FINAL REPORT

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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, 2008-2009

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I Executive Summary

A total of 15 reefs from seven Natural Reserves were included in the 2008-09 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.

The sessile-benthic community at the reef systems of Puerto Botes and Puerto Canoas (Isla Desecheo), Tourmaline Reef (Mayaguez), Cayo Coral (Guánica), West Reef (Caja de Muerto – Ponce), and Derrumbadero Reef (Ponce) presented statistically significant differences of live coral cover. Differences of live coral cover between monitoring surveys were mostly associated with a sharp decline measured during the 2006 survey, after a severe regional coral bleaching event that affected Puerto Rico and the U. S. Virgin Islands during August through October 2005. Statistically significant reductions of live coral cover continued as lingering effects of the regional bleaching mortality until 2007 at Isla Desecheo and Cayo Coral. The decline of (total) live coral cover at the reef community level during 2006 was largely driven by mortality of Boulder Star Coral, *Montastraea annularis* (complex), a highly dominant species in terms of reef substrate cover and the principal reef building species. Corresponding increments of reef substrate cover by benthic algae, cyanobacteria and abiotic categories were measured.

During the present 2008-09 monitoring survey, live coral cover presented a pattern of mild increments relative to 2007-08 levels for most reef sites monitored, related in part to what appears to be a recuperation response of *M. annularis*. Differences were not statistically significant, but the trend represents at least, a reversal from the continued decline of live coral measured until 2007. An exception to this trend was observed at the *Acropora palmata* finging reef of Tres Palmas in Rincon. This reef is now affected by an infectious disease that was preliminarily identified as “white pox”, also known as “patchy necrosis” and a trend of declining cover appears to be emerging.

Fish populations presented during the 2009 survey a general trend of stabilizing abundance and species richness within belt-transects relative to 2008 levels. Previous reductions of fish abundance were statistically significant in seven out of the 12 reef stations surveyed. These included Tourmaline Reef (Mayaguez) at 20 m; Puerto Botes Reef (Isla Desecheo) at 15 m; Tres Palmas Reef (Rincon) at 10 and 20 m; Derrumbadero Reef (Ponce) at 20 m and West Reef (Isla Caja de Muerto) at 8 m. Likewise, statistically significant reductions of fish species richness were observed at Tourmaline Reef (Mayaguez) at 20 m; Puerto Botes Reef (Isla Desecheo) at 15 m; Tres Palmas Reef (Rincon) at 10 m and West Reef (Isla Caja de Muerto) at 8 m. Variations between surveys were mostly associated with reductions of abundance by numerically dominant populations that exhibit highly aggregated distributions in the immediate vicinity of live coral heads, such as the Masked Goby (*Coryphopterus personatus*) and the Blue Chromis (*Chromis cyanea*). It is uncertain at this point if such reductions of abundance by reef fishes closely associated with coral habitats were related to the massive coral mortality exhibited by reef systems in the monitoring program. Although in low abundance, large demersal (top predator) fishes were detected during ASEC surveys in several reefs. These include Yellowfin, Tiger, Jewfish, and Nassau Groupers (*Mycteroperca venenosa, M. tigris, Epinephelus itajara, E. striatus*), and the Cubera, Dog and Mutton Snappers (*Lutjanus cyanopterus, L. jocu, L. analis*).

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Introduction

The 2008-09 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 sixth monitoring cycle at the Isla Desecheo 20m and Mayaguez 10m reef stations, the fifth 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 second monitoring survey of coral reefs from Isla de Mona, eight years after the baseline survey of 2001.

During the previous 2007-08 monitoring survey, a pattern of mild reductions of live coral cover relative to 2006-07 levels were measured at almost all reef sites monitored. Declines of live coral cover between the 2007-08 and 2006-07 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 2005-06 coral bleaching event. The decline of (total) live coral cover at the reef community level after the 2005 bleaching event 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.

A total of 179 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 2007-08 monitoring survey (García-Sais et al., 2007). Variations between surveys were mostly associated with reductions of abundance by numerically dominant populations that exhibit highly aggregated distributions, such as the Masked Goby (*Coryphopterus personatus*) and the Blue Chromis (*Chromis cyanea*). It is uncertain at this point if such reductions of abundance by reef fishes closely

associated with coral habitats are related to the massive coral mortality exhibited by reef systems after 2005. Although in low abundance, large demersal fishes that have been overfished during the last decades have been observed during previous ASEC surveys in several reefs. These include Yellowfin, Tiger, Jewfish, and Nassau Groupers (*Mycteroperca venenosa, M. tigris, Epinephelus itajara, E. striatus*), and the Cubera, Dog and Mutton Snappers (*Lutjanus cyanopterus, L. jocu, L. analis*).

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 Puerto Rico Department of Natural and Environmental Resources (PRDNER) serves as the coral reef data management center. Reports from previous surveys (García-Sais et al., 2001 a, b, c; 2004, 2005, 2006, 2007, 2008) are available to the public through the internet website coralpr.net.

III Methodology

The location of reef sites included in this 2008-09 monitoring cycle is shown in Figures 1 and 2. Table 1 presents the geographic coordinates and depths of reefs monitored.

Sessile-benthic reef communities

At each reef, a set of five 10 m long transects were surveyed. Transects are marked with metal rods drilled to the reef substrate at both ends. Sessile-benthic reef communities were characterized by the continuous intercept chain-link method (as modified from Porter, 1972), following the CARICOMP (1984) protocol. This method provides information on the percent linear cover by sessile-benthic biota and other substrate categories along 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 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

Table 1. Geographic positions and depths of coral reefs monitored during 2008-09

Site/Reef	Depth (m)	Latitude (°N)	Longitude (°W)
Isla Desecheo			
Canoas	27 - 30	18°22.706	67°29.199
Botes	18 - 20	18°22.895	67°29.316
Botes	14 - 16	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

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.

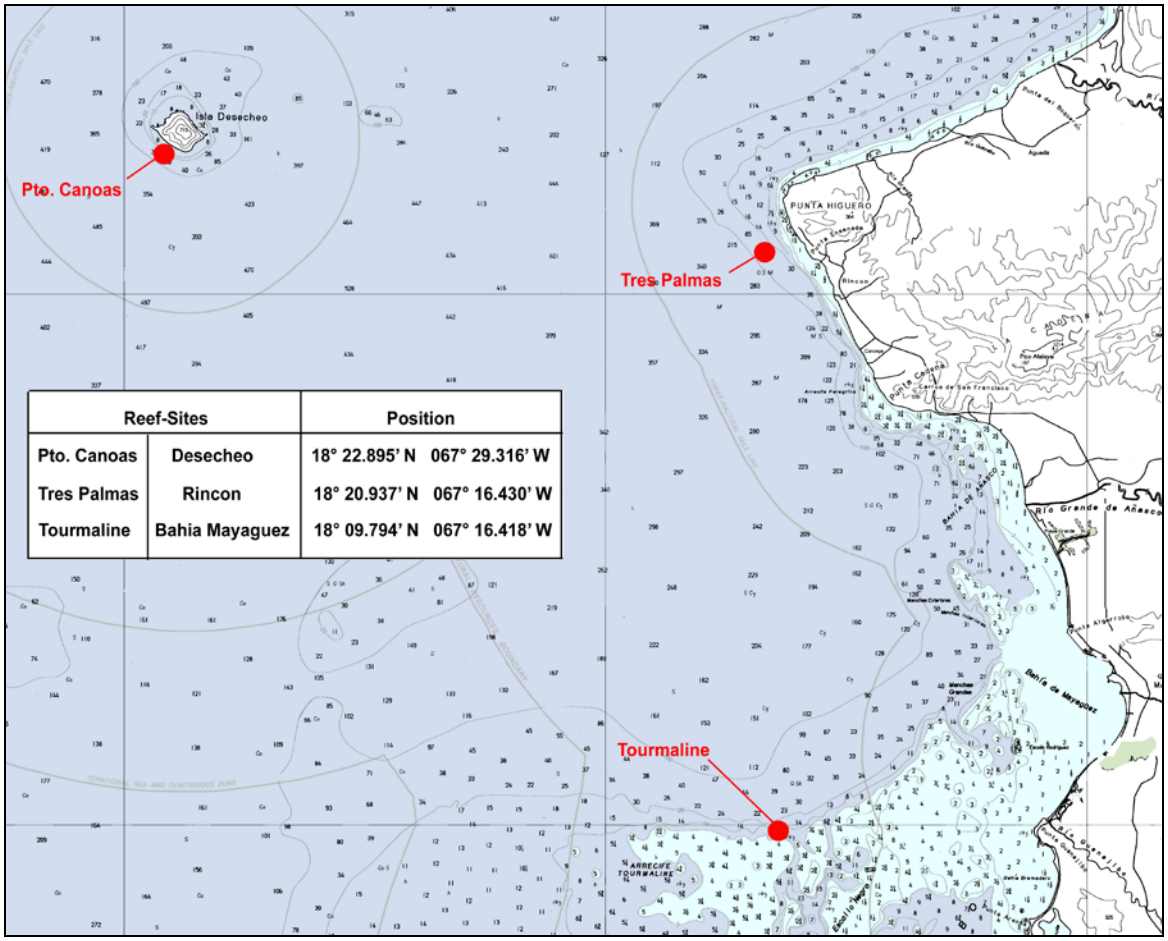


Figure 1. Location of reef sites at Isla Desecheo, Mayaguez and Rincón

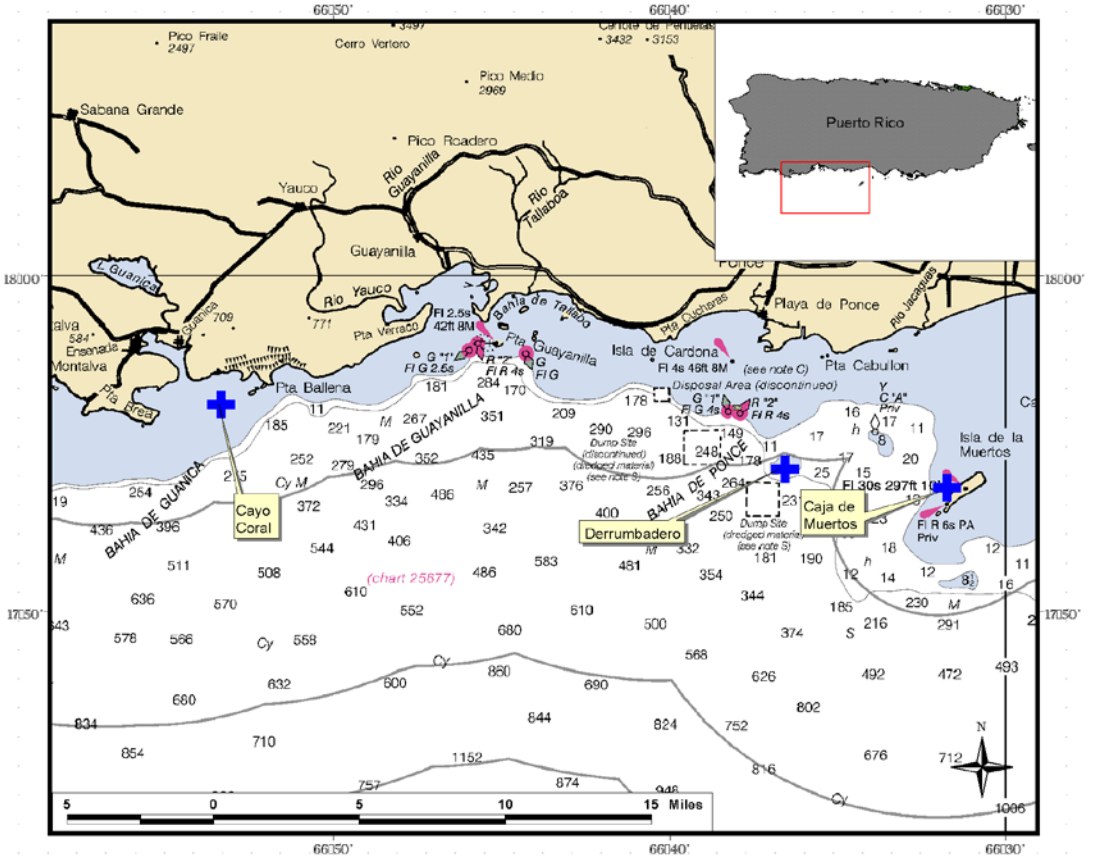


Figure 2. Location of south coast reef sites, Cayo Coral (Guánica), Derrumbadero and West Reef of Isla Caja de Muerto (Ponce)

Results

IV Baseline Characterization and Monitoring of Coral Reef Communities

A. Tres Palmas Reef System – Rincón

1.0 Fringing *Acropora palmata* (Elkhorn Coral) Reef

1.1 Sessile-benthic Reef Community

The rocky shoreline of the Tres Palmas Marine Reserve leads to a narrow backreef lagoon with coarse sandy sediments. The lagoon is a semi-protected environment associated with an extensive *Acropora palmata* (Elkhorn Coral) reef formation that has developed along a hard ground platform fringing the shoreline. The top of the platform is found at depths between 2 - 5 m. The branching Elkhorn Coral colonies are large, rising

more than one meter from the hard ground platform almost to the surface and wide, extending more than two meters horizontally in many cases. Where the hard ground platform is continuous, coral colonies grow close together forming a dense and intertwined Elkhorn Coral biotope. Sand pools and channels separate the reef where the hard ground platform breaks up. Interspersed within the *A. palmata* biotope are abundant colonies of encrusting corals, mostly *Diploria clivosa, D. strigosa* and *Porites astreoides*. These encrusting and mound shaped stony corals and gorgonians are more abundant on the seaward slope of the hard ground platform 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.) are removed by volunter groups (Surfrider, etc.) from the reef several times every year. The backreef lagoon is a popular place for bathers and divers, some of which have been observed fishing with spear guns within the no-take area.

During 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. As a result of this event, some of the permanent transect assemblage was destroyed and the monitoring data for 2007-08 was gathered in error (out of transect lines) and eliminated from the data base. Reconstruction of the original transects was performed during the present survey 2008-09. 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.

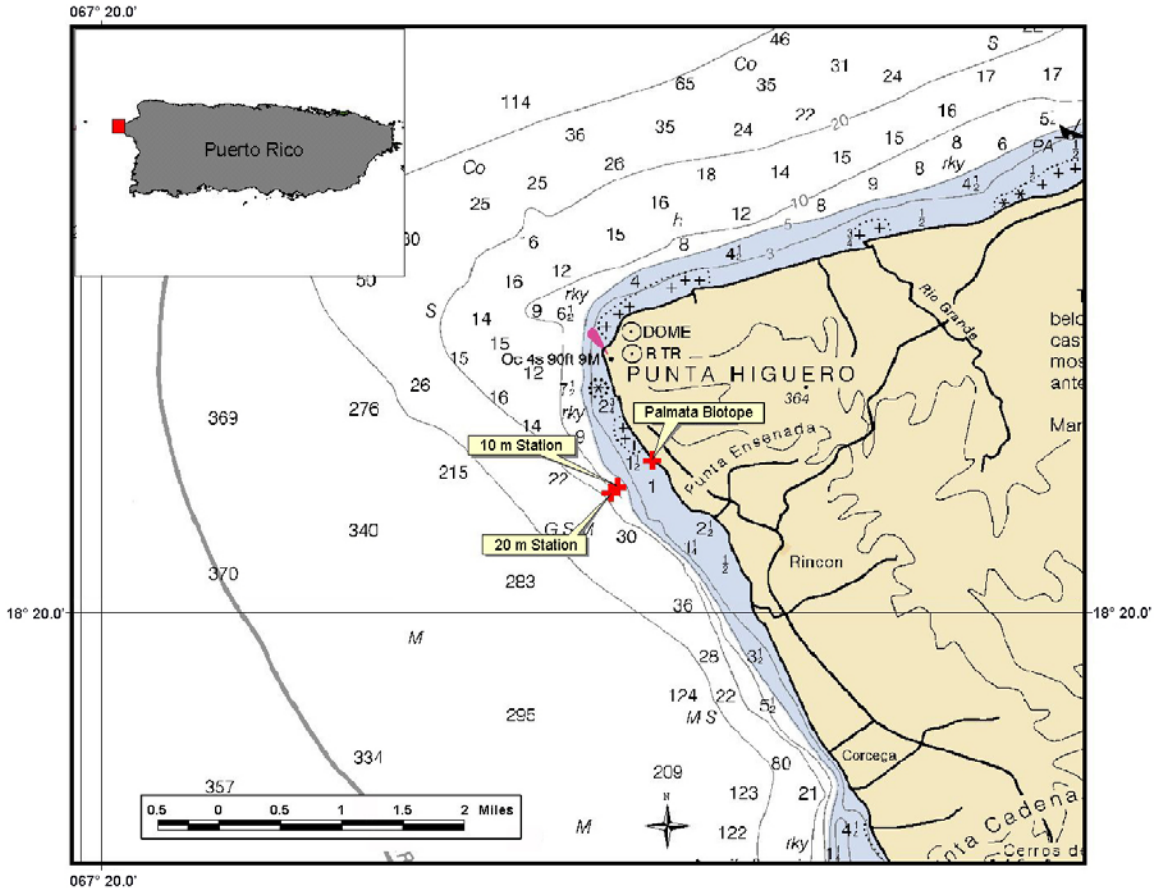


Figure 3. Location of coral reef monitoring stations off Tres Palmas, Rincón.

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 33.3% (range: 19.3 – 45.9 %). Elkhorn Coral (*A. palmata*) was the dominant species with a mean substrate cover of 25.9 % (range: 2.1 – 9.4 %), representing 77.7 % of the total live coral cover. Four additional coral species (e.g. *Diploria strigosa, P. astreoides, Montastraea annularis, and M. cavernosa*) were intersected by linear transects during our survey. A total of 17 species of stony corals were identified from the fringing reef, including the endangered species *A. cervicornis*. Hard ground substrate, including dead coral sections not colonized by corals was mostly covered by turf algae (mean cover: 44.8 %). 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 of 2.9 %. The encrusting gorgonian,

Table 2. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon 5 m. June, 2009

Depth: 2 - 5 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	3.01	2.82	4.10	4.40	1.75	**3.2**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	13.60	26.13	18.37	18.87	12.43	**17.9**
Sand					4.68	**0.9**
Total Abiotic	13.60	26.13	18.37	18.87	17.11	**18.8**
Benthic Algae						
Turf-mixed assemblage	52.27	38.14	35.67	34.47	63.57	**44.8**
Total Benthic Algae	52.27	38.14	35.67	34.47	63.57	**44.8**
Zoanthids	9.76		4.68			**2.9**
Sponges				0.71		**0.1**
Live Stony Corals						
Acropora palmata	2.06	34.48	39.08	44.23	9.45	**25.9**
Diploria strigosa	15.45				6.95	**4.5**
Montastraea annularis	4.11					**0.8**
Montastraea cavernosa			2.20		2.28	**0.9**
Porites astreoides	2.69	1.21		1.71	0.60	**1.2**
Total Stony Corals	24.31	35.69	41.28	45.94	19.28	**33.3**
Gorgonians (# col.)	n/d	n/d	n/d	n/d	n/d	n/d

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

Erythropodium caribaeorum was observed outside transects. Abiotic categories, associated with reef overhangs, gaps or holes and sand represented 18.8 % 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 38.6 % and 39.4 % during the monitoring period between 2004 and 2007, but declined to 33.3 % during this recent survey. Differences between monitoring surveys are not statistically significant (ANOVA; p = 0.691). There is a relatively high sampling variability associated with sampling this reef because of the highly irregular shape of the elkhorn coral colonies and the difficulties in following chain paths throughout the shallow reef buttress. Nevertheless, a consistent reduction of substrate cover by the main reef coral constituent, *Acropora palmata* was observed across all five transects in the present survey relative to the baseline and other previous monitoring surveys (Figure 5).

The reduction of reef substrate cover by *A. palmata* may be associated with loss of live tissue caused by an infectious disease. The irregular patterns of white spots and small patches of tissue necrosis suggest that it is an infection of white pox, caused by the coliform bacteria, *Serratia marcenscens*. This disease has been identified as the main causal agent of the collapse of *A. palmata* reefs in the Florida Keys National Marine Sanctuary (Patterson et al. 2002). The bacteria is commonly found in the intestines of humans, insects and other animals, and in water, soil and plants (Grimont and Grimont, 1994). Thus it is an agent with a possible link to human sewage pollution.

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 2008-09 monitoring survey, 58 fish species, including 24 present within belt-transects were identified from the fringing reef. The mean abundance of individuals was 109.0 Ind/30 m^2 (range: 97 - 123 Ind/30 m^2), and the mean number of species per transect was 10.8 (range: 10 - 12). The combined abundance of six species represented 93.1 % of the mean abundance within belt-transects (Table 3). The most abundant species was the Blue Tang (*Acanthurus coeruleus*) with a mean of 56.4 Ind/30 m^2 followed by the Redlip Blenny (*Ophioblennius atlanticus)*, Dusky Damselfish (*Stegastes dorsopunicans*), Yellowtail Damselfish (*Microspathodon chrysurus*), Bluehead and Clown wrasses (*Thalassoma bifasciatum, Halichoeres garnoti*). These species and were present within all five belt-transects surveyed and along with the

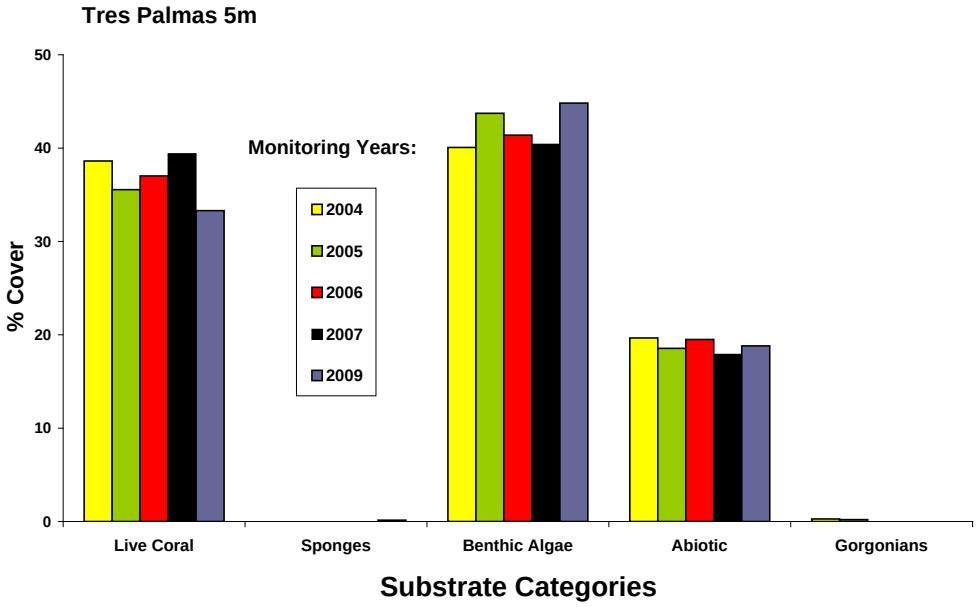


Figure 4. Monitoring trends (2004 – 2009) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon, 2- 5 m depth.

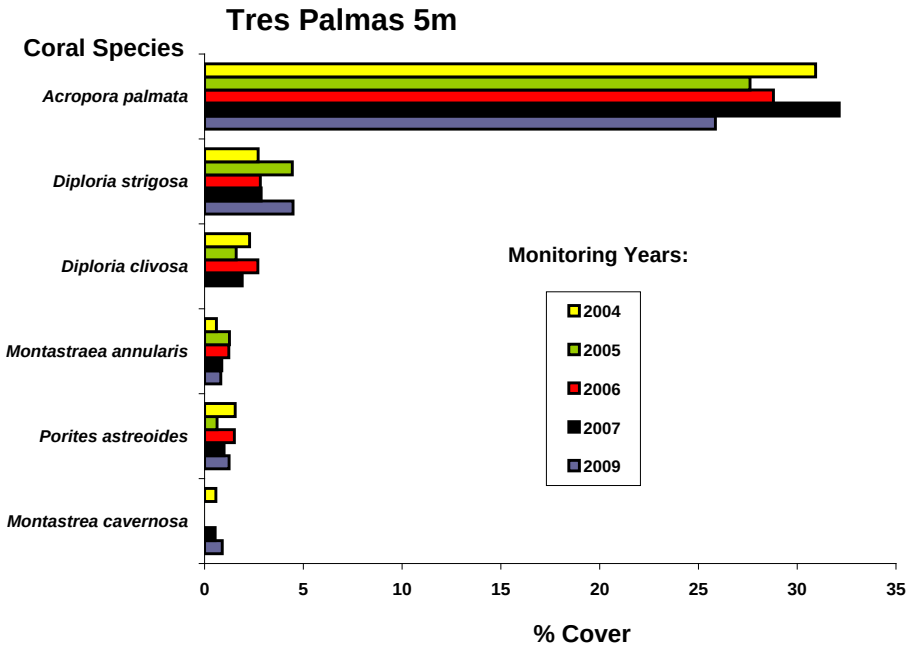


Figure 5. Monitoring trends (2004 – 2009) of mean substrate cover by stony coral species at Tres Palmas Reef, Rincon, 2 - 5 m depth.

Yellowtail and Stoplight Parrotfishes, (*Sparisoma rubripinne, S. viride*) appear to comprise the main resident demersal fish assemblage. Large schools of Blue Tangs were observed in transit over transect areas. Smaller schools of juvenile grunts, yellow goatfishes and parrotfishes were also common.

Monitoring trends of fish abundance and species richness are presented in Figure 6. No statistically significant differences of fish species richness or abundance (ANOVA; $p > 0.05$) have been detected during the monitoring period (2004-2009) 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 are common. Large pelagic piscivores, such as Cero Mackerels, Bar Jacks and Blue Runners have been observed in the sand pools of the backreef feeding upon dense aggregations of zooplanktivorous anchovies and sardines (*Anchoa spp., Harengula spp*.) near the surface. Large (adult) commercially important demersal fishes (snappers, groupers, hogfishes) were not observed.

Juvenile stages of snappers (*Lutjanus analis, L. apodus, L. mahogany, L. synagris*) were observed during the ASEC survey (Table 4), as well as during previous surveys (García-Sais et al., 2004 a, 2005, 2006, 2007, 2008), suggesting that this shallow reef functions as a nursery area for these commercially important species. This reef is also the residential and nursery habitat of the Yellowtail Damselfish (*Microspathodon chrysurus*), which in its early juvenile stage (known as “Jewel Damselfish”) is commercially important as an aquarium trade target species. One Hawksbill Turtle (*Eretmochelys imbricata*) was reported during the 2004 baseline survey (García-Sais et al., 2004a). Among motile megabenthic invertebrates, the Rock-boring Sea Urchin (*Echinometra lucunter, Eucidaris tribuloides*), was observed within belt-transect areas during this 2008-09 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).

Table 3. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef 5m**,** Rincon. June, 2009

Depth: 2 - 5m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**	(individuals/30 m2)					**MEAN**
Acanthurus coeruleus	Blue Tang	57	55	58	57	55	**56.4**
Ophioblennius atlanticus	Redlip Blenny	16	9	24	15	11	**15.0**
Stegastes dorsopunicans	Dusky Damselfish	10	12	15	17	15	**13.8**
Microspathodon chrysurus	Yellowtail Damselfish	10	8	7	7	2	**6.8**
Thalassoma bifasciatum	Bluehead Wrasse	8	6	3	3	2	**4.4**
Halichoeres maculipina	Clown Wrasse	2	2	2	5	10	**4.2**
Kyphosys sp.	Bermuda Chub	0	0	7	0	0	**1.4**
Sparisoma rubripinne	Yellowtail Parrotfish	1	1	3	0	0	**1.0**
Haemulon chrysargyreum	Smallmouth Grunt	3	0	0	2	0	**1.0**
Mulloidichthys martinicus	Yellow Goatfish	4	0	0	0	0	**0.8**
Haemulon flavolineatum	French Grunt	3	1	0	0	0	**0.8**
Bodianus rufus	Spanish Hogfish	1	0	0	1	0	**0.4**
Halichoeres bivittatus	Slipery Dick	0	0	0	0	2	**0.4**
Acanthurus bahianus	Ocean Surgeon	0	0	0	1	1	**0.4**
Pempheris schomburgki	Glasseye Sweeper	0	2	0	0	0	**0.4**
Halichoeres garnoti	Yellowhead Wrasse	0	0	0	0	1	**0.2**
Aulostomus maculatus	Trumpetfish	0	0	1	0	0	**0.2**
Serranus tigrinus	Harlequin Bass	0	0	1	0	0	**0.2**
Sparisoma viride	Stoplight Parrotfish	0	0	1	0	0	**0.2**
Haemulon macrostomum	Spanish Grunt	1	0	0	0	0	**0.2**
Gobiosoma evelynae	Sharknose Goby	0	1	0	0	0	**0.2**
Abudefduf sexatilis	Sargent Major	0	0	0	1	0	**0.2**
Scarus taeniopterus	Queen Parrotfish	0	0	0	0	1	**0.2**
Neoniphon marianus	Longjaw Squirrelfish	0	0	1	0	0	**0.2**
	TOTAL INDIVIDUALS	**116**	**97**	**123**	**109**	**100**	**109**
	TOTAL SPECIES	**12**	**10**	**12**	**10**	**10**	**10.8**

Fishes Outside Transects:

SPECIES	**COMMON NAME**
Abudefduf sexatilis	Sargent major
Anchoa sp.	Anchovy
Anisotremus surinamensis	Black margate
Anisotremus virginicus	Porgy
Calamus pennatula	Pluma
Cantherhines macrocerus	Whitespotted filefish
Canthigaster rostrata	Caribbean puffer
Caranx latus	Horse eye jack
Caranx ruber	Bar jack
Conger sp.	Conger (unid. juvenile)
Dasyathis americana	Southern stingray
Diodon histrix	Porcupinefish
Gerres cinereus	Yellowfin mojarra

Table 3. Continued	
Gramma loreto	Fairy basslet
Haemulon carbonarium	Caesar grunt
Haemulon chrysargyreum	Smallmouth grunt
Haemulon flavolineatum	French grunt
Haemulon plumieri	White grunt
Haemulon sciurus	Bluestripped grunt
Halichoeres pictus	Painted wrasse
Kyphosus bermudensis	Bermuda chub
Labrisomus nuchipinnis	Hairy blenny
Lutjanus analis	Mutton snapper
Lutjanus apodus	Schoolmaster
Lutjanus mahogany	Mahogany snapper
Lutjanus synagris	Lane snapper
Melichthys niger	Black durgon
Monacanthus sp.	Filefish
Mulloidichthys martinicus	Yellow goatfish
Pomacanthus paru	French angelfish
Scarus vetula	Queen parrotfish
Sphyraena barracuda	Great barracuda
Stegastes variabilis	Cocoa damselfish
Sparisoma chrysopterum	Redtail parrotfish

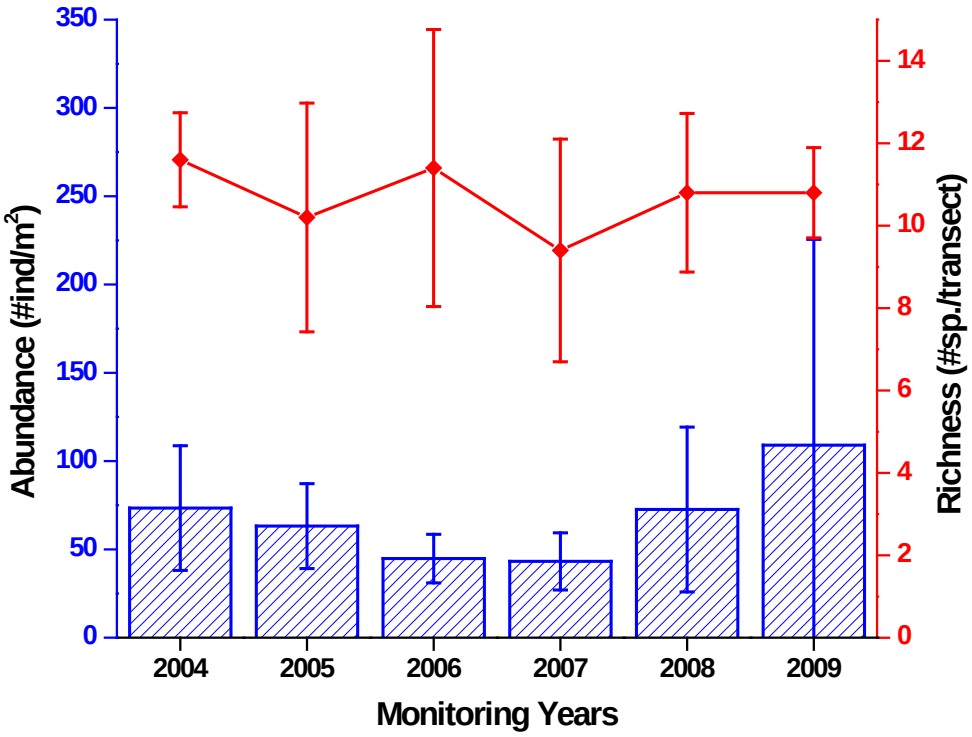


Figure 6. Monitoring trends (2004 – 2009) of fish species richness and abundance at Tres Palmas Reef, Rincon 2-5 m.

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, 2009

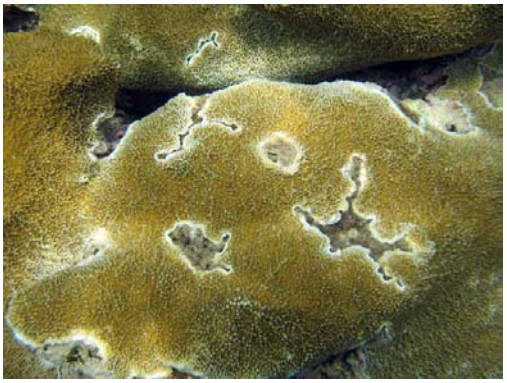
Depth range : 2 – 5 m
Duration – 30 min.

SPECIES	**COMMON NAME**	# - (cm)		
Dasyatis americana	Southern Stingray	1 – (60)		
Lutjanus analis	Mutton Snapper	1 – (30)		
Lutjanus synagris	Lane Snapper	4– (15)	5 – (25)	3 – (40)
Lutjanus apodus	Schoolmaster	5 – (20)	2 – (30)	
Lutjanus mahogany	Mahogany Snapper	2 – (15)	1 – (20)	
Ocyurus chrysurus	Yellowtail Snapper	2 – (20)	3 – (25)	3 – (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, 2009

DATE:		**TRANSECTS**					**MEAN**
Depth: 2 - 5 m		**1**	**2**	**3**	**4**	**5**	**ABUNDANCE (IND/30 m2)**
SPECIES	**COMMON NAME**						
Ophioderma sp.	Brittle Star				1		0.2
Echinometra lucunter	Rock boring Urchin		3	1			0.8
	TOTALS		3	1	1		1.0

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 15 species present and a mean density of 22.2 col./transect (range: 18 – 25 col./transect) (Table 6). The most abundant taxa included the Common Sea Fan *Gorgonia ventalina,* Sea Rods, *Eunicea spp,* Sea Plumes *Pseudopterogorgia acerosa, P. americana*, and *Plexaura spp*.

Stony corals occurred mostly as encrusting colonies of typically small size and low vertical relief. A total of 17 species of stony corals were identified from the patch reef community during our survey, including 13 species intercepted by line transects. Live stony coral cover averaged 19.4 % (range: 11.2 – 29.9 %). Great Star Coral, *Montastraea cavernosa* and Mustard-Hill Coral, *Porites astreoides* were the dominant species in terms of substrate cover with means of 5.4 and 3.8%, respectively. A total of 10 coral species were represented with less than 2% reef substrate cover. Total abiotic cover averaged 3.5 %.

Table 6. Percent substrate cover by sessile-benthic categories at Tres Palmas reef, Rincon, 10 m, June 2009

Depth: 10 m	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	1.89	2.30	2.03	2.18	1.89	**2.06**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	2.86	3.99	2.91	0.81	6.31	**3.4**
Sand				0.69		**0.1**
Total Abiotic	2.86	3.99	2.91	0.81	6.31	**3.5**
Benthic Algae						
Turf-mixed assemblage	79.58	72.09	65.92	56.32	66.44	**68.1**
Calcareous algae	2.61			0.46	1.43	**0.9**
Fleshy algae				2.22		**0.4**
Total Benthic Algae	82.19	72.09	65.92	59.00	67.87	**69.4**
Sponges	3.11	9.28	7.65	8.29	6.39	**6.9**
Cyanobacteria					0.71	**0.1**
Encrusting Gorgonian	0.59		0.57	0.69		**0.4**
Millepora spp.				0.58	0.24	**0.2**
Live Stony Corals						
Montastraea cavernosa	2.35	3.91	11.72	5.75	3.20	**5.4**
Porites astreoides	1.68	2.28	3.99	3.78	7.32	**3.8**
Colpophyllia natans	2.13		2.34	7.52		**2.4**
Agaricia agaricites	0.36	2.85	1.50	1.40	0.59	**1.3**
Montastraea annularis	4.12	1.83		0.46		**1.3**
Siderastrea siderea		0.69		2.79	2.01	**1.1**
Dendrogyra cylindrus				4.97		**1.0**
Diploria strigosa		1.71	1.29	1.72		**0.9**
Diploria labyrinthiformis				0.69	2.86	**0.7**
Siderastrea radians			1.75		1.42	**0.6**
Meandrina meandrites		0.92	0.94			**0.4**
Madracis decactis		0.46		0.82		**0.3**
Isophyllia sinuosa	0.59				0.36	**0.2**
Total Stony Corals	11.23	14.65	23.53	29.9	17.76	**19.4**
Recently dead coral						
Gorgonians (# col.)						
Gorgonia ventalina		3	4	2	5	**3.5**
Eunicea flexuosa	6	5	2	1	3	**3.4**
Pseudoptergorgia acerosa	1	6		1	3	**2.8**
Eunicea succinea	4		3	1		**2.7**
Plexaura kukenthali	4	2	1	1	5	**2.6**
Eunicea tourneforti	3	3	2	2	2	**2.4**
Pseudoptergorgia americana	1	4	3	3	1	**2.4**
Pseudoplexaura purosa				2		**2.0**

Table 6. Continued

Pseudoptergorgia acerosa yellow	2			2	2	**2.0**
Erythropodium caribaeorum	1			2		**1.5**
Ptergorgia citrina	2			1		**1.5**
Plexaura homomalla		1	2	1		**1.3**
Pseudoplexaura flagellosa or wagenaari			1	1	2	**1.3**
Eunicea laciniata		1				**1.0**
Muricea muricata				1		**1.0**
Total Gorgonians (# colonies/transect)	24	25	18	21	23	**22.2**

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

Turf algae, a mixed assemblage of short filamentous red and brown macroalgae presented the highest percent of reef substrate cover by sessile-benthic components with a mean of 68.1 % (range: 56.3 – 79.6 %). Fleshy brown (*Dictyota sp*.), red (*Galaxaura sp*.) and calcareous (*Halimeda discoidea*) macroalgae were present within transects with a combined cover of 1.3 %. Encrusting sponges were intersected by all five transects with a mean substrate cover of 6.9 % (range: 3.1 – 9.3 %). The encrusting gorgonian *Erythropodium caribaeorum* was present in three 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 3.5 % of the reef substrate cover, influenced in part by the essentially flat bathymetry and the prevailing encrusting growth pattern of corals, sponges and turf algae. Reef rugosity, which is an indicator of underwater topographic relief, was 2.1 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 19.4

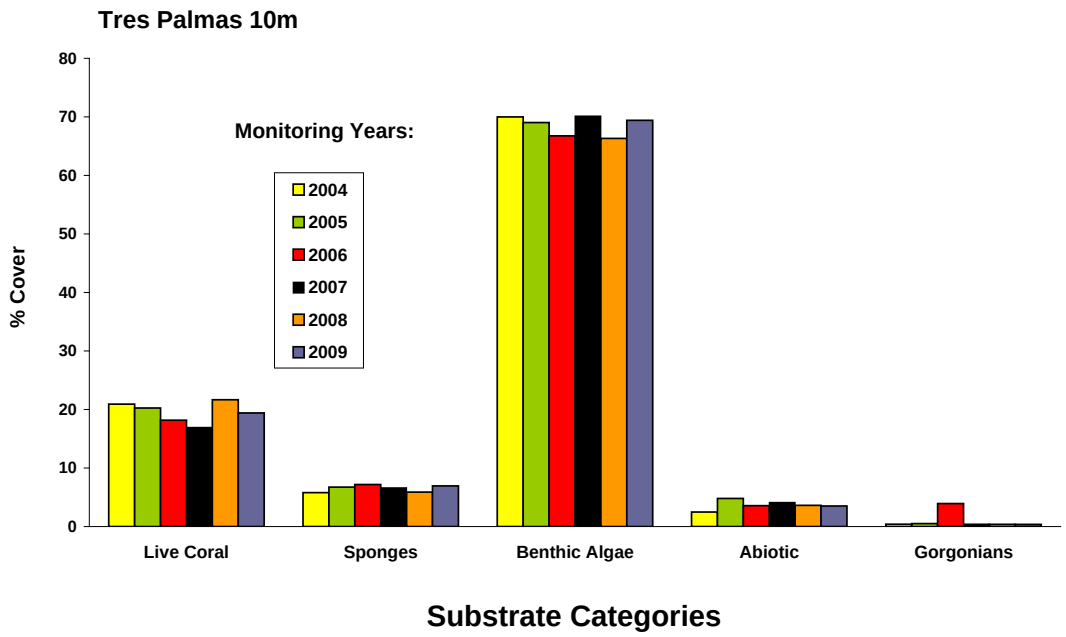


Figure 7. Monitoring trends (2004 – 2009) of mean substrate cover by sessile-benthic categories at Tres Palmas Outer Patch Reef – 10 m.

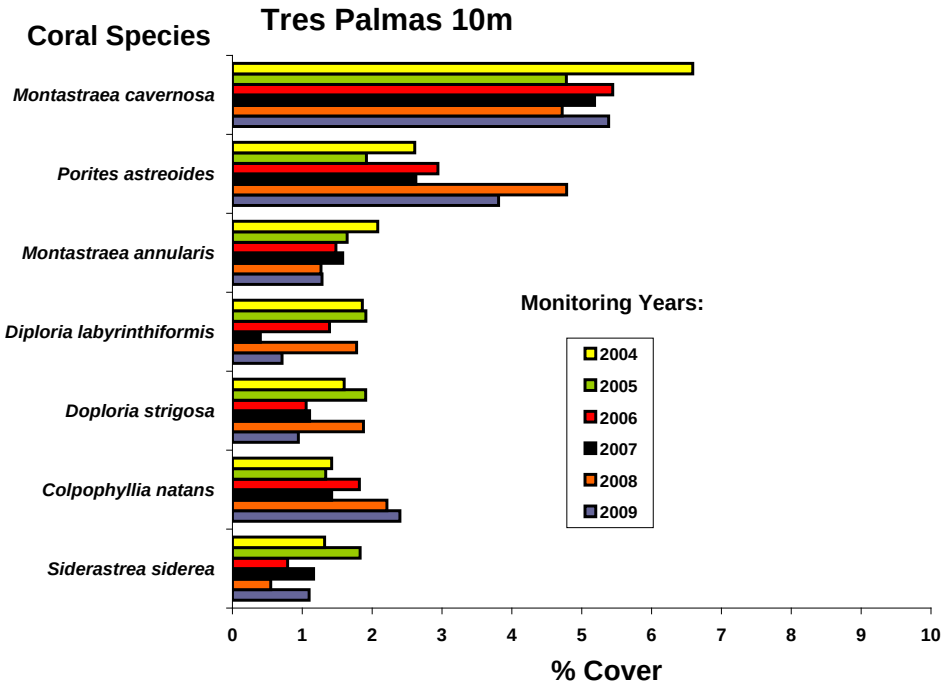


Figure 8. Monitoring trends (2004 – 2009) of mean substrate cover by stony coral species at Tres Palmas Outer Patch Reef – 10 m.

% in 2009. Small annual variations of the mean reef substrate cover by (total) live corals between monitoring surveys (2004 – 2009) were not statistically significant (ANOVA; p = 0.845).

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 2008-09 survey, mean abundance of individuals within belt-transects was 76.4 Ind/30 m^2 (range: 44 - 151 Ind/30 m^2). The mean number of species per transect was 11.8 (range: 9 - 15).

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 26.6 and 16.4 Ind/30 m^2, respectively (Table 7). The combined abundance of these two species represented 43.0 % of the community mean abundance within belt-transects. In addition to the two aforementioned species, the Sharknose Goby, Coney, Clown Wrasse, Redband Parrotfish and the Doctorfish were present in at least four of the five transects surveyed. Given their prevalence in previous surveys they represent a resident fish assemblage on this reef. Out of transects at the reef wall habitat there are several species of fish that are not typical of the reef top. These include the Fairy Basslet, Barred Cardinalfish, Glasseye, Longspine Squirrelfish, Black-bar Soldierfish, Spoted Drum, Queen Angelfish and several species of grunts. Small demersal predators, such as the Red Hind and Lane and Schoolmaster Snappers were observed over sandy bottom at the base of the wall during the ASEC survey (Table 8).

Fish abundance and species richness have declined steadily at this reef from a baseline mean abundance of 111.4Ind/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). Fish abundance and richness measured during 2009 reflect a slight increment from the 2008 survey.

Table 7. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef Rincon. Depth: 10 m. June, 2009

Depth: 10m		TRANSECTS					
		1	2	3	4	5	
SPECIES	**COMMON NAME**	(individuals/30 m2)					**MEAN**
Stagastes partitus	Bicolor Damselfish	29	25	24	33	22	**26.6**
Thalassoma bifasciatum	Bluehead Wrasse	45	1	11	25	0	**16.4**
Gobyosoma evelynae	Sharknose Goby	9	7	11	3	6	**7.2**
Chromis cyanea	Blue Chromis	27	0	2	0	3	**6.4**
Chephalopholis fulva	Coney	4	1	7	1	6	**3.8**
Halichoeres maculipinna	Clown Wrasse	13	1	2	3	0	**3.8**
Sparisoma aurofrenatum	Redband Parrotfish	6	3	1	2	0	**2.4**
Acanthurus chrirurgus	Doctorfish	3	2	2	2	1	**2.0**
Scarus taeniopterus	Princess Parrotfish	8	0	0	1	0	**1.8**
Halichoeres garnoti	Yellowhead Wrasse	1	0	0	5	2	**1.6**
Serranus tigrinus	Harlequin Bass	2	1	1	2	0	**1.2**
Chaetodon capistratus	Foureye Butterflyfish	0	1	0	1	2	**0.8**
Scarus iserti	Striped Parrotfish	1	0	1	0	0	**0.4**
Canthigaster rostrata	Sharpnose Puffer	0	1	0	0	1	**0.4**
Epinephelus guttatus	Red Hind	0	0	0	1	0	**0.2**
Gymnothorax miliaris	Goldentail Moray	0	1	0	0	0	**0.2**
Pomacanthus paru	French Angelfish	0	0	1	0	0	**0.2**
Coryphopterus sp.	Goby sp.	1	0	0	0	0	**0.2**
Acanthurus coeruleus	Blue Tang	0	0	0	1	0	**0.2**
Hypoplectrus puella	Barred Hamlet	1	0	0	0	0	**0.2**
Chaetodon striatus	Banded Butterflyfish	1	0	0	0	0	**0.2**
Microspathondon chrysurus	Yellowtail Damselfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**151**	**44**	**63**	**80**	**44**	**76.4**
	TOTAL SPECIES	**15**	**11**	**11**	**13**	**9**	**11.8**

Fishes Outside Transects:

SPECIES	**COMMON NAME**
Abudefduf saxatilis	Sergeant Major
Acanthostracion quadricornis	Scrawled cowfish
Anisotremus surinamensis	Black margate
Anisotremus virginicus	Porkfish
Apogon binotatus	Barred cardinalfish
Bodianus rufus	Spanish Hogfish
Cantherhines pullus	Tail-light triggerfish
Carangoides ruber	Horse-eye jack
Caranx crysos	Blue runner
Cephalopholis cruentatus	Graysbe
Chaetodon striatus	Banded butterflyfish
Chromis multilineata	Brown chromis
Clepticus parrae	Creole wrasse
Epinephelus guttatus	Red hind
Equetus punctatus	Spotted drum

Table 7. Continued

Flammeo marianus	Longspine squirrelfish
Gramma loreto	Fairy basslet
Gymnothorax moringa	Spotted moray
Haemulon chrysargyreum	Smallmouth grunt
Haemulon flavolineatum	French grunt
Haemulon flavolineatum	French grunt
Haemulon plumieri	White grunt
Halichoeres bivittatus	Slippery Ddick
Halichoeres radiatus	Puddinwife
Halichoeres sp.	wrasse
Holacanthus ciliaris	Queen angelfish
Holocentrus adsencionis	Longjaw squirrelfish
Hypoplectrus chlorurus	Yellowtail hamlet
Hypoplectyrus puella	Barred hamlet
Lactophrys bicaudalis	Spotted trunkfish
Lactophrys triqueter	Smooth trunkfish
Lutjanus mahogany	Mahogany snapper
Lutjanus synagris	Lane snapper
Malacanthus plumieri	Sand tilefish
Mulloides martinicus	Yellowtail goatfish
Myripristis jacobus	Blackbar soldierfish
Ocyurus chrysurus	Yellowtail snapper
Ophioblenius atlanticus	Yellowhead jawfish
Pomacanthus paru	French angelfish
Priacanthus arenatus	Glasseye
Pseudupeneus maculatus	Spotted goatfish
Ripticus saponaceus	Soapfish
Scarus vetula	Queen parrotfish
Sparisoma viride	Stoplight parrotfish
Sphaeroides greeleyi	?? Puffer
Sphyraena barracuda	Great Barracuda
Stegastes leucostictus	Beau Gregory
Stegastes variabilis	Cocoa damselfish

The high energy environment at the top of the patch reef is an appropriate habitat for opportunistic carnivores, such as Wrasses (*Thalassoma bifasciatum, Halichoeres garnoti, H. maculipinna*) which feed on small benthic (infaunal) invertebrates that become exposed upon disturbances of the substrate due to wave action. Also, herbivores (e.g. parrotfishes, doctorfishes, damselfishes) that feed on the turf algae were common. Pelagic piscivores, such as barracudas (*Sphyraena barracuda*), mackerels (*Scomberomorus regalis*) and jacks (*Caranx crysos, C. ruber*) have been previously reported from this reef (García-Sais et al., 2005, 2006, 2007, 2008). Mid size adult and juvenile Lane, Mahogany and Yellowtail snappers (*Lutjanus synagris, L. mahogony,*

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

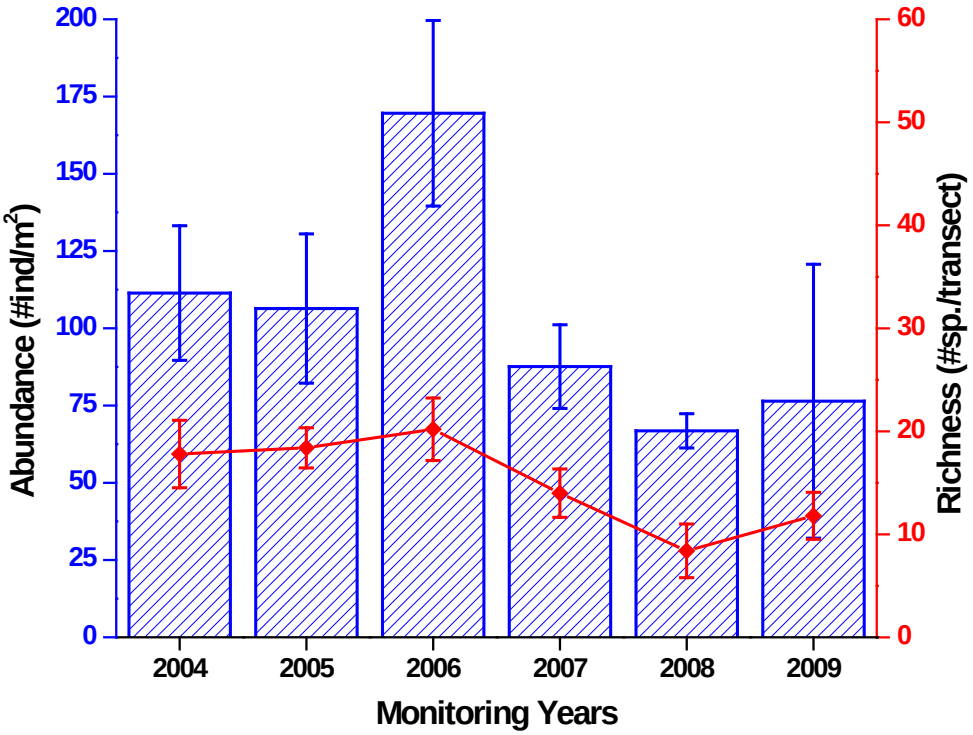


Figure 9. Monitoring trends (2004 – 2009) of fish species richness and abundance at Tres Palmas Outer Shelf Patch Reef, 10-15 m, Rincon.

Among motile megabenthic invertebrates, several spiny Lobsters (*Panulirus argus*) Slate-pencil Urchins (*Eucidaris tribuloides*), Cleaner Shrimps (*Periclimenes sp*., *Stenopus hispidus*), Arrow and Hermit Crabs (*Stenorhynchus seticornis, Paguridae*) and Sponge Brittle Stars have been previously reported from this reef (Garcia-Sais et al., 2006). Cleaner Shrimps and one Arrow Crab were observed within belt-transects during the present 2009 survey (Table 9).

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, 2009.

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

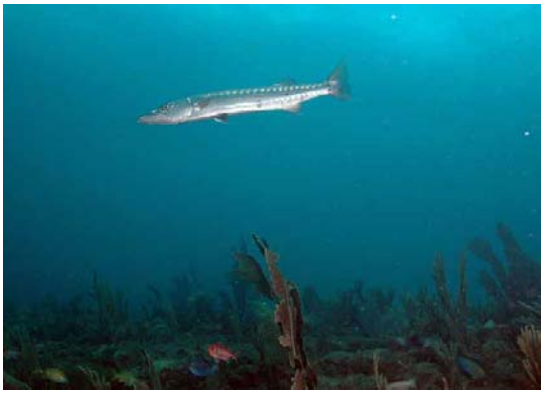
SPECIES	**COMMON NAME**	# - (cm)		
Caranx crysos	Blue Runner	2 – (40)		
Epinephelus guttatus	Red Hind	2 – (20)	1 – (25)	
Lutjanus mahogony	Mahogany Snapper	2 – (20)	1 – (25)	
Lutjanus synagris	Lane Snapper	3 – (15)	2 – (20)	
Ocyurus chrysurus	Yellowtail Snapper	3 – (20)	1 – (30)	
Sphyraena barracuda	Great Barracuda	1 – (45)		
Holacanthus ciliaris	Queen Angel	2 – (30)		
Gramma loreto	Fairy Basslet	10 – (3)	6 – (4)	2 – (5-7)

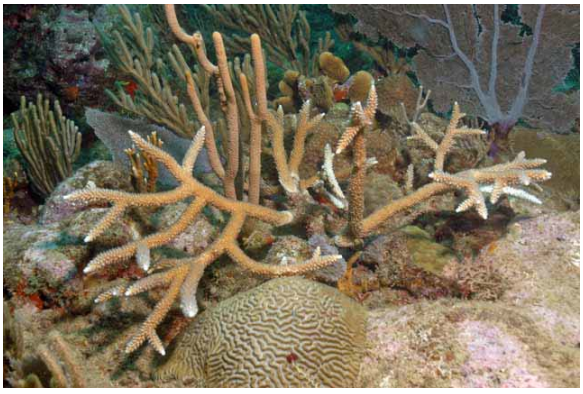
Table 9. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Reef, Rincon, 10m, June, 2009

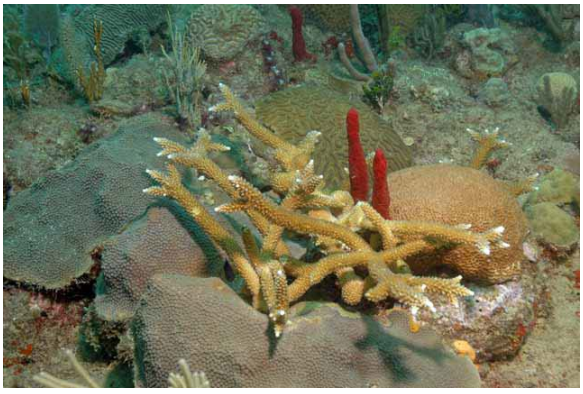
		TRANSECTS					
DATE: June 6, 2008 Depth: 10 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Periclimenes pedersoni	Cleaner Shrimp			2	1		**0.6**
Stenorhynchus seticornis	Arrow Crab	1					**0.2**
	TOTALS	1		2	1		**0.8**

Photo Album 2 (Rincon 15m

Outer Shelf Patch Reef







3.0 Tres Palmas Shelf-edge Reef

3.1 Sessile-benthic Community

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

A total of 22 stony coral species (including two hydrocorals) were identified from the shelf-edge reef off Tres Palmas, 14 of which were intercepted by line transects during the 2009 survey (Table 10). Stony corals occurred mostly as encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 23.1 % (range: 15.7 – 30.0 %). Boulder Star Coral, *Montastraea annularis* complex was the dominant species in terms of substrate cover with a mean of 10.0 % (range: 2.0 – 19.4 %), representing 43.3 % of the total cover by stony corals (Table 10). Colonies of *M. annularis* and Maze Coral (*Meandrina meandrites*) were present in all five transects. Also present in four out of the five transects were colonies of Great Star Coral, *M. cavernosa* and Lettuce Coral, *Agaricia agaricites*. Soft corals (gorgonians) were moderately abundant, with a total of 17 species within transects and an average of 26.7 colonies/transect. The main assemblage included the Corky Sea Finger, Briareum asbestinum, 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.

