FINAL REPORT

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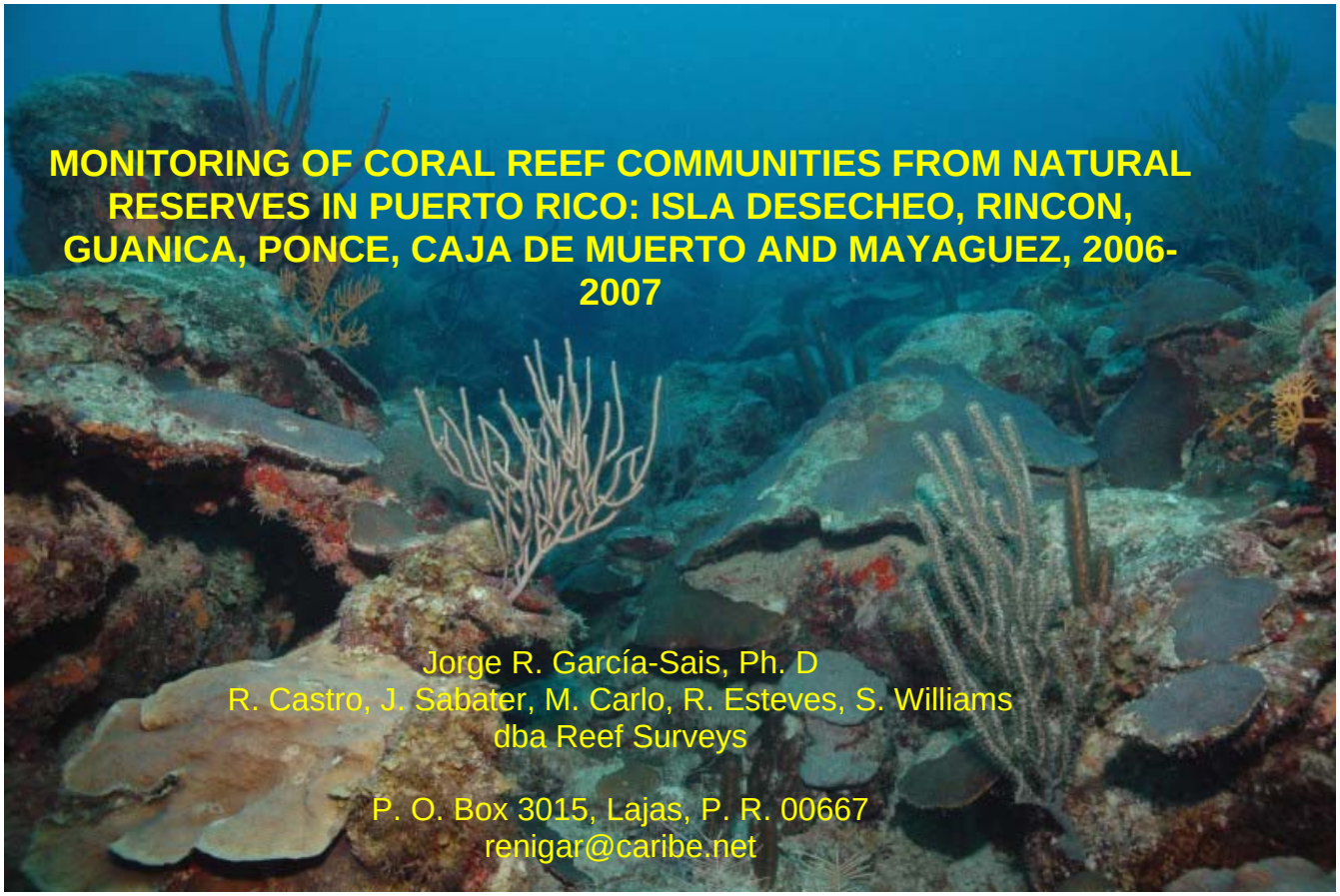

MONITORING OF CORAL REEF COMMUNITIES FROM NATURAL RESERVES IN PUERTO RICO: ISLA DESECHEO, RINCON, GUANICA, PONCE, CAJA DE MUERTO AND MAYAGUEZ, 2006-2007

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I Executive Summary

A total of 12 reefs from six Natural Reserves were included in the 2007 national coral reef monitoring program of Puerto Rico. These included reef sites at Isla Desecheo, Rincon, Mayaguéz, Guánica, Isla Caja de Muerto and Ponce. At each reef, quantitative measurements of the percent substrate cover by sessile-benthic categories and visual surveys of species richness and abundance of fishes and motile megabenthic invertebrates were performed along sets of five permanent transects.

The sessile-benthic community at the reef systems of Puerto Botes and Puerto Canoas (Isla Desecheo), Tourmaline Reef (Mayaguez), Cayo Coral (Guánica), West Reef (Caja de Muerto – Ponce), and Derrumbadero Reef (Ponce) presented statistically significant differences of live coral cover. Differences of live coral cover between monitoring surveys were mostly associated with a sharp decline measured during the 2006 survey, after a severe regional coral bleaching event that affected Puerto Rico and the U. S. Virgin Islands during August through October 2005. Live coral cover during the present 2007 monitoring survey presented a pattern of mild reductions relative to 2006 levels for almost all reef sites monitored. Declines of live coral cover between the 2007 and 2006 surveys were statistically significant (ANOVA; $p < 0.05$) at Tourmaline Reef (depth: 20 m) and at Puerto Canoas Reef (depth: 30m) in Isla Desecheo. Such reductions of live coral cover are here considered as lingering effects of the 2005 coral bleaching event. The decline of (total) live coral cover at the reef community level during 2006, and now extending into 2007 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, cyanobacteria and abiotic categories were measured.

Fish populations presented a general trend of declining abundance and species richness within belt-transects. Reductions of fish abundance were statistically significant in seven out of the 12 reef stations surveyed. These included Tourmaline Reef (Mayaguez) at 20 m; Puerto Botes Reef (Isla Desecheo) at 15 m; Tres Palmas Reef (Rincon) at 10 and 20 m; Derrumbadero Reef (Ponce) at 20 m and West Reef (Isla Caja de Muerto) at 8 m. Likewise, statistically significant reductions of fish species richness were observed at Tourmaline Reef (Mayaguez) at 20 m; Puerto Botes Reef (Isla Desecheo) at 15 m; Tres Palmas Reef (Rincon) at 10 m and West Reef (Isla Caja de Muerto) at 8 m. Variations

between surveys were mostly associated with reductions of abundance by numerically dominant populations that exhibit highly aggregated distributions in the immediate vicinity of live coral heads, 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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II Introduction

This 2006-07 coral reef monitoring survey includes quantitative and qualitative data of reef substrate cover by sessile-benthic categories and taxonomic composition and abundance of fishes and motile megabenthic invertebrates from a total of 12 reef stations within six Natural Reserve sites on the west coast (Isla Desecheo, Rincon and Mayaguez) and south coasts of Puerto Rico (Guánica, Isla Caja de Muerto and Ponce). After the initial quantitative baseline characterizations, the present work represents the fourth monitoring cycle at the Isla Desecheo 20m and Mayaguez 10m stations, and the third monitoring cycle for the Isla Desecheo 15 and 30m stations, Derrumbadero, Guánica, Caja de Muerto and Rincon 3, 10, and 20m reef stations. The initial quantitative baseline characterizations of the reefs included in this monitoring report are available in reports prepared by García-Sais et al., 2001 a, b, c).

The coral reef monitoring program has been focused on some of the best developed reefs systems within Natural Reserves in Puerto Rico, and other sites where high intensity recreational and coastal development activity was anticipated. The information here gathered contributes to an existing network and data base of U.S. coral reef monitoring sites sponsored by NOAA. The PRDNER Coastal Zone Division serves as the coral reef data management center. This data will be available to the public through the Internet website coralpr.net.

During the previous 2005-06 monitoring cycle 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 2004-05 and the 2005-06 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 throughout the Caribbean Sea. In most cases, a proportional increase of cover by turf algae was measured. 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 2004-05 and 2005-06 monitoring surveys. The fringing

shoreline reef at Tres Palmas is largely an Elkhorn Coral (*Acropora palmata*) biotope, and is dominated by 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 m depths, but differences of substrate cover by sessile-benthic components were not statistically significant at 30 m, which was the deepest station surveyed. The decline of live coral cover from the 30 m station at Puerto Canoas Reef in Isla Desecheo was less pronounced than at shallower stations (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 the 2005-06 monitoring event was associated with a severe 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 2005-06 field survey, performed approximately 6 to 9 months after the bleaching event, a relatively high proportion of live corals, particularly *Montastrea annularis* (complex) were observed to still retain partially bleached conditions. Lingering effects of the October 2005 bleaching event are here evaluated.

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 have presented in general, stable species richness and taxonomic composition, but a trend of declining abundance within belt-transects that was statistically significant in seven out of the 12 reef stations surveyed. 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*).

III Study Objectives

1- To continue the monitoring program of coral reef communities at the Puerto Canoas/Puerto Botes, Tourmaline and Tres Palmas Reefs in the west coast and at Derrumbadero, Caja de Muerto and Cayo Coral Reefs in the south coast of Puerto Rico following a standard Caribbean coral reef monitoring protocol, such as CARICOMP.

2- Perform fish surveys using the Active Search Census (ASEC) as a technique for characterization of large, elusive commercially exploited reef fish populations and provide an assessment of the status of their populations and the potential role of various reef habitats, or reef physiographic zones in reef fish life cycles.

3- Provide an analysis of temporal trends in coral reef benthic and fish community structure as available from the repeated monitoring events.

4- Produce a comprehensive digital underwater photographic documentation of the Puerto Canoas/Puerto Botes, Tourmaline and Tres Palmas Reefs in the west coast and at Derrumbadero, Caja de Muerto and El Coral Reefs.

IV Methodology

The location of reef sites included in this monitoring cycle is shown in Figures 1 and 2. Table 1 presents the geographic coordinates and depths of reefs monitored. A total of five permanent 10 m long transects were monitored from each reef station. The sampling scheme included reef zones at depths of 3-5 m (reef crest), 10-12 m (hard ground platform) and 18-20 m (shelf-edge) at the Tres Palmas Reef system in Rincón. Tourmaline Reef in Mayaguez Bay was characterized by an existing set of five permanent transects at depths of 10-12m, 18-21 m and 27-30 m along successive spurs on the reef. Puerto Canoas/Puerto Botes Reef system in Isla Desecheo was monitored at depths of 13-15 m, 18-20 m and 28-30 m. Monitoring efforts were carried out during the spring and summer to minimize potential seasonal effects.

Table 1. Geographic positions of coral reefs surveyed during 2007

Site		Latitude (°N)	Longitude (°W)
Isla Desecheo			
	Canoas 30m	18°22.706	67°29.199
	Botes 20m	18°22.8949	67°29.3160
	Botes 15m	18°22.920	67°29.300
Mayaguez			
	Tourmaline 30 m	18°09.985	67°16.581
	Tourmaline 20 m	18°09.910	67°16.512
	Tourmaline 10 m	18°09.7919	67°16.4160
Rincon			
	Tres Palmas 20m	18°20.790	67°16.248
	Tres Palmas 10m	18°20.832	67°16.206
	Tres Palmas 3m	18°21.023	67°15.959
Ponce			
	Derrumbadero 20m	17°54.2400	66°36.5159
Guánica			
	Coral 10m	17°56.1720	66°53.3040
Caja de Muerto			
	West Reef 10m	17°53.7000	66°31.7040

Sessile-benthic reef communities

Sessile-benthic reef communities were characterized by the continuous intercept chain-link method (as modified from Porter, 1972), following the CARICOMP (1984) protocol. This method provides information on the percent linear cover by sessile-benthic biota and other substrate categories along permanent transects. It allows construction of reef community profiles by assignment of metric units to each substrate transition, which serves as a high precision baseline for monitoring. The chain has links of 1.42 cm long, marked every 10 links for facilitation of counting underwater. The exact position of the chain is guided by a series of stainless steel nails hammered into available hard (abiotic) substrate at approximately every 0.5 meters in the reef. Also, a thin nylon reference line is stretched from rod to rod to guide divers over the linear transect path. Individual measurements of substrate categories, as recorded from the number of chain links are sorted, added and divided by the total distance (in chain links) on each transect to calculate the cumulative percent linear cover by each substrate category. Soft corals, with the exception of encrusting forms (e.g. *Erythropodium caribaeorum*) were identified and counted as number of colonies intercepted per transect, whenever any of their branches cross the transect reference line. The vertical relief of the reef, or rugosity, was calculated by subtracting 10 meters from the total length (links) recorded with the chain at the 10 meter marker of the reference line.

Reef fishes and motile megabenthic invertebrates

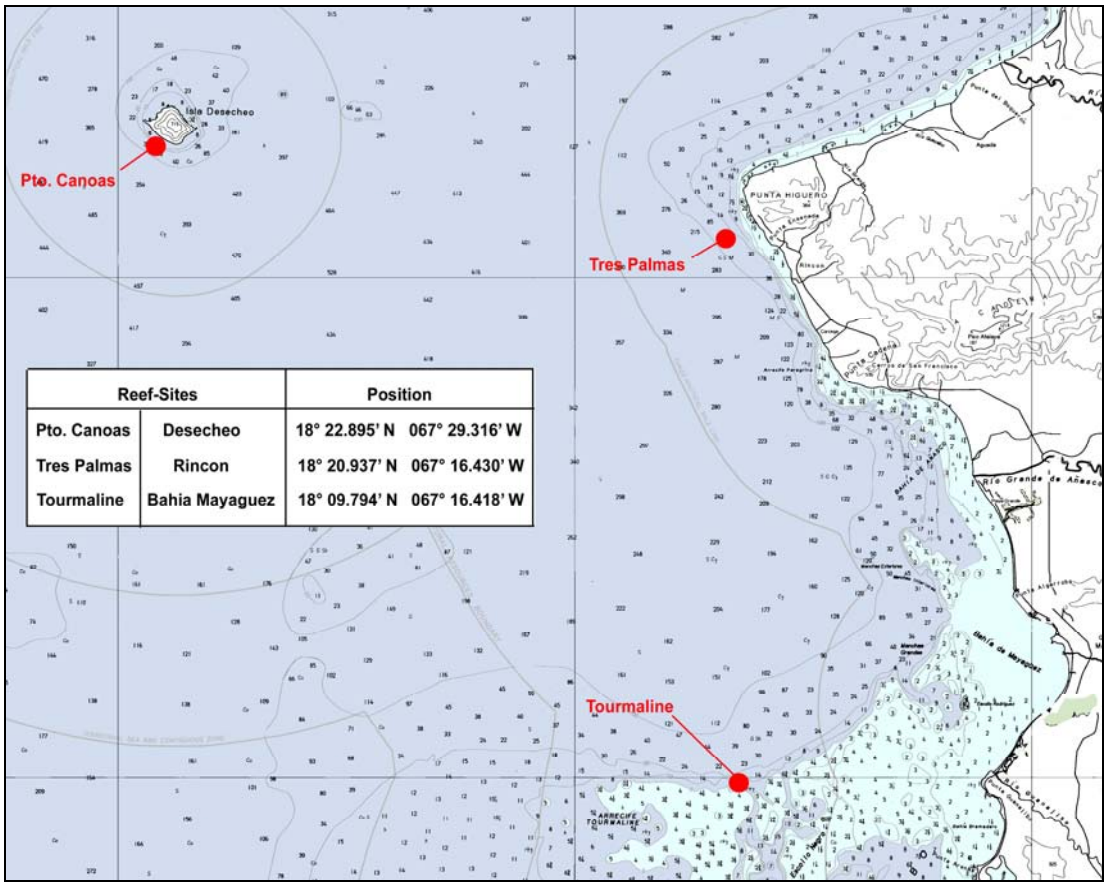
Demersal and territorial reef fish populations and motile megabenthic invertebrates were surveyed by five 10 m long by 3 m wide ($30m^2$) belt-transects centered along the reference line of transects used for sessile-benthic reef characterizations. A total of 15 belt-transects for fish and motile megabenthic invertebrates were performed at Tres Palmas Reef (Rincon), Puerto Canoas/Puerto Botes Reef (Isla Desecheo) and El Tourmaline (Mayaguez Bay). Five belt-transects were surveyed at Derrumbadero, Caja de Muerto (Ponce) and Cayo Coral Reef in Guánica, for a total of 60 belt-transects for characterization of fishes and motile megabenthic invertebrates.

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

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

Statistical Analyses

Variations between monitoring surveys of percent substrate cover by live corals, fish species richness and abundance were analyzed using one-way analysis of variance (ANOVA) procedures (StatSoft, Inc., 2005). Statistically significant differences ($p < 0.05$) between monitoring surveys were further analyzed by a multiple mean comparison test (Fisher LSD test). The sets of five transects were used as replicates for ANOVA testing. The complete statistical test results are presented in Appendices 2, 3 and 4.



Reef-Sites		Position
Pto. Canoas	Desecheo	18° 22.895' N 067° 29.316' W
Tres Palmas	Rincon	18° 20.937' N 067° 16.430' W
Tourmaline	Bahia Mayaguez	18° 09.794' N 067° 16.418' W

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

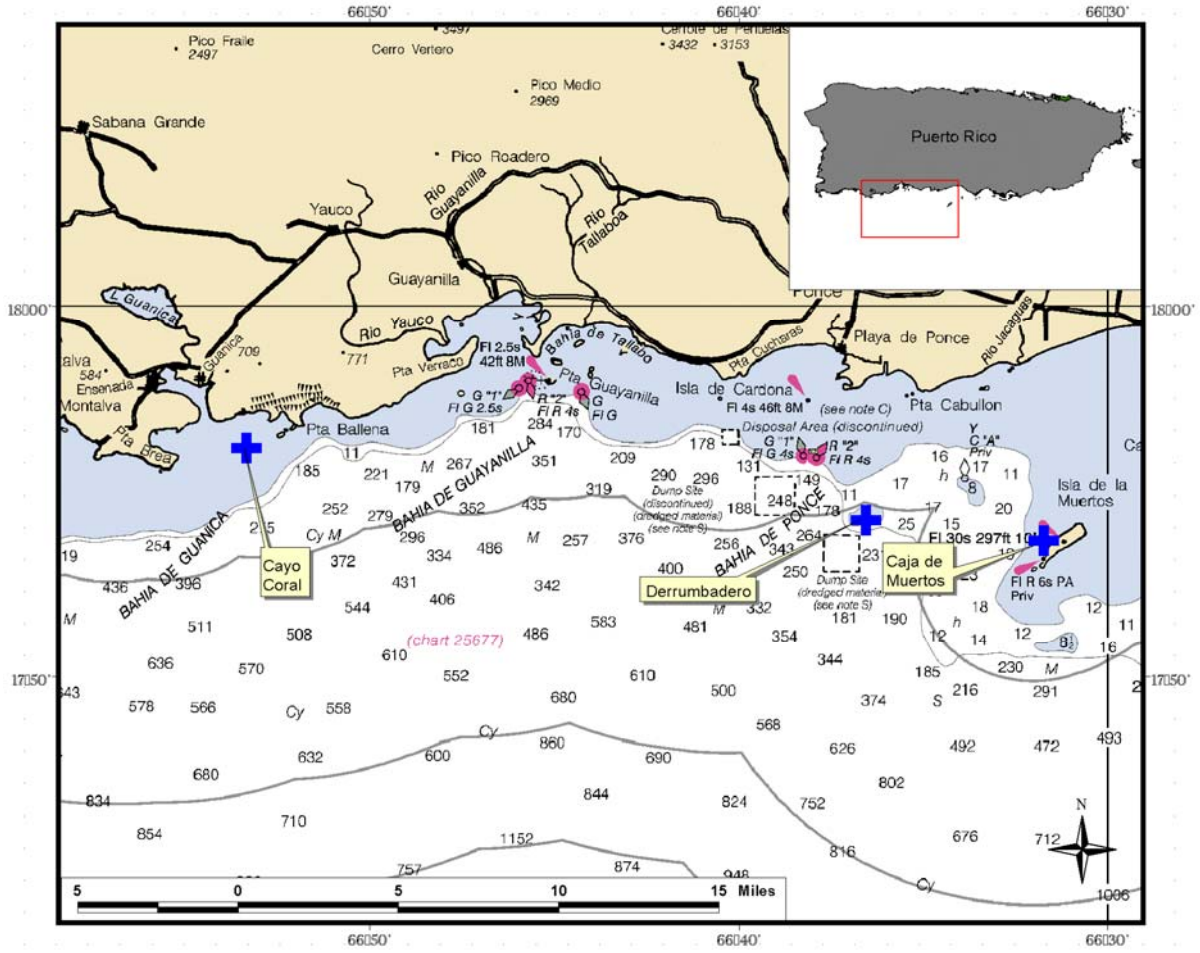


Figure 2. Location of south coast reef sites, Cayo Coral (Guánica), Derrumbadero and West Reef of Isla Caja de Muerto (Ponce)

Results

V 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 stony corals and gorgonians 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 the 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 have been observed fishing with spear guns within the no-take area. The present 2007 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.

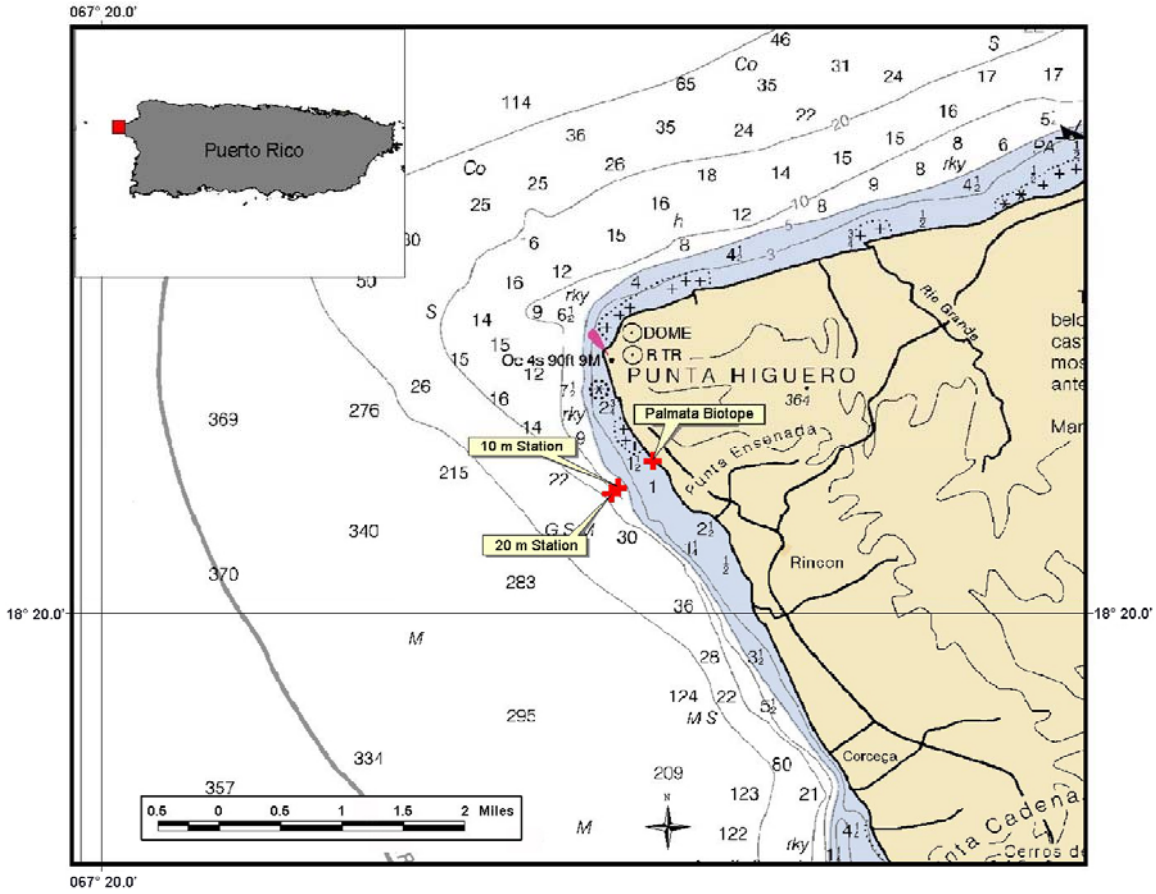


Figure 3. Location of coral reef survey stations off Tres Palmas, Rincón.

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 39.40% (range: 16.30 – 59.82 %). Elkhorn Coral (*A. palmata*) was the dominant species with a mean substrate cover of 32.13 % (range: 7.30 – 58.66 %), representing 81.5 % of the total live coral cover. Six additional coral species, mostly encrusting types (e.g. *Diploria clivosa, D. strigosa, P. astreoides* and *Montastrea annularis, M. cavernosa and Isophillia sinuosa*) were intersected by linear transects during our survey. A total of 15 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: 39.88 %). Fleshy macroalgae (*Valonia sp., Stypopodium sp*.) and red coralline algae were observed outside transect areas. The encrusting zoanthid, *Palythoa caribbea* was

Table 2. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon 5m, June 2007.

Depth: 5 m	TRANSECT					
	1	2	3	4	5	**MEAN**
Rugosity (m)	2.80	2.00	2.94	2.13	3.16	**2.61**
SUBSTRATE CATEGORY						
Abiotic						
Gaps			0.54	1.51		**0.41**
Sand					5.36	**1.07**
Reef Overhangs	23.67	19.75	13.38	10.23	15.13	**16.43**
Total Abiotic	23.67	19.75	13.92	11.74	20.49	**17.91**
Benthic Algae						
Turf-mixed assemblage	45.23	34.67	28.31	28.47	62.74	**39.88**
Calcareous		1.17	0.98		0.54	**0.54**
Total Benthic Algae	45.2	35.8	29.3	28.5	63.3	**40.4**
Cyanobacteria						
Sponges						
Zoanthids	8.98		2.47			**2.29**
Live Stony Corals						
Acropora palmata	6.16	42.58	45.94	58.66	7.30	**32.13**
Diploria strigosa	11.64				2.68	**2.86**
Diploria clivosa			5.88		3.64	**1.90**
Porites astreoides	0.44	1.92	1.42	1.16		**0.99**
Montastrea annularis	3.28		1.08			**0.87**
Montastrea cavernosa					2.68	**0.54**
Isophyllia sinuosa	0.55					**0.11**
Total Stony Corals	22.07	44.50	54.32	59.82	16.30	**39.40**
Gorgonians (# col.)						
Gorgonia ventalina	1.00		1.00	1.00	1.00	**0.80**
Plexaura flexuosa	1.00				1.00	**0.40**
Total Gorgonians (# colonies/transect)	2.00	0.00	1.00	1.00	2.00	**1.20**

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

present in two transects with a mean cover of 2.3 %. The encrusting gorgonian *Erythropodium caribaeorum* was observed outside transects. Abiotic categories, associated with reef overhangs, gaps or holes and sand represented 17.91 % of the reef substrate cover. Vertically projected soft corals (gorgonians) were found in very low abundance (mean 1.2 colonies/transect). The Common Sea Fan, *Gorgonia ventalina* and the Bent Sea Rod, *Plexaura flexuosa* were the only species present within transects. This was expected in an environment seasonally affected by very strong wave action. Other erect gorgonian species observed out of transects included *Pseudopterogorgia americana*, *Plexaura homomalla*, *Muricea spp*. and *Eunicea spp.*

Monitoring trends of the sessile-benthic community at the Tres Palmas fringing reef are presented in Figure 4. Mean live coral cover has fluctuated between 38.62 % and 39.40 % during the monitoring period between 2004 and 2007. The small variation of mean live coral cover between surveys was not statistically significant (ANOVA; $p = 0.974$) (Appendix 2). 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 or other coral species (within transects),during the 2007 survey.

Interannual fluctuations of coral cover by *Acropora palmata* have been typical at this reef. 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 constrains 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.

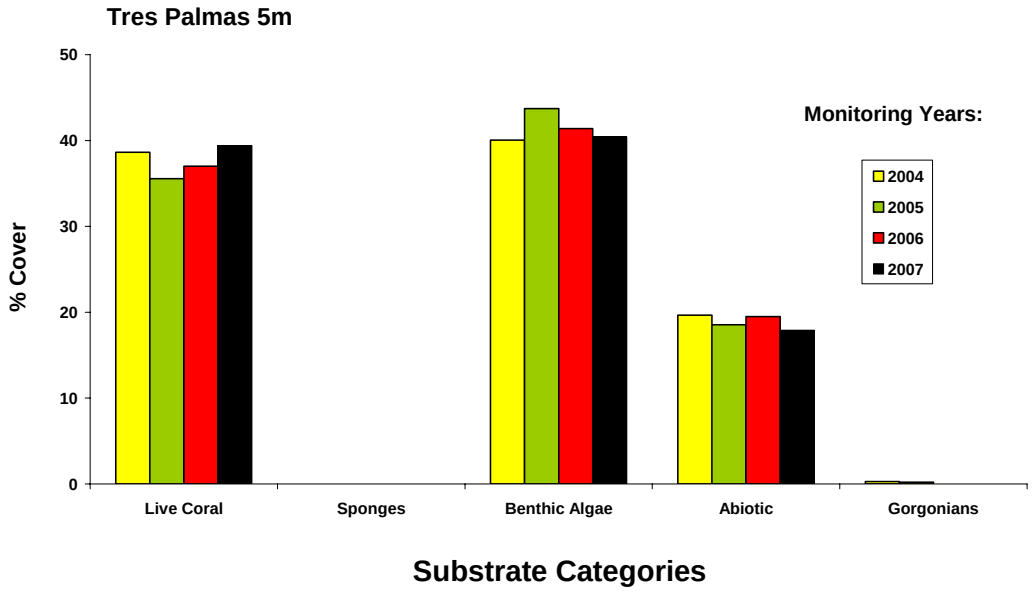


Figure 4. Monitoring trends (2004 – 2007) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon, 2- 5 m depth.

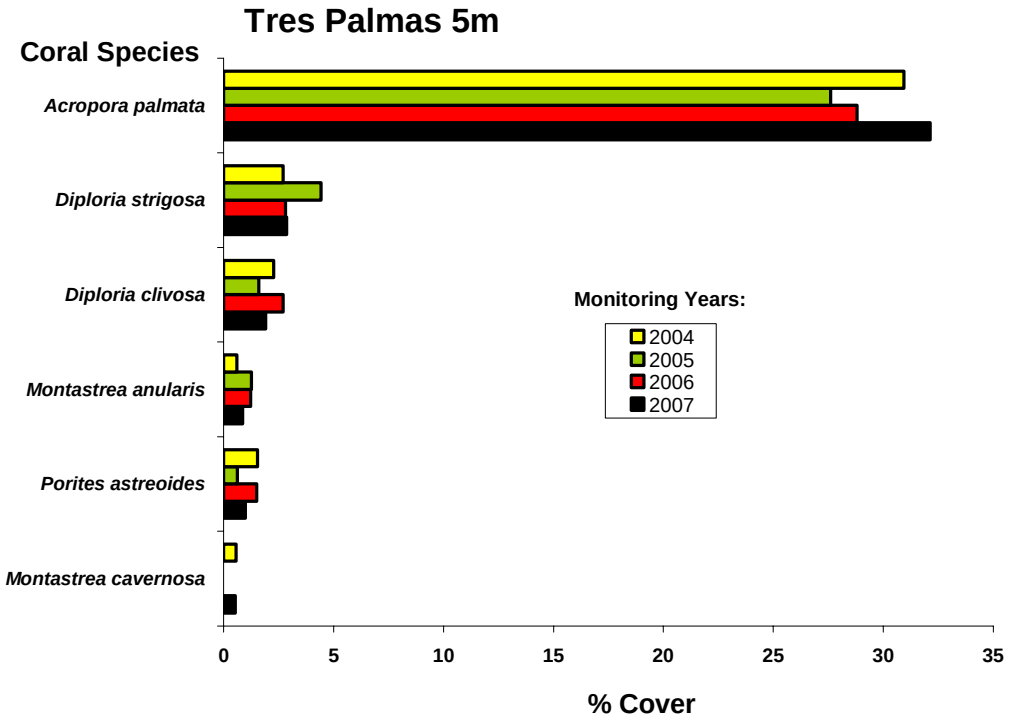


Figure 5. Monitoring trends (2004 – 2007) of mean substrate cover by dominant stony coral species at Tres Palmas Reef, Rincon, 2 - 5 m depth.

1.2 Reef Fishes and Motile Megabenthic Invertebrates

A total of 74 fish species have been identified from the *Acropora palmata* fringing reef system off Tres Palmas, Rincón within a depth range of 2 – 5 meters (Appendix 1). During the 2007 monitoring survey, 53 fish species, including 19 present within belt-transects were identified from the fringing reef. The mean abundance of individuals was 43.2 Ind/30 m^2 (range: 24 - 64 Ind/30 m^2), and the mean number of species per transect was 9 (range: 6-12). The combined abundance of six species represented 88.4 % of the mean abundance within belt-transects (Table 3). The most abundant species was the Bluehead Wrasse (*Thalassoma bifasciatum*) with a mean of 14.8 Ind/30 m^2 followed by the Dusky Damselfish (*Stegastes dorsopunicans*) with 13.2 Ind/30 m^2. The Redlip Blenny (*Ophioblennius atlanticus*), Yellowtail Damselfish (*Microspathodon chrysurus*) and the Clown Wrasse (*Halichoeres maculipina*) were present within all five belt-transects surveyed and along with the aforementioned species appear to comprise 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 and parrotfishes 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 (Appendix 3 & 4). 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, and 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 sardines (*Anchoa spp., Harengula spp*.) near the surface. Large (adult) commercially important demersal fishes (snappers, groupers, hogfishes) were not observed. Juvenile stages of snappers (*Lutjanus analis,*

Table 3. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef 5m, Rincon. June, 2007

Depth: 5m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
		Individuals/30m^2					
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead wrasse	33	6	13	18	4	**14.8**
Stegastes dorsopunicans	Dusky damselfish	13	12	15	12	14	**13.2**
Ophioblennius atlanticus	Redlip blenny	7	4	3	5	1	**4.0**
Microspathodon chrysurus	Yellowtail damselfish	3	4	3	5	1	**3.2**
Halichoeres maculipinna	Clown wrasse	2	2	2	1	3	**2.0**
Acanthurus coeruleus	Blue tang		1	2	2		**1.0**
Halichores radiatus	Pudding wife	1		1	2		**0.8**
Abudefduf sexatilis	Sargent major		2	2			**0.8**
Sparisoma viride	Stoplight parrotfish			1	2		**0.6**
Acanthurus chirurgus	Doctorfish			1	2		**0.6**
Halichoeres bivittatus	Slippery dick	1				1	**0.4**
Sparisoma radians	Bucktooth parrotfish				2		**0.4**
Stegastes partitus	Bicolor damselfish	1					**0.2**
Haemulon macrostomus	Spanish grunt				1		**0.2**
Bodianus rufus	Spanish hogfish			1			**0.2**
Sparisoma rubripinne	Yellowtail parrotfish				1		**0.2**
Haemulon flavolineatum	French grunt	1					**0.2**
Malacoctenus triangulatus	Saddled blenny	1					**0.2**
Lactophrys triqueter	Smooth trunkfish	1					**0.2**
	TOTAL INDIVIDUALS	**64**	**31**	**44**	**53**	**24**	**43.2**
	TOTAL SPECIES	**11**	**7**	**11**	**12**	**6**	**9**

L. apodus, L. mahogany, L. synagris) were observed during the 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. This reef is also the residential and nursery habitat of the Yellowtail Damselfish (*Microspathodon chrysurus*), which in its early juvenile stage (known as "Jewel Damselfish") is commercially important as an aquarium trade target species. One Hawksbill Turtle (*Eretmochelys imbricata*) was reported during the 2004 baseline survey (García-Sais et al., 2004a).

Among motile megabenthic invertebrates, the Rock-boring Sea Urchin (*Echinometra lucunter*), was observed within belt-transect areas during the 2007 monitoring survey (Table 5). Juvenile Rock Lobsters (*Panulirus guttatus*) and other sea urchins have been reported from previous surveys at this reef (García-Sais et al., 2004a).

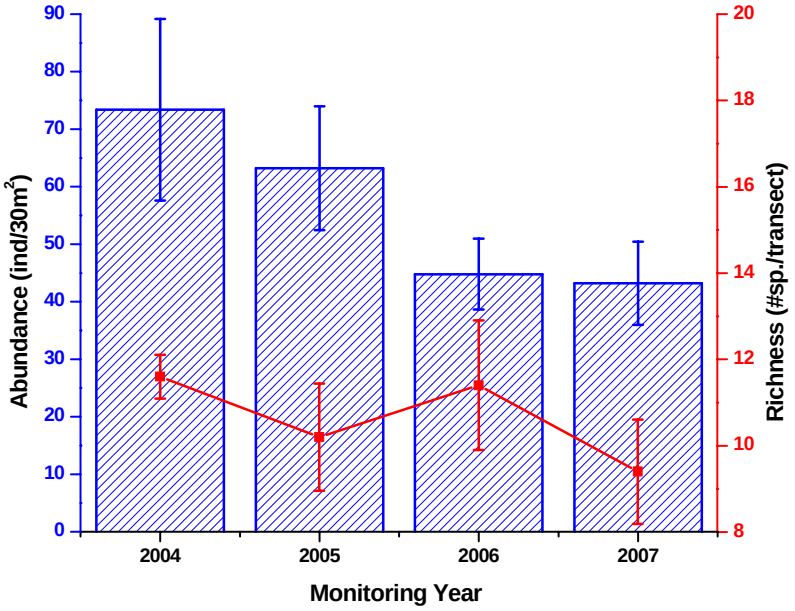


Figure 6. Monitoring trends (2004 – 2007) of fish species richness and abundance at Tres Palmas Elkhorn Coral Reef, 2-5 m depth, Rincón.

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, 2007

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

SPECIES	**COMMON NAME**	# - (cm)			
Carangoides crysos	Blue Runner	2 – (25)			
Gramma loreto	Fairy Basslet	2 – (3)	6 – (4)		
Lutjanus synagris	Lane Snapper	1 – (15)			
Lutjanus apodus	Schoolmaster	1 – (20)	3 – (25)		
Lutjanus mahogany	Mahogany Snapper	3 – (20)			
Microspathodon chrysurus	Yellowtail Damselfish	26 – (<5)	19 – (10)	4 – (15)	7 – (20)
Ocyurus chrysurus	Yellowtail Snapper	1 – (25)			

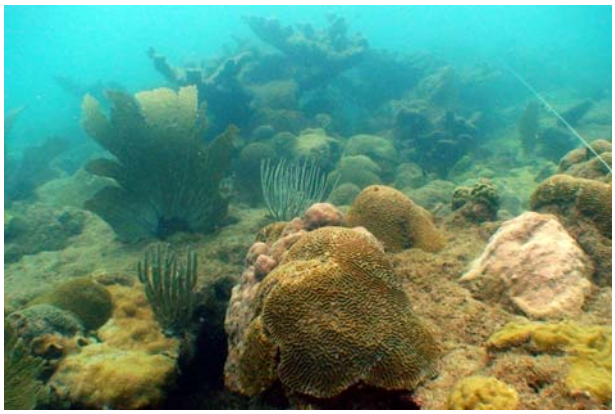
Table 5. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Elkhorn Coral Reef, 3 m depth, Rincon, June, 2007

DATE: June, 2007 Depth: 3 - 5 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	2	3	4	5	
SPECIES	**COMMON NAME**						
Echinometra lucunter	Rock boring Urchin		2		1	1	0.8
	TOTALS		2		1	1	0.8

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 21.8 col./transect (range: 15 – 33 col./transect) (Table 6). The most abundant taxa included Sea Rods, *Plexaura flexuosa, P. homomalla,* Sea Plumes *Pseudopterogorgia americana*, *P. acerosa*, and the Common Sea Fan *Gorgonia ventalina* (Table 6).

Stony corals occurred mostly as encrusting colonies of typically small size and low vertical relief. A total of 22 species of stony corals were identified from the patch reef community during our survey. Stony coral cover averaged 17.96 % (range: 10.51 – 23.67 %). Great Star Coral, *Montastrea cavernosa* was the dominant species in terms of substrate cover with a mean of 5.18 % (range: 2.29 – 10.52 %), representing 30.5 % of the total live coral cover from this reef. Eighteen coral species were intersected by linear transects, but 12 of them with less than 1 % mean cover. Recently dead coral overgrown by turf algae covering 3.01 % of the reef substrate was observed from transect 3.

Turf algae, a mixed assemblage of short filamentous red and brown macroalgae

Table 6. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon 10m, June 2007.

Depth: 10 m	TRANSECT					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	0.94	1.87	2.17	1.66	1.96	**1.72**
SUBSTRATE CATEGORY						
Abiotic						
Gaps						
Reef Overhangs	3.57	4.55	3.78	3.00	2.34	**3.45**
Sand-silt	3.48					**0.70**
Total Abiotic	7.05	4.55	3.78	3.00	2.34	**4.14**
Benthic Algae						
Turf-mixed assemblage	76.76	64.11	63.76	66.55	70.38	**68.31**
Fleshy			0.46		0.47	**0.19**
Calcareous	2.84		1.97	1.11	2.34	**1.65**
Total Benthic Algae	79.6	64.1	66.2	67.7	73.2	**70.2**
Cyanobacteria		4.13	3.04			**1.43**
Sponges	2.47	6.91	8.71	5.23	9.87	**6.64**
Encrusting Gorgonian	0.39	0.24		0.48	1.09	**0.44**
Live Stony Corals						
Montastrea cavernosa	2.29	6.40	10.52	4.37	2.34	**5.18**
Porites astreoides	1.37	3.45	1.89	2.32	4.10	**2.63**
Montastrea annularis	4.94	2.95				**1.58**
Colpophyllia natans			0.46	6.64		**1.42**
Siderastrea siderea		0.71	0.46	2.40	2.24	**1.16**
Diploria strigosa		3.20	2.08	0.24		**1.10**
Dendrogyra cylindrus				4.11		**0.82**
Siderastrea radians			1.23	0.69	1.18	**0.62**
Meandrina meandrites		1.52	0.93			**0.49**
Agaricia agaricites		0.71	0.69	0.97		**0.47**
Stephanocoenia michelini	0.90			1.09	0.35	**0.47**
Diploria labyrinthiformis					2.01	**0.40**
Madracis decactis	1.01					**0.20**
Isophyllia sinuosa					0.67	**0.13**
Diploria clivosa				0.60		**0.12**
Porites porites					0.35	**0.07**
Millepora alcicornis					0.24	**0.05**
Isophyllastrea rigida				0.24		**0.05**
Total Stony Corals	10.51	18.94	18.26	23.67	13.48	**16.97**
Recently dead coral			3.01			**0.60**
Gorgonians						
Plexaura flexuosa	9.00	10.00	3.00	3.00	4.00	**5.80**
Pseudoptergorgia americana	1.00	10.00	3.00	2.00	2.00	**3.60**
Pseudoptergorgia acerosa	6.00	4.00		3.00	1.00	**2.80**
Gorgonia ventalina	1.00	4.00	2.00	1.00	5.00	**2.60**
Eunicea turnetorti	1.00	2.00	3.00	1.00		**1.40**
Ptergorgia spp.	3.00	1.00	1.00	1.00	1.00	**1.40**
Eunicea succinea	1.00	1.00	2.00	1.00		**1.00**
Plexaura homomalla		1.00	1.00		3.00	**1.00**
Eunicea spp.	1.00			1.00	1.00	**0.60**
Pseuodoplexaura flagellosa or wargi	0.00				2.00	**0.40**
Eunicea asperula					1.00	**0.20**
Muricea spp.				1.00		**0.20**
Muriceopsis flavida				1.00		**0.20**
Plexaura kukenthali	1.00					**0.20**
Pseudoplexaura purosa					1.00	**0.20**
Pseudoptergorgia bipinnata	1.00					**0.20**
Total Gorgonians (# colonies/transect)	25.00	33.00	15.00	15.00	21.00	**21.80**

Coral Species Outside Transects: *Acropora cervicornis, Favia fragum, Millepora alcicornis, Manicina areolata*

presented the highest percent of reef substrate cover by sessile-benthic components with a mean of 68.31 % (range: 63.76 – 76.76 %). Fleshy brown (*Dictyota sp*.), red (*Galaxaura sp*.) and calcareous (*Halimeda discoidea*) macroalgae were present within transects with a combined cover of 1.84 %. Thus, the total cover by benthic algae was 70.2 %. Encrusting sponges were intersected by all five transects with a mean substrate cover of 6.64 % (range: 2.47 – 9.87 %). The encrusting gorgonian *Erythropodium caribaeorum* was present in four out of the five transects with a mean substrate cover of 0.44 %. *Palythoa caribbea,* an encrusting zoanthid was observed outside transects. Abiotic categories associated with reef overhangs and sand pockets comprised only 4.14 % 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 1.72 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).

Figure 7 shows the variations of reef substrate cover by sessile-benthic categories throughout the monitoring program starting with the baseline survey of 2004. Live coral cover has declined 4%, reflecting a very mild but consistent trend of declining cover from a mean of 20.9% in 2004 to a mean of 16.9 % in 2007. Such variations of the mean reef substrate cover by (total) live corals between monitoring surveys (2004 – 2007) are not statistically significant (ANOVA; $p = 0.686$). The most pronounced reduction of substrate cover by coral species was associated with degradation of a relatively large colony of Grooved Brain Coral, *Diploria labyrinthiformis* (in transect 3) which declined 90.2 %, from a mean of 4.07 % to 0.40 %.

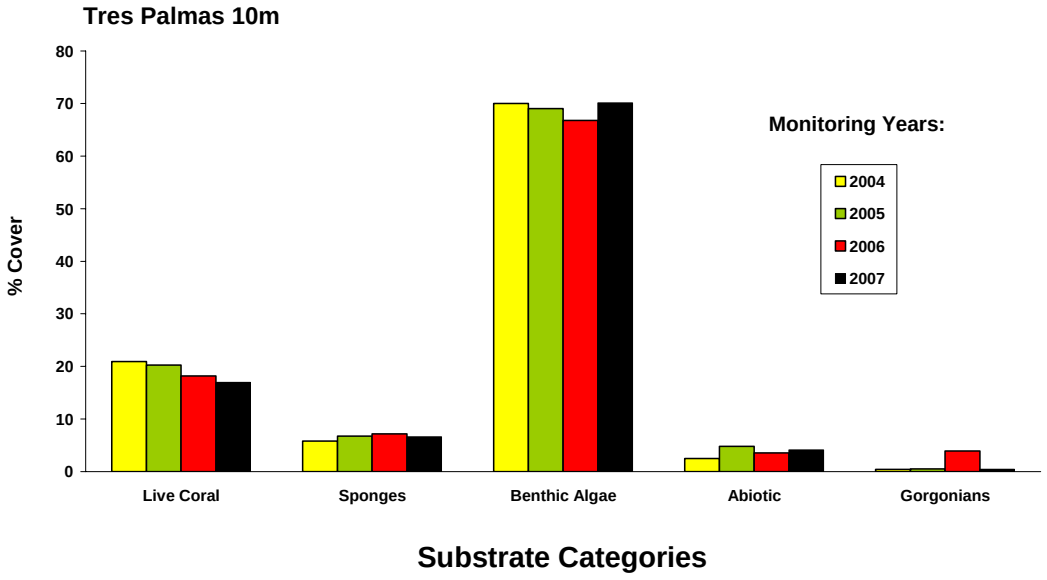


Figure 7. Monitoring trends (2004 – 2007) of mean substrate cover by sessile-benthic categories at Tres Palmas Outer Patch Reef – 10 m.

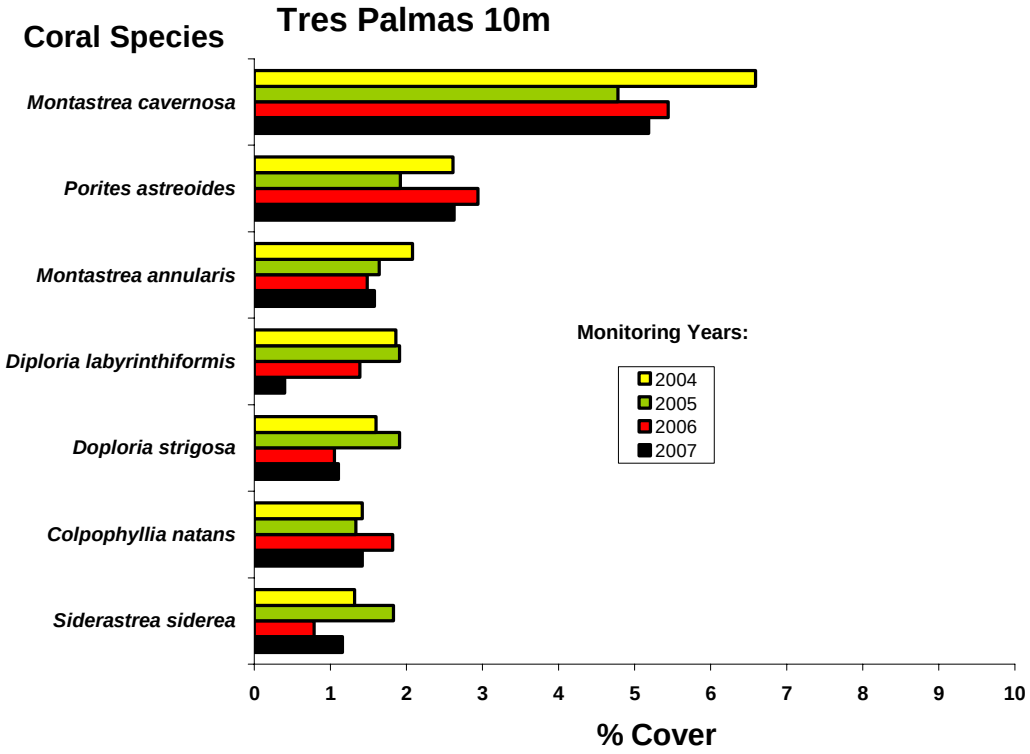


Figure 8. Monitoring trends (2004 – 2007) of mean substrate cover by dominant stony coral species at Tres Palmas Outer Patch Reef – 10 m.

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 113 fish species have been identified from the patch reef formation at the Tres Palmas Reef system of Rincón (Appendix 1). During the 2007 survey, mean abundance of individuals within belt-transects was 87.6 Ind/30 m^2 (range: 68-102 Ind/30 m^2). The mean number of species per transect was 14 (range: 12-17). Fish species richness declined by 21.3 % and mean abundance declined by 48.5 % compared to the 2005 survey (Figure 9). Species richness during the 2007 survey was lower than during all previous surveys (ANOVA; $p = 0.003$; see appendix 3). Abundance during 2007, was lower than during 2006, but similar to 2004 and 2005 (ANOVA; $p < 0.0001$; see appendix 4).

Two species, the Bicolor Damselfish (*Stegastes partitus*) and the Bluehead Wrasse (*Thalassoma bifasciatum*) were (as in previous surveys) numerically dominant within belt-transects with mean abundances of 35.0 and 29.2 Ind/30 m^2, respectively (Table 7). The combined abundance of these two species represented 73.3 % of the community mean abundance within belt-transects. In addition to the two aforementioned species, the Sharknose Goby, Redband Parrotfish, and the Coney were present within all five transects surveyed. Given their prevalence in previous surveys they represent a resident fish assemblage of 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, and damselfishes) that feed on the turf algae were common. Pelagic piscivores, such as barracudas (*Sphyraena barracuda*), mackerels (*Scomberomorus regalis*) and jacks (*Caranx crysos, C. ruber*) have been previously reported from this reef (García-Sais et al., 2005). Large (adult) commercially important demersal fishes (snappers, groupers, hogfishes) were not observed.

Table 7. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef, Rincon. Depth: 10 m. June, 2007

Depth: 10m							
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Stegastes partitus	Bicolor Damselfish	33	36	35	34	37	**35.0**
Thalassoma bifasciatum	Bluehead Wrasse	31	18	37	47	13	**29.2**
Sparisoma radians	Bucktootth Parrotfish	6	4		2		**2.4**
Sparisoma aurofrenatum	Redband Parrotifish	1	4	3	2	2	**2.4**
Halichoeres garnoti	Yellow-head Wrasse	5	3		1	3	**2.4**
Gobiosoma evelynae	Sharknose Goby	1	1	3	4	1	**2.0**
Acanthurus bahianus	Ocean Surgeon	1	2	1		5	**1.8**
Cephalopholis fulva	Coney	1	1	3	2	1	**1.6**
Scarus taeniopterus	Princess parrotfish	4			2		**1.2**
Halichoeres maculipinna	Clown wrasse	2		2	2		**1.2**
Chaetodon capistratus	Foureye Butterflyfish	2	2			2	**1.2**
Malacoctenus triangulatus	Saddled blenny				4	1	**1.0**
Coryphopterus sp.	Goby	1	1	1	1	1	**1.0**
Chromis cyanea	Blue Chromis	3	2				**1.0**
Serranus tigrinus	Harlequin bass	1	1	2			**0.8**
Scarus iserti	Stripped parrotfish		1	2		1	**0.8**
Acanthurus chirurgus	Doctorfish	2	1				**0.6**
Holocentrus rufus	Squirrelfish			1		1	**0.4**
Canthigaster rostrata	Caribbean Puffer			2			**0.4**
Microspathodon chrysurus	Yellowtail damselfish				1		**0.2**
Hypoplectyrus puella	Barred hamlet	1					**0.2**
Holacanthus tricolor	Rock beauty			1			**0.2**
Carangoides ruber	Horse-eye jack		1				**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish		1				**0.2**
Acanthurus coeruleus	BlueTang		1				**0.2**
	TOTAL INDIVIDUALS	**95**	**80**	**93**	**102**	**68**	**87.6**
	TOTAL SPECIES	**16**	**17**	**13**	**12**	**12**	**14**

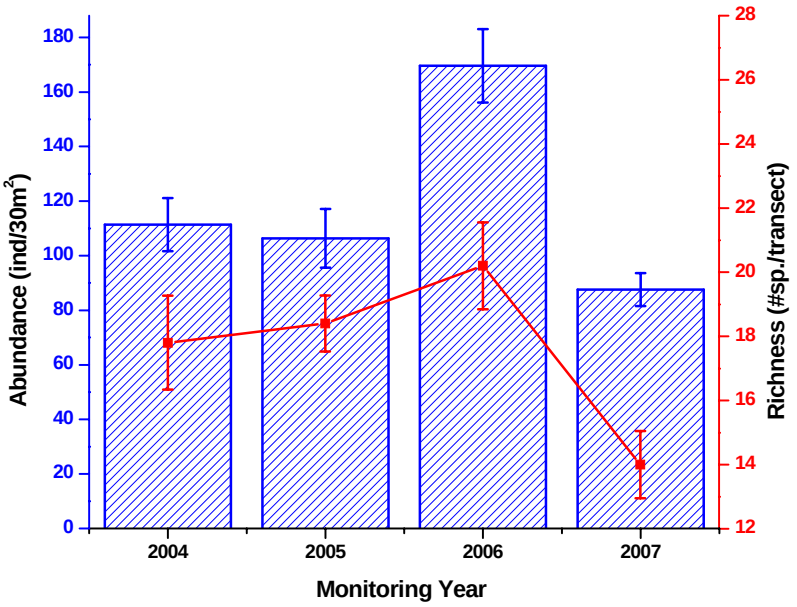


Figure 9. Monitoring trends (2004 – 2007) of fish species richness and abundance at Tres Palmas Outer Shelf Patch Reef, 10-15 m depth, Rincon.

