 31. A statistically significant decline of fish abundance during 2006, relative to previous years was detected (ANOVA; $p = 0.050$). Differences of abundance by schooling zooplanktivores with highly aggregated distributions, such as Blue Chromis (*Chromis cyanea*) and Creole Wrasse (*Clepticus parrae*) influenced the overall decline of fish community abundance during 2006. Difference of fish species richness were not statistically significant (ANOVA; $p > 0.05$).

Table 35. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, Mayaguez - 10 m depth. May, 2006

Depth: 10 m Survey Date: May, 2006		TRANSECTS					MEAN
		1	2	3	4	5	
SPECIES	COMMON NAME	Individuals/30m ²					
<i>Stegastes partitus</i>	Bicolor Damselfish	16	28	16	10	6	15.2
<i>Thalassoma bifasciatum</i>	Bluehead Wrasse	8	13	2	20	4	9.4
<i>Scarus iserti</i>	Stripped Parrotfish	1	9	11		11	6.4
<i>Chromis cyanea</i>	Blue Chromis		17	6	5	1	5.8
<i>Halichoeres garnoti</i>	Yellow-head Wrasse	5	6	2	12	2	5.4
<i>Gobiosoma evelynae</i>	Sharknose Goby	7	3	8	1	1	4.0
<i>Sparisoma aurofrenatum</i>	Redband Parrotfish	4	5	2	1	3	3.0
<i>Stegastes leucostictus</i>	Beaugregory	2	2	4	3	4	3.0
<i>Sparisoma viride</i>	Stoplight Parrotfish	3		2	4	4	2.6
<i>Chaetodon capistratus</i>	Foureye Butterflyfish	2	3	2	2	1	2.0
<i>Sparisoma radians</i>	Bucktooth Parrotfish	3			3	3	1.8
<i>Acanthurus bahianus</i>	Ocean Surgeon	2	1	1	2	2	1.6
<i>Myripristis jacobus</i>	Blackbar Soldierfish	1		2	4		1.4
<i>Gramma loreto</i>	Fairy Basslet	3			2	1	1.2
<i>Serranus tigrinus</i>	Harlequin Bass	1	1	1	1	2	1.2
<i>Amblycirrhitis pinos</i>	Redspotted Hawkfish	2		1	1	1	1.0
<i>Holacanthus tricolor</i>	Rock Beauty		1	3		1	1.0
<i>Acanthurus coeruleus</i>	BlueTang	1	1	1		1	0.8
<i>Canthigaster rostrata</i>	Caribbean Puffer		1	1	2		0.8
<i>Cephalopholis cruentatus</i>	Graysby	1		2	1		0.8
<i>Coryphopterus lipernes</i>	Peppermint Goby		2	2			0.8
<i>Holocentrus coruscus</i>	Reef Squirrelfish		2	1	1		0.8
<i>Chaetodon striatus</i>	Banded Butterflyfish				2	1	0.6
<i>Haemulon flavolineatum</i>	French Grunt		1		2		0.6
<i>Holocentrus rufus</i>	Squirrelfish	1			1	1	0.6
<i>Acanthurus chirurgus</i>	Doctorfish	1		1			0.4
<i>Stegastes planifons</i>	Yellow-eye Damselfish		1			1	0.4
<i>Anisotremus virginicus</i>	Porkfish				1		0.2
<i>Bodianus rufus</i>	Spanish Hogfish		1				0.2
<i>Carangoides ruber</i>	Bar Jack				1		0.2
<i>Equetus acuminatus</i>	Highhat				1		0.2
<i>Haemulon chrysargyreum</i>	Smallmouth Grunt				1		0.2
<i>Halichoeres maculipinna</i>	Clown Wrasse			1			0.2
<i>Hypoplectrus puella</i>	Barred Hamlet		1				0.2
<i>Hypoplectrus unicolor</i>	Butter Hamlet		1				0.2
<i>Mulloides martinicus</i>	Yellowtail Goatfish			1			0.2
<i>Scarus vetula</i>	Queen Parrotfish				1		0.2
<i>Stagastes variabilis</i>	Cocoa Damselfish	1					0.2
TOTAL INDIVIDUALS		65	100	73	85	51	74.8
TOTAL SPECIES		20	21	23	26	20	22.0

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 evidenced during our surveys in 1999, 2004, 2005, and the present survey appear to be an indication that this fish population has not recovered from the intense fishing effort that it received during the previous decade.

The Cleaner Shrimp, *Periclimenes pedersoni* was the only megabenthic invertebrate observed within belt-transects during the 2006 monitoring survey (Table 37). One juvenile Spiny Lobster, *Panulirus argus* and one spotted spiny lobster, *Panulirus guttatus* were observed outside transects during the ASEC survey.

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 depth, May, 2006

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

SPECIES	COMMON NAME	# - (cm)		
<i>Carangoides crysos</i>	Blue Runner	1 - (30)	1 - (40)	
<i>Epinephelus guttatus</i>	Red Hind	1 - (30)		
<i>Lachnolaimus maximus</i>	Hogfish	1 - (40)		
<i>Lutjanus apodus</i>	Schoolmaster	2 - (20)	5 - (30)	2 - (40)
<i>Lutjanus synagris</i>	Lane Snapper	4 - (15)	2 - (20)	2 - (25)
<i>Ocyurus chrysurus</i>	Yellowtail Snapper	2 - (20)	1 - (30)	
<i>Scomberomorus regalis</i>	Cero Mackerel	1 - (50)		
<i>Sphyaena barracuda</i>	Great Barracuda	1 - (70)		
<i>Holacanthus tricolor</i>	Rock Beauty	3 - (15)	1 - (20)	
Invertebrates				
<i>Panulirus argus</i>	Spiny Lobster	1 - (15)		
<i>Panulirus guttatus</i>	Spotted Spiny Lobster	1 - (10)		

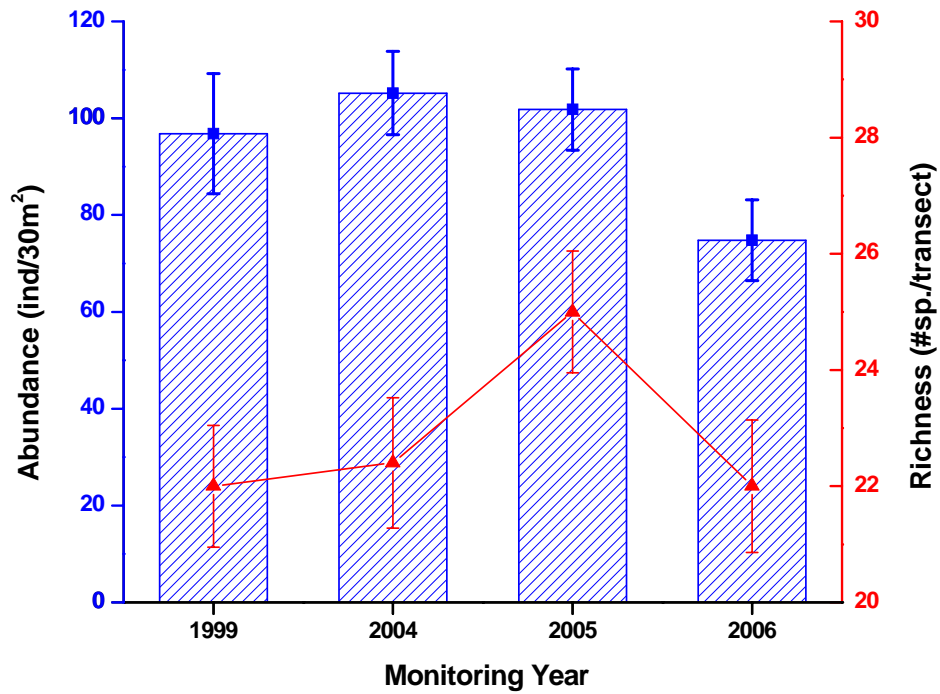


Figure 31. Monitoring trends (2004 – 2006) of fish species richness and abundance at Outer Shelf Reef Tourmaline, 10 m depth, Mayaguez Bay.

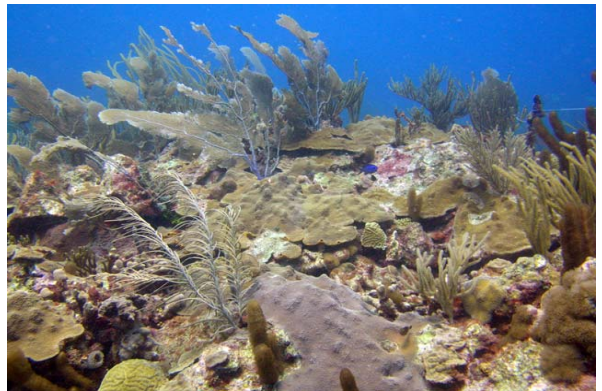
Table 37. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Outer-shelf Reef, Mayaguez. May, 2006

Depth: 10 m
Date: May, 2006

TAXA	COMMON NAME	TRANSECTS					MEAN ABUNDANCE (IND/30 m ²)
		1	2	3	4	5	
<i>Periclimenes pedersoni</i>	Cleaner Shrimp	2	0	0	0	0	0.4
TOTALS		2	0	0	0	0	0.4

Photo Album 9 (Tourmaline 10 m)
OuterShelf Reef





4.0 Cayo Coral – Guánica Natural Reserve

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

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 32). 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 an 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.

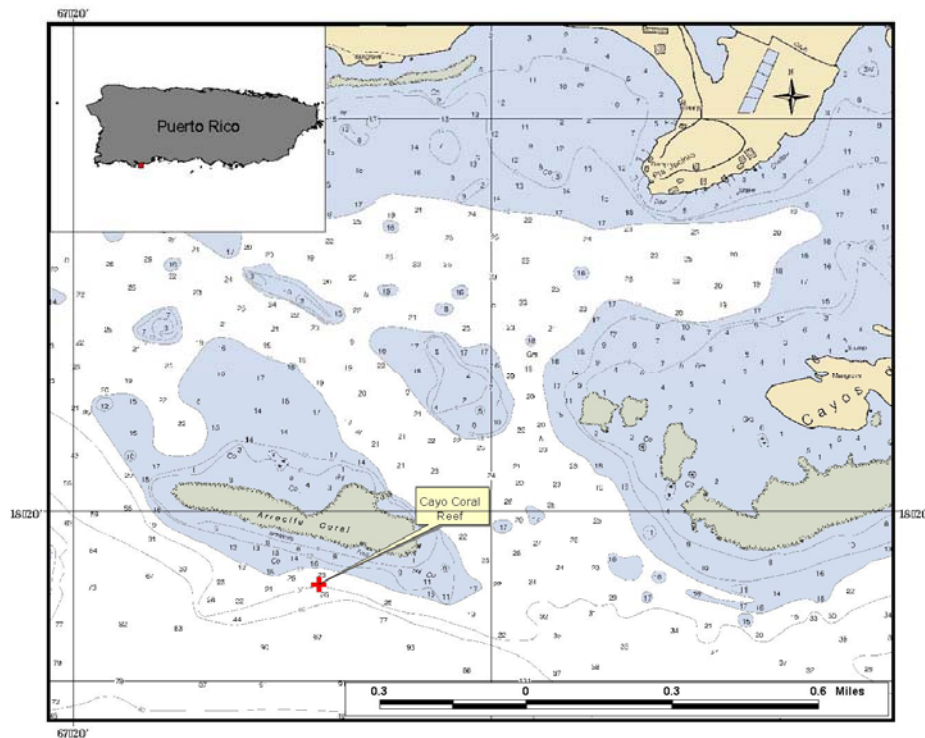


Figure 32. Location of coral reef survey stations at Cayo Coral Reef, Guánica.

4.1.0 Sessile-benthic Reef Community

A total of 22 stony corals, including 12 intersected by line transects were identified from Cayo Coral Reef during the 2006 survey. Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 13.31 % (range: 8.85 – 22.98 %). Boulder Star Coral, *Montastrea annularis* (complex) was the main species in terms of substrate cover with a mean of 2.90% (range: 0 – 2.26 %), representing 21.8 % of the total cover by stony corals (Table 38). Boulder Brain Coral (*Colpophyllia natans*) and the Symetrical Brain Coral (*Diploria strigosa*) ranked second and third in terms of substrate cover at Cayo Coral. Small colonies of Mustard-Hill Coral, *Porites astreoides* and Lettuce Coral, *Agaricia spp.* were also common. Soft corals (gorgonians) were highly abundant, with an average of 21.2 colonies/transect, and along with stony corals contributed to the high benthic habitat complexity of the reef. Small sponges and patches of colonial zoanthids (*Palythoa caribbea*) represented minor components of the reef benthos. Reef overhangs associated with growth of massive Boulder Star Coral colonies averaged 12.74 m and contributed substantially to the mean rugosity of 2.94 m.

