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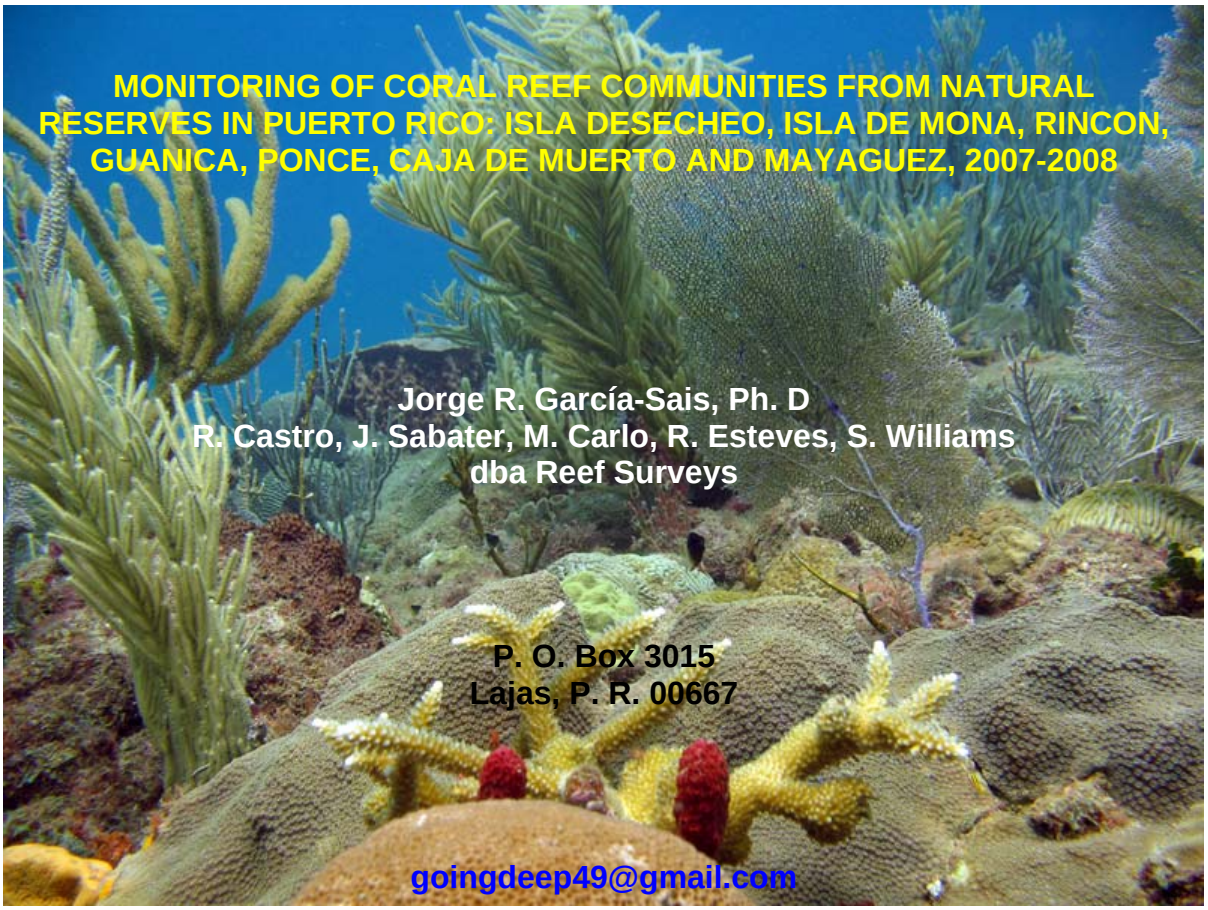

MONITORING OF CORAL REEF COMMUNITIES FROM NATURAL RESERVES IN PUERTO RICO: ISLA DESECHEO, ISLA DE MONA, RINCON, GUANICA, PONCE, CAJA DE MUERTO AND MAYAGUEZ, 2007-2008

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I Executive Summary

A total of 15 reefs from seven Natural Reserves were included in the 2008 national coral reef monitoring program of Puerto Rico. These included reef sites at Isla Desecheo, Isla de Mona, 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. Time series analyses of the biological monitoring data was performed to examine trends in the community structure of reef systems.

The sessile-benthic community at Puerto Botes and Puerto Canoas (Isla Desecheo), Playa Mujeres and Las Carmelitas (Mona Island), 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. The main inference from the 2008 monitoring survey is that reef substrate cover by live coral has stabilized to 2007 levels for almost all reef sites monitored. Lingering effects of the 2005 coral bleaching detected during 2007 were not measured in the 2008 survey. The decline of (total) live coral cover at the reef community level during 2006 was largely driven by mortality of Boulder Star Coral, *Montastraea annularis* (complex), a highly dominant species in terms of reef substrate cover and the principal reef building species. Corresponding increments of reef substrate cover by benthic algae, cyanobacteria and abiotic categories were measured. The first monitoring survey of Isla de Mona reefs detected an acute deterioration of the coral assemblage with overall reductions of total live coral in the order of 59.8 % at Las Carmelitas Reef and 67.9 % at Playa Mujeres. The reduction of reef substrate cover by the main reef building coral, Montastraea annularis was of 84.7 % for Las Carmelitas and of 88.4 % at Playa Mujeres.

Fish populations presented a general trend of declining species richness within belt-transects during 2008. Reductions of fish abundance were statistically significant in nine out of the 14 reef stations monitored. These included Tourmaline Reef (Mayaguez) at 10, 20, and 30 m; Puerto Botes Reef (Isla Desecheo) at 15 and 20 m; Tres Palmas Reef

(Rincon) at 10 m; Derrumbadero Reef (Ponce) at 20 m, West Reef (Isla Caja de Muerto) at 8 m and Cayo Coral Reef at 8 m. Likewise, statistically significant reductions of fish abundance were observed from Tres Palmas Reef (Rincon) at 10 m, West Reef, Derrumbadero reef and Cayo Coral. 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 the measured reductions of fish abundance and species richness 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 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

The 2008 coral reef monitoring survey for Puerto Rico 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 15 reef stations within seven Natural Reserve sites in Puerto Rico (Isla Desecheo, Isla de Mona, Rincon, Mayaguez, Guanica, Isla Caja de Muertos and Ponce). After the initial quantitative baseline characterizations for these sites (García-Sais et al., 2001 a, b, c), the present work represents the fifth monitoring cycle at the Isla Desecheo 20m and Mayaguez 10m reef stations, the fourth monitoring cycle for the Isla Desecheo 15 and 30m stations, Derrumbadero, Guanica, Caja de Muerto and Rincon 3, 10, and 20m reef stations, and the first monitoring survey of coral reefs from Isla de Mona, seven years after the baseline survey of 2001.

During the previous 2007 monitoring survey a pattern of mild reductions of live coral cover relative to 2006 levels were measured at 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 were 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 2008 was largely driven by mortality of Boulder Star Coral, *Montastraea annularis* (complex), a highly dominant species in terms of reef substrate cover and the principal reef building species of Puertorrican reefs. 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 in 2007. 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, and Nassau Groupers (*Mycteroperca venenosa, M. tigris, E. striatus*), and the Cubera, Dog and Mutton Snappers (*Lutjanus cyanopterus, L. jocu, L. analis*).

A total of 178 species of diurnal, non-criptic 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 included in the 2007 monitoring survey (García-Sais et al., 2007).

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. Data from previous surveys (García-Sais et al., 2001 a, b, c) is available to the public through the Internet website coralpr.net.

III Study Objectives

1- To continue the monitoring program of coral reef communities at the Puerto Canoas/Puerto Botes, Isla de Mona, 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, Isla de Mona, Tourmaline and Tres Palmas Reefs in the west coast, and at Derrumbadero, Caja de Muertos and Cayo 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. Isla de Mona reefs were monitored at Isla Mujeres and Las Carmelitas from existing sets of permanent transects at 19 m and 8.5 m depths, respectively. One “new” reef was included in the monitoring of Isla de Mona off Playa Sardinera at a depth of 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		Depth (m)	Latitude (°N)	Longitude (°W)
Isla Desecheo				
	Canoas	30	18°22.706	67°29.199
	Botes	20	18°22.8949	67°29.3160
	Botes	15	18°22.920	67°29.300
Isla de Mona				
	Playa Mujeres (T 1-3)	18.9	18°04.302	67°56.215
	Playa Mujeres (T 4-5)	16.6	18°04.309	67°56.271
	Las Carmelitas	8.5	18°05.923	67°56.300
	Playa Sardinera	30.0		
Mayaguez				
	Tourmaline	30	18°09.985	67°16.581
	Tourmaline	20	18°09.910	67°16.512
	Tourmaline	10	18°09.7919	67°16.4160
Rincon				
	Tres Palmas	20	18°20.790	67°16.248
	Tres Palmas	10	18°20.832	67°16.206
	Tres Palmas	3	18°21.023	67°15.959
Ponce				
	Derrumbadero	20	17°54.2400	66°36.5159
Guanica				
	Coral	10	17°56.1720	66°53.3040
Caja de Muertos				
	West Reef	10	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 1.0 m 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), Playa Mujeres, Playa Sardinera and Las Carmelitas (Isla de Mona) and Tourmaline Reef (Mayaguez Bay). Five belt-transects were surveyed at Derrumbadero, Caja de Muerto (Ponce) and Cayo Coral Reef (Guánica), for a total of 75 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.

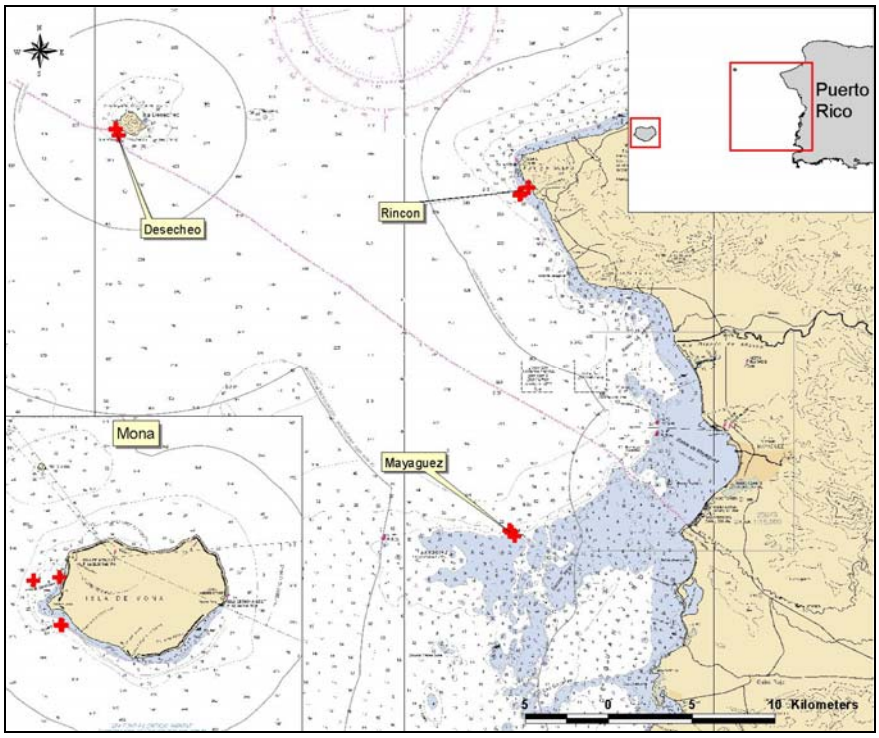


Figure 1. Location of reef sites at Isla Desecheo, Isla de Mona, Mayaguez and Rincón

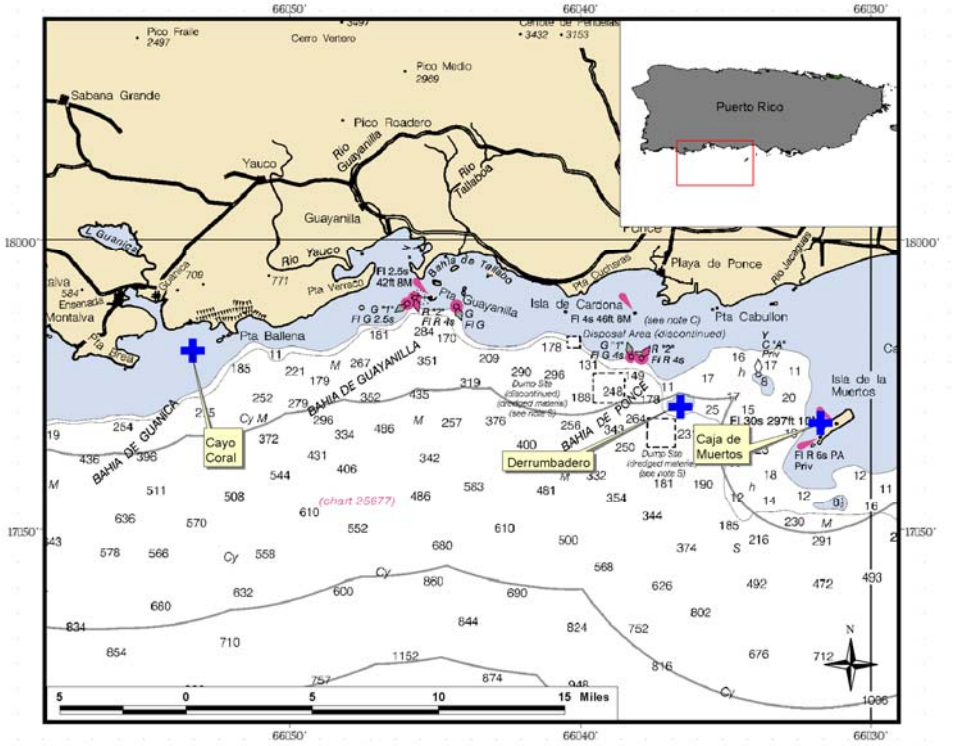


Figure 2. Location of south coast reef sites, Cayo Coral (Guánica), Derrumbadero and West Reef of Isla Caja de Muerto (Ponce)

Results

V Baseline Characterization and Monitoring of Coral Reef Communities

A. Tres Palmas Reef System – Rincón

1.0 Fringing *Acropora palmata* (Elkhorn Coral) Reef

1.1 Sessile-benthic Reef Community

The rocky shoreline of the Tres Palmas Marine Reserve leads to a narrow backreef lagoon with coarse sandy sediments. The lagoon is a semi-protected environment associated with an extensive *Acropora palmata* (Elkhorn Coral) reef formation that has developed along a hard ground platform fringing the shoreline. The top of the platform is found at depths between 2 - 5 m. The branching Elkhorn Coral colonies are large, rising more than one meter from the hard ground platform almost to the surface and wide, extending more than two meters horizontally in many cases. Where the hard ground platform is continuous, coral colonies grow close together forming a dense and intertwined Elkhorn Coral biotope. Sand pools and channels separate the reef where the hard ground platform breaks up. Interspersed within the *A. palmata* biotope are abundant colonies of encrusting corals, mostly *Diploria clivosa, D. strigosa* and *Porites astreoides*. These encrusting and mound shaped stony corals and gorgonians are more abundant on the seaward slope of the hard ground platform which ends in a sandy bottom at a depth of about six meters.

Rainfall runoff with heavy loads of terrestrial sediments has been previously reported to reach this fringing reef (García-Sais et al., 2004 a). Considerable amounts of garbage (cans, bottles, tires, etc.) is removed by volunteer groups (Surfrider, etc.) from the reef several times every year. During 2008, this reef experienced the effect of exceptionally high waves, estimated in approximately 10 m (>30') associated with winter storms in the North Atlantic during April, 2008. 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 2008 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.

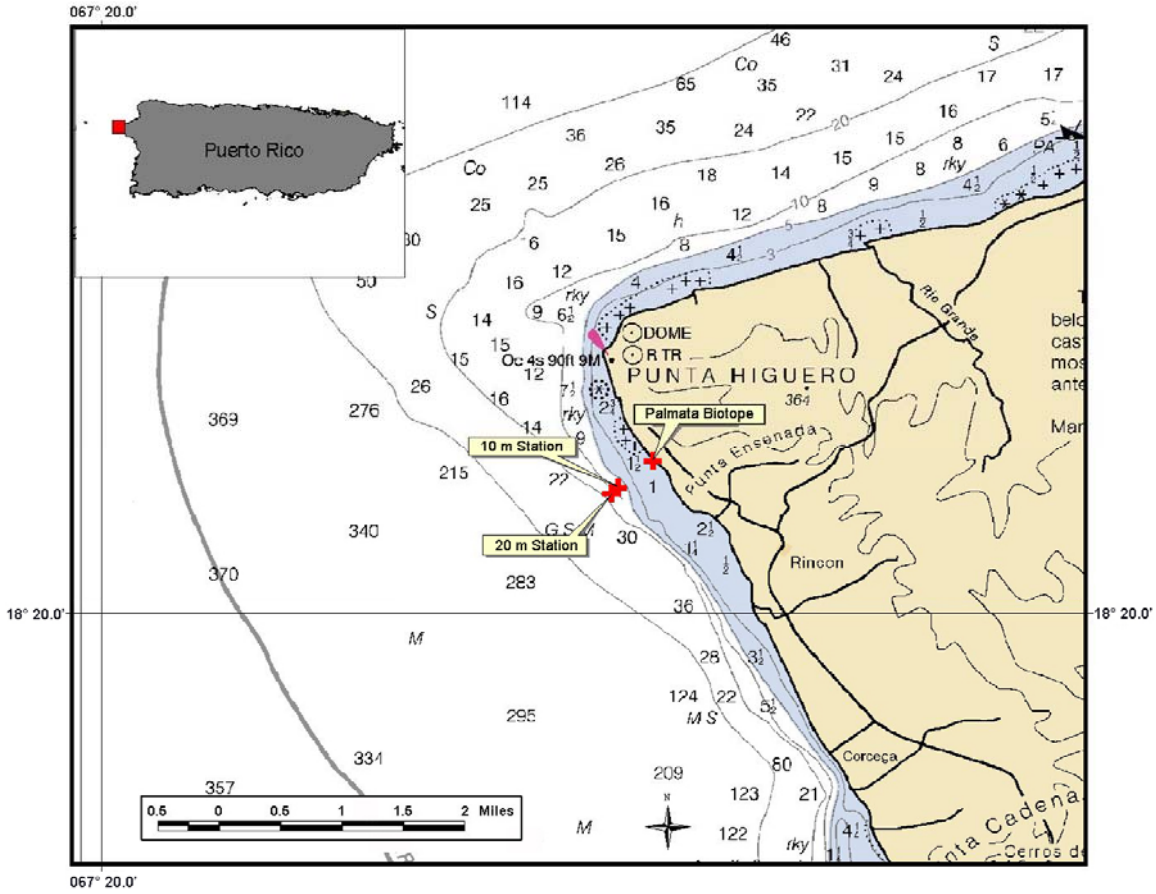


Figure 3. Location of coral reef survey stations off Tres Palmas, Rincón.

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 26.39% (range: 13.54 – 39.61 %). Elkhorn Coral (*A. palmata*) was the dominant species with a mean substrate cover of 17.81 % (range: 1.20 – 36.78 %), representing 67.5 % of the total live coral cover. Five additional coral species (e.g. *Diploria strigosa, P. astreoides, Montastraea annularis, M. cavernosa and Agaricia agaricites*) were intersected by linear transects during our survey. A total of 14 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: 38.12 %). Fleshy macroalgae (*Valonia sp., Stypopodium sp*.) and red coralline algae were observed outside transect areas. The encrusting zoanthid, *Palythoa caribbea* was present in two transects with a mean cover

Table 2. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon 2 - 5 m. June, 2008

Depth:3- 5 m	Transects					
	1	2	3	4	5	**MEAN**
Rugosity (m)	4.13	4.24	6.94	3.27	2.47	**4.21**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	23.14	20.87	32.76	24.87	13.64	**23.06**
Sand		0.89		35.64	6.78	**8.66**
Total Abiotic	23.14	21.76	32.76	60.51	20.42	**31.72**
Benthic Algae						
Turf-mixed assemblage	41.90	61.63	23.67		63.40	**38.12**
Calcareous			0.83		0.57	**0.28**
Total Benthic Algae	41.90	61.63	24.50	0.00	63.97	**38.40**
Zoanthids	10.54	1.39	3.19			**3.02**
Sponges	0.28					**0.06**
Live Stony Corals						
Acropora palmata	8.97	5.41	36.78	36.70	1.20	**17.81**
Diploria strigosa	11.18	3.09			8.27	**4.51**
Porites astreoides		6.25	0.50	1.28	0.79	**1.76**
Montastraea cavernosa			2.33		3.28	**1.12**
Montastraea annularis	3.96	0.49		1.06		**1.10**
Agaricia agaricites				0.42		**0.08**
Total Stony Corals	24.11	15.24	39.61	39.46	13.54	**26.39**
Gorgonians (# col.)	0	0	0	0	0	0
Total Gorgonians (# colonies/transect)	0	0	0	0	0	0

Coral Species Outside Transects

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

of 3.0 %. The encrusting gorgonian, *Erythropodium caribaeorum* was observed outside transects. Abiotic categories, associated with reef overhangs, gaps or holes and sand represented 31.7 % of the reef substrate cover. Vertically projected soft corals (gorgonians) were not found along transets. The Common Sea Fan, *Gorgonia ventalina* and the Bent Sea Rod, *Plexaura flexuosa* were common outside transects in deeper sections of the reef. 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 fluctuated between 38.62 % and 39.40 % during the monitoring period between 2004 and 2007, but declined to 26.4 % during this recent survey. The reduction of live coral with respect to 2007 represents a loss of 33.0%. The variation of mean live coral cover between surveys was not statistically significant (ANOVA; $p = 0.602$) because the loss of live coral was not consistent across the five transects. The reduction of live coral appears to have resulted from mechanical damage suffered by some colonies during the extreme wave action event of Holy Week in April, 2008. The reef is almost a biotope of Elkhorn Coral (*Acropora palmata*), which had not shown any major degradation of its 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 2008 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.

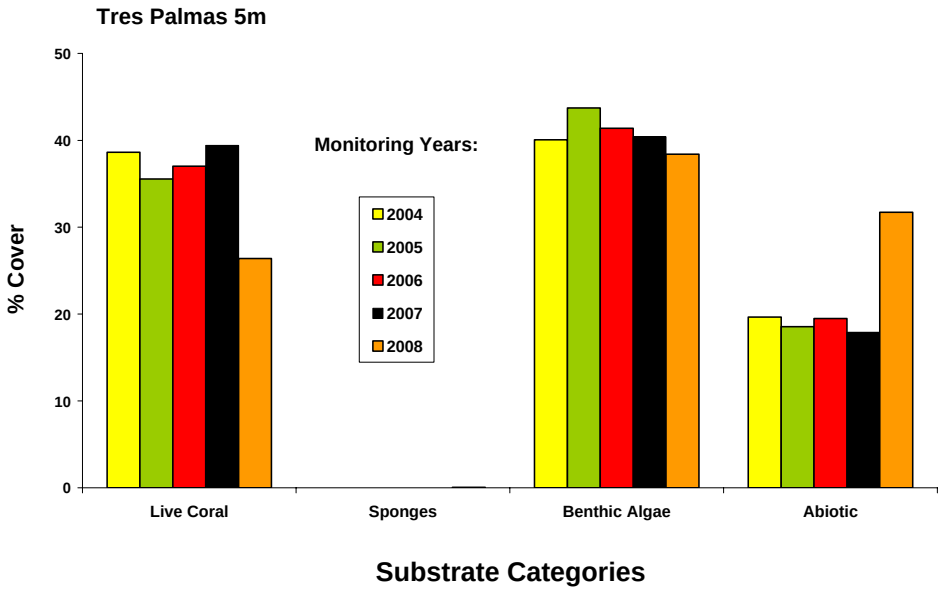


Figure 4. Monitoring trends (2004 – 2008) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon, 2- 5 m depth.

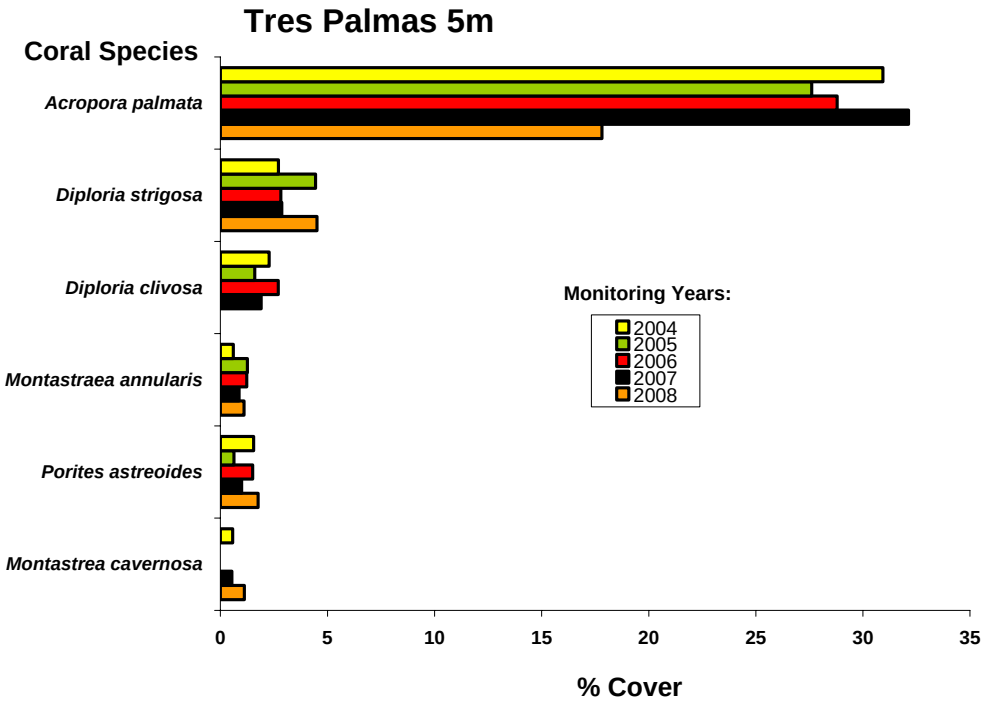


Figure 5. Monitoring trends (2004 – 2008) of mean substrate cover by stony coral species at Tres Palmas Reef, Rincon, 2 - 5 m depth.

1.2 Reef Fishes and Motile Megabenthic Invertebrates

A total of 74 fish species have been identified from the *Acropora palmata* fringing reef system off Tres Palmas, Rincón within a depth range of 2 – 5 meters (Appendix 1). During the 2008 monitoring survey, 42 fish species, including 22 present within belt-transects were identified from the fringing reef. The mean abundance of individuals was 70.4 Ind/30 m^2 (range: 38 - 151 Ind/30 m^2), and the mean number of species per transect was 11 (range: 9 - 14). The combined abundance of five species represented 86.4 % of the mean abundance within belt-transects (Table 3). The most abundant species was the Blue Tang (*Acanthurus coeruleus*) with a mean of 26.4 Ind/30 m^2 followed by the Dusky Damselfish (*Stegastes adustus*) with 11.0 Ind/30 m^2. The Bluehead Wrasse (*Thalassoma bifasciatum*), Yellowtail Damselfish (*Microspathodon chrysurus*), and Redlip Blenny (*Ophioblennius atlanticus)* were present within all five belt-transects surveyed and along with the aforementioned species appear to comprise the main resident demersal fish assemblage. Also very common were the Yellowtail and Stoplight Parrotfishes, (*Sparisoma rubripinne, S. viride*). Large schools of Blue Tangs and Yellowtail Goatfishes were observed in and 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 (2004-2008) at this reef. The shallow, high energy environment of the fringing reef appears to be an ideal habitat for opportunistic carnivores, such as Wrasses (*Thalassoma bifasciatum, Halichoeres radiatus, H. maculipinna, H. bivittatus*) and Blennies (*Ophioblennius atlanticus*) which feed on small benthic (infaunal) invertebrates that become exposed upon disturbances of the substrate due to wave action. Also, herbivores (e.g. parrotfishes, doctorfishes, 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, L. apodus, L. mahogany, L.*

Table 3. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef 2 - 5m. Rincon. June, 2008

Depth: 5m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Acanthurus coeruleus	Blue tang	25	2	100	3	2	**26.4**
Stegastes adustus	Dusky damselfish	8	11	15	9	12	**11.0**
Thalassoma bifasciatum	Bluehead wrasse	6	6	13	13	5	**8.6**
Ophioblennius atlanticus	Redlip blenny	7	7	13	9	4	**8.0**
Microspathodon chrysurus	Yellowtail damserfish	8	4	5	12	5	**6.8**
Haemulon sp.	Juvenile grunt	10					**2.0**
Hlichoeres maculipinna	Clown wrass	2	5	1		1	**1.8**
Halichoeres bivittatus	Slippery dick	3	1		2	2	**1.6**
Abudefduf sexatilis	Sargent major			1	5		**1.2**
Haemulon chrysargyreum	Smallmouth grunt	1				5	**1.2**
Pempheris schomburgki	Glassy sweeper			1	5		**1.2**
Sparisoma viride	Stoplight parrotfish		1	1			**0.4**
Bodianus rufus	Spanish hogfish		1			1	**0.4**
Haemulon flavolineatum	French grunt	2					**0.4**
Holocentrus rufus	Longspine squirlfish	1			1		**0.4**
Halichoeres radiatus	Puddinwife			1			**0.2**
Acanthurus chirurgus	Doctorfish					1	**0.2**
Sparisoma rubripinne	Yellowtail parrotfish				1		**0.2**
Malacoctenus triangulatus	Saddled blenny	1					**0.2**
Mlacoctenus gelli	Dusky blenny	1					**0.2**
Kyphosus sectatrix/incisor	Bermuda chub	1					**0.2**
Chaetodon capistratus	Foureye Butterflyfish					1	**0.2**
	TOTAL INDIVIDUALS	**76**	**38**	**151**	**60**	**38**	**72.2**
	TOTAL SPECIES	**14**	**9**	**10**	**10**	**11**	**11**

synagris) were observed during the ASEC survey (Table 4), as well as during previous surveys (García-Sais et al., 2004 a, 2005, 2006, 2007), 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 and Slete-pencil Sea Urchins (*Echinometra lucunter, Eucidaris tribuloides*), were observed within belt-transect areas during the 2008 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).

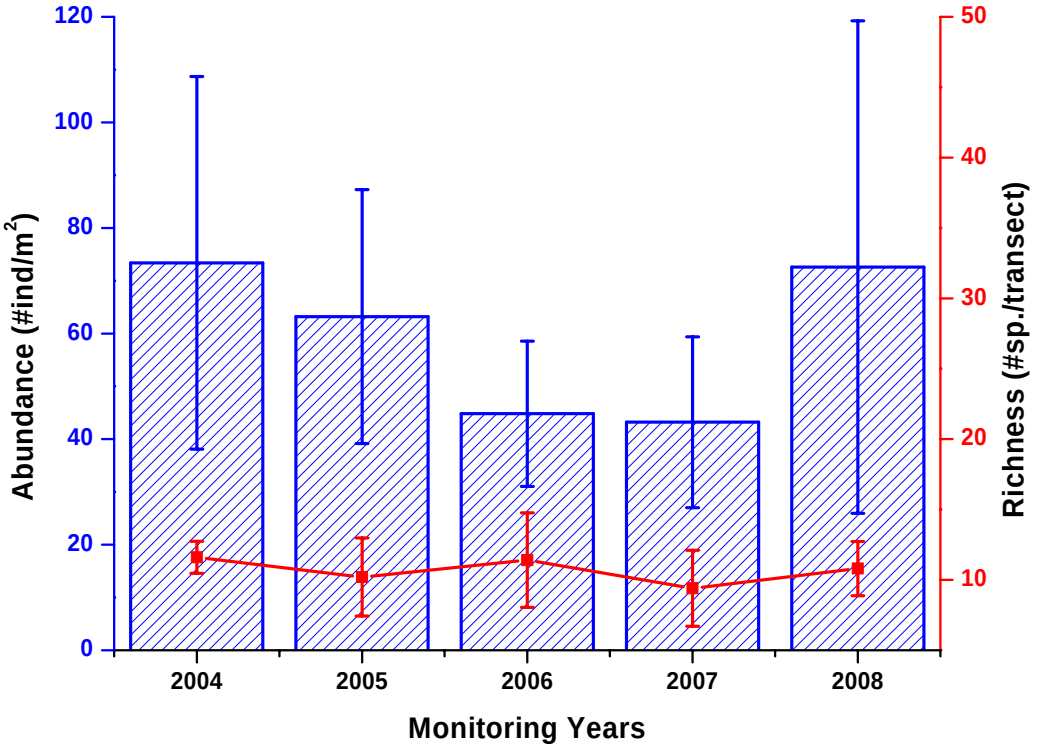


Figure 6. Monitoring trends (2004 – 2008) of fish species richness and abundance at Tres Palmas Reef, Rincon 2-5 m.

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, 2008

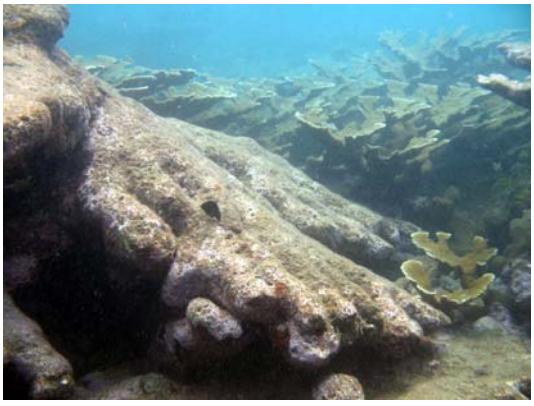
Depth range : 2 – 5 m
Duration – 30 min.

SPECIES	**COMMON NAME**		# - (cm)
Carangoides crysos	Blue Runner	1 – (35)	
Lutjanus synagris	Lane Snapper	3– (25)	7 – (30)
Lutjanus apodus	Schoolmaster	1 – (20)	3 – (25)
Lutjanus mahogany	Mahogany Snapper	3 – (15)	
Ocyurus chrysurus	Yellowtail Snapper	1 – (25)	2 – (30)

Table 5. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Elkhorn Coral Reef, 2 - 5 m depth, Rincon, June, 2008

DATE: June 13, 2008 Depth: 2 - 5 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	2	3	4	5	
SPECIES	**COMMON NAME**						
Gastropoda	Snail			1			0.2
Grapsus sp.	crab			1			0.2
Eucidaris tribuloides	Slate-pencil Urchin		1				0.2
Echinometra lucunter	Rock boring Urchin			1			0.2
	TOTALS		1	3			0.8

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



2.0 Outer Shelf Patch Coral Reefs

2.1 Sessile-benthic Community

A series of submerged patch reefs are located in the Tres Palmas outer shelf, at about 0.5 kilometers east from the shelf-edge. Patch reefs are associated with an irregular and discontinuous line of hard ground promontories that rise from a sandy bottom at depths of 12 -15 m. Our permanent transects were installed within one of these patch reef promontories at a depth of 10 m running east to west over the reef top. The reef surveyed rises from the bottom as a vertical wall on the eastern end, forming a sloping terrace toward the west. The east wall is about 5 meters high and exhibits deep crevices and overhangs. At the top, the reef platform is mostly flat, with some depressions, but without any prominent pattern of spurs and/or grooves. Large sand channels separate the reef promontories. Panoramic views of the outer shelf patch reefs are presented as Photo Album 2.

A diverse and abundant assemblage of soft corals (gorgonians) was the most prominent feature of the sessile-benthic patch reef community. Soft corals were present at all transects surveyed with a mean of 19.0 col./transect (range: 12 – 23 col./transect) (Table 6). The most abundant taxa included Sea Rods, *Plexaura kukenthali,* Sea Plumes *Pseudopterogorgia acerosa, P. americana*, 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 20 species of stony corals were identified from the patch reef community during our survey, including 15 species intercepted by line transects. Live stony coral cover averaged 21.7 % (range: 11.4 – 28.9 %). Mustard-Hill Coral, *Porites astreoides* and Great Star Coral, *Montastraea cavernosa* were the dominant species in terms of substrate cover with means of 4.8 and 4.7%, respectively. A total of 12 coral species were represented with less than 2% reef substrate cover. Total abiotic cover averaged 3.6 %.

Table 6. Percent reef substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon 10 m. June, 2008

	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	1.80	1.86	2.31	1.66	1.80	**1.89**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	2.12	5.14	3.01	3.17	4.66	**3.62**
Total Abiotic	2.12	5.14	3.01	3.17	4.66	**3.62**
Benthic Algae						
Turf-mixed assemblage	78.31	63.41	55.24	59.18	64.49	**64.13**
Calcareous	3.56	0.48	2.31		0.48	**1.37**
Coralline	0.60	0.48	0.57	1.29		**0.59**
Fleshy					1.19	**0.24**
Total Benthic Algae	82.47	64.37	58.12	60.47	66.16	**66.32**
Sponges	1.67	6.91	5.85	8.92	6.10	**5.89**
Cyanobacteria	1.44	2.61	4.14		1.91	**2.02**
Gorgonians	0.93			0.60	0.36	**0.38**
Zoanthids		0.24				**0.05**
Ascidians					0.24	**0.05**
Live Stony Corals						
Porites astreoides	0.60	5.90	5.61	3.00	8.81	**4.78**
Montastraea cavernosa	2.12	5.56	10.64	2.57	2.71	**4.72**
Colpophyllia natans			2.40	8.66		**2.21**
Diploria strigosa	0.36	4.05	3.17	1.80		**1.88**
Diploria labyrinthiformis			3.89		5.00	**1.78**
Montastraea annularis	4.32	2.02				**1.27**
Dendrogyra cylindrus				6.16		**1.23**
Agaricia agaricites	0.48	1.26	1.03	2.06	0.36	**1.04**
Siderastrea radians	0.60		0.89	2.32	1.31	**1.02**
Meandrina meandrites	1.43	1.10	0.69			**0.64**
Siderastrea siderea		0.83			1.91	**0.55**
Madracis decactis	0.85			0.24		**0.22**
Stephanocoenia michelini	0.60					**0.12**
Dichocoenia stokesi			0.57			**0.11**
Porites porites					0.48	**0.10**
Total Stony Corals	11.36	20.72	28.89	26.81	20.58	**21.67**
Gorgonians (# col.)						
Plexaura kukenthali	3	2	2	3	4	**2.80**
Pseudoptergorgia acerosa	2	5	1	4	1	**2.60**
Eunicea flexuosa	6		2	1	3	**2.40**
Gorgonia ventalina	1	3		3	5	**2.40**
Pseudoptergorgia americana	1	5	1	1	1	**1.80**
Pseudoptergorgia bipinnata (yellow)	4	1		1		**1.20**
Pterogorgia spp.	2		1	2	1	**1.20**
Eunicea turnetorti	1		2	1	1	**1.00**

Table 6. continued

Eunicea succinea	1	1	1	1		**0.80**
Erythropodium caribeorum	1			2		**0.60**
Plexaura homomalla			1		1	**0.40**
Pseudoplexaura flagellosa or wargeri			1		1	**0.40**
Briaerum asbestinum	1					**0.20**
Eunicea calyculata					1	**0.20**
Eunicea sp. 2		1				**0.20**
Muricea muricata				1		**0.20**
Muricea sp. 2				1		**0.20**
Muriceopsis flavida		1				**0.20**
Pseudoplexaura purosa					1	**0.20**
Total Gorgonians (# colonies/transect)	23	19	12	21	20	**19.0**

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

Turf algae, a mixed assemblage of short filamentous red and brown macroalgae presented the highest percent of reef substrate cover by sessile-benthic components with a mean of 64.1 % (range: 55.2 – 78.3 %). Fleshy brown (*Dictyota sp*.), red (*Galaxaura sp*.) and calcareous (*Halimeda discoidea*) macroalgae were present within transects with a combined cover of 2.2 %. Thus, the total cover by benthic algae was 66.3 %. Encrusting sponges were intersected by all five transects with a mean substrate cover of 5.9 % (range: 1.7 – 8.9 %). The encrusting gorgonian *Erythropodium caribaeorum* was present in four out of the five transects with a mean substrate cover of 0.4 %. *Palythoa caribbea,* an encrusting zoanthid was observed outside transects. Abiotic categories associated with reef overhangs and sand pockets comprised only 3.6 % 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 1.9 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 remained virtually constant from a mean of 20.9% in 2004 to a mean of 21.7 % in 2008. Small annual variations of the mean reef substrate cover by (total) live corals between monitoring surveys (2004 – 2008) are not statistically significant (ANOVA; p = 0.708) (Figure 8).

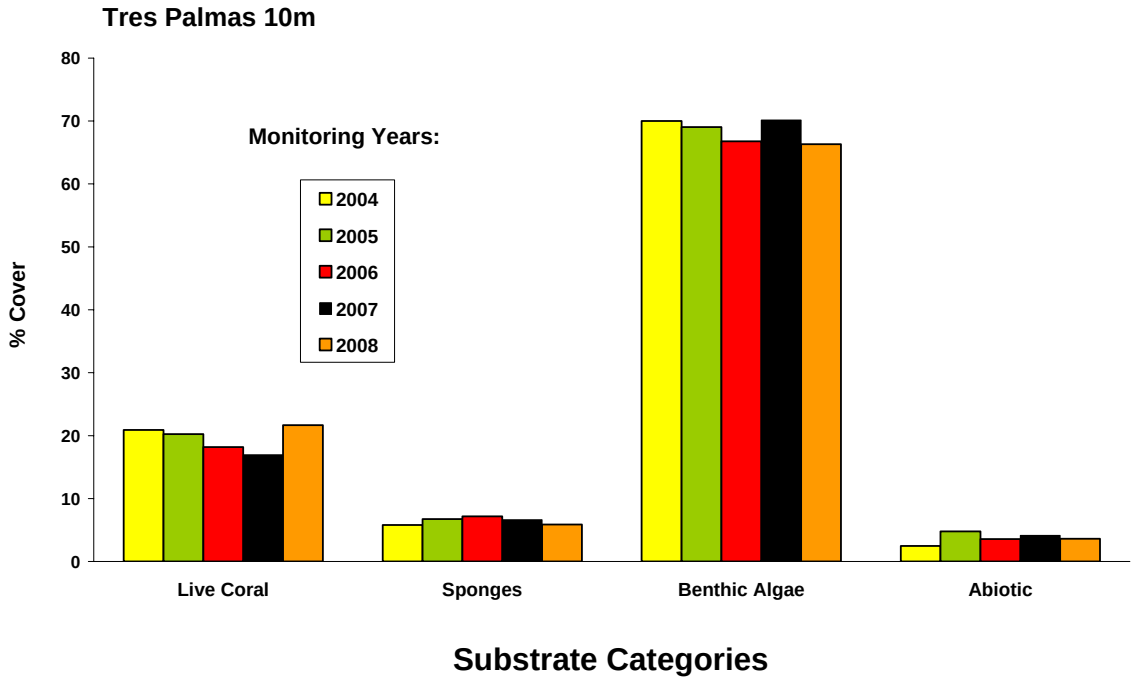


Figure 7. Monitoring trends (2004 – 2008) of mean substrate cover by sessile-benthic categories at Tres Palmas Outer Shelf Patch Reef – 10 m.

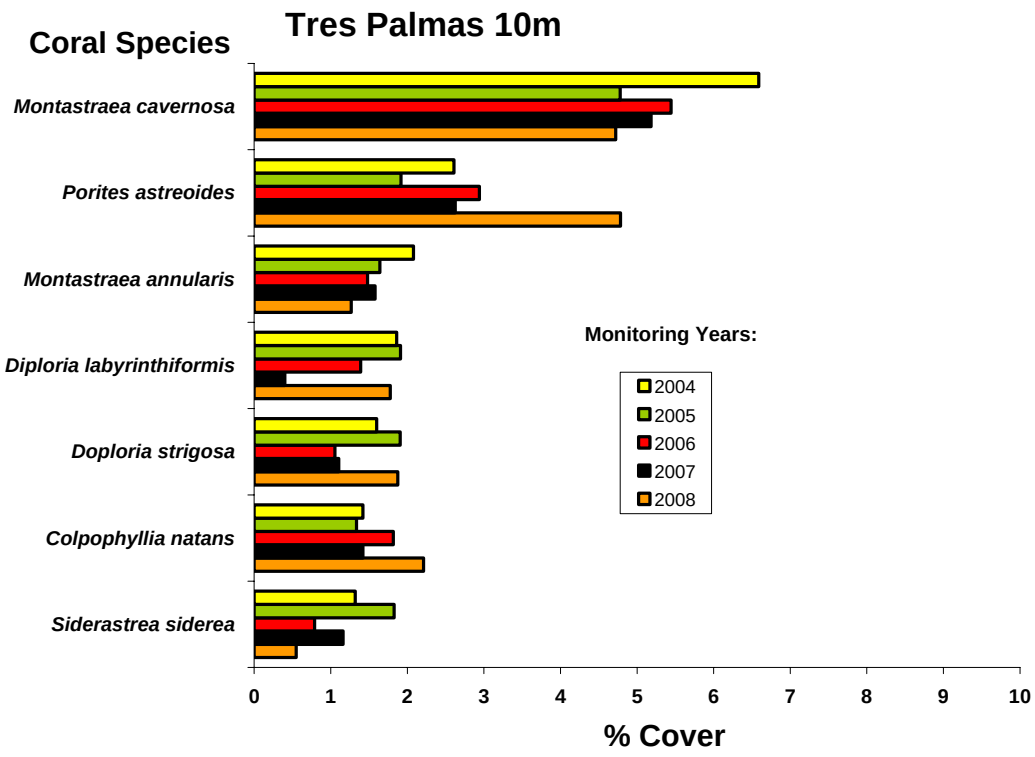


Figure 8. Monitoring trends (2004 – 2008) of mean substrate cover by stony coral species at Tres Palmas Outer Shelf Patch Reef – 10 m.

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 2008 survey, mean abundance of individuals within belt-transects was 66.8 Ind/30 m^2 (range: 59 - 72 Ind/30 m^2). The mean number of species per transect was 8.4 (range: 7 - 13).

Two species, the Bicolor Damselfish (*Stegastes partitus*) and the Bluehead Wrasse (*Thalassoma bifasciatum*) were (as in previous surveys) numerically dominant within belt-transects with mean abundances of 32.6 and 22.4 Ind/30 m^2, respectively (Table 7). The combined abundance of these two species represented 82.3 % of the community mean abundance within belt-transects. In addition to the two aforementioned species, the Sharknose Goby, Yellowhead Wrasse, Princess Parrotfish and the Coney were present four our of the five transects surveyed. Given their prevalence in previous

Table 7. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef, Rincon 10 m. June, 2008

Depth: 10 m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Stegastes partitus	Bicolor Damselfish	25	31	33	40	34	**32.6**
Thalassoma bifasciatum	Bluehead Wrasse	25	15	20	25	27	**22.4**
Gobiosoma evelynae	Sharknose Goby	6	5		2	6	**3.8**
Scarus taeniopterus	Princess Parrotfish	3	4	1		1	**1.8**
Chaetodon capistratus	Foureye Butterflyfish	2	2		2		**1.2**
Cephalopholis fulva	Coney	1	1	2		2	**1.2**
Halichoeres garnoti	Yellow-head Wrasse	1	2		1	1	**1.0**
Scarus iserti	Stripped Parrotfish		2	1			**0.6**
Serranus tigrinus	Harlequin Bass			1		1	**0.4**
Holocentrus rufus	Squirrelfish		1	1			**0.4**
Canthigaster rostrata	Caribbean Puffer		1				**0.2**
Scomberomorus regalis	Cero		1				**0.2**
Sparisoma aurofrenatum	Redband Parrotfish		1				**0.2**
Acanthurus bahianus	Ocean Surgeon	1			1		**0.4**
Halichoeres maculipinna	Clown Wrasse		1		1		**0.4**
Malacoctenus triangulatus	Saddled Blenny						**0.0**
Coryphopterus sp.	Goby						**0.0**
Chromis cyanea	Blue Chromis						**0.0**
Acanthurus chirurgus	Doctorfish						**0.0**
	TOTAL INDIVIDUALS	**64**	**67**	**59**	**72**	**72**	**66.8**
	TOTAL SPECIES	**8**	**13**	**7**	**7**	**7**	**8.4**

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.

Fish abundance and species richness have declined steadily at this reef from a baseline mean abundance of 87.6 Ind/30 m^2 and 17.8 species per transect in 2004 to a mean of 66.8 Ind/30 m^2 and 8.4 species per transect in 2008 (Figure 9). Fish abundance was lower during 2008 than during the first three surveys (2004 – 2006, ANOVA; $p < 0.0001$) and species richness during the 2008 was lower than during all previous surveys (ANOVA; $p < 0.0001$; see Appendix 3 - 4).

The high energy environment at the top of the patch reef is an appropriate habitat for opportunistic carnivores, such as Wrasses (*Thalassoma bifasciatum, Halichoeres garnoti, H. maculipinna*) which feed on small benthic (infaunal) invertebrates that become exposed upon disturbances of the substrate due to wave action. Also, herbivores (e.g. parrotfishes, doctorfishes, damselfishes) that feed on the turf algae were common. Pelagic piscivores, such as barracudas (*Sphyraena barracuda*), mackerels (*Scomberomorus regalis*) and jacks (*Caranx crysos, C. ruber*) have been previously reported from this reef (García-Sais et al., 2005). Large (adult) commercially important demersal fishes (snappers, groupers, hogfishes) were not observed.

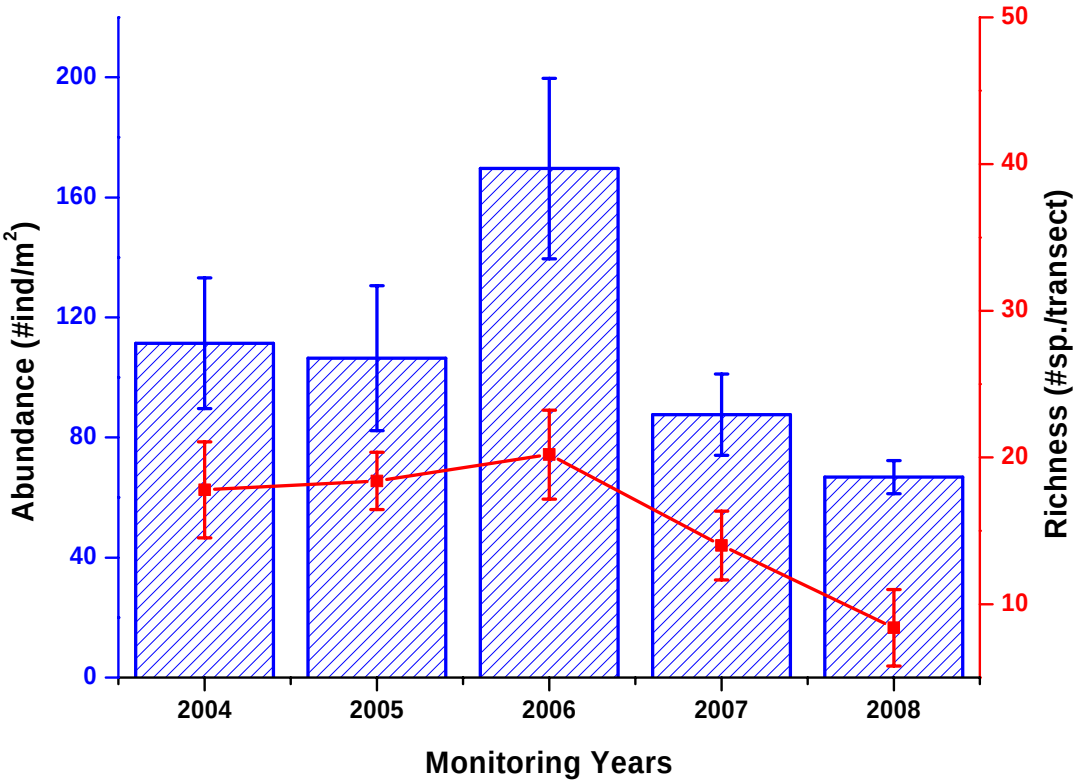


Figure 9. Monitoring trends (2004 – 2008) of fish species richness and abundance at Tres Palmas Outer Shelf Patch Reef, 10-15 m, Rincon.

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, Rincon 10 m, June, 2008.

