FINAL REPORT

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I Executive Summary

A total of 15 reefs from seven Natural Reserves were included in the 2007-10 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 most recent 2009-10 monitoring survey, live coral cover presented a pattern of mild increments relative to 2007- 09 levels for most reefs, 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 2008. Two mesophotic reef stations presented a decline of live coral cover during the 2007-10 period, Sardinera Reef 30m (Isla de Mona) and Puerto Canoas Reef 30m (Isla Desecheo). The Sardinera Reef exhibited a very marked increment of substrate cover by cyanobacteria, a condition that was also observed at other reef stations of Isla de Mona (e.g. Playa Mujeres and Las Carmelitas). The decline of coral cover at Puerto Canoas is a persisting trend that started in 2006 after the coral bleaching event, and that has prevailed until present. A gradual, corresponding increase in sponges has been measured. The *Acropora palmata* finging reef of Tres Palmas in Rincon is infected by what appears to be white pox, an infectious disease also known as “patchy necrosis”. The infection prevalence in colonies is very high (>80%) and although reef substrate cover by *A. palmata* appears to be stable, given favorable conditions for the disease massive coral mortality can be expected.

Fish populations presented in the 2010 survey a general trend of stabilized abundance and species richness relative to the 2008 levels. Statistically significant differences of abundance between annual surveys were observed in seven out of the 12 reef stations monitored. 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 differences 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 were 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 if declines 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. Lionfishes (*Pterois volitans*) were present in the vicinity of our reef monitoring stations in Puerto Canoas 30m and Puerto Botes 20m of Isla Desecheo, the shelf-edge reef at Tres Palmas in Rincon 20m, and the Sardinera Reef of Isla de Mona. Exept for the latter, reductions of both fish species richness and abundance were measured at these reefs during the 2010 survey relative to the previous 2009 survey when no lionfishes were observed. Although such declines were not statistically significant, the pattern may become more pronounced if a larger population of these piscivores is established in the reefs. Although in low abundance, large demersal (top predator) fishes were detected during ASEC surveys in several reefs during the 2007-10 monitoring period. These include Reef Sharks (*Carcharhinus perezi*), Yellowfin, Yellowmouth, Tiger, Jewfish, and Nassau Groupers (*Mycteroperca venenosa, M. interstitialis, M. tigris, Epinephelus itajara, E. striatus*), and the Cubera, Dog and Mutton Snappers (*Lutjanus cyanopterus, L. jocu, L. analis*).

Coral bleaching at the reef community level was not observed on any reef surveyed in the program during the 2007 – 10 monitoring period.

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Introduction

This is the final report corresponding to the 2007-10 funding cycle of the Puerto Rico Coral Reef Monitoring Program, sponsored by NOAA and administered by the PR Department of Natural and Environmental Resources (PRDNER). The monitoring program includes quantitative and qualitative measurements of reef substrate cover by sessile-benthic categories and characterizations of taxonomic composition and abundance of fishes and motile megabenthic invertebrates from a total of 15 reef stations within seven Natural Reserve sites in Puerto Rico (Isla Desecheo, Isla de Mona, Rincon, Mayaguez, Guánica, Isla Caja de Muertos and Ponce). Initial baseline characterization surveys for these sites were performed during 1999 - 2001 (García-Sais et al., 2001 a, b, c). Summarized time series data for all reef sites are here presented and analyzed, but detailed monitoring data is included only for the most recent 2009-10 survey, which represents the seventh event at Isla Desecheo 20m and Mayaguez 10m reefs, the sixth for Isla Desecheo 15 and 30m, Derrumbadero 20m, Guanica 10m, Caja de Muerto 10m, Rincon 3, 10, and 20m reef stations, and the third monitoring survey of coral reefs from Isla de Mona, nine years after the baseline survey of 2001. Complete data sets for all reef sites can be found in the previous annual monitoring reports prepared by García et al. (2004, 2005, 2006, 2007, 2008, 2009). Such information contributes to an existing network of U.S. coral reef monitoring sites sponsored by NOAA and administered by DNER.

During the 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, but statistically significant (ANOVA; $p < 0.05$) only at Tourmaline Reef (depth: 20 m) and at Puerto Canoas Reef (depth: 30m) in Isla Desecheo. Such reductions of live coral cover were regarded as lingering effects of the 2005-06 coral bleaching event that severely affected coral reefs in Puerto Rico and throughout the northern Caribbean (Garcia et al. 2006, 2007). The decline of (total) live coral cover at the reef community level after the 2005 bleaching event in Puerto Rico 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. After two consequtive years of measuring what appered to

be lingering effects of the 2005 coral bleaching event, subtle increments of live coral cover were measured in the 2008-09 monitoring survey (Garcia et al. 2008). Differences between years were not statistically significant, but the trend represented at least, a reversal from the continued decline of live coral cover since the 2005 monitoring survey. An exception to this trend was observed at the fringing *Acropora palmata* reef of Tres Palmas in Rincon, which presented a declining trend of live coral cover associated with a widespread infection of "white pox", a disease also known as "patchy necrosis" (Garcia et al. 2008). Monitoring trends of the sessile-benthic reef communities during the 2009-10 are included in this report.

A total of 184 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 structure, but a trend of fluctuating differences of abundance within belt-transects in seven out of the 15 reef stations surveyed (García-Sais et al., 2007, 2008, 2009). Variations between surveys were mostly associated with fluctuations of abundance by numerically dominant populations that exhibit highly aggregated distributions, such as the Masked Goby (*Coryphopterus personatus*), Blue Chromis (*Chromis cyanea*) and Creole Wrasse (*Clepticus parrae*). It is uncertain at this point if such fluctuations of abundance by reef fishes closely associated with coral habitats are related to the severe 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 ASEC surveys in several reefs. These include Yellowfin, Tiger, Jewfish, and Nassau Groupers (*Mycteroperca venenosa, M. tigris, Epinephelus itajara, E. striatus*), and the Cubera, Dog and Mutton Snappers (*Lutjanus cyanopterus, L. jocu, L. analis*).

III Methodology

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

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

Site/Reef Stations	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

Sessile-benthic reef communities

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

profiles by assignment of metric units to each substrate transition, which serves as a high precision baseline for monitoring. The chain has links of 1.42 cm long, marked every 10 links for facilitation of counting underwater. The exact position of the chain was guided by a series of steel nails hammered into available hard (abiotic) substrate at approximately every 1.0 m in the reef. Also, a thin nylon reference line was stretched from rod to rod to guide divers over the linear transect path. Individual measurements of substrate categories, as recorded from the number of chain links were sorted, added and divided by the total distance (in chain links) on each transect to calculate the cumulative percent linear cover by each substrate category. Soft corals, with the exception of encrusting forms (e.g. *Erythropodium caribaeorum*) were identified and counted as number of colonies intercepted per transect, whenever any of their branches crossed the transect reference line. The vertical relief of the reef, or rugosity, was calculated by subtracting 10 meters from the total length (links) recorded with the chain at the 10 m marker of the reference line.

Reef fishes and motile megabenthic invertebrates

Demersal and territorial reef fish populations and motile megabenthic invertebrates were surveyed by sets of five 10 m long by 3 m wide ($30m^2$) belt-transects centered along the reference line of transects used for sessile-benthic reef characterizations at each reef station. A total of 75 belt-transects for characterization of fishes and motile megabenthic invertebrates were executed during the monitoring survey at the seven marine reserve sites.

Transect width was marked with flagging tape stretched and tied to weights on both transect ends. Each transect was surveyed during 15 minutes. The initial two minutes were dedicated to detection of elusive and/or transitory species that swim away of the "belt-transect" area as soon as they detect a diver (e.g. snappers, large groupers, hogfish, mackerel, large parrotfishes, etc.). During the next four minutes, the diver swam over both sides of the transect area counting fishes that form schooling aggregations over the reef (e.g. *Chromis spp., Clepticus parrae, Bodianus*, etc.) and other transitory species as they enter the survey area, including the wrasses (e.g. *Thalassoma, Halichoeres spp*.) which tend to be attracted to divers and thereby, may increase in density during the survey. A second run over both sides of the transect was performed during the next six minutes of the survey in order to count demersal and territorial fishes

(e.g. *Stegastes spp*, *Gramma loreto*, squirrelfishes, etc.) that remain within the transect area. The last three minutes were dedicated to counting the small gobies (e.g. *Coryphopterus spp*., *Elacatinus* spp.) associated with coral heads on both sides of transects. Fish species observed outside transect areas were reported to supplement the taxonomic assessment, but were not included in abundance determinations.

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

Annual variations of the percent reef substrate cover by live corals and fish species richness and abundance were tested using repeated measurements ANOVA for each reef station on the real values (un-transformed data). Annual means of live coral cover, and fish species richness and abundance with their respective 95% confidence interval calculated from the mean square error of the ANOVA procedure are shown in Appendices 2 – 4.

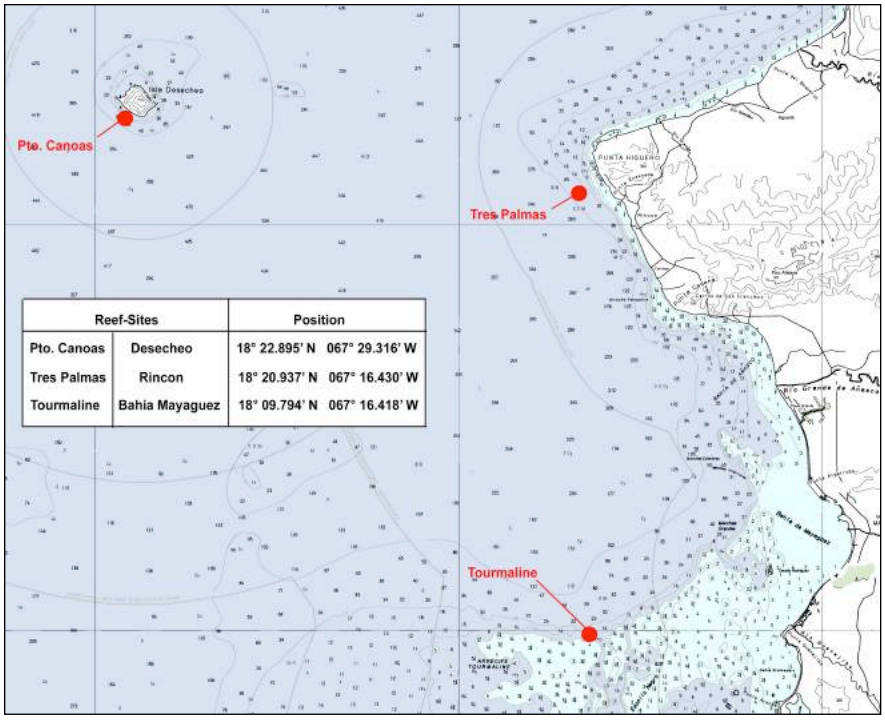


Figure 1. Location of west coast reef sites, Isla Desecheo, Mayaguez and Rincón

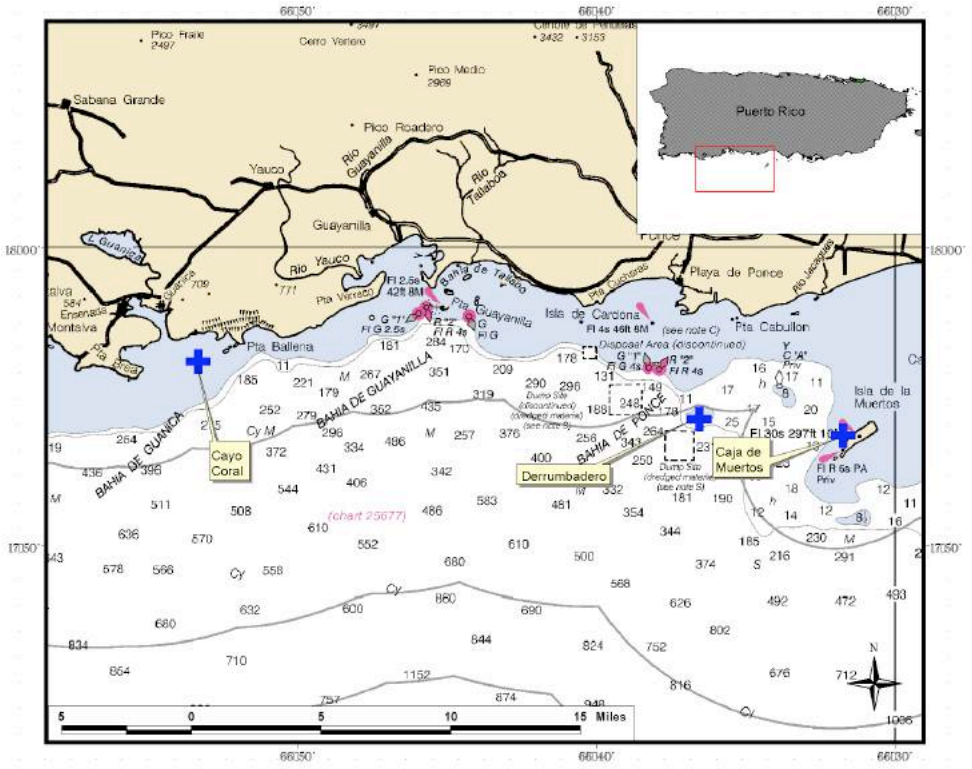


Figure 2. Location of south coast reef sites, Cayo Coral (Guánica), Derrumbadero and West Reef of Isla Caja de Muerto (Ponce)

Results

IV Baseline Characterization and Monitoring of Coral Reef Communities

A. Tres Palmas Reef System – Rincón

1.0 Fringing *Acropora palmata* (Elkhorn Coral) Reef

1.1 Sessile-benthic Reef Community

The rocky shoreline of the Tres Palmas Marine Reserve leads to a narrow backreef lagoon with coarse sandy sediments. The lagoon is a semi-protected environment associated with an extensive *Acropora palmata* (Elkhorn Coral) reef formation that has developed along a hard ground platform fringing the shoreline. The top of the platform is found at depths between 2 - 5 m. The branching Elkhorn Coral colonies are large, rising more than one meter from the hard ground platform almost to the surface and wide, extending more than two meters horizontally in many cases. Where the hard ground platform is continuous, coral colonies grow close together forming a dense and intertwined Elkhorn Coral biotope. Sand pools and channels separate the reef where the hard ground platform breaks up. Interspersed within the *A. palmata* biotope are abundant colonies of encrusting corals, mostly *Diploria clivosa, D. strigosa* and *Porites astreoides*. These encrusting and mound shaped stony corals and gorgonians are more abundant on the seaward slope of the hard ground platform 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 April 2008 this reef experienced the effect of exceptionally high waves, estimated in approximately 10 m (>30') associated with winter storms in the North Atlantic. As a result of this event, some of the permanent transect assemblage was destroyed and the

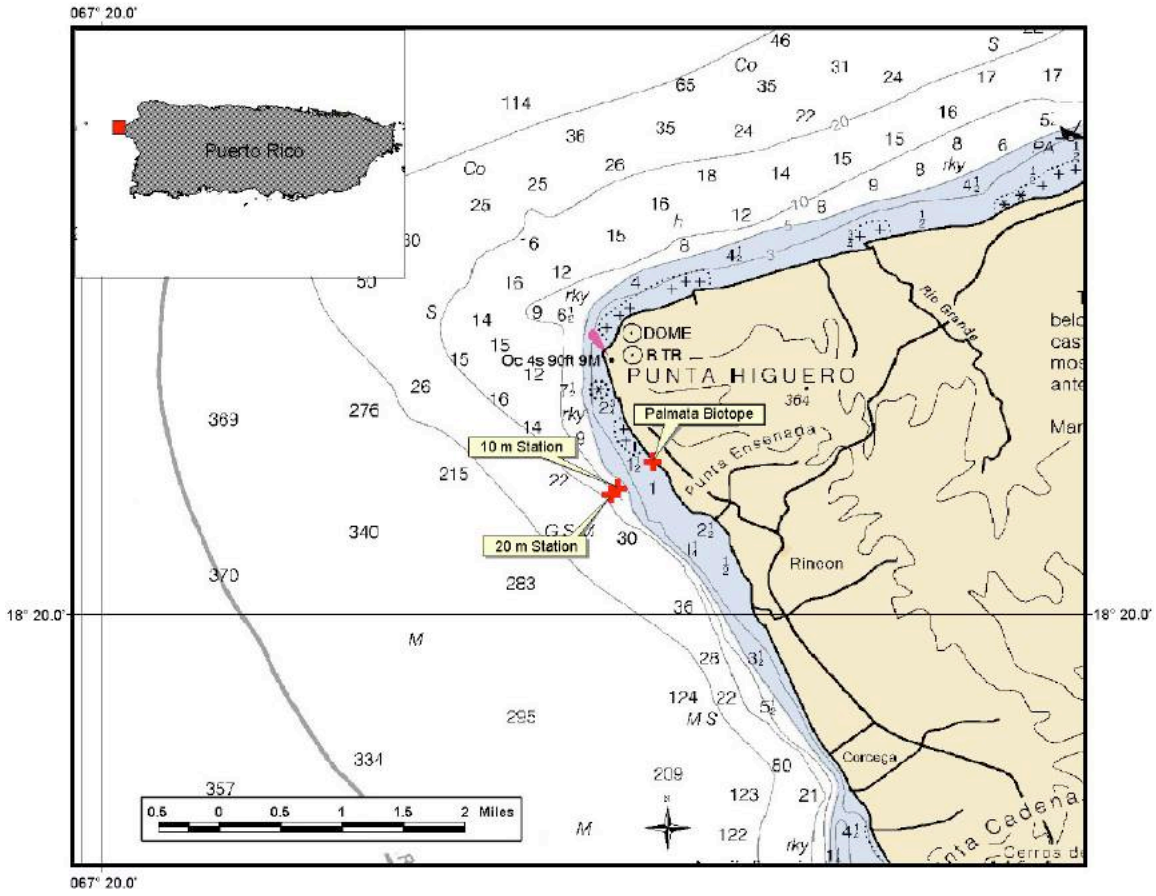


Figure 3. Location of coral reef monitoring stations off Tres Palmas, Rincón.

monitoring data for 2007-08 was gathered in error (out of transect lines) and removed from the data base. Reconstruction of the original transects was performed during the 2008-09 survey. Figure 3 shows the location of monitoring stations at the Tres Palmas Reef system in Rincón. Panoramic photos of the Tres Palmas fringing Elkhorn Coral reef are presented as Photo Album 1.

A set of five permanent transects were established along one continuous hard ground section of the fringing *Acropora palmata* reef at depths between 2 – 5 m (Figure 3). The percent of reef substrate cover by sessile-benthic categories along permanent transects during the present 2009-10 survey are presented in Table 2. Live coral cover averaged 29.2% (range: 15.9 – 52.8 %). Elkhorn Coral (*A. palmata*) was the dominant species with a mean substrate cover of 25.6 % (range: 4.6 – 52.8 %), representing 87.7 % of the total live coral cover. Five additional coral species (e.g. *Diploria strigosa, P. astreoides,*

Table 2. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon 2-5m. Survey Date: September, 2010

Depth: 2-5 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	2.7	3.7	4.3	2.3	2.8	**3.1**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	27.0	24.7	29.0	26.1	13.7	**24.1**
Gap			2.0	2.9	3.0	**1.6**
Sand				6.4	0.6	**1.4**
Total Abiotic	27.0	24.7	30.9	35.4	17.2	**27.0**
Benthic Algae						
Turf-mixed assemblage	40.8	22.5	40.0	32.5	66.9	**40.5**
Zoanthids *(Palythoa caribdea)*	16.4					**3.3**
Live Stony Corals						
Acropora palmata	14.2	52.8	26.0	30.2	4.6	**25.6**
Diploria strigosa	1.7				5.9	**1.5**
Porites astreoides			1.4	2.0	1.8	**1.0**
Montastraea cavernosa					3.2	**0.6**
Siderastrea siderea			1.7			**0.3**
Siderastrea radians					0.4	**0.1**
Total Stony Corals	15.9	52.8	29.0	32.2	16.0	**29.2**

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

Montastraea cavernosa, Siderastrea siderea and *S. radians*) were intersected by linear transects during our survey. A total of 17 species of stony corals were identified from the fringing reef. Hard ground substrates, including dead coral sections not colonized by corals were mostly covered by turf algae (mean cover: 40.5 %). Fleshy macroalgae (*Valonia sp., Stypopodium sp*.) and red coralline algae (*Amphiroa sp*.) were observed outside transect areas. The encrusting zoanthid, *Palythoa caribdea* was present in one transects with a mean cover of 2.9 %. The encrusting gorgonian, *Erythropodium caribaeorum* was observed outside transects. Abiotic categories, associated with reef overhangs, gaps or holes and sand represented 27.0 % 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 was stable during the 2004 – 2007 monitoring period (range: 38.6 % - 39.4 %), but declined to 33.3 % during the 2008-09 survey and to less than 30% during the present survey. Differences between monitoring surveys are not statistically significant (ANOVA; $p = 0.691$) because of the high variability in live coral cover within replicate transects. There is also high variability associated with sampling at this reef because of the irregular (three-dimensional) shape of the elkhorn coral colonies and the difficulties in following chain paths throughout the shallow reef buttress with wave action. A consistent decline of substrate cover by the main reef coral constituent, *Acropora palmata* was observed across all five transects during the 2008-09 survey relative to the baseline survey, but remained virtually stable during the present monitoring survey (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. Despite very high infection prevalence (almost every colony), the Tres Palmas Reef appears to be resisting the infection with new growth.

1.2 Reef Fishes and Motile Megabenthic Invertebrates

A total of 75 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 2009-10 monitoring survey, 60 fish species, including 25 present within belt-transects were identified from the fringing reef. The mean abundance of individuals was 130.6 Ind/30 m^2 (range: 97 - 167 Ind/30 m^2), and the mean number of species per transect was 12.8 (range: 10 - 15). The combined abundance of five species

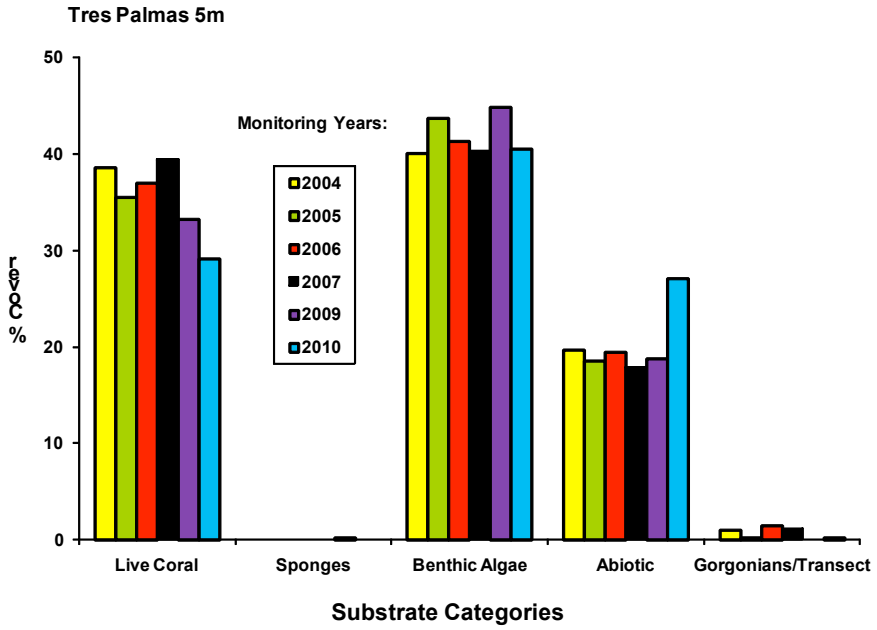


Figure 4. Monitoring trends (2004 – 2010) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon, 2 - 5 m depth.

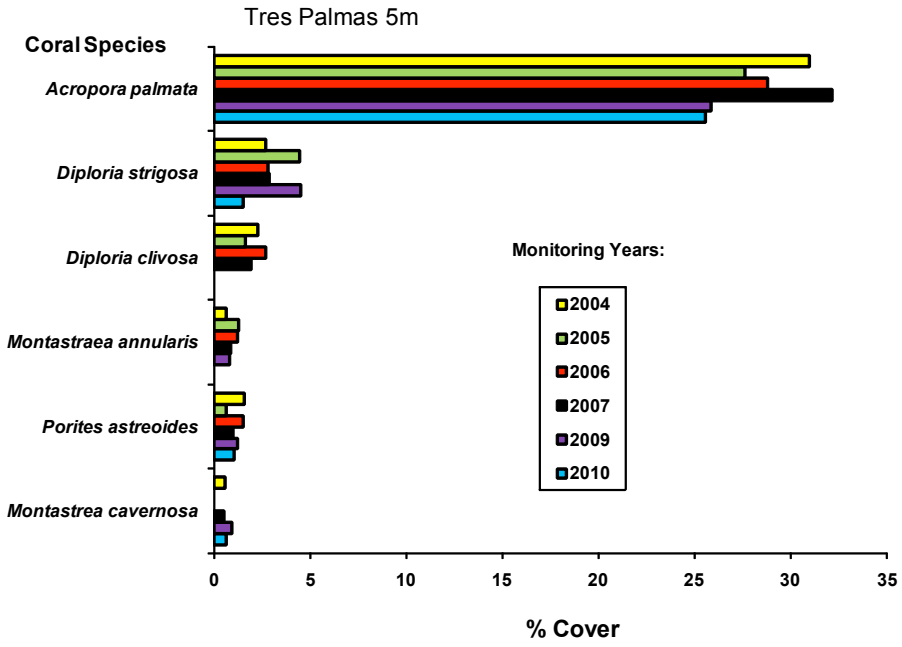


Figure 5. Monitoring trends (2004 – 2010) of mean substrate cover by stony coral species at Tres Palmas Reef, Rincon, 2 - 5 m depth.

represented 84.5 % of the mean abundance within belt-transects (Table 3). The most abundant species was the Blue Tang (*Acanthurus coeruleus*) with a mean of 70.0 Ind/30 m^2 followed by the Bluehead Wrasse (*Thalassoma bifasciatum*), Dusky Damselfish (*Stegastes dorsopunicans*), Sargeant Major (Abudefduf sexatilis) and Yellowtail Damselfish (*Microspathodon chrysurus*). These species and were present within all five belt-transects surveyed and along with the Redlip Blenny, Clown Wrasse, Glasseye Sweeper, Bermuda Chub and the Yellowtail and Stoplight Parrotfishes appear to comprise the main resident demersal fish assemblage. Large schools of Blue Tangs were observed in transit 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 (2004-2010) 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, 2009), suggesting that this shallow reef functions as a nursery area for these commercially important species. This reef is also the recruitment, nursery and residential habitat of the Yellowtail Damselfish (*Microspathodon chrysurus*), which in its early juvenile stage (known as “Jewel Damselfish”) is

Table 3. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef 3m, Rincon. Survey Date: September, 2010

Depth: 3 m		Transects					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Acanthurus coeruleus	Blue Tang	60	100	55	75	60	**70.0**
Thalassoma bifasciatum	Bluehead Wrasse	18	23	18	6	6	**14.2**
Stegastes dorsopunicans	Dusky Damselfish	16	18	21	11	3	**13.8**
Abudefduf sexatilis	Sergeant Major	22	0	13	0	3	**7.6**
Microspathodon chrysurus	Yellowtail Damselfish	3	5	7	6	3	**4.8**
Halichoeres maculipinna	Clown Wrasse	4	3	4	3	3	**3.4**
Kyphosys sectatrix	Bermuda Chub	2	8	0	0	4	**2.8**
Pempheris schomburgki	Glasseye Sweeper	6	4	1	3	0	**2.8**
Ophioblennius atlanticus	Redlip Blenny	3	1	3	3	3	**2.6**
Haemulon flavolineatum	French Grunt	1	0	0	7	0	**1.6**
Acanthurus bahianus	Ocean Surgeon	0	0	0	0	5	**1.0**
Caranx ruber	Bar Jack	0	2	0	0	2	**0.8**
Chaetodon capistratus	Four-eye Butterflyfish	0	0	0	2	2	**0.8**
Sparisoma viride	Stoplight Parrotfish	0	0	2	1	1	**0.8**
Anisotremus virginicus	Porkfish	2	1	0	0	0	**0.6**
Sparisoma rubripinne	Yellowtail Parrotfish	0	0	3	0	0	**0.6**
Bodianus rufus	Spanish Hogfish	0	1	0	1	0	**0.4**
Haemulon macrostomum	Spanish Grunt	1	0	0	1	0	**0.4**
Lutjanus apodus	Schoolmaster Snapper	2	0	0	0	0	**0.4**
Haemulon chrysargyreum	Smallmouth Grunt	1	0	0	0	0	**0.2**
Halichoeres bivittatus	Slippery Dick	0	0	0	0	1	**0.2**
Holocentrus rufus	Longspine Squirrelfish	0	0	0	1	0	**0.2**
Holocentrus vexillarius	Dusky Squirrelfish	0	1	0	0	0	**0.2**
Lutjanus analis	Mutton Snapper	0	0	0	1	0	**0.2**
Pomacanthus paru	French Angelfish	1	0	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**142**	**167**	**127**	**121**	**96**	**130.6**
	TOTAL SPECIES	**15**	**12**	**10**	**14**	**13**	**12.8**

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*), one hermit crab (*Paguristes sp.*), small Rustic Shells (*Thais rustica*), and several individuals of the corallivorous gastropod, *Coralliophila caribdea* were observed

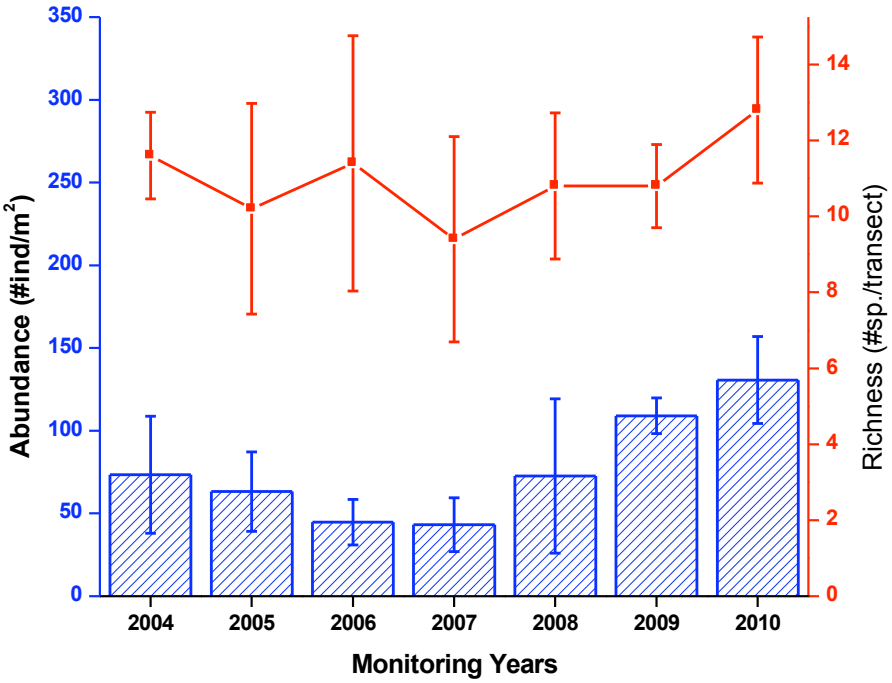


Figure 6. Monitoring trends (2004 – 2010) of fish species richness and abundance at Tres Palmas Reef, Rincon 2-5 m.

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. Survey Date: September, 2010

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

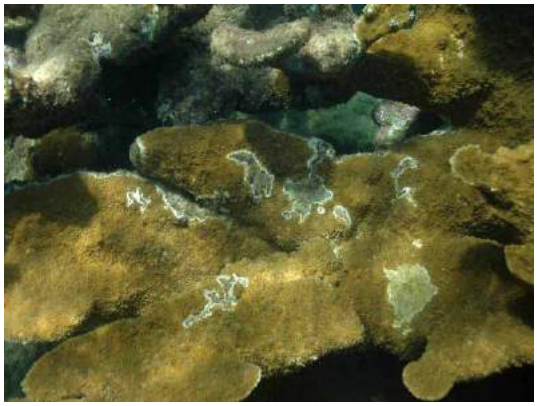
SPECIES	**COMMON NAME**	# - (cm)		
Anchoa sp.	Anchovies	>100 – (2-4)		
Caranx crysos	Blue Runner	2 – (35)		
Gerres cinereus	Yellowfin Mojarra	3 – (20)		
Lutjanus analis	Mutton Snapper	2 – (20)		
Lutjanus synagris	Lane Snapper	2– (10)	5 – (20)	1 – (30)
Lutjanus apodus	Schoolmaster	4 – (10)	4 – (20)	2 – (30)
Lutjanus mahogany	Mahogany Snapper	1 – (15)		
Ocyurus chrysurus	Yellowtail Snapper	2 – (10)	3 – (15)	
Sphyraena barracuda	Great Barracuda	1 – (50)		

within belt-transects during this 2009-10 monitoring survey (Table 5). One West Indian Sea Egg (*Tripneustes ventricosus*) was observed out of transects. Juvenile Spiny Lobsters (*Panulirus argus*), Rock Lobsters (*P. guttatus*) and other sea urchins have been reported from previous surveys at this reef (García-Sais et al., 2009).

Table 5. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Elkhorn Coral Reef, 5 m, Rincon, June 2010

Depth: 2 - 5 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	2	3	4	5	
SPECIES	**COMMON NAME**						
Coralliophila caribdea	Caribbean Coral Shell	5		3			**1.6**
Thais rustica	Rustic Shell	3	2	4	1		**2.0**
Paguristes sp.	Hermit Crab		1				**0.2**
Echinometra lucunter	Rock boring Urchin	7	1	3			**2.2**
	TOTALS	15	4	10	1	0	**6.0**

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 18 species present and a mean density of 25.0 col./transect (range: 20 – 29 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 17.8 % (range: 8.5 – 26.3 %). Great Star Coral, *Montastraea cavernosa* and Mustard-Hill Coral, *Porites astreoides* were the dominant species in terms of substrate cover with means of 5.6 and 2.4%, respectively. A total of 11 coral species were represented with less than 2% reef substrate cover. Total abiotic cover averaged 4.7 %.

Table 6. Percent substrate cover by sessile-benthic categories at Tres Palmas Reef, Rincon.
10 m Survey Date: June, 2010

Depth: 10 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	2.0	2.0	1.6	2.4	1.7	**1.9**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	2.5	6.4	4.5	5.5	4.6	**4.7**
Benthic Algae						
Turf-mixed assemblage	82.9	63.8	70.8	63.1	75.6	**71.2**
Halimeda discoidea	0.5	0.7				**0.2**
Galaxaura sp.	0.5	0.9	0.6	1.1	2.0	**1.0**
Coralline algae	0.6					**0.1**
Total Benthic Algae	84.4	65.4	71.4	64.1	77.6	**72.6**
Sponges	0.7	3.7	0.5	4.1	1.7	**2.1**
Xestospongia muta	3.3	1.2	6.9			**2.3**
Cyanobacteria	0.6	1.4				**0.4**
Live Stony Corals						
Montastraea cavernosa	2.3	5.4	9.3	4.4	6.5	**5.6**
Porites astreoides	0.4	2.8	3.9	2.2	2.7	**2.4**
Diploria labyrinthiformis		2.0		4.7	2.6	**1.9**
Montastraea annularis	4.3	4.8				**1.8**
Colpophyllia natans			0.4	8.2		**1.7**
Siderastrea siderea		0.8		1.9	2.3	**1.0**
Agaricia agaricites	0.9	1.1	0.5	1.2	0.5	**0.8**
Diploria strigosa		3.9				**0.8**
Siderastrea radians	0.6		1.2	0.7	0.6	**0.6**
Meandrina meandrites		0.7	1.3			**0.4**
Isophyllia sinuosa		0.5		1.1	0.4	**0.4**
Stephanocoenia intersepta				1.7		**0.3**
Millepora alcicornis					0.6	**0.1**
Dendrogyra cylindrus				0.3		**0.1**
Total Stony Corals	8.5	22.0	16.6	26.3	16.1	**17.9**
Erect Gorgonians						
Eunicea flexuosa	7	5	3	1	3	**3.8**
Gorgonia ventalina	4	4	5	1	5	**3.8**
Plexaura kukenthali	2	5	1	3	3	**2.8**
Pseudoptergorgia acerosa	1	5	3	2	3	**2.8**
Pseudoptergorgia americana	2	3	4	2	3	**2.8**
Eunicea tourneforti	3	0	3	1	1	**1.6**
Eunicea succinea	3	1	1	1	0	**1.2**
Pseudoplexaura flagellosa or wagenaari	0	0	1	3	2	**1.2**
Plexaura homomalla	0	1	3	0	1	**1**
Pseudoptergorgia acerosa yellow	3	0	1	0	0	**0.8**
Erythropodium caribaeorum	0	0	0	3	0	**0.6**

Table 6. continued

Eunicea spp.	0	0	0	1	2	**0.6**
Ptergorgia citrina	1	0	0	1	1	**0.6**
Briareum asbestinum	2	0	0	0	0	**0.4**
Muricea muricata	0	1	0	1	0	**0.4**
Muriceopsis flavida	0	1	0	0	0	**0.2**
Pseudoplexaura purosa	0	1	0	0	0	**0.2**
Ptergorgia guadalupensis	1	0	0	0	0	**0.2**
Total Gorgonians (#col/transect)	29	27	25	20	24	**25**

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

Turf algae, a mixed assemblage of short filamentous red and brown macroalgae presented the highest percent of reef substrate cover by sessile-benthic components with a mean of 71.2 % (range: 63.1 – 82.9 %). 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 4.4 % (range: 1.7 – 7.4 %). The encrusting gorgonian, *Erythropodium caribaeorum* and the encrusting zoanthid, *Palythoa caribbea,* were observed outside transects. Abiotic categories associated with reef overhangs and sand pockets comprised 4.7 % 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 1.9 m.

The sessile-benthic community at the patch reef surveyed is typical of high wave energy environments, dominated by encrusting stony corals and sponges and flexible soft corals. The high abundance of small coral colonies may be an indication of active recruitment. Mortality of coral colonies induced by mechanical detachment during heavy wave action is most likely to be a prevailing process in this reef which has probably led to the high species richness evidenced in this survey. The reef hard ground was mostly colonized by turf algae, which is the dominant assemblage and a quasi-permanent feature of high energy reefs in the north coast of Puerto Rico (García-Sais et al., 2003). Figure 7 shows the variations of reef substrate cover by sessile-benthic categories throughout the monitoring program starting with the baseline survey of 2004. Small annual variations of the mean reef substrate cover by (total) live corals between

monitoring surveys (2004 – 2010) at this reef were not statistically significant (ANOVA; p = 0.319). Statistical treatments are presented in Appendix 2.

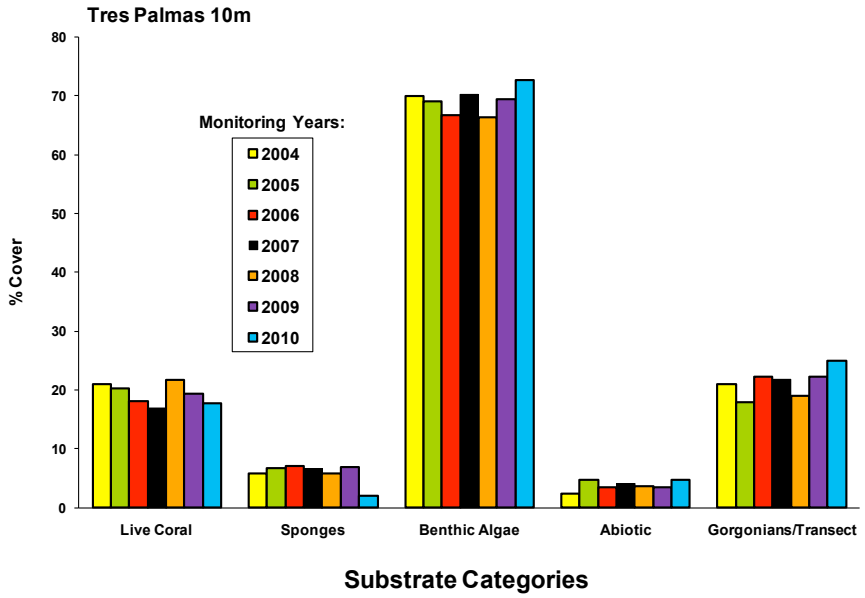


Figure 7. Monitoring trends (2004 – 2010) of mean substrate cover by sessile-benthic categories at Tres Palmas Outer Patch Reef – 10 m.

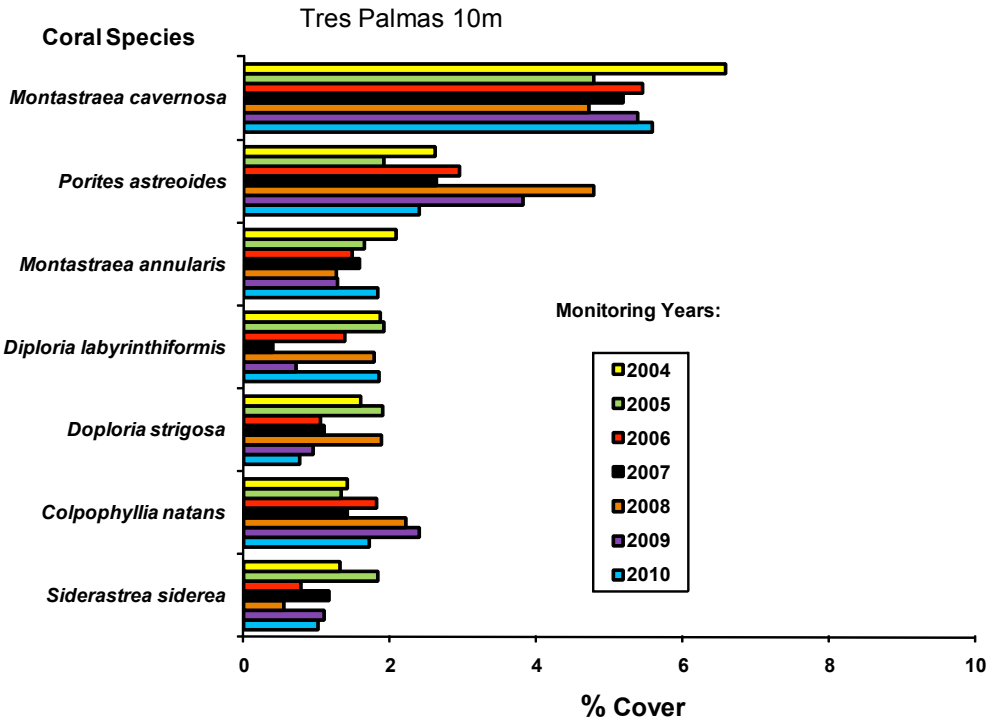


Figure 8. Monitoring trends (2004 – 2009) of mean substrate cover by stony coral species at Tres Palmas Outer Patch Reef – 10 m.

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 2009-10 survey, mean abundance of individuals within belt-transects was 63.0 Ind/30 m^2 (range: 35 - 85 Ind/30 m^2). The mean number of species per transect was 11.4 (range: 8 - 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 23.4 and 19.6 Ind/30 m^2, respectively (Table 7). The combined abundance of these two species represented 68.2 % of the community mean abundance within belt-transects. In addition to the two aforementioned species, the Striped and Redband Parrotfishes, Yellowhead Wrasse, Ocean Surgeon and Sharknose Goby 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 during 2009 showed a slight increment from the 2008 survey. During the present 2010 survey abundance reached its minimum and richness showed a mild increase, but still well below baseline levels.

Table 7. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef, Rincon. 10 m. Survey Date: June, 2010

Depth: 10 m		Transects					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Stagastes partitus	Bicolor Damselfish	22	19	20	26	30	**23.4**
Thalassoma bifasciatum	Bluehead Wrasse	15	6	28	24	25	**19.6**
Scarus iserti	Striped Parrotfish	11	1	2	0	5	**3.8**
Sparisoma aurofrenatum	Redband Parrotfish	5	2	4	3	4	**3.6**
Halichoeres garnoti	Yellowhead Wrasse	5	4	2	1	6	**3.6**
Acanthurus bahianus	Ocean Surgeon	4	0	6	1	5	**3.2**
Gobiosoma evelynae	Sharknose Goby	1	1	0	1	2	**1.0**
Chephalopholis fulva	Coney	1	0	2	0	2	**1.0**
Chaetodon capistratus	Four-eye Butterflyfish	0	1	2	2	0	**1.0**
Halichoeres maculipinna	Clown Wrasse	0	0	0	0	3	**0.6**
Serranus tigrinus	Harlequin Bass	1	0	1	0	1	**0.6**
Holocentrus rufus	Longspine Squirrelfish	0	1	1	0	1	**0.6**
Acanthurus coeruleus	Blue Tang	1	0	0	0	1	**0.4**
Chromis cyanea	Blue Chromis	1	0	0	0	0	**0.2**
Scarus taeniopterus	Princess Parrotfish	0	0	0	1	0	**0.2**
Canthigaster rostrata	Sharpnose Puffer	0	0	1	0	0	**0.2**
Microspathodon chrysurus	Yellowtail Damselfish	0	0	0	0	1	**0.2**
Sparisoma viride	Stoplight Parrotfish	1	0	0	0	0	**0.2**
Lactophryris triqueter	Smooth Trunkfish	0	0	0	1	0	**0.2**
Aulostomus maculatus	Trumpetfish	0	0	1	0	0	**0.2**
Myripristis jacobus	Blackbar Soldierfish	0	0	1	0	0	**0.2**
Bodianus rufus	Spanish Hogfish	0	0	0	0	1	**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**67**	**35**	**69**	**59**	**85**	**63.0**
	TOTAL SPECIES	**12**	**8**	**13**	**9**	**15**	**11.4**

The high energy environment at the top of the patch reef is an appropriate habitat for opportunistic carnivores, such as Wrasses (*Thalassoma bifasciatum, Halichoeres garnoti, H. maculipinna*) which feed on small benthic (infaunal) invertebrates that become exposed upon disturbances of the substrate due to wave action. Also, herbivores (e.g. parrotfishes, doctorfishes, damselfishes) that feed on the turf algae were common. Pelagic piscivores, such as barracudas (*Sphyraena barracuda*), mackerels (*Scomberomorus regalis*) and jacks (*Caranx crysos, C. ruber*) have been previously

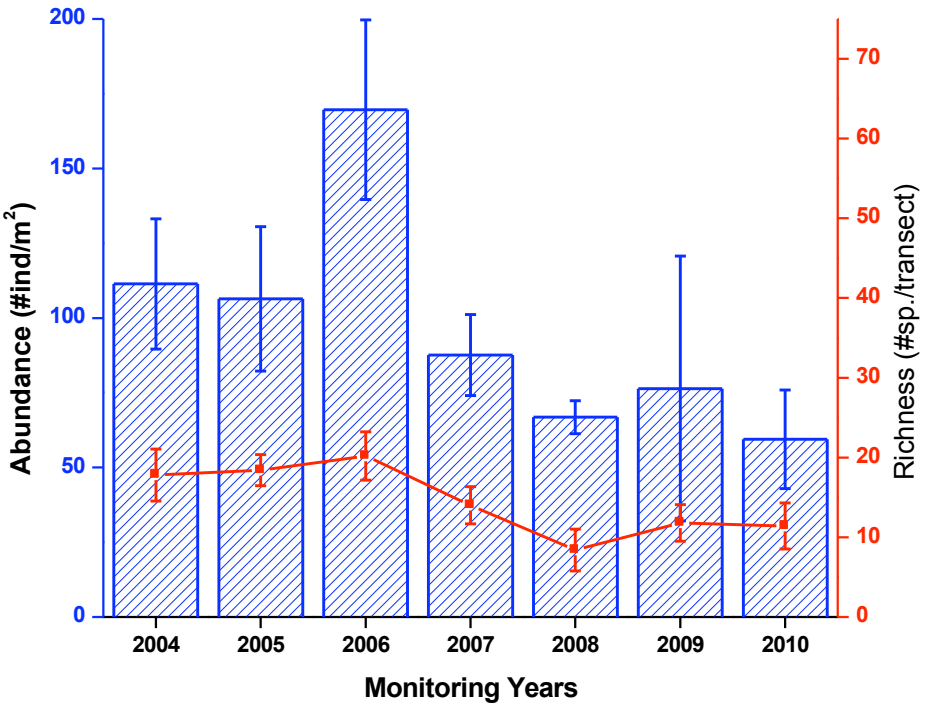


Figure 9. Monitoring trends (2004 – 2010) of fish species richness and abundance at Tres Palmas Outer Shelf Patch Reef, 10-15 m, Rincon.

reported from this reef (García-Sais et al., 2005, 2006, 2007, 2008, 2009). Mid size adult and juvenile Lane, Mahogany and Yellowtail snappers (*Lutjanus synagris, L. mahogony, Ocyurus chrysurus*) were present (Table 8). Large (adult) commercially important demersal fishes were not observed.

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 2010 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. Survey Date: June, 2010.

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

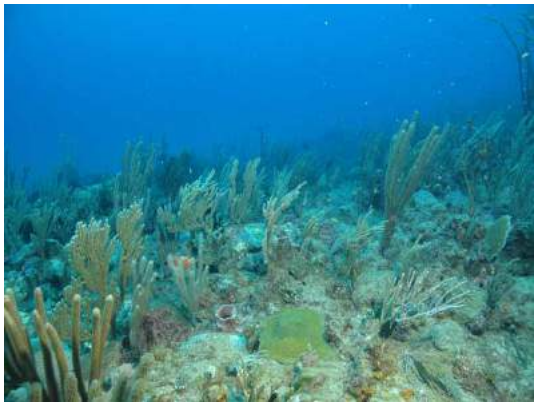
SPECIES	**COMMON NAME**		# - (cm)	
Caranx crysos	Blue Runner	2 – (30)	1 – (40)	
Epinephelus guttatus	Red Hind	2 – (30)		
Lutjanus mahogony	Mahogany Snapper	4 – (20)	1 – (25)	1 – (30)
Lutjanus synagris	Lane Snapper	2 – (10)	2 – (20)	1 – (30)
Ocyurus chrysurus	Yellowtail Snapper	5 – (15)	3 – (20)	
Sphyraena barracuda	Great Barracuda	1 – (50)		

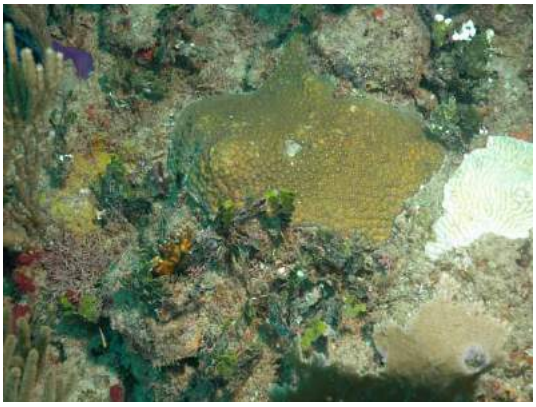
Table 9. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Reef, Rincon, 10m, June, 2010

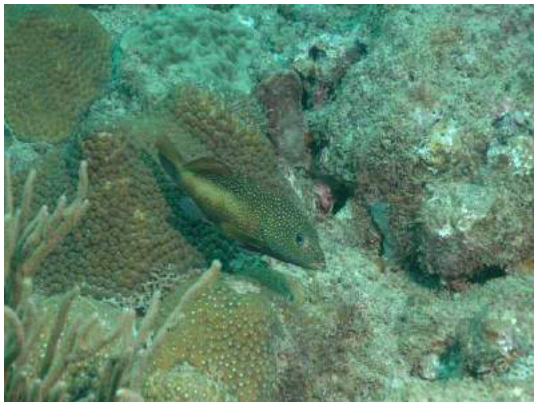
		TRANSECTS					
Depth: 10 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Periclimenes pedersoni	Cleaner Shrimp	3				3	**1.2**
Stenorhynchus seticornis	Arrow Crab			1			**0.2**
	TOTALS	3		1		3	**1.4**

Photo Album 2 (Rincon 10m)

Outer Shelf Patch Reef







3.0 Tres Palmas Shelf-edge Reef

3.1 Sessile-benthic Community

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

A total of 22 stony coral species (including two hydrocorals) were identified from the shelf-edge reef off Tres Palmas, 15 of which were intercepted by line transects during the 2010 survey (Table 10). Stony corals occurred mostly as encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 26.2 % (range: 18.5 – 34.3 %). Boulder Star Coral, *Montastraea annularis* complex was the dominant species in terms of substrate cover with a mean of 10.3 % (range: 2.5 – 19.9 %), representing 39.3 % 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 13 species within transects and an average of 13.2 colonies/transect. The main assemblage included sea plumes (*Pseudopterogorgia acerosa, P. americana*), the Corky Sea Finger, *Briareum asbestinum*, , Knobby Sea Rods, *Eunicea spp*., and the Common Sea Fan, *Gorgonia ventalina* (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. 20m. Survey Date: June 2010

Depth: 20 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	2.7	2.0	2.8	1.9	2.0	**2.3**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs		2.9	17.6	11.1	12.3	**8.8**
Benthic Algae						
Turf-mixed assemblage	68.6	57.0	45.8	54.4	55.4	**56.2**
Coralline algae	0.9				0.6	**0.3**
Fleshy Algae						
Lobophora variegata		1.4		2.4		**0.8**
Total Benthic Algae	69.5	58.4	45.8	56.8	56.0	**57.3**
Sponges	11.1	3.2	8.4	6.8	5.4	**7.0**
Encrusting Gorgonians	0.3					**0.1**
Erythropodium caribaeorum				1.7		**0.3**
Cyanobacteria	0.6	0.5				**0.2**
Live Stony Corals						
Montastraea annularis	2.5	9.2	19.9	7.9	12.0	**10.3**
Meandrina meandrites	1.5	2.7	3.4	2.7	2.7	**2.6**
Agaricia agaricites	5.1	2.5		1.2	1.9	**2.1**
Diploria strigosa	0.9	5.9			3.7	**2.1**
Montastraea cavernosa	4.0	3.1	2.0	1.2		**2.1**
Porites astreoides		5.3		2.3	1.9	**1.9**
Siderastrea siderea	0.3	5.3		1.6		**1.4**
Agaricia grahamae	2.2			1.8		**0.8**
Colpophyllia natans			1.7		1.6	**0.7**
Porites colonensis				3.2		**0.6**
Leptoseris cucullata			0.4	0.8	1.6	**0.6**
Madracis decactis	0.8			1.1	0.8	**0.5**
Agaricia lamarcki	1.1					**0.2**
Millepora alcicornis		0.7			0.2	**0.2**
Stylaster roseus		0.5				**0.1**
Total Stony Corals	18.5	35.0	27.4	23.7	26.4	**26.2**
Erect Gorgonians (# col./transect)						
Pseudoptergorgia acerosa	4	3	3	4	5	**3.8**
Briareum asbestinum	0	0	11	1	0	**2.4**
Eunicea tourneforti	2	2	3	0	2	**1.8**
Eunicea flexuosa	2	2	1	2	1	**1.6**
Plexaura kukenthali	1	1	1	2	1	**1.2**
Gorgonia ventalina	2	0	1	2	0	**1.0**
Pseudoptergorgia americana	0	2	0	0	0	**0.4**
Eunicea mammosa	0	1	0	0	0	**0.2**
Eunicea succinea	0	0	0	0	1	**0.2**
Muriceopsis flavida	0	0	0	1	0	**0.2**
Plexaura homomalla	0	0	0	1	0	**0.2**
Plexaurella fusifera	1	0	0	0	0	**0.2**
Plexaurella nutans	1	0	0	0	0	**0.2**
Total Gorgonians	12	11	20	13	10	**13.2**

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

Encrusting and erect sponges, including several large Basket Sponges, *Xestospongia muta* were present in all transects with an average cover of 7.0 %. Reef overhangs averaged 8.8 % and contributed to a topographic rugosity of 2.3 m. Turf algae, comprised by an assemblage of short filamentous red and brown macroalgae were the dominant sessile-benthic component in terms of substrate cover with an average of 56.2 % (range: 45.8 – 68.6 %). Turf algae were found overgrowing rocky substrates, as well as dead coral sections and other hard ground. Fleshy brown macroalgae, particularly *Lobophora variegata* was common in the reef, contributing an additional 0.8 % to the reef substrate cover. Isolated tufts of red coralline alga (*Amphiroa sp*, *Galaxaura sp*.) and other green filamentous algae were also present. The total reef substrate cover by benthic algae was 57.3 %. 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 (2010). A mild, but consistent trend of declining mean coral cover between monitoring surveys until 2008 is suggested by the data. This pattern ended during 2009 with a minor increment of live coral cover. The increasing pattern of live coral cover continued during the present survey (Figure 10). The variability in both magnitude and direction of live coral cover within transects is high enough to render the differences between monitoring years statistically insignificant. The increasing trend of live coral cover has been influenced by an apparent recuperation of *Montastraea annularis* (complex) from its acute degradation after the 2005 coral bleaching event.

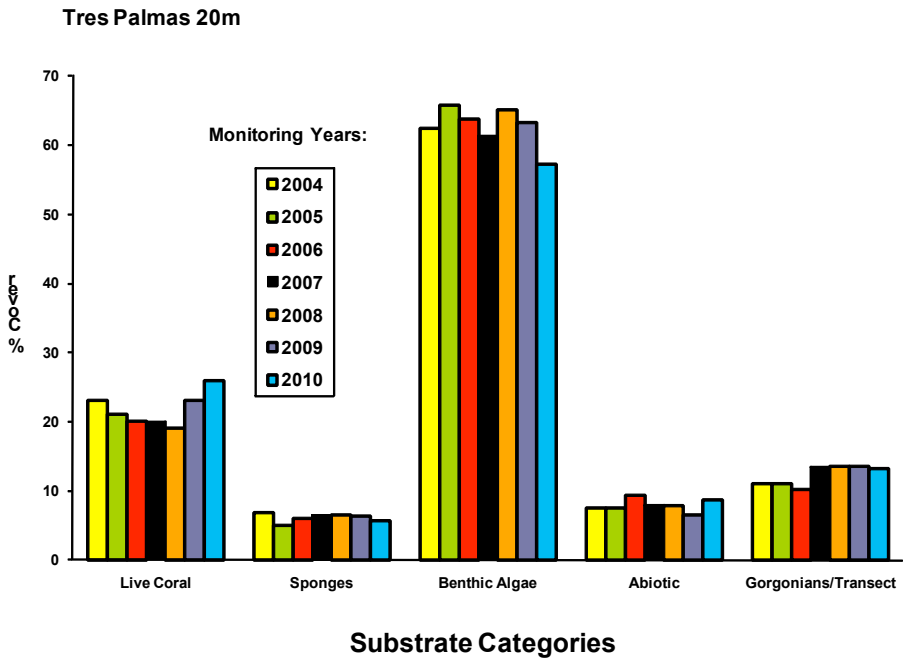


Figure 10. Monitoring trends (2004 – 2010) of mean substrate cover by sessile-benthic categories at Tres Palmas Reef – 20 m.