Benthic algae, comprised by turf, fleshy and coralline macroalgae were the most prominent sessile-benthic category in terms of substrate cover with a combined mean of 64.59 %. Turf algae was the dominant assemblage, representing 95.8 % of the total cover by benthic algae at Cayo Coral (Table 38).

Figure 33 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 and 2006. Differences of reef substrate cover by live stony corals between surveys were statistically significant (ANOVA; $p = 0.0091$), and constitute evidence of degradation of the coral reef community structure. The reduction of 11 % of mean substrate cover between the baseline survey in 1999 and the 2006 monitoring survey represents a decline of approximately 41 % of total live coral cover at Cayo Coral. The reduction of live coral cover was evidenced across the five permanent transects surveyed. A corresponding increment of cover by benthic algae has been measured.

Table 38. Percent reef substrate cover by sessile-benthic categories at Cayo Coral, Guánica
April, 2006

Depth: 8 m Survey Date: April 29, 2006		TRANSECTS					Mean
		1	2	3	4	5	
Rugosity (m)		1.56	4.33	2.34	3.62	2.84	2.94
Substrate Categories							
BENTHIC ALGAE							
Turf Algae		69.61	51.63	65.02	58.41	64.71	61.87
Fleshy Algae			4.95	2.63	1.06	2.05	2.14
Coralline Algae			0.24	2.25		0.38	0.58
Total Benthic Algae		69.61	56.82	69.89	59.46	67.14	64.59
CYANOBACTERIA						0.96	0.19
ABIOTIC							
Reef Overhang		9.81	18.15	17.34	11.52	6.89	12.74
Rubble						3.28	0.66
Sand		1.13					0.23
Total Abiotic		10.94	18.15	17.34	11.52	10.17	13.63
SPONGES		1.46	0.18	1.80	0.53	0.87	0.97
ANTHOZOANS		2.27	0.90		1.43	0.38	1.00
ENCRUSTING GORGONIANS					3.49	2.12	1.12
LIVE CORAL							
<i>Montastrea annularis</i>		2.59	2.35		4.30	5.26	2.90
<i>Colpophyllia natans</i>		4.54		5.18			1.94
<i>Diploria strigosa</i>			9.17			0.38	1.91
<i>Montastrea cavernosa</i>			4.52			2.66	1.44
<i>Porites astreoides</i>		4.46		1.58			1.21
<i>Agaricia agaricites</i>					4.55	0.89	1.09
<i>Siderastrea siderea</i>			3.98				0.80
<i>Eusmilia fastigata</i>			2.96				0.59
<i>Meandrina meandrites</i>		0.32		2.10			0.49
<i>Diploria labyrinthiformis</i>				0.30		1.63	0.39
<i>Madracis decactis</i>				1.80			0.36
<i>Siderastrea radians</i>		1.05					0.21
Total Stony Coral		12.97	22.98	10.96	8.85	10.82	13.31
GORGONIANS (# col/ transect)		18	25	27	18	18	21.20

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

Variations of the mean substrate cover by coral species during monitoring surveys are shown in Figure 34. A drastic decline of the percent substrate cover by Boulder Brain Coral, *Montastrea annularis* is evident from the monitoring data. The variations of cover by *M. annularis* between monitoring years were statistically significant (ANOVA; $p = 0.045$). Boulder Brain Coral declined its reef 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 %). The density of soft coral (gorgonian) colonies has remained virtually constant between surveys.

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 86 fish species have been identified from Cayo Coral during monitoring surveys (Appendix 1). Mean abundance within belt-transects during April, 2006 was 71.8 Ind/30 m² (range: 35 - 96 Ind/30 m²). The mean number of species per transect was 18.5 (range: 17 - 24). Bluehead Wrasse (*Thalassoma bifasciatum*), Sharknose Goby (*Gobiosoma evelynae*), Bicolor and Dusky Damselfishes (*Stegastes partitus*, *S. dorsopunicans*) were the numerically dominant species with a combined mean abundance of 38.4 Ind/30 m², representing 53.5 % of the total abundance within belt-transects (Table 39). Six species were present on all five transects surveyed, whereas other six species were present on four transects.

Small, opportunistic micro-invertebrate predators (wrasses, gobies, puffers), demersal and pelagic schooling zooplanktivores (Bicolor Damselfish, Blue Chromis, Creole Wrasse) 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. Adult Red Hind, Nassau and Yellowfin Groupers, Hogfish, Schoolmaster, Mahogany and Yellowtail Snappers represented top demersal predators observed during the 2006 ASEC survey at Cayo Coral (Table 40). One juvenile Jewfish (*Epinephelus itajara*) was observed at depth of 12 meters. Pelagic predators, such as Cero Mackerels, Great Barracudas and Blue Runners have been previously reported. Banded Coral Shrimp (*Stenopus hispidus*), and a Hermit Crab (Paguridae) were the motile megabenthic invertebrates observed within belt-transects (Table 41). One juvenile Spiny Lobster (*Panulirus argus*) were observed outside transects.

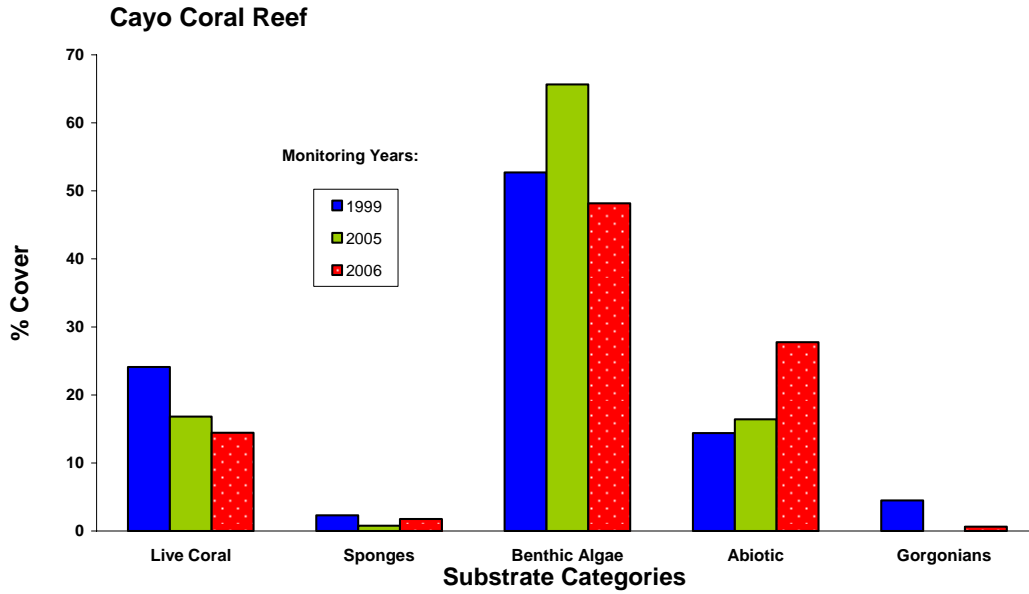


Figure 33. Monitoring trends (1999 – 2006) of mean substrate cover by sessile-benthic categories at Cayo Coral – 8 m, Guánica.

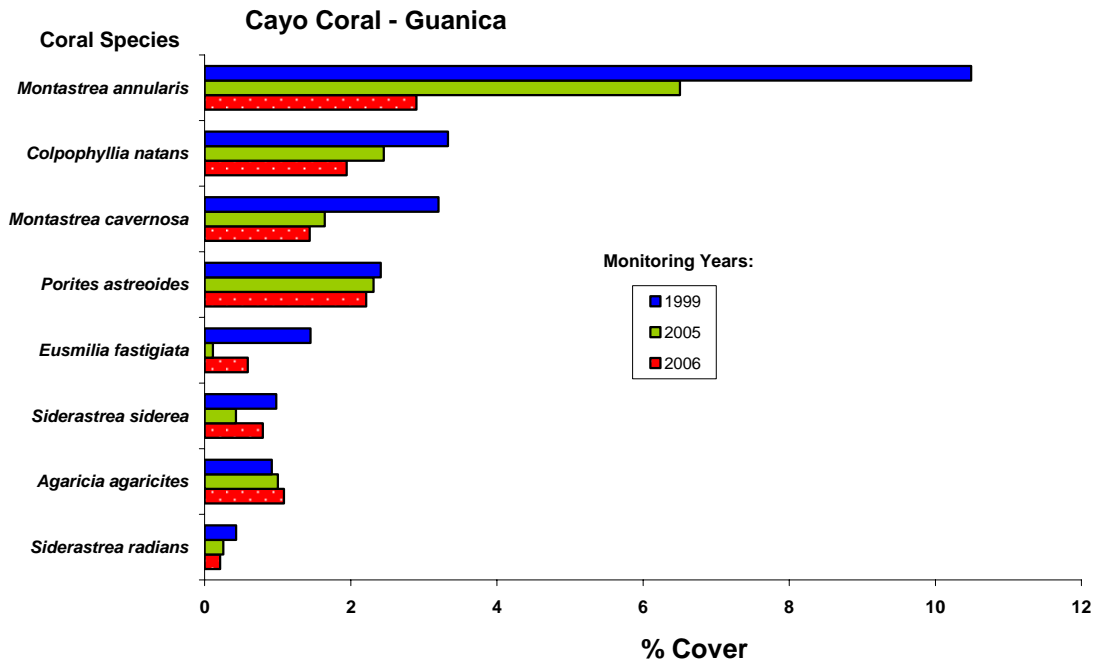


Figure 34. Monitoring trends (1999 – 2006) of mean substrate cover by stony coral species at Cayo Coral – 8 m, Guánica

Table 39. Taxonomic composition and abundance of fishes within belt-transects Cayo Coral Reef, Guanica. April, 2006

Depth: 8 m		TRANSECTS (Individuals/30 m ²)					MEAN
SPECIES	COMMON NAME	1	2	3	4	5	
<i>Thalassoma bifasciatum</i>	Bluehead Wrasse	2	4	25	26	34	18.2
<i>Gobiosoma evelynae</i>	Sharknose Goby	2	13	7	15	6	8.6
<i>Stegastes partitus</i>	Bicolor Damselfish		2	1	19	9	6.2
<i>Stegastes dorsopunicans</i>	Dusky Damselfish	7	6	5	5	4	5.4
<i>Clepticus parrae</i>	Creole Wrasse		22				4.4
<i>Scarus iserti</i>	Stripped Parrotfish	3	7		5	7	4.4
<i>Acanthurus bahianus</i>	Ocean Surgeon		4	4	2	2	2.4
<i>Cephalopholis cruentatus</i>	Graysby	3	1	2	3	2	2.2
<i>Sparisoma aurofrenatum</i>	Redband Parrotfish	3		3	3	2	2.2
<i>Sparisoma viride</i>	Stoplight Parrotfish	2	4	2	2	1	2.2
<i>Halichoeres garnoti</i>	Yellow-head Wrasse	1		1	4	4	2.0
<i>Sparisoma radians</i>	Bucktooth Parrotfish		5			4	1.8
<i>Microspathodon chrysurus</i>	Yellowtail Damselfish	2	3	1	1	1	1.6
<i>Canthigaster rostrata</i>	Caribbean Puffer		1	4		2	1.4
<i>Chaetodon capistratus</i>	Foureye Butterflyfish	2	2		2	1	1.4
<i>Chromis cyanea</i>	Blue Chromis		7				1.4
<i>Haemulon flavolineatum</i>	French grunt		2	1	2	2	1.4
<i>Halichoeres maculipinna</i>	Clown Wrasse			4	3		1.4
<i>Stegastes leucostictus</i>	Beau-gregory	1	1	3	1	1	1.4
<i>Holocentrus rufus</i>	Squirrelfish		1	1	2	1	1.0
<i>Odontoscion dentex</i>	Reef Croaker	2	1			1	0.8
<i>Scarus taeniopterus</i>	Princess Parrotfish			2	2		0.8
<i>Serranus tigrinus</i>	Harlequin Bass				2	2	0.8
<i>Acanthurus coeruleus</i>	Blue Tang	1	1	1			0.6
<i>Aulostomus maculatus</i>	Trumpetfish		1		2		0.6
<i>Holocentrus coruscus</i>	Reef Squirrelfish		1		2		0.6
<i>Scarus vetula</i>	Queen Parrotfish	1	1			1	0.6
<i>Stegastes planifrons</i>	Yellow-eye Damselfish	1	1		1		0.6
<i>Acanthurus chirurgus</i>	Doctorfish				1	1	0.4
<i>Hypoplectrus puella</i>	Barred Hamlet	1				1	0.4
<i>Pomacanthus arcuatus</i>	Gray Angelfish			1		1	0.4
<i>Anisotremus virginicus</i>	Porkfish				1		0.2
<i>Cantherhynes pullus</i>	Tail-light Filefish			1			0.2
<i>Chaetodon striatus</i>	Banded Butterflyfish		1				0.2
<i>Coryphopterus sp.</i>	Goby	1					0.2
<i>Haemulon macrostomus</i>	Spanish grunt		1				0.2
<i>Hypoplectrus indigo</i>	Indigo Hamlet		1				0.2
<i>Lutjanus apodus</i>	Schoolmaster snapper		1				0.2
<i>Mulloides martinicus</i>	Yellowtail goatfish				1		0.2
<i>Ocyurus chrysurus</i>	Yellowtail snapper		1				0.2
	TOTAL INDIVIDUALS	35	96	69	69	90	71.8
	TOTAL SPECIES	17	28	19	24	23	18.5

Table 40. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Cayo Coral. Guánica. April, 2006

Depth range : 8 - 12 m
Duration - 30 min.