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)		
Epinephelus guttatus	Red Hind	1 – (30)			
Lutjanus apodus	Schoolmaster	1 – (20)	1 - (25)		
Lutjanus synagris	Lane Snapper	1 – (20)	2– (25)	1 – (30)	
Sphyraena barracuda	Great Barracuda	1 – (90)			
Holacanthus ciliaris	Queen Angel	1 – (30)			
Gramma loreto	Fairy Basslet	13 – (3)	6 – (4)	6 – (5)	2 – (6)
Holacanthus tricolor	Rock Beauty	1 – (15)			
Pomacanthus paru	French Angel	1 – (35)			

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

Table 9. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Reef, Rincon, 10m depth, June, 2007

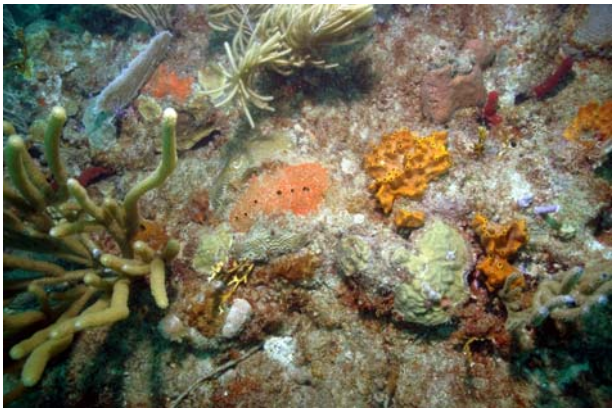
		TRANSECTS					
DATE: June 2007 Depth: 10 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Periclimenes pedersoni	Cleaner Shrimp	1	1			2	**0.6**
Echinometra lucunter	Rock boring Urchin	1					**0.2**
Stenorhynchus seticornis	Arrow Crab		1				**0.2**
	TOTALS	2	2			2	1.2

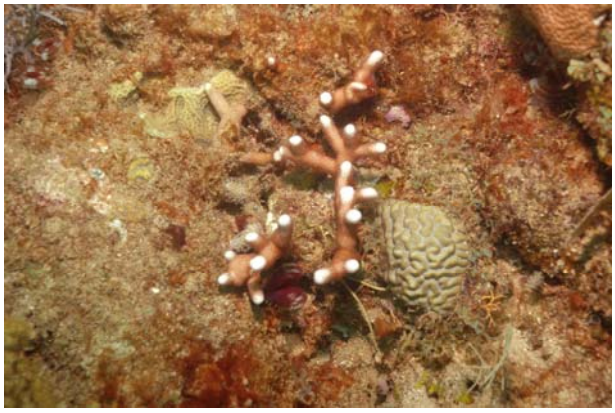
Photo Album 2 (Rincon 15m)

Outer Shelf Patch Reef



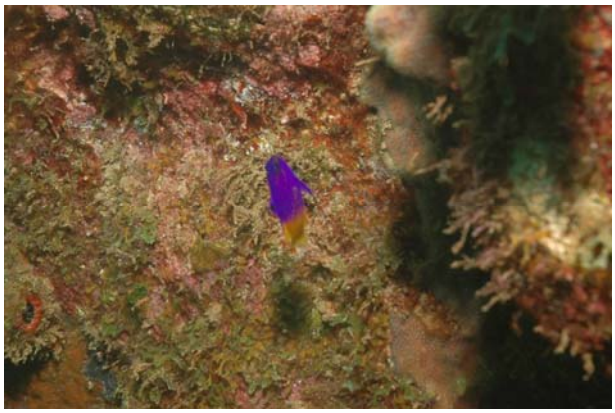






3.0 Tres Palmas Shelf-edge Reef

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, 14 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 20.04 % (range: 9.16 – 26.90 %). Boulder Star Coral, *Montastrea annularis* complex was the dominant species in terms of substrate cover with a mean of 7.74 % (range: 1.72 – 17.60 %), representing 38.6 % of the total cover by stony corals (Table 10). Colonies of *Montastrea annularis*, *M. cavernosa* and Maze Coral (*Meandrina meandrites*) were present in all five transects. Also present in four out of the five transects were colonies of Mustard-Hill Coral, *Porites astreoides*, Lettuce Coral, *Agaricia agaricites*, and Ten-Ray Star Coral, *Madracis decactis*. Soft corals (gorgonians) were moderately abundant, with a total of 10 species identified within transects and an average of 13.4 colonies/transect. The main assemblage included the Bent Sea Rod, *Plexaura flexuosa*, the sea plumes (*Pseudopterogorgia americana, P. acerosa*) and the Common Sea Fan, *Gorgonia ventalina* (Table 10). The deep water Sea Fan, *Iciligorgia schrammi* was common at the shelf-edge, particularly at the edge of rock walls and crevices.

Table 10. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon, June 2007.

Depth: 20 m	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	3.13	3.58	2.90	3.20	2.97	**3.16**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	6.32	9.43	10.39	7.35	6.55	**8.01**
Total Abiotic	6.32	9.43	10.39	7.35	6.55	**8.01**
Benthic Algae						
Turf-mixed assemblage	57.20	48.86	27.75	54.97	39.83	**45.72**
Fleshy	8.61	12.68	23.02	14.10	19.72	**15.63**
Total Benthic Algae	65.8	61.5	50.8	69.1	59.6	**61.3**
Cyanobacteria	9.22		2.71	2.81	5.08	**3.96**
Sponges	8.91	3.83	8.76	4.25	6.32	**6.41**
Encrusting Gorgonian	0.64		0.55			**0.24**
Live Stony Corals						
Montastrea annularis	1.72	4.79	17.60	3.94	10.63	**7.74**
Meandrina meandrites	0.97	2.06	3.26	4.25	1.85	**2.48**
Colpophyllia natans		3.98	3.41		1.63	**1.80**
Montastrea cavernosa	2.28	3.10	1.75	1.17	0.65	**1.79**
Diploria strigosa	1.37	2.06			2.62	**1.21**
Agaricia agaricites	1.83	1.84	0.33	1.36		**1.07**
Porites astreoides		1.55		1.59	1.54	**0.94**
Siderastrea radians		4.13				**0.83**
Madracis decactis	0.99	1.25		1.06	0.22	**0.70**
Porites colonensis				3.11		**0.62**
Siderastrea siderea					1.95	**0.39**
Leptoseris cucullata					1.41	**0.28**
Dichocoenia stokesii			0.55			**0.11**
Stephanocoenia michelini		0.42				**0.08**
Total Stony Corals	9.16	25.18	26.90	16.48	22.50	**20.04**
Gorgonians (# col.)						
Plexaura flexuosa	2.00	4.00	5.00	8.00	2.00	**4.20**
Pseudoptergorgia acerosa		2.00	4.00	3.00	3.00	**2.40**
Pseudoptergorgia americana	7.00	3.00		2.00		**2.40**
Gorgonia ventalina	1.00	2.00		3.00	2.00	**1.60**
Plexaura kukenthali	4.00					**0.80**
Eunicea turnetorti	1.00			1.00	2.00	**0.80**
Eunicea spp.			1.00	1.00		**0.40**
Pseudoplexuara flagellosa or wargi			2.00			**0.40**
Muriceopsis flavida				1.00		**0.20**
Plexaura homomalla				1.00		**0.20**
Total Gorgonians (# colonies/transect)	15.00	11.00	12.00	20.00	9.00	**13.40**

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

Encrusting and erect sponges, including several large Basket Sponges, *Xestospongia muta* were present in all transects with an average cover of 6.41 %. Reef overhangs averaged 8.01 % and contributed to a topographic rugosity of 3.16 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 with an average of 45.72 % (range : 27.75 – 57.20 %). 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 15.63 % 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 61.30 %. Reddish, slimy mats of benthic cyanobacteria were observed over the reef, mostly covering unconsolidated sediments. The mean cover by cyanobacteria was 3.96 %.

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 annual monitoring surveys up to present (2007). Mean live coral cover declined by 13.4 %, from 23.15 % in 2004 to 20.04 in 2007, but differences are not statistically significant (ANOVA, $p = 0.896$). A very mild, yet consistent trend of declining mean coral cover between monitoring surveys is suggested by the data. But 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. The mild reduction of live coral cover between the baseline and the present survey is not associated with any particularly dominant species, but rather distributed between several species of the main coral assemblage, including *Montastrea annularis, M. cavernosa, Porites astreoides and Diploria strigosa*. Nevertheless, differences of substrate cover for all of these species are very small, within sampling variability error and statistically insignificant (ANOVA; $p > 0.05$).

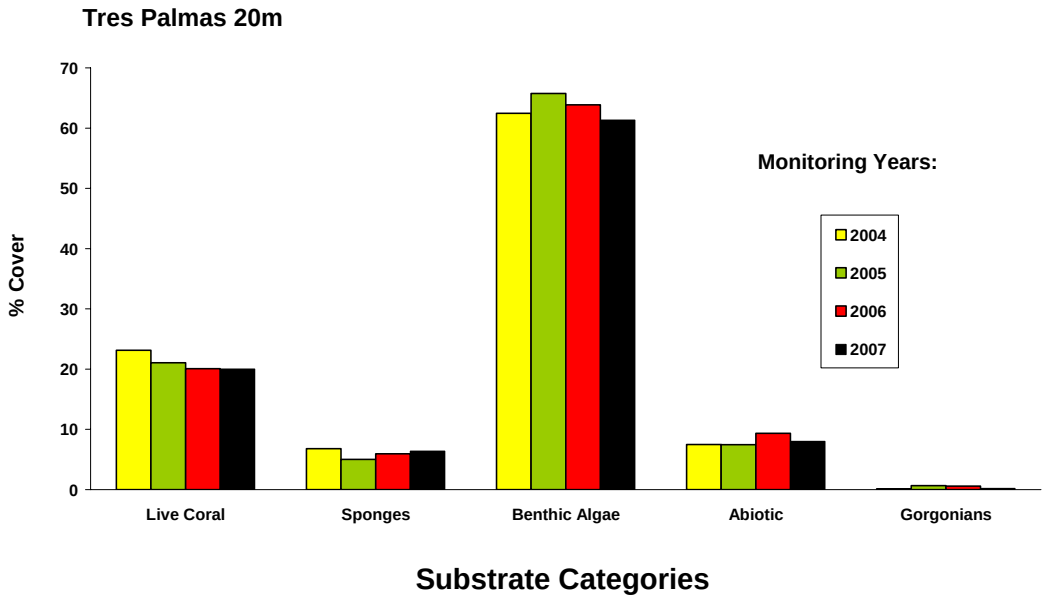


Figure 10. Monitoring trends (2004 – 2007) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef – 20 m.

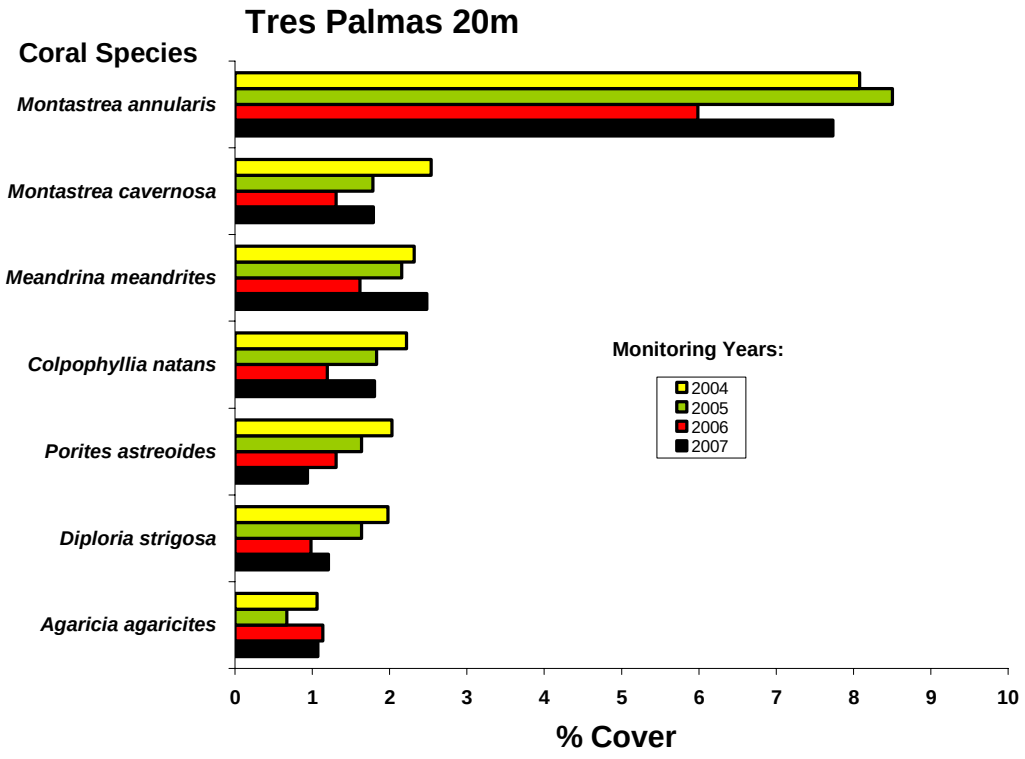


Figure 11. Monitoring trends (2004 – 2007) of mean substrate cover by dominant stony coral species at Tres Palmas Reef – 20 m.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 83 fish species have been identified during the four surveys (2004-07) from the shelf-edge reef off Tres Palmas (Appendix 1). Table 11 lists the 46 fish species observed within belt-transects during the most recent 2007 survey in decreasing order of abundance. Mean abundance within belt-transects was 189.2 Ind/30 m^2 (range: 140 – 251 Ind/30 m^2). The mean number of species per transect was 24 (range: 18– 28). An assemblage consisting of seven species represented 77.3 % of the total fish individuals within belt-transects (Table 11). The Bicolor Damselfish, Bluehead and Yellowhead Wrasse, Peppermint and Sharknose Goby, Blue Chromis, Beau Gregory and Bucktooth Parrotfish were present in all five transects surveyed. A total of 11 species were represented by only one individual amongst the five transects surveyed.

Fish species richness remained constant and mean abundance decreased by 33.8 % compared to the previous 2006 survey (Figure 12). Differences in fish species richness between monitoring surveys were not statistically significant (ANOVA; $p = 0.803$). Conversely, a consistent trend of decline of fish abundance (Figure 12), with statistically significant differences between surveys has been observed (ANOVA, $p = 0.015$). The main species that has contributed to the decline of fish abundance at this reef is the Masked Goby, *Coryphopterus personatus*. This is a small carnivorous fish (< 2.0 cm) that forms swarms of hundreds of individuals below coral ledges and near the sand-coral interface of the spur and groove reef formation. During the 2006 survey, *C. personatus* was the numerically dominant fish species at this reef, averaging 121.8 Ind/30m^2 and representing 42.6 % of the total individuals within transects. In the present 2007 survey, *C. personatus* averaged only 18.4 Ind/30m^2, representing 9.7 % of the total individuals. The temporal abundance dynamics of this species has not been studied. Thus, the factors that influence its abundance fluctuations between annual surveys remain unclear. Given its small size and high density in swarms, this goby may be an important forage (prey) species for the small piscivorous fishes in the reef.

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

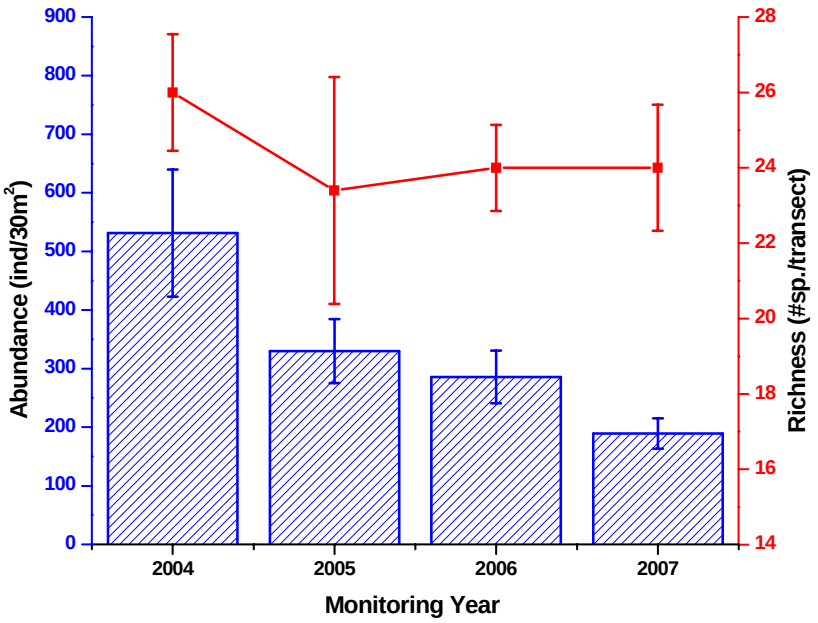


Figure 12. Monitoring trends (2004 – 2007) of fish species richness and abundance at Tres Palmas Shelf Edge Reef, 20 m depth, Rincon.

Mackerel Scad, *Decapterus macarellus* were present in mid-water over the reef. These are zooplanktivores that serve as prey for pelagic predators, such as Cero Mackerels, Blue Runners and Barracudas observed during an ASEC survey in this reef (Table 12). The Blue, Brown and Sunshine Chromis are also important zooplanktivores that were common over coral heads closer to the reef. A large variety of small invertebrate feeders were present, including wrasses, hamlets, gobies, and squirrelfishes, among others. Larger invertebrate and small fish predators included the Schoolmaster and Mahogany snappers, Coney, Graysby and Red Hind groupers, Spanish Hogfish, lizardfishes and grunts. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous assemblage.

The shelf-edge reef is an ideal habitat for adult reef fishes, as evidenced by the presence of adult Lane and Schoolmaster snappers, Red Hinds, Great Barracuda, Cero Mackerels and Blue Runners. The absence of the larger demersal predators appears to be related to the high fishing pressure, since the physical habitat and potential food (fish

Table 11. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef 20m, Rincon. June, 2007

Depth: 20m

		TRANSECTS					
		1	2	3	4	5	
		Ind/30m^2					
SPECIES	**COMMON NAME**						**MEAN**
Stegastes partitus	Bicolor Damselfish	28	16	26	38	37	**29.0**
Thalassoma bifasciatum	Bluehead Wrasse	68	10	13	2	29	**24.4**
Coryphopterus lipernes	Peppermint goby	20	30	35	28	6	**23.8**
Chromis cyanea	Blue Chromis	12	2	12	34	47	**21.4**
Coryphopterus personatus	Masked goby	1	66			25	**18.4**
Clepticus parrae	Creole wrasse			4	17	70	**18.2**
Gramma loretto	Royal gramma	55					**11.0**
Haemulon flavolineatum	French grunt	21		1	1	1	**4.8**
Halichoeres garnoti	Yellow-head Wrasse	12	1	3	3	5	**4.8**
Stegastes leucostictus	Beau Gregory	3	3	5	5	1	**3.4**
Sparisoma radians	Bucktooth Parrotfish	2	3	6	2	1	**2.8**
Chromis multilineata	Brown chromis	1		5		6	**2.4**
Cephalopholis cruentatus	Graysby	3		2	4	1	**2.0**
Gobiosoma evelynae	Sharknose Goby	1	1	5	1	2	**2.0**
Scarus iserti	Stripped parrotfish			3	3	4	**2.0**
Myripristis jacobus	Blackbar soldierfish	1		5	1	1	**1.6**
Bodianus rufus	Spanish Hogfish	3				4	**1.4**
Sparisoma aurofrenatum	Redband Parrotifish		2	2	2	1	**1.4**
Acanthurus chirurgus	Doctorfish	1	1	2	1		**1.0**
Canthigaster rostrata	Caribbean Puffer		1	1	2	1	**1.0**
Chaetodon capistratus	Foureye Butterflyfish		2		2	1	**1.0**
Chromis insulatus	Sunshine chromis	5					**1.0**
Coryphopterus sp.	Goby	1	1	1	1	1	**1.0**
Flammeo marianus	Longspine squirrelfish	1	1	2	1		**1.0**
Mulloides martinicus	Yellowtail goatfish	5					**1.0**
Scarus taeniopterus	Princess parrotfish		4			1	**1.0**
Acanthurus coeruleus	BlueTang	1	1			1	**0.6**
Amblycirrhitus pinos	Redspotted Hawkfish				1	2	**0.6**
Melychthis niger	Black durgon			2		1	**0.6**
Acanthurus bahianus	Ocean Surgeon	2					**0.4**
Anisotremus virginicus	Porkfish	2					**0.4**
Aulostomus maculatus	Trumpetfish			2			**0.4**
Holocentrus rufus	Squirrelfish				2		**0.4**
Hypoplectrus puella	Barred hamlet	1	1				**0.4**
Serranus tigrinus	Harlequin bass				2		**0.4**
Acanthostracion quadricornis	Scrawled cowfish				1		**0.2**
Caranx crysos	Blue runner			1			**0.2**
Chaetodon striatus	Banded butterflyfish					1	**0.2**
Gymnothorax moringa	Spotted moray			1			**0.2**
Haemulon chrysargyreum	Smallmouth grunt	1					**0.2**
Holacanthus tricolor	Rock beauty			1			**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	1					**0.2**
Malacanthus plumieri	Sand tilefish	1					**0.2**

Table 11. Continued							
Microspathodon chrysurus	Yellowtail damselfish	1					**0.2**
Sparisoma viride	Stoplight parrotfish					1	**0.2**
Syngnathus sp.	Pipefish				1		**0.2**
	TOTAL INDIVIDUALS	**254**	**146**	**140**	**155**	**251**	**189.2**
	TOTAL SPECIES	**28**	**18**	**24**	**24**	**26**	**24**

forage) are available. Nevertheless, large snappers and groupers may be using deeper sections of the upper insular slope as residential habitat or refuge, and the shelf-edge reef as foraging ground at night. One giant Hawksbill Turtle (*Eretmochelys imbricata*) was present at the shelf-edge reef during the 2005 monitoring survey. Commercially important species included aquarium trade targets, such as the Fairy Basslet (*Gramma loreto*), Queen and French Angelfishes (*Holacanthus ciliaris, Pomacanthus paru*), Rock Beauty (*Holacanthus tricolor*), Blue Chromis (*Chromis cyanea*) and Swissguard Basslet (*Liopropoma rubre*).

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)	
Chromis cyanea	Blue chromis	33 – (< 2)	25 – (3-4)	12 – (> 4)
Carangoides crysos	Blue Runner	1 – (40)	1 – (50)	
Gramma loreto	Fairy Basslet	4 - (< 3)	23 - (4)	7 - (6)
Holacanthus ciliaris	Queen Angel	1 - (15)	1 - (35)	
Holacanthus tricolor	Rock Beauty	1 - (15)	1 - (20)	1 - (25)
Lutjanus apodus	Schoolmaster	1 - (25)		
Lutjanus synagris	Lane Snapper	12 - (20)	13 - (25)	
Ocyurus chrysurus	Yellowtail Snapper	3 – (25)	1 - (30)	1 - (40)
Opistognathus aurifrons	Yellowhead Jawfish	4 – (4)		
Scomberomorus regalis	Cero Mackerel	1 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (70)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (12)		

Channel Clinging Crabs, *Mithrax spinosissimus*, The Arrow Crab, *Stenorhynchus seticornis,* the Cleaner Shrimp, *Periclimenes pedersoni*, and one juvenile Spiny Lobster, *Panulirus argus* were the motile megabenthic invertebrates observed within belt-transects (Table 13).

Table 13. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Shelf-edge Reef, Rincon, 20 m depth, June, 2007

DATE: June 2007		TRANSECTS					MEAN
Depth: 20 m		1	2	3	4	5	ABUNDANCE (IND/30 m2)
SPECIES	**COMMON NAME**						
Mithrax spinosissimus	Channel Clinging Crab	2				1	0.6
Stenopus hispidus	Banded coral shrimp		1				0.2
Stenorhynchus seticornis	Arrow Crab					4	0.8
Periclimenes pedersoni	Cleaner Shrimp		1	1	5	2	1.6
Panulirus argus	Spiny Lobster				1		0.2
	TOTALS	2	2	1	6	7	3.4

Photo Album 3 (Rincon 20m)

Shelf edge Reef











B. Puerto Canoas /Puerto Botes Reef - Isla Desecheo

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

1. 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* complex). There are colonies that rise from the bottom at least four meters and extend horizontally more than 5 meters, in some instances merging with other large colonies to form continuous laminar coral formations that are unique in Puerto Rico. Towards the northern end, the shelf-edge reef platform leads to an almost vertical wall with sparse coral growth down to a depth of 40 m. At the southern end, the reef platform ends in an extensive sand deposit that slopes down gently to a depth of about 70 m. Our survey was performed right at the end of the reef on the southern section. Transects were installed at a depth of 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.

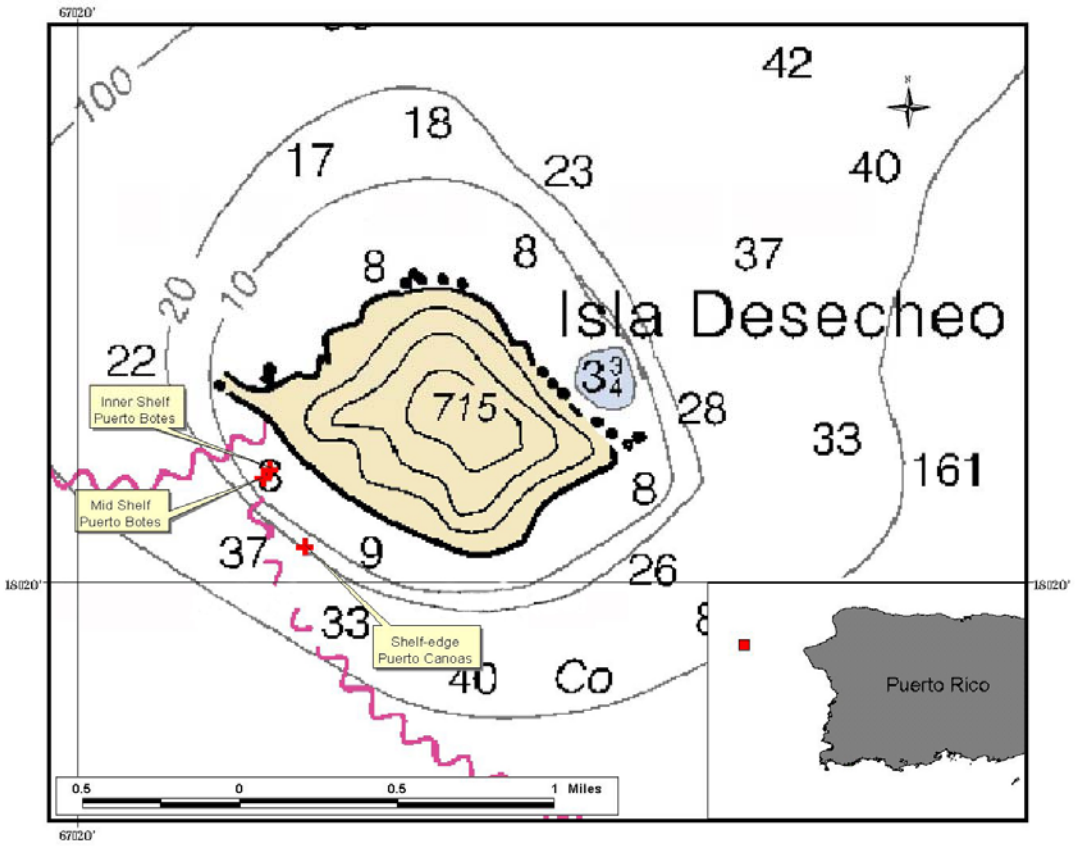


Figure 13. Location of coral reef survey stations at Puerto Canoas/Botes, Isla Desecheo.

Stony corals dominated reef substrate cover along surveyed transects with a mean of 29.4% (range: 15.96 – 43.77 %). Boulder Star Coral (*Montastrea annularis* complex), with a mean cover of 15.99 % represented 54.3 % 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 19.43 % and contributed to a mean reef substrate rugosity of 4.23. Encrusting and erect sponges were common, with a mean cover of 6.39 % (range: 0.219 – 12.98 %).

Table 14. Percent substrate cover by sessile-benthic categories at Puerto Botes Reef, Isla Desecheo, June 2007.

Depth: 30 m	TRANSECT					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	4.39	4.13	6.04	3.54	3.03	**4.23**
SUBSTRATE CATEGORY						
Abiotic						
Gaps				0.52		**0.10**
Reef Overhangs	23.89	13.38	26.51	19.42	11.14	**18.87**
Sand-silt					2.30	**0.46**
Total Abiotic	23.89	13.38	26.51	19.94	13.44	**19.43**
Benthic Algae						
Turf-mixed assemblage	16.04	22.01	27.39	26.00	12.75	**20.84**
Fleshy	15.00	22.65	9.48	15	23	**16.88**
Calcareous	0.49					**0.10**
Total Benthic Algae	31.5	44.7	36.9	40.7	35.3	**37.8**
Cyanobacteria	11.53	7.78	7.67	3.77	3.76	**6.90**
Sponges	0.29	7.15	12.98	7.83	3.69	**6.39**
Live Stony Corals						
Montastrea annularis	6.53	14.08	12.91	14.18	32.26	**15.99**
Colpophyllia natans	15.49	3.68		0.73		**3.98**
Agaricia agaricites	4.86	1.27	2.18	5.69	3.99	**3.60**
Porites astreoides	0.97	4.95	0.87	1.85	3.76	**2.48**
Eusmilia fastigiata	3.82	1.70		0.83		**1.27**
Diploria strigosa					3.76	**0.75**
Meandrina meandrites				2.07		**0.41**
Porites porites	0.20			1.56		**0.35**
Madracis decactis	0.88			0.83		**0.34**
Mycetophyllia lamarckiana		1.27				**0.25**
Total Stony Corals	32.75	26.95	15.96	27.74	43.77	**29.43**
Recently dead coral	2.35					**0.47**
Gorgonians (# col.)	0	0	0	0	0	**0**

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

Benthic macroalgae, comprised by an assemblage of turf, fleshy and calcareous types presented a combined substrate cover of 37.80 % 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 6.90 %.

Figure 14 presents the annual variations of mean percent cover by the main sessile-benthic categories from the shelf-edge reef at Puerto Canoas. Differences of mean substrate cover by stony corals, sponges and benthic algae between the 2004 baseline characterization and the 2005 monitoring surveys were all within 1 % and statistically insignificant. 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 between 2005 and 2006 was evidenced from all five transects surveyed. A corresponding increment of substrate cover by benthic algae, sponges and abiotic categories was detected (Figure 14). 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. 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.

Between the 2006 and the present 2007 survey, mean live coral cover declined 21.6%, from 37.5 % to 29.4 %. Multiple mean comparison test rendered that the reduction of live coral between 2006 and 2007 was not statistically significant ($p = 0.165$). Still, live coral cover declined in four out of the five transects surveyed. The decline of live coral measured in 2007 was mostly associated with *Montastrea annularis* (Figure 15), which was the species still showing partially bleached colonies during the 2006 monitoring survey. Thus, this further decline of live coral cover at Puerto Canoas Reef may represent in part, the lingering effects of the late 2005 massive coral bleaching event that caused a severe impact to reef corals of Isla Desecheo. Since 2005, an increasing trend of reef substrate cover by cyanobacteria growing over dead coral and unconsolidated sediments has been observed. Between 2006 and 2007, substrate cover by cyanobacteria increased 62.3 %, from means of 2.5 % (2006) to 6.9% (2007).

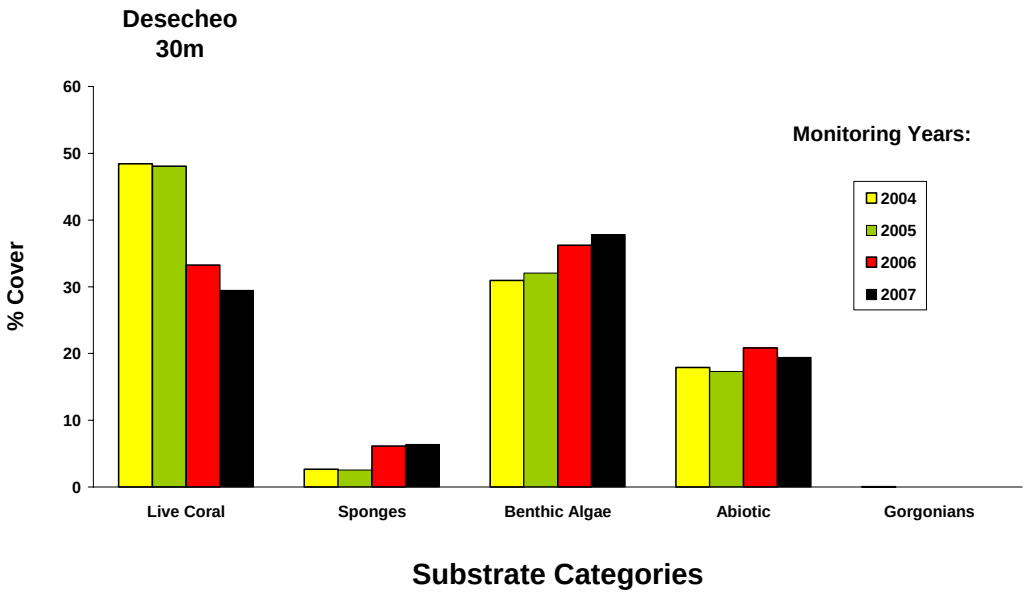


Figure 14. Monitoring trends (2004 – 07) of substrate cover by sessile-benthic categories at Puerto Canoas Reef – 30 m.

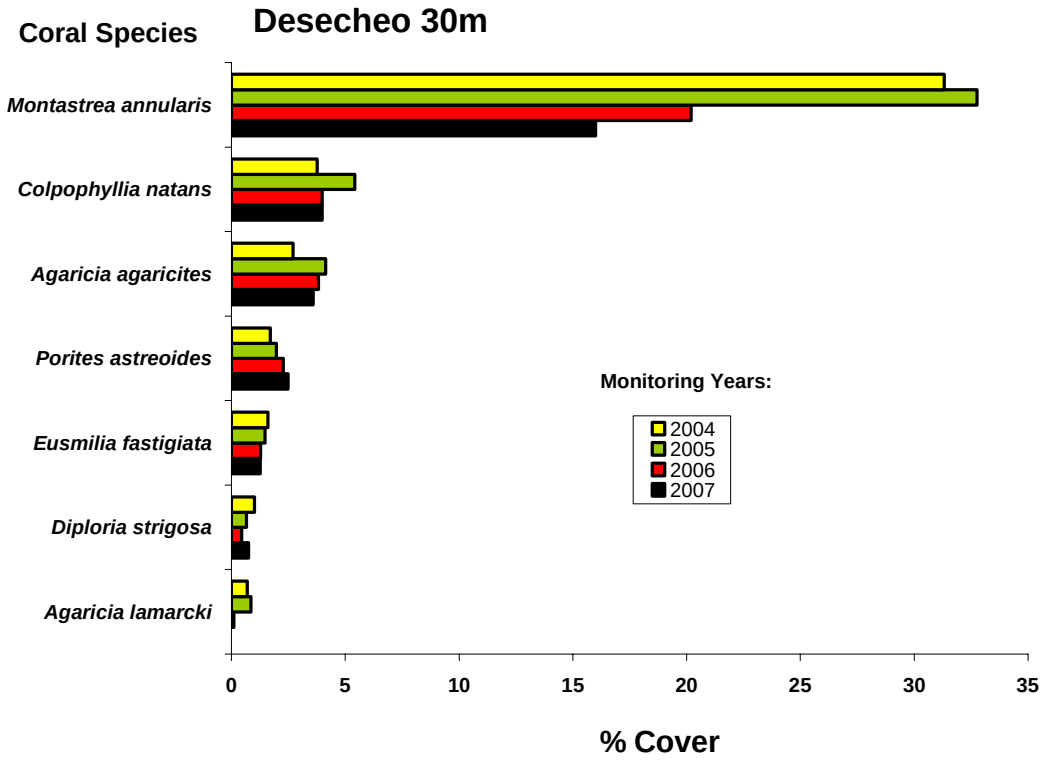


Figure 15. Monitoring trends (2004-07) of mean substrate cover by dominant stony coral species at Puerto Canoas Reef – 30 m.

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 95 fish species have been identified during the four surveys (2004-07) from the shelf-edge reef off Puerto Canoas, Isla Desecheo (Appendix 1). Mean abundance of fishes within belt-transects during June, 2007 was 435.8 Ind/30 m^2 (range: 271 – 596 Ind/30 m^2). The mean number of species per transect was 29.5 (range: 27 – 33) (Table 15). An assemblage of seven species, including the Fairy Basslet, Masked and Peppermint Gobies, Creole Wrasse, Blue and Brown Chromis, and Yellowhead Wrasse represented 72.9 % of the total fish abundance within belt-transects. The Fairy Basslet, *Gramma loreto* was the numerically dominant species with a mean abundance of 107.0 Ind/30 m^2 (range: 62 – 170 Ind/30 m^2), representing 24.6 % of the total (Table 15). A total of 13 species were present within all six belt-transects surveyed.

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.

Variations of fish abundance and species richness between monitoring surveys were not statistically significant (ANOVA; richness $p = 0.136$; abundance $p = 0.673$). Mean fish abundance increased by 7.3 % and species richness declined by 4.0 % during 2007, as compared to the 2006 survey,. The overall increment of fish abundance within belt-transects during 2007 was strongly influenced by a 71.5% abundance increment of Fairy Basslets (from 30.5 to 107.0 Ind/30 m^2). Such increment was associated with a strong recruitment pulse in which post-settlement juveniles (< 1.0 cm TL) represented 45.3 % of the total individuals within belt-transects. During this 2007 monitoring survey, a 66.1 % decline of abundance by Masked Gobies was also registered.

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

Table 15. Taxonomic composition and abundance of fishes within belt-transects at Puerto Canoas Reef 30 m, Isla Desecheo. June, 2007

Depth: 30m		TRANSECTS 1	2	3	4	5	6	
SPECIES	**COMMON NAME**							**MEAN**
Gramma loreto	Fairy Basslet	62	135	170	84	95	96	**107.0**
Clepticus parrae	Creole Wrasse	32	61	111	75	1		**46.7**
Chromis cyanea	Blue Chromis	14	50	33	18	34	116	**44.2**
Coryphopterus personatus	Masked Goby	24	40	29	16	96	60	**44.2**
Chromis multilineata	Brown Chromis	18		135	65	26		**40.7**
Coryphopterus lipernes	Peppermint Goby	25	31	27	15	26	18	**23.7**
Halichoeres garnoti	Yellow-head Wrasse	13	9	15	7	11	12	**11.2**
Stegastes partitus	Bicolor Damselfish	5	6	12	11	14	10	**9.7**
Thalassoma bifasciatum	Bluehead Wrasse	14	6	12	6	2	3	**7.2**
Gobiosoma evelynae	Sharknose Goby	5	6	14	5	5	3	**6.3**
Sparisoma radians	Bucktooth Parrotfish	5	1	5	5	1	4	**3.5**
Bodianus rufus	Spanish Hogfish	10	3		3	2	1	**3.2**
Scarus taeniopterus	Princess Parrotfish	6	4	4		2		**2.7**
Kyphosus sectatrix	Bermuda Chub	8	3	1	3			**2.5**
Cephalopholis cruentatus	Graysby	2	3	4	1	3	1	**2.3**
Halichoeres maculipinna	Clown Wrasse	2	1	2	4	2	1	**2.0**
Canthigaster rostrata	Caribbean Puffer	2		1	3	1	3	**1.7**
Chaetodon capistratus	Foureye Butterflyfish	2		2	2	2	2	**1.7**
Stegastes planifrons	Yellow-eye Damselfish	2	3			5		**1.7**
Decapterus macarellus	Mackerel Scad						8	**1.3**
Mulloides martinicus	Yellowtail Goatfish	3	2				3	**1.3**
Paranthias furcifer	Creole Fish	1	2	3	1	1		**1.3**
Lutjanus apodus	Schoolmaster	1	1	1		2	2	**1.2**
Acanthurus coeruleus	BlueTang	1	1	1	1	1	1	**1.0**
Coryphopterus glaucofraenum	Bridled Goby	1	1	1	1	1	1	**1.0**
Sparisoma viride	Stoplight Parrotfish	3		1	2			**1.0**
Amblycirrhitus pinos	Redspotted Hawkfish		2	1	1		1	**0.8**
Sparisoma aurofrenatum	Redband Parrotfish	2		1	1		1	**0.8**
Cephalopholis fulva	Coney	1					3	**0.7**
Liopropoma rubre	Swissguard Basslet	1			1	1	1	**0.7**
Caranx latus	Horse-eye Trevally			3				**0.5**
Caranx lugubris	Black Jack		1	2				**0.5**
Chaetodon aculeatus	Longsnout Butterflyfish			1		1	1	**0.5**
Lactophrys triqueter	Smooth Trunkfish	1				1	1	**0.5**
Melichthys niger	Black Durgon		1	1	1			**0.5**
Scarus iserti	Stripped Parrotfish	2					1	**0.5**
Carangoides crysos	Blue Runner		1	1				**0.3**
Chromis insolata	Sunshine chromis						2	**0.3**
Flammeo marianus	Longspine Squirrelfish		1	1				**0.3**
Holocentrus rufus	Squirrelfish					1	1	**0.3**
Microspathodon chrysurus	Yellowtail Damselfish				2			**0.3**
Myripristis jacobus	Blackbar Soldierfish	1		1				**0.3**
Synodus intermedius	Sand Diver		1				1	**0.3**

Table 15. Continued								
Acanthostracion quadricornis	Honeycomb Trunkfish	1						**0.2**
Acanthurus chirurgus	Doctorfish		1					**0.2**
Holacanthus ciliaris	Queen Angelfish					1		**0.2**
Holacanthus tricolor	Rock Beauty						1	**0.2**
Sparisoma chrysopterum	Redtail Parrotfish					1		**0.2**
Scarus vetula	Queen Parrotfish				1			**0.2**
Scomberomorus regalis	Cero Mackerel	1						**0.2**
	TOTAL INDIVIDUALS	271	377	596	596	339	359	**435.8**
	TOTAL SPECIES	33	28	31	27	28	30	**29.5**

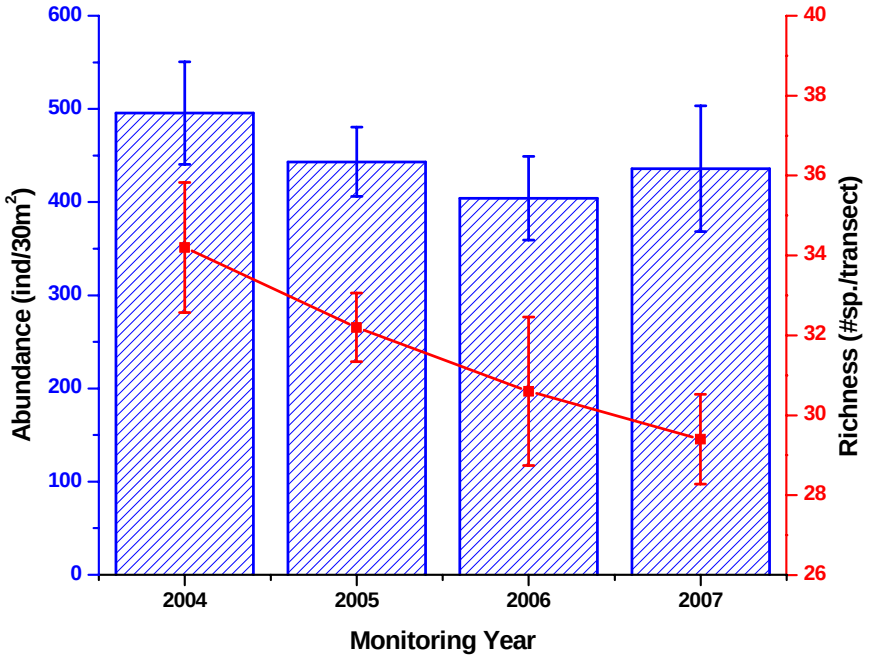


Figure 16. Monitoring trends (2004 – 2007) of fish species richness and abundance at Shelf-edge Reef Puerto Canoas, 30 m depth, Isla Desecheo.

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, 2007

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

SPECIES	**COMMON NAME**		# - (cm)	
Carangoides crysos	Blue Runner	4 – (30)	2 - (40)	2 - (50)
Alectis ciliaris	African Pompano	3 - (45)		
Caranx hippos	Horse-eye Jack	4 – (30)	6 - (40)	
Caranx lugubris	Black Jack	1 - (50)	1 - (70)	
Dasyatis americana	Southern Stingray	1 - (120)		
Epinephelus guttatus	Red Hind	3 - (30)		
Epinephelus striatus	Nassau Grouper	1 - (50)	1 - (60)	1 - (70)
Gramma loreto	Fairy Basslet	291 - (<1)	234 - (2-4)	117 -(>4)
Holacanthus ciliaris	Queen Angel	3 - (45)		
Holacanthus tricolor	Rock Beauty	2 - (20)	2 - (25)	1 - (15)
Lactophrys trigonus	Buffalo Trunkfish	1 - (35)		
Lutjanus apodus	Schoolmaster	16 - (30)	15 - (40)	3 - (50)
Lutjanus cyanopterus	Cubera Snapper	1 - (60)		
Lutjanus jocu	Dog Snapper	1 - (40)		
Lutjanus mahogany	Mahogany Snapper	2 - (25)	1 - (30)	
Mycteroperca venenosa	Yellowfin Grouper	1 - (45)		
Ocyurus chrysurus	Yellowtail Snapper	1 - (35)		
Scomberomorus regalis	Cero Mackerel	2 - (60)		
Sphyraena barracuda	Great Barracuda	1 - (45)	1 - (75)	
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (15)		
Strombus gigas	Queen Conch	2 - (25)		
Mithrax spinosissimus	Channel Clinging Crab	1 – (15)		
Sea Turtles				
Eretmochelys imbricata	Hawksbill Turtle	2 – (70)		

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 perezi*) 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 Banded Coral Shrimp, *Stenopus hispidus* were the motile megabenthic invertebrates observed within belt-transects (Table 17). One Spiny Lobster, *Panulirus argus,* the Clinging Crab, *Mithrax spinosissimus*, the cleaner shrimp, *Periclimenes pedersoni* and the Queen Conch (*Strombus gigas*) were observed outside transects during the ASEC survey.

Table 17. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Puerto Canoas Shelf-edge Reef, Isla Desecheo 30m, June 2007

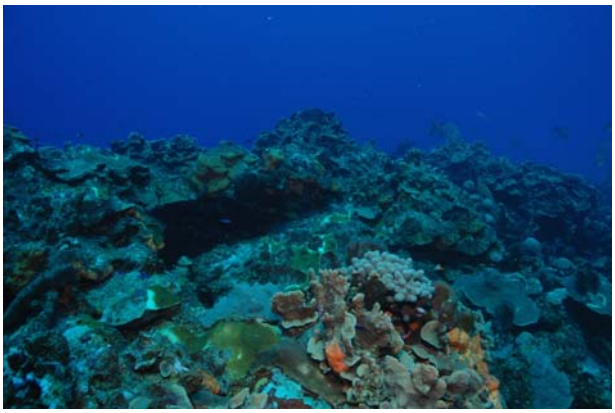
DATE: June 2007 Depth: 25 – 30 m		TRANSECTS					**MEAN ABUNDANCE (IND/30 m2)**
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						
Stenorhynchus seticornis	Arrow crab	1					**0.2**
Stenopus hispidus	Banded Coral Shrimp	1	1			1	**0.4**
	TOTALS	**2**	**1**	**0**	**0**	**1**	**0.6**

Photo Album 4 (Desecheo 30m)

Shelf Edge Reef



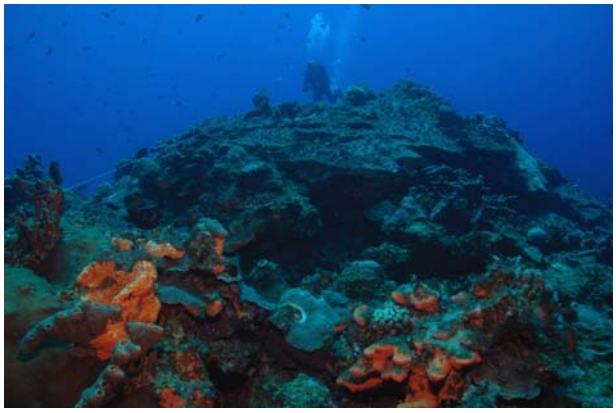


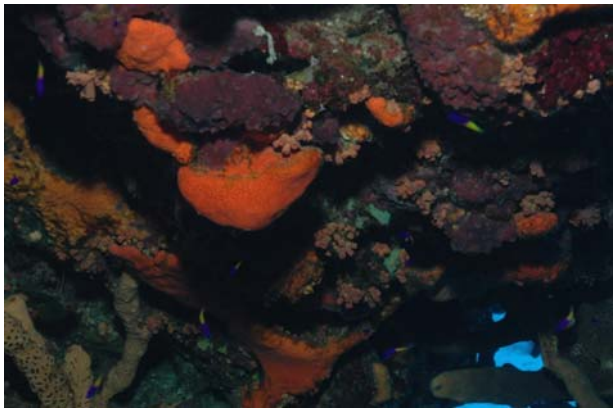












2.0 Mid-shelf Patch Reef - Puerto Botes

2.1 Sessile-benthic Reef Community

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

A total of 25 stony corals, including 12 intersected by line transects were identified during this survey. Finger Coral, *Porites porites* was the species of highest mean percent substrate cover with a mean of 5.50 % (range: 0 – 27.49). It was present as a large single colony in only one of the five transects surveyed. 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 72.9 % of the total cover by live corals at Puerto Botes (Table 18). Recently dead corals were observed in all transets with a mean cover of 24.35 % (range: 4.98 – 36.36 %). This mortality resulted after the massive coral bleaching event in October 2005.

Reef overhangs, largely associated with skeletal buildups of *M. annularis* averaged 10.31% of the reef substrate cover and contributed substantially to the reef rugosity of 3.80 m. Erect and encrusting sponges were present with a mean substrate cover of 2.85 %. Reef hard-ground substrates not colonized by stony corals or sponges were mostly overgrown by a dense algal turf (mean cover: 54.43 %), comprised of a mixed assemblage of filamentous red and brown algae. Fleshy brown (*Lobophora sp., Dictyota sp., Padina sp*.) and calcareous macroalgae contributed an additional 11.74 % to the total benthic algal cover at Puerto Botes (Table 18).

Table 18. Percent substrate cover by sessile-benthic categories at Puerto Botes Reef, Isla Desecheo, June 2007.

Depth: 20 m	TRANSECT					
	1	2	3	4	5	**MEAN**
Rugosity (m)	4.32	3.34	4.44	2.45	4.45	**3.80**
SUBSTRATE CATEGORY						
Abiotic						
Gaps		2.11				**0.42**
Reef Overhangs	8.66	6.53	12.81	9.64	13.92	**10.31**
Sand-silt				5.62		**1.12**
Total Abiotic	8.66	8.64	12.81	15.26	13.92	**11.85**
Benthic Algae						
Turf-mixed assemblage	71.79	56.19	60.73	25.70	57.76	**54.43**
Fleshy	8.00	15.53	13.00	13.90	8.00	**11.58**
Calcareous				0.79		**0.16**
Total Benthic Algae	79.79	71.72	73.73	40.39	65.76	**66.17**
Cyanobacteria	0.30			1.02	2.22	**0.71**
Sponges	1.75	3.45	1.39	4.98	2.70	**2.85**
Live Stony Corals						
Porites porites				27.49		**5.50**
Montastrea annularis	6.98	5.48	4.22	2.01	1.94	**4.13**
Agaricia agaricites	0.69	1.06	1.39	1.36	6.65	**2.23**
Montastrea cavernosa	0.39		2.24		5.19	**1.56**
Colpophyllia natans		4.73		2.60		**1.47**
Porites astreoides	0.89	4.35	0.78	1.13		**1.43**
Diploria labyrinthiformis				3.4		**0.68**
Meandrina meandrites		0.53	2.70			**0.65**
Eusmilia fastigiata	0.59				0.49	**0.22**
Millepora alcicornis			0.59	0.34		**0.19**
Mycetophyllia lamarckiana					0.78	**0.16**
Porites divaricata					0.78	**0.16**
Madracis decactis			0.29			**0.06**
Total Stony Corals	9.54	16.15	12.21	38.33	15.83	**18.41**
Recently dead coral	27.86	27.91	24.65	4.98	36.36	**24.35**
Gorgonians (# col.)						
Eunicea succinea					1.00	**0.20**
Total Gorgonians (# colonies/transect)	0.00	0.00	0.00	0.00	1.00	**0.20**

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, Stylaster roseus*

From the initial baseline characterization of 2000 until the 2005 survey, stony corals represented the most prominent sessile-benthic component of the mid-shelf reef at Puerto Botes with a mean reef substrate cover that fluctuated slightly between 47.2 % and 48.01 %. Differences of live coral cover were minimal and statistically insignificant until the 2006 monitoring survey when live coral cover declined sharply to a mean of 22.35 %, a loss of 53.4% from the mean live coral cover in 2005. During the present 2007 monitoring survey, live coral cover declined furthermore to a historical minimum of 18.41 %. Differences between the 2006 and 2007 percent cover by live corals and previous surveys, including the initial baseline survey were statistically significant (ANOVA; $p < 0.0001$). A corresponding increment of substrate cover by benthic algae, sponges and abiotic categories has been observed (Figure 17).