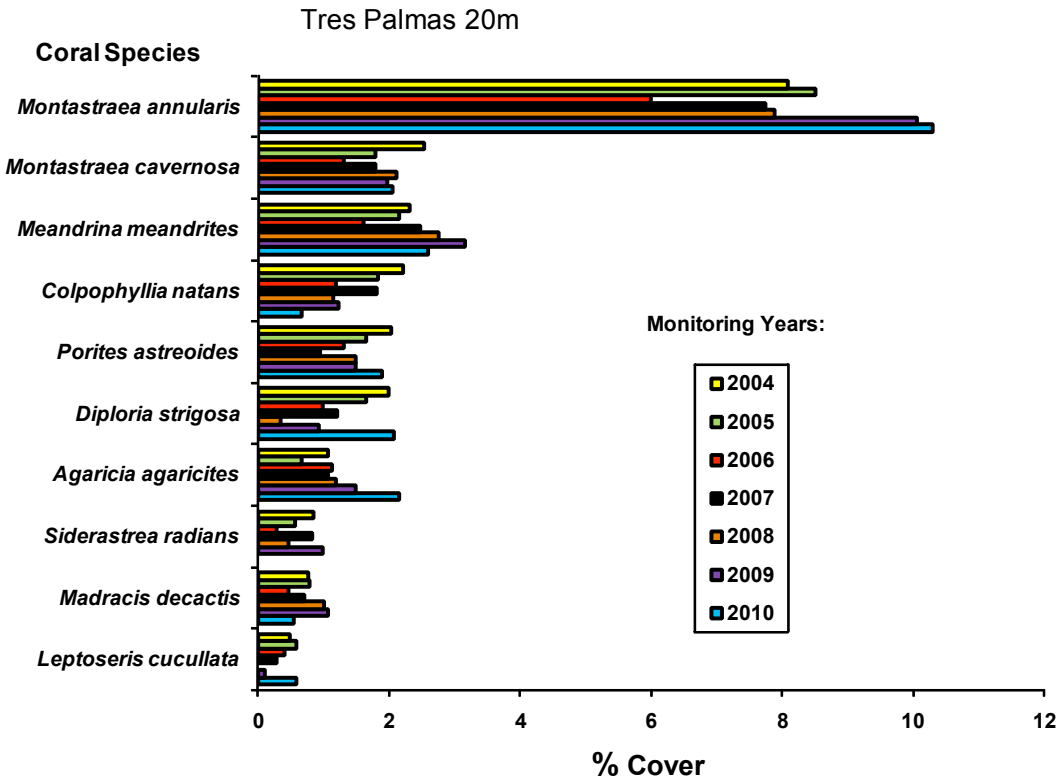


Figure 11. Monitoring trends (2004 – 2010) of mean substrate cover by stony coral species at Tres Palmas Reef – 20 m.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 85 fish species have been identified during the six surveys (2004-10) from the shelf-edge reef off Tres Palmas (Appendix 1). Table 11 lists the 44 fish species observed within belt-transects during the 2010 survey in decreasing order of abundance. Mean abundance within belt-transects was 197.1 Ind/30 m^2 (range: 137 – 285 Ind/30 m^2). The mean number of species per transect was 20.6 (range: 17– 27). An assemblage consisting of six species represented 81.2 % of the total fish individuals within belt-transects (Table 11). The Masked Goby, Peppermint Goby, Blue Chromis, Bicolor Damselfish, Bluehead and Creole Wrasse comprised the numerically dominant assemblage. In addition, The Beau Gregory, Sharknose Goby, Yellowhead Wrasse and Striped Parrotfish were present in at least four of the five transects surveyed. One adult Lionfish, *Pterois volitans* was present within transect 1 and another two individuals were observed out of transects.

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 denote a pattern of mild fluctuations. The main species that has contributed to the variability of fish abundance between monitoring surveys is the Masked Goby, *Coryphopterus personatus*. This is a small zooplanktivorous fish (< 2.0 cm) that forms swarms of hundreds of individuals below coral ledges and near the sand-coral interface of the spur and groove reef formation, thus it has highly aggregated or patchy distributions in the reef. The temporal abundance dynamics of this species has not been studied. Thus, the factors that influence its abundance fluctuations between annual surveys remain unclear. Given its small size and high density in swarms, this goby may be an importante forage (prey) species for the small piscivorous fishes in the reef. The fish community associated with the Tres Palmas shelf-edge reef appears to be well balanced in terms of trophic structure, except for the absence of large demersal predators, such

Table 11. Taxonomic composition and abundance of fishes within belt-transects at Tres Palmas Reef 20m, Rincon. Survey Date: June, 2010

Depth: 20 m		Transects					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	20	135	35	30	100	**64.0**
Clepticus parrae	Creole Wrasse	65		5		15	**28.3**
Chromis cyanea	Blue Chromis	19	1	23	28	60	**26.2**
Stegastes partitus	Bicolor Damselfish	22	13	18	19	43	**23.0**
Coryphopterus lipernes	Peppermint Goby	13	12	4	10	11	**10.0**
Thalassoma bifasciatum	Bluehead Wrasse	10	9	4	12	15	**10.0**
Chromis multilineata	Brown Chromis	0	0	5	14	15	**6.8**
Gobiosoma evelynae	Sharknose Goby	4	4	3	2	4	**3.4**
Stegastes leucostictus	Beaugregory	3	5	3	2	3	**3.2**
Haemulon carbonarium	Cesar Grunt	15	0	0	0	0	**3.0**
Halichoeres garnoti	Yellowhead Wrasse	0	3	5	3	3	**2.8**
Scarus iserti	Striped Parrotfish	0	2	3	3	2	**2.0**
Sparisoma aurofrenatum	Redband Parrotfish	0	2	0	4	2	**1.6**
Epinephelus cruentatus	Graysby	3	2	1	0	2	**1.6**
Sparisoma viride	Stoplight Parrotfish	2	3	0	2	0	**1.4**
Acanthurus bahianus	Ocean Surgeon	2	1	0	2	1	**1.2**
Myripristis jacobus	Blackbar Soldierfish	1	0	3	1	0	**1.0**
Mulloidichthys martinicus	Yellow Goatfish	5	0	0	0	0	**1.0**
Chaetodon capistratus	Four-eye Butterflyfish	0	0	0	2	2	**0.8**
Melichthys niger	Black Durgon	3	0	0	1	0	**0.8**
Canthigaster rostrata	Sharpnose Puffer	2	1	0	0	0	**0.6**
Neoniphon marianus	Longjaw Squirrelfish	0	1	2	0	0	**0.6**
Acanthurus coeruleus	Blue Tang	2	0	0	0	1	**0.6**
Haemulon flavolineatum	French Grunt	0	0	3	0	0	**0.6**
Amblycirrhitus pinos	Redspotted Hawkfish	1	0	1	0	1	**0.6**
Gramma loreto	Fairy Basslet	0	0	0	0	3	**0.6**
Epinephelus fulva	Coney	0	1	0	0	1	**0.4**
Aulostomus maculatus	Trumpetfish	1	0	0	0	1	**0.4**
Holacanthus tricolor	Rock Beauty	0	0	0	2	0	**0.4**
Equetus punctatus	Spotted Drum	0	0	1	0	0	**0.2**
Chaetodon striatus	Banded Butterflyfish	0	0	0	0	1	**0.2**
Bodianus rufus	Spanish Hogfish	1	0	0	0	0	**0.2**
Pomacanthus arcuatus	Gray Angelfish	0	0	0	1	0	**0.2**
Holocentrus rufus	Longspine Squirrelfish	0	0	0	1	0	**0.2**
Hypoplectrus nigricans	Black Hamlet	0	1	0	0	0	**0.2**
Ocyurus chrysurus	Yellowtail Snapper	1	0	0	0	0	**0.2**
Lutjanus mahogoni	Mahogani Snapper	1	0	0	0	0	**0.2**
Pterois volitans	Lionfish	1	0	0	0	0	**0.2**
Pomacanthus paru	French Angelfish	1	0	0	0	0	**0.2**
Anisotremus virginicus	Porkfish	1	0	0	0	0	**0.2**
Chaetodon sedentarius	Reef Butterflyfish	1	0	0	0	0	**0.2**
Anisotremus surinamensis	Black Margate	1	0	0	0	0	**0.2**
Microspathodon chrysurus	Yellowtail Damselfish	0	1	0	0	0	**0.2**
Chaetodon aculeatus	Longsnout Butterflyfish	0	0	0	1	0	**0.2**
	TOTAL	**193**	**19**	**28**	**137**	**285**	**197.1**
	INDIVIDUALS		**5**	**5**			
	TOTAL SPECIES	**27**	**18**	**17**	**20**	**21**	**20.6**

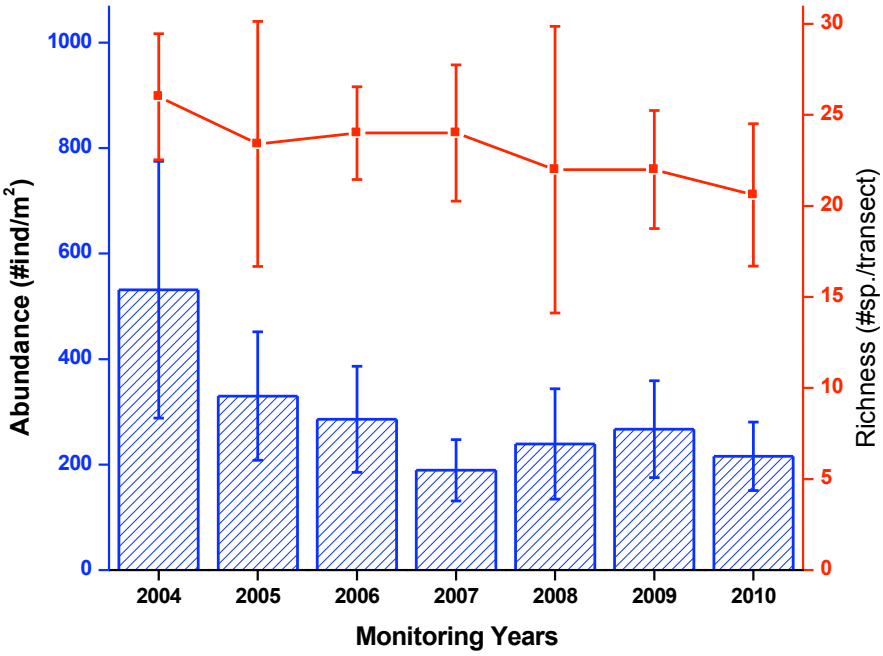


Figure 12. Monitoring trends (2004 – 2010) of fish species richness and abundance at Tres Palmas Shelf Edge Reef, Rincon, 20 m

as large snappers and groupers. However, this is the present condition of most insular coral reefs. Large schools of Creole Wrasse, *Clepticus parrae* and Mackerel Scad, *Decapterus macarellus* were present at mid-water over the reef. These are zooplanktivores that serve as prey for pelagic predators, such as Cero Mackerels, Blue Runners and Barracudas observed during an ASEC survey in this reef (Table 12).

The Blue, Brown and Sunshine Chromis are also important zooplanktivores that were common over coral heads closer to the reef. A large variety of small invertebrate feeders were present, including wrasses, hamlets, gobies, and squirrelfishes, among others. Larger invertebrate and small fish predators included the Schoolmaster and Mahogani snappers, Coney, Graysby and Red Hind groupers, Spanish Hogfish, lizardfishes and grunts. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous assemblage.

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

Motile megabenthic invertebrates, such as Arrow Crabs, *Stenorhynchus seticornis,* Cleaner Shrimps *Periclimenes pedersoni* and *Stenopus hispidus*, Common Octopus, *Octopus vulgaris*, and Spiny Lobsters, *Panulirus argus* have been previously reported within belt-transects during previous surveys at this reef. Cleaner shrimps, one arrow crab and one sea cucumber were observed withion belt-transects during 2010 (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, 2010

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

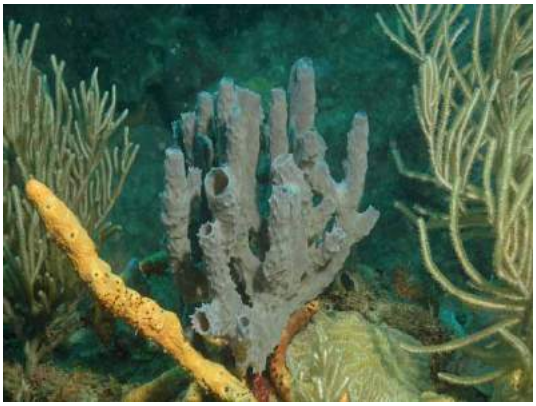
SPECIES	**COMMON NAME**		# - (cm)	
Carangoides crysos	Blue Runner	2 – (30)	1 – (40)	
Epinephelus guttatus	Red Hind	1 – (25)	2 – (30)	
Holacanthus tricolor	Rock Beauty	2 - (35)		
Lutjanus apodus	Schoolmaster	1 - (20)	2 – (30)	2 - (35)
Lutjanus mahogony	Mahogany Snapper	3 - (20)	1 - (25)	
Lutjanus synagris	Lane Snapper	2 – (25)		
Ocyurus chrysurus	Yellowtail Snapper	2 – (15)	2 – (30)	
Pterois volitans	Lionfish	1 – (15)	1 – (25)	
Scomberomorus regalis	Cero Mackerel	2 - (40)	1 - (50)	
Sphyraena barracuda	Great Barracuda	1 - (40)		

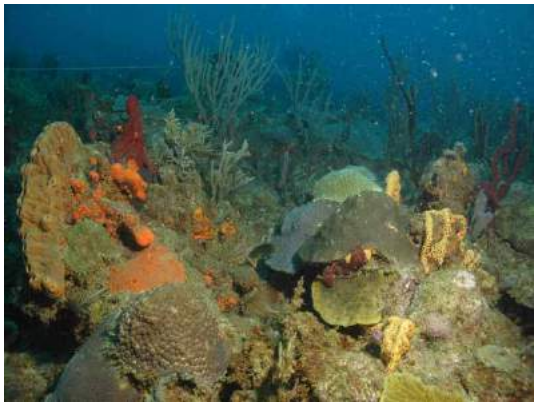
Table 13. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tres Palmas Shelf-edge Reef, Rincon 20 m, June, 2010

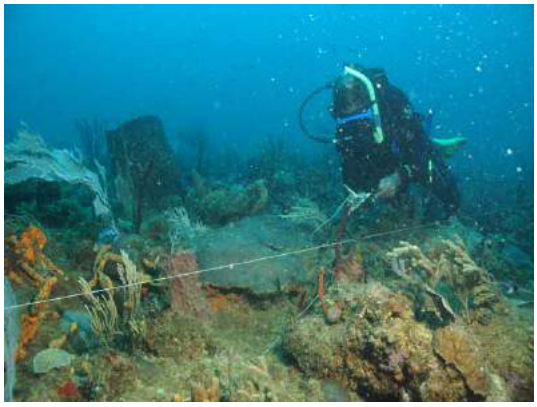
Depth: 20 m		TRANSECTS					MEAN ABUNDANCE (IND/30 m2)
		1	2	3	4	5	
SPECIES	**COMMON NAME**						
Stenorhynchus seticornis	Arrow Crab	1			1		**0.4**
Isostichopus badionotus	Three-rowed Cucumber		1				**0.2**
Periclimenes pedersoni	Cleaner Shrimp			4			**0.8**
	TOTALS	1	1	4	1	0	**1.4**

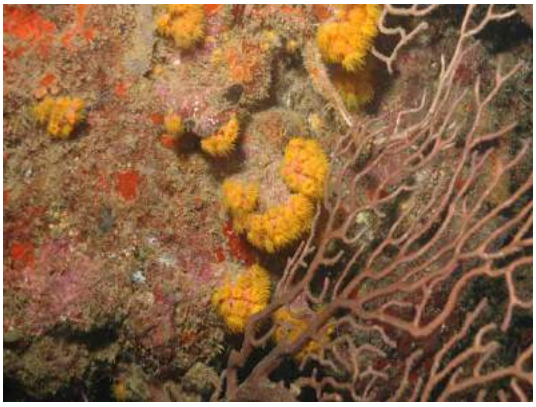
Photo Album 3 (Rincon 20m)

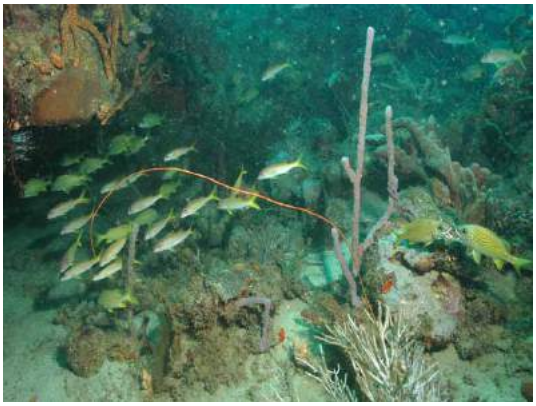
Shelf edge Reef











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 25 – 30 m, bordering the edge of three of the larger massive coral promontories. Panoramic views of the shelf edge reef at Puerto Canoas are presented as Photo Album 4.

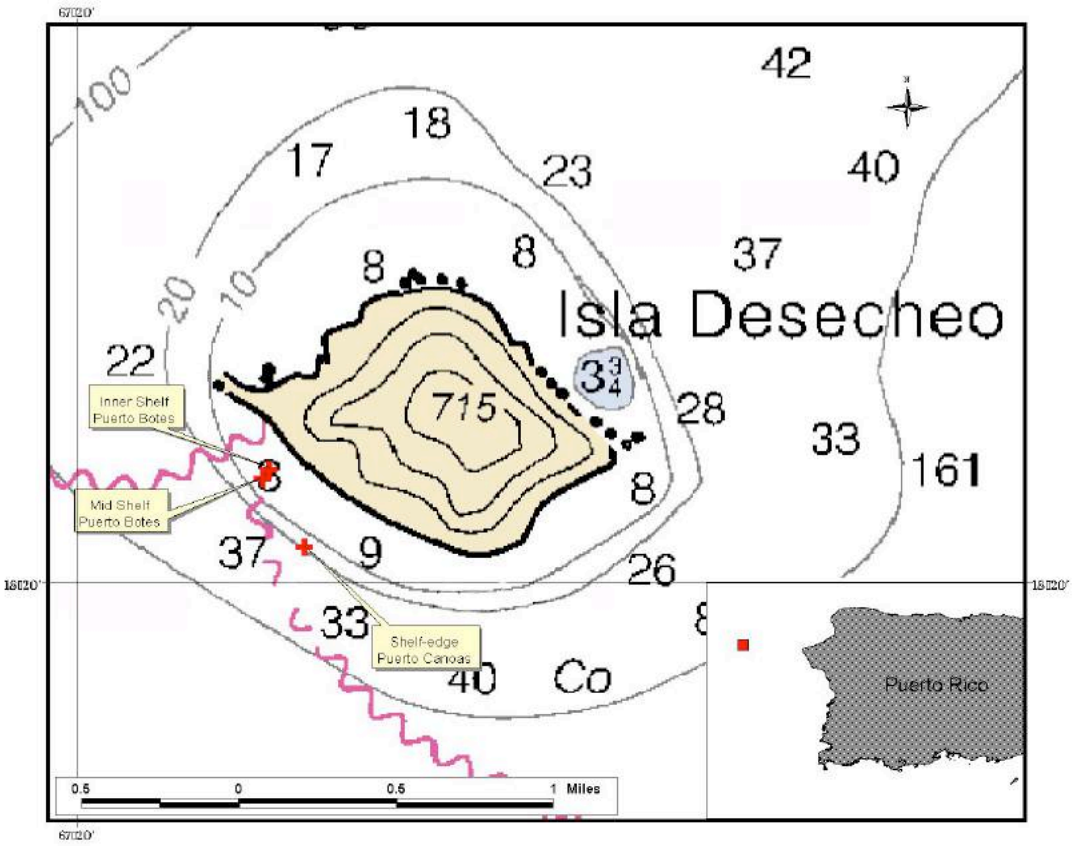


Figure 13. Location of coral reef survey stations at Puerto Canoas/Botes, Isla Desecheo.

Stony corals dominated reef substrate cover along surveyed transects with a mean of 23.6% (range: 14.0 – 32.0 %). Boulder Star Coral (*Montastraea annularis* complex), with a mean cover of 13.3 % represented 56.6 % 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 14 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 18.1 % and contributed to a mean reef substrate rugosity of 3.93. Encrusting and erect sponges were common, with a mean cover of 4.3 % (range: 7.6 – 27.8 %).

Table 14. Percent substrate cover by sessile-benthic categories at Puerto Canoas Reef, Isla Desecheo 30 m. Survey Date: May 2010

Depth: 25 – 30m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	3.5	3.7	5.5	4.0	4.7	**4.3**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	12.7	7.0	27.8	20.9	21.4	**17.9**
Gap		0.5				**0.1**
Total Abiotic	12.7	7.6	27.8	20.9	21.4	**18.1**
Benthic Algae						
Lobophora variegata	23.1	29.5	13.6	31.2	18.6	**23.2**
Turf-mixed assemblage	27.3	16.7	28.7	13.5	13.1	**19.8**
Coralline algae	0.6				0.5	**0.2**
Total Benthic Algae	51.0	46.2	42.3	44.6	32.2	**43.3**
Sponges	5.7	13.6	11.3	6.1	2.1	**7.8**
Cyanobacteria	10.0	2.9	4.7	6.1	12.4	**7.2**
Live Stony Corals						
Montastraea annularis	6.1	15.5	7.1	13.3	24.6	**13.3**
Colpophyllia natans	9.9	2.6				**2.5**
Agaricia agaricites	1.8	4.6	0.4	3.2	2.1	**2.4**
Porites astreoides	1.1	3.6	0.6	3.9	2.7	**2.4**
Agaricia tenuifolia			5.5			**1.1**
Diploria strigosa					2.6	**0.5**
Meandrina meandrites				1.5		**0.3**
Eusmilia fastigiata		1.1				**0.2**
Porites porites	1.0					**0.2**
Leptoseris cucullata		0.8				**0.2**
Madracis decactis	0.7					**0.1**
Millepora alcicornis			0.5			**0.1**
Mycetophyllia sp.		0.7				**0.1**
Stephanocoenia intersepta		0.7				**0.1**
Total Stony Corals	20.6	29.6	14.0	21.8	32.0	**23.6**
Gorgonians (# col./transect)	0	0	0	0	0	0

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

Benthic macroalgae, comprised by an assemblage of turf, fleshy and calcareous types presented a combined substrate cover of 43.3 % along permanent transects. *Lobophora variegata, Padina sp.* and *Ventricaria ventricosa* were some of the most common fleshy macroalgae present. Turf algae included an unidentified variety of short filamentous red and brown macroalgae. A slimy red cyanobacterial film was present in all five transects with a mean substrate cover of 7.2 %.

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; $p < 0.0001$). The decline of mean live coral cover was largely associated with the dominant reef building species, *Montastraea annularis*, which varied from a mean cover of 32.7 % in 2005 to 24.4 % in 2006 (Figure 15). At the time of the 2006 monitoring survey (mid June), *M annularis* still showed partially bleached conditions representing 5.7 % of its mean reef substrate cover, equivalent to 23.4 % of the remaining live coral tissue within surveyed transects at 30 m. Since 2006, a mild (statistically insignificant) trend of decreasing live cover was observed until the present 2010 survey, when a statistically significant difference between live coral cover during 2010 and 2006 has emerged (ANOVA; $p< 0.05$; see Appendix 2). A corresponding increment of substrate cover by benthic algae, cyanobacteria, sponges and abiotic categories has been detected (Figure 14).

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 97 fish species have been identified during the seven surveys (2004-10) at the shelf-edge reef off Puerto Canoas, Isla Desecheo (Appendix 1). Mean abundance of fishes within belt-transects during May, 2010 was 205.6 Ind/30 m^2 (range: 163 – 252 Ind/30 m^2). The mean number of species per transect was 24.4 (range: 19 – 30) (Table 15). An assemblage of seven species, including the Masked Goby, Blue and Brown Chromis, Bluehead and Creole Wrasse, Bermuda Chub, and Fairy Basslet represented 74.1 % of the total fish abundance within belt-transects. A total of 12 species were present within all five belt-transects surveyed. The Masked Goby, *Coryphopterus*

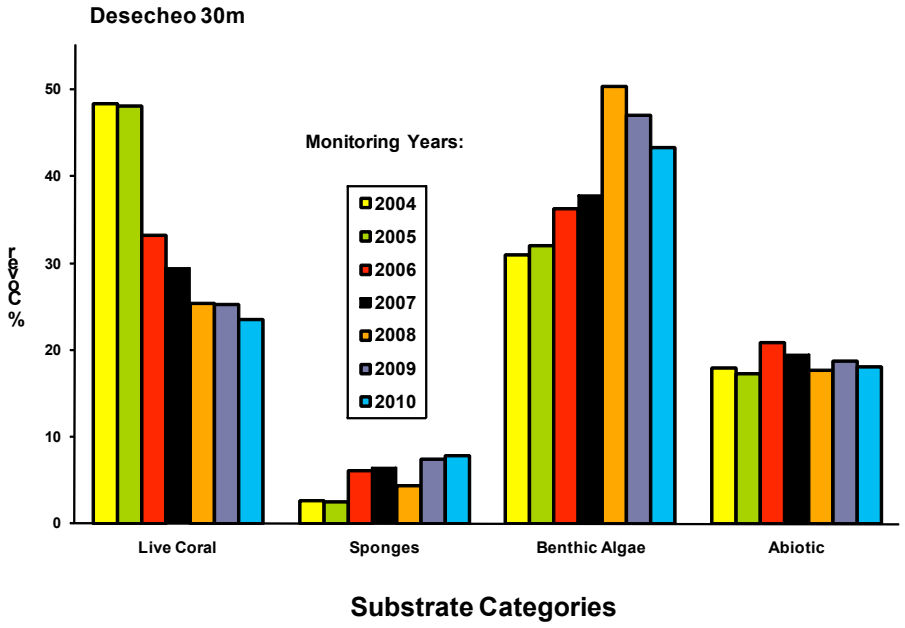


Figure 14. Monitoring trends (2004 – 10) of substrate cover by sessile-benthic categories at Puerto Canoas Reef, Desecheo Island – 30 m.

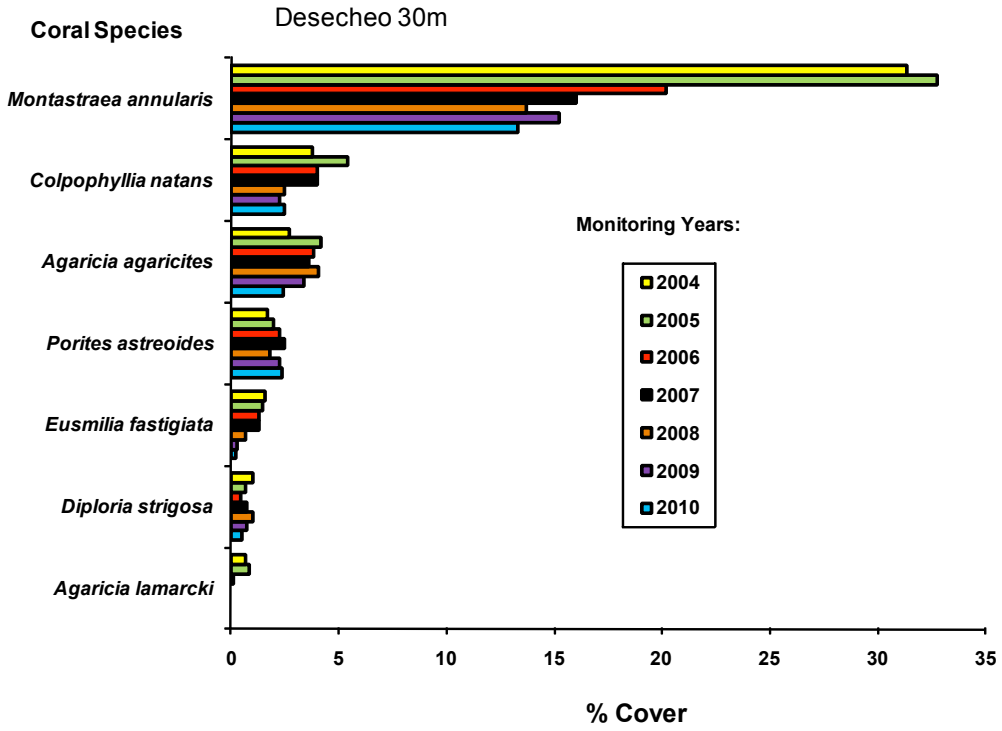


Figure 15. Monitoring trends (2004-10) of mean substrate cover by stony coral species at Puerto Canoas Reef, Desecheo Island – 30 m.

Table 15. Taxonomic composition and abundance of fishes within belt-transects at Puerto Canoas Reef, 30 m, Isla Desecheo. Survey Date: June, 2010

Depth: 30 m

		Transects					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	50	90	30	60	20	**50.0**
Chromis cyanea	Blue Chromis	12	8	50	10	42	**24.4**
Kyphosus sectatrix	Bermuda Chub	32	1	13	1	40	**17.4**
Thalassoma bifasciatum	Bluehead Wrasse	14	12	15	21	22	**16.8**
Clepticus parrae	Creole Wrasse	9	14	15	27	13	**15.6**
Chromis multilineata	Brown Chromis	6	8	36	16	7	**14.6**
Gramma loreto	Fairy Basslet	8	14	40	4	2	**13.6**
Stegastes partitus	Bicolor Damselfish	14	5	12	9	9	**9.8**
Mulloidichthys martinicus	Yellow Goatfish	0	0	0	1	48	**9.8**
Coryphopterus lipernes	Peppermint Goby	5	11	0	9	5	**6.0**
Halichoeres garnoti	Yellowhead Wrasse	1	10	4	1	11	**5.4**
Gobiosoma evelynae	Sharknose Goby	2	3	4	1	3	**2.6**
Scarus iserti	Stripped Parrotfish	0	3	4	1	4	**2.4**
Chaetodon capistratus	Four-eye Butterflyfish	1	2	2	2	2	**1.8**
Sparisoma viride	Stoplight Parrotfish	0	0	1	3	3	**1.4**
Halichoeres maculipinna	Clown Wrasse	0	1	5	0	0	**1.2**
Stegastes planifrons	Threespot Damselfish	3	1	0	0	2	**1.2**
Lactophrys triqueter	Smooth Trunkfish	1	0	2	0	2	**1.0**
Epinephelus cruentatus	Graysby	0	1	1	0	2	**0.8**
Sparisoma rubripinne	Yellowtail Parrotfish	0	0	0	1	3	**0.8**
Canthigaster rostrata	Sharpnose Puffer	0	3	1	0	0	**0.8**
Bodianus rufus	Spanish Hogfish	0	2	2	0	0	**0.8**
Chaetodon aculeatus	Longsnout Butterflyfish	2	1	1	0	0	**0.8**
Acanthurus coeruleus	Blue Tang	0	0	2	1	1	**0.8**
Scarus taeniopterus	Princess Parrotfish	0	4	0	0	0	**0.8**
Myripristis jacobus	Blackbar Soldierfish	1	2	0	0	1	**0.8**
Microspathodon chrysurus	Yellowtail Damselfish	0	0	1	1	2	**0.8**
Sparisoma radians	Bucktooth Parrotfish	0	0	0	0	4	**0.8**
Sparisoma aurofrenatum	Redband Parrotfish	0	1	1	0	0	**0.4**
Paranthias furcifer	Creolefish	1	1	0	0	0	**0.4**
Holacanthus tricolor	Rock Beauty	0	0	0	0	2	**0.4**
Caranx ruber	Bar Jack	0	0	2	0	0	**0.4**
Sphyraena barracuda	Great Barracuda	1	0	0	0	1	**0.4**
Holocentrus rufus	Longspine Squirrelfish	0	0	0	1	0	**0.2**
Melichthys niger	Black Durgon	0	1	0	0	0	**0.2**
Lutjanus apodus	Schoolmaster Snapper	0	0	0	0	1	**0.2**
Liopropoma rubre	Peppermint Basslet	0	1	0	0	0	**0.2**
Epinephelus guttatus	Red Hind	0	0	1	0	0	**0.2**
Caranx latus	Horse-eye Jack	1	0	0	0	0	**0.2**
Anisotremus surinamensis	Black Margate	0	0	1	0	0	**0.2**
Cantherhines pullus	Orange-spotted Filefish	0	0	1	0	0	**0.2**
Equetus punctatus	Spotted Drum	0	0	0	0	1	**0.2**
Equetus lanceolatus	Jackknife Fish	0	0	0	0	1	**0.2**
Epinephelus fulva	Coney	0	1	0	0	0	**0.2**
Haemulon flavolineatum	French Grunt	0	1	0	0	0	**0.2**
Holacanthus ciliaris	Queen Angelfish	0	1	0	0	0	**0.2**
Caranx crysos	Blue Runner	0	1	0	0	0	**0.2**
	TOTAL	**16**	**199**	**244**	**170**	**252**	**205.6**
	INDIVIDUALS	**3**					
	TOTAL SPECIES	**19**	**30**	**26**	**19**	**28**	**24.4**

personatus was the numerically dominant species with a mean abundance of 50.0 Ind/30 m^2 (range: 20 – 90 Ind/30 m^2), representing 24.3 % of the total (Table 15). Masked gobies were observed forming swarms below coral ledges close to the base of the reef. Large streaming schools of adult Creole Wrasse were observed throughout the water column, making frequent incursions over the reef. These are zooplanktivores that serve as forage for pelagic predators, such as Cero Mackerels, Blue Runners, and Barracudas observed during an ASEC survey in this reef (Table 16). The Blue and Brown Chromis, Masked Goby and Bicolor Damselfish are also important zooplanktivores that were common over coral heads closer to the reef. Dense swarms of mysid shrimps were present below ledges and on crevices in the reef. These small shrimps appear to be important forage for zooplanktivorous fishes in the reef.

Variations of fish abundance and species richness between monitoring surveys at Puerto Canoas 30 m are presented in Figure 16. Between 2004 and 2008, mean fish abundance fluctuated between 400 – 500 Ind/30 m^2 to stand as one of the reefs with highest fish abundance studied in Puerto Rico. During 2009 a declining trend of fish abundance that has continued to the present 2010 survey has emerged. Lower species richness and abundance were detected between the present 2010 survey and all other surveys previoud to 2009 (Figure 16). The largest decline was associated with Masked Goby, but Fairy Basslet and Blue Chromis also presented lower abundances during 2010, relative to 2009 and previous surveys. Such declines of abundance may be associated to a new predation pressure imposed by Lionfishes (*Pterois volitans*) in this reef. One adult lionfish was observed in the vicinity of our belt-transects during this 2010 survey. The predation potential of this invasive species may impose shifts in community structure directly related with its prey and still unknown cascading effects.

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

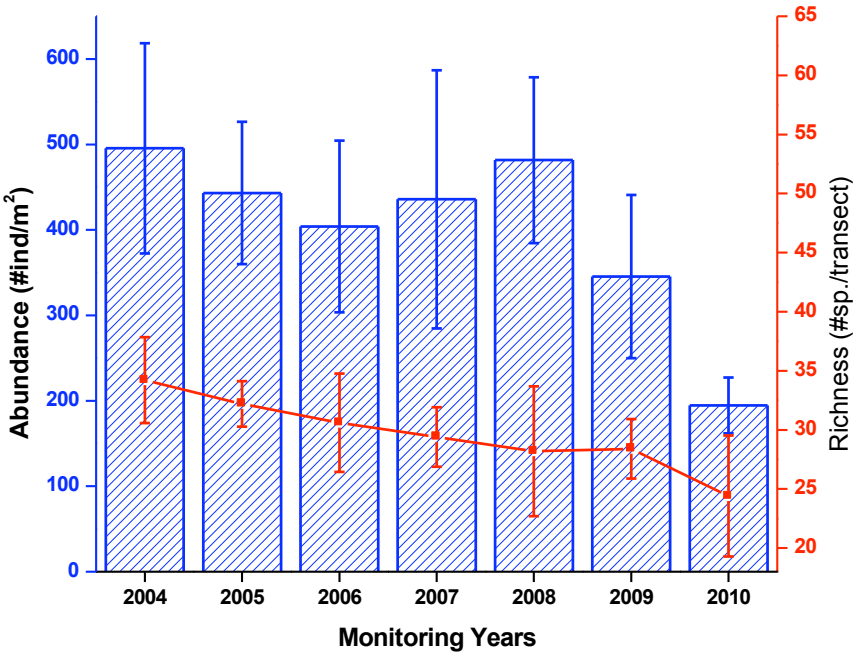


Figure 16. Monitoring trends (2004 – 2010) of fish species richness and abundance at

Table 16. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Puerto Canoas Reef, Isla Desecheo, 30m. June, 2010

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

SPECIES	**COMMON NAME**		# - (cm)	
Caranx lugubris	Black Jack	2 - (50)		
Epinephelus guttatus	Red Hind	1 – (20)	2 - (30)	
Epinephelus striatus	Nassau Grouper	2 - (40)	1 - (50)	1 - (60)
Lutjanus apodus	Schoolmaster	11 - (20)	8 - (30)	5 - (40)
Lutjanus mahogany	Mahogani Snapper	2 - (20)	6 - (30)	
Mycteroperca venenosa	Yellowfin Grouper	1 - (40)	1 - (50)	
Ocyurus chrysurus	Yellowtail Snapper	3 - (30)	2 – (40)	
Pterois volitans	Lionfish	1 – (25)		
Scomberomorus regalis	Cero Mackerel	2 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (60)		
Invertebrates				
Panulirus argus	Spiny Lobster	1 - (30)		
Strombus gigas	Queen Conch	3 - (25)	2 – (30)	
Sea Turtles				
Eretmochelys imbricata	Hawksbill Turtle	1 – (60)		

invertebrate feeders were present, including wrasses, gobies, goatfishes and squirrelfishes, among others. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous assemblage. Commercially important species for the aquarium trade market, such as the Fairy Basslet (*Gramma loreto*), Queen Angelfish (*Holacanthus ciliaris*), Rock Beauty (*Holacanthus tricolor*), Blue Chromis (*Chromis cyanea*), Yellow-head Jawfish (*Opistognathus aurifrons*) and Peppermint Bass (*Liopropoma rubre*) were common.

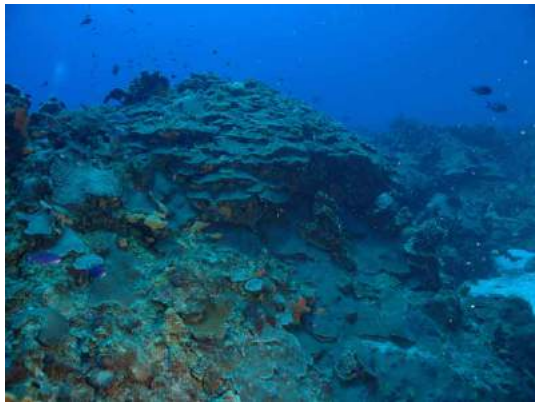
Arrow Crabs, Cleaner Shrimps and one Queen Conch were the motile megabenthic invertebrates observed within belt-transects during the 2010 survey (Table 17). One Spiny Lobster, *Panulirus argus* and several Queen Conch were observed outside transects during the ASEC survey.

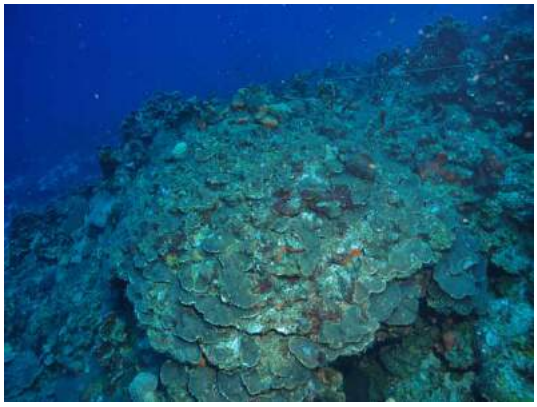
Table 17. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Puerto Canoas Shelf-edge Reef, Isla Desecheo 30m, June 2010

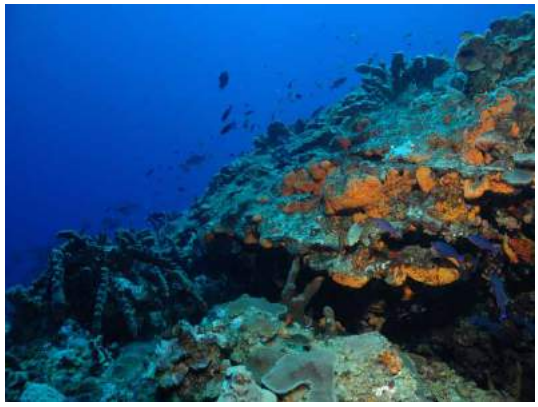
Depth: 25 – 30 m		TRANSECTS					**MEAN ABUNDANCE (IND/30 m2)**
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						
Stenorhynchus seticornis	Arrow crab	1		1			**0.4**
Strombus gigas	Queen Conch		1				**0.2**
Periclimenes pedersoni	Cleaner Shrimp	1	1			2	**0.8**
Stenopus hispidus	Banded Coral Shrimp			1			**0.2**
	TOTALS	**2**	**2**	**2**	**0**	**2**	**1.6**

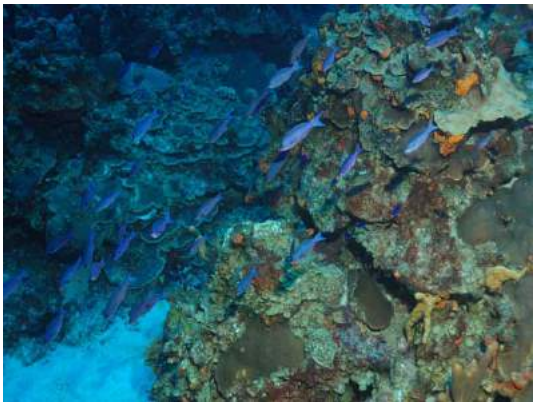
Photo Album 4 (Desecheo 30m)

Shelf Edge Reef









2.0 Mid-shelf Patch Reef - Puerto Botes

2.1 Sessile-benthic Reef Community

A series of large submerged reef patches of massive, branching and encrusting coral buildup occupy most of the mid-shelf section off Puerto Botes at depths between 17 -23 meters on the west coast of Isla Desecheo. The coral reef system is exuberant, with large stony corals growing close together and forming large promontories that provide very high topographic relief. At some points, sand channels cut through the sloping terrace of the reef towards the shelf-edge. Permanent transects were installed over two adjacent patch reef promontories separated by a narrow sand channel. The five transects lie close to the border of each patch reef at depths between 17 -19 m. The initial baseline characterization was performed in June, 2000 (García-Sais et al., 2001). This is the eight 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 5.6 % (range: 0 – 25.9). 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 80.9 % of the total cover by live corals at Puerto Botes (Table 18). Recently dead corals, indicative of continued reef degradation have been observed at this reef since the massive bleaching event of 2005-06. Until 2009, the most affected was *M. annularis*, but the declining trend included other species as well. Coversely, a mild increment of reef substrate cover by *M. annularis* appears to be emerging for *M. annularis*, as it presented slight increments in four out of the five transets surveyed in 2010, relative to 2009. Still, the small differences were within sampling variability error.

Reef overhangs, largely associated with skeletal buildups of *M. annularis* averaged 9.2 % of the reef substrate cover and contributed substantially to the reef rugosity of 4.3 m. Erect and encrusting sponges were present with a mean substrate cover of 3.4 %. Reef hard-ground substrates not colonized by stony corals or sponges were mostly overgrown

Table 18. Percent substrate cover by sessile-benthic categories at Puerto Botes Reef, Isla Desecheo, 20 m. Survey Date: May 2010.

Depth: 20 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	4.5	3.9	4.3	3.0	5.9	**4.3**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	13.4	3.2	9.9	5.0	5.7	**7.5**
Sand		0.4		4.2	1.8	**1.3**
Gap		1.7	0.7			**0.5**
Total Abiotic	13.4	5.4	10.6	9.3	7.4	**9.2**
Benthic Algae						
Fleshy algae	49.4	36.5	47.1	27.3	28.1	**37.7**
Turf-mixed assemblage	34.3	45.1	32.1	22.3	43.4	**35.4**
Coralline algae		0.6			0.6	**0.2**
Total Benthic Algae	83.7	82.3	79.2	49.6	72.1	**73.4**
Sponges		6.0	1.8	5.0	4.3	**3.4**
Cyanobacteria		0.4	1.1	2.2	2.4	**1.2**
Hydrozoa (Millepora)			0.7		0.4	**0.2**
Live Stony Corals						
Porites porites				25.9	2.0	**5.6**
Montastraea annularis		3.7	0.7	2.9	3.5	**2.1**
Agaricia agaricites	0.5	1.2	1.2	1.5	3.5	**1.6**
Montastraea cavernosa			0.9		4.4	**1.1**
Porites astreoides	0.9	1.1	0.9	1.4		**0.9**
Diploria labyrinthiformis				2.4		**0.5**
Agaricia tenuifolia	1.5		0.8			**0.5**
Eusmilia fastigiata			1.9			**0.4**
Meandrina meandrites			0.4			**0.1**
Total Stony Corals	2.9	6.0	6.7	34.0	13.3	**12.6**
Gorgonians (# col./transect)	0	0	0	0	0	0

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

by a combination of fleshy macroalgae (*Lobophora variegata., Dictyota sp., Padina sp*.) and turf algae. The assemblage of benthic algae represented the main substrate category at Puerto Botes with a combined mean cover of 73.4 % (Table 18). Cyanobacterial films were present in four out of the five transects with a mean cover of 1.2 %. Erect gorgonians were not intersected by line transects.

From the initial baseline characterization of 2000 until the 2005 survey, stony corals represented the most prominent sessile-benthic component of the mid-shelf reef at Puerto Botes with a mean reef substrate cover that fluctuated slightly between 47.2 % and 48.01 %. Differences of live coral cover were minimal and statistically insignificant until the 2006 monitoring survey when live coral cover declined sharply to a mean of 22.35 %, a loss of 53.4% from the mean live coral cover in 2005. During the present 2010 monitoring survey, live coral cover has declined furthermore to a historical minimum of 12.6 %. Differences of live coral during the 2000 – 2005 and the 2006 – 2010 monitoring surveys were statistically significant (ANOVA; $p < 0.0001$) reflecting the acute degradation experienced by the reef system after October 2005 (see Appendix 2). A corresponding increment of substrate cover by benthic algae, cyanobacteria, sponges and abiotic categories has been observed (Figure 17).

The sharp downfall of live coral at Puerto Botes Reef was triggered by the massive coral bleaching event reported for Puerto Rico and the USVI that started during late September through October 2005 (García et al., 2008; Rothenberger et al., 2008) and lingering effects that have carried further coral mortality up to the present 2010 monitoring survey. The bleaching event affected several coral species in variable magnitude, but was mostly detrimental to the dominant species in terms of substrate cover, the Boulder Star Coral, *M. annularis* (complex). This species declined in substrate cover from a mean of 25.2% in 2005 to a mean of 1.2% in 2009 (Figure 18), a statistically significant reduction (ANOVA; $p = < 0.001$). Reef substrate cover by Boulder Star Coral represented more than 53 % of the total cover by stony corals at Puerto Botes Mid-shelf Reef. Thus, its collapse after 2005 monitoring survey would be expected to have a profound ecological impact upon the coral reef system at Puerto Botes. Finger Coral (*Porites porites*), a relatively fast growing branching coral species was one of the few corals that appeared not to be severely affected by the bleaching event and maintained its reef substrate cover stable between surveys until present. Due to the

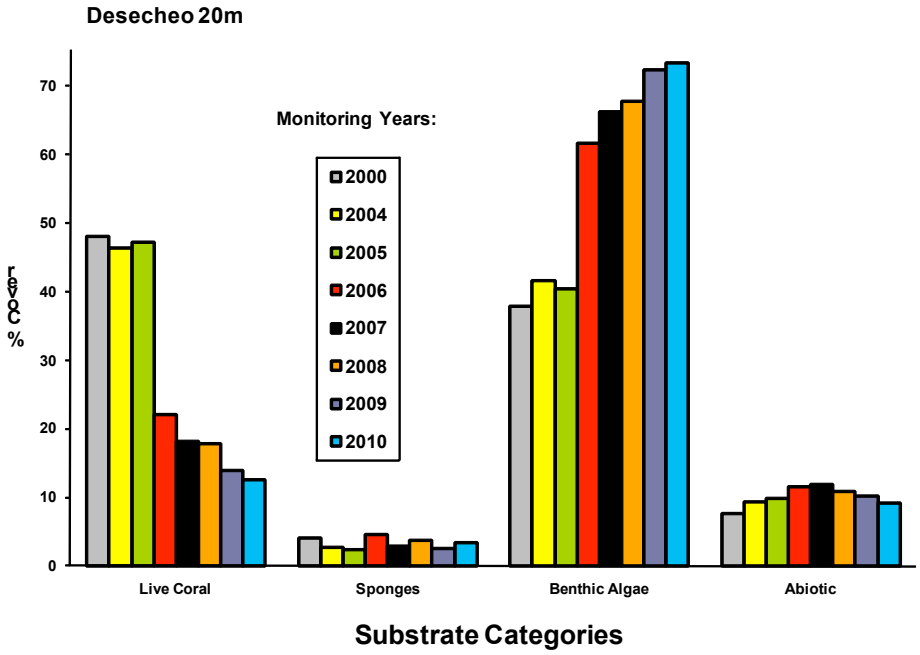


Figure 17. Monitoring trends (2000 – 10) of mean substrate cover by sessile-benthic categories at Puerto Botes Reef, Desecheo Island – 20 m.

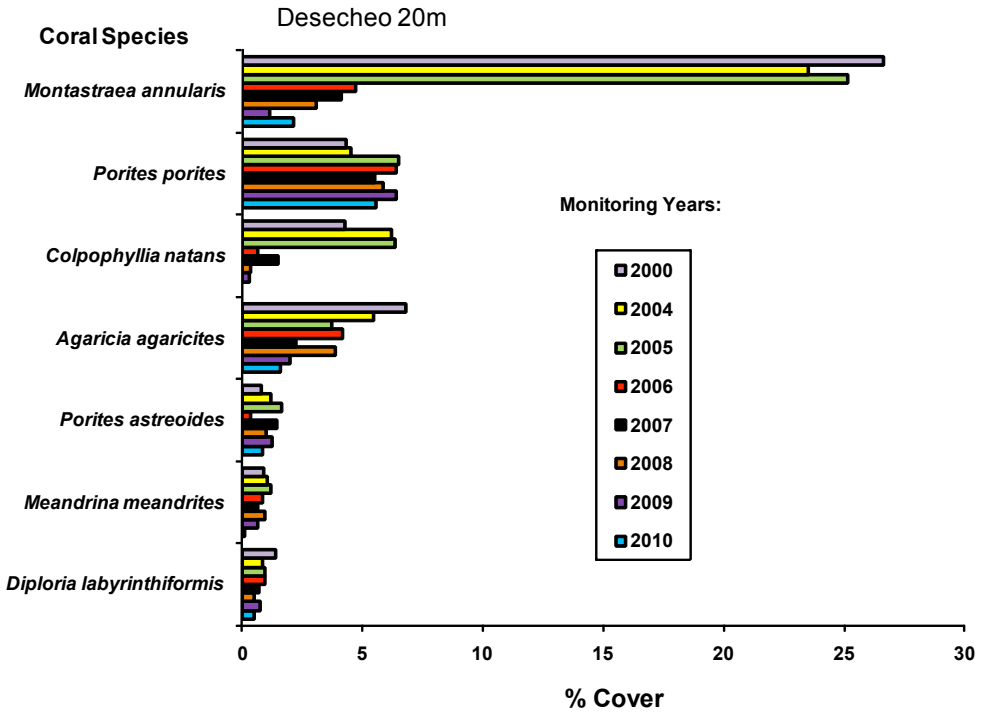


Figure 18. Monitoring trends (2000 – 10) of mean substrate cover by stony coral species at Puerto Botes Reef, Desecheo Island – 20 m.

marked decline of Boulder Star Coral, Finger Coral now stands as the main coral species in terms of live coral cover, which represents a taxonomic shift in the sessile-benthic community structure of the reef.

Benthic algae, seemingly the fastest growing component of the sessile-benthos at Puerto Botes Reef increased its substrate cover by 34.6 % between the 2005 and the 2006 monitoring surveys (Figure 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 2010 surveys, from 3.6 % in 2005 to 37.7 % in 2010.

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 43 fish species were identified within belt-transects from the mid-shelf patch reefs off Puerto Botes, Isla Desecheo during 2010 (Table 19). During the nine surveys, a total of 71 diurnal, non-criptic fishes have been reported from this reef (Appendix 1). Mean abundance of fishes within belt-transects was 158.4 Ind/30 m^2 (range: 114 - 188 Ind/30 m^2). The mean number of species per transect was 21.4 (range: 21 - 24). The Blue Chromis (*Chromis cyanea*) was the numerically dominant species within belt-transects during the 2010 survey with a mean abundance of 49.0 Ind/30 m^2. The combined abundance of six species, including the Blue and Brown Chromis, Bicolor Damselfish, Bluehead and Yellowhead Wrasses, and Yellow Goatfish represented 80.6 % of the total fish abundance within belt-transects. Five species were present in all five transects and another nine were present in four transects (Table 19).

Annual monitoring trends of fish species richness and abundance surveyed within belt-transects are presented in Figure 19. Before the 2010 survey, the mean number of fish species within transects (species richness) fluctuated between 23.0 and 29.0, and mean abundance varied between 166.8 Ind/30 m^2 and 248.6 Ind/30 m^2. The 2010 mean abundance and species richness represent the lowest record during the nine-year monitoring period at this reef. Differences of species richness and abundance between surveys were not statistically significant (ANOVA; $p > 0.05$).

Table 19. Taxonomic composition and abundance of fishes within belt-transects at Puerto Botes Reef, Isla Desecheo, 20m. Survey Date: June, 2010

Depth: 20 m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Chromis cyanea	Blue Chromis	23	59	47	78	38	**49.0**
Stegastes partitus	Bicolor Damselfish	22	28	28	45	32	**31.0**
Thalassoma bifasciatum	Bluehead Wrasse	28	18	33	20	18	**23.4**
Halichoeres garnoti	Yellowhead Wrasse	10	10	15	12	3	**10.0**
Chromis multilineata	Brown Chromis	0	4	3	0	35	**8.4**
Mulloidichthys martinicus	Yellow Goatfish	0	29	0	0	0	**5.8**
Halichoeres maculipinna	Clown Wrasse	5	6	4	6	1	**4.4**
Gobiosoma evelynae	Sharknose Goby	4	0	1	5	3	**2.6**
Sparisoma viride	Stoplight Parrotfish	3	0	5	3	1	**2.4**
Clepticus parrae	Creole Wrasse	6	5	0	0	0	**2.2**
Gramma loreto	Fairy Basslet	0	8	0	1	1	**2.0**
Myripristis jacobus	Blackbar Soldierfish	0	5	0	2	1	**1.6**
Sparisoma radians	Bucktooth Parrotfish	1	2	0	1	3	**1.4**
Epinephelus fulva	Coney	1	1	2	2	0	**1.2**
Bodianus rufus	Spanish Hogfish	0	1	1	1	3	**1.2**
Amblycirrhitus pinos	Redspotted Hawkfish	1	3	0	2	0	**1.2**
Acanthurus coeruleus	Blue Tang	1	0	1	2	2	**1.2**
Haemulon flavolineatum	French Grunt	0	0	2	1	2	**1.0**
Scarus iserti	Stripped Parrotfish	0	0	3	1	1	**1.0**
Sparisoma aurofrenatum	Redband Parrotfish	1	1	0	1	2	**1.0**
Lactophrys triqueter	Smooth Trunkfish	2	1	0	1	1	**1.0**
Epinephelus cruentatus	Graysby	1	0	1	0	1	**0.6**
Microspathodon chrysurus	Yellowtail Damselfish	1	1	0	0	1	**0.6**
Neoniphon marianus	Longjaw Squirrelfish	1	2	0	0	0	**0.6**
Scarus taeniopterus	Princess Parrotfish	0	2	0	0	0	**0.4**
Holocentrus rufus	Longspine Squirrelfish	1	0	0	0	1	**0.4**
Melichthys niger	Black Durgon	0	0	0	0	2	**0.4**
Chaetodon capistratus	Four-eye Butterflyfish	0	0	0	2	0	**0.4**
Pterois volitans	Lionfish	0	0	2	0	0	**0.4**
Coryphopterus lipernes	Peppermint Goby	0	0	1	0	1	**0.4**
Holacanthus tricolor	Rock Beauty	0	0	0	1	0	**0.2**
Sparisoma rubripinne	Yellowtail Parrotfish	0	0	1	0	0	**0.2**
Haemulon macrostomum	Spanish Grunt	0	1	0	0	0	**0.2**
Lutjanus apodus	Schoolmaster Snapper	0	1	0	0	0	**0.2**
Gobiosoma dilepsis	Orange-sided Goby	1	0	0	0	0	**0.2**
Acanthurus bahianus	Ocean Surgeon	1	0	0	0	0	**0.2**
Coryphopterus glaucofraenum	Bridled Goby	0	0	1	0	0	**0.2**
Kyphosus sectatrix	Chub	0	0	1	0	0	**0.2**
Lactophrys polygonia	Honeycomb Cowfish	1	0	0	0	0	**0.2**
Mycteroperca venenosa	Yellowfin Grouper	0	0	1	0	0	**0.2**
Xanthichthys ringens	Sargassum Triggerfish	0	0	1	0	0	**0.2**
Caranx ruber	Bar Jack	0	0	0	0	1	**0.2**
Bothus lunatus	Peacock Flounder	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**114**	**188**	**150**	**187**	**153**	**158.4**
	TOTAL SPECIES	**21**	**21**	**21**	**20**	**24**	**21.4**

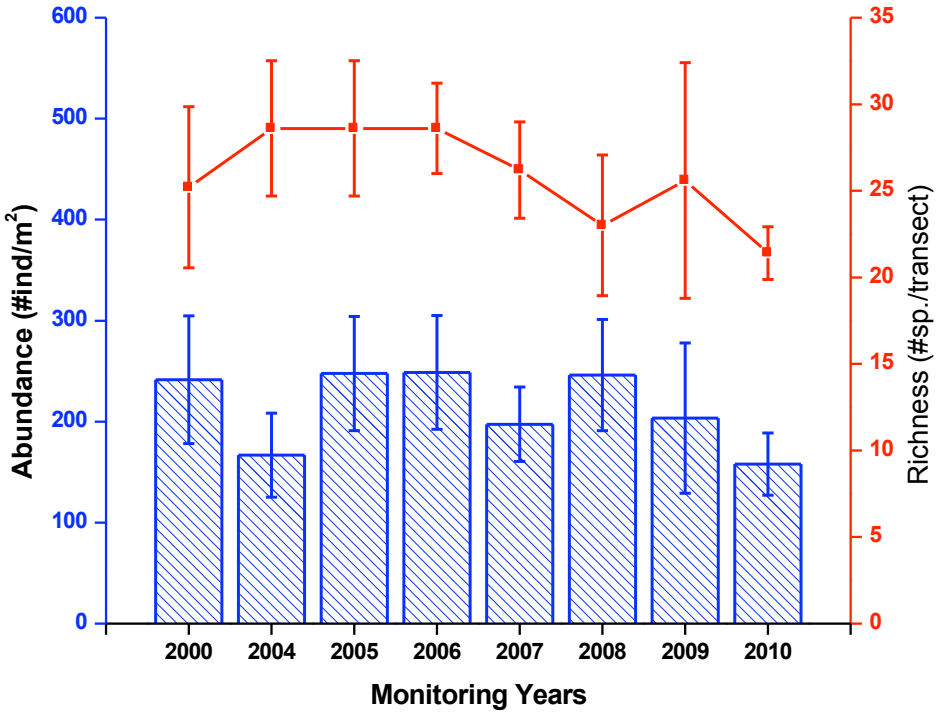


Figure 19. Monitoring trends (2000 – 2010) of fish species richness and abundance at the Mid-Shelf Reef, Puerto Botes, 20 m, Isla Desecheo.

The mid-shelf reef off Puerto Botes presented a well balanced fish community in terms of trophic structure, except for the absence of large demersal predators, which were observed to be present in deeper sections of the shelf-edge off Puerto Canoas Reef, adjacent to Puerto Botes. Pelagic schools of Creole Wrasse (15 – 25 individuals) were observed throughout the water column, making frequent incursions over the reef. These are zooplanktivores that serve as forage for large pelagic predators, such as Cero Mackerels, Black Jacks and Barracudas observed during an ASEC survey in this reef (Table 20). The Blue and Brown Chromis, Masked Goby and Bicolor Damselfish are also important zooplanktivores that were common over coral heads closer to the reef. Dense swarms of mysid shrimps were present below ledges and on crevices. These small shrimps appear to be important forage for the demersal zooplanktivorous fishes. Mid-size carnivores that are commercially exploited, such as the Yellowtail, Mahogany and

Schoolmaster Snappers, Red Hind, Coney and Queen Triggerfish were observed as adults. A large variety of small invertebrate feeders were present, including wrasses, gobies, goatfishes and squirrelfishes, among others. Parrotfishes, doctorfishes and damselfishes comprised the main herbivorous assemblage. Commercially important species for the aquarium trade market, such as the Fairy Basslet (*Gramma loreto*), Queen Angelfish (*Holacanthus ciliaris*), Rock Beauty (*Holacanthus tricolor*), Blue Chromis (*Chromis cyanea*), Yellow-head Jawfish (*Opistognathus aurifrons*) and Peppermint Bass (*Liopropoma rubre*) were common. Lionfishes were observed within belt-transects and also outside transects, which indicates that they are established in this reef. Interestingly, their presence in the reef coincides with the lowest fish abundance and species richness ever recorded during the monitoring program at Puerto Botes.