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

June 2009

Depth: 20 m	TRANSECTS					
	1	2	3	4	5	**MEAN**
Rugosity (m)	2.25	2.78	2.30	2.54	2.24	**2.42**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	7.34	8.37	10.33	3.27		**5.86**
Sand					3.19	**0.64**
Total Abiotic	7.34	8.37	10.33	3.27	0.00	**6.50**
Benthic Algae						
Turf-mixed assemblage	69.17	59.00	41.01	55.46	59.97	**56.92**
Coralline algae				4.86	1.96	**1.36**
Lobophora variegata		6.26	9.36	2.71	5.15	**4.70**
Dictyota sp.			0.81			**0.16**
Galaxaura sp.	0.49					**0.10**
Total Benthic Algae	69.66	65.26	51.18	63.03	67.08	**63.24**
Sponges	7.26	1.02	4.56	9.56	9.23	**6.33**
Gorgonians			3.91			**0.78**
Cyanobacteria						**0.00**
Hydrozoans (Millepora)						**0.00**
Live Stony Corals						
Montastraea annularis	1.95	7.90	19.45	9.64	11.27	**10.04**
Meandrina meandrites	1.61	0.99	5.94	3.11	4.17	**3.16**
Montastraea cavernosa	3.02	3.52	1.83	1.46		**1.97**
Agaricia agaricites	4.49			1.59	1.39	**1.49**
Porites astreoides		1.33		4.94	1.15	**1.48**
Colpophyllia natans		4.54	1.60			**1.23**
Madracis decactis	2.61	0.86		1.83		**1.06**
Siderastrea radians	1.14	3.76				**0.98**
Diploria strigosa	0.57	1.56			2.53	**0.93**
Agaricia grahamae				1.57		**0.31**
Porites colonensis			0.69			**0.14**
Stephanocoenia michelini	0.34	0.33				**0.13**
Manicina areolata		0.55				**0.11**
Leptoseris cucullata			0.46			**0.09**
Total Stony Corals	15.73	25.34	29.97	24.14	20.51	**23.14**
Gorgonians (# col.)						
Briareum asbestinum			9	1		**5.0**
Pseudoptergorgia acerosa	4	1	5	3	5	**3.6**
Erythropodium caribaeorum		1	4	1		**2.0**
Eunicea tourneforti	2	2		2	2	**2.0**
Eunicea flexuosa	2	1	2	2	1	**1.6**

Table 10. Continued

Gorgonia ventalina	1			2		**1.5**
Eunicea lacinata			1			**1.0**
Eunicea mammosa		1				**1.0**
Eunicea spp.				1		**1.0**
Eunicea succinea					1	**1.0**
Muriceopsis flavida				1		**1.0**
Plexaura hommomalla				1		**1.0**
Plexaura kukenthali	1	1			1	**1.0**
Plexaurella fusifera	1					**1.0**
Plexaurella nutans	1					**1.0**
Pseudoplexaura flagellosa or wagenaari			1			**1.0**
Pseudoptergorgia americana		1	1	1		**1.0**
Total Gorgonians (# colonies/transect)	12	8	23	15	10	**26.7**

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

Encrusting and erect sponges, including several large Basket Sponges, *Xestospongia muta* were present in all transects with an average cover of 6.3 %. Reef overhangs averaged 5.9 % and contributed to a topographic rugosity of 2.42 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 56.9 % (range : 41.0 – 69.2 %). 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*., *Amphiroa sp*. and *Galaxaura sp*. were also common in the reef, contributing an additional 6.4 % to the reef substrate cover. Isolated tufts of red coralline alga (*Amphiroa sp*) and other green filamentous algae were also present. The total reef substrate cover by benthic algae was 63.2 %. Patches of reddish, slimy mats of benthic cyanobacteria were observed over the reef, mostly covering sandy 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 (2009). A mild, but consistent trend of declining mean coral cover between monitoring surveys until 2008 is suggested by the data. This pattern ended this year with a minor and statistically insignificant (ANOVA; $p = 0.89$) increment of live coral cover. The

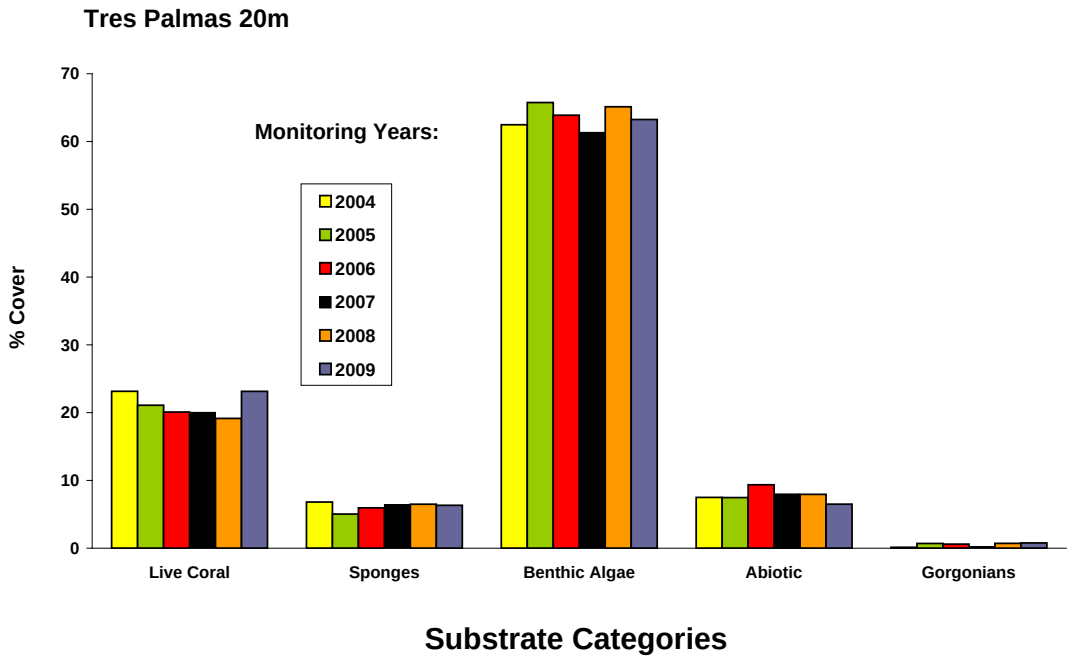


Figure 10. Monitoring trends (2004 – 2009) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef – 20 m.

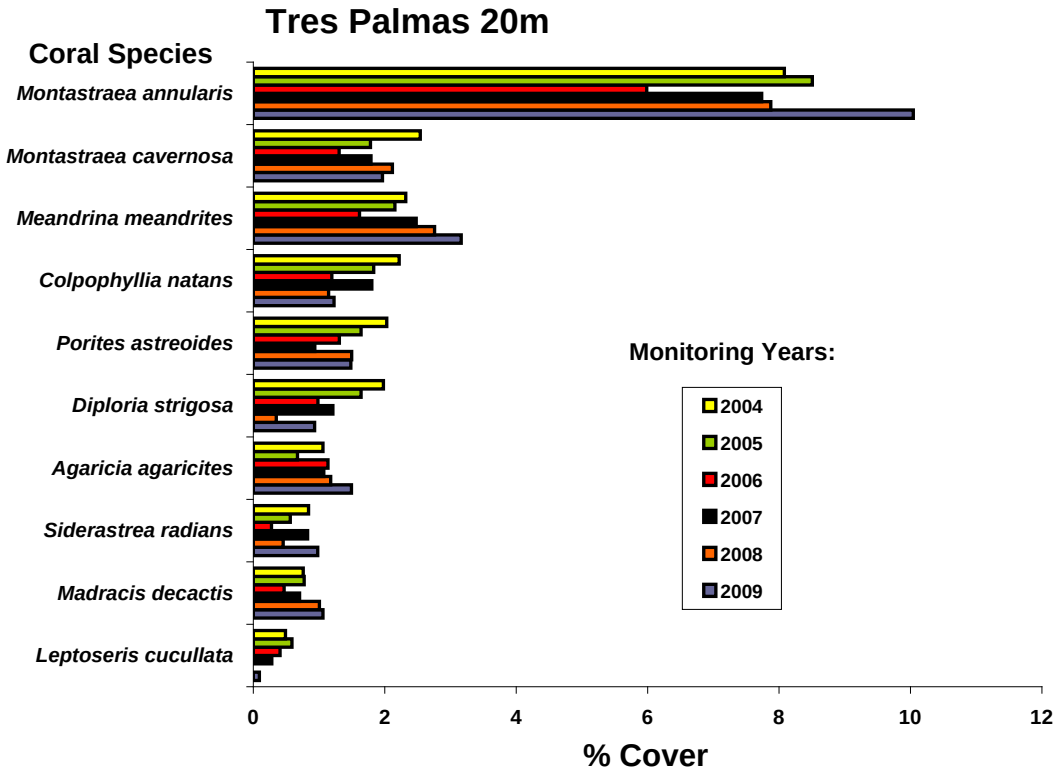


Figure 11. Monitoring trends (2004 – 2009) of mean substrate cover by stony coral species at Tres Palmas Reef – 20 m.

variability in both magnitude and direction of live coral cover within transects is high enough to render the differences between monitoring years statistically insignificant.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 83 fish species have been identified during the five surveys (2004-09) from the shelf-edge reef off Tres Palmas (Appendix 1). Table 11 lists the 39 fish species observed within belt-transects during the 2009 survey in decreasing order of abundance. Mean abundance within belt-transects was 267.2 Ind/30 m^2 (range: 147 – 380 Ind/30 m^2). The mean number of species per transect was 22 (range: 19– 26). An assemblage consisting of six species represented 80.8 % of the total fish individuals within belt-transects (Table 11). The Masked Goby, Peppermint Goby, Blue Chromis, Bicolor Damselfish, Bluehead and Creole Wrasse comprised the numerically dominant assemblage. In addition, The Beau Gregory, Sharknose Goby, Sharpnose Puffer, Blackbar Soldierfish and Four-eye Butterflyfish were present in all five transects surveyed.

Annual fluctuations of fish abundance and species richness from the baseline survey in 2004 to the present are presented in Figure 12. Fish species richness within belt-transects has remained virtually constant, but fish abundance presented statistically significant differences between survey years (ANOVA; $p = 0.003$). Mean fish abundance decreased 64.4 % from the baseline (531.4 Ind/30 m^2) in 2004 to a minimum abundance of 189.2 Ind/30 m^2 during 2007. After 2007, subsequent monitoring years show an mild increasing trend. The main species that has contributed to the variability of fish abundance between monitoring surveys is theMasked 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. The fish community associated with the Tres Palmas shelf-edge reef appears to be well balanced in terms of trophic

Table 11. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef 20 m, Rincon. June, 2009

Depth: 20m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**	(individuals/30 m2)					**MEAN**
Coryphopterus personatus	Masked Goby	52	45	111	115	26	**69.8**
Coryphopterus lipernes	Peppermint Goby	45	57	49	58	36	**49.0**
Chromis cyanea	Blue Chromis	41	46	88	18	2	**39.0**
Stegastes partitus	Bicolor Damselfish	21	15	31	38	46	**30.2**
Thalassoma bifasciatum	Bluehead Wrasse	13	25	35	7	6	**17.2**
Clepticus parrae	Creole Wrasse	0	55	0	0	0	**11.0**
Gobiosoma evelynae	Sharknose Goby	8	12	10	12	6	**9.6**
Sparisoma aurofrenatum	Redband Parrotfish	0	6	1	33	4	**8.8**
Chromis multilineata	Brown Chromis	0	2	14	5	2	**4.6**
Stegastes leucostictus	Beaugregory	3	3	6	2	4	**3.6**
Canthigaster rostrata	Sharpnose Puffer	3	5	3	2	2	**3.0**
Miripristis jacobus	Blackbar Soldierfish	1	1	7	2	1	**2.4**
Halichoeres garnoti	Yellowhead Wrasse	2	4	2	0	1	**1.8**
Chaetodon capistratus	Foureye Butterflyfish	2	2	2	2	1	**1.8**
Acanthurus chirurgus	Doctorfish	0	6	1	0	0	**1.4**
Cephalopholis cruentatus	Graysby	4	0	2	0	0	**1.2**
Scarus taeniopterus	Princess Parrotfish	1	2	3	0	0	**1.2**
Neoniphon marianus	Longjaw Squirrelfish	2	0	3	1	0	**1.2**
Scarus iserti	Striped Parrotfish	0	0	0	5	0	**1.0**
Chromis insulatus	Sunshine Chromis	1	0	0	0	3	**0.8**
Acanthurus bahianus	Ocean Surgeon	1	1	0	2	1	**1.0**
Hypoplectrus chlorurus	Yellowtail Hamlet	1	2	0	1	0	**0.8**
Haemulon flavolineatum	French Grunt	2	1	1	0	0	**0.8**
Cephalopholis fulva	Coney	0	1	0	2	1	**0.8**
Bodianus rufus	Spanish Hogfish	0	0	1	0	2	**0.6**
Halichoeres maculipina	Clown Wrasse	0	0	2	1	0	**0.6**
Acanthurus coeruleus	Blue Tang	0	0	2	0	1	**0.6**
Holocentrus rufus	Longspine Squirrelfish	1	0	1	0	0	**0.4**
Amblycirrhitus pinos	Redspoted Hawlkfish	0	0	1	1	0	**0.4**
Equetus punctatus	Spoted Drum	0	0	2	0	0	**0.4**
Chaetodon striatus	Banded Butterflyfish	0	2	0	0	0	**0.4**
Ctenogobius saepepallens	Dashed Goby	0	0	0	1	1	**0.4**
Synodus intermedius	Sand Diver	0	0	1	0	0	**0.2**
Serranus tigrinus	Harlequin Bass	0	1	0	0	0	**0.2**
Pomacanthus arcuatus	Gray Angelfish	0	1	0	0	0	**0.2**
Gymnothorax miliaris	Goldentail Moray	0	0	1	0	0	**0.2**
Haemulon carbonarium	Cesar Grunt	0	1	0	0	0	**0.2**
Hypoplectrus nigricans	Black Hamlet	0	0	0	0	1	**0.2**

Table 11. Continued							
Melichthys niger	Black Durgeon	0	1	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**204**	**297**	**380**	**308**	**147**	**267.2**
	TOTAL SPECIES	**19**	**25**	**26**	**20**	**20**	**22.0**

Fishes Outside Transects:

SPECIES	**COMMON NAME**
Abudefduf sexatilis	Sargent major
Anisotremus virginicus	Porkfish
Anisotremus surinamensis	Black margate
Apogon sp.	Cardinalfish
Cantherhines macrocerus	Whitespotted filefish
Caragoides ruber	Horse-eye jack
Cephalopholis fulva	Coney
Decapterus macarelus	Mackerel scad
Haemulon aurolineatum	Tomtate
Haemulon macrostomus	Spanish grunt
Haemulon plumieri	White grunt
Holacanthus ciliaris	Queen angelfish
Hypoplectrus unicolor	Butter hamlet
Lactophrys triqueter	Smooth trunkfish
Lutjanus apodus	Schoolmaster
Lutjanus mahogany	Mahogany snapper
Lutjanus synagris	Lane snapper
Malacanthus plumieri	Sand tilefish
Muraena sp.	Moray
Mulloides martinicus	Yellowtail goatfish
Ocyurus chrysurus	Yellowtail snapper
Opistognathus aurifrons	Yellowhead jawfish
Paranthias furcifer	Creole fish
Pomacanthus paru	French angelfish
Pseudupeneus maculatus	Spotted goatfish
Scarus chrysargyreum	Redtail parrotfish
Scomberomorus regalis	Cero
Serranus tabacarius	Tobacco fish
Sparisoma viride	Stoplight parrotfish
Synodus intermedius	Sand diver

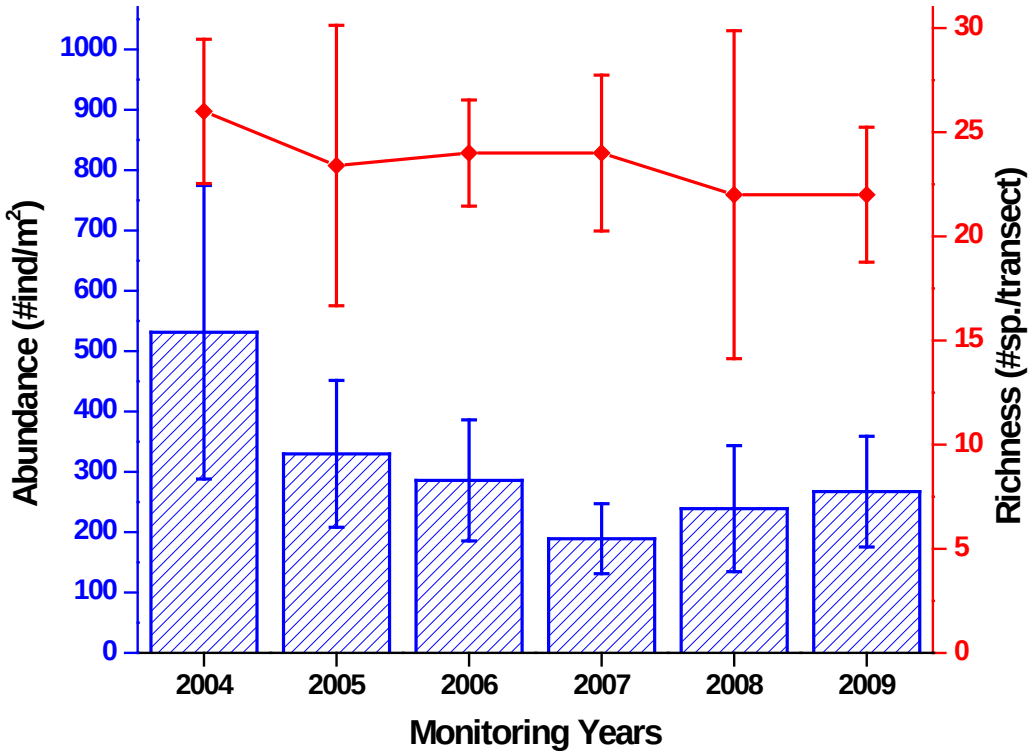


Figure 12. Monitoring trends (2004 – 2009) of fish species richness and abundance at Tres Palmas Shelf Edge Reef, Rincon.20 m,

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

The shelf-edge reef is an ideal habitat for adult reef fishes, as evidenced by the presence of adult Lane and Schoolmaster snappers, Red Hinds, Great Barracuda, Cero

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

Motile megabenthic invertebrates, such as Arrow Crabs, *Stenorhynchus seticornis,* Cleaner Shrimps *Periclimenes pedersoni* and *Stenopus hispidus*, Common Octopus, *Octopus vulgaris*, and Spiny Lobsters, *Panulirus argus* have been previously reported within belt-transects during previous surveys at this reef. Three cleaner shrimps, *P. pedersoni* and one arrow crab were observed withion belt-transects during 2009 (Table 13).

Table 12. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at the shelf-edge off Tres Palmas Reef, Rincón, June, 2009

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

SPECIES	**COMMON NAME**	# - (cm)		
Carangoides crysos	Blue Runner	2 – (40)		
Epinephelus guttatus	Red Hind	1 – (25)		
Gramma loreto	Fairy Basslet	5 - (< 3)	14 - (4-5)	4- (6-7)
Holacanthus ciliaris	Queen Angel	1 - (35)		
Holacanthus tricolor	Rock Beauty	3 - (15)	1 - (20)	1 - (25)
Lutjanus apodus	Schoolmaster	1 - (20)	2 – (25)	1 – (30)
Lutjanus mahogony	Mahogany Snapper	1 - (20)	1 - (25)	
Ocyurus chrysurus	Yellowtail Snapper	2 – (30)	1 – (40)	
Opistognathus aurifrons	Yellowhead Jawfish	5 – (6-8)		
Scomberomorus regalis	Cero Mackerel	1 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (50)		

Table 13. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Shelf-edge Reef, Rincon 20 m, June, 2009

Depth: 20 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	2	3	4	5	
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.

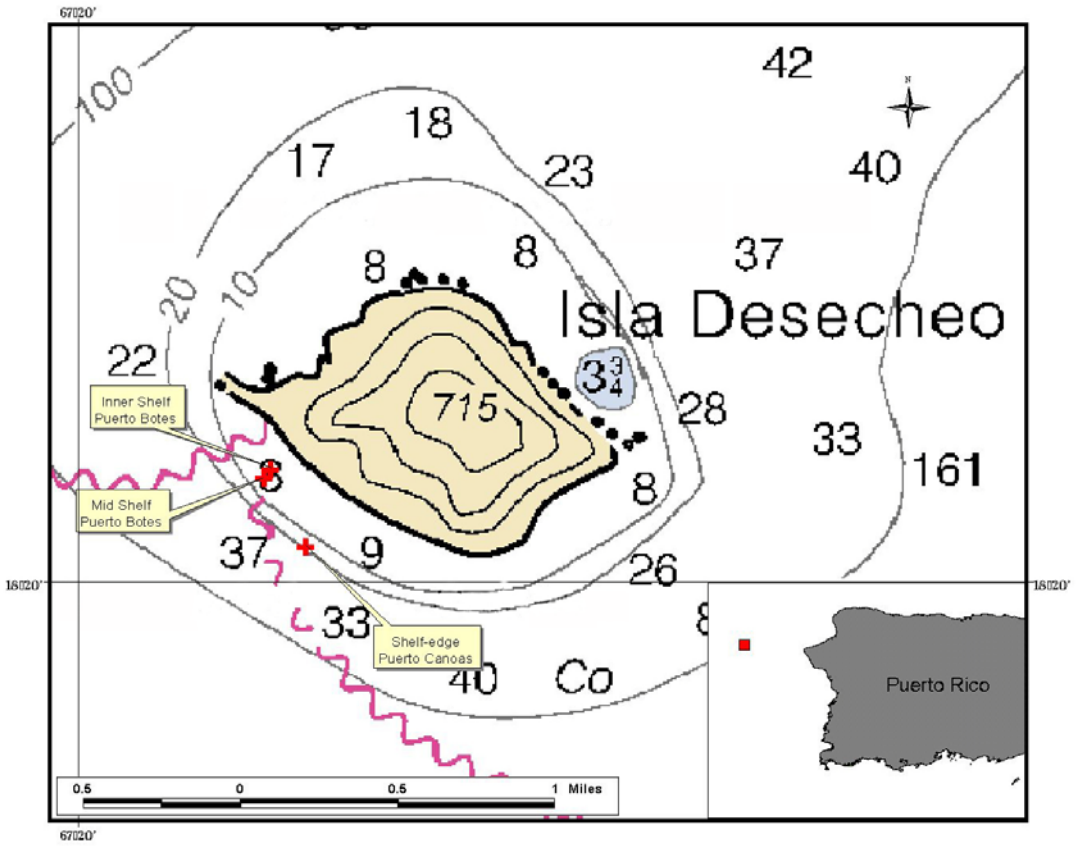


Figure 13. Location of coral reef survey stations at Puerto Canoas/Botes, Isla Desecheo.

Stony corals dominated reef substrate cover along surveyed transects with a mean of 25.2% (range: 20.8 – 32.4 %). Boulder Star Coral (*Montastraea annularis* complex), with a mean cover of 15.2 % represented 60.4 % of the total stony coral cover. In addition to *M. annularis*, Lettuce Coral (*Agaricia agaricites*) and Mustard-Hill Coral (*Porites astreoides*) were present in all five transects at the shelf-edge reef of Puerto Canoas (Table 14). A total of 18 species of stony corals were identified, including 11 intersected by line transects. Several colonies of Black Coral, *Anthipathes sp*., and Wire Coral, *Stichopathes sp*. were observed near the base of the reef and within crevices. Soft corals (gorgonians) were not intercepted by transects and were not common at the shelf-edge reef. Abiotic cover, mostly associated with reef overhangs averaged 18.7 % and contributed to a mean reef substrate rugosity of 3.93. Encrusting and erect sponges were common, with a mean cover of 7.4 % (range: 3.5 – 13.3 %).

Table 14. Percent substrate cover by sessile-benthic categories at Desecheo Island. 30 m,.June 2009

Depth: 30 m	Transects					
	1	2	3	4	5	**MEAN**
Rugosity (m)	5.38	3.72	3.49	3.11	3.93	**3.93**
SUBSTRATE CATEGORY						
Abiotic						
Sand					2.15	
Reef Overhangs	13.91	20.20	16.60	19.77	21.03	**18.30**
Total Abiotic	13.91	20.20	16.60	19.77	23.18	**18.73**
Benthic Algae						
Turf-mixed assemblage	32.05	32.97	39.96	17.40	16.15	**27.71**
Lobophora variegata	20.61	10.58	4.82	34.50	24.77	**19.06**
Coralline algae	1.37					**0.27**
Total Benthic Algae	54.03	43.55	44.78	51.90	40.92	**47.04**
Sponges	7.41	7.37	13.27	5.34	3.52	**7.38**
Cyanobacteria	3.64		2.30	2.14		**1.62**
Live Stony Corals						
Montastraea annularis	5.59	16.85	17.64	10.76	25.27	**15.22**
Agaricia agaricites	3.64	1.82	4.89	4.73	1.94	**3.40**
Colpophyllia natans	8.26	2.98				**2.25**
Porites astreoides	2.02	3.79	0.52	3.44	1.44	**2.24**
Diploria strigosa					3.73	**0.75**
Meandrina meandrites				1.91		**0.38**
Eusmilia fastigiata		1.31				**0.26**
Isophyllia rigida		1.03				**0.21**
Porites divaricata		1.03				**0.21**
Agaricia grahamae	0.91					**0.18**
Porites porites	0.55					**0.11**
Total Stony Corals	20.97	28.81	23.05	20.84	32.38	**25.21**

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 47.0 % 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 three transects with a mean substrate cover of 1.6 %.

Figure 14 shows the annual variations of mean percent cover by the main sessile-benthic categories from the shelf-edge reef at Puerto Canoas. Differences of mean substrate cover by stony corals, sponges and benthic algae between the 2004 baseline characterization and the 2005 monitoring surveys were within 1 % and statistically insignificant. A sharp, statistically significant decline of mean live coral cover was observed between the 2005 (48.07 %) and the 2006 (37.50 %) survey (ANOVA; $p < 0.0001$). A mild, but consistent trend of live coral loss followed until this 2009 monitoring survey, when live coral stabilized relative to 2008. 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 (Figure 15). 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. During 2009, *M. annularis* complex presented a mild trend of increasing live cover at this reef (Figure 15).

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 95 fish species have been identified during the five surveys (2004-09) from the shelf-edge reef off Puerto Canoas, Isla Desecheo (Appendix 1). Mean abundance of fishes within belt-transects during June, 2009 was 345.4 Ind/30 m^2 (range: 227 – 450 Ind/30 m^2). The mean number of species per transect was 28.4 (range: 24 – 30) (Table 15). An assemblage of nine species, including the Creole Wrasse, Blue and Brown Chromis, Peppermint and Masked gobies, Fairy Basslet, Bermuda Chub, Bluehead Wrasse and Bicolor Damselfish represented 85.2 % of the total fish abundance within belt-transects. The Creole Wrasse, *Clepticus parrae* was the numerically dominant species with a mean abundance of 133.0 Ind/30 m^2 (range: 50 – 175 Ind/30 m^2), representing 38.5 % of the total (Table 15). More than 90% of all the Creole Wrasse present within belt-transects were post-recruitment stages forming large swarms close to the reef substrate. Also, A total of 14 species were present within all five belt-transects surveyed. Large streaming schools of adult Creole Wrasse were observed throughout the water column, making frequent incursions over the reef. These are zooplanktivores

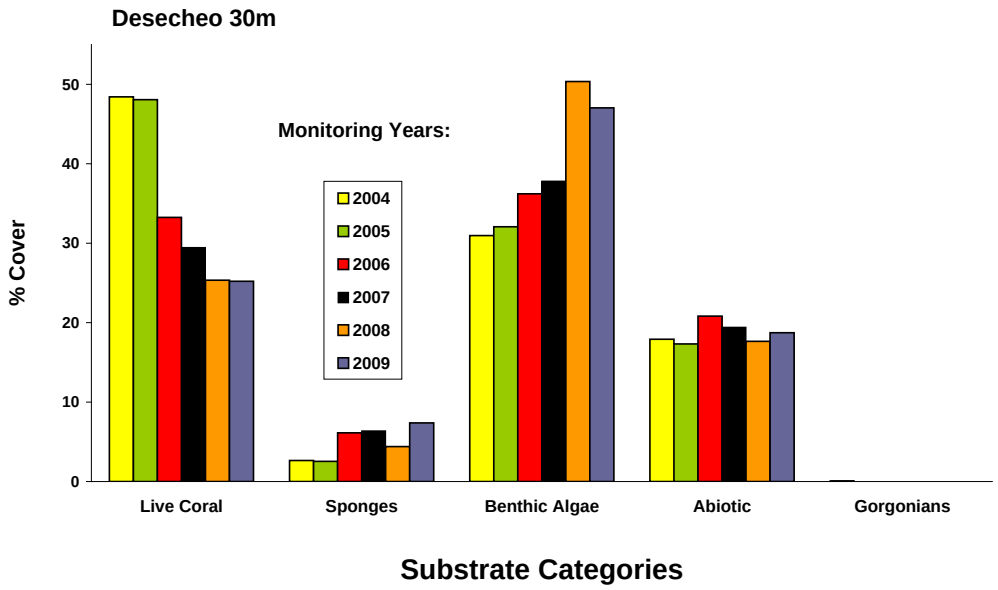


Figure 14. Monitoring trends (2004 – 09) of substrate cover by sessile-benthic categories at Puerto Canoas Reef, Desecheo Island – 30 m.

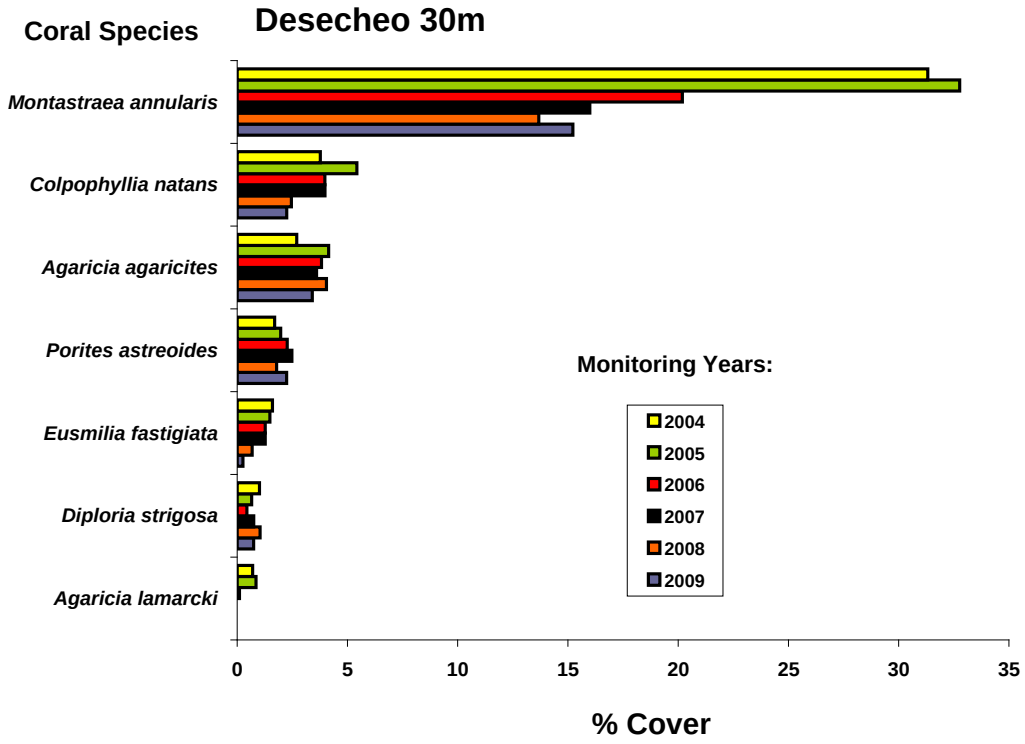


Figure 15. Monitoring trends (2004-09) of mean substrate cover by stony coral species at Puerto Canoas Reef, Desecheo Island – 30 m.

Table 15. Taxonomic composition and abundance of fishes within belt-transects at Puerto Canoas Reef 30 m, Isla Desecheo. June, 2009

Depth: 27 - 30m		TRANSECTS					
		1	2	3	4	5	
SPECIES	**COMMON NAME**	(Individuals/30 m^2)					**MEAN**
Clepticus parrae	Creole Wrasse	130	170	140	175	50	**133.0**
Chromis cyanea	Blue Chromis	15	52	20	75	35	**39.4**
Coryphopterus lipernes	Peppermint Goby	32	42	52	18	25	**33.8**
Gramma loreto	Fairy Basslet	13	32	54	7	7	**22.6**
Chromis multilineata	Brown Chromis	0	65	18	4	12	**19.8**
Coryphopterus personatus	Masked Goby	34	4	10	3	30	**16.2**
Kyphosus sectatrix	Bermuda Chub	0	13	50	0	0	**12.6**
Stegastes partitus	Bicolor Damselfish	6	8	15	5	10	**8.8**
Thalassoma bifasciatum	Bluehead Wrasse	1	4	8	20	9	**8.4**
Halichoeres maculipina	Clown Wrasse	1	11	12	10	3	**7.4**
Scarus iserti	Stripped Parrotfish	5	1	12	7	1	**5.2**
Halichoeres garnoti	Yellowhead Wrasse	1	8	2	0	11	**4.4**
Sparisoma aurofrenatum	Redband Parrotfish	0	5	4	8	2	**3.8**
Gobiosoma evelynae	Sharknose Goby	3	2	3	3	5	**3.2**
Sparisoma viride	Stoplight Parrotfish	1	2	1	2	6	**2.4**
Cephalopholis cruentatus	Graysby	1	6	1	4	0	**2.4**
Microspathodon chrysurus	Yellowtail Parrotfish	3	1	1	2	2	**1.8**
Canthigaster rostrata	Sharpnose Puffer	2	2	2	1	0	**1.4**
Holocentrus rufus	Longspine Squirrelfish	1	2	1	2	1	**1.4**
Melichthys niger	Black Durgeon	5	0	0	0	2	**1.4**
Lutjanus apodus	Schoolmaster Snapper	3	2	0	0	1	**1.2**
Chaetodon capistratus	Foureye Butterflyfish	0	3	1	1	1	**1.2**
Bodianus rufus	Spanish Hogfish	1	0	3	1	0	**1.0**
Liopropoma rubre	Peppermint Basslete	0	0	3	0	2	**1.0**
Gobiosoma horsti	Yellowline Goby	0	4	0	0	0	**0.8**
Amblycirrhitus pinos	Redspoted Hawkfish	0	2	0	2	0	**0.8**
Gobiosoma sp.	Goby sp.	3	0	0	1	0	**0.8**
Paranthias fucifer	Creolefish	1	1	0	2	0	**0.8**
Stegastes planifrons	Threespot Damselfish	2	0	0	1	0	**0.6**
Lactophrys triqueter	Smooth Trunkfish	1	1	0	0	1	**0.6**
Holocanthus tricolor	Rock Beauty	0	1	0	0	2	**0.6**
Chaetodon aculeatus	Longsnout Butterflyfish	1	0	2	0	0	**0.6**
Sparisoma atomarium	Greenblotch Parrotfish	0	3	0	0	0	**0.6**
Ctenogobius saepepallens	Dash Goby	1	0	0	0	2	**0.6**
Acanthurus coerulus	Blue Tang	1	0	2	0	0	**0.6**
Epinephelus guttatus	Red Hind	0	0	2	0	0	**0.4**
Scarus taeniopterus	Princess Parrotfish	0	1	0	0	1	**0.4**
Caranx latus	Horseye Jack	1	0	1	0	0	**0.4**
Neoniphon marianus	Longjaw Squirrelfish	1	0	0	0	1	**0.4**
Miripristis jacobus	Blackbar Soldierfish	1	0	0	0	1	**0.4**
Chaetodon striatus	Banded Butterflyfish	0	0	0	0	2	**0.4**
Chromis insolata	Sunshine Chromis	0	0	0	0	1	**0.2**
Epinephelus striatus	Nassau Grouper	0	0	1	0	0	**0.2**
Serranus tigrinus	Harlequin Bass	0	0	0	0	1	**0.2**
Gymnothorax miliaris	Goldentail Moray	0	0	1	0	0	**0.2**
Gobiosoma sp.	Goby sp2.	1	0	0	0	0	**0.2**
Blenniidae sp	Blenny sp	0	0	0	1	0	**0.2**
Anisotremus surinamensis	Black Margate	0	1	0	0	0	**0.2**

Table 15. Continued

Hypoplectrus puella	Barred Hamlet	0	1	0	0	0	**0.2**
Caranx ruber	Bar Jack	0	0	1	0	0	**0.2**
	TOTAL INDIVIDUALS	**272**	**450**	**423**	**355**	**227**	**345.4**
	TOTAL SPECIES	**30**	**30**	**29**	**24**	**29**	**28.4**

Fishes Outside Transects

SPECIES	**COMMON NAME**
Acanthurus bahianus	Ocean Surgeon
Alectis ciliaris	African Pompano
Aulostomus maculatus	Trumpetfish
Balistes vetula	Queen Triggerfish
Cantherhines surinamensis	Ocean Triggerfish
Carangoides ruber	Bar Jack
Chaetodon striatus	Banded Butterflyfish
Coryphopterus sp.	Goby
Dasyatis americana	Southern Stingray
Diodon histrix	Porcupinefish
Epinephelus guttatus	Red Hind
Epinephelus striatus	Nassau Grouper
Equetus acuminatus	Cubbyu
Gymnothorax funebris	Green Moray
Haemulon sciurus	Bluestripped Grunt
Lutjanus cyanopterus	Cubera Snapper
Lutjanus jocu	Dog Snapper
Lutjanus mahogany	Mahogany Snapper
Malacanthus plumieri	Sand Tilefish
Mycteroperca venenosa	Yellowfin Grouper
Ocyurus chrysurus	Yellowtail Snapper
Opistognathus aurifrons	Yellowhead Jawfish
Pomacanthus paru	French Angelfish
Sparisoma rubripinne	Yellowtail Parrotfish
Sphyraena barracuda	Great Barracuda

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. Differences between surveys were not statistically significant

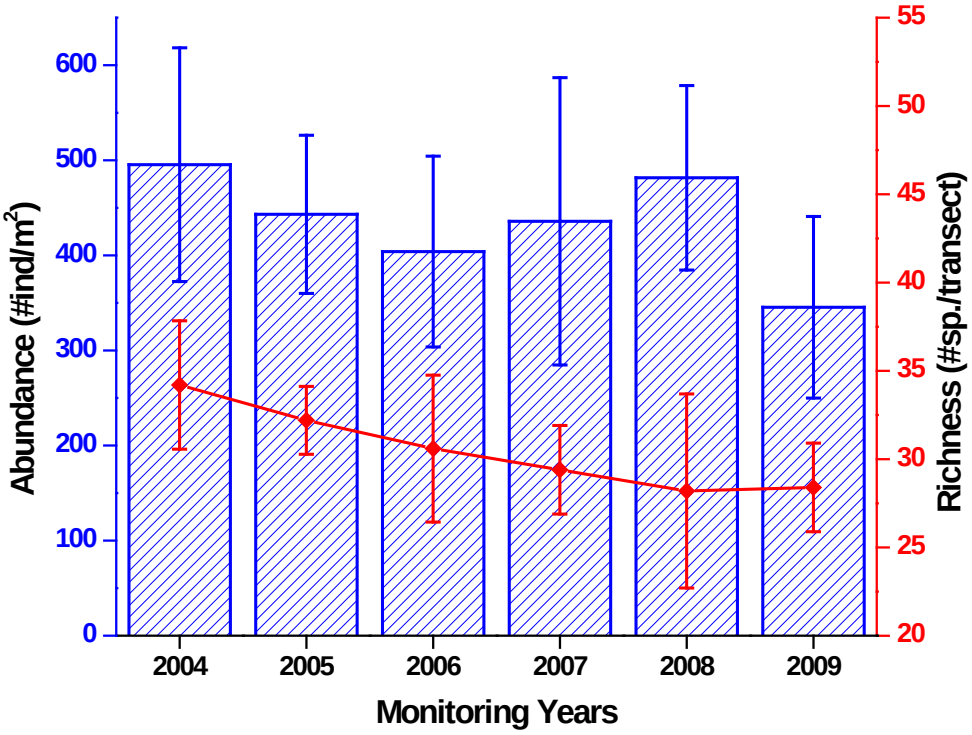


Figure 16. Monitoring trends (2004 – 2008) of fish species richness and abundance at the Shelf-edge Reef Puerto Canoas, 30 m, Isla Desecheo.

(ANOVA; richness p = 0.095; abundance p = 0.332). 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.

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

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, 2009

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

SPECIES	**COMMON NAME**		# - (cm)	
Balistes vetula	Queen Triggerfish	1 – (40)		
Caranx lugubris	Black Jack	2 - (50)		
Dasyatis americana	Southern Stingray	1 – (70)		
Epinephelus guttatus	Red Hind	1 – (20)	2 - (30)	
Epinephelus striatus	Nassau Grouper	1 - (60)		
Holacanthus ciliaris	Queen Angel	2 - (40)		
Holacanthus tricolor	Rock Beauty	2 - (15)	1 - (20)	
Lutjanus apodus	Schoolmaster	7 - (20)	14 - (30)	6 - (40)
Lutjanus mahogany	Mahogani Snapper	3 - (20)	5 - (30)	
Mycteroperca venenosa	Yellowfin Grouper	1 - (45)		
Ocyurus chrysurus	Yellowtail Snapper	3 - (25)	2 – (30)	6 – (40)
Scomberomorus regalis	Cero Mackerel	1 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (60)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (30)		
Strombus gigas	Queen Conch	5 - (25)		
Sea Turtles				
Eretmochelys imbricata	Hawksbill Turtle	1 – (60)		

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.

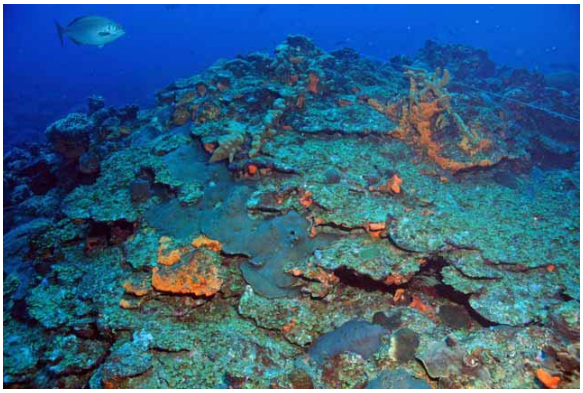
The Arrow Crab, *Stenorhynchus seticornis* and the Cleaner Shrimps, *Stenopus hispidus* and *Periclimenes pedersoni* were the motile megabenthic invertebrates observed within belt-transects (Table 17). One Spiny Lobster, *Panulirus argus* and several Queen Conch (*Strombus gigas*) were observed outside 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 2009

Depth: 25 – 30 m		TRANSECTS					**MEAN ABUNDANCE (IND/30 m2)**
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						
Stenorhynchus seticornis	Arrow crab	1		1	1		**0.6**
Periclimenes pedersoni	Cleaner Shrimp	1	1			1	**0.4**
Stenopus hispidus	Banded Coral Shrimp			1			**0.2**
	TOTALS	**2**	**1**	**2**	**1**	**1**	**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 seventh 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 10 intersected by line transects were identified during this survey. Finger Coral, *Porites porites* was the species of highest mean percent substrate cover with a mean of 6.4 % (range: 0 – 31.0). 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 Mustard Hill Coral, *P. astreoides* comprised (with Finger Coral) the most prominent coral assemblage along transects representing 77.7 % of the total cover by live corals at Puerto Botes (Table 18). Recently dead corals were observed in three transects with a mean cover of 8.2 %. *M. annularis* was the most affected. Although at a lower rate than previous years, mortality of *M. annularis* has continued on this reef after the massive coral bleaching event of October 2005.

Reef overhangs, largely associated with skeletal buildups of *Montastraea annularis* averaged 10.1 % of the reef substrate cover and contributed substantially to the reef rugosity of 3.48 m. Erect and encrusting sponges were present with a mean substrate cover of 2.6 %. Reef hard-ground substrates not colonized by stony corals or sponges were mostly overgrown by a dense algal turf (mean cover: 54.4 %), comprised of a mixed assemblage of red coralline and brown macroalgae. Fleshy brown (*Lobophora*

Table 18. Percent substrate cover by sessile-benthic categories at Desecheo Island, 20 m, June 2009

Depth: 20 m	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	4.47	3.78	3.48	2.10	3.55	**3.48**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	12.38	7.04	11.51	8.93	10.48	**10.1**
Cable			0.52			**0.1**
Total Abiotic	12.38	7.04	12.03	8.93	10.48	**10.2**
Benthic Algae						
Turf-mixed assemblage	73.65	46.11	47.07	39.70	65.31	**54.4**
Dictyota sp.	2.92	18.30	7.42	1.40	0.52	**6.1**
Lobophora variegata	2.42	12.06	20.27	2.56	12.03	**9.9**
Stypopodium zonale	2.63	1.74	2.30	1.75	1.04	**1.9**
Total Benthic Algae	81.62	78.21	77.06	45.41	78.90	**72.2**
Sponges		1.45	0.82	8.35	2.36	**2.6**
Cyanobacteria	0.49	3.38	1.57			**1.1**
Live Stony Corals						
Porites porites				31.02	1.03	**6.4**
Agaricia agaricites	2.90	1.09	2.60	0.70	2.51	**2.0**
Porites astreoides		3.92	0.73	1.51		**1.2**
Montastraea annualaris	2.44	1.31	0.63	0.47	0.96	**1.2**
Montastraea cavernosa			1.57		3.32	**1.0**
Diploria labyrinthiformis				3.61		**0.7**
Meandrina meandrites		2.03	1.15			**0.6**
Eusmilia fastigiata			1.88			**0.4**
Colpophyllia natans		1.53				**0.3**
Madracis decactis	0.19				0.44	**0.1**
Total Stony Corals	5.53	9.88	8.56	37.31	8.26	**13.9**
Recently Dead						
Montastraea annualaris			25.32	3.61	11.12	**8.0**
Montastraea cavernosa			0.73			**0.2**
Total recently dead coral	0.00	0.00	26.05	3.61	11.12	**8.2**

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

sp., Dictyota sp., Padina sp.) and calcareous macroalgae contributed an additional 17.8 % to the total benthic algal cover at Puerto Botes (Table 18).

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 2009 monitoring survey, live coral cover has declined furthermore to a historical minimum of 13.9 %. Differences of live coral between the 2000 – 2005 and the 2006 – 2009 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 2009 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 1.2 % in 2009 (Figure 18), a statistically significant reduction (ANOVA; $p = < 0.001$). Reef substrate cover by Boulder Star Coral represented more than 53 % of the total cover by stony corals at Puerto Botes Mid-shelf Reef. Thus, its collapse after 2005 monitoring survey would be expected to have a profound ecological impact upon the coral reef system at Puerto Botes. Finger Coral (*Porites porites*), a relatively fast growing branching coral species was one of the few corals that appeared not to be severely affected by the bleaching event and maintained its reef substrate cover stable between surveys until present. 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.

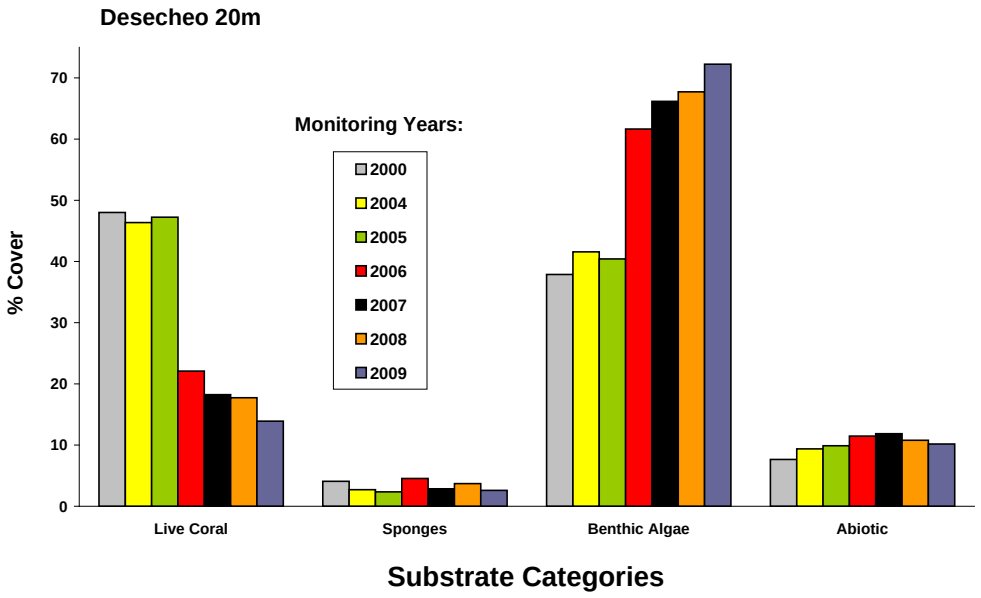


Figure 17. Monitoring trends (2000 – 09) of mean substrate cover by sessile-benthic categories at Puerto Botes Reef, Desecheo Island – 20 m.

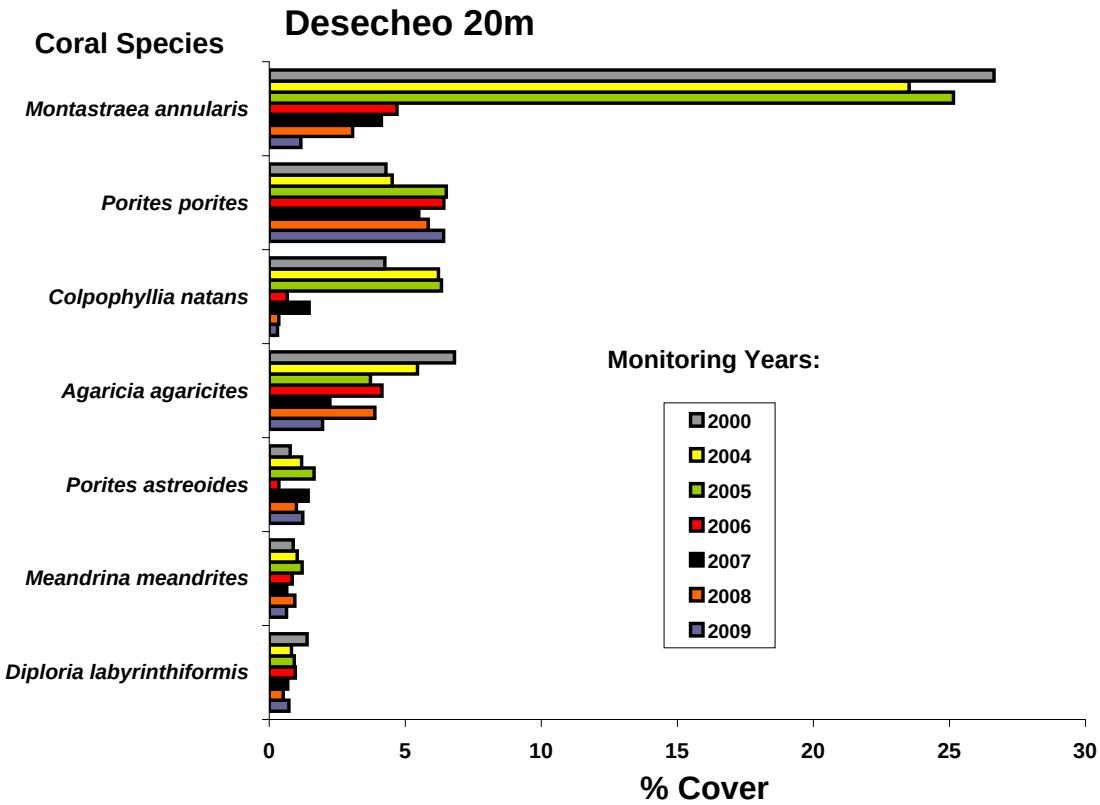


Figure 18. Monitoring trends (2000 – 09) of mean substrate cover by stony coral species at Puerto Botes Reef, Desecheo Island – 20 m.

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 (particularly *L. variegata*) showed the highest increment between the 2005 and 2009 surveys, from 3.6 % in 2005 to 17.9 % in 2008.

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 48 fish species were identified within belt-transects from the mid-shelf patch reefs off Puerto Botes, Isla Desecheo during 2009 (Table 19). During the eight 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 203.4 Ind/30 m^2 (range: 90 - 260 Ind/30 m^2). The mean number of species per transect was 25.6 (range: 17 - 33). The Blue Chromis (*Chromis cyanea*) and the Bluehead Wrasse (*Thalassoma bifasciatum*) were the numerically dominant species within belt-transects during the 2009 survey with mean abundances of 60.8 and 36.8 Ind/30 m^2, respectively. The combined abundance of six species, including the Blue and Brown Chromis, Bluehead and Yellowhead Wrasses, Creole Wrasse and Bicolor Damselfish represented 77.3 % of the total fish abundance within belt-transects. Five species were present in all five transects and another 10 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 eight 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, Isla Desecheo. June, 2009

Depth: 20m		TRANSECTS					
		1	2	3	4	5	
SPECIES	**COMMON NAME**	**(Individuals/30 m^2)**					**MEAN**
Chromis cyanea	Blue Chromis	68	75	68	0	93	**60.8**
Thalassoma bifasciatum	Bluehead Wrasse	38	35	33	48	30	**36.8**
Stegastes partitus	Bicolor Damselfish	18	33	0	0	50	**20.2**
Clepticus parrae	Creole Wrasse	20	29	48	0	25	**24.4**
Chromis multilineata	Brown Chromis	6	18	16	0	9	**9.8**
Halichoeres garnoti	Yellowhead Wrasse	2	8	2	6	8	**5.2**
Gobiosoma evelynae	Sharknose Goby	3	7	0	0	5	**3.0**
Halichoeres maculipina	Clown Wrasse	0	3	0	5	6	**2.8**
Gramma loreto	Fairy Basslet	1	8	0	0	0	**1.8**
Cephalopholis fulva	Coney	3	4	5	0	4	**3.2**
Myripristis jacobus	Blackbar Soldierfish	0	5	1	6	4	**3.2**
Sparisoma viride	Stoplight Parrotfish	3	1	4	3	4	**3.0**
Cephalopholis cruentatus	Graysby	2	3	2	5	2	**2.8**
Bodianus rufis	Spanish Hogfish	3	5	1	0	2	**2.2**
Microspathodon chrysurus	Yellowtail Damselfish	2	1	1	3	3	**2.0**
Amblycirrhitus pinos	Redspoted Hawlkfish	1	4	0	0	3	**1.6**
Sparisoma arofrenatum	Redband Parrotfish	3	2	0	2	1	**1.6**
Holocentrus rufus	Longspine Squirrelfish	0	1	5	1	1	**1.6**
Scarus iserti	Stripped Parrotfish	3	0	1	2	2	**1.6**
Lactophrys triqueter	Smooth Trunkfish	1	0	3	1	2	**1.4**
Haemulon flavolineatum	French Grunt	0	2	2	0	3	**1.4**
Sparisoma radians	Bucktooth Parrotfish	0	2	0	0	4	**1.2**
Acanthurus coeruleus	Blue Tang	0	2	1	1	2	**1.2**
Holocanthus tricolor	Rock Beauty	0	0	0	3	2	**1.0**
Neoniphon marianus	Longjaw Squirrelfish	0	1	1	0	3	**1.0**
Melichthys niger	Black Durgeon	0	1	1	0	3	**1.0**
Chaetodon capistratus	Foureye Butterflyfish	2	1	0	0	0	**0.6**
Coryphopterus glaucofraenum	Bridled Goby	0	0	1	0	1	**0.4**
Kyphosus sextatrix	Bermuda Chub	0	1	0	0	1	**0.4**
Caranx latus	Horse-eye Jack	0	0	0	1	1	**0.4**
Holocentrus adscensionis	Squirrelfish	1	1	0	0	0	**0.4**
Haemulon macrostomum	Spanish Grunt	0	0	1	0	1	**0.4**
Malacoctenus triangulatus	Saddled Blenny	0	2	0	0	0	**0.4**
Sparisoma rubripinne	Yellowtail Parrotfish	0	0	1	0	1	**0.4**
Mulloidichthys martinicus	Yellow Goatfish	0	1	0	0	0	**0.2**
Stegastes planifrons	Threespot Damselfish	0	0	0	0	1	**0.2**
Canthigaster rostrata	Sharpnose Puffer	0	0	0	0	1	**0.2**
Lutjanus apodus	Schoolmaster Snapper	0	0	0	0	1	**0.2**
Scarus vetula	Queen Parrotfish	0	1	0	0	0	**0.2**
Lipropoma rubre	Peppermint Basslet	0	0	0	1	0	**0.2**
Gobiosoma dilepis	Orangesided Goby	0	1	0	0	0	**0.2**
Acanthurus bahianus	Ocean Surgeon	1	0	0	0	0	**0.2**
Lutjanus mahogani	Mahogani Snapper	0	0	1	0	0	**0.2**
Sphyraena barracuda	Greate Barracuda	0	0	1	0	0	**0.2**
Gymnothorax miliaris	Goldentail Moray	0	0	0	1	0	**0.2**
Haemulon carbonarium	Cesar Grunt	0	1	0	0	0	**0.2**
Chaetodon striatus	Banded Butterflyfish	1	0	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**185**	**260**	**203**	**90**	**279**	**203.4**
	TOTAL SPECIES	**22**	**32**	**24**	**17**	**33**	**25.6**

Table 19 Continued

Fishes Outside Transects

SPECIES	**COMMON NAME**
Acanthurus bahianus	Ocean Surgeon
Anisotremus surinamensis	Black Margate
Balistes vetula	Queen triggerfish
Carangoides crysos	Blue runner
Carangoides ruber	Bar Jack
Caranx lugubris	Black jack
Chaetodon aculeatus	Longsnout butterflyfish
Chaetodon striatus	Banded Butterflyfish
Coryphopterus personatus	Masked Goby
Dasyatis americana	Southern stingray
Diodon hystrix	Porcupinefish
Equetus punctatus	Spotted Drum
Epinephelus guttatus	Red Hind
Haemulon melanorum	?? Grunt
Haemulon plumieri	White grunt
Halichoeres radiatus	Puddinwife
Holacanthus ciliaris	Queen Angelfish
Lactophrys bicaudalis	Spotted trunkfish
Lutjanus mahogani	Mahogani snapper
Malacoctenus triangulatus	Saddled Blenny
Ocyurus chrysurus	Yellowtail Snapper
Ophioblennius atlanticus	Yellowhead Jawfish
Pomacanthus arcuatus	Gray Angelfish
Pomacanthus paru	French Angelfish
Priacanthus arenatus	Glasseye
Scarus vetula	Queen parrotfish
Scomberomorus regalis	Cero mackerel
Serranus tabacarius	Tobbaco fish
Serranus tigrinus	Harlequin Bass
Sphyraena barracuda	Great Barracuda
Stegastes planifrons	Yellow-eye Damselfish
Syngnathus sp.	Pipefish
Xanthichthys ringens	Sargassum Triggerfish
Pseudupeneus maculatus	Spotted Goatfish
Malacanthus plumieri	Sand Tilefish
Apogon binotatus	Barred Cardinalfish

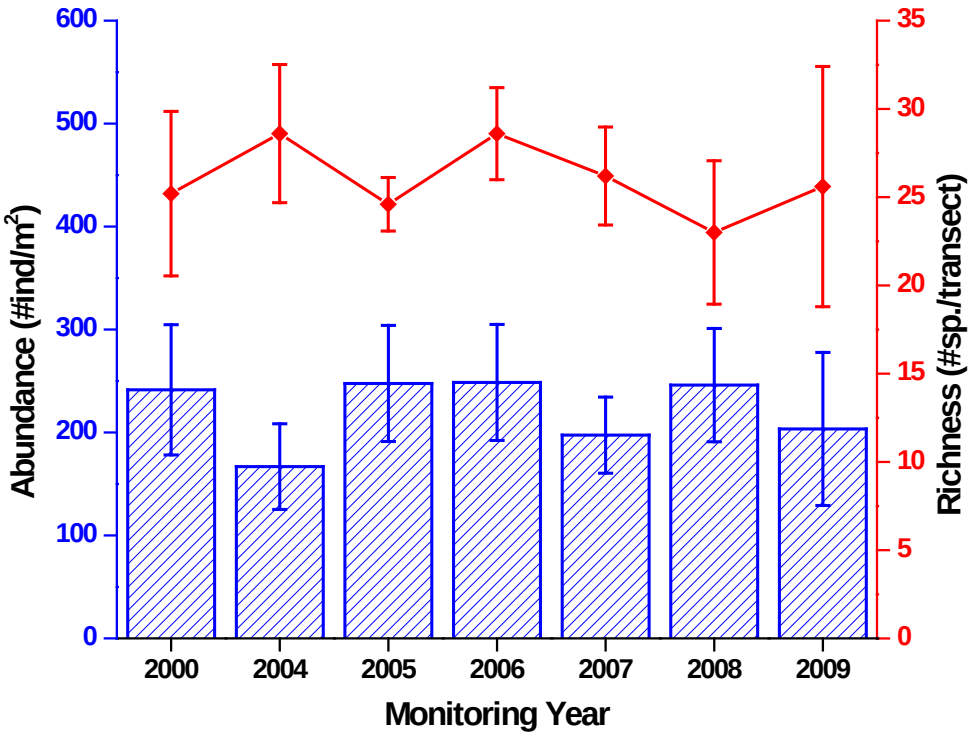


Figure 19. Monitoring trends (2000 – 2009) of fish species richness and abundance at the Mid-Shelf Reef, Puerto Botes, 20 m, Isla Desecheo.