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

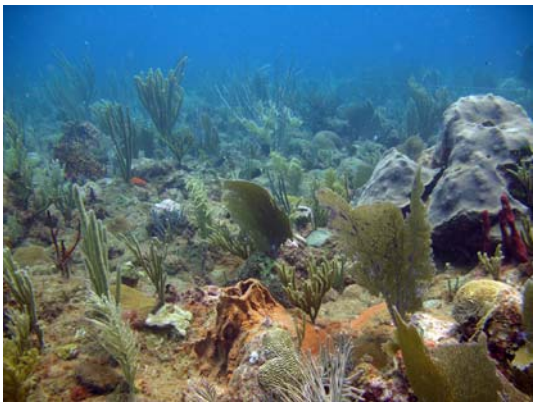
SPECIES	**COMMON NAME**		# - (cm)	
Epinephelus guttatus	Red Hind	1 – (30)	1 – (35)	
Lutjanus apodus	Schoolmaster	2 – (20)	3 - (25)	
Lutjanus synagris	Lane Snapper	1 – (20)	2– (25)	
Sphyraena barracuda	Great Barracuda	1 – (60)		
Holacanthus ciliaris	Queen Angel	1 – (35)		
Gramma loreto	Fairy Basslet	8 – (3)	11 – (4)	6 – (5-7)
Holacanthus tricolor	Rock Beauty	1 – (15)	2 – (25)	
Scomberomorus regalis	Cero Mackerel	2 – (50)		

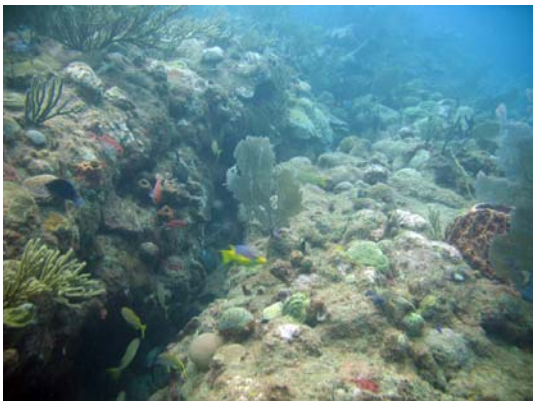
Among motile megabenthic invertebrates, several spiny Lobsters (*Panulirus argus*) Slate-pencil Urchins (*Eucidaris tribuloides*), Cleaner Shrimps (*Periclimenes sp*., *Stenopus hispidus*), Arrow and Hermit Crabs (*Stenorhynchus seticornis, Paguridae*) and Sponge Brittle Stars have been previously reported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

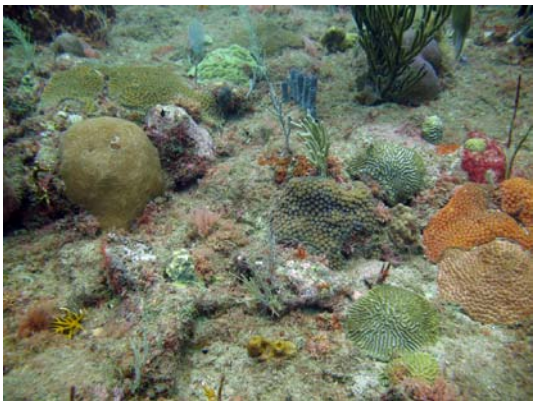
Table 9. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Reef, Rincon, 10m, June, 2008

		TRANSECTS					
DATE: June 6, 2008 Depth: 10 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Periclimenes pedersoni	Cleaner Shrimp	1	1				**0.4**
Stenorhynchus seticornis	Arrow Crab					1	**0.2**
	TOTALS	1	1			1	**0.6**

Photo Album 2 (Rincon 10 m)
Outer Shelf Patch Reef







3.0 Tres Palmas Shelf-edge Reef

3.1 Sessile-benthic Community

A “spur-and-groove” coral reef formation is found associated with the shelf-edge off Tres Palmas within a depth range of 18 – 23 m. Spurs are oriented perpendicular to the shelf-edge. The shelf breaks in a series of irregular steps, forming narrow terraces at depths from 23 – 40 m. Coral growth below 20 m was observed to occur mostly as individual massive and encrusting colonies, not forming any prominent reef buildup. There was substantial sediment transport down the shelf-edge and most of the rocky substrate was covered by fine sand and silt. Such heavy sedimentation may limit coral reef formation down the slope off Tres Palmas. The reef is not a continuous system along the shelf-edge, as there are wide sections of mostly uncolonized pavement covered by sandy-silt sediments with interspersed sponges and macroalgae. Panoramic views of the shelf-edge reef formation off Tres Palmas are presented in Photo Album 3.

A total of 22 stony coral species (including two hydrocorals) were identified from the shelf-edge reef off Tres Palmas, 13 of which were intercepted by line transects during the 2008 survey (Table 10). Stony corals occurred mostly as encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 19.2 % (range: 12.3 – 24.6 %). Boulder Star Coral, *Montastraea annularis* complex was the dominant species in terms of substrate cover with a mean of 7.9 % (range: 1.5 – 17.4 %), representing 41.1 % of the total cover by stony corals (Table 10). Colonies of *M. 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 Lettuce Coral, *Agaricia agaricites*, and Ten-Ray Star Coral, *Madracis decactis*. Soft corals (gorgonians) were moderately abundant, with a total of 16 species identified within transects and an average of 13.6 colonies/transect. The main assemblage included the sea plumes (*Pseudopterogorgia acerosa, P. americana*), Knobby Sea Rods, *Eunicea spp*., 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.

Encrusting and erect sponges, including several large Basket Sponges, *Xestospongia*

Table 10. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef shelf-edge, Rincon 20 m. June 2008

Depth: 20 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	2.13	3.47	2.79	2.17	2.70	**2.65**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	5.03	7.43	9.92	9.70	7.64	**7.94**
Total Abiotic	5.03	7.43	9.92	9.70	7.64	**7.94**
Benthic Algae						
Turf-mixed assemblage	74.47	66.83	52.03	59.57	55.79	**61.74**
Fleshy	2.89		2.34	3.78	5.67	**2.94**
Coralline			1.80	0.46		**0.45**
Total Benthic Algae	77.36	66.83	56.17	63.81	61.46	**65.13**
Sponges	4.87	3.27	5.47	7.31	11.51	**6.49**
Gorgonians	0.46		2.89		0.22	**0.71**
Cyanobacteria		0.73	0.55	0.81		**0.42**
Hydrozoans (Millepora)			0.47		0.33	**0.16**
Live Stony Corals						
Montastraea annularis	1.51	7.13	16.41	7.31	7.01	**7.87**
Meandrina meandrites	0.35	0.73	2.66	1.85	8.20	**2.76**
Montastraea cavernosa	3.71	3.27	1.21	1.39	1.00	**2.12**
Porites astreoides		1.56		4.27	1.65	**1.50**
Agaricia agaricites	2.80	0.94		1.48	0.67	**1.18**
Colpophyllia natans		3.42	2.31			**1.15**
Madracis decactis	2.31		0.99	1.40	0.33	**1.01**
Siderastrea radians	0.91	1.36				**0.45**
Siderastrea siderea		1.88				**0.38**
Diploria strigosa	0.70	1.05				**0.35**
Porites colonensis			0.99			**0.20**
Agaricia grahamae				0.58		**0.12**
Manicina areolata		0.42				**0.08**
Total Stony Corals	12.29	21.76	24.57	18.28	18.86	**19.15**
Gorgonians (# col.)						
Pseudoptergorgia acerosa	5	1	3	4	1	**2.80**
Eunicea flexuosa	2	4	1	4	2	**2.60**
Erythropodium caribeorum	1	3	3	1		**1.60**
Eunicea turnetorti	3			1	2	**1.20**
Plexaura kukenthali	1	1		1	2	**1.00**
Gorgonia ventalina	1	1		2		**0.80**
Pseudoptergorgia acerosa/americana			2		2	**0.80**
Briaerum asbestinum			2		1	**0.60**
Eunicea sp. 1			1	1		**0.40**

Table 10. continued

Eunicea sp. 2		2				**0.40**
Pseudoptergorgia americana				2		**0.40**
Eunicea sp. 3		1				**0.20**
Muriceopsis flavida				1		**0.20**
Plexaura homomalla				1		**0.20**
Plexaurella sp. 2	1					**0.20**
Plexaurella sp.1	1					**0.20**
Total Gorgonians (# colonies/transect)	15	13	12	18	10	**13.60**

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

muta were present in all transects with an average cover of 6.5 %. Reef overhangs averaged 7.9 % and contributed to a topographic rugosity of 2.65 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 61.7 % (range : 52.0 – 74.5 %). 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 2.9 % 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 65.1 %. Reddish, slimy mats of benthic cyanobacteria were observed over the reef, mostly covering unconsolidated sediments.

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 (2008). Mean live coral cover has declined by 17.1 %, from 23.15 % in 2004 to 19.2 in 2008, but differences were not statistically significant (ANOVA, $p = 0.908$). A 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 *Montastraea annularis (complex), M. cavernosa, Porites astreoides and Diploria strigosa* (Figure 11). Nevertheless, differences of substrate cover for all of these species are

very small, within sampling variability error and statistically insignificant (ANOVA; p > 0.05).

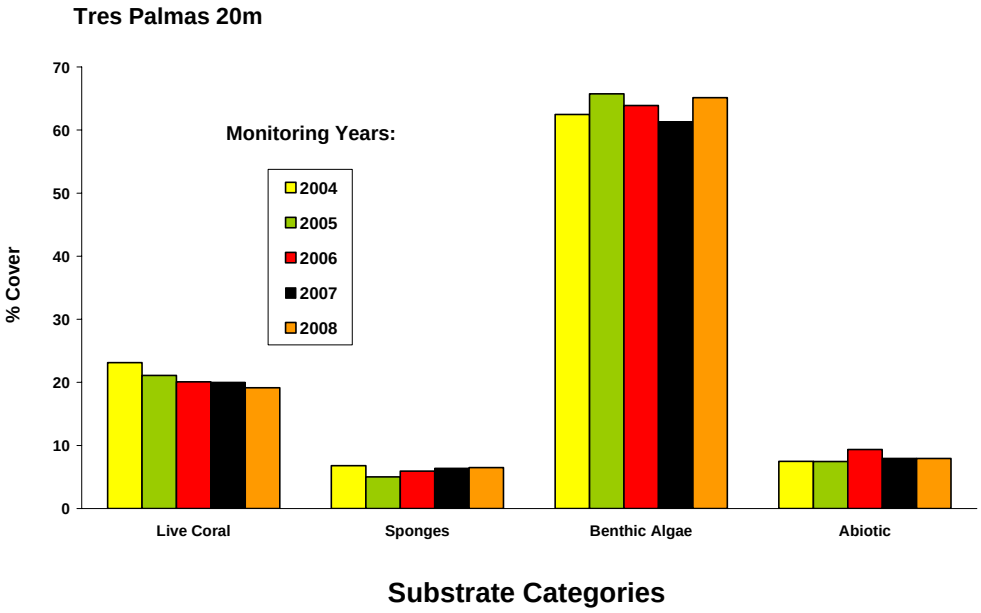


Figure 10. Monitoring trends (2004 – 2008) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef – 20 m.

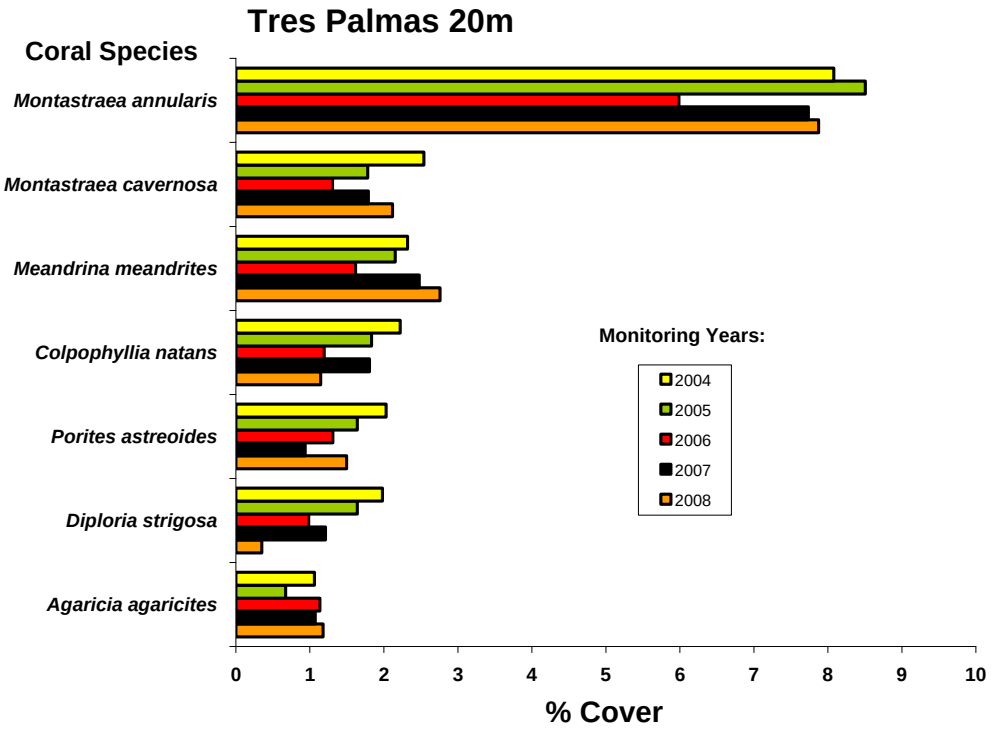


Figure 11. Monitoring trends (2004 – 2008) of mean substrate cover by stony coral species at Tres Palmas Reef – 20 m.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 83 fish species have been identified during the four surveys (2004-08) from the shelf-edge reef off Tres Palmas (Appendix 1). Table 11 lists the 47 fish species observed within belt-transects during the most recent 2008 survey in decreasing order of abundance. Mean abundance within belt-transects was 189.239.0 Ind/30 m^2 (range: 68 – 341 Ind/30 m^2). The mean number of species per transect was 22 (range: 13– 32). An assemblage consisting of six species represented 74.6 % of the total fish individuals within belt-transects (Table 11). The Masked Goby, Bicolor Damselfish, Bluehead and Creole Wrasse, Blue Chromis and Peppermint Goby comprised the numerically dominant assemblage. The Beau Gregory, Sharknose Goby, Graysbe and Yellowhead Wrasse were present in all five transects surveyed. A total of 17 species were represented by only one individual in the five transects surveyed.

The annual fluctuations of fish abundance and species richness from the baseline survey in 2004 to the present are presented in Figure 12. Fish species richness within belt-transects has remained virtually constant, but fish abundance declined consistently until the present survey. Mean fish abundance decreased 64.4 % from the baseline (531.4 Ind/30 m^2) in 2004 to a minimum abundance of 189.2 Ind/30 m^2 during 2007. Diffrences of fish abundance beween the baseline and the 2007-08 surveys were statistically significant (ANOVA; $p = 0.01$). 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, thus it has highly aggregated or patchy distributions in the reef. The temporal abundance dynamics of this species has not been studied. Thus, the factors that influence its abundance fluctuations between annual surveys remain unclear. Given its small size and high density in swarms, this goby may be an importante forage (prey) species for the small piscivorous fishes in the reef.

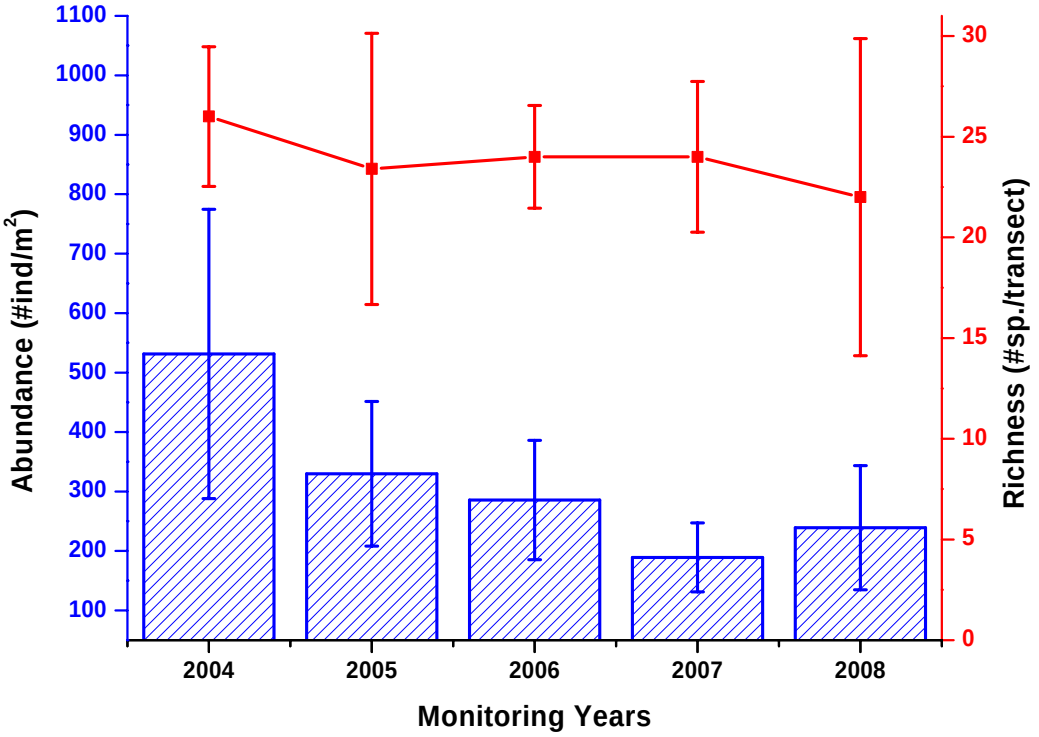


Figure 12. Monitoring trends (2004 – 2008) of fish species richness and abundance at Tres Palmas Shelf Edge Reef, Rincon.20 m,

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 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 Mahogani snappers, Coney, Graysby and Red Hind groupers, Spanish Hogfish, lizardfishes and grunts. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous assemblage.

Table 11. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef Rincon 20 m. June, 2008

Depth: 20m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	56	25	30	75		**37.2**
Stegastes partitus	Bicolor Damselfish	25	33	31	52	18	**31.8**
Clepticus parrae	Creole Wrasse	25	50	15	55	5	**30.0**
Chromis cyanea	Blue Chromis	16	26	30	53	15	**28.0**
Coryphopterus lipernes	Peppermint goby	37	16	48	19	9	**25.8**
Thalassoma bifasciatum	Bluehead Wrasse	17	25	32	50	4	**25.6**
Halichoeres garnoti	Yellow-head Wrasse	11	19	1	5	2	**7.6**
Gramma loretto	Fairy Basslet	37					**7.4**
Gobiosoma evelynae	Sharknose Goby	6	5	9	8	3	**6.2**
Haemulon flavolineatum	French Grunt	4	3	12			**3.8**
Haemulon chrysargyreum	Smallmouth Grunt	17					**3.4**
Chromis multilineata	Brown Chromis		7	3	6		**3.2**
Mulloides martinicus	Yellowtail Goatfish	16					**3.2**
Stegastes leucostictus	Beau Gregory	2	3	3	5	2	**3.0**
Scarus iserti	Stripped Parrotfish		5	1	7	2	**3.0**
Sparisoma radians	Bucktooth Parrotfish		3	6			**1.8**
Cephalopholis cruentatus	Graysby	4	1	2	1	1	**1.8**
Chaetodon capistratus	Foureye Butterflyfish	1		4		4	**1.8**
Myripristis jacobus	Blackbar Soldierfish	1	1	5		1	**1.6**
Flammeo marianus	Longspine Squirrelfish	2	2	3	1		**1.6**
Sparisoma aurofrenatum	Redband Parrotfish	1	5	1			**1.4**
Apogon sp	Cardinalfish	7					**1.4**
Canthigaster rostrata	Caribbean Puffer	2		1	3		**1.2**
Scarus taeniopterus	Princess Parrotfish		1	3		2	**1.2**
Chromis insulata	Sunshine Chromis	4					**0.8**
Acanthurus chirurgus	Doctorfish	1		1			**0.4**
Acanthurus coeruleus	BlueTang		2				**0.4**
Serranus tigrinus	Harlequin Bass	1	1				**0.4**
Sparisoma viride	Stoplight Parrotfish		2				**0.4**
Coryphopterus sp.	Goby	1					**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish		1				**0.2**
Acanthurus bahianus	Ocean Surgeon			1			**0.2**
Aulostomus maculatus	Trumpetfish	1					**0.2**
Holocentrus rufus	Squirrelfish				1		**0.2**
Hypoplectrus puella	Barred Hamlet		1				**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet			1			**0.2**
Haemulon carbonarium	Cesar Grunt	1					**0.2**
Pseudopeneus maculatus	Spotted Goatfish	1					**0.2**
Chaetodon aculeatus	Longsnout Butterflyfish	1					**0.2**
Synodus intermedius	Sand Diver	1					**0.2**
Caranx ruber	Bar Jack	1					**0.2**
Anisotremus surinamensis	Black Margate	1					**0.2**
Hypoplectrus unicolor	Butter Hamlet	1					**0.2**

Table 11. continued							
Lactophrys trigonus	Trunkfish		1				**0.2**
Cephalopholis fulva	Coney		1				**0.2**
Halichoeres maculipina	Clown Wrass			1			**0.2**
Hypoplectrus nigricans	Black Hamlet			1			**0.2**
							0.0
	TOTAL INDIVIDUALS	**302**	**239**	**245**	**341**	**68**	**239**
	TOTAL SPECIES	**32**	**25**	**25**	**15**	**13**	**22**

The shelf-edge reef is an ideal habitat for adult reef fishes, as evidenced by the presence of adult Lane and Schoolmaster snappers, Red Hinds, Great Barracuda, Cero Mackerels and Blue Runners. The absence of the larger demersal predators appears to be related to the high fishing pressure, since the physical habitat and potential food (fish forage) are available. Nevertheless, large snappers and groupers may be using deeper sections of the upper insular slope as residential habitat or refuge, and the shelf-edge reef as foraging ground at night. One giant Hawksbill Turtle (*Eretmochelys imbricata*) was present at the shelf-edge reef during the 2005 monitoring survey. Commercially important species included aquarium trade targets, such as the Fairy Basslet (*Gramma loreto*), Queen and French Angelfishes (*Holacanthus ciliaris, Pomacanthus paru*), Rock Beauty (*Holacanthus tricolor*), Blue Chromis (*Chromis cyanea*) and Swissguard Basslet (*Liopropoma rubre*).

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, 2008

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

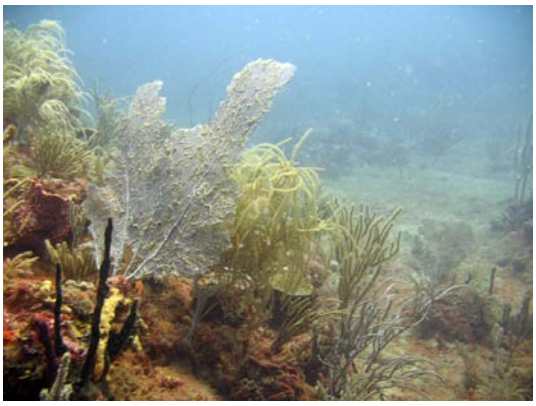
SPECIES	**COMMON NAME**	# - (cm)		
Carangoides crysos	Blue Runner	3 – (50)		
Epinephelus guttatus	Red Hind	1 – (25)		
Gramma loreto	Fairy Basslet	7 - (< 3)	32 - (4-5)	6 - (6-7)
Holacanthus ciliaris	Queen Angel	1 - (30)		
Holacanthus tricolor	Rock Beauty	1 - (20)	1 - (25)	
Lutjanus apodus	Schoolmaster	1 - (25)	2 – (35)	
Lutjanus mahogony	Mahogany Snapper	1 - (20)	1 - (25)	
Ocyurus chrysurus	Yellowtail Snapper	3 – (30)		
Opistognathus aurifrons	Yellowhead Jawfish	6 – (6-8)		
Scomberomorus regalis	Cero Mackerel	1 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (60)		

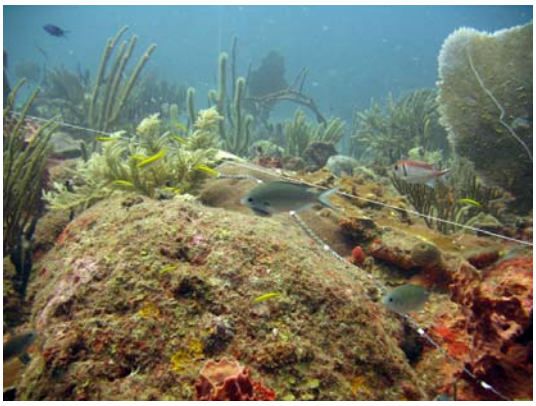
The Arrow Crab, *Stenorhynchus seticornis,* Cleaner Shrimps *Periclimenes pedersoni* and Stenopus hispidus and one Common Octopus, *Octopus vulgaris* were observed within belt-transects during the 2008 survey (Table 13).

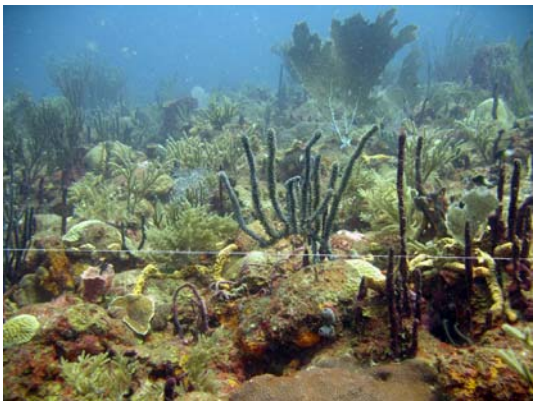
Table 13. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Shelf-edge Reef, Rincon 20 m, June, 2008

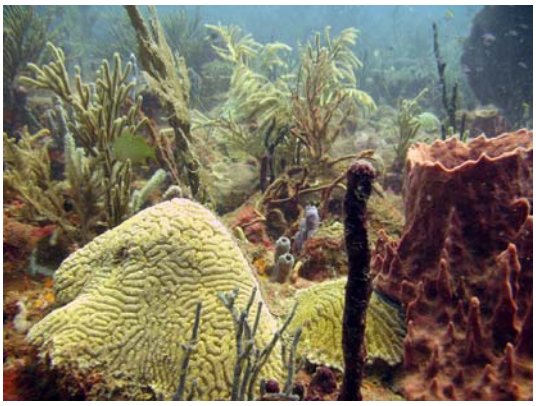
DATE: June 6. 2008		TRANSECTS					MEAN
Depth: 20 m		1	2	3	4	5	ABUNDANCE (IND/30 m2)
SPECIES	**COMMON NAME**						
Stenopus hispidus	Banded coral shrimp	1					0.2
Stenorhynchus seticornis	Arrow Crab						0
Periclimenes pedersoni	Cleaner Shrimp	2		1			0.6
Octopus vulgaris	Common Octopus			1			0.2
	TOTALS	3	0	2	0	0	1.0

Photo Album 3 (Rincon 20m)
Shelf-edge Reef









B. Puerto Canoas /Puerto Botes Reefs - Isla Desecheo

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

1.0 Shelf-edge Reef Puerto Canoas, 30 m depth

1.1 Sessile-benthic Reef Community

The shelf-edge off Puerto Canoas is at the southwest end of a massive and impressive coral buildup that has developed as a series of patch reef promontories separated by coralline sand deposits. Coral promontories are typically comprised of several very large colonies of Boulder Star Coral (*Montastraea annularis* complex). There are colonies that rise from the bottom at least four meters and extend horizontally more than 5 meters, in some instances merging with other large colonies to form continuous laminar coral formations that are unique in Puerto Rico. Towards the northern end, the shelf-edge reef platform leads to an almost vertical wall with sparse coral growth down to a depth of 40 m. At the southern end, the reef platform ends in an extensive sand deposit that slopes down gently to a depth of about 70 m. Our survey was performed right at the end of the reef on the southern section. Transects were installed at a depth of 27 – 30 m, bordering the edge of three of the larger massive coral promontories. Panoramic views of the shelf edge reef at Puerto Canoas are presented as Photo Album 4.

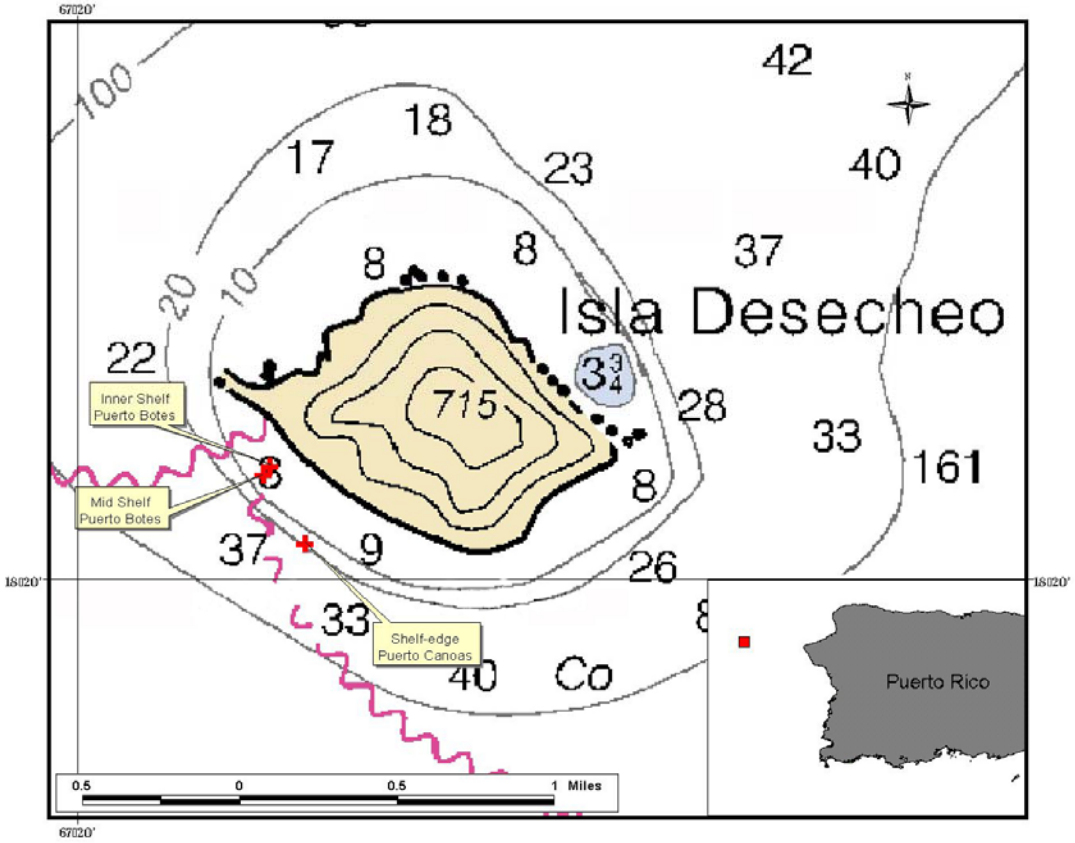


Figure 13. Location of coral reef survey stations at Puerto Canoas/Botes, Isla Desecheo.

Stony corals dominated reef substrate cover along surveyed transects with a mean of 25.3% (range: 16.8 – 35.3 %). Boulder Star Coral (*Montastraea annularis* complex), with a mean cover of 13.7 % represented 54.2 % of the total stony coral cover. In addition to *M. annularis*, Lettuce Coral (*Agaricia agaricites*) and Mustard-Hill Coral (*Porites astreoides*) were present in all five transects at the shelf-edge reef of Puerto Canoas (Table 14). A total of 17 species of stony corals were identified, including 11 intersected by line transects. Several colonies of Black Coral, *Anthipathes sp*., and Wire Coral, *Stichopathes sp*. were observed near the base of the reef and within crevices. Soft corals (gorgonians) were not intercepted by transects and were not common at the shelf-edge reef. Abiotic cover, mostly associated with reef overhangs averaged 17.6 % and contributed to a mean reef substrate rugosity of 3.81. Encrusting and erect sponges were common, with a mean cover of 4.4 % (range: 1.1 – 8.0 %).

Table 14. Percent reef substrate cover by sessile-benthic categories at Puerto Canoas Reef, Desecheo Island. 30 m. June 2008

Depth: 30 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	3.11	3.96	5.37	3.16	3.47	**3.81**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	19.76	16.85	29.52	18.84	3.27	**17.65**
Total Abiotic	19.76	16.85	29.52	18.84	3.27	**17.65**
Benthic Algae						
Turf-mixed assemblage	18.46	17.85	30.69	31.69	35.44	**26.83**
Fleshy	27.31	35.63	14.04	19.30	19.76	**23.21**
Calcareous	0.32				1.26	**0.32**
Total Benthic Algae	46.09	53.48	44.73	50.99	56.46	**50.35**
Sponges	1.14	4.52	8.00	4.18	4.16	**4.40**
Cyanobacteria	6.03	0.50	0.98	3.12	0.73	**2.27**
Live Stony Corals						
Montastraea annularis	7.40	13.05	10.34	13.60	24.00	**13.68**
Agaricia agaricites	3.13	3.87	5.98	5.70	1.56	**4.05**
Colpophyllia natans	10.07	2.22				**2.46**
Porites astreoides	0.54	2.94	0.46	1.37	3.64	**1.79**
Diporia strigosa					5.20	**1.04**
Porites porites	3.01	0.50		0.32		**0.77**
Eusmilia fastigiata	1.75	1.65				**0.68**
Meandrina meandrites				1.90		**0.38**
Agaricia grahamae	0.43				0.94	**0.27**
Madracis decactis	0.64					**0.13**
Mycetophyllia lamarckiana		0.50				**0.10**
Total Stony Corals	26.97	24.73	16.78	22.89	35.34	**25.34**
Recently dead coral	3.20		11.70	3.88	12.48	**6.25**
Gorgonians (# col.)	0	0	0	0	0	0

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

Benthic macroalgae, comprised by an assemblage of turf, fleshy and calcareous types presented a combined substrate cover of 50.4 % along permanent transects. *Lobophora variegata, Padina sp.* and *Ventricaria ventricosa* were some of the most common fleshy macroalgae present. Turf algae included an unidentified variety of short filamentous red and brown macroalgae. A slimy red cyanobacterial film was present in all five transects with a mean substrate cover of 2.3 %.

Figure 14 shows the annual variations of mean percent cover by the main sessile-benthic categories from the shelf-edge reef at Puerto Canoas. Differences of mean substrate cover by stony corals, sponges and benthic algae between the 2004 baseline characterization and the 2005 monitoring surveys were 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 %) and now extending into the present 2008 monitoring survey was observed (ANOVA; $p < 0.0001$). 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, *Montastraea 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 2007 and the present 2008 survey, mean live coral cover declined approximately 14.0 %, from 29.45 % to 25.3 %. The continued decline of live coral cover between 2007 and 2008 was within 95 % confidence limits (Appendix 2). 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 *Montastraea 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.

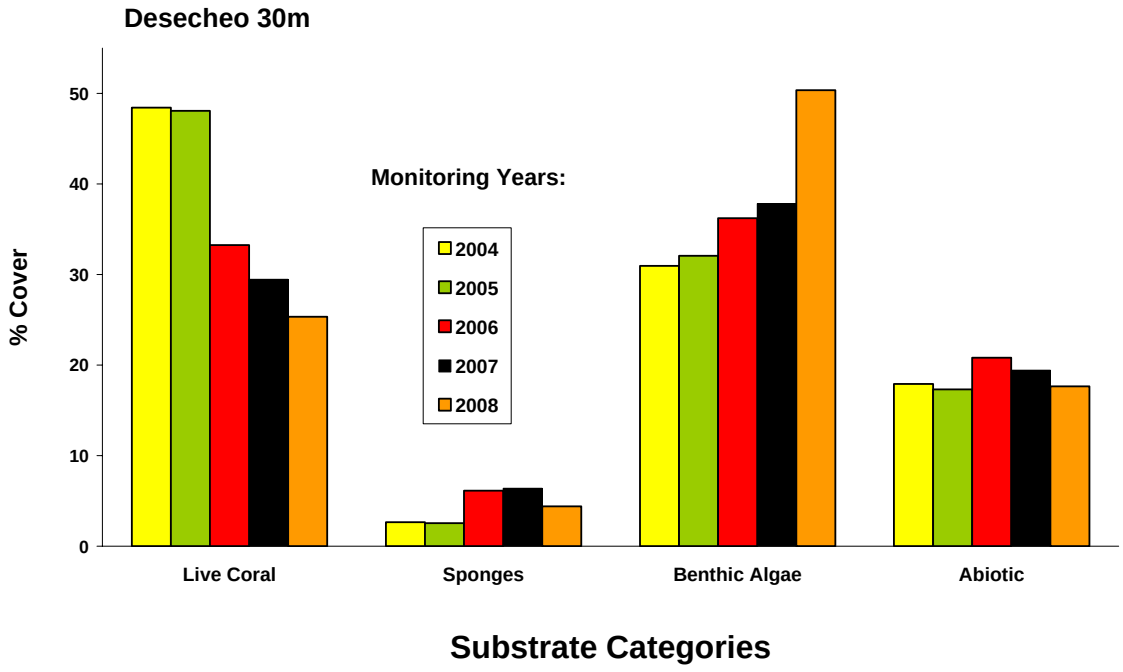


Figure 14. Monitoring trends (2004 – 08) of substrate cover by sessile-benthic categories at Puerto Canoas Reef, Desecheo Island – 30 m.

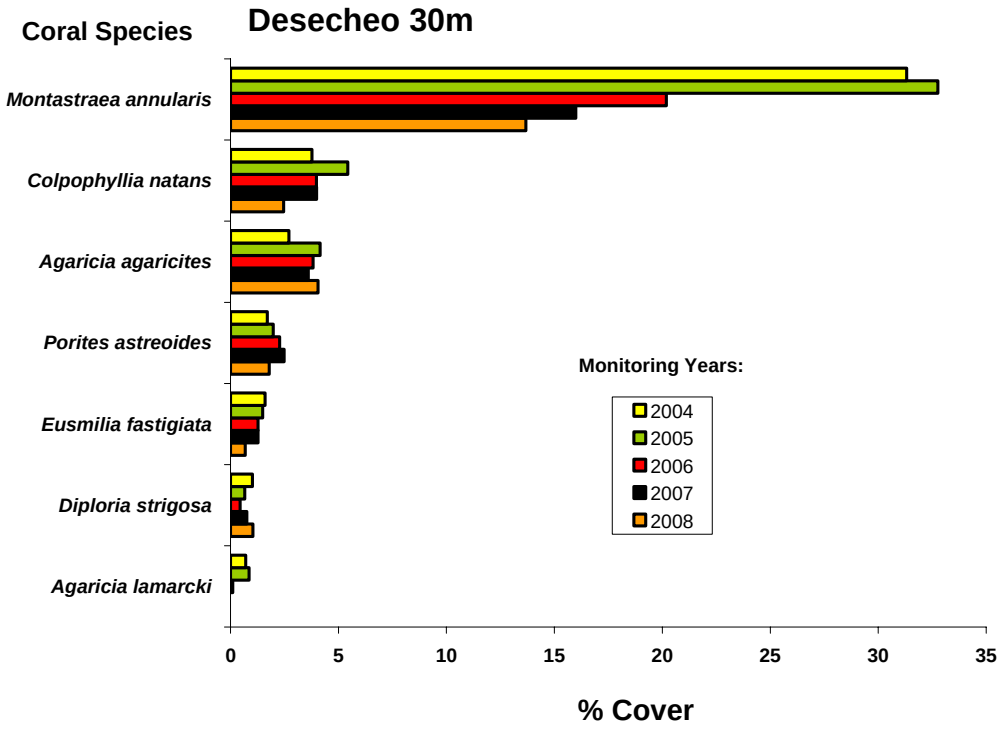


Figure 15. Monitoring trends (2004-08) of mean substrate cover by stony coral species at Puerto Canoas Reef, Desecheo Island – 30 m.

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 95 fish species have been identified during the five surveys (2004-08) from the shelf-edge reef off Puerto Canoas, Isla Desecheo (Appendix 1). Mean abundance of fishes within belt-transects during June, 2008 was 481.6 Ind/30 m^2 (range: 332 – 557 Ind/30 m^2). The mean number of species per transect was 27.2 (range: 22 – 38) (Table 15). An assemblage of eight species, including the Fairy Basslet, Masked and Peppermint Gobies, Creole Wrasse, Blue and Brown Chromis, Bluehead Wrasse and Bicolor Damselfish represented 77.3 % of the total fish abundance within belt-transects. The Blue Chromis, *Chromis cyanea* was the numerically dominant species with a mean abundance of 166.7 Ind/30 m^2 (range: 125 – 200 Ind/30 m^2), representing 34.6 % of the total (Table 15). A total of 10 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, 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 are presented in Figure 16. Diffrences between surveys were not statistically significant (ANOVA; richness $p = 0.139$; abundance $p = 0.719$). Mean fish abundance has fluctuated annually between 400 – 500 Ind/30 m^2 at Puerto Canoas 30 m to stand as one of the reefs with highest fish abundance studied in Puerto Rico. There has been a gradual decline of species richness, from 34 species/transect to 28 species per transect, but such difference is still not statistically significant (ANOVA; $p = 0.139$).

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 pelagic predators, such as Nassau and Yellowfin Groupers, Barracudas, Cero Mackerels, Blue Runners, and Black Jacks (Table 16). Yellowtail, Mahogany and

Table 15. Taxonomic composition and abundance of fishes within belt-transects at Puerto Canoas Reef 30 m, Isla Desecheo. June, 2008

Depth: 30m

		Transects						
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**6**	**MEAN**
Chromis cyanea	Blue Chromis	125	180	165	180	200	150	**166.7**
Clepticus parrae	Creole Wrasse	100	123	160	1	1		**64.2**
Gramma loreto	Royal Gramma	50	39	33	18	22	50	**35.3**
Choryphopterus lipernes	Peppermint Goby	25	38	32	31	29	16	**28.5**
Chromis multilineata	Brown Chromis	15	50	60	24	1		**25.0**
Choryphopterus personatus	Masked Goby	6	30	8	6	40	55	**24.2**
Stegastes partitus	Bicolor Damselfish	18	10	32	16	16	18	**18.3**
Thalassoma bifasciatum	Bluehead Wrasse	15	11	13	8	7	6	**10.0**
Halichoeres garnoti	Yellow-head Wrasse	6	9	8	6	7	5	**6.8**
Choryphopterus evelynae	Sharknose Goby	3	7	8	10	10	2	**6.7**
Chromis insolata	Sunshine Chromis	8	3	2			7	**3.3**
Cephalopholis cruentatus	Graysby	1	3	5	4	3	1	**2.8**
Bodianus rufus	Spanish Hogfish		2	8	2	2	3	**2.8**
Halichoeres maculipinna	Clown Wrasse	5	3	1	1		5	**2.5**
Sparisoma radians	Bucktooth Parrotfish	1	4	4	3	2	1	**2.5**
Sparisoma viride	Stoplight Parrotfish	1	2	5	2		1	**1.8**
Chaetodon capistratus	Foureye Butterflyfish	4	2		2		2	**1.7**
Paranthias furcifer	Creolefish	1	2	1	2	2		**1.3**
Melichthys niger	Black Durgon		1		1	2	1	**0.8**
Acanthurus coeruleus	Blue Tang	2	1	2	2			**1.2**
Caranx lugubris	Black Jack		1					**0.2**
Microspathodon chrysurus	Yellowtail Damselfish	1	1	1	1	1	1	**1.0**
Canthigaster rostrata	Caribbean Puffer		3	2		1		**1.0**
Kyphosus sectatrix	Bermuda Chub	2	1	1	1			**0.8**
Serranus tigrinus	Harlequin Bass		1				4	**0.8**
Scarus iserti	Striped Parrotfish	1		2				**0.5**
Chaetodon aculeatus	Longsnout Butterflyfish	1	1			1		**0.5**
Holocentrus rufus	Squirrelfish	1	1			1		**0.5**
Holacantus tricolor	Rock Beauty		1	1			1	**0.5**
Stegastes planifrons	Threespot Damselfish		2			1		**0.5**
Gobiosoma saucrum	Leopard Goby		1			2		**0.5**
Amblycirrhitus pinos	Redspotted Hawkfish		1	2				**0.5**
Lactophrys triqueter	Smooth Trunkfish				2	1		**0.5**
Neoniphon marianus	Longjaw Squirrelfish					2	1	**0.5**
Scarus taenioptuerus	Princess Parrotfish	1			1			**0.3**
Ephinephelus guttatus	Red Hind	1	1					**0.3**
Sparisoma arofrenatum	Redband Parrotfish		1		1			**0.3**
Acanthurus chirurgus	Doctorfish		1			1		**0.3**
Mulloidichthys martinicus	Yellow Goatfish				2			**0.3**
Lutjanus apodus	Schoolmaster					2		**0.3**
Cephalopholis fulva	Coney					1	1	**0.3**
Stephanolepis hispidus	Planehead filefish		1	1				**0.3**
Myripristis jacobus	Blackbar Soldierfish	1						**0.2**
Hemiramphus brasiliensis	Ballyhoo		1					**0.2**

Table 15. continued								
Choryphopterus glaucofraenum	Bridled Goby		1					**0.2**
Liopropoma rubre	Peppermint Basslet		1					**0.2**
Scarus vetula	Queen Parrotfish				1			**0.2**
Cantherhines macrocerus	Whitespotted Filefish						1	**0.2**
								0.0
	TOTAL INDIVIDUALS	**395**	**541**	**557**	**557**	**358**	**332**	**481.6**
	TOTAL SPECIES	**26**	**38**	**25**	**26**	**26**	**22**	**27.2**

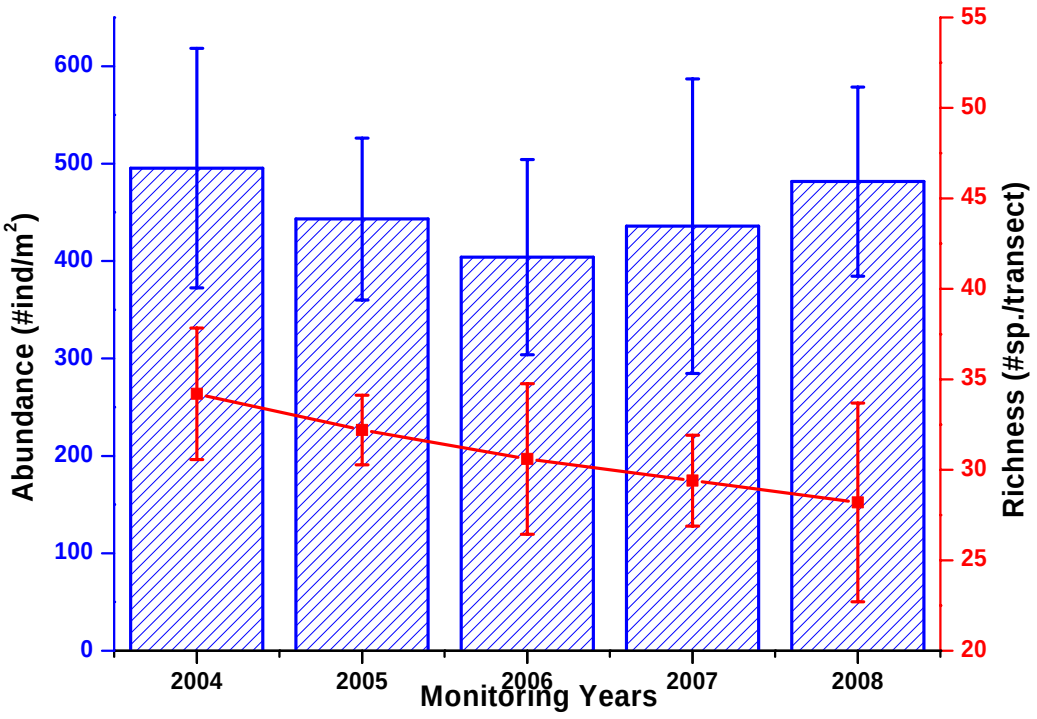


Figure 16. Monitoring trends (2004 – 2008) of fish species richness and abundance at the Shelf-edge Reef Puerto Canoas, 30 m, Isla Desecheo.

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, 2008

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

SPECIES	**COMMON NAME**		# - (cm)	
Balistes vetula	Queen Triggerfish	1 – (30)	1 – (50)	
Caranx latus	Cravelle Jack	4 – (30)		
Caranx lugubris	Black Jack	2 - (50)		
Epinephelus guttatus	Red Hind	2 - (30)		
Epinephelus striatus	Nassau Grouper	1 - (60)		
Holacanthus ciliaris	Queen Angel	3 - (45)		
Holacanthus tricolor	Rock Beauty	2 - (20)	2 - (25)	1 - (15)
Lutjanus apodus	Schoolmaster	10 - (25)	15 - (40)	20 - (50)
Lutjanus mahogany	Mahogani Snapper	8 - (25)	5 - (30)	
Mycteroperca venenosa	Yellowfin Grouper	1 - (45)	1 – (60)	
Ocyurus chrysurus	Yellowtail Snapper	3 - (40)		
Scomberomorus regalis	Cero Mackerel	2 - (60)		
Sphyraena barracuda	Great Barracuda	1 - (70)		
Invertebrates				
Panulirus argus	Spiny Lobster	2 - (30)		
Strombus gigas	Queen Conch	3 - (25)		
Sea Turtles				
Eretmochelys imbricata	Hawksbill Turtle	1 – (70)		

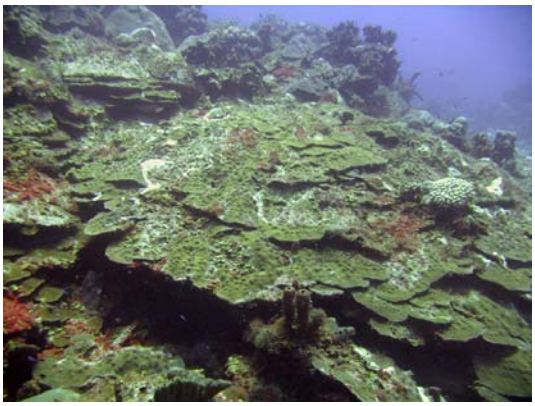
Schoolmaster Snappers, Red Hind, Coney and Queen Triggerfish were observed in full adult sizes. The Caribbean Reef Shark (*Carcharhinus perezi*) was reported in a previous survey of this reef (García-Sais et al., 2004). A large variety of small invertebrate feeders were present, including wrasses, gobies, 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.

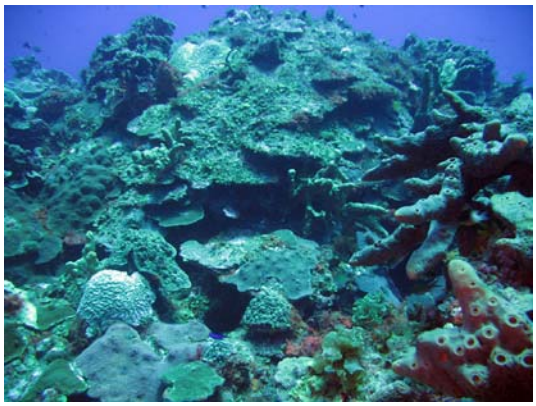
The Arrow Crab, *Stenorhynchus seticornis* and the Cleaner Shrimps, *Stenopus hispidus* and *Periclimenes pedersoni* were the motile megabenthic invertebrates observed within belt-transects (Table 17). Two Spiny Lobsters, *Panulirus argus* and the Queen Conch (*Strombus gigas*) were observed outside transects during the ASEC survey.

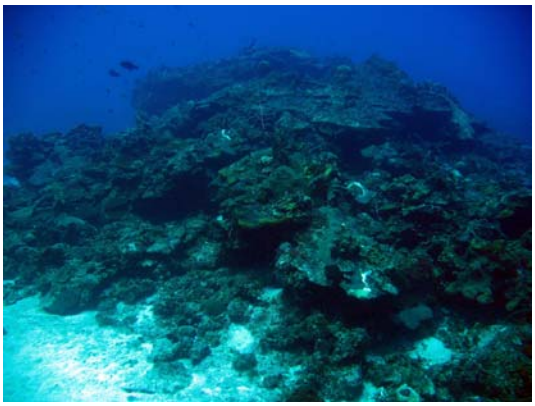
Table 17 . Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Puerto Canoas Shelf-edge Reef, Isla Desecheo 30m, June 2008

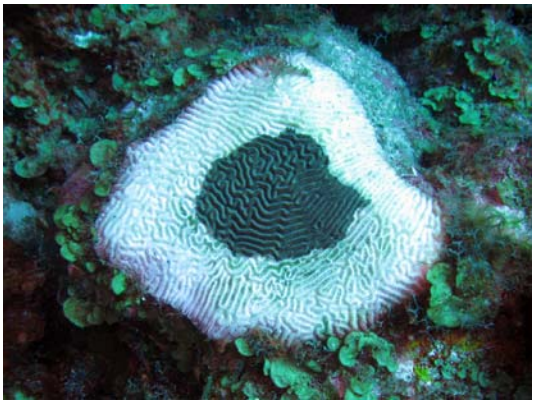
DATE: June 11, 2008 Depth: 25 – 30 m		TRANSECTS					**MEAN ABUNDANCE (IND/30 m2)**
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						
Stenorhynchus seticornis	Arrow crab	1		2	1		**0.8**
Periclimenes pedersoni	Cleaner Shrimp		1				**0.2**
Stenopus hispidus	Banded Coral Shrimp			1			**0.2**
	TOTALS	**1**	**1**	**3**	**1**	**0**	**1.2**

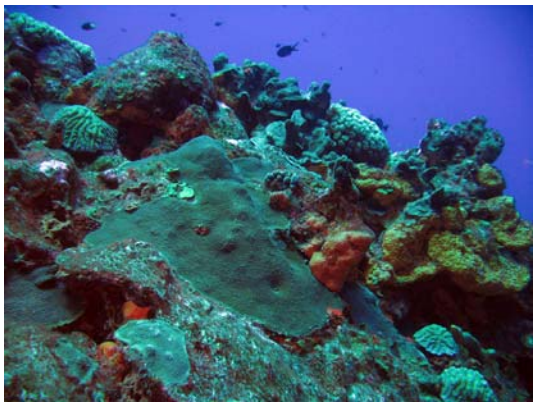
Photo Album 4 (Desecheo 30m)
Shelf Edge Reef

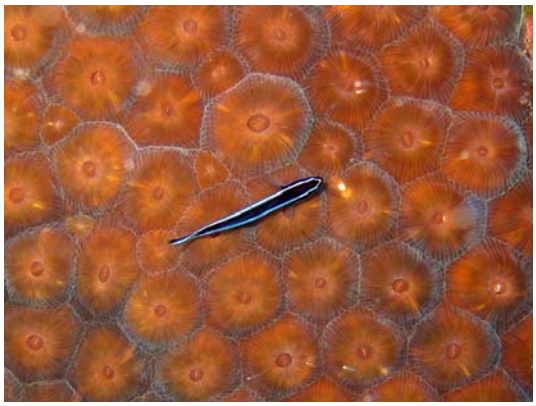












2.0 Mid-shelf Patch Reef - Puerto Botes

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 sixth monitoring survey of the mid-shelf patch reefs at Puerto Botes. Digital photos of the mid shelf patch reef at Puerto Botes are shown as Photo Album 5.