The sharp downfall of live coral at Puerto Botes Reef was triggered by the massive coral bleaching event reported for Puerto Rico and the USVI that started during late September through October 2005 (J. Miller, personal communication) and lingering effects that have carried further coral mortality up to the present 2007 monitoring survey. The bleaching event affected several coral species in variable magnitude, but was mostly detrimental to the dominant species in terms of substrate cover, the Boulder Star Coral, *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. An additional 12 % decline of reef substrate cover by *M. annularis* (complex) was measured during the 2007 survey, from 4.70 % (in 2006) to 4.13 % (in 2007) (Figure 18). 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 the 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 until present. 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.

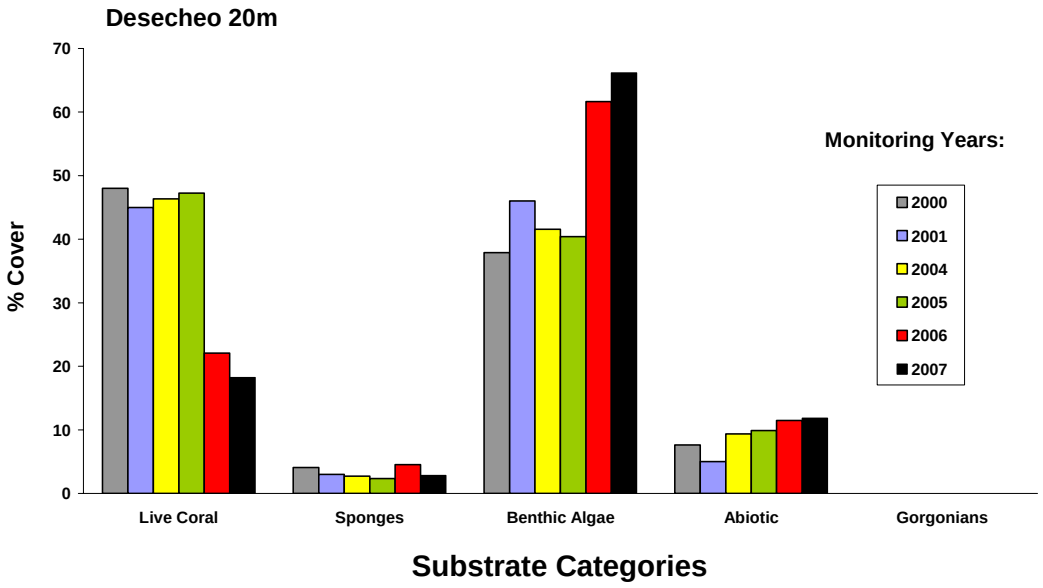


Figure 17. Monitoring trends (2000 – 07) of mean substrate cover by sessile-benthic categories at Puerto Botes Reef – 20 m.

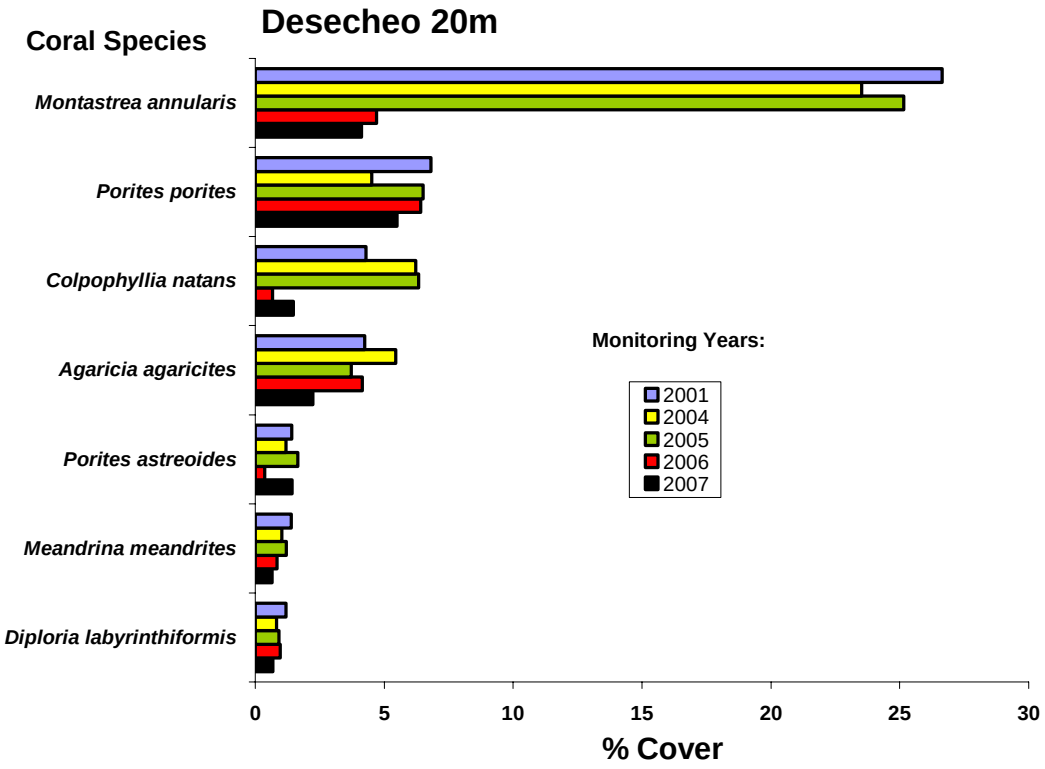


Figure 18. Monitoring trends (2000 – 07) of mean substrate cover by dominant stony coral species at Puerto Botes Reef – 20 m.

Benthic algae, seemingly the fastest growing component of the sessile-benthos at Puerto Botes Reef increased its substrate cover by 34.6 % between the 2005 and the 2006 monitoring surveys (Figure 17), colonizing recently dead coral sections. An additional increment in cover by benthic algae (ca. 7.6 %) was measured during the 2007 survey, proportional to the observed decline of live coral cover for this period. From the benthic algal assemblage, the fleshy brown macroalgae showed the highest increment between the 2005 and 2006 surveys, from 3.6 % in 2005 to 15.0 % in 2006, but declined again during 2007 to 11.58 %, yielding to an increment of cover by the more resilient turf algae. An increasing trend of reef substrate cover by abiotic categories has also been noted.

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 80 fish species were identified within belt-transects from the mid-shelf patch reefs off Puerto Botes, Isla Desecheo during June, 2007 (Table 19). During the six surveys, a total of 70 fishes have been reported from this reef (Appendix 1). Mean abundance of fishes within belt-transects was 197.4 Ind/30 m^2 (range: 159 - 238 Ind/30 m^2). The mean number of species per transect was 26.2 (range: 23 - 29). The Blue Chromis (*Chromis cyanea*) and the Bicolor Damselfish (*Stegastes partitus*) were the numerically dominant species within belt-transects during the 2007 survey with mean abundances of 43.8 and 35.4 Ind/30 m^2, respectively. The combined abundance of seven species, including the Blue and Brown Chromis, Bluehead, Yellowhead and Creole Wrasses, Sharknose Goby and Bicolor Damselfish represented 75.0 % of the total fish abundance within belt-transects. A total of nine species were present in all five transects and other eight 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 19. 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 m^2 and 248.6 Ind/30 m^2 during the six year monitoring period at this reef. Differences of species richness and abundance between surveys were not statistically significant (ANOVA; $p > 0.05$) (see Appendix 2-3).

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.

The cleaner shrimps, Periclimenes pedersoni and Stenopus hispidus were the only motile megabenthic invertebrates within belt-transects (Table 21). Spiny and Spotted Spiny Lobsters (*Panulirus argus, P. guttatus*), Sponge Brittle Stars (*Ophiothrix suensoni*), Arrow Crabs (*Stenorhynchus seticornis*) and Long-Spined Urchin (*Diadema antillarum*) were observed outside transects.

Table 19. Taxonomic composition and abundance of fishes within belt-transects at Puerto Botes Reef 20 m, Isla Desecheo. June, 2007

Depth: 20m		TRANSECTS (Ind/30m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Chromis cyanea	Blue Chromis	25	19	17	124	34	**43.8**
Stegastes partitus	Bicolor Damselfish	37	43	27	19	51	**35.4**
Thalassoma bifasciatum	Bluehead Wrasse	20	35	12	18	29	**22.8**
Halichoeres garnoti	Yellow-head Wrasse	10	20	24	20	14	**17.6**
Clepticus parrae	Creole Wrasse	27		11	20	26	**16.8**
Chromis multilineata	Brown Chromis	6	22	18		12	**11.6**
Gobiosoma evelynae	Sharknose Goby	4	8	6	6	22	**9.2**
Gramma loreto	Fairy Basslet		15	4	2	16	**7.4**
Coryphopterus lipernes	Peppermint Goby	2	3	4	3	3	**3.0**
Sparisoma radians	Bucktooth Parrotfish	3	3	5	3		**2.8**
Cephalopholis cruentatus	Graysby	2	4	3	3	1	**2.6**
Halichoeres maculipinna	Clown Wrasse	5	2	3			**2.0**
Amblycirrhitus pinos	Redspotted Hawkfish	1	2	1	3	2	**1.8**
Cephalopholis fulva	Coney	1	3	2	1		**1.4**
Acanthurus coeruleus	BlueTang	1	1	2		2	**1.2**
Sparisoma aurofrenatum	Redband Parrotfish	2	1		2	1	**1.2**
Sparisoma viride	Stoplight Parrotfish	2		1		3	**1.2**
Chaetodon capistratus	Foureye Butterflyfish	1	2	2			**1.0**
Coryphopterus glaucofraenum	Bridled Goby	1	1	1	1	1	**1.0**
Flammeo marianus	Longspine Squirrelfish		1	2		2	**1.0**
Melichthys niger	Black Durgon	2	1		2		**1.0**
Microspathodon chrysurus	Yellowtail Damselfish	1		1	1	2	**1.0**
Myripristis jacobus	Blackbar Soldierfish		3	2			**1.0**
Haemulon flavolineatum	French Grunt		1	2	1		**0.8**
Holocentrus rufus	Squirrelfish		2		1	1	**0.8**
Mulloides martinicus	Yellowtail Goatfish			4			**0.8**
Scarus iserti	Stripped Parrotfish			2	2		**0.8**
Bodianus rufus	Spanish Hogfish		2	1			**0.6**
Canthigaster rostrata	Caribbean Puffer				2	1	**0.6**
Holacanthus tricolor	Rock Beauty	1			2		**0.6**
Lactophrys triqueter	Smooth Trunkfish	1	1			1	**0.6**
Lutjanus apodus	Schoolmaster Snapper		1	1		1	**0.6**
Acanthurus chirurgus	Doctorfish	1		1			**0.4**
Kyphosus bermudensis	Sea Chub			1		1	**0.4**
Scarus vetula	Queen Parrotfish					2	**0.4**
Acanthostracion quadricornis	Scrawled Cowfish				1		**0.2**
Abudefduf sexatilis	Sargent Major		1				**0.2**
Balistes vetula	Queen Triggerfish	1					**0.2**
Coryphopterus sp.	Goby	1					**0.2**
Holocentrus coruscus	Reef Squirrelfish		1				**0.2**
Liopropoma rubre	Swissguard Basslet	1					**0.2**
Ocyurus chrysurus	Yellowtail Snapper					1	**0.2**
Scarus taeniopterus	Princess Parrotfish				1		**0.2**

Table 19. Continued							
Sparisoma chrysargyreum	Redtail Parrotfish			1			**0.2**
Synodus intermedius	Sand Diver		1				**0.2**
Xanthichthys ringens	Sargassum Triggerfish		1				**0.2**
							0.0
	TOTAL INDIVIDUALS	159	200	161	238	229	**197.4**
	TOTAL SPECIES	26	29	29	23	24	**26.2**

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, June, 2007

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

SPECIES	**COMMON NAME**	# - (cm)			
Carangoides crysos	Blue Runner	1 – (30)			
Caranx lugubris	Black Jack	1 - (50)			
Epinephelus guttatus	Red Hind	1 – (30)			
Gramma loreto	Fairy Basslet	12 - (1-3)	15 - (4-6)	10 -(7-9)	
Holacanthus ciliaris	Queen Angel	1 - (35)			
Holacanthus tricolor	Rock Beauty	2 - (15)	1- (25)		
Lutjanus apodus	Schoolmaster	6– (20)	7- (25)	10- (30)	3– (40)
Lutjanus mahogany	Mahogany Snapper	1- (20)	2 - (30)		
Ocyurus chrysurus	Yellowtail Snapper	1– (40)	2 - (45)		
Scomberomorus regalis	Cero Mackerel	1 - (50)			
Sphyraena barracuda	Great Barracuda	1 - (80)			
Invertebrates					
Panulirus guttatus	Spotted Spiny Lobster	1 - (10)			
Panulirus argus	Spiny Lobster	1 - (20)			

Table 21. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Puerto Botes Mid-shelf Reef. Isla Desecheo 20m, June 2007

		TRANSECTS					
Depth: 20 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Periclimenes pedersoni	Cleaner Shrimp	1					**0.2**
Stenopus hispidus	Banded coral shrimp	1					**0.2**
	TOTALS	**2**	**0**	**0**	**0**	**0**	**0.4**

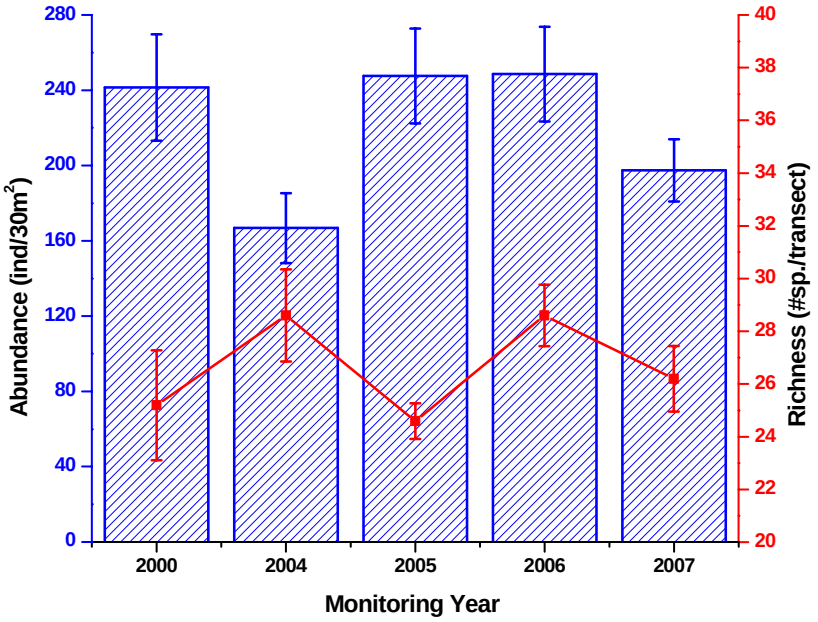
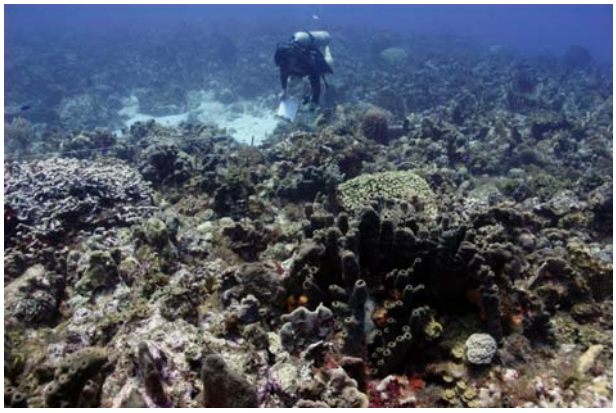
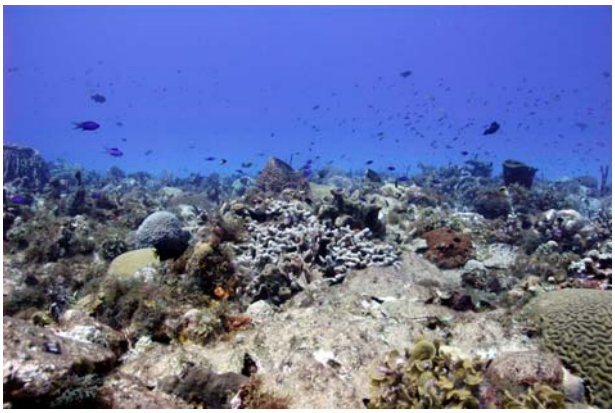


Figure 19. Monitoring trends (2000 – 2007) of fish species richness and abundance at Mid Shelf Reef Puerto Botes, 20 m depth, Isla Desecheo.

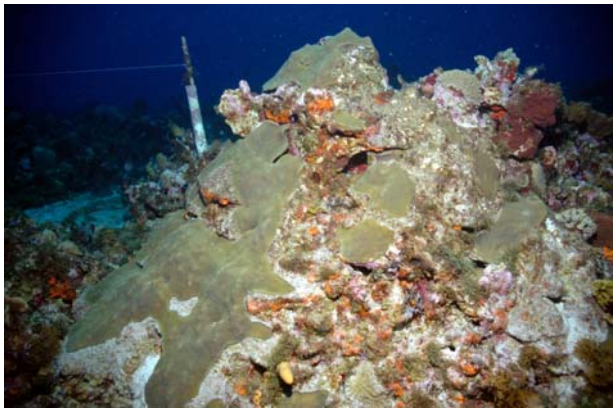
Photo Album 5 (Desecheo 20m)

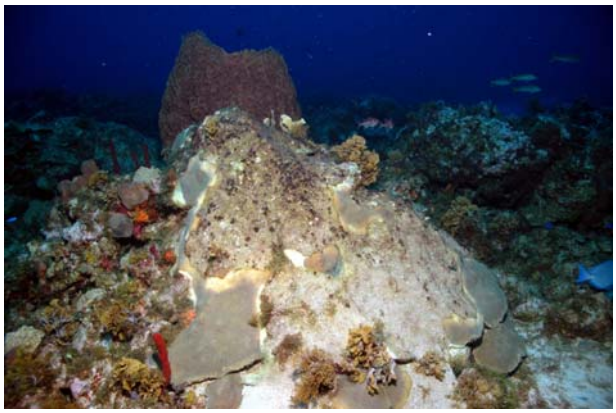
Mid Shelf Reef









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 11 intersected by line transects were identified during this 2007 monitoring survey at Puerto Botes Inner Reef. Stony corals presented a mean substrate cover of 8.06 % (range: 5.35 – 14.40 %) (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 6.64 %, representative of 82.4 % 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: 2.0 colonies /transect). Reef overhangs, largely associated with growth of *M. annularis* presented a mean substrate cover of 8.62 % and contributed substantially to the reef rugosity of 3.04 m. Total abiotic cover also included sections of sand and averaged 13.32 %. Sponges were present at all transects with a mean substrate cover of 5.68 % (Table 22).

Benthic algae, comprised of a mixed assemblage of fleshy (brown and red), calcareous and turf algae represented the main sessile-benthic reef component in terms of substrate cover with a combined mean of 71.7 % (Table 22). Fleshy brown (*Lobophora sp., Dictyota sp*., *Padina sp*.) and turf algae, a mixed assemblage of red and short filamentous brown algae 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 substrate cover by sessile-benthic categories at Puerto Botes Reef 15m, Isla Desecheo, June 2007.

Depth: 15 m	TRANSECT					
	1	2	3	4	5	**MEAN**
Rugosity (m)	3.14	3.68	3.03	2.52	2.82	**3.04**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	12.02	8.56	9.07	7.74	5.69	**8.62**
Sand-silt	8.06	6.07	1.61	6.78	0.99	**4.70**
Total Abiotic	20.08	14.63	10.68	14.52	6.68	**13.32**
Benthic Algae						
Turf-mixed assemblage	43.28	46.14	57.26	36.55	58.58	**48.36**
Fleshy	23.35	28.15	21.52	31.44	11.54	**23.20**
Calcareous		0.41		0.45		**0.17**
Total Benthic Algae	66.6	74.7	78.8	68.4	70.1	**71.7**
Cyanobacteria	0.75	1.24	1.73	1.68	0.66	**1.21**
Sponges	4.18	2.85	3.46	9.82	8.11	**5.68**
Live Stony Corals						
Montastrea annularis	0.99	1.46	1.08		6.47	**2.00**
Porites astreoides	2.36	3.51	1.15	1.22	1.40	**1.93**
Montastrea cavernosa	2.05		2.69	1.91	2.89	**1.91**
Agaricia agaricites				0.79	3.20	**0.80**
Siderastrea radians		1.68	0.43			**0.42**
Siderastrea siderea	1.61					**0.32**
Eusmilia fastigiata				1.22		**0.24**
Diploria strigosa	0.96					**0.19**
Meandrina meandrites					0.44	**0.09**
Diploria labyrinthiformis	0.43					**0.09**
Madracis decactis				0.34		**0.07**
Total Live Stony Corals	8.40	6.65	5.35	5.48	14.40	**8.06**
Recently dead coral	7.53	5.25	14.91		12.17	**7.97**
Gorgonians (# col.)						
Pseudoptergorgia spp.	10.00					**2.00**
Total Gorgonians (# colonies/transect)	10.00	0.00	0.00	0.00	0.00	**2.00**

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

Figure 20 presents the variations of mean percent cover by the main sessile-benthic categories from the inner shelf reef off Puerto Botes surveyed during the period between 2004 -07. Mean reef substrate cover by stony corals, sponges and benthic algae remained virtually stable between the 2004 baseline and the 2005 monitoring survey. Differences during 2005 were all within 1% of baseline and statistically insignificant (García-Sais et al., 2005). A reduction 49.4 % of mean live coral cover was measured during the 2006 monitoring event, from 19.49 % in 2005 to 9.86 % in 2006. Corresponding increments of substrate cover by benthic algae and abiotic categories were also measured. An additional decline of 18.3 % mean live coral cover was measured during the present 2007 survey, from 9.85 % in 2006 to 8.06 %. Differences of total live coral cover between surveys were statistically significant (ANOVA; $p = 0.0297$). Multiple mean comparison test validated the measured differences of substrate cover by live corals between the 2004-2005 and the 2006-07 surveys (see Appendix 2). The decline of coral cover during 2007 was observed in four out of the five transects surveyed. Differences of substrate cover by live corals between the 2006 and 2007 surveys were not statistically significant (ANOVA; $p= 0.686$).

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 2.55 % in 2006 (Figure 21). The reduction of percent cover by Boulder Star Coral between the 2005 and the 2006 surveys was statistically significant (ANOVA; $p = 0.027$). An additional decline of 21.5 %, from 2.55 % to 2.00 % was measured in the present 2007 for *M. annularis* (complex).

Before the massive bleaching event of October 2005, Boulder Star Coral used to represent 58.5 % of the total live 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 (1 and 2) 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.

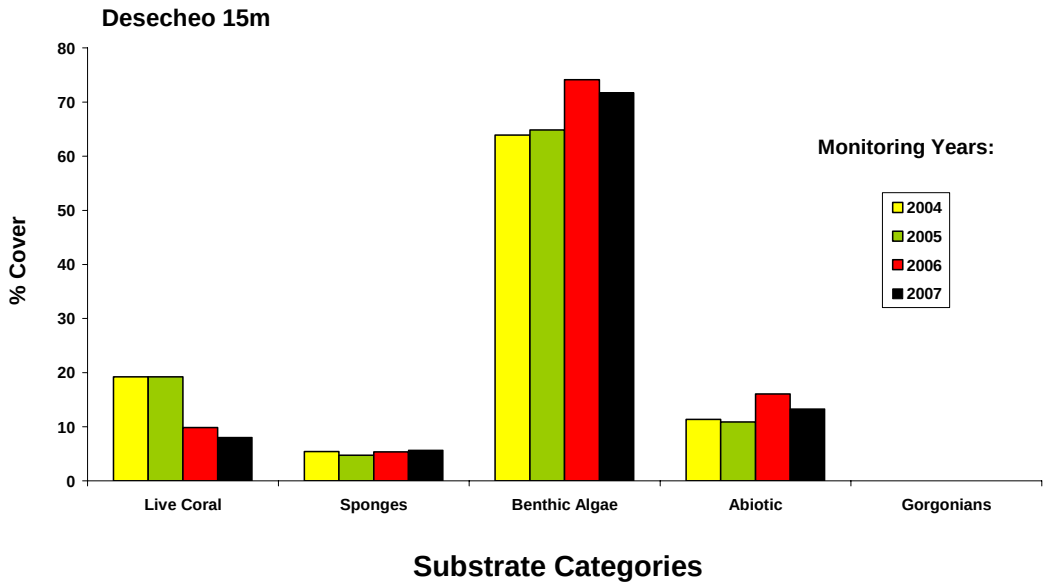


Figure 20. Monitoring trends (2004 -07) of mean substrate cover by sessile-benthic categories at Puerto Botes Reef – 15 m.

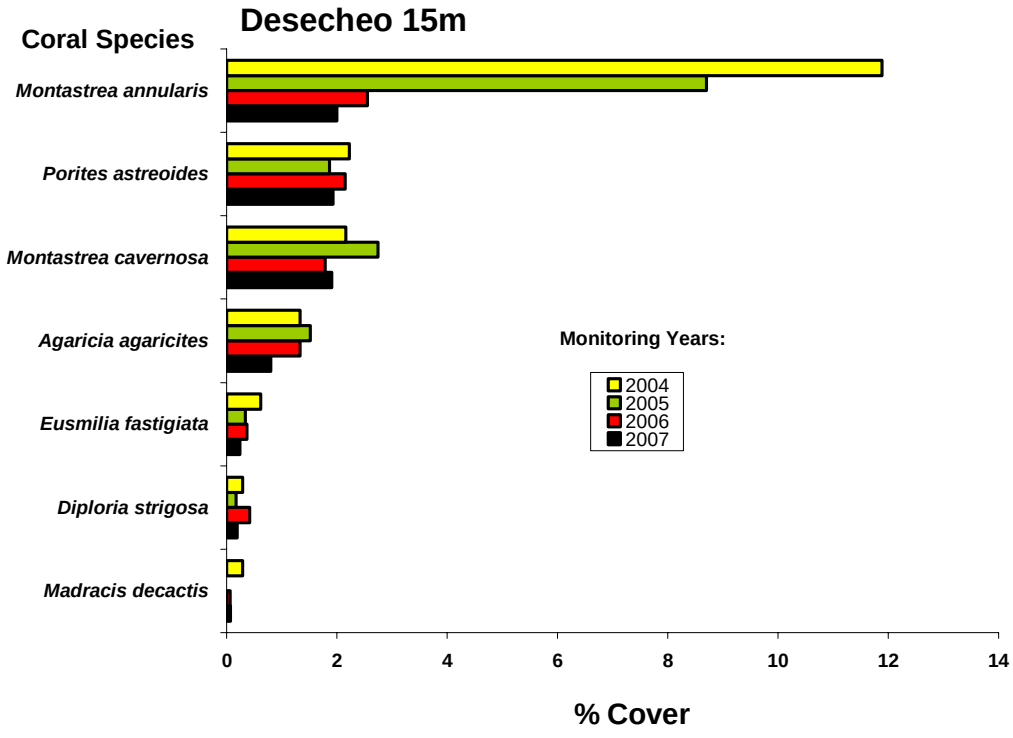


Figure 21. Monitoring trends (2004 -07) of mean substrate cover by dominant stony coral species at Puerto Botes Inner Shelf Reef – 15 m.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 76 fish species were identified within belt-transects from the Inner-Shelf Reef off Puerto Botes, Isla Desecheo during June, 2006 (Table 23). Sixtyseven (67) fish species have been identified from this reef since the baseline survey of 2004 (see Appendix 1). Mean abundance of fishes within belt-transects during the 2007 survey was 176.2 Ind/30 m^2 (range: 126 - 271 Ind/30 m^2). The mean number of species per transect was 21.8 (range: 19 - 27). The Blue Chromis, Bicolor Damselfish and the Bluehead, Yellowhead and Creole Wrasses comprised the numerically dominant fish assemblage with a combined mean abundance of 141.2 Ind/30, representing 80.1 % of the total abundance within belt-transects (Table 23). A total of 15 species were present in all five transects surveyed.

Annual monitoring trends of fish species richness and abundance surveyed within belt-transects are presented in Figure 22. The mean number of fish species within transects (species richness) has fluctuated between 21.8 and 25.2, and mean abundance has varied between 133.8 Ind/30 m^2 and 307.6 Ind/30 m^2 during the four year monitoring period at this reef. A statistically significant decline of fish species richness and abundance between the 2007 and the previous surveys of 2005 and 2006 was observed (ANOVA; $p < 0.05$). Differences of fish abundance are largely associated with species that display schooling behavior and thus, have highly aggregated spatial distribution patterns such as the Blue and Brown Chromis. Nevertheless, the marked decline of live coral may have influenced the reduction in numbers of schooling chromis from the reef. As live coral disappears, reef substrate is colonized by turf and fleshy algae, which in turn becomes the appropriate habitat for herbivorous damselfishes (e.g. *Stegastes dorsopunicans, S. planifrons*. These species are territorial and very aggressive and can drive away the schooling chromis species.

Reef zooplankton feeders, such as the Blue and Brown Chromis, the Creole Wrasse and the Bicolor Damselfish comprise the most prominent fish assemblage of this inshore reef in terms of abundance. These are important prey items of mid-size demersal piscivores that are commercially exploited, such as the Yellowtail and Schoolmaster Snappers, Red Hind and Coneys, as well as for juvenile and adult stages of pelagic fishes associated with the reef food web, such as the Great Barracuda, Cero Mackerels and jacks that

Table 23. Taxonomic composition and abundance of fishes within belt-transects at Puerto Botes Reef, Isla Desecheo. June, 2007

Depth: 15m		TRANSECTS (Ind/30m^2)					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Chromis cyanea	Blue Chromis	48	62	55	4	30	**39.8**
Stegastes partitus	Bicolor Damselfish	30	47	30	43	35	**37.0**
Clepticus parrae	Creole Wrasse					130	**26.0**
Thalassoma bifasciatum	Bluehead Wrasse	27	9	16	22	16	**18.0**
Chromis multilineata	Brown Chromis	2	2	22	12	16	**10.8**
Halichoeres garnoti	Yellow-head Wrasse	7	12	12	11	6	**9.6**
Gobiosoma evelynae	Sharknose Goby	12	11	6	5	6	**8.0**
Cephalopholis fulva	Coney	2	3	4	4	3	**3.2**
Halichoeres maculipinna	Clown Wrasse	2	4	3	3	3	**3.0**
Malacoctenus triangulatus	Saddled Blenny	1	4	3	4	1	**2.6**
Sparisoma radians	Bucktooth Parrotfish	2	3	1	5	2	**2.6**
Acanthurus coeruleus	Blue Tang	2	2	1	1	2	**1.6**
Amblycirrhitus pinos	Redspotted Hawkfish	2	2	1	1	2	**1.6**
Microspathodon chrysurus	Yellowtail Damselfish	1	1	2	1	3	**1.6**
Cephalopholis cruentatus	Graysby	1	1	1	2	2	**1.4**
Coryphopterus sp1.	Goby	1	1	1	1	1	**1.0**
Sparisoma aurofrenatum	Redband Parrotfish	1			2	1	**0.8**
Sparisoma viride	Stoplight Parrotfish		3	1			**0.8**
Acanthurus bahianus	Ocean Surgeon	1			2		**0.6**
Acanthurus chirurgus	Doctorfish	1	1	1			**0.6**
Myripristis jacobus	Blackbar Soldierfish			3			**0.6**
Scarus iserti	Stripped Parrotfish	1		2			**0.6**
Bodianus rufus	Spanish Hogfish			1	1		**0.4**
Chaetodon capistratus	Foureye Butterflyfish					2	**0.4**
Flammeo marianus	Longspine Squirrelfish			1		1	**0.4**
Holocentrus rufus	Squirrelfish			1		1	**0.4**
Liopropoma rubre	Swissguard Basslet					2	**0.4**
Melichthys niger	Black Durgon		1		1		**0.4**
Canthigaster rostrata	Caribbean puffer		1				**0.2**
Coryphopterus lipernes	Peppermint Goby					1	**0.2**
Equetus punctatus	Spotted Drum					1	**0.2**
Holacanthus tricolor	Rock Beauty					1	**0.2**
Kyphosus sectatrix	Bermuda Chub					1	**0.2**
Lactophrys triqueter	Smooth Trunkfish				1		**0.2**
Pomacanthus paru	French Angelfish					1	**0.2**
Rypticus saponaceus	Soapfish	1					**0.2**
Serranus tigrinus	Harlequin Bass					1	**0.2**
Xanthichthyis ringens	Sargassum Triggerfish	1					**0.2**
	TOTAL INDIVIDUALS	146	170	168	126	271	**176.2**
	TOTAL SPECIES	21	19	22	20	27	**21.8**

have been observed during the ASEC surveys (Table 24). 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 macro zooplankton of Puerto Botes/Puerto Desecheo Reefs six times during a year and found that zooplankton populations are depauperate and unproductive with exception of fish eggs. At least three preliminary hypotheses or interplay of these can be advanced to explain such scenario: 1) zooplankton production is high, but is continuously being consumed as it grows to an optimal size for fish consumption; 2) fishes produce a very high abundance of pelagic eggs that support the large zooplanktivorous fish populations; 3) micronekton assemblages, such as mysid shrimps supplement, or sustain to a significant extent the diets of the markedly abundant zooplanktivorous fish populations at the Puerto Botes/Puerto Canoas Reef system of Isla Desecheo.

A specious assemblage of small invertebrate feeders was also present, including wrasses, gobies, goatfishes and squirrelfishes, among others. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous assemblage. Commercially important species for the aquarium trade market were mostly represented by 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 (*Holacanthus ciliaris*) and Rock Beauty (*Holacanthus tricolor*) were also present (Table 24).

Motile megabenthic invertebrates were represented within belt-transects by Arrow Crabs, Long-spined Sea Urchins (*Diadema antillarum*) and Brittle Stars (Ophiuroids) (Table 25).

Table 24. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Puerto Botes Inner-shelf Reef, Isla Desecheo, June, 2007

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

SPECIES	**COMMON NAME**		# - (cm)	
Chromis cyanea	Blue chromis	36 - (<3)	65 - (3-5)	14 - (>5)
Decapterus macarellus	Mackerel Scad	40 - (10-12)		
Gramma loreto	Fairy Basslet	15 - (< 3)	7 - (3-5)	6 -(6-7)
Holacanthus ciliaris	French Angel	2 – (40)		
Holacanthus tricolor	Rock Beauty	1 - (20)		
Lutjanus apodus	Schoolmaster	4 - (25)	12 - (30)	4 - (40)
Lutjanus mahogany	Mahogany Snapper	1 - (30)		
Ocyurus chrysurus	Yellowtail Snapper	1 – (25)	2 – (35)	1- (50)
Scomberomorus regalis	Cero Mackerel	1 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (75)		
Invertebrates				

Table 25. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at the Puerto Botes Inner-Shelf Reef, 15 m depth, Isla Desecheo, June, 2007

DATE: June, 2007 Depth: 15 m		**TRANSECTS**					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Stenorhynchus seticornis	Arrow Crab	2					**0.4**
Diadema antillarum	Long-Spined Sea Urchin	1					**0.2**
Ophiothrix suensoni	Sponge Brittle Star				**1**		**0.2**
	TOTALS	3	0	0	1	0	0.8

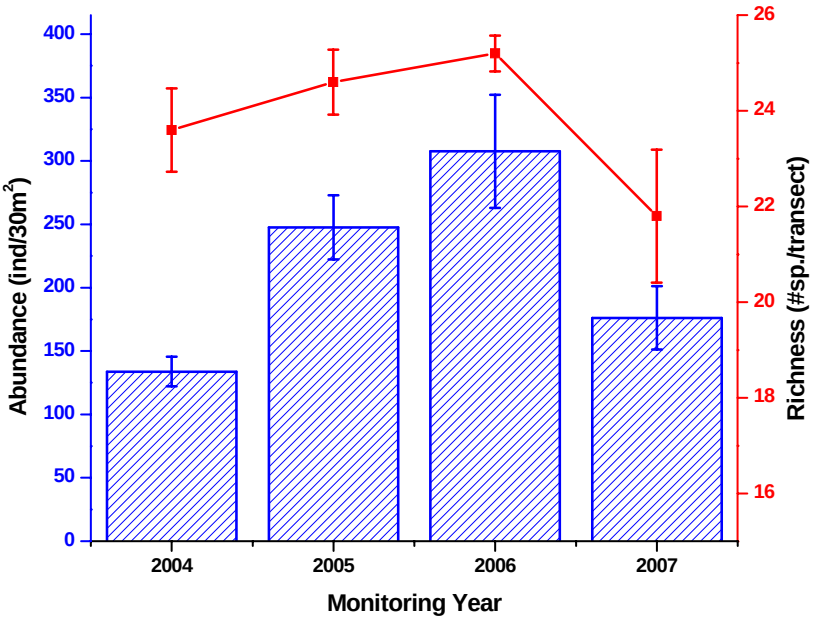


Figure 22. Monitoring trends (2004 – 2007) of fish species richness and abundance at Inner Shelf Reef Puerto Botes,15 m depth, Isla Desecheo.

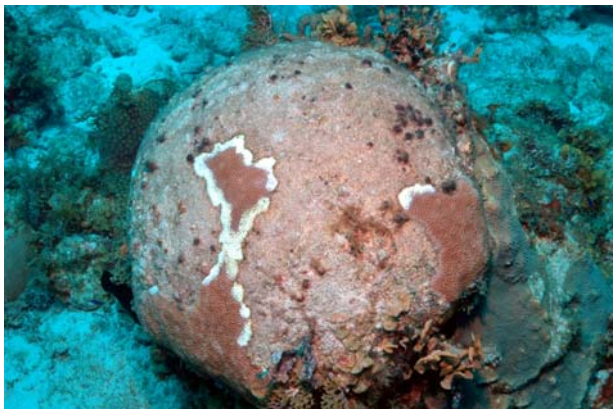
Photo Album 6 (Desecheo 15m)

Inner Shelf Reef

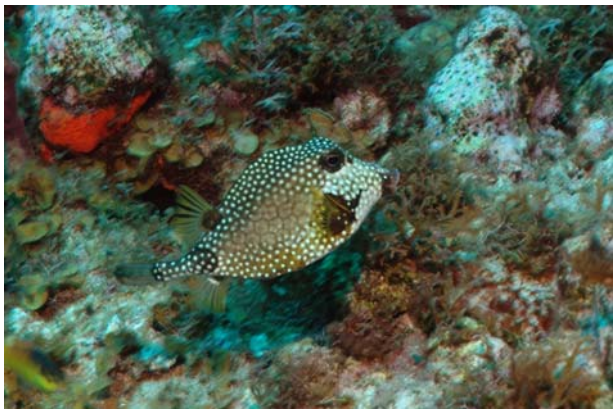












C. Tourmaline Reef System – Mayaguez Bay

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 23).

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

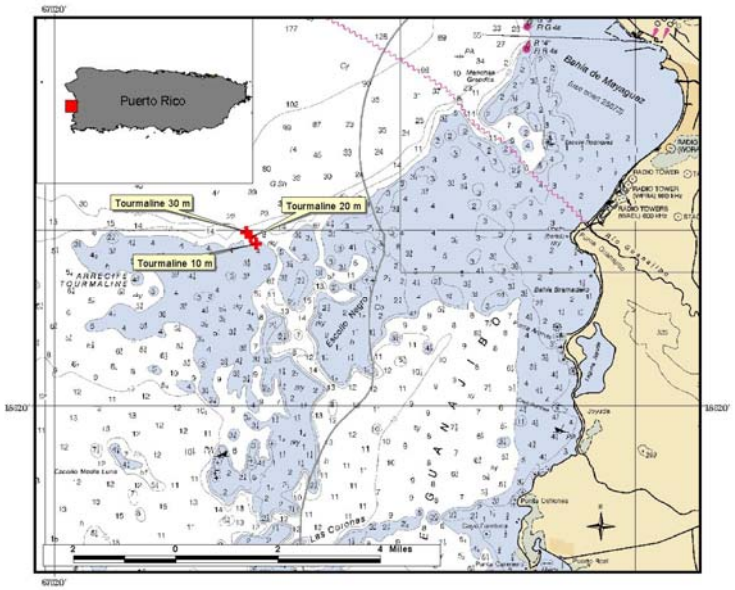


Figure 23. Location of coral reef survey stations at Tourmaline Reef, off Mayaguez Bay.

1.0 Shelf-edge Reef – 30 meters

1.1 Sessile-Benthic Reef Community

Permanent transects were oriented south - north, perpendicular to the shelf-edge and on top of the spurs at a depth of 28 - 30 m. Panoramic views of Tourmaline shelf-edge reef are presented in Photo Album 7.

A total of 19 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 13.00 % (range: 7.46 – 19.46 %). Boulder Star Coral, *Montastrea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 4.92 % (range: 2.50 – 8.63 %), representing 37.8 % of the total cover by stony corals. Isolated colonies of Lamark's Sheet Coral, *Agaricia lamarcki,* Graham's Sheet Coral, *A. grahamae*, Lettuce Coral, A. agaricites and Great Star Coral, *Montastrea cavernosa* were also prominent at the shelf-edge. Soft corals (gorgonians) were moderately abundant, with an average of 10.8 colonies/transect. The encrusting gorgonian, *Erythropodium caribaeorum* was intercepted by all five transects and presented a mean substrate cover of 2.4 %. 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 1.93 %. The Blue Bell Tunicate, *Clavelina puertosecensis* was very common throughout the shelf-edge reef. Reef overhangs, associated with substrate depressions and coral ledges averaged 28.23 % and contributed substantially to a topographic rugosity of 5.70 m.

Turf algae, comprised by an assemblage of short filamentous red and brown algae was the dominant sessile-benthic component in terms of substrate cover at the shelf-edge reef with an average of 48.97 % (range : 39.55 – 54.86%). Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard bottom. The total cover by benthic algae was 50.04 %. Cyanobacterial films were present in three out of five transects with a mean reef substrate cover of 0.51 %.

Table 26. Percent substrate cover by sessile-benthic categories at Tourmaline Reef, Mayaguez, June 2007.

Depth: 30 m

	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	5.83	5.89	7.00	5.44	4.34	**5.70**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	32.91	26.51	30.76	25.91	25.05	**28.23**
Gaps		0.89				**0.18**
Sand/Silt		7.98	2.6	4.3	3.15	**3.60**
Total Abiotic	32.91	35.38	33.36	30.21	28.2	**32.01**
Benthic Algae						
Turf-mixed assemblage	49.21	39.55	54.97	54.86	46.27	**48.97**
Fleshy	0.89	0.53	0.97	1.49	1.47	**1.07**
Total Benthic Algae	50.10	41.06	55.94	56.35	47.74	**50.04**
Cyanobacteria	0.44			0.52	1.57	**0.51**
Sponges	0.80	3.65	1.77	1.55	1.88	**1.93**
Encrusting Gorgonians	2.84	1.51	1.48	2.98	3.21	**2.40**
Live Stony Corals						
Montastrea annularis	4.61	8.63	2.57	2.50	6.28	**4.92**
Agaricia agaricites	6.32	2.14		1.64	2.93	**2.61**
Agaricia lamarcki		1.89	1.37	2.11	3.07	**1.69**
Agaricia grahamae	0.36	3.53		0.72	1.47	**1.22**
Montastrea cavernosa			2.57		2.75	**1.06**
Madracis sp.		3.27				**0.65**
Siderastrea siderea				1.32		**0.26**
Porites astreoides	0.89				0.39	**0.26**
Stephanocoenia michelini			0.63			**0.13**
Dichocoenia stokesii	0.53					**0.11**
Madracis decactis	0.18		0.32			**0.10**
Scolymia cubensis				0.03		**0.01**
Total Stony Corals	12.89	19.46	7.46	8.32	16.89	**13.00**
Recently dead coral	0.80					**0.16**
Gorgonians	9	10	9	12	14	**10.8**

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

Figure 24 presents the variations of mean percent cover by sessile-benthic categories from the shelf-edge of Tourmaline Reef at 30 m depth. The mean percent cover by stony corals between the previous 2006 and the present 2007 monitoring surveys declined 8.6 %, from 14.23 % in 2006 to 13.00 % in 2007. Differences of live coral cover between monitoring surveys were small and not statistically significant (ANOVA; $p = 0.961$). Boulder Star Coral, *Montastrea annularis* maintained its status as the dominant coral species in terms of reef substrate cover at 30 m depth (Figure 25). Although partial bleaching was reported in one colony of *M. annularis* during the previous 2006 monitoring survey widespread mortality associated with bleaching was not observed at this reef. Substrate cover by *M. annularis* declined 7.5 % between the 2006 and the present 2007 survey. The difference was not statistically significant (ANOVA; $p > 0.05$).

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 114 fish species have been identified from Tourmaline Reef at depths of 25-30 m (Appendix 1). Mean abundance within belt-transects during the 2007 monitoring survey was 290.6 Ind/30 m^2 (range: 174 - 374 Ind/30 m^2). The mean number of species per transect was 18.4 (range: 13 - 22). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 233.2 Ind/30 m^2 (range: 126 - 305 Ind/30 m^2), representing 80.2 % 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 Peppermint and Masked Gobies, Black-bar Soldierfish, Beau gregory, Bicolor Damselfish, Bluehead Wrasse, Caribbean Puffer, Blue Chromis and Striped Parrotfish were present on the five transects surveyed and comprised, along with the Creole Wrasse and Fairy Basslet, the most abundant fish assemblage at the shelf-edge reef.

Fish species richness declined 20% between the 2006 and the present 2007 survey, but differences were not statistically significant because of the relatively high variability within replicate transects. Conversely, mean fish abundance maintained its consistently increasing pattern over the study period with an increment of 28.9 % compared to the 2006 survey (Figure 26). Differences of fish abundance between monitoring surveys

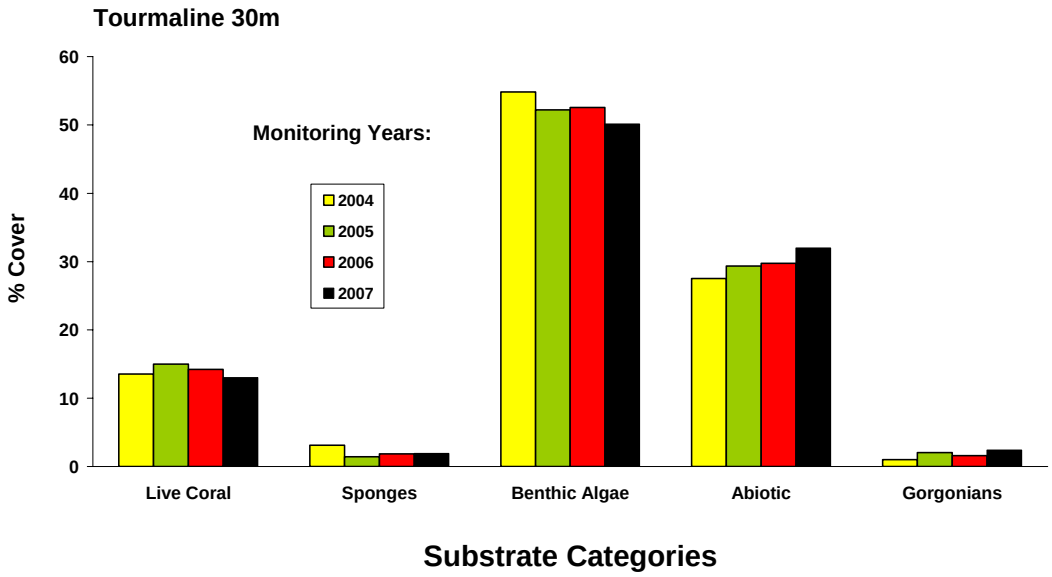


Figure 24. Monitoring trends (2004 – 2007) of mean substrate cover by sessile-benthic categories at Tourmaline Shelf-edge Reef – 30 m, Mayaguez Bay.

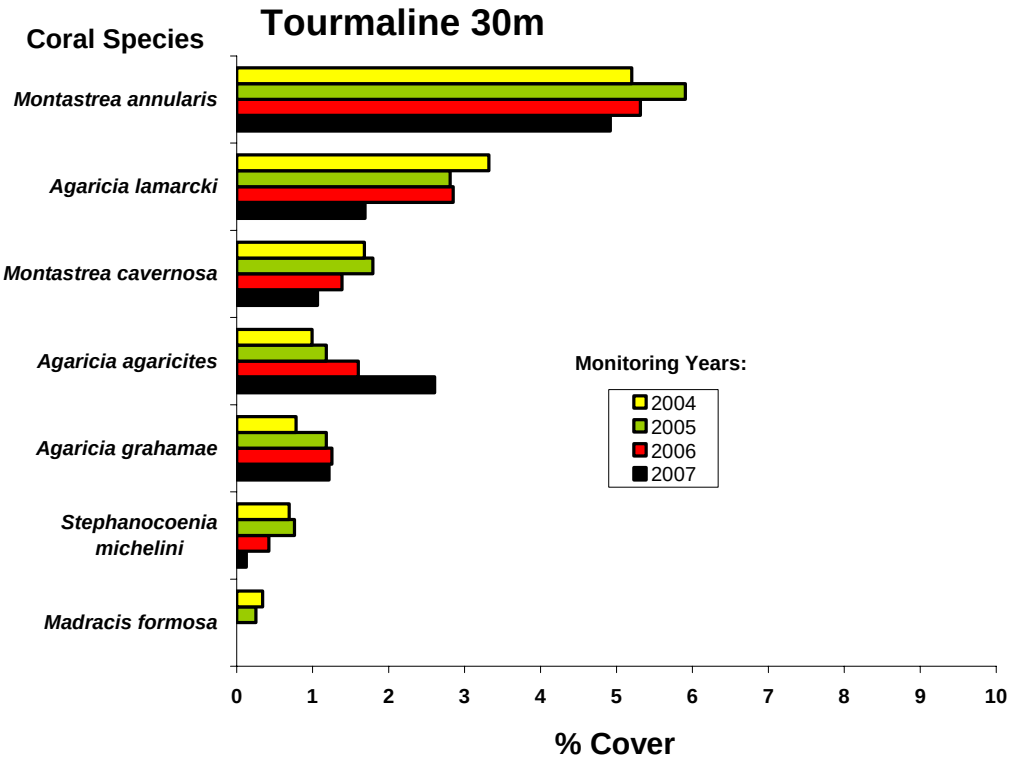


Figure 25. Monitoring trends (2004 – 2007) of mean substrate cover by dominant stony coral species at Tourmaline Reef – 30 m, Mayaguez Bay.

Table 27. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, Mayaguez Bay- 30 m depth. June, 2007

Depth: 30 m

SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	240	126	285	210	305	**233.2**
Coryphopterus lipernes	Peppermint Goby	18	6	13	7	10	**10.8**
Clepticus parrae	Creole Fish	10		18		3	**6.2**
Gramma loreto	Fairy Basslet	2	5	9	11		**5.4**
Thalassoma bifasciatum	Bluehead Wrasse	4	3	13	1	6	**5.4**
Chromis cyanea	Blue Chromis	6	4	3	3	9	**5.0**
Myripristis jacobus	Blackbar Soldierfish	1	11	5	2		**3.8**
Stegastes leucostictus	Beau gregory	2	1	4	3	2	**2.4**
Stegastes partitus	Bicolor Damselfish	2	1	5	1	3	**2.4**
Canthigaster rostrata	Caribbean Puffer	2	2	2	1	3	**2.0**
Scarus iserti	Stripped Parrotfish	1	4	1	1	3	**2.0**
Gobiosoma evelynae	Sharknose Goby		2	3		1	**1.2**
Haemulon aurolineatum	Tomtate	3	1	1	1		**1.2**
Haemulon flavolineatum	French Grunt	1	2	2			**1.0**
Sparisoma radians	Bucktooth Parrotfish	3			2		**1.0**
Cephalopholis cruentatus	Graysby	1	2	1	1	1	**1.2**
Chaetodon capistratus	Foureye Butterflyfish	2			2		**0.8**
Sparisoma aurofrenatum	Redband Parrotifish			1	1	2	**0.8**
Halichoeres garnoti	Yellow-head Wrasse	2			1		**0.6**
Acanthurus bahianus	Ocean Surgeon	2					**0.4**
Acanthurus chirurgus	Doctorfish			2			**0.4**
Cephalopholis fulva	Coney			2			**0.4**
Holacanthus tricolor	Rock Beauty	2					**0.4**
Hypoplectrus puella	Barred Hamlet		1	1			**0.4**
Aulostomus maculatus	Trumpetfish				1		**0.2**
Chaetodon aculeatus	Longsnout Butterflyfish					1	**0.2**
Flammeo marianus	Longspine Squirrelfish			1			**0.2**
Holocentrus rufus	Squirrelfish		1				**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	1					**0.2**
Hypoplectrus unicolor	Butter Hamlet		1				**0.2**
Liopropoma rubre	Swissguard Basslet			1			**0.2**
Mulloides martinicus	Yellowtail Goatfish	1					**0.2**
Ocyurus chrysurus	Yellowtail Snapper			1			**0.2**
Priacanthus cruentatus	Glasseye Snapper		1				**0.2**
Scarus vetula	Queen Parrotfish	1					**0.2**
	TOTAL INDIVIDUALS	307	174	374	249	349	**290.6**
	TOTAL SPECIES	22	18	22	17	13	**18.4**

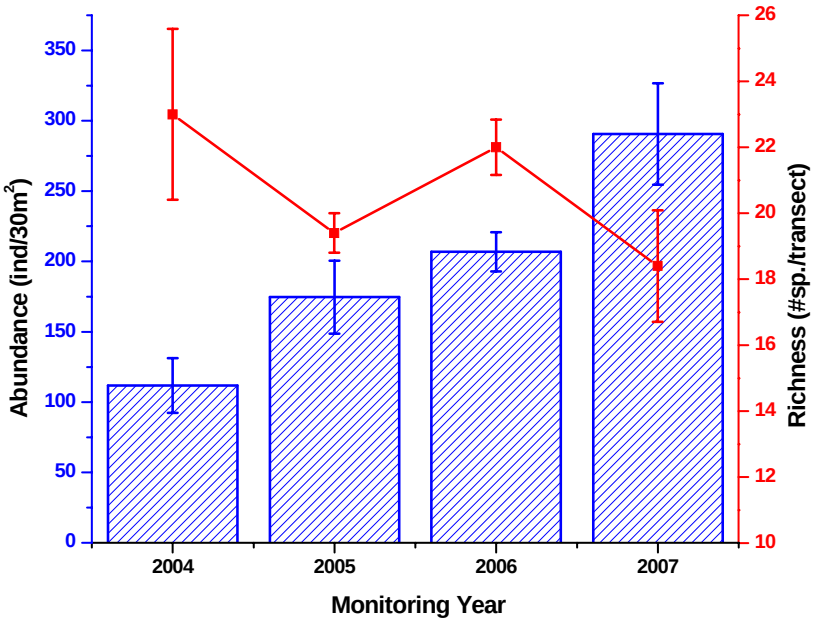


Figure 26. Monitoring trends (2004 – 2007) of fish species richness and abundance at Shelf-edge Reef Tourmaline, 30 m, Mayaguez Bay.

were statistically significant (ANOVA; p = 0.0011). An overall increment of 61 % has been observed between the present 2007 and the 2004 baseline survey. The increment of fish abundance has been mostly driven by the increasing abundance of the Masked Goby, which is the numerically dominant species within belt-transects at this reef.