SPECIES	COMMON NAME	# - (cm)		
<i>Carangoides ruber</i>	Bar Jack	2 - (25)		
<i>Epinephelus guttatus</i>	Red Hind	2 - (25)	1 - (30)	
<i>Epinephelus itajara</i>	Jewfish	1 - (125)		
<i>Epinephelus striatus</i>	Nassau Grouper	1 - (40)		
<i>Holacanthus ciliaris</i>	French Angel	1 - (30)		
<i>Lachnolaimus maximus</i>	Hogfish	1 - (25)		
<i>Lutjanus apodus</i>	Schoolmaster	7 - (25)	12 - (30)	5 - (35)
<i>Lutjanus mahogany</i>	Mahogany Snapper	1 - (15)	2 - (20)	2 - (25)
<i>Lutjanus synagris</i>	Lane Snapper	2 - (15)		
<i>Ocyurus chrysurus</i>	Yellowtail Snapper	1 - (15)	1 - (25)	
Invertebrates				
<i>Panulirus argus</i>	Spiny Lobster	1 - (15)		
Marine Mammals				
<i>Tursiops sp.</i>	Bottle-nose Dolphin	4 - (>200)		

Table 41. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Coral, 8 m depth, Guánica. April, 2006

DATE: April, 2006 Depth: 8 m	TRANSECTS					MEAN ABUNDANCE (IND/30 m²)	
	1	2	3	4	5		
TAXA	COMMON NAME						
<i>Stenopus hispidus</i>	Banded coral Shrimp	1					0.2
	Hermit Crab				1		0.2
	TOTALS	1	0	0	0	1	0.4

Figure 35 displays monitoring trends of fish abundance and species richness from Cayo Coral. Variations of abundance and species richness between monitoring surveys are not statistically significant (ANOVA; $p > 0.05$).

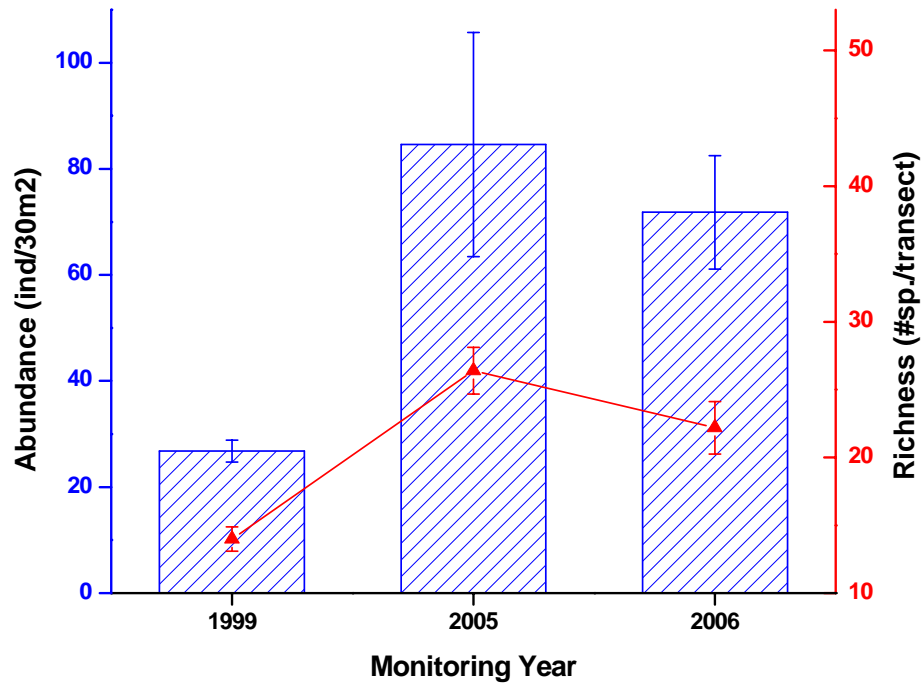


Figure 35. Monitoring trends (1999 – 2006) of fish species richness and abundance at Cayo Coral Reef, 10 m depth, Guanica Natural Reserve.

**Photo Album 10 (Guanica 10 m)
Cayo Coral Reef**





5.0 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 36). 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 11.

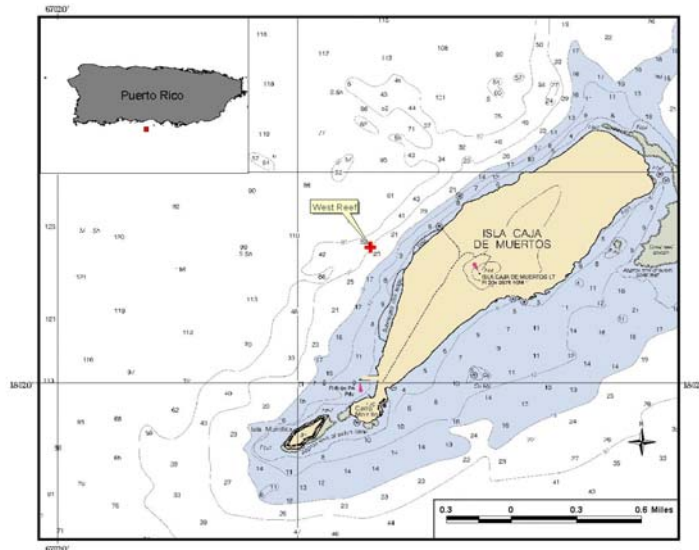


Figure 27. Location of coral reef survey stations at West Reef of Isla Caja de Muerto, Ponce.

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 56.54 % along permanent transects and represented 99 % of the total benthic algae during the 2006 survey (Table 42).

Live stony corals presented a mean substrate cover of 11.42 % (range: 5.69 – 13.96 %) along transects surveyed during 2006. The Boulder Star Coral, *Montastrea annularis* (complex) was the dominant coral species with a mean substrate cover of 4.61 % (range: 1.65 – 8.93 %), representing 40.4 % of the total substrate cover by live stony corals. A total of 21 species of stony corals were identified from West Reef, including 13 species intersected by transects. Great Star Coral (*M. cavernosa*), Mustard-Hill Coral (*Porites astreoides*), Greater and Lesser Starlet Corals, *Siderastrea siderea*, and *S. radians* were present in at least three out of the five transects surveyed, and along with Boulder Star Coral comprised the main coral assemblage of the West Reef (Table 42).

Soft corals (gorgonians) presented a mean density of 16.6 colonies/transect and included colonies of very large sizes. Some of the most abundant species included the Common Sea Fan (*Gorgonia ventalina*), Slimy Sea Plumes (*Pseudopterogorgia americana*, *Pseudopterogorgia spp.*), Corky Sea Finger, (*Briareum asbestinum*), Porous Sea Rods (*Pseudoplexaura spp.*), Knobby Sea Rods (*Eunicea spp.*) and the Encrusting Gorgonian (*Erythropodium caribaeorum*). The combined assemblage of soft and stony corals was visually the most prominent component of the sessile-benthic reef community with massive coral colonies providing most of the topographic relief. Sponges were present in all five transects with a mean substrate cover of 1.77 %.

Abiotic categories, particularly reef overhangs (mean: 21.12 %) accounted for substantial substrate cover in West Reef and contributed to a mean rugosity of 6.42 m. Coral rubble and sand accumulated within crevices, holes and gaps of the highly irregular bottom topography. The high rugosity was strongly influenced by colonies (mostly dead) of *Montastrea annularis*, which formed ledges with its “mushroom type” growth pattern.

Table 42. Percent reef substrate cover by sessile-benthic categories at West Reef, Caja de Muerto, Ponce, May, 2006.

Depth: 8 m

Survey Date: May 10, 2006

		TRANSECTS					
		1	2	3	4	5	Mean
	Rugosity (m)	4.58	5.56	7.25	7.47	7.23	6.42
Substrate Categories							
BENTHIC ALGAE							
	Turf Algae	69.27	70.1	42.4	52.99	48.06	56.54
	Coraliine Alga				2.12		0.42
	Fleshy Algae		1.48				0.30
	Total Benthic Algae	69.27	71.5	42.4	55.11	48.06	57.264
CYANOBACTERIA							
				1.39	1.2	0.81	0.68
ABIOTIC							
	Reef Overhangs	16.05	10.9	27.4	24.11	27.16	21.12
	Coral Rubble		4.05	4.17		5.98	2.84
	Silt	2.9		7.24	5.96	2.86	3.79
	Total Abiotic	18.95	15	38.8	30.07	36	27.752
SPONGES							
		4.05	0.39	3.19	0.24	0.99	1.77
ENCRUSTING GORGONIANS							
		0.19		0.35	1.78	0.9	0.64
LIVE CORAL							
	<i>Montastrea annularis</i>	1.65	8.93	6.14	2.98	3.37	4.61
	<i>Montastrea cavernosa</i>		3.08	1.04	3.89	3.02	2.21
	<i>Porites astreoides</i>	2.81		2.38	1.37	2.79	1.87
	<i>Siderastrea siderea</i>		1.09	2.61	0.4		0.82
	<i>Siderastrea radians</i>	0.48		0.64		2.26	0.68
	<i>Millepora alcicornis</i>	1.85					0.37
	<i>Colpophyllia natans</i>				1.05	0.25	0.26
	<i>Stephanocoenia michelini</i>	0.77				0.25	0.20
	<i>Meandrina meandrites</i>				0.89		0.18
	<i>Dendrogyra cylindrus</i>			0.82			0.16
	<i>Madracis decactis</i>				0.57		0.11
	<i>Agaricia grahamae</i>			0.33			0.07
	<i>Porites porites</i>					0.08	0.02
	Total Stony Coral	5.69	13.1	13.96	11.13	13.23	11.42
Recently Dead Corals							
	<i>Montastrea annularis</i>	0.53	28.4			2.55	6.30
	<i>Montastrea cavernosa</i>				1.07		0.21
	<i>Colpophyllia natans</i>				11.12		2.22
	Total Recently Dead Coral	0.53	28.4		12.18	2.55	8.74
	Partially Bleached Coral (% of coral)	37.33	58.7	18.1	3.62	23.48	28.25
GORGONIANS (# col/ transect)							
		12	8	25	18	20	16.6

Coral Species Outside Transects: *Agaricia lamarcki*, *Diploria strigosa*, *D. labyrinthiformis*, *Eusmilia fastigiata*, *Isophyllia sinuosa*, *Dichocoenia stokesii*, *Mycetophyllia lamarckiana*, *Leptoseris cucullata*

Figure 37 presents the variations of mean percent cover by sessile-benthic categories from West Reef, including the original baseline survey of 1999 and monitoring surveys of 2005 and 2006. Differences of mean percent cover by stony corals were statistically significant (ANOVA; $p < 0.01$), indicative of a degradation of the coral reef community structure. The 5 % reduction of mean substrate cover between the 1999 baseline (24.6 %) and the 2005 monitoring survey (19.32 %) represents a decline of approximately 21.5 % of total live coral cover at West Reef over a period of six years. Live coral cover declined more abruptly between the 2005 (19.32 %) and 2006 (11.42 %) monitoring surveys. The reduction of 7.9 % mean coral cover represents a difference of 40.9 % of total live coral in only one year. Recently dead coral accounted for a total of 8.74 %, associated with mortality of massive corals, such as *Montastrea annularis* and *Colpophyllia natans* (Table 37).

Variations of the mean substrate cover by coral species during the 1999 baseline and the 2005 and 2006 monitoring surveys are shown in Figure 38. Boulder Brain Coral, *Montastrea annularis* exhibited a decline of approximately 16 % between the baseline survey of 1999 and the 2005 survey, but then dropped 58.0 % between 2005 and 2006. Minor reductions of substrate cover by live corals were measured for Lettuce Coral, *Agaricia agaricites* and Boulder Brain Coral, *Colpophyllia natans*.