A total of 23 stony corals, including 11 intersected by line transects were identified during this survey. Finger Coral, *Porites porites* was the species of highest mean percent substrate cover with a mean of 5.8 % (range: 0 – 27.5). It was present as a large single colony and one smaller colony in two of the five transects surveyed. Boulder Star Coral, *Montastraea annularis* (complex), Lettuce Coral, *Agaricia agaricites*, and Great Star Coral *M. cavernosa* comprised (with Finger Coral) the most prominent coral assemblage along transects representing 72.1 % 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 26.4 % (range: 8.8 – 39.6 %). This mortality resulted after the massive coral bleaching event in October 2005.

Reef overhangs, largely associated with skeletal buildups of *Montastraea annularis* averaged 8.7 % of the reef substrate cover and contributed substantially to the reef rugosity of 3.68 m. Erect and encrusting sponges were present with a mean substrate cover of 3.7 %. Reef hard-ground substrates not colonized by stony corals or sponges were mostly overgrown by a dense algal turf (mean cover: 57.0 %), comprised of a mixed assemblage of red coralline and brown macroalgae. Fleshy brown (*Lobophora sp., Dictyota sp., Padina sp*.) and calcareous macroalgae contributed an additional 10.8 % to the total benthic algal cover at Puerto Botes (Table 18).

Table 18. Percent substrate cover by sessile-benthic categories at Puerto Botes, Desecheo Island. June, 2008

Depth: 20 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	3.86	4.75	3.47	2.07	4.23	**3.68**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	9.96	10.31	14.93	8.37		**8.71**
Sand			0.52	5.37	2.48	**1.67**
Gaps					1.97	**0.39**
Total Abiotic	9.96	10.31	15.45	13.74	4.45	**10.78**
Benthic Algae						
Turf-mixed assemblage	78.17	62.42	53.57	39.72	50.98	**56.97**
Fleshy	2.02	17.77	20.43	1.17	12.38	**10.75**
Total Benthic Algae	80.19	80.19	74.00	40.89	63.36	**67.73**
Sponges	1.73	2.17	2.08	8.96	3.59	**3.71**
Hydrozoa (Millepora)	0.41					**0.08**
Live Stony Corals						
Porites porites				27.45	1.78	**5.85**
Agaricia agaricites	3.46	2.17	1.04	0.93	11.81	**3.88**
Montastraea annularis	3.68	0.86	1.26	2.49	7.03	**3.06**
Montastraea cavernosa			1.47		5.63	**1.42**
Porites astreoides		3.32		1.28	0.40	**1.00**
Meandrina meandrites		0.96	2.75		0.99	**0.94**
Diploria labyrinthiformis				2.57		**0.51**
Eusmilia fastigiata	0.30		1.99			**0.46**
Colpophyllia natans				1.75		**0.35**
Agaricia grahamae					0.99	**0.20**
Madracis decactis	0.30					**0.06**
Total Stony Corals	7.74	7.31	8.51	36.47	28.63	**17.73**
Recently died coral	39.55	30.19	34.77	8.79	18.49	**26.36**
Gorgonians (# col.)	n/d	n/d	n/d	n/d	n/d	n/d
Total Gorgonians (# colonies/transect)	n/d	n/d	n/d	n/d	n/d	n/d

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 2008 monitoring survey, live coral cover declined furthermore to a historical minimum of 17.7 %. Differences of live coral between the 2000 – 2005 and the 2006 – 2008 monitoring surveys were statistically significant (ANOVA; $p < 0.0001$) reflecting the acute degradation experienced by the reef system after October 2005. 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 (García et al., 2008; Rothenberger et al., 2008) 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, *Montastraea 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 14 % decline of reef substrate cover by *M. annularis* (complex) was measured during the 2008 survey, from 4.7 % (in 2006) to 3.1 % (in 2008) (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.

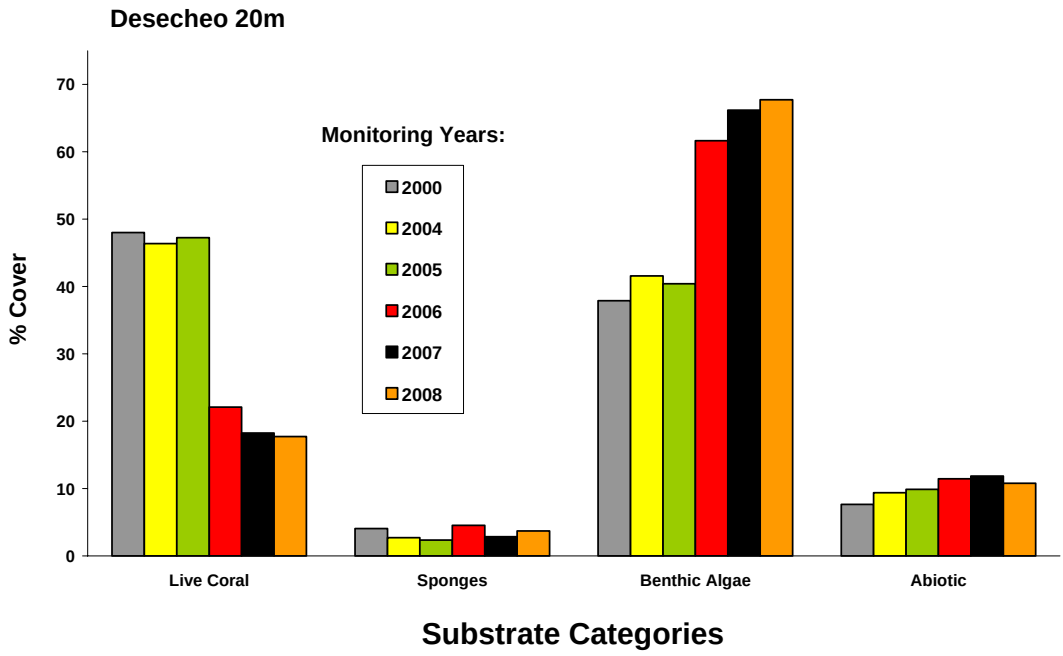


Figure 17. Monitoring trends (2000 – 08) of mean substrate cover by sessile-benthic categories at Puerto Botes Reef, Desecheo Island – 20 m.

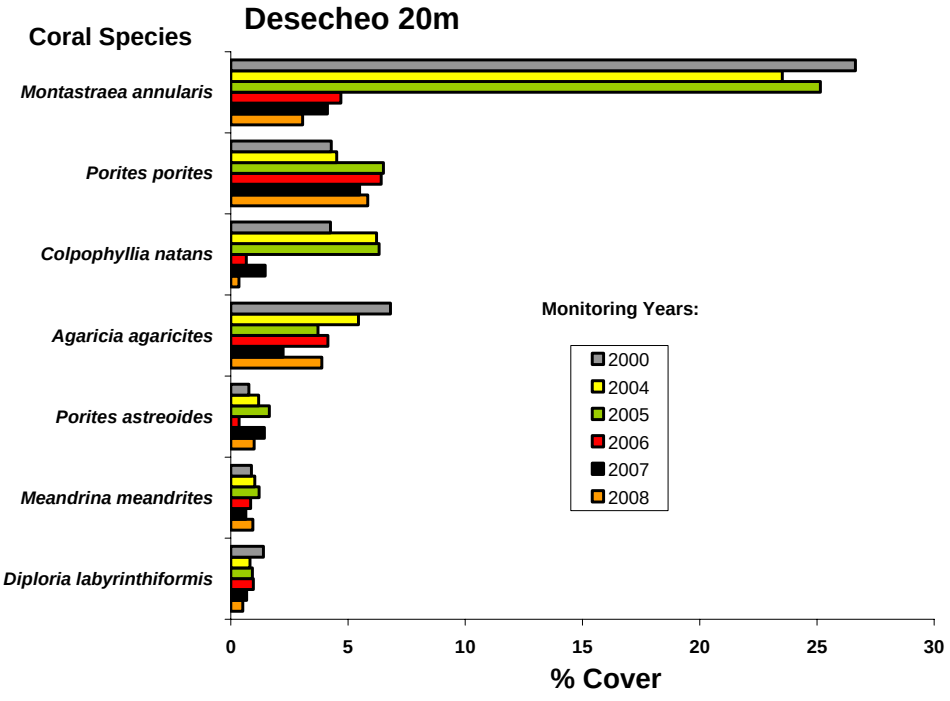


Figure 18. Monitoring trends (2000 – 08) of mean substrate cover by stony coral species at Puerto Botes Reef, Desecheo Island – 20 m.

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 was measured during the 2007, proportional to the observed decline of live coral cover for this period. From the benthic algal assemblage, the fleshy brown macroalgae showed the highest increment between the 2005 and 2008 surveys, from 3.6 % in 2005 to 10.8 % in 2008. An increasing trend of reef substrate cover by abiotic categories has also been noted.

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 42 fish species were identified within belt-transects from the mid-shelf patch reefs off Puerto Botes, Isla Desecheo during June, 2008 (Table 19). During the seven surveys, a total of 70 diurnal, non-criptic fishes have been reported from this reef (Appendix 1). Mean abundance of fishes within belt-transects was 246.0 Ind/30 m^2 (range: 184 - 330 Ind/30 m^2). The mean number of species per transect was 23.0 (range: 19 - 28). The Blue Chromis (*Chromis cyanea*) and the Bicolor Damselfish (*Stegastes partitus*) were the numerically dominant species within belt-transects during the 2008 survey with mean abundances of 91.0 and 35.6 Ind/30 m^2, respectively. The combined abundance of six species, including the Blue and Brown Chromis, Bluehead and Yellowhead Wrasses, Fairy Basslet and Bicolor Damselfish represented 74.1 % of the total fish abundance within belt-transects. A total of nine species were present in all five transects and another seven species were present in four transects (Table 19).

Annual monitoring trends of fish species richness and abundance surveyed within belt-transects are presented in Figure 19. The mean number of fish species within transects (species richness) has fluctuated between 23.0 and 29.0, and mean abundance has varied between 166.8 Ind/30 m^2 and 248.6 Ind/30 m^2 during the seven year monitoring period at this reef. Differences of species richness and abundance between surveys were not statistically significant (ANOVA; $p > 0.05$) (see Appendices 3-4).

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

Table 19. Taxonomic composition and abundance of fishes within belt-transects at Puerto Botes Reef 20 m, Desecheo Island. June, 2008

Depth: 20m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Chromis cyanea	Blue Chromis	95	150	50	75	85	**91.0**
Stegastes partitus	Bicolor Damselfish	24	23	35	51	45	**35.6**
Thalassoma bifasciatum	Bluehead Wrasse	18	18	17	15	10	**15.6**
Chromis multilineata	Brown Chromis		9		17	50	**15.2**
Halichoeres garnoti	Yellow-head Wrasse	4	9	16	25	12	**13.2**
Gramma loreto	Fairy Basslet	5	18	25		10	**11.6**
Lutjanus apodus	Schoolmaster		46			1	**9.4**
Gobiosoma evelynae	Sharknose Goby	12	15	2	6	9	**8.8**
Choryphopterus lipernes	Peppermint Goby	14	8	10	3	7	**8.4**
Scarus iserti	Striped Parrotfish	2		12	5	6	**5.0**
Clepticus parrae	Creole Wrasse				25		**5.0**
Scarus taeniopterus	Princess Parrotfish	15			1	1	**3.4**
Halichoeres maculipinna	Clown Wrasse	3	4	4	3	1	**3.0**
Sparisoma radians	Bucktooth Parrotfish	2	3	1	2	1	**1.8**
Serranus tigrinus	Harlequin Bass	3			1	5	**1.8**
Holocentrus rufus	Squirrelfish	2	3	3		1	**1.8**
Cepahlopholis fulva	Coney	2	4		2		**1.6**
Sparisoma viride	Stoplight Parrotfish	1	2		1	4	**1.6**
Acanthurus coeruleus	Blue Tang	2	2	1		1	**1.2**
Chaetodon capistratus	Foureye Butterflyfish			2		4	**1.2**
Amblycirrhitus pinos	Redspotted Hawkfish	3	1		1	1	**1.2**
Choryphopterus glaucafraenum	Bridled Goby	1	1	1	1	1	**1.0**
Bodianus rufus	Spanish Hogfish		5				**1.0**
Microspathodon chrysurus	Yellowtail Damselfish	2	1			1	**0.8**
Acanthostracion polygonia	Honeycomb Cowfish	1	1	1		1	**0.8**
Acanthurus chirurgus	Doctorfish	3					**0.6**
Myripristis jacobus	Blackbar Soldierfish				3		**0.6**
Haemulon flaviolineatum	French Grunt			1		2	**0.6**
Lactophrys triqueter	Smooth Trunkfish	1	1				**0.4**
Chaetodon striatus	Banded Butterflyfish		1	1			**0.4**
Sparisoma chrysargyreum	Redtail Parrotfish	1					**0.2**
Sparisoma aurofrenatum	Redband Parrotfish				1		**0.2**
Sargocentron coruscus	Reef Squirrelfish			1			**0.2**
Holocanthus tricolor	Rock Beauty			1			**0.2**
Cantherhines macrocerus	Whitespotted Filefish					1	**0.2**
Sparisoma rubripinne	Yellowtail Parrotfish					1	**0.2**
Neoniphon marianus	Longjaw Squirrelfish					1	**0.2**
Holocanthus ciliaris	Queen Angelfish		1				**0.2**
Cephalopholis cruentatus	Graysby		1				**0.2**
Chaetodon aculeatus	Longsnout Butterflyfish		1				**0.2**
Holocentrus adscensionis	Longjaw Squirrelfish		1				**0.2**
Equetus lanceolatus	Jackknife Fish		1				**0.2**
	TOTAL INDIVIDUALS	**216**	**330**	**184**	**238**	**262**	**246**
	TOTAL SPECIES	**23**	**28**	**19**	**19**	**26**	**23**

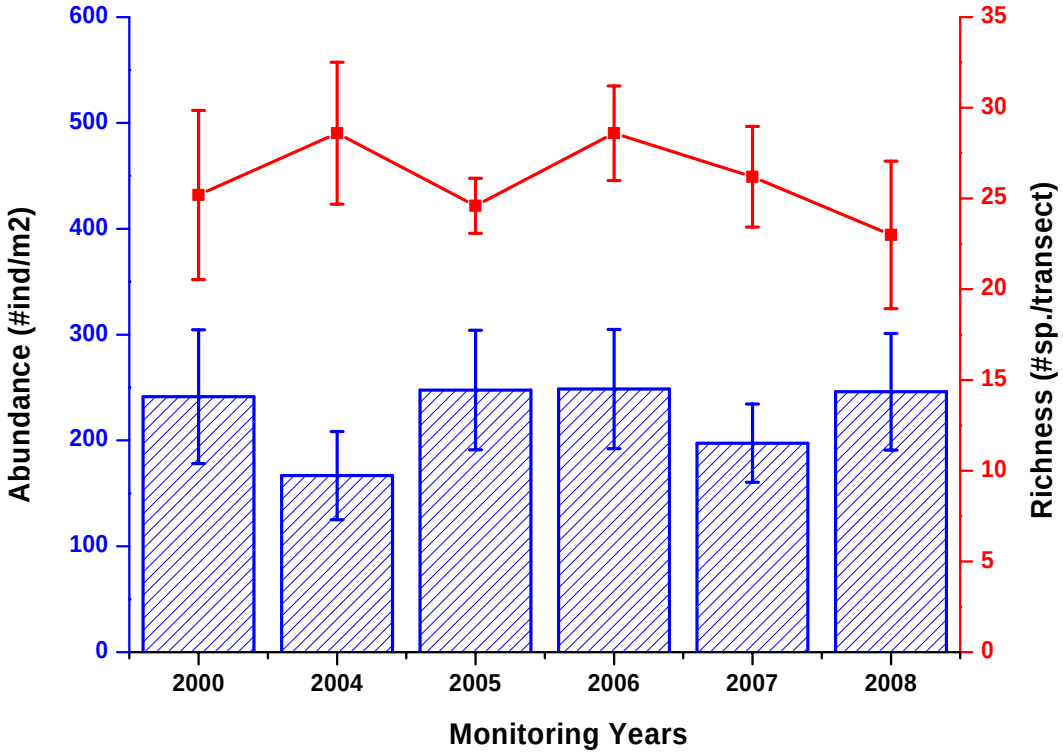


Figure 19. Monitoring trends (2000 – 2008) of fish species richness and abundance at the Mid-Shelf Reef, Puerto Botes, 20 m, Isla Desecheo.

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* and the Channel Clinging Crab, *Mithrax spinosissimus* were the only motile megabenthic invertebrates within belt-transects (Table 21). Spiny Lobster (*Panulirus argus*), Sponge Brittle Stars (*Ophiothrix suensoni*), Arrow Crabs (*Stenorhynchus seticornis*) and Long-Spined Urchin (*Diadema antillarum*) were observed outside transects.

Table 20. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Puerto Botes, Isla Desecheo 20 m, June, 2008

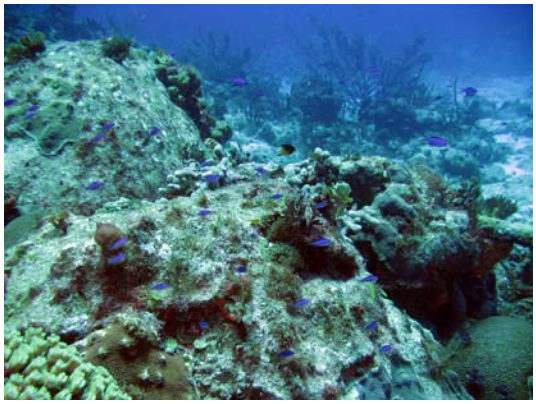
Depth range : 17 - 20 m Duration - 30 min.

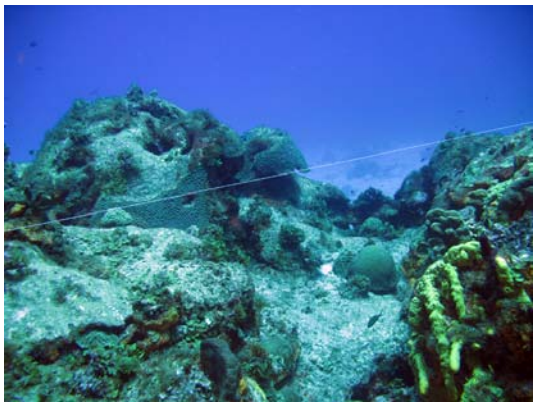
SPECIES	**COMMON NAME**		# - (cm)	
Balistes vetula	Queen Triggerfish	1 – (40)		
Carangoides crysos	Blue Runner	1 – (30)		
Caranx latus	Cravelle Jack	2 – (30)	2- (40)	
Caranx lugubris	Black Jack	2 - (50)	1 – (60)	
Epinephelus guttatus	Red Hind	1 – (30)	1 – (35)	
Gramma loreto	Fairy Basslet	12 - (1-3)	15 - (4-6)	10 -(7-9)
Holacanthus ciliaris	Queen Angel	1 - (35)		
Holacanthus tricolor	Rock Beauty	2 - (15)	1- (25)	
Lutjanus apodus	Schoolmaster	13– (25)	3- (30)	5- (40)
Lutjanus mahogany	Mahogani Snapper	3- (25)		
Ocyurus chrysurus	Yellowtail Snapper	2– (35)	3 – (40)	
Scomberomorus regalis	Cero Mackerel	1 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (80)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (20)		

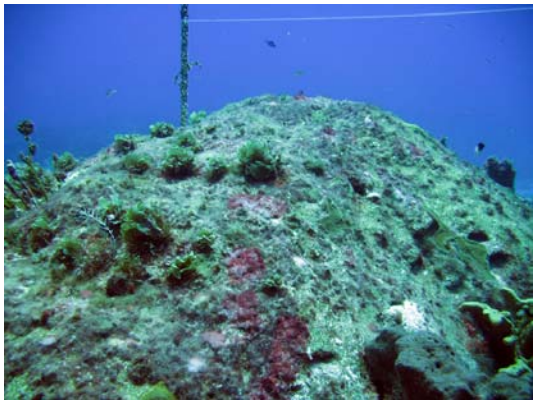
Table 21. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Puerto Botes Mid-shelf Reef. Isla Desecheo 20m, June 2008

		TRANSECTS					
Depth: 20 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Mithrax spinosissimus	Channel Clinging Crab	1					**0.2**
Periclimenes pedersoni	Cleaner Shrimp		1				**0.2**
Stenopus hispidus	Banded coral shrimp		1				**0.2**
	TOTALS	**1**	**2**	**0**	**0**	**0**	**0.6**

Photo Album 5 (Desecheo 20m)
Mid-shelf Reef







3.0 Inner Shelf Reefs – Puerto Botes

3.1 Sessile-benthic Reef Community

The rocky shoreline off Puerto Botes leads to a gently sloping hard ground terrace 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 17 stony corals, including 10 intersected by line transects were identified during this 2008 monitoring survey at Puerto Botes Inner Reef. Stony corals presented a mean substrate cover of 7.6 % (range: 5.2 – 9.7 %) (Table 22). Mustard-Hill Coral, *Porites astreoides*, Boulder Star Coral, *Montastraea annularis* (complex), Great Star Coral, *Montastraea cavernosa*, and Lettuce Coral, *Agaricia agaricites* comprised the main coral assemblage with a combined reef substrate cover of 6.4 %, representative of 84.2 % of the total live coral cover in the reef. Corals typically exhibited encrusting growth and small to moderate colony sizes, perhaps as adaptations to the strong wave and surge action seasonally acting at the shallower reef zone. Reef overhangs, largely associated with growth of *M. annularis* presented a mean substrate cover of 9.2 % and contributed substantially to the reef rugosity of 3.37 m. Total abiotic cover also included sections of sand and averaged 3.6 %. Sponges were present at all transects with a mean substrate cover of 5.8 % (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 73.6 % (Table 22). Fleshy brown (*Lobophora sp., Dictyota sp*., *Padina sp*.) and turf macroalgae, a mixed assemblage of red coralline (*Amphiroa* sp.) and short filamentous brown macroalgae were the principal components of the benthic algae. Both turf and fleshy macroalgae were observed overgrowing recently dead sections of coral colonies in the reef.

Table 22. Percent substrate cover by sessile-benthic categories at Puerto Botes Inner Reef, Desecheo Island. June 2008

Depth: 15 m	Transects					
	1	2	3	4	5	**MEAN**
Rugosity (m)	2.69	3.01	4.42	3.37	3.34	**3.37**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	5.99	11.45	8.99	10.24	9.22	**9.18**
Sand	3.47	3.36	4.67	5.61	0.95	**3.61**
Total Abiotic	9.46	14.81	13.66	15.85	10.17	**12.79**
Benthic Algae						
Turf-mixed assemblage	61.40	56.26	54.58	45.07	69.04	**57.27**
Fleshy	15.21	15.83	21.94	25.71	2.96	**16.33**
Total Benthic Algae	76.61	72.09	76.52	70.78	72.00	**73.60**
Sponges	5.52	3.46	3.68	8.00	8.10	**5.75**
Cyanobacteria			1.10			**0.22**
Hydrozoa (Millepora)	0.22					**0.04**
Live Stony Corals						
Porites astreoides	3.47	5.53	1.70	0.74	2.32	**2.75**
Montastraea annularis	0.67	0.97	1.27	0.74	4.35	**1.60**
Montastraea cavernosa	2.44		2.19	1.58	1.06	**1.45**
Agaricia agaricites	0.56	0.43		1.27	0.75	**0.60**
Colpophyllia natans		2.71				**0.54**
Diploria strigosa	0.56				0.63	**0.24**
Porites porites				0.63		**0.13**
Siderastrea radians					0.63	**0.13**
Diploria labyrinthiformis	0.56					**0.11**
Madracis decactis				0.42		**0.08**
Total Stony Corals	8.26	9.64	5.16	5.38	9.74	**7.636**
Recently dead coral	5.55	4.22	8.97	3.14	7.57	**5.89**
Gorgonians (# col.)						
Pseudoptergorgia spp.	10					**2.0**
Total Gorgonians (# colonies/transect)	10	0	0	0	0	**2.0**

Coral Species Outside Transects: *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 -08. 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 2007 survey, from 9.85 % in 2006 to 8.06 % in 2007. Differences of total live coral cover between surveys were statistically significant (ANOVA; $p = 0.008$). Multiple mean comparison test validated the measured differences of substrate cover by live corals between the 2004-2005 and the 2006-08 surveys (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 2007 and 2008 surveys were not statistically significant (Appendix 2).

The decline of live coral cover at the inner shelf reef off Puerto Botes was largely associated with a reduction of cover by the dominant species, Boulder Star Coral, *Montastraea annularis* (complex), which 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 37.2 %, from 2.55 % in 2006 to 1.6 % was measured in the present 2008 survey for *M. annularis*.

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 2008 survey, live colonies of Boulder Star Coral presented substrate cover below 1% in three out of the five transects surveyed. 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, *Montastraea cavernosa*, Lettuce Coral, *Agaricia agaricites*, and Flower Coral, *Eusmilia fastigiata* did not show any statistically significant differences in substrate cover between surveys.

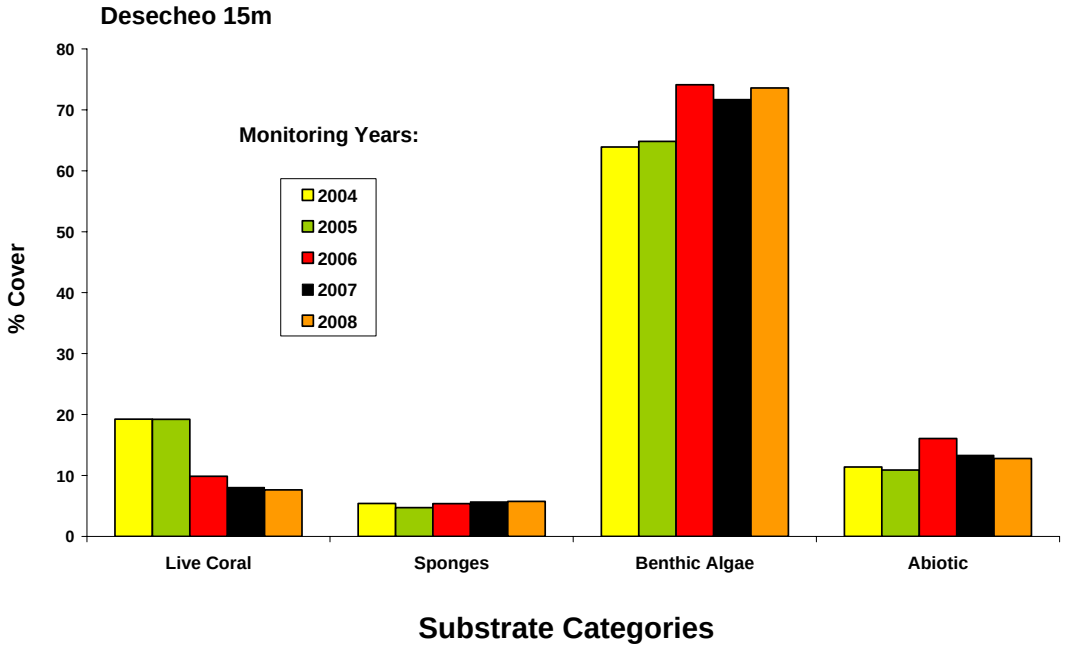


Figure 20. Monitoring trends (2004 -08) of mean substrate cover by sessile-benthic categories at Puerto Botes Inner Shelf Reef, Desecheo Island – 15 m.

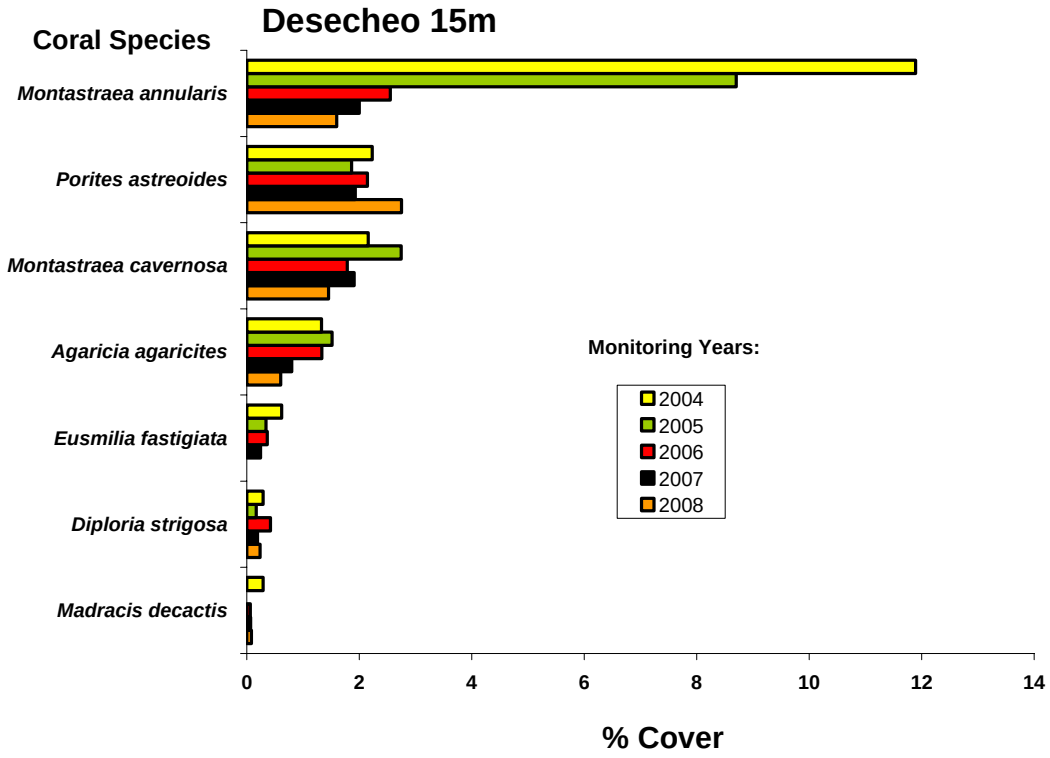


Figure 21. Monitoring trends (2004 -08) of mean substrate cover by stony coral species at Puerto Botes Inner Shelf Reef, Desecheo Island – 15 m.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 36 fish species were identified within belt-transects from the Inner-Shelf Reef off Puerto Botes, Isla Desecheo during June, 2008 (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 2008 survey was 184.4 Ind/30 m^2 (range: 106 - 290 Ind/30 m^2). The mean number of species per transect was 17.6 (range: 13 - 20). The Blue Chromis, Bicolor Damselfish, Sharknose Goby, and Bluehead, Yellowhead and Clown Wrasses comprised the numerically dominant fish assemblage with a combined mean abundance of 158.6 Ind/30, representing 86.0 % of the total abundance within belt-transects (Table 23). A total of eight 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 17.6 and 25.2, and mean abundance has varied between 133.8 Ind/30 m^2 and 307.6 Ind/30 m^2 during the five year monitoring period at this reef. A statistically significant decline of fish species richness and abundance was observed during the 2008 survey relative to previous surveys (ANOVA; $p < 0.005$). Differences of fish abundance are largely associated with species that display schooling behavior and thus, have highly aggregated spatial distribution patterns such as the Blue and Brown Chromis. 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 adustus, 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 Inner Shelf Reef, Isla Desecheo. June, 2008

Depth: 15m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Chromis cyanea	Blue Chromis	50	175	100	5	50	**76.0**
Stegastes partitus	Bicolor damselfish	47	58	48	45	38	**47.2**
Thalassoma bifasciatum	Bluehead wrasse	10	14	21	10	20	**15.0**
Gobiosoma evelynae	Sarknose goby	5	10	9	9	7	**8.0**
Halichoeres garnoti	Yellow-head wrasse	5	10	5	6	6	**6.4**
Halichoeres maculipinna	Clown wrasse	5	5	5	10	5	**6.0**
Chromis multilineata	Brown Chromis	8	1	10	8	2	**5.8**
Clepticus parrae	Creole wrasse			4			**0.8**
Amblycirrhitus pinos	Redspoted Halkfish					4	**0.8**
Scarus iserti	Striped Parrotfish	5	3	5	1		**2.8**
Choryphopterus lipernes	Peppermint Goby				2	5	**1.4**
Sparisoma radians	Bucktooth Parrotfish	4	2	2		4	**2.4**
Holocentrus rufus	Squirrelfish			2	2	5	**1.8**
Gramma loreto	Fairy Basslet					3	**0.6**
Chaetodon capistratus	Foureye Butterflyfish		2			2	**0.8**
Haemulon flaveolineatum	French Grunt					2	**0.4**
Acanthurus coeruleus	Blue Tang		2	1		2	**1.0**
Serranus tigrinus	Harlequin Bass	1		1	1	3	**1.2**
Cephalopholis fulva	Coney	1	2	1	1	2	**1.4**
Microspathodon chysurus	Yellowtail Damselfish		1	1		2	**0.8**
Acanthurus bahianus	Ocean Surgeon	1					**0.2**
Rypticus saponaceus	Soapfish	1					**0.2**
Acanthostracion quadricornis	Scrawled Cowfish		1		1		**0.4**
Caranx crysos	Blue Runner		1				**0.2**
Sparisoma aurofrenatum	Redband Parrotfish		1	1	1		**0.6**
Serranus tabacarius	Tobaccofish		1				**0.2**
Acanthemblemaria aspera	Roughhead Blenny		1				**0.2**
Lactrophrys triqueter	Smooth Trunkfish				1		**0.2**
Sparisoma viride	Stoplight Parrotfish				1		**0.2**
Bodianus rufus	Spanish Hogfish				1		**0.2**
Gymnothorax moringa	Spotted Moray					1	**0.2**
Kyphosus sectatrix	Bermuda Chub					1	**0.2**
Sparisoma rubripinne	Yellowtail Parrotfish			1			**0.2**
Holocanthus tricolor	Rock Beauty			1			**0.2**
Sparisoma atomarium	Greenblotch Parrotfish			1			**0.2**
Flammeo marianus	Longspine Squirrelfish				1		**0.2**
	TOTAL INDIVIDUALS	143	290	219	106	164	**184.4**
	TOTAL SPECIES	13	18	19	18	20	**17.6**

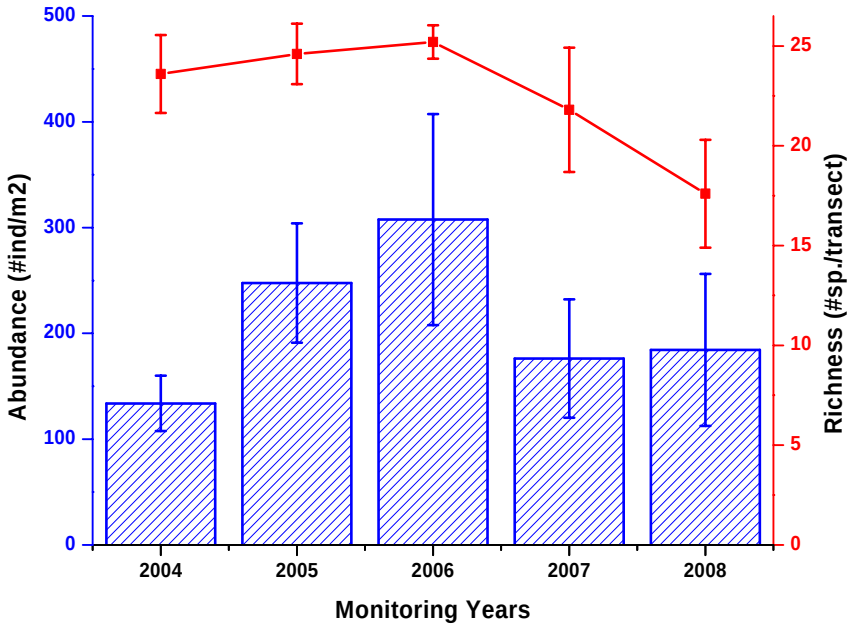


Figure 22. Monitoring trends (2004 – 2008) of fish species richness and abundance at Inner Shelf Reef Puerto Botes,15 m depth, Isla Desecheo.

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

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, Coral Crabs 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, 2008

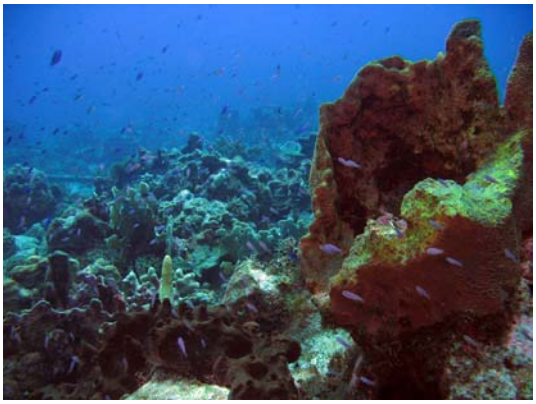
Depth range : 14 - 16 m Duration - 30 min.

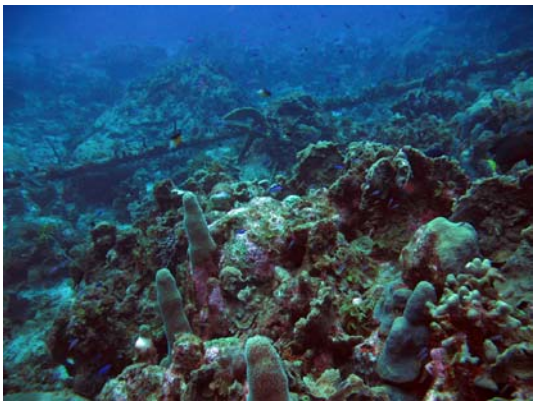
SPECIES	**COMMON NAME**		# - (cm)	
Cephalopholis fulva	Coney	1 - (10)	7 - (20)	2 - (25)
Decapterus macarellus	Mackerel Scad	60 - (10-12)		
Gramma loreto	Fairy Basslet	11 - (< 3)	8 - (3-5)	3 -(6-7)
Holacanthus ciliaris	French Angel	1 – (30)		
Holacanthus tricolor	Rock Beauty	1 - (20)		
Lutjanus apodus	Schoolmaster	4 - (30)	6 - (30)	
Lutjanus mahogany	Mahogani Snapper	2 - (25)	1 – (30)	
Ocyurus chrysurus	Yellowtail Snapper	6 – (35)	1 – (50)	
Scomberomorus regalis	Cero Mackerel	1 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (50)		

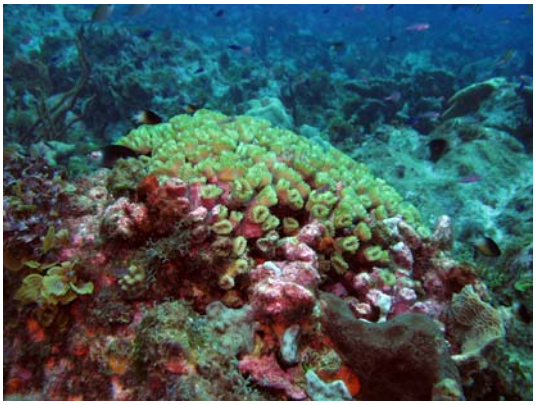
Table 25. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at the Puerto Botes Inner-Shelf Reef, 15 m, Isla Desecheo, June, 2008

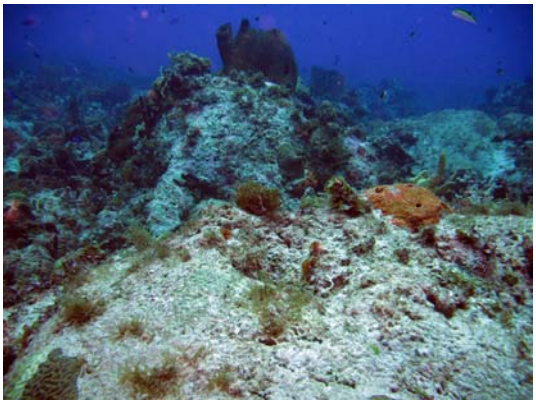
		TRANSECTS					
DATE: June 12, 2008 Depth: 15 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Stenorhynchus seticornis	Arrow Crab	1	1				**0.4**
Carpilus coralinus	Coral Crab		1				**0.2**
Ophiothrix suensoni	Sponge Brittle Star	6					**1.2**
	TOTALS	**7**	**2**	**0**	**0**	**0**	**1.8**

Photo Album 6 (Desecheo 15m)
Inner Shelf Reef









C. Tourmaline Reef System – Mayaguez Bay

Tourmaline Reef, located due west of Bahía Bramadero, Cabo Rojo was designated as a Natural Reserve in 1996 in recognition of its ecological value as the most important coral reef system of the west coast of Puerto Rico. The total extension of the Natural Reserve is 19.43 square nautical miles. The reef sits at the northern section of the Cabo Rojo platform, approximately five miles away from the coastline (Figure 23).

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

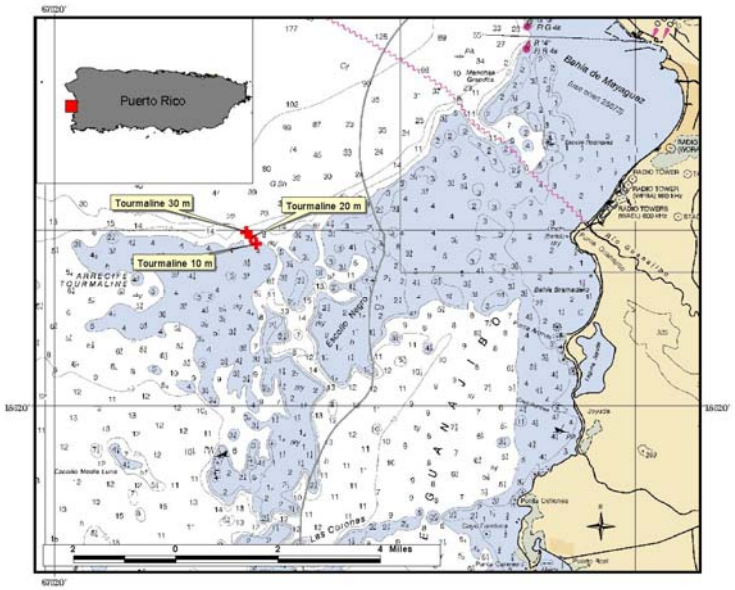


Figure 23. Location of coral reef survey stations at Tourmaline Reef, off Mayaguez Bay.

1.0 Shelf-edge Reef – 30 meters

1.1 Sessile-Benthic Reef Community

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

A total of 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 15.8 % (range: 11.0 – 21.2 %). Boulder Star Coral, *Montastraea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 7.1 % (range: 4.4 – 7.9 %), representing 44.9 % 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, *Montastraea cavernosa* were also prominent at the shelf-edge. Soft corals (gorgonians) were moderately abundant, with an average of 20.2 colonies/transect. The encrusting gorgonian, *Erythropodium caribaeorum* was intercepted by four transects and presented a mean substrate cover of 3.7 %. 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 3.5 %. The Blue Bell Tunicate, *Clavelina puertosecensis* was very common throughout the shelf-edge reef. Reef overhangs, associated with substrate depressions and coral ledges averaged 27.0 % and contributed substantially to a topographic rugosity of 5.13 m.

Turf algae, comprised by an assemblage of short filamentous red and brown macroalgae was the dominant sessile-benthic component in terms of substrate cover at the shelf-edge reef with an average of 43.7 % (range : 35.7 – 62.7%). Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard bottom. The total cover by benthic algae was 45.2 %. Cyanobacterial films were present in one transect with a mean reef substrate cover of 0.1 %.

Table 26. Percent reef substrate cover by sessile-benthic categories at Tourmaline Reef, 30 m Mayaguez. May 2008

Depth: 30 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	4.23	4.78	6.07	5.68	4.87	**5.13**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	4.15	28.50	37.71	33.35	31.32	**27.01**
Silt	0.77	6.20	1.14	4.85	8.33	**4.10**
Total Abiotic	4.92	34.70	38.85	38.20	39.65	**31.26**
Benthic Algae						
Turf-mixed assemblage	62.73	37.31	44.68	38.20	35.69	**43.72**
Fleshy		0.48	0.44	5.93		**1.37**
Calcareous					0.74	**0.15**
Total Benthic Algae	62.73	37.79	45.12	44.13	36.43	**45.24**
Gorgonians	10.20	2.17		4.21	1.81	**3.68**
Sponges	6.12	3.79	4.29	0.89	2.49	**3.52**
Ascidians		0.29	0.70			**0.20**
Cyanobacteria				0.45		**0.09**
Live Stony Corals						
Montastraea annularis	8.44	7.52	4.36	7.27	7.86	**7.09**
Agaricia lamarcki		5.21			4.70	**1.98**
Agaricia agaricites	0.77	2.37		0.96	3.90	**1.60**
Agaricia grahamae	1.97	3.25	1.49	1.15		**1.57**
Montastraea cavernosa		1.14	2.43		1.99	**1.11**
Porites astreoides	2.74			0.45		**0.64**
Stephanocoenia michelini			0.93	0.96	0.94	**0.57**
Madracis decactis	0.40	1.69		0.36		**0.49**
Mycetophyllia lamarcki	1.68		0.53			**0.44**
Siderastrea radians			0.79			**0.16**
Siderastrea siderea			0.44			**0.09**
Scolymia cubensis					0.19	**0.04**
Total Stony Corals	16	21.18	10.97	11.15	19.58	**15.776**
Gorgonians (# col.)						
Briareum asbestinum	17	9	8	2	8	**8.80**
Pseudoptergorgia acerosa	3	5	9	5	8	**6.00**
Pseudoptergorgia bipinnata	1	6		1	2	**2.00**
Eunicea flexuosa		2	1	1	2	**1.20**
Eunicea sp. 1	1			1	1	**0.60**
Pseudoplexaura purosa			1		2	**0.60**
Pseudoplexaura flagellosa or wargeri		1		1		**0.40**
Pseudoptergorgia americana	1		1			**0.40**
Gorgonia ventalina					1	**0.20**
Total Gorgonians (# colonies/transect)	23	23	20	11	24	**20.2**

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 fluctuations of mean percent cover by sessile-benthic categories from the shelf-edge of Tourmaline Reef at 30 m depth. The mean percent cover by stony corals between the previous baseline survey (13.5 %) and the present 2008 monitoring survey (15.8 %) has remained within the sampling error margin. Differences of live coral cover between monitoring surveys were small and not statistically significant (ANOVA; p = 0.987). Boulder Star Coral, *Montastraea annularis* maintained its status as the dominant coral species in terms of reef substrate cover at 30 m depth (Figure 25). Since our baseline survey in 2004, many large colonies of *M. annularis* stand dead and overgrown by turf algae on this reef, indicative of a major stress acting over this coral species some years before our original survey. Although partial bleaching was reported in one colony of *M. annularis* during the 2006 monitoring survey, widespread mortality associated with bleaching has not been observed at this reef.

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 114 fish species have been identified from Tourmaline Reef at depths of 25-30 m (Appendix 1). Mean abundance within belt-transects during the 2008 monitoring survey was 241.4 Ind/30 m^2 (range: 131 - 459 Ind/30 m^2). The mean number of species per transect was 16.2 (range: 11 - 20). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 189.0 Ind/30 m^2 (range: 105 - 400 Ind/30 m^2), representing 78.3 % of the total abundance within belt-transects (Table 27). The Masked Goby is a small carnivorous fish (< 2.0 cm) that aggregates in swarms below coral ledges and crevices near the sand-coral interface. The Peppermint and Masked Gobies, Beaugregory and Blue Chromis were the only species present on the five transects surveyed and comprised, along with the Creole Wrasse, Fairy Basslet, Longsnout Butterflyfish and Stripped Parrotfish, the most abundant fish assemblage at the shelf-edge reef.

Annual fluctuations of fish species richness and abundance at the Mayaguez 30 m reef are shown in Figure 26. Fish species richness has maintained a consistent decline since 2006, reaching a minimum of 16.2 species per transect in the present 2008 survey. Differences of species richness between annual surveys are now statistically significant (ANOVA; p = 0.045). The overall reduction in species richness from the baseline survey (23 spp/transect) to the present 2008 survey is of 30.4 %. Conversely,

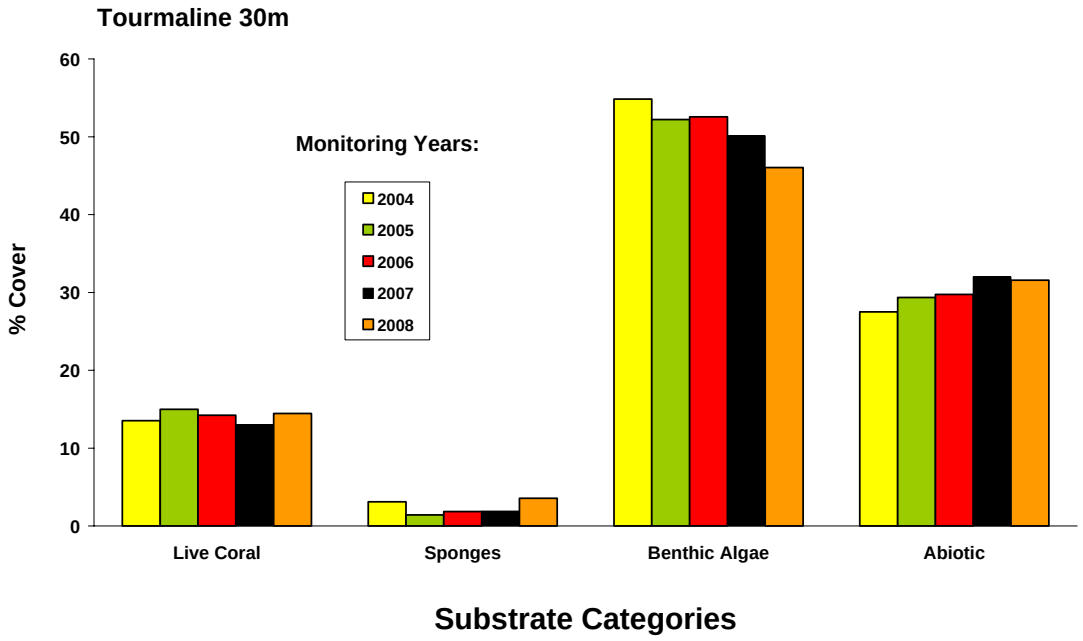


Figure 24. Monitoring trends (2004 – 2008) of mean substrate cover by sessile-benthic categories at Tourmaline Shelf-edge Reef – 30 m, Mayaguez Bay.

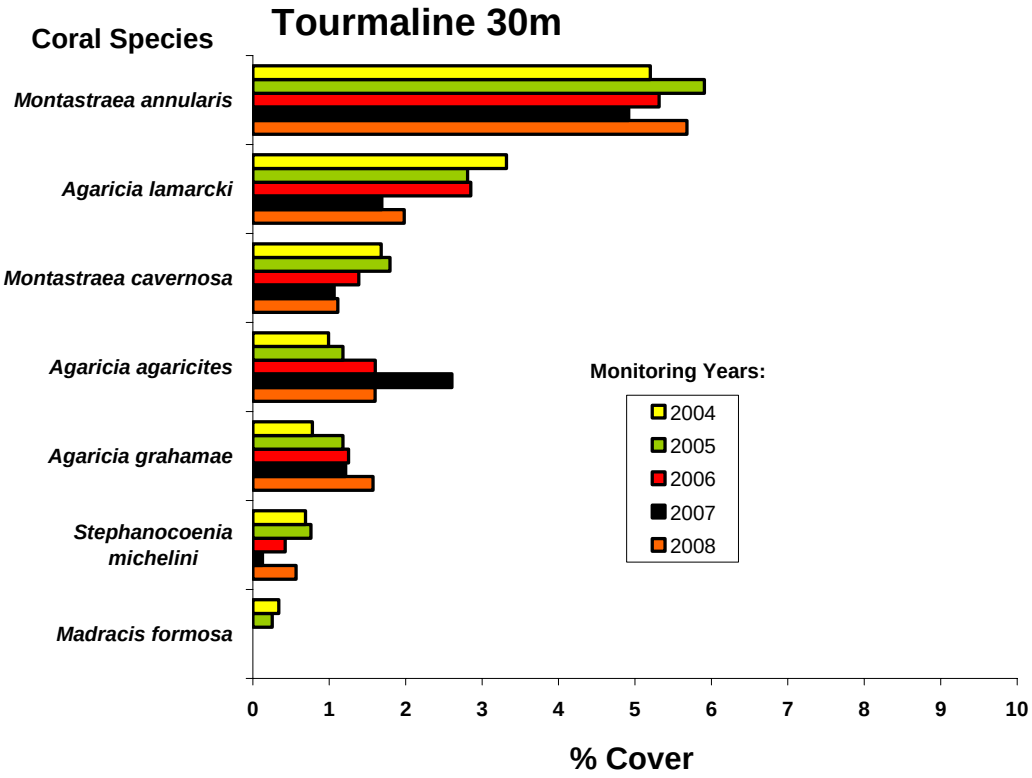


Figure 25. Monitoring trends (2004 – 2008) of mean substrate cover by stony coral species at Tourmaline Reef – 30 m, Mayaguez Bay.