Top demersal and pelagic predators, such as large snappers, groupers and mackerels have been observed at the shelf-edge reef, but in low abundance. Red Hind, Yellowfin and Nassau Groupers, along with a Hogfish and several snappers were observed during the 2007 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 Arrow Crab (*Stenorhynchus seticornis)* was present within belt-transects. One juvenile 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, 2007

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

SPECIES	**COMMON NAME**		# - (cm)
Caranx latus	Horse-eye Jack	1 - (55)	
Dasyatis americana	Southern Stingray	1 - (90)	
Epinephelus guttatus	Red Hind	1 - (35)	
Epinephelus striatus	Nassau Grouper	1 - (60)	
Lachnolaimus maximus	Hogfish	1 - (40)	
Lutjanus apodus	Schoolmaster Snapper	3 - (30)	5 – (40)
Lutjanus mahogany	Mahogany Snapper	1 - (40)	
Mycteroperca venenosa	Yellowfin Grouper	1 - (50)	
Ocyurus chrysurus	Yellowtail Snapper	1 - (30)	
Scomberomorus regalis	Cero Mackerel	3 - (40)	
Sphyraena barracuda	Great barracuda	1 - (75)	
Invertebrates			
Panulirus argus	Spiny Lobster	1 - (20)	

Table 29. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Shelf-edge Reef, 30 m depth, Mayaguez. June, 2007

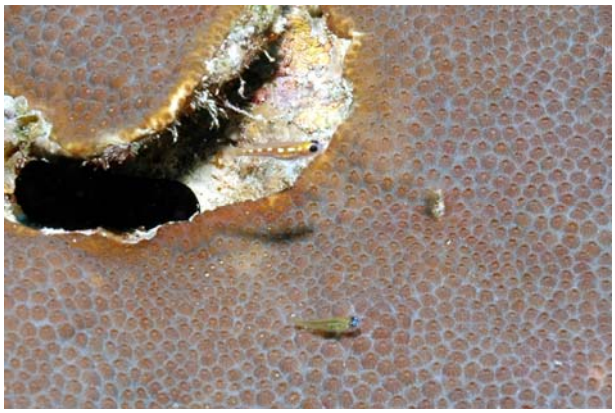
Depth: 30 m				**TRANSECTS**			**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Stenorhynchus seticornis	Arrow Crab			1			**0.2**
	TOTALS	**0**	**0**	**1**	**0**	**0**	**0.2**

Photo Album 7 (Tourmaline 30 m)

Shelf edge Reef










2.0 Tourmaline Outer Shelf Reef – 20 m

2.1 Sessile-Benthic Reef Community

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 18 stony corals and two black coral species (*Stichopathes lutkeni, Antipathes sp*.) were identified from the outer shelf reef, 11 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 22.76 % (range: 20.19 – 25.73 %). 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 16.17 % (range: 10.32 – 19.40 %), representing 71.0 % of the total cover by stony corals. Colonies of Boulder Star Coral were intercepted by all five transects. Great Star Coral (*M. cavernosa*), Mustard Hill Coral (*P. astreoides*) and Massive Starlet Coral (*Siderastrea siderea*) were intersected by four out of the five transects surveyed and along with Boulder Star Coral comprised the main stony coral assemblage.

Soft corals (gorgonians) were moderately abundant and rich in species, with an average of 13.4 colonies/transect and a total of 12 species intercepted by transects (including the encrusting species, *Erythropodium caribaeorum*). *Briareum asbestinum, Pseudoptergorgia acerosa*, *Pseudoptergorgia americana,* and *Gorgonia ventalina* were

Table 30. Percent linear cover by sessile-benthic categories at Tourmaline Reef, Mayaguez, June 2007.

Depth: 20 m	TRANSECT					
	1	2	3	4	5	**MEAN**
Rugosity (m)	3.56	6.07	4.73	6.89	5.44	**5.34**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	20.65	31.09	26.21	30.63	32.12	**28.14**
Gaps		2.99				**0.60**
Sand/Silt				2.92		**0.58**
Total Abiotic	20.65	34.08	26.21	33.55	32.12	**29.32**
Benthic Algae						
Turf-mixed assemblage	41.52	27.86	42.29	35.60	33.94	**36.24**
Fleshy	7.15	14.55	7.81	2.90	7.12	**7.91**
Total Benthic Algae	48.7	42.4	50.1	38.5	41.1	**44.1**
Cyanobacteria		0.37				**0.07**
Sponges	2.73		0.54	3.73		**1.40**
Encrusting Gorgonians	2.21	3.17	1.63	1.01	3.63	**2.33**
Live Stony Corals						
Montastrea annularis	19.40	16.92	10.32	18.84	15.35	**16.17**
Montastrea cavernosa	3.61		4.89	1.01	3.19	**2.54**
Siderastrea siderea	1.47		0.86	1.67	2.19	**1.24**
Porites astreoides		1.43	2.38	0.67	1.46	**1.19**
Colpophyllia natans		1.40			0.46	**0.37**
Diploria labyrinthiformis			1.63			**0.33**
Madracis decactis	0.73	0.44		0.33		**0.30**
Meandrina meandrites	0.52			0.67		**0.24**
Mycetophyllia lamarckiana			0.86			**0.17**
Dichocoenia stokesii			0.57			**0.11**
Agaricia grahamae					0.55	**0.11**
Total Stony Corals	25.73	20.19	21.51	23.19	23.20	**22.76**
Recently dead coral			3.12	12.26		**3.08**
Partially bleached coral		3.07				**0.61**
Gorgonians (# colonies)						
Briareum asbestinum	7.00	3.00	8.00	2.00	1.00	**4.20**
Pseudoptergorgia acerosa	2.00	2.00	2.00	5.00	9.00	**4.00**
Pseudoptergorgia americana	2.00		6.00			**1.60**
Gorgonia ventalina	1.00	1.00		3.00	2.00	**1.40**
Pseudoptergorgia bipinnaria	2.00		1.00			**0.60**
Pseudoplexaura flagellosa or wargeri	1.00	1.00				**0.40**
Eunicea turnetorti		1.00				**0.20**
Muricea spp.	1.00					**0.20**
Muriceopsis flavida	1.00					**0.20**
Plexaura homomalla	1.00					**0.20**
Plexaura kukenthali				1.00		**0.20**
Plexaura spp.				1.00		**0.20**
Total Gorgonians (# colonies/transect)	20.00	11.00	17.00	17.00	13.00	**13.40**

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

the most abundant species within transects. Colonies of Bushy Black Coral (*Antipathes caribbeana*) were present at the reef base. Encrusting sponges were present, but represented a minor component of the reef benthos (substrate cover < 2 %). Reef overhangs, associated with coral ledges of Boulder Star Coral averaged 28.14 % of the reef substrate cover and contributed markedly to the topographic rugosity of 5.34 m.

Turf algae, comprised by a mixed assemblage of short filamentous red and brown algae was the dominant sessile-benthic component in terms of substrate cover at the outer shelf reef with an average of 36.24 % (range: 27.86 – 42.29 %). 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 7.91 % to the total cover by benthic macroalgae of 44.10 %.

Figure 27 presents the variations of mean percent substrate cover by sessile-benthic categories from Tourmaline outer shelf reef at 20 m depth. Reef substrate cover by live corals has been consistently declining since the baseline characterization in 2004, when the mean cover was measured as 31.79 %. Live coral declined 9.5 % between 2004 and 2005, then declined again 12.9 % between 2005 and 2006 and during the present survey 0f 2007 another reduction of 9.0 % was measured. The overall decline of live coral cover between the present 2007 and the baseline survey of 2004 was of 28%. The difference of live coral cover between monitoring surveys was statistically significant at p= 0.0877. The difference between the 2007 and 2004 surveys was statistically significant at p= 0.020 (see Appendix 2). Reductions of live coral cover between the 2004 baseline and the present 2007 monitoring survey were evidenced in 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 28.7 % reduction of substrate cover between 2004 and 2007 (Figure 28). 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.

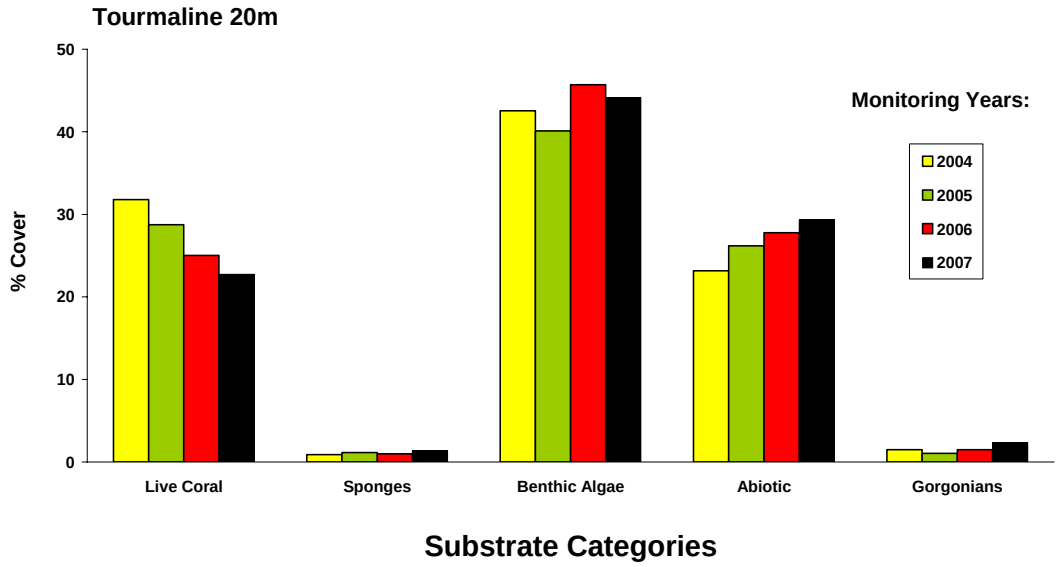


Figure 27. Monitoring trends (2004 – 2007) of mean substrate cover by sessile-benthic categories at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

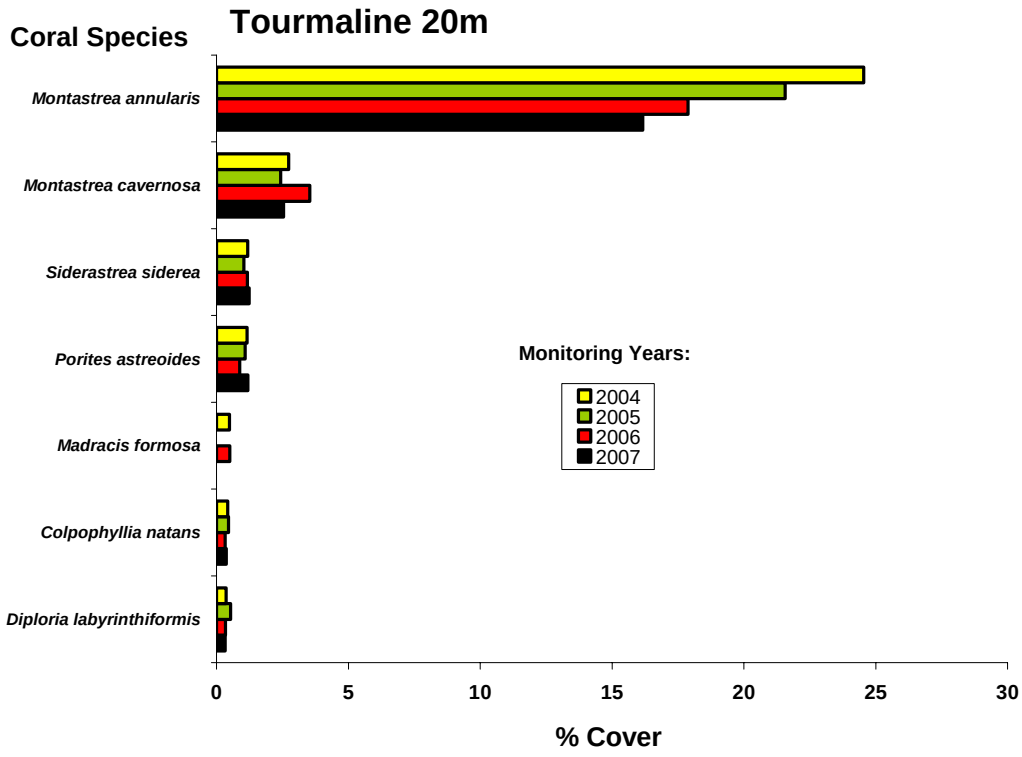


Figure 28. Monitoring trends (2004 – 2007) of mean substrate cover by dominant stony coral species at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

3.2 Fishes and Motile Megabenthic Invertebrates-

A total of 101 fish species have been identified from Tourmaline outer shelf reef (Appendix 1). Mean abundance within belt-transects during 2007 was 142.6 Ind/30 m^2 (range: 100 - 190 Ind/30 m^2). The mean number of species per transect was 21.4 (range: 19 - 24). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 84.0 Ind/30 m^2 (range: 45 – 100 Ind/30 m^2), representing 58.9 % of the total abundance within belt-transects (Table 31).

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, Sharknose and Peppermint Gobies, Fairy Basslet, Bicolor Damselfish, Bluehead Wrasse, Blue Chromis, Black-bar Soldierfish, Caribbean Puffer, and the Stoplight and Striped Parrotfishes were present in all five transects surveyed, and comprised, along with the Creole Wrasse, 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 29). 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.

Table 31. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, Mayaguez Bay, June 2007

Depth: 20 m

		TRANSECTS (Individuals/30m^2)					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	45	70	125	80	100	**84.0**
Gramma loreto	Fairy Basslet	5	7	8	4	14	**7.6**
Clepticus parrae	Creole Fish	14	5	6	3		**5.6**
Scarus iserti	Stripped Parrotfish	8	7	3	5	3	**5.2**
Thalassoma bifasciatum	Bluehead Wrasse	3	12	2	4	4	**5.0**
Chromis cyanea	Blue Chromis	2	5	11	2	3	**4.6**
Myripristis jacobus	Blackbar Soldierfish	1	1	7	7	5	**4.2**
Coryphopterus lipernes	Peppermint Goby	2	5	3	4	3	**3.4**
Stegastes partitus	Bicolor Damselfish	1	6	5	6	1	**3.8**
Canthigaster rostrata	Caribbean Puffer	2	4	1	3	2	**2.4**
Gobiosoma evelynae	Sharknose Goby	3	2	3	2	1	**2.2**
Stegastes leucostictus	Beau gregory	2	2	3	3	1	**2.2**
Sparisoma viride	Stoplight Parrotfish	3	3	2	1	1	**2.0**
Chaetodon capistratus	Foureye Butterflyfish		2	3	2		**1.4**
Acanthurus bahianus	Ocean Surgeon	1	3		1		**1.0**
Coryphopterus glaucofraenum	Bridled Goby	1	1	1	1	1	**1.0**
Chaetodon aculeatus	Longsnout Butterflyfish	1	1		1		**0.6**
Halichoeres garnoti	Yellow-head Wrasse	1	1	1			**0.6**
Sparisoma radians	Bucktooth Parrotfish			2		1	**0.6**
Chromis multilineata	Brown Chromis		2				**0.4**
Holacanthus tricolor	Rock Beauty	1	1				**0.4**
Hypoplectrus puella	Barred Hamlet		1			1	**0.4**
Hypoplectrus unicolor	Butter Hamlet			1		1	**0.4**
Lutjanus apodus	Schoolmaster Snapper	1			1		**0.4**
Scarus taeniopterus	Princess Parrotfish			2			**0.4**
Sparisoma aurofrenatum	Redband Parrotifish				1	1	**0.4**
Acanthurus chirurgus	Doctorfish		1				**0.2**
Acanthurus coeruleus	BlueTang			1			**0.2**
Anisotremus virginicus	Porkfish	1					**0.2**
Cephalopholis cruentatus	Graysby				1		**0.2**
Flammeo marianus	Longspine Squirrelfish				1		**0.2**
Haemulon flavolineatum	French Grunt				1		**0.2**
Holocentrus rufus	Squirrelfish	1					**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet					1	**0.2**
Hypoplectrus indigo	Indigo Hamlet					1	**0.2**
Lactophrys bicaudalis	Spotted Trunkfish		1				**0.2**
Liopropoma rubre	Swissguard Basslet		1				**0.2**
Mulloides martinicus	Yellowtail Goatfish	1					**0.2**
	TOTAL INDIVIDUALS	**100**	**144**	**190**	**134**	**145**	**142.6**
	TOTAL SPECIES	**22**	**24**	**20**	**22**	**19**	**21.4**

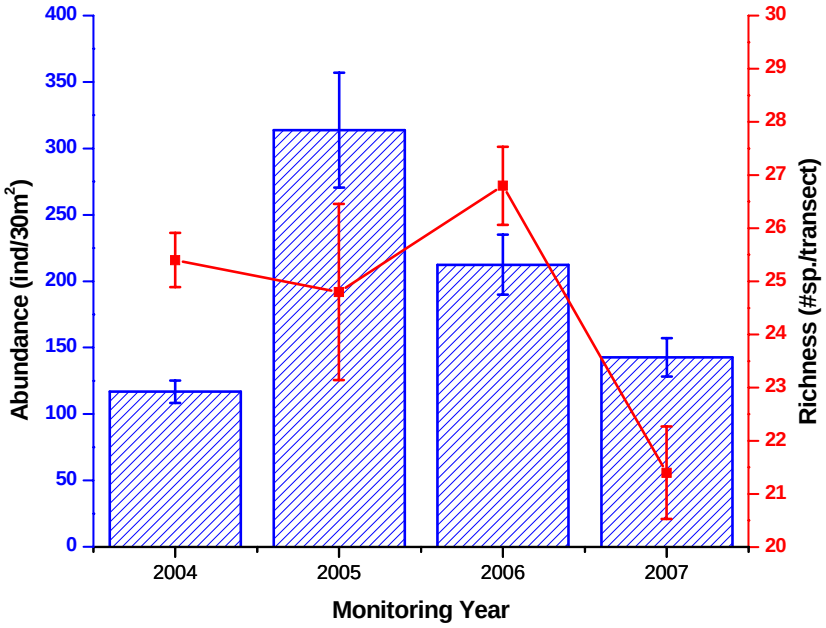


Figure 29. Monitoring trends (2004 – 2007) of fish species richness and abundance at Outer Shelf Reef Tourmaline,20 m depth, Mayaguez Bay.

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). Motile megabenthic invertebrates were not observed within belt-transects during 2007. 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, June, 2007

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

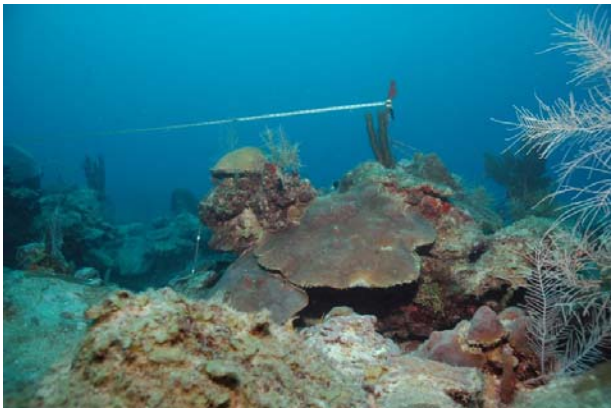
SPECIES	**COMMON NAME**		# - (cm)
Balistes vetula	Queen Triggerfish	1 - (30)	
Epinephelus guttatus	Red Hind	3 - (15)	1 - (25)
Epinephelus striatus	Nassau Grouper	1 - (40)	
Carangoides ruber	Bar Jack	1 - (25)	
Decapterus macarellus	Mackerel Scad	100 - (15)	
Holacanthus tricolor	Rock Beauty	2 - (20)	1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

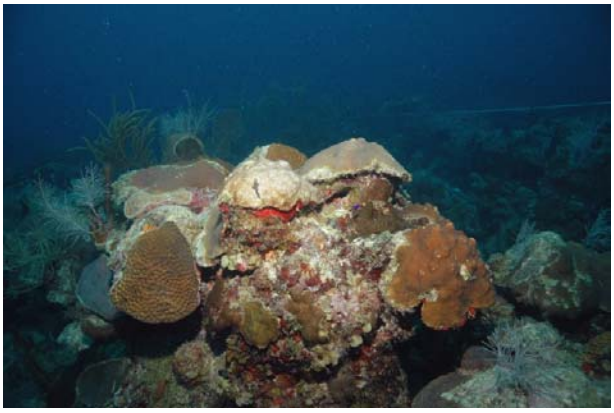
Table 33. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Outer-shelf Reef, Mayaguez, June, 2007

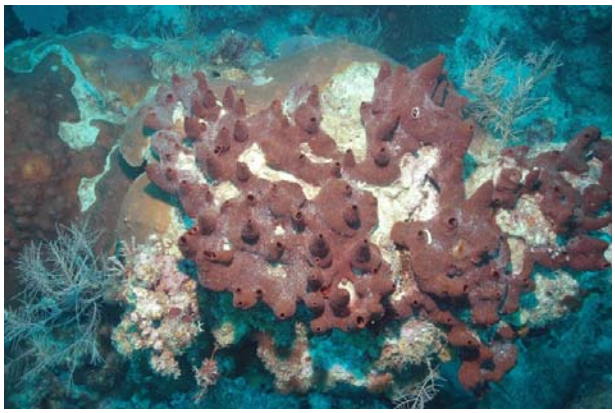
Depth: 20 m		**TRANSECTS**					**MEAN ABUNDANCE (IND/30 m^2)**
		1	**2**	**3**	**4**	**5**	
TAXA	**COMMON NAME**						
None observed			1				
	TOTALS	**0**	**1**	**0**	**0**	**0**	**0**

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 fourth time during June, 2007. Panoramic views of Tourmaline outer shelf reef at a depth of 10 m are presented in Photo Album 9.

A total of 24 stony coral species were identified from the Outer Shelf Reef at a depth of 10 m, 17 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 38.67 % (range: 24.56 – 60.54 %). Yellow Pencil Coral, *Madracis mirabilis* and Finger Coral, *Porites porites* were the dominant coral species in terms of substrate cover with means of 8.68 % and 8.31 %, respectively. Both of these species exhibit branching growth over the reef hard bottom and have kept an increasing pattern of substrate cover over the years at this reef. An extraordinarily large colony of Yellow Pencil Coral now covers more than four meters along transect two, contributing to a total cover by stony corals of 60.54 % in that transect. Colonies of Boulder Star Coral (*M. annularis* complex), Mustard Hill Coral (*Porites astreoides*), Finger Coral (*P. porites*) and Lettuce Coral (*Agaricia agaricites*) were intercepted by all five transects in the 2007 monitoring survey.

Erect soft corals (gorgonians) were highly abundant with an average of 16.8 colonies/transect and along with stony corals were the most visually prominent assemblage of the reef benthos. The most abundant species of erect gorgonians along surveyed transects were the Shelf-knob Sea Rod and the Black Sea Rod (*Eunicea*

Table 34. Percent substrate cover by sessile-benthic categories at Tourmaline Reef, Mayaguez, June 2007

	TRANSECT					
	1	2	3	4	5	**MEAN**
Rugosity (m)	3.56	3.04	2.75	4.44	4.18	**3.59**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	4.13	6.52	4.79	13.85	1.06	**6.07**
Rubble	7.30	2.70				**2.00**
Sand/Silt				0.88		**0.18**
Gaps					0.60	**0.12**
Total Abiotic	11.43	9.22	4.79	14.73	1.66	**8.37**
Benthic Algae						
Turf-mixed assemblage	39.45	23.08	49.59	50.55	59.92	**44.52**
Calcareous	0.52	0.43			2.47	**0.68**
Fleshy	1.77			0.59		**0.47**
Total Benthic Algae	41.7	23.5	49.6	51.1	62.4	**45.7**
Cyanobacteria		2.16	0.88		3.46	**1.30**
Sponges	0.73	0.65	1.10	1.04	0.60	**0.82**
Encrusting Gorgonians	6.42	3.91	0.55	6.65	5.15	**4.54**
Zoanthids	1.33		0.33	1.94		**0.72**
Live Stony Corals						
Madracis mirabilis		43.40				**8.68**
Porites porites	17.63	2.38	7.85	6.86	6.85	**8.31**
Montastrea annularis	7.82	9.59	10.51	2.56	0.60	**6.22**
Porites astreoides	4.35	4.52	8.87	3.12	6.85	**5.54**
Agaricia grahamae	0.52		1.96	5.06	3.18	**2.14**
Colpophyllia natans	2.08		8.18		0.20	**2.09**
Dendrogyra cylindrus	2.73			3.90		**1.33**
Montastrea cavernosa	0.93		1.88		2.75	**1.11**
Meandrina meandrites	1.04		2.10	0.98	0.90	**1.00**
Agaricia agaricites	0.52	0.65	0.44	2.08	0.40	**0.82**
Siderastrea siderea					2.59	**0.52**
Diploria labyrinthiformis					1.39	**0.28**
Diploria strigosa					0.90	**0.18**
Stephanocoenia michelini	0.73					**0.15**
Eusmilia fastigiata			0.55			**0.11**
Millepora sp.					0.50	**0.10**
Porites colonensis			0.44			**0.09**
Total Stony Corals	38.35	60.54	42.78	24.56	27.11	**38.67**
Recently dead coral	1.04	5.37	0.55	1.46	3.67	**2.42**
Gorgonians (# col.)						
Eunicea succinea	3.00	7.00	1.00	2.00	3.00	**3.20**
Plexaura homomalla	3.00		4.00	4.00	5.00	**3.20**
Pseudoplexaura flagellosa or wargeri	2.00	2.00		2.00	5.00	**2.20**
Gorgonia ventalina	2.00	3.00	2.00	1.00	2.00	**2.00**
Plexaura kukenthali	1.00		2.00	5.00	2.00	**2.00**
Plexaura flexuosa		1.00		3.00	3.00	**1.40**
Pseudoptergorgia purosa	2.00			1.00		**0.60**
Eunicea turnetorti	2.00	1.00				**0.60**
Pseudoptergorgia americana	1.00				1.00	**0.40**
Eunicea spp.			1.00		1.00	**0.40**
Muricea muricata	1.00					**0.20**
Muriceopsis flavida		1.00				**0.20**
Plexaura spp.				1.00		**0.20**
Pseudoptergorgia acerosa		1.00				**0.20**
Total Gorgonians (# colonies/transect)	35.00	31.00	22.00	33.00	40.00	**32.20**

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

succinea, Plexaura homomalla). Encrusting gorgonians, *Erythropodium caribaeorum* and *Briareum asbestinum* were present in all five transects with an average substrate cover of 4.54 %. Sponges and zoanthids (*Palythoa caribdea*) were also present along transects, but represented minor components of the reef benthos (substrate cover < 3 %). Reef overhangs, associated with coral ledges of Boulder Star Coral averaged 6.07 % and contributed markedly to the topographic rugosity of 3.59 m. Turf algae, comprised by a mixed assemblage of short filamentous red and brown algae presented an average substrate cover of 44.52 % (range: 23.08 – 59.92 %). Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard ground. Cyanobacterial films were present in three transects, but with a relatively low substrate cover in the reef (< 2.0 %).

Figure 30 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 four annual monitoring surveys (2004-07). 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 the 2006 monitoring survey, mean live coral cover declined 22.6%, from 44.26% in 2005 to 34.25% in 2006. 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 cover (ANOVA; $p = 0.028$) measured for *Montastrea annularis* (complex), the dominant coral species in terms of reef substrate cover at Tourmaline 10m (García-Sais et al., 2006). Reef substrate cover by *M. annularis* declined 46 % between 2005 and 2006, and was the main driver of the overall decline of live coral for this reef.

During the present 2007 survey, an additional 16.5 % decline of substrate cover by *M. annularis* was measured. Conversely, reef substrate cover by Yellow Pencil Coral, *Madracis mirabilis* continued to increase over time with an increment of 19.1 % between 2006 and the present 2007 monitoring survey (Figure 31). The growth increment of *M.*

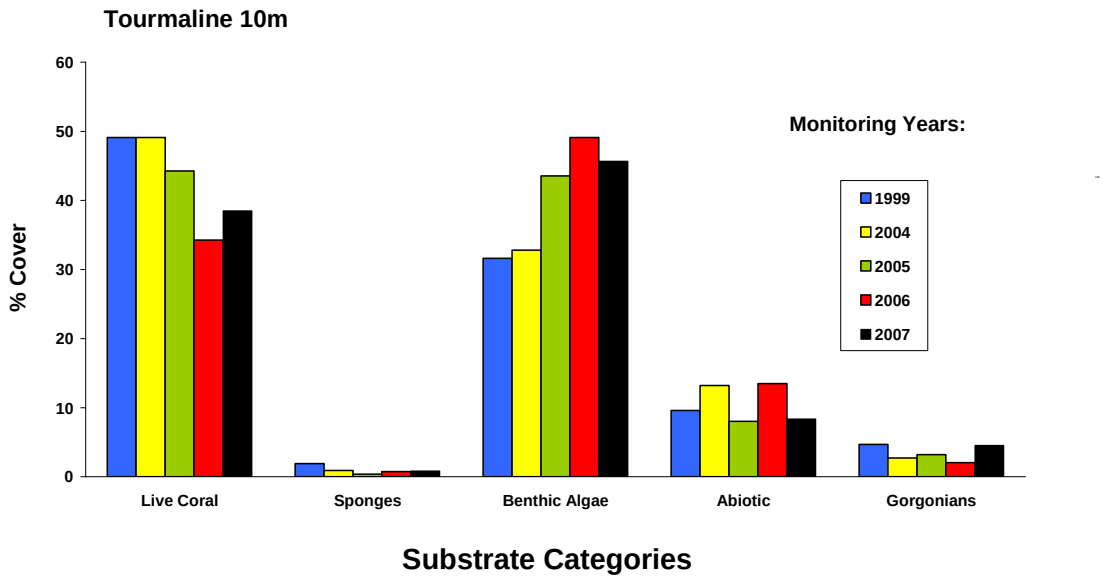


Figure 30. Monitoring trends (1999 – 2007) of mean substrate cover by sessile-benthic categories at Tourmaline Reef – 10 m, Mayaguez.

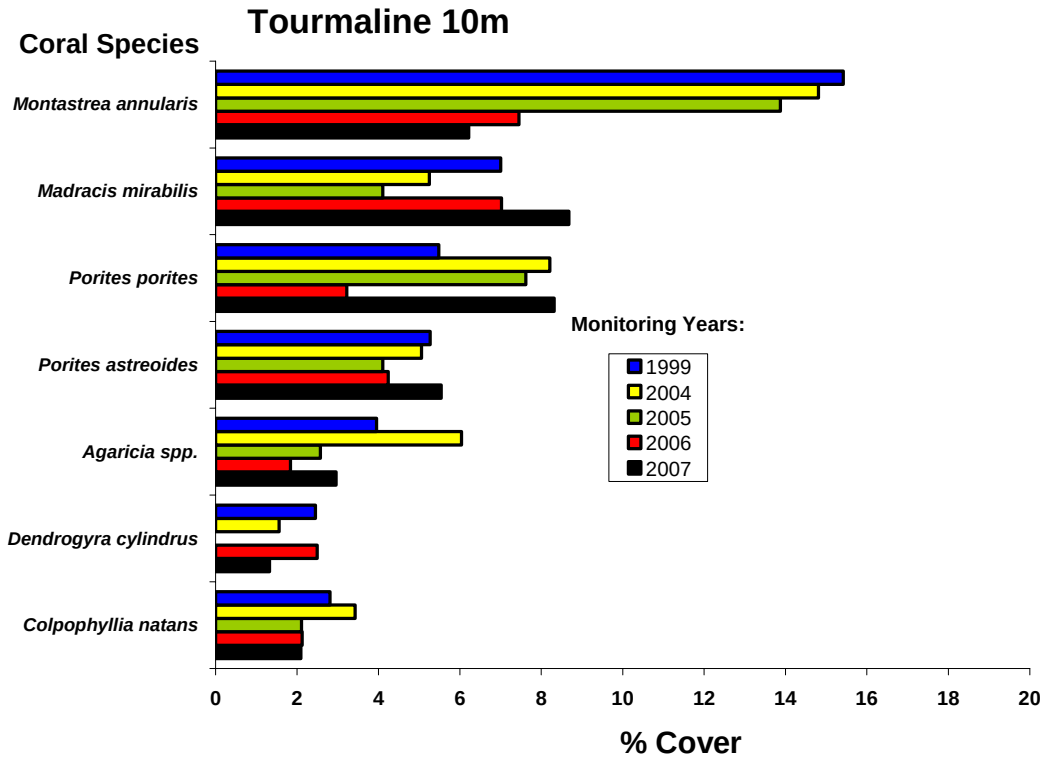


Figure 31. Monitoring trends (1999 – 2007) of mean cover by dominant stony coral species at Tourmaline Reef – 10 m, Mayaguez.

mirabilis compensated and slightly surpassed the decline in cover by *Montastrea annularis* and the overall result of live coral cover at Tourmaline Reef 10m between the 2006 and 2007 monitoring surveys was an increase of 11.2 %. Differences of live coral cover between monitoring surveys were not statistically significant ($p = 0.389$).

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 99 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 2007 survey was 97.6 Ind/30 m^2 (range: 46 - 131 Ind/30 m^2). The mean number of species per transect was 21.8 (range: 18 - 25). The Blue Chromis (Chromis cyanea), the Bicolor Damselfish (*Stegastes partitus*) and the Bluehead Wrasse (*Thalassoma bifasciatum*) were the numerically dominant species with a combined mean abundance of 49.2 Ind/30 m^2, representing 50.0 % of the total abundance within belt-transects (Table 35). A total of six species were present in all five transects. These included the Blue Chromis, Peppermint Goby, Beau gregory, Bicolor Damselfish, Redband and Striped Parrotfishes. The Bluehead Wrasse, Masked Goby and Creole Fish ranked among the top ten most abundant fishes but were not present in all transects.

Small, opportunistic micro-invertebrate predators (wrasses, gobies), demersal and pelagic schooling zooplanktivores (Blue Chromis, Creole Fish, Bicolor Damselfish,) and herbivores (*Scarus spp*., *Sparisoma spp*., *and Acanthurus spp*.) numerically dominated the reef fish community. Among large invertebrate and small demersal fish predators, small groupers such as Coneys and Graysbys were common. Adult Red Hind, Schoolmaster, Mahogany and Yellowtail Snappers represented top demersal predators observed during this and previous ASEC surveys at this reef (Table 36). Schools of Mackerel Scad, *Decapterus macarellus* and Ballyhoo, *Hemiramphus ballyhoo* were present near the surface over the reef. These serve as forage for pelagic predators, such as Cero Mackerels, Great Barracuda and Blue Runners.

Monitoring trends of fish species richness and abundance are presented in Figure 32. Only minor fluctuations have been observed for both community parameters and

Table 35. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, Mayaguez-10 m. June, 2007

Depth: 10 m

		TRANSECTS (Individuals/30m^2)					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Chromis cyanea	Blue Chromis	18	29	10	40	2	**19.8**
Thalassoma bifasciatum	Bluehead Wrasse	20	32	14	26		**18.4**
Stegastes partitus	Bicolor Damselfish	11	21	13	5	5	**11.0**
Coryphopterus personatus	Masked Goby	23	6				**5.8**
Clepticus parrae	Creole fish	1	17			6	**4.8**
Scarus iserti	Stripped Parrotfish	9	5	3	1	4	**4.4**
Stegastes leucostictus	Beau gregory	4	1	7	3	5	**4.0**
Haemulon flavolineatum	French Grunt	1		6	6		**2.6**
Halichoeres garnoti	Yellow-head Wrasse	4	4	2	3		**2.6**
Scarus taeniopterus	Princess Parrotfish	2		5	2	4	**2.6**
Sparisoma radians	Bucktooth Parrotfish	3	1	3	4	1	**2.4**
Sparisoma viride	Stoplight Parrotfish		4	2	3	3	**2.4**
Gobiosoma evelynae	Sharknose Goby	1	2	2	3		**1.6**
Sparisoma aurofrenatum	Redband Parrotifish	2	2		1	2	**1.4**
Chaetodon capistratus	Foureye Butterflyfish	2		2		2	**1.2**
Coryphopterus lipernes	Peppermint Goby	2	1	1	1	1	**1.2**
Acanthurus bahianus	Ocean Surgeon	2		1	1	1	**1.0**
Canthigaster rostrata	Caribbean Puffer	2				3	**1.0**
Myripristis jacobus	Blackbar Soldierfish			1	4		**1.0**
Flammeo marianus	Longspine squirrelfish	2	1		1		**0.8**
Gramma loreto	Fairy Basslet	2			2		**0.8**
Hypoplectrus unicolor	Butter Hamlet	1	1		1	1	**0.8**
Acanthurus chirurgus	Doctorfish	2				1	**0.6**
Acanthurus coeruleus	BlueTang			1	1	1	**0.6**
Amblycirrhitus pinos	Redspotted Hawkfish			1	2		**0.6**
Holocentrus coruscus	Reef Squirrelfish		1	1	1		**0.6**
Stegastes planifons	Yellow-eye Damselfish		2				**0.4**
Anisotremus virginicus	Porkfish			1			**0.2**
Cephalopholis cruentatus	Graysby				1		**0.2**
Chaetodon striatus	Banded Butterflyfish				1		**0.2**
Coryphopterus sp.	Goby	1					**0.2**
Cryptotomus roseus	Slender Parrotfish	1					**0.2**
Haemulon plumieri	White Grunt					1	**0.2**
Holacanthus ciliaris	Queen Angelfish					1	**0.2**
Holacanthus tricolor	Rock Beauty		1				**0.2**
Holocentrus rufus	Squirrelfish	1					**0.2**
Hypoplectrus puella	Barred Hamlet					1	**0.2**
Hypoplectrus nigricans	Black Hamlet	1					**0.2**
Microspathodon chrysurus	Yellowtail Damselfish				1		**0.2**
Monacanthus sp.	Filefish	1					**0.2**
Ocyurus chrysurus	Yellowtail Snapper					1	**0.2**
Serranus tigrinus	Harlequin Bass			1			**0.2**
Synodus intermedius	Sand Diver				1		**0.2**
	TOTAL INDIVIDUALS	**119**	**131**	**77**	**115**	**46**	**97.6**
	TOTAL SPECIES	**26**	**18**	**20**	**25**	**20**	**21.8**

temporal differences associated with monitoring surveys were statistically insignificant (ANOVA; $p > 0.05$). Variations of abundance are influenced by schooling zooplanktivores with highly aggregated distributions, such as the Blue Chromis (*Chromis cyanea*) and the Creole Wrasse (*Clepticus parrae*). Aggregated or patchy distributions tend to increase the magnitude of sampling variability and thus, increase the statistical uncertainty associated with the means.

As in deeper zones of Tourmaline outer shelf reef, the high rugosity with sand channels, crevices, large coral ledges and holes makes this reef an ideal habitat for large demersal fishes, such as snappers, groupers, hogfishes and others. Their occurrence in very low abundance may be related to the intense fishing pressure that this reef has experienced over the last 20-30 years, since the seasonal spawning aggregations of Red Hind were detected by local fishermen. Tourmaline outer reef has been seasonally (December – February) closed to fishing since 1993 to protect the declining Red Hind stock, but an intense fishing effort for finfish, lobster and conch with fish traps and SCUBA is still ongoing during the open fishing season. Although our fish surveys have been performed previous to the group spawning aggregation from December to February, the relatively low abundance of Red Hinds noted during our surveys in 1999, 2004, 2005, 2006 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 Arrow Crab, *Stenorhynchus seticornis* and the Fireworm, *Hermodice carunculata* were the only megabenthic invertebrates observed within belt-transects during the 2007 monitoring survey (Table 37). Spiny and Spotted Lobsters, *Panulirus argus*, *P. guttatus* Cleaner Shrimps, *Periclimenes pedersoni*, *Stenopus hispidus* have been previously reported observed outside transects during the ASEC surveys.

Table 36. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Tourmaline Outer Shelf Reef, 10 m, May, 2007

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

SPECIES	**COMMON NAME**		# - (cm)	
Carangoides crysos	Blue Runner	2 - (30)	1 - (40)	
Epinephelus guttatus	Red Hind	2 - (30)		
Lutjanus apodus	Schoolmaster	2 - (20)	2 - (30)	1 – (40)
Lutjanus synagris	Lane Snapper	4 - (15)	2 - (20)	2 - (25)
Lutjanus mahogany	Mahogany Snapper	1 – (25)		
Ocyurus chrysurus	Yellowtail Snapper	2 - (20)	1 – (30)	
Scomberomorus regalis	Cero Mackerel	4 - (50)	3 – (70)	
Sphyraena barracuda	Great Barracuda	1 - (75)		
Holacanthus tricolor	Rock Beauty	1 – (25)		
Invertebrates				
Panulirus guttatus	Spotted Spiny Lobster	2 – (10)		

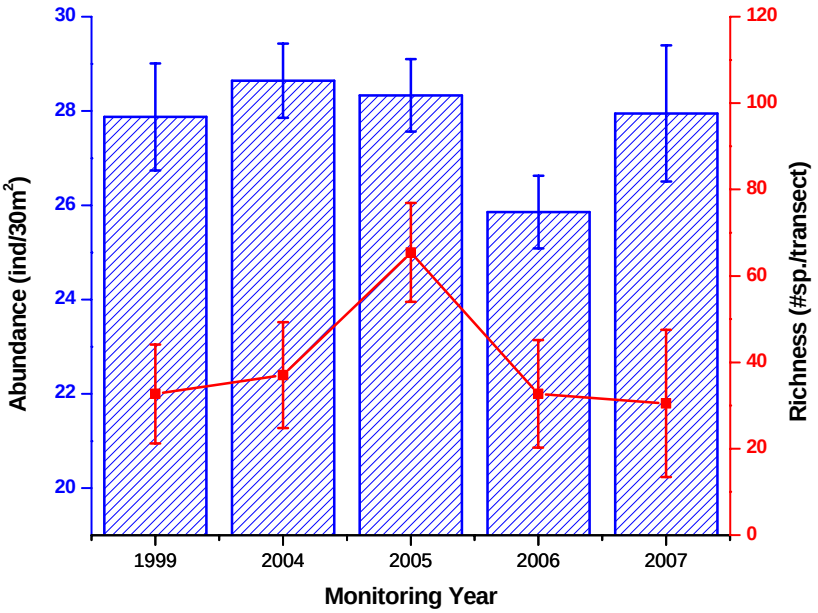


Figure 32. Monitoring trends (2004 – 2007) of fish species richness and abundance at Outer Shelf Reef Tourmaline, 10 m, Mayaguez.

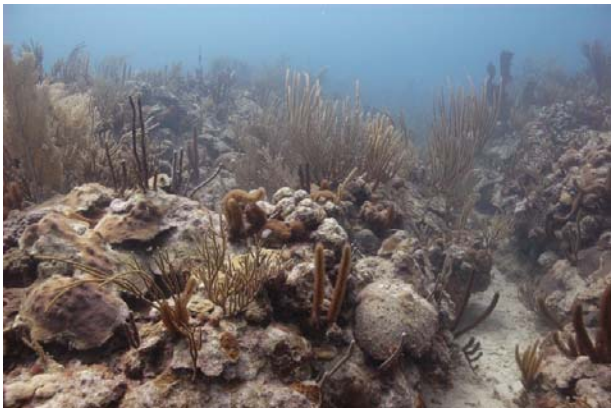
Table 37. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Outer-shelf Reef, 10 m, June, 2007

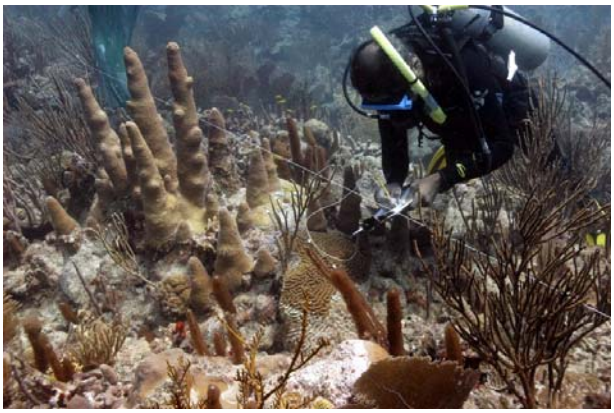
Depth: 10 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Hermodice carunculata	Bearded Fireworm		1				**0.2**
Stenorhynchus seticornis	Arrow Crab	1			1		**0.4**
	TOTALS	**1**	**1**	**0**	**1**	**0**	**0.6**

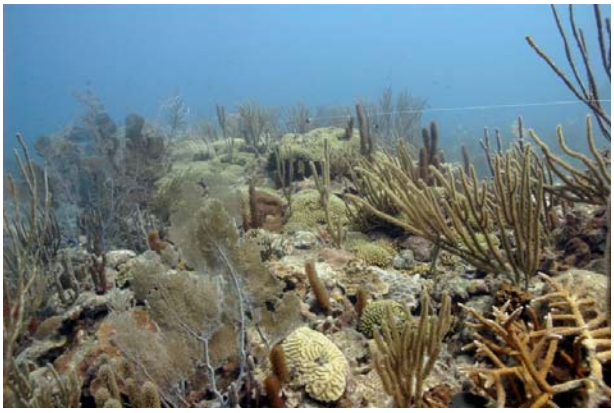
Photo Album 9 (Tourmaline 10 m)

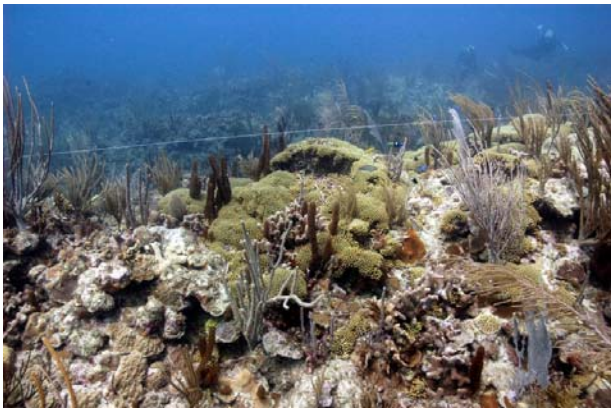
OuterShelf Reef










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 33). The reef is about two kilometers long and sits in the same platform as Caña Gorda Reef, at the landward's (northern) edge of Guánica's submarine canyon. A series of submerged patch reefs are found to the north and east of Cayo Coral. Our survey was performed on the existing set of five permanent transects at a depth of 7 - 8 meters close to the base of Cayo Coral's fore reef. Panoramic views of Cayo Coral are presented as Photo Album 10.

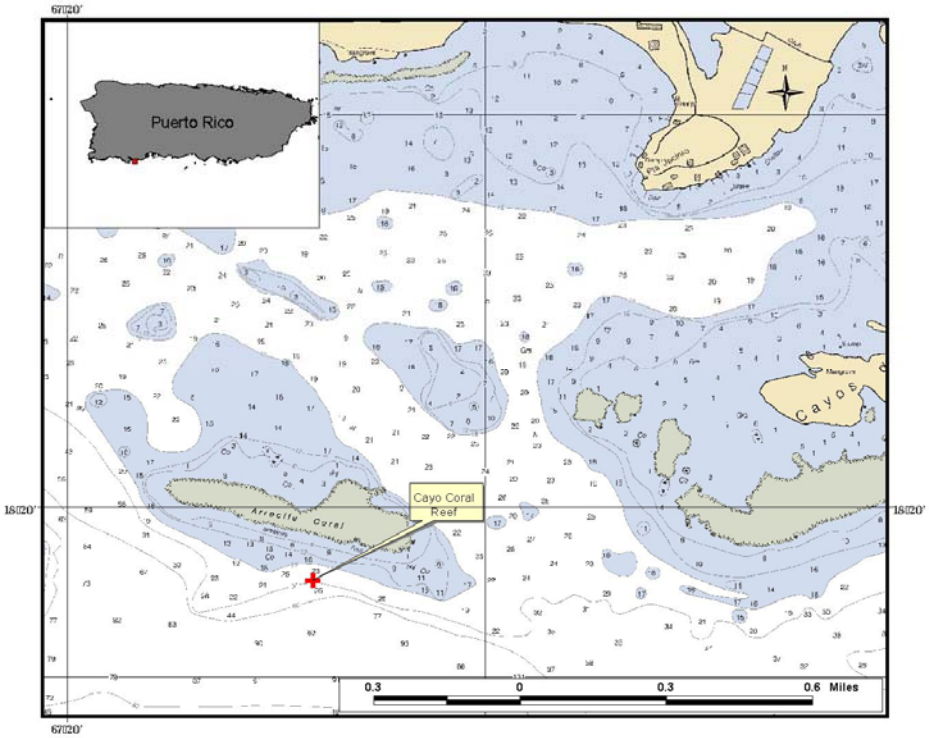


Figure 33. Location of coral reef survey stations at Cayo Coral Reef, Guánica.

4.1.0 Sessile-benthic Reef Community

A total of 19 stony corals, including nine (9) intersected by permanent line transects were identified from Cayo Coral Reef during the 2007 survey. Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 9.24 % (range: 2.50 – 15.05 %). Boulder Star Coral, *Montastrea annularis* (complex) was the main species in terms of substrate cover with a mean of 3.86% (range: 1.4 – 8.33 %), representing 41.8 % of the total cover by stony corals (Table 38). Great Star Coral, *M. cavernosa* and Mustard-Hill Coral, *Porites astreoides* ranked second and third in terms of substrate cover at Cayo Coral and along with Boulder Star Coral were the only species present in at least four out of the five transects surveyed.

Soft corals (gorgonians) were highly abundant, with a total of 24 species intercepted by the five transect matrix and an average of 21.0 colonies/transect. Sea Rods, *Pseudoplexaura flagellosa or wargeri, Plexaura kukenthali* and the Common Sea Fan, *Gorgonia ventalina* were the most abundant within transects. The high abundance of gorgonians contributed substantial complexity and substrate heterogeneity to Cayo Coral, representing an important protective habitat to reef fishes and invertebrates. Small sponges and patches of colonial zoanthids (*Palythoa caribbea***)** represented minor components of the reef benthos. Reef overhangs associated with mostly dead massive Boulder Star Coral colonies averaged 15.00 m and contributed substantially to the mean rugosity of 4.36 m. Recently dead coral accounted for a mean of 10.19 % of the reef substrate along surveyed transects. Partially bleached coral colonies were present in three out of the five transects (Table 38).

Benthic algae, comprised mostly by turf algae was the most prominent sessile-benthic category in terms of substrate cover with a mean of 63.00 % (range: 55.99 – 73.37 %). Turf algae was found colonizing hard ground substrates, including recently dead coral colonies. Recently dead coral colonies were also colonized by a reddish film of blue-green algae, or cyanobacteria. The cyanobacterial cover was most prominent in deeper sections of the fore reef slope (15 – 20 m), where it was observed to cover extensive sections of recently dead Boulder Star Coral.

Table 38. Percent linear cover by sessile-benthic categories at Cayo Coral, Guánica May 2007. Depth:

	TRANSECT					
	1	2	3	4	5	**MEAN**
Rugosity (m)	2.54	4.52	4.48	4.07	6.21	**4.36**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	9.57	19.42	11.12	18.34	16.53	**15.00**
Sand-silt	1.20		7.60	1.10	3.91	**2.76**
Rubble	6.30	6.47		15.14	7.83	**7.15**
Total Abiotic	17.07	25.89	18.72	34.58	28.27	24.91
Benthic Algae						
Turf-mixed assemblage	73.37	55.99	68.30	59.49	57.87	**63.00**
Calcareous	1.04			1.42	1.85	**0.86**
Total Benthic Algae	74.41	55.99	68.30	60.91	59.72	**63.86**
Cyanobacteria	0.48			0.78		**0.25**
Sponges	2.23	0.97		1.28	0.68	**1.03**
Zoanthids	0.56	1.45	0.58		0.26	**0.57**
Encrusting Gorgonian		0.68	0.29			**0.19**
Live Coral						
Montastrea annularis	2.95	2.41	4.21	1.40	8.33	**3.86**
Montastrea cavernosa	1.59	2.34	1.93	0.40	0.43	**1.34**
Porites astreoides	0.80	2.34	0.88		2.34	**1.27**
Siderastrea siderea		3.99				**0.80**
Eusmilia fastigiata		3.10				**0.62**
Colpophyllia natans			2.53			**0.51**
Meandrina meandrites			2.35			**0.47**
Diploria strigosa		0.87		0.70		**0.31**
Madracis decactis			0.29			**0.06**
Total Live Coral	5.34	15.05	12.19	2.50	11.10	**9.24**
Partially bleached coral	1.36	2.41	0.58	0.00	0.00	**0.87**
Recently dead coral	17.94	21.42	11.60	0.00	0.00	**10.19**
Gorgonians (# colonies)						
Pseudoplexaura flagellosa or wargeri	4.00	9.00	4.00		1.00	**3.6**
Gorgonia ventalina	3.00	3.00	2.00	4.00	2.00	**2.8**
Plexaura kukenthali		1.00	1.00	4.00	4.00	**2.0**
Briaerum asbestinum		1.00	2.00	1.00	4.00	**1.6**
Eunicea turnetorti	1.00		1.00		4.00	**1.2**
Pseudoplexaura flagellosa or wargeri				3.00	3.00	**1.2**
Eunicea succinea	2.00				2.00	**0.8**
Plexaura spp.	2.00	1.00	1.00			**0.8**
Plexaurella sp.		1.00		3.00		**0.8**
Pseudopterogorgia americana			1.00		2.00	**0.6**
Erythropodium caribeorum	2.00				1.00	**0.6**
Eunicea lacinata			1.00	1.00	1.00	**0.6**
Plexaura kuna	1.00	1.00			1.00	**0.6**
Eunicea spp.		1.00	1.00	1.00		**0.6**
Pseudoplexaura purosa				3.00		**0.6**
Muriceopsis flavida		1.00			1.00	**0.4**
Plexaura homomalla	1.00				1.00	**0.4**
Muricea elognata		1.00	1.00			**0.4**
Plexaura flexuosa	1.00		1.00			**0.4**
Pseudopterogorgia americana				1.00		**0.2**
Pseudoplexaura acerosa			1.00			**0.2**
Pseudoplexaura purosa	1.00					**0.2**
Pseudoptergorgia bipinnata	1.00					**0.2**
Pseudoplexaura purosa	1.00					**0.2**
Total Gorgonians (# colonies/transect)	**20.00**	**20.00**	**17.00**	**21.00**	**27.00**	**21.0**

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

Figure 34 presents the variations of mean percent cover by sessile-benthic categories from Cayo Coral, including data from the original baseline survey in 1999, and subsequent monitoring surveys of 2005, 2006 and 2007. Differences of reef substrate cover by live stony corals between surveys were statistically significant (ANOVA; p = 0.00015), and constitute evidence of degradation of the coral reef community structure. The reduction of 16 % of mean substrate cover between the baseline survey in 1999 and the 2007 monitoring survey represents a decline of approximately 64 % 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.