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.

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

Table 20. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Puerto Botes, Isla Desecheo 20 m, June, 2009

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

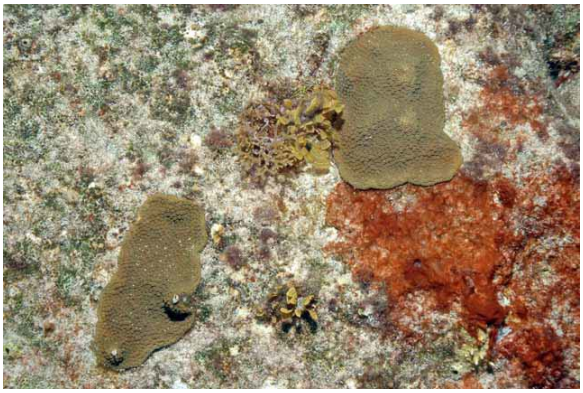
SPECIES	**COMMON NAME**		# - (cm)	
Carangoides crysos	Blue Runner	1 – (30)	2 – (40)	
Caranx lugubris	Black Jack	2 - (50)		
Epinephelus guttatus	Red Hind	2 – (30)		
Gramma loreto	Fairy Basslet	5- (1-3)	4 - (4-6)	
Holacanthus tricolor	Rock Beauty	3 - (15)	2- (25)	
Lutjanus apodus	Schoolmaster	9– (20)	3- (30)	3- (40)
Lutjanus mahogany	Mahogani Snapper	3- (20)	1 – (25)	
Ocyurus chrysurus	Yellowtail Snapper	4– (30)	2 – (40)	
Scomberomorus regalis	Cero Mackerel	1 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (70)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (20)		

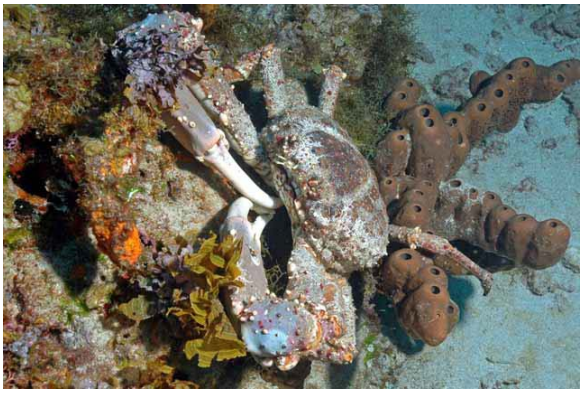
Table 21. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Puerto Botes Mid-shelf Reef. Isla Desecheo 20m, June 2008

		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 2009 monitoring survey at Puerto Botes Inner Reef. Stony corals presented a mean substrate cover of 8.7 % (range: 6.4 – 13.5 %) (Table 22). Mustard-Hill Coral, *Porites astreoides*, Boulder Star Coral, *Montastraea annularis* (complex), Great Star Coral, *Montastraea cavernosa*, and Boulder Brain Coral, *Colpophyllia natans* comprised the main coral assemblage with a combined reef substrate cover of 6.8 %, representative of 78.2 % 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 7.9 % and contributed substantially to the reef rugosity of 3.53 m. Total abiotic cover also included sections of sand and averaged 11.5 %. Sponges were present at all transects with a mean substrate cover of 4.6 % (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 74.8 % (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 Desecheo Island, 15 m, June 2009.

Depth: 15 m	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	3.37	3.75	4.06	3.28	3.20	**3.53**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	10.56	7.35	5.83	6.48	9.32	**7.9**
Sand		2.55	7.04	7.00	1.39	**3.6**
Total Abiotic	10.56	9.90	12.87	13.48	10.71	**11.5**
Benthic Algae						
Turf-mixed assemblage	72.13	66.23	68.21	69.65	44.70	**64.2**
Dictyota sp.	1.69		2.13	5.50	15.68	**5.0**
Lobophora variegata		5.46	5.19	2.41	10.53	**4.7**
Stipopodium zonale		0.92	1.49		1.82	**0.8**
Total Benthic Algae	73.82	72.61	77.02	77.56	72.73	**74.8**
Sponges	5.77	4.08	2.49	1.88	8.56	**4.6**
Cyanobacteria	1.06		0.60	0.64		**0.5**
Hydrozoa (Millepora)	0.21					**0.04**
Live Stony Corals						
Porites astreoides	4.19	3.93	2.77	3.84	1.07	**3.2**
Montastraea annularis	0.53	3.69		1.27	2.05	**1.5**
Montastraea cavernosa	0.95		1.92	0.95	1.89	**1.1**
Colpophyllia natans		5.02				**1.0**
Agaricia agaricites		0.82			2.96	**0.8**
Siderastrea siderea	1.90		1.60			**0.7**
Meandrina meandrites			0.70			**0.14**
Diploria labyrinthiformis	0.53					**0.1**
Porites porites	0.53					**0.1**
Madracis decactis				0.32		**0.06**
Total Stony Corals	8.63	13.46	6.99	6.38	7.97	**8.7**

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 -09. 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; $p = 0.008$). The decline of coral cover during 2007 was observed in four out of the five transects surveyed. After 2007, further declines of substrate cover by live corals have not been observed (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 as in the 20 m station, collapsed 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 2008 survey for *M. annularis* and still declining to 1.5 % in the present 2009 survey.

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 2009 survey, live colonies of Boulder Star Coral presented substrate cover below 2% 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.

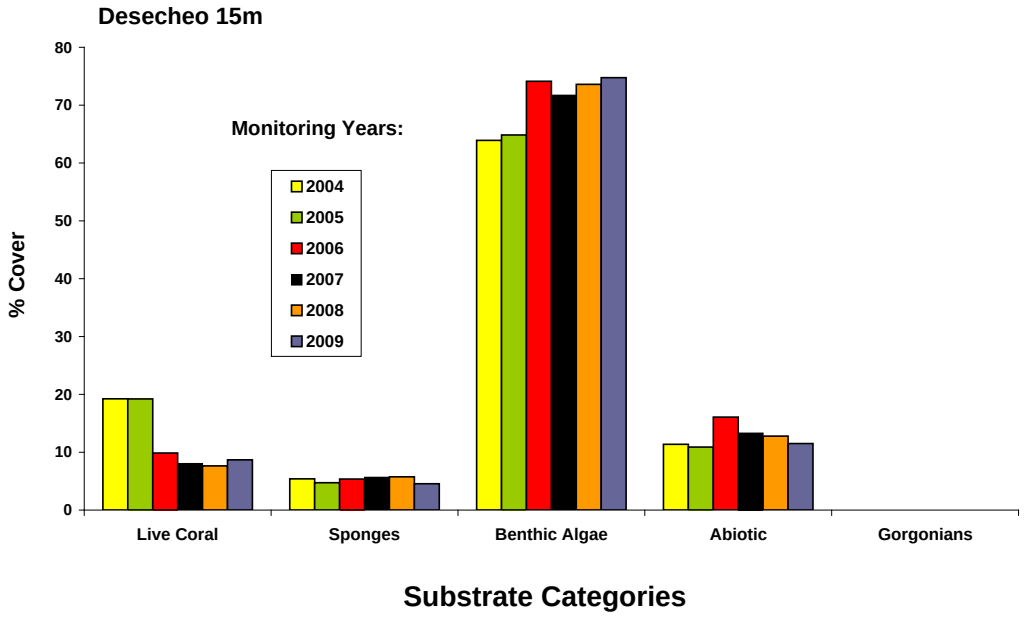


Figure 20. Monitoring trends (2004 -09) of mean substrate cover by sessile-benthic categories at Puerto Botes Inner Shelf Reef, Desecheo Island – 15 m.

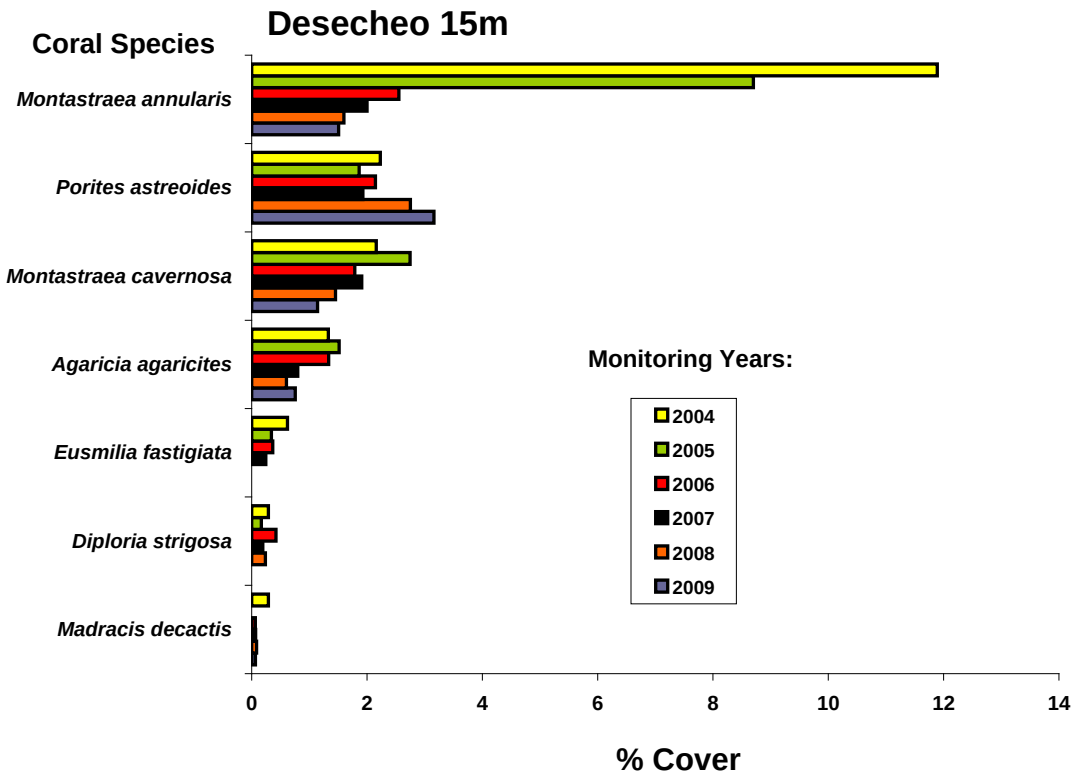


Figure 21. Monitoring trends (2004 -09) of mean substrate cover by stony coral species at Puerto Botes Inner Shelf Reef, Desecheo Island – 15 m.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 43 fish species were identified within belt-transects from the Inner-Shelf Reef off Puerto Botes, Isla Desecheo during June, 2009 (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 2009 survey was 189.4 Ind/30 m^2 (range: 113 - 278 Ind/30 m^2). The mean number of species per transect was 21.4 (range: 15 - 30). The Blue and Brown Chromis, Bicolor Damselfish, Bluehead, Yellowhead, Creole and Clown Wrasses comprised the numerically dominant fish assemblage with a combined mean abundance of 159.0 Ind/30, representing 83.9 % of the total abundance within belt-transects (Table 23). Six species were present in all five transects surveyed and another six were present in four.

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. Such distributions introduce high sampling variability and increased number of observations is needed to detect patterns. Nevertheless, the marked decline of live coral may have influenced the reduction in numbers of schooling chromis from the reef. As live coral disappears, reef substrate is colonized by turf and fleshy algae, which in turn becomes the appropriate habitat for herbivorous damselfishes (e.g. *Stegastes dorsopunicans, S. planifrons*. These species are territorial and very aggressive and can drive away the schooling chromis species.

Reef zooplankton feeders, such as the Blue and Brown Chromis, the Creole Wrasse and the Bicolor Damselfish comprise the most prominent fish assemblage of this inshore reef in terms of abundance. These are important prey items of mid-size demersal piscivores that are commercially exploited, such as the Yellowtail and Schoolmaster Snappers, Red

Table 23. Taxonomic composition and abundance of fishes within belt-transects at Puerto Botes Reef, Isla Desecheo, 15 m, June, 2009

Depth: 15m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**	(Individuals/30 m2)					**MEAN**
Chromis cyanea	Blue Chromis	26	123	51	77	96	**74.6**
Stegastes partitus	Bicolor Damselfish	29	30	46	40	11	**31.2**
Thalassoma bifasciatum	Bluehead Wrasse	28	23	41	19	4	**23.0**
Chromis multilineata	Brown Chromis	2	26	15	14	12	**13.8**
Clepticus parrae	Creole Wrasse	4	21	0	9	2	**7.2**
Halichoeres garnoti	Yellowhead Wrasse	7	9	5	2	5	**5.6**
Halichoeres maculipina	Clown Wrasse	0	8	9	1	0	**3.6**
Cephalopholis fulva	Coney	1	7	3	5	0	**3.2**
Gobiosoma evelynae	Sharknose Goby	5	5	3	0	0	**2.6**
Myripristis jacobus	Blackbar Soldierfish	0	3	2	1	5	**2.2**
Sparisoma radians	Bucktooth Parrotfish	0	10	0	1	0	**2.2**
Cephalopholis cruentatus	Graysby	2	1	5	1	1	**2.0**
Microspathodon chrysurus	Yellowtail Damselfish	0	1	2	1	5	**1.8**
Acanthurus coeruleus	Blue Tang	0	2	4	1	2	**1.8**
Sparisoma viride	Stoplight Parrotfish	2	1	3	0	1	**1.4**
Holocentrus rufus	Longspine Squirrelfish	1	3	3	0	0	**1.4**
Sparisoma rubripine	Yellowtail Parrotfish	3	0	0	0	3	**1.2**
Sparisoma aurofrenatum	Redband Parrotfish	0	2	3	1	0	**1.2**
Scarus iserti	Striped Parrotfish	1	0	0	3	1	**1.0**
Gramma loreto	Fairy Basslet	0	0	0	0	4	**0.8**
Holacanthus tricolor	Rock Beauty	0	0	2	0	2	**0.8**
Chaetodon capistratus	Foureye Butterflyfish	0	0	2	0	1	**0.6**
Lactophrys triqueter	Smooth Trunkfish	0	1	1	1	0	**0.6**
Canthigaster rostrata	Sharpnose Puffer	1	0	1	0	1	**0.6**
Amblycirrhinus pinos	Redspoted Hawlkfish	0	0	1	1	1	**0.6**
Acanthurus bahianus	Ocean Surgeon	1	0	1	0	0	**0.4**
Scarus taeniopterus	Princess Parrotfish	0	0	1	0	1	**0.4**
Lutjanus apodus	Schoolmaster Snapper	0	0	2	0	0	**0.4**
Mulloidichthys martinicus	Yellow Goatfish	0	0	0	2	0	**0.4**
Xanthichthys ringens	Sargassum Triggerfish	0	0	0	0	1	**0.2**
Rypticus saponaceus	Greater Soapfish	0	0	1	0	0	**0.2**
Mylichthys niger	Black Durgeon	0	0	1	0	0	**0.2**
Lipropoma rubre	Peppermint Basslet	0	0	0	0	1	**0.2**
Kyphosus sctatrix	Bermuda Chub	0	0	0	0	1	**0.2**
Haemulon flavolineatum	French Grunt	0	0	0	0	1	**0.2**
Coryphopterus lipernes	Peppermint Goby	0	0	0	0	1	**0.2**
Coryphopterus glaucofraenum	Bridled Goby	0	0	1	0	0	**0.2**
Chaetodon striatus	Banded Butterflyfish	0	0	1	0	0	**0.2**
Bodianus rufus	Spanish Hogfish	0	0	1	0	0	**0.2**
Acanthostracion quadricornis	Scrawled Cowfish	0	0	1	0	0	**0.2**
Acanthostracion polygonia	Trunkfish	0	0	1	0	0	**0.2**
Malacoctenus triangulatus	Saddled Blenny	0	1	0	0	0	**0.2**
Lactophrys polygonia	Honeycomb Cowfish	0	1	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**113**	**278**	**213**	**180**	**163**	**189.4**
	TOTAL SPECIES	**15**	**20**	**30**	**18**	**24**	**21.4**

Table 23. Continued

Fishes Outside Transects

SPECIES	**COMMON NAME**
Abudefduf sexatilis	Sargent Major
Acanthostracion quadricornis	Scrawled Cowfish
Cantherhines macrocerus	Whitespotted Filefish
Cantherhines macrocerus	Whitespotted Filefish
Carangoides ruber	Bar Jack
Caranx crysos	Blue Runner
Chaetodon sedentarius	Reef Butterflyfish
Chaetodon striatus	Banded Butterflyfish
Coryphopterus lipernes	Peppermint Goby
Coryphopterus personatus	Masked goby
Criptoptomus roseus	Parrotfish
Dasyatis americana	Southern stingray
Decapterus macarellus	Mackerel Scad
Diodon hystrix	Porcupinefish
Echidna catenata	Chain Moray
Epinephelus guttatus	Red Hind
Ginglymostoma cirratum	Nurse Shark
Gramma loreto	Fairy Basslet
Haemulon flavolineatum	
Haemulon macrostomum	Spanish Grunt
Halichoeres maculipinna	Clown Wrasse
Halichoeresa bivittatus	Slippery Dick
Halichoeres radiatus	Puddinwife
Kyphosus (berm) sp.	Sea Chub
Lactophrys bicaudalis	Spotted Trunkfish
Lutjanus apodus	Schoolmaster
Lutjanus mahogani	Mahogani snapper
Malacanthus plumieri	Sand Tilefish
Mulloides martinicus	Yellowtail Goatfish
Muraenidae	Moray sp.
Ocyurus chrysurus	Yellowtail Snapper
Ophiobenius atlanticus	Yellow-head jawfish
Opistognathus aurifrons	Yellowhead Jawfish
Pseudupeneus maculatus	Spotted Goatfish
Sargocentrum coruscum	Whitelined Toadfish
Scarus taeniopterus	Princess Parrotfish
Sparisoma chrysopterum	Redtail Parrotfish
Scarus vetula	Queen Parrotfsh
Scomberomorus regalis	Cero mackerel
Sphyraena barracuda	Great Barracuda
Stegastes dorsopunicans	Dusky damselfish
Stegastes variabilis	Cocoa damselfish

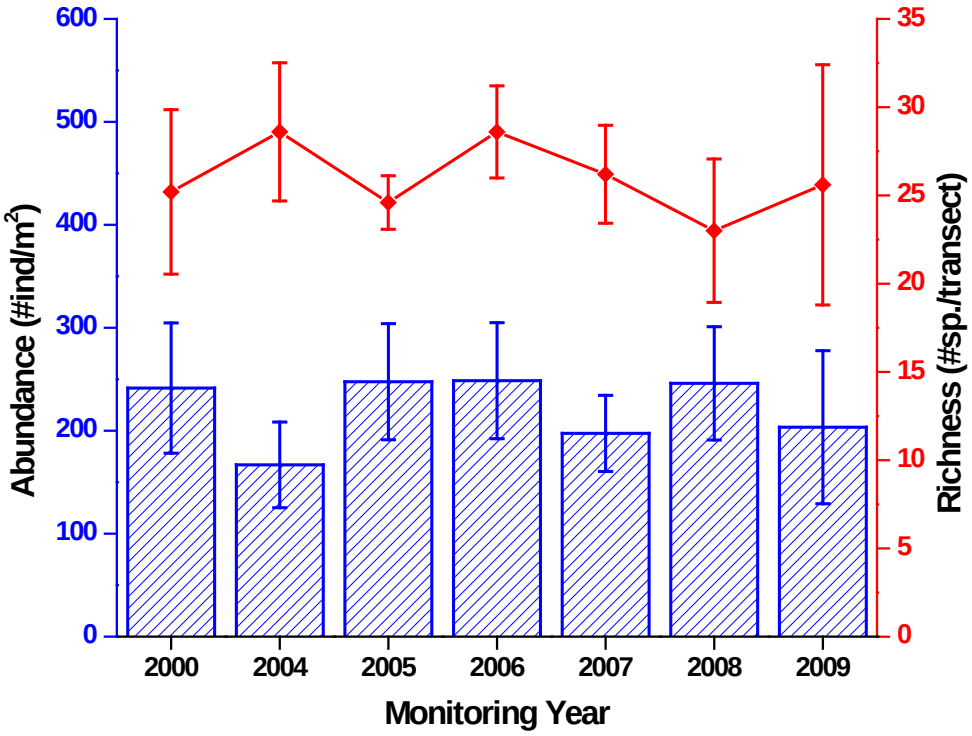


Figure 22. Monitoring trends (2004 – 2009) of fish species richness and abundance at Inner Shelf Reef Puerto Botes,15 m depth, Isla Desecheo.

Hind and Coneys, as well as for juvenile and adult stages of pelagic fishes associated with the reef food web, such as the Great Barracuda, Cero Mackerels and jacks that have been observed during the ASEC surveys (Table 24). Also, open water zooplanktivores, such as the Mackerel Scad (*Decapterus macarellus*) 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 and Cleaner Crabs (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, 2009

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

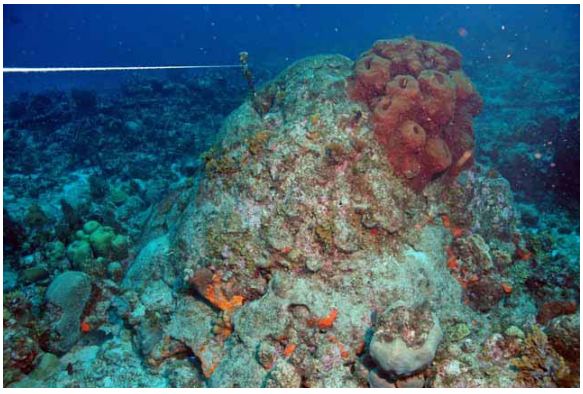
SPECIES	**COMMON NAME**	# - (cm)		
Caranx crysos	Blue Runner	2 - (30)		
Decapterus macarellus	Mackerel Scad	100 - (10-12)		
Gramma loreto	Fairy Basslet	4 - (3 - 5)		
Holacanthus ciliaris	French Angel	1 – (35)		
Holacanthus tricolor	Rock Beauty	2 - (15)	1 - (20)	1 - (25)
Lutjanus apodus	Schoolmaster	5 - (20)	6 - (30)	
Lutjanus mahogany	Mahogani Snapper	2 - (25)	1 – (30)	
Ocyurus chrysurus	Yellowtail Snapper	5 – (30)	3 – (40)	
Scomberomorus regalis	Cero Mackerel	1 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (40)		

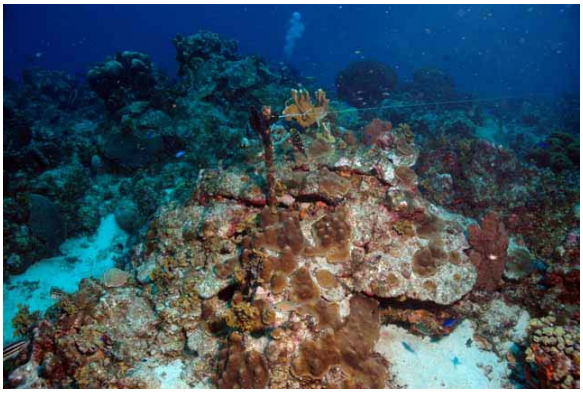
Table 25. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at the Puerto Botes Inner-Shelf Reef, 15 m, Isla Desecheo, June, 2009

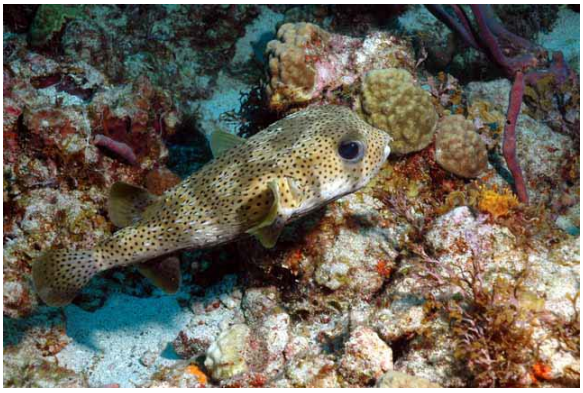
		TRANSECTS					
Depth: 15 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Stenorhynchus seticornis	Arrow Crab	1	1				**0.4**
Periclimenes pedersoni	Cleaner Shrimp		1			1	**0.4**
Ophiothrix suensoni	Sponge Brittle Star	5					**1.0**
	TOTALS	**6**	**2**	**0**	**0**	**1**	**1.8**

Photo Album 6 (Desecheo 15m)

Inner Shelf Reef







C. Tourmaline Reef System – Mayaguez Bay

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

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

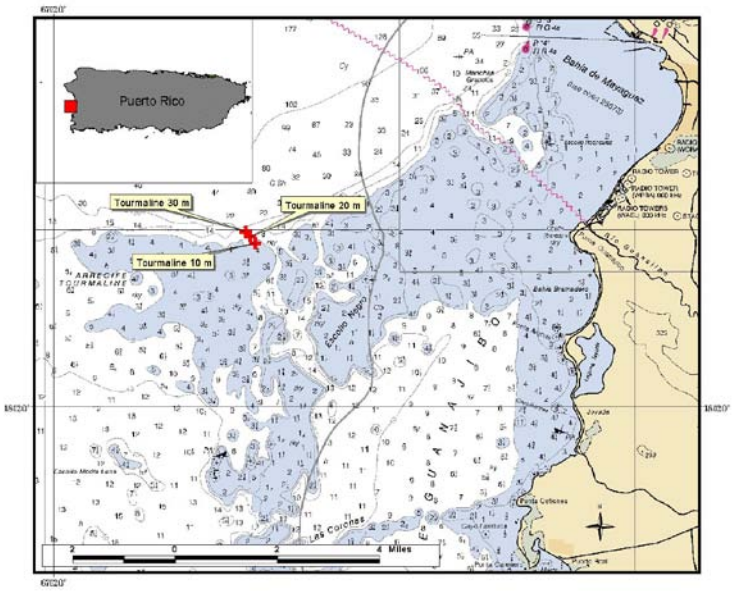


Figure 23. Location of coral reef survey stations at Tourmaline Reef, off Mayaguez Bay.

1.0 Shelf-edge Reef – 30 meters

1.1 Sessile-Benthic Reef Community

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

A total of 21 stony corals and two black coral species were identified from the shelf-edge off Tourmaline Reef, 14 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 15.1 % (range: 11.6 – 19.9 %). Boulder Star Coral, *Montastraea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 6.0 % (range: 4.7 – 7.3 %), representing 39.7 % 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 highly abundant, with an average of 24.6 colonies/transect. The encrusting gorgonian, *Erythropodium caribaeorum* was intercepted by four transects and presented a mean substrate cover of 2.9 %. 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 3.2 %. The Blue Bell Tunicate, *Clavelina puertosecensis* was very common throughout the shelf-edge reef. Reef overhangs, associated with substrate depressions and coral ledges averaged 25.0 % and contributed substantially to a topographic rugosity of 6.09 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 : 38.2 – 60.4%). Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard bottom. The total cover by benthic algae was 50.3 %. Cyanobacterial films were present in two transect with a mean reef substrate cover of 0.3 %.

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

Mayaguez, June 2009

Depth: 30 m	TRANSECT					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	5.73	5.18	6.66	8.13	4.75	**6.09**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	12.07	28.77	37.30	21.84	25.10	**25.0**
Silt	1.08	9.35	4.32	1.38		**3.2**
Total Abiotic	13.15	38.12	41.62	23.22	25.10	**28.2**
Benthic Algae						
Turf-mixed assemblage	60.42	38.18	39.82	46.61	52.37	**47.5**
Dictyota sp.	0.36	0.74	4.62	6.29		**2.4**
Calcareous	0.83			1.16		**0.4**
Total Benthic Algae	61.61	38.92	44.44	54.06	52.37	**50.3**
Gorgonians	4.76	1.84	0.90	5.52	1.42	**2.9**
Sponges	5.97	3.82	0.60	4.52	1.15	**3.2**
Cyanobacteria		0.56	0.85			**0.3**
Live Stony Corals						
Montastraea annularis	5.21	6.12	4.74	6.51	7.33	**6.0**
Agaricia grahamae	1.27	6.06	1.44	2.04	5.09	**3.2**
Agaricia agaricites	3.49	1.32	1.08	1.32	4.27	**2.3**
Montastraea cavernosa	0.36		2.64		1.82	**1.0**
Madracis decactis	0.70	2.44				**0.6**
Stephanocoenia michelini		0.46	1.18		0.48	**0.4**
Agaricia sp.				2.04		**0.4**
Porites astreoides	1.52			0.31		**0.4**
Mycetophyllia lamarckiana	1.43					**0.3**
Siderastrea siderea				0.47	0.76	**0.2**
Dichocoenia stokesi	0.54					**0.1**
Siderastrea radians			0.51			**0.1**
Agaricia lamarcki		0.39				**0.08**
Scolymia cubensis					0.19	**0.04**
Total Stony Corals	14.52	16.79	11.59	12.69	19.94	**15.11**
Gorgonians (# col.)						
Briareum asbestinum	21	7	6	8	7	**9.8**
Pseudopterogorgia acerosa		4	7	2	6	**4.8**
Eunicea flexuosa		3				**3.0**
Pseudopterogorgia bipinnata		1	4	3		**2.7**
Plexaura kukenthali		1		1	2	**1.3**
Eunicea spp.	1			1	1	**1.0**
Pseudoplexaura porosa		1	1	1		**1.0**
Pseudopterogorgia americana			1			**1.0**

Table 26. Continued

Total Gorgonians (# colonies/transect)	22	17	19	16	16	**24.6**

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 2009 monitoring survey (15.1 %) has remained within the sampling error margin. Differences of live coral cover between monitoring surveys were small and not statistically significant (ANOVA; p = 0.990). 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 2009 monitoring survey was 111.8 Ind/30 m^2 (range: 89 - 148 Ind/30 m^2). The mean number of species per transect was 17 (range: 13 - 20). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 47.0 Ind/30 m^2 (range: 23 - 85 Ind/30 m^2), representing 42.0 % 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, Fairy Basslet, Beaugregory, Blue Chromis, Tomtate, Princess Parrotfish, Sharpnose Puffer and Black-bar Soldierfish were present on the five transects surveyed and comprised the most abundant fish assemblage at the shelf-edge reef.

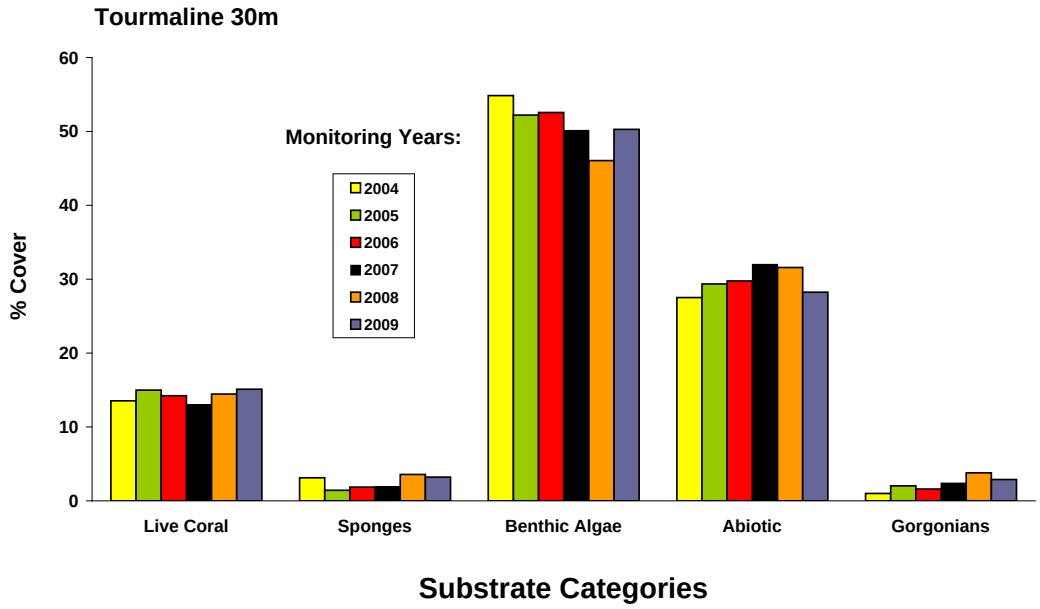


Figure 24. Monitoring trends (2004 – 2009) of mean substrate cover by sessile-benthic categories at Tourmaline Shelf-edge Reef – 30 m, Mayaguez Bay.

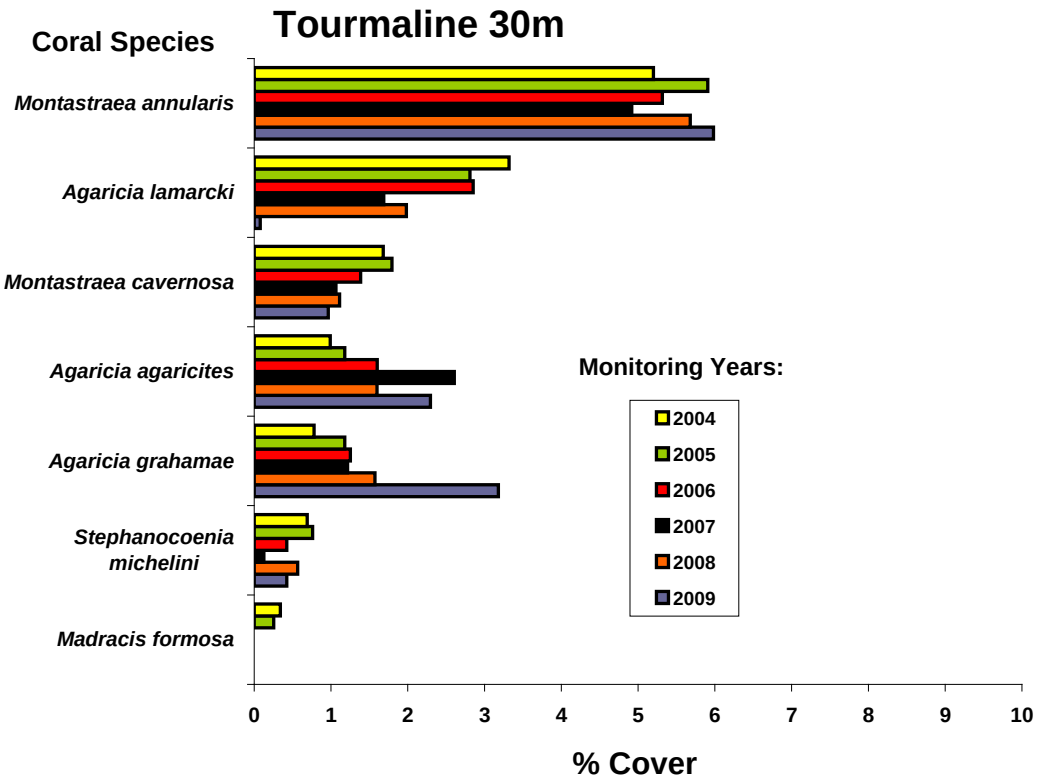


Figure 25. Monitoring trends (2004 – 2009) of mean substrate cover by stony coral species at Tourmaline Reef – 30 m, Mayaguez Bay.

Table 27. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, 30 m Mayaguez Bay. June, 2009.

Depth: 30 m		Transects					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**	(individuals/30 m2)					**MEAN**
Coryphopterus pesonatus	Masked Goby	23	46	26	85	55	**47.0**
Gramma loreto	Fairy Basslet	9	15	13	22	10	**13.8**
Scarus taeniopterus	Princess Parrotfish	25	5	6	5	1	**8.4**
Chromis cyanea	Blue Chromis	2	6	5	10	4	**5.4**
Coryphopterus lipernes	Peppermint Goby	4	7	7	1	7	**5.2**
Canthigaster rostrata	Sharpnose Puffer	3	4	4	4	5	**4.0**
Miripristis jacobus	Blackbar Soldierfish	5	9	2	2	2	**4.0**
Stegastes lecostictus	Beugregory	3	4	2	3	5	**3.4**
Haemulon aurolineatum	Tomtate	8	3	2	3	0	**3.2**
Gobiosoma evelynae	Sharknose Goby	6	5	2	0	3	**3.2**
Sparisoma aurofrenatum	Redband Parrotfish	1	4	3	3	0	**2.2**
Stegastes partitus	Bicolor Damselfish	2	0	5	2	2	**2.2**
Halichoeres garnoti	Yellowhead Wrasse	4	2	0	3	0	**1.8**
Clepticus parrae	Creole Wrasse	0	1	6	0	0	**1.4**
Haemulon flavolineatum	French Grunt	0	2	2	1	0	**1.0**
Hypoplectrus puella	Barred Hamlet	0	0	2	1	2	**1.0**
Holocentrus rufus	Longspine Squirrelfish	1	2	0	0	0	**0.6**
Chaetodon capistratus	Foureye Butterflyfish	1	0	0	0	2	**0.6**
Pseudupeneus maculatus	Spoted Goatfish	2	0	0	0	0	**0.4**
Chaetodon aculeatus	Longsnout Butterflyfish	0	0	0	1	1	**0.4**
Chaetodon cedentarius	Reef Butterflyfish	0	2	0	0	0	**0.4**
Epinephelus guttatus	Red Hind	1	1	0	0	0	**0.4**
Cephalopholis cruentatus	Graysby	0	1	0	1	0	**0.4**
Mulloidichthys martinicus	Yellow Goatfish	0	0	2	0	0	**0.4**
Heteropriacanthus cruentatus	Bigeye	1	1	0	0	0	**0.4**
Acanthurus bahianus	Ocean Surgeon	0	0	0	1	0	**0.2**
Cephalopholis fulva	Coney	1	0	0	0	0	**0.2**
Hypoplectrus nigricans	Black Hamlet	1	0	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**103**	**120**	**89**	**148**	**99**	**111.8**
	TOTAL SPECIES	**20**	**19**	**16**	**17**	**13**	**17**

Fishes Outside Transects

SPECIES	**COMMON NAME**
Acanthurus coeruleus	BlueTang
Amblicirrhitus pinnos	Redspotted Hawkfish
Anisotremus virginicus	Porkfish
Bodianus rufus	Spanish Hogfish

Table 27. Continued

Caranx latus	Horse-eye Jack
Carangoides ruber	Bar Jack
Chaetodon ocellatus	Spotfin Butterflyfish
Chaetodon sedentarius	Reef Butterflyfish
Chromis insolata	Sunshinefish
Dasyatis americana	Southern Stingray
Epinephelus guttatus	Red Hind
Epiniphelus striatus	Nassau Grouper
Gobiosoma saucrum	Leopard Goby
Holacanthus ciliaris	French Angelfish
Hypoplectrus chlorurus	Yellowtail Hamlet
Hypoplectrus niger	Black Hamlet
Lachnolaimus maximus	Hogfish
Lachtophrys triqueter	Smooth Trunkfish
Lutjanus apodus	Schoolmaster Snapper
Lutjanus synagris	Lane Snapper
Lutjanus mahogani	Mahogani Snapper
Mycteroperca venenosa	Yellowfin Grouper
Pomacanthus arcuatus	Gray Angelfish
Pseudupeneus maculatus	Yellowtail Goatfish
Scomberomorus regalis	Cero Mackerel
Synodus intermedius	Lizardfish
Sphyraena barracuda	Great Barracuda
Epinephelus striatus	Nassau Grouper
Mycteroperca venenosa	Yellowfin Grouper
Epinephelus guttatus	Red Hind
Caranx ruber	Bar Jack
Ocyurus chrysurus	Yellowtail Snapper
Sphyraena barracuda	Great Barracuda
Decapterus macarelus	Mackerel Scad
Lutjanus apodus	Schoolmaster Snapper
Balistes vetula	Queen Triggerfish
Epinephelus adscensionis	Rock Hind

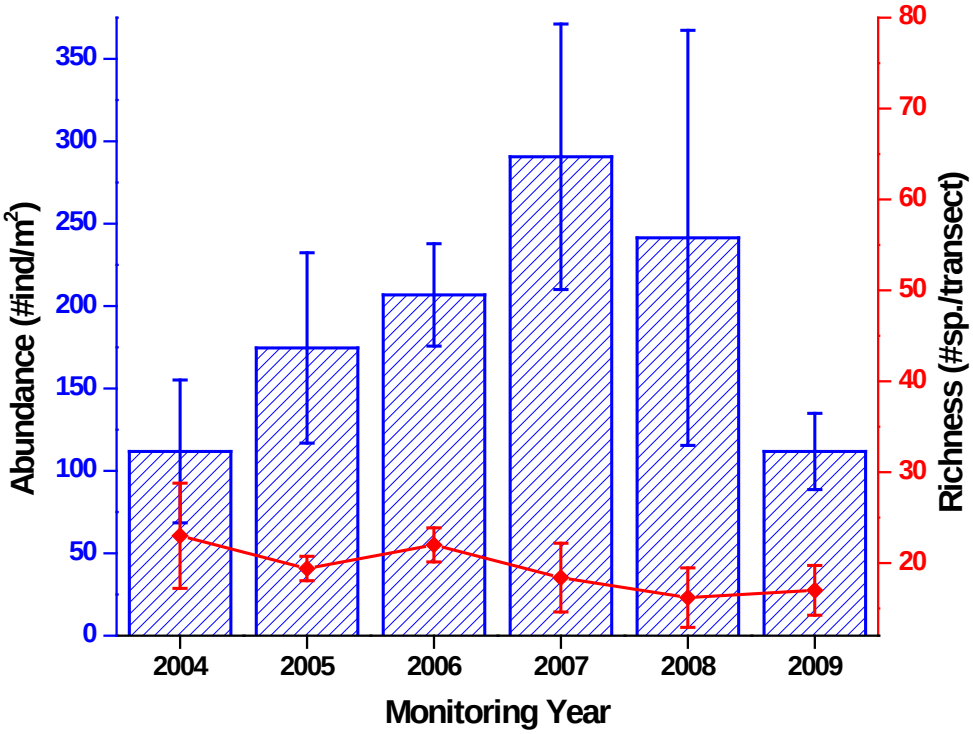


Figure 26. Monitoring trends (2004 – 2009) of fish species richness and abundance at Shelf-edge Reef Tourmaline, 30 m, Mayaguez Bay.

Annual fluctuations of fish species richness and abundance at the Mayaguez 30 m reef are shown in Figure 26. Fish species richness maintained a consistent decline after 2006, reaching a minimum of 16.2 species per transect in the 2008 survey. Differences of species richness between annual surveys are statistically significant (ANOVA; p = 0.027). The overall reduction in species richness from the baseline survey (23 spp/transect) to the present 2009 survey is of 26 %. Differences of fish abundance between monitoring surveys were also statistically significant (ANOVA; p = 0.002). Annual variations are mostly driven by the fluctuations of abundance by the Masked Goby, which is a schooling species with highly aggregated or patchy distributions. Such contagious distributions introduce high sampling variability and many observations are needed within any given reef system to detect temporal abundance patterns.

Top demersal and pelagic predators, such as large snappers, groupers and mackerels have been observed at the shelf-edge reef, but in low abundance. Red Hind, Yellowfin

and Nassau Groupers, along with a Hogfish and several snappers were observed during the 2009 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.

Cleaner Shrimp *(Periclimenes pedersoni*) were the only motile megabenthic invertebrate observed within belt-transects at the Tourmaline shelf-edge reef during this survey (Table 29). Arrow Crabs (*Stenorhynchus seticornis)* and one Spiny Lobster (*Panulirus argus*) were observed outside transects during the ASEC survey (Table 28).

Table 28. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Tourmaline Shelf-edge Reef, June, 2009

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

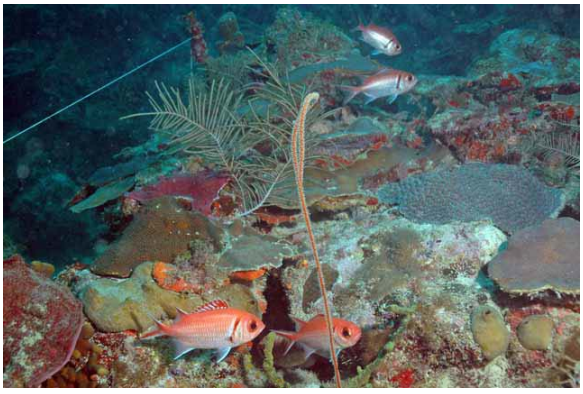
SPECIES	**COMMON NAME**		# - (cm)
Epinephelus guttatus	Red Hind	3 - (35)	1 – (40)
Epinephelus striatus	Nassau Grouper	1 - (40)	
Lachnolaimus maximus	Hogfish	1 - (40)	
Lutjanus apodus	Schoolmaster Snapper	3 - (30)	1 – (40)
Mycteroperca venenosa	Yellowfin Grouper	1 - (35)	
Ocyurus chrysurus	Yellowtail Snapper	2 - (30)	
Scomberomorus regalis	Cero Mackerel	1 - (50)	
Sphyraena barracuda	Great barracuda	1 - (60)	
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**	
Periclimenes pedersoni	Cleaner Shrimp	1				1	**0.4**
	TOTALS	**2**	**0**	**1**	**1**	**1**	**0.8**

Photo Album 7 (Tourmaline 30 m)

Shelf edge Reef



2.0 Tourmaline Outer Shelf Reef – 20 m

2.1 Sessile-Benthic Reef Community

The Tourmaline outer shelf reef is separated from the shelf-edge by an irregular fringe of sandy-silt bottom. Submerged at a depth of 16 m, the reef extends down a narrow and abrupt slope to a depth of 21 m. A rugged and diffuse"spur-and-groove" formation of massive coral buildup is the main structural feature of the reef. The spurs are rather narrow (< 2 m) and rise from the sandy channels or grooves about 2 – 3 m. At the deeper edge of the reef, where the interface with the sandy bottom is reached, massive coral colonies have grown close together forming large coral promontories that partially mask the spur and groove pattern. Permanent transects were installed on top of consecutive spurs at a depth of 20 m. Panoramic views of Tourmaline outer shelf reef are presented in Photo Album 8.

A total of 18 stony corals and two black coral species (*Stichopathes lutkeni, Antipathes sp*.) were identified from the outer shelf reef, 12 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 25.7 % (range: 22.7 – 28.3 %). Large and massive colonies of Boulder Star Coral were the most prominent feature of the reef benthos. Boulder Star Coral was the dominant species in terms of substrate cover with a mean of 18.0 % (range: 13.7 – 22.6 %), representing 70.0 % of the total cover by stony corals. Colonies of Boulder Star Coral were intercepted by all five transects. Great Star Coral (*M. cavernosa*) and Massive Starlet Coral (*Siderastrea siderea*) were intersected by four out of the five transects surveyed and along with Mustard Hill Coral (*Porites astreoides*) and Boulder Star Coral comprised the main stony coral assemblage at 20 m.

Soft corals (gorgonians) were moderately abundant with an average of 19.7 colonies/transect and seven species intercepted by transects. *Briareum asbestinum,* and *Pseudoptergorgia acerosa* were the most abundant species and were found in all transects surveyed.

Table 30. Percent substrate cover by sessile-benthic categories at Tourmaline reef, Mayaguez 20 m, June 2009

Depth: 20 m	TRANSECT					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	2.17	4.28	3.82	6.51	4.83	**4.3**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	23.50	22.39	21.14	16.80	27.51	**22.3**
Sand				4.27		**0.8**
Total Abiotic	23.50	22.39	21.14	21.43	27.51	**23.2**
Benthic Algae						
Turf-mixed assemblage	13.23	21.06	14.55	27.05	21.58	**19.5**
Coralline algae		2.10				**0.4**
Lobophora variegata	36.89	23.16	31.79	14.92	19.29	**25.2**
Dictyota sp.	1.16				2.76	**0.8**
Total Benthic Algae	51.28	46.32	46.34	41.97	43.63	**45.9**
Gorgonians		3.78	1.74	4.85	4.59	**3.0**
Sponges	0.49			3.34		**0.8**
Cyanobacteria		0.79	2.53	2.37	1.61	**1.5**
Live Stony Corals						
Montastraea annularis	21.53	17.84	13.69	22.62	14.36	**18.0**
Montastraea cavernosa	1.04		7.17	0.61	3.51	**2.5**
Siderastrea siderea	1.50		3.16	1.62	2.47	**1.8**
Porites astreoides		1.89	1.84		1.52	**1.0**
Madracis decactis		2.66		0.60		**0.6**
Colpophyllia natans		2.76				**0.6**
Meandrina meandrites		1.58		0.60	0.57	**0.6**
Diploria labyrinthiformis			1.33			**0.3**
Agaricia lamarcki	0.69					**0.1**
Dichocoenia stokesi			0.61			**0.1**
Mycetophyllia lamarcki			0.51			**0.1**
Agaricia agaricites					0.28	**0.06**
Total Stony Corals	24.76	26.73	28.31	26.05	22.71	**25.7**
Gorgonians (# col.)						
Briareum asbestinum	12	9	12	6	10	**9.8**
Pseudopterogorgia acerosa	4	11	2	2	4	**4.6**
Pseudopterogorgia americana	1		2		1	**1.3**
Eunicea flexuosa					1	**1.0**
Gorgonia ventalina	1			1	1	**1.0**
Plexaura kukenthali		1	1		1	**1.0**
Pseudopterogorgia bipinnata	1		1		1	**1.0**
Total Gorgonians (# colonies/transect)	19	21	18	9	19	**19.7**

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 < 1 %). Reef overhangs, associated with live and dead ledges of Boulder Star Coral averaged 22.3 % of the reef substrate cover and contributed markedly to the topographic rugosity of 4.3 m.

Fleshy algae, mostly *Lobophora variegata* was the dominant sessile-benthic component in terms of substrate cover at the outer shelf reef with an average of 25.2 % (range: 14.9 – 36.9 %). *Lobophora* was found overgrowing rocky substrates, as well as dead coral sections and other hard ground. Turf algae, comprised by a mixed assemblage of short filamentous red and brown macroalgae contributed with a mean cover of 19.5 % to the total cover by benthic macroalgae of 45.9 %.

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 declined consistently after the baseline characterization in 2004, when the mean cover was measured as 31.8 %. Differences of live coral cover between monitoring surveys is significant at $p = 0.065$. Live coral declined 9.5 % between 2004 and 2005, then declined 12.9 % between 2005 and 2006, and 9.0 % between 2006 and 2007. During the last two years live coral cover has stabilized, perhaps showing a slight recuperation during the present 2009 survey, in most part related to mild increments of substrate cover by M. annularis (Figure 28).

Montastraea annularis was the main driver of the declining trend of live coral decline at Tourmaline Reef 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 the benthic algal component (mostly *Lobophora*) is suggested from the monitoring data.

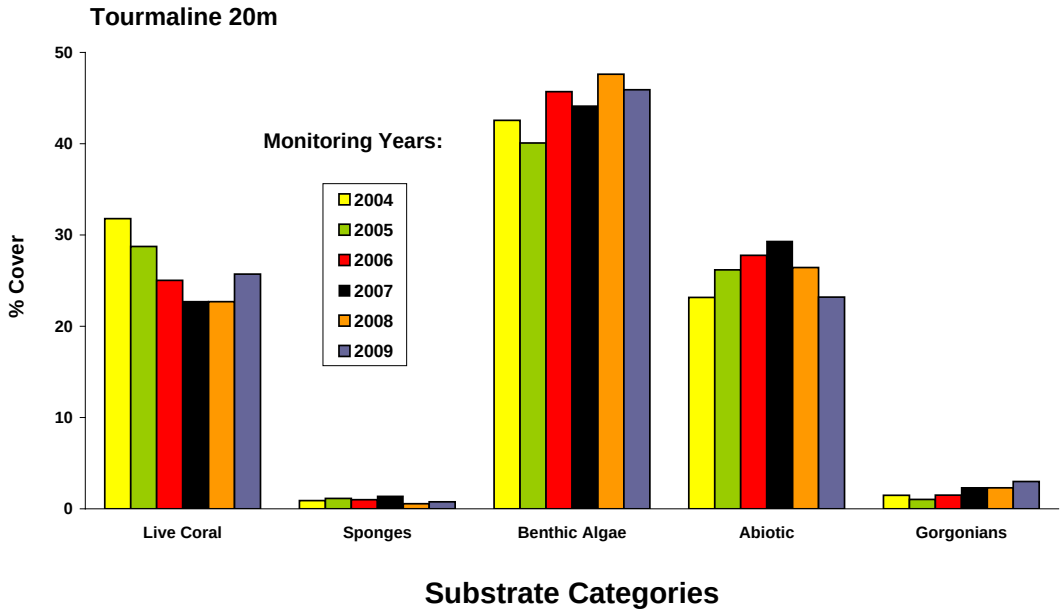


Figure 27. Monitoring trends (2004 – 2009) of mean substrate cover by sessile-benthic categories at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

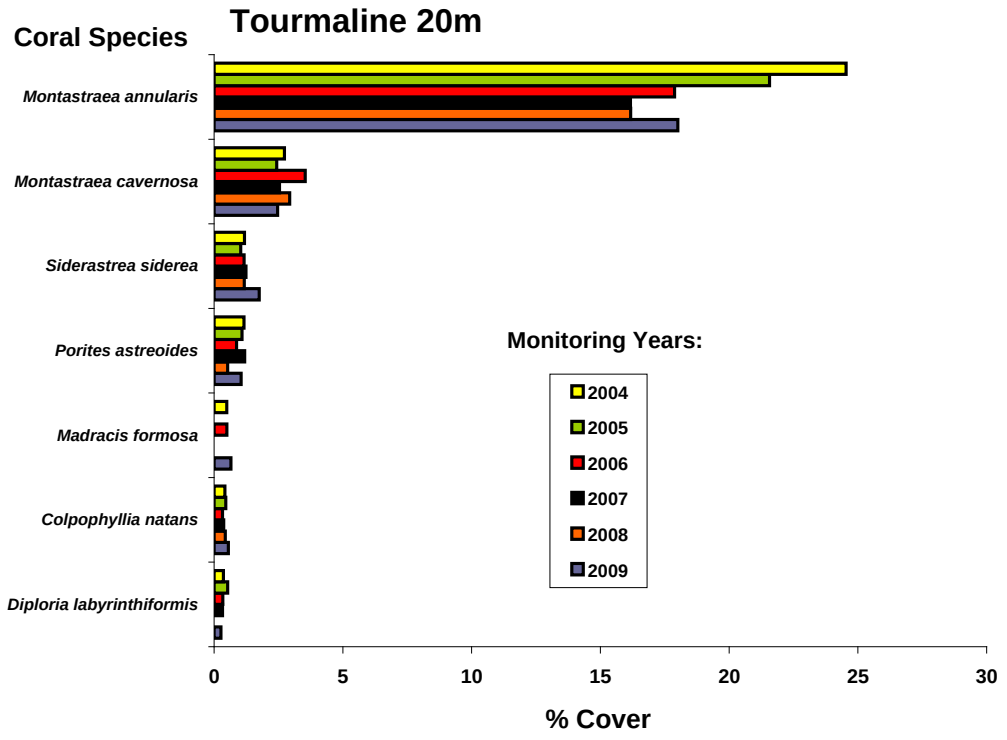


Figure 28. Monitoring trends (2004 – 2009) of mean substrate cover by stony coral species at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

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 2009 was 100.6 Ind/30 m^2 (range: 58 - 176 Ind/30 m^2). The mean number of species per transect was 15.4 (range: 14 - 17). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 48.4 Ind/30 m^2 (range: 15 – 125 Ind/30 m^2), representing 48.1 % 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, Sharpnose Puffer, Bluehead Wrasse and Redband Parrotfish comprised the most abundant fish assemblage at the outer shelf reef. All of the aforementioned species were present in all five transects, and a total of 10 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 and 4). Abundance was low in the baseline survey, then peaked in 2005 and has maintained a declining trend since 2006. Species richness has maintained a consistent decline after 2006. Differences of fish abundance at this reef have been historically driven by abundance fluctuations of the Masked Goby, a numerically dominant species with highly patchy distributions. The declines of fish species richness may be associated with changes in the quality of the benthic habitat.