Arrow Crabs and Cleaner Shrimps were the only motile megabenthic invertebrates within belt-transects (Table 21). Spiny Lobsters (*Panulirus argus*), Sponge Brittle Stars (*Ophiothrix suensoni*) and Long-Spined Urchin (*Diadema antillarum*) were observed outside transects.

Table 20. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Puerto Botes, Isla Desecheo, 20 m. Survey Date: June, 2010

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

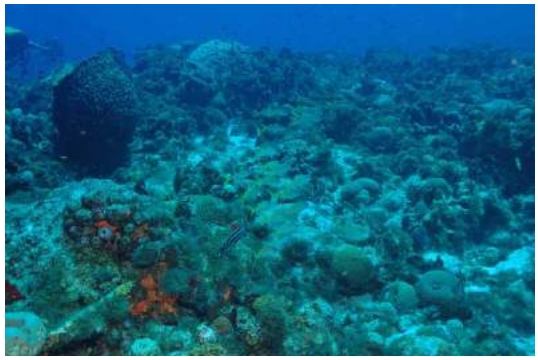
SPECIES	**COMMON NAME**		# - (cm)	
Carangoides crysos	Blue Runner	2 – (30)		
Caranx lugubris	Black Jack	1 - (50)		
Epinephelus guttatus	Red Hind	1 – (20)	2 – (30)	
Lutjanus apodus	Schoolmaster	12 – (20)	7- (30)	4- (40)
Lutjanus mahogany	Mahogani Snapper	5 - (20)	3 – (25)	
Ocyurus chrysurus	Yellowtail Snapper	2 – (30)	2 – (40)	
Pterois volitans	Lionfish	2 – (25)	1 – (30)	
Scomberomorus regalis	Cero Mackerel	1 - (40)		
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 2010

		TRANSECTS					
Depth: 20 m		**1**	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**						
Periclimenes pedersoni	Cleaner Shrimp		1	1			**0.4**
Stenopus hispidus	Banded coral shrimp	1			2		**0.6**
	TOTALS	**1**	**1**	**1**	**2**	**0**	**1.0**

Photo Album 5 (Desecheo 20m)

Mid Shelf Reef



3.0 Inner Shelf Reefs – Puerto Botes

3.1 Sessile-benthic Reef Community

The rocky shoreline off Puerto Botes leads to a gently sloping hard ground terrace colonized by corals and other encrusting biota. With increasing depth, the hard ground terrace breaks into several large promontories with a marked increment of stony coral buildup. The southern section of the terrace presents a more abrupt slope from the shoreline towards deeper waters and is heavily colonized by soft corals (gorgonians). Our survey was performed along the northern section. Five permanent transects were installed almost parallel to each other oriented north-south. Panoramic views of the inner shelf reef at Puerto Botes are presented as Photo Album 6.

A total of 19 stony corals, including 15 intersected by line transects were identified during this 2010 monitoring survey at Puerto Botes Inner Reef. Stony corals presented a mean substrate cover of 8.5 % (range: 6.4 – 10.0 %) (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 6.3 %, representative of 74.1 % 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 7.4 % and contributed substantially to the reef rugosity of 3.5 m. Total abiotic cover also included sections of sand and averaged 15.0 %. Sponges were present at all transects with a mean substrate cover of 5.8 % (Table 22).

Benthic algae, represented by a mixed assemblage of turf, fleshy (brown and red), and coralline macroalgae were the main sessile-benthic reef component in terms of substrate cover with a combined mean of 70.4 % (Table 22). Fleshy macroalgae, mostly comprised by *Lobophora variegata, Dictyota sp*., and *Padina sp*.) were the dominant component of the benthic algae with a mean cover of 20.5 %. Both turf and fleshy macroalgae were observed overgrowing dead sections of coral colonies in the reef.

Table 22. Percent substrate cover by sessile-benthic categories at Puerto Botes Reef, Isla Desecheo 15m. Survey Date: May, 2010.

Depth: 15 m

	Transects					
Transects	**1**	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	2.3	3.5	4.3	3.5	4.2	**3.5**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	0.9	9.0	5.4	12.0	9.6	**7.4**
Sand	13.3	7.0	8.5	7.6		**7.3**
Total Abiotic	15.4	16.0	13.8	19.7	10.2	**15.0**
Benthic Algae						
Fleshy algae	47.5	43.2	40.0	56.0	61.9	**49.7**
Turf-mixed assemblage	15.3	28.6	31.1	16.5	10.9	**20.5**
Coralline algae			1.0			**0.2**
Total Benthic Algae	62.8	71.8	72.1	72.5	72.8	**70.4**
Sponges	11.0	2.2	7.6	0.6	7.6	**5.8**
Cyanobacteria	0.5					**0.1**
Live Stony Corals						
Porites astreoides	3.2	6.4	1.8		0.3	**2.3**
Montastraea annularis	0.8		2.5	1.9	6.0	**2.2**
Montastraea cavernosa	2.0		2.2	1.7		**1.2**
Colpophyllia natans		3.1				**0.6**
Siderastrea siderea	2.5					**0.5**
Millepora alcicornis	0.6		0.8	0.4		**0.4**
Agaricia tenuifolia					1.9	**0.4**
Agaricia agaricites		0.5		1.0		**0.3**
Diploria labyrinthiformis	1.3					**0.3**
Eusmilia fastigiata				1.1		**0.2**
Siderastrea radians					0.8	**0.2**
Porites porites				0.7		**0.1**
Diploria strigosa					0.5	**0.1**
Madracis decactis				0.3		**0.1**
juv.coral				0.2		**0.0**
Total Stony Corals	9.7	10.0	6.4	6.9	9.5	**8.5**
Gorgonians (# col./transect)	0	0	0	0	0	0

Coral Species Outside Transects: *Acropora cervicornis, Diploria clivosa, Leptoseris cucullata, Madracis decactis, Stylaster roseus*

Figure 20 presents the variations of mean percent cover by the main sessile-benthic categories from the inner shelf reef off Puerto Botes surveyed during the period between 2004-10. Mean reef substrate cover by stony corals, sponges and benthic algae remained virtually stable between the 2004 baseline and the 2005 monitoring survey. Differences during 2005 were all within 1% of baseline and statistically insignificant (García-Sais et al., 2005). A reduction 49.4 % of mean live coral cover was measured during the 2006 monitoring event, from 19.5 % in 2005 to 9.9 % in 2006. Corresponding increments of substrate cover by benthic algae and abiotic categories were also measured. An additional decline of 18.3 % mean live coral cover was measured during the 2007 survey, from 9.8 % in 2006 to 8.1 % in 2007. Differences of total live coral cover between surveys were statistically significant (ANOVA; $p = 0.008$). The decline of coral cover during 2007 was observed in four out of the five transects surveyed. After 2007, statistically significant 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 2.6 % in 2006 (Figure 21). The reduction of percent cover by Boulder Star Coral between the 2005 and the 2006 surveys was statistically significant (ANOVA; $p = 0.027$). Additional declines of substrate cover down to a minimum of 1.5 % were measured for *M. annularis* until the 2009 survey. The declining trend for this coral species ended during the present 2010 survey with a mild, yet statistically insignificant fractional increment of 2.2 % mean substrate cover. At present, the dominant coral species in terms of reef substrate cover is the Mustard-Hill Coral, *Porites astreoides*, which implies a shift in the sessile-benthic community structure of the reef.

A total of 11 coral species were intercepted by transects at the inner shelf reef of Puerto Botes with a mean substrate cover lower than 1 % (Table 22). Some of the most common species include, Great Star Coral, *Montastraea cavernosa*, Lettuce Corals, *Agaricia agaricites*, *Agaricia tenuifolia*, and Flower Coral, *Eusmilia fastigiata*.

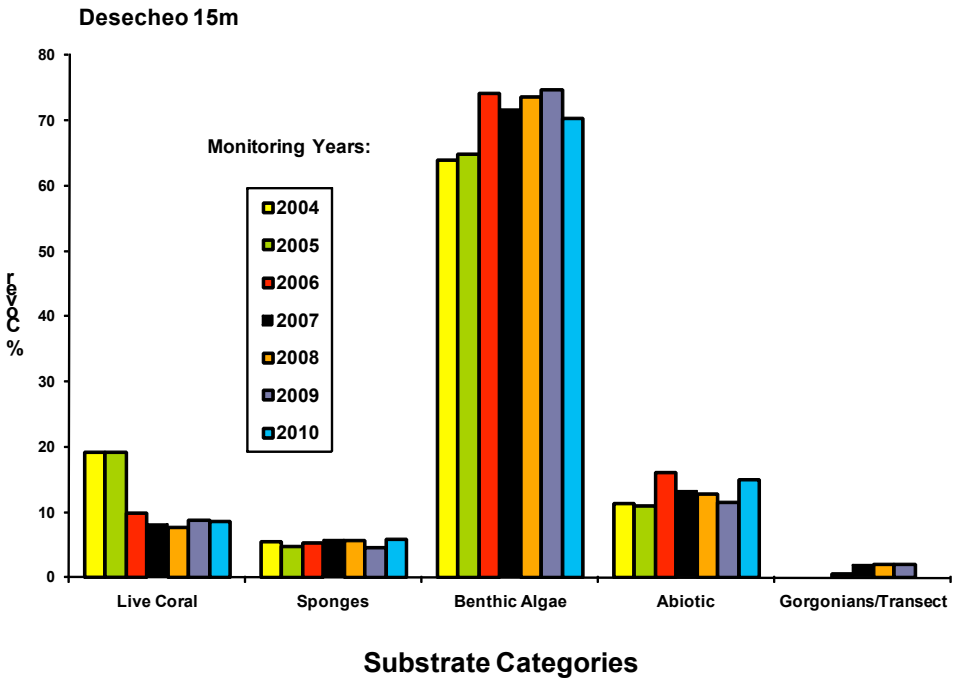


Figure 20. Monitoring trends (2004 -10) of mean substrate cover by sessile-benthic categories at Puerto Botes Inner Shelf Reef, Desecheo Island – 15 m.

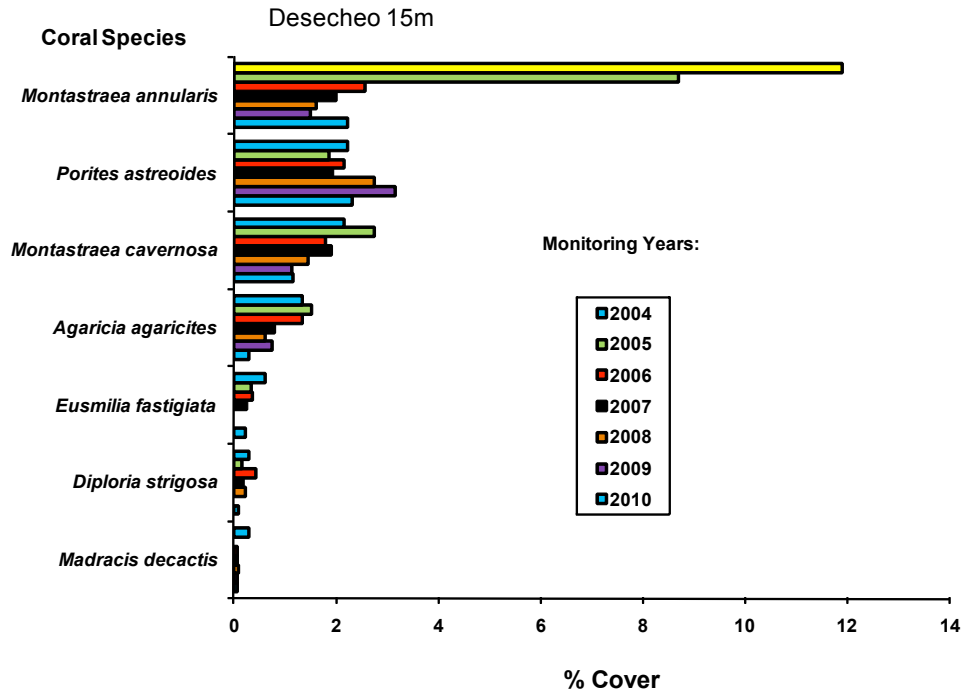


Figure 21. Monitoring trends (2004 -10) of mean substrate cover by stony coral species at Puerto Botes Inner Shelf Reef, Desecheo Island – 15 m.

3.2 Fishes and Motile Megabenthic Invertebrates

A total of 44 fish species were identified within belt-transects from the Inner-Shelf Reef off Puerto Botes, Isla Desecheo during June 2010 (Table 23). Mean abundance within belt-transects during the 2010 survey was 120.4 Ind/30 m^2 (range: 74 - 164 Ind/30 m^2). The mean number of species per transect was 20.8 (range: 13 - 25). The Bicolor Damselfish, Creole Wrasse and Blue Chromis were the numerically dominant species with a combined abundance of 79.2 Ind/30 m^2, representing 65.8 % of the total fish abundance. Seven additional species were present in at least four out of the five transects. These include the Yellowhead Wrasse, Sharknose Goby, Yellowtail Damselfish, Blue Tang, Sargassum Triggerfish and the Coney. A total of 14 species were represented by only one individual in the five belt-transects surveyed.

Annual monitoring trends of fish species richness and abundance surveyed within belt-transects are presented in Figure 22. The mean number of fish species within transects (species richness) has fluctuated between 17.6 and 25.2, and mean abundance has varied between 120.4 Ind/30 m^2 and 307.6 Ind/30 m^2 during the six-year monitoring period at this reef. A statistically significant decline of fish species richness and abundance was observed during the 2008 and 2010 surveys 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. Also, the minimum fish abundance record during the present 2010 survey coincides with the establishment of the Lionfish (*Pterois volitans*) in this reef. This invasive species is regarded as a voracious predator of small fishes and could be influencing the declining small fish abundance in the reef.

Table 23. Taxonomic composition and abundance of fishes within belt-transects at Puerto Botes Reef, 15 m, Isla Desecheo. Survey Date: June, 2010

Depth: 15m

		Transects					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Stegastes partitus	Bicolor Damselfish	26	36	35	33	28	**31.6**
Thalassoma bifasciatum	Bluehead Wrasse	19	50	32	10	24	**27.0**
Chromis cyanea	Blue Chromis	5	28	32	13	25	**20.6**
Halichoeres garnoti	Yellowhead Wrasse	7	4	10	8	3	**6.4**
Gobiosoma evelynae	Sharknose Goby	0	5	4	6	7	**4.4**
Chromis multilineata	Brown Chromis	0	0	15	1	1	**3.4**
Sparisoma viride	Stoplight Parrotfish	4	4	2	0	5	**3.0**
Cephalopholis fulva	Coney	4	1	2	3	2	**2.4**
Microspathodon chrysurus	Yellowtail Damselfish	1	1	3	2	5	**2.4**
Lutjanus apodus	Schoolmaster Snapper	0	0	5	1	4	**2.0**
Halichoeres maculipinna	Clown Wrasse	0	2	5	2	0	**1.8**
Myripristis jacobus	Blackbar Soldierfish	0	1	1	0	6	**1.6**
Acanthurus coeruleus	Blue Tang	1	1	1	1	3	**1.4**
Mulloidichthys martinicus	Yellow Goatfish	0	0	5	0	0	**1.0**
Xanthichthys ringens	Sargassum Triggerfish	1	1	2	1	0	**1.0**
Melichthys niger	Black Durgon	0	1	0	2	1	**0.8**
Chaetodon striatus	Banded Butterflyfish	2	2	0	0	0	**0.8**
Clepticus parrae	Creole Wrasse	0	0	0	2	1	**0.6**
Sparisoma radians	Bucktooth Parrotfish	0	0	1	2	0	**0.6**
Sparisoma aurofrenatum	Redband Parrotfish	0	1	0	0	2	**0.6**
Cephalopholis cruentatus	Graysby	0	1	0	1	1	**0.6**
Gramma loreto	Fairy Basslet	0	0	0	0	2	**0.4**
Sparisoma rubripinne	Yellowtail Parrotfish	0	1	0	0	1	**0.4**
Holacanthus tricolor	Rock Beauty	0	0	1	1	0	**0.4**
Scarus iserti	Striped Parrotfish	0	1	0	0	1	**0.4**
Chaetodon capistratus	Four-eye Butterflyfish	2	0	0	0	0	**0.4**
Haemulon flavolineatum	French Grunt	0	0	1	0	1	**0.4**
Bodianus rufus	Spanish Hogfish	0	0	1	0	1	**0.4**
Acanthurus bahianus	Ocean Surgeon	0	1	1	0	0	**0.4**
Lactophrys polygonia	Honeycomb Cowfish	0	0	0	1	1	**0.4**
Lactophrys triqueter	Smooth Trunkfish	0	0	1	0	0	**0.2**
Kyphosus sectatrix	Bermuda Chub	0	0	0	0	1	**0.2**
Coryphopterus glaucofraenum	Bridled Goby	0	0	1	0	0	**0.2**
Amblycirrhitus pinos	Redspotted Hawkfish	0	0	1	0	0	**0.2**
Scorpaena plumieri	Scorpion Fish	1	0	0	0	0	**0.2**
Holacanthus ciliaris	Queen Angelfish	1	0	0	0	0	**0.2**
Equetus punctatus	Spotted Drum	0	0	1	0	0	**0.2**
Acanthemblemaria aspera	Roughhead Blenny	0	0	0	1	0	**0.2**
Sphyraena barracuda	Great Barracuda	0	0	0	1	0	**0.2**
Halichoeres cyanocephalus	Yellowcheek Wrasse	0	0	0	1	0	**0.2**
Priacanthus arenatus	Glass Eye	0	1	0	0	0	**0.2**
Neoniphon marianus	Longjaw Squirrelfish	0	1	0	0	0	**0.2**
Scarus vetula	Queen Parrotfish	0	1	0	0	0	**0.2**
Diodon histrix	Porcupinefish	0	0	1	0	0	**0.2**
	TOTAL INDIVIDUALS	**74**	**145**	**164**	**93**	**126**	**120.4**
	TOTAL SPECIES	**13**	**22**	**25**	**21**	**23**	**20.8**

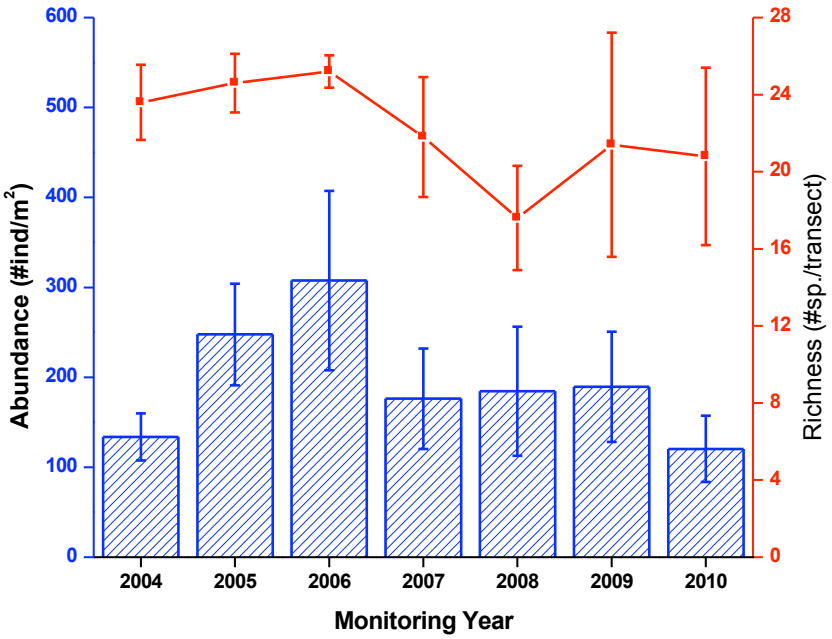


Figure 22. Monitoring trends (2004 – 2010) of fish species richness and abundance at Inner Shelf Reef, Puerto Botes, 15 m depth, Isla Desecheo.

Reef zooplankton feeders, such as the Bicolor Damselfish, Creole Wrasse and the Blue and Brown Chromis comprise the most prominent fish assemblage of this inshore reef in terms of abundance. These are important prey items of mid-size demersal piscivores that are commercially exploited, such as the Yellowtail and Schoolmaster Snappers, Red Hind and Coneys, as well as for juvenile and adult stages of pelagic fishes associated with the reef food web, such as the Great Barracuda, Cero Mackerels and jacks that have been observed during the ASEC surveys (Table 24). Also, open water zooplanktivores, such as the Mackerel Scad (*Decapterus macarellus*) 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 sponge stars, arrow crabs and cleaner shrimps (Table 25).

Table 24. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Puerto Botes Inner-shelf Reef, Isla Desecheo, June, 2010

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

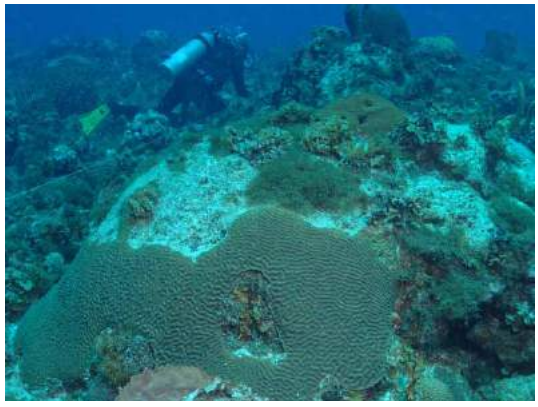
SPECIES	**COMMON NAME**		# - (cm)	
Caranx crysos	Blue Runner	2 - (30)	1 – (40)	
Decapterus macarellus	Mackerel Scad	100 - (10-12)		
Epinephelus guttatus	Red Hind	3 – (25)		
Lutjanus apodus	Schoolmaster	4 - (20)	5 - (30)	1 - (40)
Lutjanus mahogany	Mahogani Snapper	2 - (20)	2 – (25)	1 - (30)
Ocyurus chrysurus	Yellowtail Snapper	2 – (30)	1 – (40)	
Scomberomorus regalis	Cero Mackerel	1 - (50)		
Sphyraena barracuda	Great Barracuda	1 - (50)		

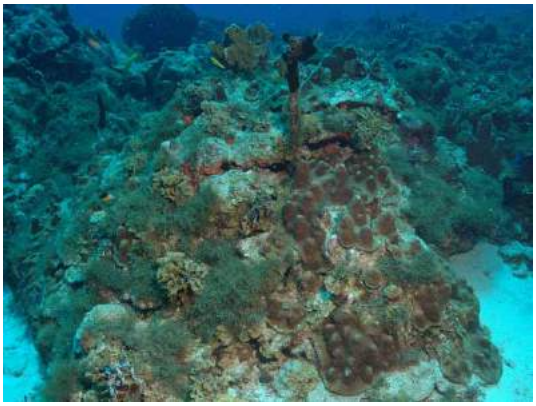
Table 25. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at the Puerto Botes Inner-Shelf Reef, 15 m, Isla Desecheo, June, 2010

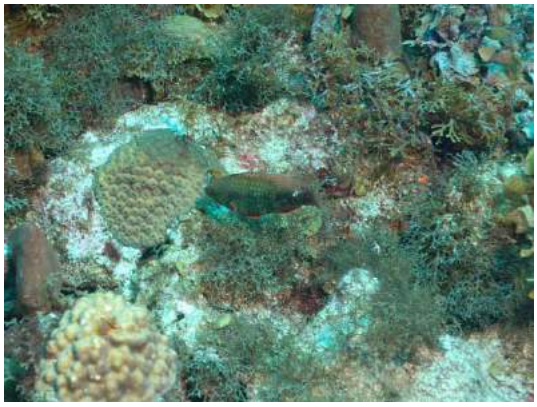
Depth: 15 m		TRANSECTS 1	2	3	4	5	MEAN ABUNDANCE (IND/30 m2)
TAXA	**COMMON NAME**						
Stenorhynchus seticornis	Arrow Crab	1			2	1	**0.8**
Periclimenes pedersoni	Cleaner Shrimp	1	1				**0.4**
Ophiothrix suensoni	Sponge Brittle Star	3					**0.6**
	TOTALS	**5**	**1**	**0**	**2**	**1**	**1.8**

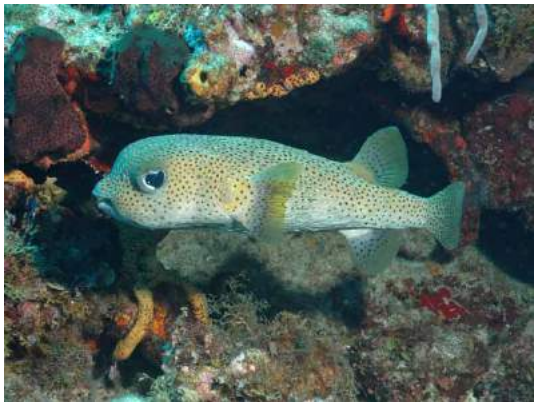
Photo Album 6 (Desecheo 15m)

Inner Shelf Reef









C. Tourmaline Reef System – Mayaguez Bay

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

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

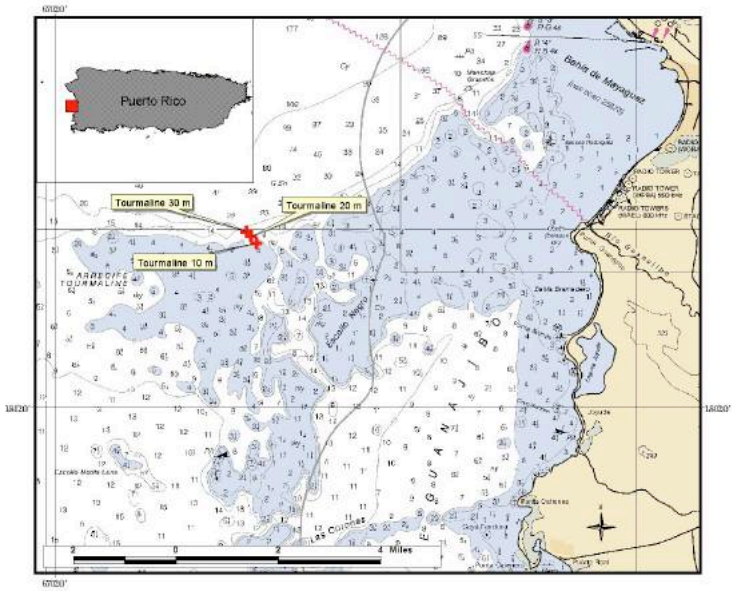


Figure 23. Location of coral reef survey stations at Tourmaline Reef, off Mayaguez Bay.

1.0 Shelf-edge Reef – 30 meters

1.1 Sessile-Benthic Reef Community

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

A total of 21 stony corals and two black coral species were identified from the shelf-edge off Tourmaline Reef, 12 of which were intercepted by line transects during our survey (Table 26). Stony corals occurred mostly as isolated encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 13.1 % (range: 9.3 – 19.1 %). Boulder Star Coral, *Montastraea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 6.6 % (range: 3.9 – 10.9 %), representing 50.4 % of the total cover by stony corals. Isolated colonies of lettuce corals, including Lamark's Sheet Coral, *Agaricia lamarcki,* Graham's Sheet Coral, *A. grahamae*, and Lettuce Coral, *A. agaricites* were also prominent at the shelf-edge. These species are difficult to discern in the generally poorly illuminated condition of the reef at 30m and are here reported as one group of species (e.g. *Agaricia spp*). Soft corals (gorgonians) were highly abundant, with an average of 15.6 colonies/transect. The Corky Sea Finger, *Briareum asbestinum* and the Sea Plume, *Pseudopterogorgia acerosa* were intercepted by at least four transects and presented means of 7.0 and 4.4 colonies per transect. A total of 10 soft coral species were intercepted by transects at this reef. 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 3.8 %. The Blue Bell Tunicate, *Clavelina puertosecensis* was very common throughout the shelf-edge reef. Reef overhangs, associated with substrate depressions and coral ledges averaged 25.2 % and contributed substantially to a topographic rugosity of 6.0 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 46.8 % (range : 34.1 – 57.7%). Turf algae was found

Table 26. Percent substrate cover by sessile-benthic categories at Tourmaline Reef, Mayaguez, 30m. Survey Date: May 2010.

Depth 30 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	6.9	4.9	6.6	6.6	5.0	**6.0**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	33.2	34.5	7.5	16.4	8.5	**20.0**
Silt	2.5	5.4	5.8	3.4	7.1	**4.8**
Gap	1.6					**0.3**
Total Abiotic	37.3	39.9	13.3	19.8	15.6	**25.2**
Benthic Algae						
Turf-mixed assemblage	42.1	34.1	57.7	50.5	49.6	**46.8**
Dictyota sp.		0.6	1.7	7.7	1.5	**2.3**
Coralline algae			3.3	0.9	2.1	**1.3**
Total Benthic Algae	42.1	34.7	62.7	59.0	53.2	**50.4**
Encrusting Gorgonians						
Erythropodium caribaeorum	2.5	0.9	1.2	5.8	3.3	**2.7**
Sponges	3.8	3.8	2.7	6.0	2.8	**3.8**
Cyanobacteria		1.7	1.2			**0.6**
Live Stony Corals						
Montastrea annularis	4.7	6.3	7.4	3.9	10.9	**6.6**
Agaricia spp.	4.6	4.6	1.1	5.4	3.5	**3.8**
Montastrea cavernosa					2.6	**0.5**
Porites astreoides		0.9	0.4		1.2	**0.5**
Madracis decactis	0.7	1.6				**0.5**
Siderastrea siderea			0.6		0.9	**0.3**
Stephanocoenia intersepta	1.3					**0.3**
Porites colonensis	0.8		0.3			**0.2**
Mycetophyllia aliciae	1.1					**0.2**
Dichocoenia stokesi	1.0					**0.2**
Total Stony Corals	14.2	13.3	9.9	9.3	19.1	**13.1**
Gorgonians (# col.)						
Briareum asbestinum	15	3	5	7	5	**7.0**
Pseudoptergorgia acerosa	0	3	10	3	6	**4.4**
Erythropodium caribaeorum	3	0	0	2	1	**1.2**
Plexaura kukenthali	1	1	0	1	2	**1.0**
Pseudoptergorgia bipinnata	0	0	0	1	2	**0.6**
Eunicea spp.	0	1	0	0	1	**0.4**
Pseudoptergorgia americana	0	1	1	0	0	**0.4**
Eunicea flexuosa	0	0	1	0	0	**0.2**
Eunicea tourneforti	0	1	0	0	0	**0.2**
Pseudoplexaura purosa	0	0	0	1	0	**0.2**
Total Gorgonians (# Col./transect)	19	10	17	15	17	**15.6**

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

overgrowing rocky substrates, as well as dead coral sections and other hard bottom. The total cover by benthic algae was 50.4 %. Cyanobacterial films were present in two transects with a mean reef substrate cover of 0.6 %.

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 2010 monitoring survey (13.1 %) has remained within the sampling error margin. Differences of live coral cover between monitoring surveys were small and not statistically significant (ANOVA; $p > 0.05$, Appendix 2). Boulder Star Coral, *Montastraea annularis* maintained its status as the dominant coral species in terms of reef substrate cover at 30 m (Figure 25). Since our baseline survey in 2004, many large colonies of *M. annularis* stand dead and overgrown by turf algae on this reef, indicative of a major stress acting over this coral species some years before our original survey. Although partial bleaching was reported in one colony of *M. annularis* during the 2006 monitoring survey, widespread mortality associated with bleaching has not been observed at this reef. After 2007, a gradual trend of increasing cover by M. annularis has been measured, reaching its peak value (mean: 6.6 %) during the present 2010 survey.

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 2010 monitoring survey was 153.6 Ind/30 m^2 (range: 96 - 219 Ind/30 m^2). The mean number of species per transect was 17 (range: 14 - 21). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 81.2 Ind/30 m^2 (range: 50 - 150 Ind/30 m^2), representing 52.9 % of the total abundance within belt-transects (Table 27). The Masked Goby is a small zooplanktivorous 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 along with Creole Wrasse comprised the most abundant fish assemblage at the shelf-edge reef.

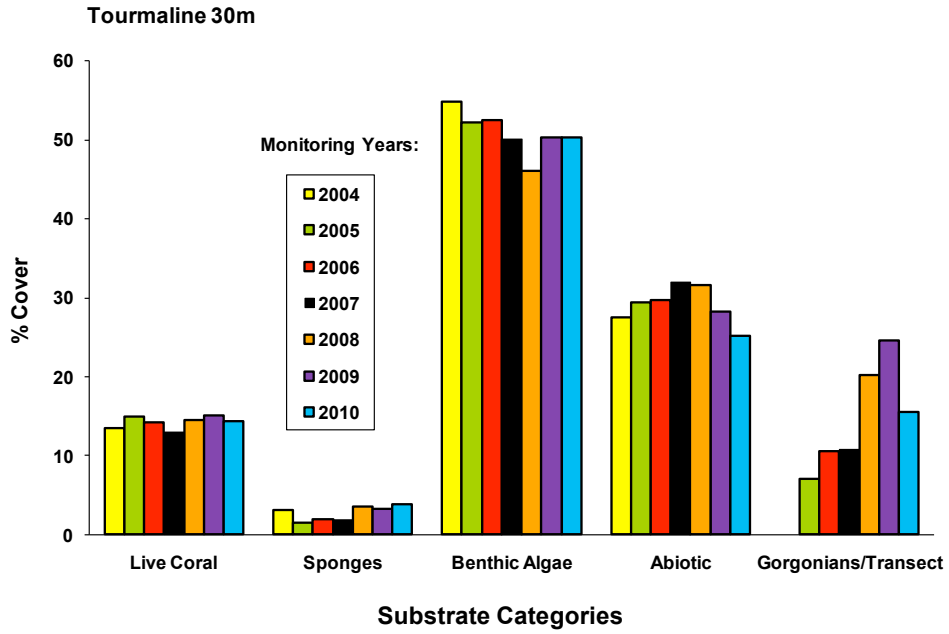


Figure 24. Monitoring trends (2004 – 2010) of mean substrate cover by sessile-benthic categories at Tourmaline Shelf-edge Reef – 30 m, Mayaguez Bay.

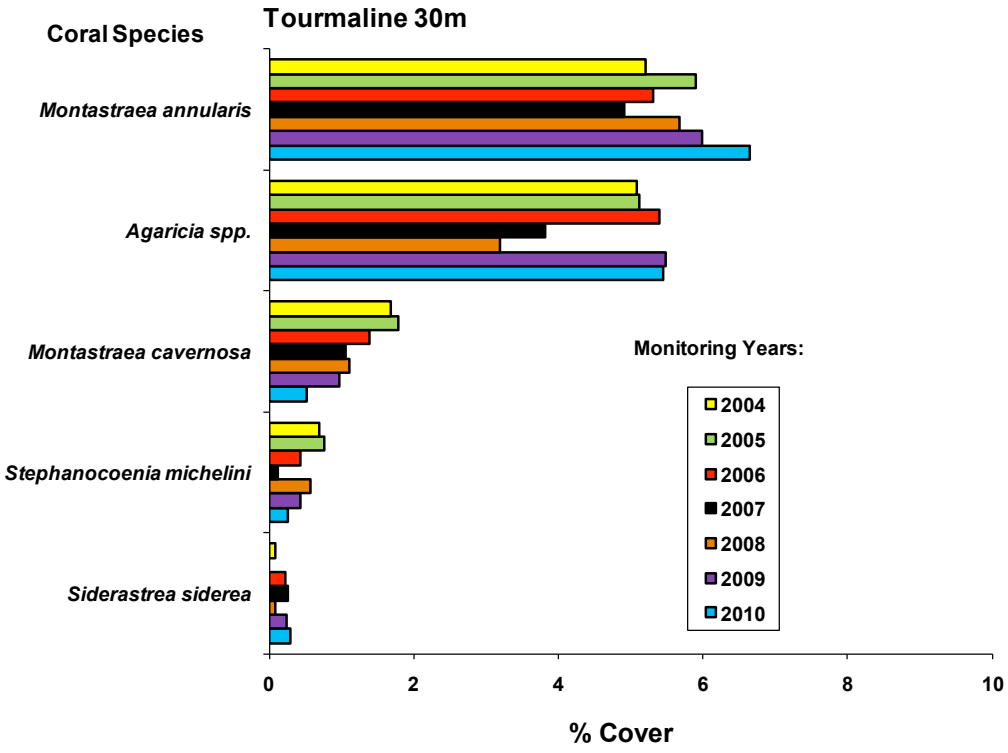


Figure 25. Monitoring trends (2004 – 2010) of mean substrate cover by stony coral species at Tourmaline Reef – 30 m, Mayaguez Bay.

Table 27. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, Mayaguez Bay, 30m. Survey Date: June, 2010

Depth: 30 m		Transects					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	50	63	87	150	56	**81.2**
Clepticus parrae	Creole Wrasse	100	0	0	0	5	**21.0**
Coryphopterus lipernes	Peppermint Goby	7	6	10	6	23	**10.4**
Chromis cyanea	Blue Chromis	15	3	20	6	6	**10.0**
Gramma loreto	Fairy Basslet	8	5	14	7	6	**8.0**
Haemulon aurolineatum	Tomtate	18	1	1	2	0	**4.4**
Myripristis jacobus	Blackbar Soldierfish	3	5	3	5	1	**3.4**
Stegastes partitus	Bicolor Damselfish	4	0	1	5	0	**2.0**
Scarus taeniopterus	Princess Parrotfish	0	2	4	0	3	**1.8**
Stegastes leucostictus	Beaugregory	1	1	3	2	1	**1.6**
Chaetodon capistratus	Four-eye Butterflyfish	2	0	1	0	4	**1.4**
Scarus iserti	Striped Parrotfish	2	1	2	0	1	**1.2**
Halichoeres garnoti	Yellowhead Wrasse	0	2	2	0	1	**1.0**
Haemulon flavolineatum	French Grunt	0	3	1	1	0	**1.0**
Chaetodon aculeatus	Longsnout Butterflyfish	3	0	0	0	2	**1.0**
Gobiosoma evelynae	Sharknose Goby	0	3	0	0	1	**0.8**
Canthigaster rostrata	Sharpnose Puffer	0	0	0	3	0	**0.6**
Hypoplectrus puella	Barred Hamlet	0	1	1	1	0	**0.6**
Cephalopholis cruentatus	Graysby	1	0	0	2	0	**0.6**
Sparisoma aurofrenatum	Redband Parrotfish	1	0	0	0	1	**0.4**
Holocentrus rufus	Longspine Squirrelfish	0	0	1	1	0	**0.4**
Mulloidichthys martinicus	Yellow Goatfish	2	0	0	0	0	**0.4**
Acanthurus bahianus	Ocean Surgeon	2	0	0	0	0	**0.4**
Lutjanus apodus	Schoolmaster Snapper	1	1	0	0	0	**0.4**
Chaetodon ocellatus	Spotfin Butterflyfish	2	0	0	0	0	**0.4**
Lactophrys triqueter	Smooth Trunkfish	0	0	0	0	2	**0.4**
Cephalopholis fulva	Coney	0	0	0	0	1	**0.2**
Lutjanus analis	Mutton Snapper	1	0	0	0	0	**0.2**
Acanthurus coeruleus	Blue Tang	1	0	0	0	0	**0.2**
Sparisoma viride	Stoplight Parrotfish	1	0	0	0	0	**0.2**
Priacanthus cruentatus	Glasseye Snapper	0	1	0	0	0	**0.2**
Scomberomorus regalis	Cero	0	0	1	0	0	**0.2**
Synodus intermedius	Sand Diver	0	0	1	0	0	**0.2**
Serranus tigrinus	Harlequin Bass	0	0	0	0	1	**0.2**
Anisotremus virginicus	Porkfish	0	0	0	0	1	**0.2**
Aulostomus maculatus	Trumpetfish	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	**219**	**96**	**15 1**	**191**	**111**	**153.6**
	TOTAL SPECIES	**21**	**15**	**17**	**14**	**18**	**17**

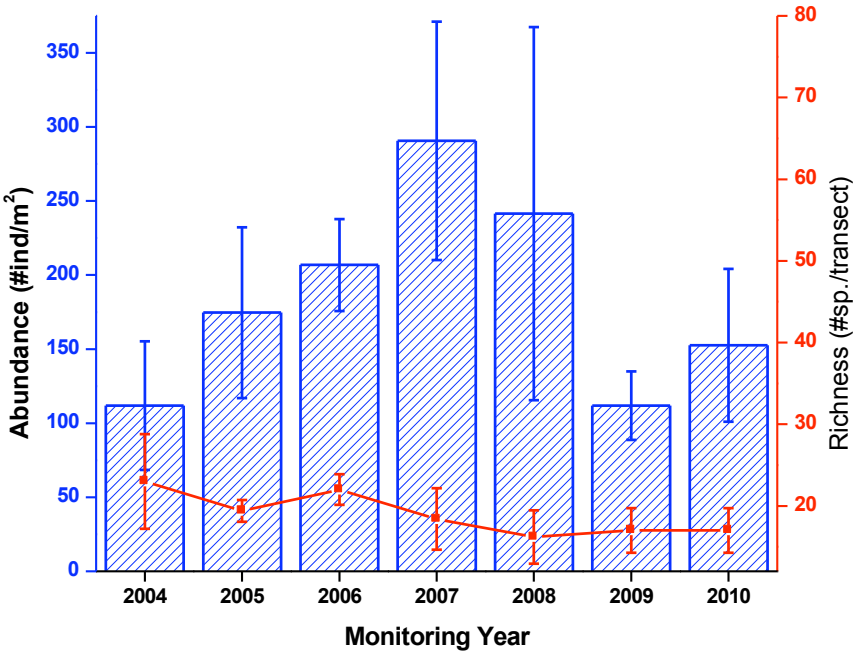


Figure 26. Monitoring trends (2004 – 2010) of fish species richness and abundance at Shelf-edge Reef Tourmaline, 30 m, Mayaguez Bay.

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 were statistically significant (ANOVA; p = 0.027). The overall reduction in species richness from the baseline survey (23 spp/transect) to the present 2010 survey was of 26 %. Differences of fish abundance between monitoring surveys were also statistically significant (ANOVA; p = 0.002). Annual variations were mostly driven by the abundance fluctuations of Masked Goby, which is a schooling species with highly aggregated or patchy distributions. Such contagious distributions introduce high sampling variability and many observations are needed within any given reef system to detect temporal abundance patterns.

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, Yellowmouth and Nassau Groupers, and several snappers were observed during the

2010 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. Lionfishes were not observed on the reef during our survey.

One coral shrimp was 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, 2010

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

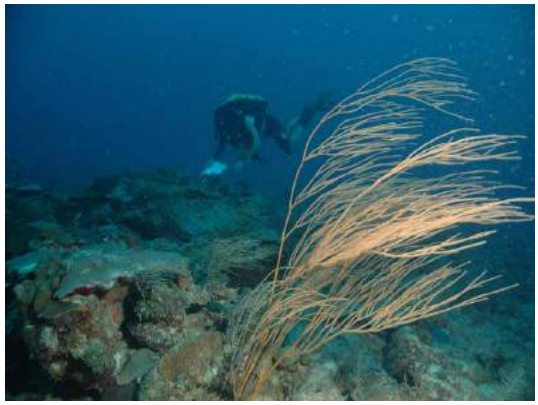
SPECIES	**COMMON NAME**	**# - (cm)**	**# - (cm)**
Epinephelus guttatus	Red Hind	2 - (30)	1 – (35)
Epinephelus striatus	Nassau Grouper	1 - (40)	
Decapterum macarellus	Mackerel Scad	>100 – (10 – 15)	
Lutjanus apodus	Schoolmaster Snapper	4 - (30)	1 – (40)
Mycteroperca interstitialis	Yellowmouth Grouper	1 - (30)	
Ocyurus chrysurus	Yellowtail Snapper	2 - (35)	
Scomberomorus regalis	Cero Mackerel	1 - (50)	
Sphyraena barracuda	Great barracuda	1 - (50)	

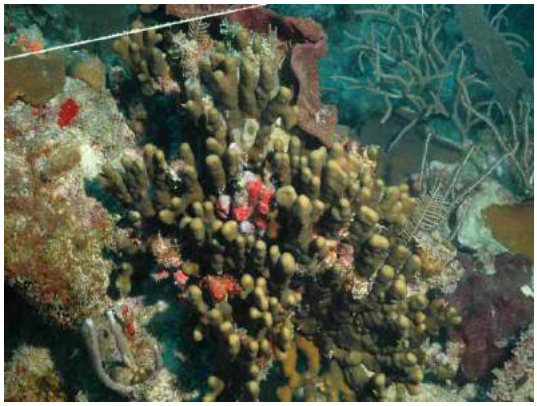
Table 29. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Shelf-edge Reef, 30 m, Mayaguez. June, 2010

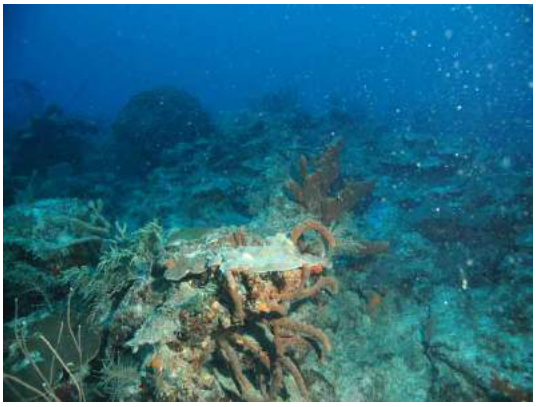
Depth: 30 m							**MEAN ABUNDANCE**
		TRANSECTS					**(IND/30 m2)**
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Stenopus hispidus	Banded Coral Shrimp				2		**0.4**
	TOTALS	**0**	**0**	**0**	**2**	**0**	**0.4**

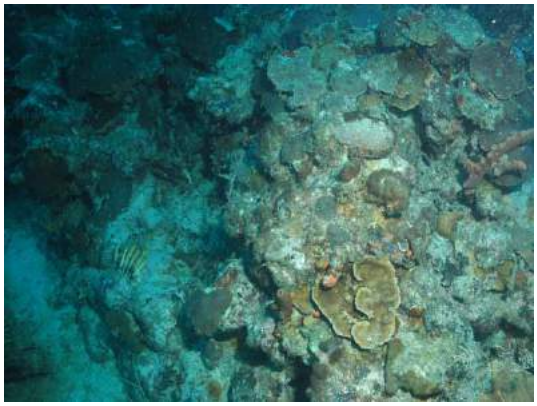
Photo Album 7 (Tourmaline 30 m)

Shelf edge Reef









2.0 Tourmaline Outer Shelf Reef – 20 m

2.1 Sessile-Benthic Reef Community

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

A total of 18 stony corals and two black coral species (*Stichopathes lutkeni, Antipathes sp*.) were identified from the outer shelf reef, 14 of which were intercepted by line transects during our survey (Table 30). Stony corals occurred as massive (*Montastraea annularis* (complex), *Siderastrea siderea*, *Colpophyllia natans, Diploria labyrinthiformis*), branching (*Madracis spp., Porites porites*), encrusting (*Mycetophyllia spp.*) and mound shaped colonies (*P. astreoides, M. cavernosa, Dichocoenia stokesii*). Substrate cover by stony corals along transects averaged 22.9 % (range: 19.3 – 29.2 %). Large and massive colonies of Boulder Star Coral were the most prominent feature of the reef benthos. Boulder Star Coral was the dominant species in terms of substrate cover with a mean of 16.9 % (range: 10.9 – 22.1 %), representing 73.8 % of the total cover by stony corals. Colonies of Boulder Star Coral were intercepted by all five transects. Great Star Coral (*M. cavernosa*) and Mustard Hill Coral (*Porites astreoides*) were intersected by four out of the five transects surveyed and along with and Boulder Star Coral comprised the main stony coral assemblage at 20 m.

Soft corals (gorgonians) were moderately abundant with an average of 19.0 colonies/transect and nine 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. Survey Date: May 2010

	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	5.3	4.7	5.2	6.3	4.5	**5.2**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	15.2	25.2	17.2	26.3	30.8	**23.0**
Gaps			1.8	0.7	1.6	**0.8**
Sand				2.7		**0.5**
Total Abiotic	15.2	25.2	19.1	29.7	32.4	**24.3**
Benthic Algae						
Turf-mixed assemblage	44.7	34.9	39.9	42.3	31.5	**38.7**
Lobophora variegata	6.2	14.2	15.9	1.7	6.6	**8.9**
Coralline algae	0.9		2.6			**0.7**
Halimeda sp.				0.8		**0.2**
Dictyota sp.					0.6	**0.1**
Total Benthic Algae	51.7	49.1	58.4	44.7	38.7	**48.5**
Encrusting Gorgonians						
Briareum asbestinum		2.6		1.4	3.7	**1.5**
Erythropodium caribaeorum	2.2		0.9			**0.6**
Sponges	1.6		1.5		2.4	**1.1**
Cyanobacteria		1.1			1.9	**0.6**
Live Stony Corals						
Montastraea annularis	22.1	17.4	10.9	20.8	13.4	**16.9**
Montastraea cavernosa	2.2		3.2	0.3	3.5	**1.8**
Porites astreoides		1.4	2.8	0.8	2.1	**1.4**
Siderastrea siderea	1.5				2.0	**0.7**
Colpophyllia natans		2.7				**0.5**
Madracis mirabilis	2.3					**0.5**
Meandrina meandrites	0.6			0.5		**0.2**
Diploria labyrinthiformis			0.9			**0.2**
Madracis decactis		0.6		0.4		**0.2**
Agaricia lamarcki	0.5		0.5			**0.2**
Agaricia agaricites			0.5			**0.1**
Dichocoenia stokesi			0.3			**0.1**
Porites porites			0.3			**0.1**
Millepora alcicornis				0.2		**0.0**
Total Stony Corals	29.2	22.1	19.3	22.9	21.0	**22.9**
Gorgonians						
Briareum asbestinum	10.0	10.0	7.0	9.0	12.0	**9.6**
Pseudoptergorgia acerosa	7.0	7.0	5.0	3.0	6.0	**5.6**
Erythropodium caribaeorum	0.0	2.0	2.0	0.0	0.0	**0.8**
Gorgonia ventalina	1.0	0.0	1.0	2.0	0.0	**0.8**
Plexaura kukenthali	0.0	1.0	1.0	0.0	2.0	**0.8**
Pseudoptergorgia americana	0.0	2.0	0.0	0.0	2.0	**0.8**
Eunicea flexuosa	0.0	0.0	0.0	0.0	1.0	**0.2**
Eunicea tourneforti	0.0	0.0	0.0	1.0	0.0	**0.2**
Pseudoplexaura flagellosa or wagenaari	0.0	0.0	0.0	0.0	1.0	**0.2**
Total Gorgonians (#col./transect)	18.0	22.0	16.0	15.0	24.0	**19.0**

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. Reef overhangs, associated with live and dead ledges of Boulder Star Coral averaged 23.0 % of the reef substrate cover and contributed markedly to the topographic rugosity of 5.2 m.

Benthic algae, comprised by turf, fleshy and coralline macroalgae algae were the dominant sessile-benthic component in terms of substrate cover at the outer shelf reef with an average of 48.5 % (range: 44.7 – 58.4 %). Turf algae, a mixed assemblage of short filamentous red and brown macroalgae contributed a reef substrate cover of 38.7%, representing 79.8% of the total benthic algae. The Encrusting Fan Alga, *Lobophora variegata* (mean cover: 8.9%) was the main component of the fleshy algal assemblage.

Figure 27 presents the variations of mean percent substrate cover by sessile-benthic categories from Tourmaline outer shelf reef at 20 m. Reef substrate cover by live corals showed a gradual decline from a baseline mean of 31.8 % in 2004 to a minimum of 22.8% in 2007. Due to the high variability within replicate transects, differences of live coral cover between monitoring surveys were still not statistically significant (ANOVA, $p = 0.145$; Appendix 2). Live coral declined 9.5 % between 2004 and 2005, then declined 12.9 % between 2005 and 2006, and 9.0 % between 2006 and 2007. During the last three years live coral cover stabilized at approximately 23%, presenting small fluctuations that appear to be within sampling variability error. Increasing trends of reef substrate cover by soft corals (gorgonians) and benthic algae is suggested from the monitoring data (Figure 27).

Montastraea annularis was the main driver of the declining trend of live coral at Tourmaline Reef between 2004 and 2007 because it was, and still is the dominant coral species (Figure 28). Other massive coral types, such as Great Star Coral, *M. cavernosa*, and Greater Starlet Coral, *Siderastrea siderea* also showed a declining trend of substrate cover during the monitoring program. Mild increments of cover have been measured for Mustard Hill Coral, *Porites astreoides*.

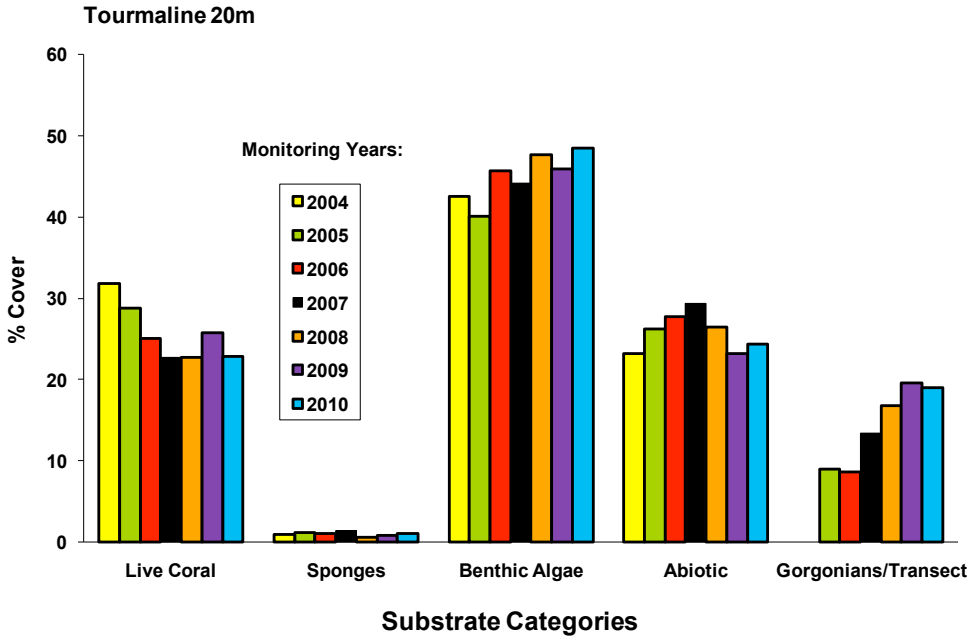


Figure 27. Monitoring trends (2004 – 2010) of mean substrate cover by sessile-benthic categories at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

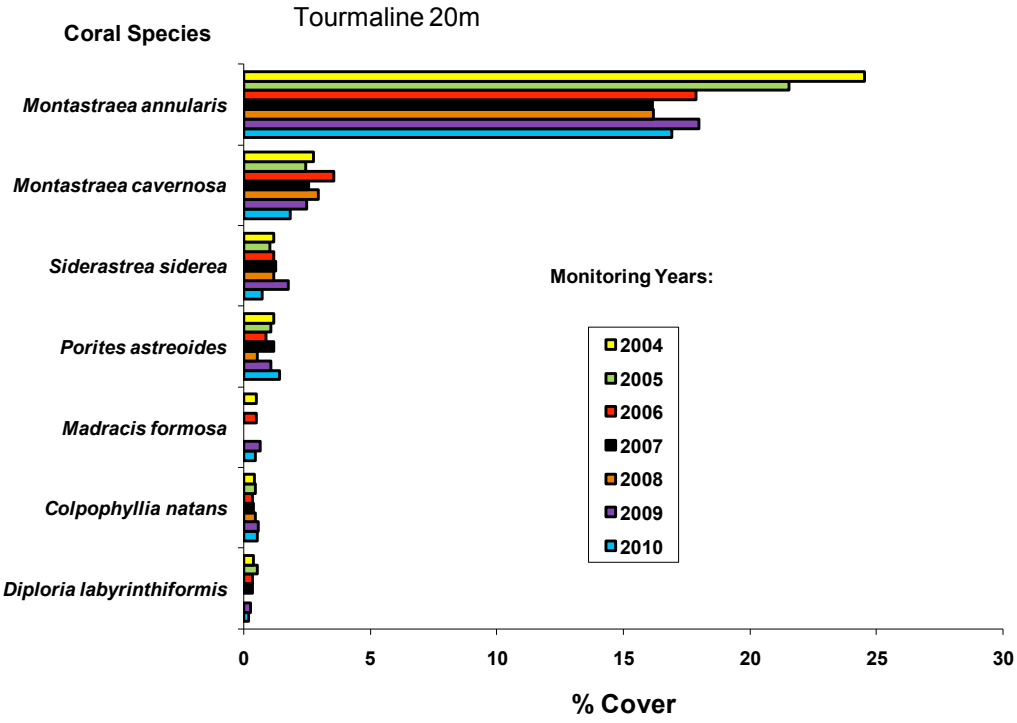


Figure 28. Monitoring trends (2004 – 2010) of mean substrate cover by stony coral species at Tourmaline Outer Shelf Reef – 20 m, Mayaguez Bay.

2.2 Fishes and Motile Megabenthic Invertebrates-

A total of 101 fish species have been identified from Tourmaline outer shelf reef at 20 m (Appendix 1). Mean abundance within belt-transects during 2010 was 95.6 Ind/30 m^2 (range: 61 - 133 Ind/30 m^2). The mean number of species per transect was 17.8 (range: 14 - 17). The Masked Goby, *Coryphopterus personatus* was the numerically dominant species with a mean abundance of 42.4 Ind/30 m^2 (range: 20 – 77 Ind/30 m^2), representing 44.4 % of the total abundance within belt-transects (Table 31).

The Masked Goby is a small zooplanktivorous fish (< 2.0 cm) that was observed hovering in small to moderate aggregations below coral ledges and crevices near the sand-coral interface. The Fairy Basslet, Bluehead Wrasse, Striped and Redband Parrotfishes, Blue Chromis and Peppermint Goby, along with the Masked Goby comprised the most abundant fish assemblage at 20 m. A total of 13 species were present in at least four of the five transects surveyed.