Variations of the mean substrate cover by coral species during monitoring surveys are shown in Figure 35. A drastic decline of the percent substrate cover by Boulder Brain Coral, *Montastrea annularis* (complex) is evident from the monitoring data. The variations of cover by *M. annularis* between monitoring years were statistically significant (ANOVA; p = 0.045). Boulder Brain Coral declined its mean substrate cover by approximately 40 % between 1999 and 2005 (from 10.49 % to 6.5%), and suffered another reduction of 55% between 2005 and 2006 (from 6.5 % to 2.9 %). Other scleractinian coral species that have shown marked declines of substrate cover at Cayo Coral include *Colpophyllia natans* and *Agaricia spp*. Conversely, the high abundance and richness of soft coral (gorgonian) colonies has remained virtually constant between surveys.

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 99 fish species have been identified from Cayo Coral during monitoring surveys (Appendix 1). Mean abundance within belt-transects during May, 2007 was 52.8 Ind/30 m^2 (range: 34 - 73 Ind/30 m^2). The mean number of species per transect was 18.0 (range: 19 - 25). Bluehead Wrasse (*Thalassoma bifasciatum*), Striped Parrotfish (*Scarus iserti*), Dusky Damselfish (*Stegastes partitus*) and Sharknose Goby (*Gobiosoma evelynae*) were the numerically dominant species with a combined mean abundance of 22.0 Ind/30 m^2, representing 41.7 % of the total abundance within belt-transects (Table 39). Nine species were present on all five transects surveyed, whereas other four species were present on four transects.

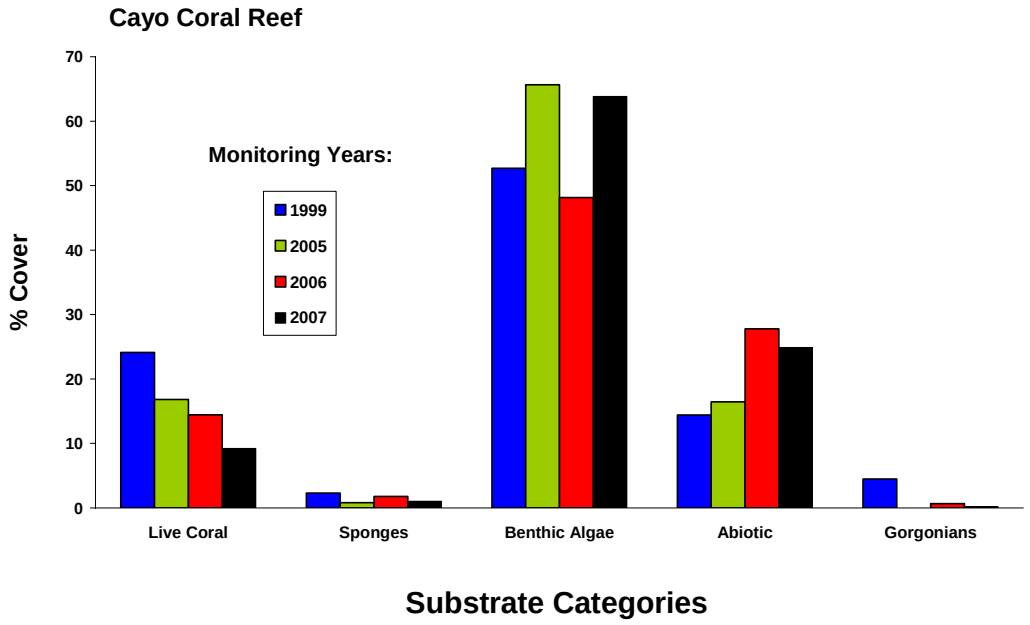


Figure 34. Monitoring trends (1999 – 2007) of mean substrate cover by sessile-benthic categories at Cayo Coral – 8 m, Guánica.

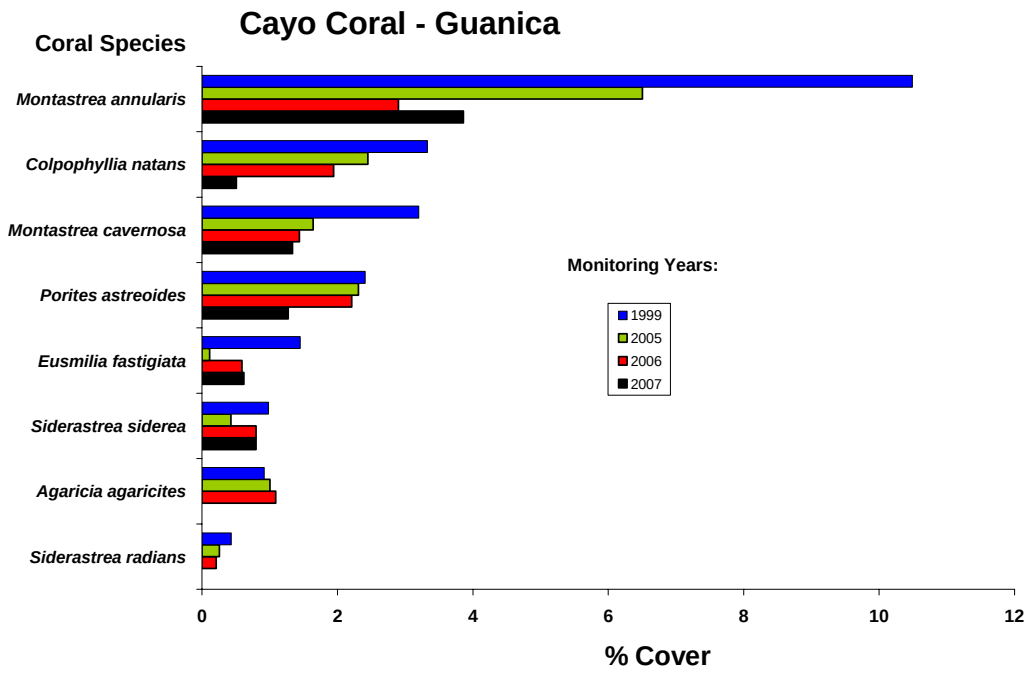


Figure 35. Monitoring trends (1999 – 2007) of mean substrate cover by dominant stony coral species at Cayo Coral – 8 m, Guánica

Table 39. Taxonomic composition and abundance of fishes within belt-transects at Cayo Coral, Guánica. May, 2007

Depth: 8 - 10m		TRANSECTS (Individuals/30m^2)					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	1	6	1	5	24	**7.4**
Scarus iserti	Stripped Parrotfish		10	5	6	8	**5.8**
Stegastes dorsopunicans	Dusky Damselfish	6	5	6	2	5	**4.8**
Gobiosoma evelynae	Sharknose Goby	2	1	8	3	6	**4.0**
Chromis cyanea	Blue Chromis		7	6			**2.6**
Halichoeres garnoti	Yellow-head Wrasse	2	4	1	2	3	**2.4**
Sparisoma aurofrenatum	Redband Parrotifish	2	1	1	3	3	**2.0**
Stegastes leucostictus	Beau gregory	2		4	3	1	**2.0**
Sparisoma viride	Stoplight Parrotfish		3		4	2	**1.8**
Stegastes planifrons	Yellow-eye Damselfish	4	4	1			**1.8**
Canthigaster rostrata	Caribbean Puffer	1	1	2	2	2	**1.6**
Microspathodon chrysurus	Yellowtail Damselfish	1	2		1	3	**1.4**
Sparisoma radians	Bucktooth Parrotfish	3			3	1	**1.4**
Cephalopholis cruentatus	Graysby	1	1	1	1	2	**1.2**
Holocentrus rufus	Squirrelfish	1	1	1	2	1	**1.2**
Stegastes partitus	Bicolor Damselfish	1	2		1	2	**1.2**
Acanthurus bahianus	Ocean Surgeon	1			2	2	**1.0**
Chaetodon capistratus	Foureye Butterflyfish	2		1	2		**1.0**
Coryphopterus sp.	Goby	1	1	1	1	1	**1.0**
Haemulon flavolineatum	French Grunt			2	2	1	**1.0**
Acanthurus chirurgus	Doctorfish		2	1		1	**0.8**
Scarus taeniopterus	Princess parrotfish		2			2	**0.8**
Serranus tigrinus	Harlequin Bass			1	1	1	**0.6**
Acanthurus coeruleus	BlueTang		1	1			**0.4**
Abudefduf sexatilis	Sargent Major			2			**0.4**
Pseudupeneus maculatus	Yellowtail Goatfish	1				1	**0.4**
Acanthostracion quadricornis	Scrawled Cowfish				1		**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish				1		**0.2**
Anisotremus virginicus	Porkfish					1	**0.2**
Chaetodon striatus	Banded Butterflyfish			1			**0.2**
Halichoeres radiatus	Puddinwife				1		**0.2**
Hypoplectrus nigricans	Black Hamlet		1				**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	1					**0.2**
Hypoplectrus unicolor	Butter Hamlet			1			**0.2**
Lutjanus mahogany	Mahogany Snapper			1			**0.2**
Mycteroperca venenosa	Yellowfin Grouper			1			**0.2**
Odontoscion dentex	Reef Croaker			1			**0.2**
Pomacanthus arcuatus	Gray Angelfish			1			**0.2**
Sparisoma chrysopterum	Redtail Parrotfish				1		**0.2**
Stegastes variabilis	Cocoa Damselfish	1					**0.2**
	TOTAL INDIVIDUALS	**34**	**55**	**52**	**50**	**73**	**52.8**
	TOTAL SPECIES	**19**	**19**	**25**	**23**	**22**	**18.0**

Small, opportunistic micro-invertebrate predators (wrasses, gobies, and puffers), demersal and pelagic schooling zooplanktivores (Blue Chromis, Creole Wrasse, Mackerel Scad, Bicolor Damselfish,) and herbivores (*Scarus spp., Sparisoma spp*., *and 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. One juvenile Yellowfin Grouper, adult Red Hind, Nassau Grouper, Hogfish, Schoolmaster, Mahogany and Yellowtail Snappers represented top demersal predators observed during the 2007 ASEC survey at Cayo Coral (Table 40). One juvenile Jewfish (*Epinephelus itajara*) was previously reported from Cayo Coral (Garcia-Sais et al., 2006). Pelagic predators, such as Cero Mackerels, Great Barracudas and Blue Runners were observed during the ASEC survey.

Table 40. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Cayo Coral. Guánica. May, 2007

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

SPECIES	**COMMON NAME**	# - (cm)		
Caranx crysos	Blue Runner	3 - (35)		
Epinephelus guttatus	Red Hind	2 - (25)	1 - (30)	
Epinephelus striatus	Nassau Grouper	1 – (40)		
Holacanthus ciliaris	French Angel	1 – (30)		
Lachnolaimus maximus	Hogfish	1 - (35)		
Lutjanus apodus	Schoolmaster	1 - (20)	3 - (30)	1 – (35)
Lutjanus mahogany	Mahogany Snapper	1 - (15)	2 – (20)	2 – (25)
Lutjanus synagris	Lane Snapper	5 - (15)	1 – (25)	
Ocyurus chrysurus	Yellowtail Snapper	3 - (15)	6 – (25)	5 - (30)
Mycteroperca venenosa	Yellowfin Grouper	1 – (30)		
Negaprion brevirostris	Nurse Shark	1 – (90)		
Invertebrates				
Panulirus guttatus	Rock Lobster	1 - (15)		
Panulirus argus	Spiny Lobster	2 - (20)		

Cleaner Shrimp (*Periclimenes pedersoni*), Queen Conch (*Strombus gigas*) and the Arrow Crab (*Stenorhinchus seticornis*) were the motile megabenthic invertebrates observed within belt-transects (Table 41). Two juvenile Spiny Lobsters (*Panulirus argus*) and one Rock Lobster (*P. guttatus*) were observed outside transects.

Table 41. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Coral, 8 m depth, Guánica. May, 2007

		TRANSECTS					
Depth: 8 -10 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Periclimenes pedersoni	Cleaner Shrimp		1				**0.2**
Stenorhynchus seticornis	Arrow Crab	1					**0.2**
Strombus gigas	Queen Conch			1			**0.2**
	TOTALS	1	1	1	0	0	**0.6**

Figure 36 displays monitoring trends of fish abundance and species richness from Cayo Coral. Variations of abundance and species richness between monitoring surveys were statistically significant (ANOVA; $p < 0.05$). Both species richness and abundance were significantly lower during the baseline survey in 1999 than in subsequent monitoring surveys. Such difference may be biased by very turbid conditions prevailing during the initial baseline survey. Differences of fish species richness and/or abundance between monitoring surveys (2004-07) were not significantly different (ANOVAS; $p > 0.5$).

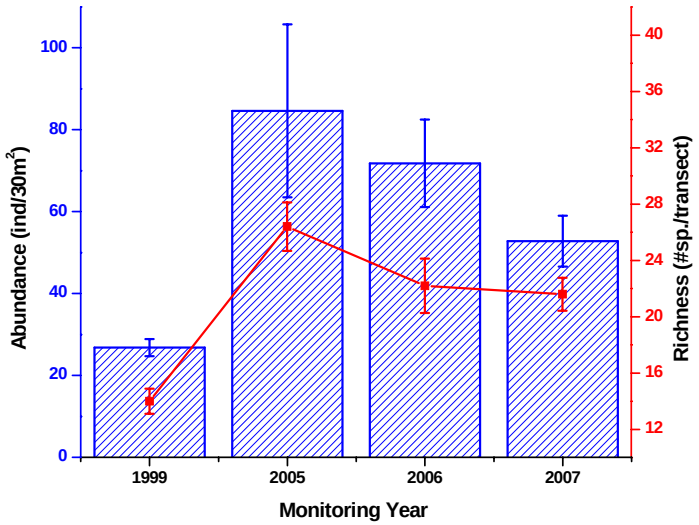


Figure 36. Monitoring trends (1999 – 2007) of fish species richness and abundance at Cayo Coral Reef, 8 m, Guánica Natural Reserve.

Photo Album 10 (Guánica 10 m)
Cayo Coral Reef

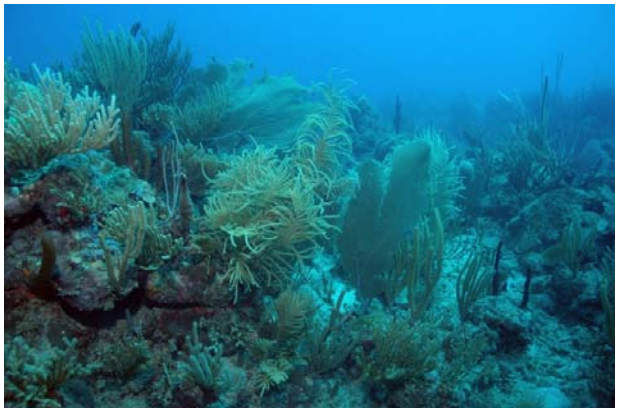















5.0 West Reef of Isla Caja de Muerto – Ponce

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 37). 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.

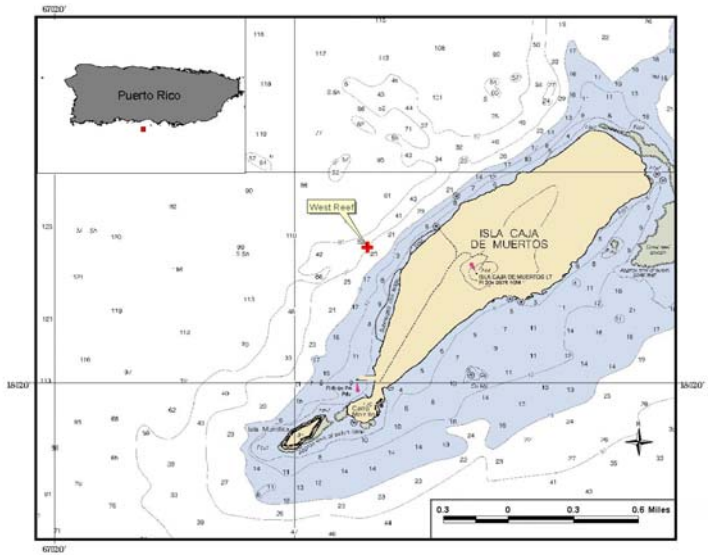


Figure 37. Location of coral reef survey stations at West Reef of Isla Caja de Muerto, Ponce.

1.0 Sessile-benthic Reef Communities

A dense algal turf, comprised by a mixed assemblage of short filamentous red and brown algae was the dominant component of the reef sessile-benthic biota in terms of substrate cover at West Reef. Turf algae averaged 45.13 % (range: 36.04 – 51.87 %) along permanent transects and was observed colonizing dead coral colonies and other hard ground substrates in the reef. Fleshy brown (*Dictyota sp*.) and calcareous (*Halimeda opuntia*) macroalgae represented minor components of the benthic algae assemblage at West Reef (Table 42). Cyanobacterial (blue-green algal) mats were prominent at the reef benthos with an average cover of 8.95 % (range: 3.75 – 14.37 %). During the 2006 survey cyanobacteria was observed at West Reef in very low cover (e.g. mean: 0.68%). This bloom appears to be associated and proportional to the amount of recently dead coral observed after the late 2005 massive coral bleaching event affecting reef systems of Puerto Rico and the USVI (García-Sais et al., 2006).

Live stony corals presented a mean substrate cover of 10.70 % (range: 4.52 – 13.99 %) along transects surveyed during 2007. Boulder Star Coral, *Montastrea annularis* (complex) was the dominant coral species with a mean substrate cover of 4.27 % (range: 1.58 – 7.14 %), representing 39.9 % of the total substrate cover by live stony corals. A total of 19 species of stony corals were identified from West Reef, including 14 species intersected by transects. Great Star Coral (*M. cavernosa*), Mustard-Hill Coral (*Porites astreoides*), and Greater Starlet Coral, *Siderastrea siderea* were present in at least three out of the five transects surveyed, and along with Boulder Star Coral comprised the main coral assemblage of the West Reef (Table 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*). Sponges were present in all five transects with a mean substrate cover of 21.50 %, representing the main sessile-benthic invertebrate in terms of substrate cover at West Reef.

Table 42. Percent substrate cover by sessile-benthic categories at West Reef, Isla Caja de Muerto, March 2007.

	TRANSECT					
Depth: 7.0 m	1	2	3	4	5	**MEAN**
Rugosity (m)	3.32	6.10	5.37	8.13	6.85	**5.95**
SUBSTRATE CATEGORY						
Abiotic						
Rubble	20.65	2.19	8.46	2.15	6.00	**7.89**
Reef Overhangs	1.48	11.99	1.01		1.25	**3.15**
Sand-silt	4.13	0.68	4.10	0.31	1.19	**2.08**
Total Abiotic	26.26	14.86	13.57	2.46	8.44	**13.12**
Benthic Algae						
Turf-mixed assemblage	46.25	49.88	36.04	51.87	41.63	**45.13**
Fleshy		0.52	0.27			**0.16**
Calcareous				0.78		**0.16**
Total Benthic Algae	46.3	50.4	36.3	52.7	41.6	**45.4**
Cyanobacteria	9.91	7.33	9.37	3.75	14.37	**8.95**
Sponges	13.06	14.35	27.85	25.85	26.37	**21.50**
Encrusting gorgonian			0.18	1.27		**0.29**
Live Stony Corals						
Montastrea annularis (complex)	1.58	7.14	6.70	3.25	2.67	**4.27**
Montastrea cavernosa		4.29		4.69	1.19	**2.03**
Porites astreoides	1.88	0.44	3.38	1.49	2.20	**1.88**
Siderastrea siderea		0.79	1.47	1.86		**0.82**
Stephanocoenia michelini	0.85			0.54	0.50	**0.38**
Siderastrea radians		0.35			1.19	**0.31**
Meandrina meandrites				1.16		**0.23**
Millepora spp.	0.21				0.59	**0.16**
Madracis decactis				0.77		**0.15**
Eusmilia fastigiata			0.72			**0.14**
Agaricia agaricites					0.59	**0.12**
Agaricia lamarcki			0.46			**0.09**
Diploria labyrinthiformis					0.33	**0.07**
Porites porites				0.23		**0.05**
Total Live Stony Corals	4.52	13.01	12.73	13.99	9.26	**10.70**
Recently dead coral	6.46	18.70	7.06	6.21		**7.69**
Partially bleached coral		1.31	6.25			**1.51**
Gorgonians (# colonies)						
Pseudoptergorgia americana	9.00	1.00	12.00	10.00	12.00	**8.80**
Briaerum asbestinum	4.00		5.00	7.00	3.00	**3.80**
Plexaura flexuosa	3.00	2.00	4.00	4.00	4.00	**3.40**
Gorgonia ventalina	2.00	2.00	3.00	3.00	5.00	**3.00**
Plexaura kukenthali	2.00		3.00	3.00	1.00	**1.80**
Pseudoplexaura flagellosa or wargeri	1.00	1.00		2.00	2.00	**1.20**
Eunicea turnetorti				2.00	1.00	**0.60**
Muriceopsis flavida	1.00		2.00			**0.60**
Pseudoptergorgia acerosa			1.00	1.00	1.00	**0.60**
Erythropodium caribeorum	1.00	1.00				**0.40**
Eunicea succinea			1.00		1.00	**0.40**
Pseudoplexaura purosa			1.00	1.00		**0.40**
Pseudoptergorgia spp.					2.00	**0.40**
Eunicea asperula					1.00	**0.20**
Plexaurella spp.				1.00		**0.20**
Pseudoptergorgia bipinnata			1.00			**0.20**
Total Gorgonians (# colonies/transect)	**23.00**	**7.00**	**33.00**	**34.00**	**33.00**	**26.00**

Coral Species Outside Transects: *Diploria strigosa, Isophyllia sinuosa, Dichocoenia stokesii, Mycetophyllia lamarckiana, Leptoseris cucullata*

Abiotic categories, including coral rubble, reef overhangs and sand/silt sediments combined for a mean substrate cover of 13.12 %. Reef overhangs contributed to a mean rugosity of 5.95 m. Coral rubble and sand accumulated within crevices, holes and gaps of the highly irregular bottom topography. The high rugosity was strongly influenced by dead coral (mostly *Montastrea annularis*).

Figure 38 presents the variations of mean percent cover by sessile-benthic categories from West Reef, including the original baseline survey of 1999 and annual monitoring surveys of 2005, 2006 and the present 2007. Differences of mean percent cover by stony corals were statistically significant (ANOVA; $p = 0.0125$), indicative of a degradation of the coral reef community structure. Such degradation has been consistently measured in every monitoring survey, but was most drastic in 2006 after the massive coral bleaching event of October 2005 (Garcia-Sais et al., 2006). The 5 % reduction of mean substrate cover by live corals 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 (ANOVA; $p = 0.233$). 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. Sharp reductions of live coral were measured in all transects surveyed and was statistically significant (ANOVA; $p = 0.0069$). During 2007 live coral declined again, but the 6.3 % decline was relatively small compared to previous records and statistically similar to the 2006 condition. Recently dead coral accounted for a total of 7.69 % during 2007, associated with mortality of massive corals, such as *Montastrea annularis* and *Colpophyllia natans* after the late 2005 coral bleaching event. Partially bleached corals were observed during the 2007 survey and represented 1.5 % of the total cover by live corals at West Reef.

Variations of the mean substrate cover by coral species are shown in Figure 39. Boulder Star Coral, *Montastrea annularis* exhibited a decline of 16 % between the baseline survey of 1999 and the 2005 survey, but then dropped 58.0 % between 2005 and 2006, driving the overall decline of live coral cover at West Reef. During the 2007 survey, *M. annularis* declined again 7.4 % from its cover in 2006. Minor reductions of substrate cover by live corals have also been measured for Lettuce Coral and Boulder Brain Coral.

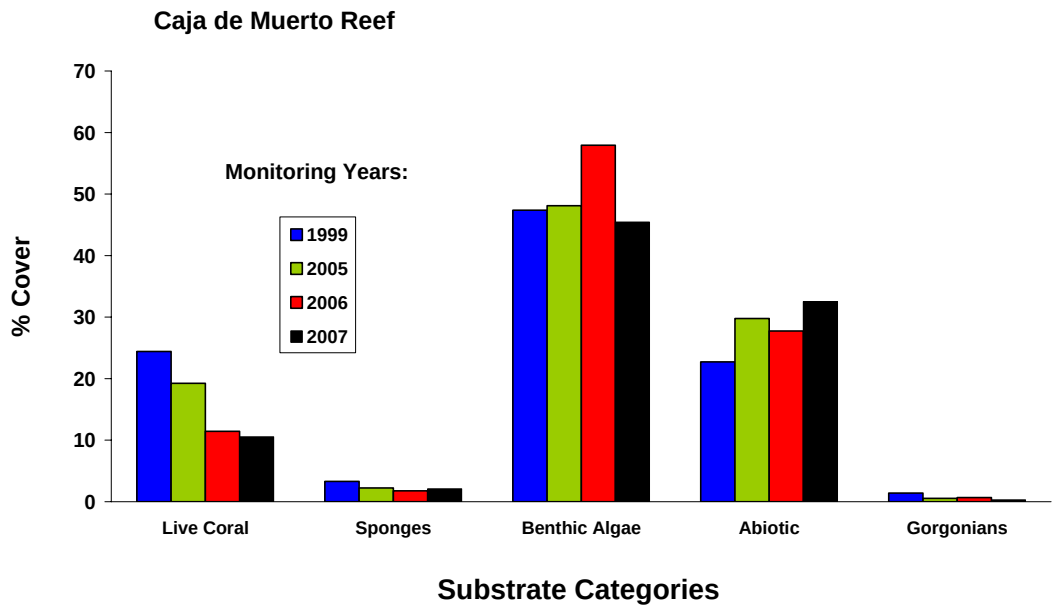


Figure 38. Monitoring trends (1999 - 2007) of mean substrate cover by sessile-benthic categories at West Reef, Isla Caja de Muerto, Ponce.

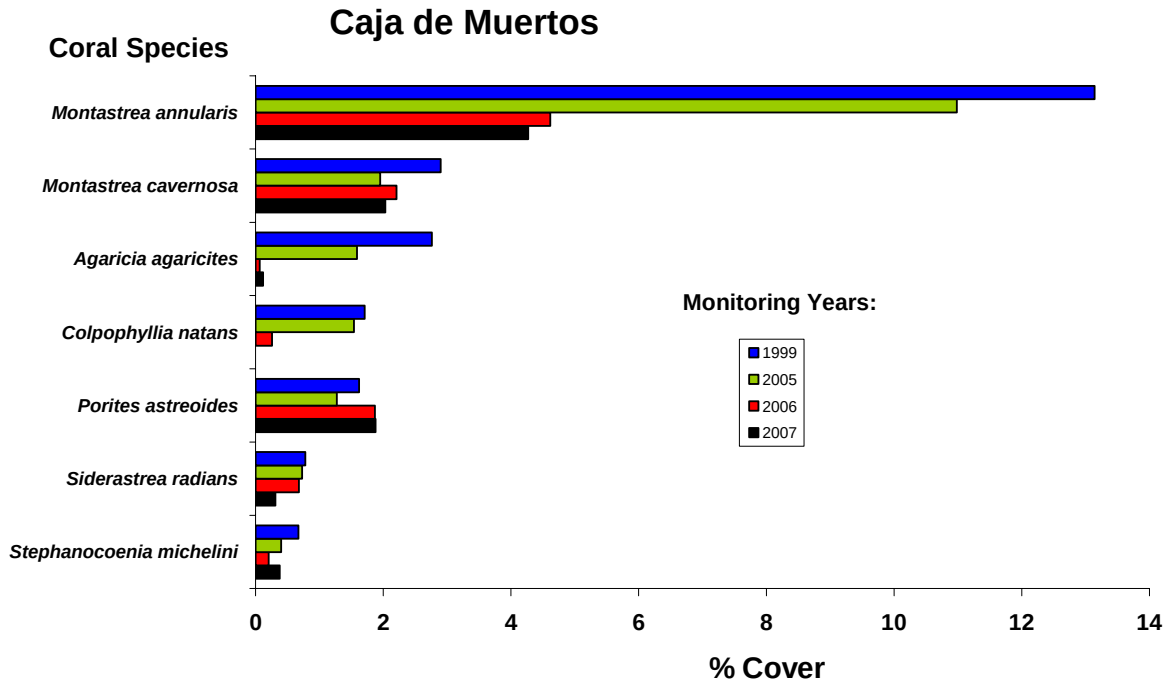


Figure 39. Monitoring trends (1999 – 2007) of mean substrate cover by dominant stony coral species at West Reef, Isla Caja de Muerto, Ponce.

Fishes and Motile Megabenthic Invertebrates

A total of 88 fish species have been identified during monitoring surveys from West Reef, Isla Caja de Muerto (Appendix 1). Mean abundance of fishes within belt-transects during March 2007 was 68.8 Ind/30 m^2 (range: 37 - 98 Ind/30 m^2). The mean number of species per transect was 18.4 (range: 13 - 25). The Masked Goby (*Coryphopterus personatus*) was the numerically dominant species with a mean abundance of 19.8 Ind/30 m^2 (range: 4 - 40 Ind/30 m^2), representing 26.7 % 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, Bicolor, and Three spot Damselfishes, Blackbar Soldierfish, and Bridled Goby were present in all five transects surveyed, and represented, along with the Masked Goby, Brown Chromis and Striped Parrotfish the main fish assemblage of West Reef (Table 43).

The fish community structure at West Reef is comprised by zooplankton feeders, including the Masked Goby, Brown Chromis, Bicolor Damselfish, Caribbean Puffer, Creole Wrasse and Mackerel Scad. Some of these species were not prominent within belt-transects, but were observed forming large schooling aggregations in the water column over the reef. These species are known to serve as forage for a diverse assemblage of top pelagic and demersal predators, including barracudas, jacks, and large groupers and snappers observed during 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, Mahogany, Lane, Grey and Schoolmaster Snappers, Red Hind, and Coney were observed during the ASEC survey (Table 44). Large Cubera Snapper (*Lutjanus cyanopterus*) and a juvenile Yellowfin Grouper (*Mycteroperca venenosa*) have been reported during previous surveys (Garcia-Sais et al., 2005*).* Large aggregations of more than 700 juvenile and young adult Lane Snappers (*Lutjanus synagris*) were observed near the base of the reef, along the reef-sand interface during the 2006 ASEC survey. During the 2007 survey such large aggregations of Lane Snappers were not observed, but it is uncertain if they were on foraging migratory movements to adjacent seagrass beds or elsewhere.

Table 43. Taxonomic composition and abundance of fishes within belt-transects at West Reef, Isla Caja de Muerto, Ponce - 15 m depth. March, 2007

Depth: 6.5 m

SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	4	40	28	6	21	**19.8**
Thalassoma bifasciatum	Bluehead Wrasse	12	12	17	18	10	**13.8**
Chromis multilineata	Brown Chromis			14	9		**4.6**
Stegastes dorsopunicans	Dusky Damselfish		10		8	3	**4.2**
Scarus iserti	Stripped Parrotfish	7		5		4	**3.2**
Stegastes partitus	Bicolor Damselfish	2	5	6	1	2	**3.2**
Stegastes planifrons	Three spot Damselfish	3	2	8	1	1	**3.0**
Chaetodon capistratus	Foureye Butterflyfish	1	2	2	2	1	**1.6**
Myripristis jacobus	Blackbar Soldierfish	1	1	3	2		**1.4**
Gobiosoma evelynae	Sharknose Goby		1		1	4	**1.2**
Sparisoma radians	Bucktootth Parrotfish			1		5	**1.2**
Acanthurus bahianus	Ocean Surgeon			2	1	2	**1.0**
Coryphopterus glaucofraenum	Bridled Goby	1	1	1	1	1	**1.0**
Halichoeres garnoti	Yellow-head Wrasse	2		1		2	**1.0**
Chromis cyanea	Blue Chromis		1	2			**0.6**
Haemulon flavolineatum	French Grunt		1		1	1	**0.6**
Scarus taeniopterus	Princess Parrotfish		2			1	**0.6**
Sparisoma aurofrenatum	Redband Parrotfish	1		2			**0.6**
Stegastes leucostictus	Beau gregory				1	2	**0.6**
Canthigaster rostrata	Caribbean Puffer		1			1	**0.4**
Cephalopholis cruentatus	Graysby			1		1	**0.4**
Holocentrus rufus	Squirrelfish				1	1	**0.4**
Hypoplectrus nigricans	Black Hamlet			1	1		**0.4**
Hypoplectrus puella	Barred Hamlet	1				1	**0.4**
Hypoplectrus unicolor	Butter Hamlet		1	1			**0.4**
Pseudupeneus maculatus	Yellowtail Goatfish		1			1	**0.4**
Acanthurus chirurgus	Doctorfish					1	**0.2**
Acanthurus coeruleus	BlueTang			1			**0.2**
Abudefduf sexatilis	Sargent Major				1		**0.2**
Aulostomus maculatus	Trumpetfish			1			**0.2**
Epinephelus guttatus	Red Hind					1	**0.2**
Equetus punctatus	Spotted Drum				1		**0.2**
Haemulon aurolineatum	Tomtate				1		**0.2**
Holacanthus tricolor	Rock Beauty					1	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet					1	**0.2**
Lutjanus mahogany	Mahogany Snapper			1			**0.2**
Pomacanthus paru	French Angelfish	1					**0.2**
Scarus vetula	Queen Parrotfish	1					**0.2**
Sparisoma viride	Stoplight Parrotfish					1	**0.2**
Synodus intermedius	Lizardfish		1				**0.2**
	TOTAL INDIVIDUALS	**37**	**82**	**98**	**57**	**70**	**68.8**
	TOTAL SPECIES	**13**	**16**	**20**	**18**	**25**	**18.4**

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 during the 2006 ASEC survey (García-Sais et al., 2006). Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous fish assemblage of West Reef.

Motile megabenthic invertebrates were represented within belt-transects by Reef and Rock boring Urchins (*Echinometra viridis, E. lucunter*), and the Three Rowed Sea Cucumber (Table 45).

Table 44. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at West Reef, Isla Caja de Muerto, March, 2007.

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

SPECIES	**COMMON NAME**		# - (cm)	
Epinephelus guttatus	Red Hind	1 - (25)		
Holacanthus tricolor	Rock Beauty	2 - (25)		
Holacanthus ciliaris	Queen Angel	1 - (25)	1 - (40)	
Lachnolaimus maximus	Hogfish	1 - (35)		
Lutjanus apodus	Schoolmaster	1 – (15)	3 - (25)	1 - (30)
Lutjanus griseus	Grey Snapper	2 - (30)		
Lutjanus mahogany	Mahogany Snapper	3 - (20)	1 - (25)	
Lutjanus griseus	Grey Snapper	2 – (25)		
Lutjanus synagris	Lane Snapper	2 – (20)	4 – (25)	
Ocyurus chrysurus	Yellowtail Snapper	43 – (25)	5 – (30)	3 – (40)
Pomacanthus paru	French Angelfish	1 – (40)		
Scomberomorus regalis	Cero Mackerel	2 - (60)	1 – (70)	
Sphyraena barracuda	Great Barracuda	1 - (60)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (12)	1 - (15)	1 - (20)

Table 45. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at West Reef, Caja de Muerto. March, 2007

DATE: March, 2007 Depth: 6 - 7 m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	DEPTH (m) COMMON NAME						
Echinometra lucunter	Rock boring Urchin			1		1	**0.4**
Echinometra viridis	Reef Urchin		1	1			**0.4**
Isostichopus badionotus	Three Rowed Sea Cucumber			1			**0.2**
	TOTALS	**0**	**1**	**3**	**0**	**1**	**1.0**

Figure 40 shows the annual trends of fish abundance and species richness during monitoring surveys at West Reef. Statistically significant differences of fish abundance (ANOVA; $p < 0.001$) were found. These differences were driven by abundance fluctuations of the dominant species within belt transects, the Masked Goby (*Coryphopterus personatus*). Differences in fish species richness within belt-transects were also detected (ANOVA; $p < 0.001$). Nevertheless, during the present 2007 survey both fish species richness and abundance remained similar to baseline values in 1999.

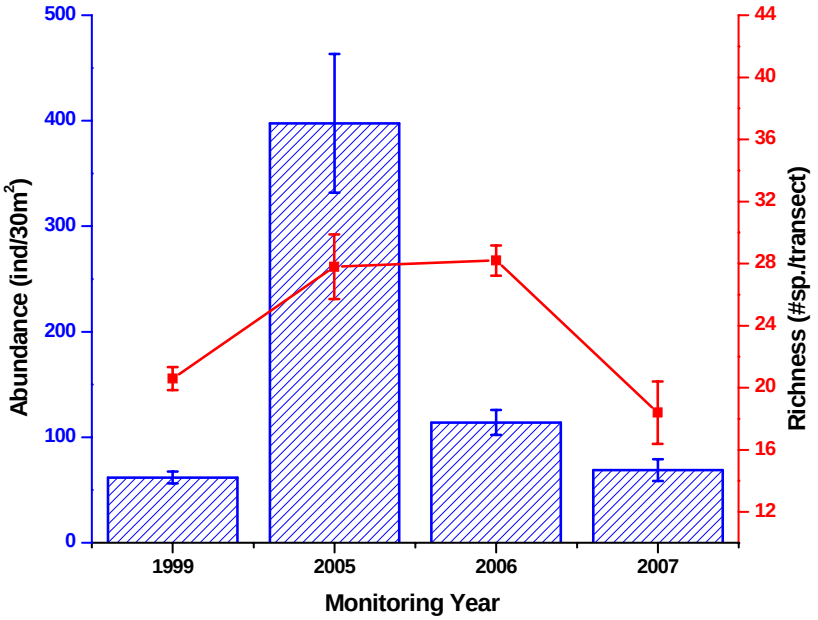
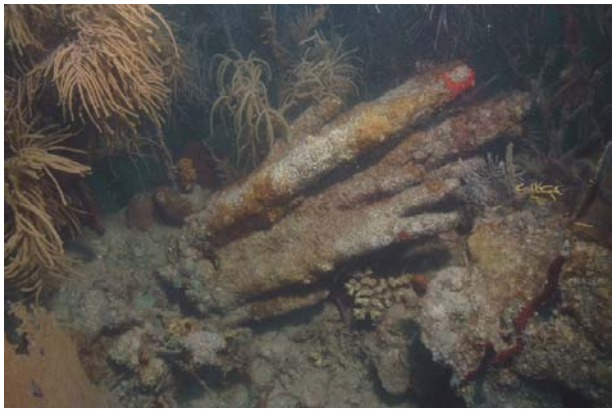


Figure 40. Monitoring trends (1999 – 2007) of fish species richness and abundance at West Reef, Isla Caja de Muerto, Ponce.

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 from the mouth of Ponce Bay (Figure 41). The promontory rises from the outer shelf at a depth of about 25 -30 m to a reef top at 15 m, and then drops down the insular slope along the south and west margins. The reef top platform has an irregular spherical shape. It measures approximately 2 kilometers from east to west and about 0.7 kilometers from north to south. Permanent transects were established at the southern edge of the reef, close to the shelf-edge drop-off wall.

Derrumbadero Reef exhibits an impressive spur-and groove coral reef formation that resembles the shelf-edge reef systems of La Parguera and Guánica. Coralline sand channels with coral rubble cut through the reef down to the shelf-edge, separating spurs of approximately 5 meters high. Massive, branching and encrusting corals and gorgonians colonize the spurs and grow towards the channels, creating a highly complex habitat of large coral mounds, ledges and overhangs. Baseline characterization of the reef community was performed during August, 2001 by García-Sais et al. (2001 c). Panoramic views of Derrumbadero Reef are presented as Photo Album 12.

1.0 Sessile-Benthic Reef Community

A total of 25 stony corals, including 12 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 14.21 % (range: 6.30 – 18.54 %). Boulder Star Coral, *Montastrea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 5.97% (range: 3.31 – 7.29 %), representing 42.0 % of the total cover by stony corals. Great Star Coral (*M. cavernosa*) and Mustard-Hill Coral (*Porites astreoides*) 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. Great Star Coral was present in four transects (Table 46).

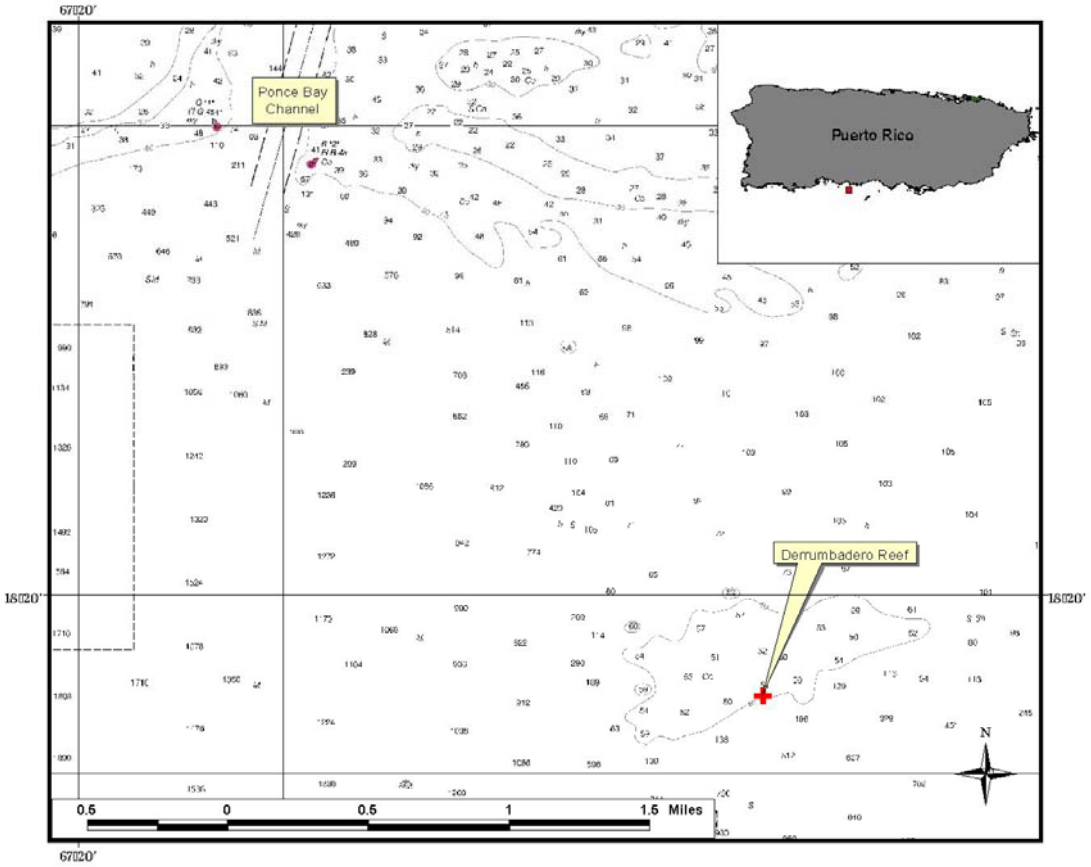


Figure 41. Location of the coral reef monitoring station at Derrumbadero Reef, Ponce.

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 corals were highly abundant (mean: 27.0 col./transect) at Derrumbadero Reef and because of their large sizes and species richness (17 spp. within transects) contributed substantially to the biological diversity and structural complexity of the reef system. The Common Sea Fan, *Gorgonia ventalina*, Sea Plumes, *Pseudopterogorgia acerosa, P. americana* and the Corky Sea Finger, *Briareum asbestinum* were present in all five transects surveyed and were the most abundant soft coral taxa (Table 46). Turf algae comprised by an assemblage of filamentous brown and red algae were the most prominent sessile-benthic category in terms of substrate cover at Derrumbadero Reef with a mean of 60.92 % (range:53.23 – 70.45 %). Sponges were also present in all five transects with a mean substrate cover of 2.40 %. Abiotic

Table 46. Percent linear cover by sessile-benthic categories at Derrumbadero Reef, Ponce March 2007.

	TRANSECT					
Depth: 7.0 m	1	2	3	4	5	**MEAN**
Rugosity (m)	3.30	2.69	3.32	3.59	2.27	**3.03**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	12.93	11.66	10.89	13.76	7.82	**11.41**
Rubble	5.11					**1.02**
Sand-silt		1.00				**0.13**
Total Abiotic	18.04	12.33	10.89	13.76	7.82	**12.57**
Benthic Algae						
Turf-mixed assemblage	53.23	70.45	62.91	57.62	60.39	**60.92**
Fleshy	12.93	6.86	5.71	7.87	9.29	**8.53**
Calcareous	1.50					**0.30**
Total Benthic Algae	67.7	77.3	68.6	65.5	69.7	**69.8**
Cyanobacteria				0.93		**0.19**
Sponges	1.58	2.13	1.28	3.02	3.99	**2.40**
Encrusting gorgonian	0.21	1.89	1.58	0.31		**0.80**
Live Stony Corals						
Montastrea annularis (complex)	7.29	3.31	4.95	7.28	7.01	**5.97**
Montastrea cavernosa		0.55	5.27	3.97	4.73	**2.90**
Porites astreoides	2.11	1.89	4.20	1.25	3.10	**2.51**
Agaricia agaricites			0.98	0.62	1.06	**0.53**
Meandrina meandrites	0.64			0.73	1.26	**0.53**
Colpophyllia natans				2.28		**0.46**
Diploria strigosa			1.80			**0.36**
Porites porites	0.83				0.81	**0.33**
Madracis decactis	0.95			0.41		**0.27**
Diploria labyrinthiformis		0.33			0.57	**0.18**
Porites colonensis	0.64					**0.13**
Eusmilia fastigiata		0.22				**0.04**
Total Live Stony Corals	**12.46**	**6.30**	**17.20**	**16.54**	**18.54**	**14.21**
Partially bleached coral	0.00	0.00	2.55	0.00	0.00	**0.51**
Recently dead coral	9.55	7.41	8.33	11.70	0.00	**7.40**
Gorgonians (# colonies)						
Gorgonia ventalina	1.00	7.00	7.00	7.00	5.00	**5.40**
Pseudoptergorgia acerosa	3.00	6.00	5.00	7.00	4.00	**5.00**
Pseudoptergorgia americana	6.00	5.00	4.00	3.00	2.00	**4.00**
Briaerum asbestinum	2.00	9.00	4.00	2.00	3.00	**4.00**
Plexaura flexuosa	2.00	4.00	4.00	1.00		**2.20**
Pseudoplexaura flagellosa or wargeri	2.00	1.00		1.00	3.00	**1.40**
Muriceopsis flavida		3.00		1.00	1.00	**1.00**
Eunicea turnetorti	1.00	1.00		2.00		**0.80**
Eunicea spp.	2.00	1.00			1.00	**0.80**
Plexaurella spp.		1.00		1.00		**0.40**
Pseudoplexaura purosa	2.00					**0.40**
Pseudoptergorgia bipinnata	1.00		1.00			**0.40**
Erythropodium caribeorum	1.00	1.00				**0.40**
Eunicea asperula				1.00		**0.20**
Eunicea succinea			1.00			**0.20**
Muricea spp.	1.00					**0.20**
Plexaura kukenthali	1.00					**0.20**
Total Gorgonians (# colonies/transect)	**25.00**	**39.00**	**26.00**	**26.00**	**19.00**	**27.00**

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

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 3.03 m (Table 46).

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, 2006 and 2007. Differences of mean total percent cover by stony corals between monitoring surveys were statistically significant (ANOVA; $p < 0.0001$), 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 %) represented a decline of 16.7 % over a period of four years. A much more drastic decline was observed between 2005 and the 2006 monitoring survey. Total live coral declined 59.11 %, from 34.63 % in 2005 to 14.16 % in 2006. A proportional increment of cover by benthic algae was measured. Such drastic, short term collapse of the Derrumbadero coral reef system was associated with the massive regional coral bleaching event that affected Puerto Rico and the USVI during late September through October 2005 (García-Sais et al., 2006). From the reported live coral intercepted by transects during the 2006 monitoring survey, approximately 35.9 % was partially bleached. Most of the partially bleached coral colonies appear to have recuperated because during the present 2007 survey, live coral cover remained virtually stable (mean:14. 21 %) as compared to the 2006 condition (Figure 42). Partially bleached coral declined to a mean substrate cover of 0.51 % during 2007.

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 cervicorni*s. Soft corals (gorgonian) were not adversely affected by the environmental conditions affecting scleractinian corals, reflecting a minor increment (23/27) between the 2005 and the 2007 surveys.

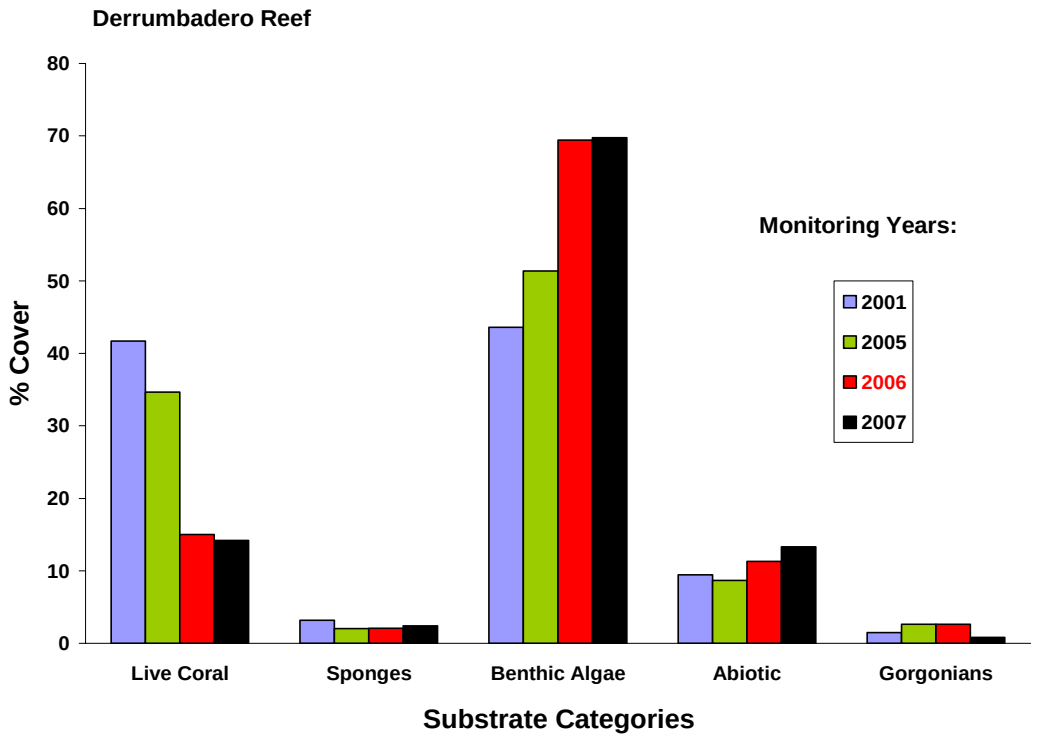


Figure 42. Monitoring trends (2001 – 2007) of mean substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce.

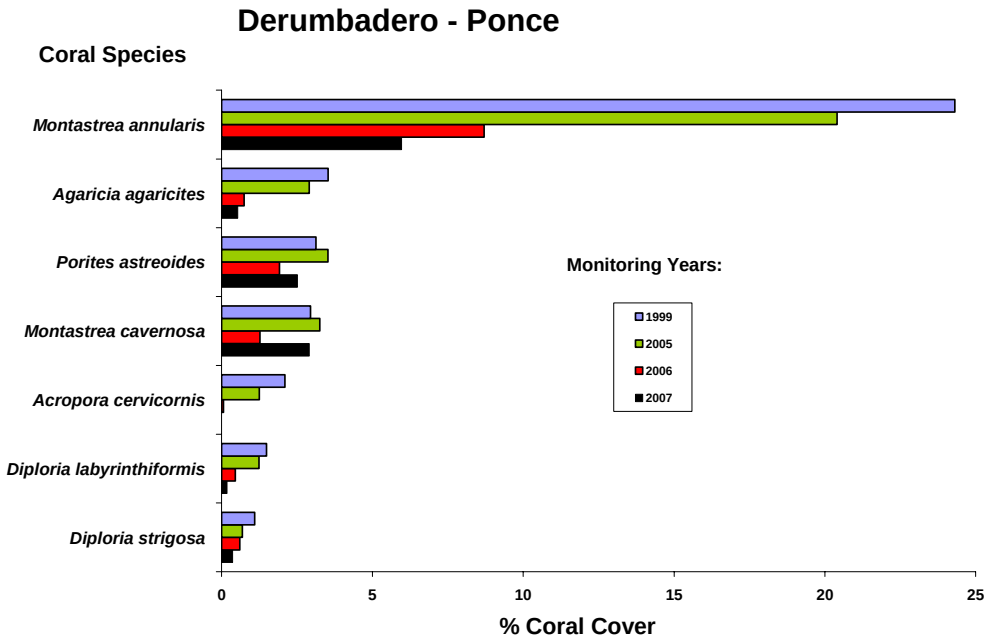


Figure 43. Monitoring trends (2001 – 2007) of mean substrate cover by dominant coral species at Derrumbadero Reef, Ponce

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 86 fish species have been identified from Derrumbadero Reef during monitoring surveys (Appendix 1). Mean abundance within belt-transects during 2007 was 71.0 Ind/30 m^2 (range: 54 - 93 Ind/30 m^2). The mean number of species per transect was 18.5 (range: 17 - 25). The Blue Chromis, *Chromis cyanea* was the numerically dominant species with a mean abundance of 12.0 Ind/30 m^2 (range: 1 - 33 Ind/30 m^2), 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. A total of 12 fish species were present on at least four out of the five transects surveyed. These included the Bicolor Damselfish, Bluehead Wrasse, Striped, Redband and Princess Parrotfishes, Four-eye Butterflyfish, Blue Tang, Doctorfish and Blackbar Soldierfish. The combined abundance of these 12 species represented 76.3 % 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 previously reported from Derrumbadero Reef (García-Sais et al., 2006), such as Yellowfin and Tiger Groupers, Cubera, Mutton, Schoolmaster and Dog Snappers also feed from the small zooplanktivorous fishes 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 Mahogany snappers, Coney, Graysby and Red Hind groupers, lizardfishes and grunts.