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, 20 m Mayaguez Bay. June, 2008.

Depth: 20 m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**	(individuals/30 m2)					**MEAN**
Coryphopterus personatus	Masked Goby	15	54	33	15	125	**48.4**
Gramma loreto	Fairy Basslet	14	16	13	20	11	**14.8**
Canthigaster rostrata	Sharpnose Puffer	5	6	7	13	7	**7.6**
Chromis cyanea	Blue Chromis	2	5	1	12	13	**6.6**
Coryphopterus lipernes	Peppermint Goby	8	9	2	4	6	**5.8**
Thalassoma bifasciatum	Bluehead Wrasse	1	4	3	3	1	**2.4**
Sparisoma aurofrenatum	Redband Parrotfish	2	2	2	2	1	**1.8**
Scarus iserti	Striped Parrotfish	0	5	1	1	0	**1.4**
Miripristis jacobus	Blackbar Soldierfish	0	0	1	3	3	**1.4**
Scarus taeniopterus	Princess Parrotfish	0	1	0	5	0	**1.2**
Stegastes partitus	Bicolor Damselfish	3	1	0	2	0	**1.2**
Gobiosoma evelynae	Sharknose Goby	0	0	2	1	2	**1.0**
Chaetodon capistratus	Foureye Butterflyfish	2	1	2	0	0	**1.0**
Halichoeres garnoti	Yellowhead Wrasse	0	0	2	1	1	**0.8**
Stegastes variabilis	Cocoa Damselfish	0	0	2	0	2	**0.8**
Acanthurus chirurgus	Doctorfish	0	0	2	1	0	**0.6**
Stegastes leucostictus	Beugregory	2	1	0	0	0	**0.6**
Amblycirrhitus pinos	Redspoted Hawlkfish	0	1	0	0	1	**0.4**
Cephalopholis cruentatus	Graysby	0	1	0	1	0	**0.4**
Neoniphon marianus	Longjaw Squirrelfish	0	1	0	1	0	**0.4**
Aulostomus maculatus	Trumpetfish	0	0	0	0	1	**0.2**
Anisotremus virginicus	Porkfish	1	0	0	0	0	**0.2**
Lopropoma rube	Pepperment Basslet	0	1	0	0	0	**0.2**
Acanthurus bahianus	Ocean Surgeon	1	0	0	0	0	**0.2**
Chaetodon aculeatus	Longsnout Butterflyfish	1	0	0	0	0	**0.2**
Holocentrus rufus	Longspine Squirrelfish	0	0	0	0	1	**0.2**
Acanthurus coeruleus	Blue Tang	0	0	0	1	0	**0.2**
Caranx crysos	Blue Runner	0	0	0	0	1	**0.2**
Hypoplectrus puella	Barred Hamlet	0	0	1	0	0	**0.2**
Microspathodon chrysurus	Yellowtail Hamlet	1	0	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**58**	**109**	**74**	**86**	**176**	**100.6**
	TOTAL SPECIES	**14**	**16**	**15**	**17**	**15**	**15.4**

Fishes Outside Transects

SPECIES	**COMMON NAME**
Anisotremus surinamensis	Black Margate
Aulostomus maculatus	Trumpetfish

Table 31. Continued

Balistes vetula	Queen Triggerfish
Bodianus rufus	Spanish Hogfish
Bothus lunatus	Peacock Flounder
Carangoides ruber	Bar Jack
Caranx crysos	Blue Runner
Chaetodon ocellatus	Spotfin Butterflyfish
Decapterus macarelus	Mackerel Scad
Epiniphelus striatus	Nassau Grouper
Equetus acuminatus	Highhat
Haemulon macrostomus	Spanish Grunt
Holacanthus ciliaris	French Angelfish
Holacanthus tricolor	Rock Beauty
Holocentrus coruscus	Reef Squirrelfish
Hypoplectrus indigo	Indigo Hamlet
Hypoplectrus niger	Black Hamlet
Lactophrys polygonia	Honeycomb Cowfish
Lachnolaimus maximus	Hogfish
Lutjanus cyanopterus	Cubera Snapper
Lutjanus mahogany	Mahogany Snapper
Malacoctenus triangulatus	Saddled Blenny
Ocyurus chrysurus	Yellowtail Snapper
Pempheris schomburgki	Glassy Sweeper
Pomacanthus arcuatus	Gray Angelfish
Priacanthus cruentatus	Glasseye Snapper
Pseudupeneus maculatus	Yellowtail Goatfish
Scarus vetula	
Scomberomorus regalis	Cero Mackerel
Sphyraena barracuda	Great Barracuda
Stegastes planifons	Yellow-eye Damselfish
Synodus intermedius	Sand Diver

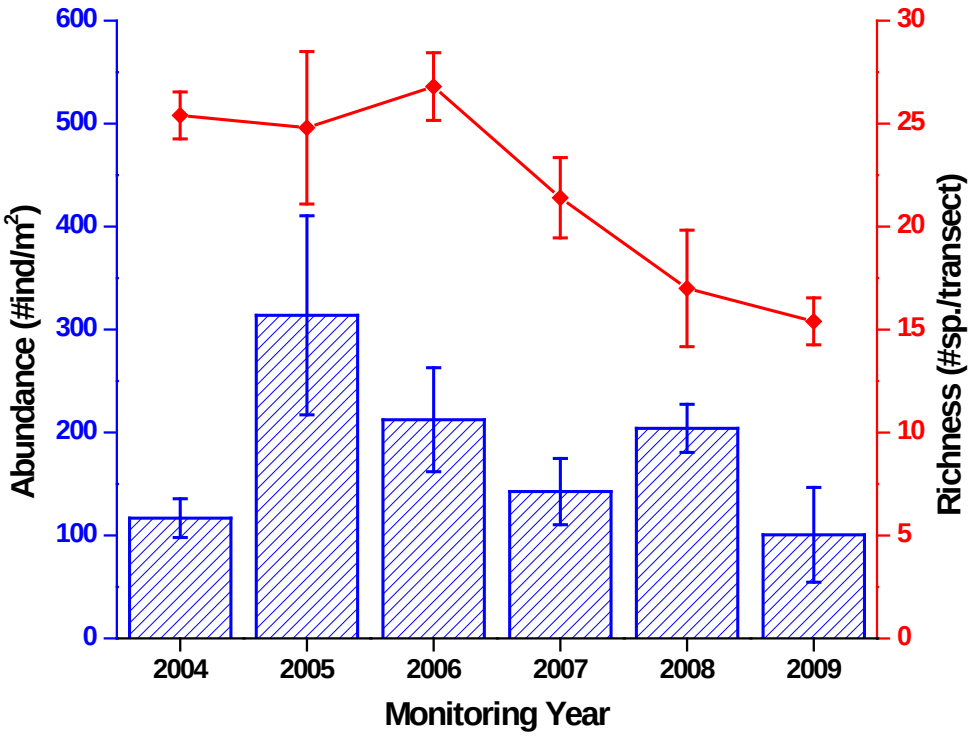


Figure 29. Monitoring trends (2004 – 2009) of fish species richness and abundance at Outer Shelf Reef Tourmaline, 20 m, Mayaguez Bay.

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, 2009

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

SPECIES	**COMMON NAME**		# - (cm)
Epinephelus guttatus	Red Hind	1 - (30)	1 – (35)
Epinephelus striatus	Nassau Grouper	1 - (40)	
Holacanthus ciliaris	French Angelfish	2 - (40)	
Lachnolaimus maximus	Hogfish	1 – (50)	
Lutjanus apodus	Schoolmaster	1 - (30)	1 – (40)
Lutjanus mahogany	Mahogany Snapper	2 - (20)	1 – (30)
Ocyurus chrysurus	Yellowtail Snapper	3 - (25)	1 - (30)
Scomberomorus regalis	Cero Mackerel	2 - (40)	
Sphyraena barracuda	Great Barracuda	1 - (50)	1 – (60)
Invertebrates			

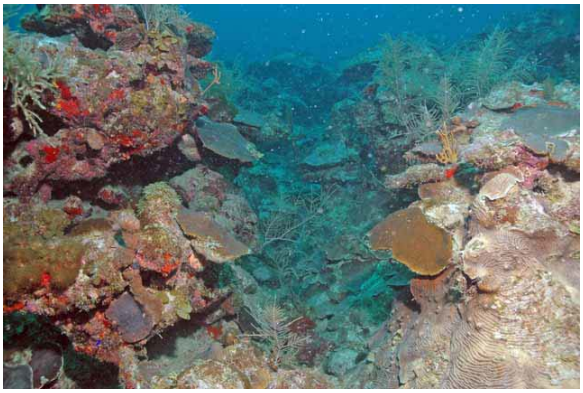
Cubera and Dog Snappers have been identified from previous ASEC surveys at this reef (García-Sais et al, 2005). One Arrow Crab and one Banded Coral Shrimp were the only motile megabenthic invertebrates observed within belt-transects during 2009.

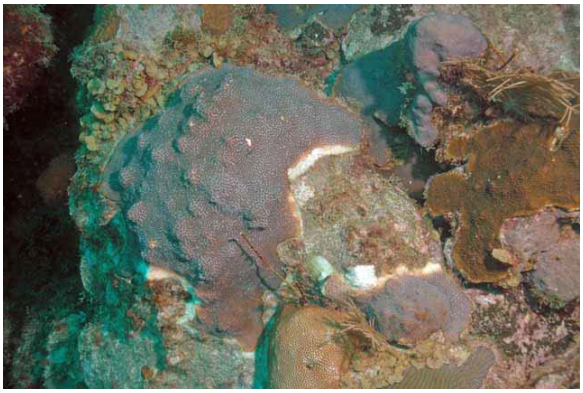
Table 33. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Outer-shelf Reef, Mayaguez, June, 2009

Depth: 20 m		**TRANSECTS**					**MEAN ABUNDANCE (IND/30 m^2)**
		1	**2**	**3**	**4**	**5**	
TAXA	**COMMON NAME**						
Stenopus hispidus	Banded Coral Shrimp				1		**0.2**
Stenorhynchus seticornis	Arrow Crab		1				**0.2**
	TOTALS	**0**	**1**	**0**	**0**	**0**	**0.40**

Photo Album 8 (Tourmaline 20 m)

OuterShelf Reef





3.0 Tourmaline Outer Shelf Reef – 10 m

3.1 Sessile-benthic Reef Community

At a depth of 10 m, Tourmaline Outer Shelf Reef exhibits a very well defined "spur-and-groove" formation that runs perpendicular to the shelf-edge and ends in a sandy-silt deposit at a depth of 14 m. Spurs are about 2 - 3 m tall, separated by coralline sand and coral rubble deposited at the grooves. Stony corals grow on top of the spurs and along the walls in massive, branching and encrusting colonies. Soft corals are common and a visually prominent feature of the reef benthos. An existing set of five permanent transects established on top of the spurs during the baseline characterization in 1999 by García et al. (2001) was monitored for the 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 23 stony coral species were identified from the Outer Shelf Reef at a depth of 10 m, 16 of which were intercepted by line transects during this survey (Table 34). Stony corals occurred as massive (*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 41.1 % (range: 21.6 – 70.0 %). 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 10.6 % and 9.3 %, 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 53.0 % 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 2009 monitoring survey and comprised in addition to *M. mirabilis* the main stony coral assemblage at this reef.

Erect soft corals (gorgonians) were highly abundant with an average of 29.0 colonies/transect and along with stony corals were the most visually prominent

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

June 2009

Depth: 10 m

	1	2	3	4	5	**MEAN**
Rugosity (m)	3.10	3.52	2.30	3.45	3.44	**3.16**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	7.18	7.32	7.48	9.14	5.95	**7.4**
Total Abiotic	7.18	7.32	7.48	9.14	5.95	**7.4**
Benthic Algae						
Turf-mixed assemblage	46.11	14.28	48.28	54.28	63.32	**45.2**
Fleshy algae				0.84		**0.2**
Halimeda tuna				1.04		**0.2**
Dictyota sp.		5.40	1.71	3.05	3.27	**2.7**
Total Benthic Algae	46.11	19.68	49.99	59.21	66.59	**48.3**
Gorgonians	2.67	2.59	0.57	0.82	3.57	**2.0**
Sponges	0.46	0.52			1.79	**0.6**
Zoanthids	0.76			3.05		**0.8**
Cyanobacteria	0.65			1.26	0.52	**0.45**
Live Stony Corals						
Madracis mirabilis		52.96				**10.6**
Porites porites	20.31	0.52	12.52	7.51	5.65	**9.3**
Montastraea annularis	7.40	11.39	7.07	3.35	3.65	**6.6**
Porites astreoides	6.03	2.37	12.28	2.90	1.71	**5.1**
Agaricia agaricites	0.32	0.83	3.58	2.90	2.08	**1.9**
Colpohyllia natans			7.56		0.94	**1.7**
Agaricia grahamae			0.65	5.06	2.53	**1.6**
Dendrogyra cylindrus	2.67			2.72		**1.1**
Meandrina meandrites	1.83	0.73	1.03	1.15		**1.0**
Montastraea cavernosa			1.37	0.31	2.08	**0.8**
Diploria labyrinthiformis			1.95		1.57	**0.7**
Porites colonensis		1.15		0.63		**0.4**
Madracis decactis	0.75					**0.2**
Diploria strigosa					0.52	**0.1**
Stephanocoenia michelini					0.42	**0.1**
Agaricia lamarcki					0.42	**0.1**
Total Stony Corals	39.31	69.95	48.01	26.53	21.57	**41.1**
Gorgonians (# col.)						
Briareum asbestinum	18	9	8	14	13	**12.4**
Plexaura kukenthali	4	2	3	6	4	**3.8**
Plexaura homomalla	2		3	5	3	**3.2**
Pseudoplexaura sp.	2	2		4	4	**2.4**

Table 34. Continued

Eunicea succinea	3	7	2	1	1	**2.8**
Gorgonia ventalina	1	2	1	2	4	**2.0**
Erythropodium caribaeorum	3		1			**0.8**
Eunicea flexuosa				2	2	**0.8**
Eunicea tourneforti					1	**0.2**
Muricea muricata		1				**0.2**
Pseudoptergorgia acerosa	1					**0.2**
Pseudoptergorgia americana					**1**	**0.2**
Total Gorgonians (# colonies/transect)	34	23	18	34	34	**29.0**

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

assemblage of the reef benthos. The most abundant species included the Corky Sea Finger, *Briareum asbestinum*, sea rods, *Plexaura spp*. *Pseudoplexaura spp*., and sea fans, *Gorgonia ventalina*. Encrusting gorgonians, *Erythropodium caribaeorum* were present in all five transects with an average substrate cover of 2.0 %. Sponges and zoanthids (*Palythoa caribdea*) were also present along transects, but represented minor components of the reef benthos (substrate cover < 1 %). Reef overhangs, associated with coral ledges of Boulder Star Coral averaged 7.4 % and contributed markedly to the topographic rugosity of 3.16 m. Turf algae, comprised by a mixed assemblage of short filamentous red and brown macroalgae presented an average substrate cover of 45.2 % (range: 14.3 – 63.3 %). Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard ground. Cyanobacterial films were present in three transects with low substrate cover (< 1.5%).

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 five annual monitoring surveys (2004-09). 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 = 0.662), perhaps due to the high variability associated with the magnitude (not direction) of the variations within transects. At the population level, a statistically significant decline of live coral cover (ANOVA; p = 0.028) was found for *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 2009 survey. The trend of increasing reef substrate cover by branching corals, *Madracis mirabilis* and *Porites porites* (*divaricata*) now extends to the 2009 survey (Figure 31), and is driving an overall trend of increasing live coral cover at this reef.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 99 diurnal, non-criptic fish species have been identified during monitoring surveys from Tourmaline Outer Shelf Reef at a depth of 10 m (Appendix 1). Mean abundance during the 2009 survey was 87.2 Ind/30 m^2 (range: 47 - 118 Ind/30 m^2). A total of 39 species were observed within belt-transects and the mean number of species per transect was 19.4 (range: 15 - 22). 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 41.8 Ind/30 m^2, representing 48.0 % of the total abundance within belt-transects (Table 35). In addition to the aforementioned species, 9 more species were present in at least four transects. These included the Yellowhead Wrasse, Princess, Redband, Stoplight and Striped Parrotfishes, Sharpnose Puffer, French Grunt, Four-eye Butterflyfish, and Beaugregory. Eight 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.

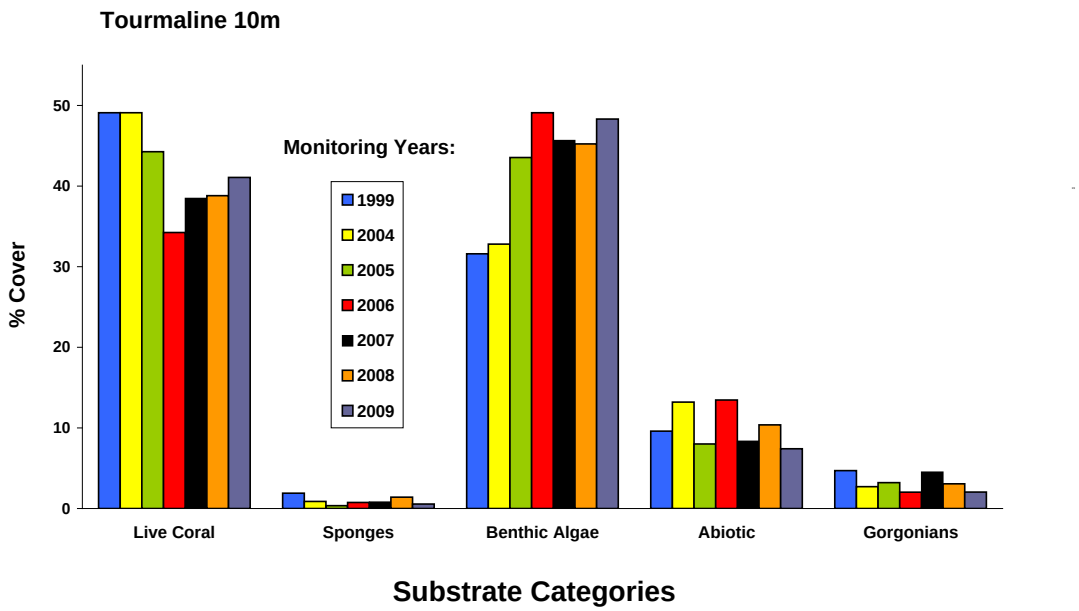


Figure 30. Monitoring trends (1999 – 2009) of mean substrate cover by sessile-benthic categories at Tourmaline Reef – 10 m, Mayaguez.

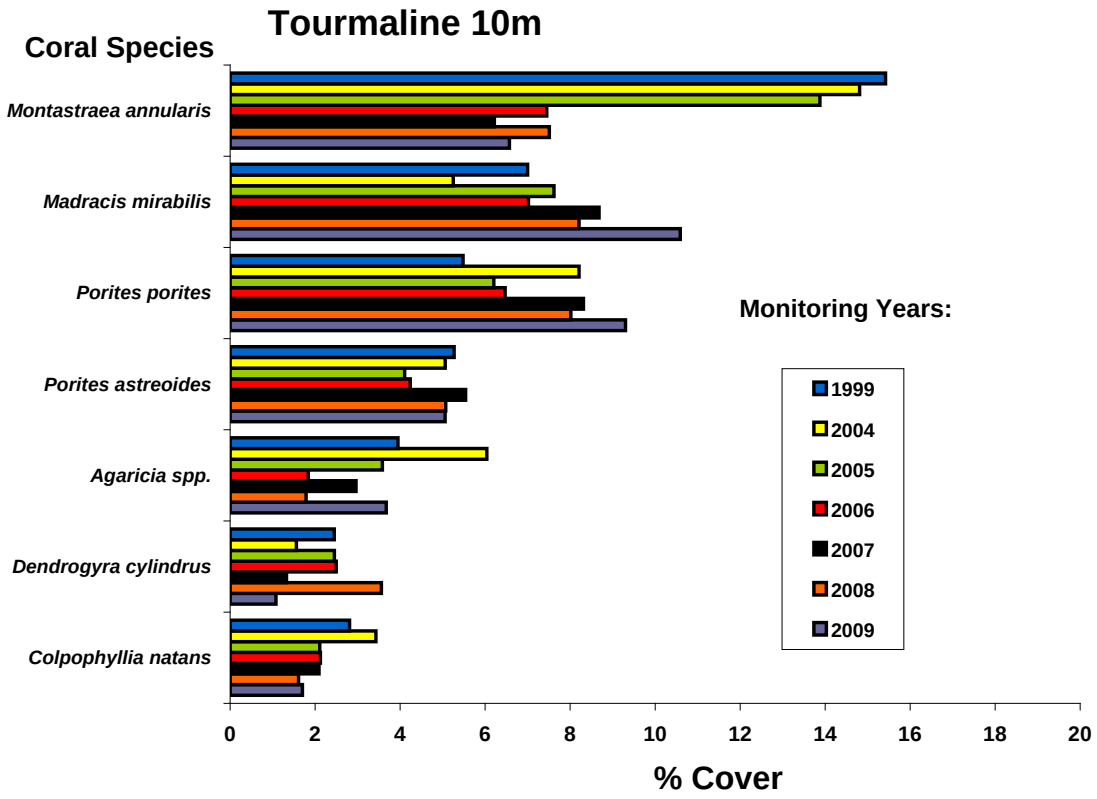


Figure 31. Monitoring trends (1999 – 2009) of mean cover by stony coral species at Tourmaline Reef – 10 m, Mayaguez.

Table 35. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, 10 m Mayaguez Bay. June, 2009.

Depth: 10 m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**	(individuals/30 m2)					**MEAN**
Chromis cyanea	Blue Chromis	0	34	33	19	31	**23.4**
Thalassoma bifasciatum	Bluehead Wrasse	0	28	6	6	6	**9.2**
Stegastes partitus	Bicolor Damselfish	6	23	8	3	6	**9.2**
Scarus iserti	Stripped Parrotfish	3	0	14	5	10	**6.4**
Scarus taeniopterus	Princess Parrotfish	10	7	0	0	9	**5.2**
Microspathodon chrysurus	Yellowhead Wrasse	4	0	8	4	3	**3.8**
Sparisoma aurofrenatum	Redband Parrotfish	8	3	4	0	1	**3.2**
Gobiosoma evelynae	Sharknose Goby	0	0	6	0	7	**2.6**
Miripristis jacobus	Blackbar Soldierfish	0	1	2	8	2	**2.6**
Haemulon flavolineatum	French Grunt	0	2	1	6	1	**2.0**
Gramma loreto	Fairy Basslet	1	3	0	6	0	**2.0**
Stegastes leucostictus	Beaugregory	2	2	3	0	2	**1.8**
Chaetodon capistratus	Foureye Butterflyfish	1	0	2	2	3	**1.6**
Sparisoma viride	Stoplight Parrotfish	2	2	1	1	1	**1.4**
Canthigaster rostrata	Sharpnose Puffer	1	4	0	1	1	**1.4**
Halichoeres maculipinna	Clown Wrasse	0	0	2	0	5	**1.4**
Neoniphon marianus	Longjaw Squirrelfish	0	3	0	1	2	**1.2**
Cephalopholis cruentatus	Graysby	3	0	1	1	0	**1.0**
Acanthurus bahianus	Ocean Surgeon	2	1	1	0	0	**0.8**
Epinephelus guttatus	Red Hind	0	0	3	0	0	**0.6**
Anisotremus virginicus	Porkfish	0	0	0	3	0	**0.6**
Acanthurus coeruleus	Blue Tang	2	0	0	1	0	**0.6**
Aoulostomus maculatus	Trumpetfish	0	0	1	0	1	**0.4**
Stegastes planifrons	Threespot Damselfish	1	1	0	0	0	**0.4**
Holocanthus tricolor	Rock Beauty	0	0	1	1	0	**0.4**
Coryphopterus lipernes	Peppermint Goby	0	0	1	0	1	**0.4**
Hypoplectrus indigo	Indigo Hamlet	0	1	0	0	1	**0.4**
Holocentrus rufus	Longspine Squirrelfish	0	0	2	0	0	**0.4**
Acanthururs chirurgus	Doctorfish	0	0	0	2	0	**0.4**
Hypoplectrus unicolor	Butter Hamlet	0	1	0	1	0	**0.4**
Hypoplectrus puella	Barred Hamlet	0	1	0	1	0	**0.4**
Cantherhines macrocerus	Whitespoted Filefish	0	0	0	0	1	**0.2**
Pseudopeneus maculatus	Spoted Goatfish	0	0	1	0	0	**0.2**
Malacoctenus triangulatus	Saddled Blenny	0	1	0	0	0	**0.2**
Amblycirrhius pinos	Redspoted Hawlkfish	0	0	0	1	0	**0.2**
Serranus tigrinus	Harlequin Bass	1	0	0	0	0	**0.2**
Caranx crysos	Blue Runner	0	0	0	1	0	**0.2**
Chaetodon striatus	Banded Butterflyfish	0	0	0	0	1	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	0	1	0	0	**0.2**

Table 35. Continued

TOTAL INDIVIDUALS	**47**	**118**	**102**	**74**	**95**	**87.2**
TOTAL SPECIES	**15**	**18**	**22**	**21**	**21**	**19.4**

Fishes Outside Transects

SPECIES	**COMMON NAME**
Acanthostracion quadricornis	Scrawled Cowfish
Aulostomus maculatus	Trumpetfish
Balistes vetula	Queen Triggerfish
Bodianus rufus	Spanish Hogfish
Carangoides ruber	Bar Jack
Cephalopholis fulva	Coney
Clepticus parrae	Creole Wrasse
Echeneis naucrates	Sharksucker
Epinephelus guttatus	Red Hind
Equetus acuminatus	Highhat
Gymnothorax moringa	Spotted Moray
Flammeo marianus	Lonspine Squirelfish
Haemulon chrysargyreum	Smallmouth Grunt
Halichoeres maculipinna	Clown Wrasse
Halichoeres radiatus	Puddinwife
Holocentrus adsensionis	Longjaw Squirrelfish
Hypoplectrus indigo	Indigo Hamlet
Lachnolaimus maximus	Hogfish
Lutjanus apodus	Schoolmaster
Malacanthus plumieri	Sand Tilefish
Mulloides martinicus	Yellowtail Goatfish
Pomacanthus paru	French Angelfish
Pseudupeneus maculatus	Spotted Goatfish
Scarus vetula	Queen Parrotfsh
Scomberomorus regalis	Cero
Stagastes variabilis	Cocoa Damselfish
Sphyraena barracuda	Great Barracuda
Panulirus guttatus	Rock Lobster

Annual monitoring trends of fish species richness and abundance are presented in Figure 32. Minimum mean values of fish abundance and species richness were observed during 2008, when mean abundance declined 31.4 % relative to the baseline survey, but during the present 2009 a declining trend was not observed. Differences between annual surveys are not statistically significant (ANOVA; $p = 0.453$). 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 (Appendix 3 – 4).

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, 2008 and the present survey (Table 36) 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 2009 monitoring survey (Table 37). Spiny and Spotted Lobsters, *Panulirus argus*, *P. guttatus*, have been previously reported observed outside transects during the ASEC surveys.

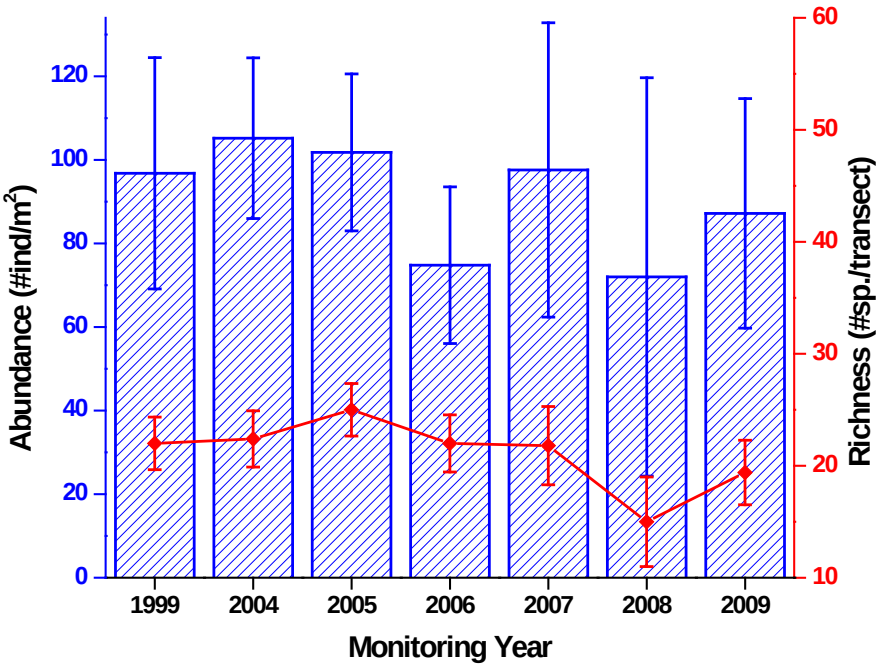


Figure 32. Monitoring trends (2004 – 2009) of fish species richness and abundance at Outer Shelf Reef Tourmaline, 10 m, Mayaguez.

Table 36. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Tourmaline Outer Shelf Reef, 10 m, June, 2009

Duration - 30 min.	Depth range : 10 - 13 m			
SPECIES	**COMMON NAME**	# - (cm)		
Balistes vetula	Queen Triggerfish	1 - (40)		
Carangoides crysos	Blue Runner	2 - (40)		
Epinephelus guttatus	Red Hind	2 - (25)	1 – (30)	
Lutjanus synagris	Lane Snapper	3 - (15)	3 - (20)	1 - (25)
Ocyurus chrysurus	Yellowtail Snapper	2 - (25)	2 – (30)	1 - (40)
Scomberomorus regalis	Cero Mackerel	2 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (60)		
Holacanthus tricolor	Rock Beauty	1 – (10)	1 – (20)	
Invertebrates				
Panulirus guttatus	Rock Lobster	1 – (20)		

Table 37. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Outer-shelf Reef, 10 m, June, 2009

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 10 m)

OuterShelf 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.

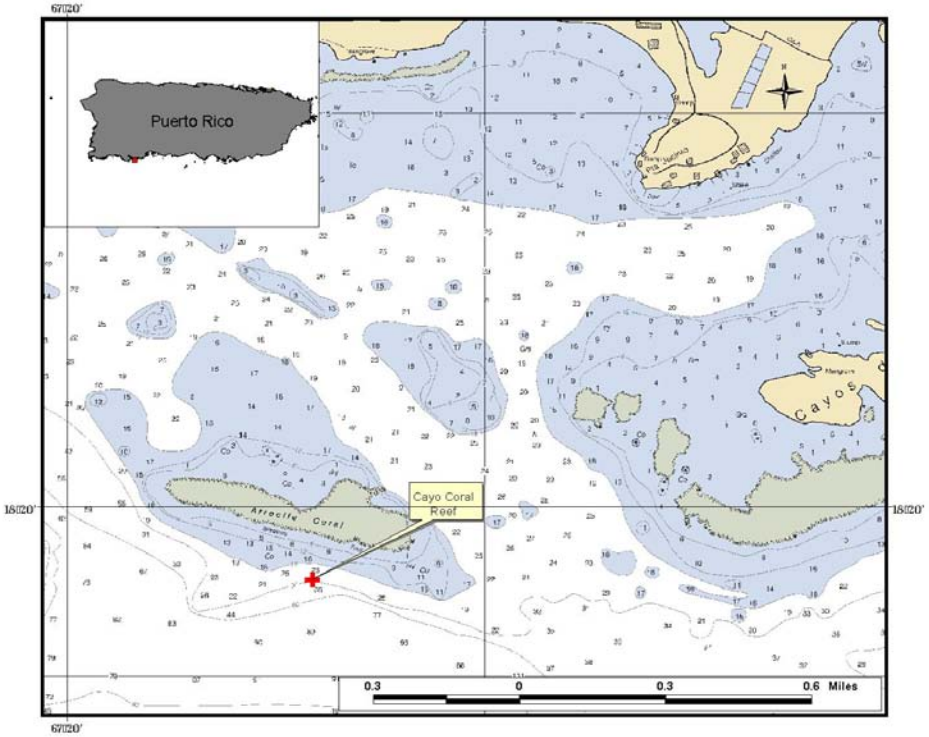


Figure 33. Location of coral reef survey stations at Cayo Coral Reef, Guánica.

1.0 Sessile-benthic Reef Community

A total of 17stony corals, including 10 intersected by permanent line transects were identified from Cayo Coral Reef during the 2009 survey (Table 38). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 10.0 % (range: 3.8 – 12.2%). Boulder Star Coral, *Montastraea annularis* (complex) was the main species in terms of substrate cover with a mean of 3.6% (range: 1.9 – 7.4 %), representing 36.0 % 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 30.5 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 the Corky Sea Finger, Briareum asbestinum, Sea Rods, *Plexaura kukenthali*, *Plexaura sp*., *Eunicea spp*. and the Common Sea Fan, *Gorgonia ventalina*. The high abundance of gorgonians contributed substantial complexity and substrate heterogeneity to Cayo Coral, representing an important protective habitat to reef fishes and invertebrates. Small sponges and patches of colonial zoanthids (*Palythoa caribbea*) represented minor components of the reef benthos. Reef overhangs associated with mostly dead massive Boulder Star Coral colonies averaged 4.0 m and contributed substantially to the mean rugosity of 3.6 m. Recently dead corals were not observed during this survey, ending the continued trend of annual reductions of live coral cover at this reef.

Benthic algae, comprised mostly by turf algae was the most prominent sessile-benthic category in terms of substrate cover with a mean of 78.7 % (range: 76.3 – 81.7 %). 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 dead Boulder Star Coral.

Table 38. Percent substrate cover by sessile-benthic categories at Cayo Coral, Guanica, 10 m, March 2009

Depth: 10 m	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	2.28	4.27	4.39	1.18	5.90	**3.60**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	2.61	4.06	2.71	7.60	3.08	**4.0**
Sand					0.89	**0.2**
Total Abiotic	2.61	4.06	2.71	7.60	3.97	**4.2**
Benthic Algae						
Turf-mixed assemblage	80.54	74.58	77.01	74.60	75.85	**76.5**
Fleshy algae	1.15	1.68	0.69	4.65	1.77	**2.0**
Amphiroa sp.				0.50	0.63	**0.2**
Total Benthic Algae	81.69	76.26	77.70	79.75	78.25	**78.7**
Cyanobacteria					4.97	**1.0**
Sponges	3.42	4.83	3.34	6.44	2.89	**4.2**
Gorgonians	2.44	2.59	2.09	2.50		**1.9**
Live Stony Corals						
Montastraea annularis	3.09	2.73	2.71	1.89	7.36	**3.6**
Porites astreoides	2.77	1.38	2.57		1.76	**1.7**
Montastraea cavernosa	3.01	1.08	0.69	1.01		**1.2**
Siderastrea siderea		4.62		0.88		**1.1**
Colpophyllia natans			5.07			**1.0**
Meandrina meandrites			2.22			**0.4**
Porites porites		0.79	0.90			**0.3**
Diploria strigosa	1.03	0.59				**0.3**
Agaricia agaricites		0.39			0.82	**0.2**
Eusmilia fastigiata		0.63				**0.1**
Total Stony Corals	9.9	12.21	14.16	3.78	9.94	**10.0**
Gorgonians (# col.)						
Briareum asbestinum	6	10	7	7	7	**7.4**
Plexaura kukenthali	5	4	4	2	6	**4.2**
Pseudoplexaura sp.	4	4	4	6	1	**3.8**
Eunicea succinea	6		3	2		**3.7**
Plexaura homomalla	2	3	3	4	3	**3.0**
Gorgonia ventalina	5	2	2	3	1	**2.6**
Eunicea flexuosa	1	3			2	**1.2**
Eunicea tourneforti	1	1	2	1	4	**1.8**
Eunicea asperula	1			1		**0.4**
Eunicea spp. 1		1			1	**0.4**
Plexaurella fusifera				1		**0.2**
Plexaurella nutans	1			1		**0.4**

Table 38. Continued

Pseudoplexaura purosa		1				**0.2**
Pseudoptergorgia acerosa	1				1	**0.4**
Pseudoptergorgia americana	1			1		**0.4**
Pseuodplexaura purosa		1	1			**0.4**
Total Gorgonians (# colonies/transect)	34	30	26	29	26	**30.5**

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 2005-09. Differences of reef substrate cover by live stony corals between surveys were statistically significant (ANOVA; $p < 0.0001$, Appendix 2) and constitute evidence of degradation of the coral reef community structure. Total live coral cover at Cayo Coral declined consistently throughout the monitoring program from a mean of 25.3 % in 1999 to a mean of 8.9 % in 2008, an overall reduction of 64.8 %. The reduction of live coral cover was evidenced across the five permanent transects surveyed. A corresponding increment of cover by benthic algae has been measured (Figure 34). During 2009, the aforementioned declinig trend of live corasl cover has stabilized, with several massive coral species showing a mild recuperation trend.

Variations of the mean substrate cover by coral species during monitoring surveys are shown in Figure 35. A drastic decline of the percent substrate cover by Boulder Brain Coral, *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 Brain Coral declined its mean substrate cover by approximately 40 % between 1999 and 2005 (from 10.49 % to 6.5%), and suffered another reduction of 55% between 2005 and 2006 (from 6.5 % to 2.9 %). Other scleractinian coral species that have shown marked declines of substrate cover at Cayo Coral include *Colpophyllia natans, M. cavernosa, P. astreoides* and *Agaricia spp*. Conversely, the high abundance and richness of soft coral (gorgonian) colonies has remained virtually constant between surveys.

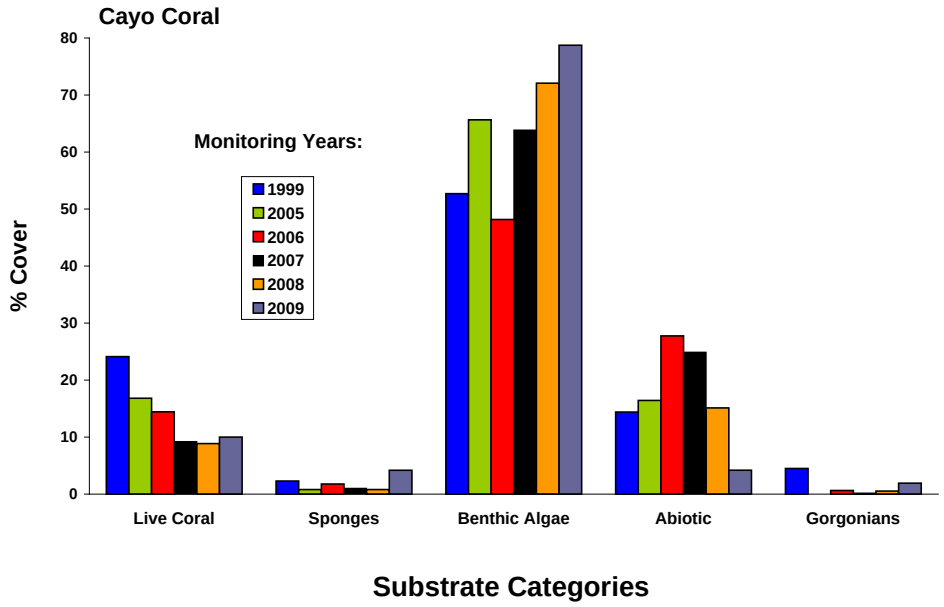


Figure 34. Monitoring trends (1999 – 2009) of mean substrate cover by sessile-benthic categories at Cayo Coral – 8 m, Guánica.

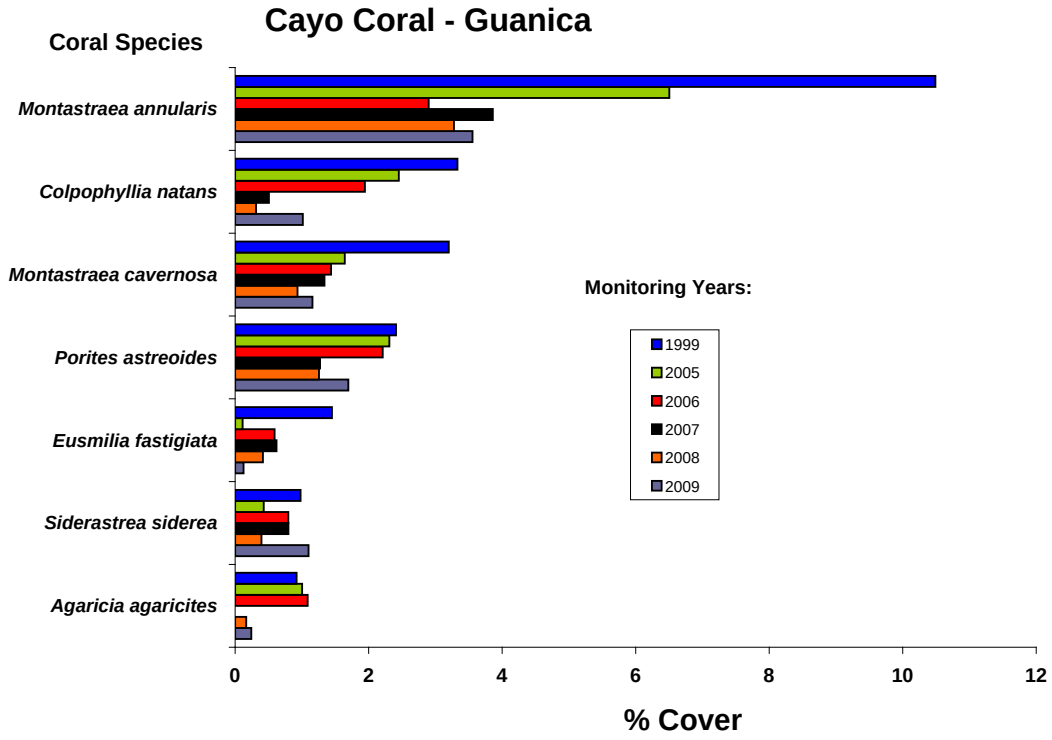


Figure 35. Monitoring trends (1999 – 2009) of mean substrate cover by stony coral species at Cayo Coral – 8 m, Guánica

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, 2009 was 59.4 Ind/30 m^2 (range: 36 - 86 Ind/30 m^2). The mean number of species per transect was 16.8 (range: 15 - 19). Mackerel Scad, *Decapterus macarellus*, Bluehead and Yellowhead Wrasse (*Thalassoma bifasciatum, Halichoeres garnoti*), Sharknose Goby (*Gobiosoma evelynae*), Dusky Damselfish (*Stegastes partitus*) and the Redband, Stoplight and Striped Parrotfishes (*Sparisoma aurofrenatum, S. viride, Scarus iserti*) were the numerically dominant species with a combined mean abundance of 41.4 Ind/30 m^2, representing 69.7 % of the total abundance within belt-transects (Table 39). Except for the Mackerel Scad, which is a schooling transitory species, all of the aforementioned species were present in at least 4 transects and comprise the main reef fish assemblage at Cayo Coral.

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 was biased by turbulent water conditions prevailing during the initial baseline survey. However, the declining trend of species richness after the 2005 survey appears to be real and may be more related to the collapse of live coral cover after the massive bleaching of late 2005. Nevertheless, a mild, statistically insignificant increment of fish abundance was registered during 2009.

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 previous ASEC surveys at Cayo Coral (Garcia-Sais et al., 2006). Table 40 shows the fish species observed during the 2009 ASEC survey.

Table 39. Taxonomic composition and abundance of fishes within belt-transects at Cayo Coral 10 m, Guanica. March, 2009

Depth: 10m		TRANSECTS					
		1	2	3	4	5	
SPECIES	COMMON NAME	(Individuals/30 m2)					MEAN
Decapterus macarellus	Mackerel Scad	0	50	0	0	0	**10**
Thalassoma bifasciatum	Bluehead Wrase	4	0	6	20	3	**6.6**
Stegastes dorsopunicans	Dusky Damselfish	7	3	5	7	6	**5.6**
Halichoeres garnoti	Yellowhead Wrase	2	3	6	2	11	**4.8**
Gobiosoma evelynae	Sharknose Goby	7	6	3	2	4	**4.4**
Scarus iserti	Stripped Parrotfish	1	0	8	10	0	**3.8**
Sparisoma aurofrenatum	Redband Parrotfish	2	0	6	3	5	**3.2**
Sparisoma viride	Stoplight Parrotfish	1	1	3	4	6	**3**
Chromis cyanea	Blue Chromis	4	0	7	0	2	**2.6**
Microspathodon chrysurus	Yellowtail Damselfish	1	3	1	1	1	**1.4**
Acanthurus bahianus	Ocean Surgeon	0	2	0	3	2	**1.4**
Stegastes partitus	Bicolor Damselfish	1	0	1	0	5	**1.4**
Haemulon flavolineatum	French Grunt	0	4	2	0	0	**1.2**
Chaetodon capistratus	Foureye Butterflyfish	1	1	3	0	1	**1.2**
Stegastes variabillis	Cocoa Damselfish	1	3	1	0	1	**1.2**
Stegastes leucostictus	Beaugregory	1	1	1	2	1	**1.2**
Scarus taeniopterus	Princess Parrotfish	0	0	0	4	0	**0.8**
Holocentrus rufus	Longspine Squirrelfish	1	3	0	0	0	**0.8**
Cephalopholis cruentatus	Graysby	0	2	0	1	1	**0.8**
Stegastes planifrons	Threespoted Damselfish	0	1	0	2	0	**0.6**
Serranus tigrinus	Harlequin Bass	0	0	0	2	1	**0.6**
Acanthurus coerulus	Blue Tang	1	0	0	1	1	**0.6**
Canthigaster rostrata	Sharpnose Puffer	0	0	0	1	1	**0.4**
Lutjanus apodus	Schoolmaster Snapper	0	2	0	0	0	**0.4**
Ocyurus chrysurus	Yellowtaill Snapper	0	0	0	0	1	**0.2**
Mulloidichthys martinicus	Yellow Goatfish	0	0	0	0	1	**0.2**
Aulostomus maculatus	Trumpetfish	1	0	0	0	0	**0.2**
Amblycirrhitus pinos	Redspoted Hawkfish	0	0	0	1	0	**0.2**
Equetus punctatus	Spotted Drum	0	0	1	0	0	**0.2**
Epinephelus guttatus	Red Hind	0	0	0	1	0	**0.2**
Gobiosoma sp.	Goby sp.	0	1	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**36**	**86**	**54**	**67**	**54**	**59.4**
	TOTAL SPECIES	**16**	**16**	**15**	**18**	**19**	**16.8**

Fishes Outside Transects

SPECIES	**COMMON NAME**
Aluterus scriptus	Scrawled Filefish
Anisotremus surinamensis	Black margate
Aulostomus maculatus	Trumpetfish
Bodianus rufus	Spanish hogfish
Cantherhynes pullus	Tail-light Filefish
Carangoides ruber	Bar jack

Table 39. Continued

Chaetodon ocellatus	Spotfin Butterflyfish
Chaetodon striatus	Banded Butterflyfish
Chromis multilineata	Brown Chromis
Clepticus parrae	Creole Wrasse
Coryphopterus glaucofraenum	Bridled goby
Coryphopterus lipernes	Peppermint goby
Decapterus macarellus	Mackerel Scad
Epinephelus guttatus	Red hind
Epinephelus itajara	Jewfish
Epinephelus striatus	Nassau Grouper
Equetus punctatus	Spotted Drum
Flammeo marianus	Longspine Squirrelfish
Ginglymostoma cirratum	Nurse Shark
Gramma loreto	Fairy Basslet
Haemulon aurolineatum	Tomtate
Haemulon chrysargireum	Smallmouth grunt
Haemulon macrostomus	Spanish Grunt
Haemulon plumieri	White grunt
Haemulon sciurus	Bluestipped grunt
Halichoeres maculipinna	Clown Wrasse
Hemiramphus ballyhoo	Ballyhoo
Holacanthus ciliaris	Queen angelfish
Holocentrus ascensionis	Lonjaw Squirrelfish
Holocentrus coruscus	Reef Squirrelfish
Hypoplectrus chlorurus	Yellowtail hamlet
Hypoplectrus indigo	Indigo Hamlet
Hypoplectrus puella	Barred hamlet
Hypoplectrus unicolor	Butter hamlet
Lachnolaimus maximus	Hogfish
Lachtophrys triqueter	Smooth trunkfish
Lactophrys bicaudalis	Spotted trunkfish
Lutjanus apodus	Schoolmaster snapper
Lutjanus cyanopterus	Cubera snapper
Lutjanus mahogany	Mahogany snapper
Lutjanus synagris	Lane snapper
Mulloides martinicus	Yellowtail Goatfish
Myripristis jacobus	Black-bar soldierfish
Ocyurus chrysurus	Yellowtail Snapper
Priacanthus arenatus	Glass-eye
Pseudupeneus maculatus	Spotted goatfish
Scarus vetula	Queen Parrotfish

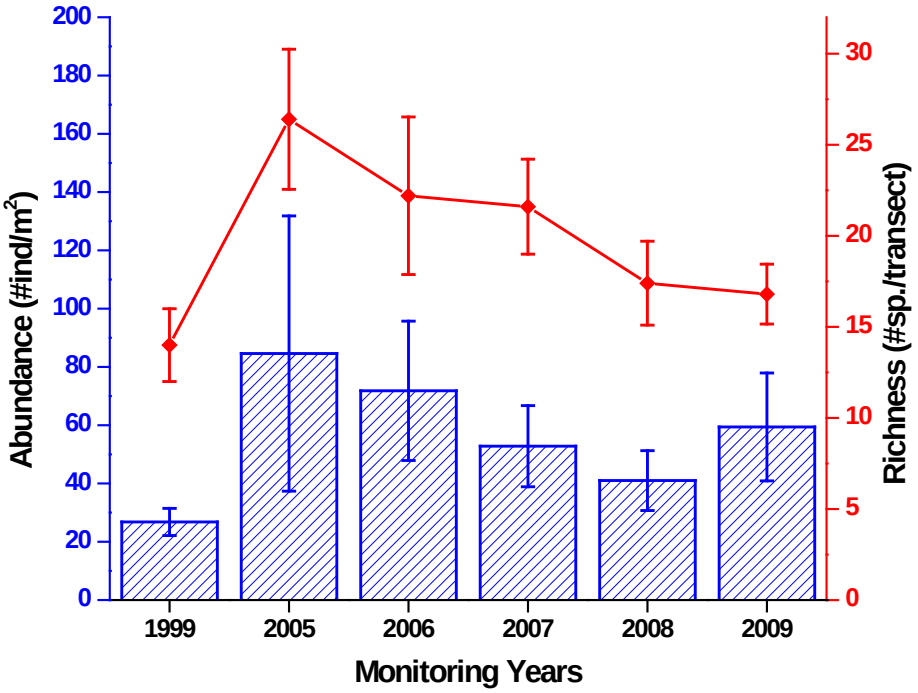


Figure 36. Monitoring trends (1999 – 2009) of fish species richness and abundance at Cayo Coral Reef, 8 m, Guanica Natural Reserve

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

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

SPECIES	**COMMON NAME**	# - (cm)		
Caranx crysos	Blue Runner	1 - (40)		
Epinephelus guttatus	Red Hind	1 - (25)	1 - (30)	
Lachnolaimus maximus	Hogfish	2 - (20)	1 – (30)	
Lutjanus apodus	Schoolmaster	1 - (20)	3 - (30)	2 – (35)
Lutjanus mahogany	Mahogany Snapper	3 - (20)	2 – (25)	
Lutjanus synagris	Lane Snapper	4 - (15)	3 – (20)	1 – (25)
Ocyurus chrysurus	Yellowtail Snapper	2 - (20)	2 – (25)	1 - (30)
Scomberomorus regalis	Cero Mackerel	1 – (40)		
Sphyraena barracuda	Great Barracuda	1 - (50)		
Invertebrates				
Panulirus argus	Spiny Lobster	2 - (20)		

Cleaner Shrimp (*Periclimenes pedersoni*) and Arrow Crab (*Stenorhynchus seticornis*) were the motile megabenthic invertebrates observed within belt-transects (Table 41). One juvenile Spiny Lobster (*Panulirus argus*) was observed outside transects.

Table 41. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Coral 8 m, Guánica. March, 2009

Depth: 8 -10 m		TRANSECTS					MEAN
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**ABUNDANCE (IND/30 m2)**
Periclimenes pedersoni	Cleaner Shrimp	1		1			**0.4**
Stenorhynchus seticornis	Arrow Crab					1	**0.2**
	TOTALS	1	0	1	0	1	**0.6**

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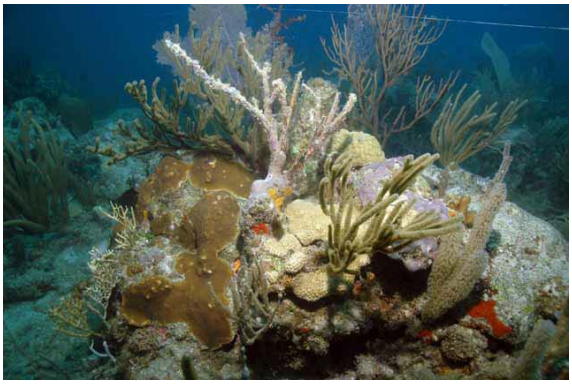
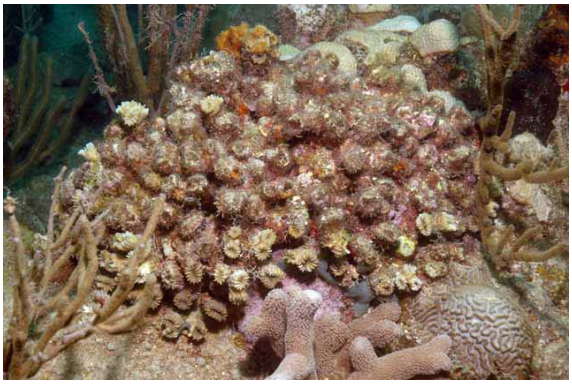
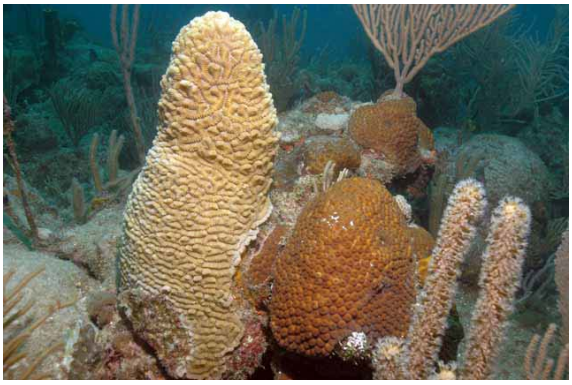
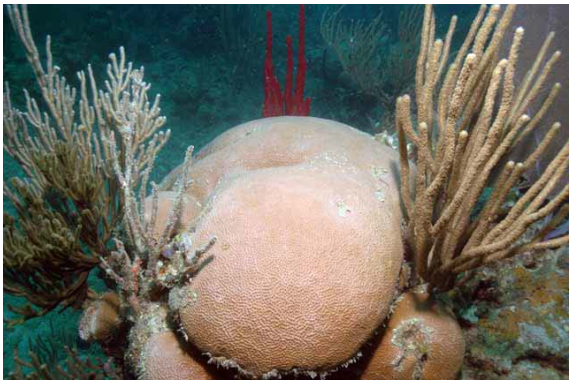
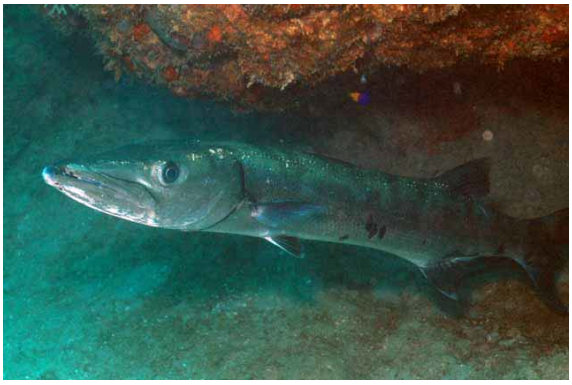
Photo Album 10 (Guanica 10 m)
Cayo Coral Reef











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.

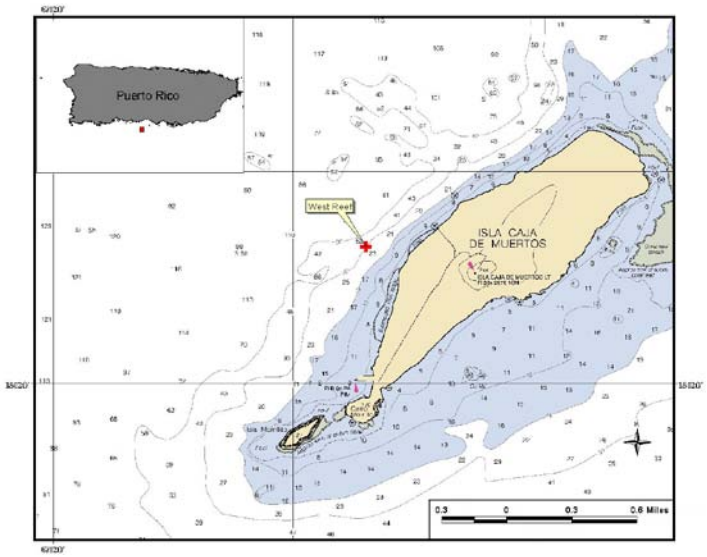


Figure 37. Location of coral reef survey stations at West Reef, Isla Caja de Muerto, Ponce.

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 59.0 % (range: 48.9 – 70.1 %) 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 tune, H. 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 low cover out of transects. The cyanobacterial bloom appeared to be associated and proportional to the amount of recently dead coral observed after the late 2005 massive coral bleaching event that impacted reef systems of Puerto Rico and the USVI (García-Sais et al., 2006).

A total of 20 stony coral species, icluding 15 within transect were identified from West Reef in the 2009 survey (Table 42). Live stony corals presented a mean substrate cover of 12.9 % (range: 9.3 – 15.6 %). Boulder Star Coral, *Montastraea annularis* (complex) was the dominant coral species with a mean substrate cover of 4.9 % (range: 1.7 – 9.9 %), representing 38.0 % of the total substrate cover by live stony corals. Great Star Coral (*M. cavernosa*), Mustard-Hill Coral (*Porites astreoides*), and the Greater and Lesser Starlet Corals, *Siderastrea siderea*, *S. radians* were present in at least three out of the five transects surveyed, and along with Boulder Star Coral comprised the main coral assemblage of the West Reef (Table 42).