Table 27. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, 30 m Mayaguez Bay. June, 2008

Depth: 30 m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	400	105	175	110	155	**189.0**
Coryphopterus lipernes	Peppermint Goby	7	3	4	15	14	**8.6**
Chromis cyanea	Blue Chromis	5	2	5	15	5	**6.4**
Clepticus parrae	Creole Fish				30		**6.0**
Chaetodon aculeatus	Longsnout Butterflyfish		9	2	5	3	**3.8**
Stegastes leucostictus	Beaugregory	3	4	3	3	4	**3.4**
Scarus iserti	Stripped Parrotfish	5		3	2	5	**3.0**
Gobiosoma evelynae	Sharknose Goby	3		3	3	4	**2.6**
Stegastes partitus	Bicolor Damselfish	3	1	2	3	3	**2.4**
Gramma loreto	Fairy Basslet	5	3	1		2	**2.2**
Canthigaster rostrata	Caribbean Puffer		1	2	5	2	**2.0**
Haemulon flavolineatum	French Grunt	5	1	2			**1.6**
Halichoeres garnoti	Yellow-head Wrasse	5				2	**1.4**
Myripristis jacobus	Blackbar Soldierfish	6					**1.2**
Haemulon aurolineatum	Tomtate	2	1	1	1	1	**1.2**
Thalassoma bifasciatum	Bluehead Wrasse	3		2			**1.0**
Chaetodon capistratus	Foureye Butterflyfish			2	2		**0.8**
Hypoplectrus chlorurus	Yellowtail Hamlet				2	2	**0.8**
Cephalopholis cruentatus	Graysby		1			2	**0.6**
Hypoplectrus puella	Barred Hamlet	1			1	1	**0.6**
Sparisoma aurofrenatum	Redband Parrotfish	1				1	**0.4**
Flammeo marianus	Longspine Squirrelfish			1	1		**0.4**
Holocentrus rufus	Squirrelfish			2			**0.4**
Aulostomus maculatus	Trumpetfish			1			**0.2**
Hypoplectrus unicolor	Butter Hamlet				1		**0.2**
Liopropoma rubre	Swissguard Basslet	1					**0.2**
Ocyurus chrysurus	Yellowtail Snapper				1		**0.2**
Stephanolepis setifier	Pygmy Filefish	1					**0.2**
Lutjanus apodus	Schoolmaster	1					**0.2**
Choryphopterus glaucofraenum	Bridled Goby	1					**0.2**
Mulloides martinicus	Yellowtail Goatfish						**0.0**
	TOTAL INDIVIDUALS	459	131	211	200	206	**241.4**
	TOTAL SPECIES	20	11	17	17	16	**16.2**

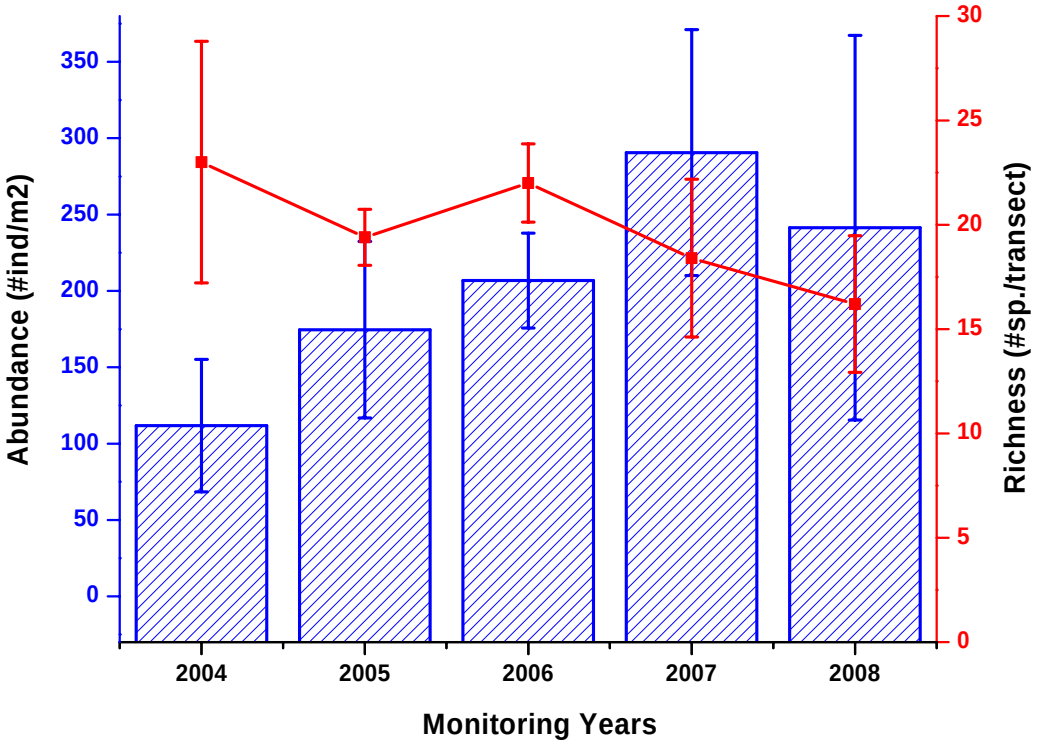


Figure 26. Monitoring trends (2004 – 2008) of fish species richness and abundance at Shelf-edge Reef Tourmaline, 30 m, Mayaguez Bay.

mean fish abundance has shown an increasing pattern that peaked during the 2007 survey. Differences of fish abundance between monitoring surveys were statistically significant (ANOVA; p = 0.015). An overall increment of 53.6 % has been observed between the 2004 baseline and the present 2008 survey. The increment of fish abundance has been mostly driven by the increasing abundance of the Masked Goby, which is at present 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 2008 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 Almaco Jack, Cero Mackerels and Barracudas. The Blue Chromis is also an important zooplanktivore that was common over coral heads closer to the reef. A large variety of small invertebrate feeders were present, including wrasses, gobies, goatfishes and squirrelfishes among others.

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)* and the Cleaner Shrimp *(Periclimenes pedersoni*) were 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, 2008

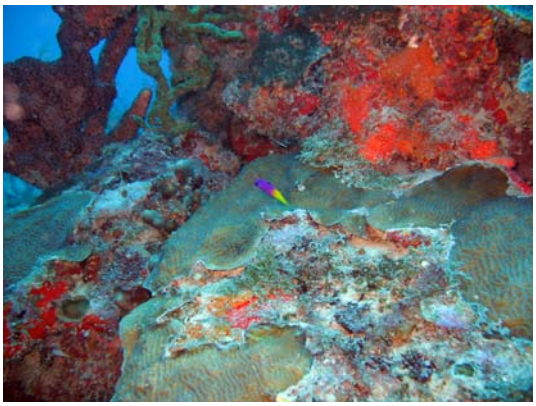
Depth range : 25 - 32 m
Duration - 30 min.

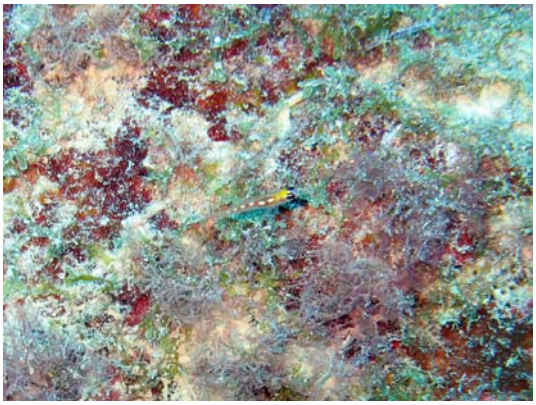
SPECIES	**COMMON NAME**		# - (cm)
Dasyatis americana	Southern Stingray	1 - (80)	
Epinephelus guttatus	Red Hind	1 - (35)	1 – (40)
Epinephelus striatus	Nassau Grouper	1 - (40)	1 - (60)
Lachnolaimus maximus	Hogfish	1 - (50)	
Lutjanus apodus	Schoolmaster Snapper	2 - (30)	3 – (50)
Mycteroperca venenosa	Yellowfin Grouper	1 - (50)	
Ocyurus chrysurus	Yellowtail Snapper	2 - (30)	2 – (40)
Scomberomorus regalis	Cero Mackerel	1 - (60)	
Seriola rivoliana	Almaco Jack	1 - (70)	
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, Mayaguez. June, 2008

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

Photo Album 7 (Tourmaline 30m)
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 17 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 (*Montastraea 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 22.7 % (range: 20.0 – 25.7 %). Large and massive colonies of Boulder Star Coral were the most prominent feature of the reef benthos. Boulder Star Coral was the dominant species in terms of substrate cover with a mean of 16.1 % (range: 10.3 – 19.4 %), representing 71.8 % 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 at 20 m.

Soft corals (gorgonians) were moderately abundant and rich in species, with an average of 16.8 colonies/transect and a total of nine species intercepted by transects (including the encrusting species, *Erythropodium caribaeorum*). *Briareum asbestinum,* and *Pseudoptergorgia acerosa* were the most abundant species within transects.

Table 30. Percent reef substrate cover by sessile-benthic categories at Tourmaline Reef, 20m Mayaguez. March 2008

Depth: 20 m	TRANSECTS					
	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				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	48.67	42.41	50.10	38.50	41.06	**44.15**
Gorgonians	2.21	3.17	1.63	1.01	3.63	**2.33**
Sponges	2.73		0.54	3.73		**1.40**
Cyanobacteria		0.37				**0.07**
Live Stony Corals						
Montastraea annularis	19.40	16.72	10.32	18.84	15.35	**16.13**
Montastraea 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	19.99	21.51	23.19	23.2	**22.72**
Recently dead coral			3.12	12.26		**3.08**
Partially bleached coral		3.07				**0.61**
Gorgonians (# col.)						
Briareum asbestinum	6	12	7	9	5	**7.80**
Pseudoptergorgia acerosa	6	9	3	2	1	**4.20**
Erythropodium caribeorum				3	5	**1.60**
Pseudoptergorgia bipinnata	1	1	1		3	**1.20**
Pseudoptergorgia americana			2		1	**0.60**
Eunicea flexuosa					2	**0.40**
Gorgonia ventalina	1			1		**0.40**
Plexaura kukenthali			1		1	**0.40**
Eunicea sp. 2		1				**0.20**
Total Gorgonians (# colonies/transect)	14	23	14	15	18	**16.8**

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

Colonies of Bushy Black Coral (*Antipathes caribbeana*) were present at the reef base. Encrusting sponges were present, but represented a minor component of the reef benthos (substrate cover < 2 %). Reef overhangs, associated with live and dead 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 macroalgae 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 44.2 %.

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 31.8 %. Live coral declined 9.5 % between 2004 and 2005, then declined 12.9 % between 2005 and 2006, and 9.0 % between 2006 and 2007. During the present survey of 2008 live coral cover was stable at the 2007 level. The overall decline of live coral cover between the present 2008 and the baseline survey of 2004 is of 28%. The difference of live coral cover between monitoring surveys was statistically significant at p= 0.068 (see Appendix 2). Reductions of live coral cover between the 2004 baseline and the present 2008 monitoring survey were measured in all five transects.

The main driver of the declining trend of live coral decline at Tourmaline Reef was Boulder Star Coral, *Montastraea annularis*, which has presented a 28.7 % reduction of substrate cover between 2004 and 2008 (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.

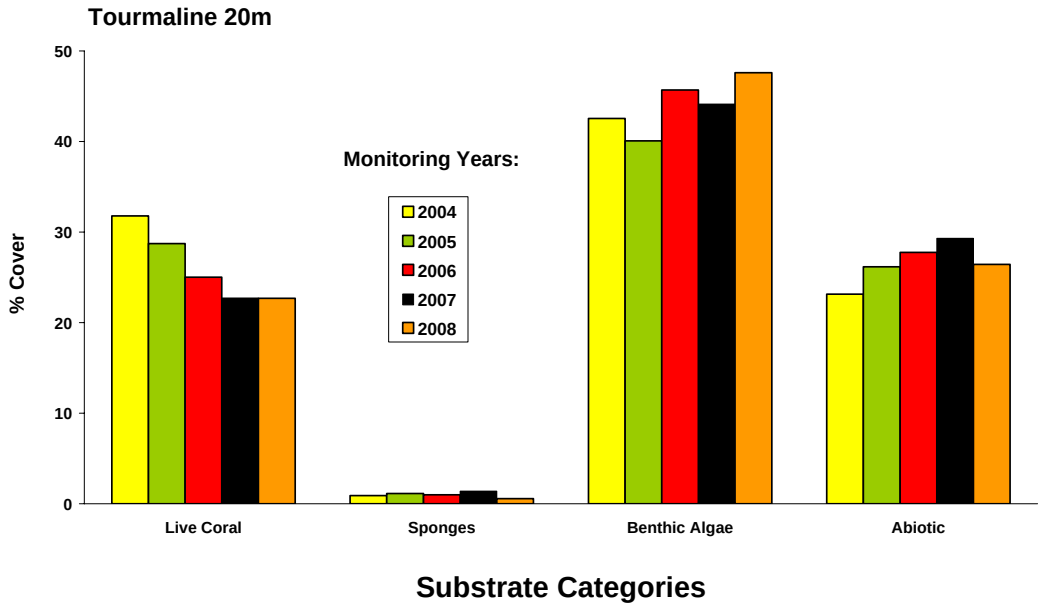


Figure 27. Monitoring trends (2004 – 2008) of mean substrate cover by sessile-benthic categories at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

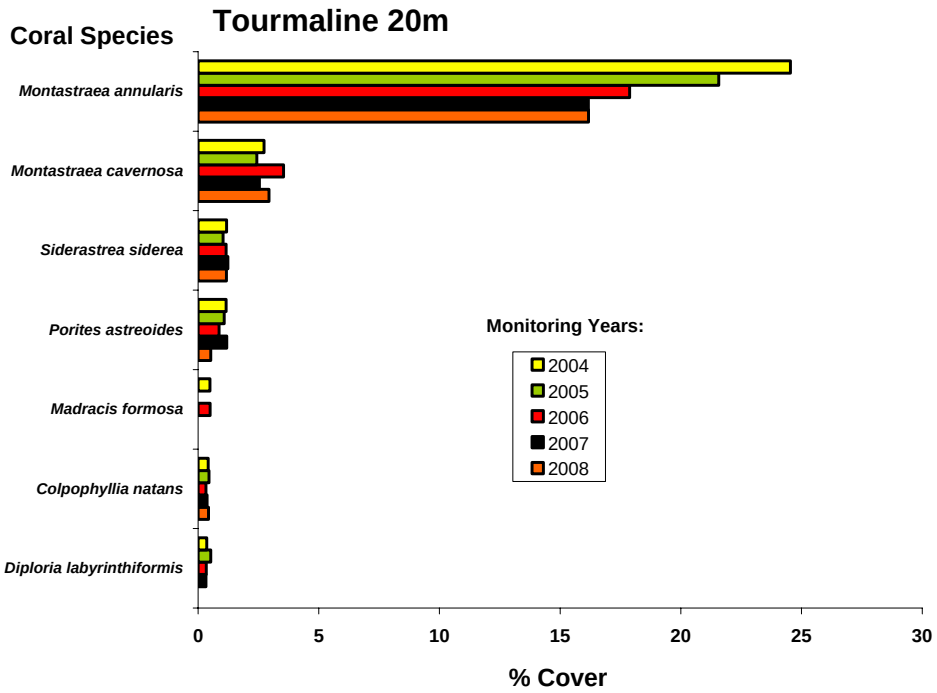


Figure 28. Monitoring trends (2004 – 2008) of mean substrate cover by stony coral species at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

2.2 Fishes and Motile Megabenthic Invertebrates-

A total of 101 fish species have been identified from Tourmaline outer shelf reef (Appendix 1). Mean abundance within belt-transects during 2008 was 204.0 Ind/30 m^2 (range: 181 - 238 Ind/30 m^2). The mean number of species per transect was 17.0 (range: 14 - 20). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 143.6 Ind/30 m^2 (range: 75 – 210 Ind/30 m^2), representing 70.4 % 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 and Peppermint Gobies, Blue Chromis, Fairy Basslet, Bluehead and Creole Wrasses, Striped Parrotfish and Bicolor Damselfish comprised the most abundant fish assemblage at the outer shelf reef. Five of the aforementioned species were present in all five transects, and a total of 11 species were only represented by one individual within belt-transects (Table 31)

Annual variations of fish abundance and species richness are presented in Figure 29. Differences of fish abundance between surveys were statistically significant (ANOVA; $p < 0.0001$, Appendix 3). The main pattern reflects lower abundance during the baseline survey compared with the subsequent monitoring surveys. Differences of fish abundance at this reef have been historically driven by abundance fluctuations of the Masked Goby, a numerically dominant species. Fish species richness during 2008 maintained a declining trend that started in 2007. Differences of fish abundance between the 2007-08 period and previous surveys were statistically significant (ANOVA; $p < 0.001$, Appendix 4).

The high reef rugosity with sand channels, crevices, large coral ledges and holes makes Tourmaline outer shelf reef an ideal habitat for large demersal fishes, such as snappers, groupers, hogfishes and others. It is surprising not to see them in the reef and the apparent cause for their absence is probably that the reef was severely overfished during the last decades. Tourmaline outer reef has been identified as a Red Hind 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,

Table 31. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, Mayaguez - 20 m. June, 2008

Depth: 20 m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	148	210	135	75	150	**143.6**
Chromis cyanea	Blue Chromis	3	1	10	50	10	**14.8**
Gramma loreto	Fairy Basslet	15	8	10	5	6	**8.8**
Thalassoma bifasciatum	Bluehead Wrasse		5		14	4	**4.6**
Clepticus parrae	Creole Wrasse		1		20		**4.2**
Scarus iserti	Stripped Parrotfish	9	2	5		4	**4.0**
Stegastes partitus	Bicolor Damselfish	1	3	6	5	4	**3.8**
Coryphopterus lipernes	Peppermint Goby	10	1	1	1	3	**3.2**
Caranx crysos	Blue Runner					14	**2.8**
Holocentrus rufus	Squirrelfish			5	1	4	**2.0**
Gobiosoma evelynae	Sharknose Goby		2	1	2	1	**1.2**
Chaetodon capistratus	Foureye Butterflyfish	2		2	1		**1.0**
Sparisoma radians	Bucktooth Parrotfish	4	1				**1.0**
Halichoeres garnoti	Yellowhead Wrasse	1	1	1	2		**1.0**
Acanthurus chirurgus	Doctorfish	2			1	1	**0.8**
Acanthurus coerulus	Blue Tang	1	1	1	1		**0.8**
Stegastes leucostictus	Beaugregory	1		2			**0.6**
Myripristis jacobus	Blackbar Soldierfish	3					**0.6**
Microspathodon chrysusrus	Yellowtail Damselfish					3	**0.6**
Sparisoma arofrenatum	Redband Parrotfish	1			1		**0.4**
Sparisoma viride	Stoplight Parrotfish	1			1		**0.4**
Chaetodon aculeatus	Longsnout Butterflyfish	1				1	**0.4**
Canthigaster rostrata	Caribbean Puffer	1	1				**0.4**
Hypoplectrus indigo	Indigo Hamlet			1		1	**0.4**
Coryphopterus glaucofraenum	Briddled Goby				1	1	**0.4**
Chaetodon sedentarius	Reef Butterflyfish	1					**0.2**
Acanthurus bahianus	Ocean Surgeon	1					**0.2**
Hypoplectrus unicolor	Butter Hamlet	1					**0.2**
Chaetodon striatus	Banded Butterflyfish		1				**0.2**
Aulostomus maculatus	Trumpetfish			1			**0.2**
Cephalopholis cruentatus	Graysby				1		**0.2**
Epinephelus guttatus	Red Hind					1	**0.2**
Equetus punctatus	Spotted Drum					1	**0.2**
Synodus intermedius	Sand Diver				1		**0.2**
Mulloidichthys martinicus	Yellow Goatfish					1	**0.2**
Epinephelus striatuus	Nassau Grouper					1	**0.2**
	TOTAL INDIVIDUALS	**207**	**238**	**181**	**183**	**211**	**204.0**
	TOTAL SPECIES	**20**	**14**	**14**	**18**	**19**	**17.0**

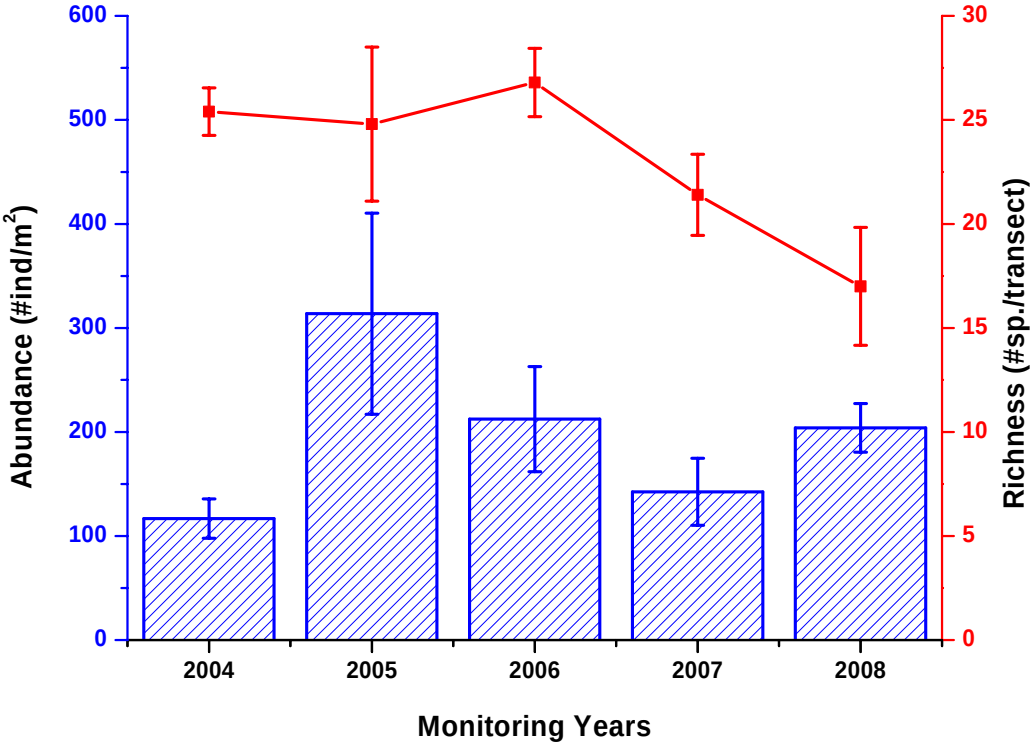


Figure 29. Monitoring trends (2004 – 2008) of fish species richness and abundance at Outer Shelf Reef Tourmaline, 20 m, Mayaguez Bay.

has decimated the populations of commercially important fishes, conch and lobster. Clear signs of recuperation of the Red Hind population are not yet evident.

Small zooplanktivorous fishes, such as the Masked Goby, Blue Chromis, Bicolor Damselfish and micro-invertebrate predators, including wrasses, gobies, basslets, hamlets, and squirrelfishes numerically dominate the reef fish community. Parrotfishes (*Scarus spp., Sparisoma spp*.), represented by seven species and doctorfishes (*Acanthurus spp*.), represented by three species comprised the main herbivorous fish assemblage. Among large invertebrate and small demersal fish predators, Nassau Grouper, Red Hinds, Schoolmaster Snapper, Great Barracuda and Cero Mackerels were observed during an ASEC survey (Table 32). Also, several juvenile and adult Schoolmaster, Mahogany and Yellowtail Snappers were observed close to the reef-sand interface. Schools of Mackerel Scad, *Decapterus macarellus* were present in mid-water over the reef. These are zooplanktivores that serve as forage for pelagic predators, such as Cero Mackerels and Barracudas.

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, 2008

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

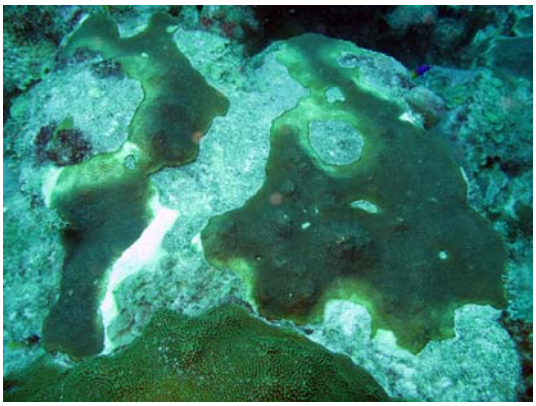
SPECIES	**COMMON NAME**		# - (cm)
Epinephelus guttatus	Red Hind	1 - (45)	
Epinephelus striatus	Nassau Grouper	1 - (50)	
Decapterus macarellus	Mackerel Scad	50 - (10-15)	
Holacanthus tricolor	Rock Beauty	1 - (20)	
Holacanthus ciliaris	French Angelfish	2 - (40)	
Lutjanus apodus	Schoolmaster	1 - (50)	
Lutjanus mahogany	Mahogany Snapper	1 - (25)	2 – (30)
Ocyurus chrysurus	Yellowtail Snapper	3 - (25)	1 - (40)
Scomberomorus regalis	Cero Mackerel	2 - (30)	
Sphyraena barracuda	Great Barracuda	1 - (70)	
Invertebrates			
Panulirus argus	Spiny Lobster	1 - (25)	

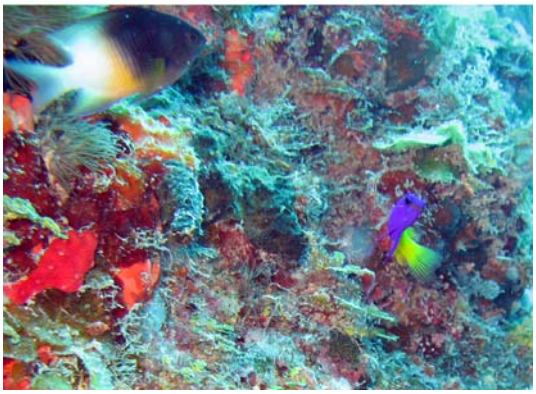
Hogfish, Cubera and Dog Snappers have been identified from previous ASEC surveys at this reef (García-Sais et al, 2005). Motile megabenthic invertebrates were not observed within belt-transects during 2008. One small Spiny Lobster, *Panulirus argus* was observed outside transects.

Table 33. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Outer-shelf Reef, Mayaguez, June, 2008

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**

Album 8 (Tourmaline 20m)
Outer Shelf 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 fifth time during March, 2008. 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, 21 of which were intercepted by line transects during this survey (Table 34). Stony corals occurred as massive (*Montastraea annularis*, *Colpophyllia natans, Diploria labyrinthiformis*), branching (*Madracis spp., Porites porites*), encrusting (*Mycetophyllia spp.*) and mound shaped colonies (*P. astreoides, M. cavernosa, Dichocoenia stokesii*). Substrate cover by stony corals along transects averaged 38.81 % (range: 25.7 – 63.3 %). Yellow Pencil Coral, *Madracis mirabilis* and Finger Coral, *Porites porites* (forma *divaricata*) were the dominant coral species in terms of substrate cover with means of 8.2 % and 8.1 %, 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 63.3 % 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 2008 monitoring survey.

Erect soft corals (gorgonians) were highly abundant with an average of 25.4 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 reef substrate cover by sessile-benthic categories at Tourmaline Reef, 10 m Mayaguez. June, 2008

Depth: 10 m	Transects					
	1	2	3	4	5	**MEAN**
Rugosity (m)	4.38	3.35	1.72	2.94	4.03	**3.28**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	7.64	9.81	5.20	11.74	7.84	**8.45**
Silt				4.90		**0.98**
Rubble	4.24	0.53				**0.95**
Total Abiotic	11.88	10.34	5.20	16.64	7.84	**10.38**
Benthic Algae						
Turf-mixed assemblage	47.15	22.47	44.93	43.96	48.68	**41.44**
Fleshy	3.54	1.90	3.24	2.63	5.20	**3.30**
Calcareous		0.53	0.48		1.43	**0.49**
Total Benthic Algae	50.69	24.90	48.65	46.59	55.31	**45.23**
Gorgonians	5.21	0.52		5.25	4.35	**3.07**
Sponges	0.49	0.97	0.60		4.99	**1.41**
Zoanthids	2.08			1.09	1.10	**0.85**
Anthozoa				0.54		**0.11**
Cyanobacteria					0.50	**0.10**
Hydrozoa (Millepora)					0.20	**0.04**
Live Stony Corals						
Madracis mirabilis		41.05				**8.21**
Porites porites (divaricata)	9.86	0.95	15.35	7.72	6.20	**8.02**
Montastraea annularis	3.54	15.81	10.49	4.79	2.92	**7.51**
Porites astreoides	2.57	4.04	5.03	6.10	7.63	**5.07**
Dendrogyra cylindrus	10.00			7.80		**3.56**
Colpophyllia natans			8.05			**1.61**
Montastraea cavernosa			1.56	2.39	1.28	**1.05**
Agaricia grahamae		0.32	2.04	1.09	0.60	**0.81**
Agaricia agaricites	1.25				2.14	**0.68**
Meandrina meandrites	0.49	1.12	1.68			**0.66**
Diploria labyrinthiformis					1.61	**0.32**
Agaricia lamarcki	0.49				1.00	**0.30**
Siderastrea siderea	0.88					**0.18**
Eusmilia fastigiata			0.72			**0.14**
Diploria strigosa					0.70	**0.14**
Leptoseris cucullata	0.59					**0.12**
Madracis decactis					0.50	**0.10**
Mycetophyllia lamarckiana					0.40	**0.08**
Stephanocoenia michelini					0.40	**0.08**
Porites colonensis			0.36			**0.07**
Acropora cervicornis			0.24			**0.05**
Total Stony Corals	29.67	63.29	45.52	29.89	25.68	**38.81**
Recently dead coral				0.65	2.51	**0.63**

Table 34. continued

Gorgonians (# col.)						
Briaerum asbestinum	11	15	9	11	9	**11.00**
Plexaura homomalla	3		4	3	4	**2.80**
Eunicea succinea	2	3	3	1	3	**2.40**
Pseudoplexaura flagellosa or wargeri	1	2		2	7	**2.40**
Eunicea flexuosa	3	1		2	3	**1.80**
Gorgonia ventalina	2	3	1		2	**1.60**
Plexaura kukenthali		1	1	4		**1.20**
Erythropodium caribeorum	1	1			2	**0.80**
Pseudoptergorgia acerosa	1			1	1	**0.60**
Muricea spp.		1				**0.20**
Pseudoplexaura purosa	1					**0.20**
Pseudoptergorgia americana					1	**0.20**
Pseudoptergorgia bipinnata				1		**0.20**
Total Gorgonians (# colonies/transect)	25	27	18	25	32	**25.4**

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 3.1 %. 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 8.4 % and contributed markedly to the topographic rugosity of 3.28 m. Turf algae, comprised by a mixed assemblage of short filamentous red and brown macroalgae presented an average substrate cover of 41.4 % (range: 22.5 – 48.7 %). Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard ground. Cyanobacterial films were present in one transect with low substrate cover (< 1.0 %).

Figure 30 presents the monitoring trends of reef substrate cover by sessile-benthic categories from Tourmaline outer shelf reef at 10 m, including the baseline survey of 1999 and four annual monitoring surveys (2004-08). During the 2006 monitoring survey, mean live coral cover declined 22.6%, from 44.26% in 2005 to 34.25%. An additional decline of 16.5 % was measured from 2006 to 2007. 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. At the population level, a statistically significant decline of

live coral cover (ANOVA; p = 0.028) was found for *Montastraea annularis* (complex), the dominant coral species in terms of reef substrate cover at Tourmaline 10 m (García-Sais et al., 2006). Reef substrate cover by *M. annularis* declined 46 % between 2005 and 2006 (Figure 31), and was the main driver of the overall decline of live coral for this reef. No further losses of live coral cover were measured during the present 2008 survey. A trend of increasing reef substrate cover by branching corals, *Madracis mirabilis* and *Porites porites* (*divaricata*) appears to be emerging from the most recent monitoring surveys.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 99 diurnal, non-criptic fish species have been identified during monitoring surveys from Tourmaline Outer Shelf Reef at a depth of 10 m (Appendix 1). Mean abundance within belt-transects during the 2008 survey was 72.0 Ind/30 m^2 (range: 16 - 148 Ind/30 m^2). The mean number of species per transect was 15.0 (range: 9 - 19). The Blue Chromis (*Chromis cyanea*), Bluehead Wrasse (*Thalassoma bifasciatum*), and the Bicolor Damselfish (*Stegastes partitus*) were the numerically dominant species with a combined mean abundance of 42.8 Ind/30 m^2, representing 59.4 % of the total abundance within belt-transects (Table 35). Four species were present in all five transects. These included the Blue Chromis, Beugregory, Creole Wrasse and Bicolor Damselfish. Nine species were represented by only one individual within belt-transects.

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

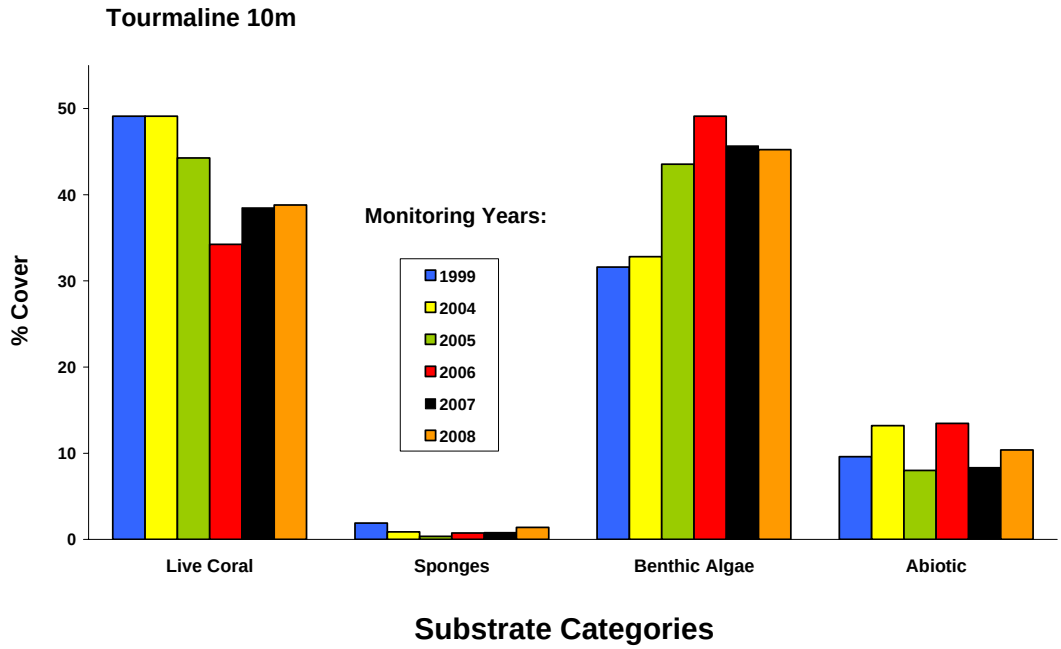


Figure 30. Monitoring trends (1999 – 2008) of mean substrate cover by sessile-benthic categories at Tourmaline Reef – 10 m, Mayaguez.

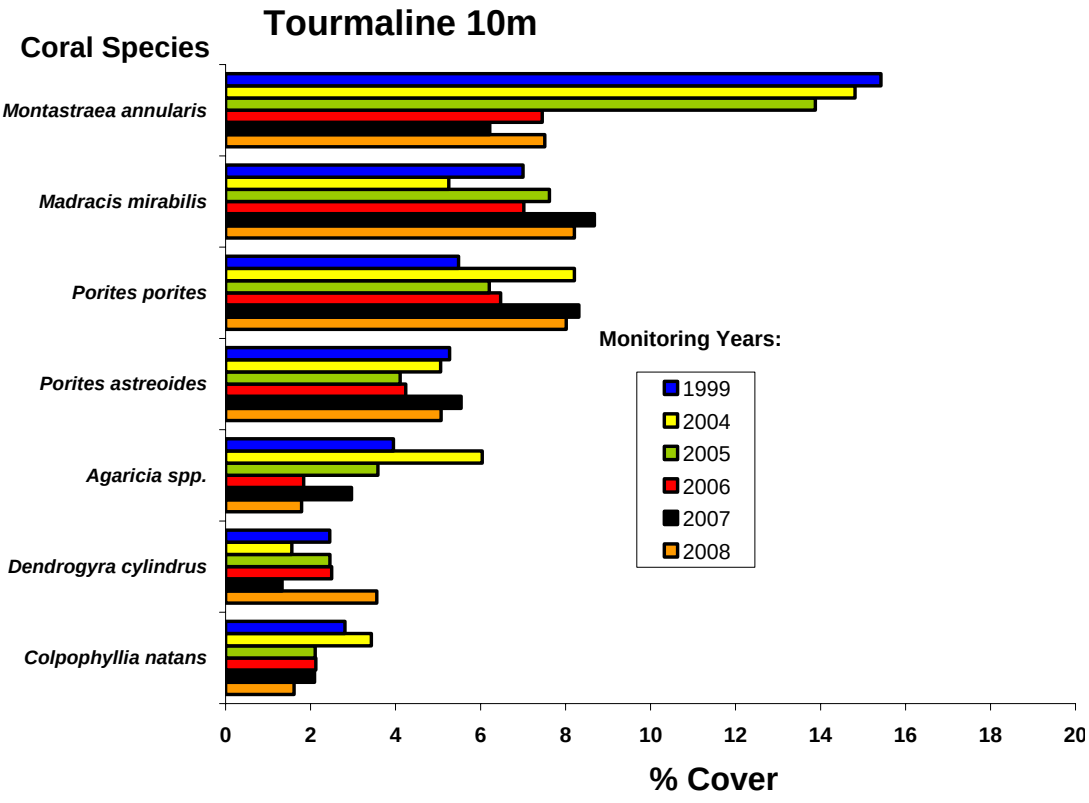


Figure 31. Monitoring trends (1999 – 2008) of mean cover by stony coral species at Tourmaline Reef – 10 m, Mayaguez.

Table 35. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, Mayaguez Bay- 10 m depth. June, 2008

Depth: 10 m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Chromis cyanea	Blue Chromis	10	66	10	15	2	**20.6**
Thalassoma bifasciatum	Bluehead Wrasse	8	32	3	26		**13.8**
Stegastes partitus	Bicolor Damselfish	7	18	9	4	4	**8.4**
Gobiosoma evelynae	Sharknose Goby		1	15	2		**3.6**
Halichoeres garnoti	Yellow-head Wrasse	8	6	2			**3.2**
Clepticus parrae	Creole Wrasse	2	5	2	5	1	**3**
Coryphopterus personatus	Masked Goby	12					**2.4**
Stegastes leucostictus	Beugregory	2	3	1	2	3	**2.2**
Scarus iserti	Stripped Parrotfish	6	2		1	1	**2**
Haemulon flaveolineatum	French Grunt	1	1	4	3		**1.8**
Sparisoma viride	Stoplight Parrotfish	2	4	1		1	**1.6**
Chaetodon capistratus	Foureye Butterflyfish		1	2	2		**1**
Sparisoma radians	Bucktooth Parrotfish		1	2		2	**1**
Holocentrus coruscus	Reef Squirrelfish		1	3			**0.8**
Scarus taeniopterus	Princess Parrotfish	1		1		1	**0.6**
Chromis multilineata	Brown Chromis	3					**0.6**
Acanthurus coeruleus	Blue Tang	1			2		**0.6**
Gramma loreto	Fairy Basslet	1			2		**0.6**
Sparisoma aurofrenatum	Redband Parrotfish		2			1	**0.6**
Myripristis jacobus	Blackbar Soldierfish				3		**0.6**
Acanthurus bahianus	Ocean Surgeon	1			1		**0.4**
Stephalnolepis setifier	Pygmy Filefish	2					**0.4**
Chaetodon striatus	Banded Butterflyfish			2			**0.4**
Acanthurus chirurgus	Doctorfish	1					**0.2**
Holocanthus tricolor	Rock Beauty		1				**0.2**
Stegastes planifons	Threespoted Damselfish		1				**0.2**
Cephalopholis cruentatus	Graysby		1				**0.2**
Hypoplectrus unicolor	Butter Hamlet		1				**0.2**
Hypoplectrus puella	Barred Hamlet			1			**0.2**
Pseudupeneus maculatus	Spotted Goatfish		1				**0.2**
Acanthemblemaria chaplini	Papillose Blenny			1			**0.2**
Holocanthus rufus	Squirrelfish			1			**0.2**
							0.0
	TOTAL INDIVIDUALS	**68**	**148**	**60**	**68**	**16**	**72**
	TOTAL SPECIES	**17**	**19**	**17**	**13**	**9**	**15.0**

Annual monitoring trends of fish species richness and abundance are presented in Figure 32. Minimum mean values of fish abundance and species richness were observed during 2008. Mean abundance declined 31.4 % relative to the baseline survey, but differences are not statistically significant (ANOVA; $p = 0.290$). Variations of abundance are influenced by schooling zooplanktivores with highly aggregated distributions, such as the Blue Chromis (*Chromis cyanea*) and the Creole Wrasse (*Clepticus parrae*). Aggregated or patchy distributions tend to increase the magnitude of sampling variability and thus, increase the statistical uncertainty associated with the means. In the case of fish species richness, the differences between annual surveys were statistically significant (ANOVA; $p < 0.001$), influenced mostly by a sharp decline of species during 2008 relative to all other surveys.

As in deeper zones of Tourmaline outer shelf reef, the high rugosity with sand channels, crevices, large coral ledges and holes makes this reef an ideal habitat for large demersal fishes, such as snappers, groupers, hogfishes and others. Their occurrence in very low abundance may be related to the intense fishing pressure that this reef has experienced over the last 20-30 years, since the seasonal spawning aggregations of Red Hind were detected by local fishermen. Tourmaline outer reef has been seasonally (December – February) closed to fishing since 1993 to protect the declining Red Hind stock, but an intense fishing effort for finfish, lobster and conch with fish traps and SCUBA is still ongoing during the open fishing season. Although our fish surveys have been performed previous to the group spawning aggregation from December to February, the relatively low abundance of Red Hinds noted during our surveys in 1999, 2004, 2005, 2006, 2007 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 Cleaner Shrimp, *Periclimenes pedersoni* were the only megabenthic invertebrates observed within belt-transects during the 2008 monitoring survey (Table 37). One Sea Cucumber was observed outside transects. Spiny and Spotted Lobsters, *Panulirus argus*, *P. guttatus*, have been previously reported observed outside transects during the ASEC surveys.

Table 36. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Tourmaline Outer Shelf Reef, 10 m, June, 2008

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

SPECIES	**COMMON NAME**		# - (cm)	
Carangoides crysos	Blue Runner	2 - (40)	1 – (45)	
Epinephelus guttatus	Red Hind	3 - (25)	1 – (35)	
Epinephelus striatus	Nassau Grouper	1 – (40)		
Lutjanus apodus	Schoolmaster	2 - (20)		
Lutjanus synagris	Lane Snapper	4 - (15)	2 - (20)	2 - (25)
Negaprion brevirostris	Nurse Shark	1 – (120)		
Ocyurus chrysurus	Yellowtail Snapper	2 - (25)		
Scomberomorus regalis	Cero Mackerel	1 - (40)	2 – (50)	
Sphyraena barracuda	Great Barracuda	1 - (90)		
Holacanthus tricolor	Rock Beauty	1 – (25)		
Invertebrates				
Holothuria mexicana	Donkey's Dong	1 – (25)		

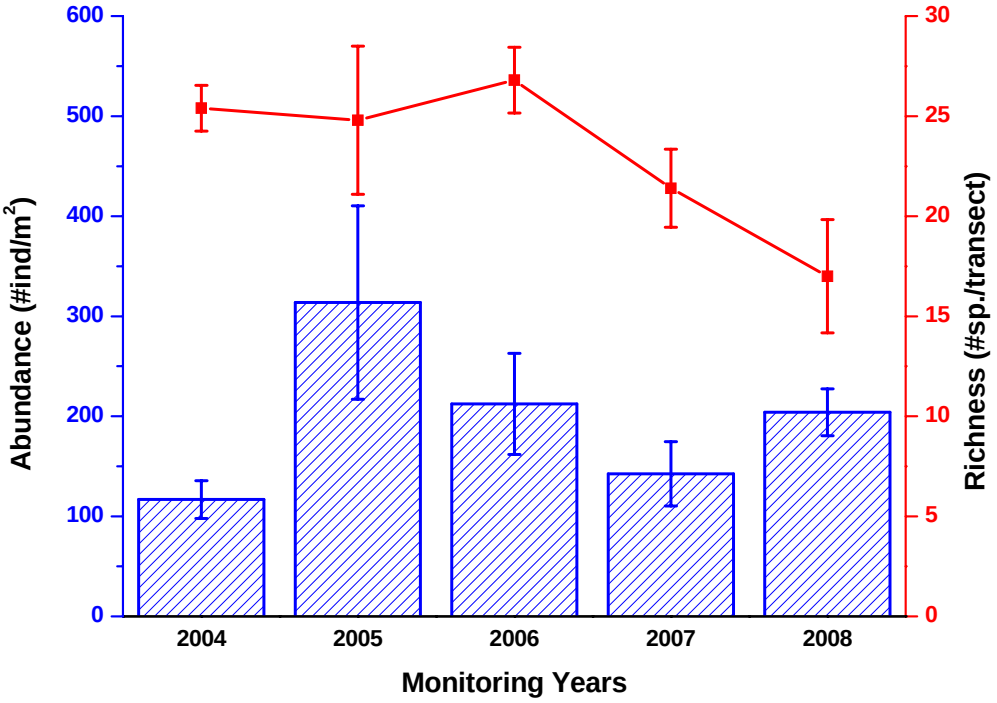
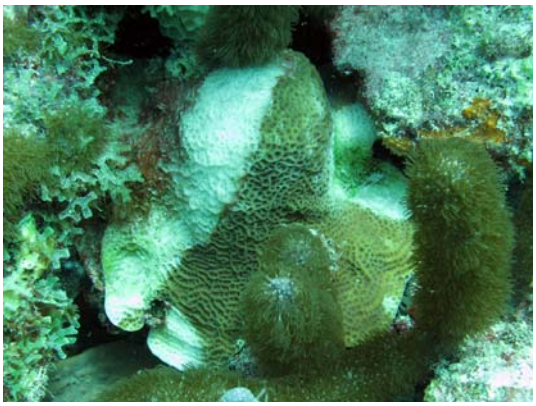


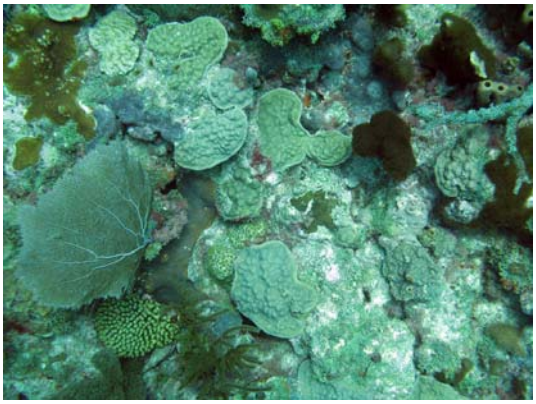
Figure 32. Monitoring trends (2004 – 2008) of fish species richness and abundance at Tourmaline Outer Shelf Reef, 10 m, Mayaguez.

Table 37. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Outer-shelf Reef, 10 m, June, 2008

Depth: 10 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Periclimenes pedersoni	Cleaner Shrimp			3			**0.6**
Stenorhynchus seticornis	Arrow Crab	2			1		**0.6**
	TOTALS	**1**	**1**	**0**	**1**	**0**	**1.2**

Photo Album 9 (Tourmaline 10m)
Outer Shelf Reef





D. 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.

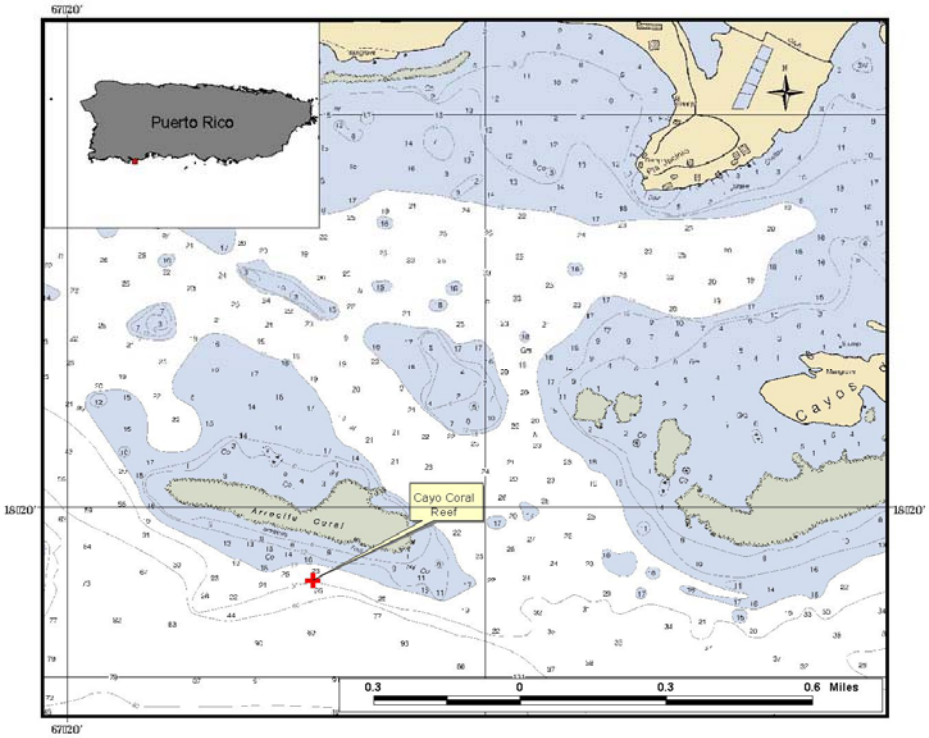


Figure 33. Location of coral reef survey stations at Cayo Coral Reef, Guánica.

1.0 Sessile-benthic Reef Community

A total of 19 stony corals, including 12 intersected by permanent line transects were identified from Cayo Coral Reef during the 2008 survey. Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 8.9 % (range: 8.6 – 11.1 %). Boulder Star Coral, *Montastraea annularis* (complex) was the main species in terms of substrate cover with a mean of 3.3% (range: 1.0 – 8.2 %), representing 37.0 % of the total cover by stony corals (Table 38). Mustard-Hill Coral, *Porites astreoides* and Great Star Coral, *M. cavernosa* 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 an average of 25.4 colonies/transect. A total of 24 species of gorgonians are known to ocurr at this reef (García-Sais et al. 2007). Some of the numerically dominant species present include 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 12.7 m and contributed substantially to the mean rugosity of 4.26 m. Recently dead coral accounted for a mean of 2.2 % of the reef substrate along surveyed 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 72.1 % (range: 66.6 – 78.5 %). 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 reef substrate cover by sessile-benthic categories at Cayo Coral, Guanica. 8 m. March 2008

	Transects					
Depth: 10 m	**1**	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	2.96	4.80	4.34	3.18	6.01	**4.26**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	7.20	12.96	10.12	16.99	16.43	**12.74**
Sand			3.63	4.06	1.76	**1.89**
Rubble				2.46		**0.49**
Total Abiotic	7.20	12.96	13.75	23.51	18.19	**15.12**
Benthic Algae						
Turf-mixed assemblage	76.10	72.18	74.18	66.23	67.65	**71.27**
Fleshy algae	2.40	0.88				**0.66**
Calcareous				0.32	0.44	**0.15**
Total Benthic Algae	78.50	73.06	74.18	66.55	68.09	**72.08**
Cyanobacteria	2.60	0.88		3.95	1.87	**1.86**
Sponges	1.40	1.01		1.37	0.25	**0.81**
Zoanthids	1.50	0.54	0.49	0.46	0.62	**0.72**
Gorgonians	0.20	0.68	0.49	1.29		**0.53**
Live Stony Corals						
Montastraea annularis	0.76	3.71	2.72	0.96	8.24	**3.28**
Porites astreoides	1.54	1.01	2.23		1.50	**1.26**
Montastraea cavernosa	2.61	0.19	0.59	0.75	0.53	**0.93**
Diploria strigosa	1.52	2.36				**0.78**
Meandrina meandrites		0.68	2.58			**0.65**
Eusmilia fastigiata		1.55		0.53		**0.42**
Siderastrea siderea		1.33		0.64		**0.39**
Colpophyllia natans			1.57			**0.31**
Siderastrea radians	1.09		0.39			**0.30**
Porites porites	0.33		0.59		0.26	**0.24**
Agaricia agaricites			0.39		0.44	**0.17**
Acropora cervicornis	0.76					**0.15**
Total Stony Corals	8.61	10.83	11.06	2.88	10.97	**8.87**
Recently dead coral	4.17	1.42	2.93	2.28	0.44	**2.25**
Total Gorgonians (# col/transect)	**26**	**37**	**22**	**21**	**21**	**25.4**

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 2005-08. Differences of reef substrate cover by live stony corals between surveys were statistically significant (ANOVA; $p < 0.0001$, Appendix 2) and constitute evidence of degradation of the coral reef community structure. Total live coral cover at Cayo Coral has declined consistently throughout the monitoring program from a mean of 25.3 % in 1999 to a mean of 8.9 % at present, an overall reduction of 64.8 %. The reduction of live coral cover was evidenced across the five permanent transects surveyed. A corresponding increment of cover by benthic algae has been measured (Figure 34).

Variations of the mean substrate cover by coral species during monitoring surveys are shown in Figure 35. A drastic decline of the percent substrate cover by Boulder Star Coral, *Montastraea annularis* (complex) is evident from the monitoring data. The variations of cover by *M. annularis* between monitoring years were statistically significant (ANOVA; $p = 0.045$). Boulder Star Coral declined its mean substrate cover by approximately 40 % between 1999 and 2005 (from 10.49 % to 6.5%), and suffered another reduction of 55% between 2005 and 2006 (from 6.5 % to 2.9 %). Other scleractinian coral species that have shown marked declines of substrate cover at Cayo Coral include *Colpophyllia natans, M. cavernosa, P. astreoides* 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 March, 2008 was 41.0 Ind/30 m^2 (range: 25 - 50 Ind/30 m^2). The mean number of species per transect was 17.4 (range: 14 - 20). Bluehead Wrasse (*Thalassoma bifasciatum*), Sharknose Goby (*Gobiosoma evelynae*), Yellowhead Wrasse (Halichoeres garnoti), Dusky Damselfish (*Stegastes partitus*) and Redband Parrotfish (*Sparisoma aurofrenatum*) were the numerically dominant species with a combined mean abundance of 22.0 Ind/30 m^2, representing 53.6 % of the total abundance within belt-transects (Table 39). Only four species were present on all five transects, whereas other five were present in four.