Table 47. Taxonomic composition and abundance of fishes within belt-transects at Derrumbadero Reef, Ponce. March, 2007

Depth: 20m		TRANSECTS (Individuals/30m^2)					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Chromis cyanea	Blue Chromis	8	33	1	14	4	**12.0**
Thalassoma bifasciatum	Bluehead Wrasse	22	8		3	18	**10.2**
Clepticus parrae	Creole Wrasse	1	22	7		15	**9.0**
Stegastes partitus	Bicolor Damselfish	16	5	10	5	9	**9.0**
Scarus iserti	Stripped Parrotfish	1	4	5		2	**2.4**
Scarus taeniopterus	Princess parrotfish	3		4	2	3	**2.4**
Halichoeres garnoti	Yellow-head Wrasse	2	3	3	1	1	**2.0**
Sparisoma aurofrenatum	Redband Parrotfish	2	2	2	3	1	**2.0**
Chaetodon capistratus	Foureye Butterflyfish	3	2	1	1	2	**1.8**
Gobiosoma evelynae	Sharknose Goby				1	8	**1.8**
Sparisoma radians	Bucktooth Parrotfish			5	2		**1.4**
Acanthurus coeruleus	BlueTang	1	2	1		2	**1.2**
Myripristis jacobus	Blackbar Soldierfish	2		2	1	1	**1.2**
Acanthurus chirurgus	Doctorfish	1	2		1	1	**1.0**
Canthigaster rostrata	Caribbean puffer				3	1	**0.8**
Chromis multilineata	Brown Chromis	2			2		**0.8**
Acanthurus bahianus	Ocean Surgeon	1		1	1		**0.6**
Chaetodon striatus	Banded Butterflyfish		1			2	**0.6**
Coryphopterus personatus	Masked Goby		3				**0.6**
Haemulon flavolineatum	French grunt			1	1	1	**0.6**
Haemulon sciurus	Bluestriped Grunt	1			1	1	**0.6**
Holocentrus rufus	Squirrelfish	1			2		**0.6**
Hypoplectrus puella	Barred hamlet	1		1	1		**0.6**
Ocyurus chrysurus	Yellowtail snapper		2		1		**0.6**
Scarus vetula	Queen parrotfish	1		1	1		**0.6**
Stegastes leucostictus	Beau-gregory	1	1	1			**0.6**
Cephalopholis cruentatus	Graysby	1		1			**0.4**
Coryphopterus lipernes	Peppermint Goby	1		1			**0.4**
Holacanthus tricolor	Rock Beauty	1			1		**0.4**
Hypoplectrus unicolor	Butter Hamlet		1		1		**0.4**
Melichthys niger	Black Durgon		1			1	**0.4**
Pseudupeneus maculatus	Spotted goatfish			1		1	**0.4**
Serranus tigrinus	Harlequin bass	1				1	**0.4**
Sparisoma viride	Stoplight Parrotfish			2			**0.4**
Amblycirrhitus pinos	Redspotted Hawkfish			1			**0.2**
Cephalopholis fulva	Coney		1				**0.2**
Chaetodon aculeatus	Longsnout butterflyfish					1	**0.2**
Flammeo marianus	Longspine Squirrelfish	1					**0.2**
Epinephelus guttatus	Red hind			1			**0.2**
Holacanthus ciliaris	Queen Angelfish					1	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet					1	**0.2**
Mulloides martinicus	Yellowtail Goatfish			1			**0.2**
Pomacanthus arcuatus	Gray Angelfish				1		**0.2**
Synodus intermedius	Sand Diver	1					**0.2**
	TOTAL INDIVIDUALS	76	93	54	54	78	**71.0**
	TOTAL SPECIES	25	17	23	23	23	**18.5**

Table 48. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Derrumbadero Reef, Ponce. March, 2007

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

SPECIES	**COMMON NAME**		# - (cm)
Carangoides crysos	Blue Runner	3 – (40)	1 – (50)
Epinephelus guttatus	Red Hind	1 – (30)	
Holacanthus ciliaris	Queen Angel	3 - (25)	1 - (40)
Holacanthus tricolor	Rock Beauty	1 - (25)	
Lachnolaimus maximus	Hogfish	1 – (40)	
Lutjanus apodus	Schoolmaster	2 - (20)	2 – (40)
Lutjanus mahogany	Mahogany Snapper	2 - (25)	1 – (30)
Lutjanus synagris	Lane Snapper	2 - (20)	
Ocyurus chrysurus	Yellowtail Snapper	2 – (30)	1 - (40)
Scomberomorus regalis	Cero Mackerel	2 - (50)	1 – (60)
Sphyraena barracuda	Great Barracuda	1 - (50)	
Trachinotus falcatus	Permit	1 – (60)	
Invertebrates			
Panulirus argus	Spiny Lobster	1 - (15)	

Parrotfishes, doctorfishes, and damselfishes comprised the main herbivorous assemblage.

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, 2006 and 2007 A statistically significant decline of fish abundance within belt-transects was detected. The higher fish abundance of the 2001 and 2005 surveys compared to the most recent 2006 and 2007 surveys was largely driven by an abundance decline 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 10 fold between the 2001-05 and the 2006-07 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.

The Cleaner Shrimp, *Periclimenes pedersoni* and one small Spiny Lobster (*Panulirus argus*) represented megabenthic invertebrates within belt transects during the 2007 survey (Table 49).

Table 49. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Derrumbadero Reef, 20 m depth, Ponce. March, 2007

DATE: March, 2007 Depth: 20 m		**TRANSECTS**					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	DEPTH (m) COMMON NAME						
Periclimenes pedersoni	Cleaner Shrimp	1					**0.2**
Panulirus argus	Spiny Lobster		1				**0.2**
	TOTALS	**1**	**1**	**0**	**0**	**0**	**0.4**

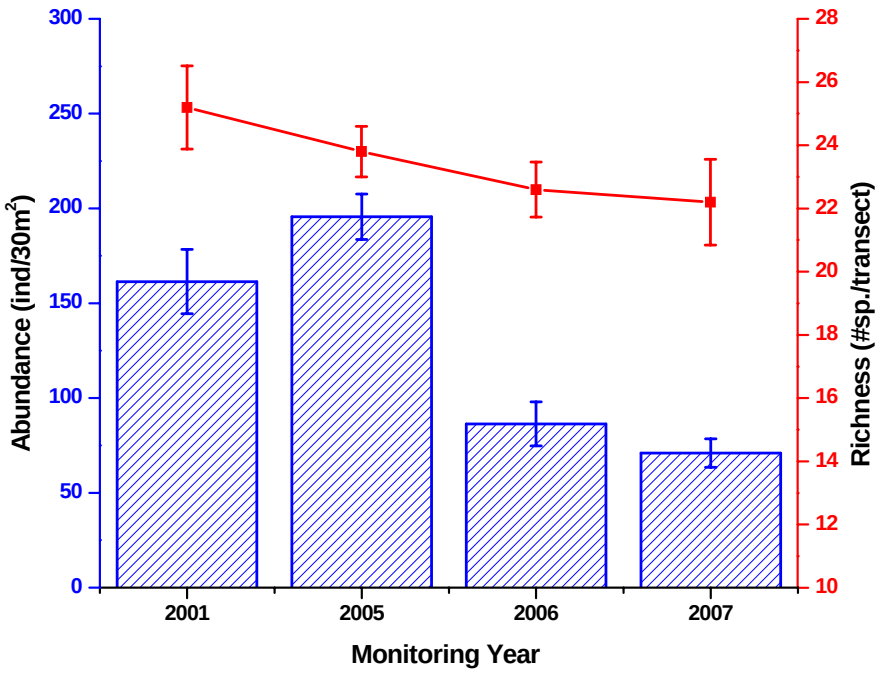


Figure 44. Monitoring trends (1999 – 2007) of fish species richness and abundance at Derrumbadero Reef, Ponce.

Photo Album 12 (Ponce
Derrumbadero Reef











VI 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 differences of live coral cover.

Differences of live coral cover between monitoring surveys were mostly associated with a sharp decline measured during the 2006 survey, after a severe regional coral bleaching event that affected Puerto Rico and the U. S. Virgin Islands during August through October 2005.

Live coral cover during the present 2007 monitoring survey presented a pattern of mild reductions relative to 2006 levels for almost all reef sites monitored. Declines of live coral cover between the 2007 and 2006 surveys were statistically significant (ANOVA; $p < 0.05$) at Tourmaline Reef 20m in Mayaguez, and at Puerto Canoas Reef 30m in Isla Desecheo. Such reductions of live coral cover are here considered as lingering effects of the 2005 coral bleaching event.

The decline of (total) live coral cover at the reef community level during 2006 and now extending into 2007 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, cyanobacteria and abiotic categories were measured.

Fish populations presented a general trend of declining abundance and species richness within belt-transects. Reductions of fish abundance were statistically significant in seven out of the 12 reef stations surveyed. These included Tourmaline Reef (Mayaguez) at 20 m; Puerto Botes Reef (Isla Desecheo) at 15 m; Tres Palmas Reef (Rincon) at 10 and 20 m; Derrumbadero Reef (Ponce) at 20 m and West Reef (Isla Caja de Muerto) at 8 m. Likewise, statistically significant reductions of fish species richness were observed at Tourmaline Reef (Mayaguez) at 20 m; Puerto Botes Reef (Isla Desecheo) at 15 m; Tres Palmas Reef (Rincon) at 10 m and West Reef (Isla Caja de Muerto) at 8 m.

Variations between surveys were mostly associated with reductions of abundance by numerically dominant populations that exhibit highly aggregated distributions in the immediate vicinity of live coral heads, 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-Guánica

Total Species Database **REEF SITES**

Species	**Common Name**	**M30**	**M20**	**M10**	**R5**	**R10**	**R20**	**D30**	**D20**	**D15**	**CDM**	**Derr**	**Gua**
Abudefduf sexatilis	Sergeant Major	x	x	x	x	x	x		x		x	x	x
Abudefduf taurus	Night Sergeant				x	x							
Acanthurus bahianus	Ocean Surgeon	x	x	x	x	x	x	x	x	x	x	x	x
Acanthurus chirurgus	Doctorfish	x	x	x	x	x	x	x	x	x	x	x	x
Acanthurus coeruleus	BlueTang	x	x	x	x	x	x	x	x	x	x	x	x
Aetobatus narinari	Spotted Eagle Ray			x								x	
Aluthera scriptus	Scrawled Filefish	x		x		x		x	x		x	x	x
Amblycirrhitus pinos	Redspotted Hawkfish	x	x	x		x	x	x	x	x	x	x	x
Anchoa sp.	Anchovy				x								
Anisotremus surinamensis	Black margate					x		x					
Anisotremus virginicus	Porkfish	x	x	x	x	x	x				x	x	x
Apogon sp.	Cardinalfish					x	x	x					x
Apogon townsendi	Belted Cardinalfish								x				
Aulostomus maculatus	Trumpetfish	x	x	x	x	x	x	x	x	x	x	x	x
Balistes vetula	Queen Triggerfish			x				x	x	x	x		
Bodianus rufus	Spanish Hogfish	x	x	x	x	x	x	x	x	x	x	x	x
Bothus lunatus	Peacock flounder	x	x				x						
Calamus pennatula	Pluma				x						x	x	
Calamus bajonado	Jolthead Porgy							x					
Cantherhines macrocerus	Whitespotted filefish	x		x	x		x	x	x	x		x	
Cantherhines pullus	Tail-light Filefish	x	x		x	x							x
Cantherhines surinamensis	Ocean Triggerfish	x	x	x		x		x	x			x	x
Canthigaster rostrata	Caribbean Puffer	x	x	x	x	x	x	x	x	x	x	x	x
Carangoides crysos	Blue Runner	x	x	x	x	x	x	x	x		x	x	x
Carangoides ruber	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	Cdm	Derr	Gua
Caranx bartholomaei	Yellow jack												x
Caranx hippos	Horse-eye Jack				x			x					
Caranx lugubris	Black Jack	x	x	x	x	x		x	x			x	x
Caranx ruber	Bar Jack				x								
Carcharhinus limbatus	Caribbean Reef Shark							x					
Centropyge argi	Cherubfish												x
Cephalopholis cruentatus	Graysby	x	x	x		x	x	x	x	x	x	x	x
Cephalopholis fulva	Coney	x	x	x	x	x	x	x	x	x	x	x	x
Chaetodon aculeatus	Longsnout Butterflyfish	x	x	x		x	x	x	x			x	x
Chaetodon capistratus	Four-eye Butterflyfish	x	x	x	x	x	x	x	x	x	x	x	x
Chaetodon ocellatus	Spotfin Butterflyfish	x	x									x	x
Chaetodon sedentarius	Reef Butterflyfish	x							x				
Chaetodon striatus	Banded Butterflyfish	x	x	x		x	x		x	x	x	x	x
Chromis cyanea	Blue chromis	x	x	x		x	x	x	x	x	x	x	x
Chromis insolata	Sunshine Chromis	x					x	x					
Chromis multilineata	Brown Chromis	x	x	x	x	x	x	x	x	x	x	x	x
Clepticus parrae	Creole Wrasse	x	x	x		x	x	x	x	x	x	x	x
Coryphopterus glaucofraenum	Bridled Goby	x	x	x		x		x			x	x	x
Coryphopterus lipernes	Peppermint Goby	x	x	x		x	x	x	x	x	x	x	x
Coryphopterus personatus	Masked goby	x	x	x		x	x	x	x	x	x	x	x
Coryphopterus sp1.	Goby	x	x	x		x	x	x	x	x	x	x	x
Criptoptomus roseus	Parrotfish			x						x			
Dasyatis americana	Southern stingray				x			x	x				
Decapterus macarelus	Mackerel Scad	x	x				x	x		x	x		x
Diodon holacanthus	Porcupinefish				x	x		x		x			
Diodon hystrix	Balloonfish							x					
Echeneis naucrates	Sharksucker			x									
Echidna catenata	Chain Moray									x			
Elagatis bipinnulatus	Rainbow Runner							x					
Epinephelus adscensionis	Rock Hind	x	x		x	x							
Epinephelus guttatus	Red hind	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
Epinephelus itajara	Jewfish												x
Epinephelus striatus	Nassau Grouper	x	x					x	x				x
Equetus acuminatus	Highhat	x	x	x		x		x	x	x		x	x
Equetus lanceolatus	Jackknife Fish	x	x			x	x				x		
Equetus punctatus	Spotted Drum					x	x				x		x
Flammeo marianus	Longspine Squirrelfish	x	x	x		x	x	x	x	x		x	x
Gerres cinereus	Yellowfin mojarra	x	x	x	x	x					x		x
Ginglymostoma cirratum	Nurse Shark									x			
Gobiosoma evelynae	Sharknose Goby	x	x	x		x	x	x	x	x	x	x	x
Gobiosoma saucrum	Leopard Goby	x	x	x		x		x			x	x	x
Gobiosoma sp.	Goby				x								
Gramma loreto	Fairy Basslet	x	x	x	x	x	x	x	x		x	x	x
Gymnothorax funebris	Green Moray							x					
Gymnothorax moringa	Spotted Moray	x	x	x		x			x	x		x	x
Ginglymostoma cirratum	Nurse Shark												x
Haemulon aurolineatum	Tomtate	x	x	x		x			x		x		x
Haemulon carbonarium	Caesar's Grunt				x								
Haemulon chrysargyreum	Smallmouth Grunt	x	x	x	x	x					x		
Haemulon flavolineatum	French Grunt	x	x	x	x	x	x	x	x	x	x	x	x
Haemulon macrostomum	Spanish Grunt	x	x	x		x	x		x	x	x	x	x
Haemulon melanurum	Cottonwick	x	x	x		x	x						
Haemulon plumieri	White Grunt			x	x	x					x		x
Haemulon sciurus	Bluestriped Grunt	x	x	x	x	x		x		x	x	x	x
Haemulon sp	Juvenile Grunts				x								
Haemulon steindachneri	Latin grunt												x
Halichoeres bivitatus	Slippery Dick				x	x							
Halichoeres cyanocephalus	Yellowcheek Wrasse											x	
Halichoeres garnoti	Yellow-head Wrasse	x	x	x		x	x	x	x	x	x	x	x
Halichoeres maculipinna	Clown Wrasse	x	x	x	x	x		x	x	x		x	x
Halichoeres pictus	Painted wrasse				x								
Halichoeres radiatus	Puddinwife	x	x	x	x	x			x	x	x	x	x

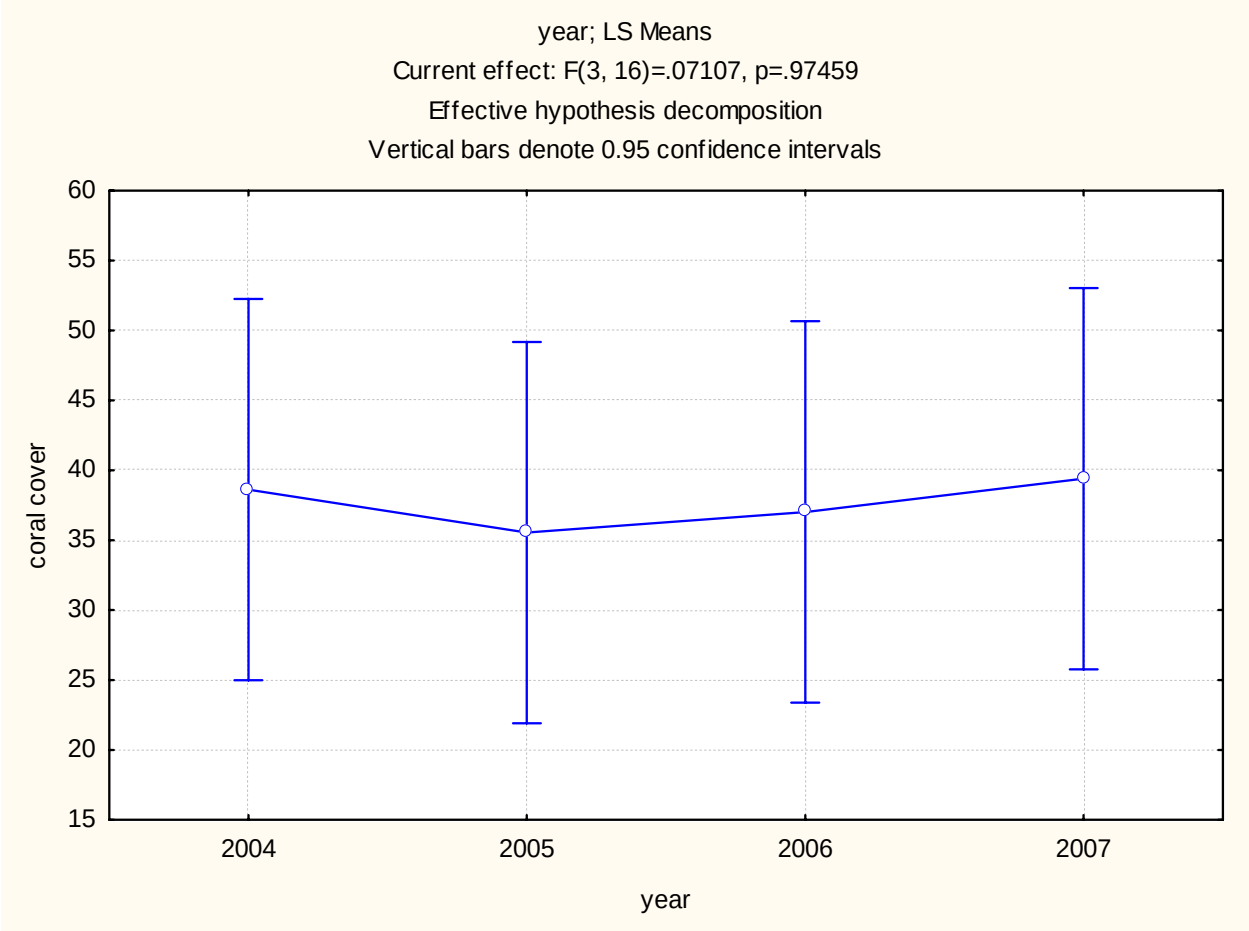
Species	**Common Name**	**M30**	**M20**	**M10**	**R5**	**R10**	**R20**	**D30**	**D20**	**D15**	**CJm**	**Derr**	**Gua**
Halichoeres sp.	wrasse					x							
Hemiramphus ballyhoo	Ballyhoo					x	x	x	x	x			x
Holacanthus ciliaris	Queen Angelfish	x	x	x		x	x	x	x	x		x	x
Holacanthus tricolor	Rock Beauty	x	x	x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

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

Species	**Common Name**	**M30**	**M20**	**M10**	**R5**	**R10**	**R20**	**D30**	**D20**	**D15**	**CJm**	**Derr**	**Gua**
Serranus tigrinus	Harlequin Bass	x	x	x		x	x	x	x	x	x	x	x
Sparisoma aurofrenatum	Redband Parrotfish	x	x	x	x	x	x	x	x	x	x	x	x
Sparisoma chrysopterum	Redtail Parrotfish						x	x	x				
Sparisoma radians	Bucktooth Parrotfish	x	x	x	x	x	x	x	x	x	x	x	x
Sparisoma rubripinne	Yellowtail Parrotfish				x	x		x	x				
Sparisoma sp. (juv.)	parrotfish										x		
Sparisoma viride	Stoplight Parrotfish	x	x	x	x	x	x	x	x	x	x	x	x
Sphaeroides sp.	Puffer	x		x									
Sphoeroides greeleyi	Green Puffer					x							
Sphoeroides testudineus	Checkered Puffer	x	x	x		x							
Sphyraena barracuda	Great Barracuda	x	x	x	x	x	x	x	x	x	x	x	
Stagastes variabilis	Cocoa Damselfish	x		x									x
Stegastes dorsopunicans	Dusky Damselfish	x		x	x					x	x		x
Stegastes leucostictus	Beaugregory	x	x	x		x	x	x			x	x	x
Stegastes partitus	Bicolor Damselfish	x	x	x	x	x	x	x	x	x	x	x	x
Stegastes planifrons	Yellow-eye Damselfish	x	x	x		x	x	x	x		x	x	x
Stegastes variabilis	Cocoa damselfish				x	x				x	x		
Synodus intermedius	Sand Diver	x	x	x		x	x			x	x		
Synodontidae sp.	Lizardfish	x			x						x		
Thalassoma bifasciatum	Bluehead Wrasse	x	x	x	x	x	x	x	x	x	x	x	x
Trachinotus falcatus	Permit											x	
Xanthichthyis ringens	Sargassum Triggerfish									x			
	TOTALS =	**114**	**101**	**99**	**65**	**109**	**83**	**95**	**79**	**76**	**88**	**86**	**99**

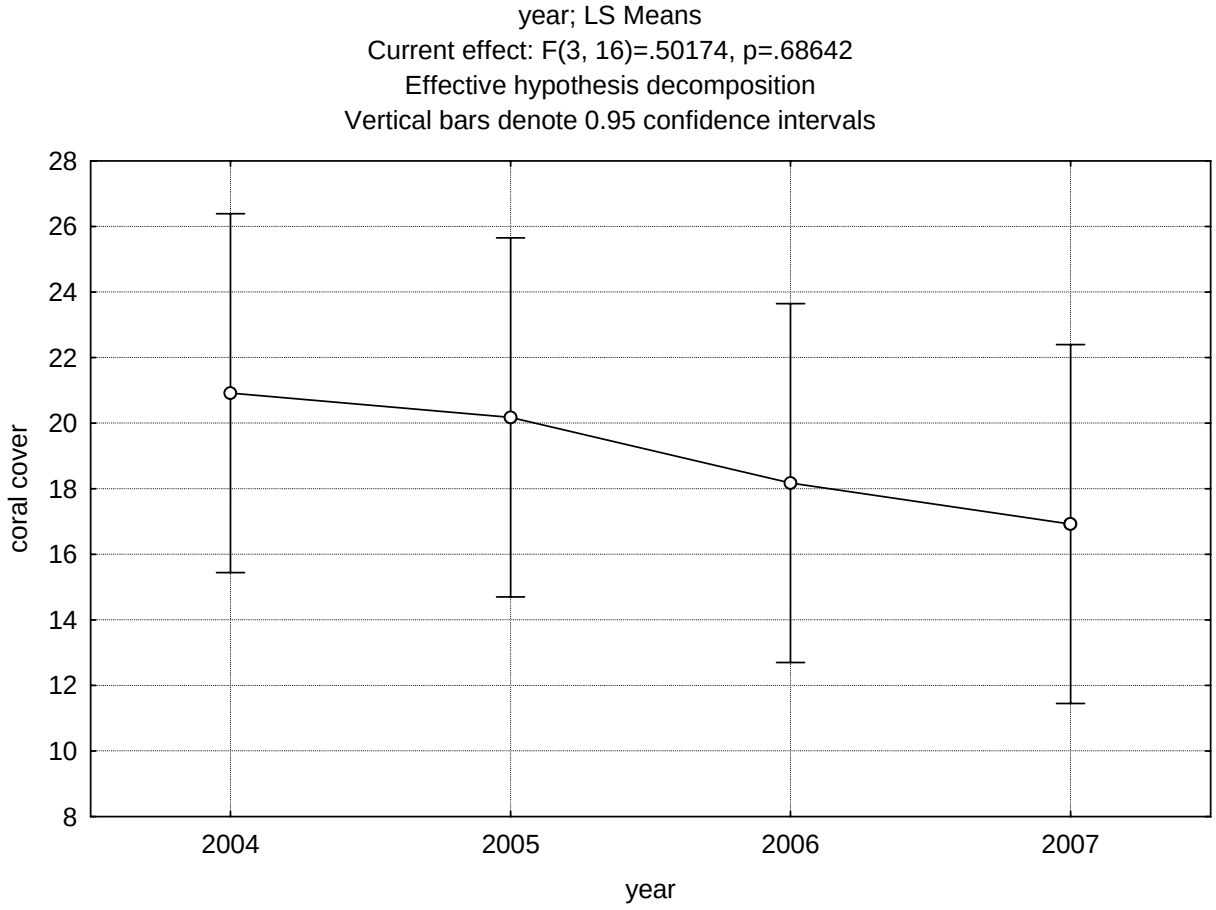
Appendix 2. Analysis of variance (ANOVA) procedure testing differences in live coral cover between annual monitoring surveys

2.1 Rincon-5m



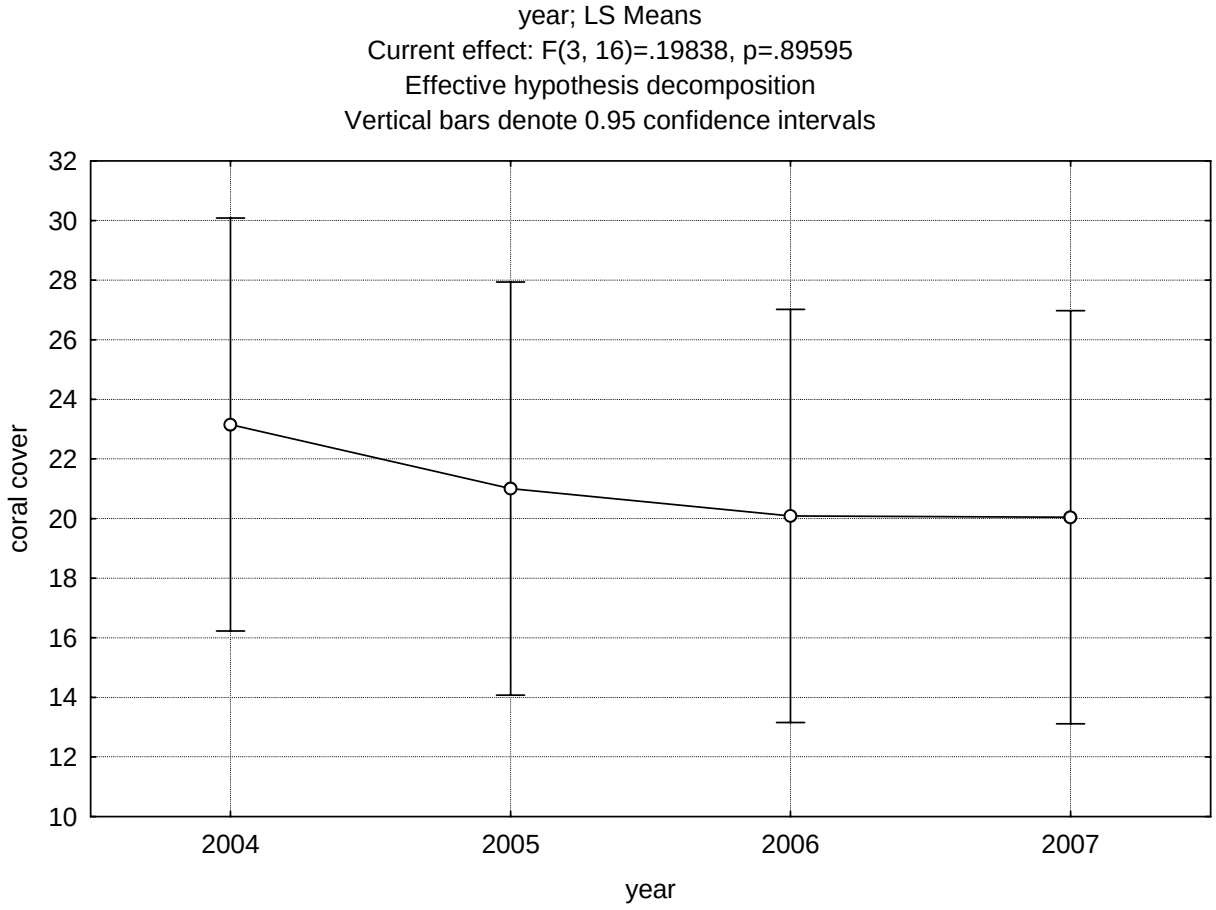
year		LSD Test; Variable: coral cover (Spreadsheet27 Marked differences are significant at p < .05000			
		{1} M=38.618	{2} M=35.548	{3} M=37.018	{4} M=39.402
2004	{1}		0.740180	0.862601	0.932400
2005	{2}	0.740180		0.873678	0.677498
2006	{3}	0.862601	0.873678		0.796632
2007	{4}	0.932400	0.677498	0.796632	

2.2 Rincon-10m



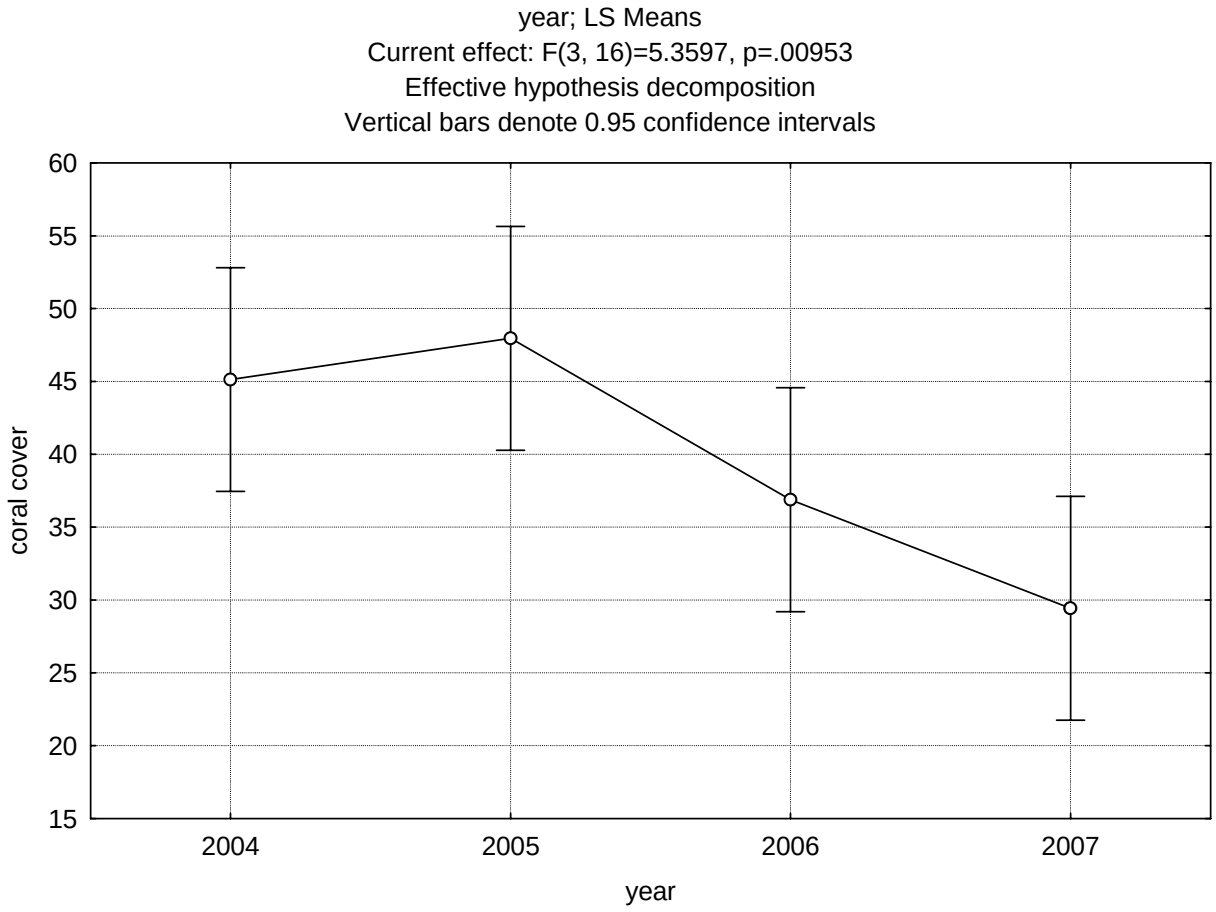
		LSD Test; Variable: coral cover (Spreadsheet3(Marked differences are significant at p < .05000			
year		{1} M=20.915	{2} M=20.176	{3} M=18.172	{4} M=16.924
2004	{1}		0.842170	0.463482	0.290632
2005	{2}	0.842170		0.590756	0.386396
2006	{3}	0.463482	0.590756		0.736989
2007	{4}	0.290632	0.386396	0.736989	

2.3 Rincon-20m



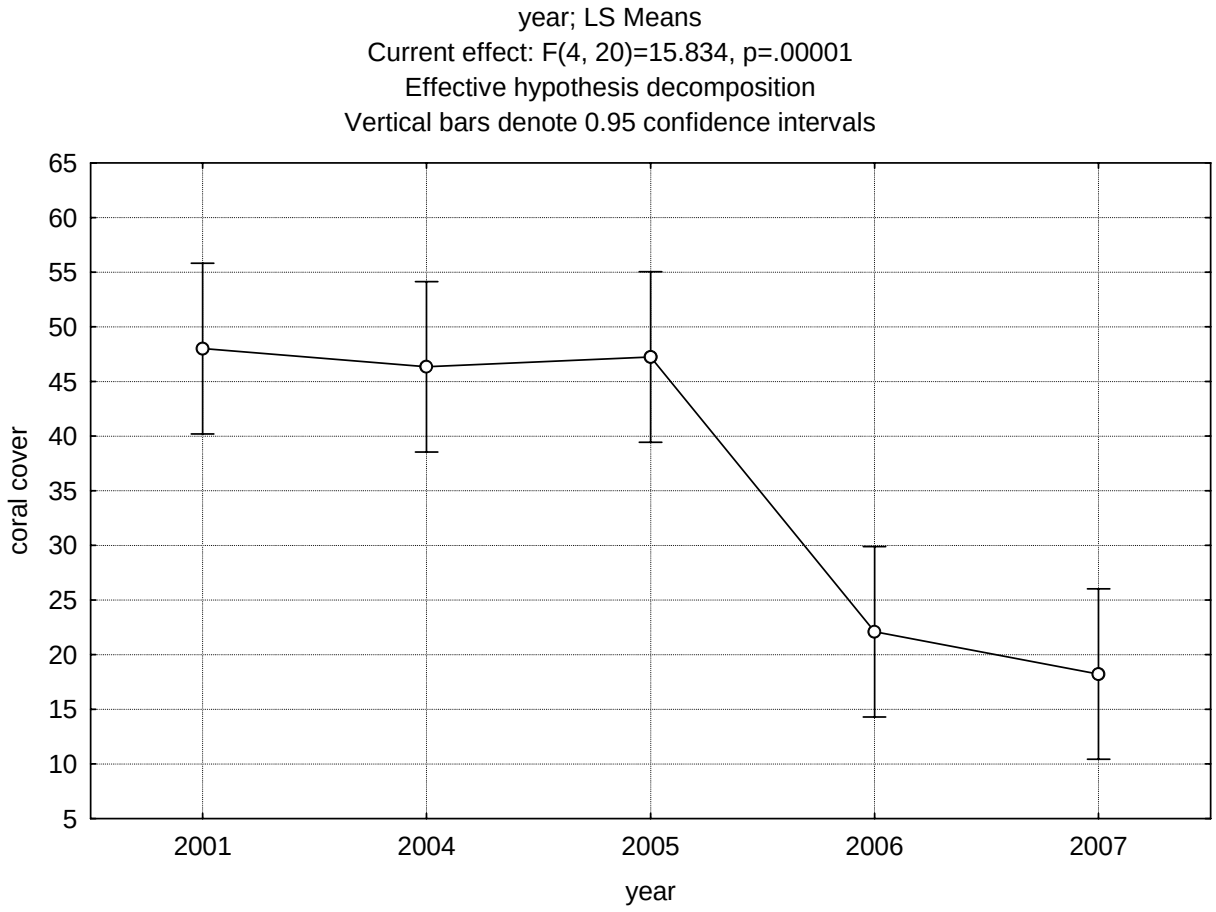
year		LSD Test; Variable: coral cover (Spreadsheet3 Marked differences are significant at p < .05000			
		{1} M=23.153	{2} M=21.006	{3} M=20.087	{4} M=20.044
2004	{1}		0.648625	0.516704	0.510930
2005	{2}	0.648625		0.844990	0.837854
2006	{3}	0.516704	0.844990		0.992706
2007	{4}	0.510930	0.837854	0.992706	

2.4 Desecheo-30m



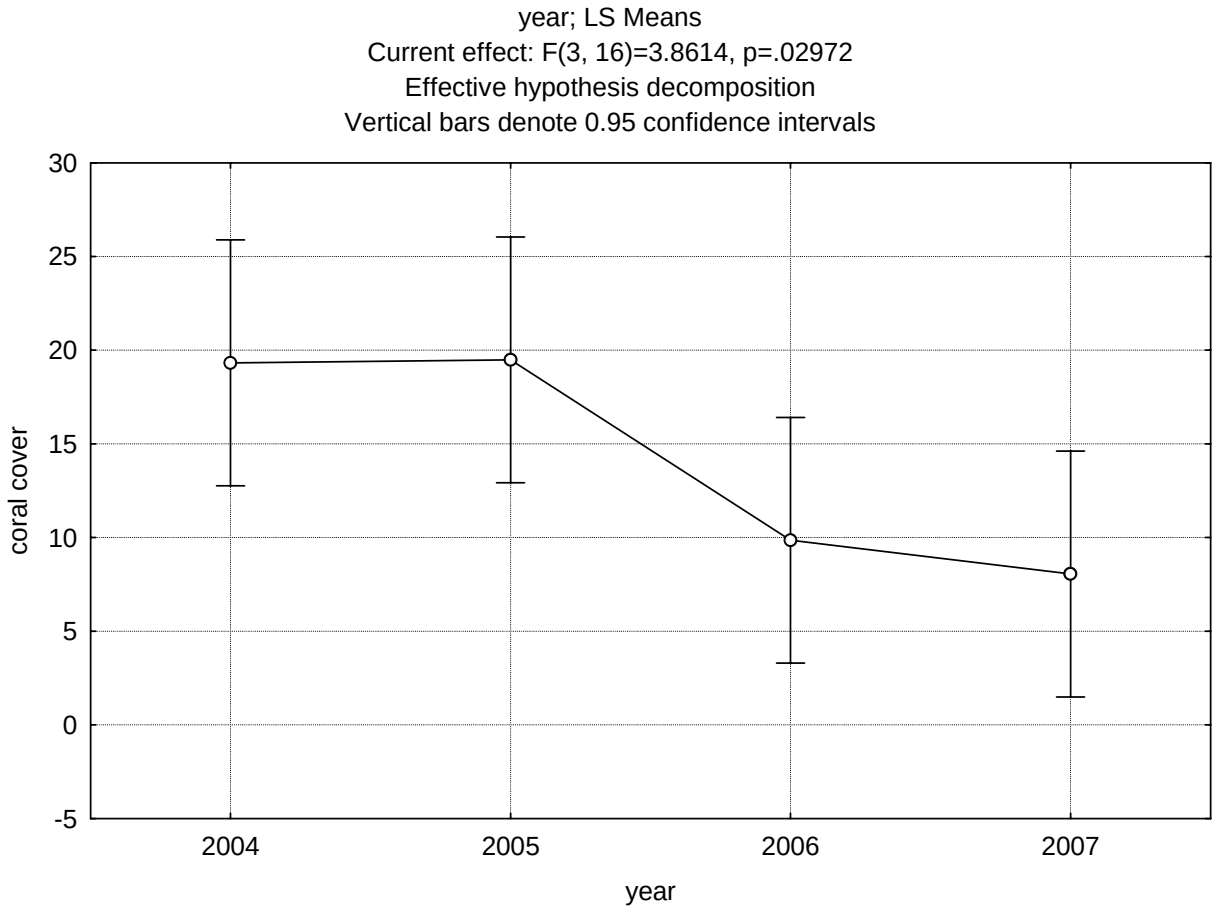
year		LSD Test; Variable: coral cover (Spreadsheet4 Marked differences are significant at p < .05000			
		{1} M=45.132	{2} M=47.964	{3} M=36.886	{4} M=29.434
2004	{1}		0.588163	0.127009	0.007415
2005	{2}	0.588163		0.046084	0.002315
2006	{3}	0.127009	0.046084		0.165151
2007	{4}	0.007415	0.002315	0.165151	

2.5 Desecheo-20m



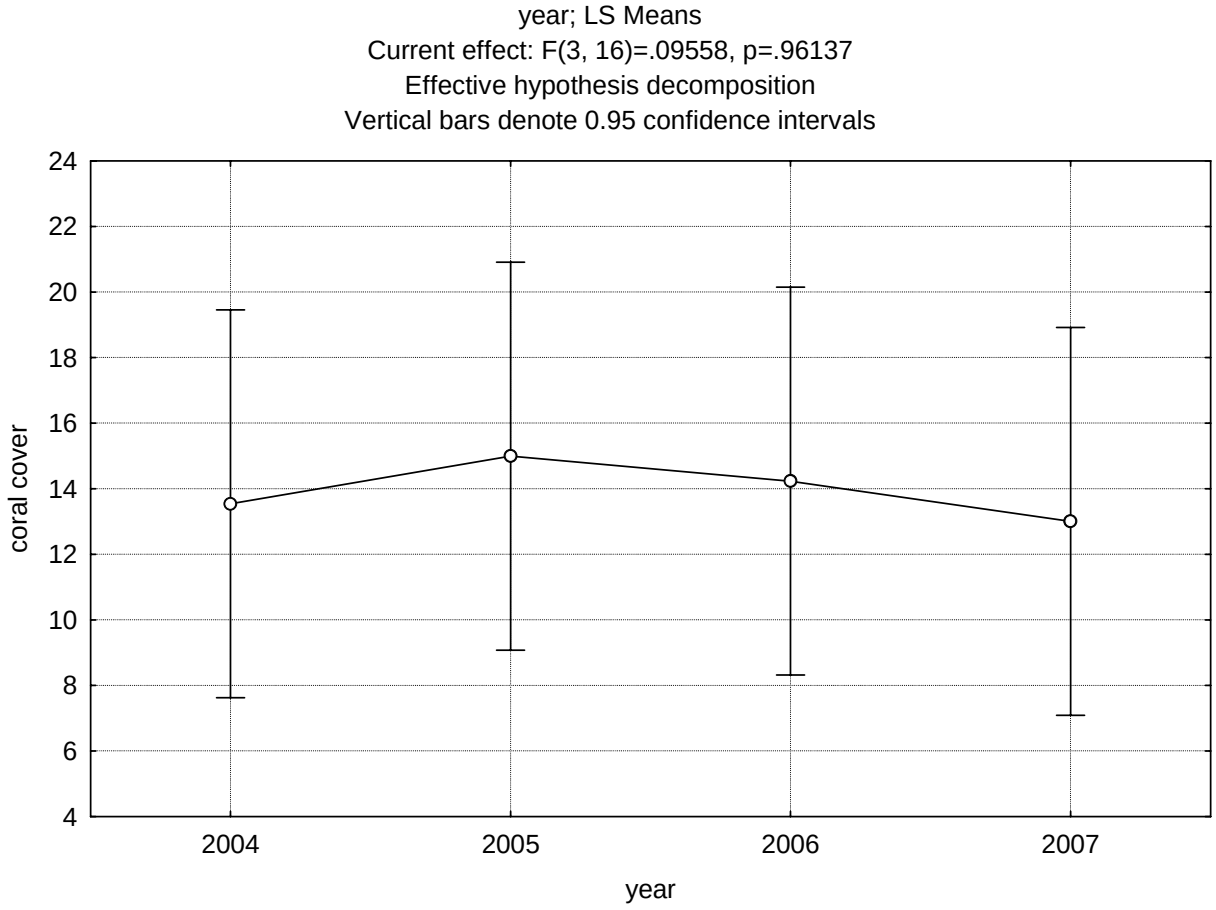
year		LSD Test; Variable: coral cover (Spreadsheet39) Marked differences are significant at p < .05000				
		{1} M=48.008	{2} M=46.338	{3} M=47.242	{4} M=22.091	{5} M=18.226
2001	{1}		0.755467	0.886310	0.000087	0.000016
2004	{2}	0.755467		0.865992	0.000180	0.000034
2005	{3}	0.886310	0.865992		0.000121	0.000023
2006	{4}	0.000087	0.000180	0.000121		0.473501
2007	{5}	0.000016	0.000034	0.000023	0.473501	

2.6 Desecheo-15m



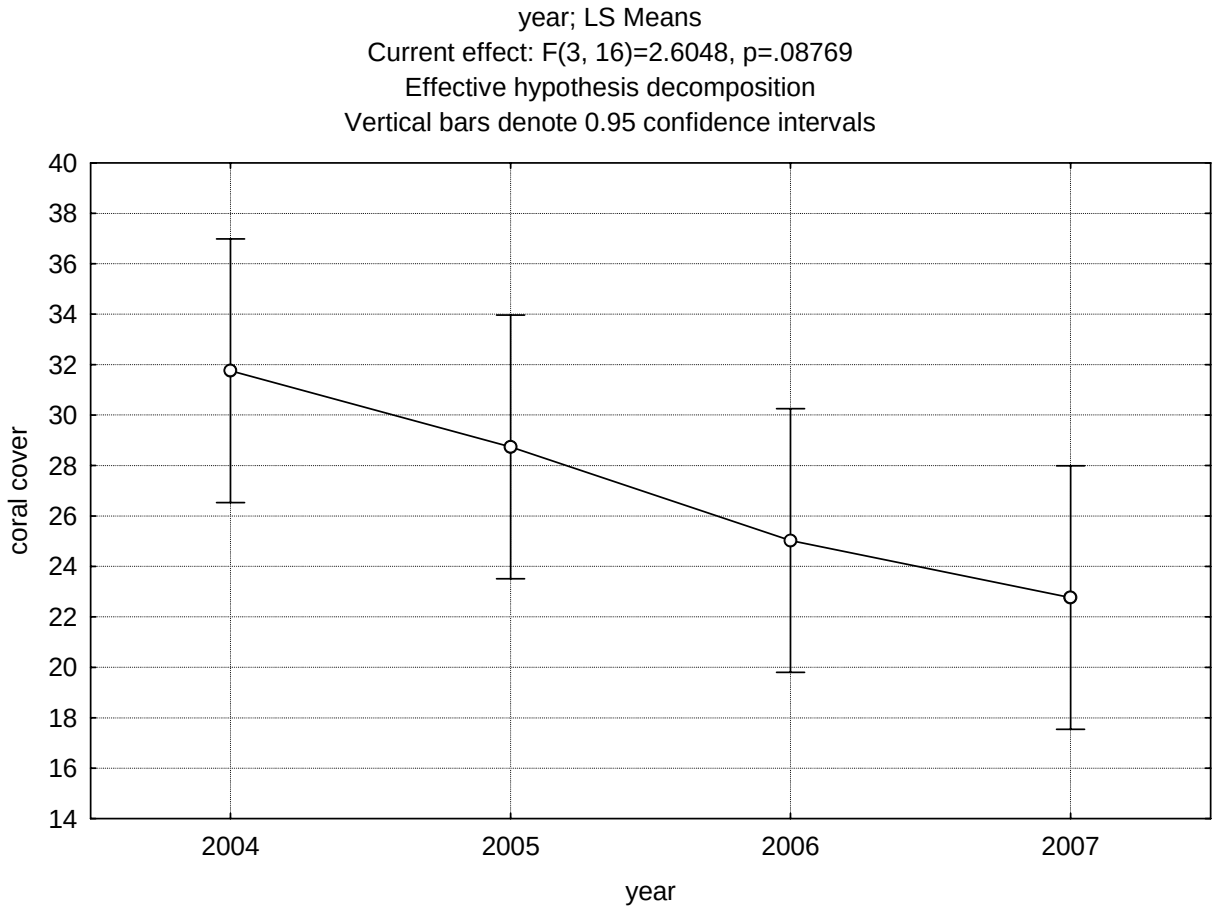
year		LSD Test; Variable: coral cover (Spreadsheet3€ Marked differences are significant at p < .05000			
		{1} M=19.328	{2} M=19.490	{3} M=9.8554	{4} M=8.0560
2004	{1}		0.970948	0.045866	0.020306
2005	{2}	0.970948		0.042698	0.018836
2006	{3}	0.045866	0.042698		0.686371
2007	{4}	0.020306	0.018836	0.686371	

2.7 Tourmaline-30m



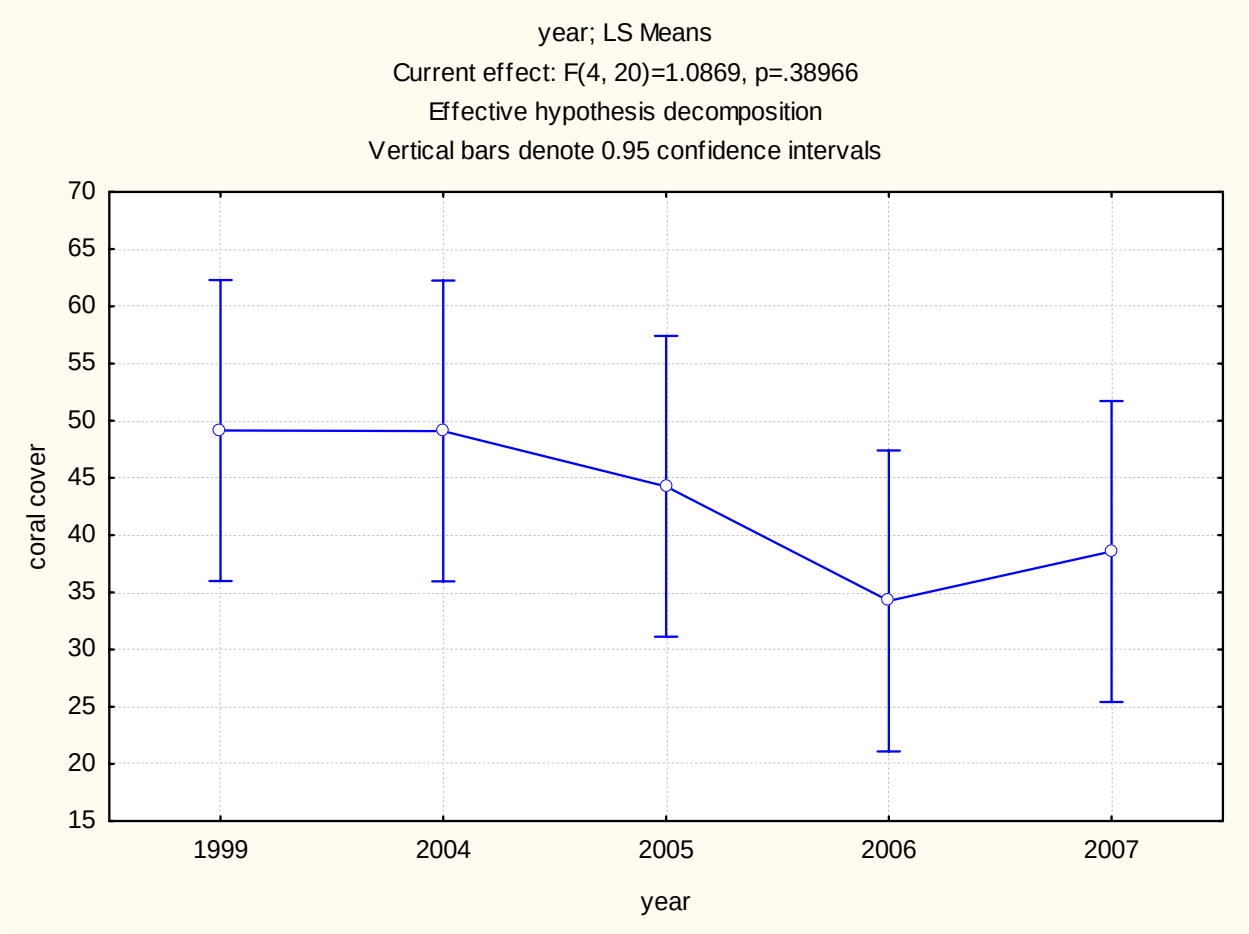
| | | LSD Test; Variable: coral cover (Spreadsheet2
Marked differences are significant at p < .05000 | | | |
|---|---|---|---|---|---|
| year | | {1} M=13.540 | {2} M=14.994 | {3} M=14.233 | {4} M=13.004 |
| 2004 | {1} | | 0.717422 | 0.862766 | 0.893603 |
| 2005 | {2} | 0.717422 | | 0.849606 | 0.620948 |
| 2006 | {3} | 0.862766 | 0.849606 | | 0.759405 |
| 2007 | {4} | 0.893603 | 0.620948 | 0.759405 | |