Soft corals (gorgonians) presented a mean density of 24.6 colonies/transect and included colonies of very large size. Some of the most abundant species included the Slimy Sea Plumes (*Pseudopterogorgia americana, Pseudopterogorgia spp.*), Porous Sea Rods (*Pseudoplexaura spp*.), 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 1.4 %. Abiotic categories combined for a mean substrate cover of 26.8 %. Coral rubble and sand accumulated within crevices, holes and gaps of the highly irregular bottom topography. The high rugosity measured at 5.8 m was strongly influenced by large dead coral heads (mostly *Montastraea annularis*).

Table 42. Percent substrate cover by sessile-benthic categories at West Reef in Caja de Muerto, Ponce. June 2009.

Depth: 6.5 m	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	4.52	6.07	5.56	6.09	6.86	**5.8**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	10.07	12.63	24.34	24.88	28.77	**20.1**
Silt			8.35	4.04	7.00	**3.9**
Rubble	8.16	3.92	1.72			**2.8**
Total Abiotic	18.23	16.55	34.41	28.92	35.77	**26.8**
Benthic Algae						
Turf-mixed assemblage	65.93	70.13	50.03	59.83	48.93	**59.0**
Halimeda tuna				1.06		**0.2**
Total Benthic Algae	65.93	70.13	50.03	60.89	48.93	**59.2**
Sponges	3.17	0.44	2.44		1.19	**1.4**
Gorgonians	0.29			0.53		**0.2**
Anthozoa *(Lebrunia danae)*				0.44		**0.1**
Live Stony Corals						
Montastraea annularis	4.07	9.89	5.52	1.74	3.50	**4.94**
Porites astreoides	4.34	0.81	1.80	1.31	4.86	**2.62**
Montastraea cavernosa		3.48	1.28	2.72	3.02	**2.10**
Siderastrea radians	2.41	0.44	0.71		1.48	**1.01**
Siderastrea siderea	0.78	0.96	1.16	1.84		**0.95**
Meandrina meandrites			0.54	0.79		**0.27**
Dendrogyra cylindrus			1.18			**0.24**
Madracis decactis				0.87		**0.17**
Stephanocoenia michelini	0.29				0.50	**0.16**
Porites porites	0.49					**0.10**
Agaricia agaricites					0.42	**0.08**
Agaricia lamarcki			0.36			**0.07**
Diploria labyrinthiformis					0.33	**0.07**
Eusmilia fastigiata			0.18			**0.04**
Porites colonensis			0.36			**0.07**
Total Stony Corals	12.38	15.58	13.09	9.27	14.11	**12.9**
Recently dead coral						
Montastraea annularis		2.8				
Gorgonians (# col.)						
Pseudoptergorgia americana	12		12	5	13	**8.4**
Eunicea flexuosa			5	4	4	**2.6**
Gorgonia ventalina		4	5	4	4	**3.4**
Briareum asbestinum	3	1	2	7	5	**3.6**
Plexaura kukenthali	3	3	2	2	2	**2.4**
Eunciea succinea			1	3		**0.8**

Table 43. Continued

Eunicea spp.	2					**0.4**
Erythropodium caribaeorum	2			1		**0.6**
Plexaura homomalla			2	1		**0.6**
Pseudoptergorgia acerosa	3		1	1	1	**1.2**
Eunicea tourneforti	1					**0.2**
Muriceopsis flavida	1					**0.2**
Plexaurella dichotoma	1					**0.2**
Plexaurella nutans			1	1	1	**0.4**
Pseudoplexaura sp				1	**1**	**0.2**
Total Gorgonians (# colonies/transect)	28	8	31	29	31	**24.6**

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

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 2005-09. Differences of reef substrate cover by stony corals between annual surveys were statistically significant (ANOVA; p = 0.002), 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 stabilized during the 2008 and seem to be recuperating, as suggested by the increment in cover measured in the 2009.

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

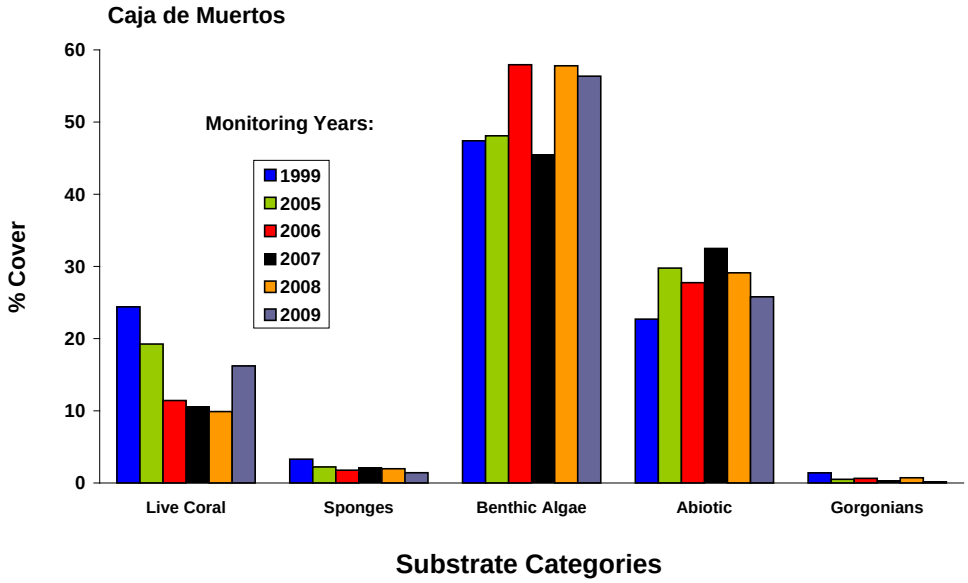


Figure 38. Monitoring trends (1999 - 2009) of mean substrate cover by sessile-benthic categories at West Reef, Isla Caja de Muerto, Ponce.

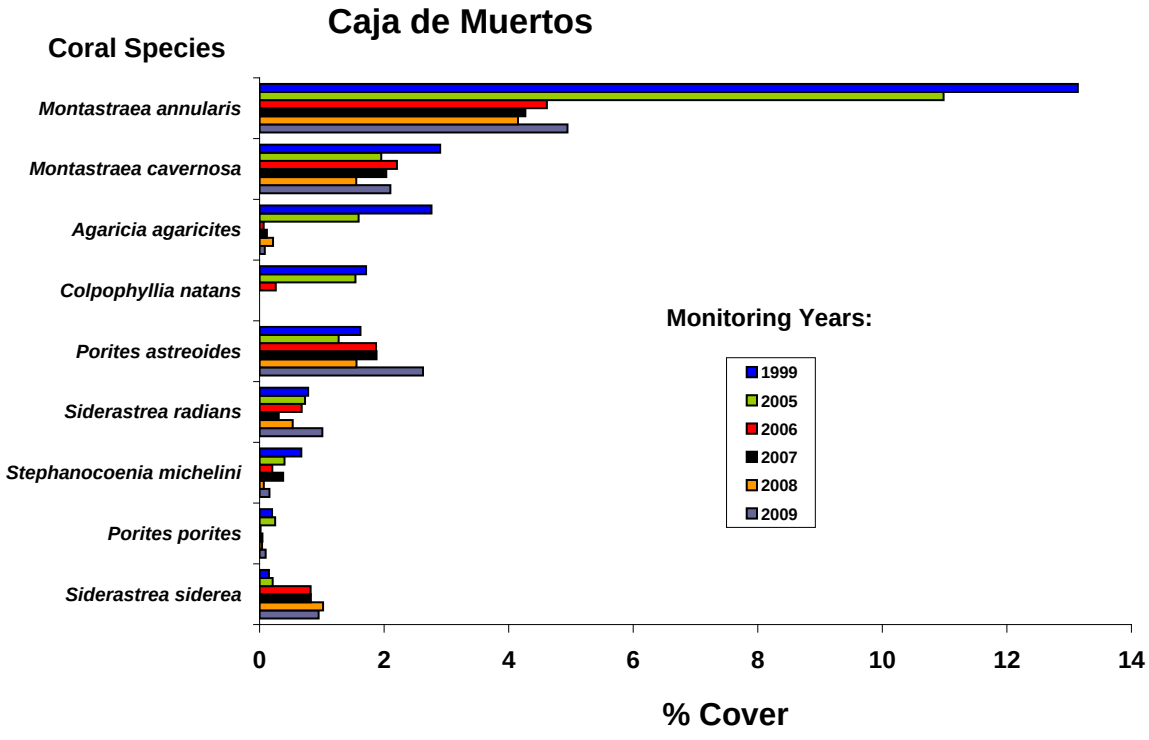


Figure 39. Monitoring trends (1999 – 2009) of mean substrate cover by stony coral species at West Reef, Isla Caja de Muerto, Ponce.

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, and then stabilized during the 2008 survey (Figure 39). Sharp reductions of substrate cover by live corals were also measured until 2007 for *Agaricia agaricites, Colpophyllia natans* and *Stephanocoenia michelini*. Conversely, mild increments of substrate cover by *M. annularis*, *P. astreoides* and *Siderastrea radians* were measured in the present 2009 survey.

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 2009 was 169.6 Ind/30 m^2 (range: 98 - 228 Ind/30 m^2). The mean number of species per transect was 22.6 (range: 16- 29). The Masked Goby (*Coryphopterus personatus*) was the numerically dominant species with a mean abundance of 96.4 Ind/30 m^2 (range: 25 - 132 Ind/30 m^2), representing 56.6 % of the total abundance within belt-transects (Table 43). The Masked Goby was present in swarms of 15 - 100 individuals close to the reef substrate, below ledges, in front of crevices and other protective microhabitats of the reef. The Bluehead Wrasse, Sharpnose Puffer, Bicolor, Dusky and Beaugregory Damselfishes, Schoolmaster, and the Stoplight 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

Table 43. Taxonomic composition and abundance of fishes within belt-transects at West Reef, 6.5 m Isla Caja de Muerto, Ponce. June, 2009.

Depth: 6.5 m		TRANSECTS					
		1	2	3	4	5	
SPECIES	COMMON NAME	(individuals/30 m2)					MEAN
Coryphopterus personatus	Masked Goby	98	132	98	25	129	**96.4**
Thalassoma bifasciatum	Bluehead Wrasse	35	26	9	25	0	**19.0**
Canthigaster rostrata	Sharpnose Puffer	8	9	8	3	5	**6.6**
Stegastes partitus	Bicolor Damselfish	6	9	10	1	4	**6.0**
Scarus taeniopterus	Princess Parrotfish	11	6	6	1	4	**5.6**
Lutjanus apodus	Schoolmaster Snapper	0	3	2	11	3	**3.8**
Stegastes leucostictus	Beugregory	3	5		4	3	**3.75**
Sparisoma viride	Stoplight Parrotfish	5	4	2	1	1	**2.6**
Hypoplectrus puella	Barred Hamlet	4	1	0	5	1	**2.2**
Stegastes dorsopunicans	Dusky Damselfish	1	5	0	3	1	**2.0**
Gobiosoma evelynae	Sharknose Goby	2	1	5	1	0	**1.8**
Chaetodon capistratus	Foureye Butterflyfish	2	3	2	0	2	**1.8**
Stegastes planifrons	Threespoted Damselfish	3	0	3	1	1	**1.6**
Myripristis jacobus	Blackbar Soldierfish	4	1	2	1	0	**1.6**
Aulostomus maculatus	Trumpetfish	0	3	1	2	0	**1.2**
Acanthurus bahianus	Ocean Surgeon	0	1	1	3	2	**1.4**
Cephalopholis cruentatus	Graysby	2	2	1	0	0	**1.0**
Sparisoma aurofrenatum	Redband Parrotfish	0	2	1	2	0	**1.0**
Lutjanus mahogany	Mahogany Snapper	0	0	5	0	0	**1.0**
Chromis multilineata	Brown Chromis	0	1	1	3	0	**1.0**
Chromis cyanea	Blue Chromis	0	4	1	0	0	**1.0**
Haemulon chrysargyreum	Smallmouth Grunt	0	0	0	3	1	**0.8**
Epinephelus guttatus	Red Hind	3	1	0	0	0	**0.8**
Stegastes variabilis	Cocoa Damselfish	1	2	1	0	0	**0.8**
Neoniphon marianus	Longjaw Squirrelfish	0	1	2	0	0	**0.6**
Halichoeres garnoti	Yellowhead Wrasse	1	0	1	0	0	**0.4**
Pseudopeneus maculatus	Spoted Goatfish	1	0	0	1	0	**0.4**
Equetus punctatus	Spoted Drum	0	0	1	1	0	**0.4**
Serranus tigrinus	Harlequin Bass	0	1	1	0	0	**0.4**
Haemulon flavolineatum	French Grunt	0	0	2	0	0	**0.4**
Acanthurus chirurgus	Doctorfish	0	0	1	0	1	**0.4**
Hypoplectrus unicolor	Butter Hamlet	0	1	1	0	0	**0.4**
Ocyurus chysurus	Yellowtail Snapper	1	0	0	0	0	**0.2**
Gobiosoma hoorsti	Yellowline Goby	0	0	0	1	0	**0.2**
Scarus iserti	Striped Parrotfish	0	0	1	0	0	**0.2**
Haemulon macrostomum	Spanish Grunt	0	1	0	0	0	**0.2**
Abudefduf sextilis	Sargent Major	0	1	0	0	0	**0.2**
Anisotremus virginicus	Porkfish	0	0	1	0	0	**0.2**
Holocentrus rufus	Longspine Squirrelfish	0	0	1	0	0	**0.2**
Gramma loreto	Fairy Basslet	0	1	0	0	0	**0.2**
Coryphopterus glaucofraenum	Bridled Goby	0	1	0	0	0	**0.2**
Acanthurus coeruleus	Blue Tang	0	0	0	0	1	**0.2**
Muraena robusta	Stout Moray	0	0	0	0	1	**0.2**

Table 43. Continued

TOTAL INDIVIDUALS	**191**	**228**	**171**	**98**	**160**	**169.6**
TOTAL SPECIES	**19**	**28**	**29**	**21**	**16**	**22.6**

Fishes Outside Transects

SPECIES	**COMMON NAME**
Balistes vetula	Queen Triggerfish
Bodianus rufus	Spanish Grunt
Calamus bajonado	Jolthead Porgy
Calamus pluma	Pluma
Carangoides ruber	Bar Jack
Caranx crysos	Blue Runner
Cephalopholis fulva	Coney
Clepticus parrae	Creole Wrasse
Chaetodon striatus	Banded Butterflyfish
Decapterus macarellus	Mackerel Scad
Gramma loreto	Fairy Basslet
Haemulon sciurus	Bluestripped Grunt
Haemulon plumieri	White Grunt
Heteroconger halis	Brown Garden Eel
Holocentrus coruscus	Reef Squirelfish
Hypoplectrus indigo	Indigo Hamlet
Lachnolaimus maximus	Hogfish
Lutjanus analis	Mutton Snapper
Lutjanus apodus	Schoolmaster Snapper
Lutjanus griseus	Gray Snapper
Lutjanus synagris	Lane Snapper
Malacanthus plumieri	Sand Tilefish
Mulloides martinicus	Yellowtail Goatfish
Ocyurus chrysurus	Yellowtail Snapper
Ophioblennius atlanticus	Redlip Blenny
Pomacanthus arcuatus	Gray Angelfish
Scarus vetula	Queen Parrotfish
Scarus coelestinus	Midnight Parrotfish
Sparisoma chrysopterus	Redtail Parrotfish
Scomberomorus regalis	Cero Mackerel
Scorpaena plumieri	Spotted Scorpionfish
Sparisoma chrysopterum	Redtail Parrotfish
Sphyraena barracuda	Great Barracuda
Stegastes variabilis	Cocoa Damselfish

within belt-transects, but were observed forming large schooling aggregations in the water column over the reef. These species are known to serve as forage for a diverse assemblage of top pelagic and demersal predators, including barracudas, jacks, and large groupers and snappers observed during the ASEC survey at this reef (Table 44).

A specious assemblage of small invertebrate feeders was also present, including wrasses, gobies, puffers, goatfishes and squirrelfishes, among others. Mid-size carnivores that are commercially exploited, such as the Yellowtail, Mahogany, Lane, Grey and Schoolmaster Snappers, Red Hind, and Coney were observed during the ASEC survey (Table 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 survey, and again during the present 2009 ASEC survey. The aggregation of these Lane Snappers at West Reef is most impressive and represents a highly valuable resource.

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

Motile megabenthic invertebrates were represented within belt-*transects by the Cleaner Shrimp, Periclimenes pedersoni and Arrow Crabs, Stenorhynchus* seticornis (Table 45). Adult sized Spiny and rock lobsters, *Panulirus argus, P. guttatus*, Flamingo Tongue, *Cyphoma gibbosum* and Queen Conch, *Strombus gigas* were present outside transects.

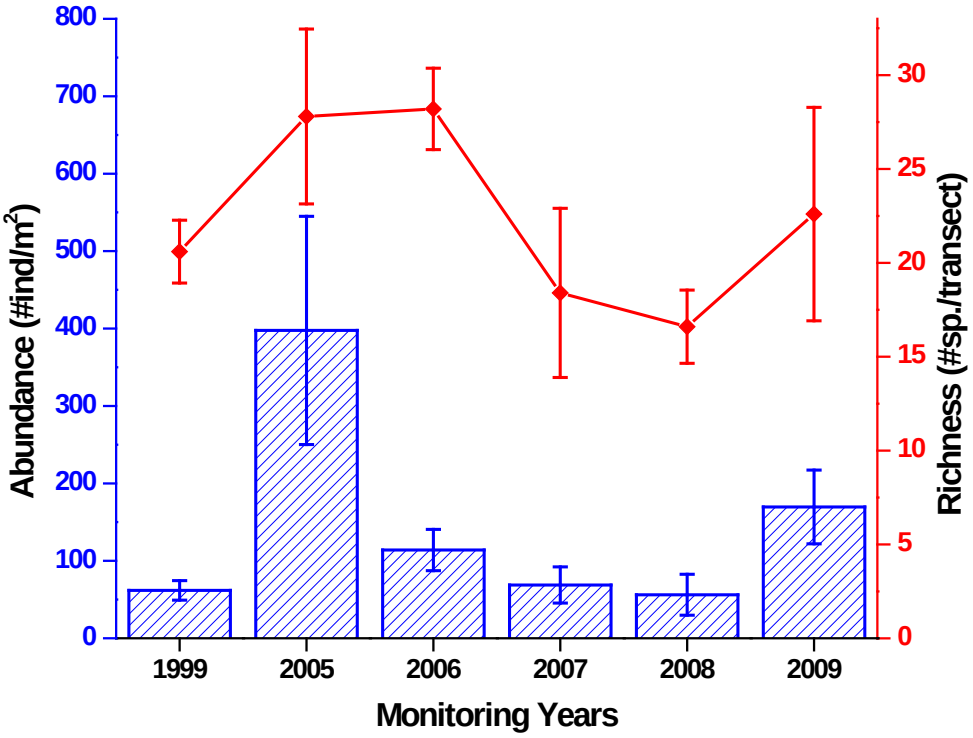


Figure 41. Monitoring trends (1999 – 2009) of fish species richness and abundance at West Reef, Isla Caja de Muerto, Ponce

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.

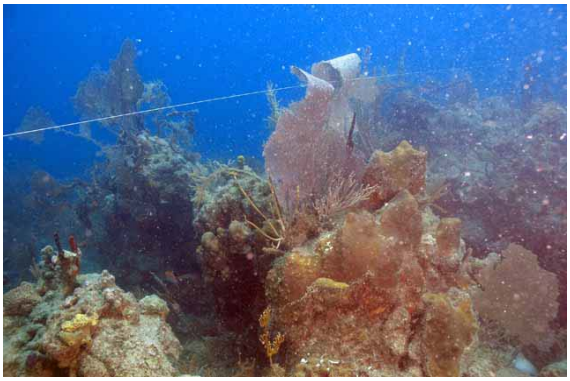
Depth range : 7 – 15 m Duration - 30 min.

SPECIES	**COMMON NAME**		# - (cm)	
Epinephelus guttatus	Red Hind	1 - (25)	1 – (30)	
Holacanthus tricolor	Rock Beauty	2 - (15)		
Holacanthus ciliaris	Queen Angel	1 - (30)		
Lutjanus apodus	Schoolmaster	11 – (20)	4 – (30)	4 – (50)
Lutjanus mahogany	Mahogani Snapper	3 - (25)	2 - (30)	
Lutjanus synagris	Lane Snapper	600 – (10-15)	100 – (25)	10 – (30)
Ocyurus chrysurus	Yellowtail Snapper	15 – (15)	10– (25)	3 – (30)
Scomberomorus regalis	Cero Mackerel	2 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (60)		
Invertebrates				
Strombus gigas	Queen Conch	1 – (25)		
Panulirus guttatus	Rock Lobster	1 – (25)		
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, 2009

Depth: 6 - 7 m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	DEPTH (m) COMMON NAME						
Periclimenes pedersoni	Cleaner Shrimp	1		1			**0.4**
Stenorhynchus seticornis	Arrow Crab		1	1		1	**0.6**
	TOTALS	**1**	**1**	**2**	**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 21 stony corals, including 11 intersected by line transects were identified from Derrumbadero Reef at a depth of 20 m during 2009 (Table 46). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 14.2 % (range: 7.9 – 16.5 %). Boulder Star Coral, *Montastraea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 6.2 % (range: 4.2 – 9.4 %), representing 43.7 % of the total cover by stony corals. Mustard-Hill Coral (*Porites astreoides*), and Great Star Coral (*M. cavernosa*) ranked second and third in terms of substrate cover by stony corals. Boulder Star and Great Star Corals, Mustard-Hill Coral and Lettuce Coral (*Agaricia agaricites*) were present in at least four transects and comprised the main stony coral assemblage at Derrumbadero Reef (Table 46).

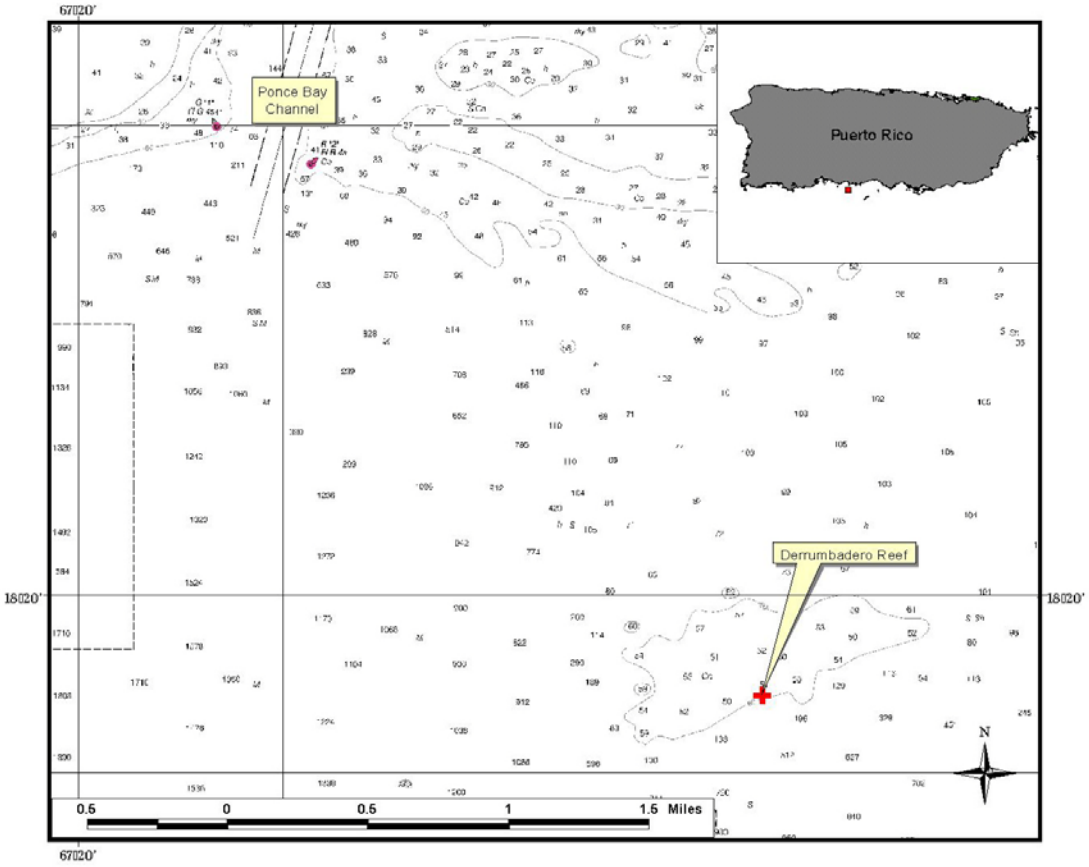


Figure 42. Location of the coral reef monitoring station at Derrumbadero Reef, Ponce.

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: 33.0 col./transect) at Derrumbadero Reef and because of their large sizes and species richness (17 spp within transects) contributed substantially to the biological diversity and structural complexity of the reef system. Sea Plumes, *Pseudopterogorgia acerosa, P. americana* Corky Sea Finger, *Briareum asbestinum*, Common Sea Fan, *Gorgonia ventalina* and Sea Rod, *Plexaura flexuosa* 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 58.0 % (range:50.6 – 65.5 %). Sponges were also present in all five transects with a mean substrate cover of 2.8 %. Abiotic categories were represented by

Table 46. Percent substrate cover by sessile-benthic categories at Derrumbadero reef, Ponce, 20 m**,** June 2009

Depth: 20 m	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	4.30	2.35	3.00	2.87	3.48	**3.20**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	4.75	15.05	11.38	10.63	10.24	**10.4**
Total Abiotic	4.75	15.05	11.38	10.63	10.24	**10.4**
Benthic Algae						
Turf-mixed assemblage	52.69	58.50	62.92	65.48	50.59	**58.0**
Coralline algae	1.89					**0.4**
Halimeda tuna		0.91				**0.2**
Lobophora variegata	15.09	12.46	9.54	4.19	21.74	**12.6**
Total Benthic Algae	69.67	71.87	72.46	69.67	72.33	**71.0**
Sponges	5.10	2.51	1.08	3.96	1.26	**2.8**
Gorgonians	2.94	2.75	0.65			**1.3**
Cyanobacteria	0.39					**0.1**
Anthozoa	0.59					**0.1**
Live stony corals						
Montastraea annularis	9.43	4.21	4.23	4.81	8.23	**6.2**
Porites astreoides	3.63	2.05	2.46	1.32	3.04	**2.5**
Montastraea cavernosa		0.81	5.00	4.19	1.56	**2.3**
Agaricia agaricites	0.59		0.76	1.86	2.00	**1.0**
Diploria strigosa			1.52	0.66		**0.4**
Porites porites	2.10					**0.4**
Colpophyllia natans				1.86		**0.4**
Porites colonensis			0.43	1.09		**0.3**
Meandrina meandrites					1.36	**0.3**
Diploria labyrinthiformis		0.80				**0.2**
Madracis decactis	0.79					**0.2**
Total Stony Corals	16.54	7.87	14.40	15.79	16.19	**14.2**
Gorgonians (# col.)						
Pseudopterogorgia acerosa	5	7	6	14	7	**7.8**
Briareum asbestinum	7	9	6	3	4	**5.8**
Gorgonia ventalina	1	7	6	7	5	**5.2**
Erythropodium caribaeorum	4	2	4	1	3	**2.8**
Eunicea flexuosa	1	3	3	3	2	**2.4**
Eunciea succinea	2	1		3		**1.2**
Eunicea tourneforti	2	3	1	2		**1.6**
Pseudopterogorgia americana	1	2	3	2	1	**1.8**
Eunicea spp.	2		2		1	**1.0**
Pseudoplexaura porosa	2	2	1			**1.0**
Pseudoplexaura flagellosa or wagenaari	1		1	1	2	**1.0**
Erythropodium caribaeorum	1					**0.2**

Table 46. Continued

Eunciea asperula			1			**0.2**
Muricea laxa		1				**0.2**
Muriceopsis flavida		1				**0.2**
Plexaura homomalla			1	1		**0.4**
Plexaurella nutans	1					**0.2**
Total Gorgonians (# colonies/transect)	30	38	35	37	25	**33.0**

Coral Species Outside Transects

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

reef overhangs mostly produced by mounds and ledges of Boulder Star Coral (*M. annularis*),and contributed to the reef mean topographic rugosity of 3.20 m (Table 46).

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 2005-09. 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 2008 survey. Partially bleached coral declined to a mean substrate cover of 0.6 % during 2008. A mild, statistically insignificant increment of live coral cover was measured during the present 2009 survey (Figure 43).

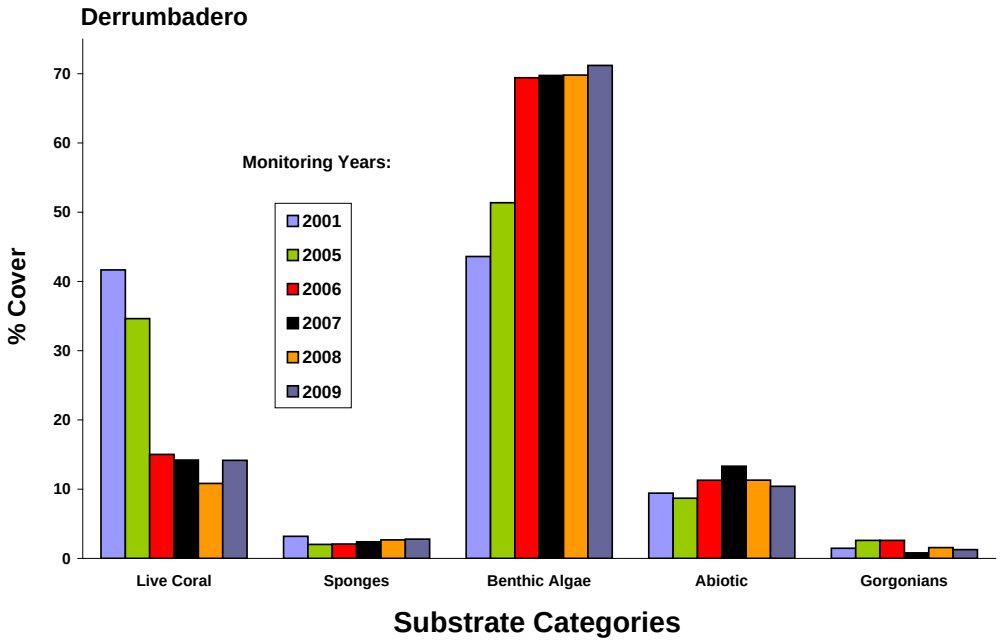


Figure 43. Monitoring trends (2001 – 2009) of mean substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce.

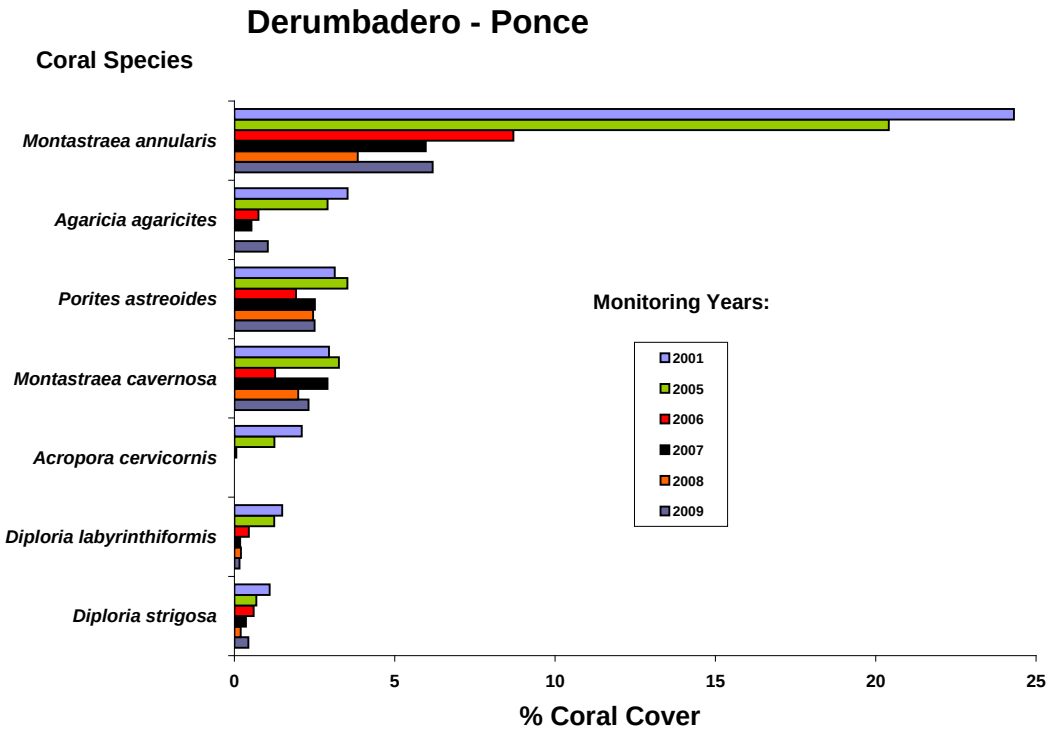


Figure 44. Monitoring trends (2001 – 2009) of mean substrate cover by coral species at Derrumbadero Reef, Ponce

Monitoring trends of mean substrate cover by coral species at Derrumbadero Reef are shown in Figure 44. In 2005, Boulder Brain Coral was the dominant coral species in terms of reef substrate cover at Derrumbadero Reef, representing then almost 62 % of the total cover by live corals. 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. During the present 2009 survey, a mild increment of live cover by *M. annularis* was measured at Derrumbadero Reef, consistent with observations at West Reef in Caja de Muerto, Cayo Coral in Guanica and Tourmaline Reef in Mayaguez . Soft corals (gorgonian) were not adversely affected by the environmental conditions affecting scleractinian corals after 2005 in Derrumbadero Reef, reflecting a solid trend of increment from 23 to 33 col/transect between the 2006 and the 2009 surveys.

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 2009 was 48.8 Ind/30 m^2 (range: 30 - 73 Ind/30 m^2). The mean number of species per transect was 18 (range: 13 - 26). The Sharpnose Puffer, Bluehead Wrasse, Bicolor Damselfish, and the Peppermint and Sharknose Goby were the numerically dominant species with a combined mean abundance of 27.4 Ind/30 m^2 representing 56.1 % of the total abundance within belt-transects (Table 47). A total of 12 fish species were present on at least four out of the five transects surveyed. In addition to the aforementioned assemblage, these include the Blue Chromis, Yellowhead Wrasse, Princess and Redband Parrotfishes, Beaugregory, Doctorfish and Four-eye Butterflyfish. Thirteen 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 2005-09 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 2006-09 surveys

Table 47. Taxonomic composition and abundance of fishes within belt-transects at Derrumbadero Reef, Ponce. March, 2009

Depth: 20m		TRANSECTS					
		1	2	3	4	5	
SPECIES	COMMON NAME	(Individuals/30 m2)					MEAN
Canthigaster rostrata	Sharpnose Puffer	6	6	8	2	7	**5.8**
Thalassoma bifasciatum	Bluehead Wrasse	6	0	15	3	4	**5.6**
Coryphopterus lipernes	Peppermint Goby	4	0	4	2	14	**4.8**
Gobiosoma evelynae	Sharknose Goby	3	1	5	2	10	**4.2**
Stegastes partitus	Bicolor Damselfish	5	6	2	3	4	**4.0**
Scarus taeniopterus	Princess Parrotfish	0	2	7	3	3	**3.0**
Scarus iserti	Striped Parrotfish	2	0	10	0	1	**2.6**
Chromis cyanea	Blue Chromis	1	3	8	0	1	**2.6**
Halichoeres garnoti	Yellowhead Wrasse	3	0	1	1	3	**1.6**
Sparisoma viride	Stoplight Parrotfish	1	4	0	0	3	**1.6**
Stegastes leucostictus	Beaugregory	1	1	3	2	1	**1.6**
Chaetodon capistratus	Foureye Butterflyfish	1	0	1	4	1	**1.4**
Acanturus chirurgus	Doctorfish	0	2	1	1	2	**1.2**
Holocentrus rufus	Longspine Squirrelfish	0	0	1	1	3	**1.0**
Hypoplectrus puella	Barred Hamlet	1	0	0	2	2	**1.0**
Sparisoma arofrenatum	Redband Parrotfish	1	0	1	1	0	**0.6**
Anisotrumus virginicus	Porkfish	0	1	0	1	1	**0.6**
Acantrurus coeruleus	Blue Tang	0	1	2	0	0	**0.6**
Chaetodon ocellatus	Spotfih Butterflyfish	0	0	0	0	2	**0.4**
Epinephelus guttatus	Red Hind	1	0	0	1	0	**0.4**
Coryphopterus personatus	Masked Goby	0	0	0	0	2	**0.4**
Cephalopholis cruentatus	Graysby	0	1	0	1	0	**0.4**
Hypoplectrus unicolor	Butter Hamlet	0	0	1	0	1	**0.4**
Stegastes variabilis	Cocoa Damselfish	0	0	2	0	0	**0.4**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	1	0	0	0	**0.2**
Aulostomus maculatus	Trumpetfish	0	0	0	1	0	**0.2**
Bodianus rufus	Spanish Hogfish	0	0	0	0	1	**0.2**
Haemulon macrostomum	Spanish Grunt	0	0	1	0	0	**0.2**
Holocanthus ciliaris	Queen Angelfish	0	0	0	0	1	**0.2**
Serranus tigrinus	Harlequin Bass	0	1	0	0	0	**0.2**
Neoniphon marianus	Gallo Amarillo	0	0	0	0	1	**0.2**
Haemulon flavolineatum	French Grunt	0	0	0	0	1	**0.2**
Lutjanus cyanopterus	Cubera Snapper	0	0	0	1	0	**0.2**
Melichtys niger	Black Durgeon	0	0	0	0	1	**0.2**
Caranx ruber	Bar Jak	0	0	0	0	1	**0.2**
Chaetodon striatus	Banded Butterflyfish	1	0	0	0	0	**0.2**
Myripristis jacobus	Balckbar Soldierfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**37**	**30**	**73**	**32**	**72**	**48.8**
	TOTAL SPECIES	**15**	**13**	**18**	**18**	**26**	**18**

Table 47. Continued
Fishes Outside Transects

SPECIES	**COMMON NAME**
Abudefduf sexatilis	Sargent fish
Acanthostrascion quadriformis	Honeycomb trunkfish
Anisotremus virginicus	Porkfish
Aulostomus maculatus	Trumpetfish
Carangoides ruber	Bar jack
Caranx crysos	Blue Runner
Chaetodon ocellatus	Spotfin Butterflyfish
Chaetodon striatus	Banded butterflyfish
Gymnothorax funebris	Green Moray
Haemulon chrysargyreum	Smallmouth grunt
Haemulon macrostomus	Spanish grunt
Haemulon plumieri	White grunt
Holacanthus ciliaris	Queen angelfish
Holacanthus tricolor	Rock Beauty
Lachtophrys triqueter	Smooth trunkfish
Lactophrys bicaudalis	Spotted Trunkfish
Lutjanus apodus	Schoolmaster snapper
Lutjanus cyanopterus	Cubera snapper
Lutjanus mahogany	Mahogany snapper
Pomacanthus arcuatus	Gray angelfish
Aulostomus maculatus	Trumpetfish
Bodianus rufus	Spanish Hogfish
Carangoides crysos	Blue Runner
Coryphopterus glaucofraenum	Bridled Goby
Gobiosoma saucrum	Leopard goby
Halichoeres cyanocephalus	Yellowcheek Wrasse
Holocentrus coruscus	Reef Squirrelfish
Lachnolaimus maximus	Hogfish
Mycteroperca tigris	Tiger Grouper
Scorpaena plumieri	Spotted Scorpionfish
Stegastes planifrons	Yellow-eye damselfish
Scomberomorus regalis	Cero
Trachinotus falcatus	Permit
Centropyge argi	Cherubfish
Calamus pluma	Pluma

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 2006-09 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

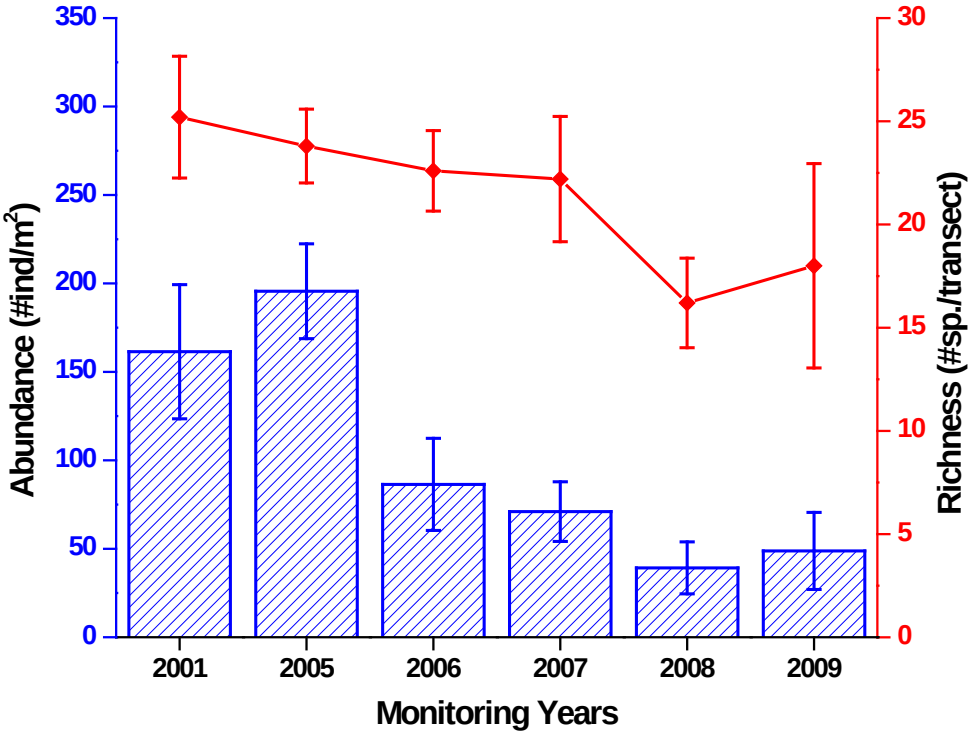


Figure 44. Monitoring trends (1999 – 2009) of fish species richness and abundance at Derrumbadero Reef, Ponce

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 (Paddack et al. 2009).

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 and Barracudas observed during an ASEC survey in this reef (Table 48). Large demersal predators previously reported from Derrumbadero Reef (García-Sais et

Table 48. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Derrumbadero Reef, Ponce. March, 2009

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

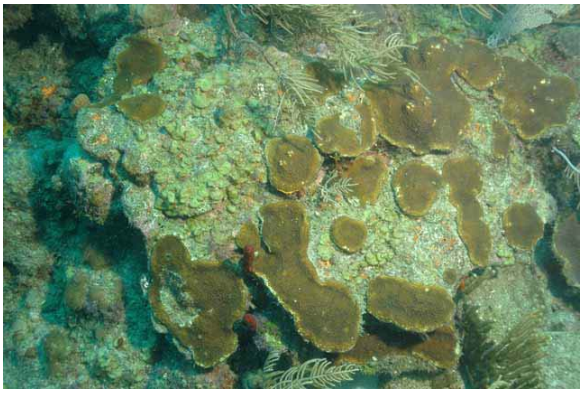
SPECIES	**COMMON NAME**	# - (cm)	
Balistes vetula	Queen Triggerfish	1 – (35)	
Epinephelus guttatus	Red Hind	3 – (30)	
Holacanthus ciliaris	Queen Angel	1 - (40)	
Holacanthus tricolor	Rock Beauty	1 - (20)	1 – (25)
Lachnolaimus maximus	Hogfish	1 – (25)	1 – (40)
Lutjanus apodus	Schoolmaster	2 - (20)	4 – (30)
Lutjanus mahogany	Mahogani Snapper	1 - (15)	2 – (25)
Lutjanus synagris	Lane Snapper	2 - (20)	
Ocyurus chrysurus	Yellowtail Snapper	3 – (25)	2 - (30)
Scomberomorus regalis	Cero Mackerel	2 - (50)	
Sphyraena barracuda	Great Barracuda	2 - (60)	
Invertebrates			
Panulirus argus	Spiny Lobster	1 - (25)	

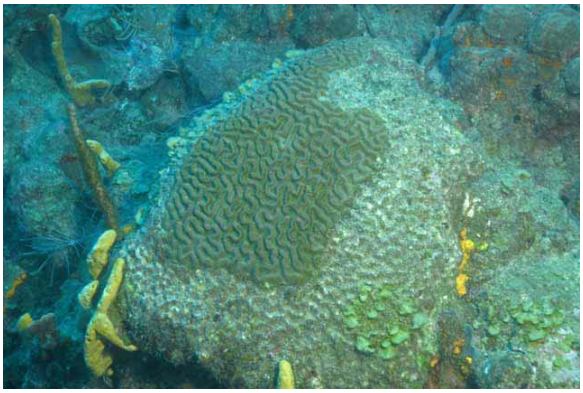
al., 2006), such as Yellowfin and Tiger Groupers, Cubera, Mutton, Schoolmaster and Dog Snappers also feed from the small zooplanktivorous fishes which remain close to the reef benthos. A large variety of small invertebrate feeders were present, including wrasses, hamlets, gobies, squirrelfishes, and others. Larger invertebrate and small fish predators included the Hogfish, Schoolmaster and 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 Arrow Crabs, *Stenorhynchus seticornis* represented megabenthic invertebrates within belt transects during the 2009 survey (Table 49).

Table 49. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Derrumbadero Reef, 20 m, Ponce, March, 2009

Depth: 20 m		**TRANSECTS**					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	DEPTH (m) COMMON NAME						
Periclimenes pedersoni	Cleaner Shrimp	1	2				**06**
Stenorhynchus seticornis	Arrow Crab		2	1			**0.6**
	TOTALS	**1**	**04**	**1**	**0**	**0**	**1.2**

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 exist 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 second monitoring survey of the reefs at Playa Mujeres and Carmelitas and the first monitoring survey of the Sardinera Reef after the baseline survey in 2008. 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 coral patches and rocky outcrops 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).

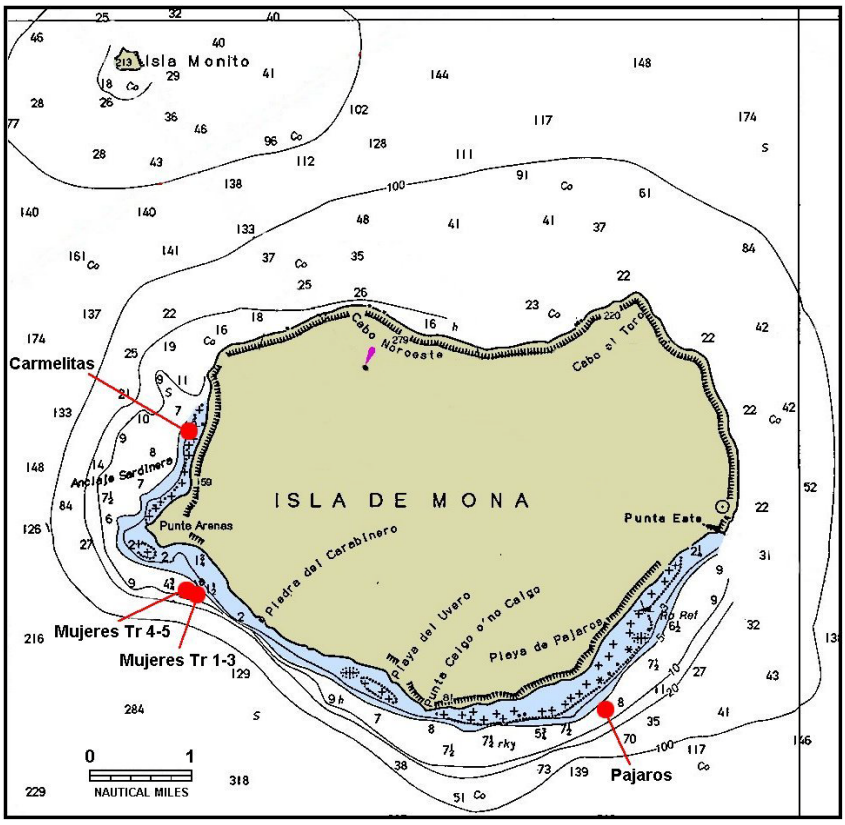


Figure 45. Location of reef sites surveyed at Isla de Mona Natural Reserve

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 10 species intersected by line transects (Table 50). The mean surface cover by stony corals during the 2009 monitoring survey was 13.5% (range: 7.6 – 19.3 %). Boulder Brain Coral, *Colpophyllia natans* and Boulder Star Coral, Mustard Hill Coral (*Porites astreoides*) were the main coral species in terms of reef substrate cover with means of 4.1 and 2.9 %, respectively. *P. astreoides* was the only coral species present at all five transects surveyed. Agaricia agaricites was present in four transects and *C. natans*, *D. strigosa*, *S. siderea* and *M. meandrites* were present in three. Branching corals were represented out of transects by Ten-Ray Star Coral (*Madracis decactis*). Fleshy corals (*Mycetophyllia* spp) were observed in vertical

Table 50. Percent substrate cover by sessile-benthic categories at Mona Island. 20 m, August 2009

Depth:20 m	1	2	3	4	5	**MEAN**
Rugosity (m)	2.69	2.01	3.69	2.49	2.89	**2.75**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	3.78	2.08	3.58	5.52	4.89	**4.0**
Sand	8.75	8.58	10.59	4.32	4.73	**7.4**
Total Abiotic	12.53	10.66	14.17	9.84	9.62	**11.4**
Benthic Algae						
Turf-mixed assemblage	17.10	26.98	16.29	36.11	36.70	**26.6**
Coralline algae		4.66	1.68	1.44	2.64	**2.1**
Calcareous algae				0.48	0.54	**0.2**
Dictyota sp.		0.83	0.44	0.80		**0.4**
Lobophora variegata	27.90	37.05	39.66	27.70	14.12	**29.3**
Total Benthic Algae	45.00	69.52	58.07	66.53	54.00	**58.6**
Sponges	17.42	3.83	12.42	11.37	17.30	**12.5**
Cyanobacteria	5.75	8.33	2.70	0.56	2.87	**4.4**
Live Stony Corals						
Colpophyllia natans	6.22			3.38	10.94	**4.1**
Porites astreoides	4.33	1.67	3.58	2.00	2.72	**2.9**
Agaricia agaricites		1.25	1.75	2.96	1.16	**1.4**
Diploria strigosa	3.00	2.23	0.72			**1.2**
Montastraea annularis	1.11		4.24			**1.1**
Siderastrea siderea		0.94	2.06		1.40	**0.9**
Eusmilia fastigiata	0.44			3.04		**0.7**
Montastraea cavernosa	3.22					**0.6**
Meandrina meandrites	1.00	1.17		0.34		**0.5**
Porites porites		0.35	0.31			**0.13**
Total Stony Corals	19.32	7.61	12.66	11.72	16.22	**13.5**

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*.

sections of the reef, mostly growing encrusted to walls and within holes and gaps formed by growth of other coral colonies.

Recently dead coral presented a mean substrate cover of 6.9 % in 2008, but during the present 2009 survey no further recently dead coral was observed within transects. Total abiotic cover averaged 11.4 % and was mostly contributed by reef overhangs from rocky outcrops and dead

skeletons of Boulder Star Coral, *Montastraea annularis* and other stony corals. Erect and encrusting sponges were present at all five transects surveyed with a mean cover of 12.5 % (range : 3.8 – 17.4 %). 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 26.6 % (range: 16.3 – 36.7 %). Fleshy algae, mostly *Lobophora* sp. with minor contribution from *Dyctiota sp.* presented a mean surface cover of 29.7 %. *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 2008 and 2009 monitoring surveys are presented in Figure 46. Live coral cover declined 67.8 % between 2000 and 2008, 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. During the present 2009 survey, substrate cover by live coral did not exhibit any significant change from the previous 2008 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. In the 2008 survey, *M. annularis* presented a mean substrate cover of 2.5 %, a reduction of 88.4 % over the eight year period. Such collapse of live coral cover mirror the pattern observed for other coral reef systems in Puerto Rico associated with the regional bleaching event of 2005. Degradation of *M. annularis* continued during 2009 down to a mean cover of 1.1 %. Contrary to the mainland reefs, where a mild recuperation of *M. annularis* was detected, continued degradation of *M. annularis* appears to be the pattern at the offshore islands of Mona and Desecheo. Conversely, increments of coral cover during 2009 at this reef were observed for *Porites astreoides* and *Colpophyllia natans* (Figure 47). Due to small changes and the inherently high sampling variability associated with the low number of colonies present in the transects, such increments are not statistically significant, but may be emerging patterns observed at other reefs during this 2009 survey.

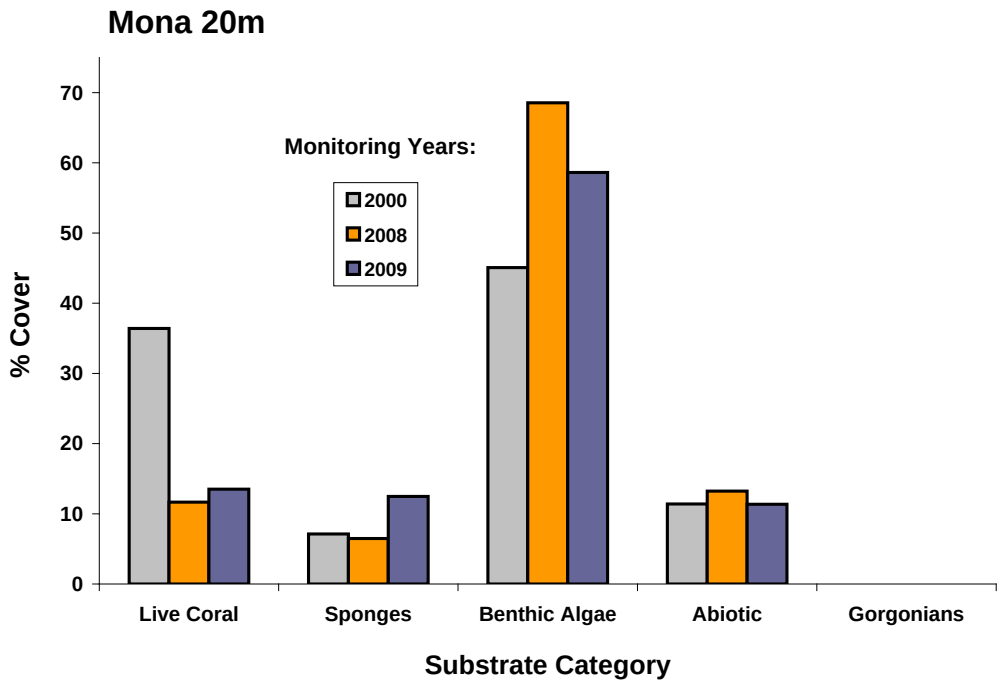


Figure 46. Monitoring trends (2000 - 2009) of mean substrate cover by sessile-benthic categories at c, Mona Island

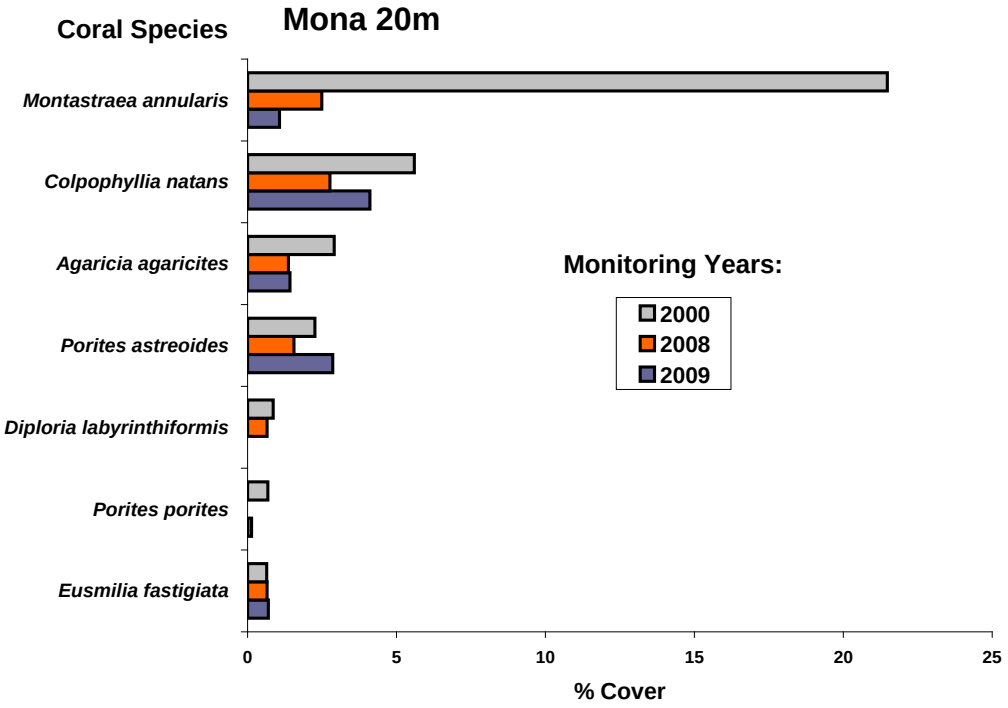


Figure 47. Monitoring trends (2000 - 2009) of mean substrate cover by coral species at Playa Mujeres Reef, Mona Island

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 68 fish species were identified at at Playa Mujeres Reef, including 42 within belt-transects during the 2008 survey (Table 51). The mean abundance of individuals per transect was 116.4 Ind/30 m^2 (range: 92 - 140 Ind/30 m^2) and the mean number of species per transect was 20.6 (range: 19 – 22). Eight species represented approximately 78.7 % of the total individuals within belt-transect areas. The numerically dominant fish assemblage included the Bluehead and Creole Wrasse (*Thalassoma bifasciatum, Clepticus parrae*), Masked and Peppermint Goby (*Coryphopterus personatus, C. lipernes*), Blue and Brown Chromis (*Chromis cyanea, C. multilineata*), Bicolor Damselfish (*Stegastes partitus*), and Fairy Basslet (*Gramma loreto*). Eight 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 Princess Parrotfish (*Scarus taeniopterus*) was the most abundant herbivore (mean :3.0 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*), Black, Horse-eye and Bar Jacks (*Caranx lugubris, C. hippos, Carangoides ruber*), Rainbow Runner (*Elagatis bipinnulata*) and the Reef Shark (*Carcharhinus perezi*) represented pelagic (piscivorous) predators. Large demersal fish predators present included the Tiger, Yellowfin and Yellowmouth Grouper (*Mycteroperca tigris, M. venenosa, M. intersticialis*) and Dog Snapper (*Lutjanus jocu*) (Table 52).