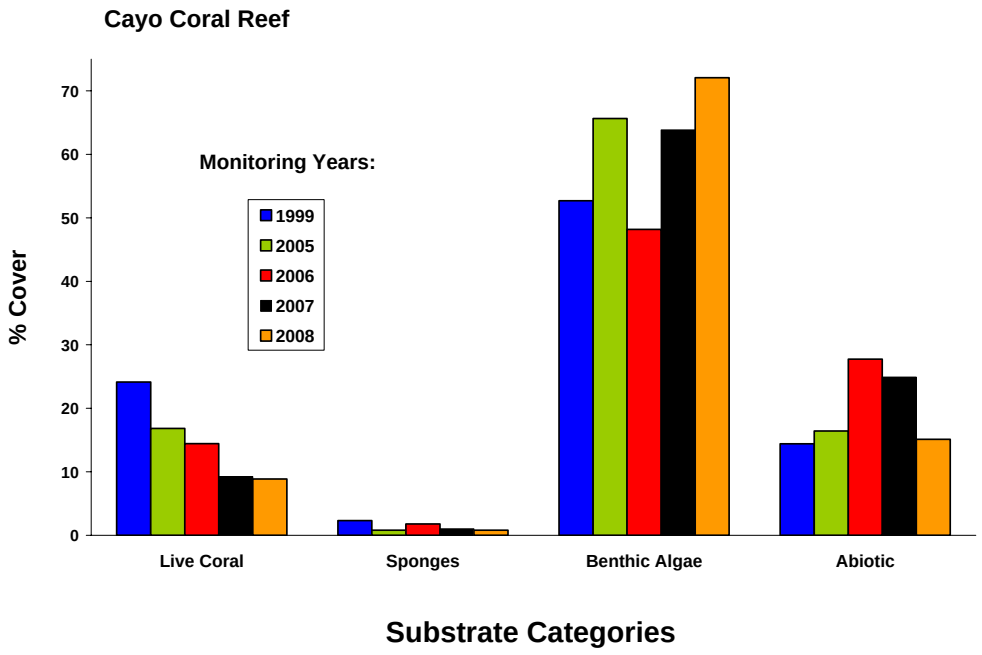


Figure 34. Monitoring trends (1999 – 2008) of mean substrate cover by sessile-benthic categories at Cayo Coral – 8 m, Guánica.

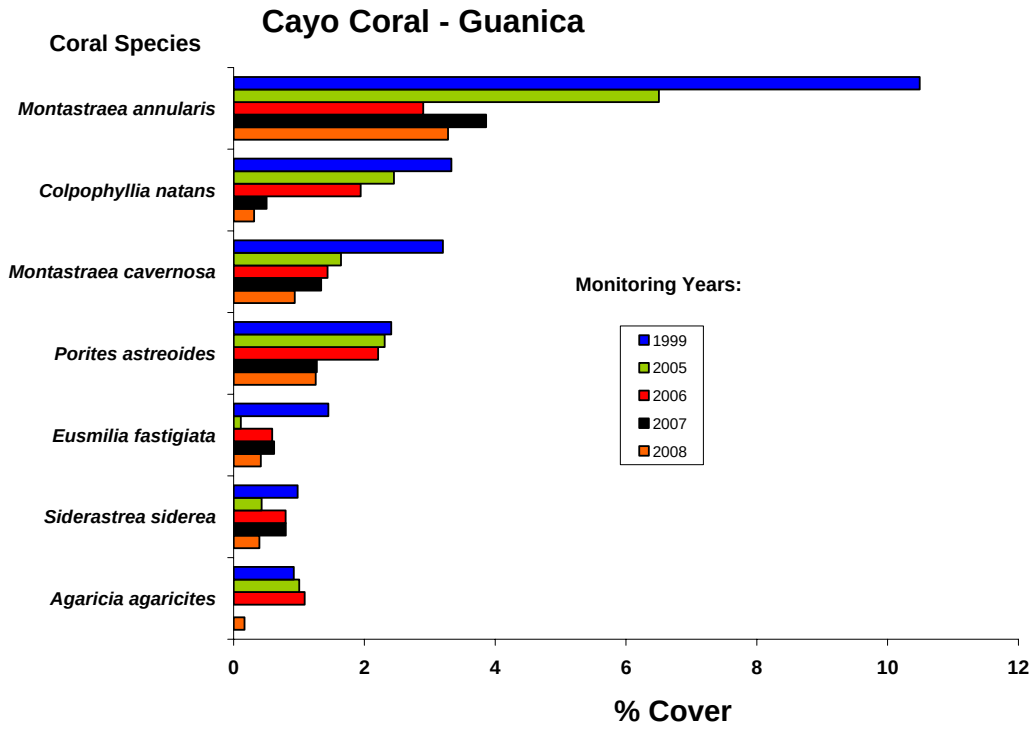


Figure 35. Monitoring trends (1999 – 2008) of mean substrate cover by stony coral species at Cayo Coral – 8 m, Guánica

Table 39. Taxonomic composition and abundance of fishes within belt-transects at Cayo Coral ReefGuanica. March, 2008

Depth: 8 m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Thalassoma bifasciatum	Bluehead Wrass	5	12	7	22	3	**9.8**
Gobiosoma evelynae	Sharknose Goby	3	8	8	1	3	**4.6**
Halichoeres garnoti	Yellowhead Wrass			2	2	11	**3.0**
Stegastes adustus	Dusky Damselfish		1	6	3	2	**2.4**
Sparismoma aurofrenatum	Redband Parrotfish	1	1	3	2	4	**2.2**
Acanthurus bahianus	Ocean Surgeon		2	3	1	3	**1.8**
Michospathodon chrysurus	Yellowtail Damselfish	1	1	2	3	1	**1.6**
Scarus iserti	Stripped Parrotfish		1		4	2	**1.4**
Holocentrus rufus	Squirrelfish	2		2	1	1	**1.2**
Chromis cyanea	Blue Chromis		1	5			**1.2**
Chaetodon capistratus	Foureye Butterflyfish	2	2			1	**1.0**
Stegastes partitus	Bicolor Damselfish			1	2	2	**1.0**
Cephalopholis cruentatus	Graysby	1	1		1	1	**0.8**
Scarus taeniopterus	Princess Parrotfish	4					**0.8**
Stegastes planifrons	Yellow-eye Damselfish	1	1	2			**0.8**
Sparisoma viride	Stoplight Parrotfish		1	1	1	1	**0.8**
Serranus tigrinus	Harlequiem Bass	1	1			1	**0.6**
Caranx ruber	Bar Jack		3				**0.6**
Canthigaster rostrata	Caribbean Puffer	1	1	1			**0.6**
Choryphopterus glaucofraenum	Briddled Goby		1	1	1		**0.6**
Sparisoma radians	Bucktooth Parrotfish				3		**0.6**
Stegastes leucostictus	Beaugregory	1			1		**0.4**
Acanthurus chirurgus	Doctorfish		1			1	**0.4**
Abudefduf sexatilis	Sargent Mayor			1		1	**0.4**
Anisotremus virginicus	Porkfish	1					**0.2**
Hypoplectrus unicolor	Butter Hamlet	1					**0.2**
Haemulon flavolineatum	French Grunt			1			**0.2**
Chaenopsis ocellata	Bluethroat Pikeblenny			1			**0.2**
Myripristis jacobus	Blackbar Soldierfish			1			**0.2**
Acanthurus coeruleus	Blue Tang			1			**0.2**
Hypoplectrus puella	Barred Hamlet			1			**0.2**
Sparisoma chysopterum	Redtail Parrotfish				1		**0.2**
Hypoplectrus indigo	Indigo Hamlet				1		**0.2**
Epinephelus guttatus	Red Hind					1	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet					1	**0.2**
Lutjanus apodus	Schoolmaster					1	**0.2**
	TOTAL INDIVIDUALS	**25**	**39**	**50**	**50**	**41**	**41.0**
	TOTAL SPECIES	**14**	**17**	**20**	**17**	**19**	**17.4**

Figure 36 displays monitoring trends of fish abundance and species richness from Cayo Coral. Variations of fish abundance and species richness between monitoring surveys were statistically significant (ANOVA; $p < 0.05$, Appendix 3-4). Both species richness and abundance were significantly lower during the baseline survey in 1999 than in subsequent monitoring surveys. Such difference may be biased by very turbid conditions prevailing during the initial baseline survey. However, the declining trend of species richness after the 2005 survey appears to be real and may not respond to turbid conditions, which certainly influenced the low number of species per transect during the baseline survey.

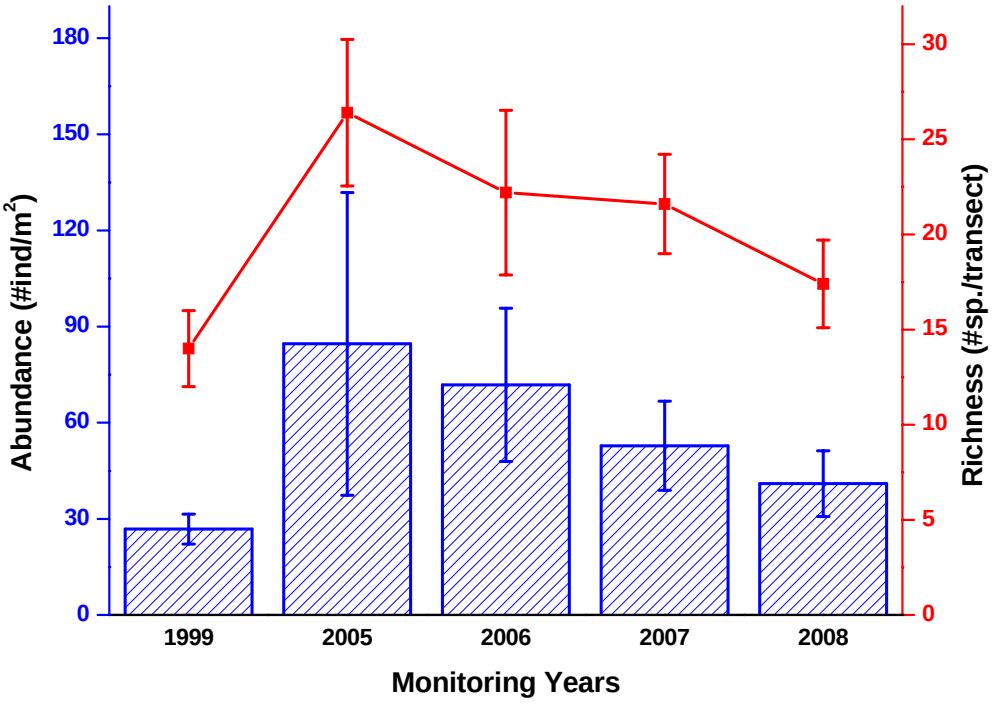


Figure 36. Monitoring trends (1999 – 2008) of fish species richness and abundance at Cayo Coral Reef, 8 m, Guanica Natural Reserve

Small, opportunistic micro-invertebrate predators (wrasses, gobies, puffers), demersal and pelagic schooling zooplanktivores (Blue Chromis, Creole Wrasse, Mackerel Scad, Bicolor Damselfish,) and herbivores (*Scarus spp., Sparisoma spp*., *Acanthurus spp*.) comprised the most prominent assemblage of the reef fish community. Among large invertebrate and small demersal fish predators, small growing groupers such Graysbys and Coneys were common. Juvenile Yellowfin Grouper and Jewfish, Red Hind, Nassau Grouper, Hogfish, Schoolmaster, Mahogany and Yellowtail Snappers have been observed during ASEC surveys at Cayo Coral (Garcia-Sais et al., 2006). Table 40 shows the fish species observed during the 2008 ASEC survey. Most individuals from the few ciommercially important species observed were present in juvenile stages.

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	1 - (40)		
Epinephelus guttatus	Red Hind	2 - (25)		
Lachnolaimus maximus	Hogfish (juvenile)	1 - (20)		
Lutjanus apodus	Schoolmaster	1 - (20)	6 - (30)	1 – (35)
Lutjanus mahogany	Mahogany Snapper	1 - (25)	2 – (30)	
Lutjanus synagris	Lane Snapper	5 - (15)	1 – (25)	
Ocyurus chrysurus	Yellowtail Snapper	8 - (20)	2 – (25)	
Invertebrates				
Panulirus argus	Spiny Lobster	2 - (20)		

Cleaner Shrimp (*Periclimenes pedersoni*) and Flamingo Tongue (*Cyphoma gibbosum*) were the motile megabenthic invertebrates observed within belt-transects (Table 41). One juvenile Spiny Lobster (*Panulirus argus*) and one Conch (*Strombus gigas*) were observed outside transects.

Table 41. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Coral 8 m, Guánica. March, 2008

		TRANSECTS					**MEAN**
Depth: 8 -10 m		**1**	**2**	**3**	**4**	**5**	**ABUNDANCE**
TAXA	**COMMON NAME**						**(IND/30 m2)**
Periclimenes pedersoni	Cleaner Shrimp	1					**0.2**
Xiphoma gibbosum	Flamingo Tongue	3		0			**0.6**
	TOTALS	4	0	0	0	0	**0.8**

Photo Album 10 (Guanica 10m)
Cayo Coral Reef

E. West Reef of Isla Caja de Muerto – Ponce

Caja de Muerto is an island located approximately 8.5 km off the south coast of Puerto Rico, between Ponce and Santa Isabel, within the insular shelf (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.

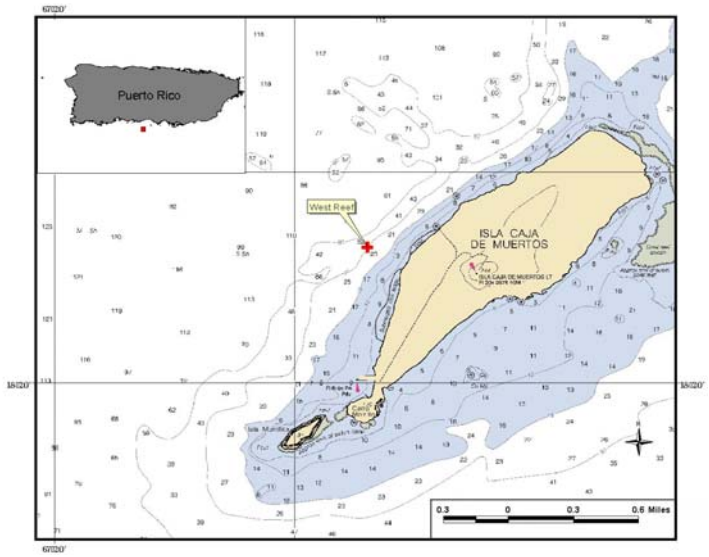


Figure 37. Location of coral reef survey stations at West Reef, Isla Caja de Muerto, Ponce.

1.0 Sessile-benthic Reef Communities

A dense algal turf, comprised by a mixed assemblage of short filamentous coralline algae and brown macroalgae was the dominant component of the reef sessile-benthic biota in terms of substrate cover at West Reef. Turf algae averaged 57.7 % (range: 47.6 – 67.0 %) 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). Durig the 2007 survey, cyanobacterial (blue-green algal) mats were prominent at the reef benthos with an average cover of 8.95 %, at present were only found in one transect with relatively low cover (0. 4 %). The cyanobacterial bloom appeared to be associated and proportional to the amount of recently dead coral observed after the late 2005 massive coral bleaching event that impacted reef systems of Puerto Rico and the USVI (García-Sais et al., 2006).

Live stony corals presented a mean substrate cover of 9.9 % (range: 7.14 – 13.8 %) along transects surveyed during 2008. Boulder Star Coral, *Montastraea annularis* (complex) was the dominant coral species with a mean substrate cover of 4.2 % (range: 1.5 – 8.6 %), representing 41.9 % 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 30.8 colonies/transect and included colonies of very large sizes. Some of the most abundant species included the Slimy Sea Plumes (*Pseudopterogorgia americana, Pseudopterogorgia spp.*), Porous Sea Rods (*Pseudoplexaura spp*.), Common Sea Fan (*Gorgonia ventalina*), Knobby Sea Rods (*Eunicea spp*.) and the Encrusting Gorgonian (*Erythropodium caribaeorum*). Sponges were present in all five transects with a mean substrate cover of 2.0 %.

Abiotic categories, including coral rubble, reef overhangs and sand/silt sediments combined for a mean substrate cover of 29.1 %. Reef overhangs contributed to a mean

Table 42. Percent reef substrate cover by sessile-benthic categories at West Reef, Isla Caja de Muerto, Ponce. March 2008

Depth: 10 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	4.32	6.39	7.75	6.96	6.44	**6.37**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	13.69	11.41	22.38	29.42	29.91	**21.36**
Silt	10.20	1.72	7.72	2.74	3.28	**5.13**
Rubble		4.21	7.44		1.46	**2.62**
Total Abiotic	23.89	17.34	37.54	32.16	34.65	**29.12**
Benthic Algae						
Turf-mixed assemblage	66.97	65.04	47.63	54.66	54.11	**57.68**
Fleshy algae		0.26		0.33		**0.12**
Total Benthic Algae	66.97	65.30	47.63	54.99	54.11	**57.80**
Sponges	0.56	1.71	4.51	0.42	2.68	**1.98**
Gorgonians				2.42	1.20	**0.72**
Cyanobacteria		1.83				**0.37**
Hydrozoa (Millepora)	0.39				0.26	**0.13**
Zoanthids						**0.00**
Live Stony Corals						
Montastrea annularis	4.12	8.60	4.45	2.06	1.52	**4.15**
Porites astreoides	1.68	0.92	2.54	1.24	1.40	**1.56**
Montastrea cavernosa		3.44	0.71	3.01	0.60	**1.55**
Siderastrea siderea	1.77	0.86	0.48	1.99		**1.02**
Siderastrea radians			0.24	0.17	2.25	**0.53**
Dendrogyra cylindrus			1.27			**0.25**
Agaricia agaricites	0.39				0.69	**0.22**
Meandrina meandrites				0.91		**0.18**
Madracis decactis				0.65		**0.13**
Porites colonensis			0.40			**0.08**
Manicina areolata					0.34	**0.07**
Stephanocoenia michelini					0.34	**0.07**
Eusmilia fastigiata			0.24			**0.05**
Porites porites	0.20					**0.04**
Total Stony Corals	8.16	13.82	10.33	10.03	7.14	**9.90**
Recently dead coral	6.7	20.1	4.9	6.07	1.7	**7.89**
Partially bleached coral	2.16			0.88		**0.61**
Gorgonians (# col.)						
Pseudoptergorgia americana	13		13	11	16	**10.60**
Plexaura flexuosa	7	2	10	3	3	**5.00**
Plexaura homomalla kukenthali	4	4	2	5	2	**3.40**
Gorgonia ventalina	2	3	3	4	4	**3.20**
Briaerum asbestinum	2		2	6	3	**2.60**
Pseudoplexaura flagellosa or wargeri	3		1	2	2	**1.60**
Pseudoptergogia acerosa	6		1		1	**1.60**
Plexaura homomalla		3	2			**1.00**
Muriceopsis flavida	1		2			**0.60**

Table 42. continued

Eunicea turnetorti			1	1		**0.40**
Eunicea sp.1	1					**0.20**
Eunicea sp.2				1		**0.20**
Eunicea sp.3					1	**0.20**
Plexaurella spp.				1		**0.20**
Total Gorgonians (# colonies/transect)	39	12	37	34	32	**30.8**

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

rugosity of 6.37 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 *Montastraea 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 2005-08. Differences of reef substrate cover by stony corals between annual surveys were statistically significant (ANOVA; $p = 0.003$), indicative of a degradation of the coral reef community structure. Such degradation was acute in 2006, after the massive coral bleaching event of October 2005 (Garcia-Sais et al., 2006). Live coral cover declined abruptly between the 2005 (19.32 %) and 2006 (11.42 %) monitoring surveys. The reduction represented a difference of 40.9 % of total live coral in only one year. Sharp reductions of live coral were measured in all transects surveyed 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 7.7 % during 2007, associated with mortality of massive corals, such as *Montastraea annularis* and *Colpophyllia natans* after the late 2005 coral bleaching event. Partially bleached corals were observed during the 2007 survey and represented 1.5 % of the total cover by live corals at West Reef. Live coral cover during the present 2008 survey did not reflect any further statistically significant degradation in this reef (Appendix 2).

Variations of the mean substrate cover by coral species are shown in Figure 39. Boulder Star Coral, *Montastraea annularis* exhibited a decline of 16 % between the baseline survey of 1999 and the 2005 survey, but then droped 58.0 % between 2005

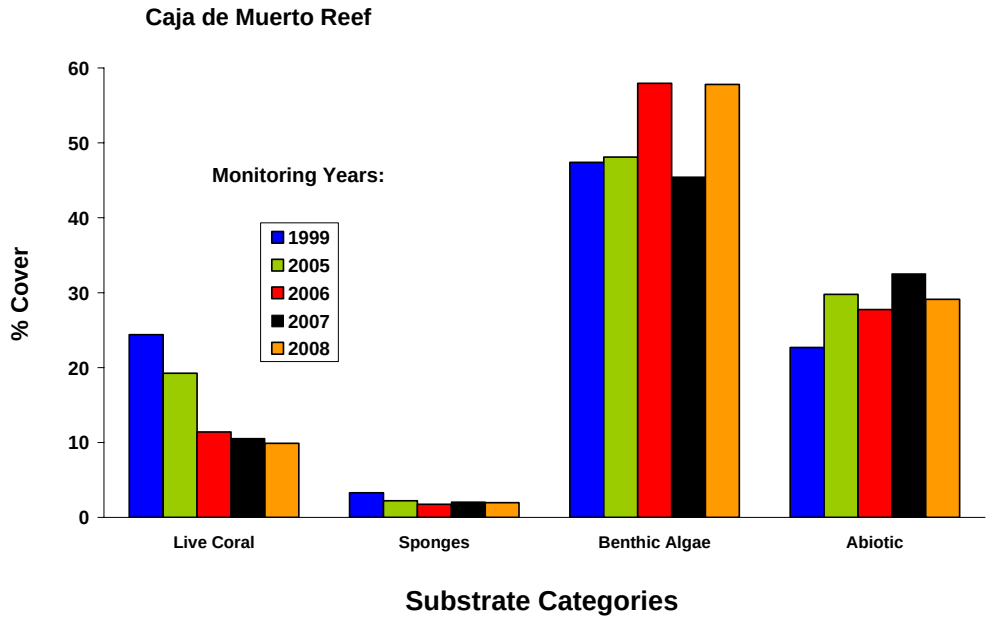


Figure 38. Monitoring trends (1999 - 2008) of mean substrate cover by sessile-benthic categories at West Reef, Isla Caja de Muerto, Ponce.

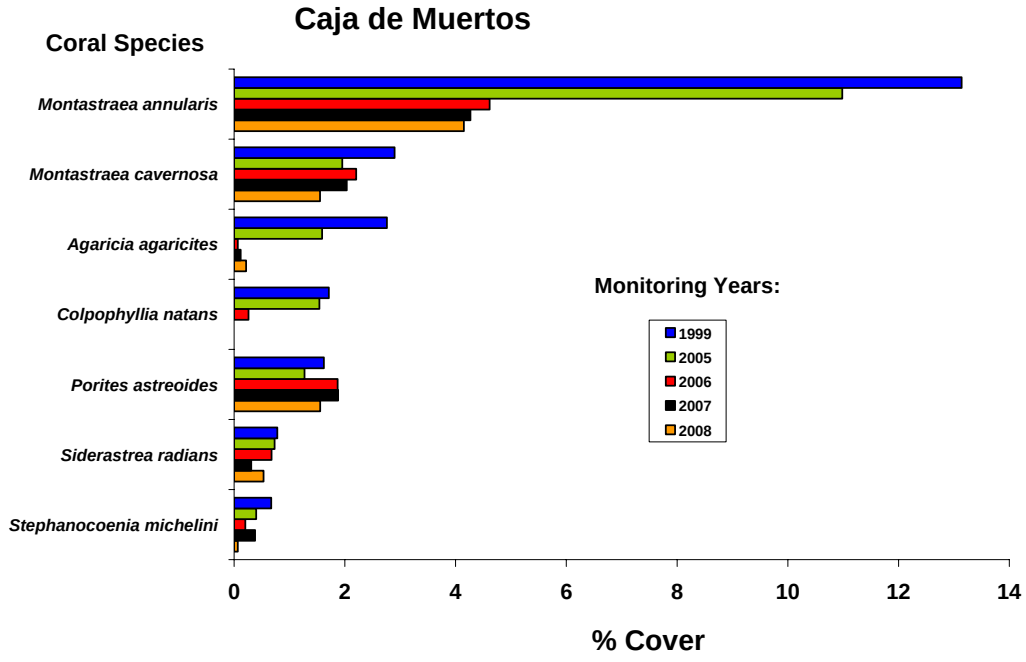


Figure 39. Monitoring trends (1999 – 2008) of mean substrate cover by stony coral species at West Reef, Isla Caja de Muerto, Ponce.

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, but remained rather stable during the present 2008 survey (Figure 39). Reductions of substrate cover by live corals have also been measured for *M. cavernosa, Agaricia agaricites, Colpophyllia natans* and *Stephanocoenia michelini*.

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 88 fish species have been identified during monitoring surveys from West Reef, Isla Caja de Muerto (Appendix 1). Mean abundance of fishes within belt-transects during March 2008 was 56.2 Ind/30 m^2 (range: 33 - 93 Ind/30 m^2). The mean number of species per transect was 16.6 (range: 15 - 20). The Masked Goby (*Coryphopterus personatus*) was the numerically dominant species with a mean abundance of 20.6 Ind/30 m^2 (range: 0 - 42 Ind/30 m^2), representing 36.6 % 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, Dusky and Threespot Damselfishes, and the Striped and Princess Parrotfishes were along with the Masked Goby the main fish assemblage of West Reef (Table 43).

Figure 41 shows the annual trends of fish abundance and species richness during monitoring surveys at West Reef. Statisticaly significant differences of fish abundance (ANOVA; $p < 0.001$) 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; $p < 0.001$). The main pattern was a decline of the number of species per transect during the 2007 and 2008 relative to previous surveys.

The fish community structure at West Reef is strongly represented by zooplankton feeders, including the Masked Goby, Brown Chromis, Bicolor Damselfish, 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

Table 43. Taxonomic composition and abundance of fishes within belt-transects at West Reef, Isla Caja de Muerto, Ponce - 15 m. March, 2008

Depth: 6.5 m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Coryphopterus personatus	Masked Goby	17	42	35		9	**20.6**
Thalassoma bifasciatum	Bluehead Wrasse	10	22	6	12		**10.0**
Scarus iserti	Stripped Parrotfish			10	3	5	**3.6**
Stegastes partitus	Bicolor Damselfish	1	6	5	1	1	**2.8**
Stegastes adustus	Dusky Damselfish	3	5	1	1	4	**2.8**
Stegastes planifrons	Threespot Damselfish		1	6	1	1	**1.8**
Scarus taeniopterus	Princess Parrotfish	1	5				**1.2**
Coryphopterus glaucofraenum	Briddeld Goby	1	1	1	1	1	**1.0**
Canthigaster rostrata	Caribbean Puffer	2	1	1			**0.8**
Chromis cyanea	Blue Chromis	1	3				**0.8**
Chaetodon capistratus	Foureye Butterflyfish			2	2		**0.8**
Stegastes leucostictus	Beaugregory	1	1		1		**0.6**
Haemulon flavolineatum	French Grunt		1	1		1	**0.6**
Halichoeres garnoti	Yellowhead Wrasse		1	1		1	**0.6**
Gobioisoma evelynae	Sharknose Goby		1		2		**0.6**
Acanthurus bahianus	Ocean Surgeon			1	1	1	**0.6**
Pomacanthus arcuatus	Gray Angelfish				2	1	**0.6**
Cephalopholis cruentatus	Graysby	1	1				**0.4**
Chaetodon striatus	Barred Butterflyfish	2					**0.4**
Lutjanus apodus	Schoolmaster			2			**0.4**
Chromis multilineata	Brown Chromis			1		1	**0.4**
Caranx ruber	Bar Jack					2	**0.4**
Myripristis jacobus	Blackbar Soldierfish				1	1	**0.4**
Hypoplectrus nigricans	Black Hamlet				1	1	**0.4**
Abudefduf sexatilis	Sargent Major				2		**0.4**
Bodianus rufus	Spanish Grunt					1	**0.2**
Hypoplectrus puella	Barred Hamlet	1					**0.2**
Halichoeres maculipinna	Clown Wrasse	1					**0.2**
Coryphopterus lipernes	Peppermint Goby	1					**0.2**
Haemulon plumieri	White Grunt				1		**0.2**
Seriola rivoliana	Almaco Jack	1					**0.2**
Haemulon sciurus	Bluestriped Grunt		1				**0.2**
Epinephelus guttatus	Red Hind		1				**0.2**
Lutjanus mahogani	Mahogani Snapper			1			**0.2**
Acanthurus coeruleus	Blue Tang			1			**0.2**
Apogon maculatus	Flamefish					1	**0.2**
Holocentrus rufus	Longspine Squirrelfish					1	**0.2**
Sparisoma viride	Stoplight Parrotfish					1	**0.2**
Sparisoma aurofrenatum	Redband Parrotfish					1	**0.2**
Serranus tigris	Harlequin Bass					1	**0.2**
Anisotremus virginicus	Porkfish				1		**0.2**
	TOTAL INDIVIDUALS	**44**	**93**	**75**	**33**	**36**	**56.2**
	TOTAL SPECIES	**15**	**16**	**16**	**16**	**20**	**16.6**

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 2008 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.

Juvenile and some adult Yellowtail Snappers (*Ocyurus chrysurus*) concentrate at the face of the fore-reef slope (wall), with small juveniles (< 5 cm) using the dense soft coral (gorgonian) forest as protective habitat. Schoolmasters (*L. apodus*) were mostly observed as juvenile/adult stages swimming in and out of caves and crevices within the fore-reef slope. Juvenile and young adult Mutton Snappers (*L. analis*) were observed foraging along with the large Lane Snapper aggregation during the 2006 ASEC survey (García-Sais et al., 2006). Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous fish assemblage of West Reef.

Motile megabenthic invertebrates were represented within belt-transects only by the Cleaner Shrimp, *Periclimenes pedersoni* (Table 45). Adult sized Spiny lobster, *Panulirus argus,* Flamingo Tongue, *Cyphoma gibbosum* and one Donkeys' Dong, *Holothuria mexicana* were present outside transects.

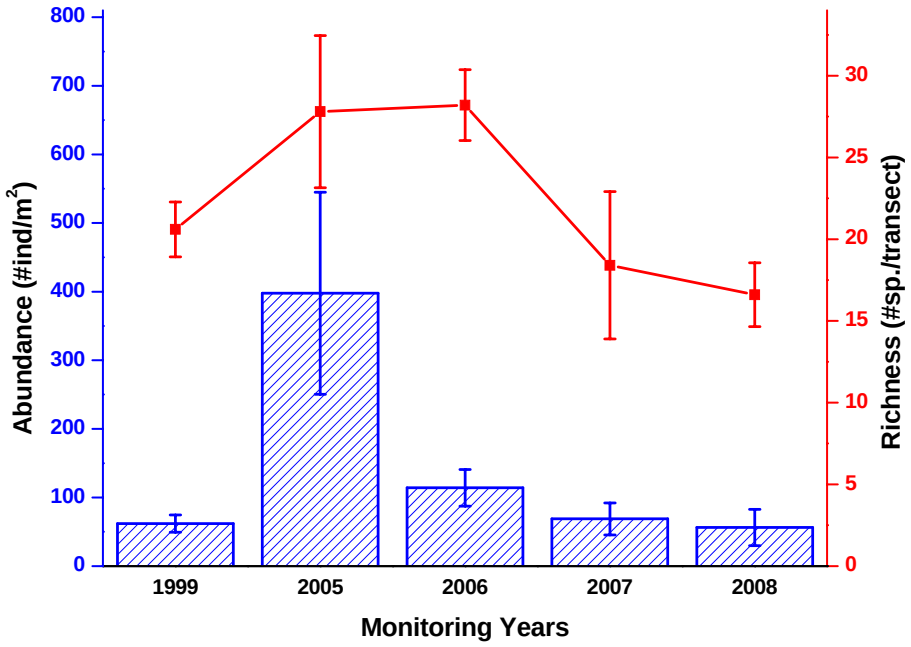


Figure 41. Monitoring trends (1999 – 2008) of fish species richness and abundance at West Reef, Isla Caja de Muerto, Ponce

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, 2008.

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

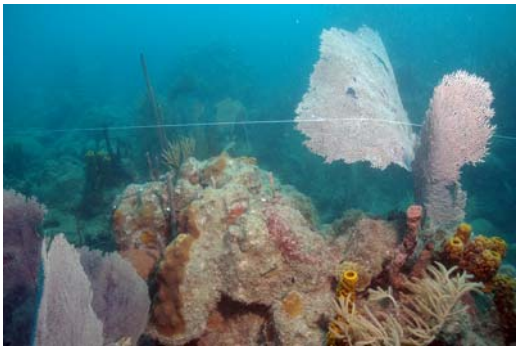
SPECIES	**COMMON NAME**	# - (cm)		
Epinephelus guttatus	Red Hind	1 - (25)		
Holacanthus tricolor	Rock Beauty	2 - (25)		
Holacanthus ciliaris	Queen Angel	1 - (30)		
Lutjanus apodus	Schoolmaster	6 – (20)	5 – (30)	4 – (50)
Lutjanus cyanopterus	Cubera Snapper	1 – (60)		
Lutjanus griseus	Grey Snapper	2 - (25)	1 – (30)	
Lutjanus jocu	Dog Snapper	1 – (50)		
Lutjanus mahogany	Mahogani Snapper	11 - (25)	2 - (30)	
Lutjanus synagris	Lane Snapper	2 – (15)	10 – (25)	3 – (30)
Ocyurus chrysurus	Yellowtail Snapper	30 – (20)	15 – (25)	8 – (40)
Scomberomorus regalis	Cero Mackerel	2 - (60)		
Seriola rivoliana	Almaco Jack	1 – (50)		
Sphyraena barracuda	Great Barracuda	1 - (60)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (30)		

Table 45. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at West Reef, Caja de Muerto. March, 2008

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**

Photo Album 11 (Caja de Muerto)

West Reef



F. Derrumbadero Reef – Ponce

Derrumbadero is a submerged promontory fringing the shelf-edge, 2.2 nautical miles southeast off from the mouth of Ponce Bay (Figure 42). The promontory rises from the outer shelf at a depth of about 25 -30 m to a reef top at 15 m, and then drops down the insular slope along the south and west margins. The reef top platform has an irregular spherical shape. It measures approximately 2 kilometers from east to west and about 0.7 kilometers from north to south. Permanent transects were established at the southern edge of the reef, close to the shelf-edge drop-off wall.

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

1.0 Sessile-Benthic Reef Community

A total of 25 stony corals, including 9 intersected by line transects were identified from Derrumbadero Reef at a depth of 20 m during March, 2008 (Table 46). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 10.8 % (range: 7.4 – 14.8 %). Boulder Star Coral, *Montastraea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 3.8 % (range: 1.1 – 9.0 %), representing 35.6 % of the total cover by stony corals. Mustard-Hill Coral (*Porites astreoides*), and Great Star Coral (*M. cavernosa*) ranked second and third in terms of substrate cover by stony corals. Boulder Star Coral, Mustard-Hill Coral and Lettuce Coral (*Agaricia agaricites*) were the only species present in all five transects surveyed (Table 46).

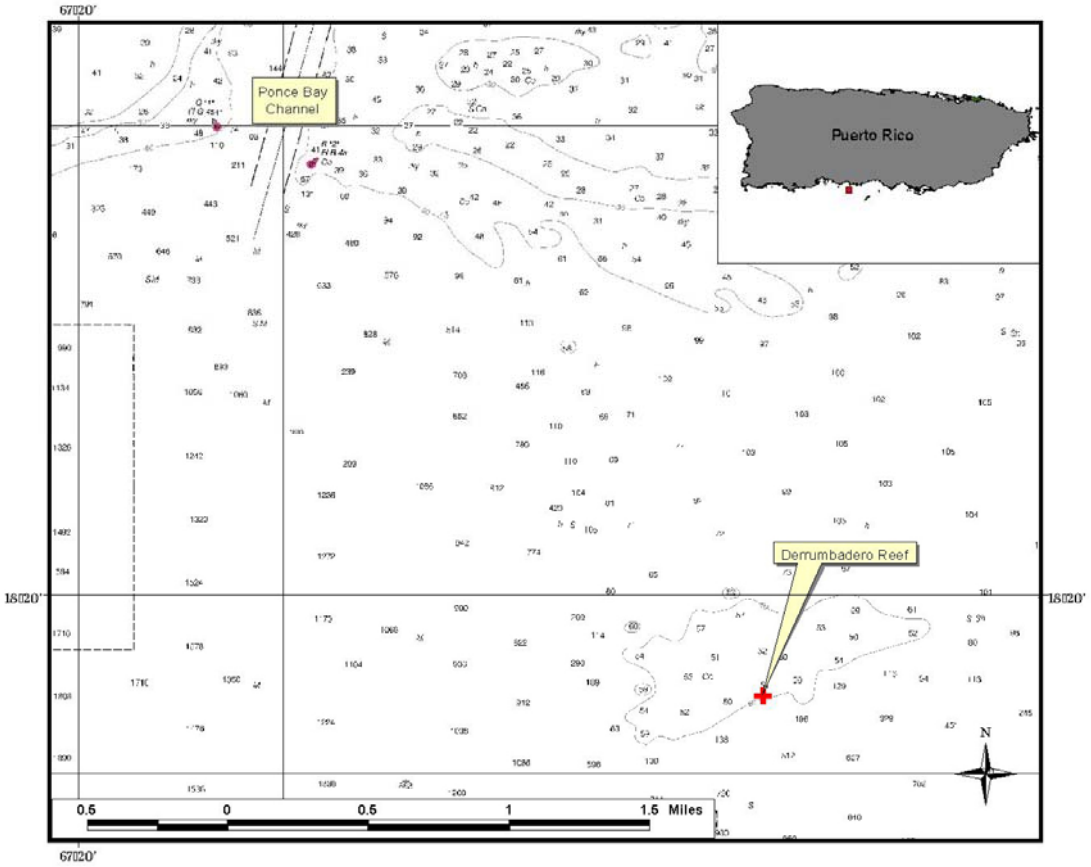


Figure 42. Location of the coral reef monitoring station at Derrumbadero Reef, Ponce.

Black corals (Antipatharia) were observed off the shelf-edge at depths of 25 – 30 m. These included the Wire Black Coral (*Stichopathes lutkeni*), and the Bushy Black Coral (*Antipathes caribbeana*). Soft corals were highly abundant (mean: 31.8 col./transect) at Derrumbadero Reef and because of their large sizes and species richness (14 spp within transects) contributed substantially to the biological diversity and structural complexity of the reef system. Sea Plumes, *Pseudopterogorgia acerosa, P. americana* Common Sea Fan, *Gorgonia ventalina*, 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 brown and red algae were the most prominent sessile-benthic category in terms of substrate cover at Derrumbadero Reef with a mean of 62.4 % (range:53.8 – 67.1 %). Sponges were also present in all five transects with a mean substrate cover of 2.7 %. Abiotic categories were represented by reef overhangs mostly produced by mounds and ledges of Boulder Star Coral (*M. annularis*),and contributed to the reef mean topographic rugosity of 3.03 m (Table 46).

Table 46. Percent reef substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce, March 2008

	Transects					
Depth: 20 m	**1**	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	3.38	2.34	3.72	3.30	2.62	**3.07**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	12.41	10.29	7.00	12.41	10.70	**10.56**
Sand			3.70			**0.74**
Total Abiotic	12.41	10.29	10.70	12.41	10.70	**11.30**
Benthic Algae						
Turf-mixed assemblage	61.14	66.53	63.35	67.14	53.82	**62.40**
Fleshy algae	6.13	7.86	6.56	6.92	9.59	**7.41**
Total Benthic Algae	67.27	74.39	69.91	74.06	63.41	**69.81**
Sponges	2.77	1.38	6.49	2.11	0.63	**2.68**
Gorgonians	0.82	5.27	0.80	0.45	0.45	**1.56**
Cyanobacteria	1.87	1.22	1.02			**0.82**
Live stony corals						
Montastraea annularis	8.97	2.59	3.50	3.08	1.09	**3.85**
Porites astreoides	1.87	1.94	3.21	1.13	4.12	**2.45**
Montastraea cavernosa		1.70	3.21	2.12	2.93	**1.99**
Agaricia agaricites	1.12	0.68	1.23	1.05	0.89	**0.99**
Porites porites	2.84					**0.57**
Colpophyllia natans				2.65		**0.53**
Diploria labyrinthiformis		0.46			0.56	**0.20**
Diploria strigosa				0.98		**0.20**
Siderastrea siderea					0.22	**0.04**
Total Stony Corals	14.80	7.37	11.15	11.01	9.81	**10.83**
Recently dead corals	4.41	4.46	6.34	19.70	3.49	**7.68**
Partially bleached coral	1.58				1.34	**0.58**
Gorgonians (# col.)						
Briaerum asbestinum	12	17	2	3	5	**7.80**
Pseudoptergorgia acerosa	5	11	7	9	5	**7.40**
Gorgonia ventalina	1	5	6	8	6	**5.20**
Pseudoptergorgia americana	4	2	5	4	3	**3.60**
Plexaura flexuosa	1	4	3	3	2	**2.60**
Eunicea turnetorti	2	2	1	2	1	**1.60**
Eunicea sp.1	2		2	1		**1.00**
Pseudoplexaura flagellosa/wargeri					3	**0.60**
Pseudoplexaura purosa				2	1	**0.60**
Eunicea asperula		1		1		**0.40**
Muriceopsis flavida		2				**0.40**
Eunicea succinea	1					**0.20**
Plexaura homomalla			1			**0.20**
Plexaurella spp.	1					**0.20**
Total Gorgonians (# col/transect)	29	44	27	33	26	**31.8**

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

Figure 43 presents the variations of mean percent cover by sessile-benthic categories from Derrumbadero Reef including the original baseline survey in 2001 and subsequent monitoring surveys of 2005-08. 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 reef coral 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 59.1 %, from 34.6 % in 2005 to 14.2 % in 2006. A proportional increment of cover by benthic algae was measured. Such drastic, short term collapse of the Derrumbadero coral reef system was associated with the massive regional coral bleaching event that affected Puerto Rico and the USVI during late September through October 2005 (García-Sais et al., 2006). From the reported live coral intercepted by transects during the 2006 monitoring survey, approximately 35.9 % was partially bleached. Most of the partially bleached coral colonies appear to have recuperated because during the 2007 survey, live coral cover remained virtually stable (mean:14. 2 %) as compared to the 2006 condition. Nevertheless, another decline of 24% from the cover in 2007 was measured during the present 2008 survey (Figure 43). Partially bleached coral declined to a mean substrate cover of 0.6 % during 2008.

Monitoring trends of mean substrate cover by coral species at Derrumbadero Reef are shown in Figure 44. In 2005, Boulder Star 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 *Montastraea 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 solid trend of increment from 23 to 32 col/transect between the 2005 and the 2008 surveys.

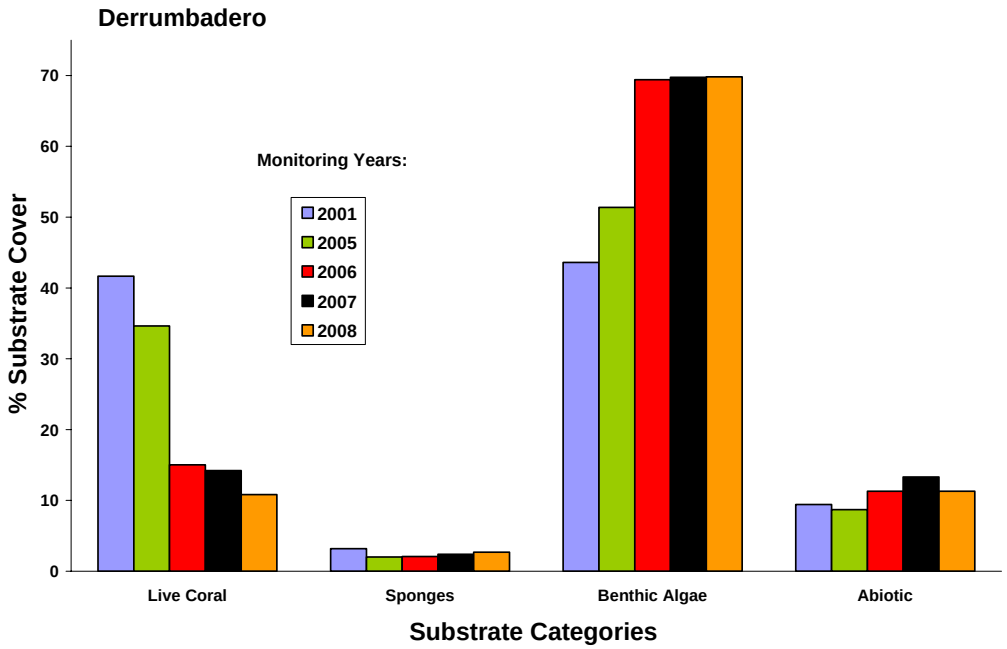


Figure 43. Monitoring trends (2001 – 2008) of mean substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce.

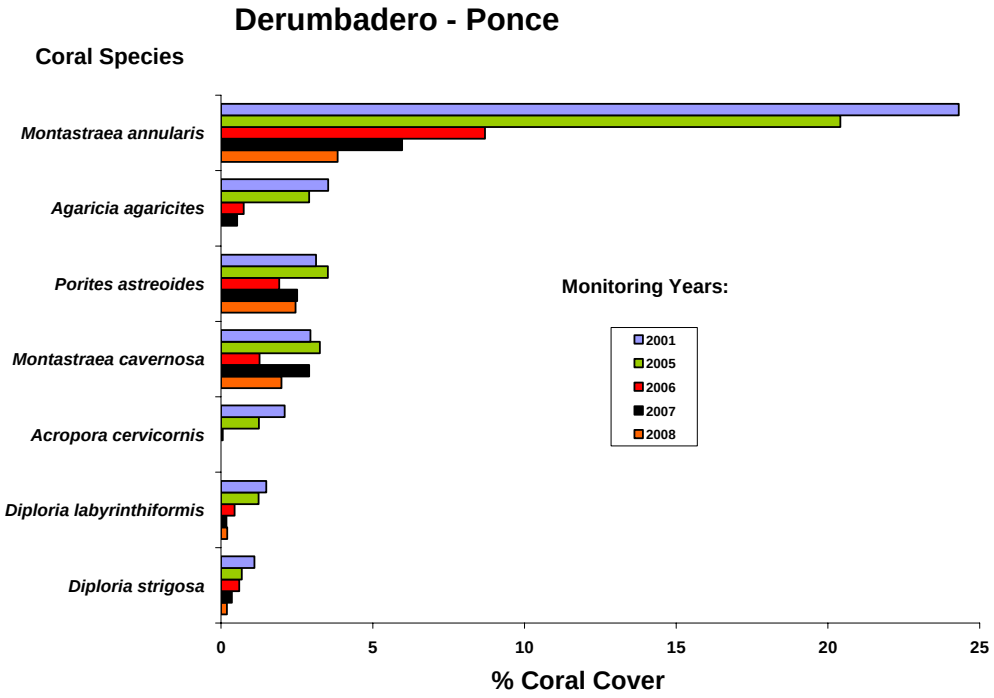


Figure 44. Monitoring trends (2001 – 2008) of mean substrate cover by coral species at Derrumbadero Reef, Ponce

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 2008 was 39.2 Ind/30 m^2 (range: 28 - 64 Ind/30 m^2). The mean number of species per transect was 16.2 (range: 14 - 19). The Bicolor Damselfish, *Stegastes partitus* and the Peppermint Goby, Coryphopterus lipernes were the numerically dominant species with a mean abundance of 7.6 Ind/30 m^2 and 6.6 Ind/30 m^2, respectively. Their combined abundance represented 36.2 % of the total abundance within belt-transects (Table 47). A total of eight fish species were present on at least four out of the five transects surveyed. These included the Bicolor Damselfish, Peppermint and Bridled Gobies, Blue Chromis, Bluehead Wrasse, Ocean Surgeon and Beaugregory. Seven species were represented by only one individual within belt-transects.

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 2005-08 Statistically significant declines of fish abundance and species richness (ANOVA; $p < 0.001$, Appendix 3-4) within belt-transects was detected. The higher fish abundance of the 2001 and 2005 surveys compared to the most recent 2006-08 surveys was largely driven by an abundance decline of Masked Goby, *Coryphopterus personatus*, a species that was numerically dominant in the baseline and 2005 surveys. This is a small zooplanktivorous species that forms dense swarms below coral ledges. Its mean abundance within belt-transects declined more than 10 fold between the 2001-05 and the 2006-08 monitoring surveys. It is uncertain if the decline in abundance of the Masked Goby, and perhaps other reef fishes is correlated with the abrupt decline of live coral cover in Derrumbadero and other reef systems in the monitoring program. However, a marked drop of fish species richness (# species per transect) was also observed in the 2006 survey, coincident with the massive coral mortality associated with the 2005 regional bleaching event. The large scale loss of habitat quality associated with decreased live coral cover may be having earlier than expected consequences for the reef fish community structure as it affects microhabitat availability and food webs.

Table 47. Taxonomic composition and abundance of fishes within belt-transects at Derrumbadero Reef, Ponce. March, 2008

Depth: 20m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Stegastes partitus	Bicolor Damselfish	13	7	7	6	5	**7.6**
Coryphopterus lipernes	Peppermint Goby	2	28	1	2		**6.6**
Gobiosoma evelynae	Sharknose Goby	2	1	2	2	6	**2.6**
Chromis cyanea	Blue Chromis	5		2	4	1	**2.4**
Scarus iserti	Stripped Parrotfish	5	4		3		**2.4**
Thalassoma bifasciatum	Bluehead Wrasse	4	1	2	1	3	**2.2**
Halichoeres garnoti	Yellowhead Wrasse	1	7			1	**1.8**
Myripristis jacobus	Blackbar Soldierfish	1		3		3	**1.4**
Scarus taeniopterus	Princess Parrotfish	1		2		2	**1.0**
Stegastes leucostictus	Beaugregory		1	2	1	1	**1.0**
Coryphopterus glaucofraenum	Briddled Goby	1	1	1	1	1	**1.0**
Acanthurus bahianus	Ocean Surgeon	1	1		1	1	**0.8**
Sparisoma arofrenatum	Redband Parrotfish	2			1	1	**0.8**
Holocentrus rufus	Longspine Squirrelfish		1	1	1	1	**0.8**
Acanthurus coeruleus	Blue Tang		1	1		1	**0.6**
Coryphopterus personatus	Masked Goby		3				**0.6**
Elagatis bipinnulata	Rainbow Runner		3				**0.6**
Flameo marianus	Longjaw Squirrelfish	2		1			**0.6**
Cephalopolis cruentatus	Graysby			2	1		**0.6**
Chaetodon capistratus	Foureye Butterflyfish	1	1				**0.4**
Scarus vetula	Queen Parrotfish		1	1			**0.4**
Canthigaster rostrata	Caribbean Puffer			1		1	**0.4**
Haemulon flaveolineatum	French Grunt			2			**0.4**
Chaenopsis ocellata	Bluethroat Pikeblenny				2		**0.4**
Chaetodon ocellatus	Spotfin Butterflyfish				2		**0.4**
Serranus tigris	Harlequin Bass		1				**0.2**
Chaetodon aculeatus	Longsnout Butterflyfish		1				**0.2**
Sparisoma viride	Stoplight Parrotfish		1				**0.2**
Haemulon squamipinna	Yellowstriped Grunt			1			**0.2**
Chromis multilineata	Brown Chromis				1		**0.2**
Acanthurus chirurgus	Doctorfish				1		**0.2**
Hypopletrus puella	Barred Hamlet				1		**0.2**
	TOTAL INDIVIDUALS	41	64	32	31	28	**39.2**
	TOTAL SPECIES	14	19	17	17	14	**16.2**

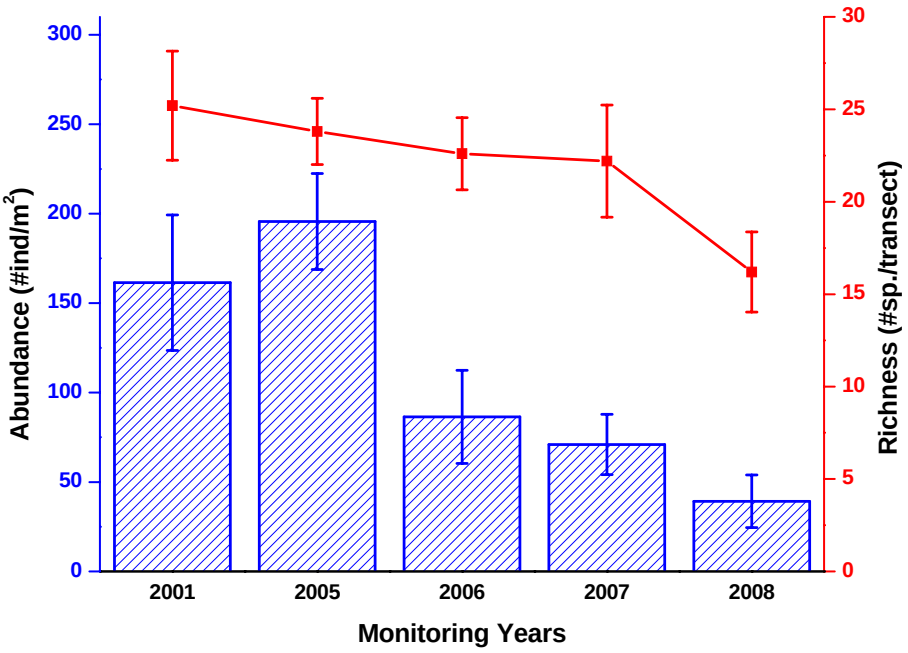


Figure 44. Monitoring trends (1999 – 2008) of fish species richness and abundance at Derrumbadero Reef, Ponce

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, Rainbow Runners, Cravelle 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,

Table 48. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Derrumbadero Reef, Ponce. March, 2008

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

SPECIES	**COMMON NAME**	# - (cm)	
Aetobatis narinari	Spotted Eagle Ray	1 – (120)	
Balistes vetula	Queen Triggerfish	1 – (35)	
Carangoides latus	Cravelle Jack	1 – (50)	
Elagatis bipinnulata	Rainbow Runner	3 – (50)	
Epinephelus guttatus	Red Hind	1 – (30)	
Holacanthus ciliaris	Queen Angel	2 - (40)	
Holacanthus tricolor	Rock Beauty	3 - (20)	1 – (25)
Lachnolaimus maximus	Hogfish	1 – (25)	4 – (40)
Lutjanus apodus	Schoolmaster	2 - (20)	2 – (30)
Lutjanus cyanopterus	Cubera Snapper	1 – (40)	1 (50)
Lutjanus mahogany	Mahogani Snapper	1 - (25)	
Lutjanus synagris	Lane Snapper	2 - (20)	
Ocyurus chrysurus	Yellowtail Snapper	5 – (25)	7 - (40)
Scomberomorus regalis	Cero Mackerel	2 - (60)	1 – (70)
Sphyraena barracuda	Great Barracuda	2 - (70)	
Trachinotus falcatus	Permit	1 – (60)	
Invertebrates			
Panulirus argus	Spiny Lobster	1 - (30)	

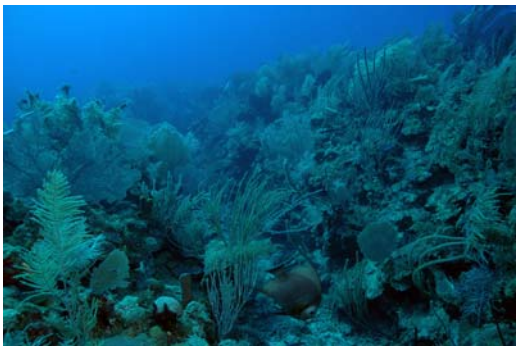
Schoolmaster and Mahogani snappers, Coney, Graysby and Red Hind groupers, lizardfishes and grunts. Parrotfishes, doctorfishes, and damselfishes comprised the main herbivorous assemblage. The Cleaner Shrimp, *Periclimenes pedersoni* and one Conch (*Strombus sp.*) represented megabenthic invertebrates within belt transects during the 2008 survey (Table 49).