The recent mortality of corals appears to be a direct consequence of the massive bleaching event that affected Puerto Rico and the US Virgin Islands during late September and October, 2005. The bleaching event was associated with an extended period of elevated sea surface temperatures that affected the U. S. Virgin Islands and Puerto Rico. Up to 15 degree heating weeks (DHW), an indicator of thermal stress acting upon corals was measured by NOAA-NESDIS 50 km operational night-only satellite infrared radiometer during mid October, 2005 (NOAA, 2005) (Figure 39). A plot of the monthly mean and maximum sea surface temperatures in relation to historical means for Puerto Rico is included as Appendix 2. Approximately 28% of the remaining live coral was still partially bleached during the 2006 monitoring survey at West Reef, suggesting that lingering effects of the massive bleaching event may result in still further degradation of live coral cover.

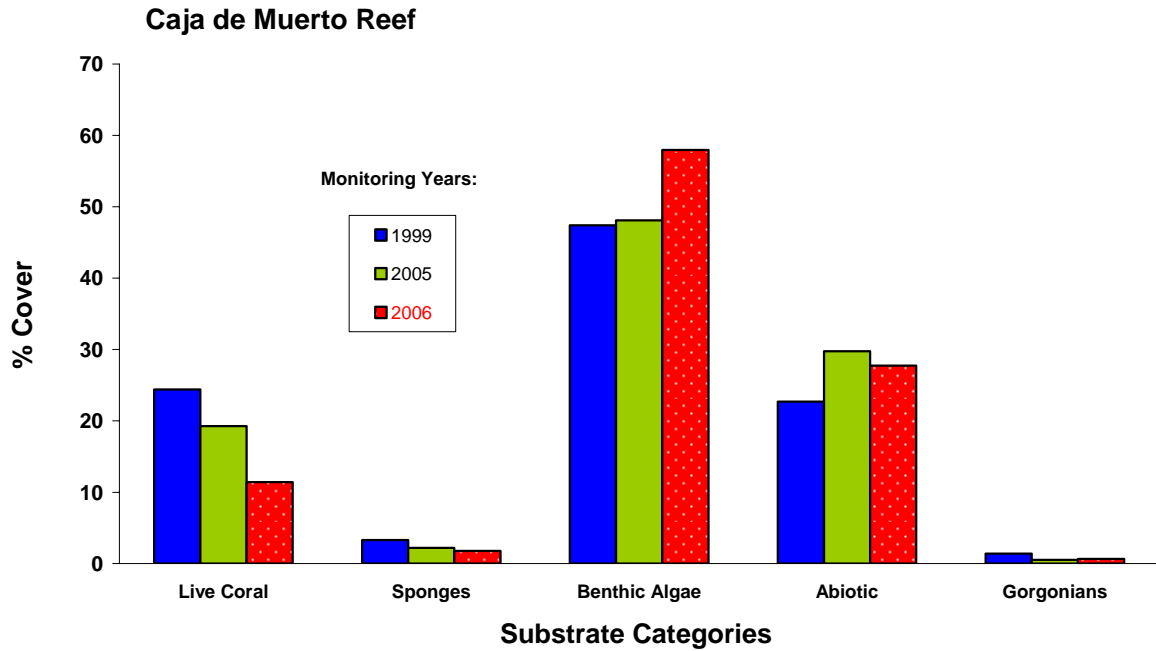


Figure 37. Monitoring trends (1999 - 2006) of mean substrate cover by sessile-benthic categories at West Reef of Isla Caja de Muerto, Ponce.

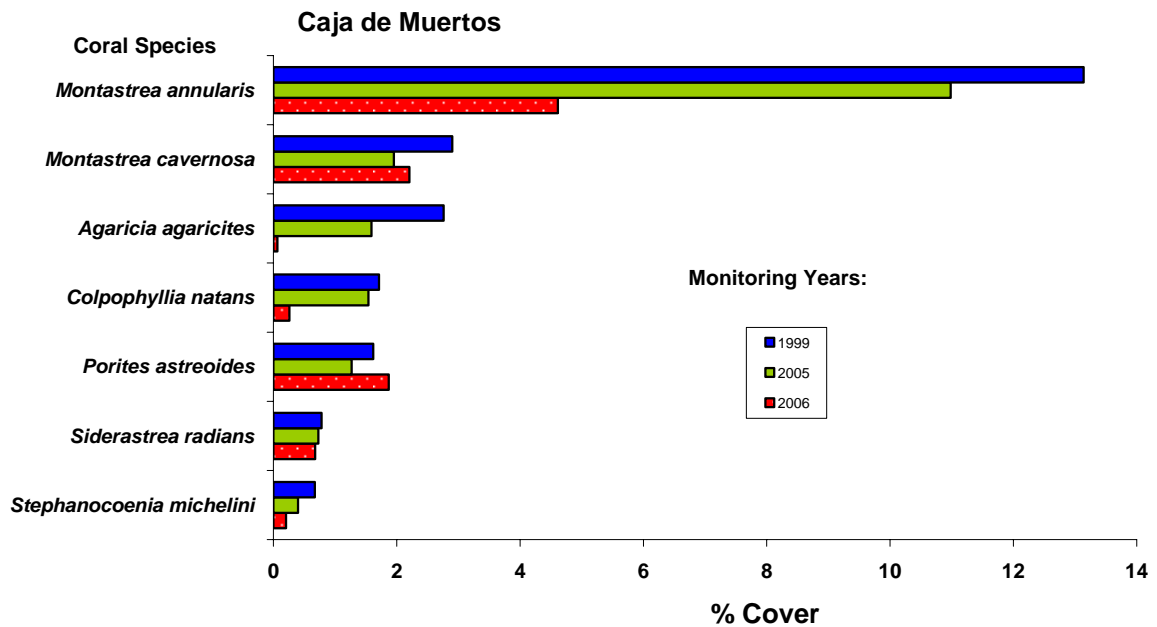


Figure 38. Monitoring trends (1999 – 2006) of mean substrate cover by stony coral species at West Reef of Isla Caja de Muerto, Ponce.

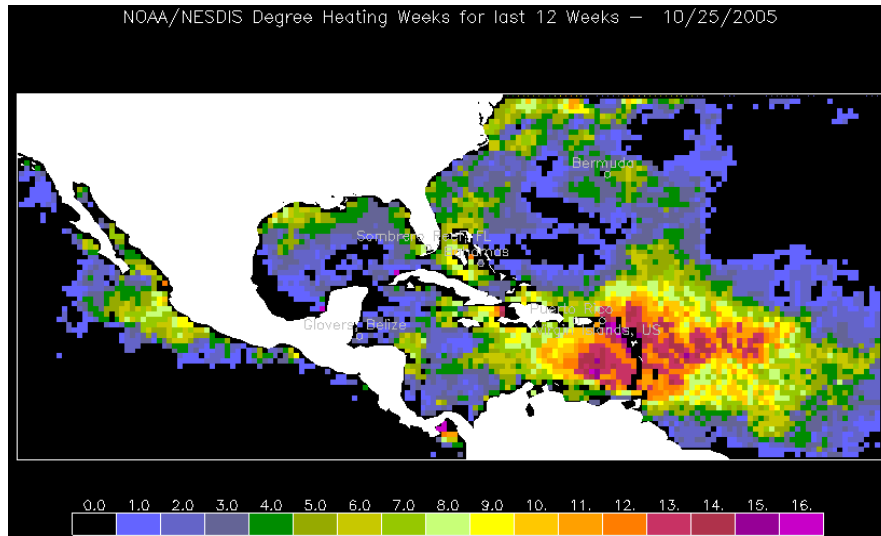


Figure 39. Chart of Degree Heating Weeks (DHN) derived from the NOAA-NESDIS 50 km operational night-only Sea Surface Temperature (SST) analysis corresponding to October 25, 2005. DHS indicate the accumulation of thermal stress that coral reefs have experienced over the last 12 weeks.

Fishes and Motile Megabenthic Invertebrates

A total of 83 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 May, 2006 was 114.0 Ind/30 m² (range: 75 - 149 Ind/30 m²). The mean number of species per transect was 28.2 (range: 25 - 31). The Masked Goby (*Coryphopterus personatus*) was the numerically dominant species with a mean abundance of 29.8 Ind/30 m² (range: 14 - 56 Ind/30 m²), representing 26.1 % of the total abundance within belt-transects (Table 43). The Masked Goby was present in swarms of 10 - 15 individuals close to the reef substrate, below ledges, in front of crevices and other protective microhabitats of the reef. The Bluehead Wrasse, Striped, Redband and Bucktooth Parrotfishes, Bicolor, Threespot and Dusky Damselfishes, Blue and Brown Chromis, Sharknose Goby, Graysby, Blackbar Soldierfish, and Caribbean Puffer were present in at least four out of the five transects surveyed, and represented, along with the Masked Goby the main fish assemblage of West Reef (Table 43).

Reef zooplankton feeders, including the Masked Goby, Blue and Brown Chromis, Bicolor Damselfish and Caribbean Puffer comprised the most prominent fish assemblage within belt-transects. Also, open water zooplanktivores, such as the Creole Wrasse (*Clepticus*

Table 43. Taxonomic composition and abundance of fishes within belt-transects at West Reef Isla Caja de Muerto, Ponce - 15 m depth. May, 2006

Depth: 15 m Survey Date: May, 2006		TRANSECTS					MEAN
		1	2	3	4	5	
SPECIES	COMMON NAME	(individuals/30 m ²)					
<i>Coryphopterus personatus</i>	Masked Goby	14	35	24	20	56	29.8
<i>Thalassoma bifasciatum</i>	Bluehead Wrasse	10	11	6	28	33	17.6
<i>Chromis multilineata</i>	Brown Chromis		8	6	18	7	7.8
<i>Stegastes partitus</i>	Bicolor Damselfish	8	10	9	4	5	7.2
<i>Scarus iserti</i>	Stripped Parrotfish	7	4	3	4	8	5.2
<i>Stegastes dorsopunicans</i>	Dusky Damselfish	2	8	5	7	3	5.0
<i>Stegastes planifrons</i>	Threespot Damselfish	1	3	8	1	3	3.2
<i>Sparisoma radians</i>	Bucktooth Parrotfish	5	3	2	1	4	3.0
<i>Myripristis jacobus</i>	Blackbar Soldierfish	2	3	6	1	2	2.8
<i>Gobiosoma evelynae</i>	Sharknose Goby	1	3	2	7		2.6
<i>Sparisoma aurofrenatum</i>	Redband Parrotfish	2	3	1	3	4	2.6
<i>Sparisoma viride</i>	Stoplight Parrotfish	1	3		6		2.0
<i>Chromis cyanea</i>	Blue Chromis	2	2	4		1	1.8
<i>Scarus taeniopterus</i>	Princess Parrotfish		2	4		3	1.8
<i>Acanthurus bahianus</i>	Ocean Surgeon	1		2	3	1	1.4
<i>Cephalopholis cruentatus</i>	Graysby	1	2	2		2	1.4
<i>Hypoplectrus unicolor</i>	Butter Hamlet	1	1	1	1	2	1.2
<i>Stegastes leucostictus</i>	Beaugregory	5			1		1.2
<i>Canthigaster rostrata</i>	Caribbean Puffer	2	1	1		1	1.0
<i>Coryphopterus glaucofraenum</i>	Bridled Goby	1	1	1	1	1	1.0
<i>Haemulon flavolineatum</i>	French Grunt		2	3			1.0
<i>Halichoeres garnoti</i>	Yellow-head Wrasse	2	1	2			1.0
<i>Mulloidides martinicus</i>	Yellowtail Goatfish			3		2	1.0
<i>Aulostomus maculatus</i>	Trumpetfish	1		1	1	1	0.8
<i>Chaetodon capistratus</i>	Foureye Butterflyfish	1		2		1	0.8
<i>Chaetodon striatus</i>	Banded Butterflyfish		1		2	1	0.8
<i>Hypoplectrus puella</i>	Barred Hamlet	1	1	1		1	0.8
<i>Pseudupeneus maculatus</i>	Yellowtail Goatfish	2	1	1			0.8
<i>Acanthurus coeruleus</i>	BlueTang			2	1		0.6
<i>Carangoides ruber</i>	Bar Jack		3				0.6
<i>Gramma loreto</i>	Fairy Basslet				2	1	0.6
<i>Holocentrus rufus</i>	Squirrelfish				2	1	0.6
<i>Stegastes variabilis</i>	Cocoa Damselfish				1	2	0.6
<i>Acanthurus chirurgus</i>	Doctorfish		1	1			0.4
<i>Haemulon aurolineatum</i>	Tomtate		1		1		0.4
<i>Holocentrus coruscus</i>	Reef Squirrelfish		1	1			0.4
<i>Hypoplectrus chlorurus</i>	Yellowtail Hamlet				1	1	0.4
<i>Hypoplectrus niger</i>	Black Hamlet			1	1		0.4
<i>Lutjanus apodus</i>	Schoolmaster Snapper			2			0.4
<i>Lutjanus mahogany</i>	Mahogany Snapper			1	1		0.4
<i>Ophioblennius atlanticus</i>	Redlip Blenny				1	1	0.4
<i>Cephalopholis fulva</i>	Coney		1				0.2
<i>Equetus lanceolatus</i>	Jackknife Fish		1				0.2

Table 43. Continued							
<i>Holocanthus ciliaris</i>	French Angelfish				1	0.2	
<i>Hypoplectrus indigo</i>	Indigo Hamlet			1		0.2	
<i>Scorpaena plumieri</i>	Spotted Scorpionfish	1				0.2	
<i>Synodus intermedius</i>	Lizardfish	1				0.2	
TOTAL INDIVIDUALS		75	117	108	121	149	114.0
TOTAL SPECIES		25	29	31	28	28	28.2

parrae) and Mackerel Scad (*Decapterus macarellus*) were present outside transects in large aggregations. Therefore, zooplanktivorous fishes comprised an important and prominent component of the ichthyofaunal community structure at West Reef. These species are known to serve as forage for a diverse assemblage of top pelagic and demersal predators, including barracudas, jacks, and large groupers and snappers observed during the ASEC survey at this reef (Table 44).