Table 51. Taxonomic composition and abundance of fishes within belt-transects at Playa Mujeres Reef, Isla de Mona, 20 m, August, 2009

Depth: 20m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**	(Individuals/30 m2)					**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	14	15	4	36	25	**18.8**
Clepticus parrae	Creole Wrasse	17	7	11	42	15	**18.4**
Choryphopterus personatus	Masked Goby	14	35	32	2	0	**16.6**
Chromis cyanea	Blue Chromis	10	22	5	10	12	**11.8**
Stegastes partitus	Bicolor Damselfish	7	1	22	14	7	**10.2**
Gramma loreto	Fairy Basslet	6	9	12	0	6	**6.6**
Choryphopterus lipernes	Peppermint Goby	1	5	8	4	7	**5.0**
Chromis multilineata	Brown Chromis	2	5	3	7	4	**4.2**
Scarus taeniopterus	Princess Parrotfish	1	5	1	5	3	**3.0**
Gobiosoma evelynae	Sharknose Goby	0	3	4	2	5	**2.8**
Halichoeres garnoti	Yellowhead Wrasse	2	2	2	2	3	**2.2**
Holocentrus rufus	Longspine Squirrelfish	0	0	1	2	4	**1.4**
Melichthys niger	Black Durgeon	5	0	0	2	0	**1.4**
Kyphosus sp.	Bermuda Chub	0	0	0	1	6	**1.4**
Stegastes planifrons	Threespot Damselfish	1	4	0	0	1	**1.2**
Sparisoma aurofrenatum	Redband Parrotfish	2	1	0	2	0	**1.0**
Microspathodon chrysurus	Yellowtail Damselfish	0	1	1	1	1	**0.8**
Haemulon flavolineatum	French Grunt	0	0	0	2	2	**0.8**
Myripristis jacobus	Blackbar Soldierfish	0	0	0	0	4	**0.8**
Malacoctenus triangulatus	Saddled Blenny	0	0	1	0	2	**0.6**
Holocanthus tricolor	Rock Beauty	3	0	0	0	0	**0.6**
Chaetodon capistratus	Foureye Butterflyfish	0	1	0	0	2	**0.6**
Halichoeres maculipina	Clown Wrasse	0	3	0	0	0	**0.6**
Acanthurus coeruleus	Blue Tang	0	2	1	0	0	**0.6**
Ocyurus chrysurus	Yellowtail Snapper	0	1	1	0	0	**0.4**
Equetus punctatus	Spoted Drum	0	1	0	0	1	**0.4**
Canthigaster rostrata	Sharpnose Puffer	1	0	0	1	0	**0.4**
Epinephelus cruentatus	Graysby	1	0	1	0	0	**0.4**
Lutjanus jocu	Dog Snapper	0	0	0	2	0	**0.4**
Stegastes variabilis	Cocoa Damselfish	1	0	1	0	0	**0.4**
Holocentrus marianus	Longjaw Squirrelfish	0	0	0	0	2	**0.4**
Pseudupeneus maculatus	Spotted Goatfish	0	0	0	1	0	**0.2**
Bodianus rufus	Spanish Hogfish	1	0	0	0	0	**0.2**
Chaetodon aculeatus	Longsnout Butterflyfish	1	0	0	0	0	**0.2**
Acanthemblemaria maria	Secretary Blenny	0	0	0	1	0	**0.2**
Carcharhinus perezi	Reef Shark	1	0	0	0	0	**0.2**
Scomberomorus cavalla	King Mackerel	0	0	0	1	0	**0.2**

Caranx latus	Horse-eye Jack	0	0	1	0	0	**0.2**
Serranus tigrinus	Harlequin Bass	0	0	1	0	0	**0.2**
Table 51. Continued							
Carangoides ruber	Bar Jack	1	0	0	0	0	**0.2**
Lactophrys triqueter	Smooth Trunkfish	0	0	0	0	1	**0.2**
Amblycirrhitus pinos	Redspoted Hawkfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**92**	**123**	**113**	**140**	**114**	**116.4**
	TOTAL SPECIES	**21**	**19**	**20**	**21**	**22**	**20.6**

Fishes Outside Transects

SPECIES	**COMMON NAME**
Abudefduf sexatilis	Sargent Major
Acanthostracion quadricornis	Scrawled Cowfish
Cantherhines macrocerus	Whitespotted Filefish
Carangoides crysos	Blue Runner
Echidna catenata	Chain Moray
Epinephelus guttatus	Red Hind
Ginglymostoma cirratum	Nurse Shark
Lactophrys bicaudalis	Spotted Trunkfish
Muraenidae	Moray sp.
Scarus taeniopterus	Princess Parrotfish
Sparisoma chrysopterum	Redtail Parrotfish
Scarus vetula	Queen Parrotfsh
Sphyraena barracuda	Great Barracuda
Mycteroperca tigris	Tiger Grouper
Lutjanus mahogoni	Mahogany Snapper
Ocyurus chrysurus	Yellowtail Snapper
Aetobatus narinari	Spotted Eagle Ray
Elagatis bipinnulata	Rainbow Runner
Mycteroperca venenosa	Yellowfin Grouper
Mycteroperca tigris	Tiger Grouper
Sphyraena barracuda	Greate Barracuda
Cephalopholis fulva	Conney
Lutjanus apodus	Schoolmaster Snapper

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. Banded Coral Shrimp (Stenopus hispidus) and Arrow Crabs (Stenorhynchus seticornis) represented motile megabenthic invertebrates within belt-transects during the 2009 survey (Table 53).

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

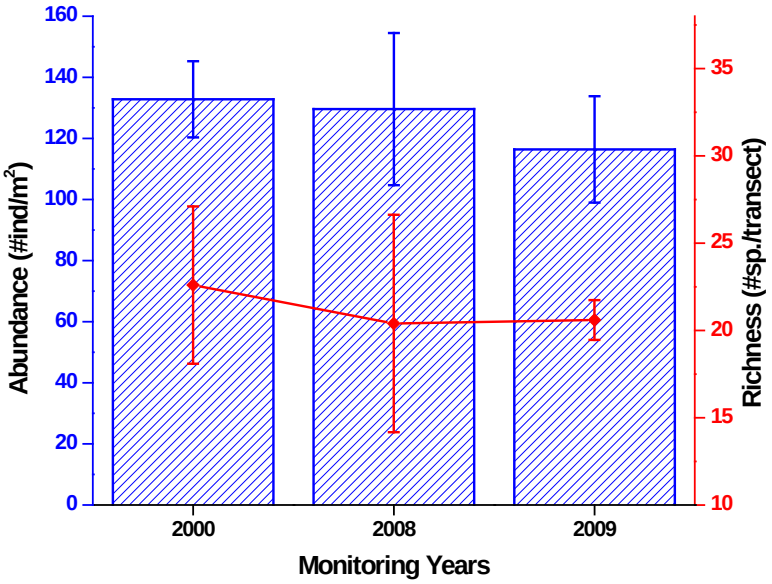


Figure 48. Monitoring trends (1999 – 2009) of fish species richness and abundance at Playa Mujeres Reef, Mona Island

Table 52. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Playa Mujeres Reef, Mona. August, 2009

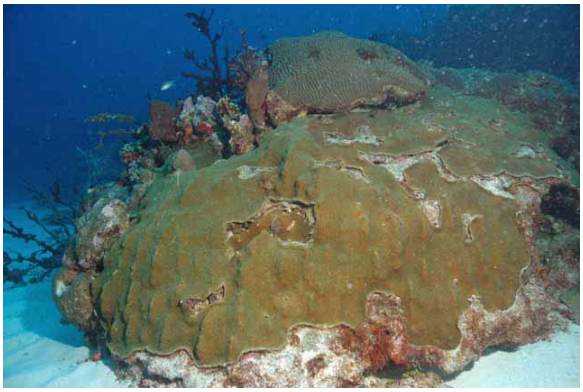
Duration - 30 min. Depth range : 18 - 22 m

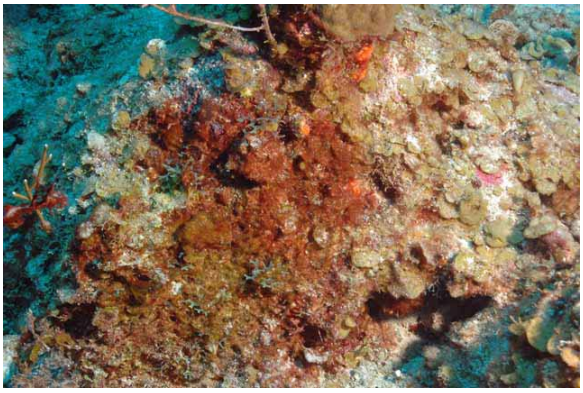
SPECIES	**COMMON NAME**	# - (cm)		
Balistes vetula	Queen Triggerfish	1 – (35)		
Carcharhinus perezi	Reef Shark	1 – (80)		
Elagatis bipinnulata	Rainbow Runner	2 – (50)		
Epinephelus guttatus	Red Hind	2 – (30)	2- (35)	
Ginglymostoma cirratum	Nurse Shark	1 – (90)		
Lutjanus apodus	Schoolmaster	4 - (20)	3 – (30)	1 – (40)
Lutjanus jocu	Mahogani Snapper	1 - (50)	1 – (60)	
Ocyurus chrysurus	Yellowtail Snapper	3 – (25)	2 - (30)	
Mycteroperca tigris	Tiger Grouper	1 – (40)		
Mycteroperca intersticialis	Yellowmouth Grouper	1 – (35)		
Mycteroperca venenosa	Yellowfin Grouper	1 – (50)		
Sphyraena barracuda	Great Barracuda	2 - (60)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (25)		

Table 53. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at at Playa Mujeres Reef, Mona. August, 2009

Depth: 20 m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	DEPTH (m) COMMON NAME						
Stenopus hispidus	Banded Coral Shrimp	1					**0.2**
Stenorhynchus seticornis	Arrow Crab		1	1		1	**0.6**
	TOTALS	**1**	**1**	**1**	**0**	**1**	**0.8**

Photo Album 13 (Isla de Mona)
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 meters. 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 are found at a depth of approximately 10 meters. 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 meters, 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 meters.

2.1 Sessile-Benthic Reef Community

A dense algal turf, combined with fleshy macroalgae and cyanobacteria covering a rugged rocky outcrop seascape was the most prominent feature of Las Carmelitas Reef benthos. Total substrate cover by benthic algae averaged 67.4 % along transects, with turf algae representing 76.7 % of the total (Table 54). The Encrusting Fan Alga, *Lobophora variegata* was the main component of the fleshy algal assemblage with a mean cover of 14.1 %. A redish, slimmy cover by cyanobacteria contributed an additional 6.0 % to the reef benthos as it occurred in patches interspersed with the algal turf.

Live coral cover averaged 11.5 % (range: 4.5 – 19.2 %). Coral growth was observed mostly as small isolated colonies along the edges of the spur walls and within crevices and other hard ground substrate depressions. This is an indication that strong wave

Table 54. Percent substrate cover by sessile-benthic categories at Mona Island, 8.5 m August 2009

Depth: 10 m	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	4.96	6.23	2.98	3.04	1.55	**3.8**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	3.28	8.57		2.61	1.56	**3.2**
Gap			0.85	1.38		**0.4**
Sand	0.94	0.86	1.16	2.30		**1.0**
Total Abiotic	4.22	9.43	2.01	6.29	1.56	**4.7**
Benthic Algae						
Turf-mixed assemblage	46.12	39.09	50.42	68.51	54.77	**51.8**
Lobophora variegata	15.44	25.15	1.77	6.36	21.84	**14.1**
Dictyota sp.			0.54			**0.1**
Coralline algae	0.40	0.86	1.39			**0.5**
Calcareous algae	1.20	1.97	1.08			**0.8**
Total Benthic Algae	63.16	67.07	55.20	74.87	76.61	**67.4**
Cyanobacteria	2.07	2.96	7.40	3.91	13.52	**6.0**
Sponges	26.00		22.90	1.53	0.35	**10.2**
Zoanthids		1.23				**0.2**
Live Stony Corals						
Montastraea annularis		15.04	1.74	2.16		**3.8**
Porites astreoides	1.87	2.84	1.54	6.51	4.68	**3.5**
Agaricia agaricites	1.67	0.49	3.16	0.86	0.98	**1.4**
Diploria strigosa			2.31	1.76		**0.8**
Montastraea cavernosa		0.86	1.09	1.30		**0.6**
Colpophyllia natans			2.71			**0.5**
Meandria meadrites					2.32	**0.5**
Eusmilia fastigiata	0.94					**0.2**
Siderastrea siderea				0.86		**0.2**
Total Stony Corals	4.48	19.23	12.55	13.45	7.98	**11.5**
Gorgonians (# col./transect)	2	0	3	12	0	**3.4**

Coral Species Outside Transects:
Dendrogyra cylindrus, Dichocoenia stokesii, Isophyllia rigida, I. sinuosa, Mycetophyllia lamarckiana, Millepora complanata, Stephanocoenia michelini,

action is probably an important factor regulating coral growth. Reef overhangs, largely associated with rock outcrops and massive coral growth averaged 3.2 % and contributed to an average substrate rugosity of 3.75 m. Erect gorgonians were present, but not abundant with a mean of 3.2 colonies per transect. Sponges were observed in four transects with a mean cover of 10.2 %. The Giant Barrel Sponge, *Xetospongia muta* was prominent in the reef and contributed substantially to the overall substrate rugosity.

A total of 15 species of scleractinian corals and one hydrocoral (*Millepora* sp) were identified from Las Carmelitas Reef, including nine intercepted by transects during 2009 (Table 54). Great Star Coral (*Montastraea annularis*) and Mustard Hill Coral (*Porites astreoides*) were the dominant species in terms of linear cover with a mean of 3.8 % and 3.5 %, respectively, representing 63.0 % of the total cover by live stony corals. Mustard-Hill Coral and Lettuce Coral, *Agaricia agaricites* were the only coral species intersepted by all five transects. *M. annularis* was only intercepted by three transects during the present 2009 survey.

Monitoring trends of substrate categories at Playa Carmelitas Reef are shown in Figure 49. Between the baseline survey in 2000 and the 2008 monitoring survey live coral cover declined 49.2 %, from a mean of 25.4 % to a mean of 12.5%. The pronounced reduction of live coral cover was possibly associated with the regional coral bleaching event of 2005 (García-Sais et al. 2006). The decline of live coral cover was largely driven by the collapse of Boulder Star Coral, *M. annularis* complex. With a mean cover of 21.5 % *M. annularis* was the dominant coral species at Las Carmelitas Reef during the baseline survey in 2000, representing then 85.7 % of the total cover by live corals. In the 2008 survey, substrate cover by live *M. annularis* dropped to 2.5 %, a reduction of 88.4 % over the eight year period. A mild increase of live coral cover by *M. annularis* was measured during 2009, consistent with findings in other reefs throughout Puerto Rico (Figure 50).

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 61 fish species were identified during our visual surveys at Las Carmelitas Reef, 41 of which were present within belt-transect areas (Table 55). The mean number of species per transect was 20.4 (range 16 – 25), and the mean density of fishes was

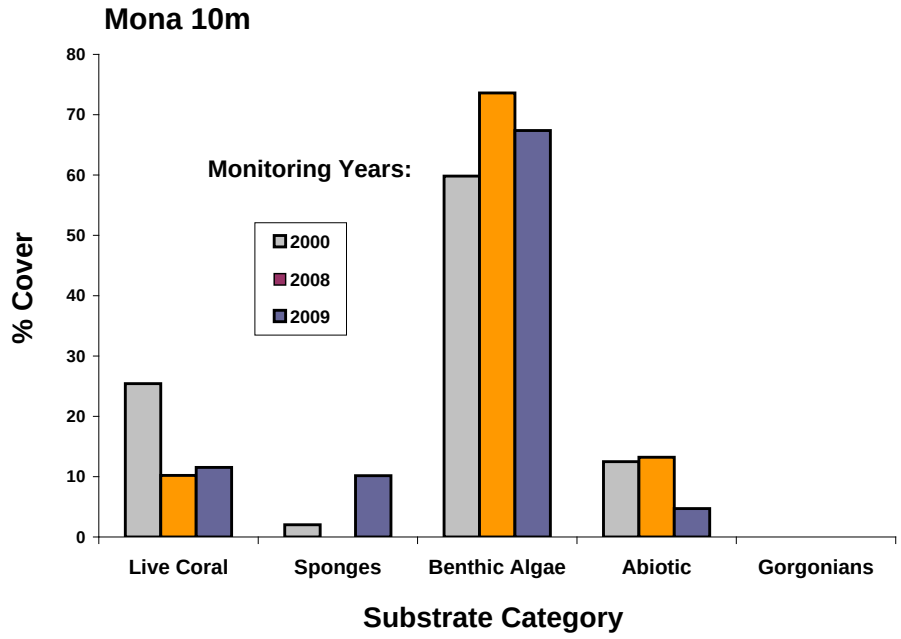


Figure 49. Monitoring trends (2000 - 2009) of mean substrate cover by sessile-benthic categories at Playa Carmelitas Reef, Mona Island

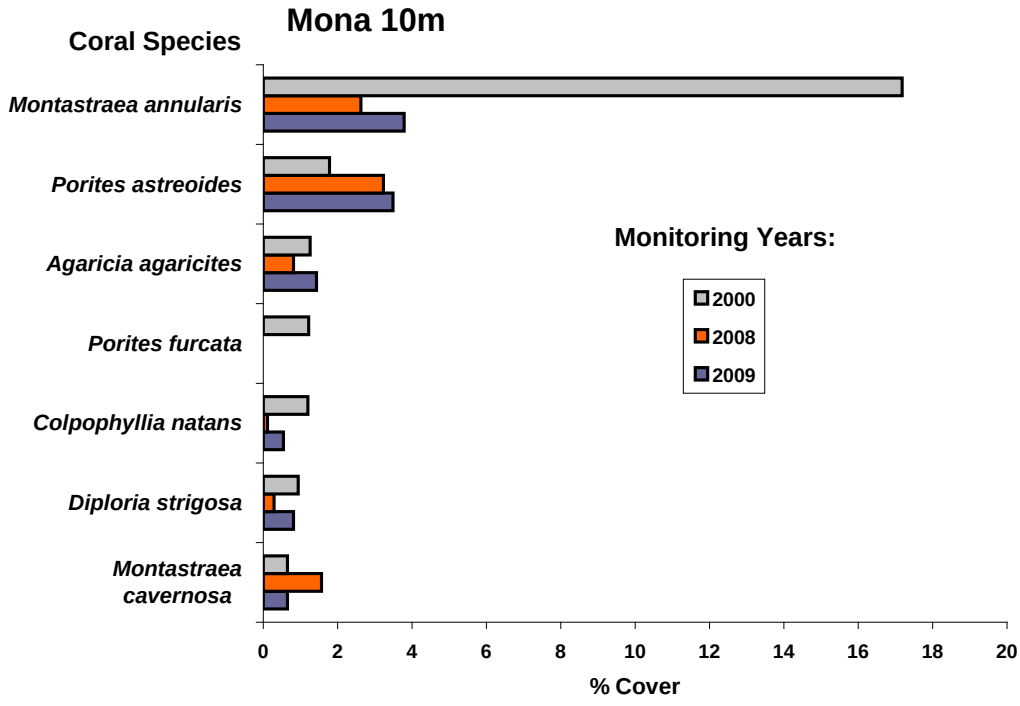


Figure 50. Monitoring trends (2000 - 2009) of mean substrate cover by coral species at Playa Carmelitas Reef, Mona Island

133.2 Individuals/30 m^2 (range: 81 - 174 Individuals/30 m^2). Seven species represented approximately 76.1 % of the total individuals within belt-transect areas. The numerically dominant species included the Fairy Basslet (*Gramma loreto*), Bluehead and Clown Wrasse (*Thalassoma bifasciatum, Halichoeres maculipinna*), Blue and Brown Chromis (*Chromis cyanea*, *C. multilineata*), Yellowtail Damselfish (*Microspathodon chrysurus*) and the Bicolor Damselfish (*Stegastes partitus*). With the exception of Brown Chromis, the aforementioned species were found in at least four transects and comprise the main resident fish assemblage at Las Carmelitas Reef. Fairy Basslets were abundant under coral ledges at the walls of the reef spurs, whereas *Chromis* spp. and the Bluehead Wrasse were mostly aggregated in schools (guilds) over coral promontories in the reef.

Bicolor Damselfishes occupied demersal territories within the reef top. 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 highly prominent at the reef top. Bicolor Damselfish, Creole Wrasse and the Blue and Brown Chromis were the main components of the zooplanktivorous assemblage. 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*), Rainbow Runner (*Elagatis bipinnulata*) and the Bar Jack (*Carangoides ruber*) represented pelagic (piscivorous) predators. Demersal fish predators of larger reef invertebrates and fishes, such as large snappers and groupers were represented by juvenile Tiger Grouper (*Mycteroperca tigris*), Dog Snapper (Lutjanus jocu) and an adult Red Hind (*Epinephelus guttatus*) (Table 56). Monitoring data on fish abundance and species richness within belt-transects is shown in Figure 51. Differences between surveys were minor and not statistically significant (ANOVA; $p > 0.05$, Appendix 3 - 4).

Table 55. Taxonomic composition and abundance of fishes within belt-transects at Carmelitas Reef, Mona. August, 2009

Depth: 8.5 m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**	(Individuals/30 m2)					**MEAN**
Gramma loreto	Fairy Basslet	15	59	34	33	16	**31.4**
Thalassoma bifasciatum	Bluehead Wrasse	65	19	9	34	3	**26**
Chromis cyanea	Blue Chromis	26	16	12	38	5	**19.4**
Chromis multilineata	Brown Chromis	17	0	0	25	3	**9.0**
Mychrospathodon chrysurus	Yellowtail Damselfish	1	1	1	1	33	**7.4**
Halichoeres maculipinna	Clown Wrasse	16	1	6	1	0	**4.8**
Stagastes partitus	Bicolor Damselfish	7	1	3	0	6	**3.4**
Clepticus parrae	Creole Wrasse	5	1	8	0	1	**3.0**
Coryphopterus personatus	Masked Goby	0	14	0	0	0	**2.8**
Holocentrus rufus	Longspine Squirrelfish	1	11	0	0	1	**2.6**
Halichoeres garnoti	Yellowhead Wrasse	0	5	0	5	1	**2.2**
Malacoctenus triangulatus	Saddled Blenny	1	8	1	0	1	**2.2**
Kryphosus sp.	Bermuda Chub	0	1	10	0	0	**2.2**
Sparisoma viride	Stoplight Parrotfish	1	0	3	5	0	**1.8**
Scarus taeniopterus	Princess Parrotfish	1	0	0	6	1	**1.6**
Epinephelus cruentatus	Graysby	1	2	1	1	2	**1.4**
Stegastes fuscus	Dusky Damselfish	2	1	0	0	4	**1.4**
Mulloidichthys martinicus	Yellow Goatfish	4	0	0	0	0	**0.8**
Gobiosoma evelynae	Sharknose Goby	0	3	1	0	0	**0.8**
Acanthurus bahianus	Ocean Surgeon	2	0	0	1	1	**0.8**
Acanthurus coeruleus	Blue Tang	1	1	1	0	1	**0.8**
Carangoides ruber	Bar Jack	0	2	1	1	0	**0.8**
Serranus tabacarius	Tabaccofish	0	0	0	4	0	**0.8**
Canthigaster rostrata	Sharpnose Puffer	1	1	1	0	0	**0.6**
Sparisoma aurofrenatum	Redband Parrotfish	2	0	0	1	0	**0.6**
Haemulon flavolineatum	French Grunt	1	1	1	0	0	**0.6**
Haemulon chrysargyreum	Smallmouth Grunt	1	0	1	0	0	**0.4**
Halichoeres radiatus	Pudingwife	0	2	0	0	0	**0.4**
Liopropoma rubre	Peppermint Bass	0	1	1	0	0	**0.4**

Myripristis jacobus	Blackbar Soldierfish	0	1	1	0	0	**0.4**
Chaetodon striatus	Banded Butterflyfish	2	0	0	0	0	**0.4**
Bodianus rufus	Spanish Hogfish	0	1	0	0	0	**0.2**
Table 55. Continued							
Abudefduf sextatilis	Sargent Mayor	0	1	0	0	0	**0.2**
Holocentrus marianus	Longjaw Squirrelfish	0	1	0	0	0	**0.2**
Melichthys niger	Black Durgeon	1	0	0	0	0	**0.2**
Priacanthus cruentatus	Glasseye Snapper	0	0	1	0	0	**0.2**
Stegastes leucostictus	Beugrerory	0	0	1	0	0	**0.2**
Urolophus jamaicensis	Yellow Stingray	0	0	0	1	0	**0.2**
Cephalopholis fulva	Conney	0	0	0	1	0	**0.2**
Stegastes variabilis	Cocoa Damselfish	0	0	0	0	1	**0.2**
Gymnothorax miliaris	Goldentail Moray	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**174**	**155**	**98**	**158**	**81**	**133.2**
	TOTAL SPECIES	**23**	**25**	**21**	**16**	**17**	**20.4**

Fishes Outside Transects

SPECIES	**COMMON NAME**
Abudefduf sexatilis	Sargent Major
Acanthostracion quadricornis	Scrawled Cowfish
Cantherhines macrocerus	Whitespotted Filefish
Caranx crysos	Blue Runner
Coryphopterus lipernes	Peppermint Goby
Echidna catenata	Chain Moray
Elagatis bipinnulata	Rainbow Runner
Epinephelus guttatus	Red Hind
Ginglymostoma cirratum	Nurse Shark
Lactophrys bicaudalis	Spotted Trunkfish
Malacanthus plumieri	Sand Tilefish
Muraenidae	Moray sp.
Sparisoma chrysopterum	Redtail Parrotfish
Scarus vetula	Queen Parrotfsh
Sphyraena barracuda	Great Barracuda
Lutjanus jocu	Dog Snapper
Mycteroperca tigris	Tiger Grouper
Lutjanus mahogoni	Mahogany Snapper
Bodianus rufus	

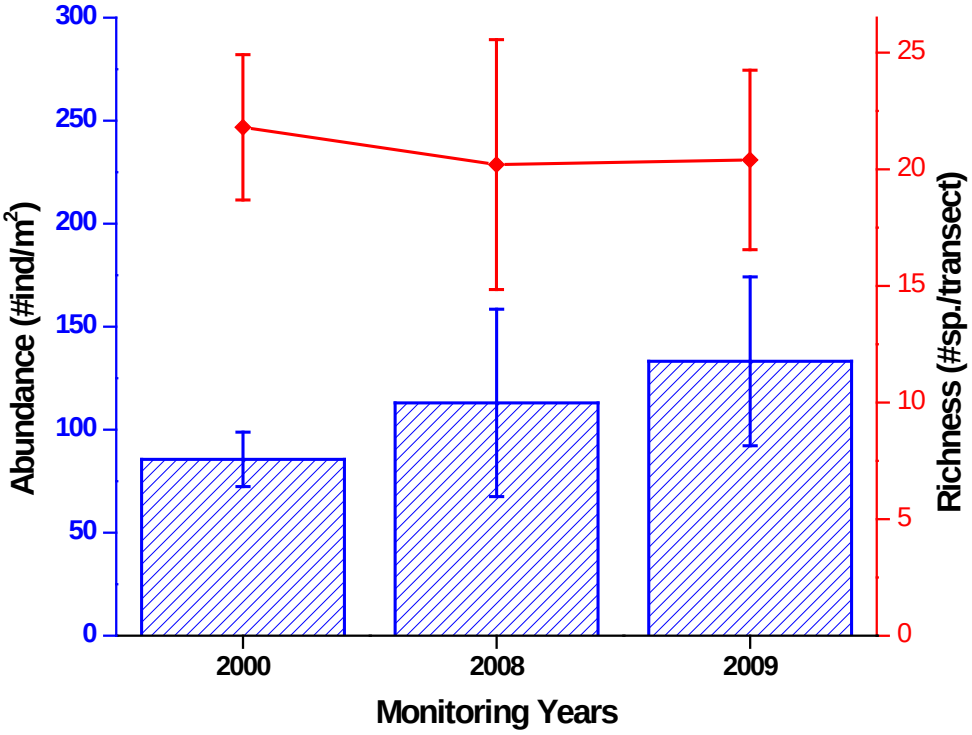


Figure 51. Monitoring trends (2000 – 2009) of fish species richness and abundance at Playa Las Carmelitas Reef, Mona Island.

Table 56. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Playa Carmelitas Reef, Mona. August, 2009

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

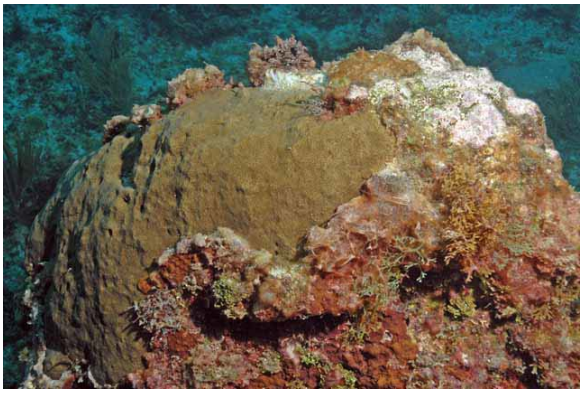
SPECIES	**COMMON NAME**		# - (cm)
Elagatis bipinnulata	Rainbow Runner	2 – (40)	1 – (50)
Epinephelus guttatus	Red Hind	2 – (25)	
Ginglymostoma cirratum	Nurse Shark	1 – (70)	
Lutjanus apodus	Schoolmaster	2 - (20)	3 – (30)
Lutjanus jocu	Dog Snapper	1 - (30)	
Ocyurus chrysurus	Yellowtail Snapper	3 – (15)	2 – (25)
Mycteroperca tigris	Tiger Grouper	1 – (30)	
Mycteroperca venenosa	Yellowfin Grouper	1 – (40)	
Sphyraena barracuda	Great Barracuda	2 - (50)	

Motile megabenthic invertebrates were represented within belt-transects by the Batwing Coral Crab, *Carpilius corallinus* and the Flamingo Tongue, *Cyphoma gibbosum* (Table 57).

Table 57. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at at Playa Carmelitas Reef, Mona. August, 2009

Depth: 20 m		**TRANSECTS**					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	DEPTH (m) COMMON NAME						
Carpilius coralinus	Batwing Coral Crab	1					**0.2**
Cyphoma gibbosum	Flamingo Tongue		1				**0.2**
	TOTALS	**1**	**1**	**0**	**0**	**0**	**0.4**

Photo Album 14 (Isla de Mona)
Playa Carmelitas Reef



3.0. Playa Sardinera

Physical Description of Playa Sardinera Reef

At a distance of 1.8 nautical miles off Playa Sardinera the shelf drops off leading to an slope of about 45-50 degrees. The insular slope is a colonized pavement benthic habitat with many large erect sponges (*Xetospongia muta, Agelas spp*.) and isolated massive coral heads (*Montastraea annularis, M. cavernosa, P. astreoides, Siderastrea siderea, Colpophyllia natans*) interspersed throughout the hard bottom. Available substrate not colonized by sessile-benthic invertebrates is covered by a carpet of algal turf and/or fleshy algae, mostly *Lobophora variegata*. At a depth of approximately 38 -40 m the hard ground slope gives to a sandy deposit that continues to increase in depth along a gentler slope. Our sets of transects were aligned north-south at a depth of 27 – 30 m.

3.1. Sessile-benthic Reef Community

A total of 16 stony corals, including 10 intersected by line transects were identified from Playa Sardinera Reef at a depth of 30 m during 2009 (Table 58). Stony corals occurred as isolated massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 4.3 % (range:0.4– 13.3 %). Boulder Star Coral, *Montastraea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 2.0 % (range: 0– 8.7 %), representing 46.5 % of the total cover by stony corals. *M. annularis* and Lamark's Coral, *Agaricia Lamarki* were the only coral species present in two transects. All other species were present in only one transect. Symetrical Brain Coral (*Diploria strigosa*) and Great Star Coral (*M. cavernosa*) ranked second and third in terms of substrate cover and comprised the main stony coral assemblage at 30 m. The Wire and Bushy Black Corals, *Stichopathes lutkeni* and *Antipathes caribbeana* were present at the slope.

Turf algae and the fleshy encrusting Fan Leaf Alga, *Lobophora variegata* dominated substrate cover by sessile-benthic reef categories at 30 m with a combined cover of 60.6 % (Table 58). *Lobophora* was found covering uncolonized hard ground and unconsolidated sandy substrates, sometimes forming large patches in the reef. Reddish cyanobacterial films were also commonly found over abiotic substrates with a mean cover of 6.7 %.

Table 58. Percent substrate cover by sessile-benthic categories at Playa Sardinera, 30 m Mona Island, August 2009

Depth: 30 m	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	1.92	2.93	3.58	2.86	3.23	**2.9**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	1.76	1.93	7.88	2.72	13.52	**5.6**
Sand	10.66	15.40	12.44	7.69	6.27	**10.5**
Rubble				7.69		**1.5**
Total Abiotic	12.42	17.33	20.32	18.10	19.79	**17.6**
Benthic Algae						
Turf-mixed assemblage	36.86	42.96	44.62	39.70	25.45	**37.9**
Coralline algae				0.78		**0.2**
Lobophora variegata	25.19	23.22	18.78	15.46	30.74	**22.7**
Total Benthic Algae	62.05	66.18	63.40	55.94	56.19	**60.8**
Cyanobacteria	11.08	4.57	6.41	5.13	6.42	**6.7**
Sponges	9.91	9.13	8.91	20.36	3.32	**10.3**
Millepora alcicornis		0.33			0.98	**0.3**
Live Stony Corals						
Montastraea annularis complex	1.54				8.69	**2.0**
Diploria strigosa		2.48				**0.5**
Montastraea cavernosa	2.25					**0.4**
Agaricia lamarcki			0.93		1.17	**0.4**
Isophyllia rigida					1.60	**0.3**
Meandrina meandrites					1.06	**0.2**
Madracis decactis					0.74	**0.2**
juvenile coral				0.47		**0.1**
Agaricia agaricites	0.35					**0.1**
Siderastrea siderea	0.35					**0.1**
Total Stony Corals	4.49	2.48	0.93	0.47	13.26	**4.3**
Gorgonians (# col.)	7	4	7	9	4	**6.2**

Coral Species Outside Transects

Eusmilia fastigiata, Diploria labyrinthiformis, Mycetophyllia sp. Porites astreoides, Porites sp., Stylaster roseus, Stichopathes lutkeni, Antipathes caribbeana

With a mean cover of 10.5 %, erect sponges were the most prominent sessile-benthic invertebrate in the reef. Giant Basket Sponge (*Xetospongia muta*), Tube Sponges (*Agelas conifera, Agelas Clathrodes*, *Aplysina spp*) contributed substantially to the substrate rugosity and habitat complexity at Playa Sardinera 30 m.

Monitoring trends of substrate categories at Playa Sardinera Reef are shown in Figure 52. Differences between the baseline characterization in 2008 and the present 2009 monitoring survey were small and statistically insignificant for the main substrate categories. Figure 53 displays the variations of coral species between monitoring years at theis reef. Differences were small and within the high sampling variability margin imposed by low sample size at this reef station.

3.2. Fishes and Motile Megabenthic Invertebrates

A total of 60 fish species were identified during our visual surveys at Playa Sardinera Reef, 42 of which were observed within belt-transects (Table 59). The mean number of species per transect was 20.2 (range 16 – 25), and the mean density of fishes was 147.0 Individuals/30 m^2 (range: 66 - 187 Individuals/30 m^2). Six species represented 78.9 % of the total individuals within belt-transect areas. The numerically dominant species included the Blue Chromis (*Chromis cyanea*), Creole Wrasse (Clepticus parrae), Masked Goby (*Coryphopterus personatus*), Bicolor Damselfish (*Stegastes partitus*), Fairy Basslet (*Gramma loreto*) and the Bluehead Wrasse (*Thalassoma bifasciatum*). With the exception of Creole Wrasse, the aforementioned species were found in at least four transects and comprised, along with Peppermint Goby, Yellowhead Wrasse, Redband parrotfish, Sharknose Goby and the Graysbe the main resident fish assemblage at Playa Sardinera Reef.

Demersal territories were mostly occupied by the Bicolor Damselfish, Bluehead and Yellowhead wrasses, Squirrelfishes and Graysbe. Guilds of juvenile Blue Chromis were common over coral heads and also associated with branching sponges. Other species of schooling post-recruitment juveniles associated with sponges included the Creole Wrasse and the Sunshine Chromis. Schools of adult Creole Wrasse (*Clepticus parrae*), Creole Fish (Paranthias furcifer), Black Durgon (*Melichthys niger*), Bar Jacks (*Carangoides ruber*) and Bermuda Chubs (*Kyphosus* sp.) were transient across reef

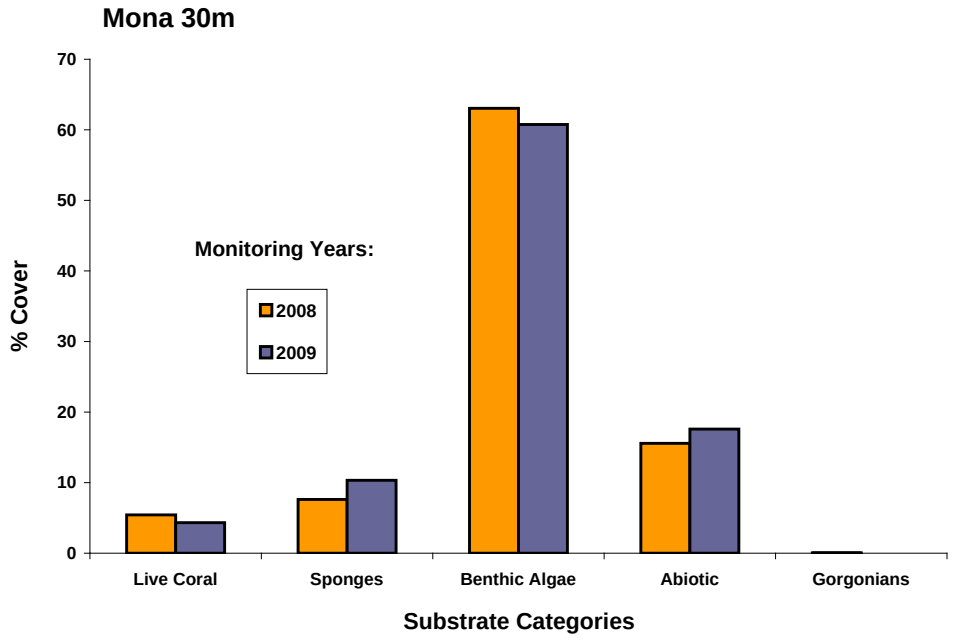


Figure 52. Monitoring trends (2000 - 2009) of mean substrate cover by sessile-benthic categories off Playa Sardinera Reef, 30 m, Mona Island

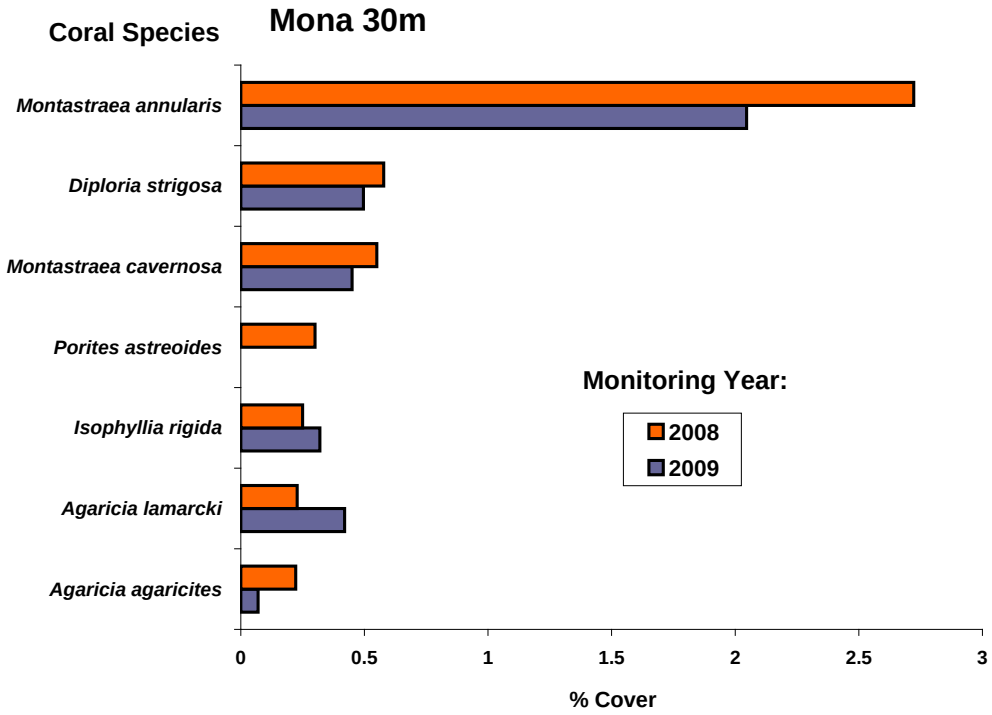


Figure 53. Monitoring trends (2000 - 2009) of mean substrate cover by coral species off Playa Sardinera Reef, 30 m, Mona Island

Table 59. Taxonomic composition and abundance of fishes within belt-transects at Sardinera Reef, 30 m, Isla de Mona. August, 2009

Depth: 30m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**	(Individuals/30 m2)					**MEAN**
Chromis cyanea	Blue Chromis	50	12	49	62	47	**44**
Clepticus parrae	Creole Wrasse	32	0	42	42	0	**23.2**
Coryphopterus personatus	Masked Goby	5	15	39	25	15	**19.8**
Stegastes partitus	Bicolor Damselfish	13	12	14	14	8	**12.2**
Gramma loreto	Fairy Basslet	7	0	9	11	30	**11.4**
Thalassoma bifasciatum	Bluehead Wrasse	10	5	1	5	6	**5.4**
Coryphopterus lipernes	Peppermint Goby	0	2	0	0	16	**3.6**
Halichoeres garnoti	Yellowhead Wrasse	4	3	1	7	0	**3**
Sparisoma aurofrenatum	Redband Parrotfish	1	3	4	1	2	**2.2**
Gobiosoma evelynae	Sharknose Goby	1	1	3	2	2	**1.8**
Epinephelus cruentatus	Graysby	2	0	2	2	3	**1.8**
Halichoeres maculipina	Clown Wrasse	0	4	2	1	4	**2.2**
Scarus taeniopterus	Princess Parrotfish	4	2	0	1	1	**1.6**
Chromis multilineata	Brown Chromis	0	0	0	0	7	**1.4**
Chaetodon capistratus	Foureye Butterflyfish	0	0	2	0	4	**1.2**
Apogon townsendi	Belted Cardinalfish	0	0	6	0	0	**1.2**
Acanthurus bahianus	Ocean Surgeon	1	1	1	0	1	**0.8**
Holocentrus rufus	Longspine Squirrelfish	0	1	1	1	1	**0.8**
Chaetodon striatus	Banded Butterflyfish	0	0	2	0	2	**0.8**
Kryphosus sextatrix	Bermuda Chub	0	0	0	4	0	**0.8**
Holocanthus tricolor	Rock Beauty	1	0	0	0	2	**0.6**
Caranx latus	Horse-eye Jack	0	0	1	2	0	**0.6**
Serranus tegrinus	Harlequin Bass	0	1	1	1	0	**0.6**
Acanthurus coeruleus	Blue Tang	1	2	0	0	0	**0.6**
Lactophyris triqueter	Smooth Trunkfish	1	0	1	0	0	**0.4**
Canthigaster rostrata	Sharpnose Puffer	1	0	1	0	0	**0.4**
Sphyraena barracuda	Great Barracuda	0	0	2	0	0	**0.4**
Cephalopholis fulva	Coney	0	1	0	0	1	**0.4**
Chaetodon aculeatus	Longsnout Butterflyfish	0	0	0	2	0	**0.4**
Chaetodon ocellatus	Spotfin Butterflyfish	0	0	0	2	0	**0.4**
Myripristis jacobus	Blackbar Soldierfish	0	0	0	0	2	**0.4**
Mellichthys niger	Black Durgeon	0	0	0	0	2	**0.4**
Haemulon flavolineatum	French Grunt	0	0	0	0	2	**0.4**
Sparisoma automarium	Greenblotch Parrotfish	0	1	0	0	0	**0.2**
Paranthias fucifer	Creolefish	0	0	1	0	0	**0.2**

Centropige argy	Cherubfish	0	0	1	0	0	**0.2**
Carchahinus perezi	Reef Shark	0	0	0	1	0	**0.2**
Chromis insolata	Sunshinefish	0	0	0	1	0	**0.2**
Pomacanthus paru	French Angelfish	0	0	0	0	1	**0.2**
Holocentrus marianus	Longjaw Squirrelfish	0	0	0	0	1	**0.2**
Amblycirrihitus pinos	Redspoted Hawlfish	0	0	0	0	1	**0.2**
Scarus iserti	Stoplight Parrotfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**134**	**66**	**186**	**187**	**162**	**147**
	TOTAL SPECIES	**17**	**16**	**23**	**20**	**25**	**20.2**

Fishes Outside Transects (30 – 40 m)

SPECIES	**COMMON NAME**
Abudefduf sexatilis	Sergeant Major
Acanthostrascion quadricornis	Scrawled Cowfish
Cantherhines macrocerus	Whitespotted Filefish
Carangoides ruber	Bar Jack
Caranx crysos	Blue Runner
Coryphopterus lipernes	Peppermint Goby
Echidna catenata	Chain Moray
Epinephelus guttatus	Red Hind
Ginglymostoma cirratum	Nurse Shark
Lactophrys bicaudalis	Spotted Trunkfish
Muraenidae	Moray sp.
Sparisoma chrysopterum	Redtail Parrotfish
Scarus vetula	Queen Parrotfish
Sphyraena barracuda	Great Barracuda
Lutjanus jocu	Dog Snapper
Mycteroperca tigris	Tiger Grouper
Lutjanus mahogoni	Mahogany Snapper
Urolophus jamaicensis	Yellow Stingray
Bodianus rufus	Spanish Hogfish
Acanthurus chirurgus	Doctorfish
Mulloidichthys martinicus	Yellow Goatfish
Chaetodon striatus	Banded Butterflyfish
Lutjanus apodus	Schoolmaster Snapper
Sparisoma radians	Bucktooth Parrotfish
Equetus lanceolatus	Jackknife Fish
Holocanthus tricolor	Rock Beauty
Holacanthus ciliaris	Queen Angelfish
Xanthichthys ringens	Sargassum Triggerfish
Holocentrus adscensionis	Squirrelfish
Haemulon chrysargyreum	Smallmouth Grunt
Gymnotorax funebris	Green Moray
Antennarius bermudensis	Island Frogfish
Epinephelus guttatus	Red Hind
Rypticus saponaceus	Greater Soapfish
Sparisoma viride	Stoplight Parrotfish

survey sites. Sand Tilefish (*Malacanthus plumieri*) was common at the base of the reef in sandy habitats.

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) represented at least 50 % of the species present. Bicolor Damselfish, Creole Wrasse and the Blue and Brown Chromis were the main components of the zooplanktivorous assemblage comprised by nine species and 60 % of the total individuals within transects. Herbivorous taxa included mostly parrotfishes, damselfishes and doctorfishes (Acanthuridae). The combined herbivorous assemblage represented less than 10 % of the total individuals within belt-transect areas. The Great Barracuda (*Sphyraena barracuda*), Rainbow Runner (*Elagatis bipinnulata*), Reef Shark (Carcharhinus perezi) and the Bar Jack (*Carangoides ruber*) represented pelagic (piscivorous) predators. Demersal fish predators of larger reef invertebrates and fishes, such as large snappers and groupers were represented by juvenile Tiger Grouper (*Mycteroperca tigris*), Dog Snapper (Lutjanus jocu) and an adult Red Hind (*Epinephelus guttatus*) (Table 60). Monitoring data on fish abundance and species richness within belt-transects is shown in Figure 54. Differences between surveys were minor and not statistically significant (ANOVA; $p > 0.05$, Appendix 3 - 4).

Table 60. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Playa Sardinera Reef, Mona, 30 m, August, 2009

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

SPECIES	**COMMON NAME**		# - (cm)
Carcharhinus perezi	Reef Shark	1 – (70)	
Caranx crysos	Blue Runner	3 – (35)	
Epinephelus guttatus	Red Hind	2 – (25)	1 – (30)
Ginglymostoma cirratum	Nurse Shark	1 – (80)	
Lutjanus apodus	Schoolmaster	2 - (20)	3 – (30)
Lutjanus jocu	Dog Snapper	1 - (30)	
Mycteroperca tigris	Tiger Grouper	1 – (35)	
Sphyraena barracuda	Great Barracuda	2 - (50)	

Cleaner Shrimp (*Periclimenes pedersoni*) and Arrow Crab (*Stenorhynchus seticornis*) represented motile megabenthic invertebrates within belt-transects st Playa Sardinera Reef (Table 61).

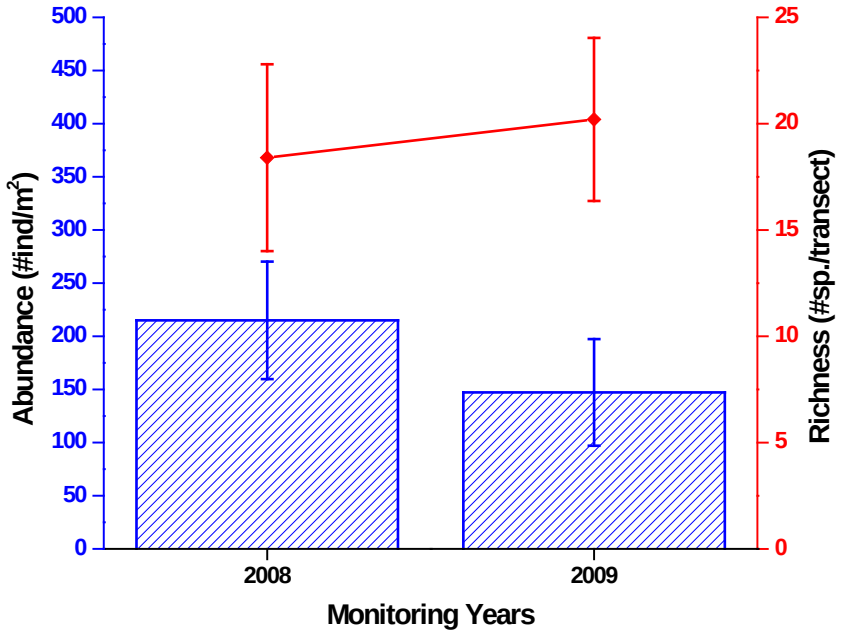
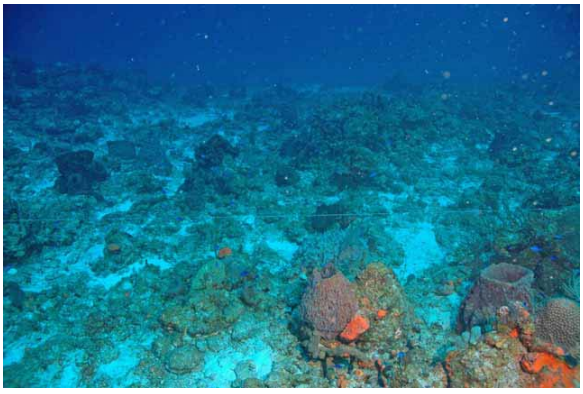


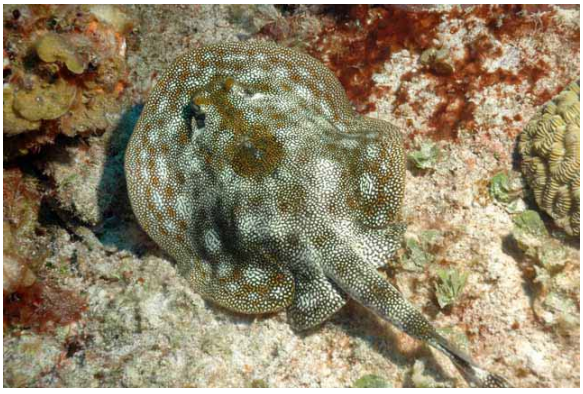
Figure 54. Monitoring trends (2000 – 2009) of fish species richness and abundance at Playa Sardinera Reef, 30 m, Mona Island.

Table 61. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at at Playa Sardinera Reef, 30 m, Mona. August, 2009

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

Photo Album 15 (Isla de Mona)
Playa Sardinera Reef





V Conclusions

The sessile-benthic community at the reef systems of Puerto Botes and Puerto Canoas (Isla Desecheo), Tourmaline Reef (Mayaguez), Cayo Coral (Guánica), West Reef (Caja de Muerto – Ponce), and Derrumbadero Reef (Ponce) presented statistically significant 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 decline of (total) live coral cover at the reef community level during 2006, but that extended until 2008 (lingering effects) was largely driven by mortality of Boulder Star Coral, *Montastraea annularis* (complex), a highly dominant species in terms of reef substrate cover and the principal reef building species. Corresponding increments of reef substrate cover by benthic algae, cyanobacteria and abiotic categories were measured.

During the present 2009 monitoring survey live coral cover presented a pattern of mild increments in most reefs surveyed, particularly associated with what appears to be an indication of partial recuperation of *Montastraea annularis* colonies previously affected by bleaching. Differences were not statistically significant, but the trend certainly represents a reversal from the continued decline of live coral triggered by the 2005 regional bleaching event, with lingering effects until 2007. An exception to this trend was observed at the *Acropora palmata* finging reef of Tres Palmas in Rincon. This reef is now affected by an infectious disease that was preliminarily identified as “white pox”, also known as “patchy necrosis” and a trend of declining cover appears to be emerging.

Fish populations presented in the 2009 survey a general trend of stabilizing abundance and species richness relative to the 2008 levels. Previous reductions of fish abundance were statistically significant in seven out of the 12 reef stations surveyed. These included Tourmaline Reef (Mayaguez) at 20 m; Puerto Botes Reef (Isla Desecheo) at 15 m; Tres Palmas Reef (Rincon) at 10 and 20 m; Derrumbadero Reef (Ponce) at 20 m and West Reef (Isla Caja de Muerto) at 8 m. Likewise, statistically significant reductions of fish species richness were observed at Tourmaline Reef (Mayaguez) at 20 m; Puerto Botes Reef (Isla Desecheo) at 15 m; Tres Palmas Reef (Rincon) at 10 m and West Reef (Isla Caja de Muerto) at 8 m.

Abundance variations between surveys are mostly associated with fluctuations of 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 Reef Shark (Carcharhinus perezi), Yellowfin, Tiger, Jewfish, and Nassau Groupers (*Mycteroperca venenosa, M. tigris, Epinephelus itajara, E. striatus*), and the Cubera, Dog and Mutton Snappers (*Lutjanus cyanopterus, L. jocu, L. analis*).