Annual variations of fish abundance and species richness are presented in Figure 29. Differences of fish abundance between surveys were statistically significant (ANOVA; $p < 0.0001$). Abundance was low in the baseline survey, peaked in 2005 and has maintained a declining trend since 2006, reaching its lowest record (95.6 Ind/30 m^2) during the present 2010 survey. Species richness also presented a consistent decline after 2006, but a slight increment was documented in 2010. 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, Mayaguez Bay, 20 m. Survey Date: May, 2010

Depth: 20 m		Transects					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	25	40	50	20	77	**42.4**
Gramma loreto	Fairy Basslet	24	15	14	11	5	**13.8**
Thalassoma bifasciatum	Bluehead Wrasse	5	12	12	5	3	**7.4**
Scarus iserti	Striped Parrotfish	6	1	14	0	10	**6.2**
Chromis cyanea	Blue Chromis	1	3	3	11	0	**3.6**
Coryphopterus lipernes	Peppermint Goby	2	3	2	0	11	**3.6**
Sparisoma aurofrenatum	Redband Parrotfish	6	2	1	1	5	**3.0**
Stegastes partitus	Bicolor Damselfish	3	1	4	1	0	**1.8**
Stegastes leucostictus	Beaugregory	2	1	2	0	4	**1.8**
Myripristis jacobus	Blackbar Soldierfish	2	0	0	2	4	**1.6**
Acanthurus bahianus	Ocean Surgeon	1	1	2	1	3	**1.6**
Halichoeres garnoti	Yellowhead Wrasse	0	1	1	1	4	**1.4**
Chaetodon capistratus	Four-eye Butterflyfish	2	0	1	2	1	**1.2**
Canthigaster rostrata	Sharpnose Puffer	1	0	1	3	0	**1.0**
Sparisoma viride	Stoplight Parrotfish	2	2	1	0	0	**1.0**
Gobiosoma evelynae	Sharknose Goby	2	0	1	0	0	**0.6**
Holocentrus rufus	Longspine Squirrelfish	0	1	1	0	1	**0.6**
Ocyurus chrysurus	Yellowtail Snapper	1	1	0	0	1	**0.6**
Cephalopholis cruentatus	Graysby	0	1	0	0	1	**0.4**
Neoniphon marianus	Longjaw Squirrelfish	0	0	0	1	1	**0.4**
Chaetodon aculeatus	Longsnout Butterflyfish	0	0	2	0	0	**0.4**
Haemulon flavolineatum	French Grunt	0	0	0	1	1	**0.4**
Hypoplectrus unicolor	Butter Hamlet	0	0	0	1	1	**0.4**
Mulloidichthys martinicus	Yellow Goatfish	1	1	0	0	0	**0.4**
Acanthurus chirurgus	Doctorfish	0	0	0	1	0	**0.2**
Anisotremus virginicus	Porkfish	0	1	0	0	0	**0.2**
Acanthurus coeruleus	Blue Tang	0	0	1	0	0	**0.2**
Hypoplectrus puella	Barred Hamlet	0	0	0	1	0	**0.2**
Microspathodon chrysurus	Yellowtail Hamlet	0	0	0	0	1	**0.2**
Holocentrus adcensionis	Squirrelfish	0	0	0	0	1	**0.2**
Gymnothorax moringa	Spotted Moray	1	0	0	0	0	**0.2**
Lactophrys triqueter	Smooth Trunkfish	0	0	0	1	0	**0.2**
	TOTAL INDIVIDUALS	**86**	**86**	**112**	**61**	**133**	**95.6**
	TOTAL SPECIES	**18**	**17**	**18**	**17**	**19**	**17.8**

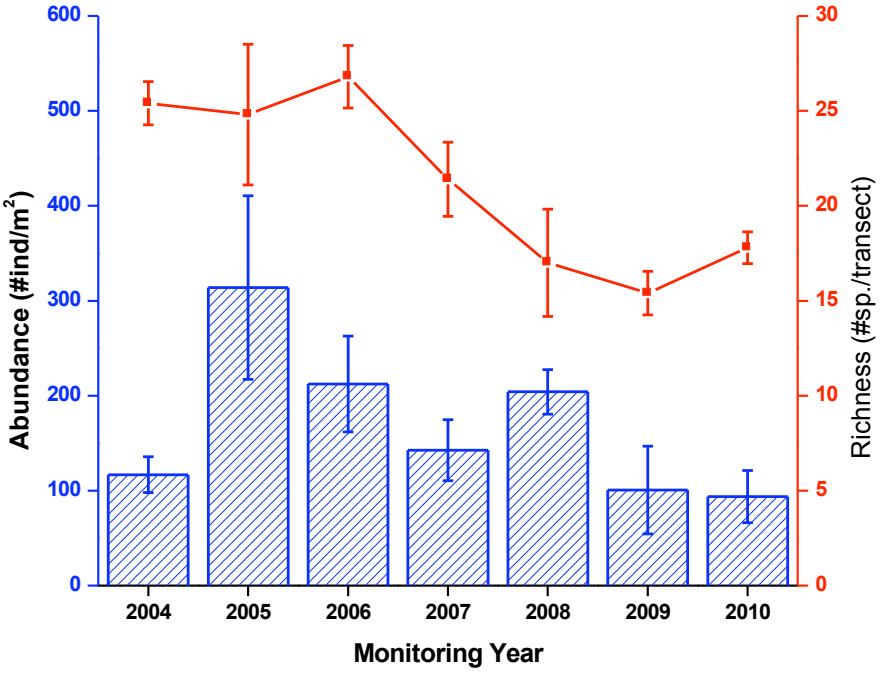


Figure 29. Monitoring trends (2004 – 2010) of fish species richness and abundance at outer shelf reef Tourmaline, 20 m, Mayaguez.

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

Small zooplanktivorous fishes, such as the Masked Goby, Blue Chromis, Bicolor Damselfish and micro-invertebrate predators, including wrasses, gobies, basslets, hamlets, and squirrelfishes numerically dominate the reef fish community. Parrotfishes (*Scarus spp., Sparisoma spp*.), represented by 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

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, May, 2010

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

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

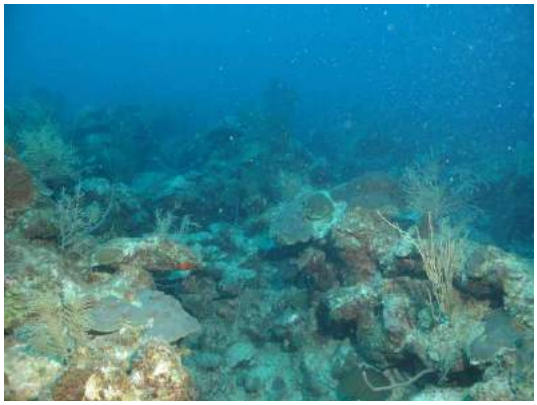
over the reef. These are zooplanktivores that serve as forage for pelagic predators, such as Cero Mackerels and Barracudas. Cubera and Dog Snappers have been identified from previous ASEC surveys at this reef (García-Sais et al, 2005). One Arrow Crab and one Banded Coral Shrimp were the only motile megabenthic invertebrates observed within belt-transects during 2009. One spiny lobster was observed out of transects.

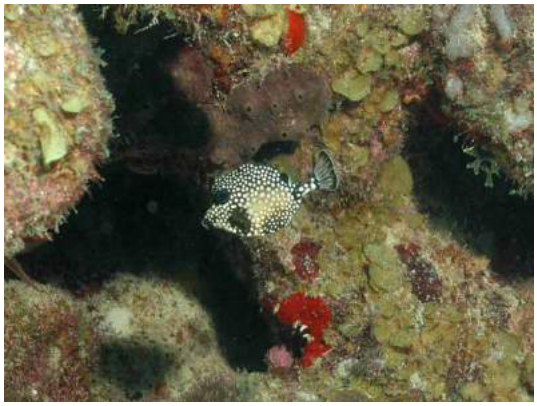
Table 33. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Outer-shelf Reef, Mayaguez, May, 2010

Depth: 20 m		**TRANSECTS**					**MEAN ABUNDANCE (IND/30 m^2)**
		1	**2**	**3**	**4**	**5**	
TAXA	**COMMON NAME**						
Astropecten muricatum	Giant Basket Star		1				**0.2**
Cyphoma gibbosum	Flamingo Tongue			3			**0.6**
	TOTALS	**0**	**1**	**3**	**0**	**0**	**0.8**

Photo Album 8 (Tourmaline 20 m)

OuterShelf Reef





3.0 Tourmaline Outer Shelf Reef – 10 m

3.1 Sessile-benthic Reef Community

At a depth of 10 m, Tourmaline Outer Shelf Reef exhibits a very well defined "spur-and-groove" formation that runs perpendicular to the shelf-edge and ends in a sandy-silt deposit at a depth of 14 m. Spurs are about 2 - 3 m tall, separated by coralline sand and coral rubble deposited at the grooves. Stony corals grow on top of the spurs and along the walls in massive, branching and encrusting colonies. Soft corals are common and a visually prominent feature of the reef benthos. An existing set of five permanent transects established on top of the spurs during the baseline characterization in 1999 by García et al. (2001) was monitored for the seventh time during June, 2010. Panoramic views of Tourmaline outer shelf reef at a depth of 10 m are presented in Photo Album 9.

A total of 25 stony coral species were identified from the Outer Shelf Reef at a depth of 10 m, 19 of which were intercepted by line transects during this survey (Table 34). Stony corals occurred as massive (*Montastraea annularis*, *Colpophyllia natans, Diploria labyrinthiformis*), branching (*Madracis spp., Porites porites*), encrusting (*Mycetophyllia spp.*) and mound shaped colonies (*P. astreoides, M. cavernosa, Dichocoenia stokesii*). Substrate cover by stony corals along transects averaged 40.5 % (range: 22.2 – 74.7 %). Yellow Pencil Coral, *Madracis mirabilis* was the dominant coral species in terms of substrate cover with a mean of 11.1 %. This species exhibits branching growth over the reef hard bottom and has kept an increasing pattern of substrate cover over the years at this reef, reaching its maximum cover during the present 2010 survey. An extraordinarily large colony of Yellow Pencil Coral now covers more than four meters along transect two, contributing to a total cover by stony corals of 74.7 % in that transect, which is the highest in the monitoring program. Boulder Star Coral (*M. annularis* complex), Finger Coral (*P. porites*), Mustard Hill Coral (*Porites astreoides*), and Lettuce Coral (*Agaricia agaricites*) were intercepted by at least four of the five transects in the 2010 monitoring survey and comprised in addition to *M. mirabilis* the main stony coral assemblage at this reef. A total of 11 coral species were represented with less than 1% substrate cover.

Erect soft corals (gorgonians) were highly abundant with an average of 33.0 colonies/transect and along with stony corals were the most visually prominent

Table 34. Percent substrate cover by sessile-benthic categories at Tourmaline Reef, Mayaguez. 10m. Survey Date: May 2010.

Depth 10 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	3.6	3.7	3.1	4.3	3.6	**3.7**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	3.6	1.2	8.7	1.3	6.1	**4.2**
Total Abiotic	3.6	1.2	8.7	1.3	6.1	**4.2**
Benthic Algae						
Turf-mixed assemblage	51.8	20.6	45.9	63.1	61.6	**48.6**
Fleshy Algae						
Dictyota sp.	1.3	1.1		4.8	1.0	**1.6**
Coralline Algae			0.5			**0.1**
Calcareous Algae						
Halimeda tuna					0.3	**0.1**
Total Benthic Algae	53.1	21.7	46.5	67.9	63.5	**50.5**
Encrusting Gorgonians					0.8	**0.2**
Erythropodium caribaeorum		1.5		5.7	1.1	**1.7**
Briareum asbestinum	3.0				4.1	**1.4**
Total Encrusting Gorgonians	3.0	1.5	0.0	5.7	6.0	**3.3**
Zoanthids (*Palythoa caribaeorum*)	2.5			1.6	0.8	**1.0**
Sponges		0.8	0.4		0.6	**0.4**
Cyanobacteria					0.8	**0.2**
Live Stony Corals						
Madracis mirabilis		55.3				**11.1**
Montastraea annularis	2.9	13.3	10.6	3.9	5.4	**7.2**
Porites porites	14.2	0.7	7.2	2.5	2.0	**5.3**
Porites astreoides	5.6	4.6	7.4	1.5	3.8	**4.6**
Agaricia agaricites	3.3	0.3		9.7	4.7	**3.6**
Dendrogyra cylindrus	9.1		0.8	2.7		**2.5**
Colpophyllia natans			7.0			**1.4**
Agaricia grahamae			5.1		1.7	**1.4**
Meandrina meandrites	0.6		1.6	1.0	0.8	**0.8**
Montastraea cavernosa			1.4	1.4	1.0	**0.7**
Diploria strigosa					2.1	**0.4**
Acropora cervicornis			1.8			**0.4**
Porites colonensis	0.6		0.8			**0.3**
Madracis decactis	0.5				0.8	**0.3**
Siderastrea siderea	0.9					**0.2**
Millepora alcicornis		0.4	0.3			**0.1**
Stephanocoenia intersepta				0.6		**0.1**
Eusmilia fastigiata			0.4			**0.1**
Leptoseris cucullata				0.4		**0.1**
Total Stony Corals	37.7	74.7	44.4	23.5	22.2	**40.5**
Gorgonians						
Briareum asbestinum	15	11	12	20	18	**15.2**
Plexaura kukenthali	2	1	3	7	5	**3.6**
Pseudoplexaura flagellosa or wagenaari	2	2	1	5	6	**3.2**
Eunicea succinea	1	6	3	0	3	**2.6**
Erythropodium caribaeorum	3	0	1	1	7	**2.4**

Table 34. Continued

Gorgonia ventalina	3	0	1	3	3	**2**
Plexaura homomalla	1	0	3	1	3	**1.6**
Eunicea tourneforti	0	0	0	1	2	**0.6**
Eunicea flexuosa	1	0	0	2	0	**0.6**
Pseudoptergorgia acerosa	1	0	0	0	1	**0.4**
Pseudoptergorgia americana	0	0	0	0	2	**0.4**
Muriceopsis flavida	1	0	0	0	0	**0.2**
Eunicea spp.	1	0	0	0	0	**0.2**
Total Gorgonians (# colonies/transect)	31	20	24	40	50	**33.0**

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

assemblage of the reef benthos. The most abundant species included the Corky Sea Finger, *Briareum asbestinum*, sea rods, *Plexaura spp*. *Pseudoplexaura spp*., and sea fans, *Gorgonia ventalina*. Encrusting gorgonians, *Erythropodium caribaeorum* were present with an average substrate cover of 1.7 %. Sponges and zoanthids (*Palythoa caribdea*) were also present along transects, but represented minor components of the reef benthos (substrate cover < 1 %). Reef overhangs, associated with coral ledges of Boulder Star Coral averaged 4.2 % and contributed markedly to the topographic rugosity of 3.7 m. Turf algae, comprised by a mixed assemblage of short filamentous red and brown macroalgae presented an average substrate cover of 48.6 % (range: 20.6 – 63.1 %). 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 (< 1.0%).

Figure 30 presents the monitoring trends of reef substrate cover by sessile-benthic categories from Tourmaline outer shelf reef at 10 m, including the baseline survey of 1999 and seven annual monitoring surveys (2004-10). During the 2006 monitoring survey, mean live coral cover declined 22.6%, from 44.26% in 2005 to 34.25%. This decline was measured after the regional coral bleaching event that affected most of the northern Caribbean (Garcia-Sais et al, 2008). An additional decline of 16.5 % was measured from 2006 to 2007 attributed to lingering effects of the late 2005-bleaching event. At the community level, the variation of total live coral cover was not statistically significant (ANOVA; p = 0.662), 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. The loss of reef substrate by *M. annularis* was aggressively colonized by the branching and fast growing Yellow Pencil Coral, *M. mirabilis,* which is now the dominant coral in terms of substrate cover at Tourmaline 10 m. The trend of increasing reef substrate cover by *M. mirabilis* stabilized during the present 2010 survey perhaps due to the lack of hard ground space to grow. Between 1999 and 2010, *M. mirabilis* more than doubled its substrate cover in transect 2 from 27.4% to 55.3 %. Such growth growth has influenced a partial recuperation of live coral cover at Tourmaline 10 m. Finger Coral, *Porites porites* also displayed a very active growth pattern after the 2005-bleaching event, increasing cover from a baseline mean of 5.3 % to a peak of 9.3 % in 2009. After 2009 (last year), this species has suffered from what appears to be an infectious disease and exhibited substantial colony degradation and loss of substrate cover back to its baseline mean of 5.3%.

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 2010 survey was 107.6 Ind/30 m^2 (range: 31 - 267 Ind/30 m^2). A total of 32 species were observed within belt-transects and the mean number of species per transect was 16 (range: 10 - 20). The Creole Wrasse (Clepticus parrae), Blue Chromis (*Chromis cyanea*), Bluehead Wrasse (*Thalassoma bifasciatum*), Bicolor Damselfish (*Stegastes partitus*) and the Striped Parrotfish (*Scarus iserti*) were the numerically dominant species with a combined mean abundance of 77.4 Ind/30 m^2, representing 71.9 % of the total abundance within belt-transects (Table 35). In addition to the aforementioned species, six more species were present in at least four transects. These included the Yellowhead Wrasse, Redband and Stoplight Parrotfishes, Four-eye Butterflyfish, and Blue Tang. A total of 13 species were represented by only one individual within belt-transects.

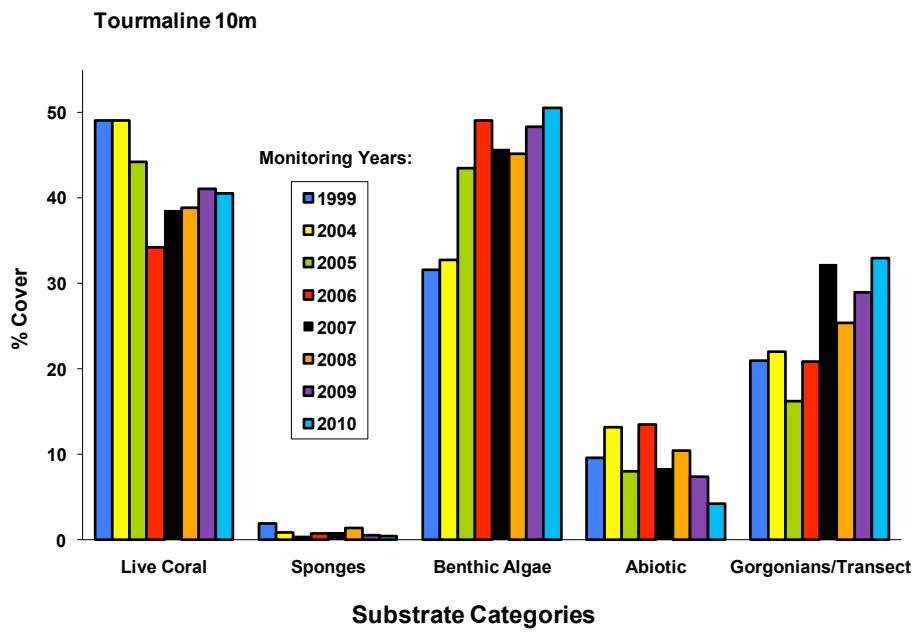


Figure 30. Monitoring trends (1999 – 2010) of mean substrate cover by sessile-benthic categories at Tourmaline Reef – 10 m, Mayaguez.

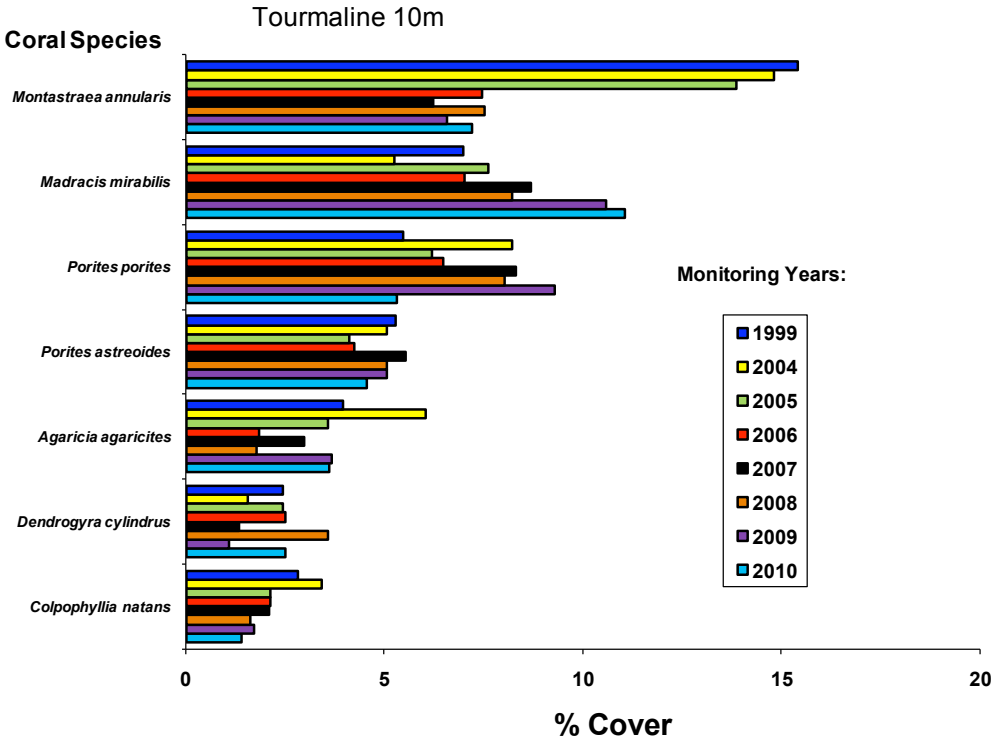


Figure 31. Monitoring trends (1999 – 2010) of mean cover by stony coral species at Tourmaline Reef – 10 m, Mayaguez.

Table 35. Taxonomic composition and abundance of fishes within belt-transects at Tourmaline Reef, 10 m, Mayaguez Bay. May, 2010

Depth: 10 m		Transects					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**			**(Ind/30m^2)**			**MEAN**
Clepticus parrae	Creole Wrasse	0	150	1	0	0	**30.2**
Chromis cyanea	Blue Chromis	3	58	13	7	0	**16.2**
Thalassoma bifasciatum	Bluehead Wrasse	20	12	5	24	0	**12.2**
Stegastes partitus	Bicolor Damselfish	6	20	12	5	6	**9.8**
Scarus iserti	Stripped Parrotfish	25	5	4	4	7	**9.0**
Sparisoma viride	Stoplight Parrotfish	6	3	5	2	4	**4.0**
Stegastes leucostictus	Beaugregory	1	2	3	4	4	**2.8**
Microspathodon chrysurus	Yellowhead Wrasse	2	3	1	2	4	**2.4**
Sparisoma aurofrenatum	Redband Parrotfish	2	3	4	2	0	**2.2**
Myripristis jacobus	Blackbar Soldierfish	0	0	1	9	0	**2.0**
Chaetodon capistratus	Four-eye Butterflyfish	0	2	3	2	2	**1.8**
Haemulon flavolineatum	French Grunt	0	4	1	3	0	**1.6**
Acanthurus bahianus	Ocean Surgeon	4	0	2	1	0	**1.4**
Gramma loreto	Fairy Basslet	0	1	0	4	0	**1.0**
Canthigaster rostrata	Sharpnose Puffer	1	0	2	2	0	**1.0**
Acanthurus coeruleus	Blue Tang	1	1	1	1	0	**0.8**
Amblycirrhitus pinos	Redspotted Hawkfish	1	0	1	0	2	**0.8**
Neoniphon marianus	Longjaw Squirrelfish	0	1	2	0	0	**0.6**
Cantherhines macrocerus	Whitespotted Filefish	0	0	1	1	0	**0.4**
Gobiosoma evelynae	Sharknose Goby	0	1	0	0	0	**0.2**
Halichoeres maculipinna	Clown Wrasse	0	0	1	0	0	**0.2**
Cephalopholis cruentatus	Graysby	0	0	0	1	0	**0.2**
Epinephelus guttatus	Red Hind	0	0	0	0	1	**0.2**
Aulostomus maculatus	Trumpetfish	0	1	0	0	0	**0.2**
Coryphopterus lipernes	Peppermint Goby	0	0	1	0	0	**0.2**
Hypoplectrus indigo	Indigo Hamlet	1	0	0	0	0	**0.2**
Holocentrus rufus	Longspine Squirrelfish	0	0	0	0	1	**0.2**
Serranus tigrinus	Harlequin Bass	0	0	0	0	1	**0.2**
Chaetodon striatus	Banded Butterflyfish	0	0	0	1	0	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	0	0	1	0	**0.2**
Chaetodon ocellatus	Spotfin Butterflyfish	0	0	0	1	0	**0.2**
Scarus vetula	Queen Parrotfish	1	0	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**73**	**267**	**64**	**31**	**102**	**107.6**
	TOTAL SPECIES	**14**	**16**	**20**	**20**	**10**	**16**

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.

Annual monitoring trends of fish species richness and abundance are presented in Figure 32. Minimum mean values of fish abundance and species richness were observed during 2008, when mean abundance declined 31.4 % relative to the baseline survey. Differences between annual surveys were 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.

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

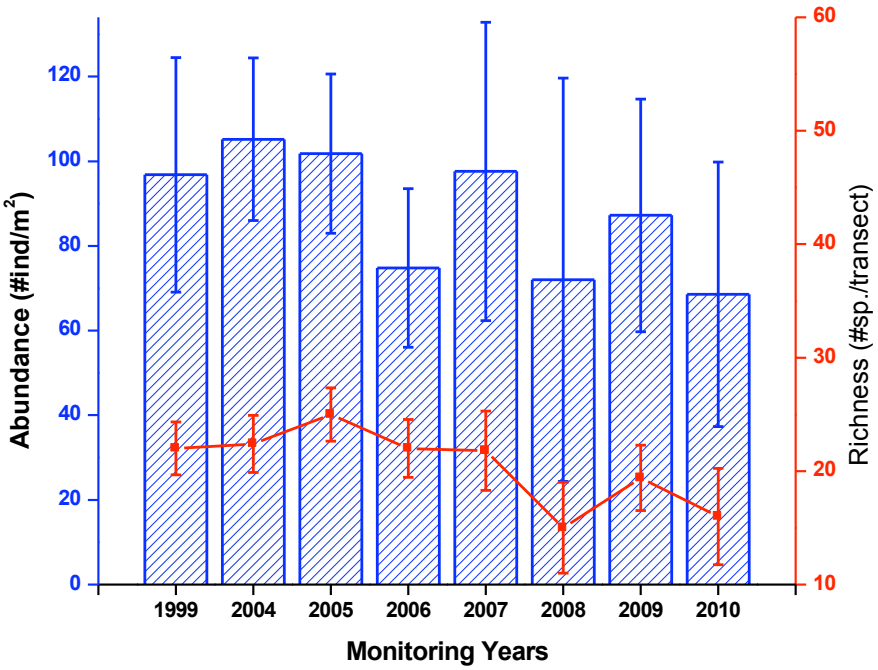


Figure 32. Monitoring trends (2004 – 2010) of fish species richness and abundance at Outer Shelf Reef Tourmaline, 10 m, Mayaguez.

performed previous to the group spawning aggregation from December to February, the relatively low abundance of Red Hinds noted during our monitoring surveys is indicative that this fish population has not recovered from the intense fishing effort that it received during the previous decade.

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.

Table 36. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Tourmaline Outer Shelf Reef, 10 m, May, 2010

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

SPECIES	**COMMON NAME**		# - (cm)	
Balistes vetula	Queen Triggerfish	1 - (30)		
Carangoides crysos	Blue Runner	2 - (30)	2 - (40)	
Epinephelus guttatus	Red Hind	1 - (15)	2 – (25)	
Lutjanus synagris	Lane Snapper	4 - (15)	2 - (20)	
Ocyurus chrysurus	Yellowtail Snapper	5 - (15)	3– (20)	1 - (30)
Scomberomorus regalis	Cero Mackerel	1 - (40)		
Sphyraena barracuda	Great Barracuda	1 - (60)		

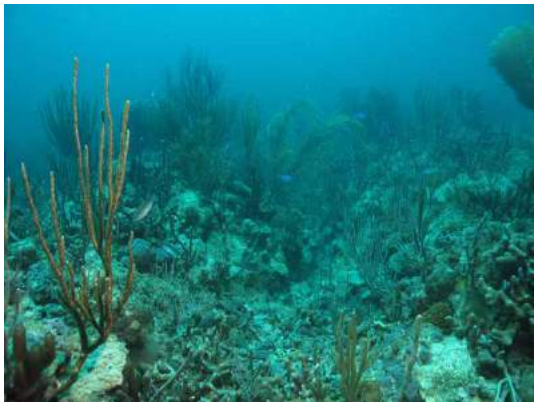
Table 37. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Tourmaline Outer-shelf Reef, 10 m, May, 2010

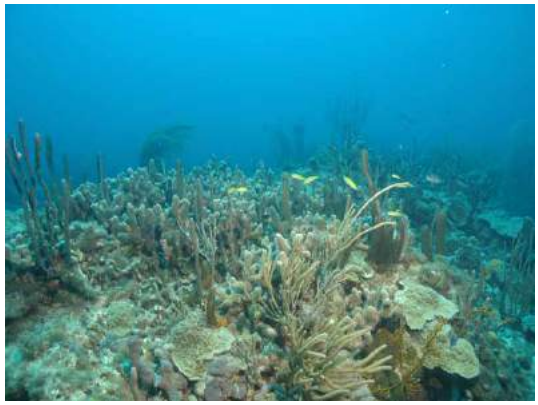
Depth: 10 m

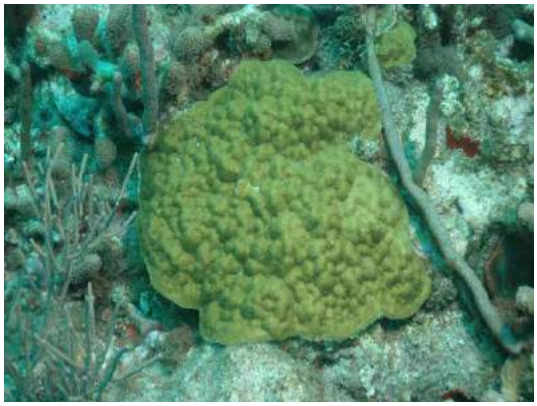
		TRANSECTS					**MEAN ABUNDANCE (IND/30 m2)**
TAXA	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	
Cyphoma gibbosum	Flamingo Tongue	1				1	**0.4**
Stenophus hispidus	Banded Coral Shrimp					1	**0.2**
	TOTALS	**1**	**0**	**0**	**0**	**2**	**0.6**

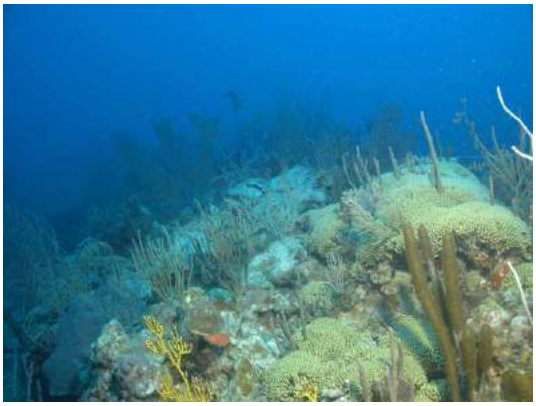
Photo Album 9 (Tourmaline 10 m)

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.

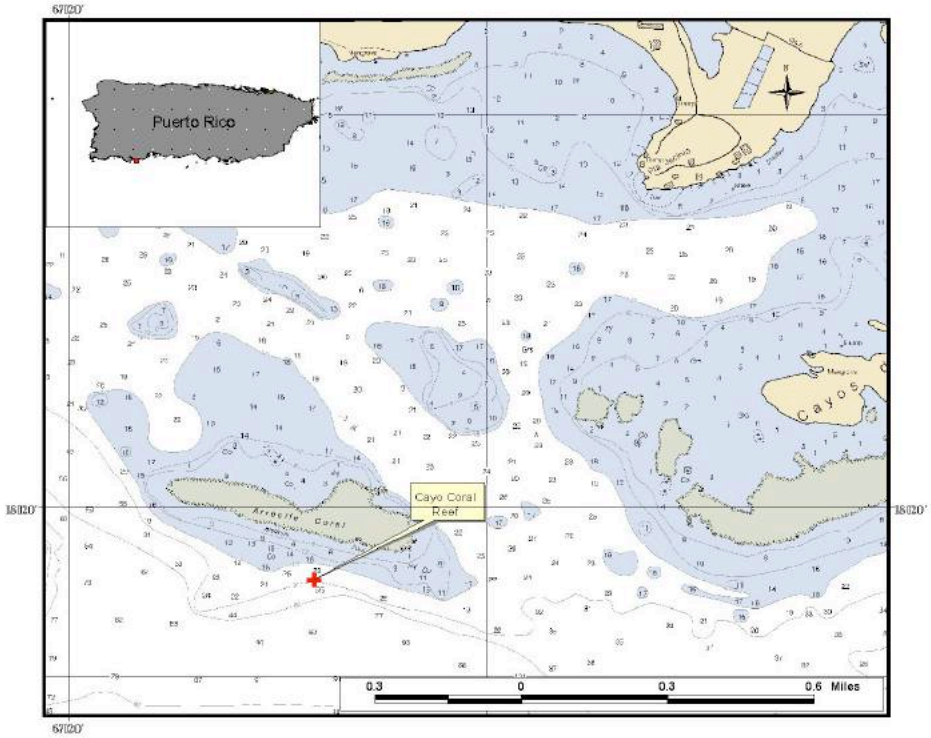


Figure 33. Location of coral reef survey stations at Cayo Coral Reef, Guánica.

1.0 Sessile-benthic Reef Community

A total of 17stony corals, including nine intersected by permanent line transects were identified from Cayo Coral Reef during the 2010 survey (Table 38). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 12.4 % (range: 7.2 – 17.0%). Boulder Star Coral, *Montastraea annularis* (complex) was the main species in terms of substrate cover with a mean of 5.5% (range: 2.8 – 10.5 %), representing 44.4 % of the total cover by stony corals (Table 38). Mustard-Hill Coral, *Porites astreoides*, Great Star Coral, *M. cavernosa* and Massive Starlet Coral, *Siderastrea siderea* were intercepted by all transects, and along with Boulder Star Coral and Boulder Brain Coral, *Colpophyllia natans* comprised the main coral assemblage of the reef at a depth of 7-10m.

Soft corals (gorgonians) were highly abundant with an average of 28.2 colonies/transect. A total of 24 species of gorgonians are known to ocurr at this reef (García-Sais et al. 2007), 15 of which were intercepted by line transects during this 2010 survey. Some of the numerically dominant species present included the Corky Sea Finger, Briareum asbestinum, Sea Rods, *Plexaura homomalla*, *Pseudoplexaura spp*., *Eunicea spp*. and the Common Sea Fan, *Gorgonia ventalina*. The high abundance of gorgonians contributed substantial complexity and substrate heterogeneity to Cayo Coral, representing an important protective habitat to reef fishes and invertebrates. Small sponges and patches of colonial zoanthids (*Palythoa caribbea*) represented minor components of the reef benthos. Reef overhangs associated with mostly dead massive Boulder Star Coral colonies averaged a substrate cover of ***7.3*** % and contributed substantially to the mean rugosity of 3.6 m.

Benthic algae, comprised mostly by turf algae was the most prominent sessile-benthic category in terms of substrate cover with a mean of 64.1 % (range: 59.1 – 69.5 %). Turf algae was found colonizing hard ground substrates, particularly dead coral colonies. Some dead coral colonies were also colonized by a reddish film of blue-green algae, or cyanobacteria, which presented a mean cover of 1.2 % in transects surveyed. 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. 8 m Survey Date: February 2010.

Depth: 8 - 10m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	6.3	15.0	3.8	4.3	2.4	**6.4**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	12.6	16.4		4.7	2.8	**7.3**
Sand	3.4	6.6	10.2	4.5		**5.0**
Total Abiotic	16.0	24.0	10.2	9.3	2.8	**12.5**
Benthic Algae						
Turf-mixed assemblage	66.2	59.1	64.6	61.3	69.5	**64.1**
Fleshy algae	2.6	3.9		1.5	7.0	**3.0**
Coralline algae (Rhodophyta)				1.0	1.2	**0.4**
Galaxaura sp.			0.5			**0.1**
Halimeda sp.			0.5			**0.1**
Total Benthic Algae	68.8	63.0	65.6	63.7	77.7	**67.8**
Cyanobacteria	0.9		1.7		3.4	**1.2**
Zoanthids				0.4		**0.1**
Sponges	1.2	2.3	5.0	3.8	4.5	**3.4**
Encrusting Gorgonians		3.5	0.5	4.5		**1.7**
Live Stony Corals						
Montastraea annularis	10.5	2.8	2.8	6.4	5.1	**5.5**
Porites astreoides	1.7	1.2	2.5	1.4	1.5	**1.6**
Colpophyllia natans			6.4			**1.3**
Montastraea cavernosa	0.5	1.4	0.9	1.2	1.1	**1.0**
Siderastrea siderea	0.2	0.9	0.6	1.7	1.3	**0.9**
Porites porites		0.9	1.8	1.2		**0.8**
Meandrina meandrites			1.8		1.1	**0.6**
Diploria strigosa	0.4			0.9	1.4	**0.5**
Agaricia agaricites				0.4		**0.1**
Total Stony Corals	13.2	7.2	17.0	13.1	11.5	**12.4**
Gorgonians						
Briareum asbestinum	9	9	8	14	8	**9.6**
Plexaura homomalla	5	6	5	3	1	**4.0**
Pseudoplexaura flagellosa or wagenaari	2	4	3	5	3	**3.4**
Gorgonia ventalina	1	3	3	4	4	**3.0**
Plexaura kukenthali	4	4	3	3	0	**2.8**
Eunicea tourneforti	3	1	3	0	1	**1.6**
Eunicea succinea	2	0	1	0	3	**1.2**
Eunicea flexuosa	3	0	1	2	0	**1.2**
Eunicea laxispica	1	0	0	0	0	**0.2**
Muricea atlantica	0	0	0	1	0	**0.2**
Muriceopsis flavida	0	0	1	0	0	**0.2**
Plexaurella nutans	0	0	0	0	1	**0.2**
Plexaurella sp.	0	1	0	0	0	**0.2**
Pseudoplexaura porosa	1	0	0	0	0	**0.2**
Pseudopterogorgia acerosa	1	0	0	0	0	**0.2**
Total Gorgonians (#colonies/transect)	32	28	28	32	21	**28.2**

Table 38. Continued

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 2005-10. 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 was documented (Figure 34). The high abundance and richness of soft coral (gorgonian) colonies remained virtually constant between surveys. The aforementioned declining trend of live coral cover stabilized during 2009, with several massive coral species showing a mild recuperation trend. During the present 2010 survey, live coral cover showed an increasing trend for the first time during the monitoring program. Such increasing trend was mostly driven by the mild but consistent recuperation of Boulder Star Coral, *Montastraea annularis* (Figure 35).

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

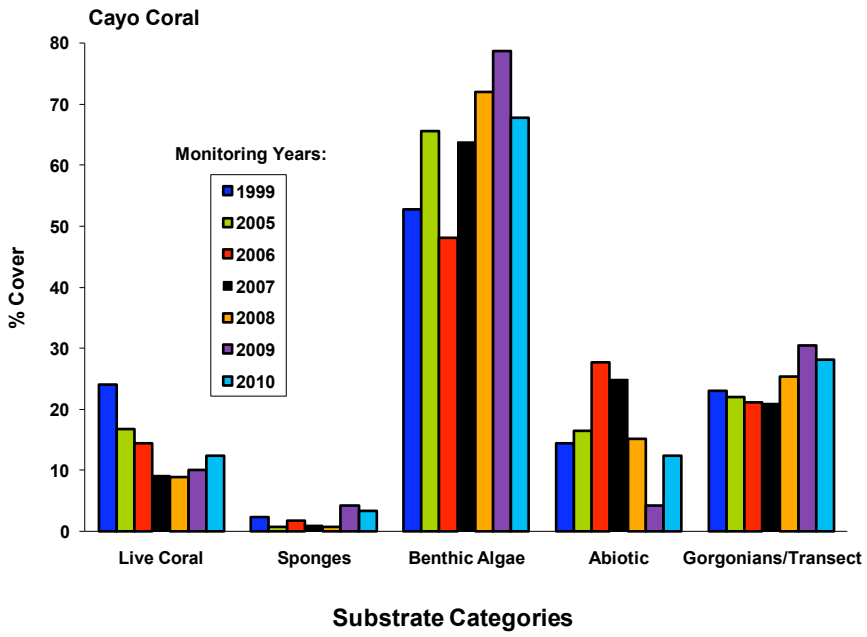


Figure 34. Monitoring trends (1999 – 2010) of mean substrate cover by sessile-benthic categories at Cayo Coral – 8 m, Guánica.

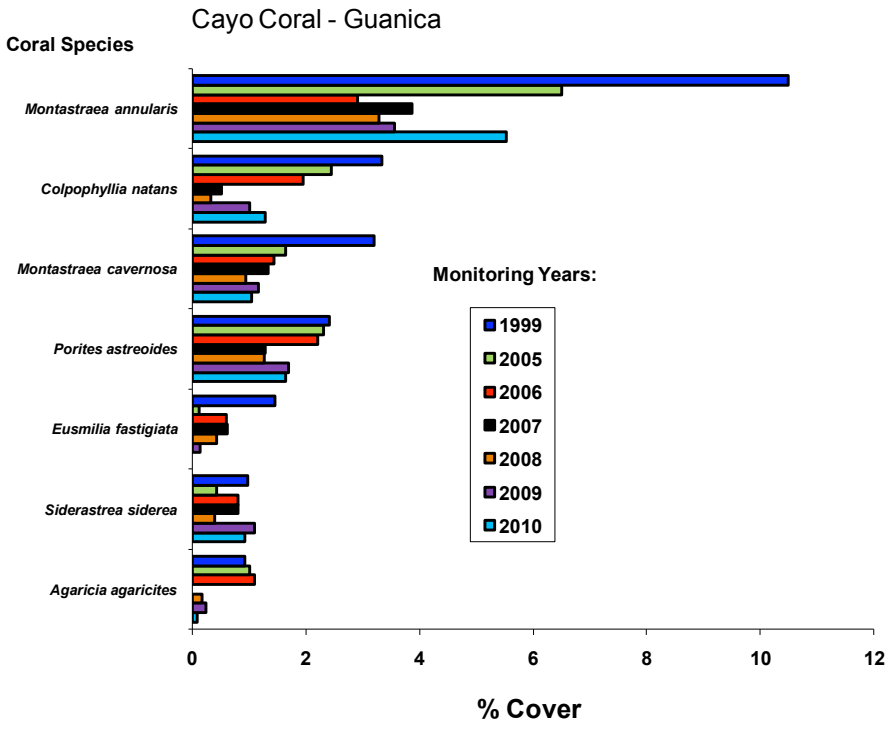


Figure 35. Monitoring trends (1999 – 2010) of mean substrate cover by stony coral species at Cayo Coral – 8 m, Guánica

scleractinian coral species that have shown marked declines of substrate cover at Cayo Coral include *Colpophyllia natans, M. cavernosa, P. astreoides* and *Agaricia spp*.

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 February 2010 was 56.0 Ind/30 m^2 (range: 51 - 60 Ind/30 m^2). The mean number of species per transect was 16.6 (range: 15 - 20). Bluehead Wrasse (*Thalassoma bifasciatum*), Sharknose Goby (*Gobiosoma evelynae*), Blue Chromis (Chromis cyanea), Dusky Damselfish (*Stegastes partitus*) and the Redband and Striped Parrotfishes (*Sparisoma aurofrenatum, Scarus iserti*) were the numerically dominant species with a combined mean abundance of 36.0 Ind/30 m^2, representing 64.3 % of the total abundance within belt-transects (Table 39). All of the aforementioned species were present in at least 4 transects and along with the Beaugregory, Yellowhead Wrasse and Four-eye Butterflyfish 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. Interestingly, a mild, statistically insignificant increment of fish abundance since 2009, now extending to the present 2010 survey, coincides with the coral recuperation pattern previously mentioned for this reef.

Small, opportunistic micro-invertebrate predators (wrasses, gobies, puffers), demersal and pelagic schooling zooplanktivores (Blue Chromis, Creole Wrasse, Bicolor Damselfish,) and herbivores (*Scarus spp., Sparisoma spp*., *Acanthurus spp*.) comprised the most prominent assemblage of the reef fish community. Among large invertebrate and small demersal fish predators, small growing groupers such Graysbys and Coneys were common. Juvenile Yellowfin Grouper and Jewfish, Red Hind, Nassau

Table 39. Taxonomic composition and abundance of fishes within belt-transects at Cayo Coral, Guanica, 10 m. February 2010

Depth: 8 -10m

		Transects					
SPECIES	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**MEAN**
Thalassoma bifasciatum	Bluehead Wrasse	20	15	1	5	6	**9.4**
Gobiosoma evelynae	Sharknose Goby	1	6	23	4	11	**9.0**
Chromis cyanea	Blue Chromis	0	1	3	13	8	**5.0**
Scarus iserti	Stripped Parrotfish	3	5	3	3	9	**4.6**
Stegastes dorsopunicans	Dusky Damselfish	4	4	5	4	4	**4.2**
Sparisoma aurofrenatum	Redband Parrotfish	6	4	4	3	2	**3.8**
Halichoeres garnoti	Yellowhead Wrasse	0	6	1	2	5	**2.8**
Stegastes leucostictus	Beaugregory	4	1	4	3	1	**2.6**
Chaetodon capistratus	Four-eye Butterflyfish	0	4	2	2	2	**2.0**
Clepticus parrae	Creole Wrasse	10	0	0	0	0	**2.0**
Acanthurus coeruleus	Blue Tang	1	0	1	4	1	**1.4**
Microspathodon chrysurus	Yellowtail Damselfish	1	0	1	3	1	**1.2**
Holocentrus rufus	Longspine Squirrelfish	1	1	0	3	0	**1.0**
Acanthurus bahianus	Ocean Surgeon	1	1	1	1	0	**0.8**
Haemulon flavolineatum	French Grunt	0	1	1	1	1	**0.8**
Stegastes variabilis	Cocoa Damselfish	0	0	0	0	4	**0.8**
Sparisoma viride	Stoplight Parrotfish	2	0	1	0	0	**0.6**
Stegastes partitus	Bicolor Damselfish	1	0	0	0	2	**0.6**
Lutjanus mahogoni	Mahogany Snapper	1	0	0	0	2	**0.6**
Canthigaster rostrata	Sharpnose Puffer	1	0	1	0	0	**0.4**
Epinephelus cruentatus	Graysby	0	1	1	0	0	**0.4**
Neoniphon marianus	Longjaw Squirrelfish	0	0	2	0	0	**0.4**
Serranus tigrinus	Harlequin Bass	1	0	0	0	0	**0.2**
Aulostomus maculatus	Trumpetfish	1	0	0	0	0	**0.2**
Chaetodon ocellatus	Spotfin Butterflyfish	1	0	0	0	0	**0.2**
Hypoplectrus chlorurus	Yellowtail Hamlet	0	1	0	0	0	**0.2**
Calamus calamus	Saucereye Porgy	0	0	1	0	0	**0.2**
Coryphopterus lipernes	Peppermint Goby	0	0	1	0	0	**0.2**
Gramma loreto	Fairy Basslet	0	0	1	0	0	**0.2**
Echenes naucrates	Sharksucker	0	0	0	1	0	**0.2**
Scarus taeniopterus	Princess Parrotfish	0	0	0	0	0	**0.0**
	TOTAL INDIVIDUALS	**60**	**51**	**58**	**52**	**59**	**56.0**
	TOTAL SPECIES	**18**	**15**	**20**	**15**	**15**	**16.6**

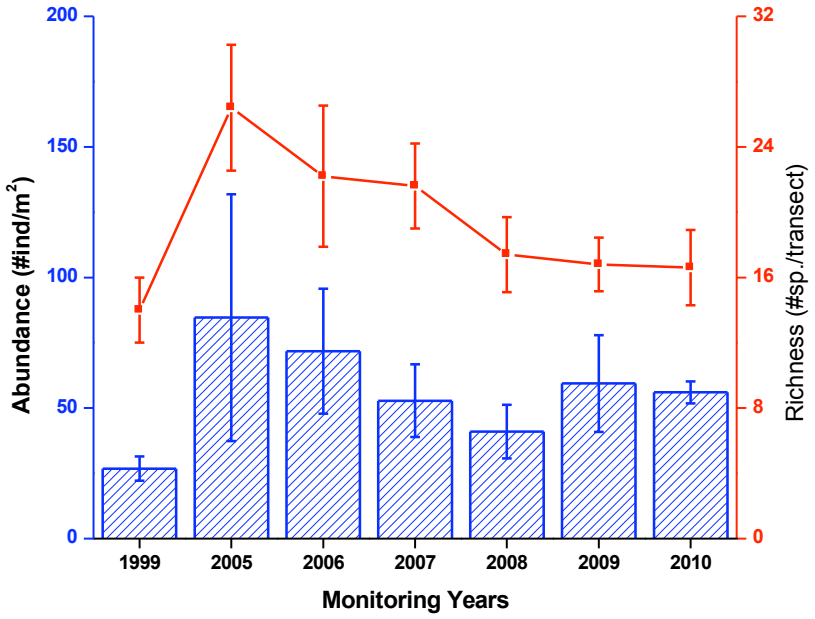


Figure 36. Monitoring trends (1999 – 2010) of fish species richness and abundance at Cayo Coral Reef, 8 m, Guanica Natural Reserve

Grouper, Hogfish, Schoolmaster, Mahogany and Yellowtail Snappers have been observed during previous ASEC surveys at Cayo Coral (Garcia-Sais et al., 2006). Schooling zooplanktivore species, such as the Mackerel Scad are common at Cayo Coral and serve as forage for several pelagic predators, particularly Cero Mackerels and Great Barracudas observed during the 2010 (and previous) ASEC surveys (Table 40). Several Bottlenose dolphins were also present at Cayo Coral during the 2010 survey.

Table 40. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Cayo Coral. Guánica. February, 2010

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

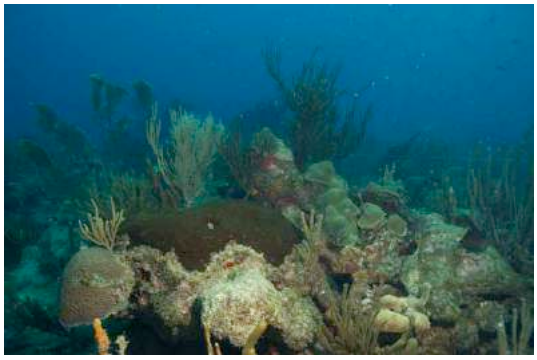
SPECIES	**COMMON NAME**	# - (cm)		
Caranx crysos	Blue Runner	3 - (30)		
Epinephelus guttatus	Red Hind	2 - (20)	1 - (30)	
Lutjanus apodus	Schoolmaster	4 - (20)	1 - (30)	
Lutjanus mahogany	Mahogany Snapper	3 - (20)	1 – (25)	
Lutjanus synagris	Lane Snapper	2 - (15)	2 – (20)	2 – (25)
Ocyurus chrysurus	Yellowtail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

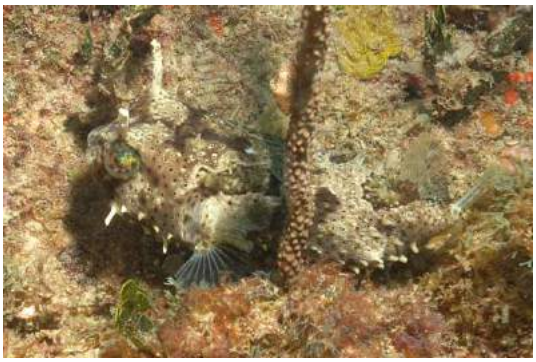
Mootile megabenthic invertebrates observed within belt-transects included the Flamingo Tongue, a predator of soft coral polyps and the Arrow Crab (Table 41).

Table 41. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Cayo Coral 8 m, Guánica. February 2010

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

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.

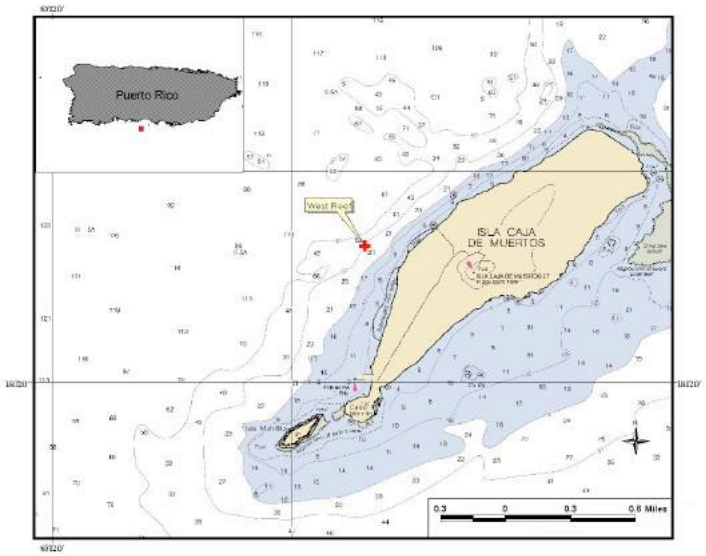


Figure 37. Location of coral reef survey stations at West Reef, Isla Caja de Muerto, Ponce.

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 51.6 % (range: 39.7 – 61.5 %) along permanent transects and was observed colonizing dead coral colonies and other hard ground substrates in the reef (Table 42). Fleshy brown (*Dictyota sp*.) and calcareous (*Halimeda tune, H. opuntia*) macroalgae represented minor components of the benthic algae assemblage at West Reef. During the 2007 survey, cyanobacterial (blue-green algal) mats were prominent at the reef benthos with an average cover of 9.0 %, but since 2008 have declined to a mean of 2.8 % during the present 2010 survey. The cyanobacterial bloom appeared to be associated and proportional to the amount of recently dead coral observed after the late 2005 massive coral-bleaching event that impacted reef systems of Puerto Rico and the USVI (García-Sais et al., 2006).

A total of 20 stony coral species, icluding 13 within transect were identified from West Reef in the 2010 survey (Table 42). Live stony corals presented a mean substrate cover of 12.2 % (range: 9.1 – 15.1 %). Boulder Star Coral, *Montastraea annularis* (complex) was the dominant coral species with a mean substrate cover of 5.0 % (range: 1.7 – 9.5 %), representing 41.0 % of the total substrate cover by live stony corals. Great Star Coral (*M. cavernosa*), Mustard-Hill Coral (*Porites astreoides*), and the Greater Starlet Coral, *Siderastrea siderea* were present in at least four out of the five transects surveyed, and along with Boulder Star Coral comprised the main coral assemblage of the West Reef (Table 42).

Soft corals (gorgonians) presented a mean density of 24.2 colonies/transect and included colonies of very large size. Some of the most abundant species included the Slimy Sea Plumes (*Pseudopterogorgia americana, Pseudopterogorgia spp.*), Porous Sea Rods (*Pseudoplexaura spp*.), Corky Sea Finger (*Briareum asbestinum*), Common Sea Fan (*Gorgonia ventalina*), Knobby Sea Rods (*Eunicea spp*.) and the Encrusting Gorgonian (*Erythropodium caribaeorum*). Sponges were present in all five transects with a mean substrate cover of 1.6 %. Abiotic categories combined for a mean substrate cover of 31.6 %. 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 Caja de Muertos Reef, Ponce. 10 m Survey Date: March 2010.

Depth: 8 – 10 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	4.5	5.7	7.0		6.0	**5.8**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	16.3	16.5	24.6	25.0	23.7	**21.2**
Silt	17.3	2.6	8.8	1.9	5.5	**7.2**
Sand/Rubble	1.2	2.3	6.3	4.6	1.8	**3.2**
Total Abiotic	34.8	21.4	39.7	31.4	30.9	**31.6**
Benthic Algae						
Turf-mixed assemblage	48.8	61.5	39.7	52.5	55.3	**51.6**
Total Benthic Algae	48.8	61.5	39.7	52.5	55.3	**51.6**
Sponges	2.3	0.7	3.7	0.4	0.9	**1.6**
Cyanobacteria	5.0	1.3	4.7	1.6	1.4	**2.8**
Live Stony Corals						
Montastraea annularis	3.4	9.5	7.3	1.7	2.9	**5.0**
Montastraea cavernosa		3.4	0.8	5.3	3.3	**2.6**
Porites astreoides	0.9	1.2	2.5	1.3	2.8	**1.7**
Siderastrea siderea	1.2	1.0	0.4	2.0	0.3	**1.0**
Meandrina meandrites			0.6	1.3		**0.4**
Stephanocoenia intersepta	1.0			0.3	0.5	**0.4**
Agaricia agaricites	1.2				0.3	**0.3**
Agaricia lamarcki			0.3	1.1		**0.3**
Siderastrea radians	0.6		0.3		0.4	**0.3**
Madracis decactis				0.9		**0.2**
Porites porites	0.8					**0.2**
Colpophyllia natans					0.5	**0.1**
Agaricia grahamae				0.3		**0.1**
Total Stony Corals	9.1	15.1	12.2	14.0	10.8	**12.2**
Gorgonians						
Pseudopterogorgia americana	7	0	11	8	12	**7.6**
Plexaura kukenthali	5	5	6	7	5	**5.6**
Briareum asbestinum	4	4	0	6	4	**3.6**
Gorgonia ventalina	1	4	4	2	4	**3.0**
Eunicea flexuosa	1	0	4	1	2	**1.6**
Plexaurella nutans	0	0	1	2	0	**0.6**
Eunicea tourneforti	0	0	1	0	1	**0.4**
Muriceopsis flavida	0	0	1	1	0	**0.4**
Pseudopterogorgia acerosa	1	0	1	0	0	**0.4**
Pseudopterogorgia bipinnata	2	0	0	0	0	**0.4**
Erythropodium caribaeorum	1	0	0	0	0	**0.2**
Eunicea succinea	0	0	0	0	1	**0.2**
Pseudopterogorgia americana	1	0	0	0	0	**0.2**
Total Gorgonians (#colonies/transect)	23.0	13.0	29.0	27.0	29.0	**24.2**

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 2005-10. 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 (Appendix 2). Recently dead coral accounted for a total of 7.7 % during 2007, associated with mortality of massive corals, such as *Montastraea annularis* and *Colpophyllia natans* after the late 2005 coral bleaching event. Partially bleached corals were observed during the 2007 survey and represented 1.5 % of the total cover by live corals at West Reef. Live coral cover has stabilized since the 2008 monitoring survey and seem to be slowly recuperating, as suggested by the increment in cover measured during the last two surveys (e.g. 2009 and 2010). Soft corals (gorgonians) increased markedly after 2006 (Figure 38) suggesting that the massive mortality of stony corals after the 2005 bleachin event may have stimulated an increse of recruitment by soft corals at West Reef.

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 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*. Mild increments of substrate cover by *M. annularis*, *P. astreoides* and *Siderastrea radians* were measured in the 2009 and 2010 surveys.

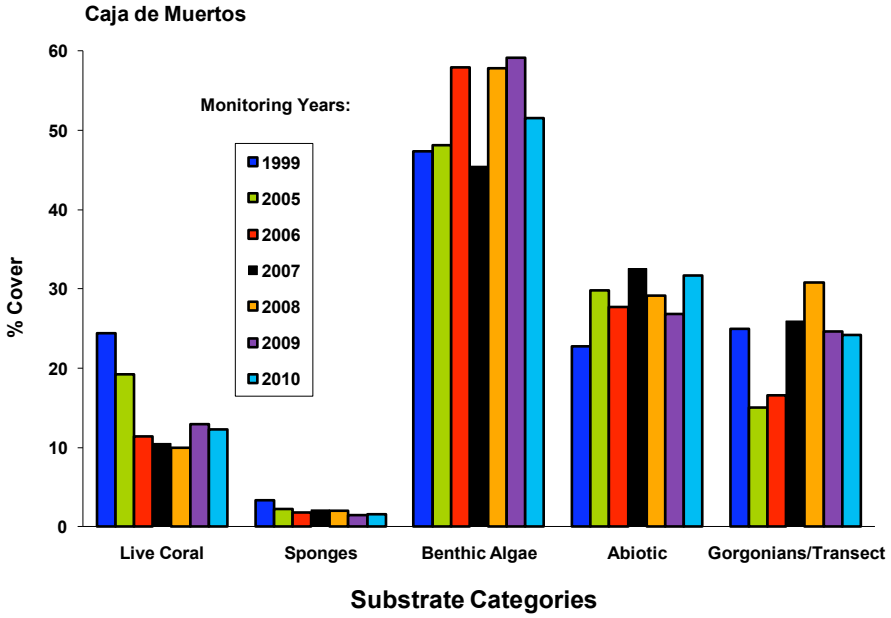


Figure 38. Monitoring trends (1999 - 2010) of mean substrate cover by sessile-benthic categories at West Reef, Isla Caja de Muerto, Ponce.