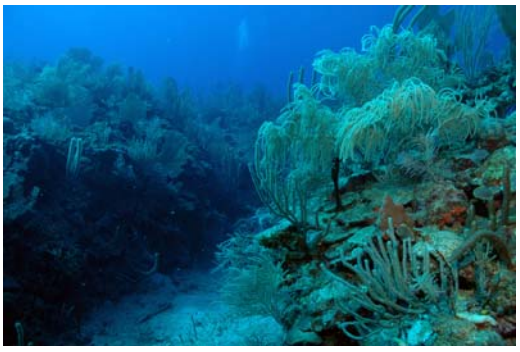
Table 49. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Derrumbadero Reef, 20 m, Ponce. March, 2008

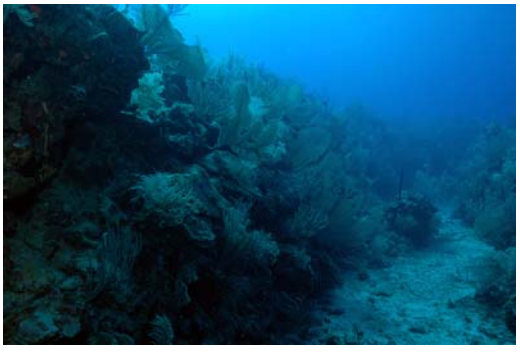
DATE: March 13, 2008 Depth: 20 m

		TRANSECTS					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	DEPTH (m) COMMON NAME						
Periclimenes pedersoni	Cleaner Shrimp	1					**0.2**
Strombus sp. (raninus)	Conch				1		**0.2**
	TOTALS	**1**	**0**	**0**	**1**	**0**	**0.4**

Photo Album 12 (Ponce)
Derrumbadero Reef







G. Isla de Mona Natural Reserve

General Description

Isla de Mona and Monito are oceanic islands in the Mona Passage located between Puerto Rico and the Dominican Republic. Both of these islands were included in the designation of Isla de Mona Natural Reserve in 1986 by DNER. The total surface area of Mona Island is 54.9 km^2 (DNER, 1999). Mona is much larger than Monito and the only with well developed coral reefs. The north and east sections of the island are vertical walls that drop down to oceanic depths. Coral reefs develop along the south and west coasts of Isla de Mona where the insular shelf is wider. The island climate is semi-arid with no rivers and an average rainfall of 100 cm per year (Canals et al. 1981).

The first qualitative description of the coral reefs and other benthic habitats in Mona Island was prepared by Cintrón et al. (1975). Quantitative studies of the coral reef systems at Playa Pájaros, Uvero, Carabinero, Sardinera and Monito were reported by Canals et al. (1981). Quantitative baseline surveys of coral reefs at Isla de Mona were performed in June 2000 (García-Sais et al., 2001). Community surveys were performed off Sardinera in the south coast and off Playa Mujeres and Playa Carmelitas on the west and northwest coasts of the island. This is the first monitoring survey of the reefs at Playa Mujeres and Carmelitas. The coral community work at Sardinera is included as a baseline survey. The location of sampling stations is shown in Figure 4.

1.0 Playa Mujeres Reef

Physical Description of Playa Mujeres Reef

Playa Mujeres is located on the southwest corner of Isla de Mona, between Piedra del Carabinero and Punta Arenas. Most of the shelf benthic habitat is a hard ground platform with abundant sand patches and coral rubble. Isolated massive and encrusting coral colonies are interspersed among the hard ground platform. Some erect sponges, mostly the Basket Sponge, *Xestospongia muta* are common. The coral reef system consists of a series of discontinuous patches associated with the shelf-edge. Our coral reef community survey off Playa Mujeres was performed at two separate (although adjacent) sections of the shelf where coral reef patches were found (Figure 45).

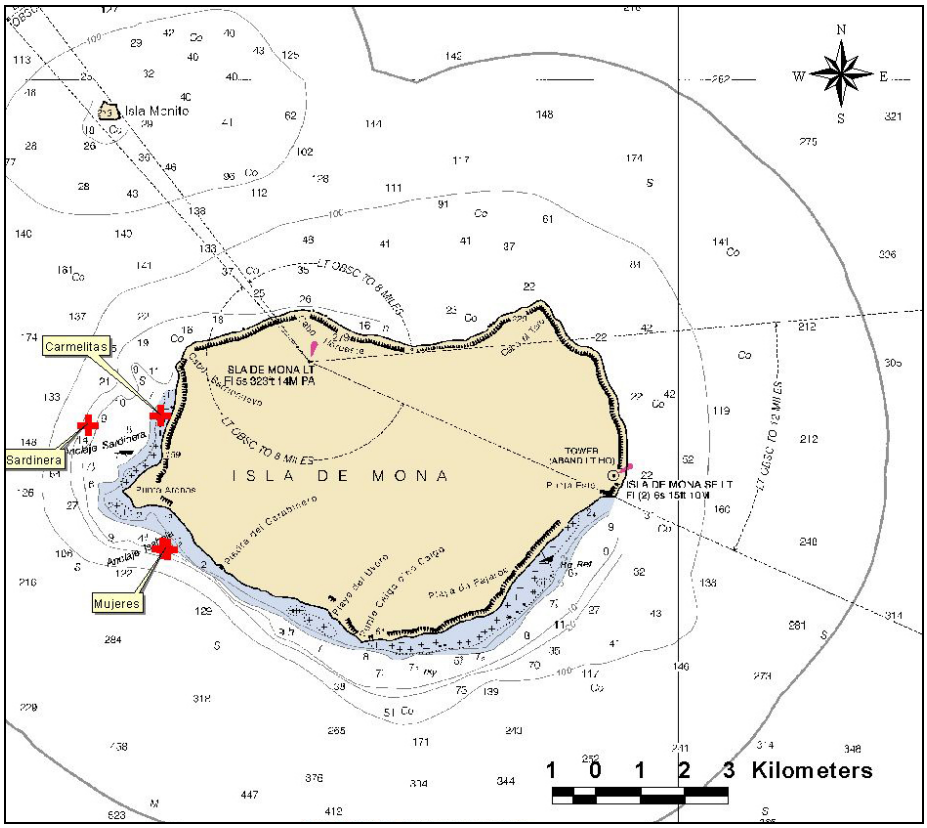


Figure 45. Location of reef sites surveyed at Isla de Mona Natural Reserve

1.1 Sessile-Benthic Reef Community

A coral reef system was found at a depth of 18 – 20 m associated with the shelf-edge off Playa Mujeres. Stony corals grow along a rather narrow band at the drop-off and also form a series of patch reefs adjacent to the shelf edge providing substantial topographic relief and structural habitat. Coarse coralline sand and rubble sediments separate patch reef sections of variable size dimensions. A total of 22 scleractinian corals and one hydrocoral (*Millepora alcicornis*) were identified during our monitoring survey at Playa Mujeres Reef, including 12 species intersected by line transects. The mean surface cover by stony corals during the 2008 monitoring survey was 11.7 % (range: 7.1 – 15.6 %). Boulder Brain Coral, *Colpophyllia natans* and Boulder Star Coral, *Montastraea annularis* complex were the dominant coral species in terms of reef substrate cover with means of 2.8 and 2.5 %, respectively (Table 50). Mustard Hill Coral (*Porites astreoides*) was the only coral species present at all five transects surveyed. *Colpophyllia natans* was present in two transects and *M. annularis* was present in four. Branching corals were represented by Ten-Ray Star Coral (*Madracis decactis*). Fleshy corals (*Mycetophyllia* spp) were observed in vertical sections of the reef, mostly growing encrusted to walls and within holes and gaps formed by growth of other coral colonies.

Table 50. Percent reef substrate cover by sessile-benthic categories at Playa Mujeres Reef, Mona Island. 20 m, June 2008

Depth:20 m	Transects					
	1	2	3	4	5	**MEAN**
Rugosity (m)	2.86	4.58	3.85	2.04	2.94	**3.25**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	13.45	11.11	13.22	5.15	12.44	**11.07**
Sand	0.99		1.52	1.66	4.02	**1.64**
Gaps	0.88	0.97			0.76	**0.52**
Total Abiotic	15.32	12.08	14.74	6.81	17.22	**13.23**
Benthic Algae						
Turf-mixed assemblage	37.09	31.76	57.37	80.56	64.65	**54.29**
Fleshy	31.03	32.10	6.00		2.18	**14.26**
Total Benthic Algae	68.12	63.86	63.37	80.56	66.83	**68.55**
Sponges	2.88	15.36	8.53	5.15	0.44	**6.47**
Cyanobacteria				0.35		**0.07**
Live Stony Corals						
Colpophyllia natans		1.55			12.28	**2.77**
Montastraea annularis	2.41	4.18	4.70	1.17		**2.49**
Porites astreoides	2.33	1.06	1.08	2.66	0.65	**1.56**
Agaricia agaricites	1.94		4.48		0.44	**1.37**
Siderastrea siderea	1.42		2.24		0.44	**0.82**
Diploria labyrinthiformis	2.30				0.98	**0.66**
Eusmilia fastigiata				3.28		**0.66**
Siderastrea radians	0.44	0.39	0.79		0.77	**0.48**
Montastraea cavernosa	1.53					**0.31**
Meandrina meandrites	1.32					**0.26**
Madracis decactis		1.03				**0.21**
Mycetophyllia aliciae		0.48				**0.10**
Total Stony Corals	13.69	8.69	13.29	7.11	15.56	**11.67**
Recently dead coral		2.40		18.94	13.36	**6.94**

Coral species Outside Transects: *Diploria strigosa, Mycetophyllia ferox, M. lamarckiana, Millepora alcicornis, Agaricia fragilis, Dichocoenia stokesii, Porites sp., Acropora cervicornis, Leptoceris cucullata, Mussa sp., Madracis sp*.

Recently dead coral colonies accounted for a mean substrate cover of 6.9 %. Total abiotic cover averaged 13.2 % and was mostly contributed by reef overhangs from mostly dead skeletons of Boulder Star Coral, *Montastraea annularis* and other stony corals accounted Erect and encrusting sponges were present at all five transects surveyed with a mean cover of 6.5 % (range : 0.4 – 15.4 %). Large Basket Sponges (*Xestospongia muta*) were prominent at this reef.

Algal turf was the dominant sessile-benthic category in terms of reef substrate cover with a mean of 54.3 % (range: 31.8 – 80.5 %). Fleshy algae, mostly *Lobophora* sp. *Dyctiota* sp. and *Padina* sp. combined for a mean surface cover of 14.3 %. *Dyctiota* sp. and *Padina* sp. occurred mostly in small bundles attached to the reef hard ground, whereas *Lobophora* was found overlying dead coral sections and intermixed with other low relief algae, forming an algal mat over reef sections not colonized by stony corals or sponges.

Variations of the percent cover by sessile-benthic categories between the baseline survey in 2000 and the present monitoring survey are presented in Figure 46. Live coral cover declined 67.8 % between surveys, from a mean of 36.4 % in 2000 to 11.7 % in 2008, a statistically significant reduction (ANOVA; p = 0.001) indicative of an acute degradation of the reef community. Increments of reef substrate cover by benthic algae and abiotic categories were measured during the 2008 monitoring survey.

Monitoring trends of mean substrate cover by coral species at Playa Mujeres Reef are shown in Figure 47. In 2000, Boulder Star Coral, *Montastraea annularis* complex with a mean cover of 21.5 % was the dominant coral species, representing then 53.6 % of the total cover by live corals. During the 2000 – 2008 period, *M. annularis* declined 88.4 %, strongly influencing the total live coral cover at the reef ecosystem level. Such pronounced reductions of live coral cover mirror somewhat the pattern observed for other coral reef systems in Puerto Rico associated with the regional bleaching event of 2005, particularly from the standpoint of the lack of other antropogenically induced stressors that could have had such profound effect in the community structure of this reef located in an offshore island.

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 43 fish species were present within belt-transect areas during the 2008 survey at Playa Mujeres Reef (Table 51). The mean abundance of individuals per transect was 129.6 Ind/30 m^2 (range: 88 - 148 Ind/30 m^2) and the mean number of species per transect was 20.4 (range: 15 – 31). Seven species represented approximately 71.6 % of the total individuals within belt-transect areas. The numerically dominant fish assemblage included the Blue and Brown Chromis (*Chromis cyanea, C. multilineata*), Bicolor Damselfish (*Stegastes partitus*), Bluehead and Creole Wrasse (*Thalassoma bifasciatum, Clepticus parrae*), Peppermint Goby (*Coryphopterus lipernes*) and Bermuda

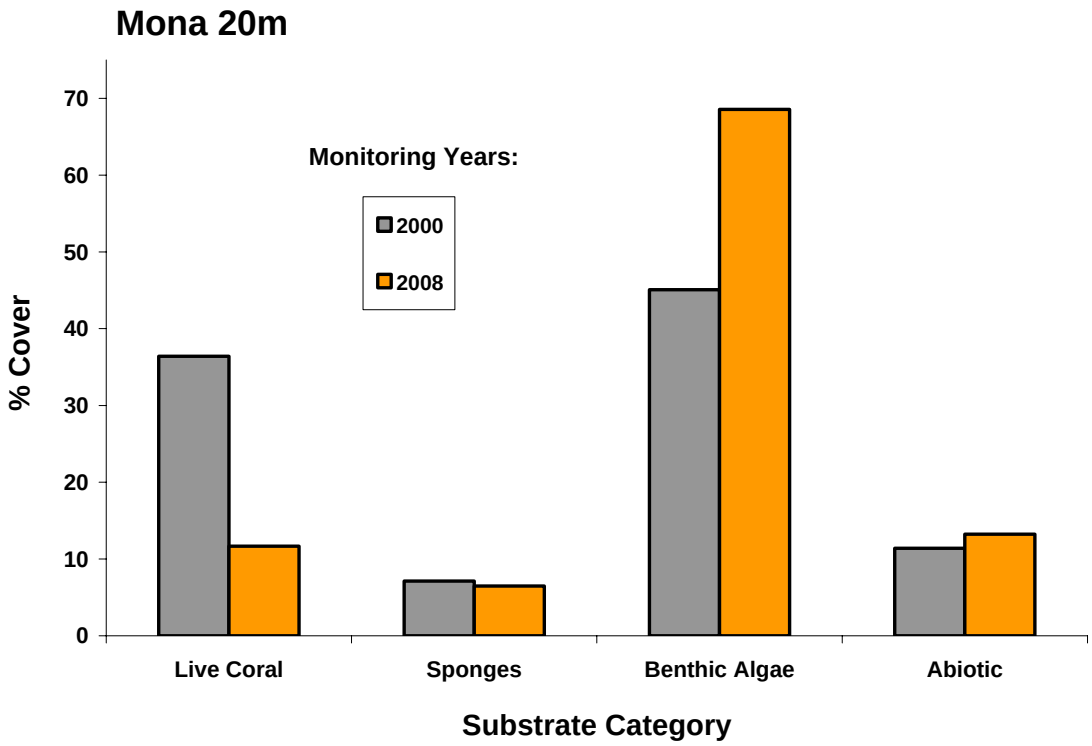


Figure 46. Monitoring trends (2000 and 2008) of mean substrate cover by sessile-benthic categories at Playa Mujeres Reef, Isla de Mona

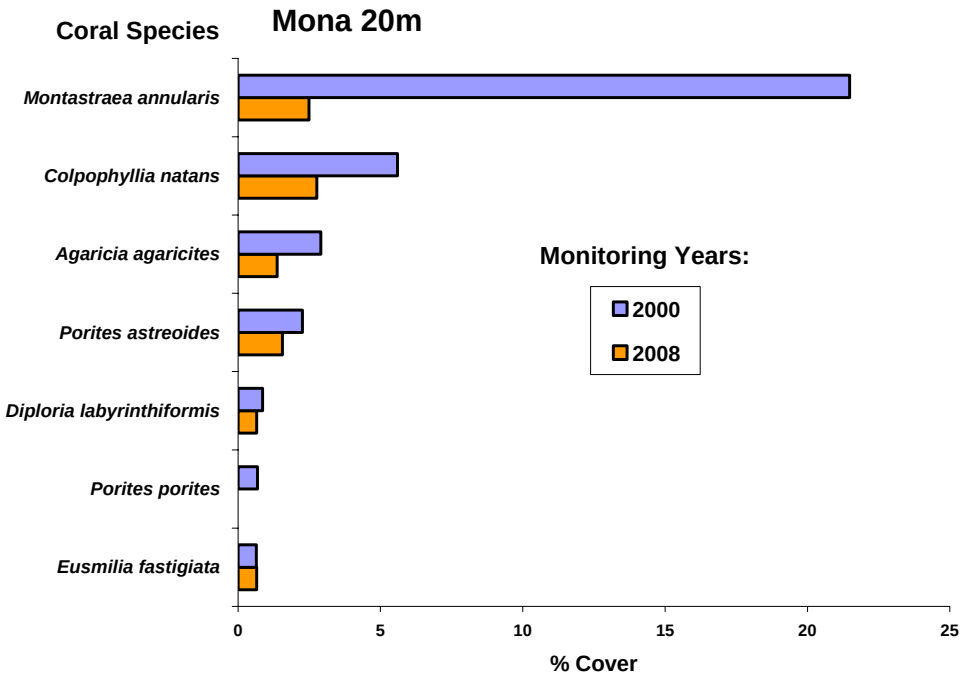


Figure 47. Monitoring trends (2000 and 2008) of mean substrate cover by coral species at Playa Mujeres Reef, Isla de Mona

Table 51. Taxonomic composition and abundance of fishes within belt-transects at Mujeres Reef, Isla de Mona. 20 m. June, 2008

Depth: 20m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Chromis cyanea	Blue Chromis	32	50	6	30	40	**31.6**
Stegastes partitus	Bicolor Damselfish	28	12	32	28	14	**22.8**
Thalassoma bifasciatum	Bluehead Wrasse	13	16	6	6	16	**11.4**
Coryphopterus lipernes	Pepperming Goby	13	10	10	8	7	**9.6**
Chromis multilineata	Brown Chromis	15	6		7	5	**6.6**
Clepticus parrae	Creole Wrasse	20	8		1		**5.8**
Kryphosus sectatrix	Bermuda Chub		2		7	16	**5**
Halichoeres garnoti	Yellowhead Wrasse	8		4	1	5	**3.6**
Lutjanus apodus	Schoolmaster		8		9		**3.4**
Chaetodon capistratus	Foureye Butterflyfish	3	4	6	1	2	**3.2**
Gramma loreto	Fairy Basslet			9	7		**3.2**
Gobiosoma evelynae	Sharknose Goby	2	2	1	5	5	**3**
Scarus iserti	Striped Parrotfish	1	6	1	1	2	**2.2**
Stegastes planifrons	Threespot Damselfish		5	5			**2**
Sparisoma aurofrenatum	Redband Parrotfish			3	6	1	**2**
Myripristis jacobus	Blackbar Soldierfish				7	2	**1.8**
Coryphopterus personatus	Masked Goby	5			1		**1.2**
Stegastes adustus	Dusky Damselfish		6				**1.2**
Bodianus rufus	Spanish Hogfish		5				**1**
Epinephelus guttatus	Red Hind	3	1				**0.8**
Cephalopholis cruentatus	Graysby		1	1	2		**0.8**
Halichoeres bivittatus	Slippery Dick	1			1	1	**0.6**
Haemulon flavolineatum	French Grunt		1		1	1	**0.6**
Acanthurus coeruleus	Blue Tang			2	1		**0.6**
Holocentrus adscensionis	Squirrelfish				1	2	**0.6**
Holocentrus rufus	Squirrelfish				2	1	**0.6**
Holocanthus tricolor	Rockbeauty	1			1		**0.4**
Melichthys niger	Black Durgeon	1			1		**0.4**
Scarus taeniopterus	Princess Parrotfish	1		1			**0.4**
Sparisoma radians	Bucktooth Parrotfish				1	1	**0.4**
Apogon townsendi	Belted Cardinalfish					2	**0.4**
Neoniphon marianus	Longjaw Squirrelfish	1					**0.2**
Coryphopterus glaucofraenum	Bridled Goby		1				**0.2**
Calamus calamus	Saucereye Porgy		1				**0.2**
Bothus lunatus	Peacock Flounder			1			**0.2**
Acanthemblemaria spinosa	Sinyhead blenny					1	**0.2**
Malacoctenus triangulatus	Saddled Belnny					1	**0.2**
Mycteroperca tigris	Tiger Grouper				1		**0.2**
Gobiosoma saucrum	Leopard Goby				1		**0.2**
Gymnothorax moringa	Spotted Moray				1		**0.2**
Epinephelus adscensionis	Rock Hind				1		**0.2**
Acanthostracion polygonia	Honeycomb Cowfish				1		**0.2**
Acanthemblemaria aspera	Roughhead Blenny				1		**0.2**
							0
	TOTAL INDIVIDUALS	148	145	88	142	125	129.6
	TOTAL SPECIES	17	19	15	31	20	20.4

Chub (*Kyphosus sectatrix*). Four species were present at all transects surveyed. Bicolor Damselfishes occupied demersal territories within the reef, whereas *Chromis* spp. and the Bluehead Wrasse were mostly aggregated in schools (guilds) over coral promontories. Schools of Creole Wrasse (*Clepticus parrae*), Black Durgon (*Melichthys niger*), Ocean Triggerfish (*Canthidermis sufflamen*) and Bermuda Chubs (*Kyphosus* sp.) were transient across reef survey sites, occupying mid-water depths in the water column. Sandy areas were the habitat of numerous individuals of the Sand Tilefish (*Malacanthus plumieri*).

The zooplanktivorous fish assemblage was prominent at Playa Mujeres Reef. Blue and Brown Chromis (*C. cyanea, C. multilineata*) and the Bicolor Damselfish were the main components of the zooplanktivorous assemblage. In addition, juvenile stages of many reef fishes could be associated with zooplankton as their primary food source before undertaking ontogenetic shifts in their diets. Opportunistic carnivores, which feed on benthic invertebrates and small fishes, such as wrasses (Labridae), gobies (Gobiidae), squirrelfishes (Holocentridae), grunts (Haemulidae), trumpetfishes (Aulostomidae) and small groupers (e.g. Coney, Red Hind, Graysbe) and snappers (Schoolmaster, Yellowtail) were present within and outside belt-transect areas.

Herbivorous taxa included mostly parrotfishes and doctorfishes (Acanthuridae). The Striped Parrotfish (*Scarus iserti*) was the most abundant herbivore (mean : 2.4 Individuals/30 m^2). The combined herbivorous assemblage represented less than 10 % of the total individuals within belt-transect areas. The Great Barracuda (*Sphyraena barracuda*) and Black and Bar Jacks (*Caranx lugubris, Carangoides ruber*) represented pelagic (piscivorous) predators. Demersal fish predators of larger reef invertebrates and fishes, such as large snappers and groupers were only represented by one juvenile Tiger Grouper (*Mycteroperca tigris*) during our snapshot survey at the shelf-edge reef off Playa Mujeres. As it applies for Playa de Pájaros Reef, this reef section of the shelf-edge was notorious for the high abundance of very large snappers and groupers during the previous decade. Thus, the drastic decline of such large predators represent major shifts in reef community structure.

Monitoring data on fish abundance and species richness within belt-transects is shown in Figure 48. Differences between surveys were minor and not statidtically significant (ANOVA; $p > 0.05$, Appendix 3-4).

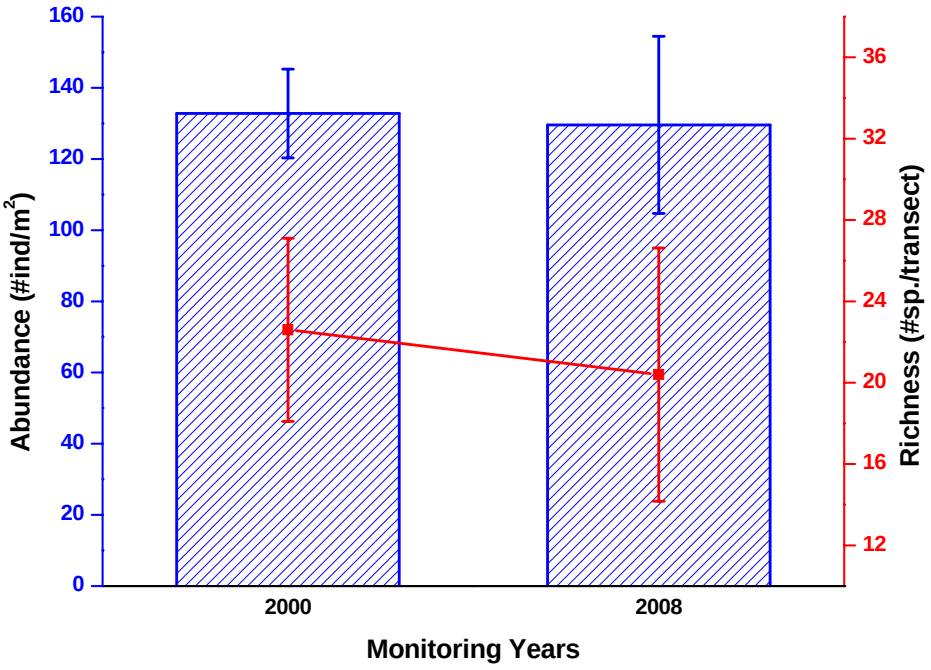
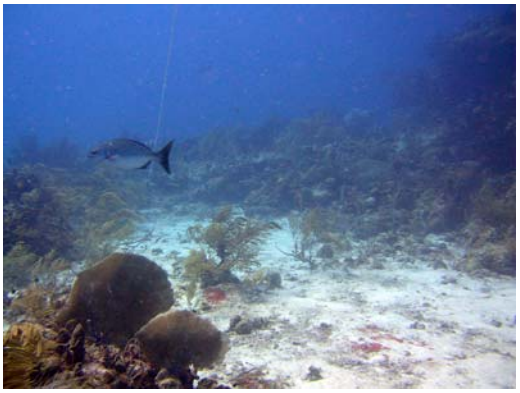
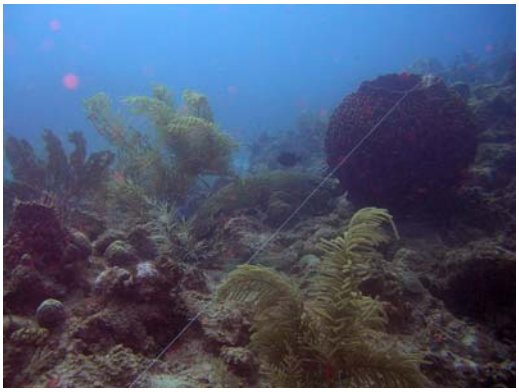
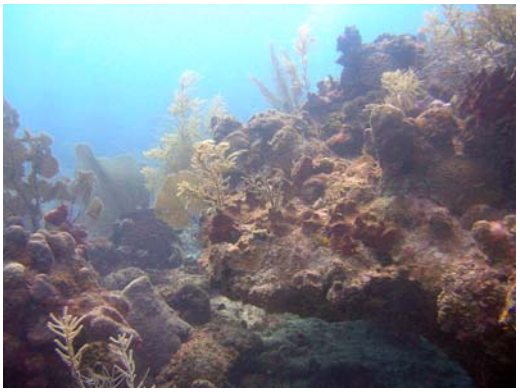


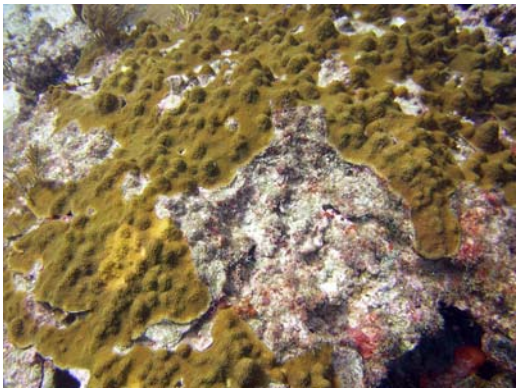
Figure 48. Monitoring trends (2000 and 2008) of fish species richness and abundance at Playa Mujeres Reef, Isla de Mona

Photo Album 13 (Mona 20m)
Playa Mujeres Reef









2.0 Las Carmelitas Reef

Physical Description of Las Carmelitas Reef

Las Carmelitas Reef is located due north of Playa Sardinera along the west coast of Isla de Mona (Figure 45). The reef extends from the shoreline to a depth of approximately 20 m. From the shoreline, a white sand shallow backreef lagoon with isolated scattered coral heads is protected from wave action by a fringe of emergent rocks, or reef crest. Many dead colonies of Elkhorn Coral (*Acropora palmata*) are found along the margin of the backreef lagoon close to the reef crest. Bundles of fleshy algae, sea urchins (*Echinometra* sp.) and encrusting biota cover most of the rock substrate, but stony coral growth at the reef crest is minimal. Seaward from the reef crest, a series of rock outcrops were found to a depth of approximately 10 m. This zone is exposed to heavy wave action and sand movement. Encrusting zoanthids (*Palythoa sp.*) and turf algae colonize most of the rock outcrop surface. Few scattered stony coral colonies grow encrusted to the walls of rock outcrops. Also, small mounds of the Mustard Hill Coral, *Porites astreoides* were observed within this zone. Below a depth of approximately 10 m, the reef slope takes on a diffuse spur-and-groove pattern as wide and deep sand channels separate the gently sloping hard bottom terraces where mostly massive and encrusting stony corals grow. The reef ends into a fine sand bottom that leads to the shelf-edge. Permanent transects were installed along the edges of reef spurs at a depth of 8.5 m.

2.1 Sessile-Benthic Reef Community

During the baseline survey in 2000, the widespread incidence of diseased stony corals was the most striking feature of Las Carmelitas Reef. Diseased corals included the Boulder Star Coral (*Montastraea annularis*) and the Symmetrical Brain Coral (*Diploria strigosa*). The disease showed up as white/yellowish rings (or bands) usually on top of the coral colonies, leaving the inside sections of the rings exposed to algal growth. During our first monitoring survey of Las Carmelitas Reef live coral cover averaged 10.2 % (range: 4.2 - 20.5 % %) along permanent transects (Table 52). Coral growth was observed mostly along the edges of the spur walls and within crevices and other hard ground substrate depressions. This is an indication that strong wave action is probably an important factor regulating coral growth. Reef overhangs, largely associated with dead coral skeletons averaged 13.2 % and contributed to an average rugosity of 2.82 m.

Table 52. Percent reef substrate cover by sessile-benthic categories at Las Carmelitas Reef, Isla de Mona, June 2008.

Depth: 10 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	2.44	5.65	2.85	2.52	0.66	**2.82**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	14.95	18.43	13.15	8.55	10.98	**13.21**
Total Abiotic	14.95	18.43	13.15	8.55	10.98	**13.21**
Benthic Algae						
Turf-mixed assemblage	78.70	50.38	73.00	72.02	28.80	**60.58**
Fleshy	2.15	9.63	0.44	3.36	47.94	**12.70**
Calcareous			1.64			**0.33**
Total Benthic Algae	80.85	60.01	75.08	75.38	76.74	**73.61**
Cyanobacteria			4.20	4.40	5.25	**2.77**
Zoanthids		1.08				**0.22**
Live Stony Corals						
Porites astreoides	1.85	2.42	3.42	3.68	4.78	**3.23**
Montastraea annularis (complex)		12.12		1.01		**2.63**
Montastraea cavernosa		3.59	2.33	1.91		**1.57**
Agaricia agaricites	1.13	1.47		1.20	0.26	**0.81**
Agaricia tenuifolia			1.86			**0.37**
Porites divaricata				1.69		**0.34**
Siderastrea siderea				1.60		**0.32**
Agaricia grahamae	0.68	0.90				**0.32**
Diploria strigosa					1.45	**0.29**
Eusmilia fastigiata	0.57					**0.11**
Colpophyllia natans				0.56		**0.11**
Madracis decactis					0.53	**0.11**
Total Stony Corals	4.23	20.5	7.61	11.65	7.02	**10.20**
Recently dead coral	32.64	9.06	33.77			**15.09**

Turf algae was the dominant category in terms of reef substrate cover during the 2008 survey at Las Carmelitas with a mean cover of 60.6 % (range: 28.8– 78.7 %). Fleshy algae contributed an additional 12.7 % for a total cover by benthic algae of 73.6 %. Cyanobacterial films were present over the reef with an average cover of 2.8 %.

A total of 20 species of scleractinian corals and one hydrocoral (*Millepora* sp) were identified from Las Carmelitas Reef (Table 52). Mustard Hill Coral (*Porites astreoides*) was the dominant species in terms of linear cover with a mean of 3.2 % (range : 1.8 – 4.8 %) and was the only coral species present in the five transects surveyed. Boulder Star Coral (*Montastraea annularis*) ranked second in reef substrate cover with a mean of 2.6 % and was present in only two transects. The combined cover of the aforementioned species represented 57.4 % of the total cover by live corals. Recently dead coral, represented quantitatively by turf algae averaged 15.1 % in transects surveyed.

Monitoring trends of sessile-benthic categories at Las Carmelitas Reef are shown in Figure 49. Live coral cover declined 59.8 %, from 25.4 % in 2000, to 10.2 % in 2008. The difference of live coral cover between surveyes was statistically significant (ANOVA; $p = 0.017$, Appendix 2) and represents a major degradation of reef community structure. The high prevalence of recently dead coral from the 2008 monitoring survey suggests that the decline of live coral from Las Carmelitas Reef is a relatively recent phenomena and mostly related to the massive coral mortality associated with the 2005 regional coral bleaching event (García-Sais et al., 2006, García-Sais et al., 2008; Rothenberger et al., 2008). Consisten with the pattern observed in other reefs around Puerto Rico and the U. S. Virgin Islands, the coral species that suffrered the highest mortality between monitoring surveys at Las Carmelitas Reef was the Boulder Star Coral, *Montastraea annularis* complex (Figure 50). During the baseline survey of 2000, M. annularis had a mean cover of 17.2 %. The mean cover of 2.6 in 2008 represents a decline of 84.9 %, consistent with the reduction measured at Playa Mujeres during the 2008 monitoring survey. Boulder Star coral was the dominat coral species of Las Carmelitas Reef, where it was present in all five transects and represented 70.0 % of the total live coral. At present, live colonies were only found along two transects and with only 1.0 % in one of the transects. Lettuce Coral, *Agaricia agaricites*, Boulder Brain Coral, *Colpophyllia natans*, Symmetrical Brain Coral, *Diploria strigosa* and Branched Finger Coral, *Porites furcata* also showed marked reductions of reef substrate cover beween monitoring surveys at Las Carmelitas. Conversely, a trend of increasing cover was measured for Mustard Hill Coral, *Porites astreoides* (Figure 50).

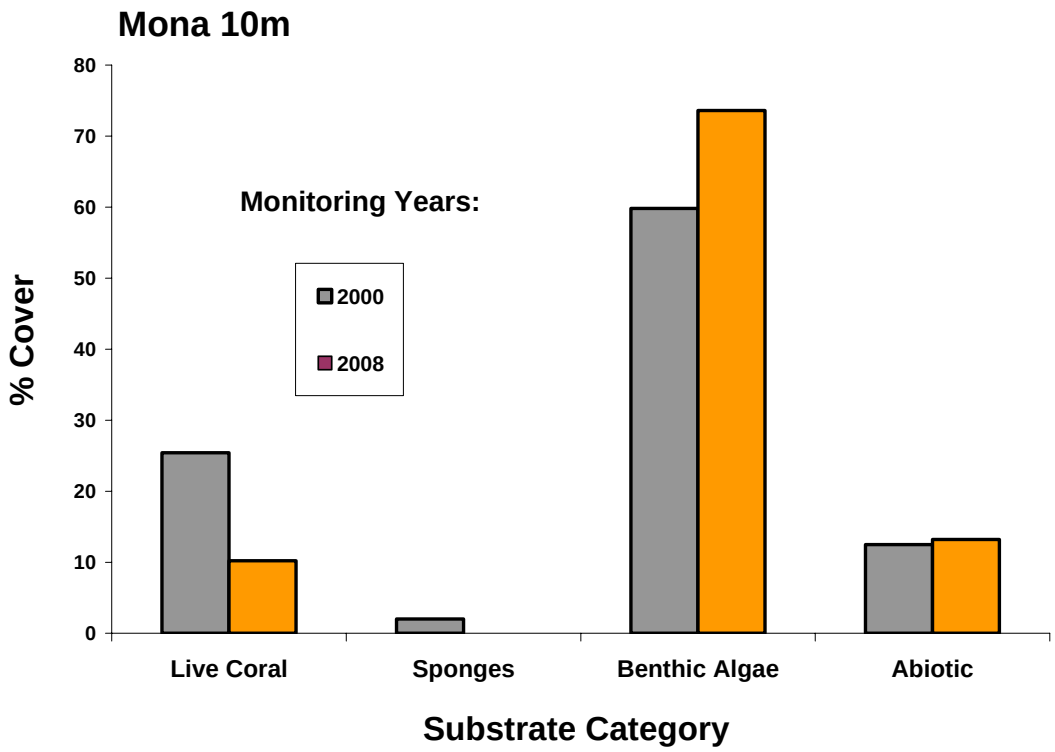


Figure 49. Monitoring trends (2000 and 2008) of mean substrate cover by sessile-benthic categories at Las Carmelitas Reef, Isla de Mona

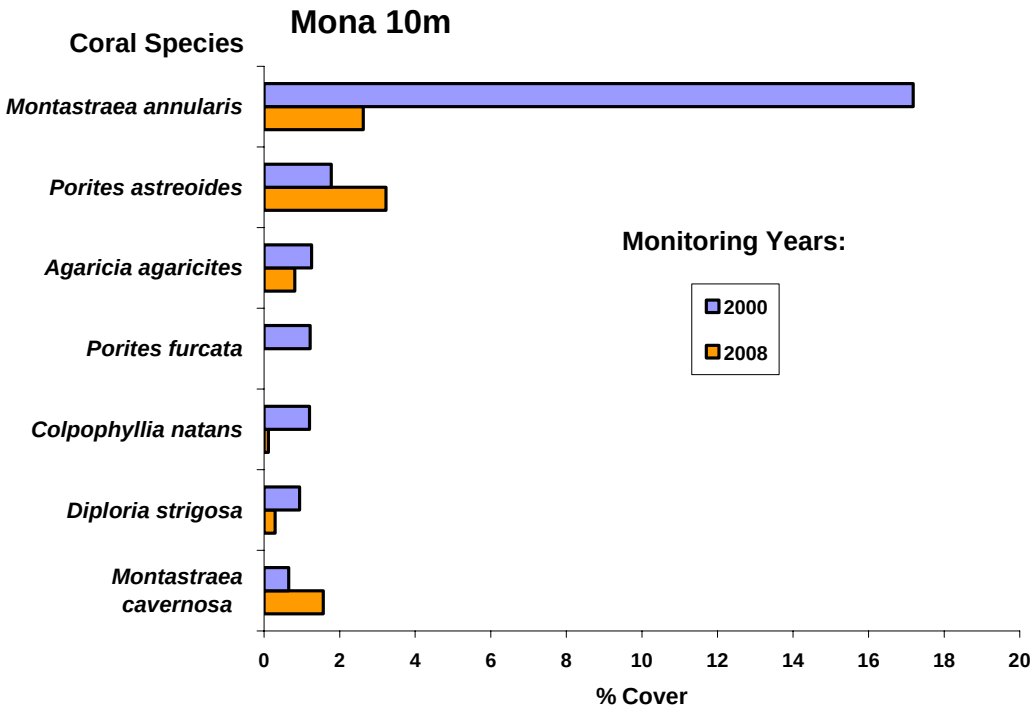


Figure 50. Monitoring trends (2000 and 2008) of mean substrate cover by coral species at Las Carmelitas Reef, Isla de Mona

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 65 fish species were identified during our visual surveys at Las Carmelitas Reef, 36 of which were present within belt-transect areas (Table 53). The mean number of species per transect was 20.2 (range 15 – 28), and the mean abundance of individuals was 113.0 Ind/30 m^2 (range: 57 - 168 Ind/30 m^2). Seve species represented approximately 77.3 % of the total individuals within belt-transect areas. The numerically dominant fish assemblage included the Fairy Basslet (*Gramma loreto*), Bluehead and yellowhead Wrasses (*Thalassoma bifasciatum, Halichoeres garnoti*), Bicolor Damselfish (*Stegastes partitus*), Blue and Brown Chromis (*Chromis cyanea*, *C. multilineata*), and Sharknose Goby (Gobiosoma evelynae). These seven species were present at all transects surveyed. Bicolor Damselfishes occupied demersal territories within the reef, whereas *Chromis* spp. and the Bluehead Wrasse were mostly aggregated in schools (guilds) over coral promontories in the reef. Fairy Basslets were abundant under coral ledges at the walls of the reef spurs. Schools of Creole Wrasse (*Clepticus parrae*), Black Durgon (*Melichthys niger*), Bar Jacks (*Carangoides ruber*) and Bermuda Chubs (*Kyphosus* sp.) were transient across reef survey sites, occupying mid-water depths in the water column. Sandy areas were colonized by the Sand Tilefish (*Malacanthus plumieri*).

Opportunistic carnivores, which feed on small benthic invertebrates, such as wrasses (Labridae), gobies (Gobiidae), squirrelfishes (Holocentridae), grunts (Haemulidae), trumpetfishes (Aulostomidae) and small groupers (e.g. Coney, Red Hind, Graysbe) and snappers (Schoolmaster, Yellowtail) were common. The zooplanktivorous fish assemblage, represented by the Bicolor Damselfish and the Blue and Brown Chromis was also prominent. In addition, juvenile stages of many reef fishes use zooplankton as their primary food source before undertaking ontogenetic shifts in their diets.

Herbivorous taxa included mostly parrotfishes and doctorfishes (Acanthuridae). The combined herbivorous assemblage represented less than 10 % of the total individuals within belt-transect areas. The Great Barracuda (*Sphyraena barracuda*) and the Bar Jack (*Carangoides ruber*) represented pelagic (piscivorous) predators. Demersal fish predators of larger reef invertebrates and fishes were represented by one juvenile Tiger Grouper (*Mycteroperca venenosa*) and an adult Red Hind (*Epinephelus guttatus*) during our snapshot survey at Las Carmelitas Reef. Motile megabenthic invertebrates were not observed within belt-transect areas. Figure 51 shows the fluctuations between monitoring surveys. Diffreneces were not statistically significant (ANOVA; $p > 0.05$).

Table 53. Taxonomic composition and abundance of fishes within belt-transects at Las Carmelitas Reef, 10 m, Isla de Mona. June, 2008

Depth: 10m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Gramma loreto	Royal Gramma	15	38	50	30	6	**27.8**
Thalassoma bifaciatum	Bluehead Wrasse	17	46	32	7	17	**23.8**
Stegastes partitus	Bicolor Damselfish	14	5	6	13	6	**8.8**
Gobiosoma evelynae	Sharknose Goby	6	15	8	10	2	**8.2**
Chromis cyanea	Blue Chromis	4	6	10	18	1	**7.8**
Chromis multilineata	Brown Chromis	4	4	15	5	5	**6.6**
Halichoeres garnoti	Yellowhead Wrasse	3	6	5	3	5	**4.4**
Stegastes adustus	Dusky Damserfish	8	1	2		2	**2.6**
Stegastes leucostictus	Beaugregory		1	3	2	5	**2.2**
Coryphopterus personatus	Masked Goby		10				**2.0**
Scarus iserti	Striped Parrotfish	1	4	4			**1.8**
Acanthurus coeruleus	Blue Tang	1	2	3	2		**1.6**
Malacoctenus triangulatus	Saddled Blenny		4	1	1	2	**1.6**
Sparisoma viride	Stoplight Parrotfish	2	1	2	1	2	**1.6**
Sparisoma radians	Bucktooth Parrotfish	1	2		4		**1.4**
Microspathodon chrysurus	Yellowtail Damselfish	1	1	4		1	**1.4**
Bodianus rufus	Spanish Hogfish	1	4				**1.0**
Holocentrus adscensionis	Squirrelfish	1	3	1			**1.0**
Canthigaster rostrata	Caribbean Puffer	1	1	1	2		**1.0**
Acanthurus bahianus	Ocean Surgeonfish	2				1	**0.6**
Holacanthus tricolor	Rock Beauty	1	2				**0.6**
Haemulon flaveolineatum	French Grunt		2	1			**0.6**
Myripristis jacobus	Blackbar Soldierfish		2	1			**0.6**
Epinephelus adscencionis	Rock Hind		2				**0.4**
Pempheris schomburgki	Glassy Sweeper		2				**0.4**
Chaetodon striatus	Banded Butterflyfish				2		**0.4**
Halichoeres maculipinna	Clown Wrasse	1				1	**0.4**
Cephalopholis cruentatus	Graysby		1		1		**0.4**
Neoniphon marianus	Longspine Squirrelfish	1	1				**0.4**
Stegastes planifrons	Threespot Damselfish	1		1			**0.4**
Chaetodon capistratus	Foureye Butterflyfish	1					**0.2**
Abudefduf saxatilis	Sargent Major	1					**0.2**
Lutjanus apodus	Schoolmaster		1				**0.2**
Clepticus parrae	Creole Wrass		1				**0.2**
Halichoeres bivittatus	Slippery Dick				1		**0.2**
Epinephelus guttatus	Red Hind					1	**0.2**
	TOTAL INDIVIDUALS	88	168	150	102	57	**113.0**
	TOTAL SPECIES	23	28	19	16	15	**20.2**

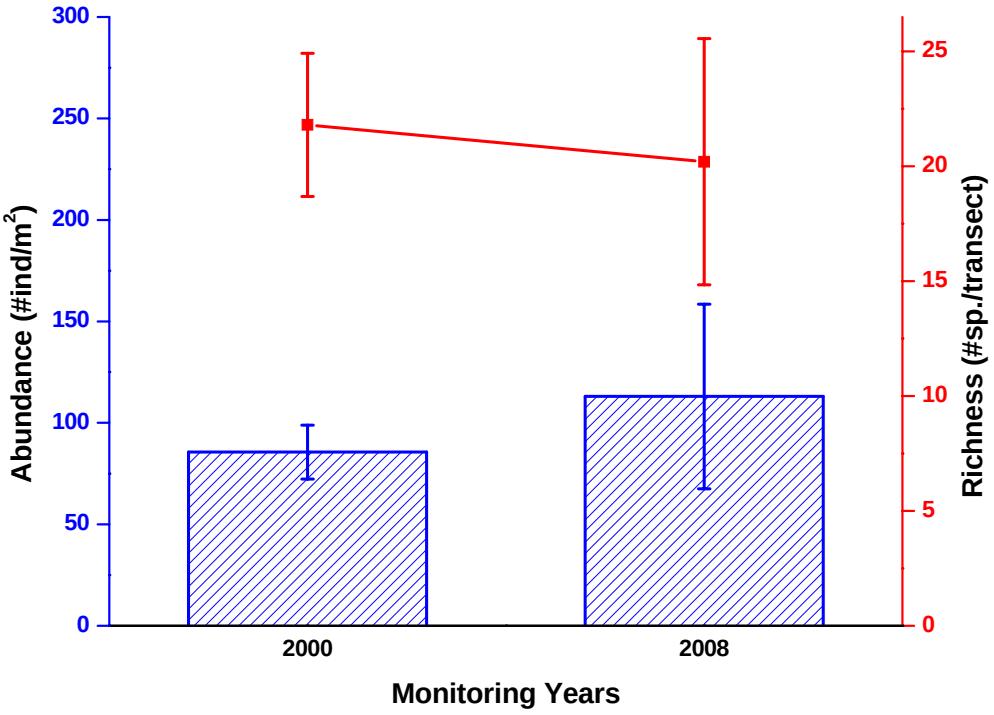
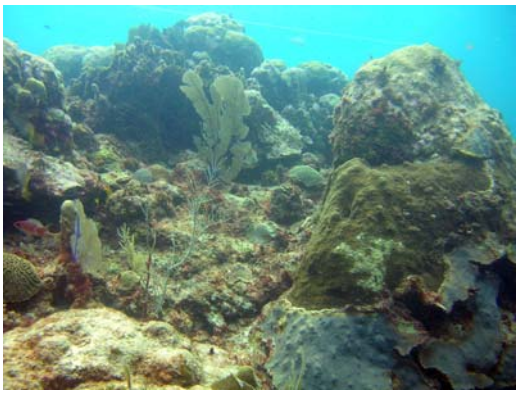
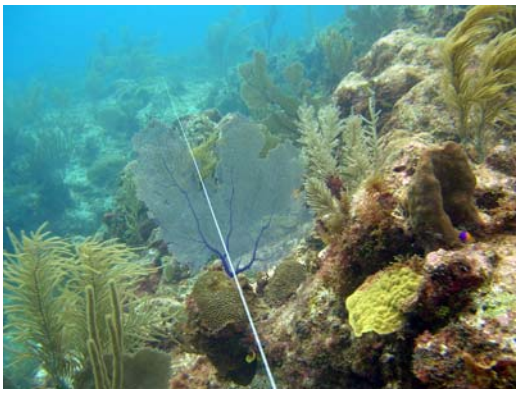
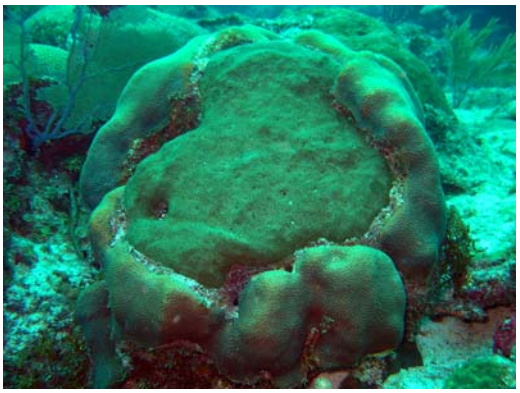


Figure 51. Monitoring trends (2000 and 2008) of fish species richness and abundance at Carmelitas Reef, Isla de Mona

Photo Album 14 (Mona 15m)
Carmelitas Inner Shelf Reef







3.0 Playa Sardinera Reef

A series of five permanent transects were established at a depth of 30 m off Playa Sardinera in a colonized pavement environment with scattered coral growth. The present 2008 characterization represents the baseline survey of the reef community at Isla de Mona

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3.1 Sessile-benthic Community

A total of 19 scleractinian corals, two hydrocorals and one antipatharian (black coral) were identified from Playa Sardinera Reef at a depth of 30 m. Eleven species of scleractinian corals were intercepted by line transects (Table 54), with a mean reef substrate cover of 5.4 % (range: 0.8 – 13.5 %). Stony corals occurred mostly as isolated colonies, contributing moderate topographic relief. Boulder Star Coral, *Montastraea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 2.7 % (range: 0 – 10.0 %), representing 50.4 % of the total cover by stony corals. Seven out of the 11 coral species were represented by only one colony within transects. Coral species represented in at least two transects included the Boulder Star Coral (*M. annularis*), Great Star Coral (*M. cavernosa*), and Lettuce Coral (*Agaricia agaricites*). Hydrocorals were represented by the rosy Lace Coral, *Stylaster roseus* and the Fire Coral, *Millepora sp*. The Wire Black Coral, *Stichopathes lutkeni* was common. One colony of *C. natans* was affected by what appeared to be a" white plague" disease.

Soft corals (gorgonians) were present in moderate abundance, with a mean of 9.2 colonies per transect (range:5 – 14 col/transect). The most common species included Sea Plumes *Pseudopterogorgia americana, Muriceopsis flavida, Pseudopterogorgia sp*, and the Common Sea Fan, *Gorgonia ventalina*.