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

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

Total Species Database **REEF SITES**

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

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

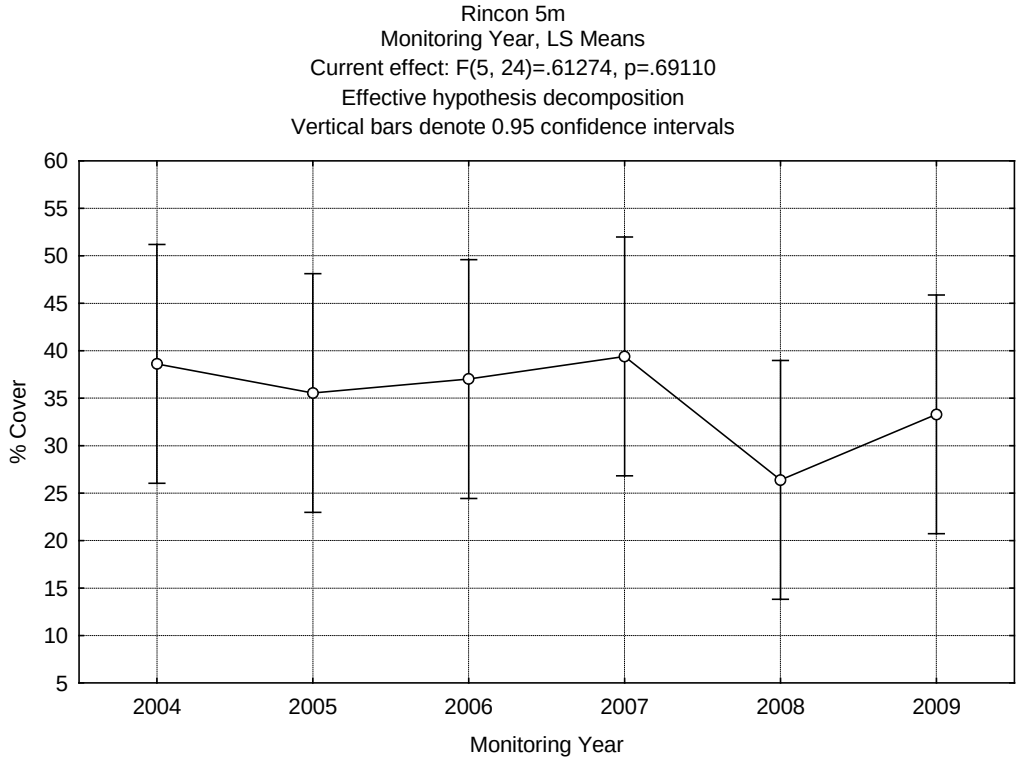
Species	Common Name	M30	M20	M10	R5	R10	R20	D30	D20	D15	CJm	Derr	Gua
Epinephelus itajara	Jewfish												x
Epinephelus striatus	Nassau Grouper	x	x					x	x				x
Equetus acuminatus	Highhat	x	x	x		x		x	x	x		x	x
Equetus lanceolatus	Jackknife Fish	x	x			x	x				x		
Equetus punctatus	Spotted Drum					x	x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

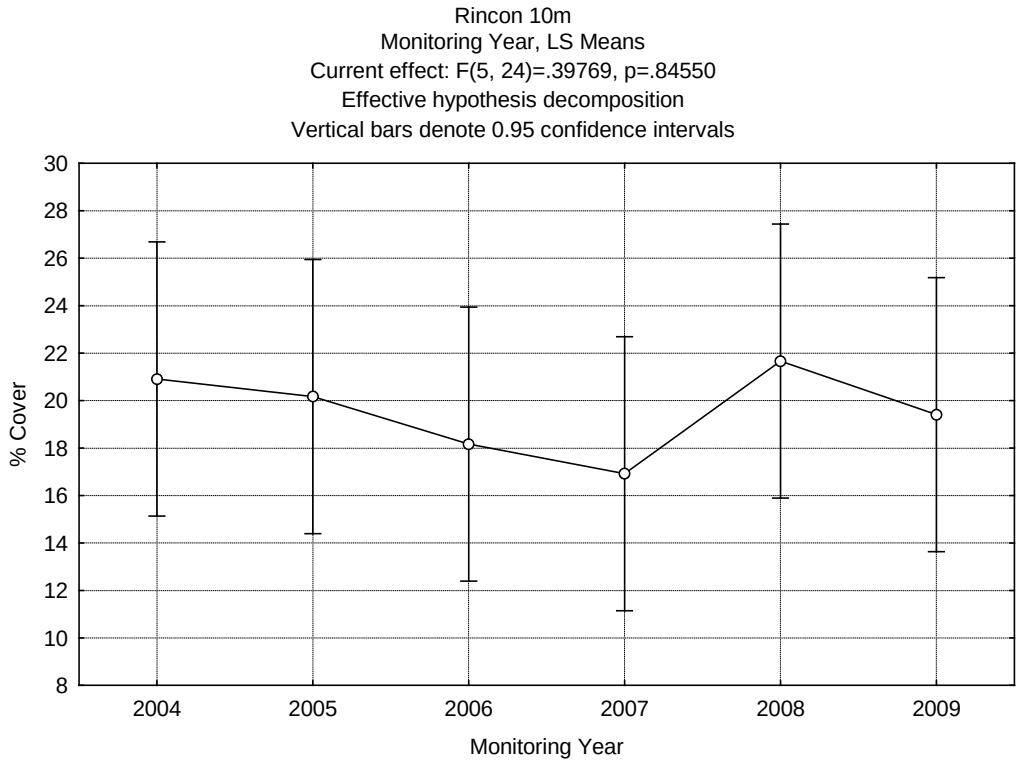
Species	**Common Name**	**M30**	**M20**	**M10**	**R5**	**R10**	**R20**	**D30**	**D20**	**D15**	**CJm**	**Derr**	**Gua**
Halichoeres sp.	wrasse					x							
Hemiramphus ballyhoo	Ballyhoo					x	x	x	x	x			x
Holacanthus ciliaris	Queen Angelfish	x	x	x		x	x	x	x	x		x	x
Holacanthus tricolor	Rock Beauty	x	x	x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

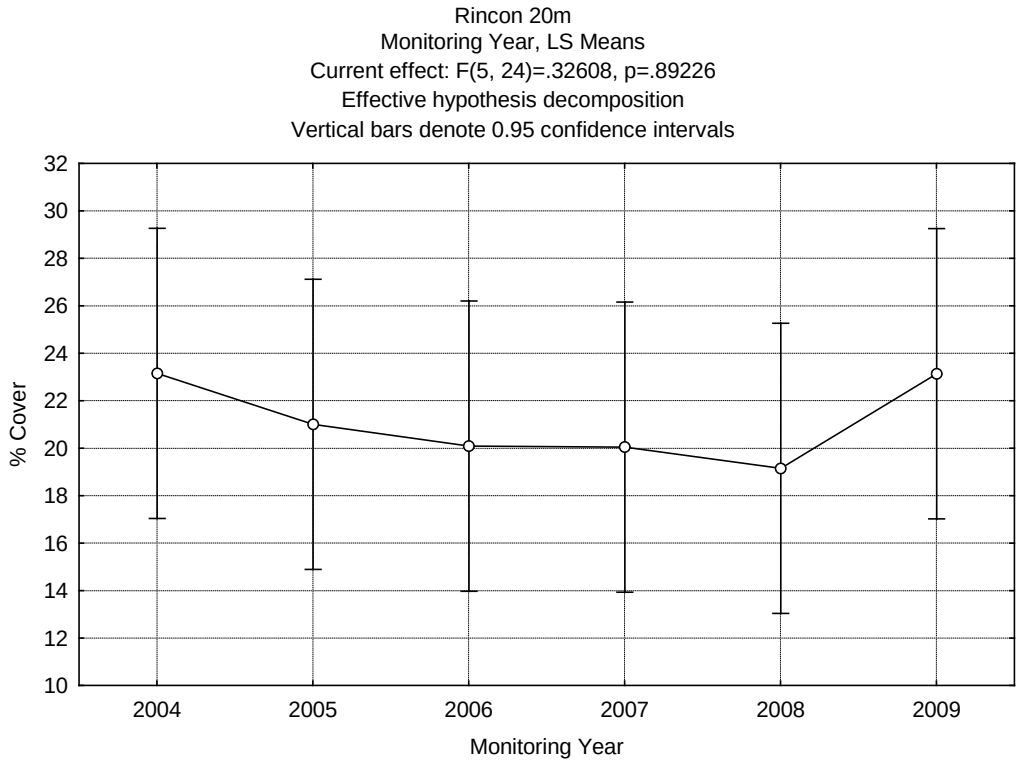
Species	Common Name	M30	M20	M10	R5	R10	R20	D30	D20	D15	CJm	Derr	Gua
Malacoctenus versicolor	Barfin Blenny					x							
Melichthys niger	Black Durgon	x	x	x	x	x	x	x	x	x		x	x
Microspathodon chrysurus	Yellowtail Damselfish	x	x	x	x	x	x	x	x	x	x	x	x
Mulloides martinicus	Yellowtail Goatfish	x	x	x	x	x	x	x	x	x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

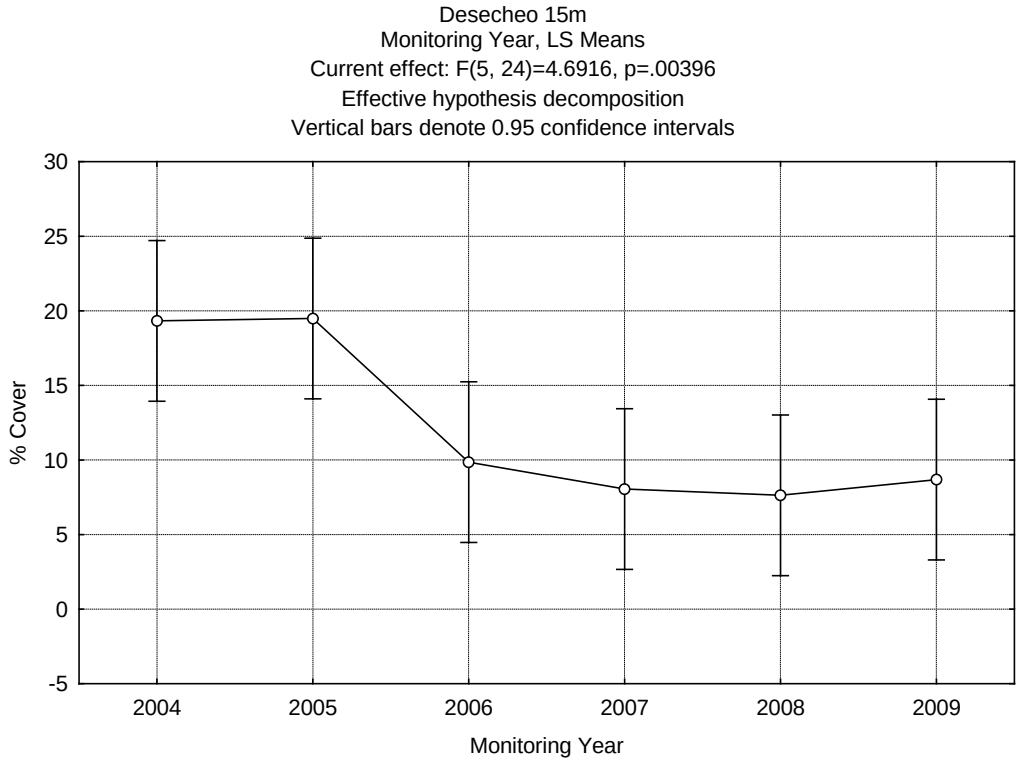
Species	**Common Name**	**M30**	**M20**	**M10**	**R5**	**R10**	**R20**	**D30**	**D20**	**D15**	**CJm**	**Derr**	**Gua**
Serranus tigrinus	Harlequin Bass	x	x	x		x	x	x	x	x	x	x	x
Sparisoma aurofrenatum	Redband Parrotfish	x	x	x	x	x	x	x	x	x	x	x	x
Sparisoma chrysopterum	Redtail Parrotfish						x	x	x				
Sparisoma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

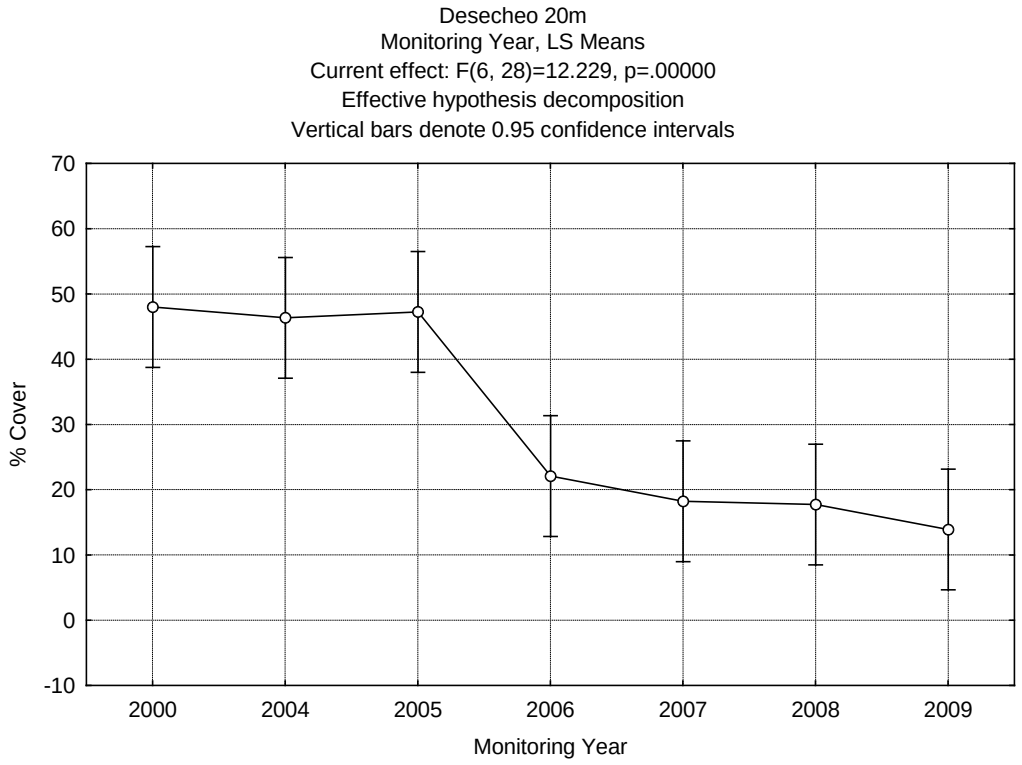
Appendix 2. Analysis of variance (ANOVA) procedure testing differences of live coral cover in annual monitoring surveys through 2009.

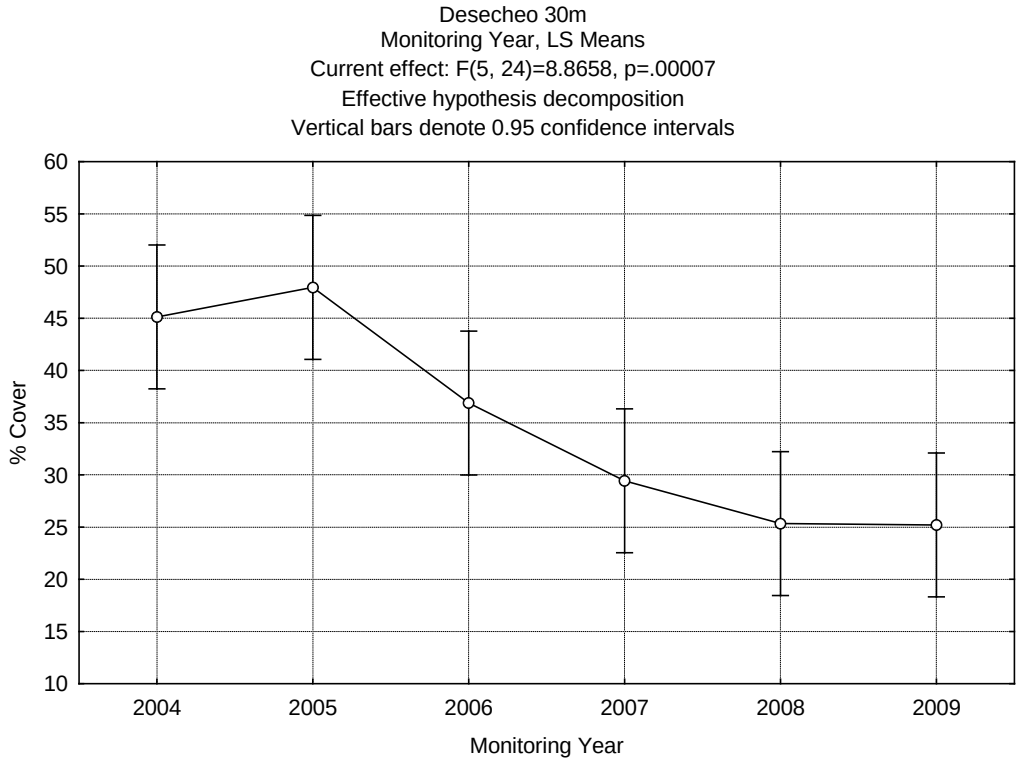




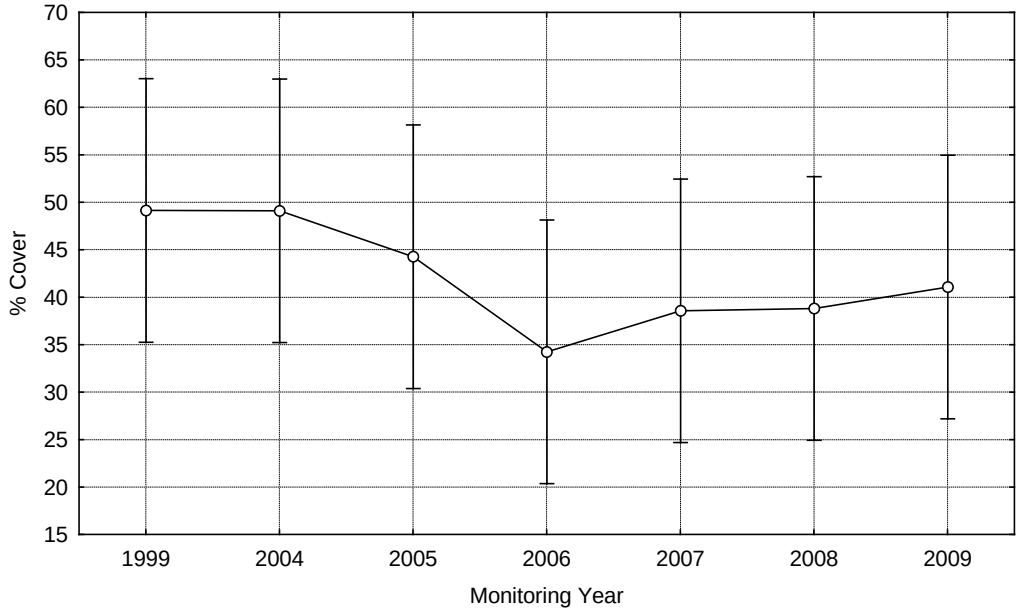

Rincon 20m
Monitoring Year, LS Means
Current effect: F(5, 24)=.32608, p=.89226
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Cover
32
30
28
26
24
22
20
18
16
14
12
10
2004
2005
2006
2007
2008
2009
Monitoring Year


Desecheo 15m
Monitoring Year, LS Means
Current effect: F(5, 24)=4.6916, p=.00396
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Cover
30
25
20
15
10
5
0
-5
2004
2005
2006
2007
2008
2009
Monitoring Year

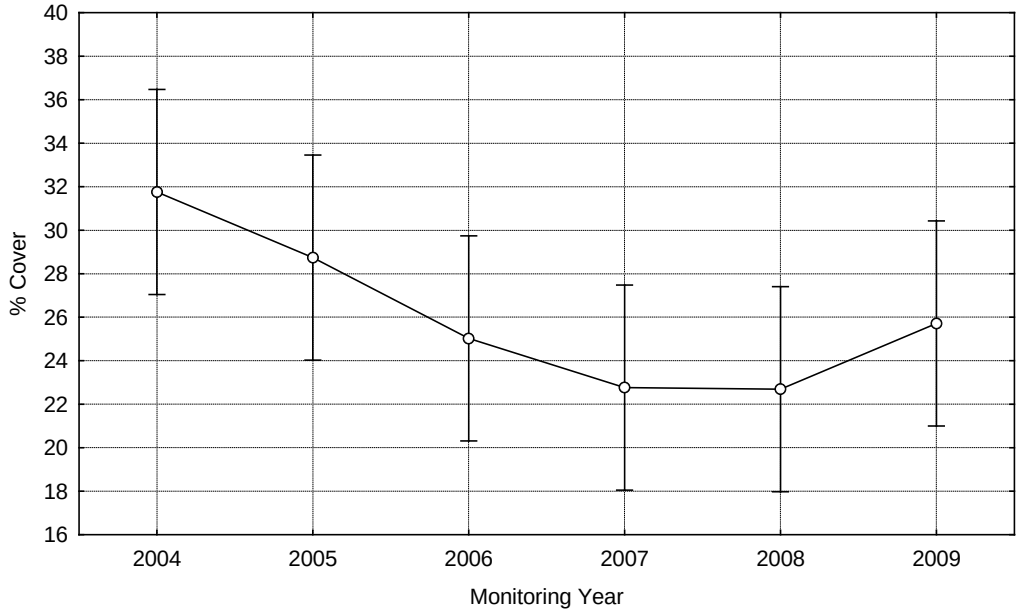

Desecheo 20m
Monitoring Year, LS Means
Current effect: F(6, 28)=12.229, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
70
60
50
40
30
20
10
0
-10
% Cover
2000
2004
2005
2006
2007
2008
2009
Monitoring Year

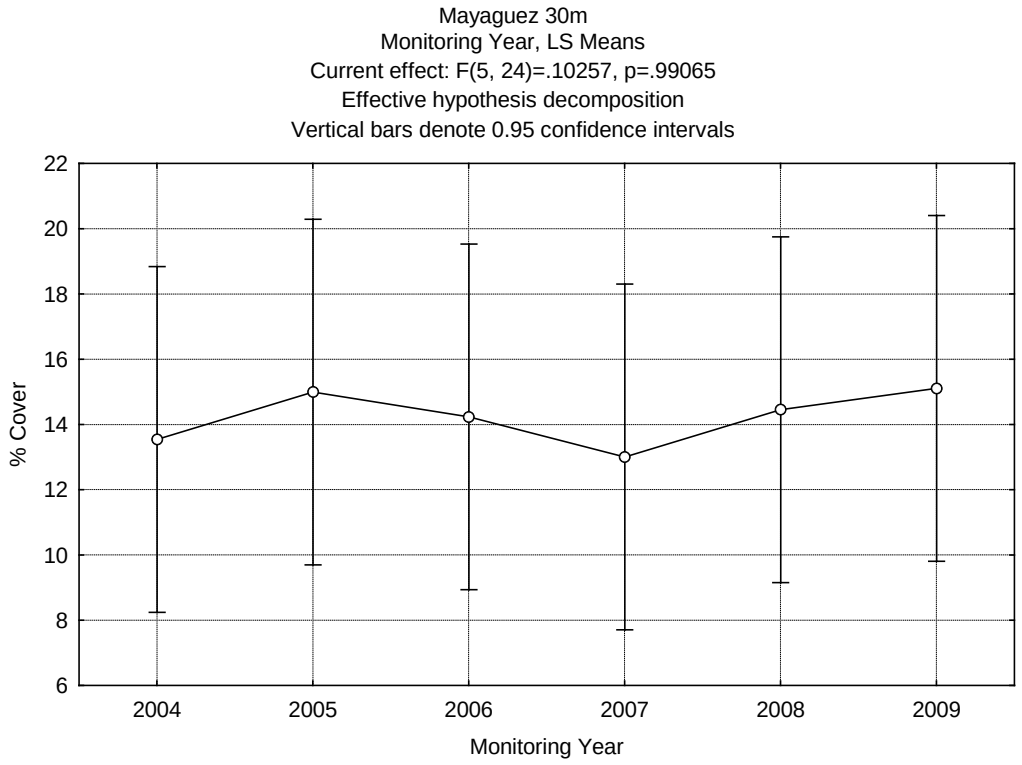

Desecheo 30m
Monitoring Year, LS Means
Current effect: F(5, 24)=8.8658, p=.00007
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
60
55
50
45
40
35
30
25
20
15
10
% Cover
2004
2005
2006
2007
2008
2009
Monitoring Year

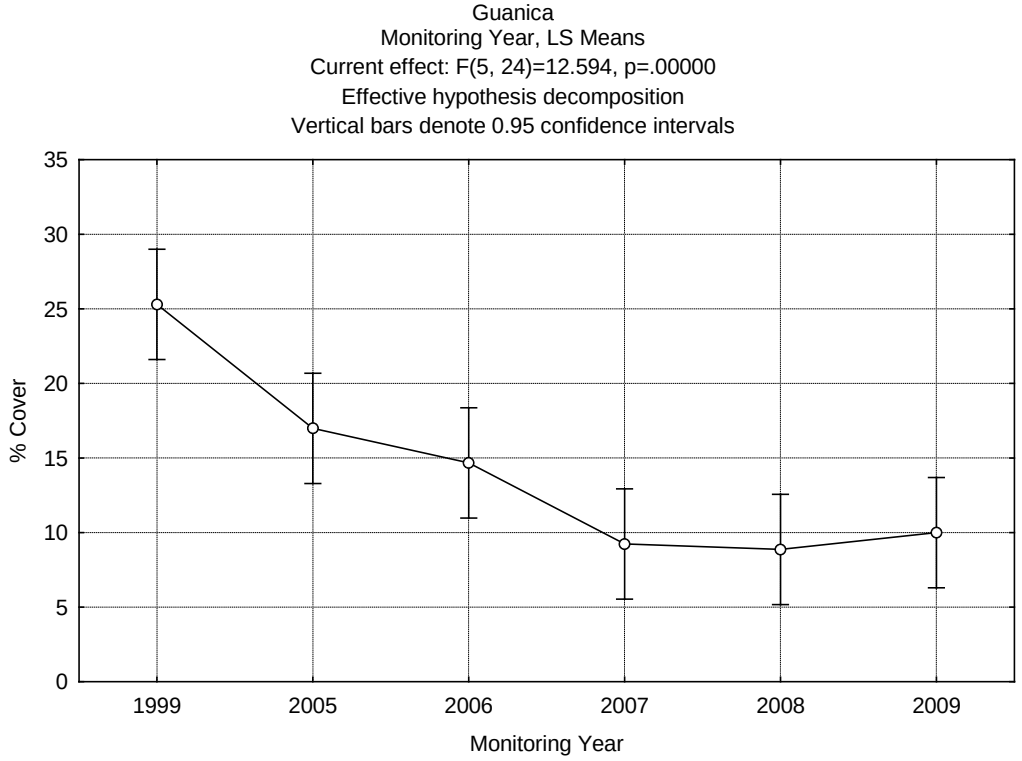
Mayaguez 10m
Monitoring Year, LS Means
Current effect: F(6, 28)=.68673, p=.66189
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals

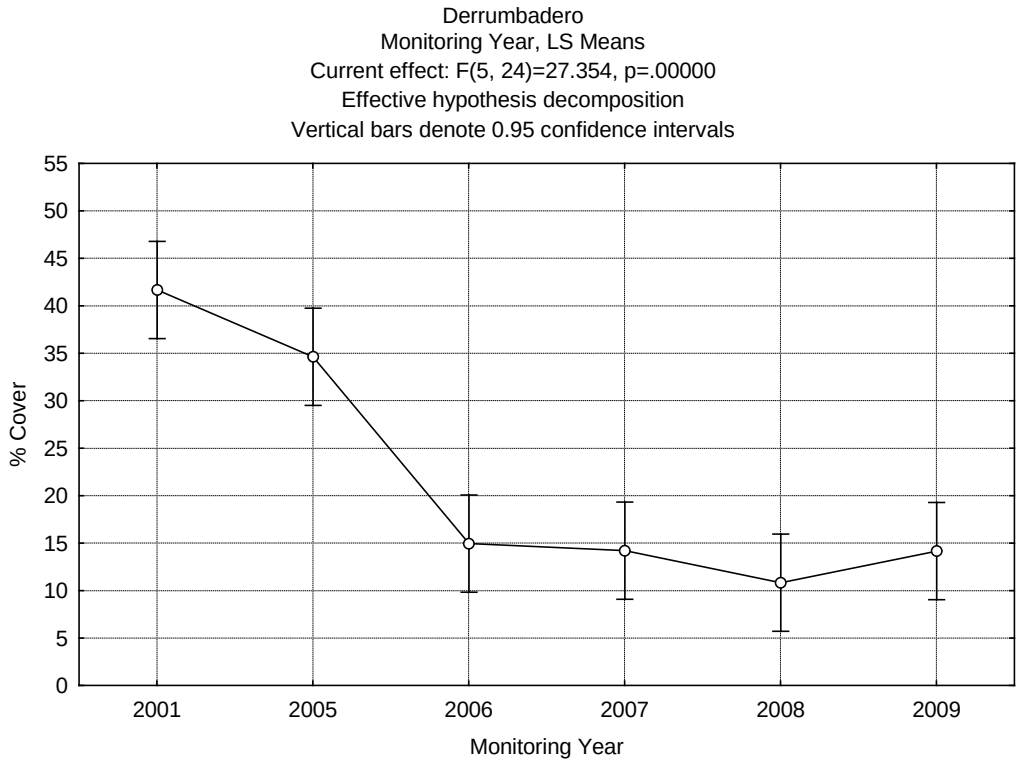


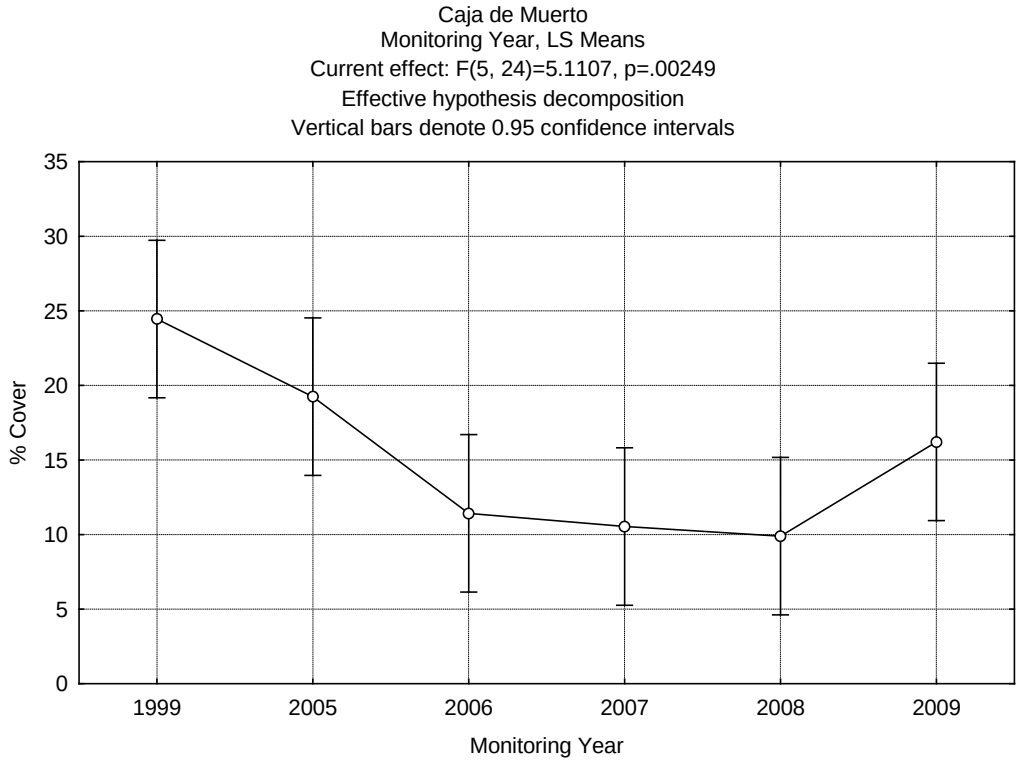
Mayaguez 20m
Monitoring Year, LS Means
Current effect: F(5, 24)=2.4156, p=.06566
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals

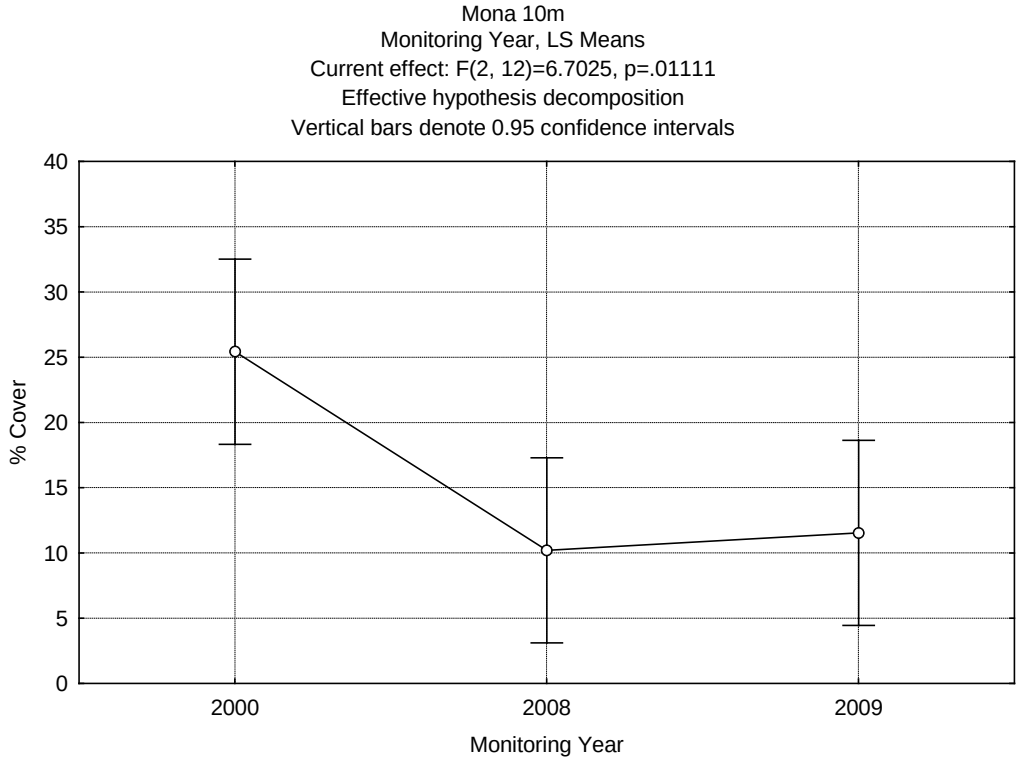


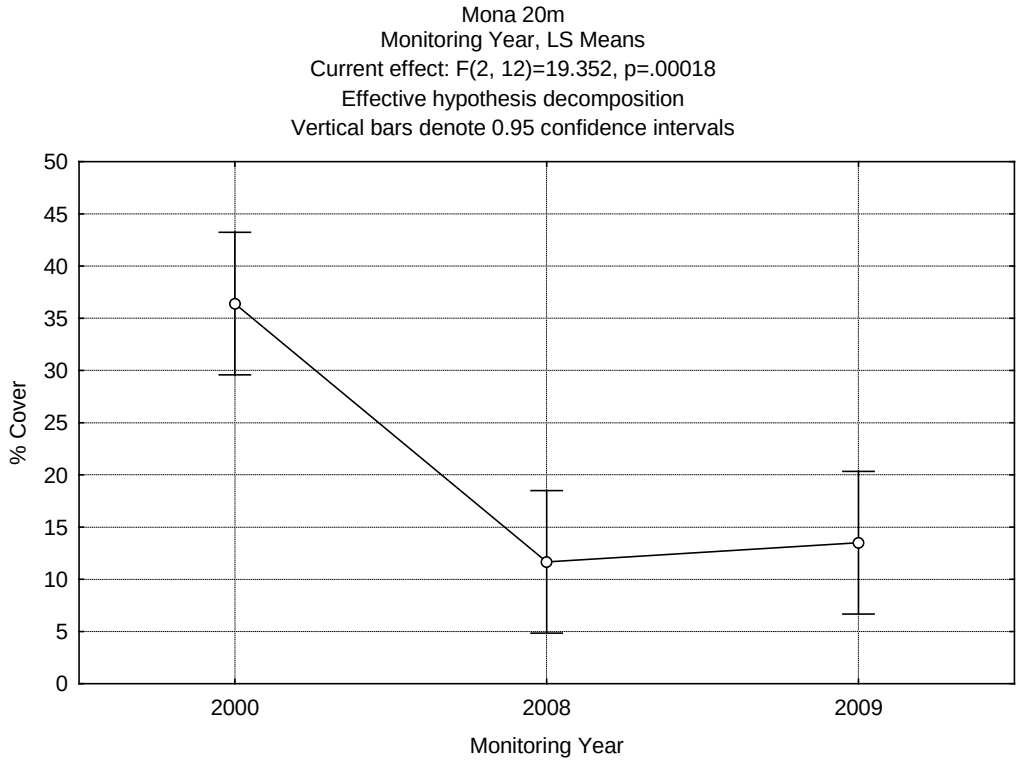

Mayaguez 30m
Monitoring Year, LS Means
Current effect: F(5, 24)=.10257, p=.99065
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Cover
22
20
18
16
14
12
10
8
6
2004
2005
2006
2007
2008
2009
Monitoring Year

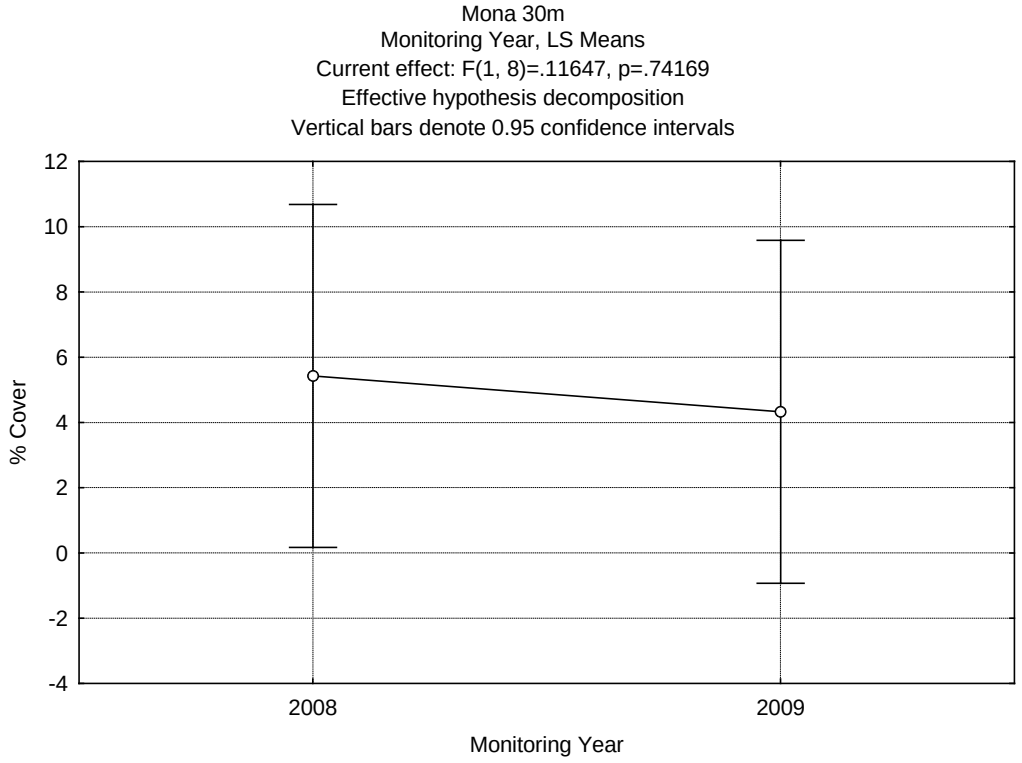

Guanica
Monitoring Year, LS Means
Current effect: F(5, 24)=12.594, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Cover
35
30
25
20
15
10
5
0
1999
2005
2006
2007
2008
2009
Monitoring Year


Derrumbadero
Monitoring Year, LS Means
Current effect: F(5, 24)=27.354, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Cover
55
50
45
40
35
30
25
20
15
10
5
0
2001
2005
2006
2007
2008
2009
Monitoring Year

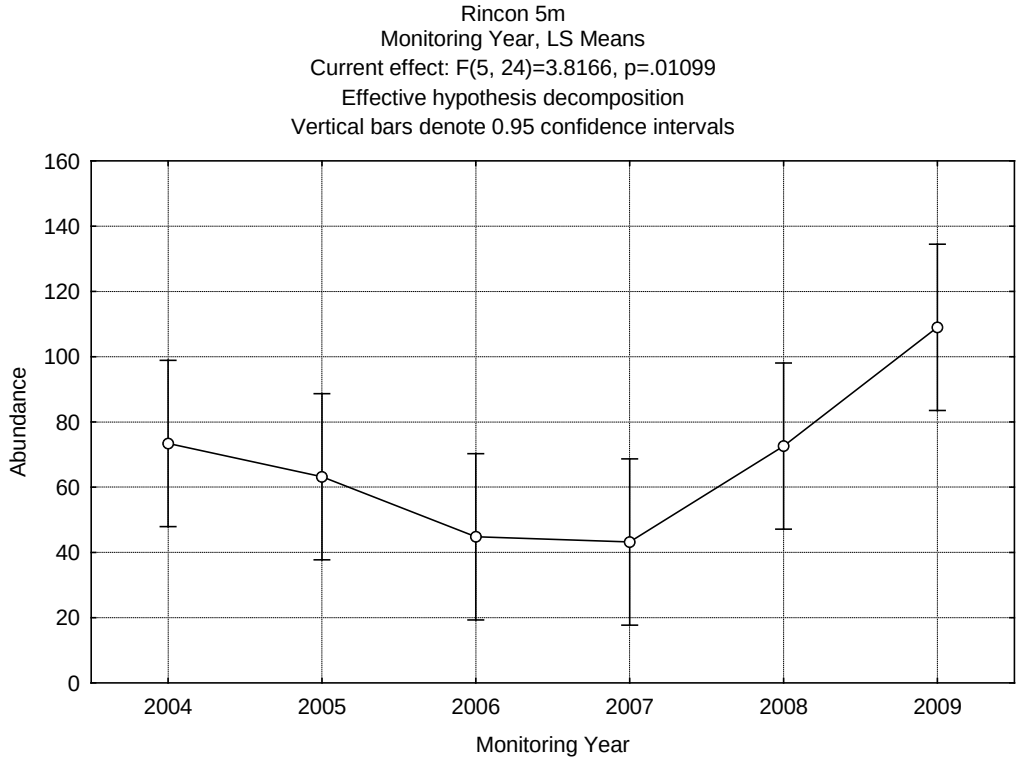

Caja de Muerto
Monitoring Year, LS Means
Current effect: F(5, 24)=5.1107, p=.00249
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Cover
35
30
25
20
15
10
5
0
1999
2005
2006
2007
2008
2009
Monitoring Year

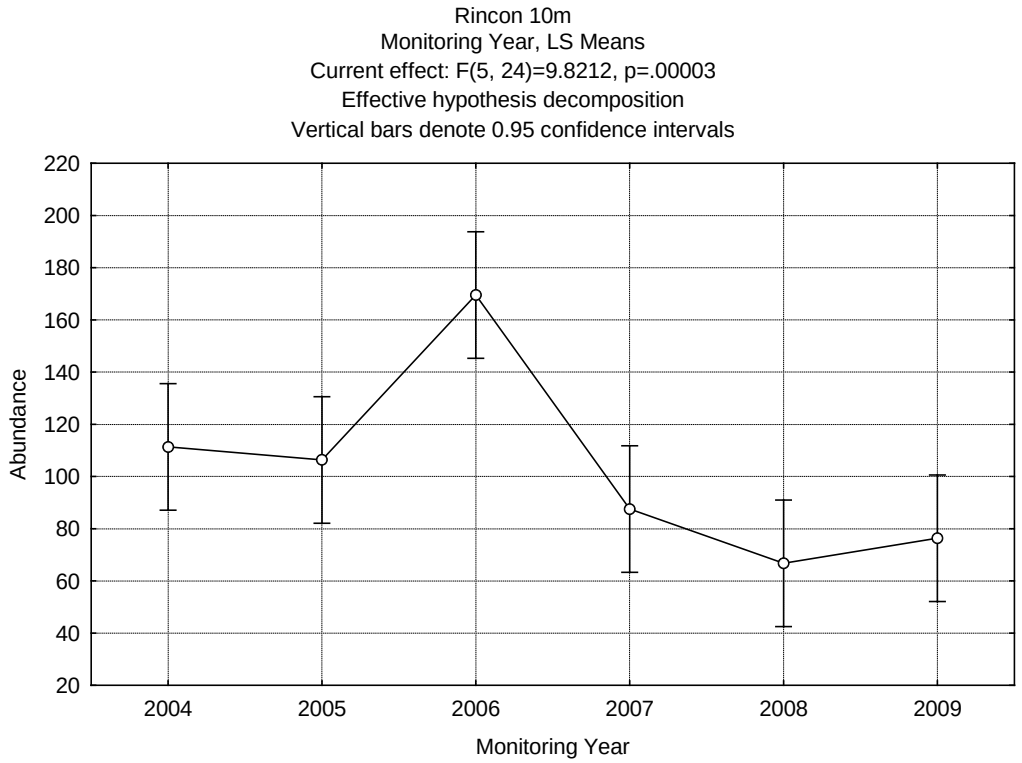

Mona 10m
Monitoring Year, LS Means
Current effect: F(2, 12)=6.7025, p=.01111
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Cover
0
5
10
15
20
25
30
35
40
2000
2008
2009
Monitoring Year

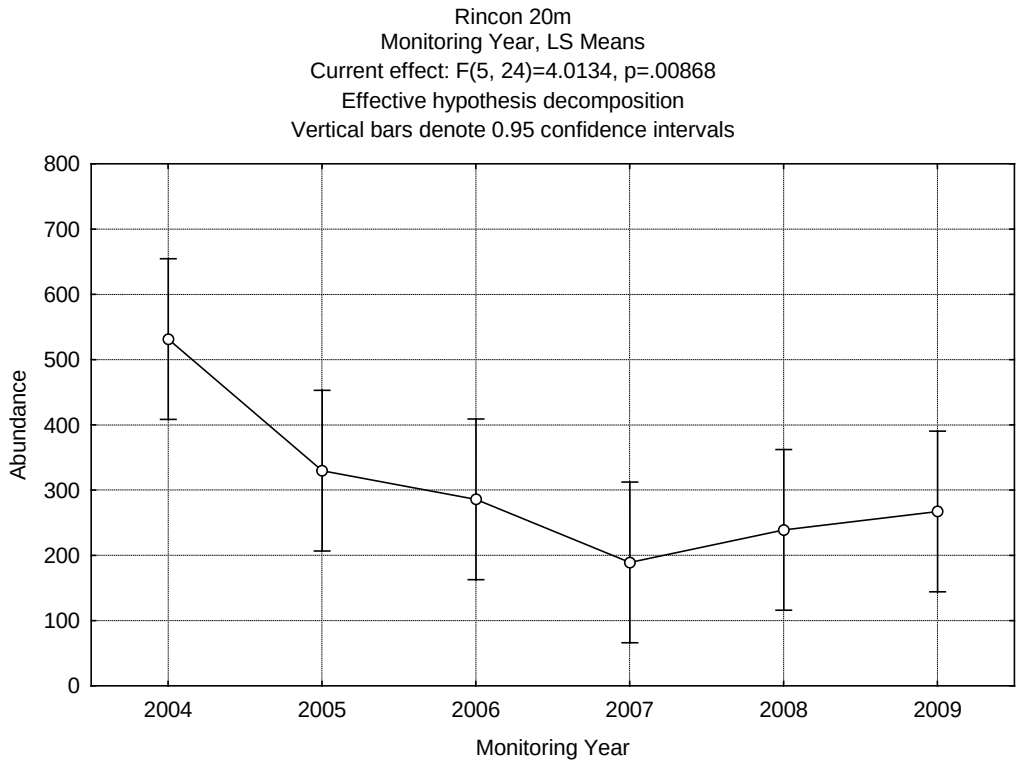

Mona 20m
Monitoring Year, LS Means
Current effect: F(2, 12)=19.352, p=.00018
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Cover
0
5
10
15
20
25
30
35
40
45
50
2000
2008
2009
Monitoring Year

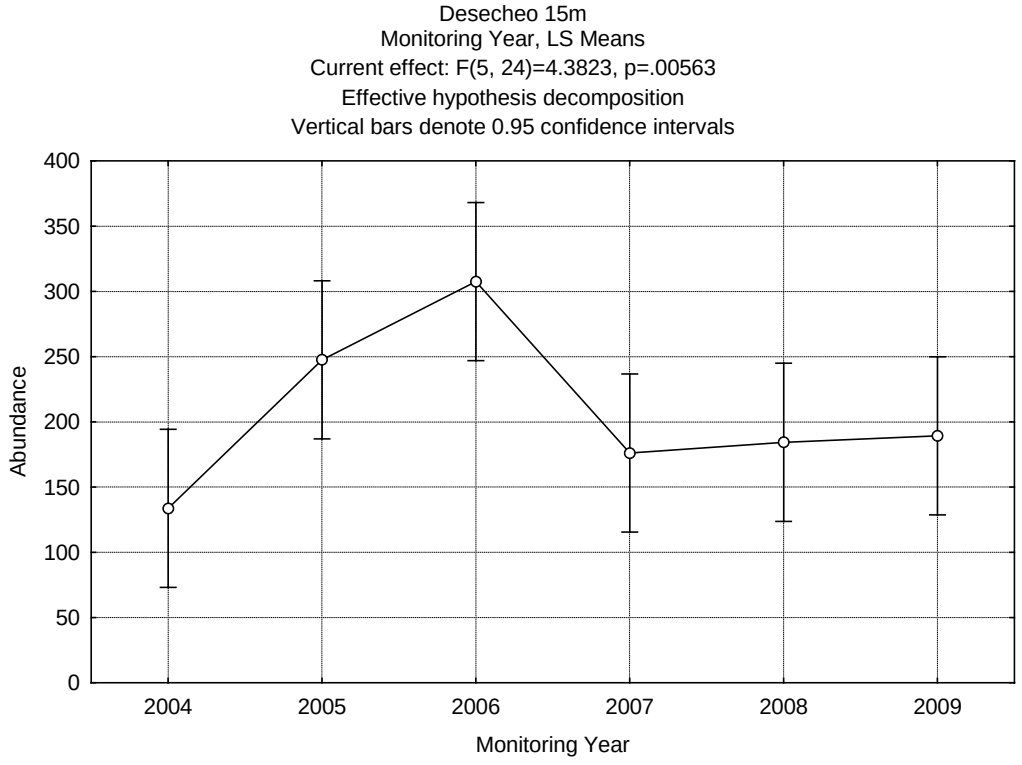

Mona 30m
Monitoring Year, LS Means
Current effect: F(1, 8)=.11647, p=.74169
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
12
10
8
6
4
2
0
-2
-4
% Cover
2008
2009
Monitoring Year

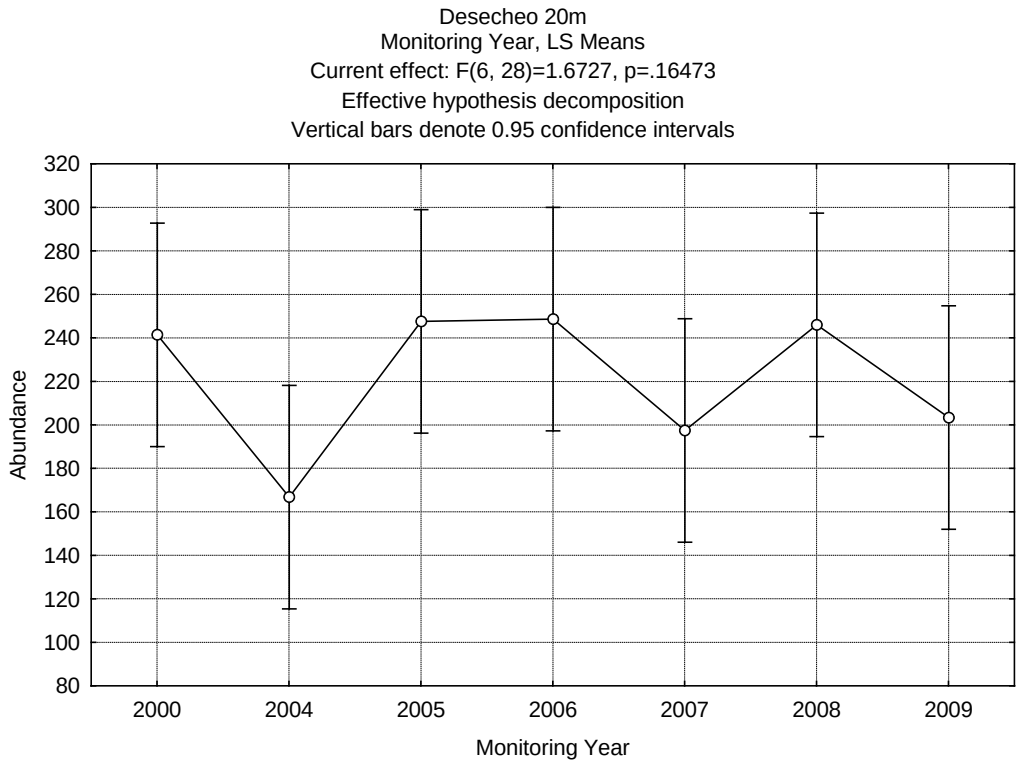
Appendix 3. Analysis of variance (ANOVA) procedure testing difference of fish species abundance (spp/transect) between monitoring surveys.