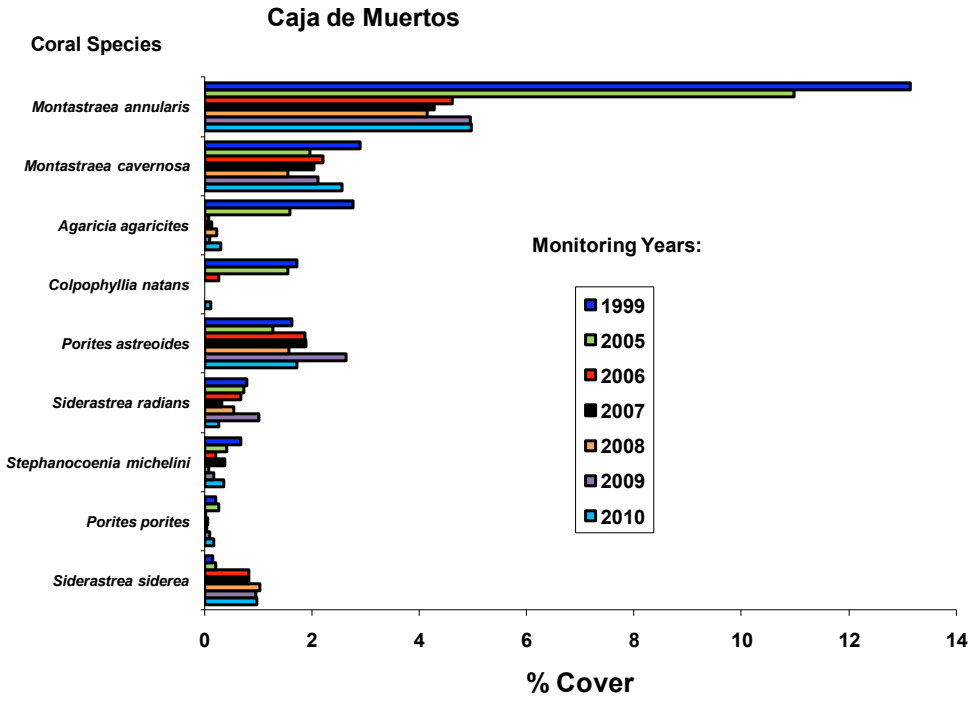


Figure 39. Monitoring trends (1999 – 2010) of mean substrate cover by stony coral species at West Reef, Isla Caja de Muerto, Ponce.

2.0 Fishes and Motile Megabenthic Invertebrates

A total of 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 2010 was 123.4 Ind/30 m^2 (range: 81 - 150 Ind/30 m^2). The mean number of species per transect was 20.8 (range: 12- 29). The Masked Goby (*Coryphopterus personatus*) was the numerically dominant species with a mean abundance of 65.0 Ind/30 m^2 (range: 50 - 95 Ind/30 m^2), representing 52.7 % of the total abundance within belt-transects (Table 43). The Masked Goby was present in swarms of 15 – 50 individuals close to the reef substrate, below ledges, in front of crevices and other protective microhabitats of the reef. The Bluehead Wrasse, Tomtate, Bicolor, Striped and Redband Parrotfishes, Brown Chromis, Dusky and Bicolor Damselfishes, and the French Grunt were present in at least four of the five transects surveyed and comprised along with Masked Goby, the main fish assemblage of West Reef (Table 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 Masked Goby, a dominant species within belt transects. Abundances were relatively lower during the baseline survey and then again in the period of 2006-08 relative to the 2009 and the present 2010 surveys. Differences in fish species richness within belt-transects were also detected (ANOVA; $p < 0.001$). The main pattern was a decline of the number of species per transect during the 2007 and 2008 relative to previous surveys.

The fish community structure at West Reef is strongly represented by zooplankton feeders, including the Masked Goby, Brown Chromis, Bicolor Damselfish, Creole Wrasse and Mackerel Scad. Some of these species were not prominent within belt-transects, but were observed forming large schooling aggregations in the water column over the reef. These species are known to serve as forage for a diverse assemblage of top pelagic and demersal predators, including barracudas, jacks, and large groupers and snappers observed during 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

Table 43. Taxonomic composition and abundance of fishes within belt-transects at West Reef, Isla Caja de Muerto, 6.5 m, Ponce. Survey Date: March 2010.

Depth: 6.5 m

		Transects					
		1	**2**	**3**	**4**	**5**	**MEAN**
SPECIES	**COMMON NAME**						
Coryphopterus personatus	Masked Goby	90	50	50	70	65	**65.0**
Thalassoma bifasciatum	Bluehead Wrasse	5	7	3	5	15	**7.0**
Haemulon aurolineatum	Tomtate	0	0	30	5	0	**7.0**
Scarus iserti	Striped Parrotfish	13	7	4	2	4	**6.0**
Sparisoma aurofrenatum	Redband Parrotfish	3	1	3	3	8	**3.6**
Chromis multilineata	Brown Chromis	0	0	7	10	0	**3.4**
Stegastes partitus	Bicolor Damselfish	2	1	8	4	1	**3.2**
Stegastes dorsopunicans	Dusky Damselfish	3	6	1	5	1	**3.2**
Haemulon flavolineatum	French Grunt	0	3	4	6	0	**2.6**
Scarus taeniopterus	Princess Parrotfish	1	1	5	0	5	**2.4**
Stegastes planifrons	Three-spotted Damselfish	1	0	3	6	2	**2.4**
Lutjanus apodus	Schoolmaster Snapper	0	0	3	6	0	**1.8**
Chromis cyanea	Blue Chromis	0	2	3	3	0	**1.6**
Canthigaster rostrata	Sharpnose Puffer	1	1	1	1	2	**1.2**
Stegastes leucostictus	Beaugregory	2	0	2	1	1	**1.2**
Myripristis jacobus	Blackbar Soldierfish	0	0	4	2	0	**1.2**
Aulostomus maculatus	Trumpetfish	0	0	1	2	1	**0.8**
Holocentrus rufus	Longspine Squirrelfish	1	0	0	1	2	**0.8**
Caranx ruber	Bar Jack	0	0	3	1	0	**0.8**
Chaetodon capistratus	Four-eye Butterflyfish	1	0	2	0	0	**0.6**
Acanthurus bahianus	Ocean Surgeon	1	0	0	1	1	**0.6**
Lutjanus mahogany	Mahogany Snapper	0	0	0	3	0	**0.6**
Halichoeres garnoti	Yellowhead Wrasse	1	0	0	2	0	**0.6**
Acanthurus coeruleus	Blue Tang	1	0	1	0	1	**0.6**
Epinephelus cruentatus	Graysby	1	1	1	0	0	**0.6**
Sparisoma viride	Stoplight Parrotfish	0	0	1	0	1	**0.4**
Hypoplectrus puella	Barred Hamlet	0	0	1	1	0	**0.4**
Serranus tigrinus	Harlequin Bass	0	0	2	0	0	**0.4**
Hypoplectrus unicolor	Butter Hamlet	0	0	1	0	1	**0.4**
Ocyurus chrysurus	Yellowtail Snapper	0	0	0	0	2	**0.4**
Gobiosoma evelynae	Sharknose Goby	0	0	0	1	0	**0.2**
Pseudupeneus maculatus	Spotted Goatfish	0	0	0	0	1	**0.2**
Equetus punctatus	Spotted Drum	0	0	1	0	0	**0.2**
Acanthurus chirurgus	Doctorfish	0	0	1	0	0	**0.2**
Haemulon macrostomum	Spanish Grunt	0	0	1	0	0	**0.2**
Abudefduf sexatilis	Sergeant Major	0	0	0	1	0	**0.2**
Anisotremus virginicus	Porkfish	0	0	1	0	0	**0.2**
Gramma loreto	Fairy Basslet	0	0	1	0	0	**0.2**
Coryphopterus glaucofraenum	Bridled Goby	0	0	0	1	0	**0.2**
Bodianus rufus	Spanish Hogfish	0	0	1	0	0	**0.2**
Pomacanthus paru	French Angelfish	0	0	0	1	0	**0.2**
Hypoplectrus nigricans	Black Hamlet	0	1	0	0	0	**0.2**
Pomacanthus arcuatus	Gray Angelfish	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**12 7**	**81**	**15 0**	**14 4**	**11 5**	**123.4**
	TOTAL SPECIES	**18**	**12**	**29**	**26**	**19**	**20.8**

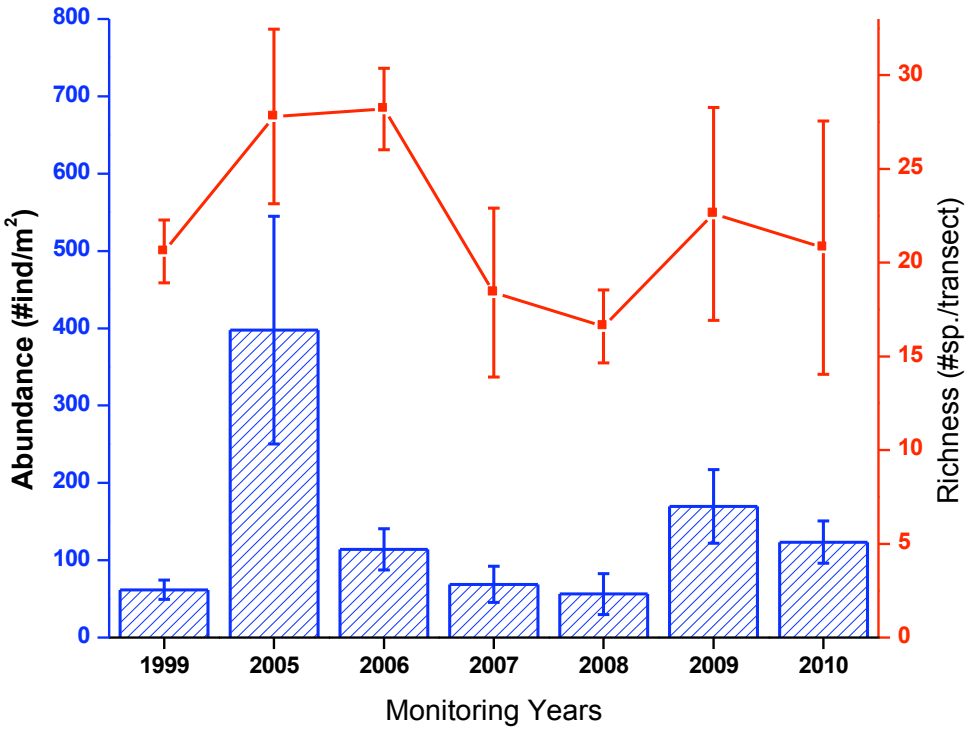


Figure 41. Monitoring trends (1999 – 2010) of fish species richness and abundance at West Reef, Isla Caja de Muerto, Ponce

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 2009 and 2010 ASEC surveys. 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 Banded Coral Shrimps and Arrow Crabs (Table 45). One adult spiny lobster, *Panulirus argus*, several Flamingo Tongue, Cleaner Shrimps, and adult Queen Conch, *Strombus gigas* were observed outside transects.

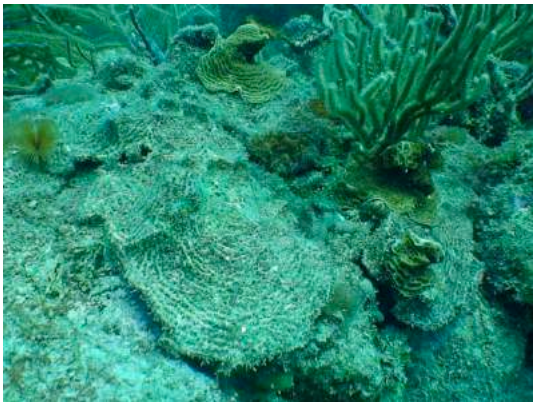
Table 44. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at West Reef, Isla Caja de Muerto, March 2010.

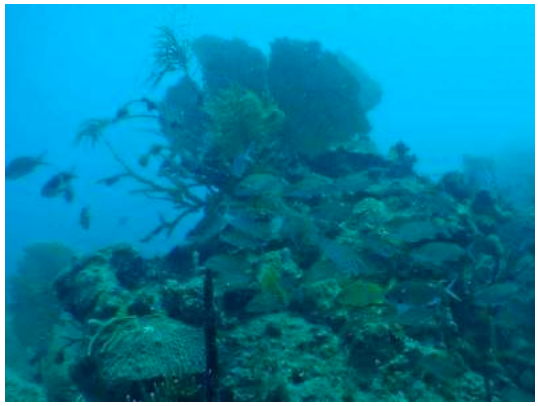
Depth range : 7 – 15 m	Duration - 30 min.			
SPECIES	**COMMON NAME**		# - (cm)	
Epinephelus guttatus	Red Hind	2 - (25)	2 – (30)	
Lutjanus apodus	Schoolmaster	8 – (15)	6 – (20)	5 – (30)
Lutjanus mahogany	Mahogani Snapper	4 - (20)	3- (30)	
Lutjanus synagris	Lane Snapper	500 – (10-15)	100 – (25)	20 – (30)
Ocyurus chrysurus	Yellowtail Snapper	20 – (1 - 15)	10 – (25)	5 – (30)
Scomberomorus regalis	Cero Mackerel	1 - (40)	1 - (50)	
Sphyraena barracuda	Great Barracuda	1 - (60)		
Invertebrates				
Strombus gigas	Queen Conch	3 – (25-30)		
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 2010

Depth: 6 - 7 m		**TRANSECTS**					**MEAN ABUNDANCE**
		1	**2**	**3**	**4**	**5**	**(IND/30 m2)**
TAXA	**COMMON NAME**						
Stenopus hispidus	Banded Coral Shrimp	1		1			**0.4**
Stenorhynchus seticornis	Arrow Crab		1			1	**0.4**
	TOTALS	**1**	**1**	**1**	**0**	**1**	**0.8**

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 12 intersected by line transects were identified from Derrumbadero Reef at a depth of 20 m during 2010 (Table 46). Stony corals occurred as massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 15.4 % (range: 8.7 – 21.6 %). Boulder Star Coral, *Montastraea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 8.3 % (range: 3.0 – 14.1 %), representing 53.9 % of the total cover by stony corals. Great Star Coral (*M. cavernosa*) and Mustard-Hill Coral (*Porites astreoides*) ranked second and third in terms of substrate cover by stony corals. Boulder Star and Great Star Corals, Mustard-Hill Coral and Lettuce Coral (*Agaricia agaricites*) were present in at least three transects and comprised the main stony coral assemblage at Derrumbadero Reef (Table 46).

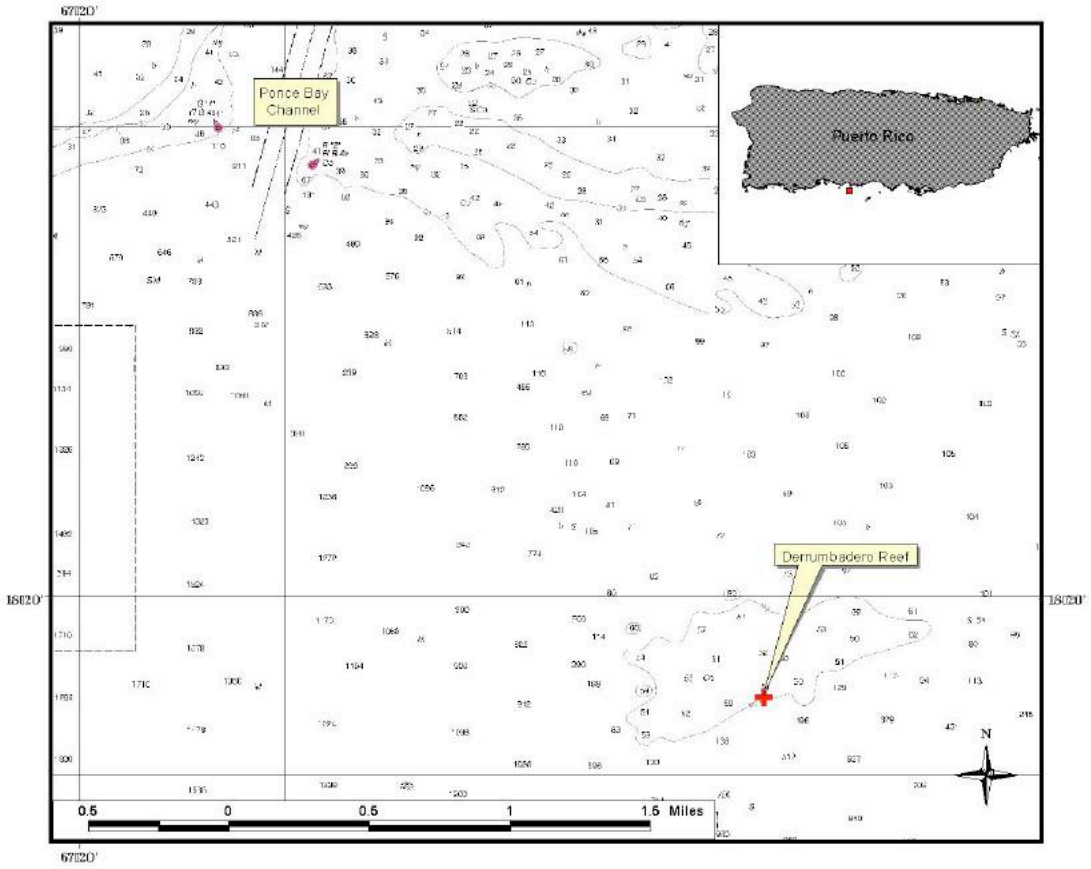


Figure 42. Location of the coral reef monitoring station at Derrumbadero Reef, Ponce.

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: 30.4 col./transect) at Derrumbadero Reef and because of their large sizes and species richness (14 spp within transects) contributed substantially to the biological diversity and structural complexity of the reef system. Sea Plumes, *Pseudopterogorgia acerosa, P. americana* 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).

Table 46. Percent substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce, 20 m March 2010. Survey Date: March 2010

Depth: 20m

	Transects					
Transects	**1**	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	3.3	2.6	2.8	3.0	2.6	**2.8**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	16.8	14.3	11.9		1.8	**9.0**
Rubble				2.7		**0.5**
Sand				2.2		**0.4**
Total Abiotic	0.0	0.0	0.0	2.2	0.0	**9.9**
Benthic Algae						
Turf-mixed assemblage	38.9	44.9	44.1	42.4	59.3	**45.9**
Coralline algae				0.7	2.6	**0.6**
Dictyota sp.	10.7	10.7	17.0	28.2	8.3	**15.0**
Lobophora variegata	12.2	14.5	8.6	3.0	3.3	**8.3**
Total Benthic Algae	61.8	70.0	69.8	74.2	73.5	**69.8**
Sponges	3.4	1.8	2.5	5.2	4.3	**3.5**
Gorgonians	1.0	5.3	1.2	0.3	0.6	**1.7**
Cyanobacteria					1.1	**0.2**
Ascidians				0.3		**0.1**
Live stony corals						
Montastraea annularis	11.7	3.0	5.7	7.1	14.1	**8.3**
Montastraea cavernosa			3.8	6.3	3.9	**2.8**
Porites astreoides	2.3	3.8	1.2		2.2	**1.9**
Agaricia agaricites	0.5	1.0	1.9	1.4	1.1	**1.2**
Diploria strigosa			1.8			**0.4**
Diploria labyrinthiformis		0.9				**0.2**
Porites porites	0.8					**0.2**
Millepora alcicornis				0.3	0.3	**0.1**
Madracis decactis	0.6					**0.1**
Porites colonensis	0.5					**0.1**
Stephanocoenia intersepta	0.5					**0.1**
Agaricia lamarcki			0.4			**0.1**
Total Stony Corals	17.0	8.7	14.7	15.1	21.6	**15.4**
Gorgonians						
Pseudopterogorgia acerosa	4	6	9	11	6	**7.2**
Gorgonia ventalina	4	4	9	10	6	**6.6**
Briareum asbestinum	8	13	3	1	2	**5.4**
Eunicea flexuosa	1	3	2	3	1	**2.0**
Pseudopterogorgia americana	4	1	0	4	1	**2.0**
Eunicea tourneforti	2	3	2	1	1	**1.8**
Pseudoplexaura flagellosa or wagenaari	3	0	2	1	1	**1.4**
Eunicea asperula	0	1	1	2	0	**0.8**
Eunicea spp.	0	2	1	0	1	**0.8**
Muriceopsis flavida	0	3	0	0	1	**0.8**
Plexaura kukenthali	1	0	1	1	0	**0.6**
Erythropodium caribaeorum	0	2	0	0	0	**0.4**

Table 46. Continued

Eunicea succinea	0	0	0	1	1	**0.4**
Plexaura homomalla	0	0	1	0	0	**0.2**
Total Gorgonians (# col./transect)	27	38	31	35	21	**30.4**

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

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 45.9 % (range: 38.9 – 59.3 %). Sponges were also present in all five transects with a mean substrate cover of 3.5 %. Abiotic categories were represented by jreef overhangs mostly produced by mounds and ledges of Boulder Star Coral (*M. annularis*), and contributed to the reef mean topographic rugosity of 2.8 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 2005-10. Differences of mean total percent cover by stony corals between monitoring surveys were statistically significant (ANOVA; $p < 0.0001$; Appendix 2), indicative of a severe degradation of the reef coral community. The reduction of mean live coral cover between the baseline survey of 2001 (41.6 %) and the first monitoring survey of 2005 (34.6 %) represented a decline of 16.7 % over a period of four years. A much more drastic decline was observed between 2005 and the 2006 monitoring survey. Total live coral declined 59.1 %, from 34.6 % in 2005 to 14.2 % in 2006. A proportional increment of cover by benthic algae was measured. Such drastic, short-term collapse of the Derrumbadero coral reef system was associated with the massive regional coral bleaching event that affected Puerto Rico and the USVI during late September through October 2005 (García-Sais et al., 2006, 2007, 2008). From the reported live coral intercepted by transects during the 2006 monitoring survey, approximately 35.9 % was partially bleached. Most of the partially bleached coral colonies 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 mean cover in 2007 was measured during the 2008 survey. Partially bleached coral declined to a mean substrate cover of

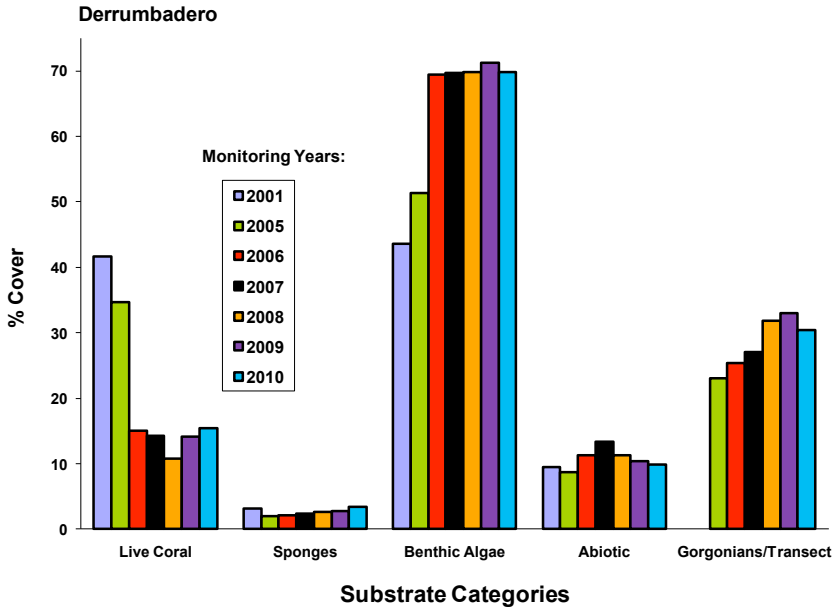


Figure 43. Monitoring trends (2001 – 2010) of mean substrate cover by sessile-benthic categories at Derrumbadero Reef, Ponce.

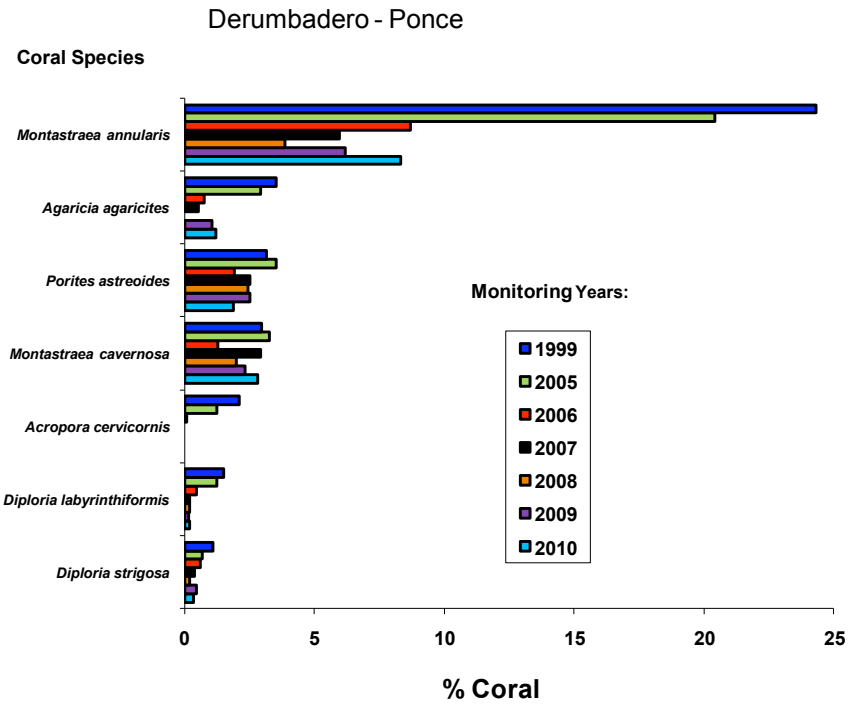


Figure 44. Monitoring trends (2001 – 2010) of mean substrate cover by coral species at Derrumbadero Reef, Ponce

0.6 % during 2008. A mild (statistically insignificant), yet consistent increment of live coral cover was measured during the 2009 and present 2010 surveys (Figure 43).

Monitoring trends of mean substrate cover by coral species at Derrumbadero Reef are shown in Figure 44. In 2005, Boulder Brain Coral was the dominant coral species in terms of reef substrate cover at Derrumbadero Reef, representing then almost 62 % of the total cover by live corals. Thus, its sharp decline of 57.4 % between the 2005 (20.4 %) and 2006 (8.7 %) monitoring surveys had a profound influence on the total live coral at the reef ecosystem level. Marked reductions of mean substrate cover by live corals were also measured for *Montastraea cavernosa*, *Agaricia agaricites, Diploria labyrinthiformis*, and *Acropora cervicorni*s. Since the 2009 survey, now extending to the present 2010 survey, a mild increment of live cover by *M. annularis* was measured at Derrumbadero Reef, consistent with similar observations at several other reefs included in the monitoring program. Soft corals (gorgonian) were not adversely affected by the environmental conditions affecting scleractinian corals after 2005 in Derrumbadero Reef. They have shown an increment from 23 to 30 col/transect between the 2006 and the 2010 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), including 41 within belt-transects during 2010. Mean abundance within belt-transects during 2010 was 73.4 Ind/30 m^2 (range: 41 - 108 Ind/30 m^2). The mean number of species per transect was 21.8 (range: 19 - 28). The Masked Goby, Blue Chromis, Bluehead Wrasse and the Bicolor Damselfish were the numerically dominant species with a combined mean abundance of 39.6 Ind/30 m^2 representing 54.0 % of the total abundance within belt-transects (Table 47). In addition to the aforementioned species, the Yellowhead Wrasse, Princess, Striped and Redband Parrotfishes, Peppermint and Sharknose Gobies, Beaugregory, Four-eye Butterflyfish, Black-bar Soldierfish and Longspine Squirrelfish were present in at least four of the five transects surveys and were part of the resident fish assemblage at Derumbadero Reef. Fourteen species were represented by only one individual within belt-transects.

Table 47. Taxonomic composition and abundance of fishes within belt-transects at Derrumbadero Reef, 20 m, Ponce. March 2010

Depth: 20m

		Transects					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	16	10	5	0	25	**11.2**
Chromis cyanea	Blue Chromis	4	0	35	6	7	**10.4**
Thalassoma bifasciatum	Bluehead Wrasse	15	6	5	6	15	**9.4**
Stegastes partitus	Bicolor Damselfish	13	7	5	4	14	**8.6**
Sparisoma aurofrenatum	Redband Parrotfish	4	5	5	2	3	**3.8**
Coryphopterus lipernes	Peppermint Goby	3	1	0	4	5	**2.6**
Scarus iserti	Striped Parrotfish	3	2	1	0	6	**2.4**
Chaetodon capistratus	Four-eye Butterflyfish	5	1	2	2	2	**2.4**
Scarus taeniopterus	Princess Parrotfish	4	1	1	1	3	**2.0**
Holocentrus rufus	Longspine Squirrelfish	1	1	4	2	2	**2.0**
Gobiosoma evelynae	Sharknose Goby	0	2	0	1	6	**1.8**
Myripristis jacobus	Blackbar Soldierfish	4	0	1	1	3	**1.8**
Halichoeres garnoti	Yellowhead Wrasse	1	4	2	0	1	**1.6**
Acanthurus coeruleus	Blue Tang	1	2	1	1	1	**1.2**
Stegastes leucostictus	Beaugregory	0	2	3	0	1	**1.2**
Acanthurus bahianus	Ocean Surgeon	1	2	1	0	2	**1.2**
Aulostomus maculatus	Trumpetfish	1	0	2	1	1	**1.0**
Clepticus parrae	Creole Wrasse	5	0	0	0	0	**1.0**
Sparisoma viride	Stoplight Parrotfish	1	0	1	0	1	**0.6**
Cephalopholis cruentatus	Graysby	1	0	1	0	1	**0.6**
Serranus tigrinus	Harlequin Bass	0	2	1	0	0	**0.6**
Neoniphon marianus	Gallo Amarillo	1	1	0	0	1	**0.6**
Haemulon flavolineatum	French Grunt	1	1	1	0	0	**0.6**
Chaetodon striatus	Banded Butterflyfish	0	0	1	2	0	**0.6**
Holacanthus tricolor	Rock beauty	1	1	0	0	1	**0.6**
Chaetodon ocellatus	Spotfin Butterflyfish	0	0	0	2	0	**0.4**
Calamus calamus	Saucereye porgy	1	0	0	1	0	**0.4**
Canthigaster rostrata	Sharpnose Puffer	0	0	0	0	1	**0.2**
Acanthurus chirurgus	Doctorfish	0	0	0	1	0	**0.2**
Hypoplectrus puella	Barred Hamlet	0	1	0	0	0	**0.2**
Anisotremus virginicus	Porkfish	0	0	0	0	1	**0.2**
Epinephelus guttatus	Red Hind	0	0	0	1	0	**0.2**
Melichthys niger	Black Durgon	0	0	0	0	1	**0.2**
Chromis multilineata	Brown Chromis	1	0	0	0	0	**0.2**
Ocyurus chrysurus	Yellowtail Snapper	0	0	0	1	0	**0.2**
Balistes vetula	Queen Triggerfish	0	0	0	1	0	**0.2**
Hypoplectrus indigo	Indigo Hamlet	0	0	0	1	0	**0.2**
Synodus saurus	Lizzardfish	0	0	0	0	1	**0.2**
Epinephelus fulva	Coney	0	0	0	0	1	**0.2**
Equetus punctatus	Spotted Drum	0	0	0	0	1	**0.2**
Coryphopterus glaucofraenum	Briddled Goby	0	0	0	0	1	**0.2**
	TOTAL INDIVIDUALS	**88**	**52**	**78**	**41**	**108**	**73.4**
	TOTAL SPECIES	**22**	**19**	**19**	**21**	**28**	**21.8**

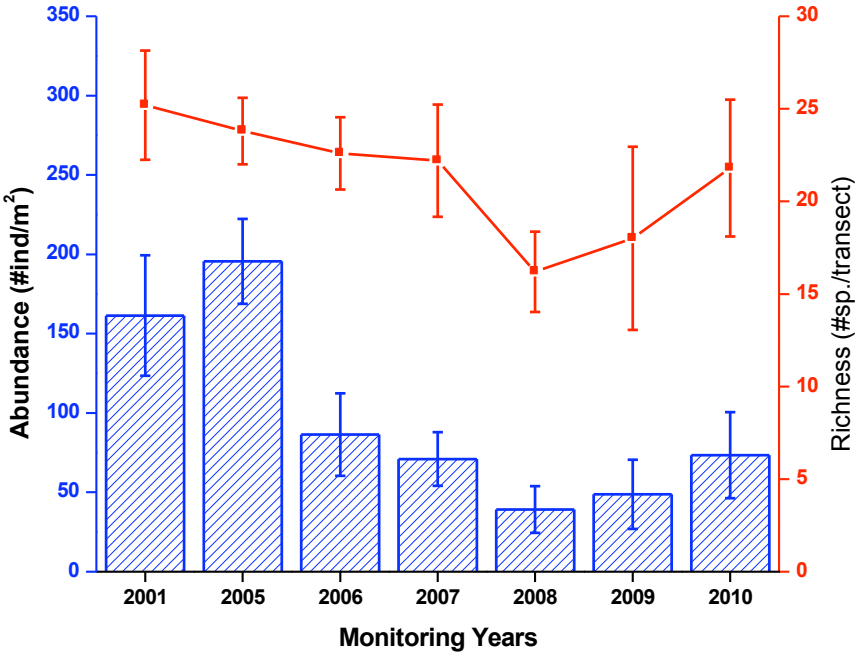


Figure 44. Monitoring trends (1999 – 2010) of fish species richness and abundance at Derrumbadero Reef, Ponce

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

community structure as it affects microhabitat availability and food webs (Paddack et al. 2009). Conversely, with the gradual improvement of live coral cover at Derrumbadero an increasing trend of both fish species richness and abundance has emerged during the last two years of the monitoring program (e.g. 2009 and 2010, Figure 44).

The fish community of Derrumbadero Reef appears to be well balanced in terms of trophic structure, including the presence of large demersal predators, such as large snappers and groupers. There is a strong plankton based food web that serves to transfer energy up to the top predators of the reef system. Numerically dominant species, such as the Masked Goby, Blue and Brown Chromis, Bicolor Damselfish, Bluehead, Yellowhead and Creole Wrasse, and juvenile snappers and grunts (which are piscivorous or demersal feeders as adults) comprise the zooplanktivorous assemblage of the reef system. These in turn serve as forage for large pelagic species, such as Cero Mackerels and Barracudas observed during an ASEC survey in this reef (Table 48). Large demersal predators previously reported from Derrumbadero Reef (García-Sais et al., 2006), such as Yellowfin and Tiger Groupers, Cubera, Mutton, Schoolmaster and Dog Snappers also feed from the small zooplanktivorous fishes that remain close to the reef benthos. A large variety of small invertebrate feeders were present, including wrasses, hamlets, gobies, squirrelfishes, and others. Larger invertebrate and small fish predators included the Hogfish, Schoolmaster and Mahogani snappers, Coney, Graysby and Red Hind groupers, lizardfishes and grunts. Parrotfishes, doctorfishes, and damselfishes comprised the main herbivorous assemblage.

Table 48. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Derrumbadero Reef, Ponce. March 2010

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

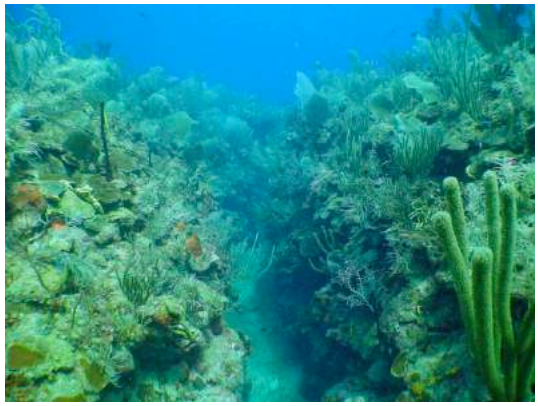
SPECIES	**COMMON NAME**	# - (cm)		
Balistes vetula	Queen Triggerfish	1 – (35)		
Epinephelus guttatus	Red Hind	2 – (30)	1 – (35)	
Lachnolaimus maximus	Hogfish	2 – (30)		
Lutjanus apodus	Schoolmaster	2 - (20)	4 – (30)	1 – (50)
Lutjanus mahogany	Mahogani Snapper	2 - (25)		
Lutjanus synagris	Lane Snapper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

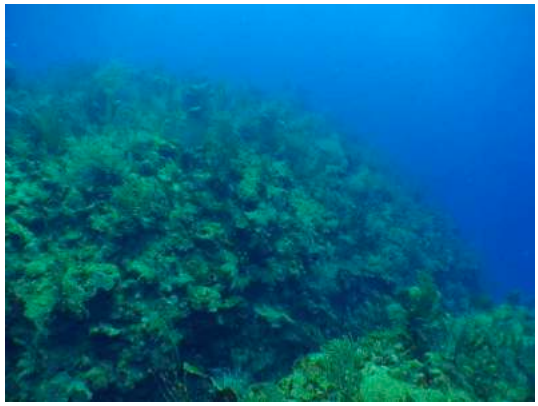
Arrow Crabs and a Coral Crab and represented megabenthic invertebrates within belt transects during the 2010 survey (Table 49). The Cleaner Shrimp, *Periclimenes pedersoni* and one juvenile spiny lobster were observed outside transects.

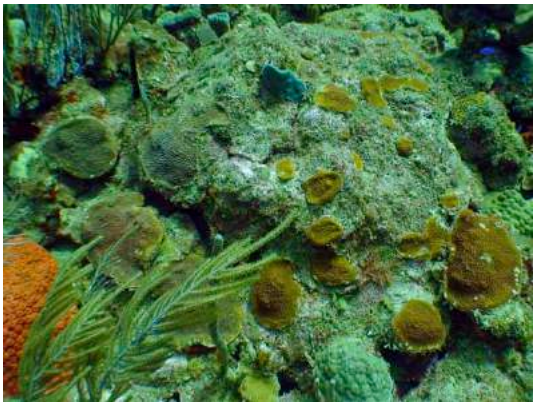
Table 49. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Derrumbadero Reef, 20 m, Ponce, March, 2010

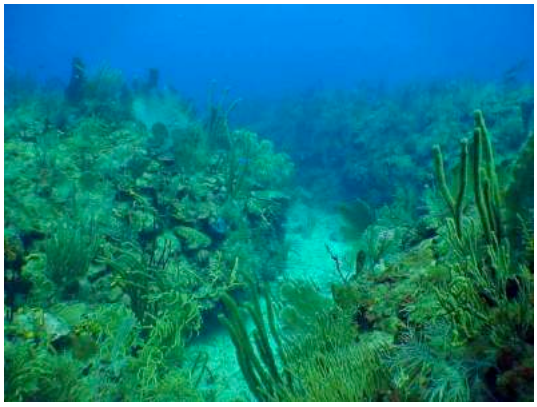
Depth: 20 m		**TRANSECTS**					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	DEPTH (m) **COMMON NAME**						
Carpilus coralinus	Batwing Coral Crab				1		**0.2**
Stenorhynchus seticornis	Arrow Crab		2	1			**0.6**
	TOTALS	**0**	**2**	**1**	**1**	**0**	**0.8**

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 of Isla de Mona 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). The quantitative baseline survey of coral reefs at Isla de Mona were performed by García-Sais et al. (2001) in the summer of June 2000. 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 third monitoring survey of the reefs at Playa Mujeres and Carmelitas and the second monitoring survey of the Sardinera Reef, after the baseline survey of 2008. The location of sampling stations is shown in Figure 45.

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

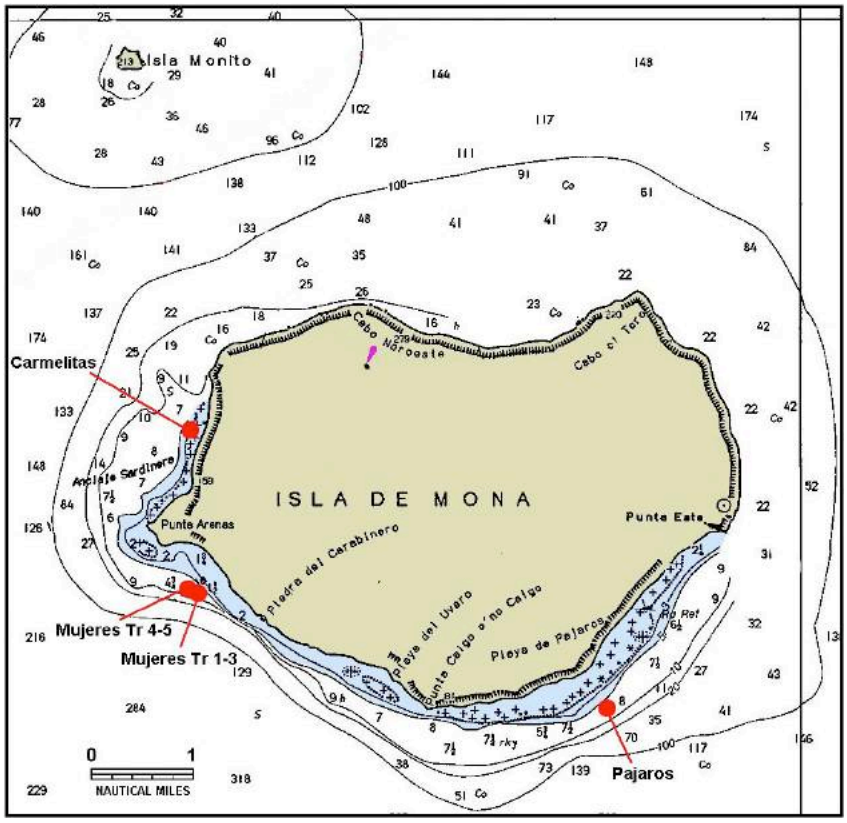


Figure 45. Location of reef sites surveyed at Isla de Mona Natural Reserve

two separate (although adjacent) sections of the shelf where coral reef patches were found (Figure 45).

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 two hydrocoral (*Millepora alcicornis, Stylaster roseus*) 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 2010 monitoring survey was

Table 50. Percent substrate cover by sessile-benthic categories at Playa Mujeres Reef, Isla de Mona, 20m. Survey Date: August 2010

Depth:20 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	2.2	3.3	2.6	1.8	1.9	**2.4**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	4.4	3.2	4.6	3.6	7.2	**4.6**
Sand	11.3		6.8	1.7		**4.0**
Rubble					3.2	**0.6**
Gap		0.6				**0.1**
Total Abiotic	15.7	3.8	11.4	5.3	10.4	**9.3**
Benthic Algae						
Fleshy Algae						
Dictyota sp.	2.3		3.0	9.5	2.4	**3.4**
Lobophora variegata	56.2	32.6	40.4	43.1	13.6	**37.2**
Turf-mixed assemblage	9.0	20.4	14.6	19.6	20.6	**16.8**
Coralline algae	2.5	6.1	2.2	0.2	5.7	**3.4**
Calcareous algae		1.3			1.2	**0.5**
Total Benthic Algae	70.1	60.4	60.0	72.3	43.4	**61.2**
Sponges (unident)	1.6	8.3	5.0	13.5	14.9	**8.7**
Xestospongia muta		11.6				**2.3**
Total sponges	1.6	19.9	5.0	13.5	14.9	**11.0**
Cyanobacteria	3.0	4.6	11.2	2.0	13.0	**6.8**
Live Stony Corals						
Colpophyllia natans		3.4			11.5	**3.0**
Porites astreoides	2.2	1.4	2.0	2.4	1.4	**1.9**
Siderastrea siderea	3.1		1.7		3.4	**1.7**
Agaricia agaricites	1.6	1.3	4.3	0.5	0.4	**1.6**
Montastraea annularis	2.6	3.7	0.9			**1.4**
Eusmilia fastigiata				4.0		**0.8**
Diploria labyrinthiformis			2.0		1.2	**0.6**
Porites porites		1.5				**0.3**
Agaricia lamarckiana			1.5			**0.3**
Millepora alcicornis					0.5	**0.1**
Total Stony Corals	9.6	11.2	12.4	6.8	18.4	**11.7**

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*., *Stylaster roseus*

11.7% (range: 6.8 – 18.4 %). Boulder Brain Coral, Mustard Hill Coral, Massive Starlet Coral, Lettuce Coral and Boulder Brain Coral comprised the dominant stony coral assemblage in terms of reef substrate cover with a combined mean of 9.6%, representing 82.8% of the toal cover by stony corals at Playa Mujeres Reef (Table 50). Mustard-Hill Coral (P. astreoides) and Lettuce Coral (A. agaricites) were the only coral species present in the five transects. Branching corals were represented out of transects by Ten-Ray Star Coral (*Madracis decactis*). Fleshy corals (*Mycetophyllia* spp) were observed in vertical sections of the reef, mostly growing encrusted to walls and within holes and gaps formed by growth of other coral colonies.

Benthic algae were the dominant sessile-benthic category in terms of reef substrate cover with a mean of 61.2 % (range: 43.4 – 72.3 %). Fleshy algae, mostly *Lobophora* variegata with minor contribution from *Dyctiota sp.* Were the main component of the benthic algal assemblage with a combined mean of 40.6%, representing 66.3% of the total cover by benthic algae (Table 50). *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. Reddish films of cyanobacteria were observed on all five transects at Playa Mujeres Reef with a mean substrate cover of 6.8% (range: 2.0 – 11.2%). Sponges, represented by several species, particularly *Xestospongia muta* and *Agelas spp*. were also present in all transects with a combined mean of 8.7%. Recently dead soft corals skeletons were observed in and out of transects at this reef. They appear to have been attacked by some kind of disease, massive predation or a combination of both, resulting in very high mortality across the ref system. Total abiotic cover averaged 9.3 % and was mostly contributed by reef overhangs from rocky outcrops and dead skeletons of Boulder Star Coral, *Montastraea annularis* and other stony corals.

Variations of the percent cover by sessile-benthic categories between the baseline survey in 2000 and the 2008 - 2010 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

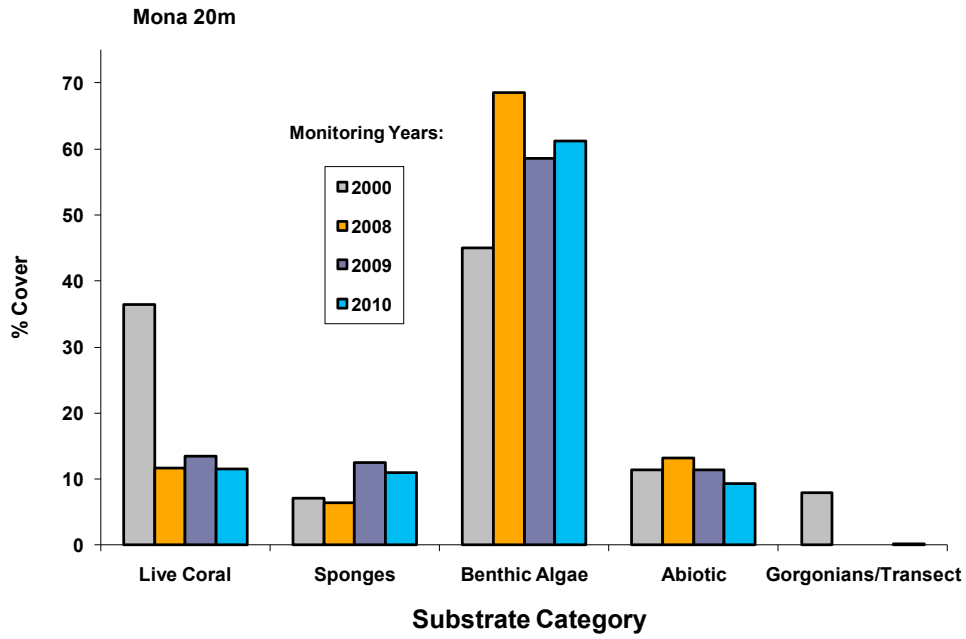


Figure 46. Monitoring trends (2000 - 2010) of mean substrate cover by sessile-benthic categories at Playa Mujeres Reef, Mona Island

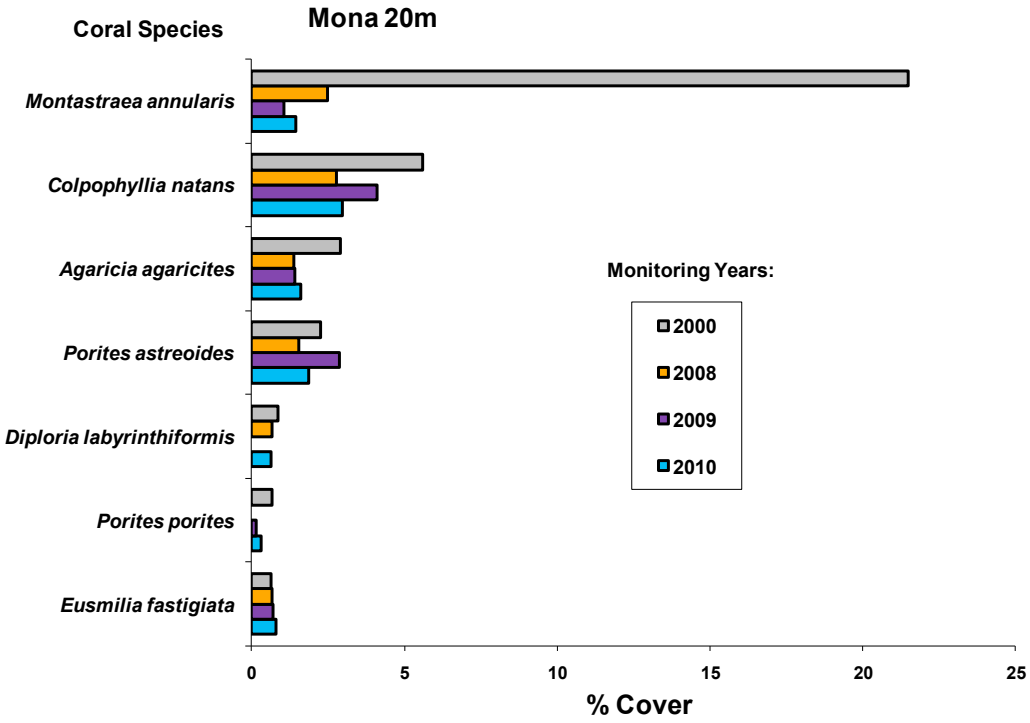


Figure 47. Monitoring trends (2000 - 2010) of mean substrate cover by coral species at Playa Mujeres Reef, Mona Island

the present 2010 survey, substrate cover by live coral did not exhibit any significant change from the previous 2008 and 2009 surveys.

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 %. The declining trend appears to have ended in 2010, with a mean cover of 1.4%, which is essentially constant from the previous 2009 survey.

1.2 Fishes and Motile Megabenthic Invertebrates

A total of 68 fish species were identified at at Playa Mujeres Reef, including 40 within belt-transects during the 2010 survey (Table 51). The mean abundance of individuals per transect was 394.6 Ind/30 m^2 (range: 226 - 712 Ind/30 m^2) and the mean number of species per transect was 23.8 (range: 22 – 26). The numerically dominant species was the Masked Goby, *Coryphopterus personatus* with a mean abundance of 186 Ind/30 m^2, representing 47.1% of the total fish abundance. A total of 18 species were present in at least four out of the five transects and nine wer present in all five transects. Along with the Masked Goby, the main fish assemblage included the Bluehead, Yellowhead and Creole Wrasse, Blue and Brown Chromis, Bicolor Damselfish, Peppermint Goby and Fairy Basslet. 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*).

Table 51. Taxonomic composition and abundance of fishes within belt-transects at Mujeres Reef, 20 m, Isla de Mona. August, 2010

Depth: 20m		Transects					
		1	**2**	**3**	**4**	**5**	
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	10	100	120	250	450	**186.0**
Thalassoma bifasciatum	Bluehead Wrasse	35	50	70	11	55	**44.2**
Stegastes partitus	Bicolor Damselfish	43	44	43	27	33	**38.0**
Chromis cyanea	Blue Chromis	55	30	30	10	25	**30.0**
Coryphopterus lipernes	Peppermint Goby	3	14	20	25	55	**23.4**
Clepticus parrae	Creole Wrasse	39	0	12	15	25	**18.2**
Chromis multilineata	Brown Chromis	15	15	10	5	30	**15.0**
Gramma loreto	Fairy Basslet	6	0	15	6	5	**6.4**
Halichoeres garnoti	Yellowhead Wrasse	2	5	5	3	7	**4.4**
Scarus taeniopterus	Princess Parrotfish	3	1	4	3	3	**2.8**
Halichoeres maculipinna	Clown Wrasse	0	5	1	5	3	**2.8**
Melichthys niger	Black Durgon	0	3	5	0	3	**2.2**
Gobiosoma evelynae	Sharknose Goby	1	4	0	4	1	**2.0**
Caranx ruber	Bar Jack	0	0	1	8	0	**1.8**
Sparisoma aurofrenatum	Redband Parrotfish	1	1	0	3	2	**1.4**
Epinephelus cruentatus	Graysby	2	1	2	1	1	**1.4**
Bodianus rufus	Spanish Hogfish	1	1	2	3	0	**1.4**
Stegastes planifrons	Threespot Damselfish	1	0	0	4	1	**1.2**
Holocentrus rufus	Longspine Squirrelfish	1	2	0	1	2	**1.2**
Chaetodon capistratus	Four-eye Butterflyfish	1	2	0	2	1	**1.2**
Mulloidichthys martinicus	Yellow Goatfish	0	5	0	0	0	**1.0**
Microspathodon chrysurus	Yellowtail Damselfish	1	1	1	2	0	**1.0**
Caranx latus	Horse-eye Jack	0	5	0	0	0	**1.0**
Acanthurus coeruleus	Blue Tang	0	0	1	0	3	**0.8**
Myripristis jacobus	Blackbar Soldierfish	2	1	0	0	0	**0.6**
Holocentrus marianus	Longjaw Squirrelfish	0	1	0	0	2	**0.6**
Sparisoma atomarium	Greenblotch Parrotfish	0	1	0	0	1	**0.4**
Lutjanus apodus	Schoolmaster Snapper	0	0	0	2	0	**0.4**
Lactophrys polygonia	Honeycomb Cowfish	1	1	0	0	0	**0.4**
Kyphosus sectatrix	Bermuda Chub	0	1	0	0	1	**0.4**
Hypoplectrus unicolor	Butter Hamlet	0	0	1	1	0	**0.4**
Holacanthus tricolor	Rock Beauty	1	0	1	0	0	**0.4**
Epinephelus fulva	Coney	0	0	1	0	1	**0.4**
Canthidermis sufflamen	Ocean Triggerfish	1	0	1	0	0	**0.4**
Balistes vetula	Queen Triggerfish	0	1	0	0	1	**0.4**
Sparisoma viride	Stoplight Parrotfish	0	0	0	1	0	**0.2**
Malacoctenus triangulatus	Saddled Blenny	0	0	1	0	0	**0.2**
Haemulon flavolineatum	French Grunt	1	0	0	0	0	**0.2**
Chaetodon striatus	Banded Butterflyfish	0	0	0	0	1	**0.2**
Aulostomus maculatus	Trumpetfish	0	1	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**226**	**296**	**347**	**392**	**712**	**394.6**
	TOTAL SPECIES	**23**	**26**	**22**	**23**	**25**	**23.8**

The zooplanktivorous fish assemblage was prominent at Playa Mujeres Reef. Masked Goby, Blue and Brown Chromis, 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 : 2.8 Ind/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*), Permit (*Trachinotus falcatus*) 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 the Dog and Cubera Snappers (*Lutjanus jocu, L. cyanopterus*) (Table 52).

Monitoring data on fish abundance and species richness within belt-transects is shown in Figure 48. Differences between surveys were statistically significant (ANOVA; $p < 0.05$). The main pattern was a marked increment of abundance driven by peak abundance of Masked Goby during 2010.

Arrow Crabs (*Stenorhynchus seticornis*) were the only motile megabenthic invertebrate observed within belt-transects at Playa Mujeres Reef during the 2010 survey (Table 53). One large Spiny Lobster (*Panulirus argus*), Banded Coral Shrimps (*Stenopus hispidus*), Channel Clinging Crab, *Mithrax spinosissimus* and several adult Queen Conch (*Strombus gigas*) were observed out of transects.

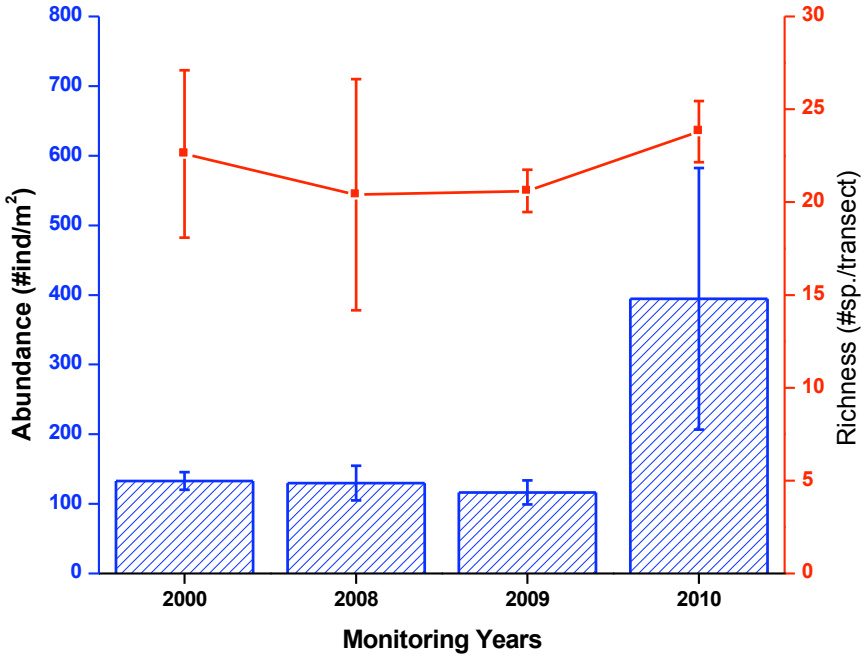


Figure 48. Monitoring trends (1999 – 2010) of fish species richness and abundance at Playa Mujeres Reef, Mona Island

Table 52. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Playa Mujeres Reef, Mona. August 2010

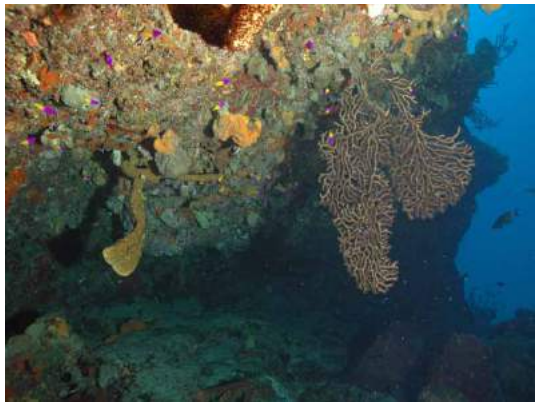
Duration - 30 min. Depth range : 18 - 22 m

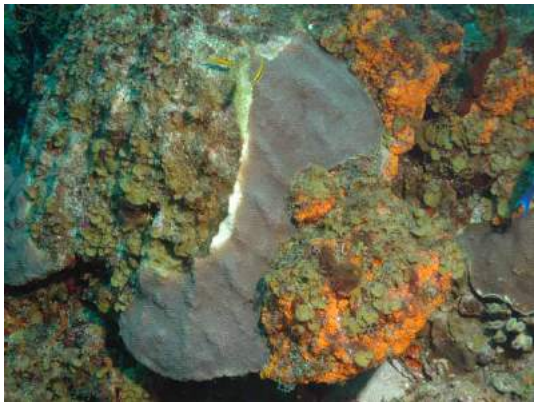
SPECIES	**COMMON NAME**	# - (cm)		
Balistes vetula	Queen Triggerfish	1 – (35)		
Carcharhinus perezi	Reef Shark	1 – (90)		
Dasyatis americana	Souther Stingray	1 – (90)		
Elagatis bipinnulata	Rainbow Runner	4 – (50-60)		
Epinephelus guttatus	Red Hind	2 – (30)	2 - (35)	1 – (40)
Ginglymostoma cirratum	Nurse Shark	1 – (90)		
Lutjanus apodus	Schoolmaster	6 - (20)	7 – (30)	3– (40)
Lutjanus jocu	Mahogani Snapper	2 - (40)	1 – (50)	
Ocyurus chrysurus	Yellowtail Snapper	2– (25)	4 - (30)	
Mycteroperca tigris	Tiger Grouper	1 – (50)		
Mycteroperca venenosa	Yellowfin Grouper	1 – (50)		
Sphyraena barracuda	Great Barracuda	2 - (60)		
Trachinotus falcatus	Permit	3 – (40)		
Invertebrates				
Strombus gigas	Queen Conch	2 – (25)		
Panulirus argus	Spiny Lobster	1 - (35)		

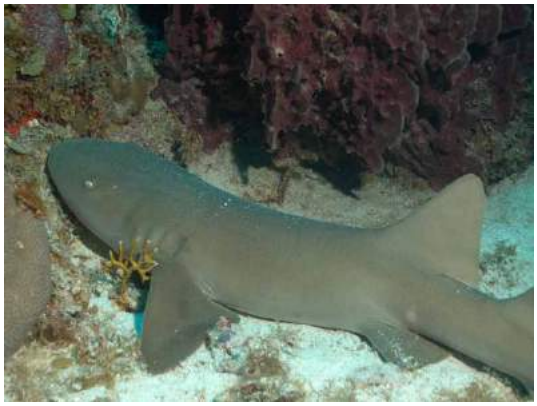
Table 53. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at at Playa Mujeres Reef, Mona. August 2010

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

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 m. From the shoreline, a white sand shallow backreef lagoon with isolated scattered coral heads is protected from wave action by a fringe of emergent rocks, or reef crest. Many dead colonies of Elkhorn Coral (*Acropora palmata*) are found along the margin of the backreef lagoon close to the reef crest. Bundles of fleshy algae, sea urchins (*Echinometra* sp.) and encrusting biota cover most of the rock substrate, but stony coral growth at the reef crest is minimal. Seaward from the reef crest, a series of rock outcrops 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 reddish cyanobacterial film, combined with turf and fleshy macroalgae covering a rugged rocky outcrop seascape was the most prominent benthic feature of Las Carmelitas Reef. Total substrate cover by cyanobacteria averaged 39.9 % (range: 15.4 – 65.2%), representing the highest cover by cyanobacteria ever measured for reefs in the Puerto Rico monitoring program (Table 54). Cyanobacteria was found in all five transects. It covered all surface types except most living corals and sponges. It was observed growing interspersed with the algal turf, over hard substrates and consolidated sand patches. Some corals were partially covered by cyanobacteria as well. The Y-twig

Table 54. Percent substrate cover by sessile-benthic categories at Las Carmelitas Reef, Mona Island, 10m. Survey Date: August 2010

Depth: 8 - 10 m	Transects					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	4.6	4.9	4.1	3.8	2.3	**4.0**
SUBSTRATE CATEGORY						
Abiotic						
Reef Overhangs	5.3	7.6	1.2	5.1	4.0	**4.6**
Sand			4.8	8.7		**2.7**
Gap		2.2				**0.4**
Total Abiotic	5.3	9.7	6.0	13.8	4.0	**7.8**
Benthic Algae						
Turf-mixed assemblage	36.9	26.7	26.4	17.4	22.8	**26.0**
Fleshy Algae	2.7	11.3		3.5	3.0	**4.1**
Coralline algae	2.2	0.6	1.7			**0.9**
Calcareous algae	2.7			0.4		**0.6**
Total Benthic Algae	44.4	38.6	28.1	21.3	25.8	**31.6**
Cyanobacteria	15.4	29.4	38.4	51.2	65.2	**39.9**
Sponges	2.5	0.9	19.5	0.8		**4.8**
Anthosigmella varians	26.5					**5.3**
Total sponges	29.1	0.9	19.5	0.8	0.0	**10.1**
Erythropodium caribaeorum	0.9			0.5		**0.3**
Live Stony Corals						
Porites astreoides	2.9	1.6	1.8	8.1	2.3	**3.3**
Montastraea annularis		11.3	2.7			**2.8**
Agaricia agaricites	2.1	0.7	1.6	1.2		**1.1**
Diploria strigosa		0.9		0.8	2.8	**0.9**
Montastraea cavernosa		1.4		1.2		**0.5**
Colpophyllia natans			2.1			**0.4**
Siderastrea siderea				1.0		**0.2**
Total Stony Corals	5.0	15.8	8.2	12.4	5.0	**9.3**
Gorgonians (#col./transect)	n/d	n/d	n/d	n/d	n/d	**n/d**

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

Alga, *Dictyota sp.* and the Encrusting Fan Alga, *Lobophora variegata* were the main components of the fleshy algal assemblage with a mean cover of 4.1 %. Coralline and calcareous algae (*Halimeda spp.*) were observed to be minor components of the benthic algal assemblage (< 2.0%).