2.8 Tourmaline -20m



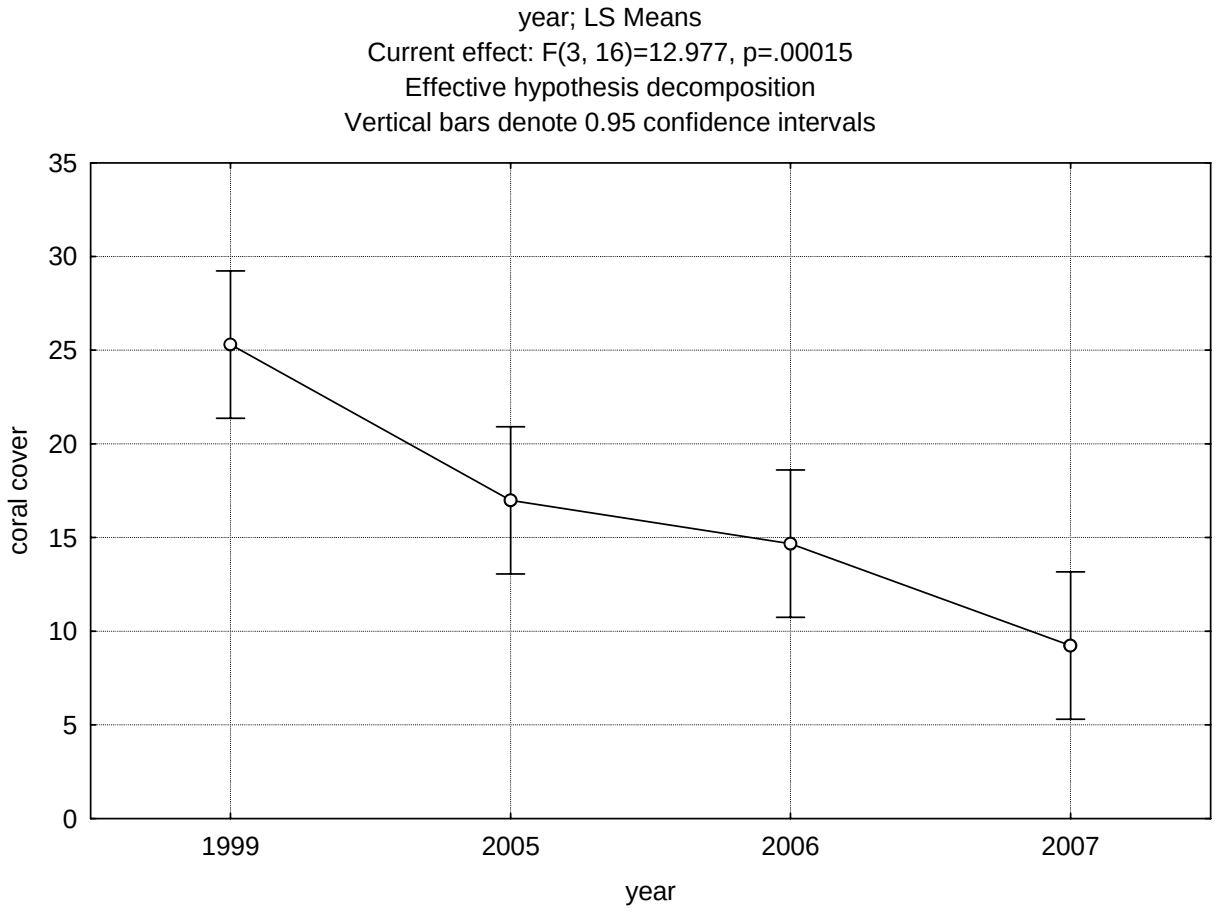
		LSD Test; Variable: coral cover (Spreadsheet21 Marked differences are significant at p < .05000			
year		{1} M=31.759	{2} M=28.740	{3} M=25.025	{4} M=22.764
2004	{1}		0.399339	0.071355	0.020147
2005	{2}	0.399339		0.302501	0.105840
2006	{3}	0.071355	0.302501		0.525837
2007	{4}	0.020147	0.105840	0.525837	

2.9 Tourmaline -10m



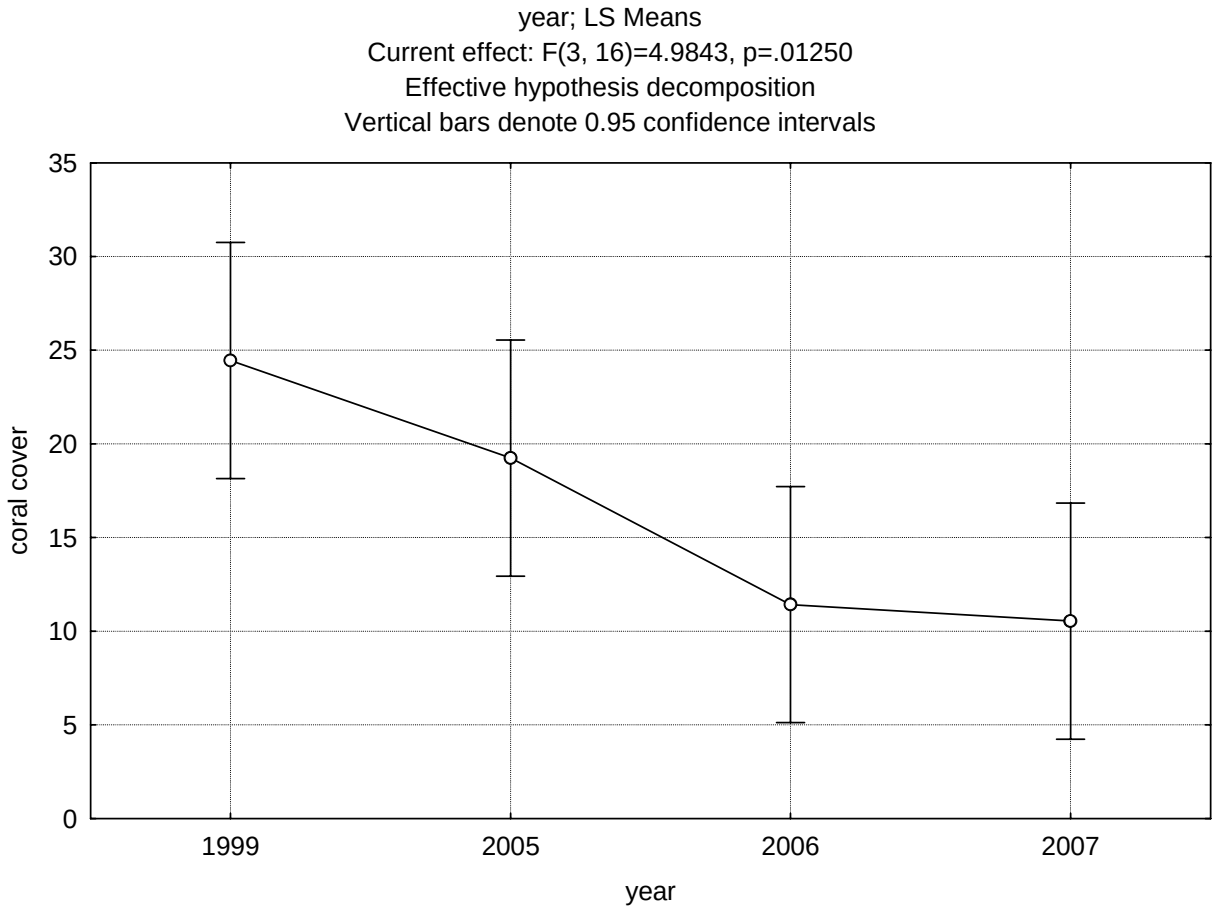
year		LSD Test; Variable: coral cover (Spreadsheet18) Marked differences are significant at p < .05000				
		{1} M=49.142	{2} M=49.101	{3} M=44.262	{4} M=34.245	{5} M=38.568
1999	{1}		0.996338	0.590234	0.110337	0.249556
2004	{2}	0.996338		0.593370	0.111269	0.251355
2005	{3}	0.590234	0.593370		0.274528	0.530317
2006	{4}	0.110337	0.111269	0.274528		0.633024
2007	{5}	0.249556	0.251355	0.530317	0.633024	

2.10 Cayo Coral



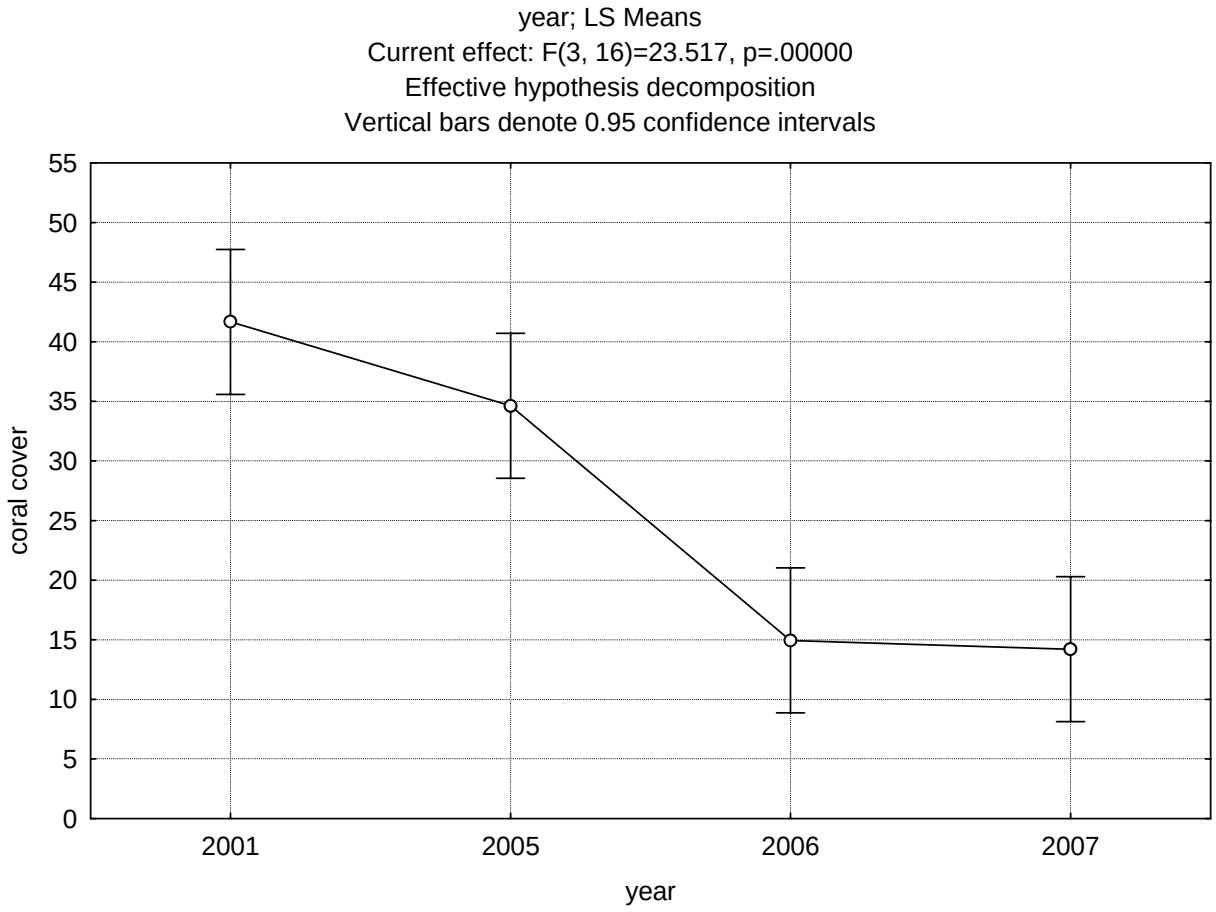
year		LSD Test; Variable: coral cover (Spreadsheet12) Marked differences are significant at p < .05000			
		{1} M=25.302	{2} M=16.986	{3} M=14.674	{4} M=9.2360
1999	{1}		0.005917	0.000922	0.000015
2005	{2}	0.005917		0.390903	0.009293
2006	{3}	0.000922	0.390903		0.054563
2007	{4}	0.000015	0.009293	0.054563	

2.11 Caja de Muerto



year		LSD Test; Variable: coral cover (Spreadsheet3 Marked differences are significant at p < .0500			
		{1} M=24.452	{2} M=19.246	{3} M=11.424	{4} M=10.542
1999	{1}		0.233233	0.006874	0.004422
2005	{2}	0.233233		0.081150	0.054852
2006	{3}	0.006874	0.081150		0.836395
2007	{4}	0.004422	0.054852	0.836395	

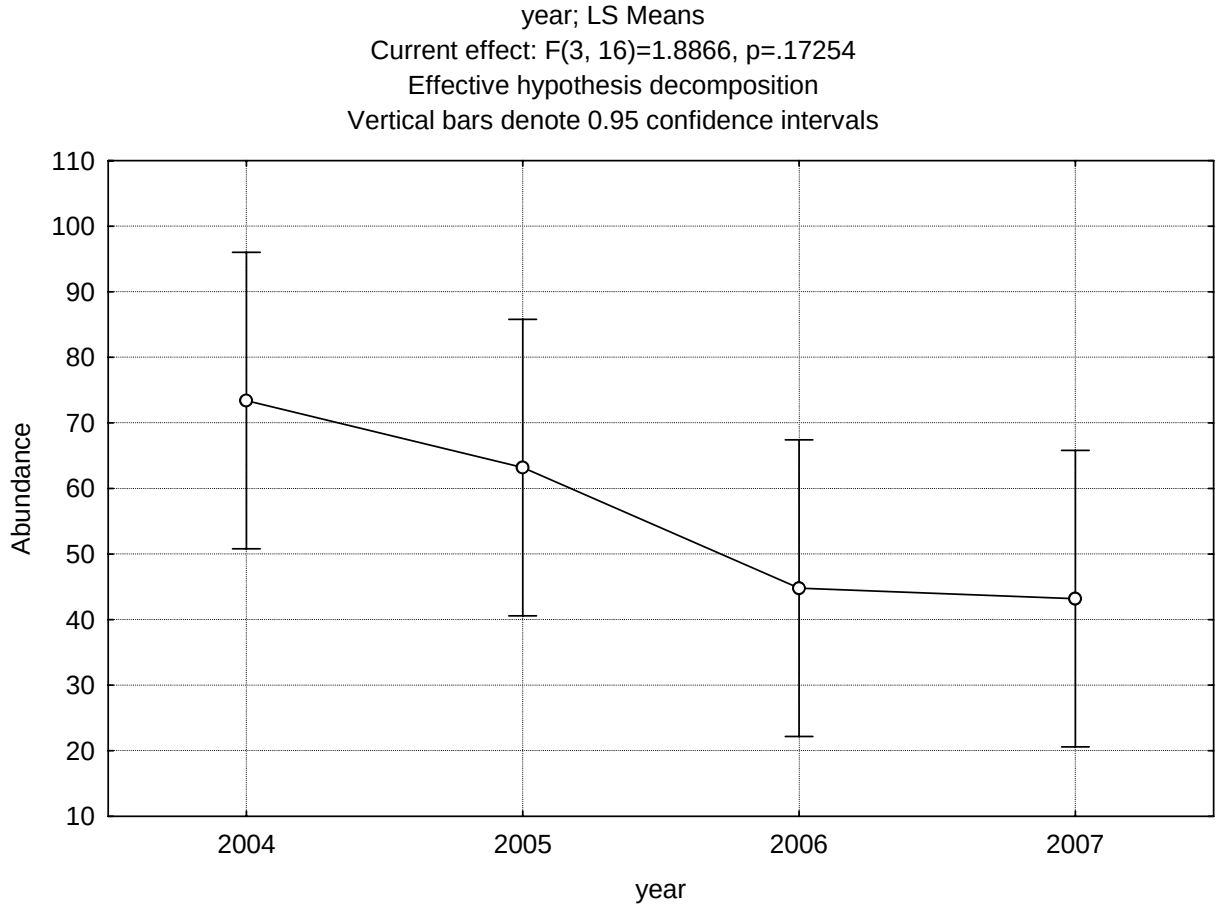
2.12 Derrumbadero



year		LSD Test; Variable: coral cover (Spreadsheet15 Marked differences are significant at p < .05000			
		{1} M=41.668	{2} M=34.625	{3} M=14.948	{4} M=14.208
2001	{1}		0.101760	0.000006	0.000005
2005	{2}	0.101760		0.000177	0.000122
2006	{3}	0.000006	0.000177		0.857551
2007	{4}	0.000005	0.000122	0.857551	

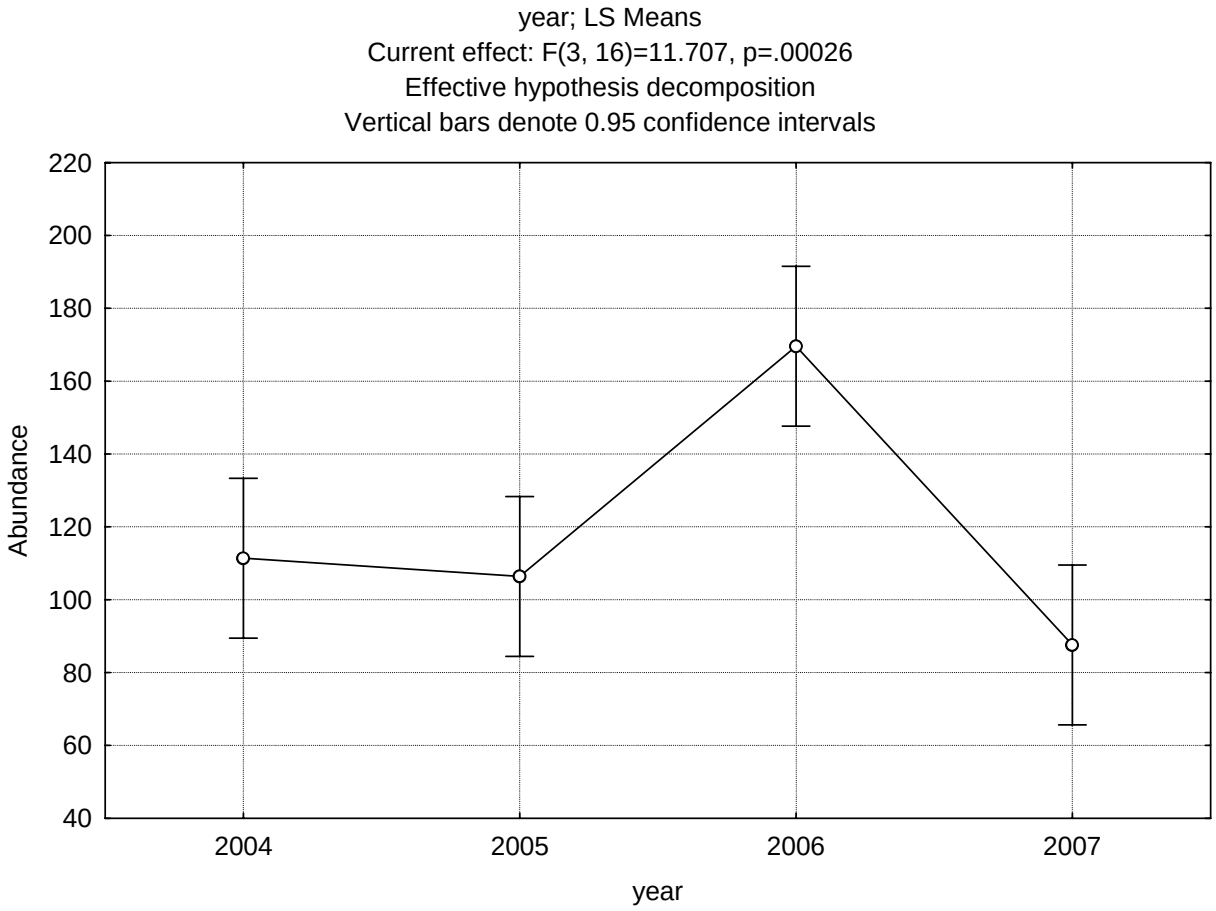
Appendix 3. Analysis of variance (ANOVA) procedure testing differences in fish abundance cover between annual monitoring surveys

3.1 Rincon-5m



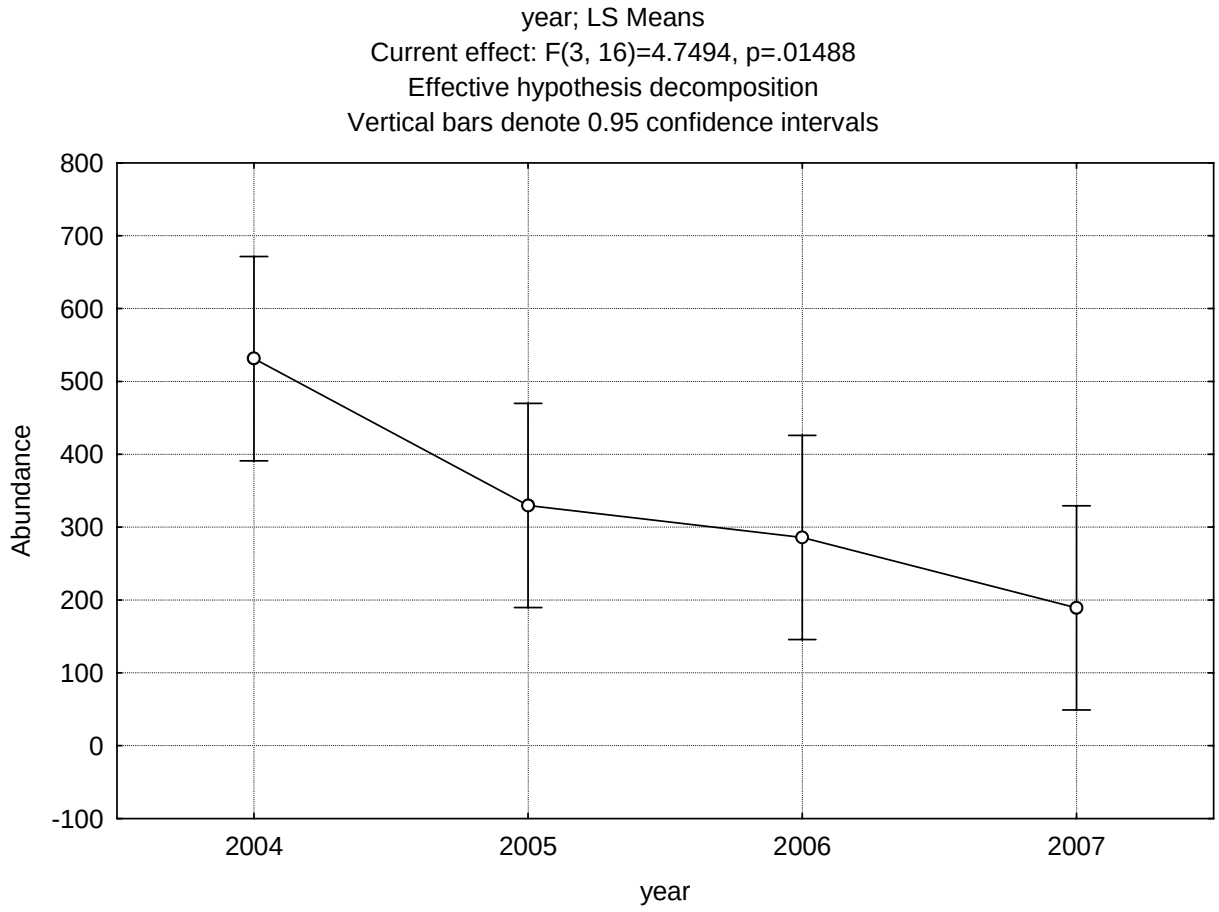
| | | LSD Test; Variable: Abundance (Spreadsheet67
Marked differences are significant at p < .05000 | | | |
|---|---|---|---|---|---|
| year | | {1} M=73.400 | {2} M=63.200 | {3} M=44.800 | {4} M=43.200 |
| 2004 | {1} | | 0.508529 | 0.076140 | 0.062503 |
| 2005 | {2} | 0.508529 | | 0.240167 | 0.203454 |
| 2006 | {3} | 0.076140 | 0.240167 | | 0.916836 |
| 2007 | {4} | 0.062503 | 0.203454 | 0.916836 | |

3.2 Rincon-10m



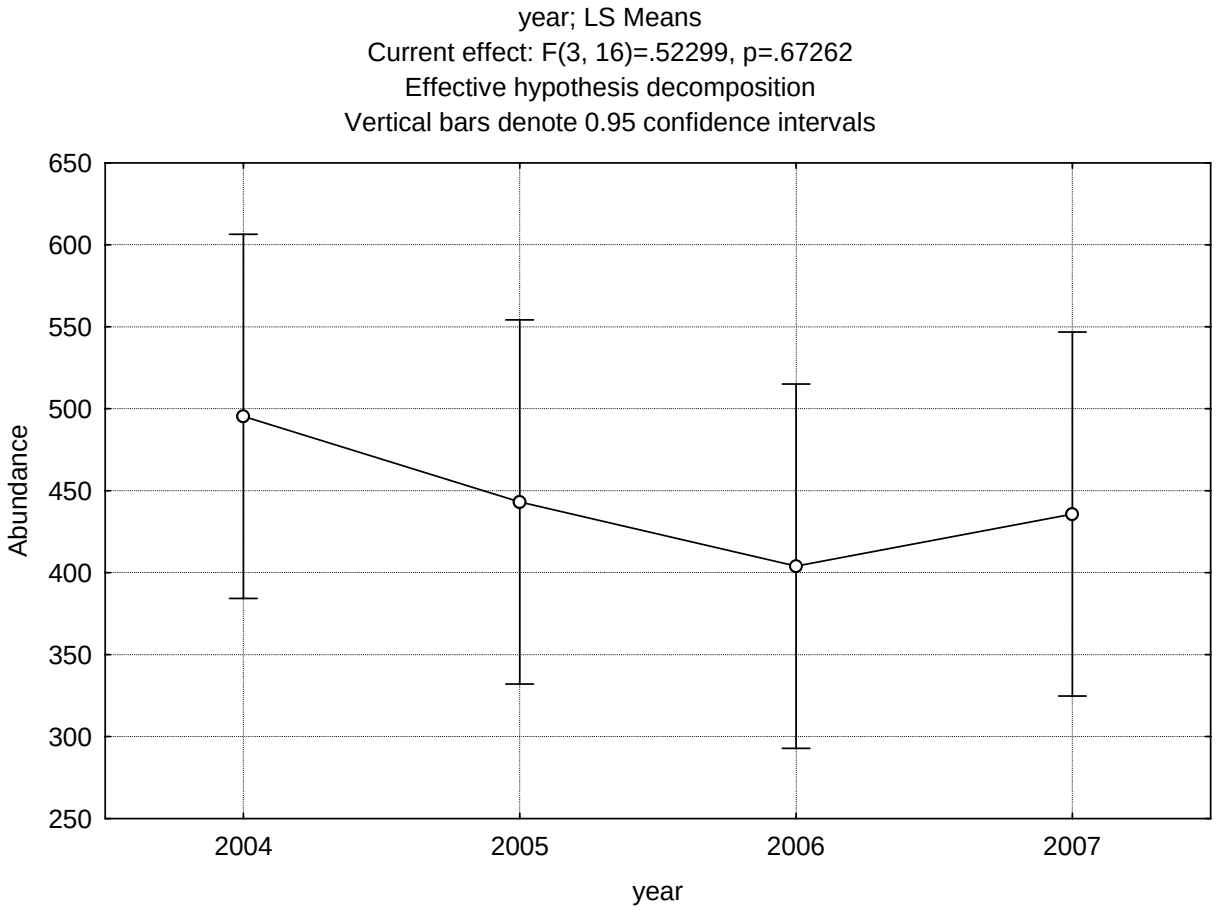
year		LSD Test; Variable: Abundance (Spreadsheet7(Marked differences are significant at p < .05000			
		{1} M=111.40	{2} M=106.40	{3} M=169.60	{4} M=87.600
2004	{1}		0.737114	0.001086	0.123501
2005	{2}	0.737114		0.000531	0.217312
2006	{3}	0.001086	0.000531		0.000040
2007	{4}	0.123501	0.217312	0.000040	

3.3 Rincon-20m



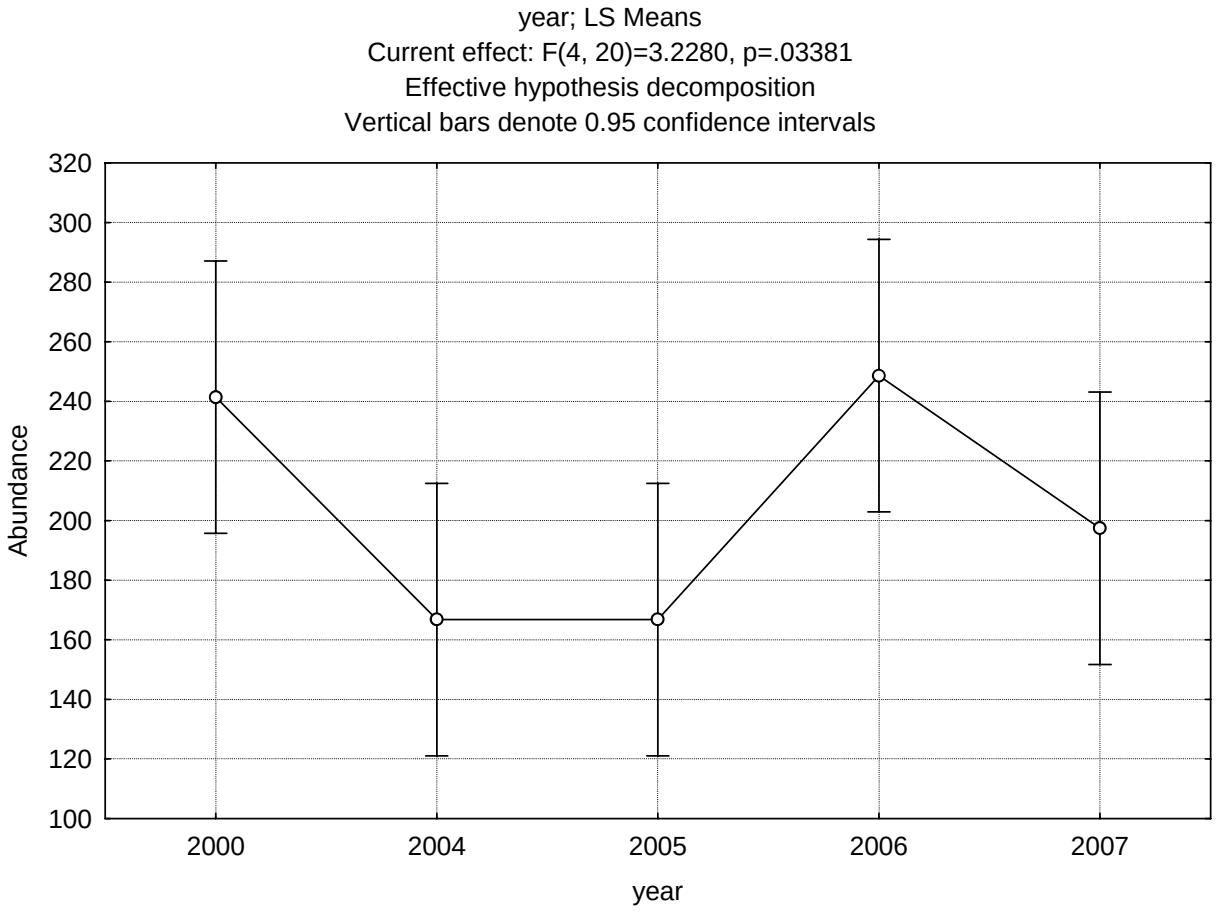
year		LSD Test; Variable: Abundance (Spreadsheet7 Marked differences are significant at p < .05000			
		{1} M=531.40	{2} M=329.80	{3} M=285.80	{4} M=189.20
2004	{1}		0.046628	0.018313	0.002113
2005	{2}	0.046628		0.644271	0.152111
2006	{3}	0.018313	0.644271		0.316874
2007	{4}	0.002113	0.152111	0.316874	

3.4 Desecheo-30m



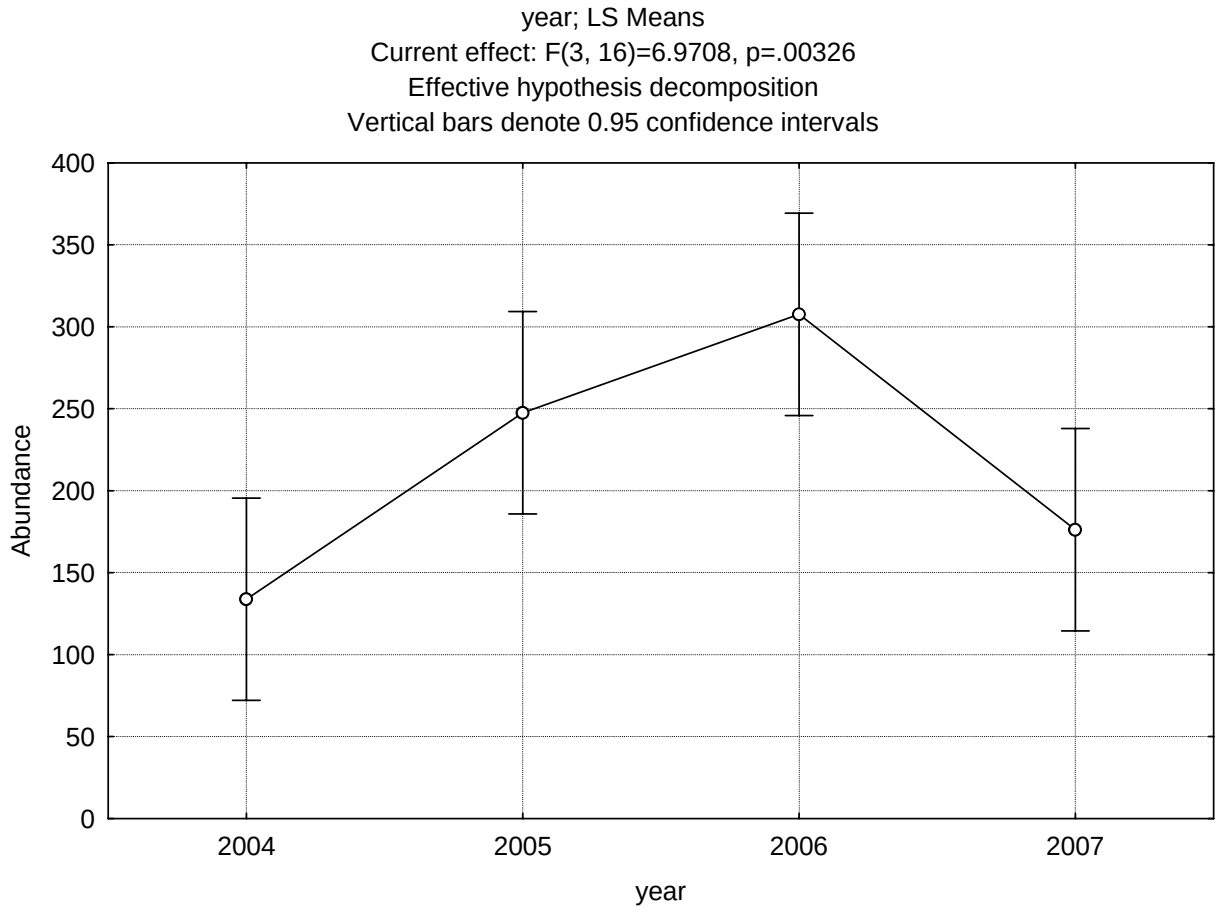
		LSD Test; Variable: Abundance (Spreadsheet64 Marked differences are significant at p < .05000			
year		{1} M=495.40	{2} M=443.20	{3} M=404.00	{4} M=435.80
2004	{1}		0.491325	0.235265	0.433052
2005	{2}	0.491325		0.604097	0.921701
2006	{3}	0.235265	0.604097		0.673571
2007	{4}	0.433052	0.921701	0.673571	

3.5 Desecheo-20m



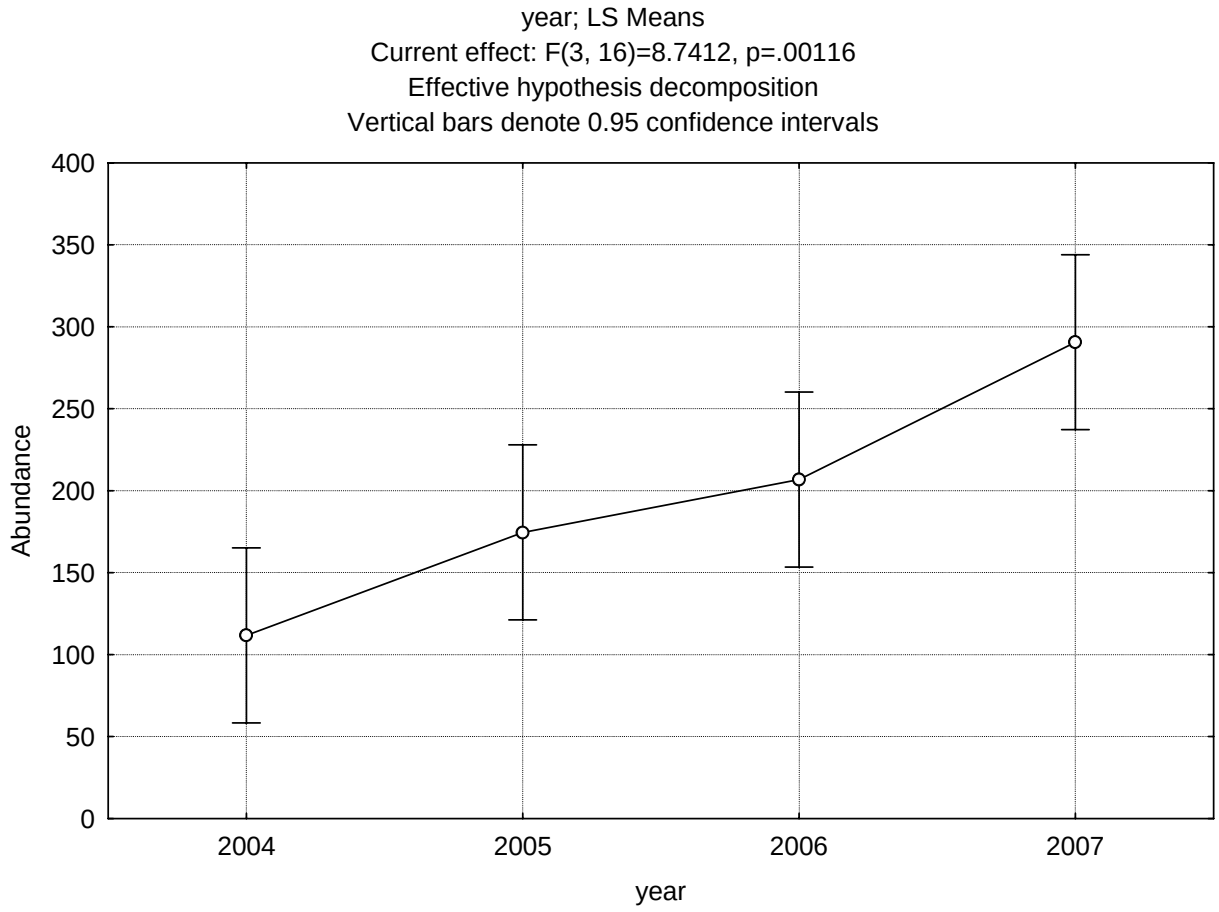
year		LSD Test; Variable: Abundance (Spreadsheet61) Marked differences are significant at p < .05000				
		{1} M=241.40	{2} M=166.80	{3} M=166.80	{4} M=248.60	{5} M=197.40
2000	{1}		0.025839	0.025839	0.818622	0.171021
2004	{2}	0.025839		1.000000	0.015710	0.335187
2005	{3}	0.025839	1.000000		0.015710	0.335187
2006	{4}	0.818622	0.015710	0.015710		0.114084
2007	{5}	0.171021	0.335187	0.335187	0.114084	

3.6 Desecheo-15m



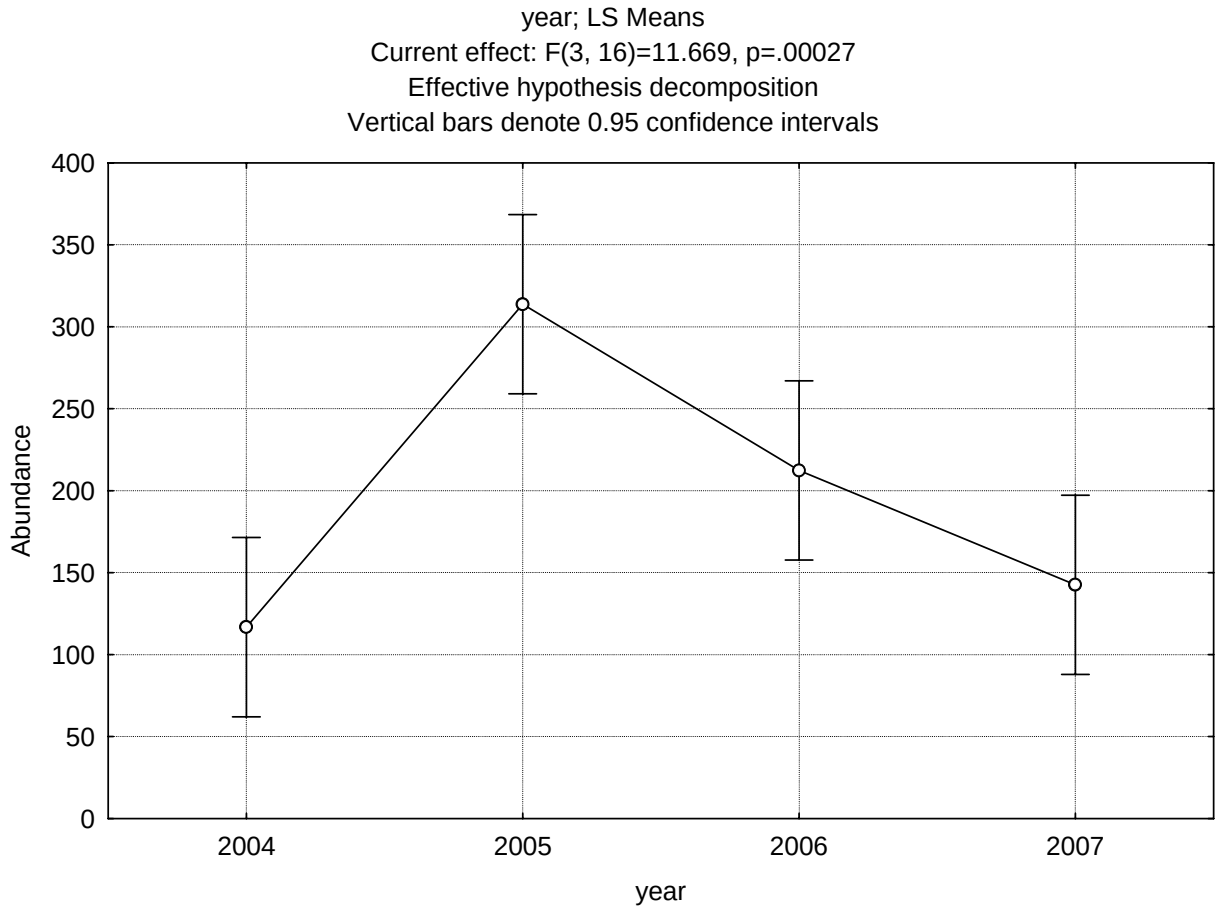
year		LSD Test; Variable: Abundance (Spreadsheet57 Marked differences are significant at p < .05000			
		{1} M=133.80	{2} M=247.60	{3} M=307.60	{4} M=176.20
2004	{1}		0.013840	0.000650	0.318473
2005	{2}	0.013840		0.164435	0.102149
2006	{3}	0.000650	0.164435		0.005684
2007	{4}	0.318473	0.102149	0.005684	

3.7 Tourmaline-30m



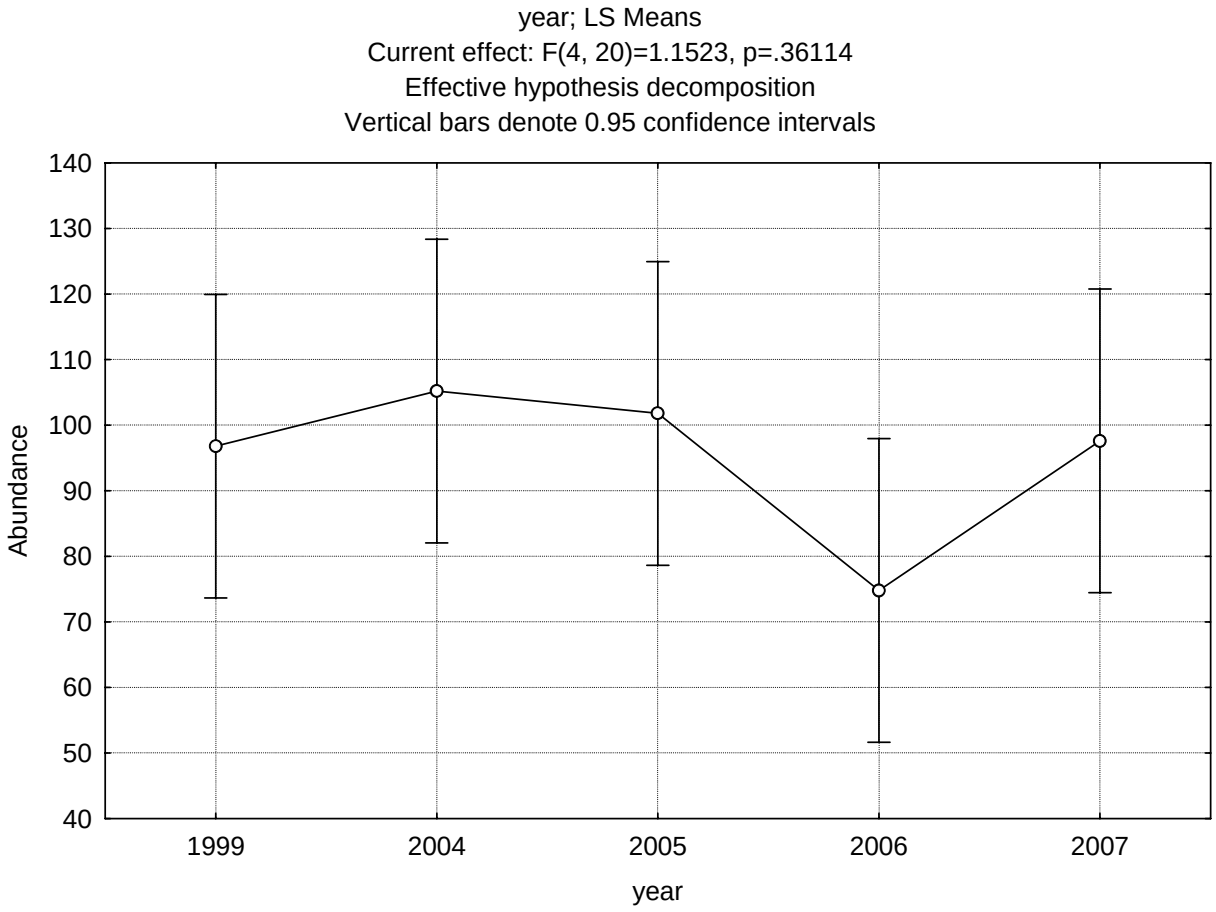
year		LSD Test; Variable: Abundance (Spreadsheet54 Marked differences are significant at p < .05000			
		{1} M=111.80	{2} M=174.60	{3} M=206.80	{4} M=290.60
2004	{1}		0.096768	0.016809	0.000125
2005	{2}	0.096768		0.379094	0.004929
2006	{3}	0.016809	0.379094		0.031670
2007	{4}	0.000125	0.004929	0.031670	

3.8 Tourmaline -20m



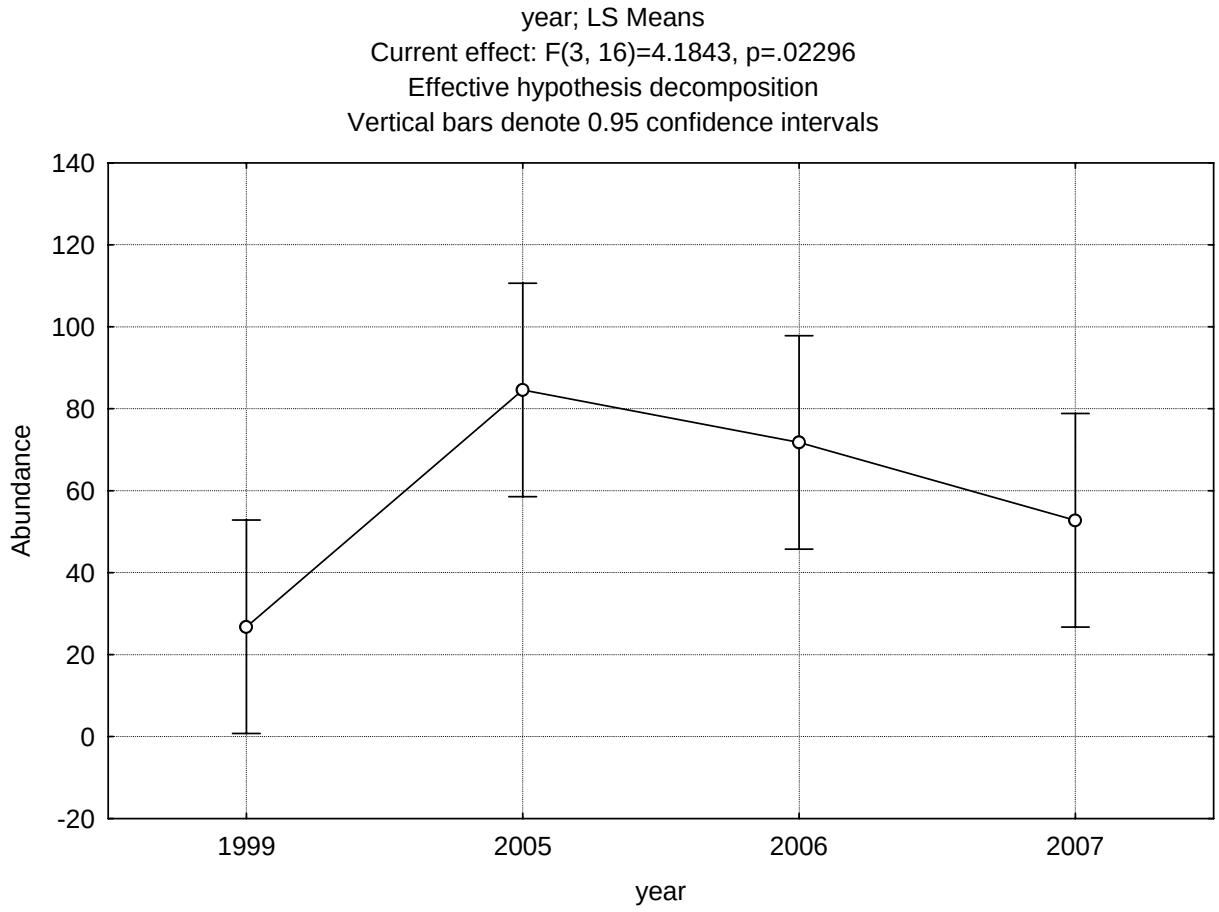
year		LSD Test; Variable: Abundance (Spreadsheet4 Marked differences are significant at p < .05000			
		{1} M=116.80	{2} M=313.80	{3} M=212.40	{4} M=142.60
2004	{1}		0.000059	0.018495	0.489369
2005	{2}	0.000059		0.013353	0.000243
2006	{3}	0.018495	0.013353		0.073629
2007	{4}	0.489369	0.000243	0.073629	

3.9 Tourmaline -10m



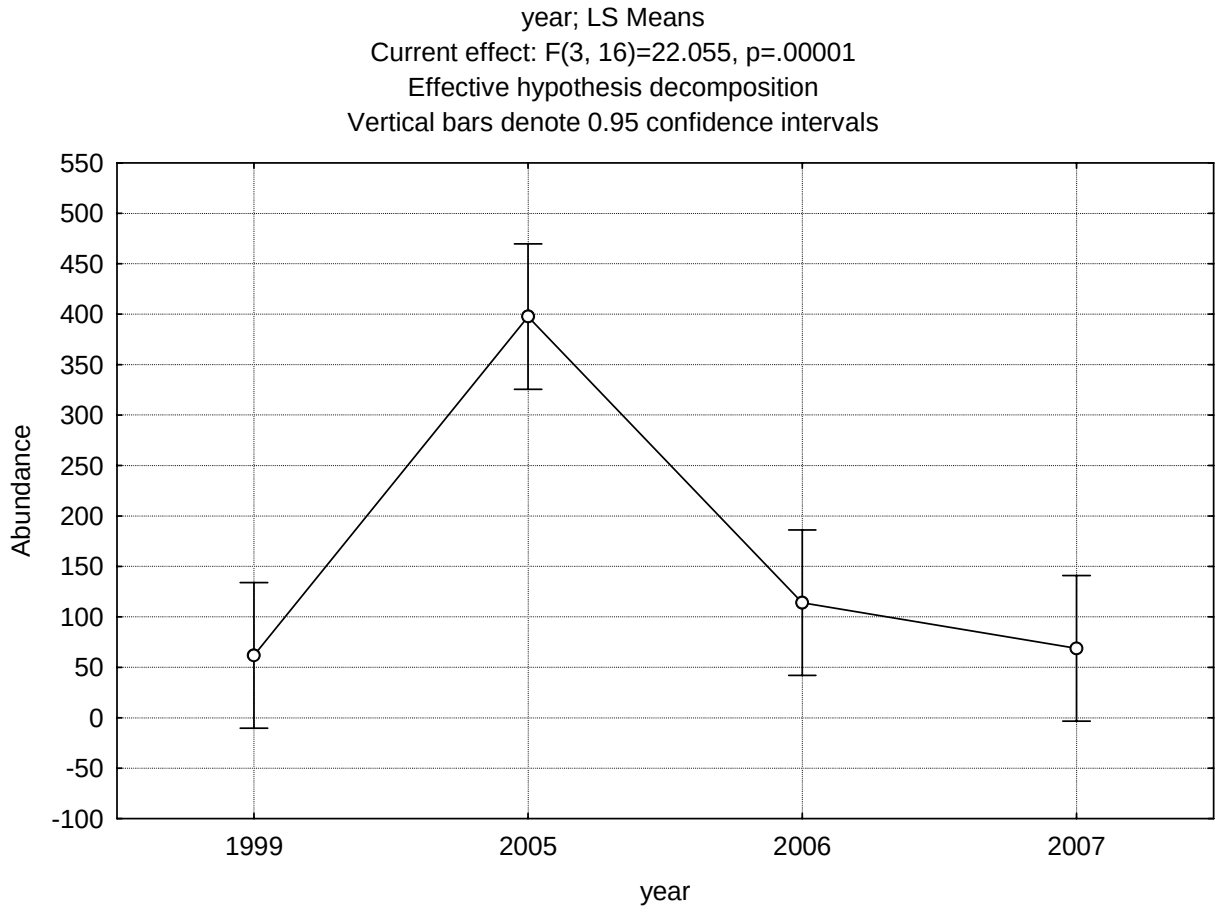
year		LSD Test; Variable: Abundance (Spreadsheet51) Marked differences are significant at p < .05000				
		{1} M=96.800	{2} M=105.20	{3} M=101.80	{4} M=74.800	{5} M=97.600
1999	{1}		0.598525	0.753428	0.176458	0.959866
2004	{2}	0.598525		0.830744	0.067089	0.633589
2005	{3}	0.753428	0.830744		0.100916	0.791810
2006	{4}	0.176458	0.067089	0.100916		0.161945
2007	{5}	0.959866	0.633589	0.791810	0.161945	