A specious assemblage of small invertebrate feeders was also present, including wrasses, gobies, goatfishes and squirrelfishes, among others. Mid-size carnivores that are commercially exploited, such as the Yellowtail, Mutton, Lane and Schoolmaster Snappers, Red Hind, and Coney were observed during the ASEC survey (Table 44). Large Cubera Snapper (*Lutjanus cyanopterus*) and 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. Juvenile and some adult Yellowtail Snappers (*Ocyurus chrysurus*) were concentrated at the face of the fore-reef slope (wall), with small juveniles (< 5 cm) using the dense soft coral (gorgonian) forest as protective habitat. Schoolmasters (*L. apodus*) were mostly observed as juvenile/adult stages swimming in and out of caves and crevices within the fore-reef slope. Juvenile and young adult Mutton Snappers (*L. analis*) were observed foraging along with the large Lane Snapper aggregation. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous fish assemblage of West Reef.

Motile megabenthic invertebrates were represented within belt-transects by Arrow Crabs (*Stenohynchus seticornis*), Spiny Lobsters (*Panulirus argus*), Reef Urchins (*Echinometra viridis*), Flamingo Tongue (*Cyphoma gibbosum*) and Atlantic wing oyster (*Pteria colymbus*) (Table 45).

Table 44. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at the West Reef of Isla Caja de Muerto, May, 2006.

Depth range : 7 – 15 m

Duration - 30 min.

SPECIES	COMMON NAME	# - (cm)		
<i>Balistes vetula</i>	Queen Triggerfish	1 - (35)		
<i>Epinephelus guttatus</i>	Red Hind	1 - (25)		
<i>Holacanthus tricolor</i>	Rock Beauty	2 - (25)		
<i>Holacanthus ciliaris</i>	Queen Angel	1 - (30)		
<i>Lachnolaimus maximus</i>	Hogfish	1 - (25)	2 – (30)	2 – (40)
<i>Lutjanus analis</i>	Mutton Snapper	1 – (25)	3 – (30)	1 – (50)
<i>Lutjanus apodus</i>	Schoolmaster	1 – (15)	3 - (25)	1 - (30)
<i>Lutjanus mahogany</i>	Mahogany Snapper	3 - (20)	2 - (25)	
<i>Lutjanus griseus</i>	Grey Snapper	2 – (25)		
<i>Lutjanus synagris</i>	Lane Snapper	500 – (10-15)	200 – (15-20)	4 – (30)
<i>Ocyurus chrysurus</i>	Yellowtail Snapper	20 – (25)	4 – (30)	6 – (40)
<i>Scomberomorus regalis</i>	Cero Mackerel	1 - (70)		
<i>Sphyræna barracuda</i>	Great Barracuda	1 - (70)		
Invertebrates				
<i>Panulirus argus</i>	Spiny Lobster	1 - (12)	1 - (15)	1 - (20)

Table 45. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at West Reef, 8 m depth, Caja de Muerto. May, 2006

DATE: May 10, 2006		TRANSECTS					MEAN ABUNDANCE (IND/30 m²)
Depth: 8 m		1	2	3	4	5	
TAXA	DEPTH (m) COMMON NAME						
<i>Stenorhynchus seticornis</i>	Arrow Crab				1		0.2
<i>Cyphoma gibbosum</i>	Flamingo Tongue	5					1.0
<i>Panulirus argus</i>	Spiny Lobster	1					0.2
<i>Echinometra viridis</i>	Reef Urchin	2		1		2	1.0
<i>Pteria columbus</i>	Atlantic wing Oyster	1	1				0.4
TOTALS		9	1	1	1	2	2.8

Figure 40 displays the annual trends of fish abundance and species richness during monitoring surveys at West Reef. Statistically significant differences of fish abundance (ANOVA; $p = 0.003$) driven by a decline of abundance during 2006 of the dominant species within belt transects, the Masked Goby (*Coryphopterus personatus*) was found. No differences in species richness were detected.

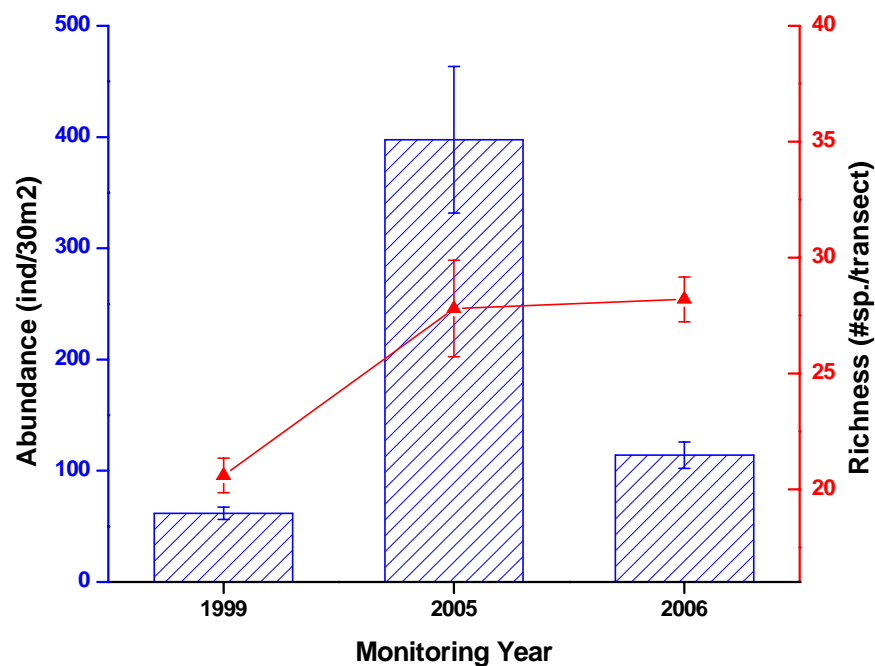


Figure 40. Monitoring trends (1999 – 2006) of fish species richness and abundance at West Reef of Isla Caja de Muerto, Ponce.

**Photo Album 11 (Caja de Muerto)
West Reef**





5.0 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 41). The promontory, or seamount 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 23 stony corals, including 13 intersected by line transects were identified from Derrumbadero Reef at a depth of 20 m (Table 46). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 14.16 % (range: 6.26 – 20.97 %). Boulder Star Coral, *Montastrea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 8.70% (range: 3.07 – 13.72 %), representing 61.44 % 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 Coral and Mustard-Hill Coral were the only species present in all five transects surveyed. Lettuce Coral (*Agaricia agaricites*) was present in four transects (Table 46).

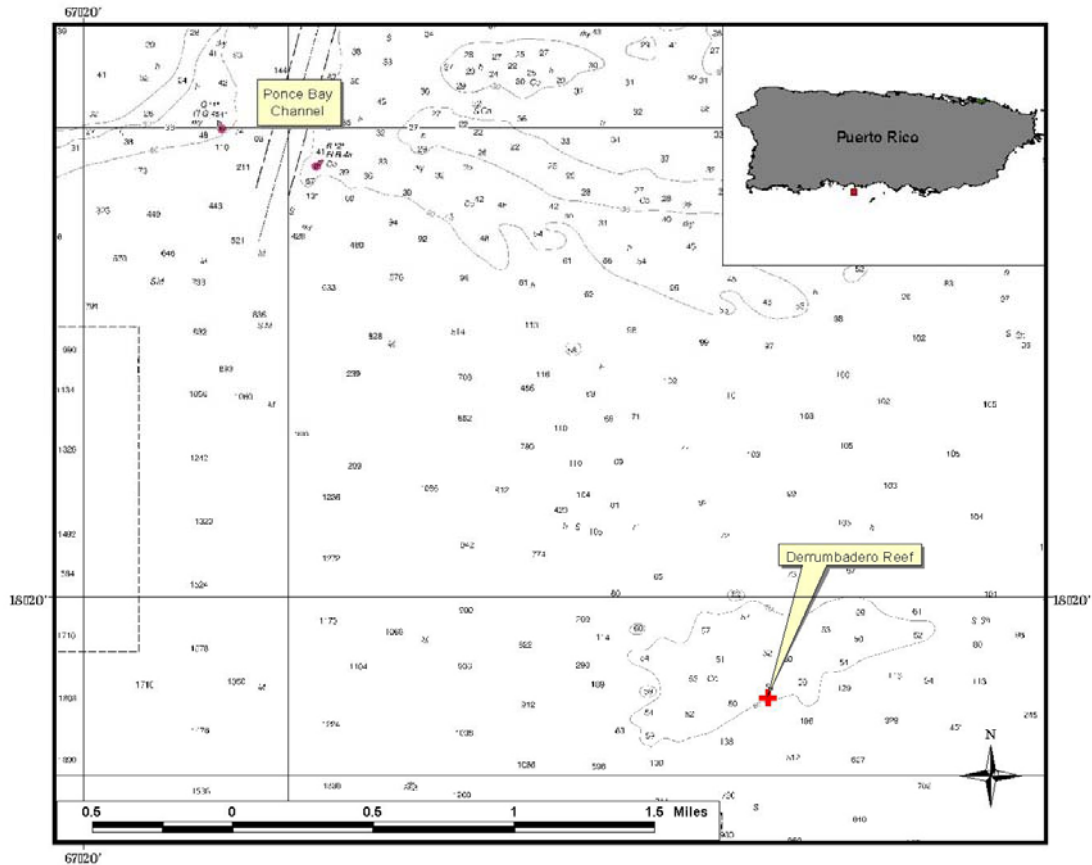


Figure 41. Location of the coral reef monitoring station at Derrumbadero Reef, Ponce.

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 coral colonies were highly abundant at Derrumbadero (mean: 25.4 col./transect) and because of their large sizes and species richness contributed substantially to the biological diversity and structural complexity of the reef system. 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 63.66 %. A reddish cyanobacterial film was observed spreading over reef hard ground and well packed sand and rubble. It was present in all transects surveyed with a mean cover of 5.70 %. Sponges were also present in all five transects with a mean substrate cover of 2.07 %. Abiotic categories were represented by reef overhangs mostly produced by mounds and ledges of Boulder Star Coral (*M. annularis*), and contributed to the reef mean topographic rugosity of 3.59 m (Table 46).

Table 46. Percent reef substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce, April, 2006.

Substrate Categories	TRANSECTS					Mean
	1	2	3	4	5	
Depth: 20 m						
Survey Date: April 6, 2006						
Rugosity (m)	3.63	4.2	3.17	4.11	2.83	3.59
BENTHIC ALGAE						
Turf Algae	57.49	70.8	66.67	66.69	56.63	63.66
Calcareous Algae			0.32			0.06
Total Benthic Algae	57.49	70.8	66.99	66.69	56.63	63.72
CYANOBACTERIA	7.42	1.27	5.24	4.11	10.45	5.70
ABIOTIC						
Reef Overhang	14.68	12.68	5.47	13.47	10.14	11.29
ENCRUSTING GORGONIANS	2.35	5.99	1.39		0.66	2.08
SPONGES	2.79	1.48	3.42	1.49	1.17	2.07
LIVE CORALS						
<i>Montastrea annularis</i>	10.23	3.07	7.59	8.88	13.72	8.70
<i>Porites astreoides</i>	1.34	1.69	3.42	0.5	2.63	1.92
<i>Montastrea cavernosa</i>		0.6	2.89		2.42	1.18
<i>Agaricia agaricites</i>	1.14	0.6	0.53	1.50		0.75
<i>Diploria strigosa</i>			2.99			0.60
<i>Diploria labyrinthiformis</i>	0.72				1.54	0.45
<i>Millepora alcicornis</i>		0.3			0.66	0.19
<i>Madracis decactis</i>	0.52					0.10
<i>Porites porites</i>	0.52					0.10
<i>Porites colonensis</i>	0.41					0.08
<i>Siderastrea siderea</i>	0.41					0.08
Total Stony Coral	15.29	6.26	17.42	10.88	20.97	14.16
Recently Dead Corals (RD)						
<i>C. natans</i>				2.99		0.60
<i>Diploria sp.</i>			2.03			0.41
<i>M. annularis</i>	0.83	2.78	0.96	9.68	4.39	3.73
<i>M. cavernosa</i>				5.19		1.04
<i>P. asteroides</i>				1.00		0.20
Total RD Corals	0.83	2.78	2.99	18.86	4.39	5.97
Partially Bleached Coral (% of coral)	49.64	24.7	0.8	26.41	78.08	35.93
GORGONIANS (# Col/transect)	24	28	24	31	20	25.40

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

Figure 42 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 and 2006. Differences of mean total percent cover by stony corals between monitoring surveys were statistically significant (ANOVA; $p = 0.0008$), and indicative of a severe degradation of the coral reef community. The reduction of mean live coral cover between the baseline survey of 2001 (41.61 %) and the first monitoring survey of 2005 (34.63 %) was of approximately 7 %, which represented a decline of 16.7 % over a period of four years. A much more drastic decline was observed between 2005 and the most recent 2006 monitoring survey. Total live coral declined by 59.11 %, from 34.63 % in 2005 to 14.16 % in 2006. A proportional increment of cover by benthic algae was measured. Almost 6 % of the reef substrate cover measured during our 2006 survey corresponded to recently dead coral, overgrown by a thin veneer of turf algae. From the reported live coral intercepted by transects during the 2006 monitoring survey, approximately 35.9 % was partially bleached. Such drastic, short term collapse of the Derrumbadero coral reef system appears to be strongly related to the massive regional coral bleaching event, associated with elevated sea surface temperatures that affected Puerto Rico and the USVI during late September and August (Figure 39).