Live coral cover averaged 9.3 % (range: 5.0 – 15.8 %). 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 action is probably an important factor regulating coral growth. Reef overhangs, largely associated with rock outcrops and massive coral growth averaged 4.6 % and contributed to an average substrate rugosity of 4.0 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 10.1 %. The Giant Barrel Sponge, *Xetospongia muta* and was prominent in the reef and contributed substantially to the overall substrate rugosity. The Variegated Sponge, *Anthosigmella varians* was also common in transects.

A total of 15 species of scleractinian corals and one hydrocoral (*Millepora* sp) were identified from Las Carmelitas Reef, including seven intercepted by transects during 2010 (Table 54). Mustard Hill Coral (*Porites astreoides*), Great Star Coral (*Montastraea annularis*) and and Lettuce Coral, *Agaricia agaricites* were the most prominent coral species in terms of linear cover with means of 3.3 % and 2.8 % and 1.1%, respectively, Mustard-Hill Coral was the only coral species intersepted by all five transects. *M. annularis* was only intercepted by two transects during the present 2010 survey. Other coral species were present with mean cover below 1%.

Monitoring trends of substrate categories at Playa Carmelitas Reef are shown in Figure 49. Between the 2000 baseline survey 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 %

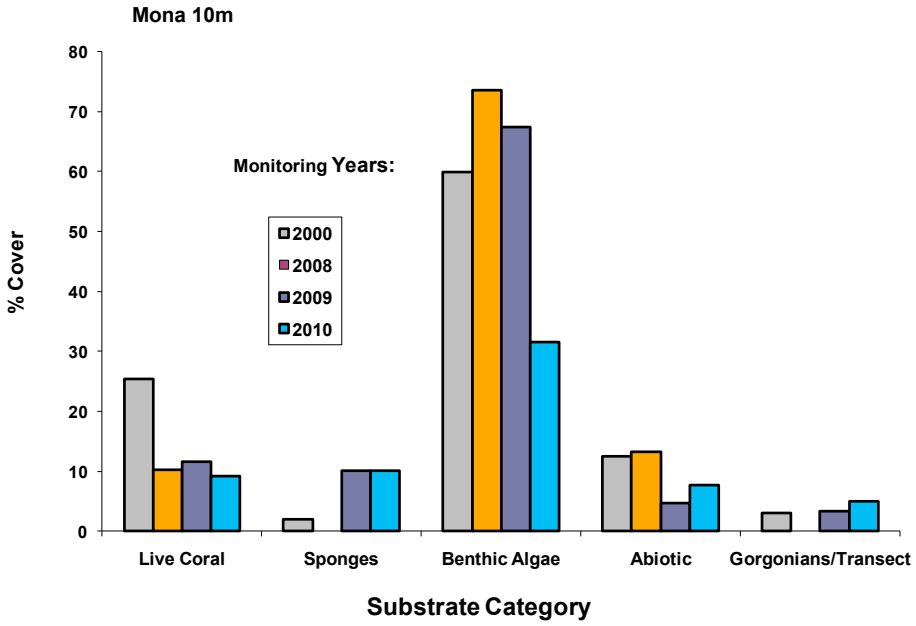


Figure 49. Monitoring trends (2000 - 2010) of mean substrate cover by sessile-benthic categories at Playa Carmelitas Reef, Mona Island

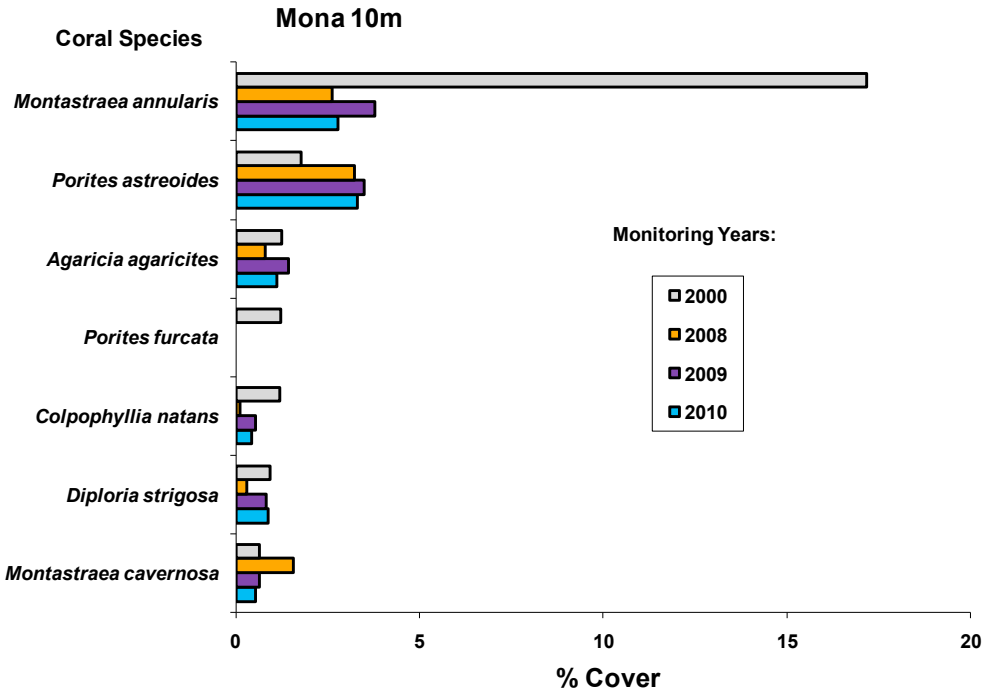


Figure 50. Monitoring trends (2000 - 2010) of mean substrate cover by coral species at Playa Carmelitas Reef, Mona Island

over the eight-year period. During the 2009 – 2010 period, substrate cover by *M. annularis* has remained below 4.0 %.

2.2 Fishes and Motile Megabenthic Invertebrates

A total of 61 fish species were identified during our visual surveys at Las Carmelitas Reef, 38 of which were present within belt-transect areas (Table 55). The mean number of species per transect was 21.2 (range 19 – 24), and the mean abundance was 181.2 Individuals/30 m^2 (range: 115 - 252 Individuals/30 m^2). Seven species represented approximately 83.4 % of the total individuals within belt-transect areas. The numerically dominant species included the Masked Goby, Fairy Basslet, Bluehead Wrasse and Clown Wrasses, Blue and Brown Chromis and the Bicolor Damselfish (*Stegastes partitus*). All of the aforementioned species were found in at least four transects and along with the Princess, Yellowtail, Redband and Stoplight Parrotfishes, Creole Wrasse, Beaugregory and Blue Tang comprised 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. Masked gobies were present in swarms of up to 50 individuals below coral ledges.

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. Masked Goby, 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

Table 55. Taxonomic composition and abundance of fishes within belt-transects at Carmelitas Reef, Isla de Mona, 10 m. Survey Date: August 2010

Depth: 8 -10m		Transects					
		1	2	3	4	5	
SPECIES	**COMMON NAME**						**MEAN**
Coryphopterus personatus	Masked Goby	50	100	75	30	0	**51.0**
Gramma loreto	Fairy Basslet	14	42	50	65	17	**37.6**
Thalassoma bifasciatum	Bluehead Wrasse	50	24	13	15	16	**23.6**
Chromis cyanea	Blue Chromis	5	30	15	6	12	**13.6**
Halichoeres maculipinna	Clown Wrasse	5	5	10	0	45	**13.0**
Chromis multilineata	Brown Chromis	5	10	15	2	0	**6.4**
Stagastes partitus	Bicolor Damselfish	8	4	5	5	8	**6.0**
Scarus taeniopterus	Princess Parrotfish	3	3	5	7	1	**3.8**
Halichoeres garnoti	Yellowhead Wrasse	4	1	5	6	1	**3.4**
Acanthurus coeruleus	Blue Tang	2	5	6	1	1	**3.0**
Clepticus parrae	Creole Wrasse	0	10	0	0	0	**2.0**
Stegastes leucostictus	Beaugregory	4	2	0	2	2	**2.0**
Kyphosus sectatrix	Bermuda Chub	0	0	1	8	0	**1.8**
Melichthys niger	Black Durgon	4	2	1	0	1	**1.6**
Microspathodon chrysurus	Yellowtail Damselfish	3	1	2	1	0	**1.4**
Sparisoma aurofrenatum	Redband Parrotfish	1	1	0	4	1	**1.4**
Cephalopholis fulva	Coney	1	0	0	0	4	**1.0**
Sparisoma viride	Stoplight Parrotfish	0	3	0	1	0	**0.8**
Stegastes adustus	Dusky Damselfish	3	0	1	0	0	**0.8**
Malacoctenus triangulatus	Saddled Blenny	0	0	1	2	1	**0.8**
Halichoeres radiatus	Puddingwife	0	0	1	1	2	**0.8**
Gobiosoma evelynae	Sharknose Goby	0	3	0	0	0	**0.6**
Haemulon flavolineatum	French Grunt	0	1	2	0	0	**0.6**
Acanthurus bahianus	Ocean Surgeon	1	0	0	1	1	**0.6**
Abudefduf sexatilis	Sergeant Mayor	0	0	1	1	1	**0.6**
Holacanthus tricolor	Rock Beauty	1	2	0	0	0	**0.6**
Holocentrus rufus	Longspine Squirrelfish	0	1	0	1	0	**0.4**
Epinephelus cruentatus	Graysby	0	0	1	1	0	**0.4**
Canthigaster rostrata	Sharpnose Puffer	1	1	0	0	0	**0.4**
Myripristis jacobus	Blackbar Soldierfish	0	1	1	0	0	**0.4**
Bodianus rufus	Spanish Hogfish	1	0	0	0	1	**0.4**
Caranx ruber	Bar Jack	0	0	1	0	0	**0.2**
Holocentrus marianus	Longjaw Squirrelfish	0	0	1	0	0	**0.2**
Coryphopterus lipernes	Peppermint goby	1	0	0	0	0	**0.2**
Anisotremus virginicus	Spotted Goatfish	0	0	0	0	1	**0.2**
Sparisoma rubripinne	Yellowtail Parrotfish	0	0	0	0	1	**0.2**
Aulostomus maculatus	Trumpetfish	0	1	0	0	0	**0.2**
	TOTAL INDIVIDUALS	**166**	**252**	**213**	**160**	**115**	**181.2**
	TOTAL SPECIES	**21**	**24**	**22**	**20**	**19**	**21.2**

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. Statistically significant differences between surveys (ANOVA; $p < 0.05$) were largely associated with the abundance fluctuations of the Masked Goby, *C. personatus*, which is a small schooling species with highly aggregated distributions. The natural seasonal and/or interannual variability of this fish population in Puertorrican reefs has not been studied and deserves special attention because of its abundance and food quality for demersal piscivores.

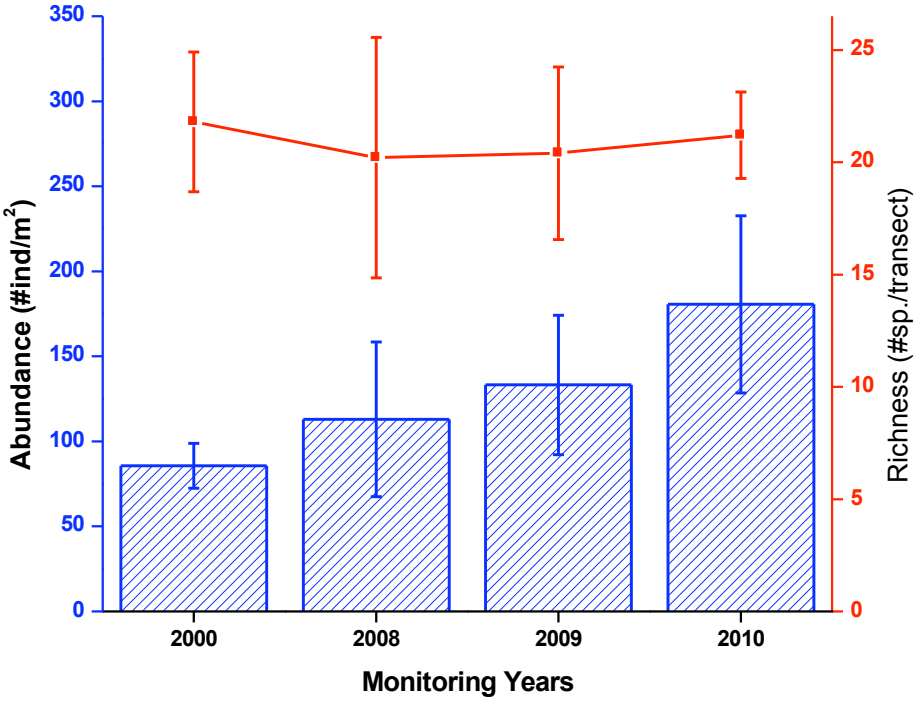


Figure 51. Monitoring trends (2000 – 2010) of fish species richness and abundance at Playa Las Carmelitas Reef, Mona Island.

Table 56. Size-frequency distribution of large and/or commercially important reef fishes identified during an ASEC survey at Playa Carmelitas Reef, Mona, 10 m. August, 2010

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

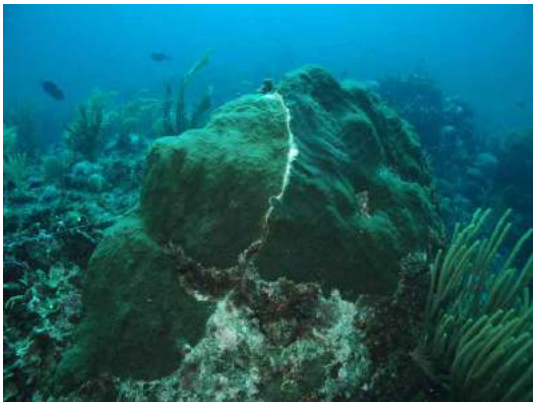
SPECIES	**COMMON NAME**		# - (cm)
Elagatis bipinnulata	Rainbow Runner	1 – (40)	
Epinephelus guttatus	Red Hind	1 – (20)	1 – (30)
Lutjanus apodus	Schoolmaster	2 - (20)	3 – (30)
Lutjanus jocu	Dog Snapper	1 - (30)	
Ocyurus chrysurus	Yellowtail Snapper	3 – (15)	3– (30)
Mycteroperca tigris	Tiger Grouper	1 – (30)	
Mycteroperca venenosa	Yellowfin Grouper	1 – (40)	
Sphyraena barracuda	Great Barracuda	1 - (60)	

Motile megabenthic invertebrates were represented within belt-transects by one juvenile Queen Conch, sea urchins, cleaner shrimps and arrow crabs (Table 57). Batwing Coral Crabs, *Carpilius coralinus* and Flamingo Tongue, *Cyphoma gibbosum* were reported in previous surveys.

Table 57. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at at Playa Carmelitas Reef, Mona, August, 2010

Depth: 10 m		**TRANSECTS**					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	DEPTH (m) **COMMON NAME**						
Ecinometra lucunter	Rock-boring Urchin	1					**0.2**
Trineustes ventricosus	West Indian Sea Egg	2					**o.4**
Periclimenes pedersoni	Cleaner Shrimp			1			**0.2**
Strombus gigas	Queen Conch		1				**0.2**
	TOTALS	**1**	**1**	**0**	**0**	**0**	**1.0**

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 a slope of about 45-50 degrees. The benthic habitat of the insular slope is a colonized pavement 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* and cyanobacteria. 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 2010 (Table 58). Stony corals occurred as isolated massive, encrusting and mound shaped colonies. Substrate cover by stony corals along transects averaged 4.8 % (range: 0.6 – 10.5 %). Boulder Star Coral, *Montastraea annularis* (complex) was the dominant species in terms of substrate cover with a mean of 1.7 % (range: 0 – 6.1 %), representing 37.0 % of the total cover by stony corals. *M. annularis* and Mustard-Hill Coral, *Porites astreoides* were the only coral species present in at least three transects. Stony corals were present mostly as isolated, mound shaped colonies, but some coral build-ups were observed. Coral – sponge associations, forming bioherms were also common and contributed substantially to the topographic relief and reef habitat complexity. 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 by benthic algae of 44.5 % (Table 58). Reddish cyanobacterial films were ubiquitous over the reef benthos with a mean substrate cover in transects of 25.8% (range: 7.6 – 32.9%). Cyanobacteria, in most instances occurring intermixed with fleshy and turf

Table 58. Percent substrate cover by sessile-benthic categories at Sardinera Reef, 30m, Mona Island. Survey Date: August 2010

Depth: 30 m	Transects					
	1	2	3	4	5	**MEAN**
Rugosity (m)	0.9	2.7	3.1	3.2	3.0	**2.6**
SUBSTRATE CATEGORY						
Abiotic						
Sand	5.8	10.4	2.6	17.6	2.4	**7.8**
Reef Overhangs	1.9	6.0	6.1	6.5	13.0	**6.7**
Rubble					6.2	**1.2**
Total Abiotic	7.7	16.4	8.7	24.1	21.6	**15.7**
Benthic Algae						
Turf-mixed assemblage	38.6	28.6	34.3	10.0	19.9	**26.3**
Calcareous algae				2.6		**0.5**
Coralline algae					0.5	**0.1**
Fleshy Algae						
Dictyota sp.			3.8	1.3		**1.0**
Lobophora variegata	11.7	6.2	15.3	17.6	32.0	**16.6**
Total Benthic Algae	50.4	34.8	53.4	31.5	52.4	**44.5**
Cyanobacteria	30.1	30.3	28.3	32.9	7.6	**25.8**
Sponges	7.8	10.3	6.4	2.4	8.0	**7.0**
Xestospongia muta		2.4		8.6		**2.2**
Total sponges	7.8	12.8	6.4	10.9	8.0	**9.2**
Live Stony Corals						
Montastraea annularis		2.0	0.4		6.1	**1.7**
Porites astreoides	0.9	0.9	1.8			**0.7**
Agaricia lamarcki		1.8			1.8	**0.7**
Montastraea cavernosa	2.5	0.8				**0.7**
unident. coral					1.4	**0.3**
Siderastrea siderea			1.0			**0.2**
Stephanocoenia intersepta					0.9	**0.2**
Millepora alcicornis	0.6	0.2				**0.2**
Agaricia agaricites				0.6		**0.1**
Madracis decactis					0.3	**0.1**
Total Stony Corals	4.0	5.7	3.2	0.6	10.5	**4.8**
Gorgonians (# col./transect)	n/d	n/d	n/d	n/d	n/d	**n/d**

Coral Species Outside Transects

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

macroalgae was found covering uncolonized hard ground and unconsolidated sandy substrates, sometimes forming large reddish-green patches in the reef. With a mean cover of 7.0 %, 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 the mesophotic reef off Playa Sardinera are shown in Figure 52. The most prominent feature involves the displacement of benthic macroalgae by cyanobacteria, which increased more than three-fold, from 6.7% in 2009 to 25.8% in 2010. Differences of cover by benthic algae and cyanobacteria between monitoring survey were statistically significant (ANOVA, p=). Variations of coral cover were small and within sampling variability error. Figure 53 displays the variations of substrate cover by coral species between monitoring years at this reef. Differences were small and within the high sampling variability margin imposed by low sample size at this reef station. Reef substrate cover by Boulder Star Coral, *Montastraea annularis* presented a declining trend, which is in contrast to the increasing pattern exhibited by most other reefs from the mainland.

3.2. Fishes and Motile Megabenthic Invertebrates

A total of 60 fish species were identified during our visual surveys at Playa Sardinera Reef, 39 of which were observed within belt-transects in 2010 (Table 59). The mean number of species per transect was 18.8 (range 17 – 23), and the mean abundance of fishes was 299.8 Individuals/30 m^2 (range: 86 - 411 Individuals/30 m^2). The Masked Goby (*Coryphopterus personatus*) was the numerically dominant species with a mean abundance of 162 , representing 54.0% of the total fish individuals within transects. A total of 12 species were present in at least four transects, these included the Masked and Sharknose Gobies, Blue Chromis, Bicolor Damselfish, Fairy Basslet, Bluehead and Clown Wrasse, Peppermint Goby, Yellowhead Wrasse, Redband Parrotfishand the Graysbe. Along with the Creole Wrasse, the aforementioned species comprised the main resident fish assemblage at Playa Sardinera Reef.

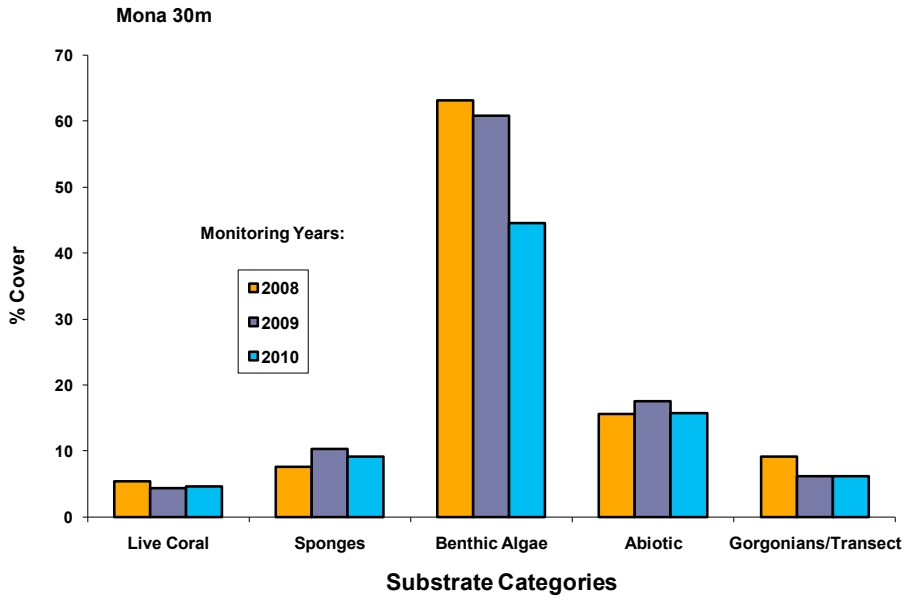


Figure 52. Monitoring trends (2000 - 2010) of mean substrate cover by sessile-benthic categories off Playa Sardinera Reef, 30 m, Mona Island

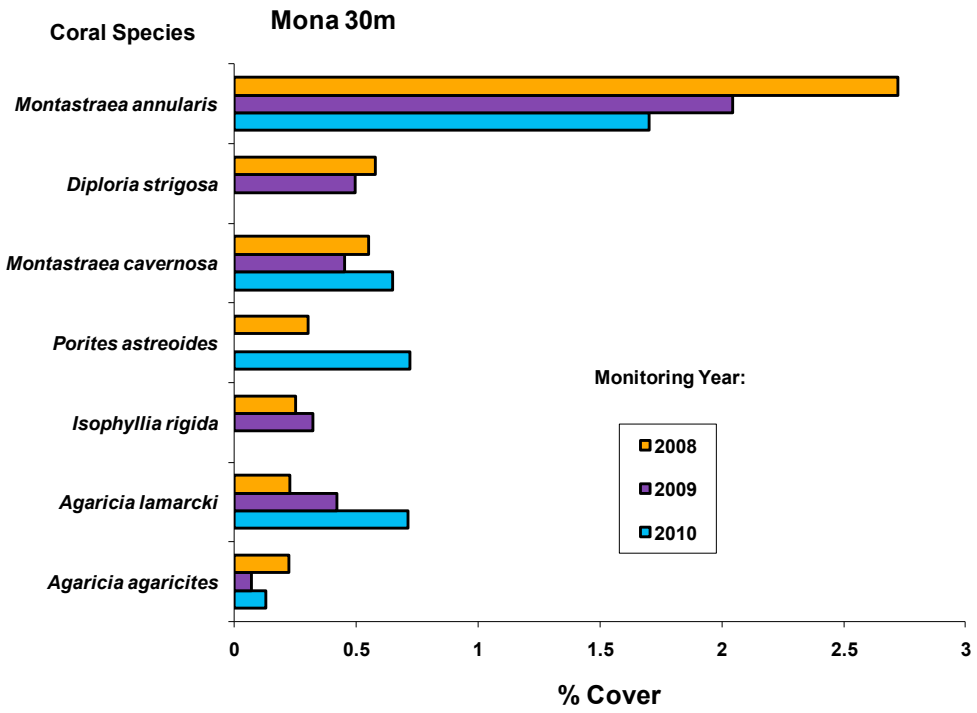


Figure 53. Monitoring trends (2000 - 2010) of mean substrate cover by coral species off Playa Sardinera Reef, 30 m, Mona Island

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 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 30 % of the species present. Masked Goby, Bicolor Damselfish, Creole Wrasse and the Blue and Brown Chromis were the main components of the zooplanktivorous assemblage comprised by more than 10 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 adult Red Hinds (*Epinephelus guttatus*) (Table 60). Lionfishes (*Pterois volitans*) were common at the mesophotic Reef off Sardinera. A total of five adult Lionfishes were observed during our snapshot survey.

Monitoring data on fish abundance and species richness within belt-transects is shown in Figure 54. Differences between surveys were within sampling variability error (ANOVA; $p > 0.05$).

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, 2010

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)		
Pterois volitans	Lionfish	2 – (15)	2 – (20)	1 – (25)
Sphyraena barracuda	Great Barracuda	2 - (50)		

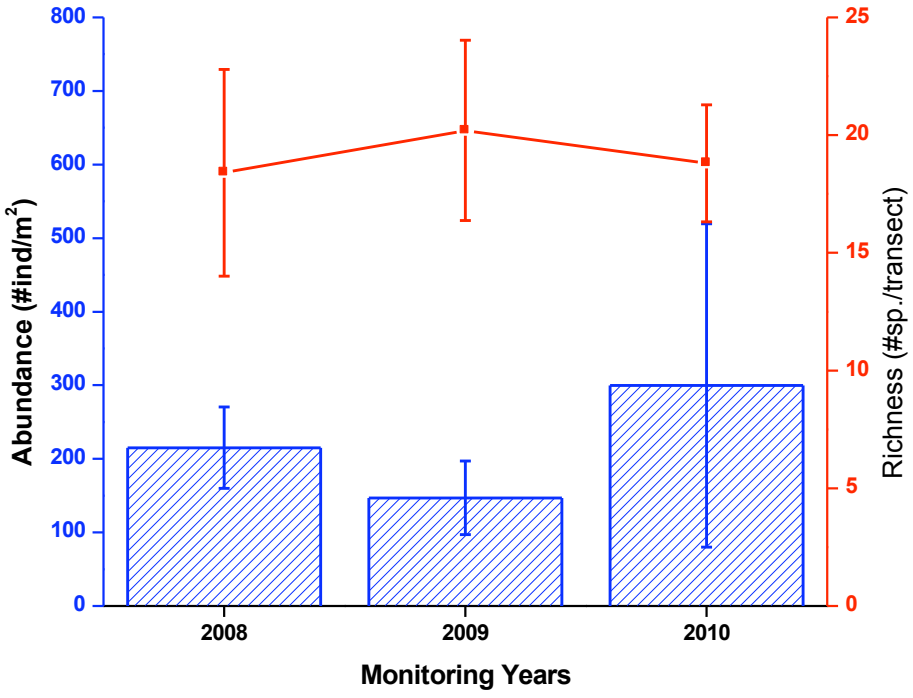


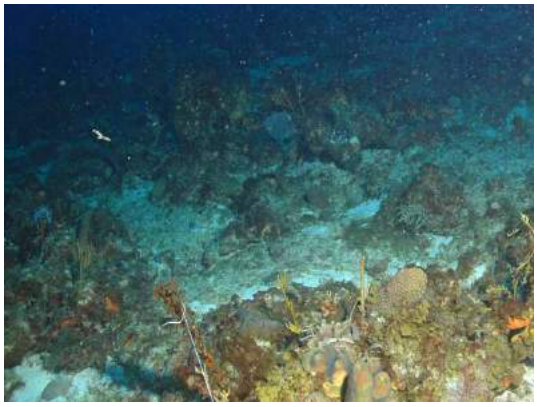
Figure 54. Monitoring trends (2000 – 2010) of fish species richness and abundance at Playa Sardinera Reef, 30 m, Mona Island.

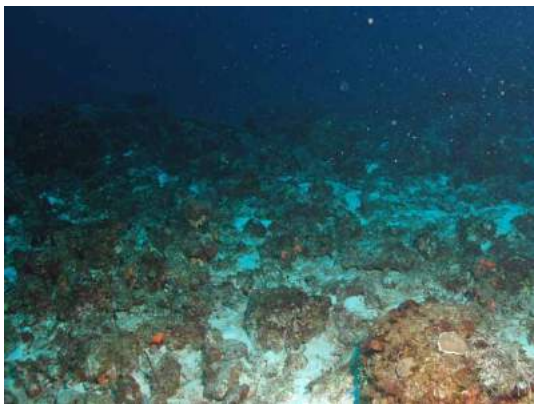
Cleaner shrimps and arrow crabs, represented motile megabenthic invertebrates within belt-transects st Playa Sardinera Reef (Table 61). Two gravid spiny lobsters were present outside transects.

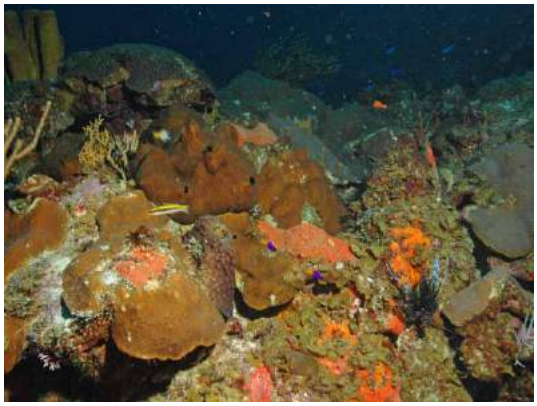
Table 61. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at at Playa Sardinera Reef, 30 m, Mona. August 2010

Depth: 30 m		TRANSECTS					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE (IND/30 m2)**
TAXA	DEPTH (m) **COMMON NAME**						
Stenopus hispidus	Banded Coral Shrimp		2			1	**0.6**
Periclimenes pedersoni	Cleaner Shrimp	2		1			**0.6**
Stenorhynchus seticornis	Arrow Crab				4	1	**1.0**
	TOTALS	**2**	**2**	**1**	**4**	**2**	**2.2**

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 during the monitoring program 2001 - 2010.

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 late 2005. Lingering effects with continued live coral cover losses were measured for the aforementioned reefs until 2008.

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

During the present 2010 monitoring survey live coral cover presented a pattern of mild increments in nine out of the 15 reef stations surveyed. Increments of coral cover were contributed in most instances by *M. annularis* in what appears to be an indication of partial recuperation of 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 2008. Other four reef stations presented the same live coral cover as in 2009.

Two mesophotic reef stations presented a decline of live coral cover, Sardinera Reef 30m (Isla de Mona) and Puerto Canoas Reef 30m (Isla Desecheo). The Sardinera Reef exhibited a marked incerement of substrate cover by cyanobacteria, a condition that was also observed at other reef stations of Isla de Mona (e.g. Playa Mujeres and Las Carmelitas). The decline of coral cover at Puerto Canoas is the continuation of a trend that started in 2006 after the coral bleaching event and that has prevailed until present. A gradual, corresponding increase in sponges has been measured.

The *Acropora palmata* finging reef of Tres Palmas in Rincon is infected by what appears to be white pox, an infectious disease also known as “patchy necrosis”. The infection prevalence in colonies is very high (>80%) and although reef substrate cover by *A. palmata* was stable relative to 2009, given favorable conditions for the disease massive coral mortality can be expected.

Fish populations presented in the 2010 survey a general trend of stabilized abundance and species richness relative to the 2008 levels. Statistically significant differences of abundance were observed 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 differences 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 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, Yellowmouth, Tiger, Jewfish, and Nassau Groupers (*Mycteroperca venenosa, M. interstitialis, M. tigris, Epinephelus itajara, E. striatus*), and the Cubera, Dog and Mutton Snappers (*Lutjanus cyanopterus, L. jocu, L. analis*).

Coral bleaching at the reef community level was not observed on any reef surveyed in the program during the 2007 – 10 monitoring period.

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Appendix 1

Species Name	Common Name	M30	M20	M10	D30	D20	D15	R5	R10	R20	Mo30	Mo20	Mo10	CM	G	Der
Abudefduf sexatilis	Sergeant Major	x	x	x		x		x	x	x			x	x	x	
Abudefduf taurus	Night Sergeant							x	x							
Acanthemblemaria aspera	Roughhead Blenny											x				
Acanthemblemaria chaplini	Papillose Blenny			x												
Acanthemblemaria spinosa	Sinyhead blenny											x				
Acanthostracion plygonia	Scrawled Cowfish										x	x				
Acanthostrascion quadricornis	Honeycomb Cowfish				x	x				x					x	
Acanthurus bahianus	Ocean Surgeon	x	x	x	x	x	x	x	x	x	x		x	x	x	x
Acanthurus chirurgus	Doctorfish	x	x	x	x	x	x	x	x	x		x	x	x	x	x
Acanthurus coeruleus	BlueTang	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Alutherus scriptus	Scrawled Filefish	x		x	x	x			x			x	x	x	x	x
Amblicirrhitos pinnos	Redspotted Hawkfish	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Anchoa sp.	Anchovy							x								
Anisotremus surinamensis	Black Margate				x				x	x		x				
Anisotremus virginicus	Porkfish	x	x	x				x	x	x		x	x	x	x	x
Apogon townsendi	Belted Cardinalfish				x	x			x	x		x				
Aulostomus maculatus	Trumpetfish	x	x	x	x	x	x	x	x	x		x		x	x	x
Balistes vetula	Queen Triggerfish				x	x	x				x	x				x
Bodianus rufus	Spanish Hogfish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Bothus lunatus	Peacock Flounder	x	x							x		x				
Calamus calamus	Saucereye Porgy							x				x			x	x
Calamus pennatula	Pluma				x			x								
Cantherhines macrocerus	Whitespotted Filefish				x	x	x	x		x						x
Cantherhines pullus	Orangespotted Filefish	x	x	x				x	x						x	
Cantherhines surinamensis	Ocean Triggerfish	x	x	x	x	x			x			x			x	x
Canthigaster rostrata	Caribbean Puffer	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Species Name	**Common Name**	**M30**	**M20**	**M10**	**D30**	**D20**	**D15**	**R5**	**R10**	**R20**	**Mo30**	**Mo20**	**Mo10**	**CM**	**G**	**Der**
Caranx bartholomaei	Yellow Jack										x				x	
Caranx crysos	Blue Runner	x	x	x	x	x		x	x	x				x	x	x
Caranx hippos	Horse-eye Jack	x			x			x	x	x		x				
Caranx latus	Crevalle Jack				x											
Caranx lugubris	Black Jack	x	x	x	x	x		x	x		x	x			x	x
Caranx ruber	Bar Jack	x	x	x	x	x	x	x	x	x		x	x	x	x	x
Carcharhinus limbatus	Caribbean Reef Shark				x											
Chaenopsis ocellata	Bluethroat Pikeblenny														x	x
Chaetodipterus faber	Atlantic Spadefish	x														
Chaetodon aculeatus	Longsnout Butterflyfish	x	x	x	x	x			x	x	x				x	x
Chaetodon capistratus	Four-eye Butterflyfish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Chaetodon ocellatus	Spotfin Butterflyfish	x	x	x											x	x
Chaetodon sedentarius	Reef Butterflyfish	x				x				x	x					
Chaetodon striatus	Banded Butterflyfish	x	x	x		x	x		x	x		x	x	x	x	x
Chilomycterus antillarum	Web Burrfish	x	x						x							
Chromis cyanea	Blue Chromis	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Chromis insolata	Sunshine Chromis	x			x					x	x					
Chromis multilineata	Brown Chromis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Clepticus parrae	Creole Wrasse	x	x	x	x	x	x		x	x	x	x	x		x	x
Coryphopterus glaucofraenum	Bridled Goby	x	x	x	x				x		x	x		x	x	x
Coryphopterus lipernes	Peppermint Goby	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Coryphopterus personatus	Masked goby	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Criptoptomus roseus	Bluelip Parrotfish						x									
Ctenogobius saepepallens	Dashed Goby									x						
Dasyatis americana	Southern Stingray				x	x		x								
Decapterus macarelus	Mackerel Scad	x	x		x		x			x					x	
Diodon holacanthus	Balloonfish				x			x	x							

Species Name	Common Name	M30	M20	M10	D30	D20	D15	R5	R10	R20	Mo30	Mo20	Mo10	CM	G	Der
Diodon hystrix	Porcupinefish				x		x									
Echenes naucrates	Sharksucker														x	
Echidna catenata	Chain Moray						x									
Elagatis bipinnulata	Rainbow Runner				x											x
Epinephelus adsensionis	Rock Hind	x	x					x	x			x	x			
Epinephelus cruentatus	Graysby	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Epinephelus fulvus	Coney	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Epinephelus guttatus	Red Hind	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Epinephelus striatus	Nassau Grouper	x	x		x	x										
Equetus acuminatus	Highhat	x	x	x	x	x	x		x	x				x	x	x
Equetus lanceolatus	Jackknife Fish	x	x						x	x						
Equetus punctatus	Spotted Drum													x	x	x
Gerres cinereus	Yellowfin Mojarra	x	x	x				x	x					x	x	
Ginglymostoma cirratum	Nurse Shark	x					x									
Gobiosoma evelynae	Sharknose Goby	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Gobiosoma hoorsti	Yellowline Goby													x		
Gobiosoma saucrum	Leopard Goby	x	x	x	x			x	x			x		x	x	x
Gramma loreto	Fairy Basslet	x	x	x	x	x		x	x	x	x	x	x	x	x	x
Gymnothorax funebris	Green Moray				x											
Gymnothorax miliaris	Goldentail Moray								x	x		x				
Gymnothorax moringa	Spotted Moray	x	x	x		x	x		x	x		x			x	x
Haemulon aurolineatum	Tomtate	x	x	x		x			x					x	x	
Haemulon carbonarium	Caesar's Grunt							x		x			x			
Haemulon chrysargyreum	Smallmouth Grunt	x	x	x				x	x	x				x		
Haemulon flavolineatum	French grunt	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Haemulon macrostomum	Spanish Grunt	x	x	x		x	x	x	x	x			x	x	x	x
Haemulon melanurum	Cottonwick	x	x	x					x	x						
Haemulon plumieri	White Grunt							x	x			x		x	x	
Haemulon sciurus	Bluestriped Grunt	x		x					x					x		

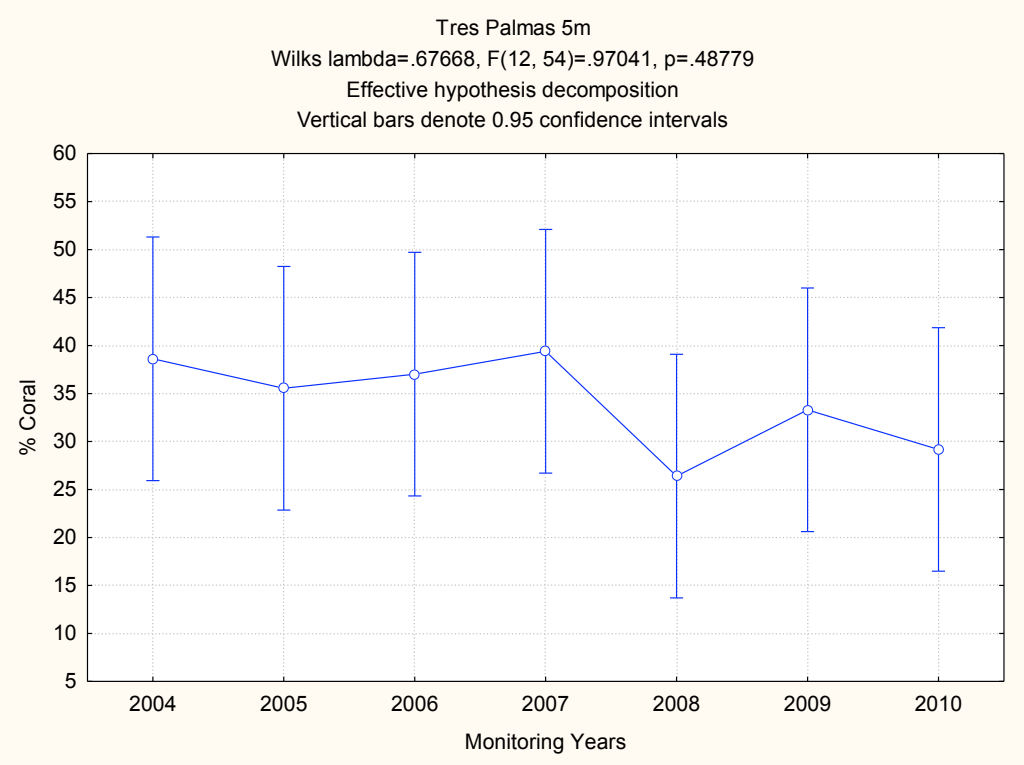
Species Name	Common Name	M30	M20	M10	D30	D20	D15	R5	R10	R20	Mo30	Mo20	Mo10	CM	G	Der
Haemulon sciurus	Bluestriped Grunt	x	x		x		x	x							x	x
Haemulon steindachneri	Latin grunt														x	
Halichoeres bivitatus	Slippery Dick							x	x			x	x			
Halichoeres cyanocephalus	Yellowcheek Wrasse															x
Halichoeres garnoti	Yellow-head Wrasse	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Halichoeres maculipinna	Clown wrasse	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Halichoeres pictus	Painted wrasse							x								
Halichoeres radiatus	Puddinwife	x	x	x		x	x	x	x				x	x	x	x
Hemiramphus ballyhoo	Ballyhoo				x	x	x		x	x						
Holacanthus ciliaris	Queen Angelfish	x	x	x	x	x	x		x	x				x	x	x
Holacanthus tricolor	Rock Beauty	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Holocentrus adscensionis	Longjaw Squirrelfish					x		x	x		x	x	x		x	x
Holocentrus coruscus	Reef Squirrelfish	x	x	x										x	x	x
Holocentrus marianus	Longjaw Squirrelfish										x	x	x			
Holocentrus rufus	Squirrelfish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Holocentrus vexillarius	Dusky Squirrelfish							x								
Hypoplectrus aberrans	Yellowbelly hamlet	x	x	x											x	
Hypoplectrus chlorurus	Yellowtail Hamlet								x	x				x	x	x
Hypoplectrus guttavarius	Shy Hamlet	x	x	x					x					x	x	x
Hypoplectrus indico	Indigo Hamlet	x	x	x										x	x	x
Hypoplectrus nigricans	Black Hamlet	x	x	x	x				x	x				x	x	x
Hypoplectrus puella	Barred Hamlet	x	x	x					x	x				x	x	x
Hypoplectrus unicolor	Butter Hamlet	x	x	x	x				x	x		x		x	x	x
Kyphosus sp.	Bermuda Chub	x	x	x	x	x	x	x	x		x	x	x		x	x
Lachnolaimus maximus	Hogfish	x														x
Lactophrys bicaudalis	Spotted Trunkfish	x	x				x									
Lactophrys polygonia	Honeycomb Cowfish	x	x	x	x	x			x		x	x			x	x
Lactophrys trigonus	Trunkfish				x					x						
Lactophrys triqueter	Smooth Trunkfish	x	x		x	x	x	x	x			x	x		x	x

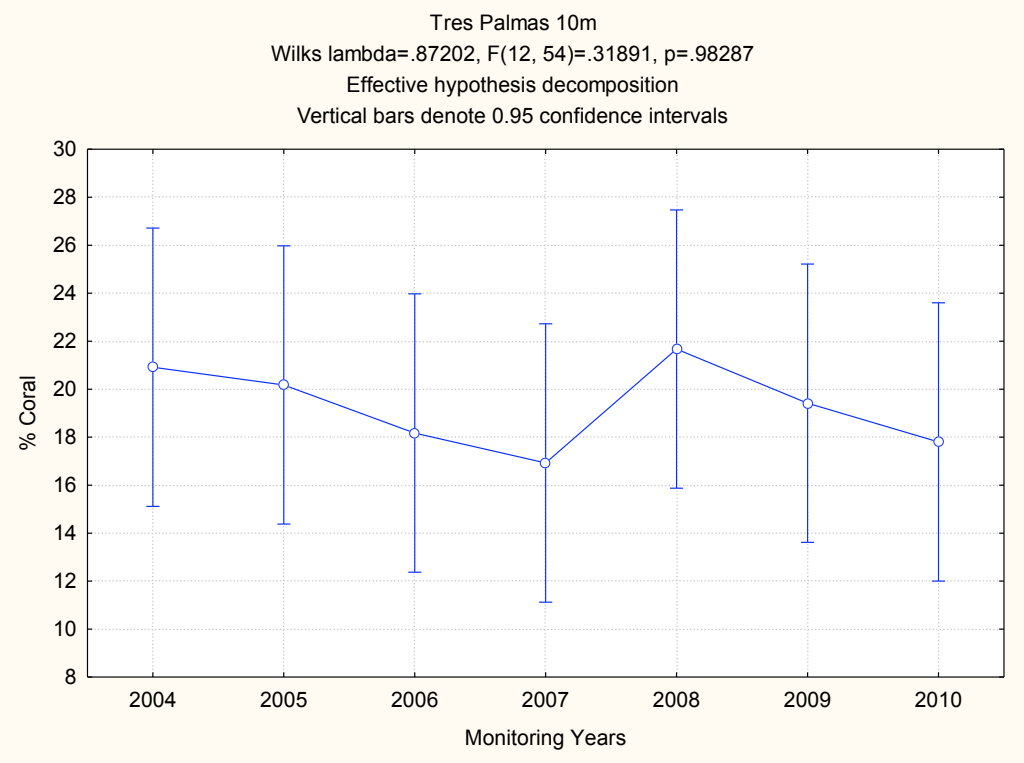
Species Name	**Common Name**	**M30**	**M20**	**M10**	**D30**	**D20**	**D15**	**R5**	**R10**	**R20**	**Mo30**	**Mo20**	**Mo10**	**CM**	**G**	**Der**
Liopropoma carmabi	Candy Basslet	x														
Liopropoma rubre	Swissguard Basslet	x	x	x	x	x			x	x					x	x
Lutjanus analis	Mutton Snapper							x		x						
Lutjanus apodus	Schoolmaster Snapper	x	x	x	x	x	x	x	x	x		x		x	x	x
Lutjanus cyanopterus	Cubera Snapper	x	x													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						
Malacoctenus triangulatus	Saddled Blenny	x	x	x	x	x	x	x	x		x	x	x			
Malacoctenus versicolor	Barfin Blenny								x							
Melichthys niger	Black Durgon	x	x	x	x	x	x	x	x	x	x	x	x		x	x
Microspatodon chrysurus	Yellowtail damselfish	x	x	x	x	x	x	x	x	x		x	x	x	x	x
Mlacoctenus gelli	Dusky blenny							x								
Mulloides martinicus	Yellowtail Goatfish	x	x	x	x	x	x	x	x	x		x		x	x	x
Muraena robusta	Stout Moray						x							x		
Mycteroperca tigris	Tiger Grouper											x				x
Mycteroperca venenosa	Yellowfin Grouper	x			x										x	
Myripristis jacobus	Blackbar Soldierfish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Neoniphon marianus	Longjaw Squirrelfish	x	x	x	x	x	x	x		x	x	x	x	x	x	x
Ocyurus chrysurus	Yellowtail Snapper	x	x	x	x	x	x		x	x		x		x	x	x
Odontoscion dentex	Reef Croaker	x	x	x				x	x					x	x	
Ophioblennius atlanticus	Redlip Blenny	x	x	x		x	x	x	x	x		x		x		
Paranthias fucifer	Creolefish	x	x	x	x	x			x	x	x				x	x
Pempheris schomburgki	Glassy Sweeper	x	x					x					x			
Pomacanthus arcuatus	Gray Angelfish	x	x		x	x	x		x	x				x	x	x
Priacanthus arenatus	Glasseye	x	x	x		x		x	x	x	x			x	x	x
Pseudopeneus maculatus	Spotted Goatfish	x	x	x			x	x	x	x	x	x		x	x	x

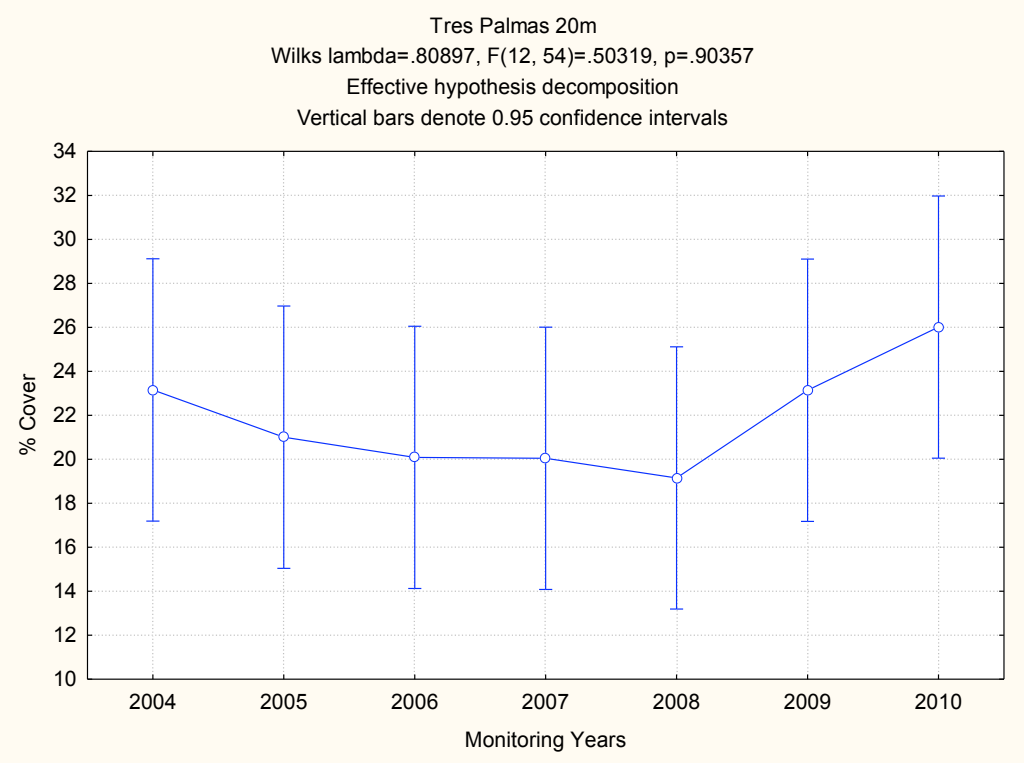
Species Name	Common Name	M30	M20	M10	D30	D20	D15	R5	R10	R20	Mo30	Mo20	Mo10	CM	G	Der
Pterois volitans	Lionfish					x				x	x					
Sanopus greenfieldorum	Whitelined Toadfish								x							
Scarus coelestinus	Midnight Parrotfish							x								
Scarus coeruleus	Blue Parrotfish	x	x	x					x					x	x	
Scarus guacamaia	Rainbow Parrotfish											x				
Scarus iserti	Stripped Parrotfish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Scarus taeniopterus	Princess Parrotfish	x	x	x		x	x	x	x	x	x	x	x	x	x	x
Scarus vetula	Queen Parrotfish	x	x	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
Scorpaena plumieri	Spotted Scorpionfish						x							x		x
Seriola rivoliana	Almaco Jack													x		
Serranus baldwini	Lantern Bass				x											
Serranus chionaraia	Snow Bass								x							
Serranus dewegeri	Vieja										x					
Serranus tabacarius	Tobacco Fish				x			x								
Serranus tegrinus	Harlequin Bass	x	x	x	x	x	x		x	x	x			x	x	x
Sparimoma radians	Bucktootth Parrotfish				x											
Sparisoma atomarium	Greenblotch Parrofish											x				
Sparisoma aurofrenatum	Redband Parrotifish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Sparisoma chrysopterum	Redtail Parrotfish				x	x				x						
Sparisoma radians	Bucktootth Parrotfish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Sparisoma rubripinne	Yellowtail Parrotfish				x	x		x	x				x			
Sparisoma viride	Stoplight Parrotfish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Sphoeroides greeleyi	Green Puffer								x							
Sphoeroides testudineus	Checkered Puffer	x	x	x					x							
Sphyraena barracuda	Greate Barracuda	x	x	x	x	x	x	x	x	x	x					x
Stegastes dorsopunicans	Dusky Damselfish	x		x			x	x				x	x	x	x	
Stegastes leucostictus	Beaugregory	x	x	x	x				x	x			x	x	x	x
Stegastes partitus	Bicolor Damselfish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

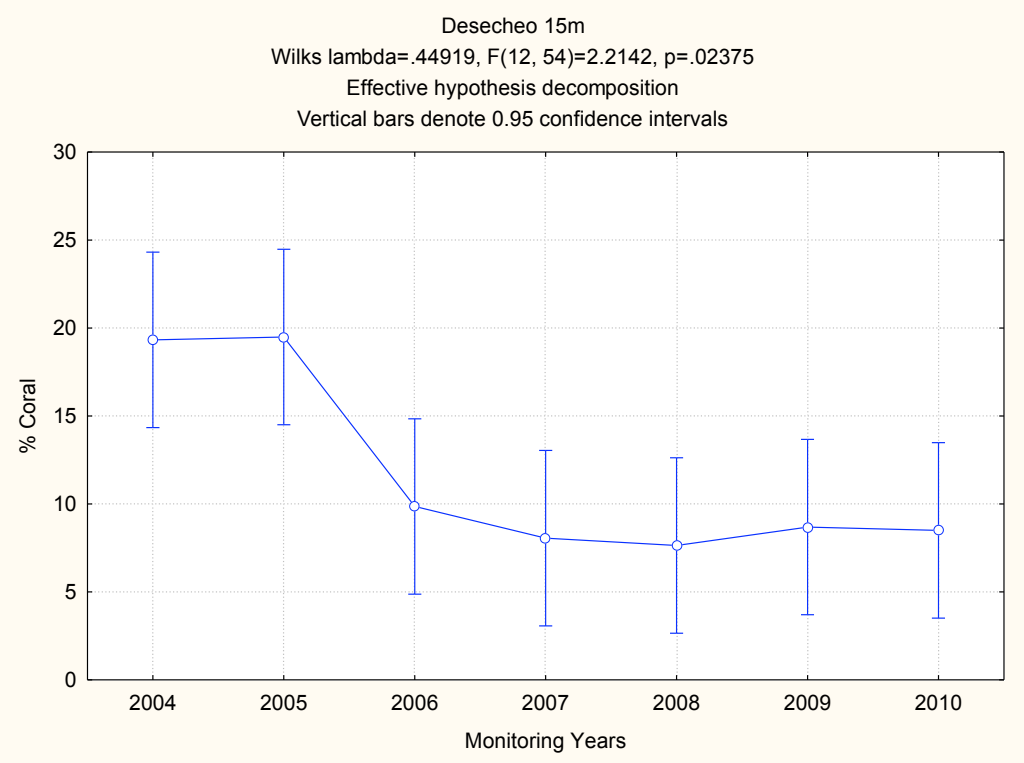
Species Name	**Common Name**	**M30**	**M20**	**M10**	**D30**	**D20**	**D15**	**R5**	**R10**	**R20**	**Mo30**	**Mo20**	**Mo10**	**CM**	**G**	**Der**
Stegastes planifons	Yellow-eye Damselfish	x	x	x	x	x			x	x		x	x	x	x	x
Stegastes variabilis	Cocoa Damselfish	x	x	x			x	x	x					x	x	x
Stephalnolepis setifier	Pygmy Filefish	x		x												
Synodus intermedius	Sand Diver	x	x	x			x	x	x	x				x		x
Thalasoma bifaciatum	Bluehead wrass	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Urolophus jamaicensis	Yellowspotted Stingray										x	x	x			
Xanthichthyis ringens	Sargassum Triggerfish						x									
		112	99	91	89	78	67	74	105	87	52	74	55	79	95	90

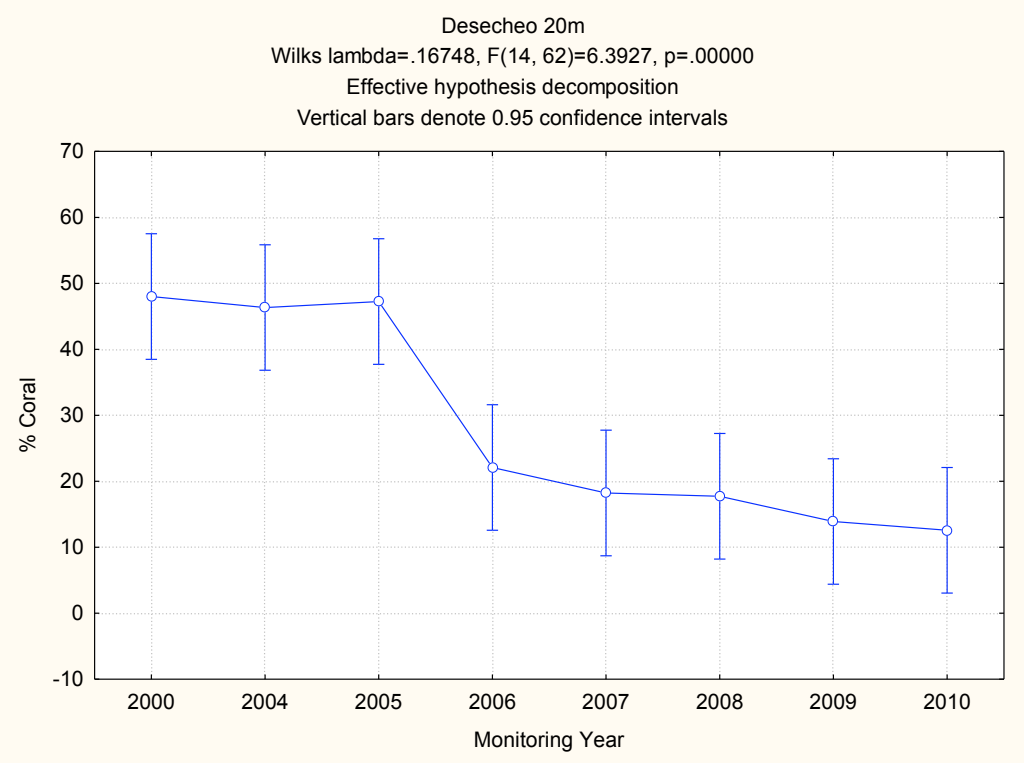
Appendix 2. Analysis of variance (ANOVA) procedure testing differences of live coral cover in annual monitoring surveys through 2009.