Turf algae, a mixed assemblage of short red and brown macroalgae was the dominant category in terms of reef substrate cover during the 2008 baseline survey at Playa Sardinera with a mean cover of 50.4 % (range: 29.0– 57.7 %; see Table 54). Fleshy algae, mostly comprised by the Encrusting Fan Alga, *Lobophora variegata* were present in all five transects forming extensive carpets over the reef. The fleshy algae component contributed an additional 12.7 % for a total cover by benthic algae of 63.0 % (Table 54). Cyanobacterial films were highly prominent on all transects with an average cover of 8.3 %. Sponges were also present in all transects with an average cover of 7.6 %. The

Table 54. Percent reef substrate cover by sessile-benthic categories at Playa Sardinera, 30 m, Mona Island, June 2008

	Transects					
Depth: 30 m	**1**	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	2.23	3.14	2.80	3.94	3.56	**3.13**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	10.71	11.79	12.93	13.41	21.37	**14.04**
Sand		1.29	3.17			**0.89**
Gaps		0.96	1.70		0.52	**0.64**
Total Abiotic	10.71	14.04	17.80	13.41	21.89	**15.57**
Benthic Algae						
Turf-mixed assemblage	57.73	56.05	57.67	51.33	28.96	**50.35**
Fleshy	4.50	8.97	10.44	14.27	25.35	**12.71**
Total Benthic Algae	62.23	65.02	68.11	65.60	54.31	**63.05**
Cyanobacteria	12.92	10.72	9.40	4.87	3.54	**8.29**
Sponges	7.60	6.77	1.61	15.34	6.78	**7.62**
Encrusting gorgonians		0.23				**0.05**
Live Stony Corals						
Montastraea annularis	1.96		1.70		9.95	**2.72**
Diploria strigosa		2.89				**0.58**
Montastraea cavernosa	2.07		0.68			**0.55**
Porites astreoides	1.50					**0.30**
Isophyllia rigida					1.25	**0.25**
Agaricia lamarcki					1.14	**0.23**
Agaricia agaricites		0.30		0.81		**0.22**
Stephanocoenia michelini	1.06					**0.21**
Meandrina meandrites					0.93	**0.19**
Leptoseris cucullata			0.68			**0.14**
Madracis decactis					0.21	**0.04**
Total Stony Corals	6.59	3.19	3.06	0.81	13.48	**5.43**
Erect Gorgonians (# col/transect)	11	9	5	14	7	**9.2**

Stony Corals Outside Transects: *Diploria labyrinthiformis, Dichocoenia stokessi, Eusmilia fastigiata, Colpophyllia natans, Millepora sp., Stylaster roseus, Siderastrea radians, Stichopathes lutkeni, Agaricia tenuifolia*

main species included the Giant Barrel Sponge, *Xestospongia muta*, Rope Sponges, *Aplysina spp*., and *Agelas spp*.

Abiotic categories averaged 15.6 % at Playa Sardinera Reef. Reef overhangs, formed by what apper to be erosional features of the seafloor were the main abiotic component of the reef with an average of 14.0 %.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 65 fish species were identified during our visual surveys at Playa Sardinera Reef, 37 of which were present within belt-transect areas (Table 55). The mean number of species per transect was 18.4 (range 15 – 26), and the mean abundance of individuals was 215.0 Ind/30 m^2 (range: 130 - 2428 Ind/30 m^2). Seven species represented approximately 83.6 % of the total individuals within belt-transect areas. The numerically dominant fish assemblage included the Blue Chromis (*Chromis cyanea*), Bluehead and Creole Wrasses (*Thalassoma bifasciatum, Clepticus parrae*), Fairy Basslet (*Gramma loreto*), Bicolor Damselfish (*Stegastes partitus*), and the Masked and Sharknose Gobies (*Coryphopterus personatus, Gobiosoma evelynae*).

Zooplanktivorous fishes were the most prominent assemblage at Playa Sardinera Reef, represented by six out of the top seven species ranked in terms of numerical abundance within belt-transects. Opportunistic carnivores, which feed on small benthic invertebrates, such as wrasses (Labridae), gobies (Gobiidae), squirrelfishes (Holocentridae), grunts (Haemulidae), trumpetfishes (Aulostomidae) and small groupers (e.g. Coney, Red Hind, Graysbe) were common. Herbivorous taxa included mostly parrotfishes and doctorfishes (Acanthuridae). The combined herbivorous assemblage represented less than 10 % of the total individuals within belt-transect areas.

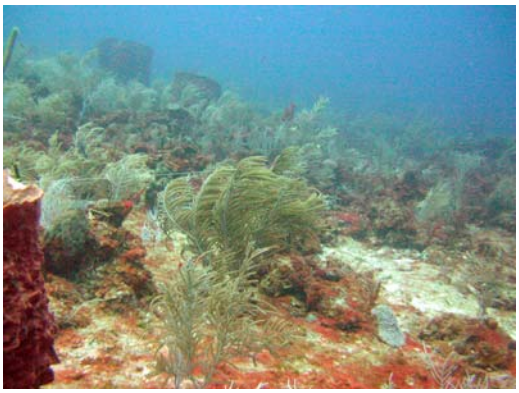
The Great Barracuda (*Sphyraena barracuda*) and the Black Jack (*Caranxs lugubris*) and Rainbow Runner (*Elagatis bipinnulata*) represented pelagic (piscivorous) predators. Demersal fish predators of larger reef invertebrates and fishes were represented by one an adult Red Hind (*Epinephelus guttatus*). Motile megabenthic invertebrates observed outside transect areas included the Coral Crab, *Carpilus corallinus* and the Queen Conch, *Strombus gigas*..

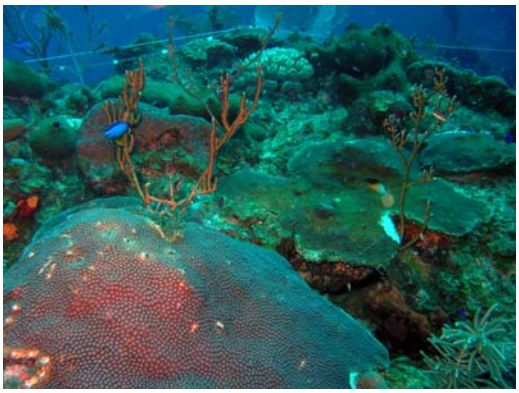
Table 55. Taxonomic composition and abundance of fishes within belt-transects at Playa Sardinera Reef, 30 m, Isla de Mona. June, 2008

Depth: 30m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Chromis cyanea	Blue Chromis	60	42	64	75	25	**53.2**
Clepticus parrae	Creole Wrasse	50		100	48	60	**51.6**
Stegastes partitus	Bicolor Damselfish	32	42	24	43	32	**34.6**
Gobiosoma evelynae	Sharknose Goby	11	18	12	13	21	**15.0**
Gramma loreto	Fairy Basslet	13	2	10	13	34	**14.4**
Coryphopterus personatus	Masked Goby			10	15	30	**11.0**
Thalassoma bifasciatum	Bluehead Wrasse	15	7	4	6	11	**8.6**
Halichoeres garnoti	Yellow head Wrasse	5	4	10	3	5	**5.4**
Scarus iserti	Striped Parrotfish		1	2	1	13	**3.4**
Coryphopterus lipernes	Peppermint Goby	1				14	**3.0**
Chromis multilineata	Brown Chromis				6	7	**2.6**
Sparisoma aurofrenatum	Redband Parrotfish	2	3	1	1		**1.4**
Cephalopholis cruentatus	Graysby	2		3		1	**1.2**
Chromis insolata	Sunshinefish			1	1	4	**1.2**
Acanthurus bahianus	Ocean Surgeon	1	1			1	**0.6**
Holacanthus tricolor	Rock Beauty	1			1	1	**0.6**
Serranus dewegeri	Vieja	1	2				**0.6**
Neoniphon marianus	Longjaw Squirrelfish		1			2	**0.6**
Pomacanthus paru	French Angelfish					3	**0.6**
Myripristis jacobus	Blackbar Soldierfish					3	**0.6**
Holocentrus adscensionis	Longjaw Squirrelfish	1			1		**0.4**
Sparisoma viride	Stoplight Parrotfish	1				1	**0.4**
Acanthostracion polygonia	Honeycomb Cowfish	1			1		**0.4**
Chaetodon sedentarius	Reef Butterflyfish		2				**0.4**
Bodianus rufus	Spanish Hogfish			1		1	**0.4**
Epinephelus guttatus	Red Hind				1	1	**0.4**
Chaetodon capistratus	Foureye Butterflyfish					2	**0.4**
Cephalopholis fulva	Coney		1				**0.2**
Chaetodon aculeatus	Longsnout Butterflyfish		1				**0.2**
Acanthurus coeruleus	Blue Tang		1				**0.2**
Malacoctenus triangulatus	Saddled Blenny		1				**0.2**
Canthigaster rostrata	Caribbean Puffer		1				**0.2**
Sparisoma radians	Bucktooth Parrotfish				1		**0.2**
Haemulon flavolineatum	French Grunt					1	**0.2**
Halichoeres maculipinna	Clown Wrasse					1	**0.2**
Sphyraena barracuda	Greate Barracuda					1	**0.2**
Caranx lugubris	Black Jack					1	**0.2**
	TOTAL INDIVIDUALS	**197**	**130**	**242**	**230**	**276**	**215**
	TOTAL SPECIES	**16**	**17**	**15**	**18**	**26**	**18.4**

Photo Album 15 (Mona 30m)
Playa Sardinera Reef





V Conclusions

The sessile-benthic community at the reef systems of Puerto Botes and Puerto Canoas (Isla Desecheo), Playa Mujeres and Las Carmelitas in Isla de Mona, Tourmaline Reef (Mayaguez), Cayo Coral (Guánica), West Reef (Caja de Muerto – Ponce), and Derrumbadero Reef (Ponce) all presented statistically significant differences of live coral cover between monitoring surveys.

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 2008 monitoring survey remained stable at 2007 levels on all reef sites.

The decline of (total) live coral cover at the reef community level during 2006 and now extending into 2008 was largely driven by mortality of Boulder Star Coral, *Montastraea annularis* (complex), a highly dominant species in terms of reef substrate cover and the principal reef building species. Corresponding increments of reef substrate cover by benthic algae, cyanobacteria and abiotic categories were measured.

Fish populations presented a general trend of declining species richness and abundance within belt-transects. Reductions of fish species richness were statistically significant in nine out of the 14 reef stations monitored. These included Tourmaline Reef (Mayaguez) at 10, 20 and 30 m; Puerto Botes Reef (Isla Desecheo) at 15 and 20 m; Tres Palmas Reef (Rincon) at 10 m; Derrumbadero Reef, West Reef and Cayo Coral. Likewise, statistically significant reductions of fish abundance were observed at Tres Palmas Reef -10 m, Derrumbadero Reef, West Reef and Cayo Coral.

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, and Nassau Groupers (*Mycteroperca venenosa, M. tigris, Epinephelus itajara, E. striatus*), and the Cubera, Dog and Mutton Snappers (*Lutjanus cyanopterus, L. jocu, L. analis*).

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Appendix 1. List of fish species identified at coral reef monitoring sites

M: Mayaguez; R: Rincon; D Isla Desecheo; CDM: Caja de Muerto; Derr: Derrumbadero-Ponce; Gua: Cayo Coral-Guanica

Total Species Database **REEF SITES**

Species	**Common Name**	**M30**	**M20**	**M10**	**R5**	**R10**	**R20**	**D30**	**D20**	**D15**	**CDM**	**Derr**	**Gua**
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

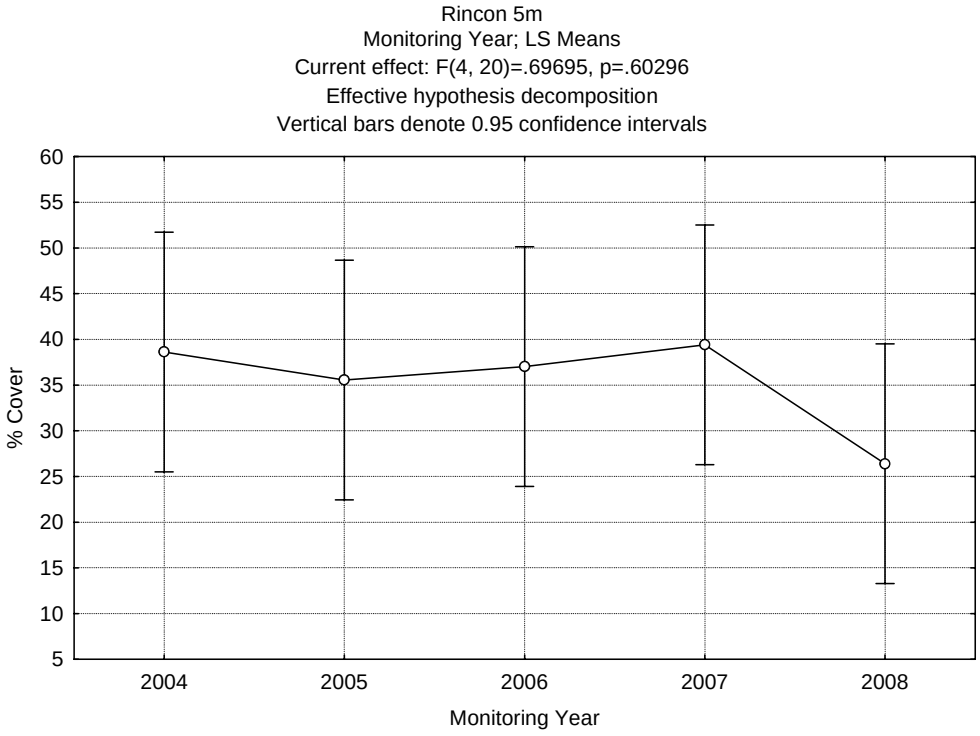
Species	Common Name	M30	M20	M10	R5	R10	R20	D30	D20	D15	CJm	Derr	Gua
Epinephelus itajara	Jewfish												x
Epinephelus striatus	Nassau Grouper	x	x					x	x				x
Equetus acuminatus	Highhat	x	x	x		x		x	x	x		x	x
Equetus lanceolatus	Jackknife Fish	x	x			x	x				x		
Equetus punctatus	Spotted Drum					x	x				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

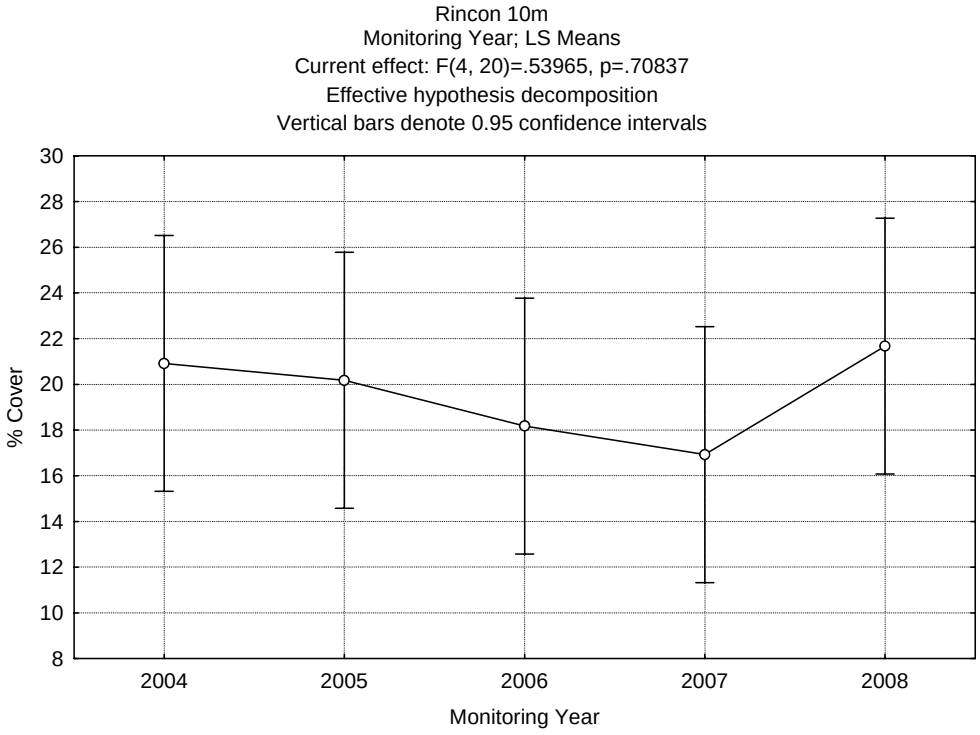
Species	Common Name	M30	M20	M10	R5	R10	R20	D30	D20	D15	CJm	Derr	Gua
Halichoeres sp.	wrasse					x							
Hemiramphus ballyhoo	Ballyhoo					x	x	x	x	x			x
Holacanthus ciliaris	Queen Angelfish	x	x	x		x	x	x	x	x		x	x
Holacanthus tricolor	Rock Beauty	x	x	x		x	x	x	x	x	x	x	x
Holocentrus adscensionis	Longjaw Squirrelfish			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					

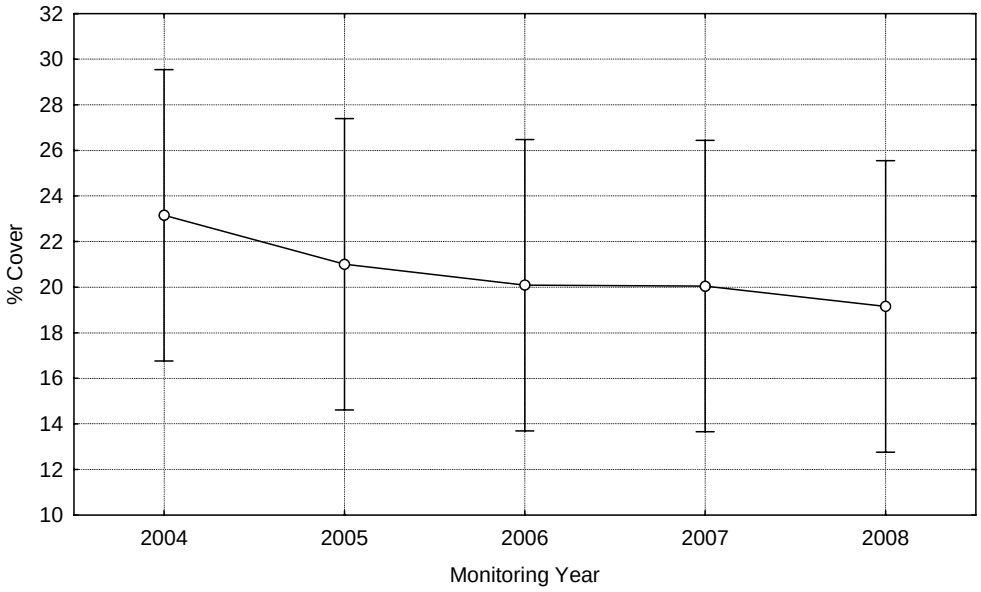
Species	**Common Name**	**M30**	**M20**	**M10**	**R5**	**R10**	**R20**	**D30**	**D20**	**D15**	**CJm**	**Derr**	**Gua**
Serranus tigrinus	Harlequin Bass	x	x	x		x	x	x	x	x	x	x	x
Sparisoma aurofrenatum	Redband Parrotfish	x	x	x	x	x	x	x	x	x	x	x	x
Sparisoma chrysopterum	Redtail Parrotfish						x	x	x				
Sparisoma 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 adustus	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			
	REEF TOTALS =	**114**	**101**	**99**	**65**	**109**	**83**	**95**	**79**	**76**	**88**	**86**	**99**

Appendix 2. Analysis of variance (ANOVA) procedure testing differences of live coral cover in annual monitoring surveys through 2008

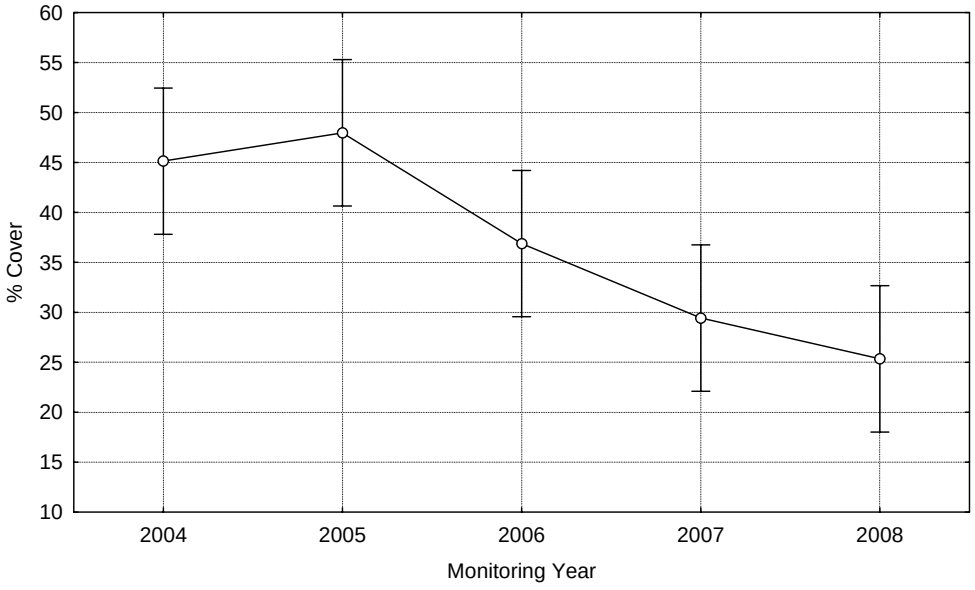


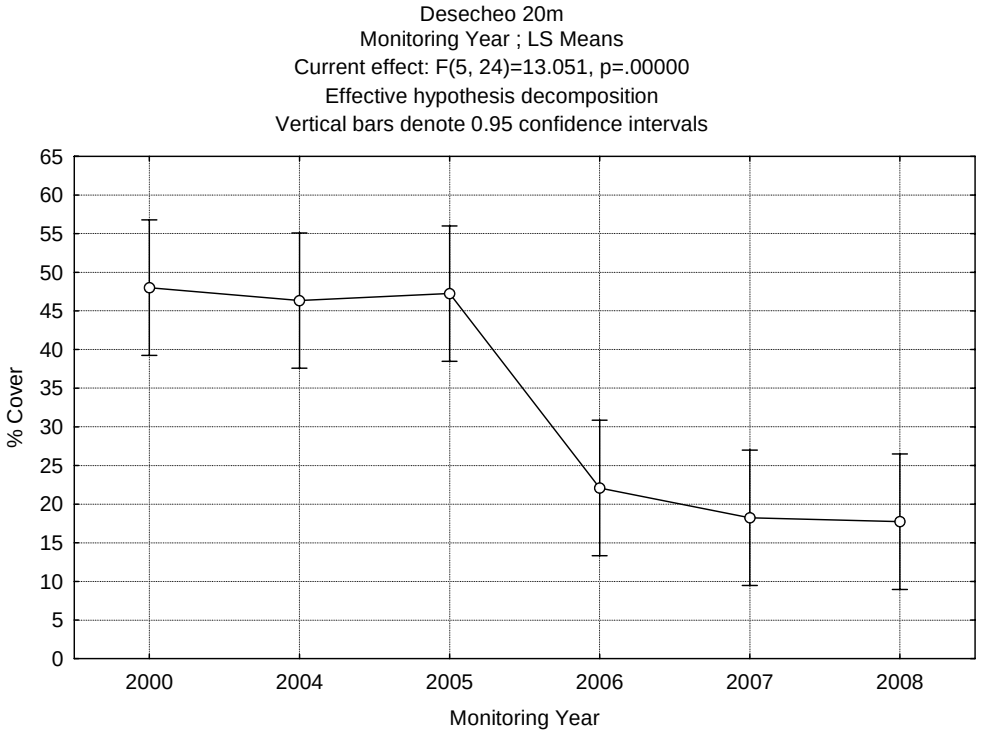


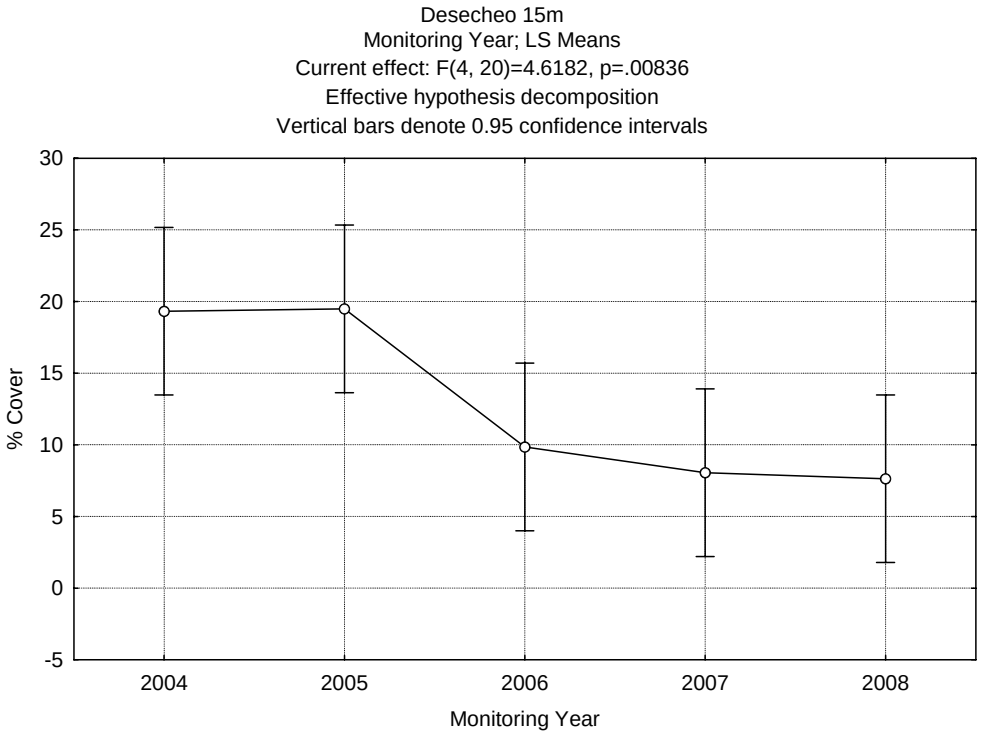
Rincon 20m
Monitoring Year; LS Means
Current effect: F(4, 20)=.24790, p=.90754
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals



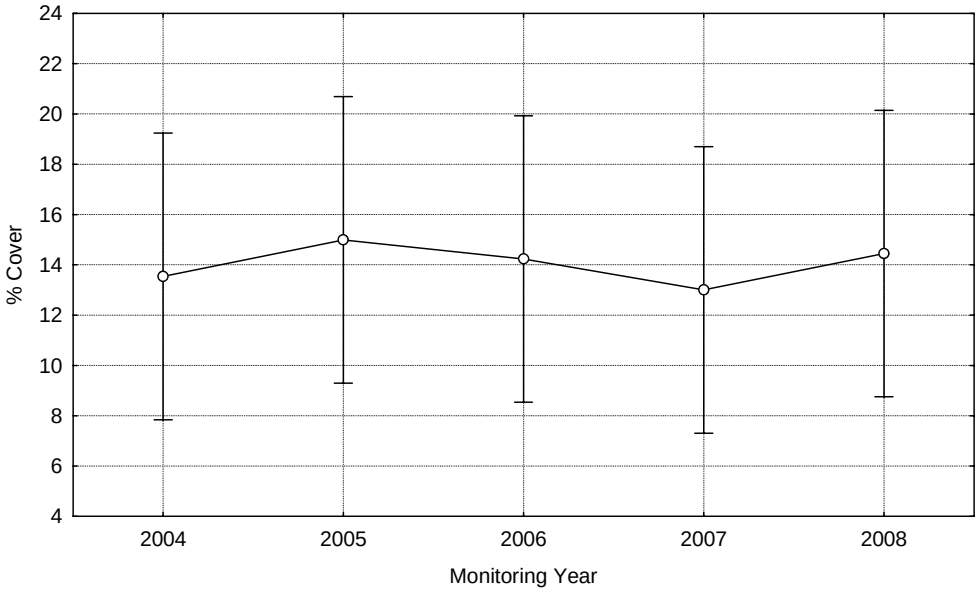
Desecheo 30m
Monitoring Year; LS Means
Current effect: F(4, 20)=7.6996, p=.00063
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals



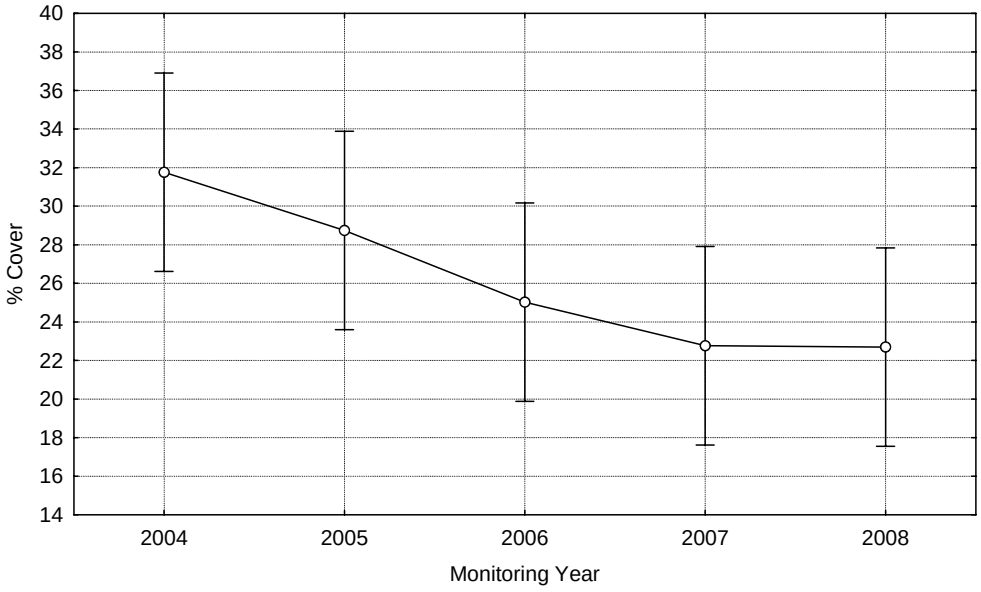

Desecheo 20m
Monitoring Year ; LS Means
Current effect: F(5, 24)=13.051, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Cover
65
60
55
50
45
40
35
30
25
20
15
10
5
0
2000
2004
2005
2006
2007
2008
Monitoring Year


Desecheo 15m
Monitoring Year; LS Means
Current effect: F(4, 20)=4.6182, p=.00836
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Cover
30
25
20
15
10
5
0
-5
2004
2005
2006
2007
2008
Monitoring Year

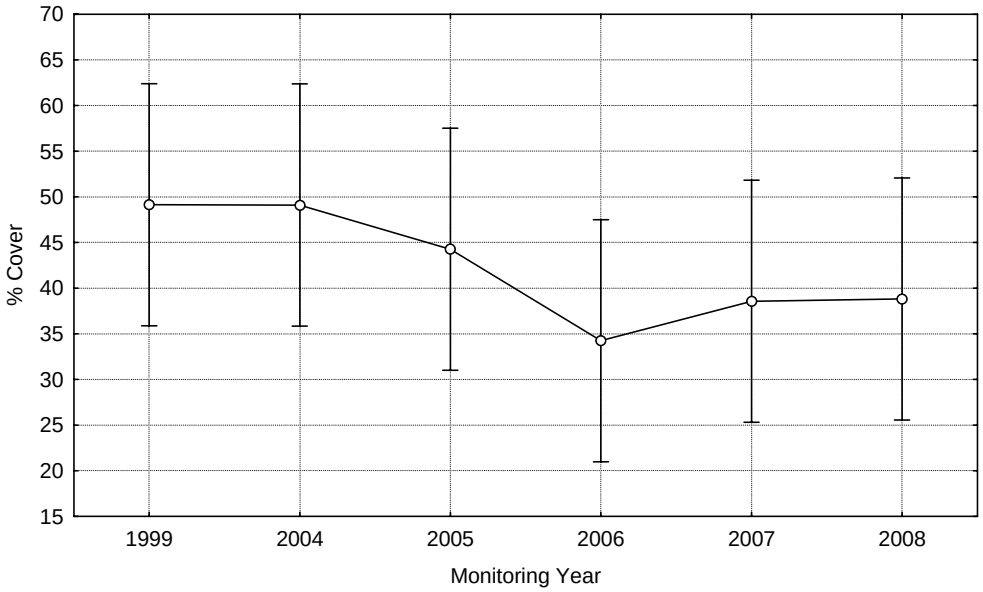
Mayaguez 30m
Monitoring Year; LS Means
Current effect: F(4, 20)=.08180, p=.98706
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals



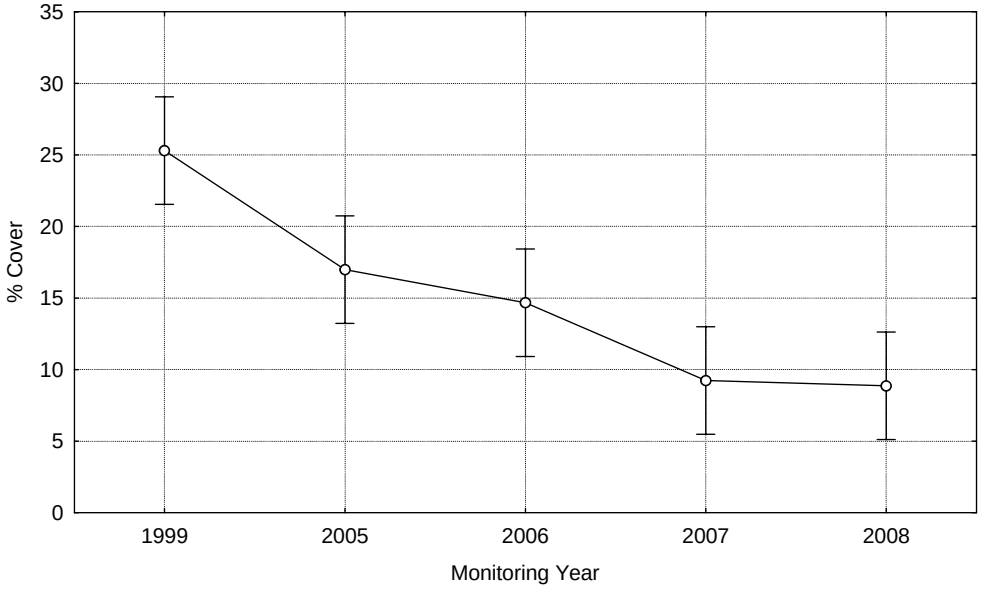
Mayaguez 20m
Monitoring Year; LS Means
Current effect: F(4, 20)=2.5819, p=.06853
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals



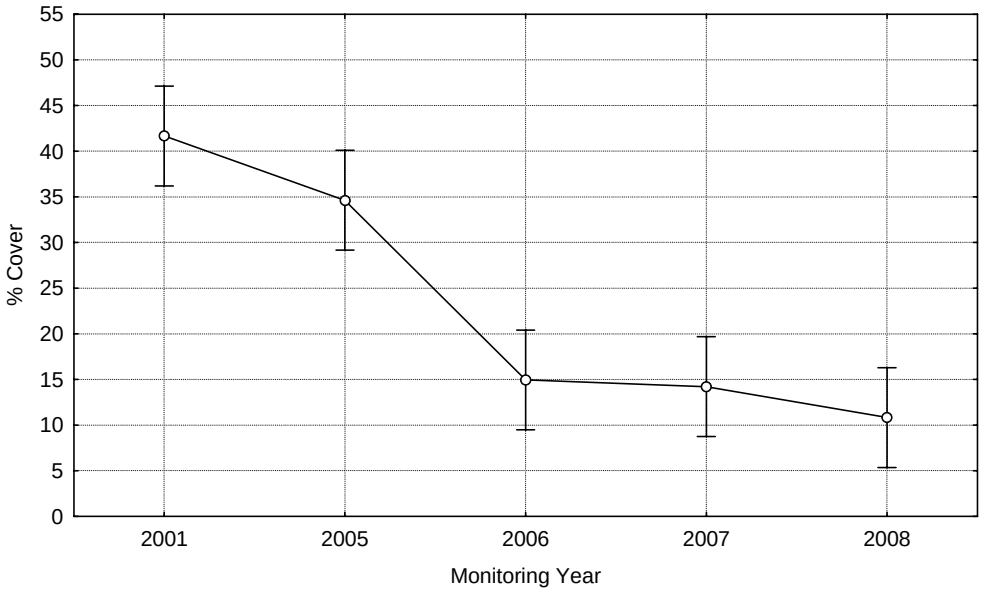
Mayaguez 10m
Monitoring Year; LS Means
Current effect: F(5, 24)=.91009, p=.49099
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals



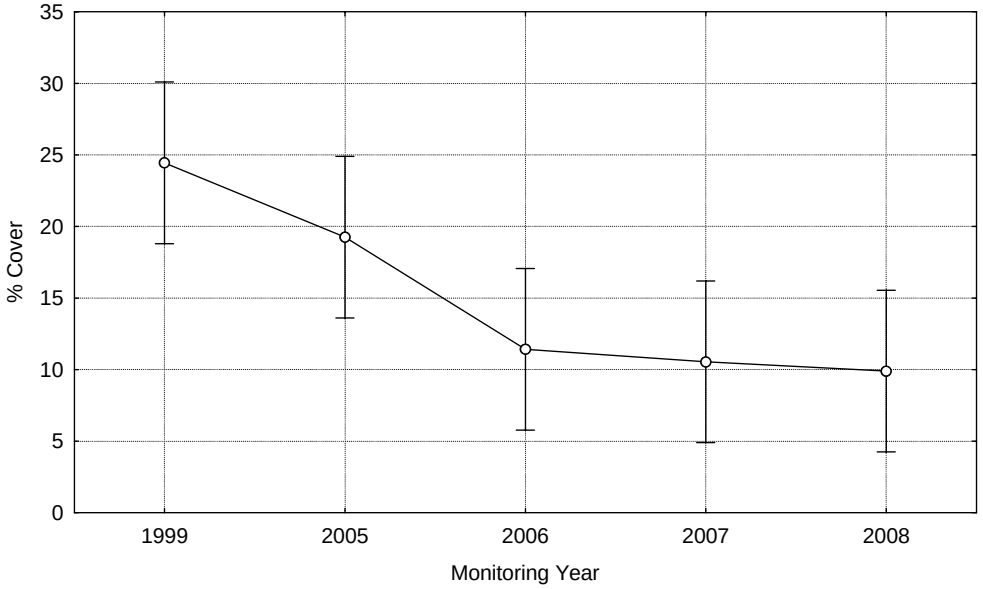
Guanica
"Monitoring Year"; LS Means
Current effect: F(4, 20)=13.967, p=.00001
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals

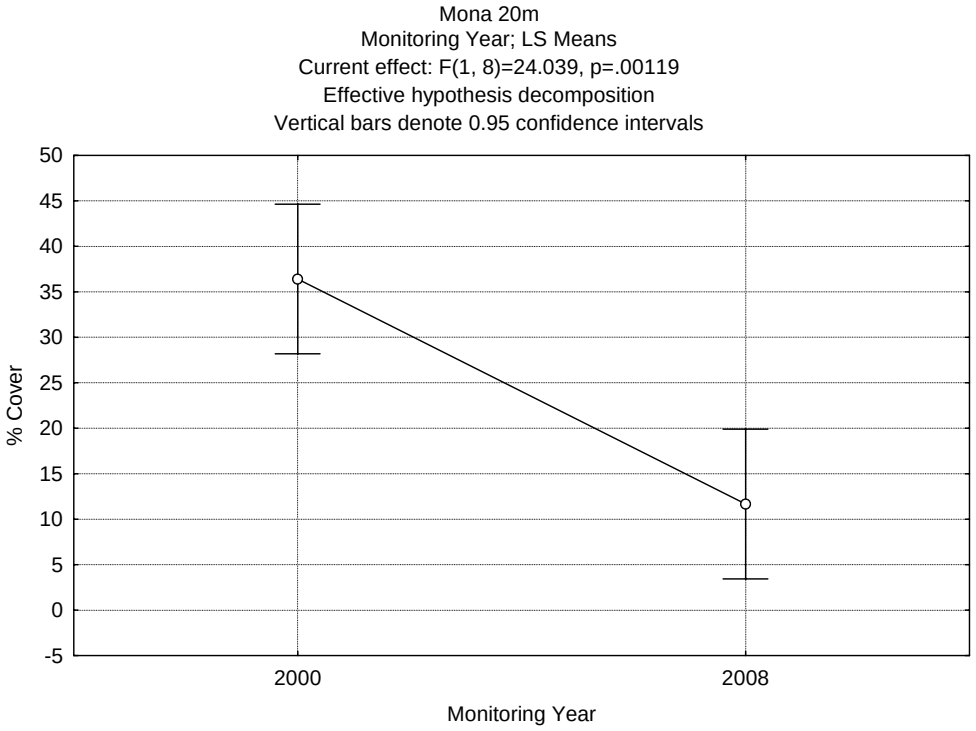


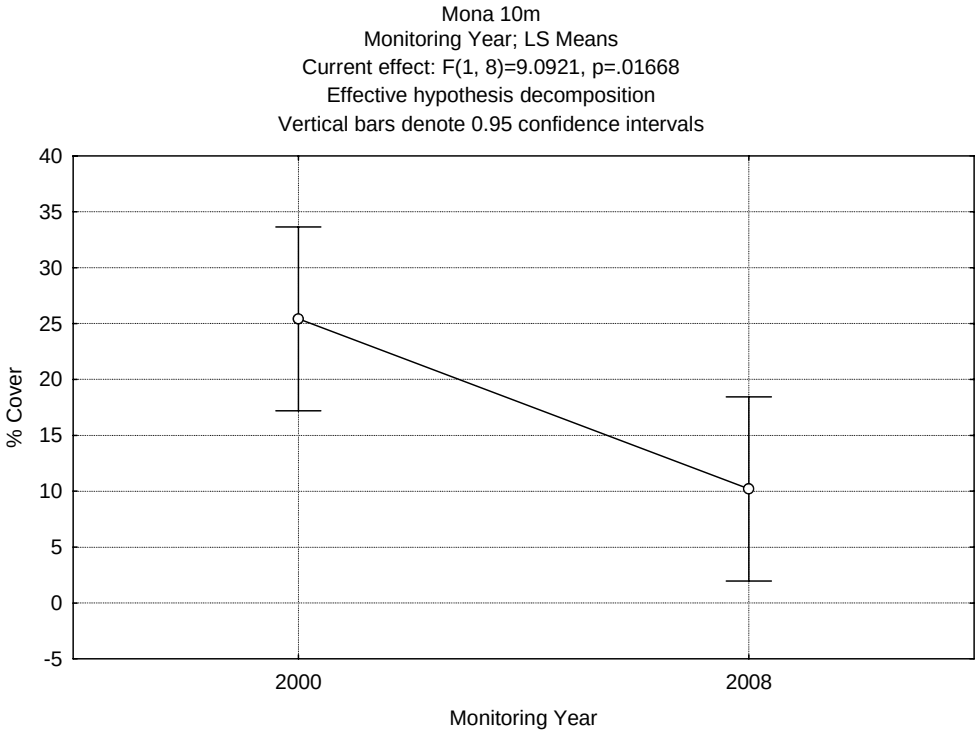
Derrumbadero
"Monitoring Year"; LS Means
Current effect: F(4, 20)=28.143, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals



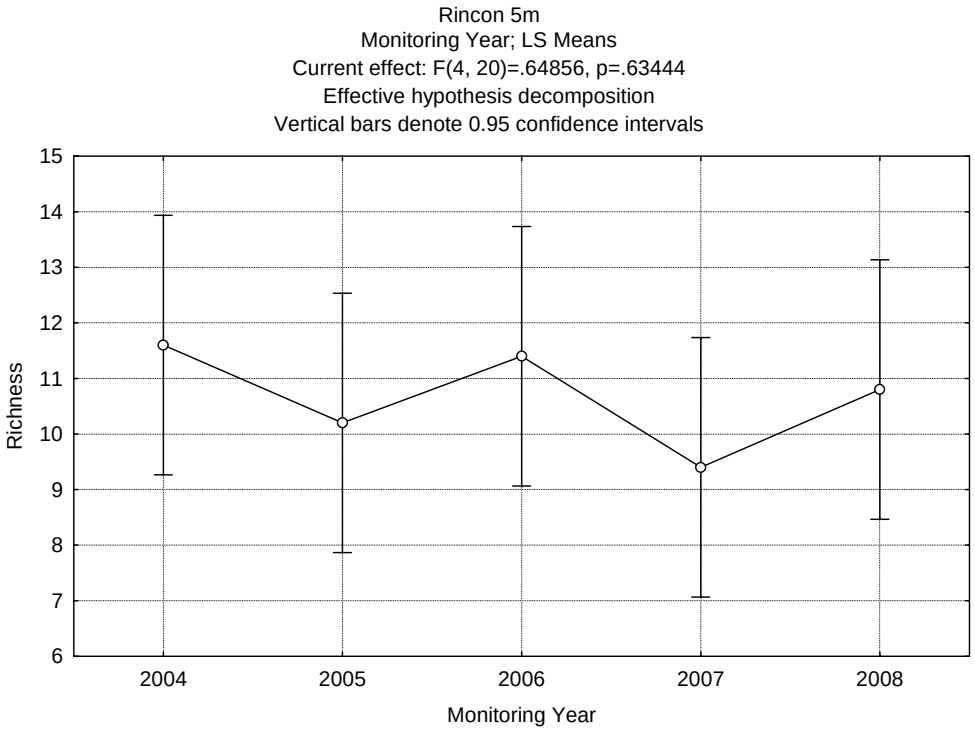
Caja de Muertos
"Monitoring Year"; LS Means
Current effect: F(4, 20)=5.6662, p=.00323
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals

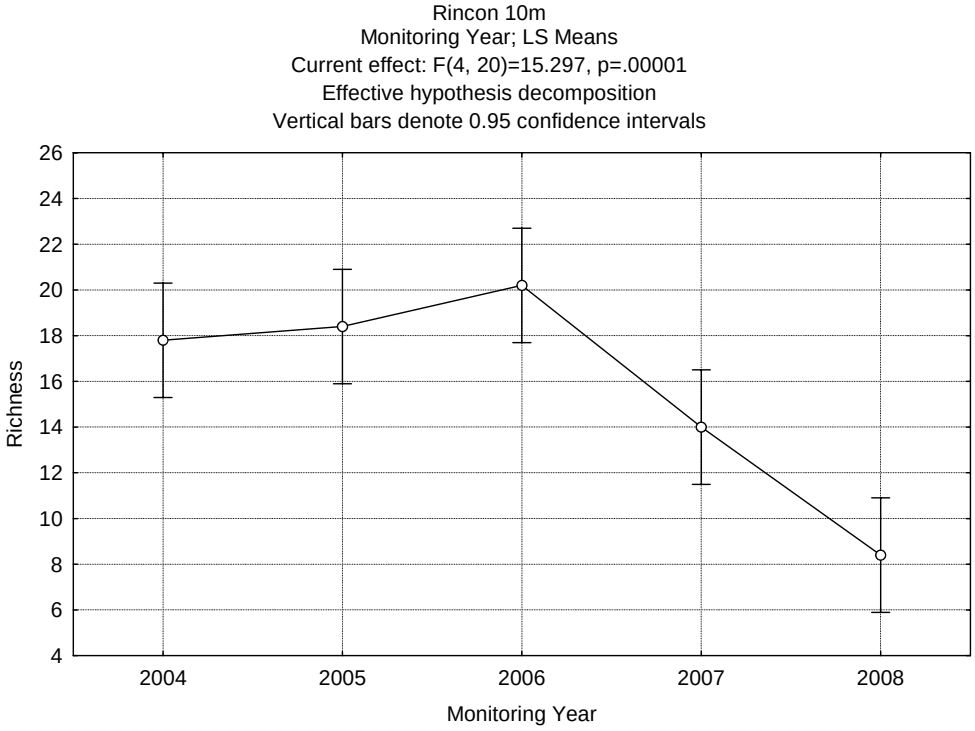


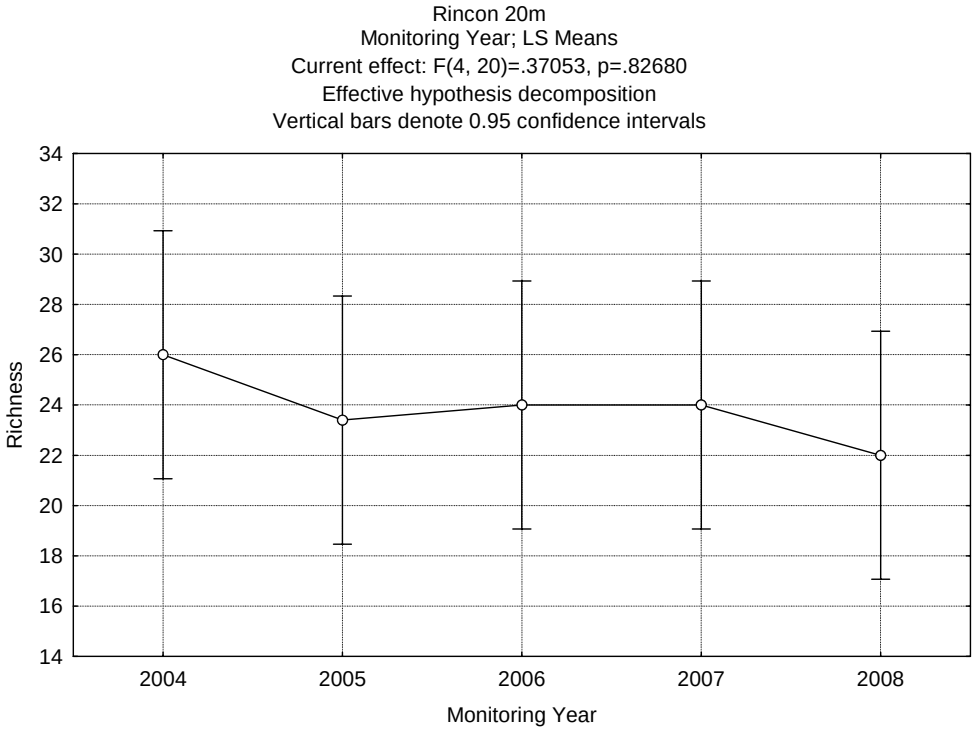

Mona 20m
Monitoring Year; LS Means
Current effect: F(1, 8)=24.039, p=.00119
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
50
45
40
35
30
25
20
15
10
5
0
-5
% Cover
2000
2008
Monitoring Year

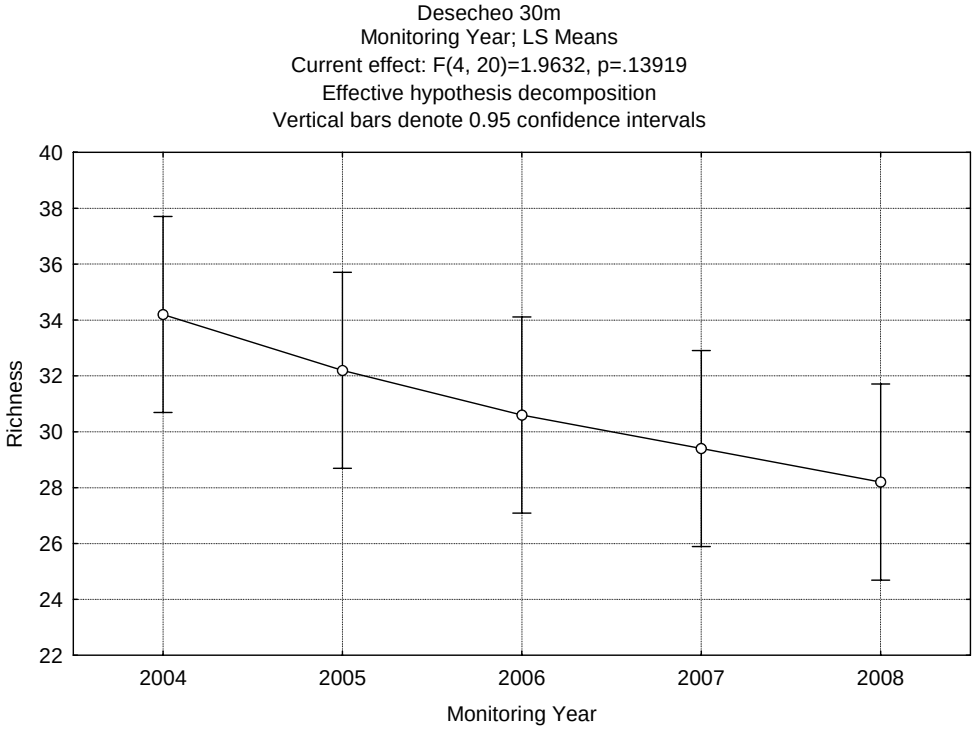

Mona 10m
Monitoring Year; LS Means
Current effect: F(1, 8)=9.0921, p=.01668
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
40
35
30
25
20
15
10
5
0
-5
% Cover
2000
2008
Monitoring Year