Monitoring trends of mean substrate cover by coral species at Derrumbadero Reef are shown in Figure 43. 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. Therefore, its sharp decline of 57.4 % between the 2005 (20.41 %) and 2006 (8.7 %) monitoring surveys had a profound influence on the total live coral at the reef ecosystem level. Marked reductions of the mean percent substrate cover by live corals resulted also for *Montastrea cavernosa*, *Agaricia agaricites*, *Diploria labyrinthiformis*, and *Acropora cervicornis*. Soft corals (gorgonian) were not adversely affected by the environmental conditions affecting scleractinian corals, reflecting a minor increment (23/25) during the 2006 survey.

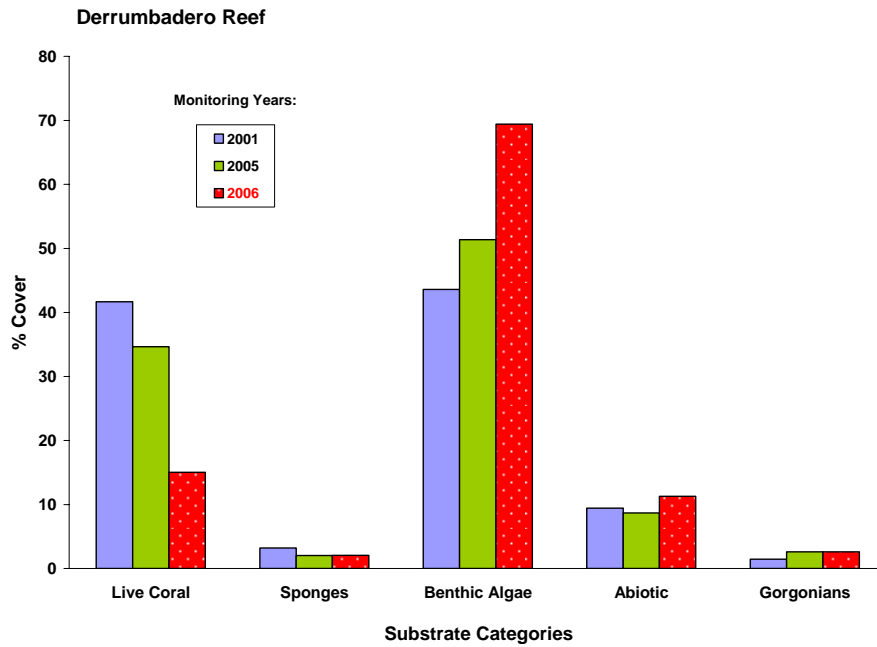


Figure 42. Monitoring trends (2001 – 2006) of mean substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce.

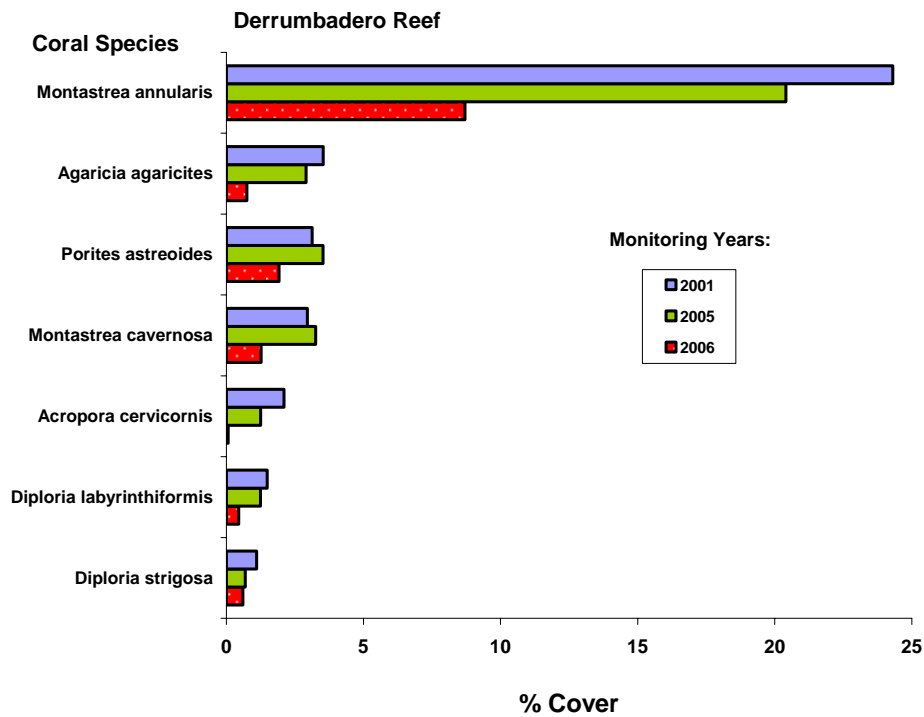


Figure 43. Monitoring trends (2001 – 2006) of mean substrate cover by coral species at Derrumbadero Reef, Ponce

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 78 fish species have been identified from Derrumbadero Reef during monitoring surveys (Appendix 1). Mean abundance within belt-transects during 2006 was 86.4 Ind/30 m² (range: 62 - 125 Ind/30 m²). The mean number of species per transect was 22.6 (range: 20 - 25). The Blue Chromis, *Chromis cyanea* was the numerically dominant species with a mean abundance of 14.6 Ind/30 m² (range: 0 - 40 Ind/30 m²), representing 16.9 % of the total abundance within belt-transects (Table 47). The Blue Chromis is small zooplanktivorous species that forms aggregations over coral heads and promontories. Schooling aggregations rise to mid-water over the reef, but approach the reef structure often, especially during periods of strong currents, and when potential predators are near. The Bicolor Damselfish, Sharknose, Bridled and Peppermint Gobies, Bluehead Wrasse, Striped, Redband and Bucktooth Parrotfishes, Four-eye Butterflyfish and Graysby were present on at least four out of the five transects surveyed. The combined abundance of these 10 species represented 53.9 % of the total fish individuals within belt-transects.

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 Blue and Brown Chromis, Masked Goby, Bicolor Damselfish, Puffers, 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, Blue Runners, Black Jacks and Barracudas observed during an ASEC survey in this reef (Table 48). Large demersal predators, such as Yellowfin and Tiger Groupers, Cubera, Mutton, Schoolmaster and Dog Snappers also feed from the small zooplanktivorous fishes which 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.

Table 47. Taxonomic composition and abundance of fishes within belt-transects at Derrumbadero Reef, Ponce. April, 2006

SPECIES	COMMON NAME	TRANSECTS					MEAN
		1	2	3	4	5	
Depth: 20m							
		(Individuals/30 m ²)					
<i>Chromis cyanea</i>	Blue Chromis	30			40	3	14.6
<i>Stegastes partitus</i>	Bicolor Damselfish	18	7	5	8	8	9.2
<i>Thalassoma bifasciatum</i>	Bluehead Wrasse	16	5	12		8	8.2
<i>Scarus iserti</i>	Stripped Parrotfish	8	11	8	3	9	7.8
<i>Clepticus parrae</i>	Creole Wrasse					29	5.8
<i>Gobiosoma evelynae</i>	Sharknose Goby	11	1	5	6	6	5.8
<i>Coryphopterus lipernes</i>	Peppermint Goby		7	11	3	5	5.2
<i>Coryphopterus personatus</i>	Masked Goby	16	2				3.6
<i>Sparisoma radians</i>	Bucktooth Parrotfish		4	4	6	1	3.0
<i>Halichoeres garnoti</i>	Yellow-head Wrasse	3	4			5	2.4
<i>Sparisoma aurofrenatum</i>	Redband Parrotfish	2	3	3		2	2.0
<i>Cephalopholis cruentatus</i>	Graysby	1	2	3	1	1	1.6
<i>Chaetodon capistratus</i>	Foureye Butterflyfish	1	2		2	2	1.4
<i>Myripristis jacobus</i>	Blackbar Soldierfish	1		2	2	2	1.4
<i>Acanthurus bahianus</i>	Ocean Surgeon	1	2		1	2	1.2
<i>Acanthurus coeruleus</i>	BlueTang	3				3	1.2
<i>Carangoides crysos</i>	Blue Runner					6	1.2
<i>Scarus taeniopterus</i>	Princess parrotfish		2	3	1		1.2
<i>Coryphopterus glaucofraenum</i>	Bridled Goby	1	1	1	1	1	1.0
<i>Canthigaster rostrata</i>	Caribbean puffer			2	1	1	0.8
<i>Holocentrus rufus</i>	Squirrelfish	3	1				0.8
<i>Haemulon flavolineatum</i>	French grunt		1	3			0.8
<i>Hypoplectrus puella</i>	Barred hamlet		1	1	1	1	0.8
<i>Stegastes leucostictus</i>	Beau-gregory			1	3		0.8
<i>Acanthurus chirurgus</i>	Doctorfish			2	1		0.6
<i>Scarus vetula</i>	Queen parrotfish	1	1	1			0.6
<i>Sparisoma viride</i>	Stoplight Parrotfish	1	1			1	0.6
<i>Hypoplectrus unicolor</i>	Butter Hamlet		2		1		0.6
<i>Amblycirrhitus pinos</i>	Redspotted Hawkfish			1		1	0.4
<i>Chaetodon aculeatus</i>	Longsnout butterflyfish			1	1		0.4
<i>Chromis multilineata</i>	Brown Chromis	2					0.4
<i>Stegastes planifrons</i>	Yellow-eye damselfish	1	1				0.4
<i>Holocentrus coruscus</i>	Reef Squirrelfish			1	1		0.4
<i>Ocyurus chrysurus</i>	Yellowtail snapper	1				1	0.4
<i>Serranus tigrinus</i>	Harlequin bass		1			1	0.4
<i>Aulostomus maculatus</i>	Trumpetfish	1					0.2
<i>Bodianus rufus</i>	Spanish Hogfish			1			0.2
<i>Cephalopholis fulva</i>	Coney			1			0.2
<i>Holacanthus ciliaris</i>	Queen Angelfish	1					0.2
<i>Gobiosoma saucrum</i>	Leopard goby					1	0.2
<i>Halichoeres cyanocephalus</i>	Yellowcheek Wrasse	1					0.2
<i>Lachnolaimus maximus</i>	Hogfish					1	0.2
<i>Mycteroperca tigris</i>	Tiger Grouper	1					0.2

Table 47. Continued							
<i>Scorpaena plumieri</i>	Spotted Scorpionfish	1					0.2
TOTAL INDIVIDUALS		125	62	72	72	101	86.4
TOTAL SPECIES		24	22	22	20	25	18.8

Table 48. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Derrumbadero Reef, Ponce. June, 2005

Depth range : 18 - 22 m
Duration - 30 min.