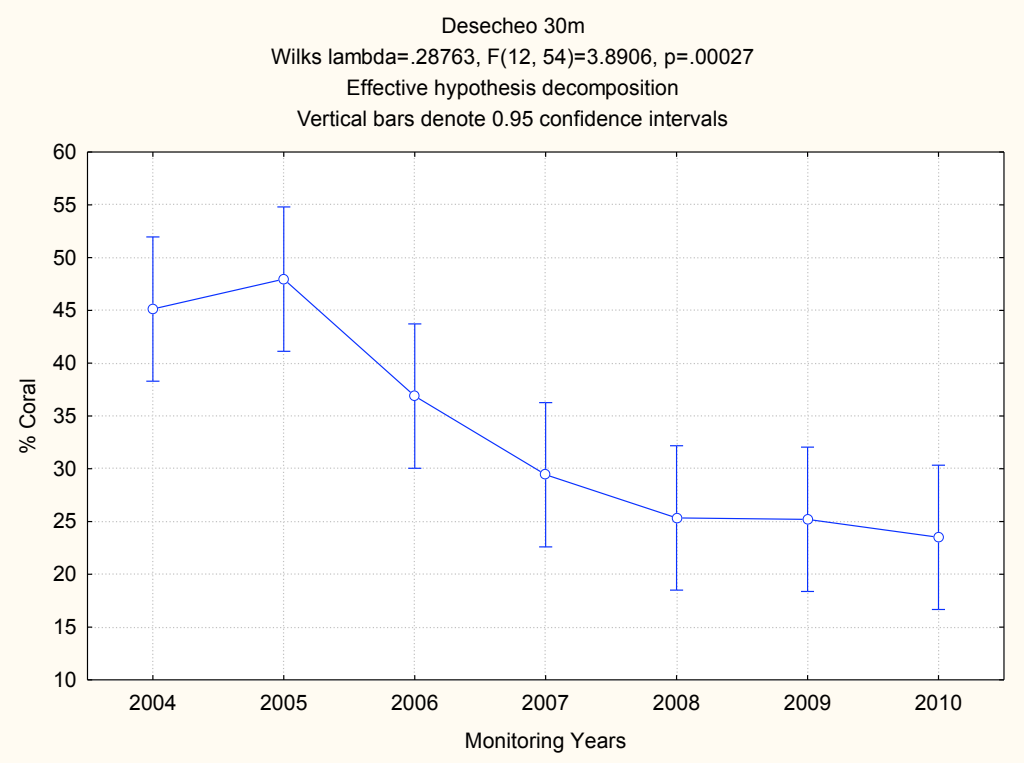


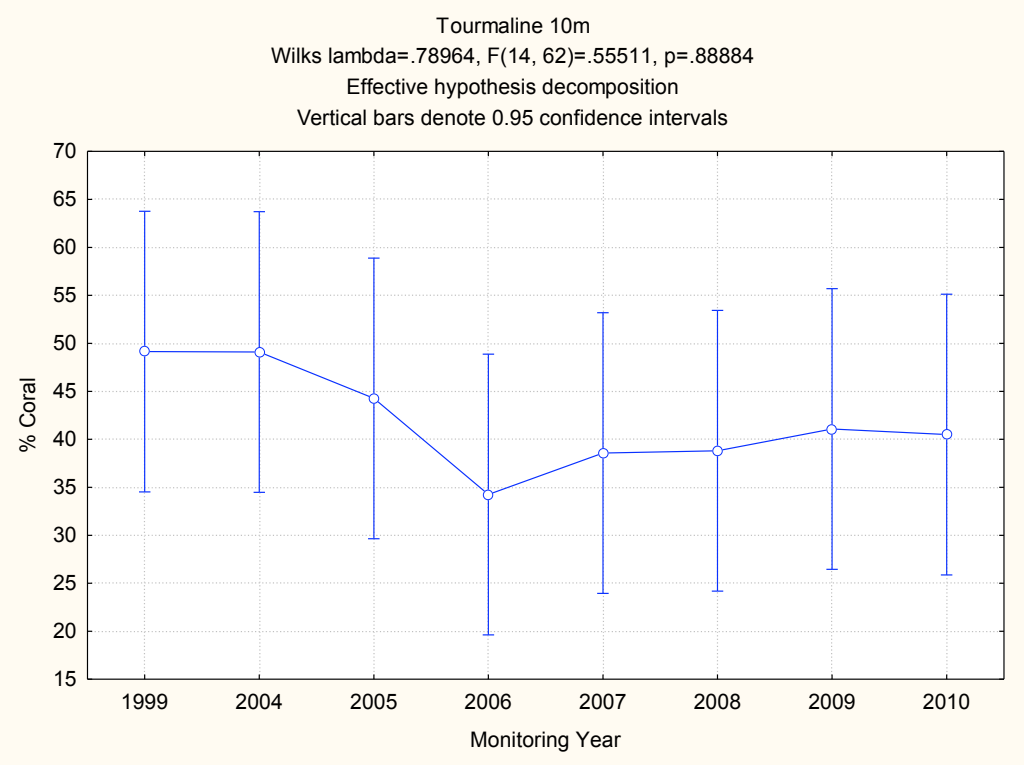


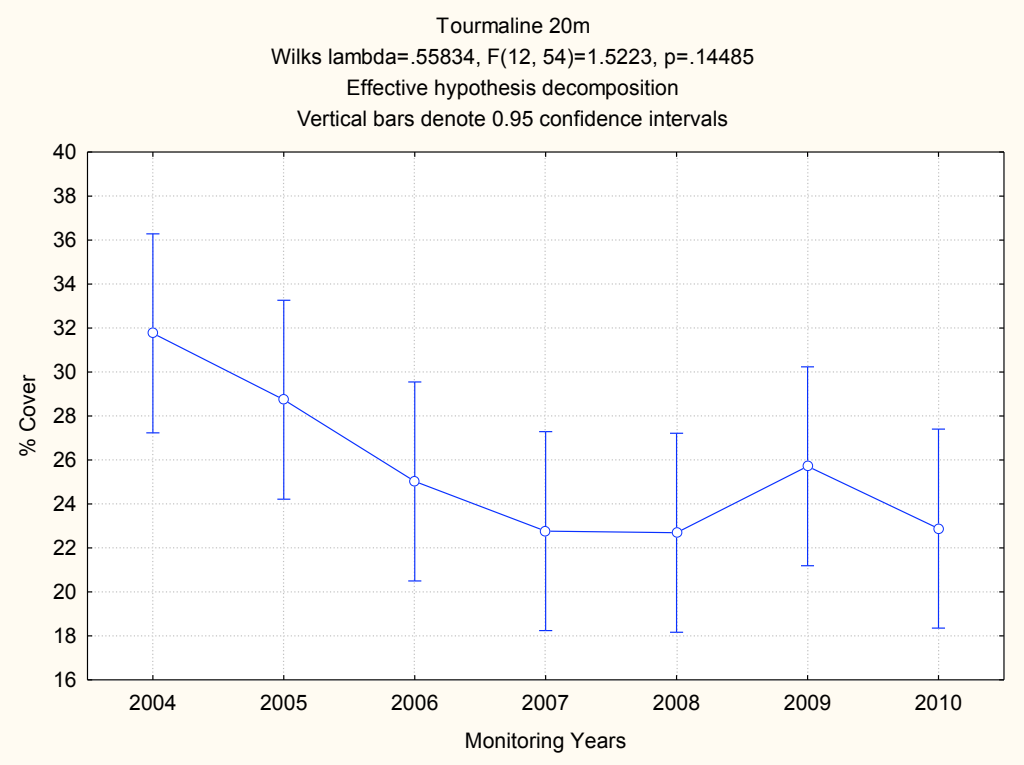

Tres Palmas 20m
Wilks lambda=.80897, F(12, 54)=.50319, p=.90357
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Cover
34
32
30
28
26
24
22
20
18
16
14
12
10
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

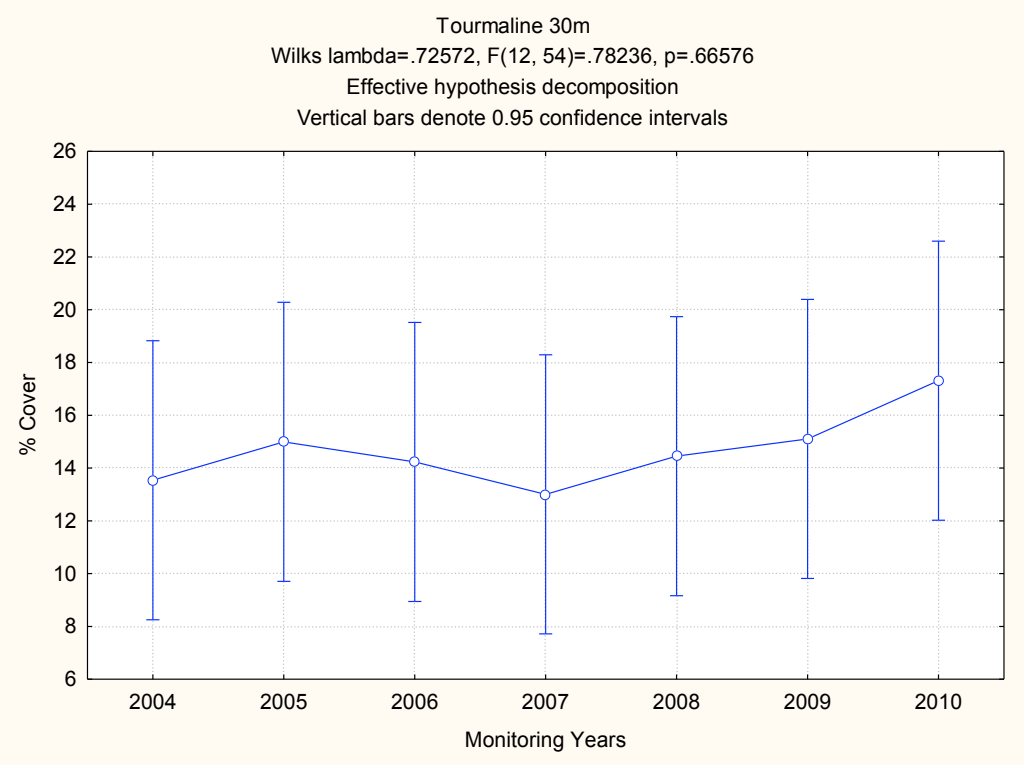

Desecheo 15m
Wilks lambda=.44919, F(12, 54)=2.2142, p=.02375
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Coral
30
25
20
15
10
5
0
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

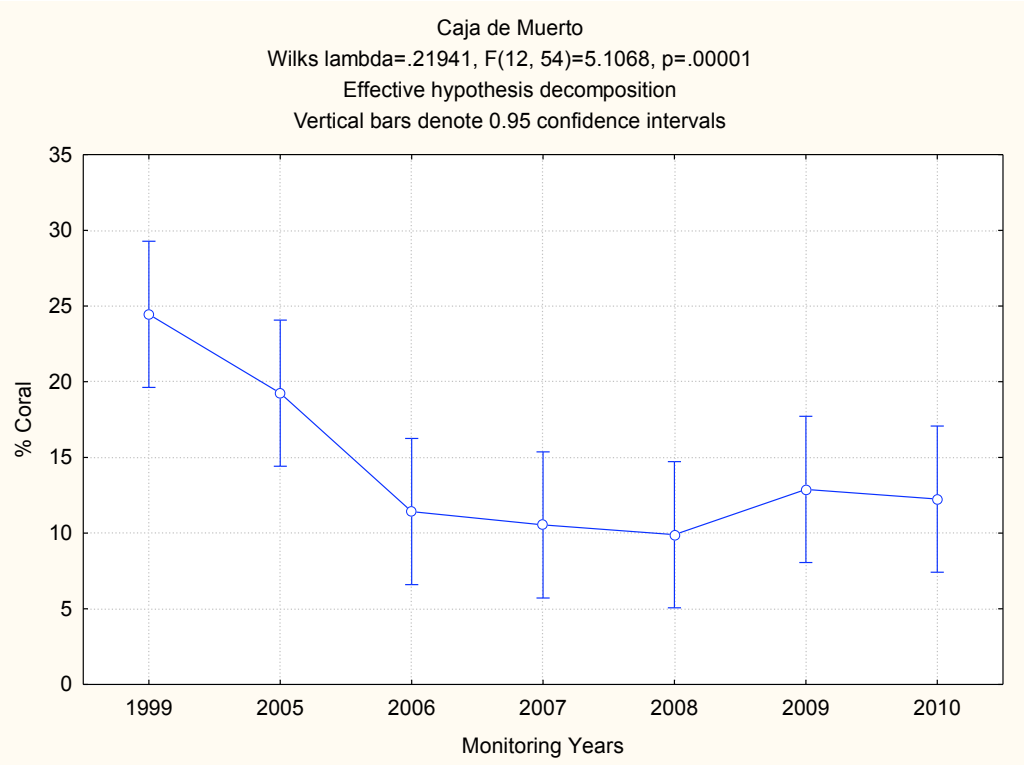

Desecheo 20m
Wilks lambda=.16748, F(14, 62)=6.3927, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Coral
70
60
50
40
30
20
10
0
-10
2000
2004
2005
2006
2007
2008
2009
2010
Monitoring Year

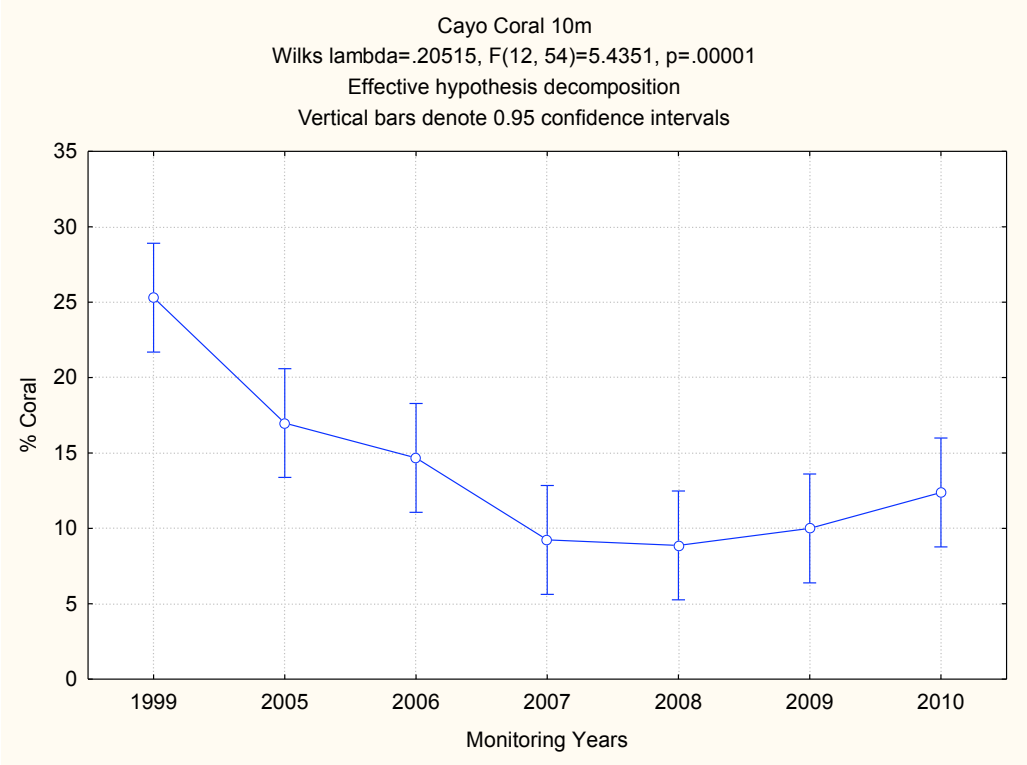

Desecheo 30m
Wilks lambda=.28763, F(12, 54)=3.8906, p=.00027
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Coral
60
55
50
45
40
35
30
25
20
15
10
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

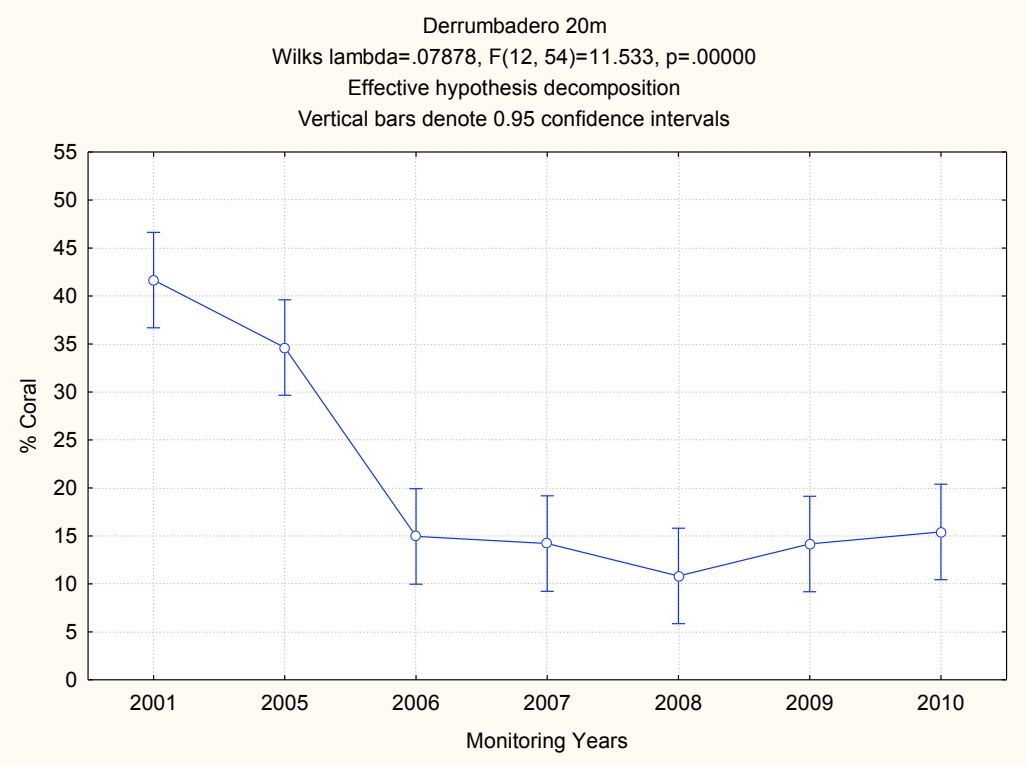

Tourmaline 10m
Wilks lambda=.78964, F(14, 62)=.55511, p=.88884
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Coral
70
65
60
55
50
45
40
35
30
25
20
15
1999
2004
2005
2006
2007
2008
2009
2010
Monitoring Year

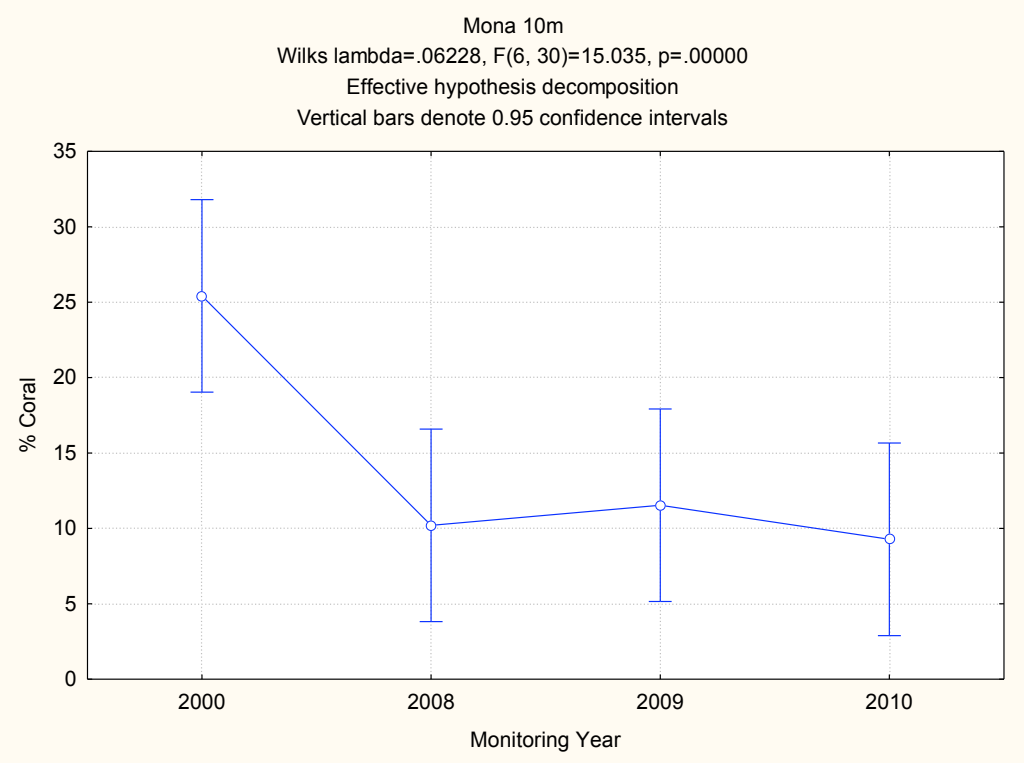

Tourmaline 20m
Wilks lambda=.55834, F(12, 54)=1.5223, p=.14485
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Cover
40
38
36
34
32
30
28
26
24
22
20
18
16
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

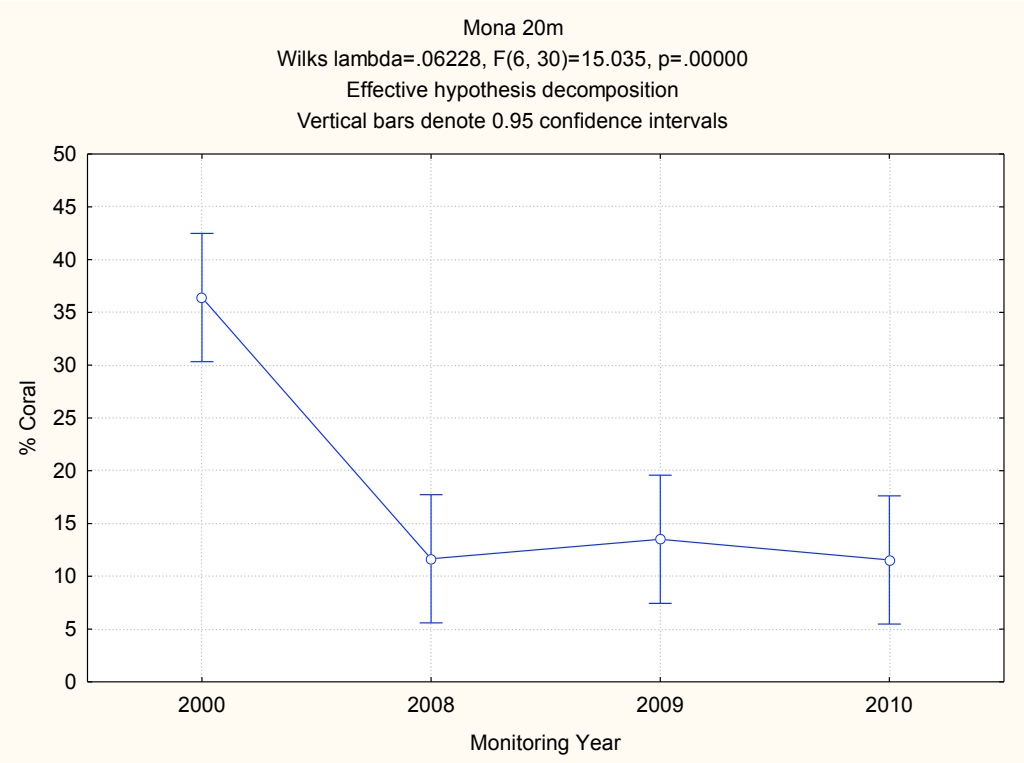

Tourmaline 30m
Wilks lambda=.72572, F(12, 54)=.78236, p=.66576
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Cover
26
24
22
20
18
16
14
12
10
8
6
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

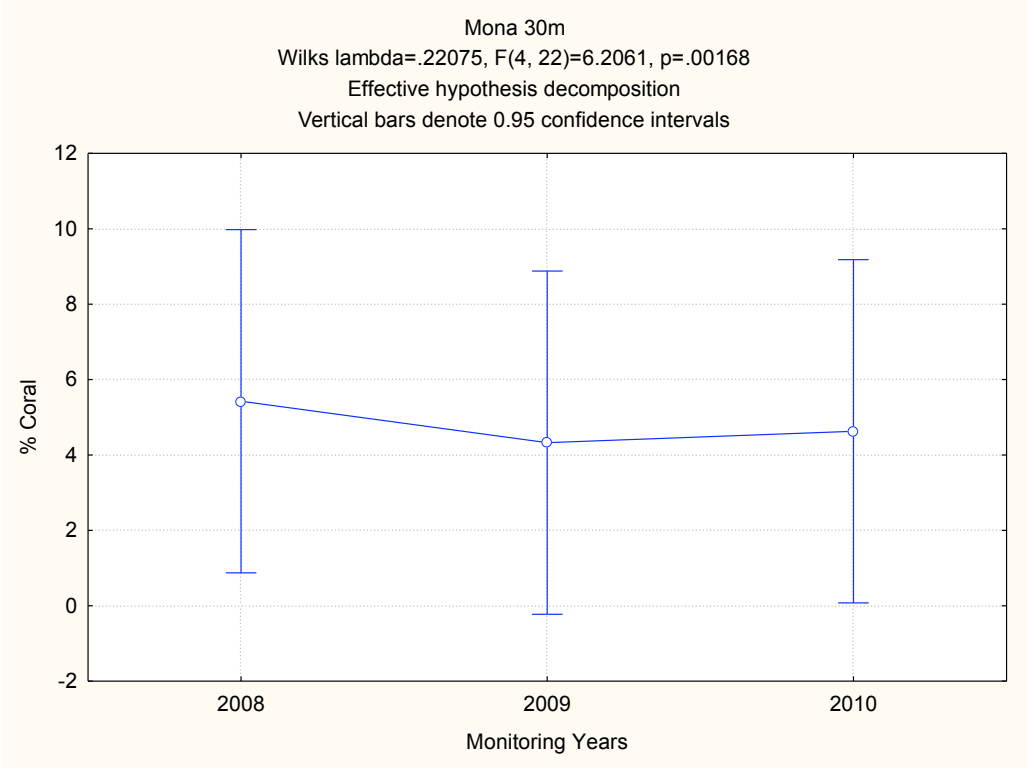

Caja de Muerto
Wilks lambda=.21941, F(12, 54)=5.1068, p=.00001
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Coral
35
30
25
20
15
10
5
0
1999
2005
2006
2007
2008
2009
2010
Monitoring Years


Cayo Coral 10m
Wilks lambda=.20515, F(12, 54)=5.4351, p=.00001
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Coral
0
5
10
15
20
25
30
35
1999
2005
2006
2007
2008
2009
2010
Monitoring Years

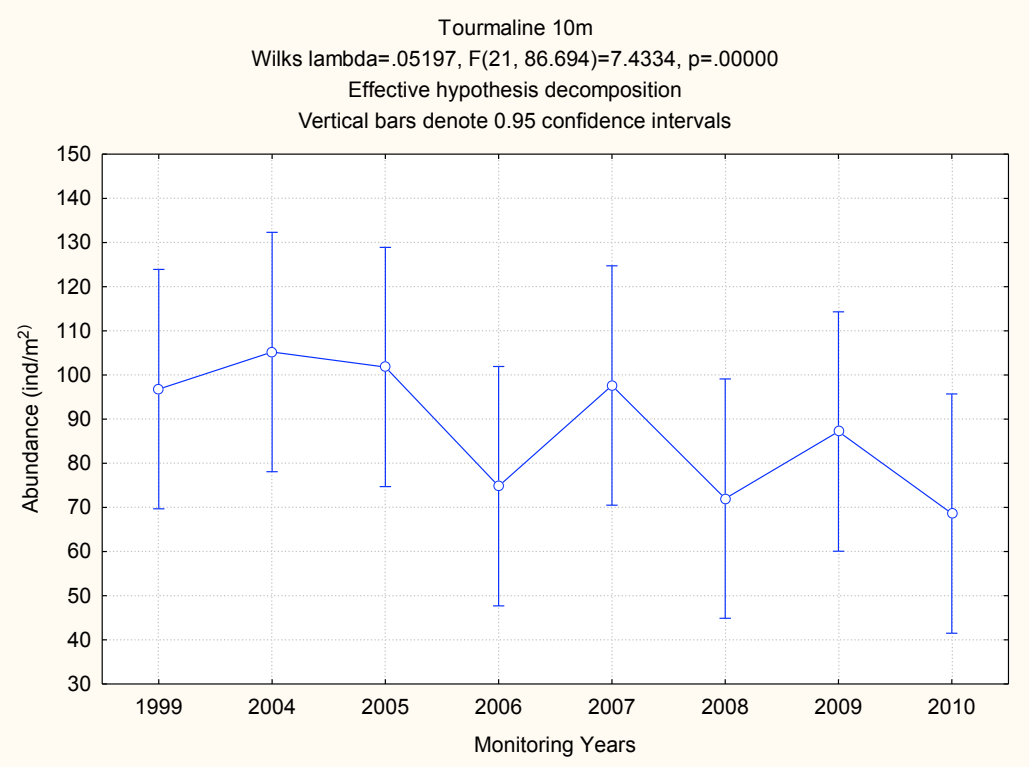

Derrumbadero 20m
Wilks lambda=.07878, F(12, 54)=11.533, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Coral
0
5
10
15
20
25
30
35
40
45
50
55
2001
2005
2006
2007
2008
2009
2010
Monitoring Years

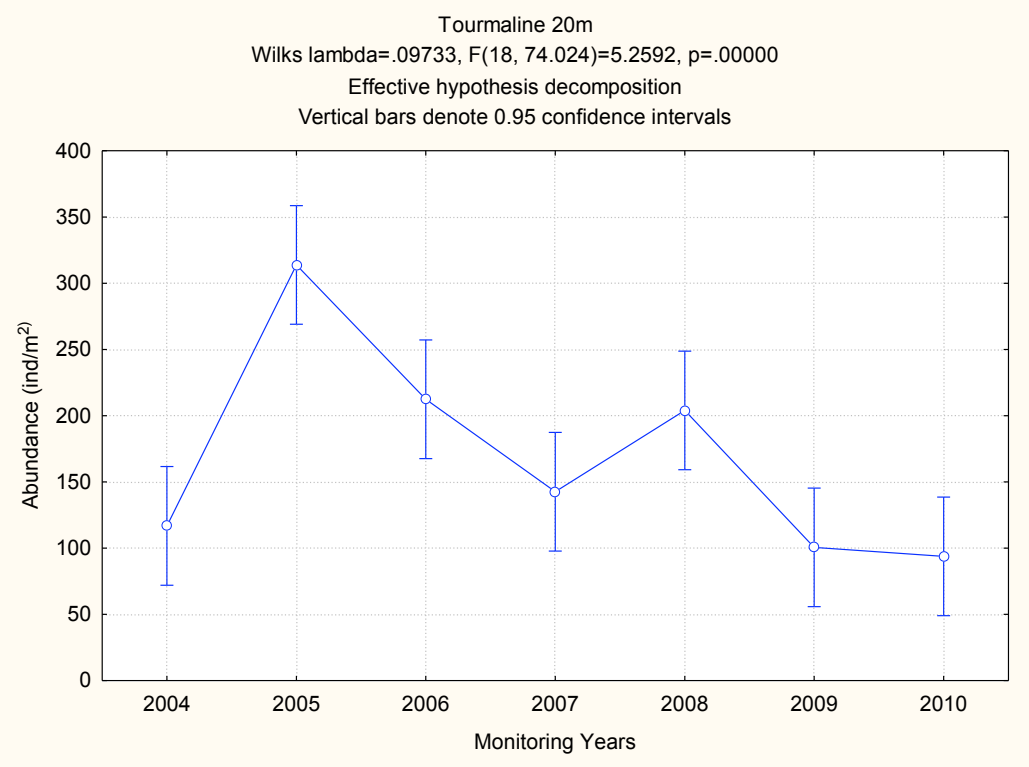

Mona 10m
Wilks lambda=.06228, F(6, 30)=15.035, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Coral
0
5
10
15
20
25
30
35
2000
2008
2009
2010
Monitoring Year

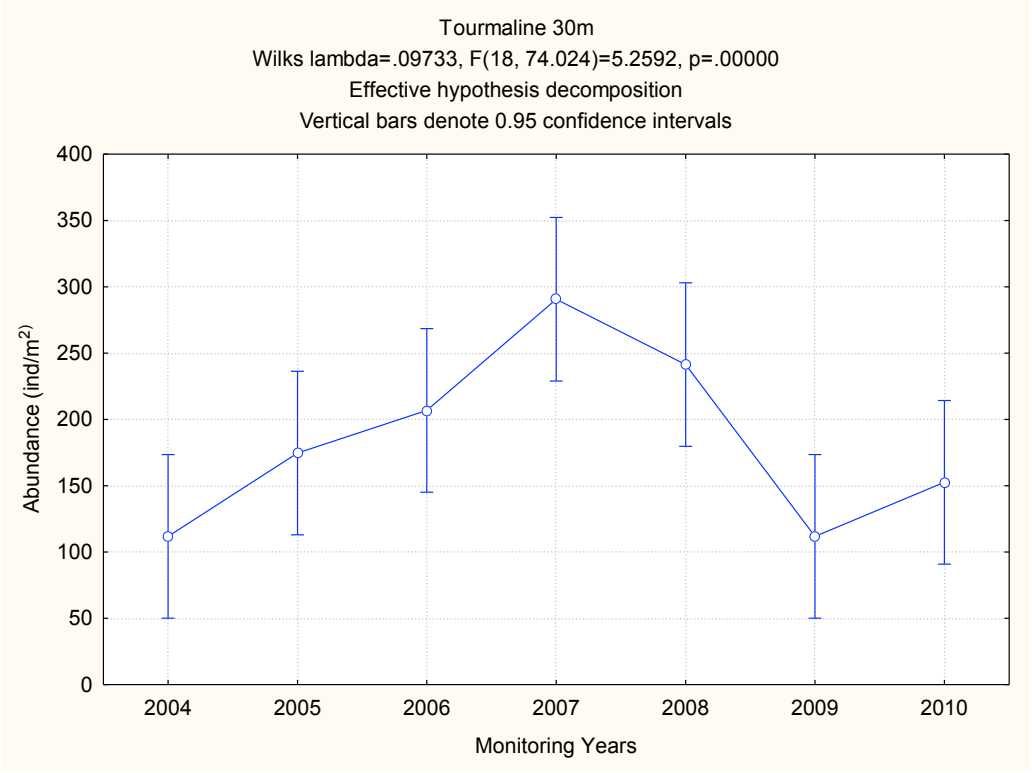

Mona 20m
Wilks lambda=.06228, F(6, 30)=15.035, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
% Coral
0
5
10
15
20
25
30
35
40
45
50
2000
2008
2009
2010
Monitoring Year

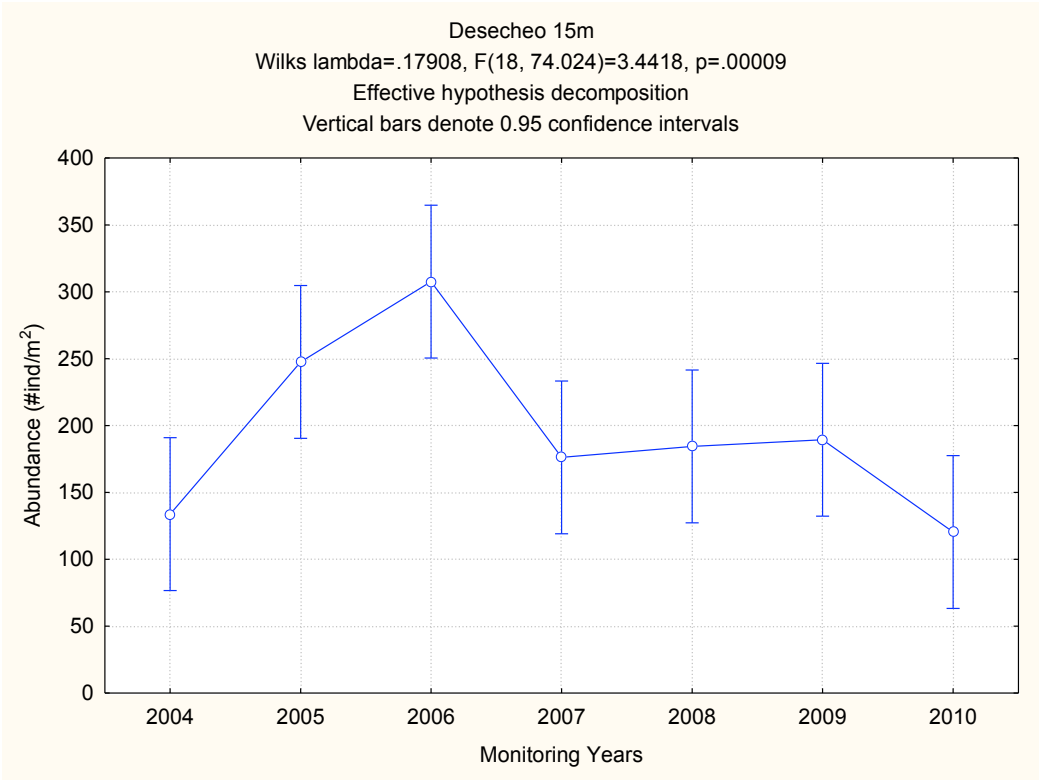

Mona 30m
Wilks lambda=.22075, F(4, 22)=6.2061, p=.00168
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
12
10
8
6
4
2
0
-2
% Coral
2008
2009
2010
Monitoring Years

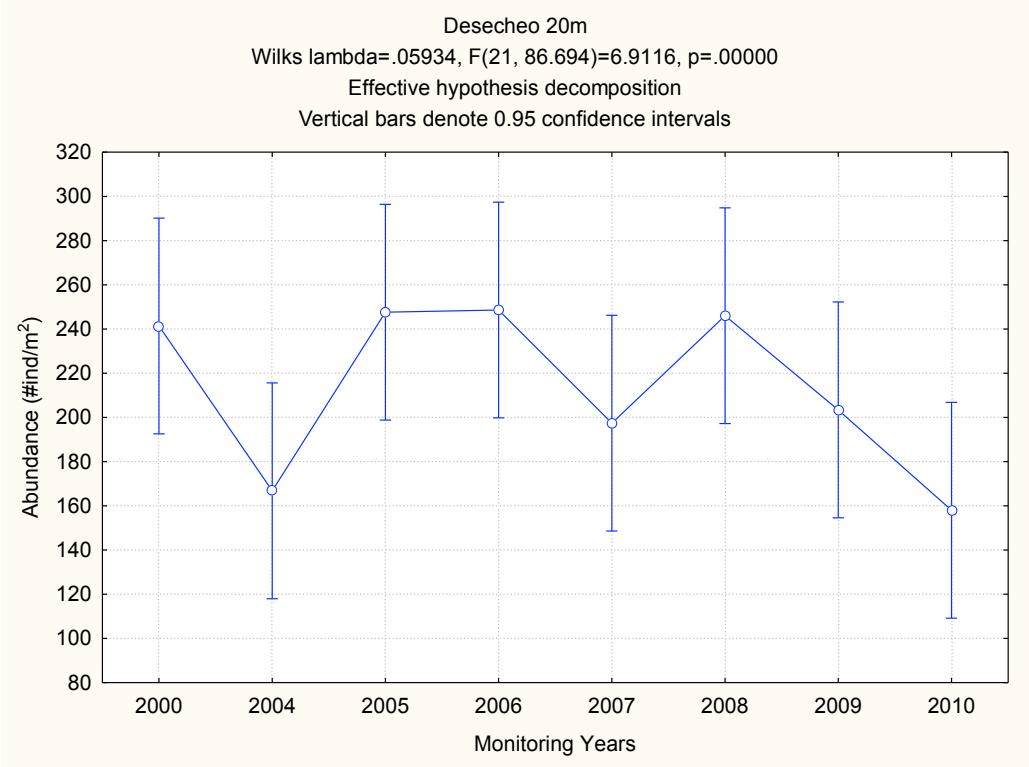
Appendix 3. Analysis of variance (ANOVA) procedure testing difference of fish species abundance (spp/transect) between monitoring surveys.

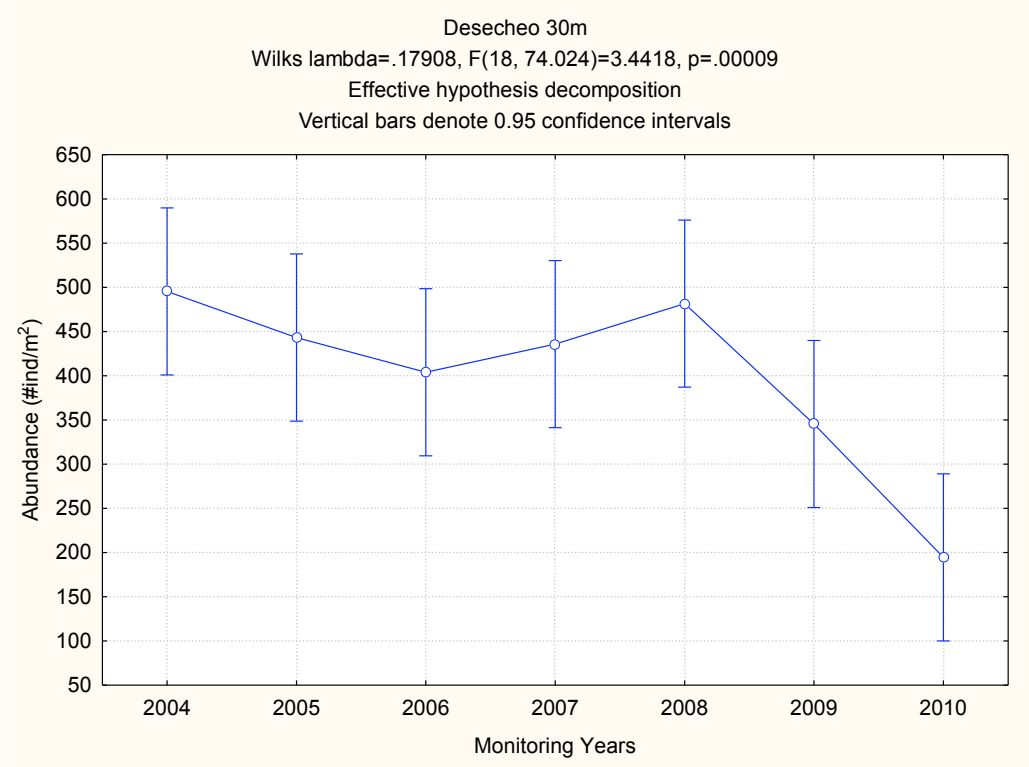


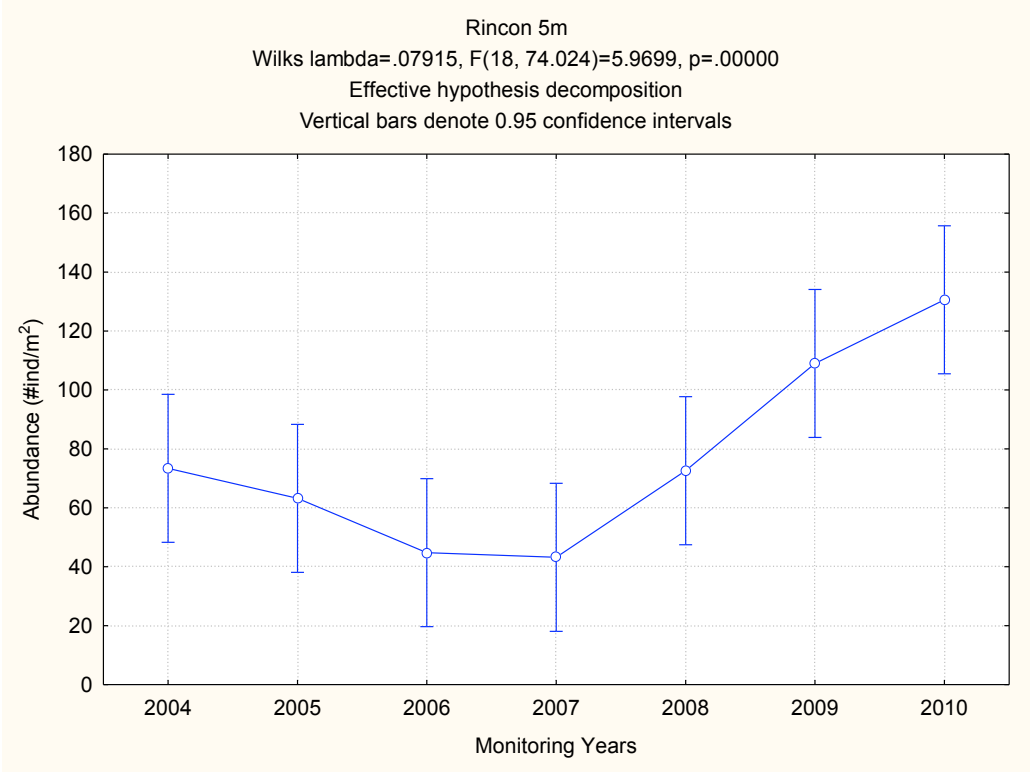


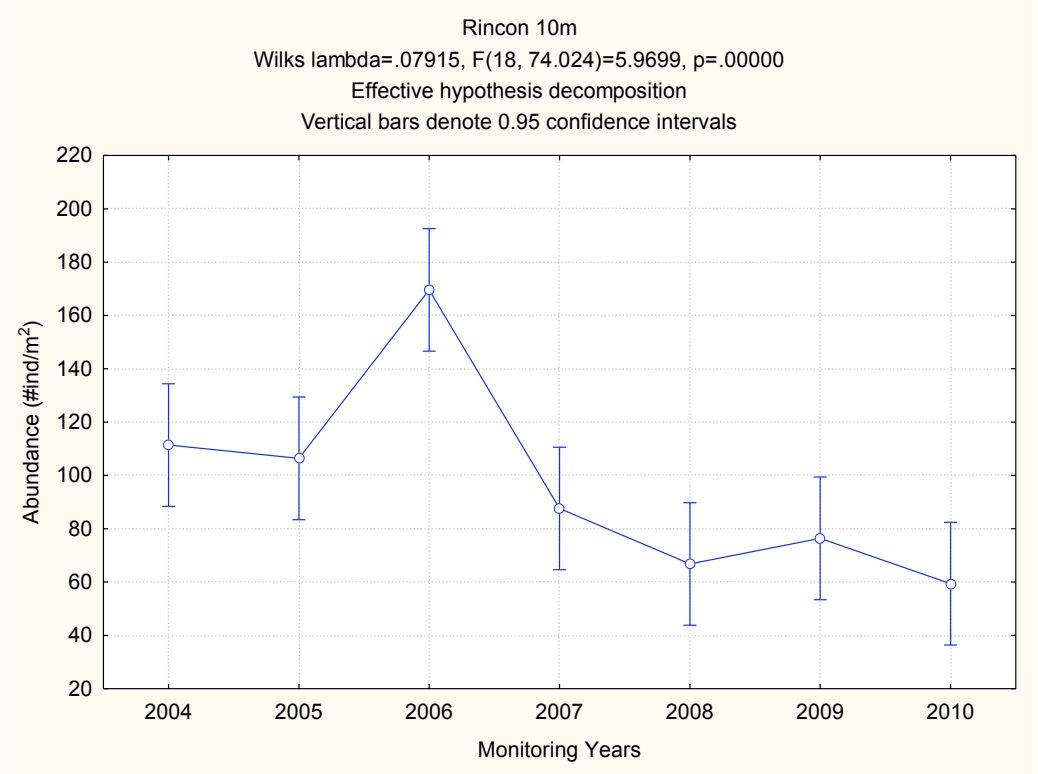

Tourmaline 30m
Wilks lambda=.09733, F(18, 74.024)=5.2592, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (ind/m2)
400
350
300
250
200
150
100
50
0
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

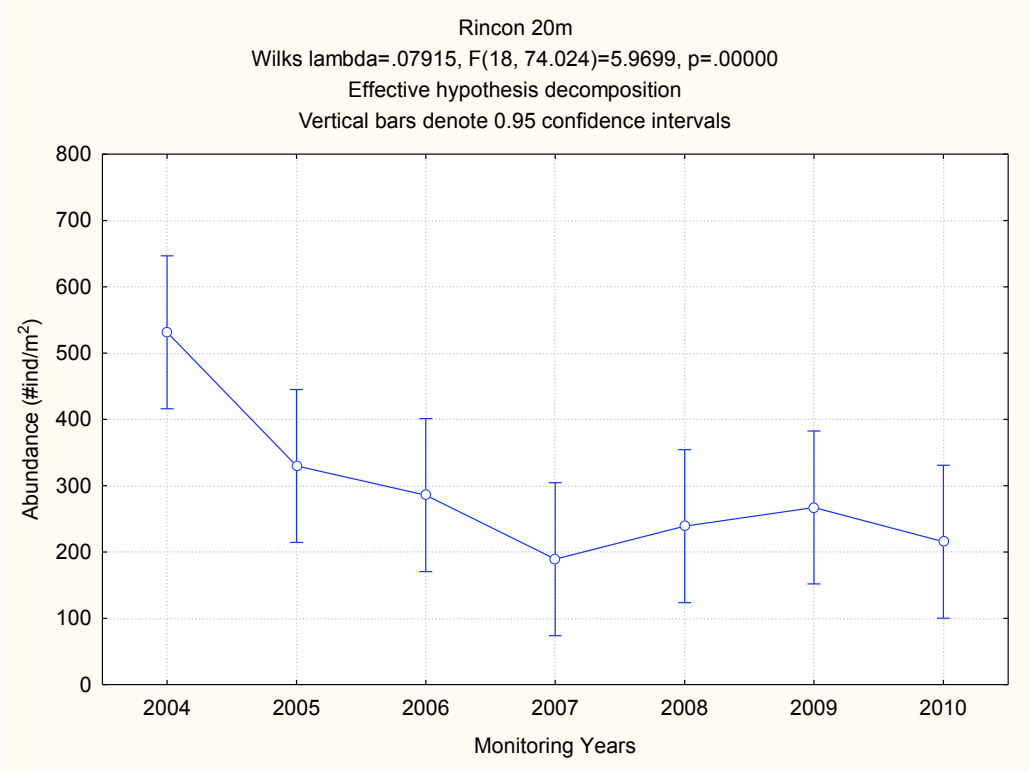

Desecheo 15m
Wilks lambda=.17908, F(18, 74.024)=3.4418, p=.00009
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
400
350
300
250
200
150
100
50
0
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

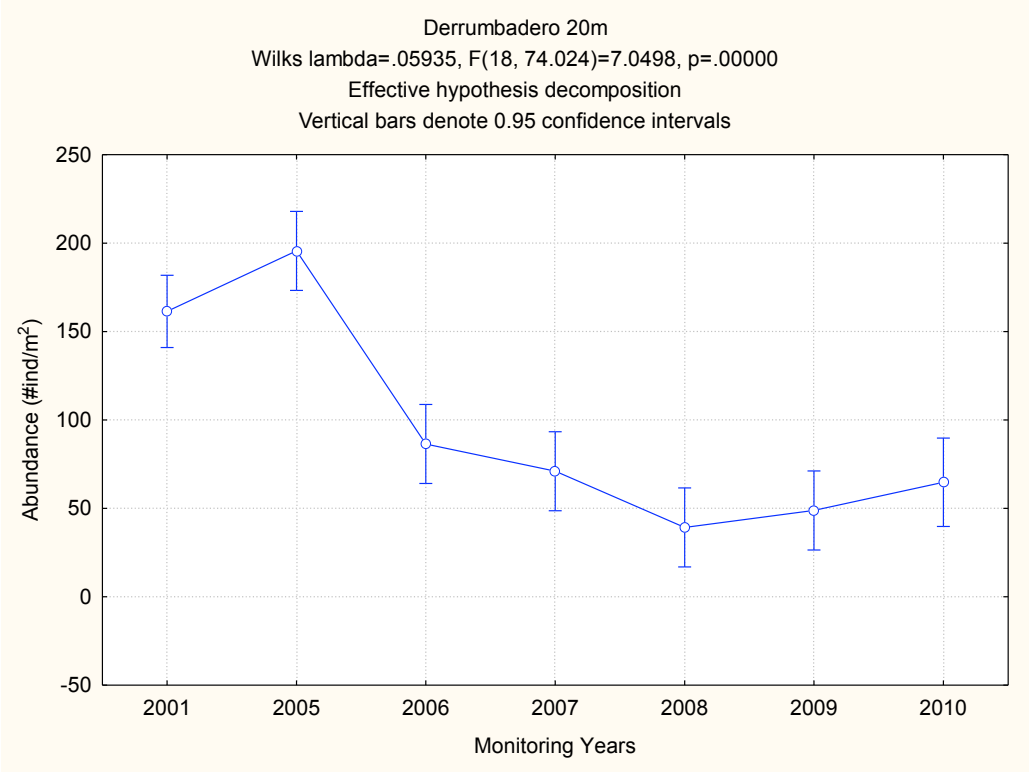

Desecheo 20m
Wilks lambda=.05934, F(21, 86.694)=6.9116, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
320
300
280
260
240
220
200
180
160
140
120
100
80
2000
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

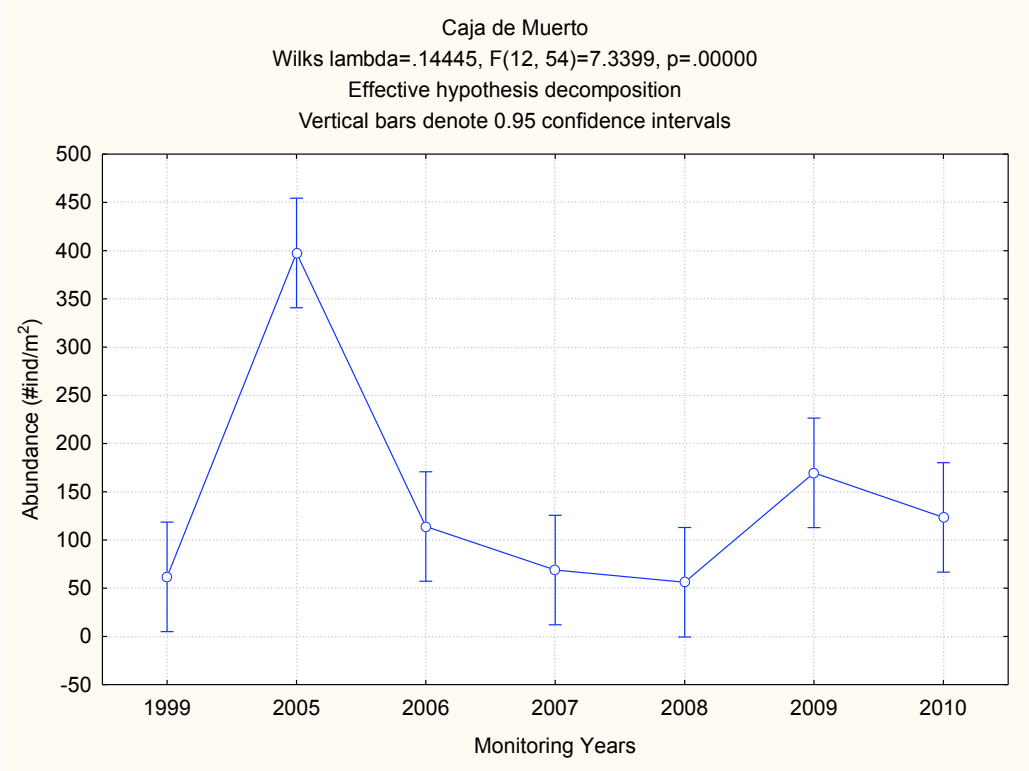

Desecheo 30m
Wilks lambda=.17908, F(18, 74.024)=3.4418, p=.00009
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
650
600
550
500
450
400
350
300
250
200
150
100
50
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

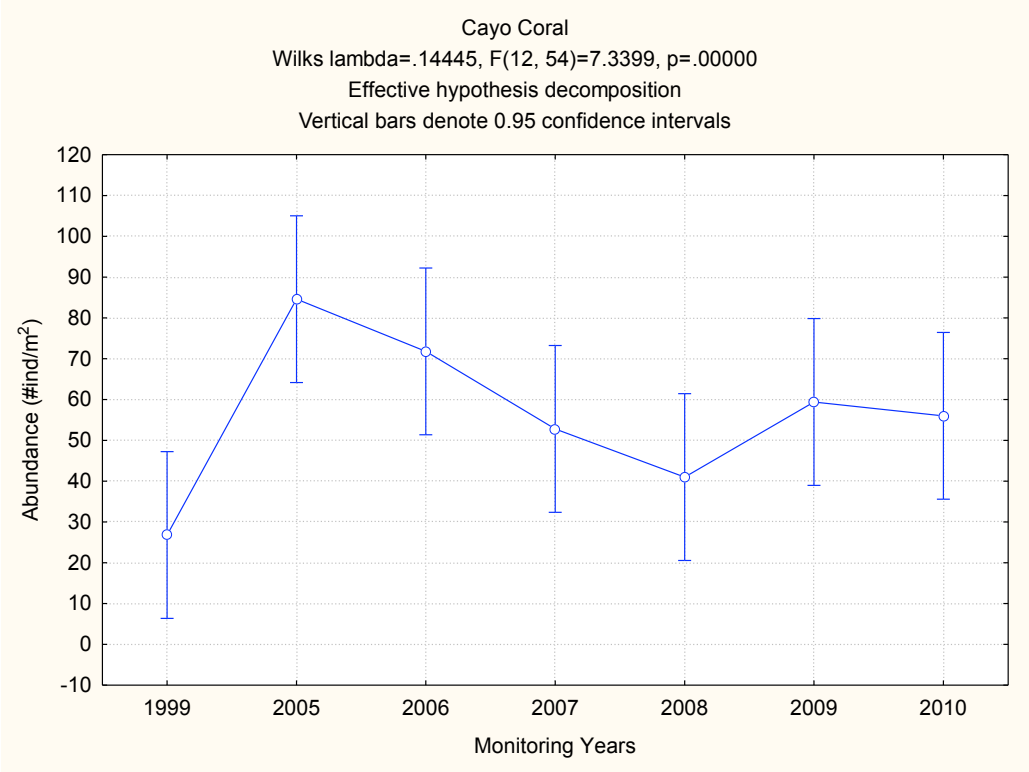

Rincon 5m
Wilks lambda=.07915, F(18, 74.024)=5.9699, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
180
160
140
120
100
80
60
40
20
0
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