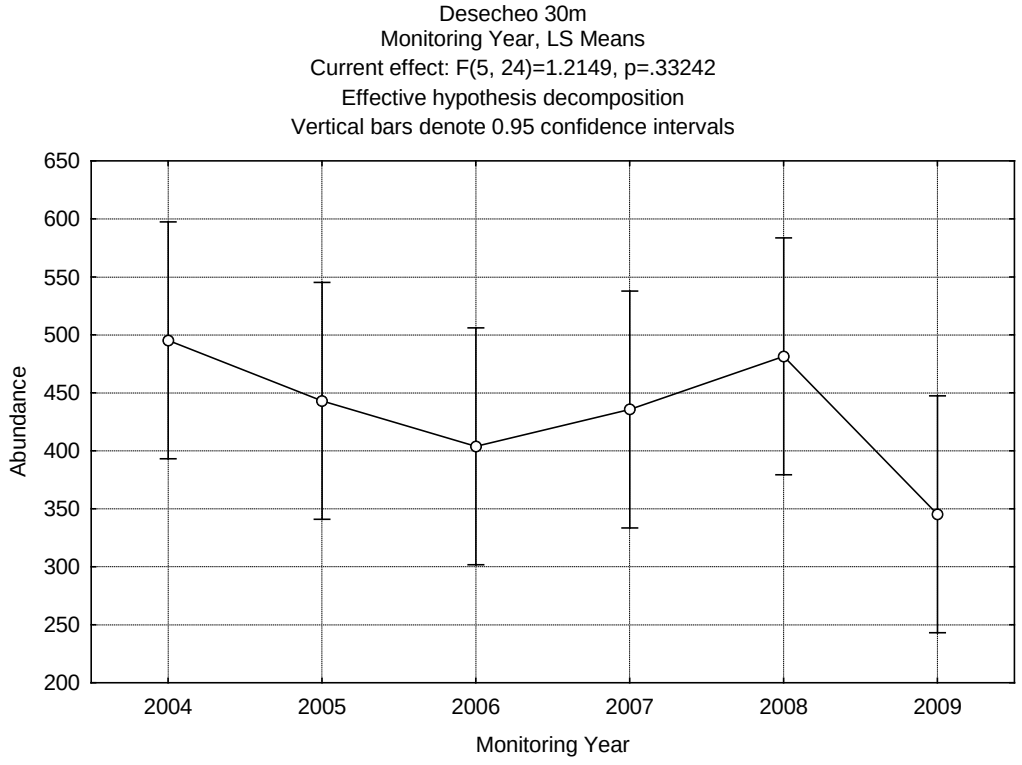


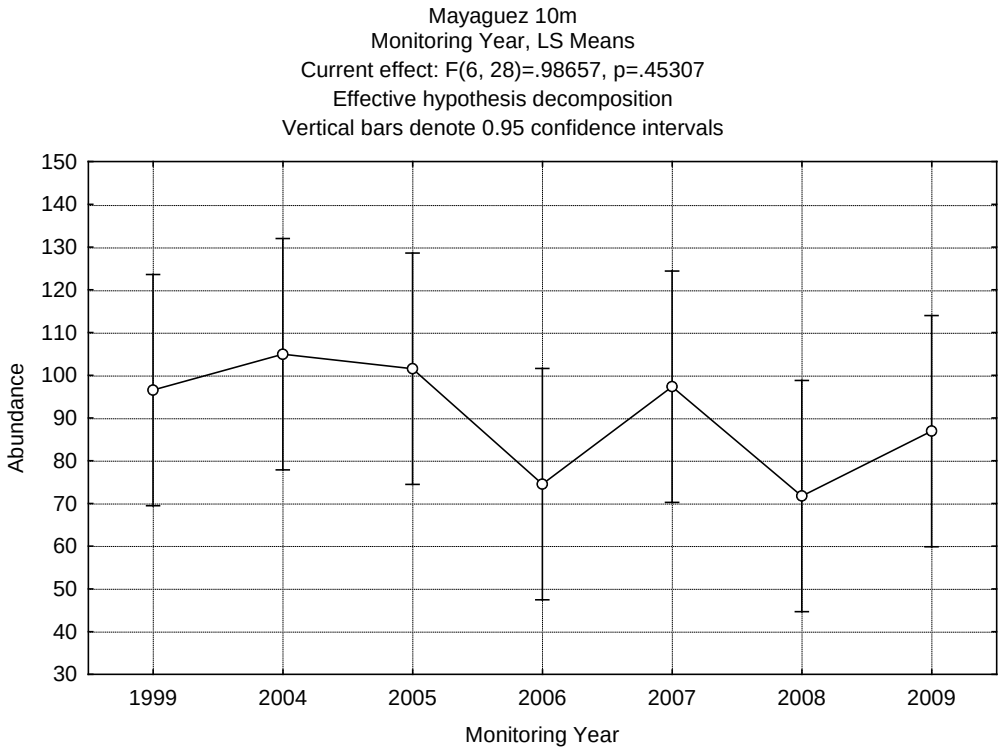


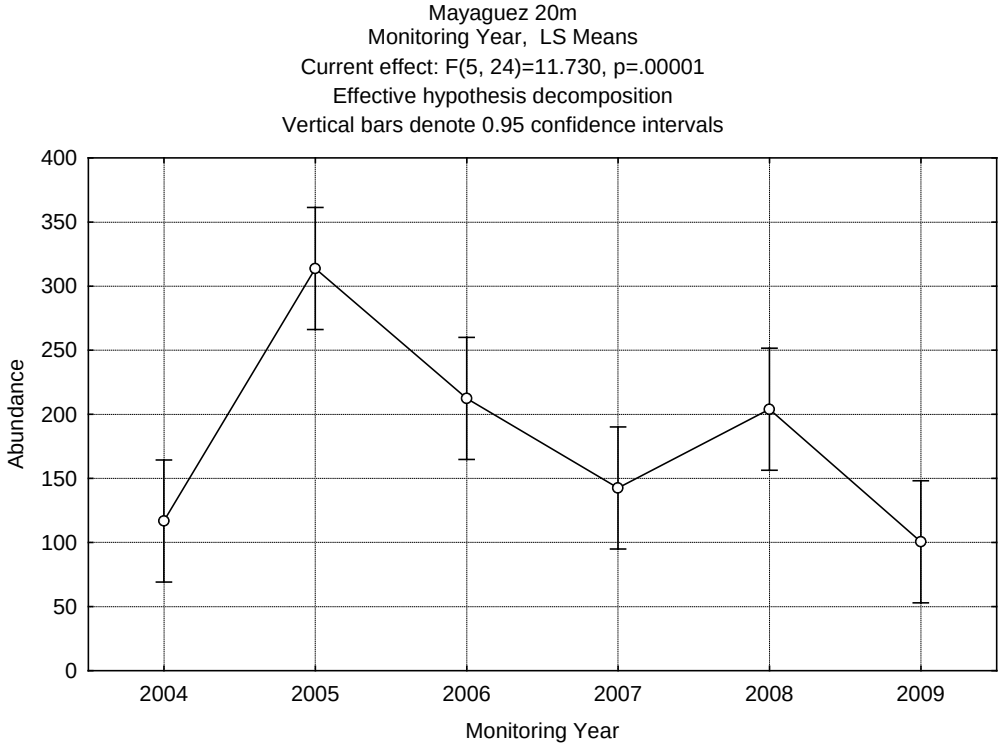

Rincon 20m
Monitoring Year, LS Means
Current effect: F(5, 24)=4.0134, p=.00868
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
800
700
600
500
400
300
200
100
0
2004
2005
2006
2007
2008
2009
Monitoring Year

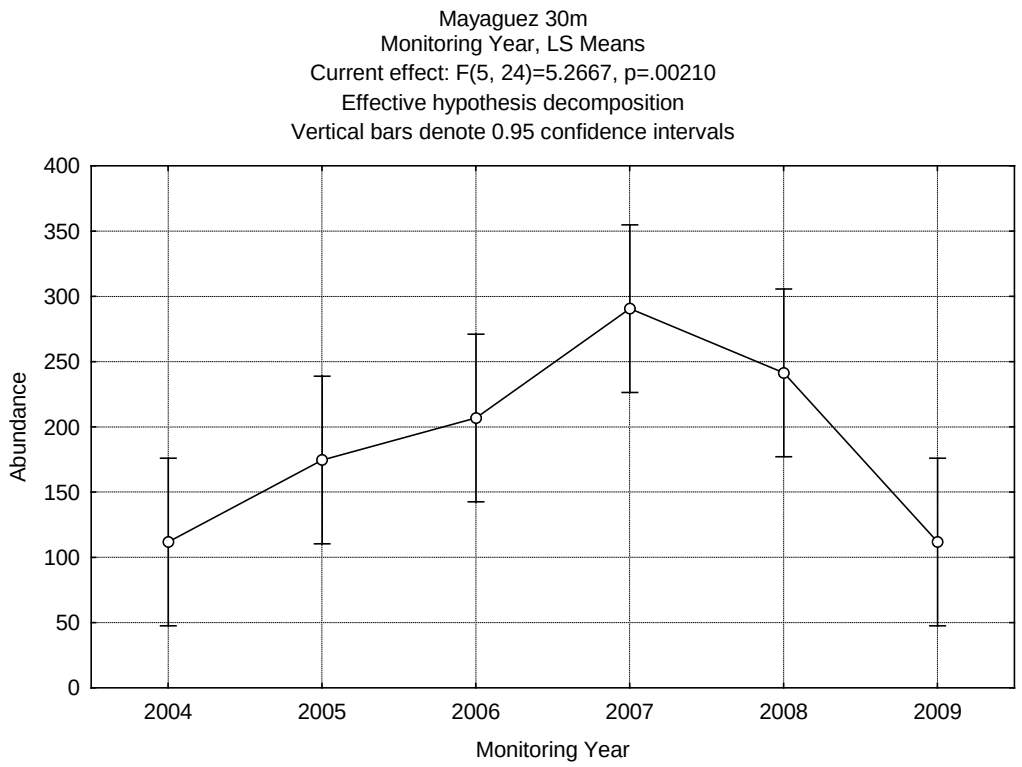

Desecheo 15m
Monitoring Year, LS Means
Current effect: F(5, 24)=4.3823, p=.00563
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
400
350
300
250
200
150
100
50
0
2004
2005
2006
2007
2008
2009
Monitoring Year

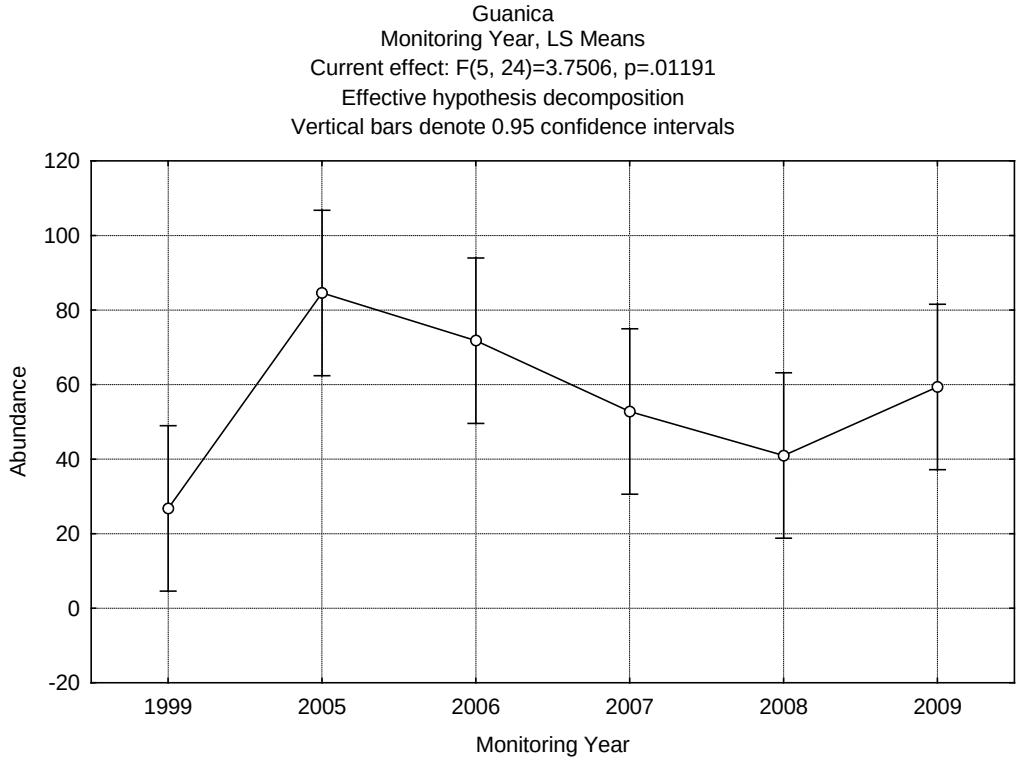

Desecheo 20m
Monitoring Year, LS Means
Current effect: F(6, 28)=1.6727, p=.16473
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
320
300
280
260
240
220
200
180
160
140
120
100
80
2000
2004
2005
2006
2007
2008
2009
Monitoring Year

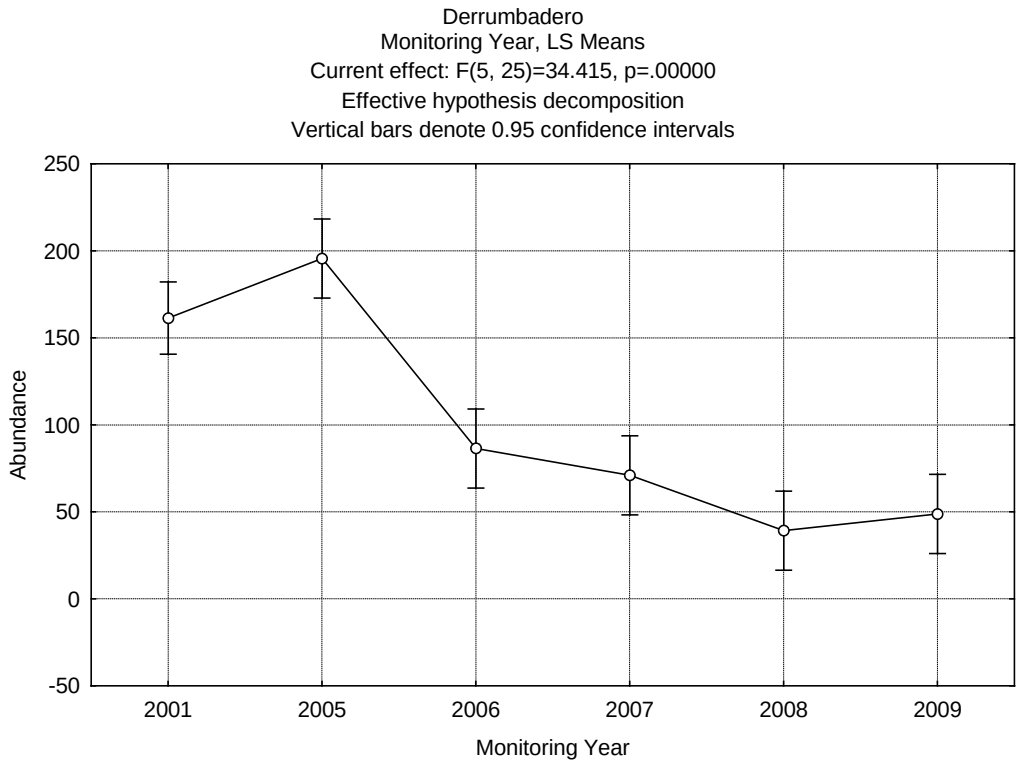

Desecheo 30m
Monitoring Year, LS Means
Current effect: F(5, 24)=1.2149, p=.33242
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
650
600
550
500
450
400
350
300
250
200
2004
2005
2006
2007
2008
2009
Monitoring Year

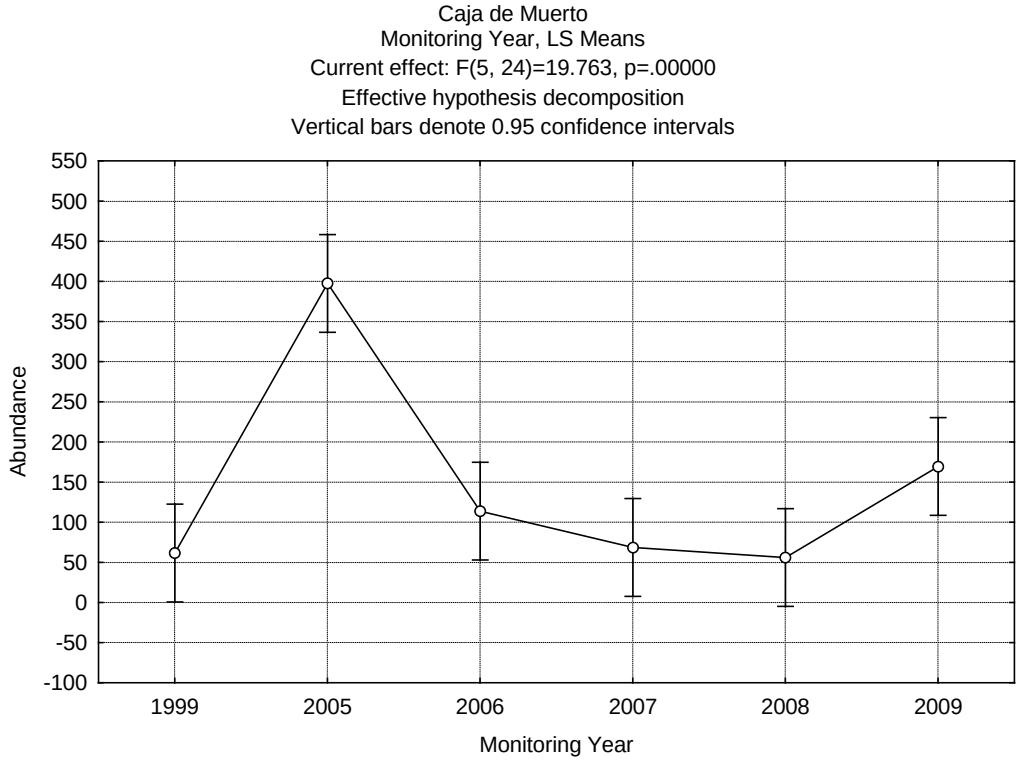

Mayaguez 10m
Monitoring Year, LS Means
Current effect: F(6, 28)=.98657, p=.45307
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
150
140
130
120
110
100
90
80
70
60
50
40
30
1999
2004
2005
2006
2007
2008
2009
Monitoring Year

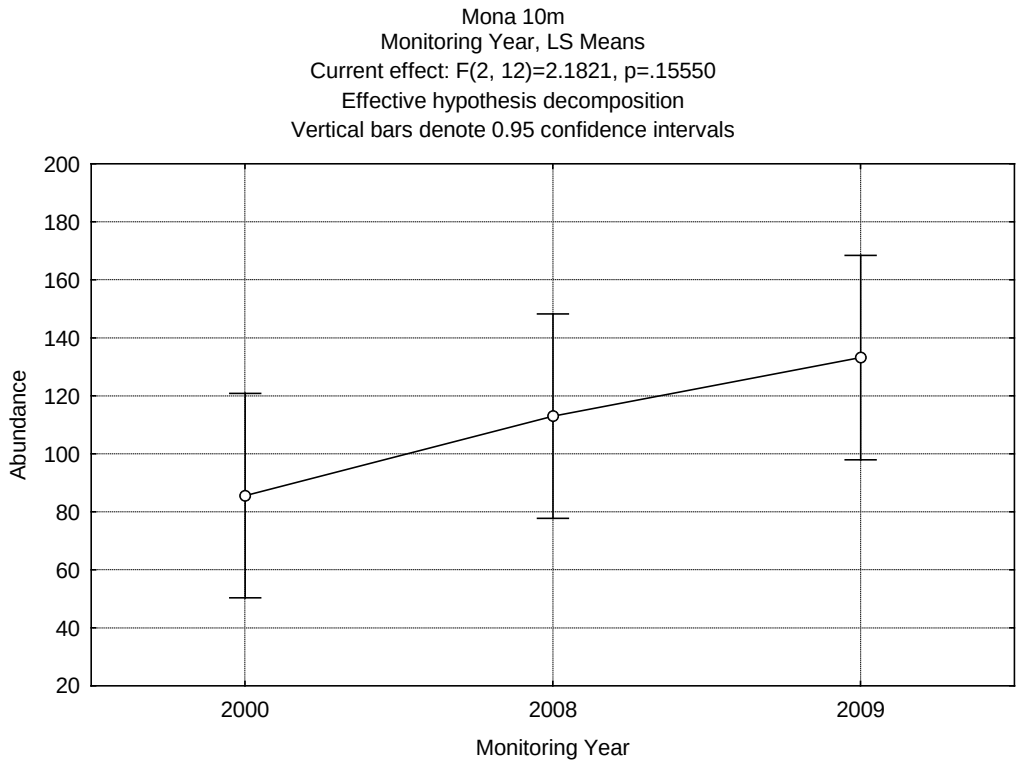

Mayaguez 20m
Monitoring Year, LS Means
Current effect: F(5, 24)=11.730, p=.00001
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
400
350
300
250
200
150
100
50
0
2004
2005
2006
2007
2008
2009
Monitoring Year

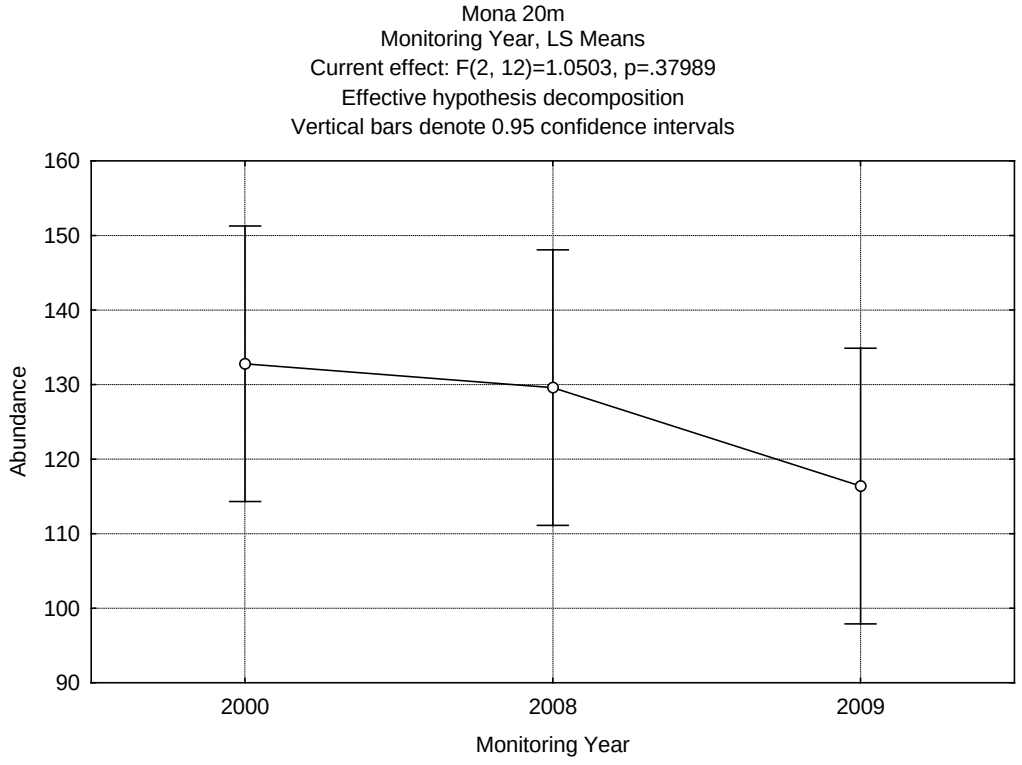

Mayaguez 30m
Monitoring Year, LS Means
Current effect: F(5, 24)=5.2667, p=.00210
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
400
350
300
250
200
150
100
50
0
2004
2005
2006
2007
2008
2009
Monitoring Year

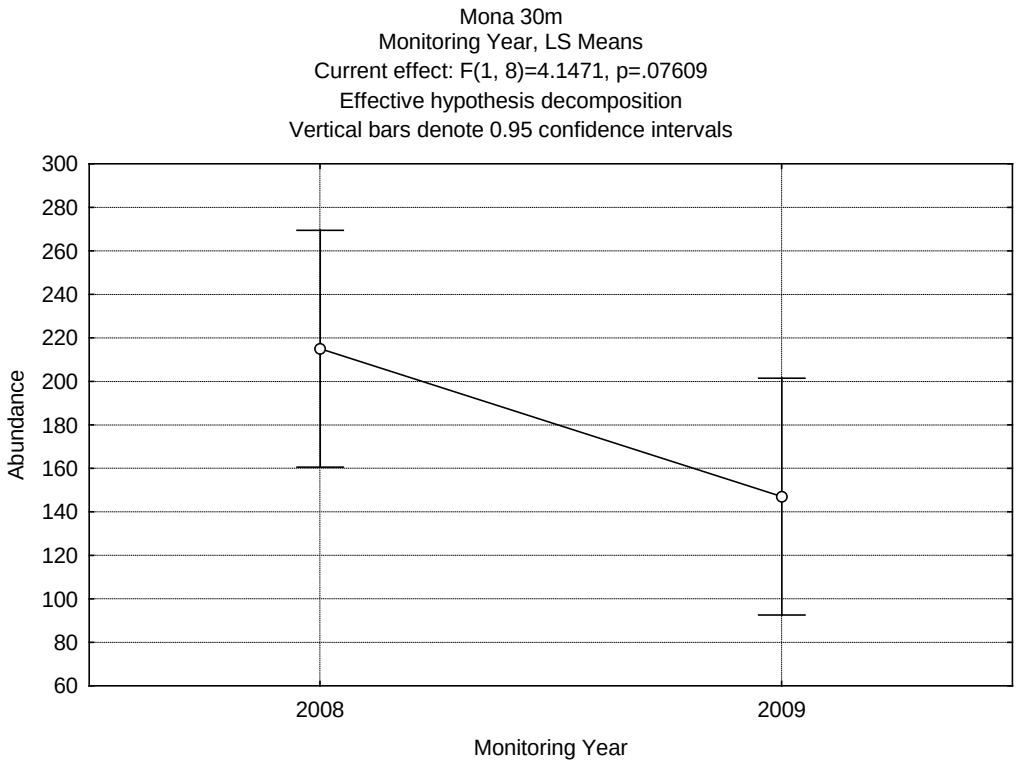

Guanica
Monitoring Year, LS Means
Current effect: F(5, 24)=3.7506, p=.01191
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
120
100
80
60
40
20
0
-20
1999
2005
2006
2007
2008
2009
Monitoring Year


Derrumbadero
Monitoring Year, LS Means
Current effect: F(5, 25)=34.415, 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
2009
Monitoring Year

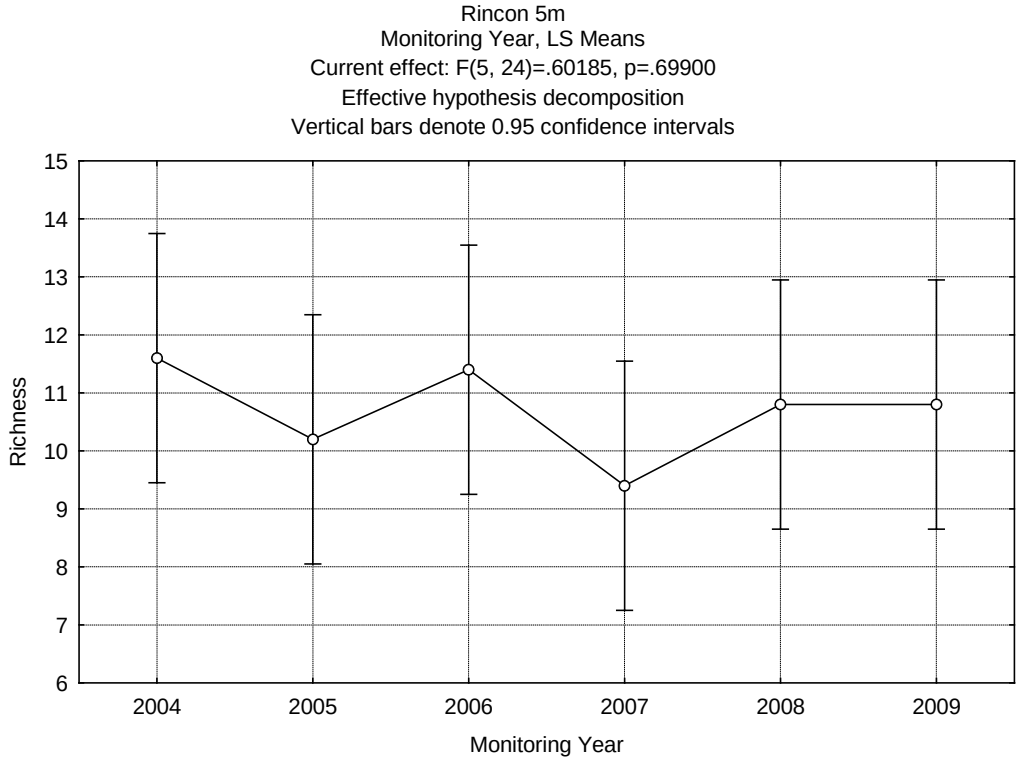

Caja de Muerto
Monitoring Year, LS Means
Current effect: F(5, 24)=19.763, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
550
500
450
400
350
300
250
200
150
100
50
0
-50
-100
1999
2005
2006
2007
2008
2009
Monitoring Year

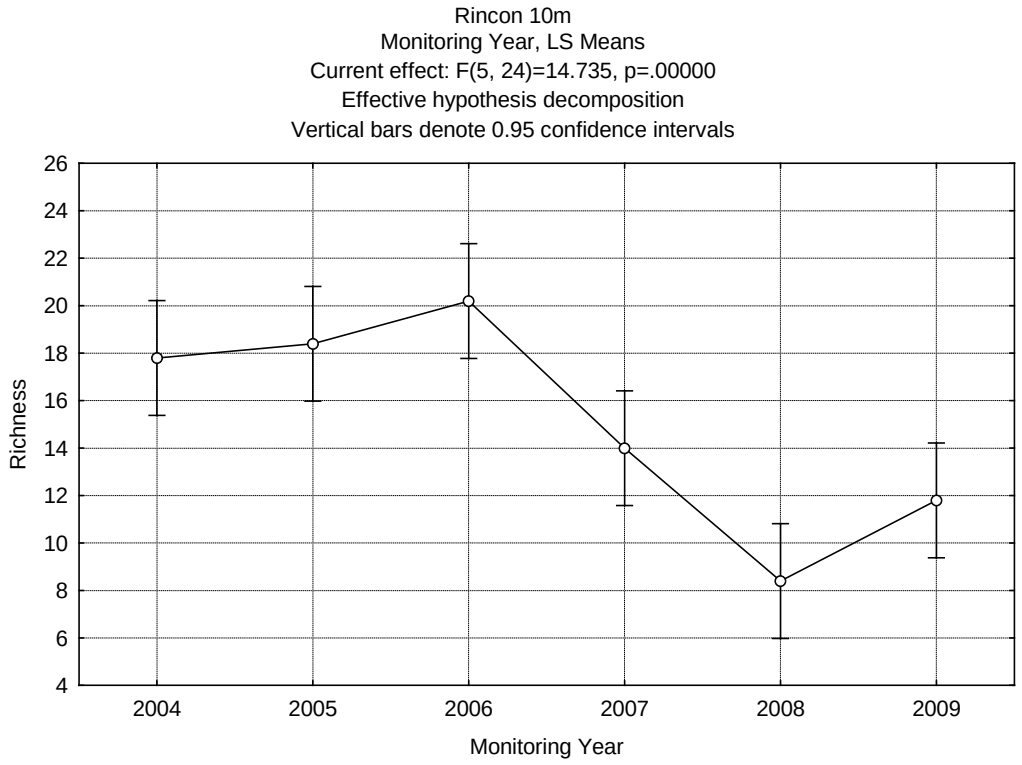

Mona 10m
Monitoring Year, LS Means
Current effect: F(2, 12)=2.1821, p=.15550
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
200
180
160
140
120
100
80
60
40
20
2000
2008
2009
Monitoring Year


Mona 20m
Monitoring Year, LS Means
Current effect: F(2, 12)=1.0503, p=.37989
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance
160
150
140
130
120
110
100
90
2000
2008
2009
Monitoring Year

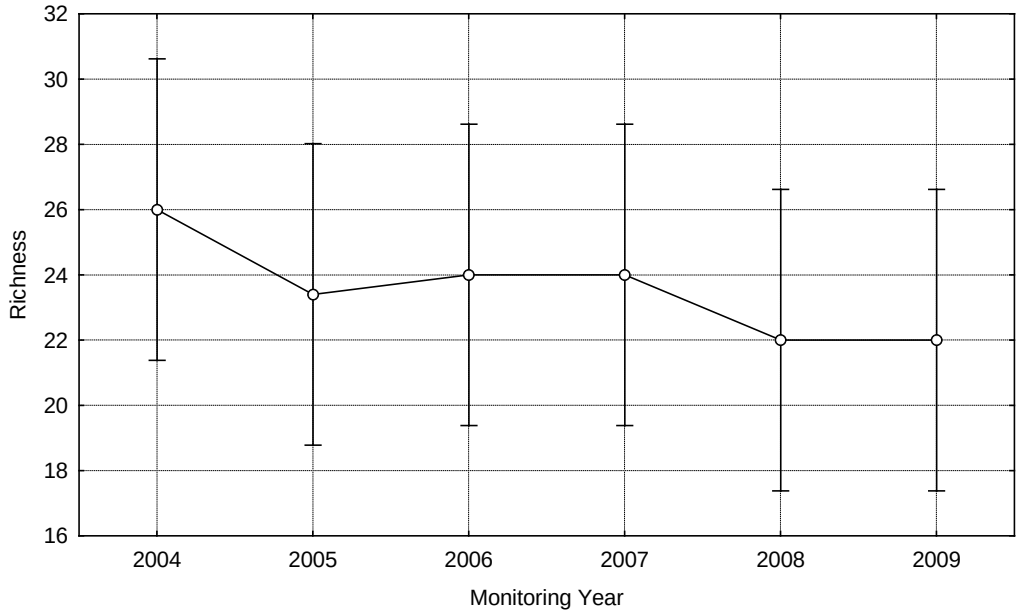

Mona 30m
Monitoring Year, LS Means
Current effect: F(1, 8)=4.1471, p=.07609
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
300
280
260
240
220
200
180
160
140
120
100
80
60
Abundance
2008
2009
Monitoring Year

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

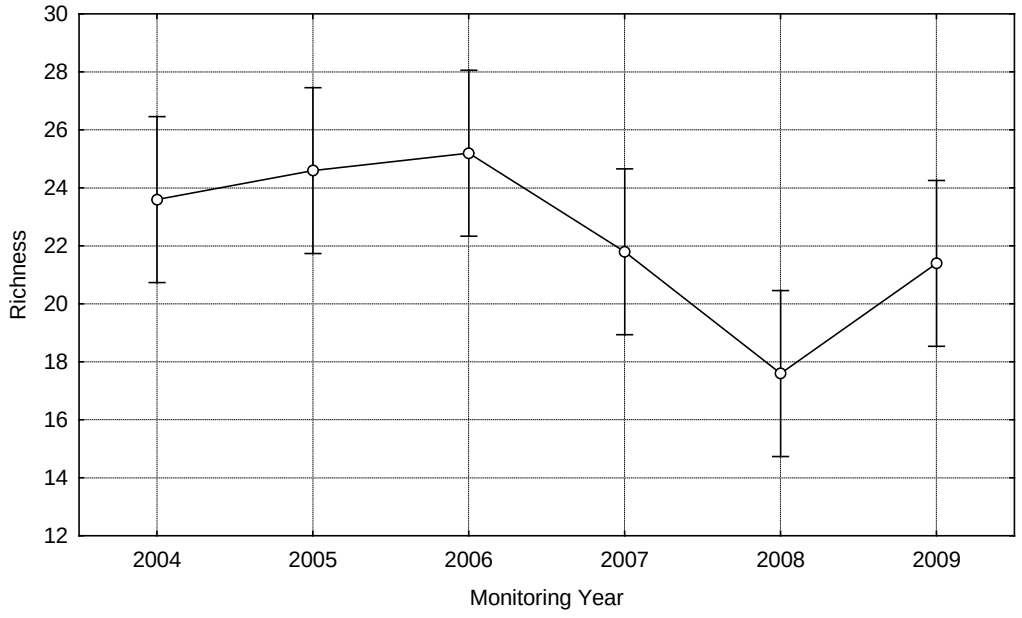


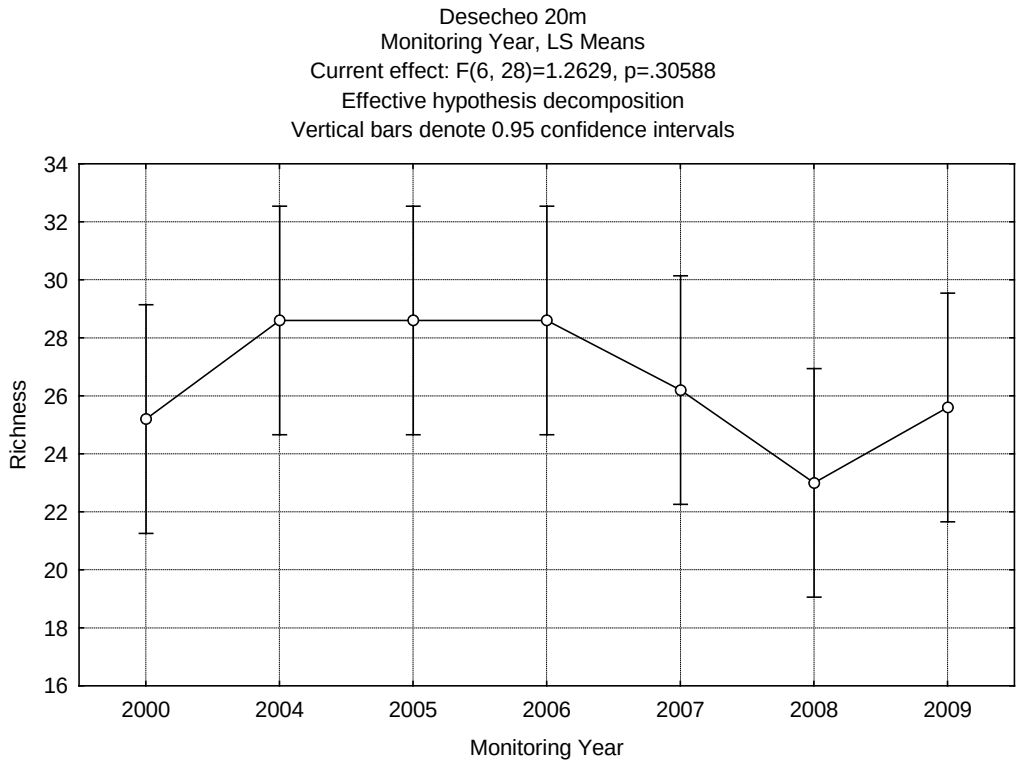


Rincon 20m
Monitoring Year, LS Means
Current effect: F(5, 24)=.44844, p=.81016
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals



Desecheo 15m
Monitoring Year, LS Means
Current effect: F(5, 24)=4.0118, p=.00870
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals




Desecheo 20m
Monitoring Year, LS Means
Current effect: F(6, 28)=1.2629, p=.30588
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
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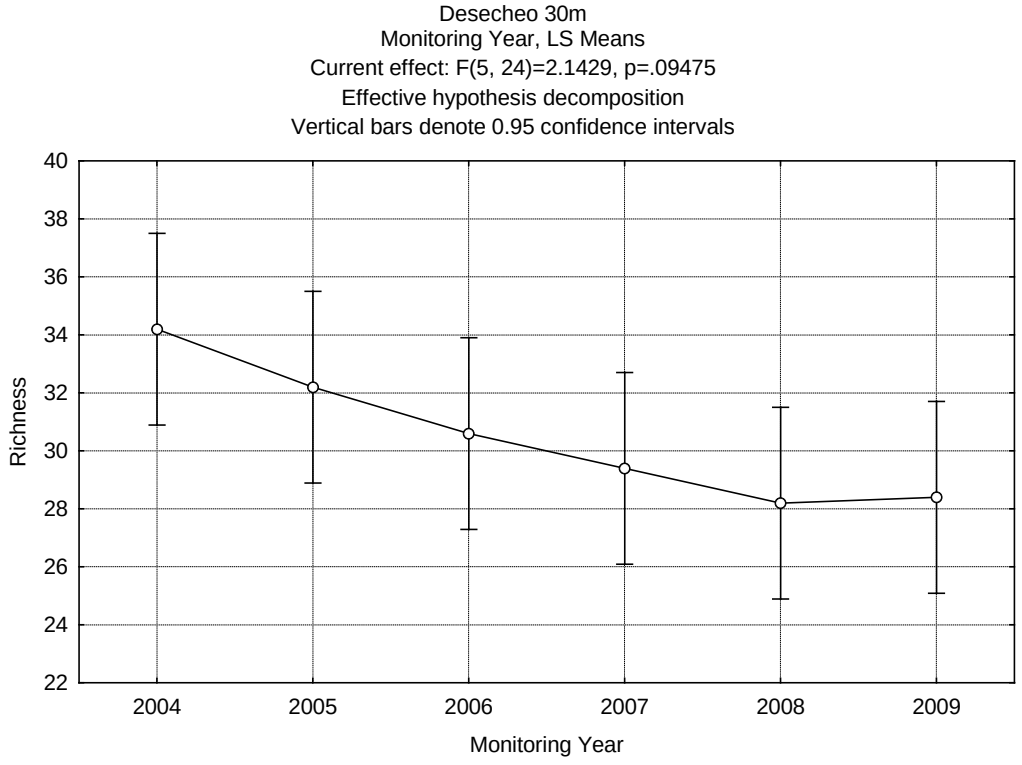
2008
2009
Monitoring Year


Desecheo 30m
Monitoring Year, LS Means
Current effect: F(5, 24)=2.1429, p=.09475
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
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2004
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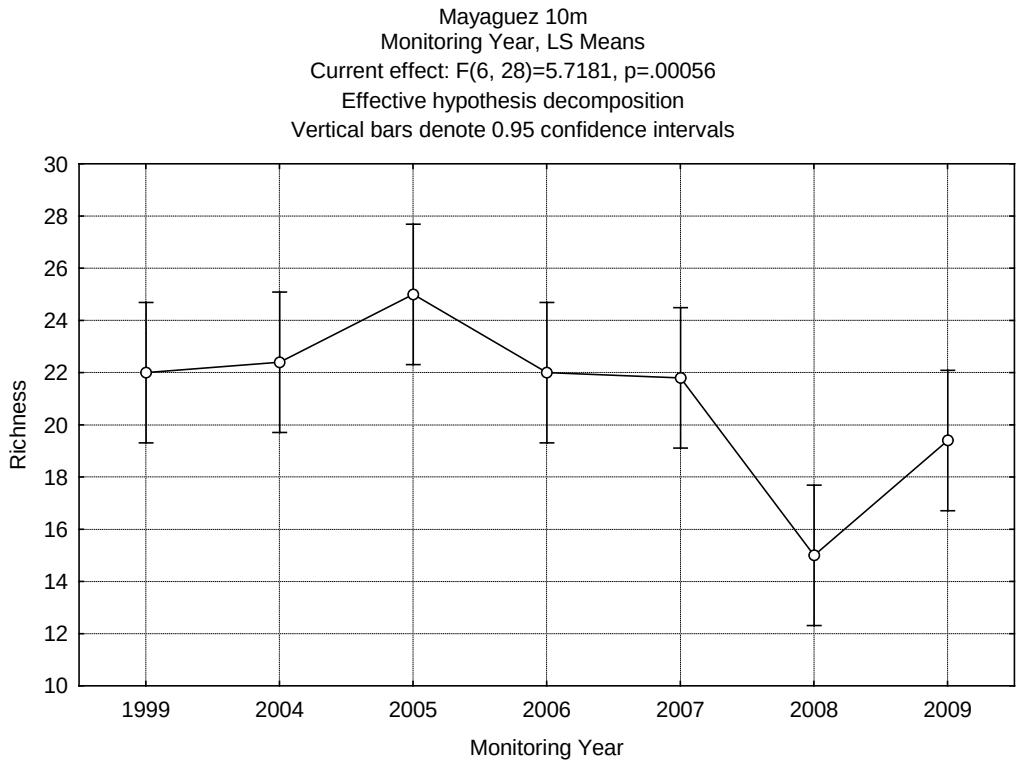
Monitoring Year


Mayaguez 10m
Monitoring Year, LS Means
Current effect: F(6, 28)=5.7181, p=.00056
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
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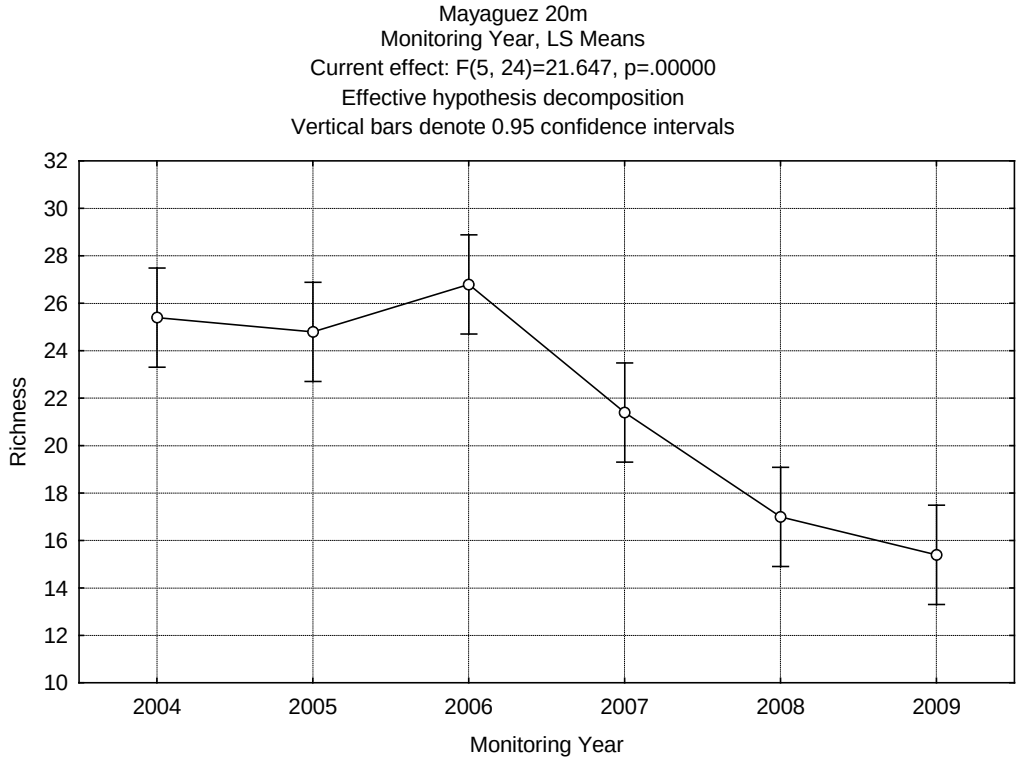
Monitoring Year


Mayaguez 20m
Monitoring Year, LS Means
Current effect: F(5, 24)=21.647, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
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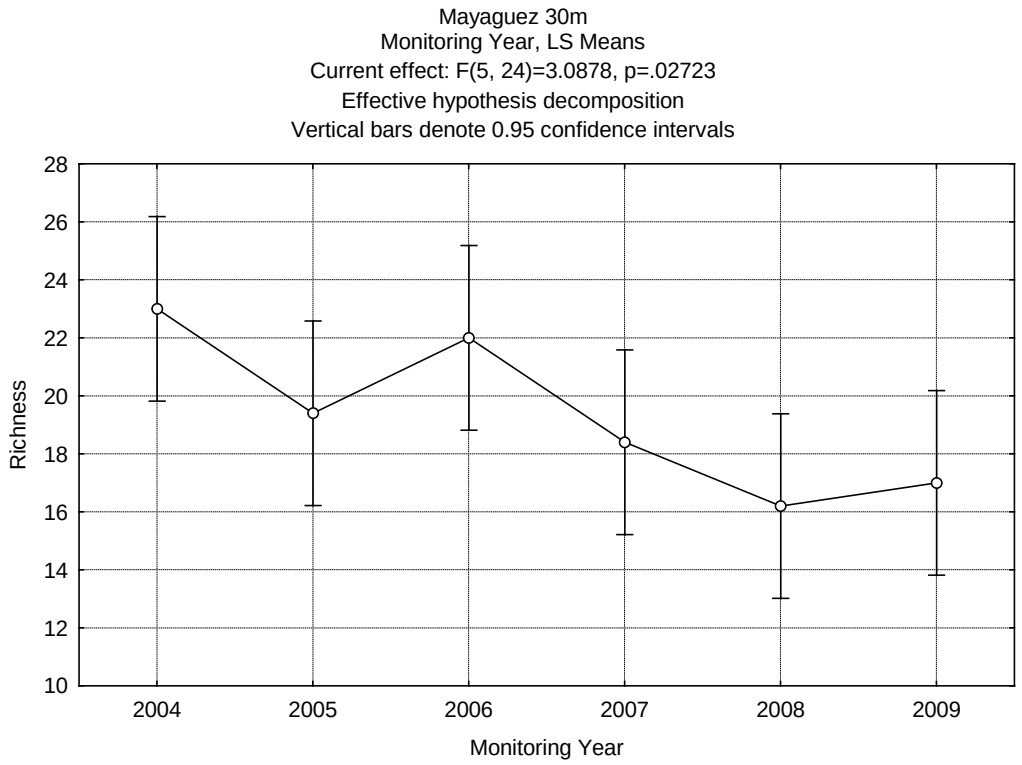
Monitoring Year


Mayaguez 30m
Monitoring Year, LS Means
Current effect: F(5, 24)=3.0878, p=.02723
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
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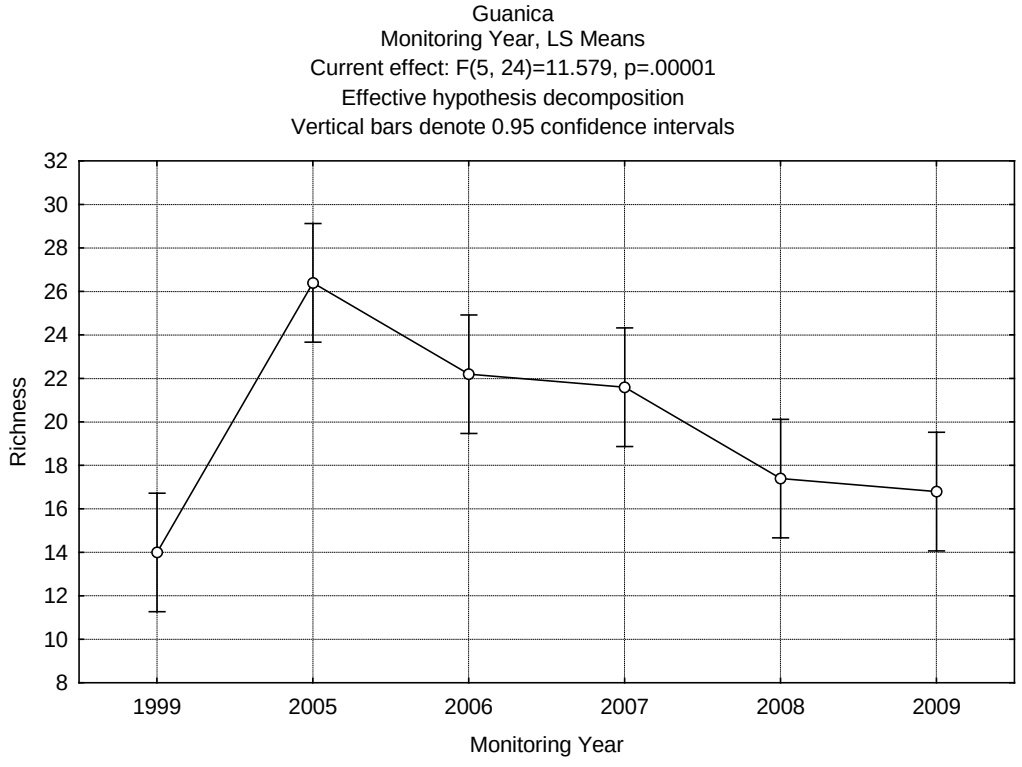
Monitoring Year


Guanica
Monitoring Year, LS Means
Current effect: F(5, 24)=11.579, p=.00001
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
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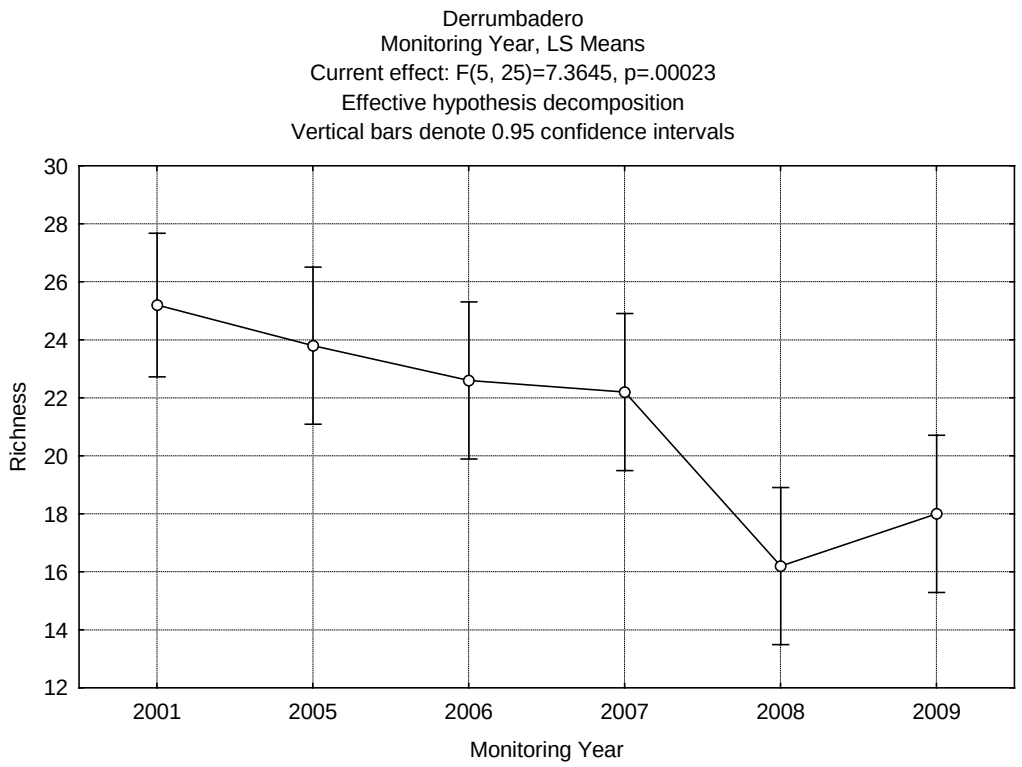
Monitoring Year


Derrumbadero
Monitoring Year, LS Means
Current effect: F(5, 25)=7.3645, p=.00023
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
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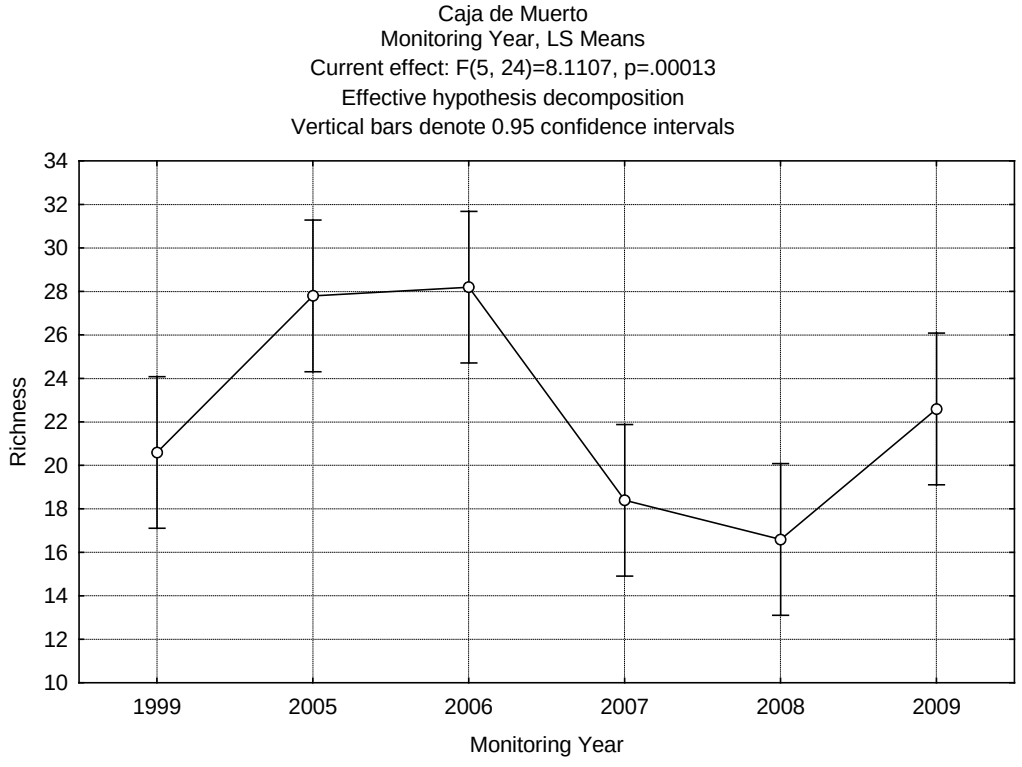
Monitoring Year


Caja de Muerto
Monitoring Year, LS Means
Current effect: F(5, 24)=8.1107, p=.00013
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
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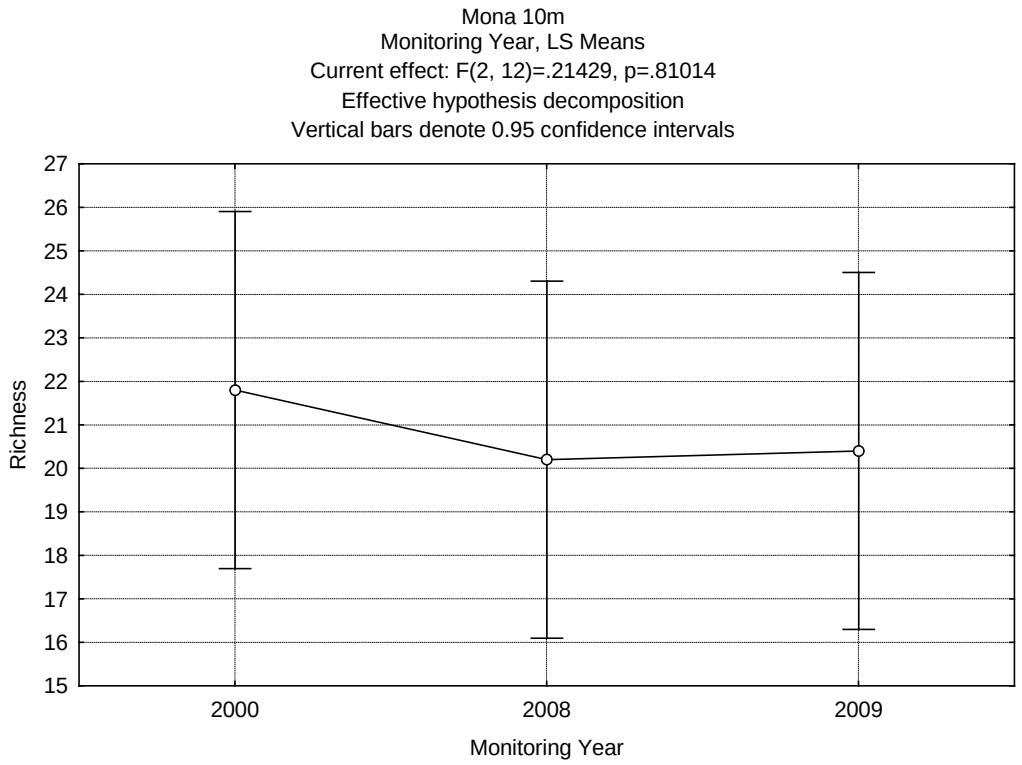
Monitoring Year


Mona 10m
Monitoring Year, LS Means
Current effect: F(2, 12)=.21429, p=.81014
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
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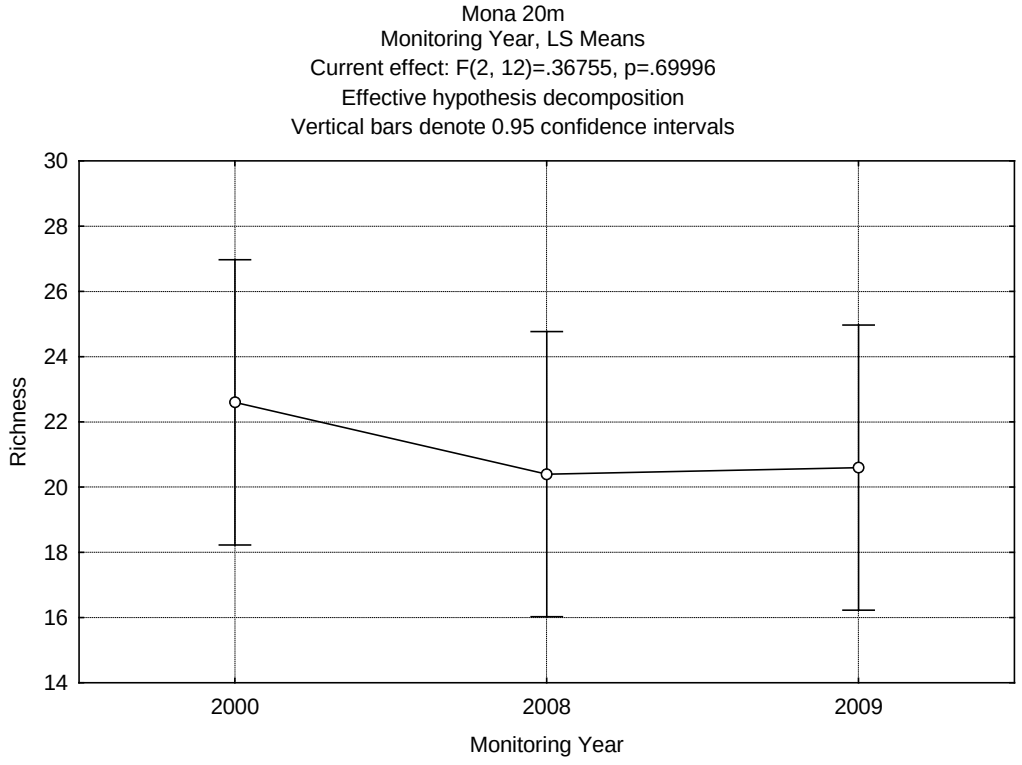
Monitoring Year


Mona 20m
Monitoring Year, LS Means
Current effect: F(2, 12)=.36755, p=.69996
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness
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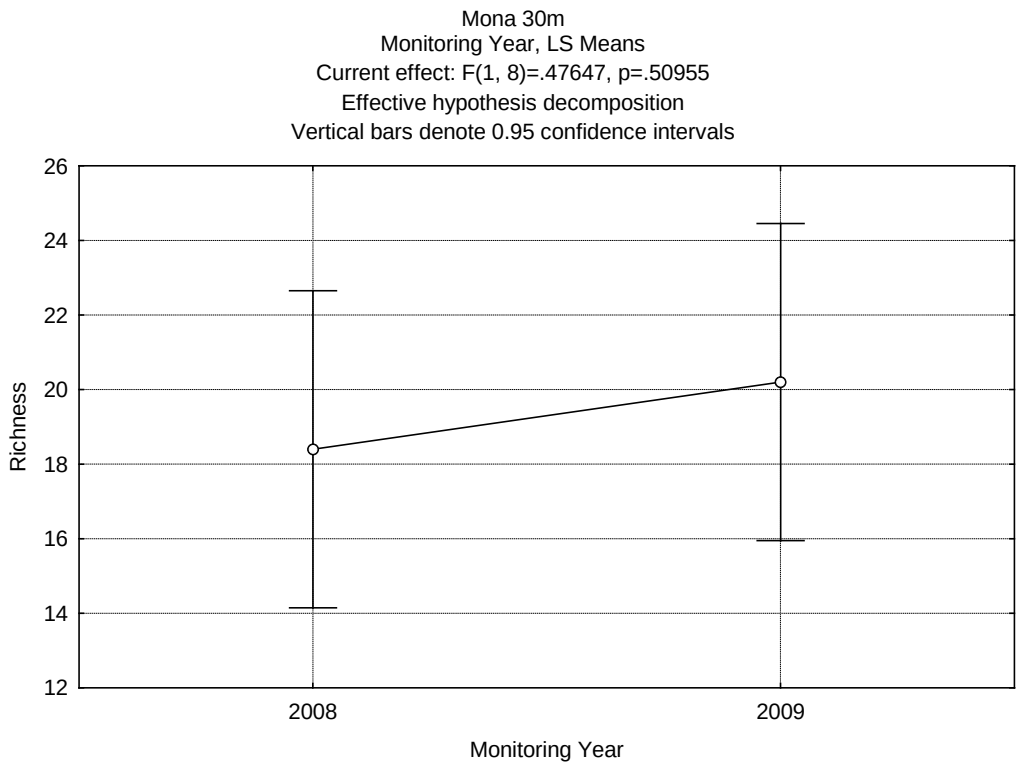
2009
Monitoring Year


Mona 30m
Monitoring Year, LS Means
Current effect: F(1, 8)=.47647, p=.50955
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
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Richness
2008
2009
Monitoring Year