SPECIES	COMMON NAME	# - (cm)		
<i>Carangoides ruber</i>	Bar Jack	60 – (10)		
<i>Carangoides crysos</i>	Blue Runner	1 – (10)	20 – (25)	15 – (30)
<i>Caranx lugubris</i>	Black Jack	1 – (50)		
<i>Chaetodon aculeatus</i>	Longsnout Butterflyfish	4 - (7)		
<i>Epinephelus guttatus</i>	Red Hind	1 – (30)		
<i>Holacanthus ciliaris</i>	Queen Angel	1 - (25)	1 - (35)	
<i>Holacanthus tricolor</i>	Rock Beauty	1 - (20)		
<i>Lachnolaimus maximus</i>	Hogfish	2 – (30)	1 – (40)	
<i>Lutjanus analis</i>	Mutton Snapper	1 – (40)		
<i>Lutjanus apodus</i>	Schoolmaster	1 - (20)	2 – (30)	
<i>Lutjanus cyanopterus</i>	Cubera snapper	1 – (60)		
<i>Lutjanus jocu</i>	Dog Snapper	2 – (50)		
<i>Lutjanus mahogany</i>	Mahogani Snapper	2 - (25)	1 – (30)	
<i>Lutjanus synagris</i>	Lane Snapper	2 - (20)		
<i>Mycteroperca tigris</i>	Tiger Grouper	1 – (40)	1 - (50)	
<i>Mycteroperca venenosa</i>	Yellowfin Grouper	1 – (45)		
<i>Ocyurus chrysurus</i>	Yellowtail Snapper	2 – (15)	1 - (20)	
<i>Opistognathus aurifrons</i>	Yellowhead Jawfish	12 – (10)		
<i>Scomberomorus regalis</i>	Cero Mackerel	2 - (50)		
<i>Sphyrnaena barracuda</i>	Great Barracuda	1 - (50)		
Invertebrates				
<i>Panulirus argus</i>	Spiny Lobster	1 - (15)		

Figure 44 presents the temporal trends of fish abundance and species richness within belt-transects during the baseline characterization of 2001 and monitoring surveys of 2005 and 2006. A statistically significant decline of fish abundance within belt-transects was detected. The difference of abundance was largely driven by a reduction of a species that was numerically dominant in previous surveys, the Masked Goby, *Coryphopterus personatus*. This is a small zooplanktivorous species that forms dense swarms below coral ledges. Its mean abundance within belt-transects declined more than 14 fold between the 2005 and 2006 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.

Cleaner Shrimps, one Flamingo Tongue (*Cyphoma gibbosum*) and one Giant Basket Star (*Astrophyton muricatum*) represented megabenthic invertebrates within belt transects. One small Spiny Lobster (*Panulirus argus*) was observed out of transects.

Table 49. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Derrumbadero Reef, 20 m depth, Ponce. April, 2006

DATE: April 6, 2006 Depth: 20 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m ²)
		1	2	3	4	5	
TAXA	COMMON NAME						
<i>Astrophyton muricatum</i>	Giant Basket Star					1	0.2
<i>Periclimenes pedersoni</i>	Cleaner Shrimp	4			1		1.0
<i>Cyphoma gibbosum</i>	Flamingo Tongue					1	0.2
TOTALS		4	0	0	1	2	1.4

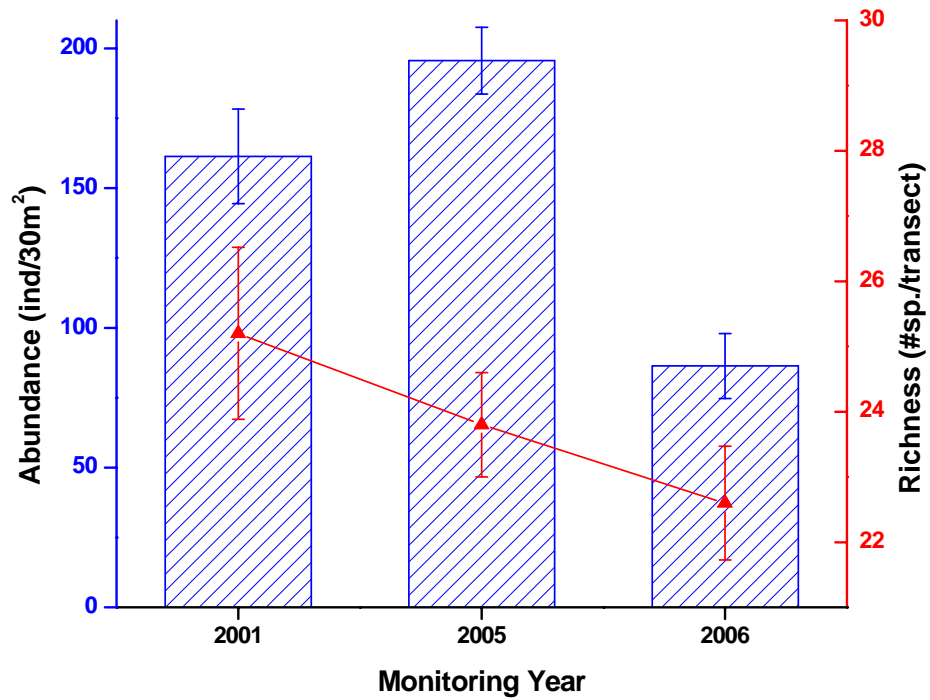
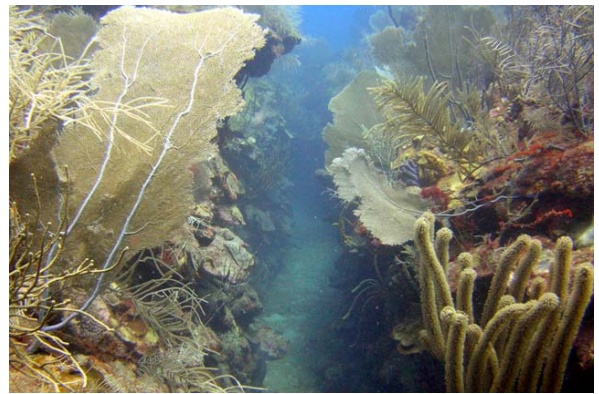
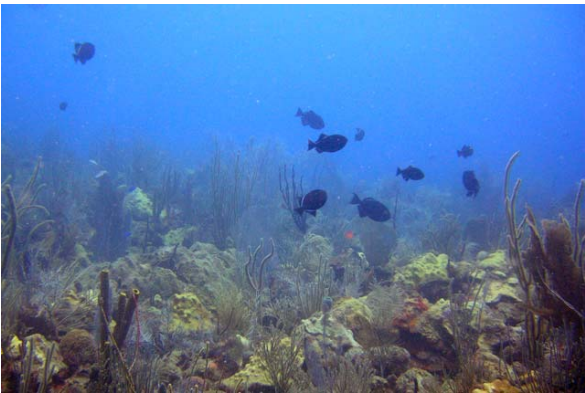
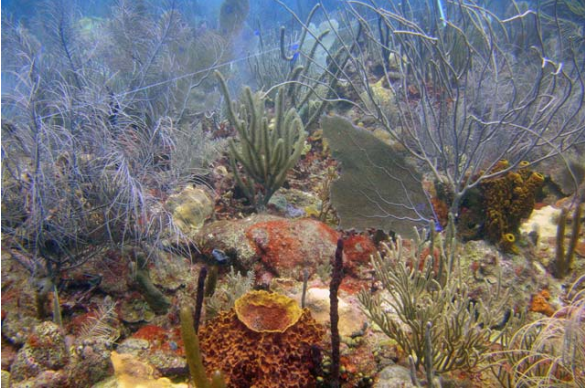


Figure 40. Monitoring trends (1999 – 2006) of fish species richness and abundance at Derrumbadero Reef, Ponce.

**Photo Album 12 (Ponce
Derrumbadero Reef**





V Conclusions

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 reductions of live coral cover.

The decline of (total) live coral cover at the reef community level was largely driven by mortality of Boulder Star Coral, *Montastrea 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 were measured.

The sharp decline of live coral cover was associated to a severe regional coral bleaching event that affected reef systems of the US Virgin Islands and Puerto Rico between September and late October, 2005. The massive bleaching of corals coincided with an extended period of elevated sea surface temperatures (SST) between September and late October, 2005.

The Tres Palmas Reef system of Rincon did not exhibit any major structural changes, nor statistically significant variations of percent substrate cover by live corals at any of the three depths surveyed between the initial baseline characterization and subsequent 2005 and 2006 monitoring surveys. The fringing shoreline reef at Tres Palmas is largely an Elkhorn Coral (*Acropora palmata*) biotope, and is dominated by encrusting Great Star Coral (*Montastrea cavernosa*) at the patch reef formations of the mid-shelf (10 m depth). These coral species appear to have been more tolerant to the increased SST than Boulder Star Coral.

Fish populations presented in general, stable species richness and taxonomic composition in most cases, but a consistent trend of declining abundance within belt-transects that was statistically significant in seven out of the 12 reef stations surveyed. These included Tourmaline Reef at 10, 20 and 30 meters; Puerto Botes Reef at 15 m; Tres Palmas Reef at 10 m; Derrumbadero Reef at 20 m, and West Reef at 8 m.

Variations between surveys were mostly associated with reductions of abundance by numerically dominant populations that exhibit highly aggregated distributions, such as the Masked Goby (*Coryphopterus personatus*) and the Blue Chromis (*Chromis cyanea*). It is uncertain at this point if such reductions of abundance by reef fishes closely associated with coral habitats are related to the massive coral mortality exhibited by reef systems in the monitoring program.

Although in low abundance, large demersal (top predator) fishes were detected 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*).

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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; Derr: Derrumbadero-Ponce; Gua: Cayo Coral-Guanica

Total Species Database

REEF SITES

Species	Common Name	M30	M20	M10	R5	R10	R20	D30	D20	D15	CDM	Derr	Gua
<i>Abudefduf sexatilis</i>	Sergeant Major	x	x	x	x	x	x		x		x		X
<i>Abudefduf taurus</i>	Night Sergeant				x	x							
<i>Acanthurus bahianus</i>	Ocean Surgeon	x	x	x	x	x	x	x	x	x	x	x	X
<i>Acanthurus chirurgus</i>	Doctorfish	x	x	x	x	x	x	x	x	x	x	x	X
<i>Acanthurus coeruleus</i>	BlueTang	x	x	x	x	x	x	x	x	x	x	x	X
<i>Aetobatus narinari</i>	Spotted Eagle Ray											x	
<i>Aluthera scriptus</i>	Scrawled Filefish	x		x		x		x	x		x	x	X
<i>Amblycirrhitus pinos</i>	Redspotted Hawkfish	x	x	x		x	x	x	x	x	x	x	X
<i>Anchoa sp.</i>	Anchovy				x								
<i>Anisotremus surinamensis</i>	Black margate					x		x					
<i>Anisotremus virginicus</i>	Porkfish	x	x	x	x	x	x				x		X
<i>Apogon sp.</i>	Cardinalfish					x	x	x					X
<i>Apogon townsendi</i>	Belted Cardinalfish								x				
<i>Aulostomus maculatus</i>	Trumpetfish	x	x	x	x	x	x	x	x	x	x	x	X
<i>Balistes vetula</i>	Queen Triggerfish							x	x	x			
<i>Bodianus rufus</i>	Spanish Hogfish	x	x	x	x	x	x	x	x	x	x	x	X
<i>Bothus lunatus</i>	Peacock flounder	x	x				x						
<i>Calamus pennatula</i>	Pluma				x						x		
<i>Calamus bajonado</i>	Jolthead Porgy							x					
<i>Cantherhines macrocerus</i>	Whitespotted filefish	x		x	x		x	x	x	x		x	
<i>Cantherhines pullus</i>	Tail-light Filefish	x	x		x	x							X
<i>Cantherhines surinamensis</i>	Ocean Triggerfish	x	x	x		x		x	x			x	X
<i>Canthigaster rostrata</i>	Caribbean Puffer	x	x	x	x	x	x	x	x	x	x	x	X
<i>Carangoides crysos</i>	Blue Runner	x	x	x	x	x	x	x	x		x	x	X
<i>Carangoides ruber</i>	Bar Jack	x	x	x		x	x	x	x	x	x	x	X