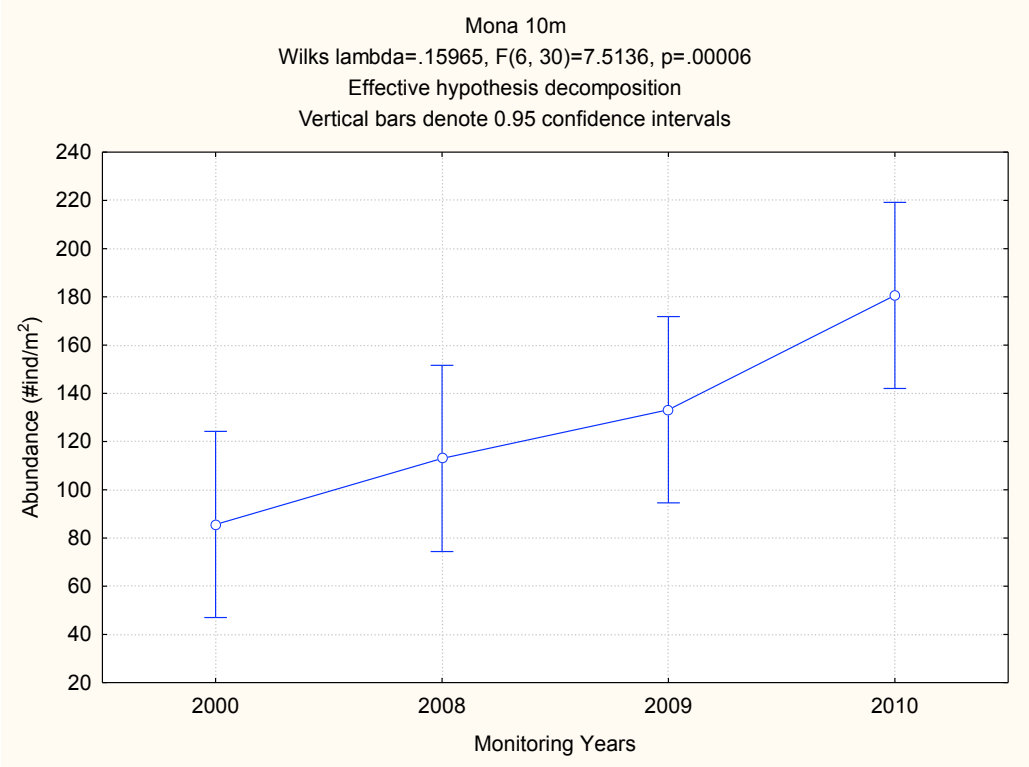

Rincon 10m
Wilks lambda=.07915, F(18, 74.024)=5.9699, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
220
200
180
160
140
120
100
80
60
40
20
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

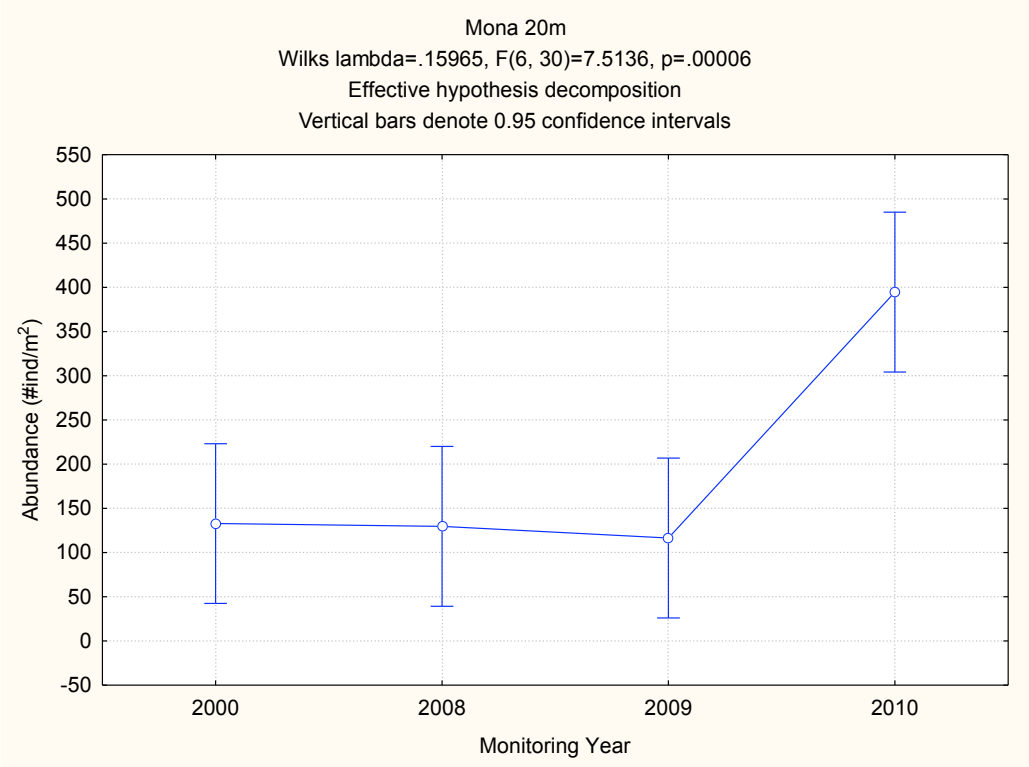

Rincon 20m
Wilks lambda=.07915, F(18, 74.024)=5.9699, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
800
700
600
500
400
300
200
100
0
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

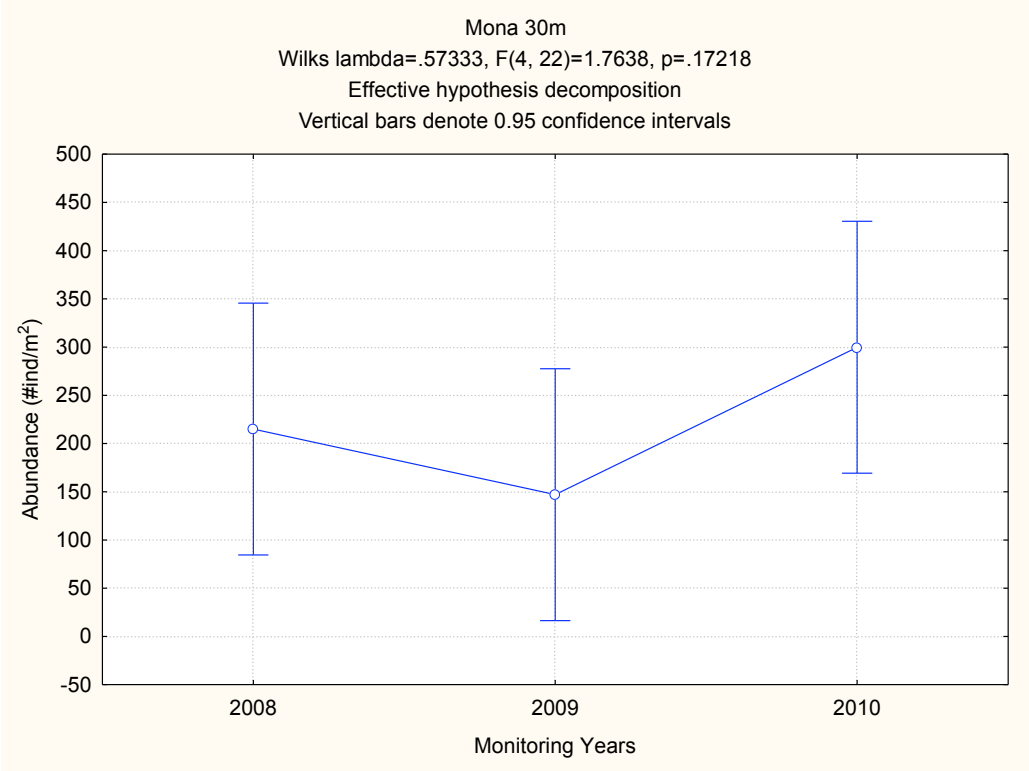

Derrumbadero 20m
Wilks lambda=.05935, F(18, 74.024)=7.0498, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
250
200
150
100
50
0
-50
2001
2005
2006
2007
2008
2009
2010
Monitoring Years


Caja de Muerto
Wilks lambda=.14445, F(12, 54)=7.3399, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
500
450
400
350
300
250
200
150
100
50
0
-50
1999
2005
2006
2007
2008
2009
2010
Monitoring Years

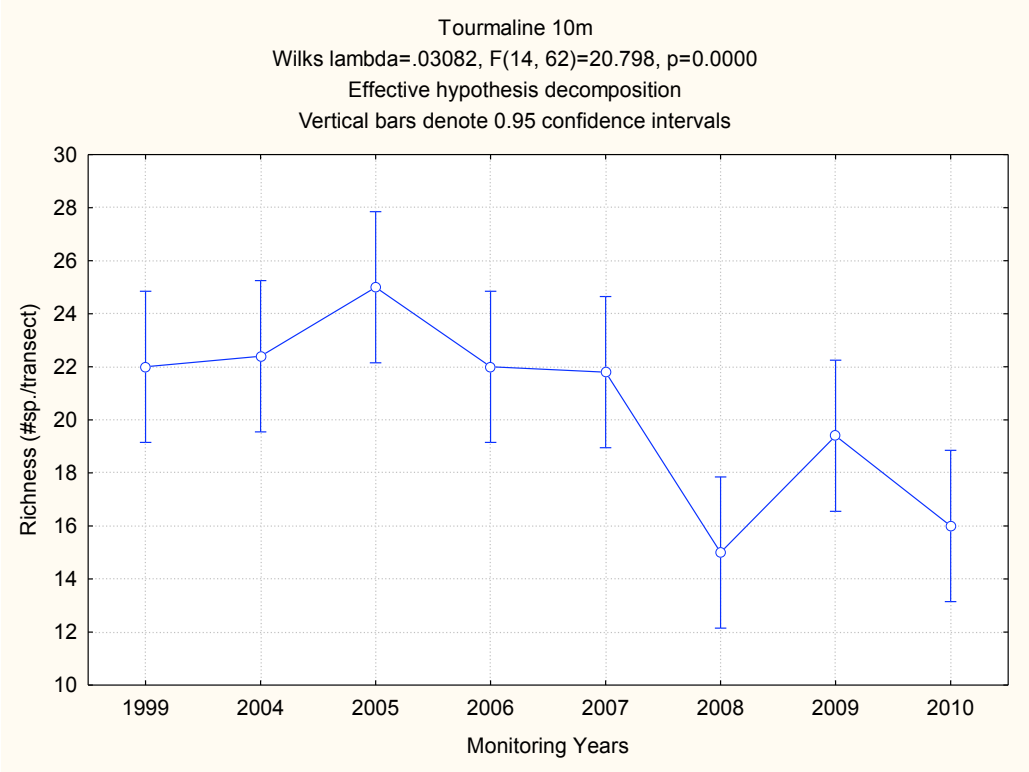

Cayo Coral
Wilks lambda=.14445, F(12, 54)=7.3399, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
1999
2005
2006
2007
2008
2009
2010
Monitoring Years

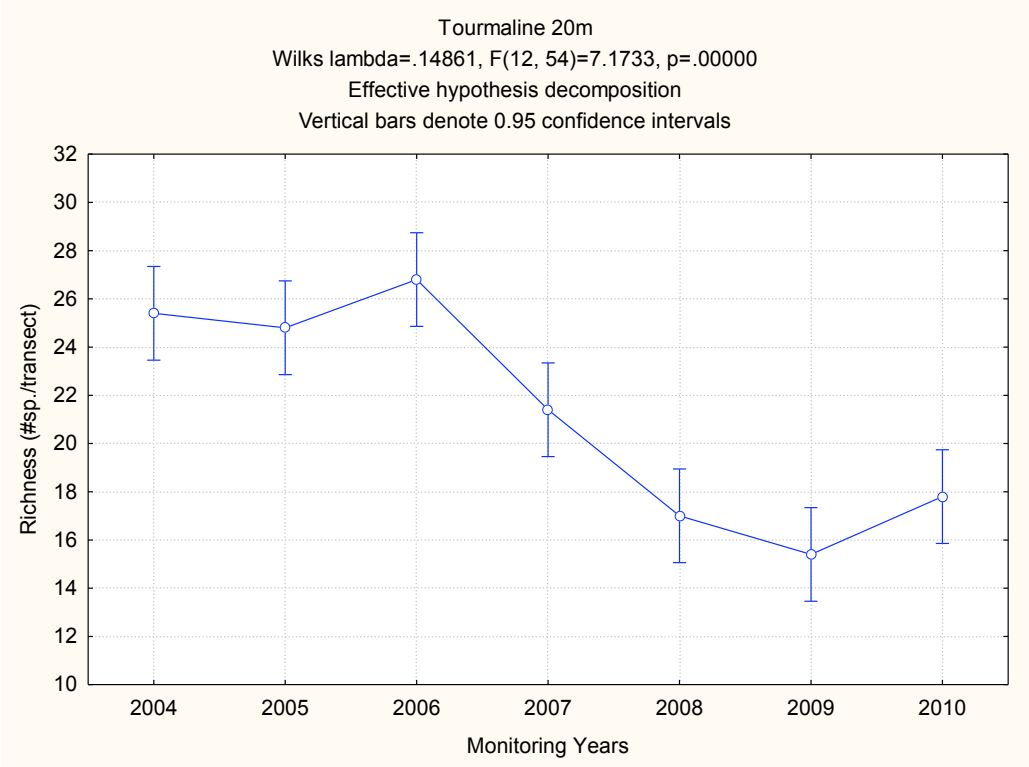

Mona 10m
Wilks lambda=.15965, F(6, 30)=7.5136, p=.00006
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
240
220
200
180
160
140
120
100
80
60
40
20
2000
2008
2009
2010
Monitoring Years

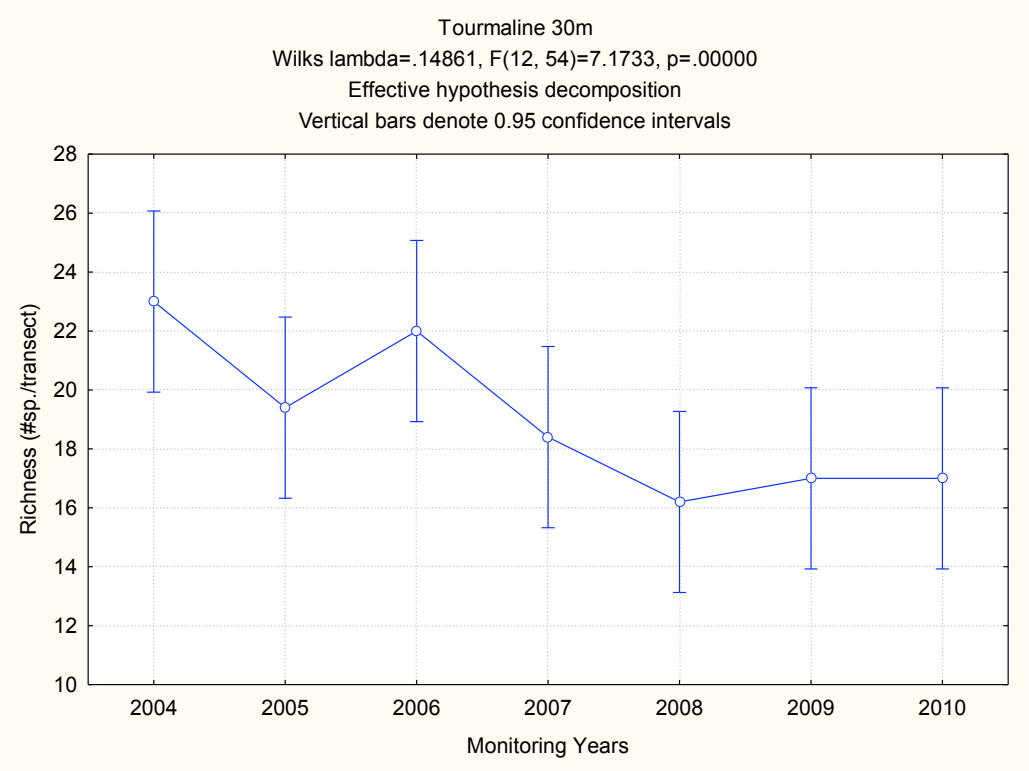

Mona 20m
Wilks lambda=.15965, F(6, 30)=7.5136, p=.00006
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Abundance (#ind/m2)
550
500
450
400
350
300
250
200
150
100
50
0
-50
2000
2008
2009
2010
Monitoring Year

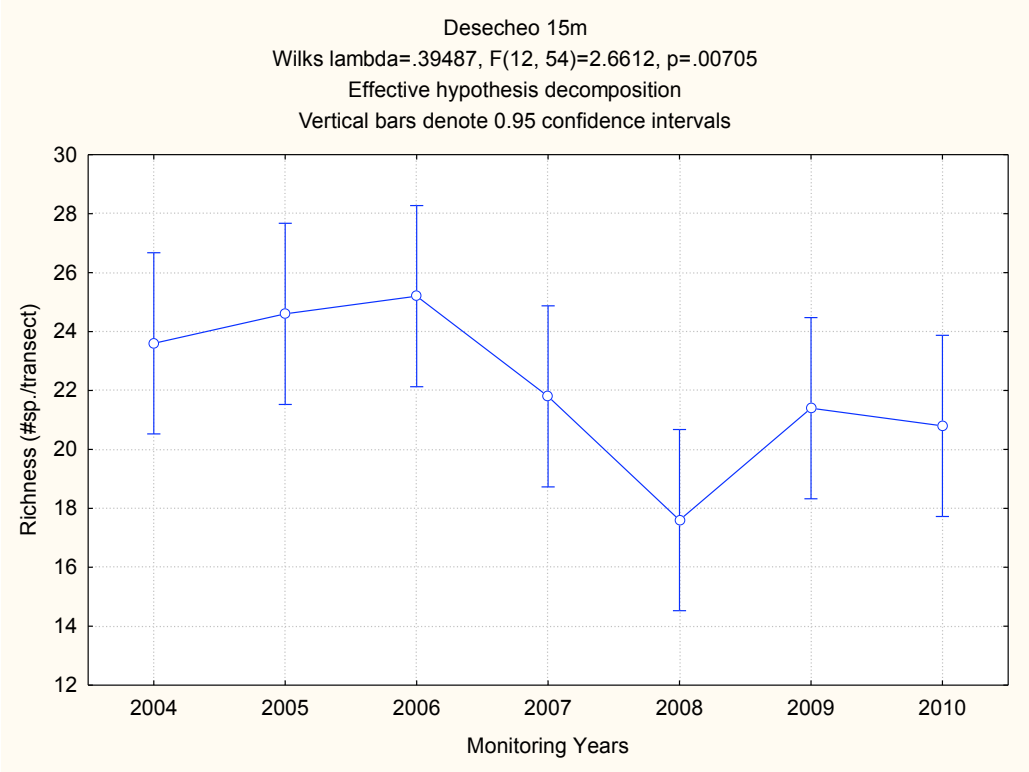

Mona 30m
Wilks lambda=.57333, F(4, 22)=1.7638, p=.17218
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
500
450
400
350
300
250
200
150
100
50
0
-50
Abundance (#ind/m2)
2008
2009
2010
Monitoring Years

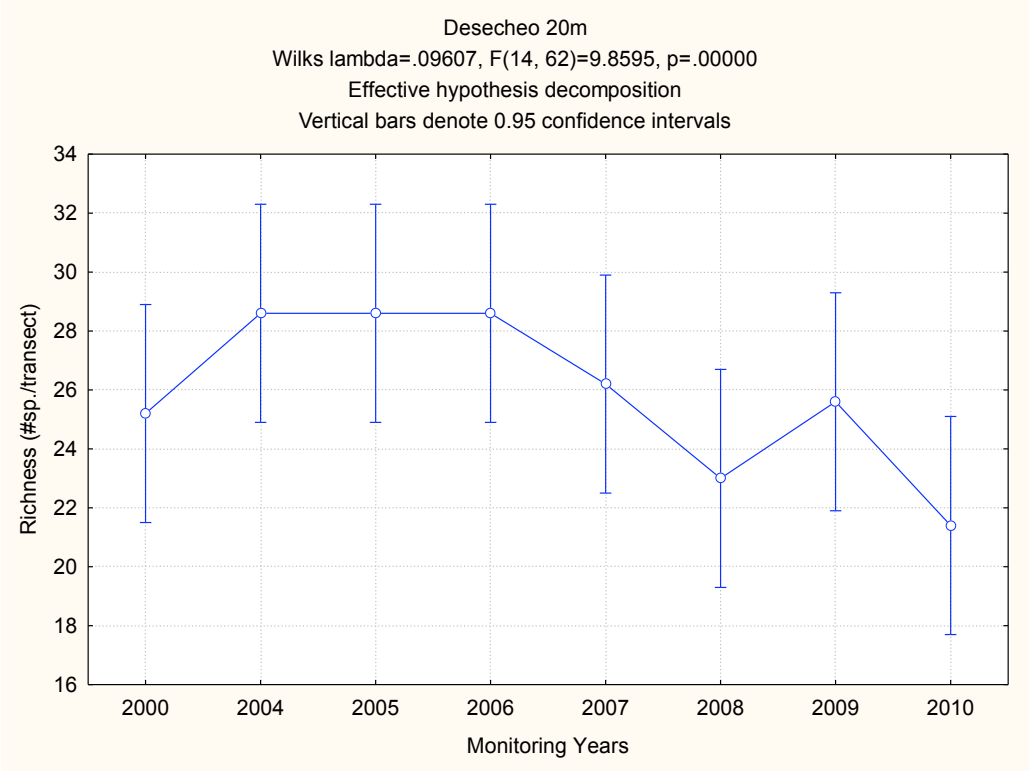
Appendix 4. Analysis of variance (ANOVA) procedure testing difference of fish richness (ind/30m^2) between monitoring surveys.

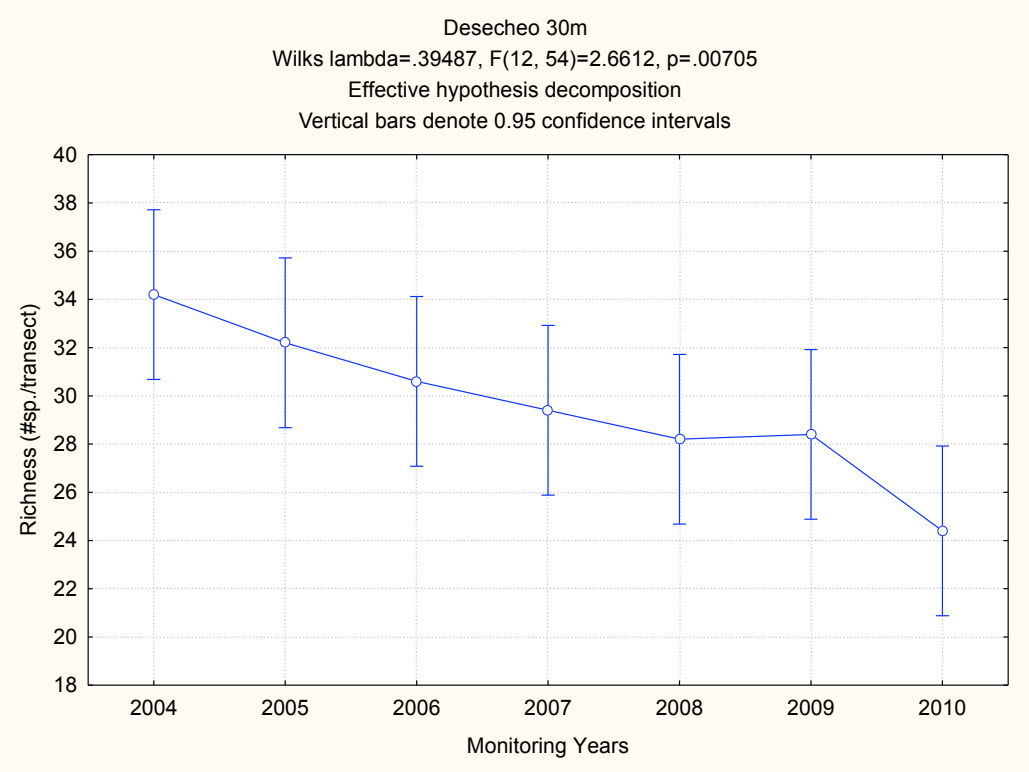


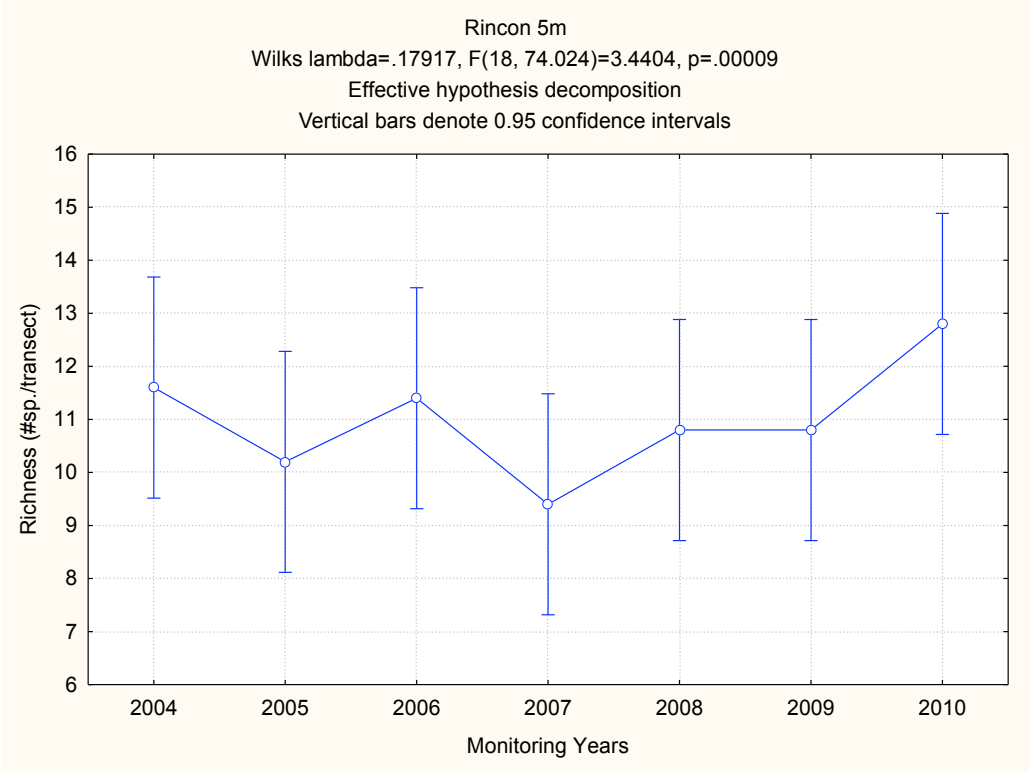


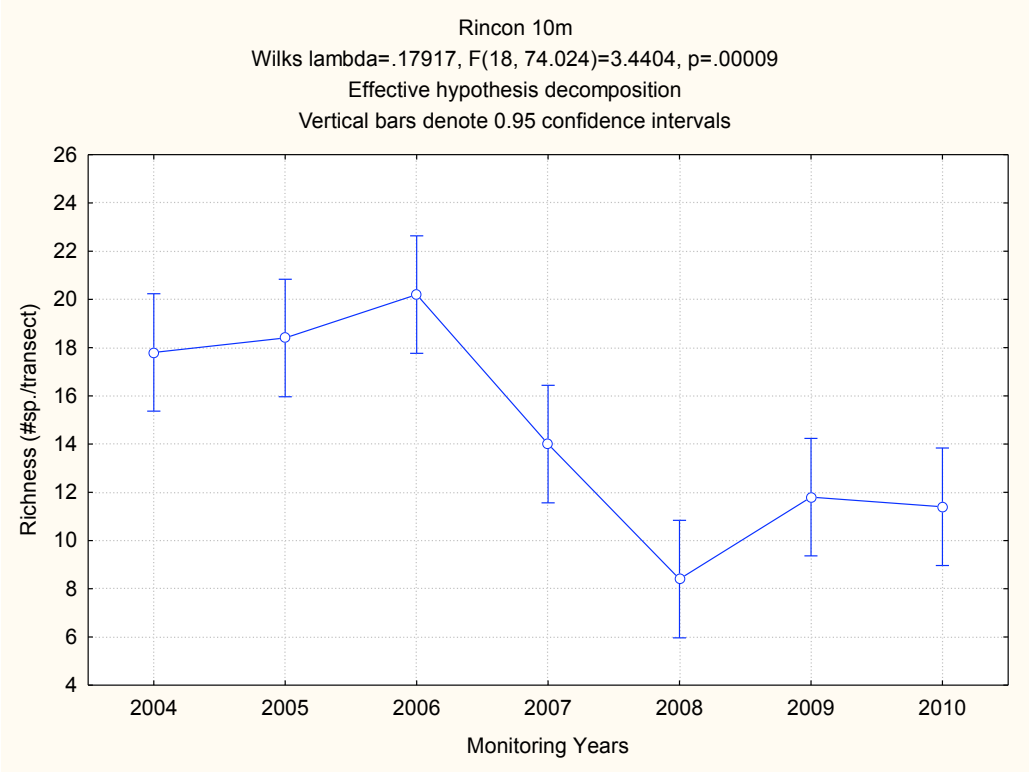

Tourmaline 30m
Wilks lambda=.14861, F(12, 54)=7.1733, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
28
26
24
22
20
18
16
14
12
10
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

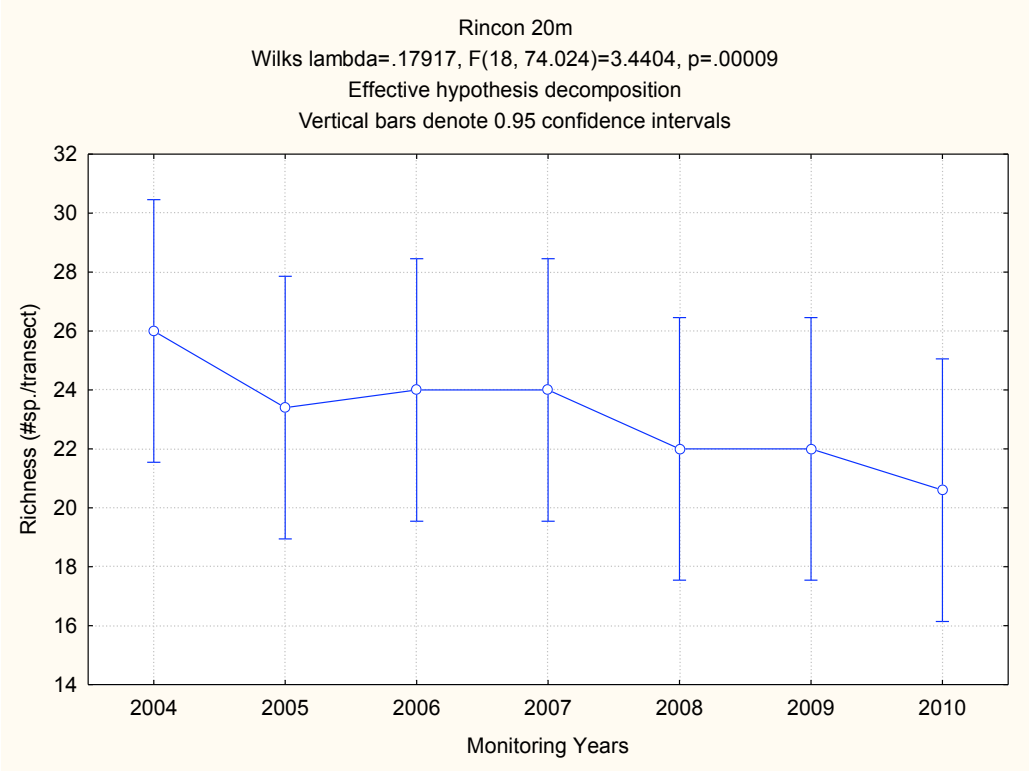

Desecheo 15m
Wilks lambda=.39487, F(12, 54)=2.6612, p=.00705
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
30
28
26
24
22
20
18
16
14
12
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

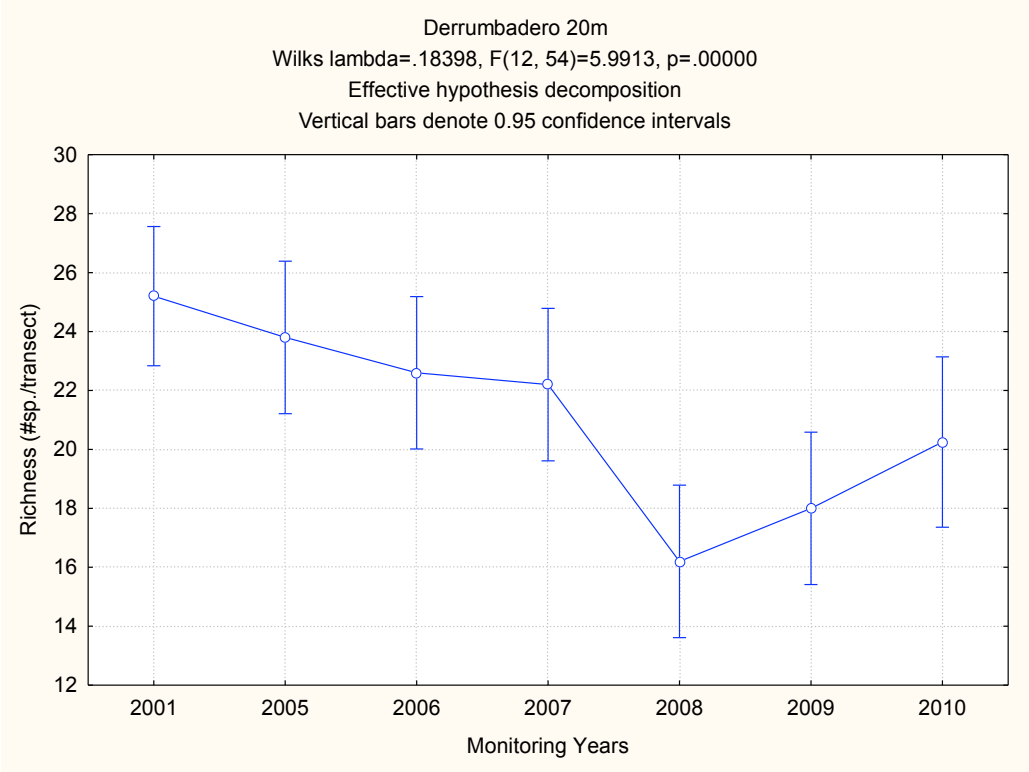

Desecheo 20m
Wilks lambda=.09607, F(14, 62)=9.8595, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
34
32
30
28
26
24
22
20
18
16
2000
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

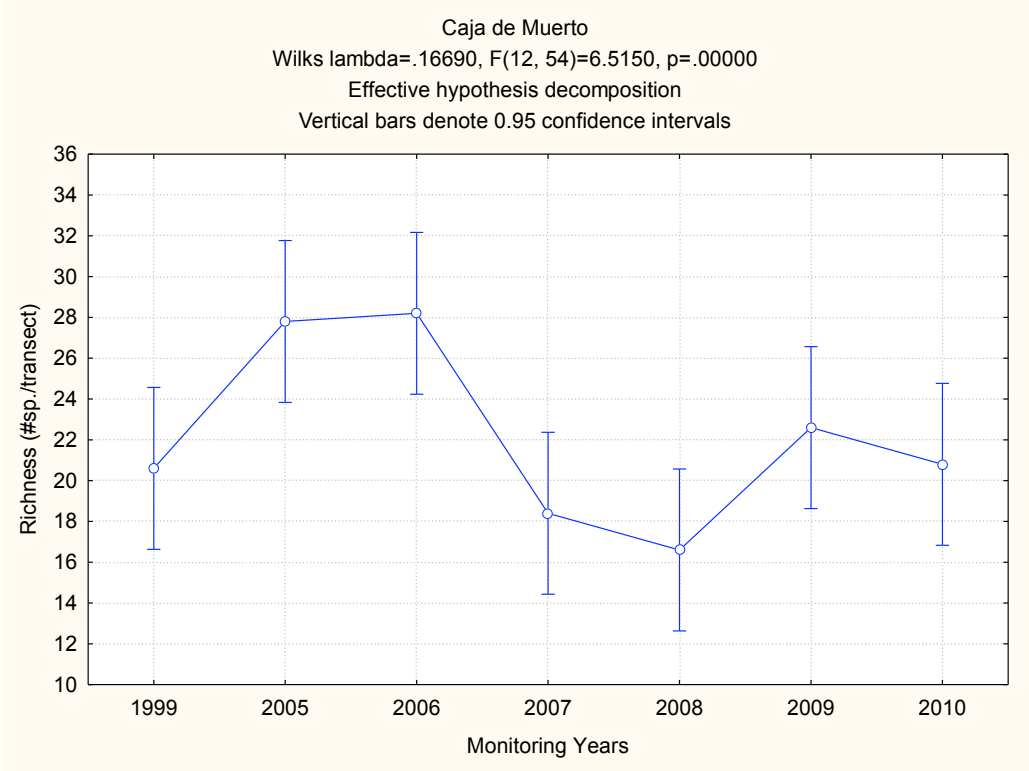

Desecheo 30m
Wilks lambda=.39487, F(12, 54)=2.6612, p=.00705
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
40
38
36
34
32
30
28
26
24
22
20
18
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

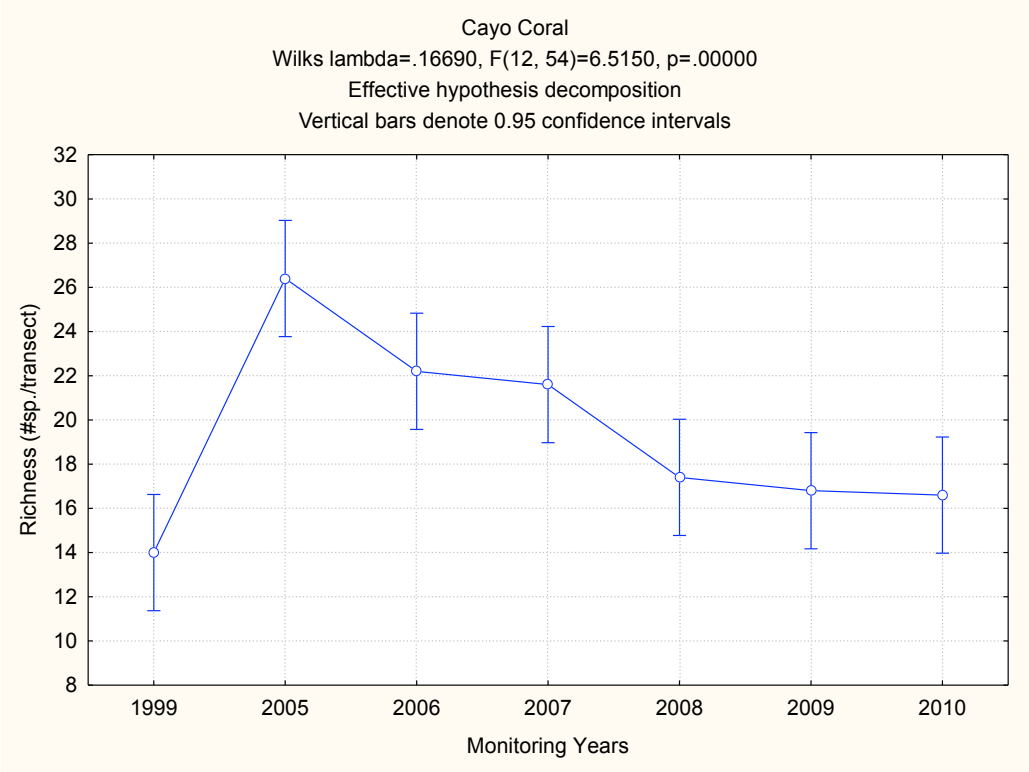

Rincon 5m
Wilks lambda=.17917, F(18, 74.024)=3.4404, p=.00009
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
16
15
14
13
12
11
10
9
8
7
6
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

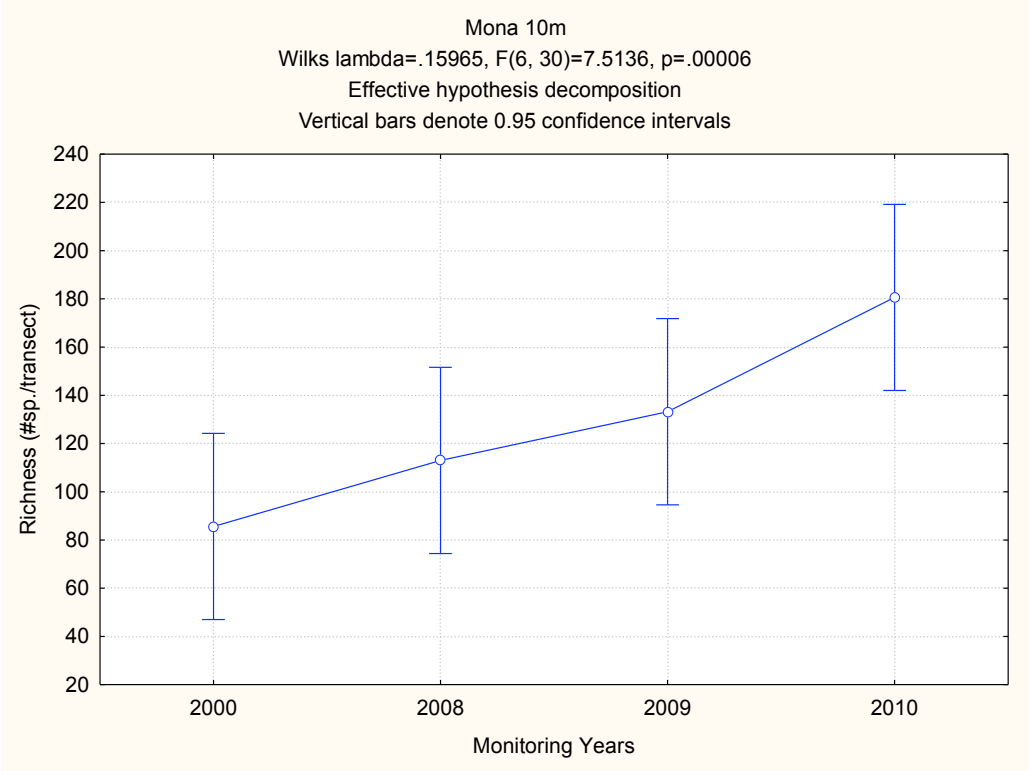

Rincon 10m
Wilks lambda=.17917, F(18, 74.024)=3.4404, p=.00009
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
26
24
22
20
18
16
14
12
10
8
6
4
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

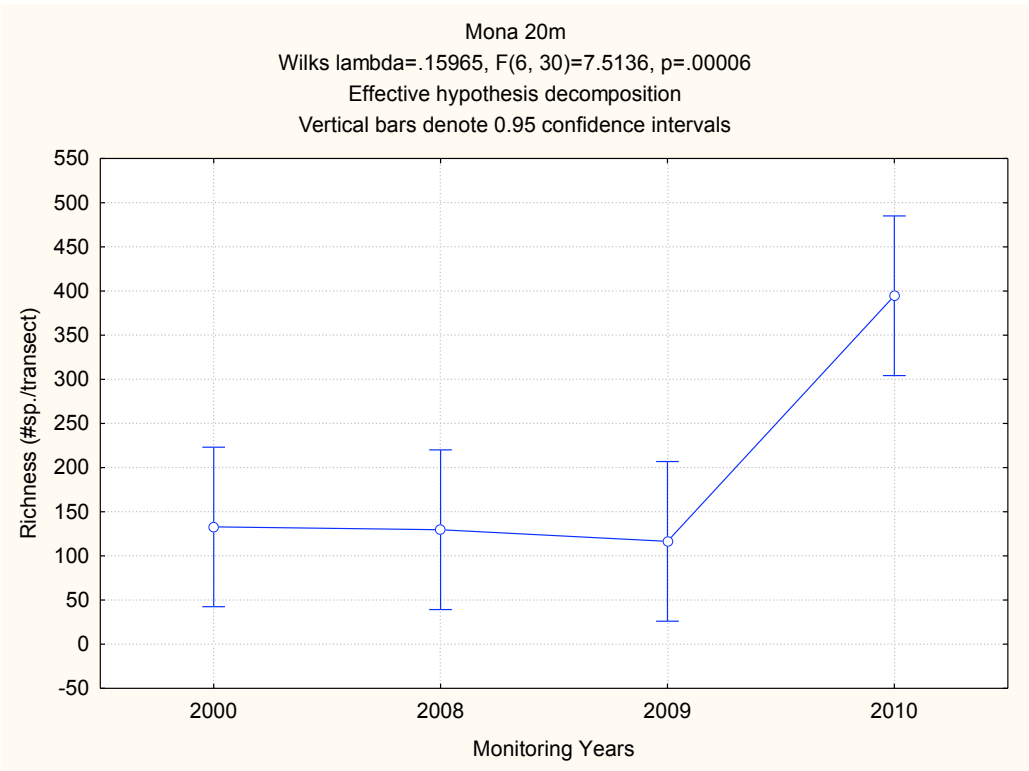

Rincon 20m
Wilks lambda=.17917, F(18, 74.024)=3.4404, p=.00009
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
32
30
28
26
24
22
20
18
16
14
2004
2005
2006
2007
2008
2009
2010
Monitoring Years

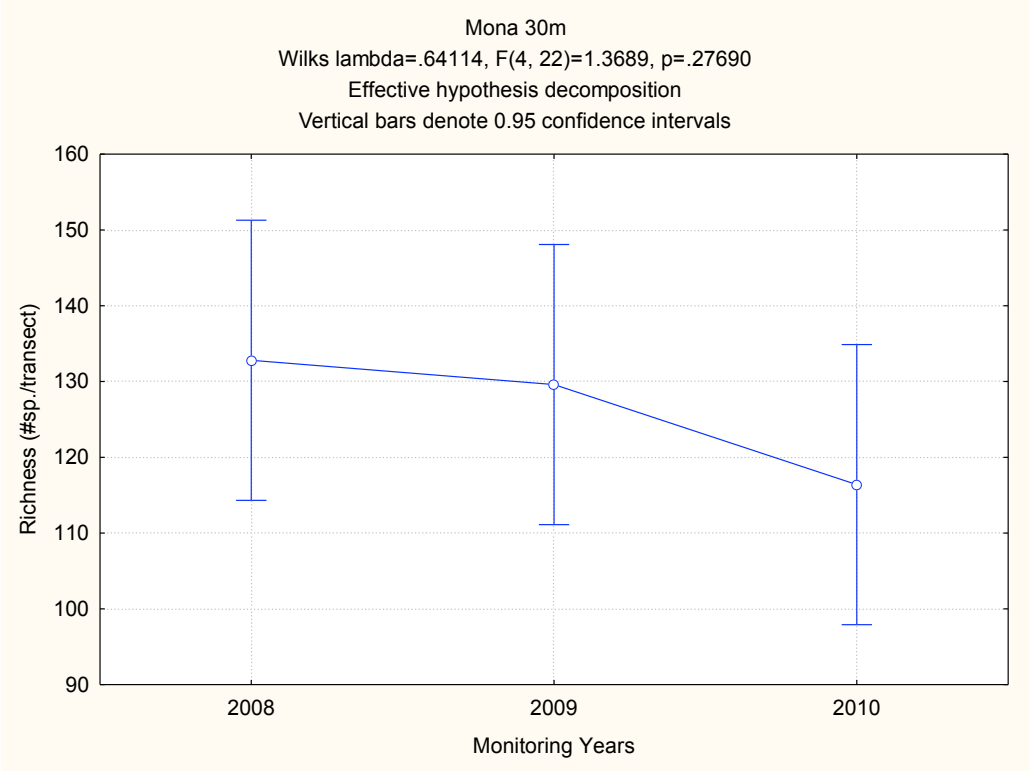

Derrumbadero 20m
Wilks lambda=.18398, F(12, 54)=5.9913, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
30
28
26
24
22
20
18
16
14
12
2001
2005
2006
2007
2008
2009
2010
Monitoring Years


Caja de Muerto
Wilks lambda=.16690, F(12, 54)=6.5150, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
36
34
32
30
28
26
24
22
20
18
16
14
12
10
1999
2005
2006
2007
2008
2009
2010
Monitoring Years

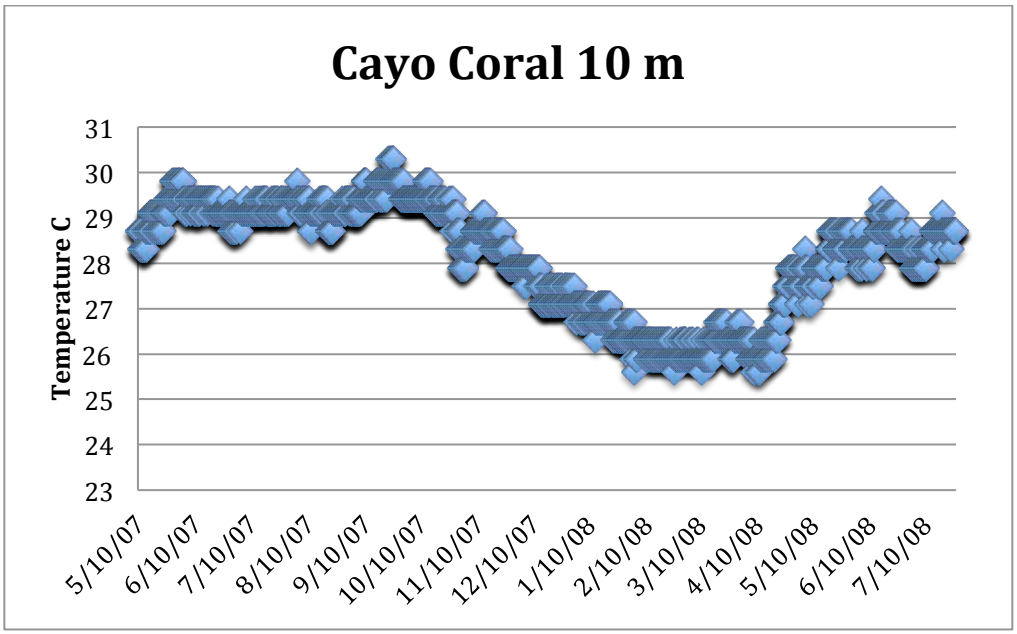

Cayo Coral
Wilks lambda=.16690, F(12, 54)=6.5150, p=.00000
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
32
30
28
26
24
22
20
18
16
14
12
10
8
1999
2005
2006
2007
2008
2009
2010
Monitoring Years

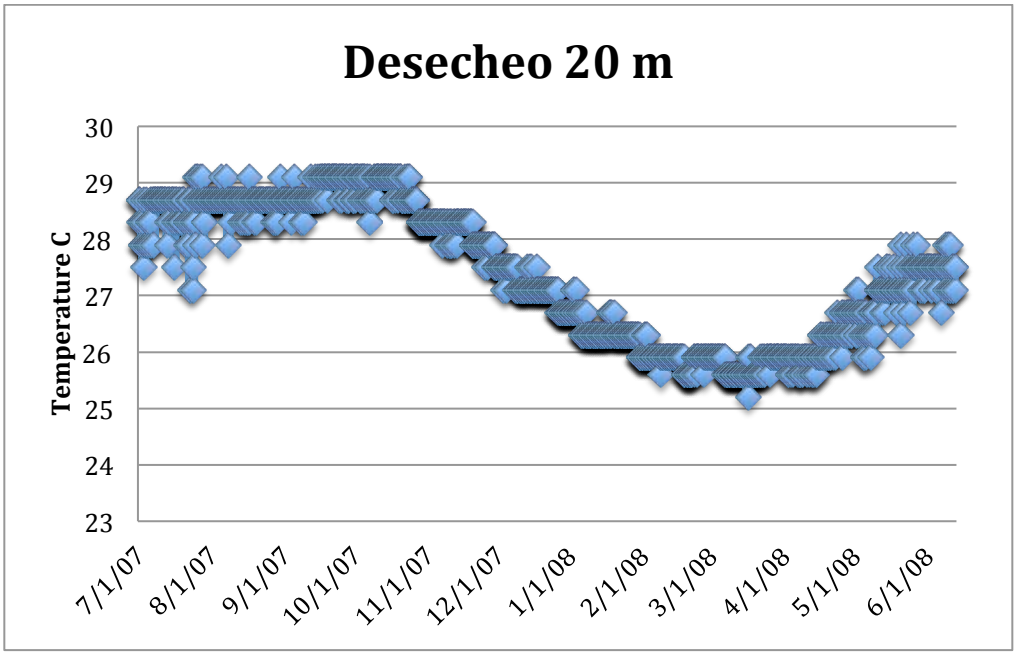

Mona 10m
Wilks lambda=.15965, F(6, 30)=7.5136, p=.00006
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
240
220
200
180
160
140
120
100
80
60
40
20
2000
2008
2009
2010
Monitoring Years

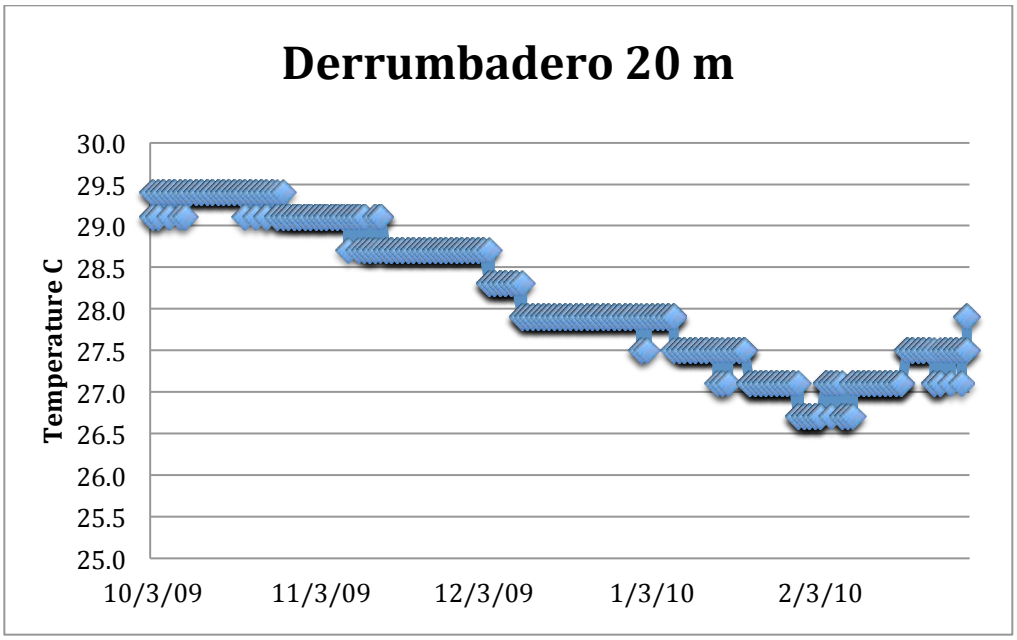

Mona 20m
Wilks lambda=.15965, F(6, 30)=7.5136, p=.00006
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Richness (#sp./transect)
550
500
450
400
350
300
250
200
150
100
50
0
-50
2000
2008
2009
2010
Monitoring Years

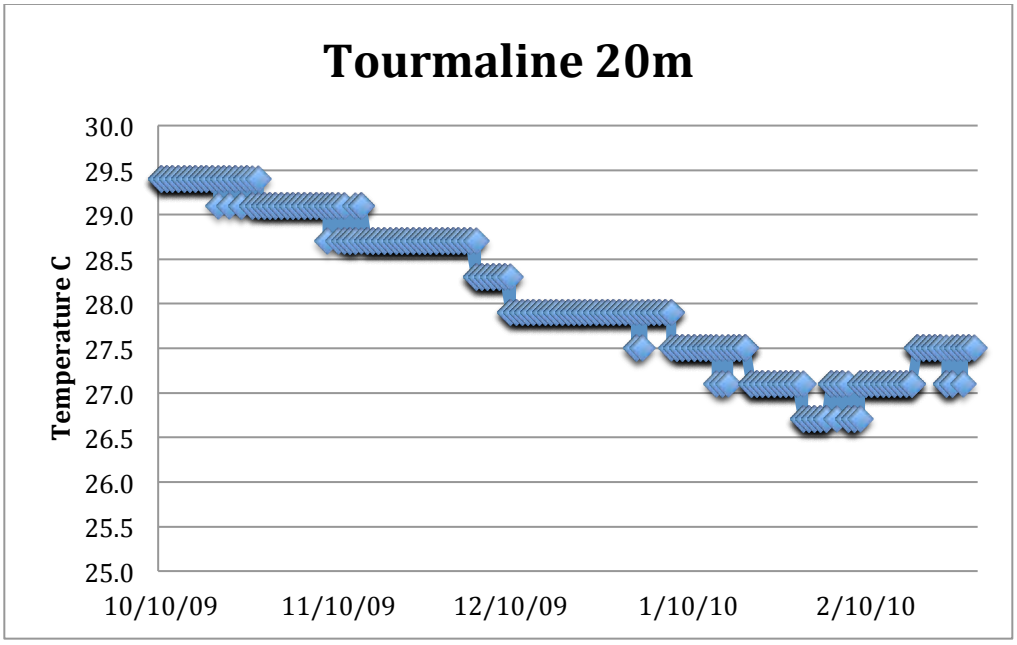

Mona 30m
Wilks lambda=.64114, F(4, 22)=1.3689, p=.27690
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
160
150
140
130
120
110
100
90
Richness (#sp./transect)
2008
2009
2010
Monitoring Years

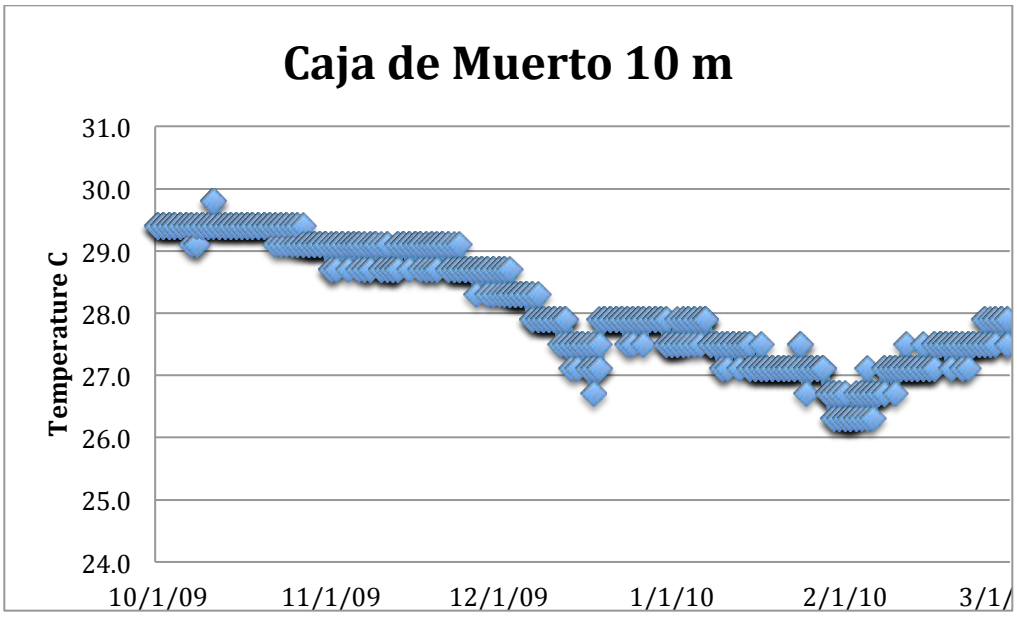
Appendix 5. Water temperature data taken at different reef sites using Onset Hobo Temperature Loggers.






Derrumbadero 20 m
Temperature C
30.0
29.5
29.0
28.5
28.0
27.5
27.0
26.5
26.0
25.5
25.0
10/3/09
11/3/09
12/3/09
1/3/10
2/3/10


Tourmaline 20m
Temperature C
30.0
29.5
29.0
28.5
28.0
27.5
27.0
26.5
26.0
25.5
25.0
10/10/09
11/10/09
12/10/09
1/10/10
2/10/10


Caja de Muerto 10 m
Temperature C
31.0
30.0
29.0
28.0
27.0
26.0
25.0
24.0
10/1/09
11/1/09
12/1/09
1/1/10
2/1/10
3/1/