3.10 Cayo Coral



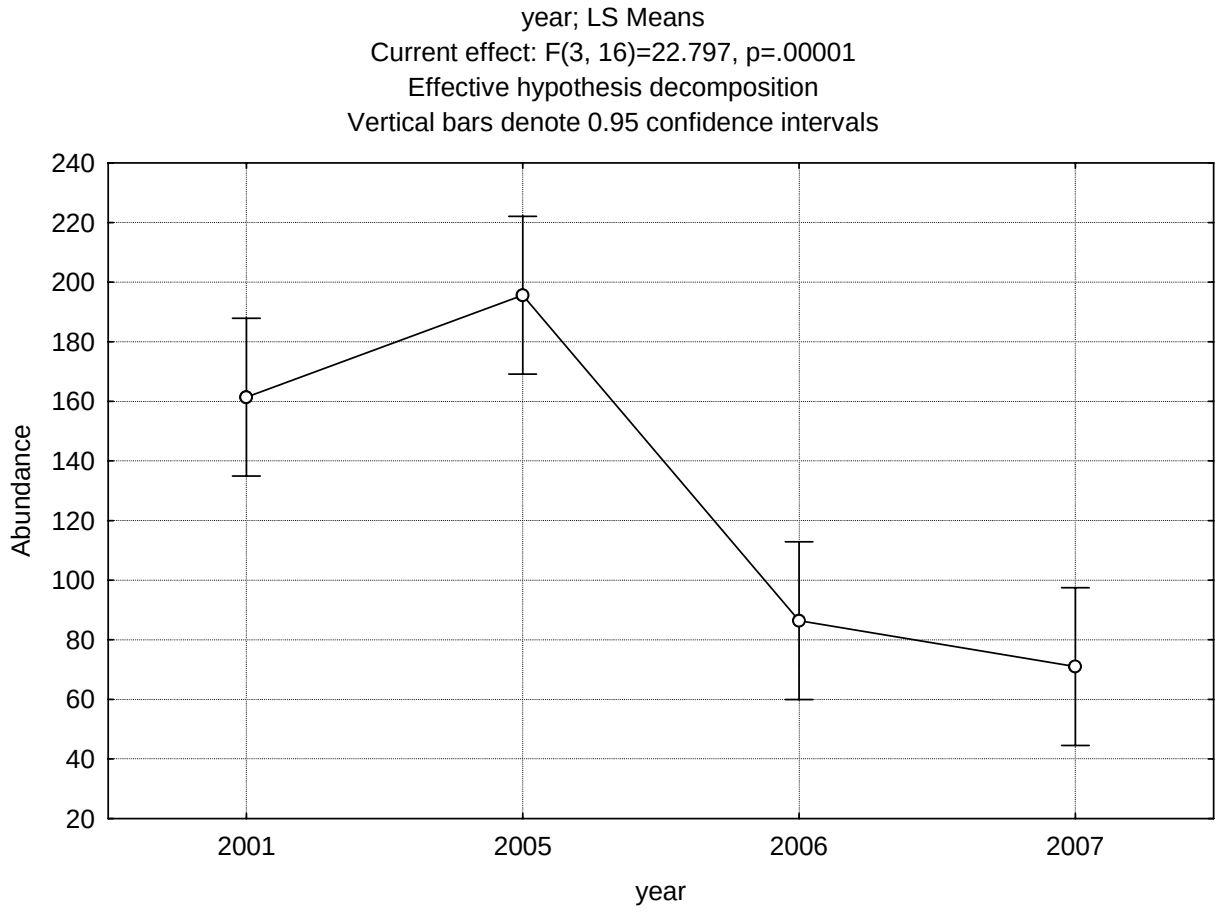
year		LSD Test; Variable: Abundance (Spreadsheet82 Marked differences are significant at p < .05000			
		{1} M=26.800	{2} M=84.600	{3} M=71.800	{4} M=52.800
1999	{1}		0.004270	0.019732	0.153981
2005	{2}	0.004270		0.471939	0.085886
2006	{3}	0.019732	0.471939		0.290315
2007	{4}	0.153981	0.085886	0.290315	

3.11 Caja de Muerto



		LSD Test; Variable: Abundance (Spreadsheet7 Marked differences are significant at p < .05000			
year		{1} M=61.800	{2} M=397.60	{3} M=114.00	{4} M=68.800
1999	{1}		0.000003	0.293863	0.886102
2005	{2}	0.000003		0.000023	0.000004
2006	{3}	0.293863	0.000023		0.361304
2007	{4}	0.886102	0.000004	0.361304	

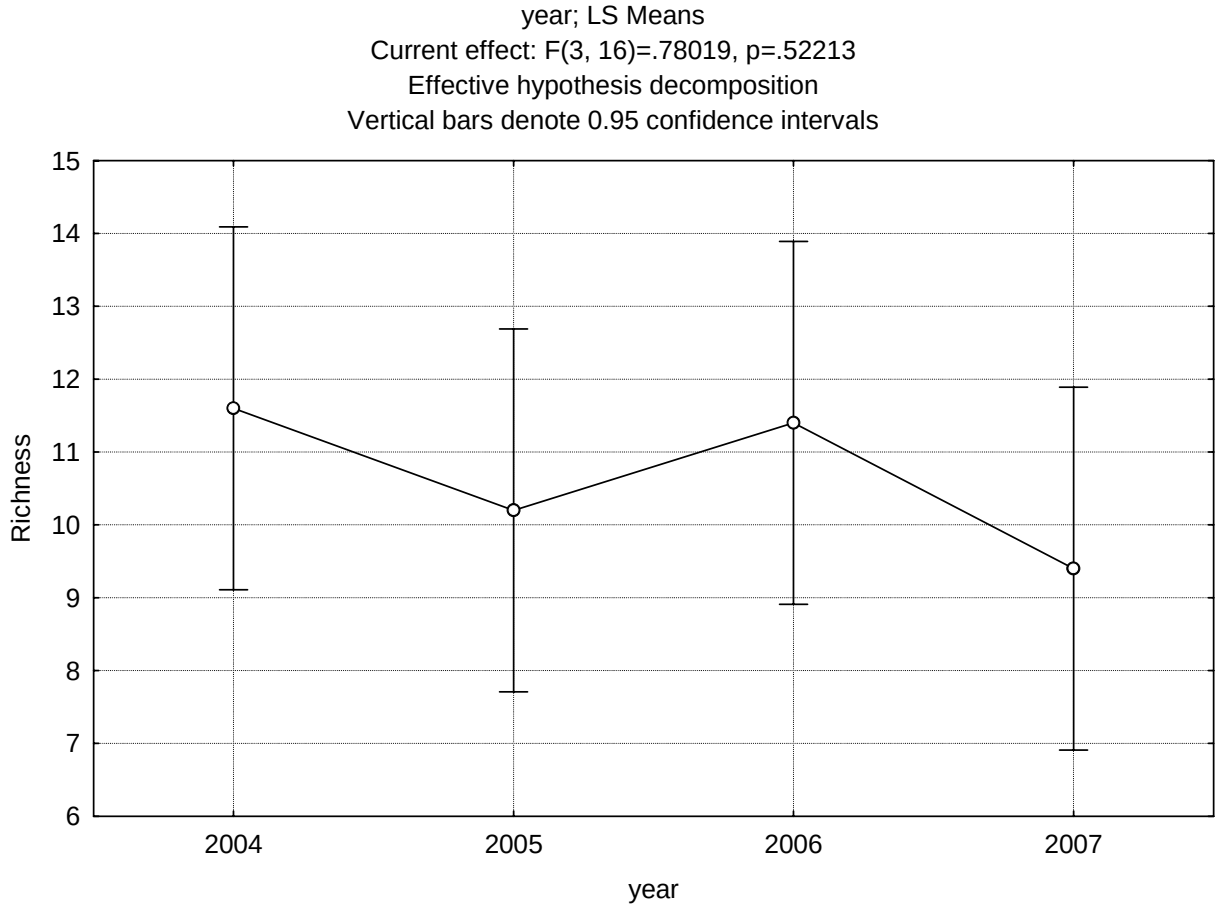
3.12 Derrumbadero



year		LSD Test; Variable: Abundance (Spreadsheet7€ Marked differences are significant at p < .05000			
		{1} M=161.40	{2} M=195.60	{3} M=86.400	{4} M=71.000
2001	{1}		0.070648	0.000615	0.000103
2005	{2}	0.070648		0.000013	0.000003
2006	{3}	0.000615	0.000013		0.396065
2007	{4}	0.000103	0.000003	0.396065	

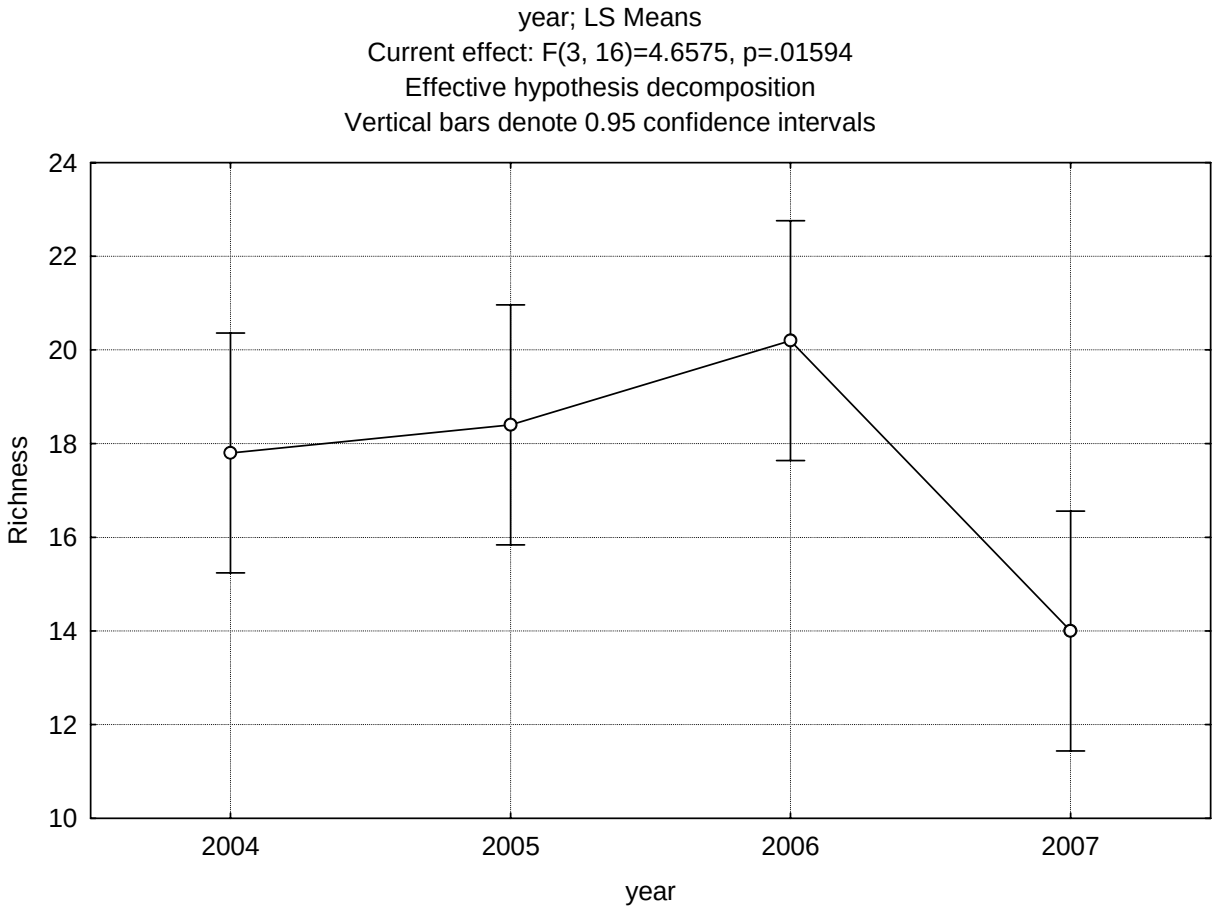
Appendix 4. Analysis of variance (ANOVA) procedure testing differences in fish species richness between annual monitoring surveys

4.1 Rincon-5m



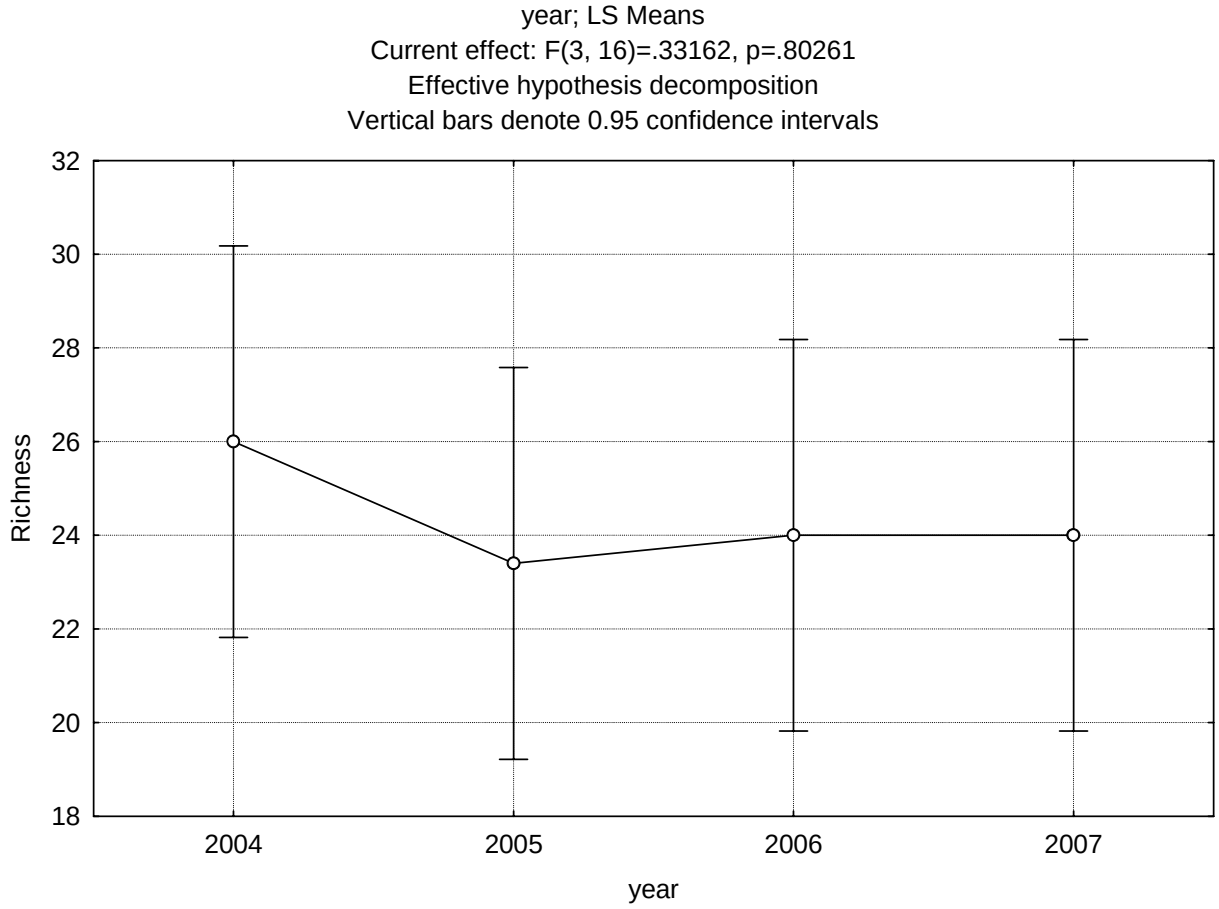
year		LSD Test; Variable: Richness (Spreadsheet103 Marked differences are significant at p < .05000			
		{1} M=11.600	{2} M=10.200	{3} M=11.400	{4} M=9.4000
2004	{1}		0.411816	0.905676	0.204028
2005	{2}	0.411816		0.480526	0.636650
2006	{3}	0.905676	0.480526		0.246153
2007	{4}	0.204028	0.636650	0.246153	

4.2 Rincon-10m



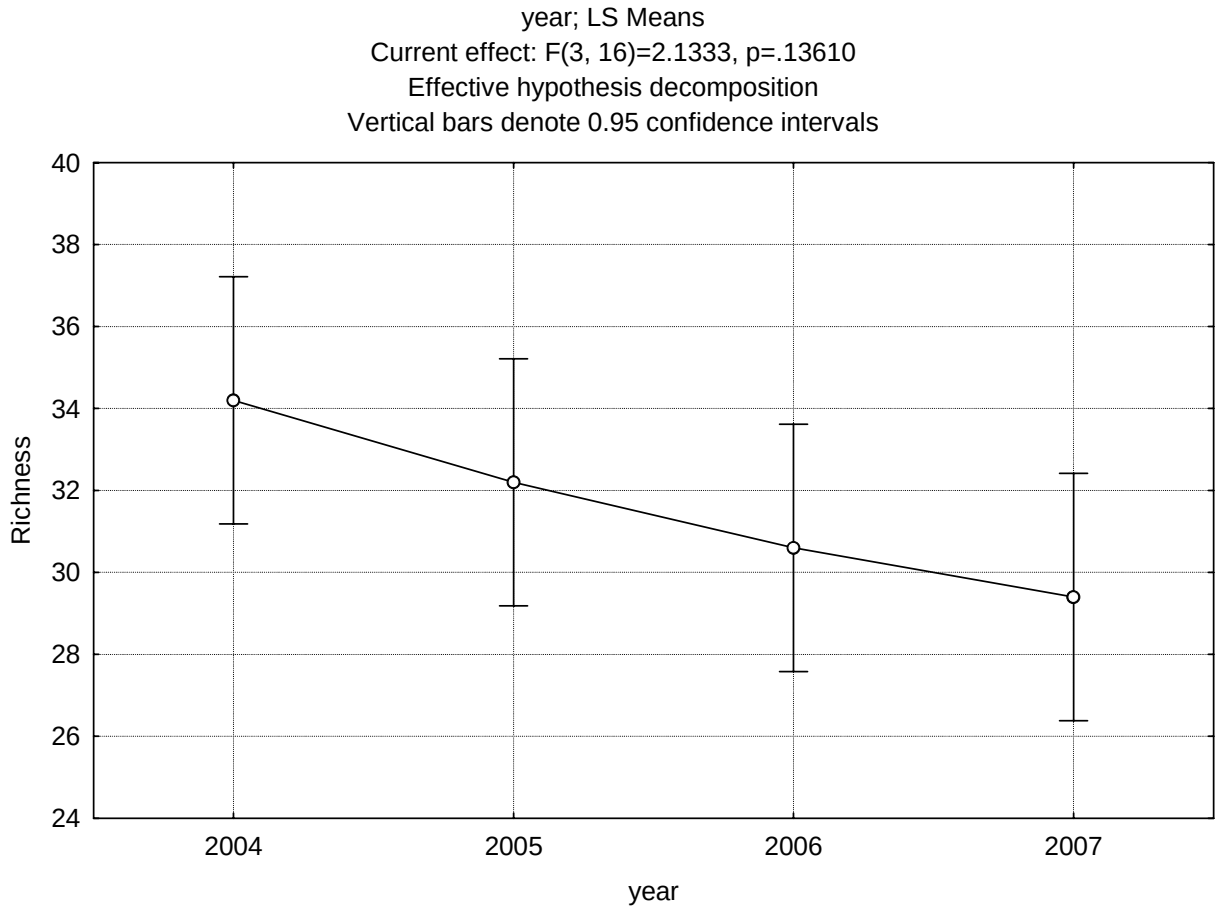
year		LSD Test; Variable: Richness (Spreadsheet107 Marked differences are significant at p < .05000			
		{1} M=17.800	{2} M=18.400	{3} M=20.200	{4} M=14.000
2004	{1}		0.730077	0.179287	0.040912
2005	{2}	0.730077		0.307820	0.020351
2006	{3}	0.179287	0.307820		0.002260
2007	{4}	0.040912	0.020351	0.002260	

4.3 Rincon-20m



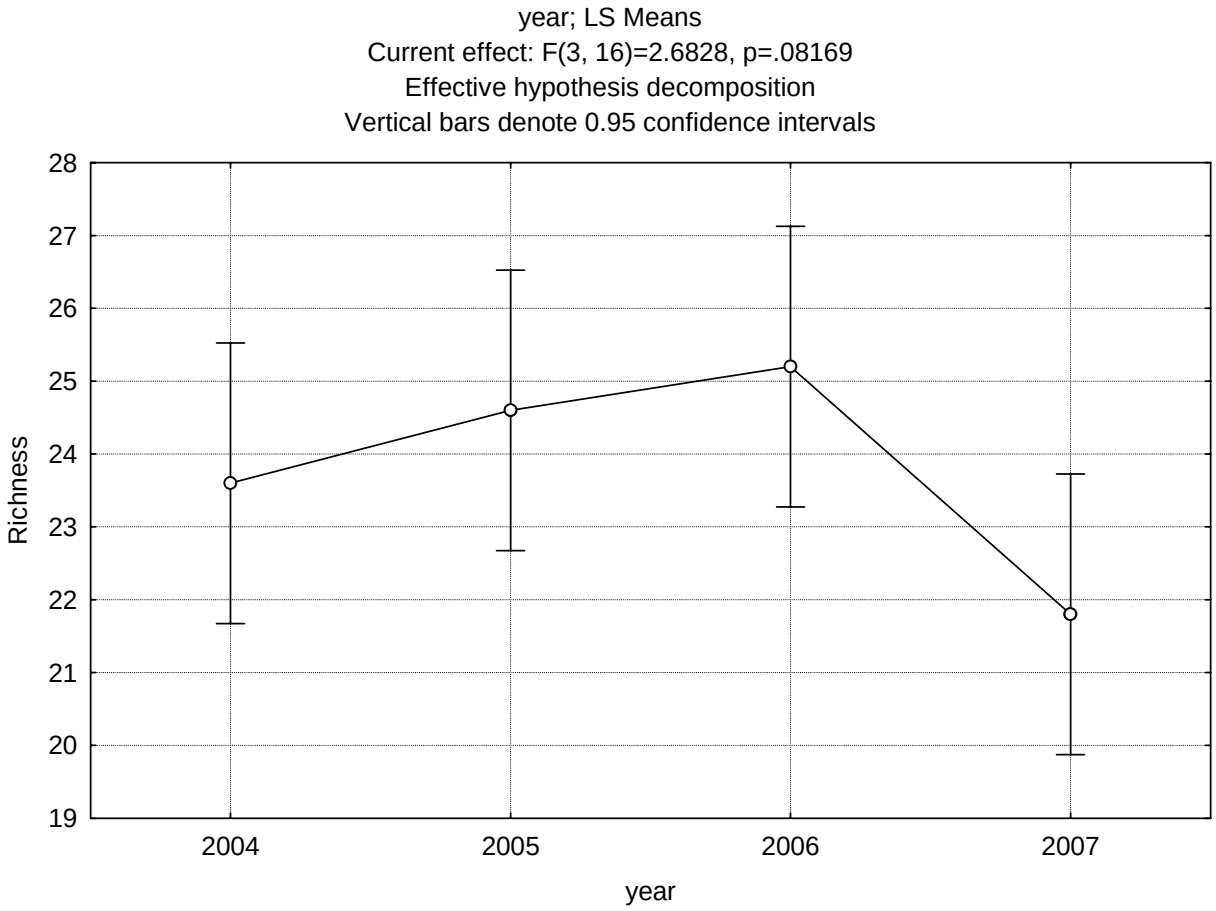
year		LSD Test; Variable: Richness (Spreadsheet110 Marked differences are significant at p < .05000			
		{1} M=26.000	{2} M=23.400	{3} M=24.000	{4} M=24.000
2004	{1}		0.365115	0.483690	0.483690
2005	{2}	0.365115		0.832399	0.832399
2006	{3}	0.483690	0.832399		1.000000
2007	{4}	0.483690	0.832399	1.000000	

4.4 Desecheo-30m



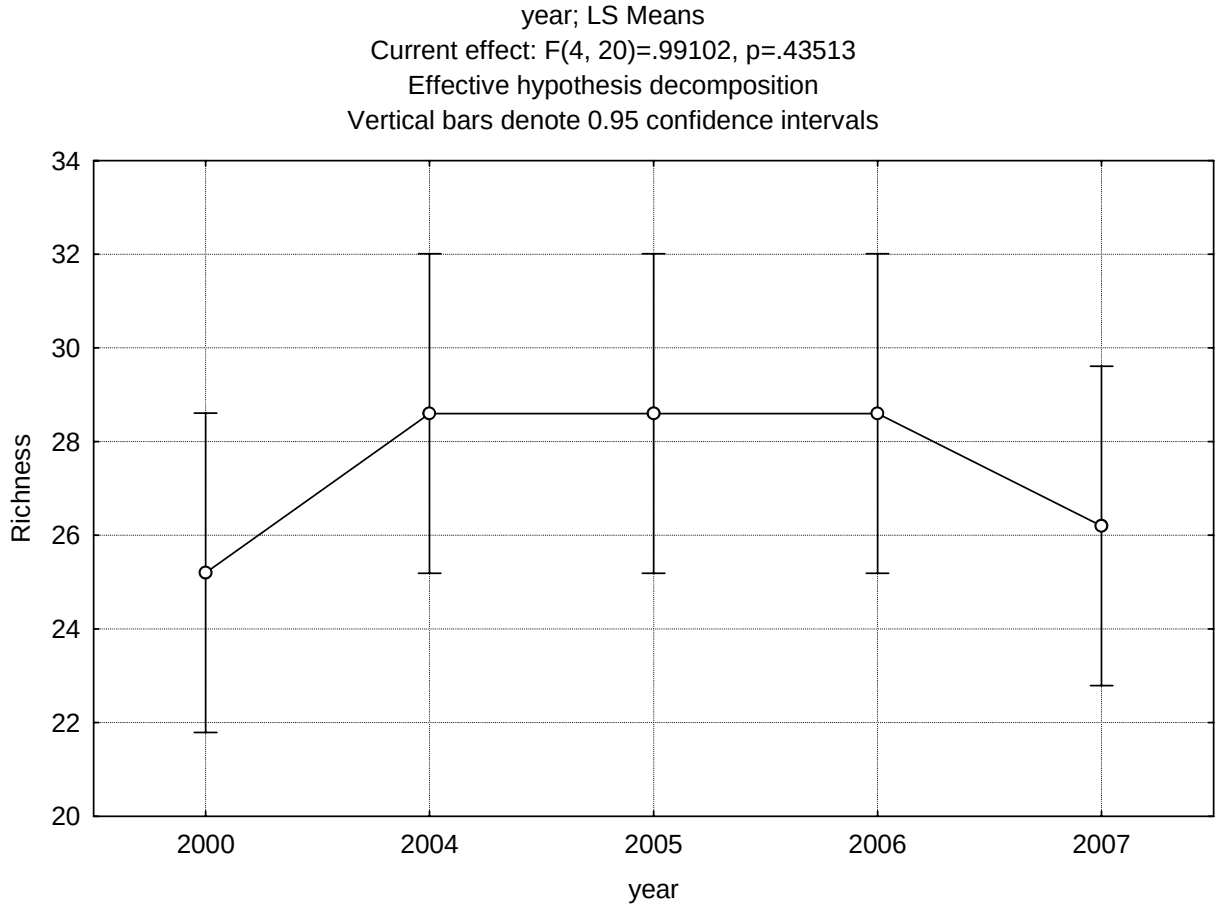
year		LSD Test; Variable: Richness (Spreadsheet100 Marked differences are significant at p < .05000			
		{1} M=34.200	{2} M=32.200	{3} M=30.600	{4} M=29.400
2004	{1}		0.335109	0.092586	0.029787
2005	{2}	0.335109		0.438222	0.183170
2006	{3}	0.092586	0.438222		0.559327
2007	{4}	0.029787	0.183170	0.559327	

4.5 Desecheo-15m



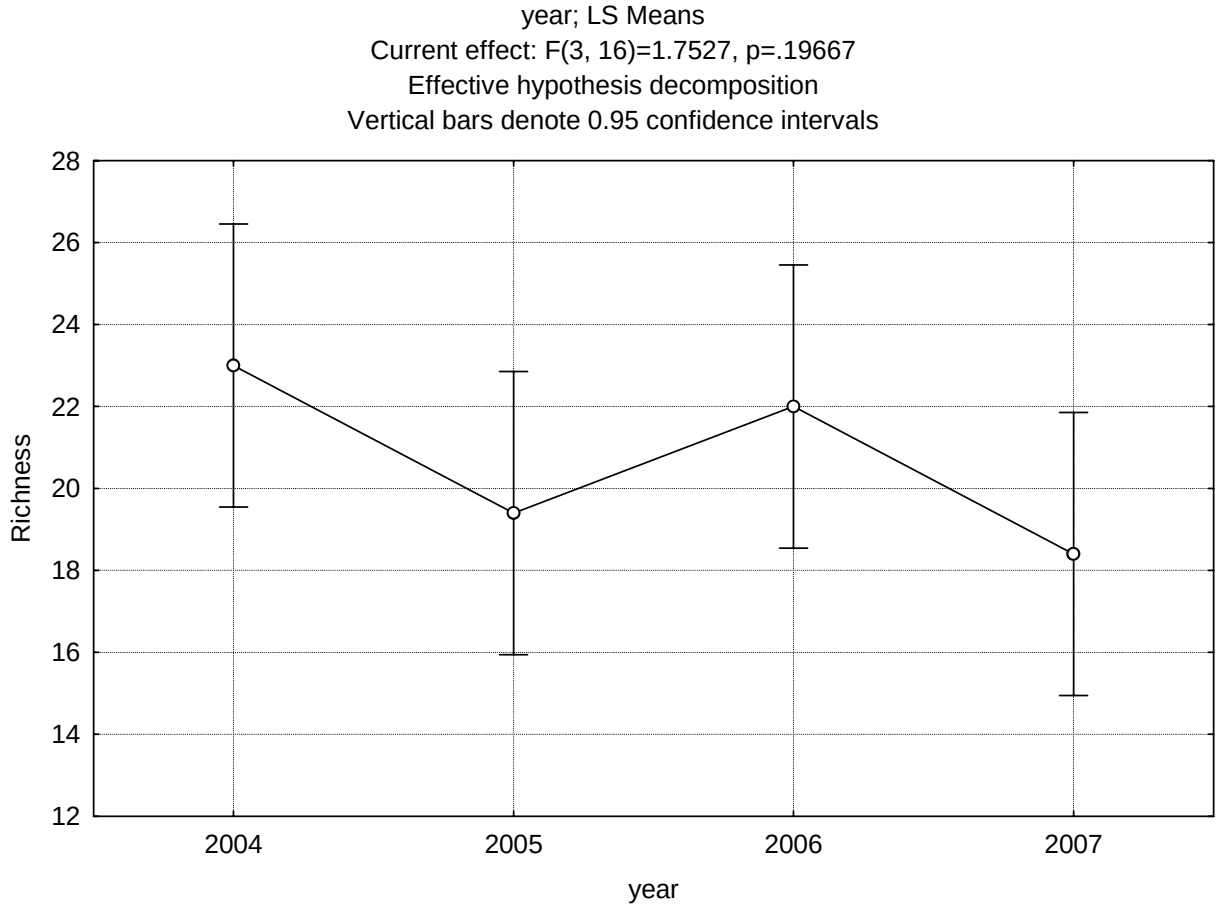
year		LSD Test; Variable: Richness (Spreadsheet94) Marked differences are significant at p < .0500			
		{1} M=23.600	{2} M=24.600	{3} M=25.200	{4} M=21.800
2004	{1}		0.447636	0.230845	0.180223
2005	{2}	0.447636		0.646727	0.044556
2006	{3}	0.230845	0.646727		0.017580
2007	{4}	0.180223	0.044556	0.017580	

4.6 Desecheo-20m



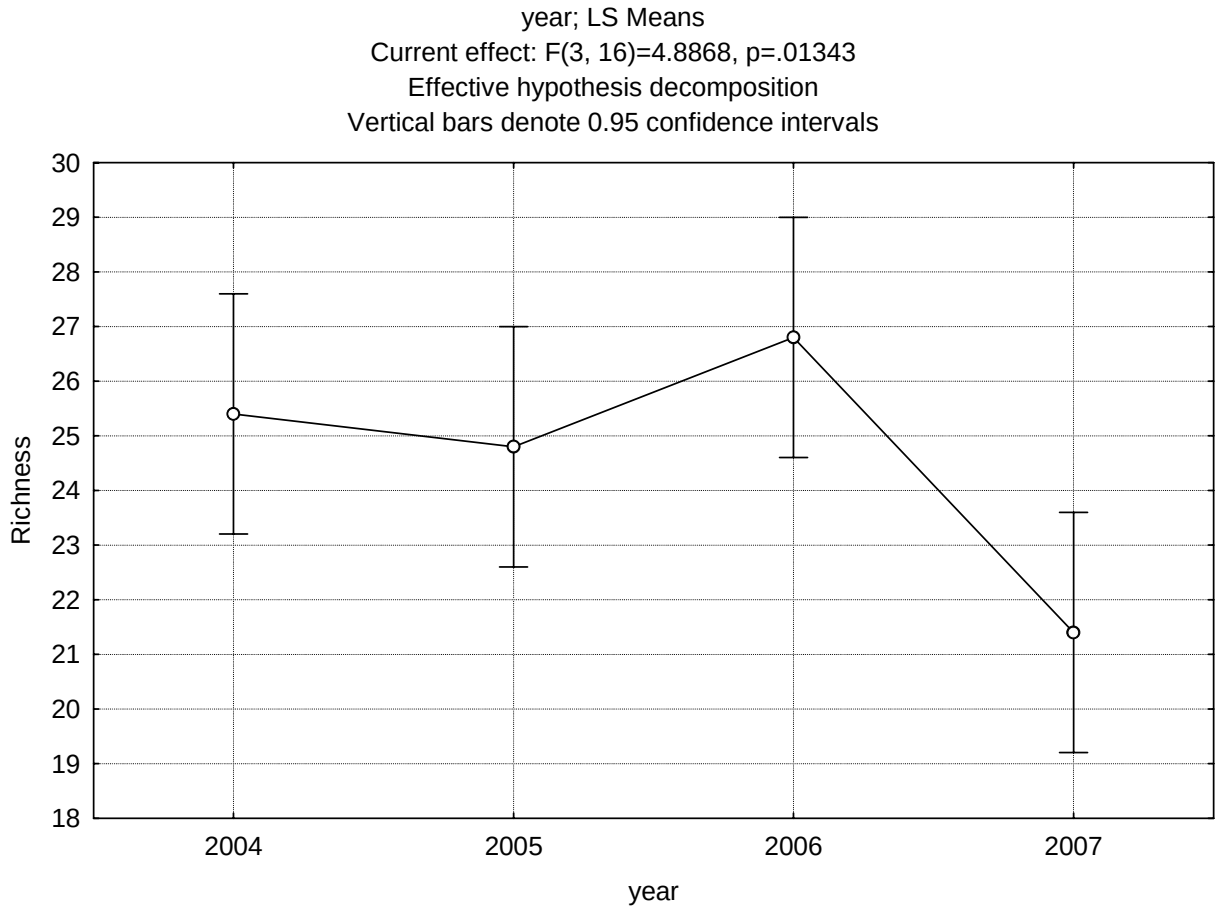
year		LSD Test; Variable: Richness (Spreadsheet97) Marked differences are significant at p < .05000				
		{1} M=25.200	{2} M=28.600	{3} M=28.600	{4} M=28.600	{5} M=26.200
2000	{1}		0.156911	0.156911	0.156911	0.669948
2004	{2}	0.156911		1.000000	1.000000	0.311570
2005	{3}	0.156911	1.000000		1.000000	0.311570
2006	{4}	0.156911	1.000000	1.000000		0.311570
2007	{5}	0.669948	0.311570	0.311570	0.311570	

4.7 Tourmaline-30m



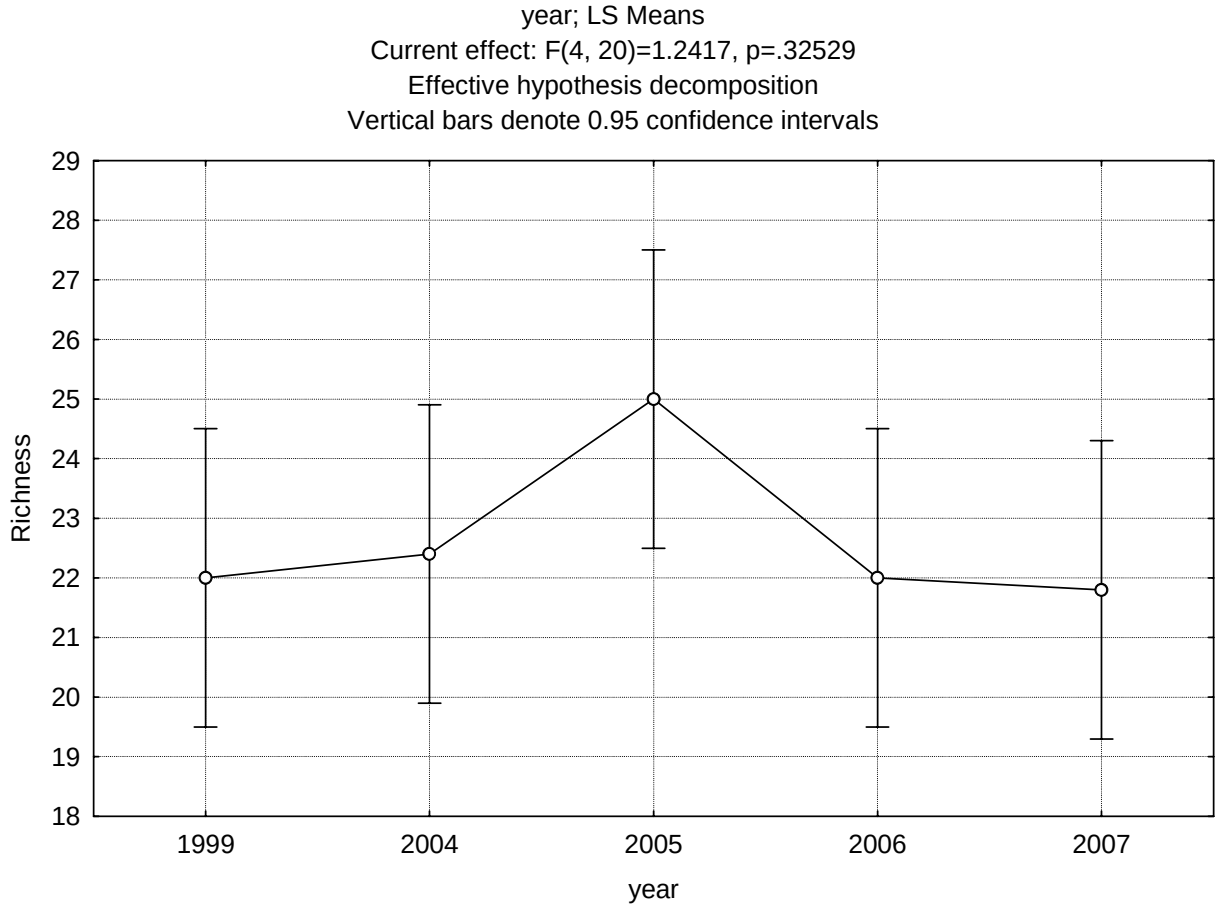
year		LSD Test; Variable: Richness (Spreadsheet91) Marked differences are significant at p < .0500			
		{1} M=23.000	{2} M=19.400	{3} M=22.000	{4} M=18.400
2004	{1}		0.137785	0.670110	0.063218
2005	{2}	0.137785		0.275827	0.670110
2006	{3}	0.670110	0.275827		0.137785
2007	{4}	0.063218	0.670110	0.137785	

4.8 Tourmaline -20m



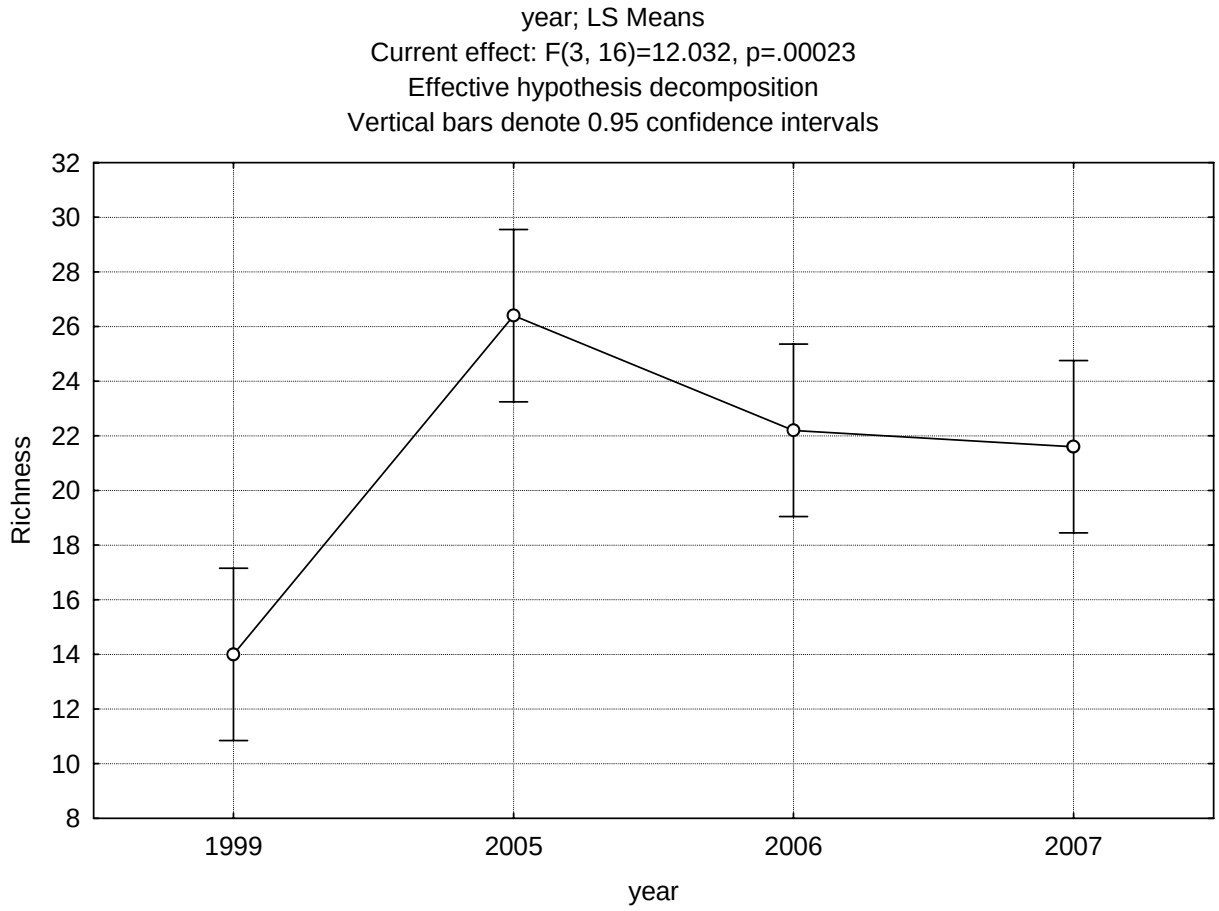
year		LSD Test; Variable: Richness (Spreadsheet88) Marked differences are significant at p < .0500			
		{1} M=25.400	{2} M=24.800	{3} M=26.800	{4} M=21.400
2004	{1}		0.687821	0.353887	0.014893
2005	{2}	0.687821		0.191453	0.033966
2006	{3}	0.353887	0.191453		0.002014
2007	{4}	0.014893	0.033966	0.002014	

4.9 Tourmaline -10m



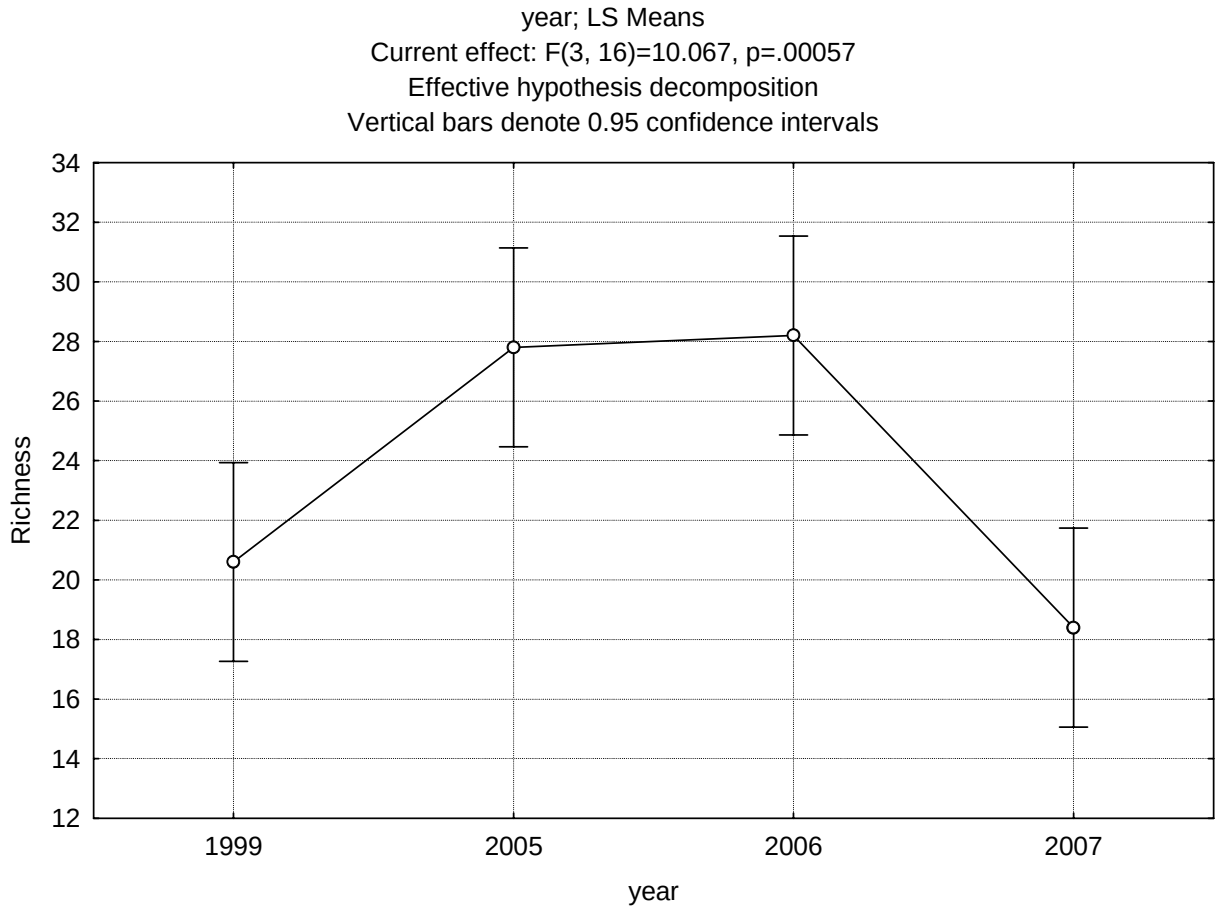
year		LSD Test; Variable: Richness (Spreadsheet85) Marked differences are significant at p < .05000				
		{1} M=22.000	{2} M=22.400	{3} M=25.000	{4} M=22.000	{5} M=21.800
1999	{1}		0.816061	0.092354	1.000000	0.907361
2004	{2}	0.816061		0.141172	0.816061	0.727373
2005	{3}	0.092354	0.141172		0.092354	0.073957
2006	{4}	1.000000	0.816061	0.092354		0.907361
2007	{5}	0.907361	0.727373	0.073957	0.907361	

4.10 Cayo Coral



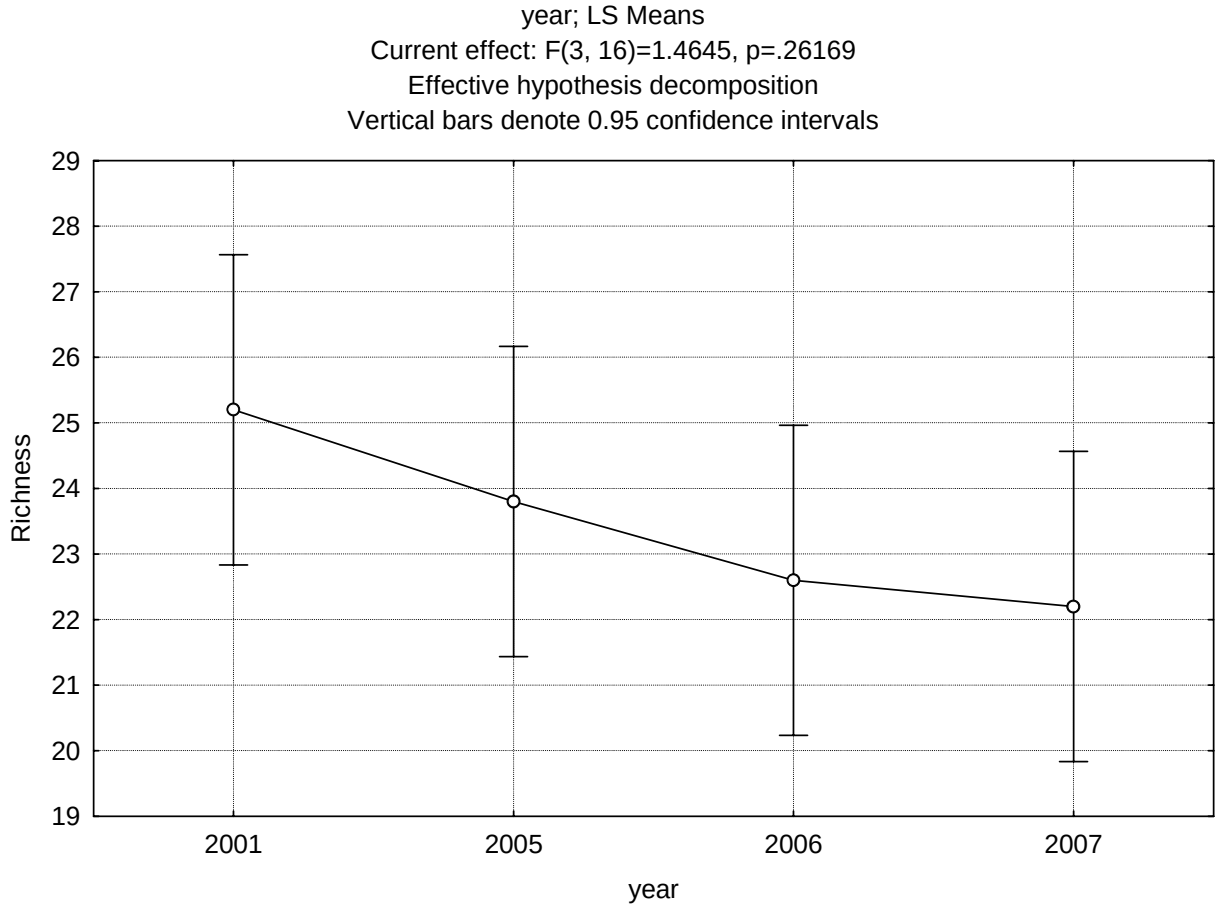
year		LSD Test; Variable: Richness (Spreadsheet119 Marked differences are significant at p < .05000			
		{1} M=14.000	{2} M=26.400	{3} M=22.200	{4} M=21.600
1999	{1}		0.000023	0.001285	0.002345
2005	{2}	0.000023		0.063307	0.036618
2006	{3}	0.001285	0.063307		0.779249
2007	{4}	0.002345	0.036618	0.779249	

4.11 Caja de Muerto



year		LSD Test; Variable: Richness (Spreadsheet116 Marked differences are significant at p < .05000			
		{1} M=20.600	{2} M=27.800	{3} M=28.200	{4} M=18.400
1999	{1}		0.005169	0.003539	0.337467
2005	{2}	0.005169		0.859577	0.000644
2006	{3}	0.003539	0.859577		0.000443
2007	{4}	0.337467	0.000644	0.000443	

4.12 Derrumbadero



year		LSD Test; Variable: Richness (Spreadsheet113 Marked differences are significant at p < .05000			
		{1} M=25.200	{2} M=23.800	{3} M=22.600	{4} M=22.200
2001	{1}		0.388106	0.118913	0.075446
2005	{2}	0.388106		0.458035	0.325691
2006	{3}	0.118913	0.458035		0.803118
2007	{4}	0.075446	0.325691	0.803118	