Species	Common Name	M30	M20	M10	R5	R10	R20	D30	D20	D15	CJm	Derr	Gua
<i>Caranx bartholomaei</i>	Yellow jack												X
<i>Caranx hippos</i>	Horse-eye Jack				x			x					
<i>Caranx lugubris</i>	Black Jack	x	x	x	x	x		x	x			x	X
<i>Caranx ruber</i>	Bar Jack				x								
<i>Carcharhinus limbatus</i>	Caribbean Reef Shark							x					
<i>Cephalopholis cruentatus</i>	Graysby	x	x	x		x	x	x	x	x	x	x	X
<i>Cephalopholis fulva</i>	Coney	x	x	x	x	x	x	x	x	x	x	x	X
<i>Chaetodon aculeatus</i>	Longsnout Butterflyfish	x	x	x		x	x	x	x			x	X
<i>Chaetodon capistratus</i>	Four-eye Butterflyfish	x	x	x	x	x	x	x	x	x	x	x	X
<i>Chaetodon ocellatus</i>	Spotfin Butterflyfish	x	x										
<i>Chaetodon sedentarius</i>	Reef Butterflyfish	x							x				
<i>Chaetodon striatus</i>	Banded Butterflyfish	x	x	x		x	x		x	x	x	x	X
<i>Chromis cyanea</i>	Blue chromis	x	x	x		x	x	x	x	x	x	x	X
<i>Chromis insolata</i>	Sunshine Chromis	x					x	x					
<i>Chromis multilineata</i>	Brown Chromis	x	x	x	x	x	x	x	x	x	x	x	X
<i>Clepticus parrae</i>	Creole Wrasse	x	x	x		x	x	x	x	x		x	X
<i>Coryphopterus glaucofraenum</i>	Bridled Goby	x	x	x		x		x			x	x	X
<i>Coryphopterus lipernes</i>	Peppermint Goby	x	x	x		x	x	x	x	x	x	x	X
<i>Coryphopterus personatus</i>	Masked goby	x	x	x		x	x	x	x	x	x		X
<i>Coryphopterus sp1.</i>	Goby	x	x	x		x	x	x	x	x	x	x	X
<i>Crioptomus roseus</i>	Parrotfish									x			
<i>Dasyatis americana</i>	Southern stingray				x			x	x				
<i>Decapterus macarellus</i>	Mackerel Scad	x	x				x	x		x			
<i>Diodon holacanthus</i>	Porcupinefish				x	x		x		x			
<i>Diodon hystrix</i>	Balloonfish							x					
<i>Echidna catenata</i>	Chain Moray									x			
<i>Elagatis bipinnulatus</i>	Rainbow Runner							x					
<i>Epinephelus adscensionis</i>	Rock Hind	x	x		x	x							
<i>Epinephelus guttatus</i>	Red hind	x	x	x		x	x	x	x	x	x		

Species	Common Name	M30	M20	M10	R5	R10	R20	D30	D20	D15	CJm	Derr	Gua
<i>Epinephelus striatus</i>	Nassau Grouper	x	x					x	x				
<i>Equetus acuminatus</i>	Highhat	x	x	x		x		x	x	x		x	X
<i>Equetus lanceolatus</i>	Jackknife Fish	x	x			x	x				x		
<i>Equetus punctatus</i>	Spotted Drum					x	x						
<i>Flammeo marianus</i>	Longspine Squirrelfish	x	x	x		x	x	x	x	x		x	
<i>Gerres cinereus</i>	Yellowfin mojarra	x	x	x	x	x					x		X
<i>Ginglymostoma cirratum</i>	Nurse Shark									x			
<i>Gobiosoma evelynae</i>	Sharknose Goby	x	x	x		x	x	x	x	x	x	x	X
<i>Gobiosoma saucrum</i>	Leopard Goby	x	x	x		x		x			x	x	X
<i>Gobiosoma sp.</i>	Goby				x								
<i>Gramma loreto</i>	Fairy Basslet	x	x	x	x	x	x	x	x		x	x	X
<i>Gymnothorax funebris</i>	Green Moray							x					
<i>Gymnothorax moringa</i>	Spotted Moray	x	x	x		x			x	x		x	X
<i>Haemulon aurolineatum</i>	Tomtate	x	x	x		x			x		x		X
<i>Haemulon carbonarium</i>	Caesar's Grunt				x								
<i>Haemulon chrysargyreum</i>	Smallmouth Grunt	x	x	x	x	x					x		
<i>Haemulon flavolineatum</i>	French Grunt	x	x	x	x	x	x	x	x	x	x	x	X
<i>Haemulon macrostomum</i>	Spanish Grunt	x	x	x		x	x		x	x	x	x	X
<i>Haemulon melanurum</i>	Cottonwick	x	x	x		x	x						
<i>Haemulon plumieri</i>	White Grunt				x	x					x		X
<i>Haemulon sciurus</i>	Bluestriped Grunt	x	x	x	x	x		x		x	x	x	X
<i>Haemulon sp</i>	Juvenile Grunts				x								
<i>Haemulon steindachneri</i>	Latin grunt												X
<i>Halichoeres bivittatus</i>	Slippery Dick				x	x							
<i>Halichoeres cyanocephalus</i>	Yellowcheek Wrasse											x	
<i>Halichoeres garnoti</i>	Yellow-head Wrasse	x	x	x		x	x	x	x	x	x	x	X
<i>Halichoeres maculipinna</i>	Clown Wrasse	x	x	x	x	x		x	x	x		x	X
<i>Halichoeres pictus</i>	Painted wrasse				x								
<i>Halichoeres radiatus</i>	Puddinwife	x	x	x	x	x			x	x	x	x	X
<i>Halichoeres sp.</i>	wrasse					x							

Species	Common Name	M30	M20	M10	R5	R10	R20	D30	D20	D15	CJm	Derr	Gua
<i>Hemiramphus ballyhoo</i>	Ballyhoo					x	x	x	x	x			
<i>Holacanthus ciliaris</i>	Queen Angelfish	x	x	x		x	x	x	x	x		x	X
<i>Pomacanthus paru</i>	French Angelfish										x		
<i>Holacanthus tricolor</i>	Rock Beauty	x	x	x		x	x	x	x	x	x	x	X
<i>Holocentrus adscensionis</i>	Longjaw Squirrelfish				x	x			x			x	X
<i>Holocentrus coruscus</i>	Reef Squirrelfish	x	x	x		x					x	x	X
<i>Holocentrus rufus</i>	Squirrelfish	x	x	x	x	x	x	x	x	x	x	x	X
<i>Hypoplectrus aberrans</i>	Yellowbelly hamlet												X
<i>Hypoplectrus chlorurus</i>	Yellowtail Hamlet	x	x	x		x	x				x	x	X
<i>Hypoplectrus guttavarius</i>	Shy Hamlet	x	x	x		x					x	x	X
<i>Hypoplectrus indico</i>	Indico Hamlet	x									x		X
<i>Hypoplectrus niger</i>	Black Hamlet	x	x			x	x	x			x	x	X
<i>Hypoplectrus puella</i>	Barred Hamlet		x	x		x	x				x	x	X
<i>Hypoplectrus unicolor</i>	Butter Hamlet	x	x	x		x	x	x			x	x	X
<i>Kyphosus bermudensis</i>	Bermuda Chub	x	x	x	x	x		x	x	x		x	X
<i>Lachnolaimus maximus</i>	Hogfish	x										x	
<i>Lactophrys bicaudalis</i>	Spotted Trunkfish	x								x			
<i>Lactophrys polygonia</i>	Honeycomb Cowfish	x	x	x		x		x	x			x	X
<i>Lactophrys trigonus</i>	Buffalo Trunkfish							x					
<i>Lactophrys triqueter</i>	Smooth Trunkfish	x	x			x		x	x	x		x	X
<i>Liopropoma rubre</i>	Peppermint Bass	x	x	x		x	x	x	x			x	X
<i>Lutjanus analis</i>	Mutton Snapper				x		x						
<i>Lutjanus apodus</i>	Schoolmaster	x	x	x	x	x	x	x	x	x	x	x	X
<i>Lutjanus cyanopterus</i>	Cubera Snapper	x	x										
<i>Lutjanus jocu</i>	Dog Snapper	x	x					x					
<i>Lutjanus mahogani</i>	Mahogani Snapper	x	x	x		x	x	x	x		x	x	X
<i>Lutjanus synagris</i>	Lane snapper	x	x	x		x	x				x		
<i>Malacanthus plumieri</i>	Sand Tilefish					x	x						
<i>Malacoctenus sp.</i>	Blenny	x							x	x			
<i>Malacoctenus triangulatus</i>	Saddled Blenny	x	x		x	x		x	x	x			

Species	Common Name	M30	M20	M10	R5	R10	R20	D30	D20	D15	CJm	Derr	Gua
<i>Malacoctenus versicolor</i>	Barfin Blenny					x							
<i>Melichthys niger</i>	Black Durgon	x	x	x	x	x	x	x	x	x		x	X
<i>Microspathodon chrysurus</i>	Yellowtail Damselfish	x	x	x	x	x	x	x	x	x	x	x	X
<i>Mulloides martinicus</i>	Yellowtail Goatfish	x	x	x	x	x	x	x	x	x	x	x	X
<i>Muraena sp.</i>	Moray					x	x			x			
<i>Mycteroperca tigris</i>	Tiger Grouper											x	
<i>Mycteroperca venenosa</i>	Yellowfin Grouper	x						x					
<i>Myripristis jacobus</i>	Blackbar Soldierfish	x	x	x	x	x	x	x	x	x	x	x	X
<i>Ocyurus chrysurus</i>	Yellowtail snapper	x	x	x		x		x	x	x	x	x	X
<i>Odontoscion dentex</i>	Reef Croaker	x	x	x	x	x					x		X
<i>Opistognathus aurifrons</i>	Yellowhead jawfish				x	x	x		x				
<i>Ophioblennius atlanticus</i>	Redlip Blenny	x	x	x	x	x			x	x	x		
<i>Paranthias furcifer</i>	Creole Fish	x	x	x		x	x	x	x			x	X
<i>Pempheris schomburgki</i>	Glassy Sweeper	x	x		x	x							
<i>Pomacanthus arcuatus</i>	Gray Angelfish	x	x			x	x	x	x	x	x	x	X
<i>Priacanthus arenatus</i>	Glasseye	x	x	x	x	x			x		x	x	X
<i>Pseudupeneus maculatus</i>	Spotted Goatfish		x	x		x				x	x		X
<i>Sparisoma chrysopteron</i>	Redtail Parrotfish							x					
<i>Scarus coelestinus</i>	Midnight Parrotfish				x								
<i>Scarus coeruleus</i>	Blue Parrotfish	x	x	x		x					x		X
<i>Scarus iserti</i>	Striped parrotfish	x	x	x	x	x	x	x	x	x	x	x	X
<i>Scarus sp.</i>	Parrotfish	x	x	x		x							
<i>Scarus taeniopterus</i>	Princess Parrotfish	x	x	x		x	x		x	x	x	x	X
<i>Scarus vetula</i>	Queen Parrotfish	x	x	x	x	x	x	x	x		x	x	X
<i>Scomberomorus regalis</i>	Cero Mackerel	x	x	x	x	x	x	x	x			x	X
<i>Scorpaena plumieri</i>	Spotted Scorpionfish										x	x	
<i>Seriola sp.</i>	Jack						x						
<i>Serranus baldwini</i>	Lantern Bass							x					
<i>Serranus sp.</i>	Bass					x	x	x					
<i>Serranus tabacarius</i>	Tobacco Fish							x					

<i>Species</i>	Common Name	M30	M20	M10	R5	R10	R20	D30	D20	D15	CJm	Derr	Gua
<i>Serranus tigrinus</i>	Harlequin Bass	x	x	x		x	x	x	x	x	x	x	X
<i>Sparisoma aurofrenatum</i>	Redband Parrotfish	x	x	x	x	x	x	x	x	x	x	x	X
<i>Sparisoma chrysopterygum</i>	Redtail Parrotfish						x	x	x				
<i>Sparisoma radians</i>	Bucktooth Parrotfish	x	x	x	x	x	x	x	x	x	x	x	X
<i>Sparisoma rubripinne</i>	Yellowtail Parrotfish				x	x		x	x				
<i>Sparisoma sp. (juv.)</i>	parrotfish										x		
<i>Sparisoma viride</i>	Stoplight Parrotfish	x	x	x	x	x	x	x	x	x	x	x	X
<i>Sphaeroides sp.</i>	Puffer	x		x									
<i>Sphaeroides greeleyi</i>	Green Puffer					x							
<i>Sphaeroides testudineus</i>	Checkered Puffer	x	x	x		x							
<i>Sphyraena barracuda</i>	Great Barracuda	x	x	x	x	x	x	x	x	x		x	
<i>Stegastes variabilis</i>	Cocoa Damselfish	x		x									
<i>Stegastes dorsopunicans</i>	Dusky Damselfish	x		x	x					x	x		X
<i>Stegastes leucostictus</i>	Beaugregory	x	x	x		x	x	x			x	x	X
<i>Stegastes partitus</i>	Bicolor Damselfish	x	x	x	x	x	x	x	x	x	x	x	X
<i>Stegastes planifrons</i>	Yellow-eye Damselfish	x	x	x		x	x	x	x		x	x	X
<i>Stegastes variabilis</i>	Cocoa damselfish				x	x				x	x		
<i>Synodus intermedius</i>	Sand Diver	x	x	x		x	x			x			
<i>Synodontidae sp.</i>	Lizardfish	x			x						x		
<i>Thalassoma bifasciatum</i>	Bluehead Wrasse	x	x	x	x	x	x	x	x	x	x	x	X
<i>Xanthichthys ringens</i>	Sargassum Triggerfish									x			
	TOTALS =	108	97	88	65	109	76	89	79	68	76	78	86

Appendix 2. Sea Surface Temperature (SST) and Degree Heating Weeks (DHW) time series for Puerto Rico during the years of 2004 – 2005.