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

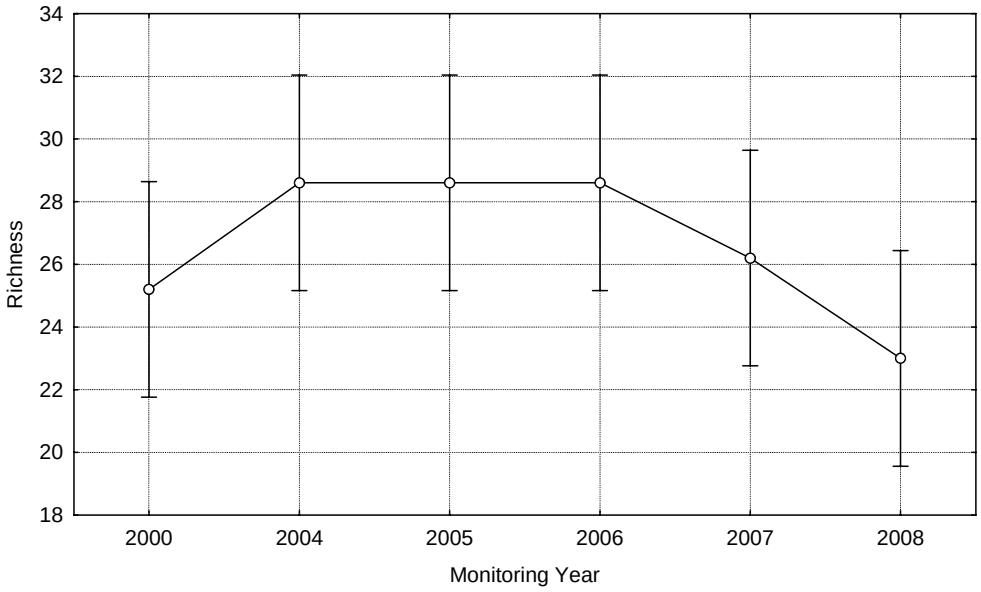




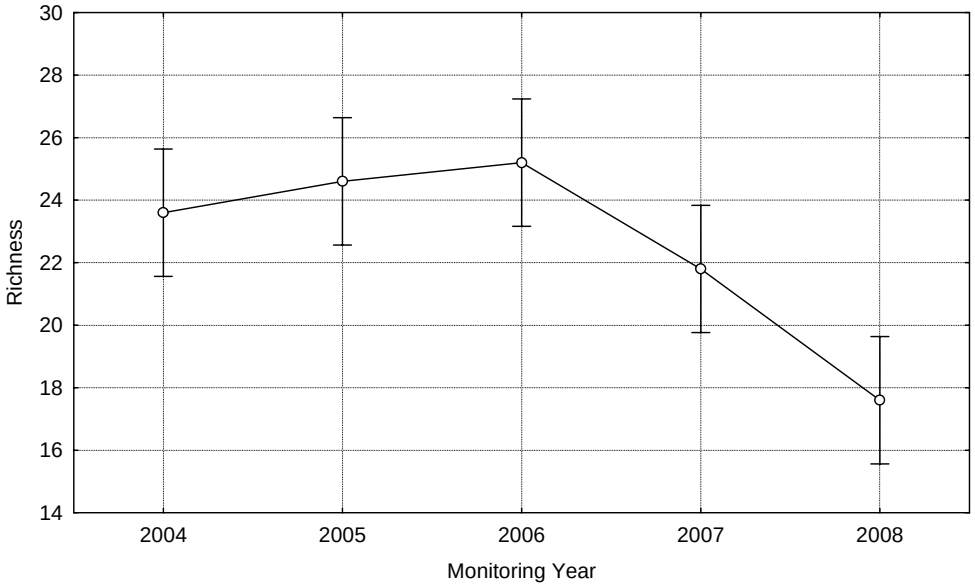

Rincon 20m
Monitoring Year; LS Means
Current effect: F(4, 20)=.37053, p=.82680
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
34
32
30
28
26
24
22
20
18
16
14
2004
2005
2006
2007
2008
Monitoring Year

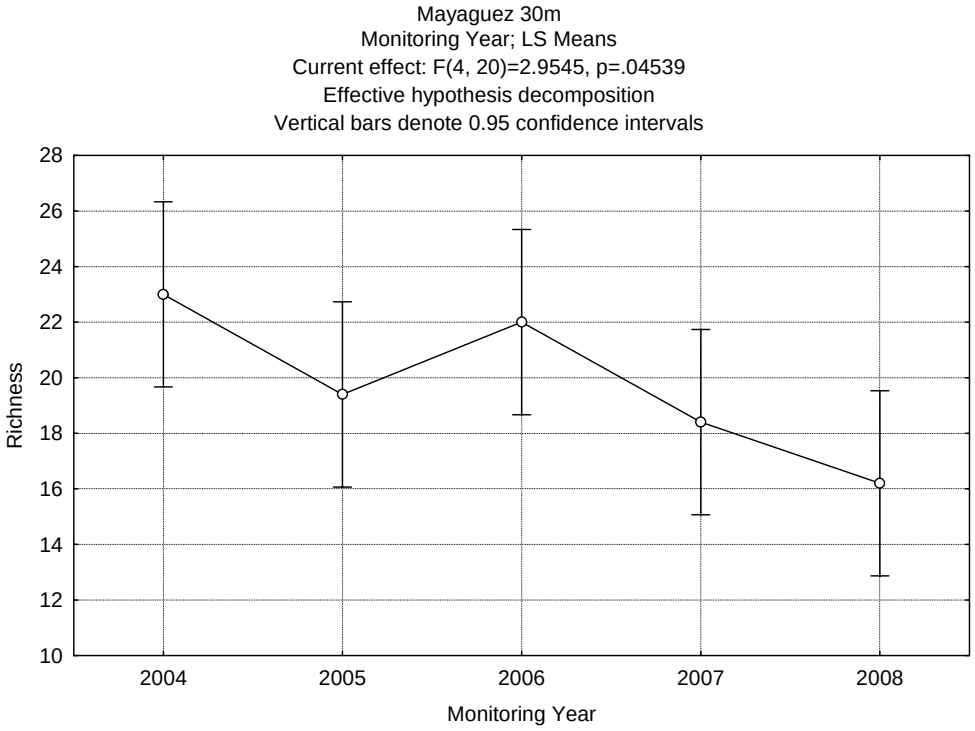

Desecheo 30m
Monitoring Year; LS Means
Current effect: F(4, 20)=1.9632, p=.13919
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
40
38
36
34
32
30
28
26
24
22
2004
2005
2006
2007
2008
Monitoring Year

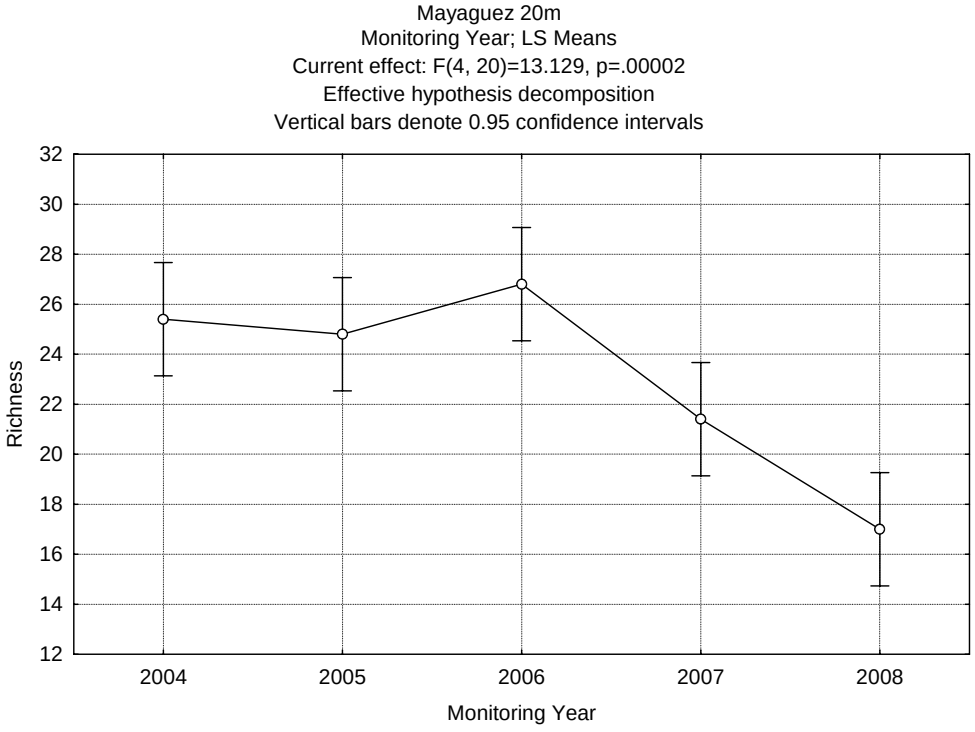
Desecheo 20m
Monitoring Year; LS Means
Current effect: F(5, 24)=1.9462, p=.12372
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals



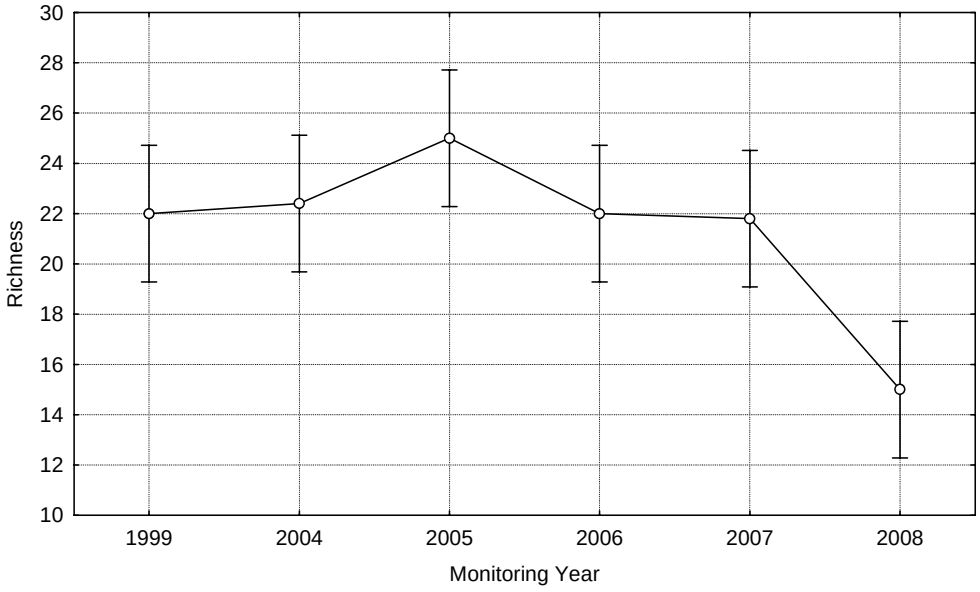
Desecheo 15m
Monitoring Year; LS Means
Current effect: F(4, 20)=9.8193, p=.00015
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals



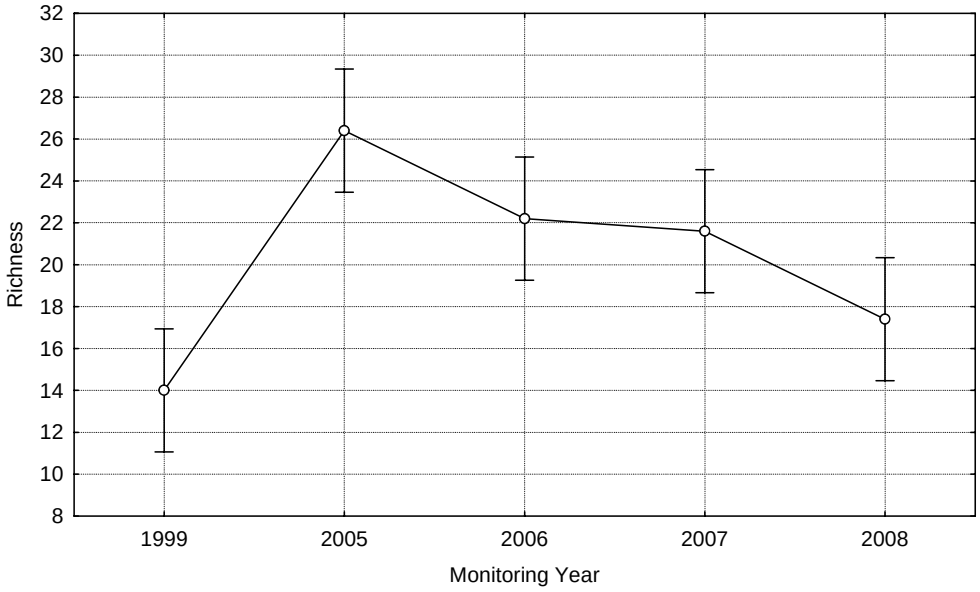

Mayaguez 30m
Monitoring Year; LS Means
Current effect: F(4, 20)=2.9545, p=.04539
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
28
26
24
22
20
18
16
14
12
10
2004
2005
2006
2007
2008
Monitoring Year

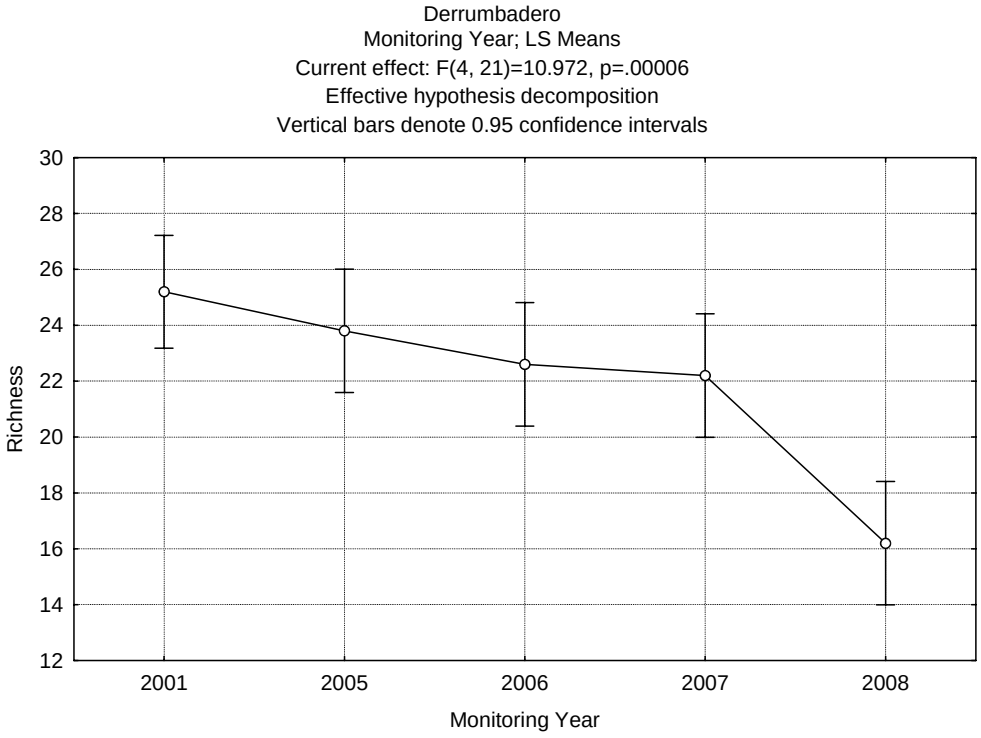

Mayaguez 20m
Monitoring Year; LS Means
Current effect: F(4, 20)=13.129, p=.00002
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
32
30
28
26
24
22
20
18
16
14
12
2004
2005
2006
2007
2008
Monitoring Year

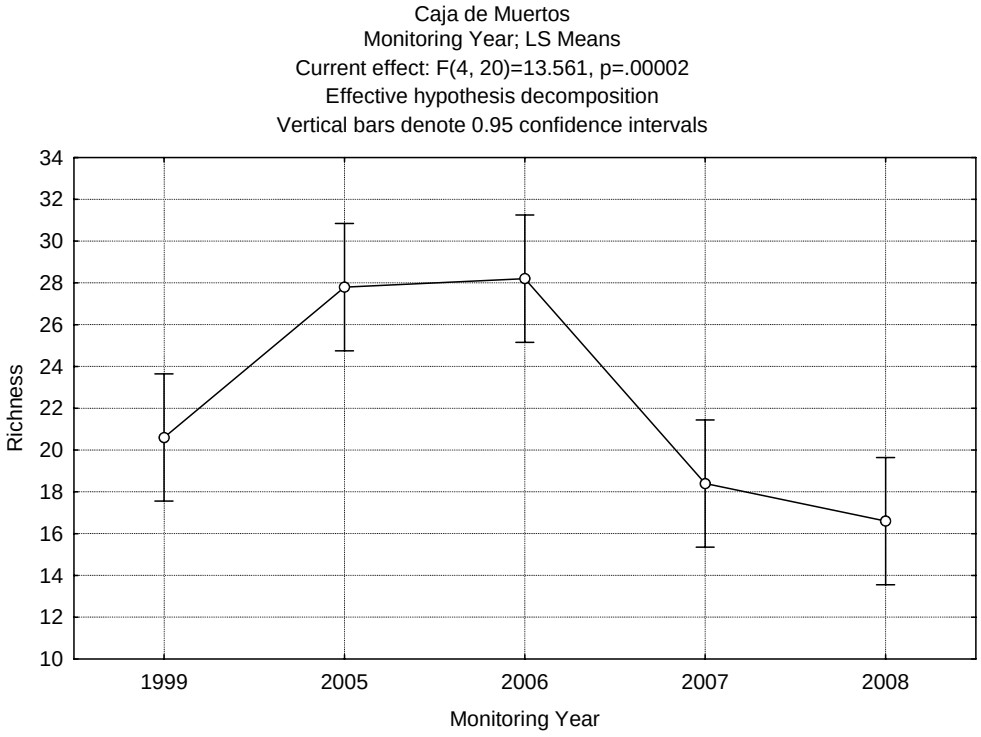
Mayaguez 10m
Monitoring Year; LS Means
Current effect: F(5, 24)=6.4377, p=.00063
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals

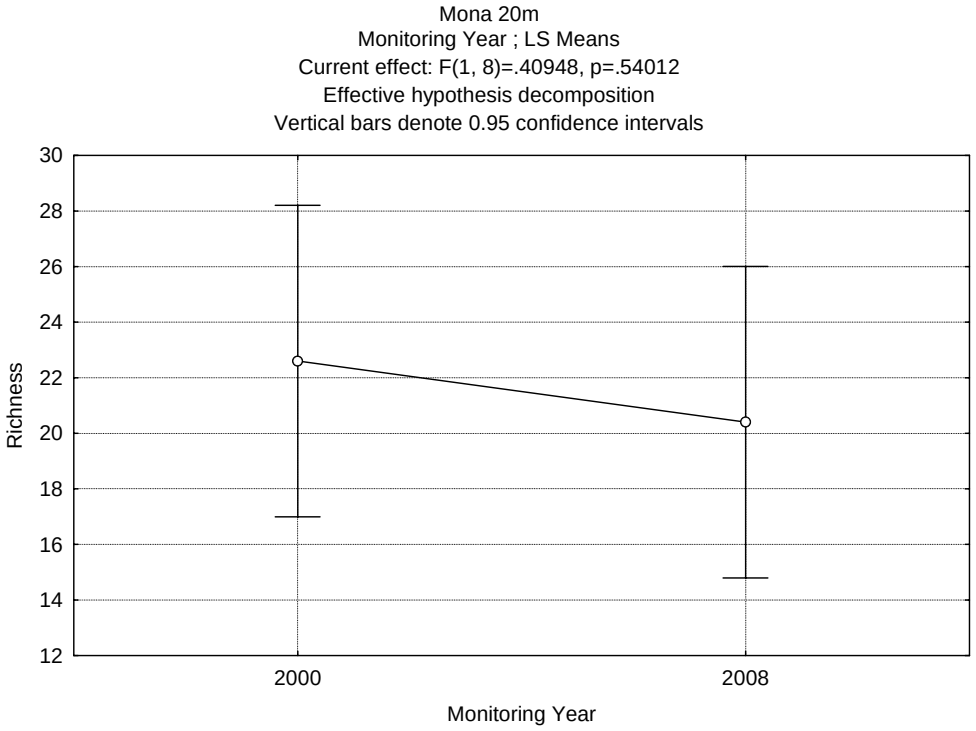


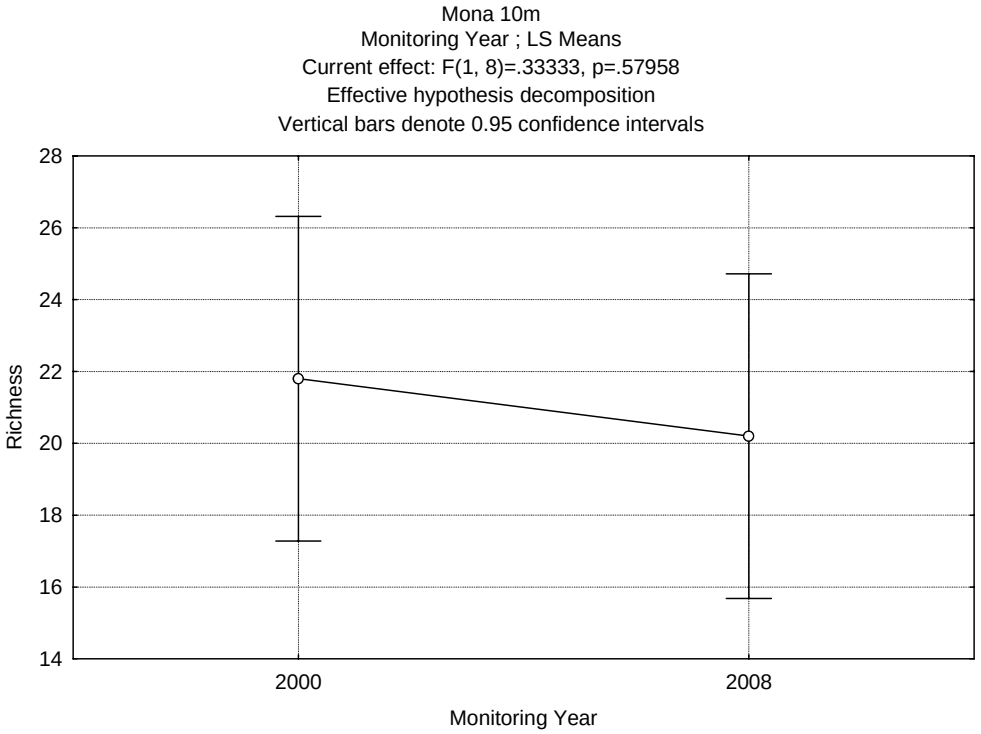
Guanica
Monitoring Year; LS Means
Current effect: F(4, 20)=11.417, p=.00005
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals



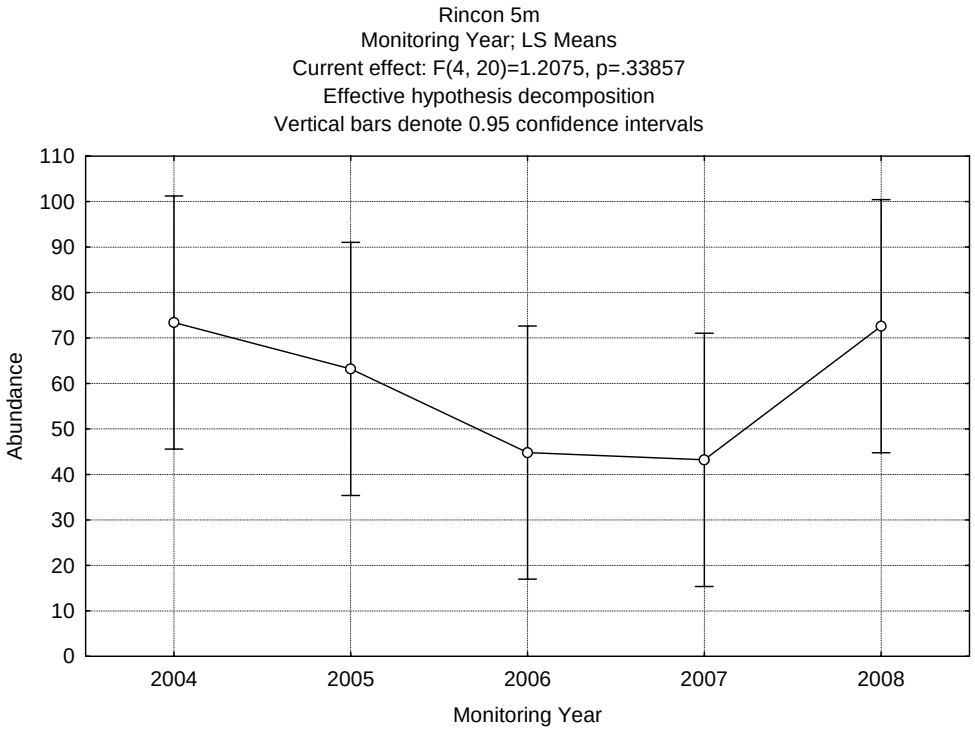

Derrumbadero
Monitoring Year; LS Means
Current effect: F(4, 21)=10.972, p=.00006
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
30
28
26
24
22
20
18
16
14
12
2001
2005
2006
2007
2008
Monitoring Year

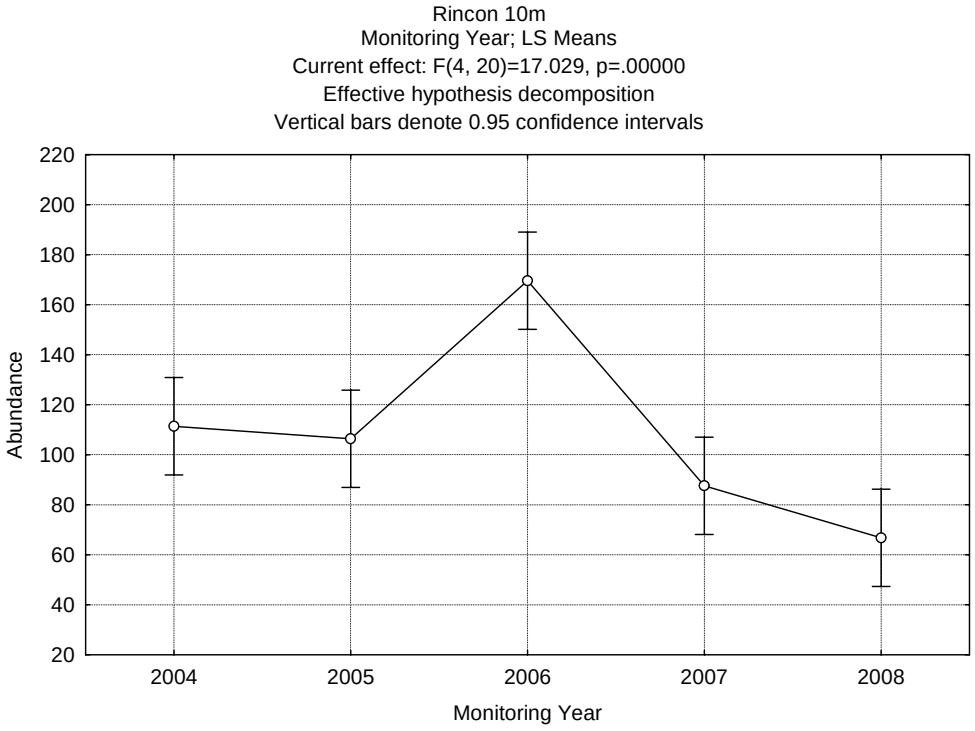

Caja de Muertos
Monitoring Year; LS Means
Current effect: F(4, 20)=13.561, p=.00002
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
34
32
30
28
26
24
22
20
18
16
14
12
10
1999
2005
2006
2007
2008
Monitoring Year

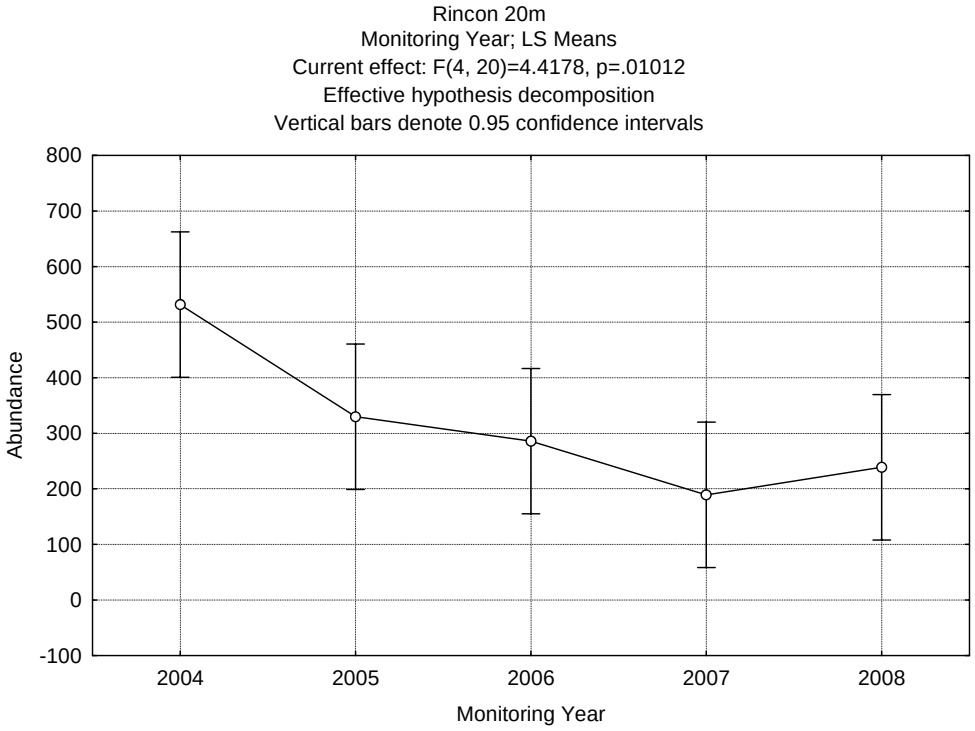

Mona 20m
Monitoring Year ; LS Means
Current effect: F(1, 8)=.40948, p=.54012
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
30
28
26
24
22
20
18
16
14
12
Richness
2000
2008
Monitoring Year

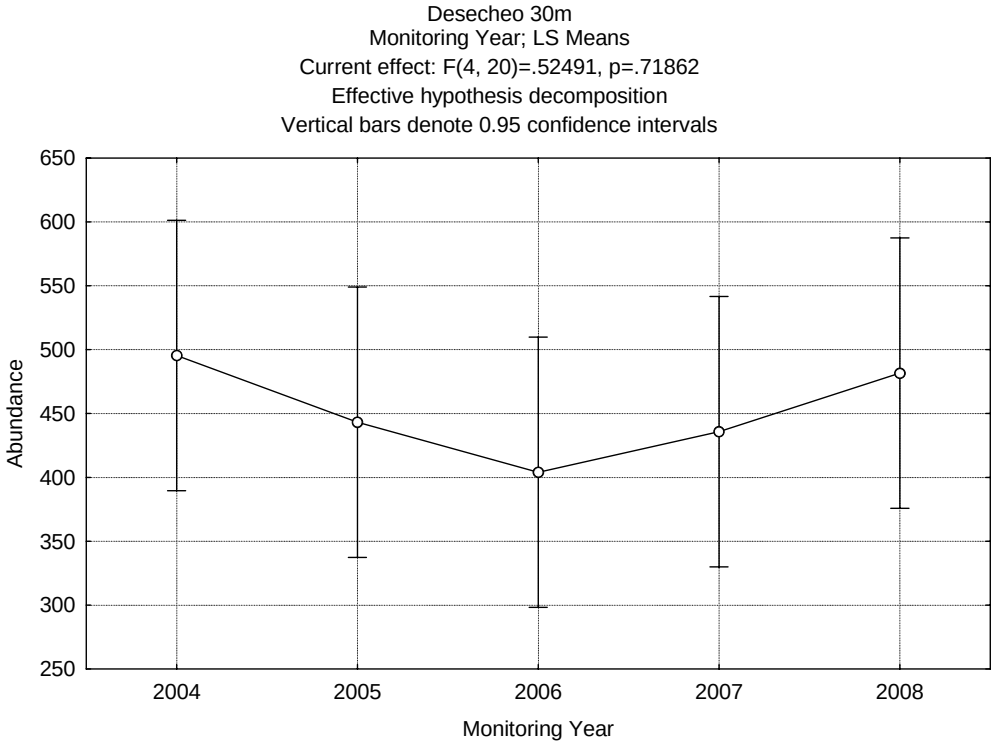

Mona 10m
Monitoring Year ; LS Means
Current effect: F(1, 8)=.33333, p=.57958
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
28
26
24
22
20
18
16
14
Richness
2000
2008
Monitoring Year

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

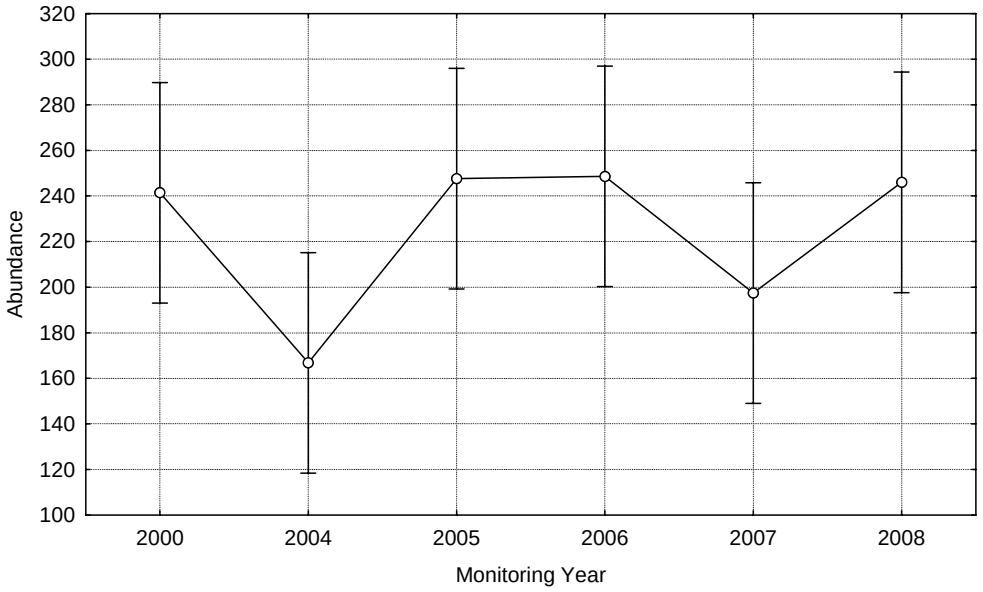




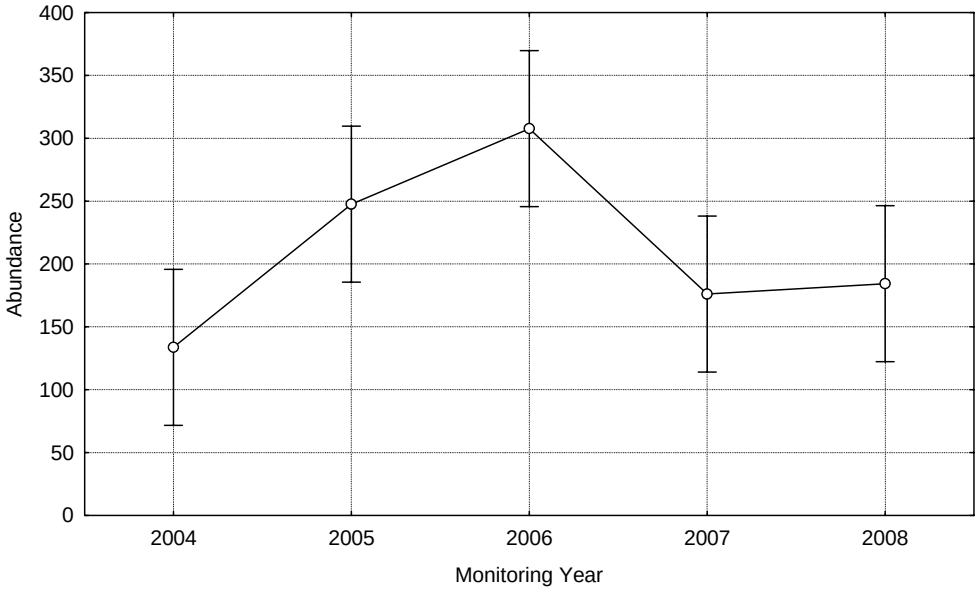

Rincon 20m
Monitoring Year; LS Means
Current effect: F(4, 20)=4.4178, p=.01012
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
800
700
600
500
400
300
200
100
0
-100
Abundance
2004
2005
2006
2007
2008
Monitoring Year


Desecheo 30m
Monitoring Year; LS Means
Current effect: F(4, 20)=.52491, p=.71862
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
650
600
550
500
450
400
350
300
250
Abundance
2004
2005
2006
2007
2008
Monitoring Year

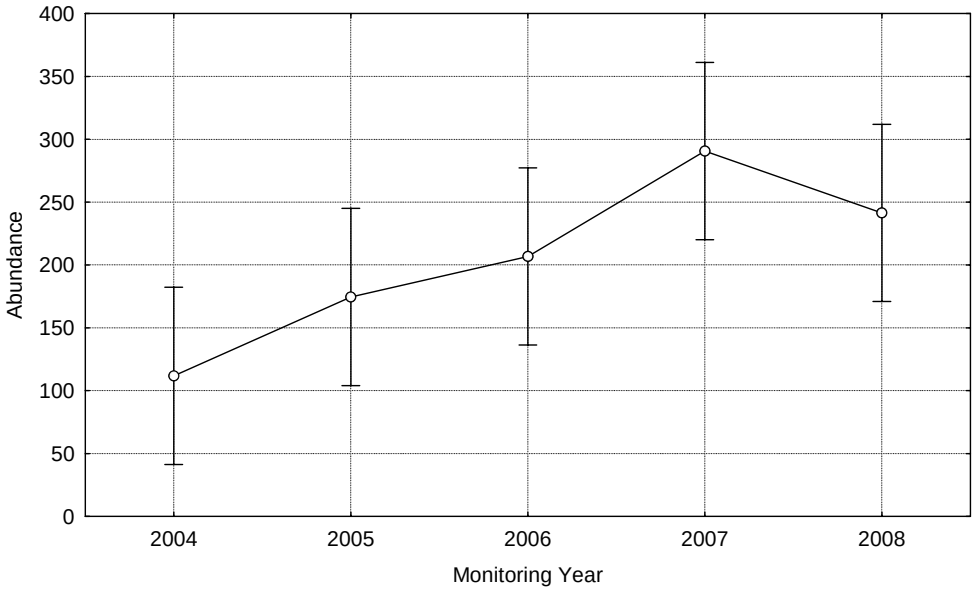
Desecheo 20m
Monitoring Year; LS Means
Current effect: F(5, 24)=2.1570, p=.09296
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals



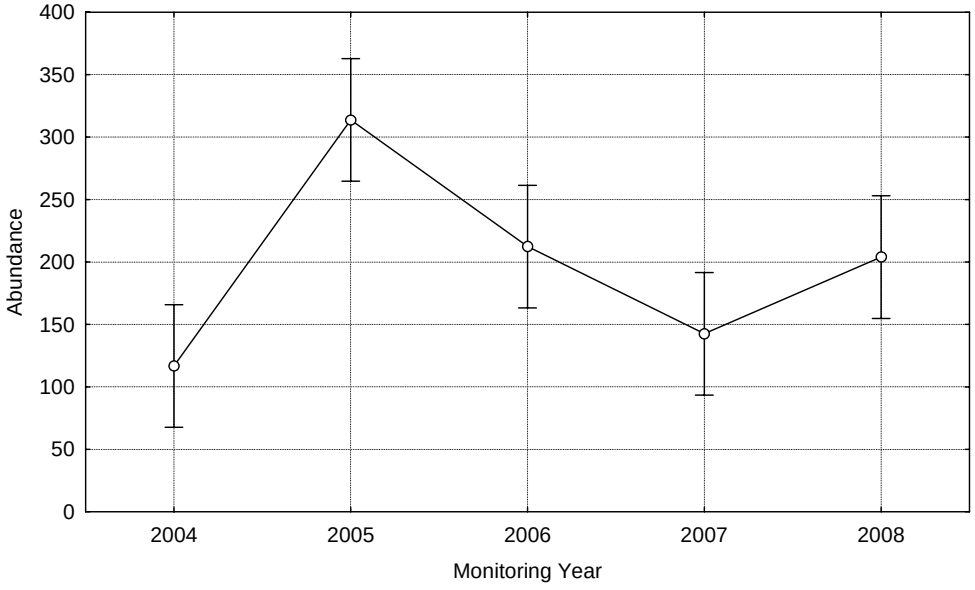
Desecheo 15m
Monitoring Year; LS Means
Current effect: F(4, 20)=5.2413, p=.00471
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals



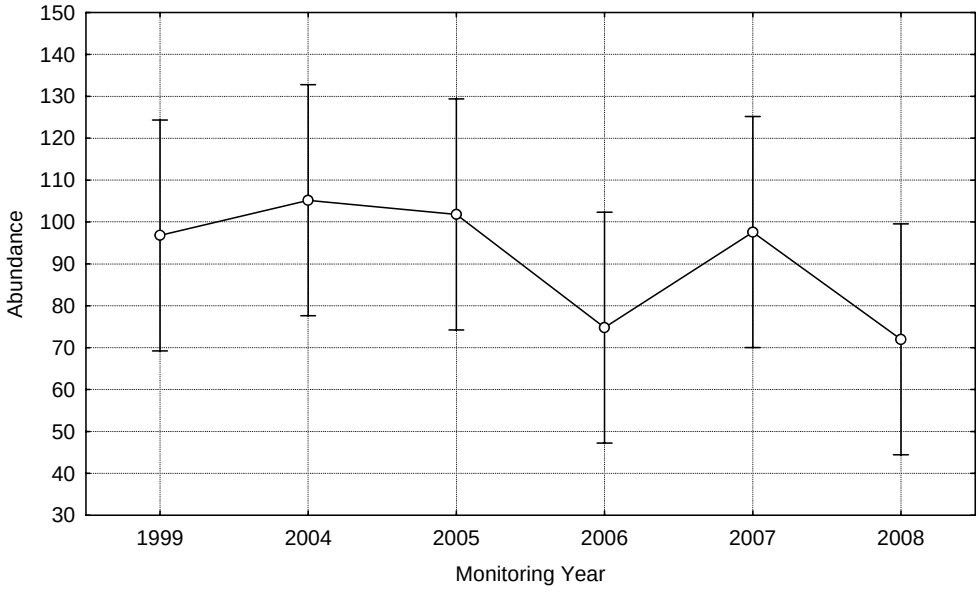
Mayaguez 30m
Monitoring Year; LS Means
Current effect: F(4, 20)=4.0018, p=.01522
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals



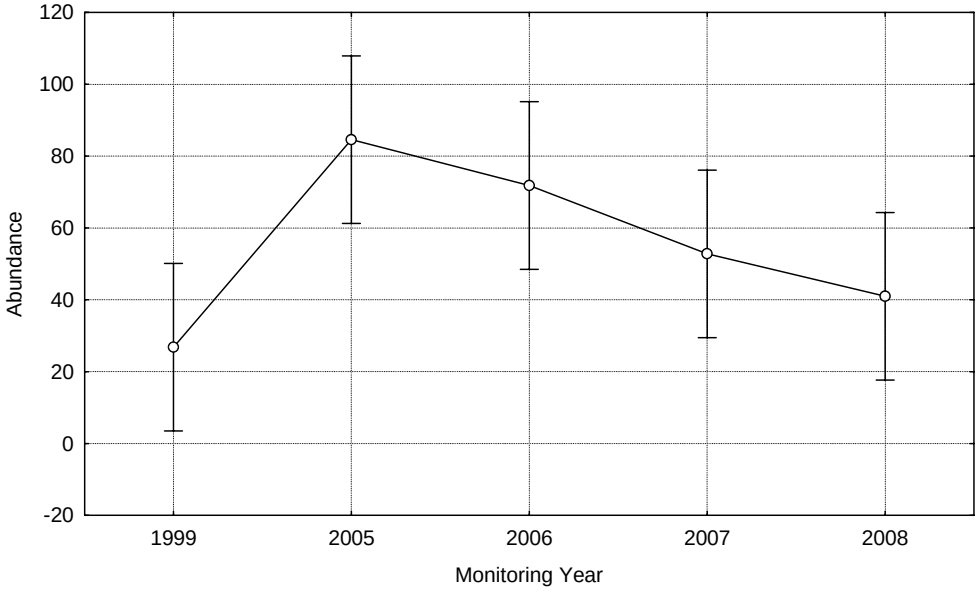
Mayaguez 20m
Monitoring Year; LS Means
Current effect: F(4, 20)=10.529, p=.00009
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals

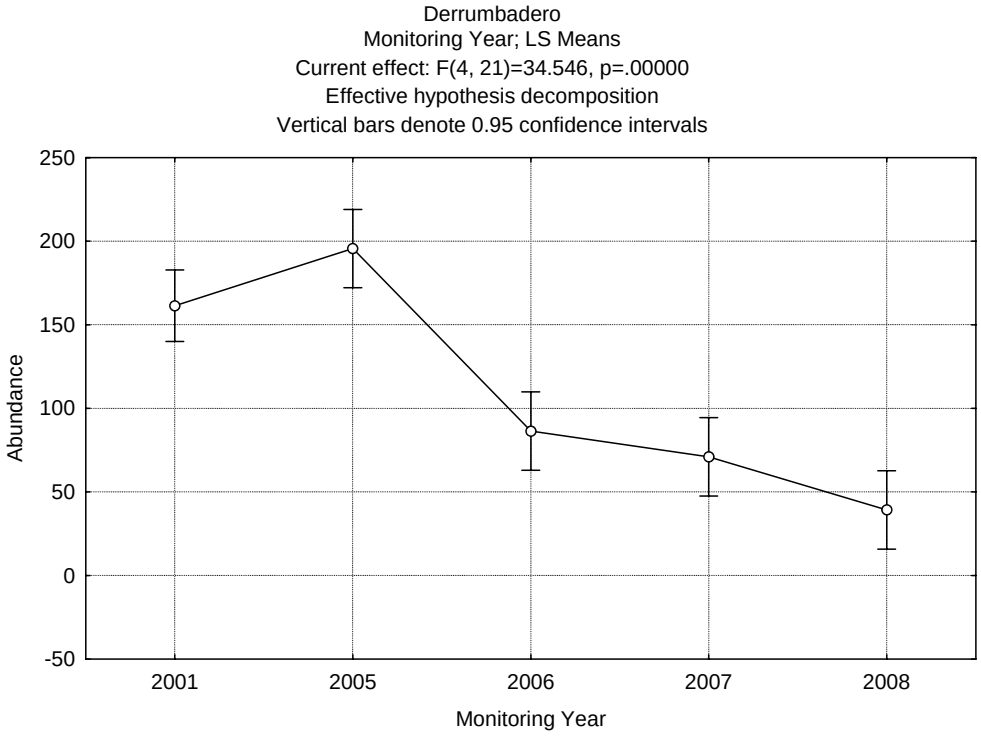


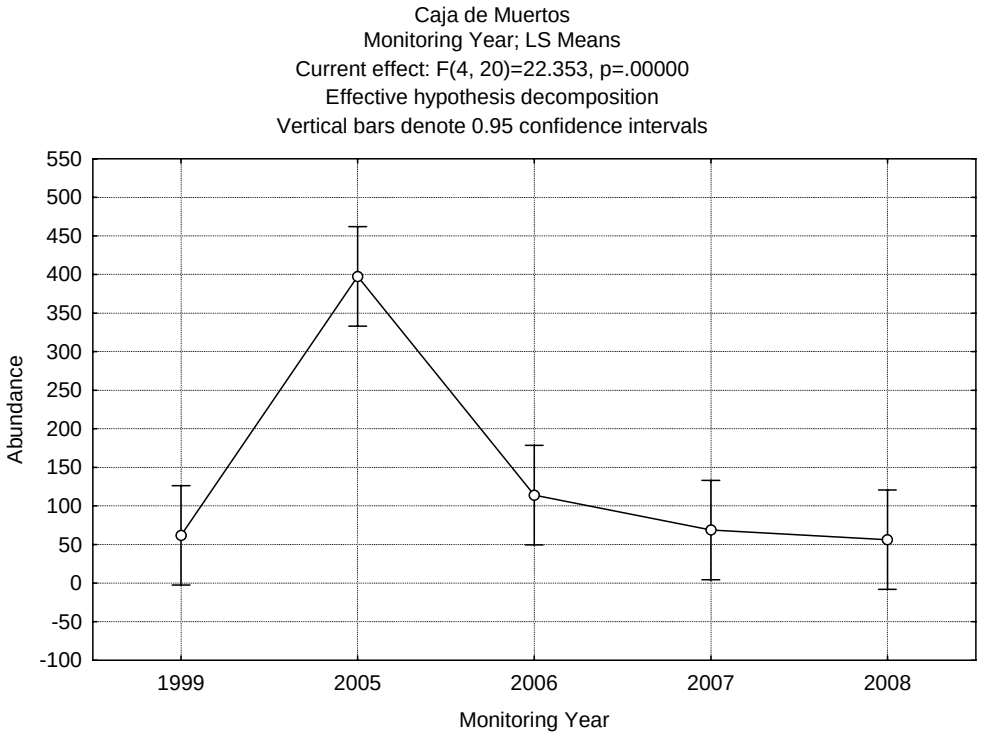
Mayaguez 10m
Monitoring Year; LS Means
Current effect: F(5, 24)=1.1411, p=.36615
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals

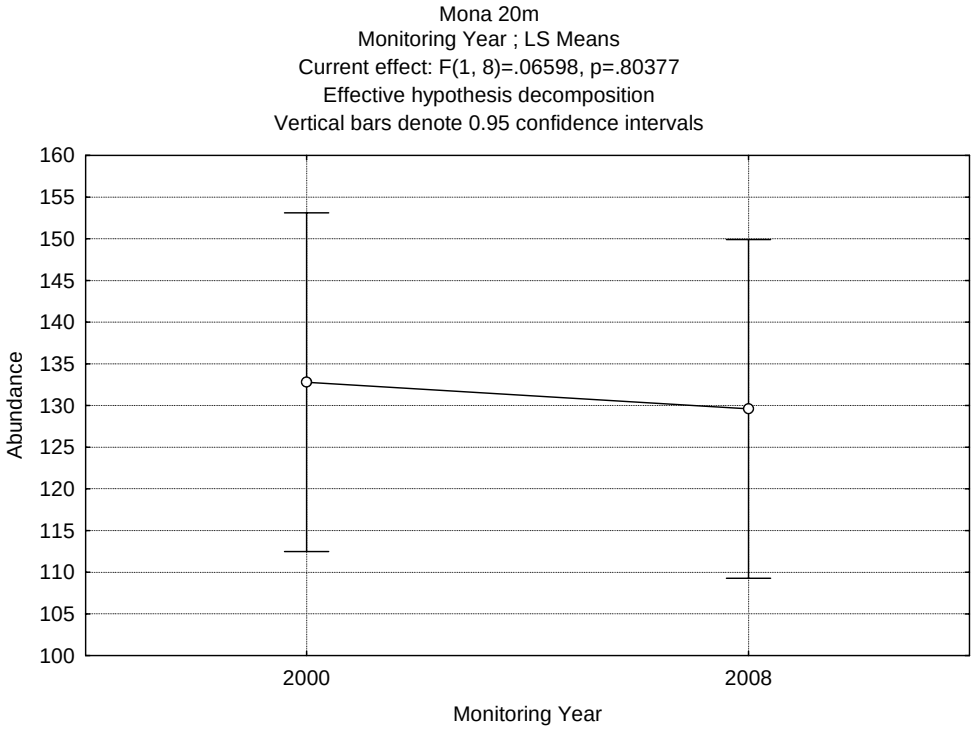


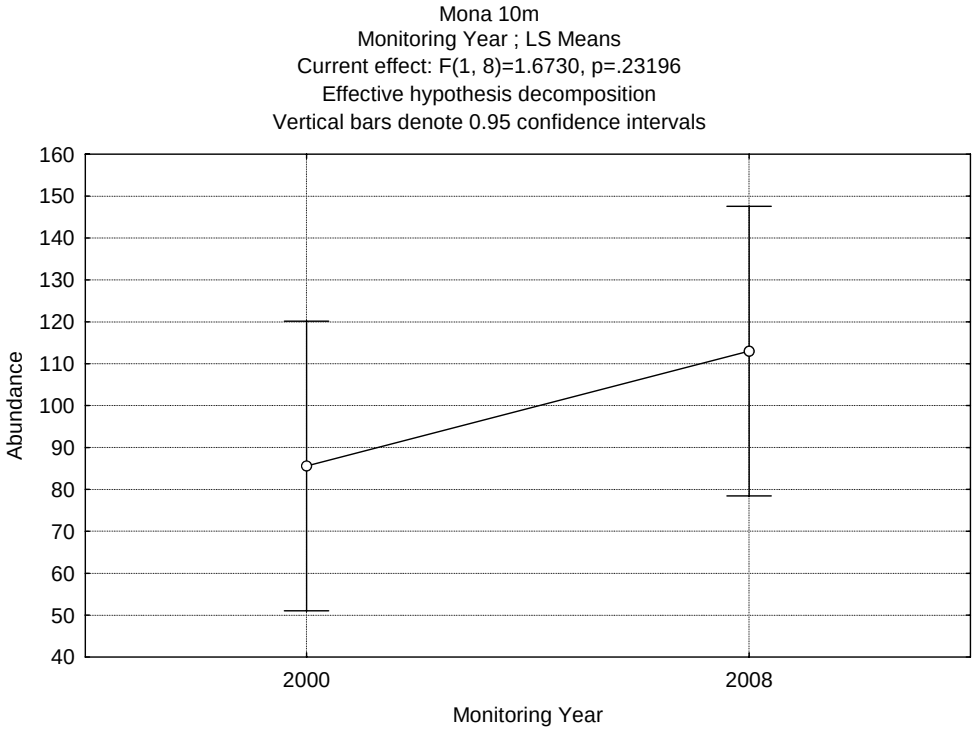
Guanica
Monitoring Year; LS Means
Current effect: F(4, 20)=4.3089, p=.01125
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals




Derrumbadero
Monitoring Year; LS Means
Current effect: F(4, 21)=34.546, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
250
200
150
100
50
0
-50
2001
2005
2006
2007
2008
Monitoring Year


Caja de Muertos
Monitoring Year; LS Means
Current effect: F(4, 20)=22.353, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
550
500
450
400
350
300
250
200
150
100
50
0
-50
-100
1999
2005
2006
2007
2008
Monitoring Year


Mona 20m
Monitoring Year ; LS Means
Current effect: F(1, 8)=.06598, p=.80377
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
160
155
150
145
140
135
130
125
120
115
110
105
100
2000
2008
Monitoring Year


Mona 10m
Monitoring Year ; LS Means
Current effect: F(1, 8)=1.6730, p=.23196
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
160
150
140
130
120
110
100
90
80
70
60
50
40
2000
2008
Monitoring Year