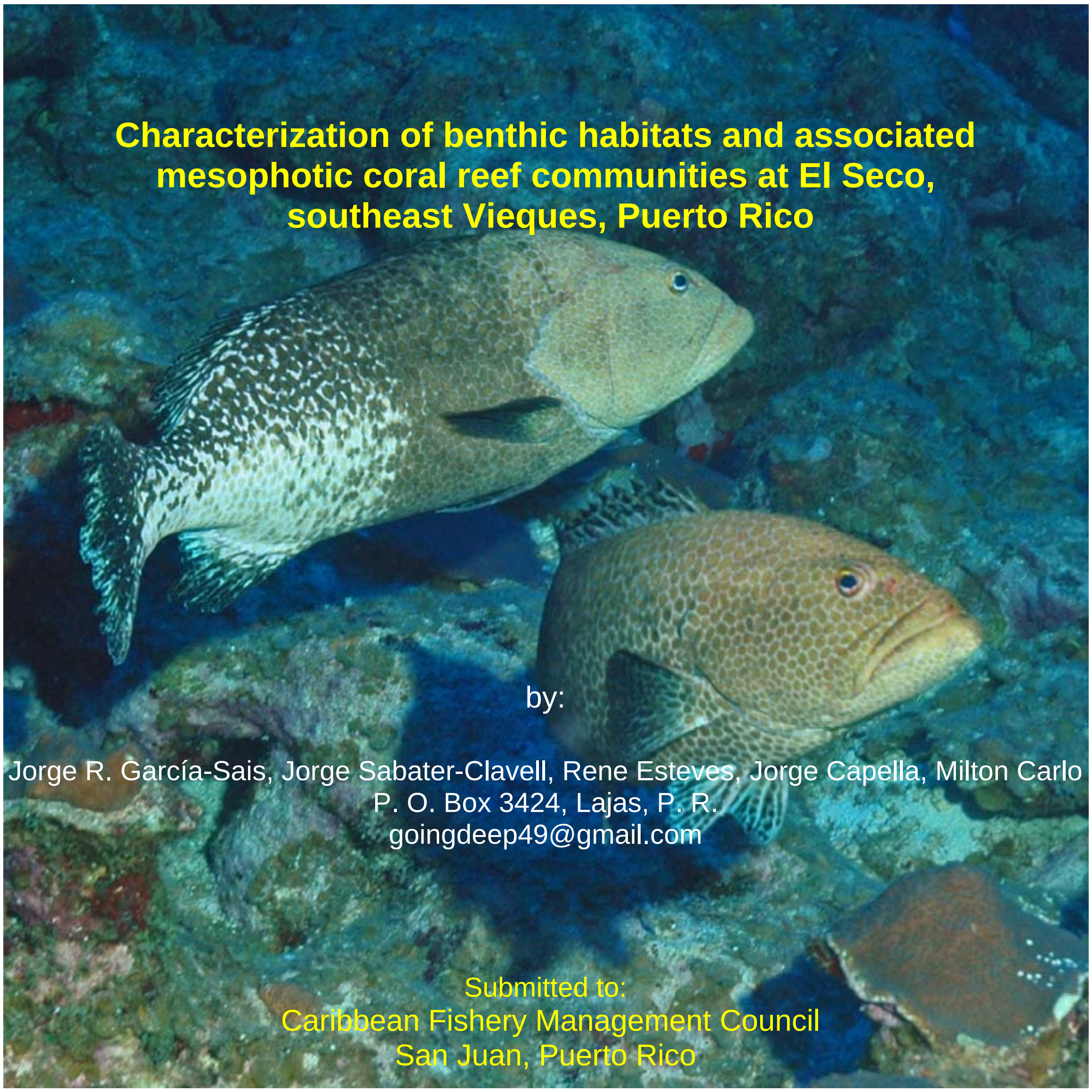
FINAL REPORT



Characterization of benthic habitats and associated mesophotic coral reef communities at El Seco, southeast Vieques, Puerto Rico

by:

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I. Executive summary

This research forms part of an initiative by the Caribbean Fishery Management Council (CFMC) to explore, map and provide quantitative and qualitative characterizations of benthic habitats and associated fish and shellfish communities present within the Caribbean EEZ, Puerto Rico and the USVI, with particular interest on shelf areas that have been seasonally closed to fishing in protection of fish spawning aggregations such as that of tiger grouper (*Mycteroperca tigris*) at "El Seco", Vieques, Puerto Rico.

The main objectives of the study included the construction of a georeferenced benthic habitat map of the mesophotic zone at "El Seco" within a depth range of 30 – 50 m, along with a quantitative, qualitative and photographic characterization of the predominant sessile-benthic, fish and motile-megabenthic invertebrate communities associated with these mesophotic habitats. Production of the benthic habitat map was based on a series of field observations and habitat classifications of the main reef topographic features by rebreather divers, as suggested from a multi-beam bathymetry footprint produced by the R/V Nancy Foster (NOAA). A total of 75 stations were occupied for direct field verification of benthic habitats, including 40 -10 m long transects for determinations of percent cover by sessile-benthic categories and 40 - 20 m long x 3 m wide belt-transects for quantification of demersal reef fishes and motile megabenthic invertebrates. Determinations of densities of each species per belt-transect were recorded.

El Seco, located in the outer shelf of southeast Vieques is an extensive mesophotic ecosystem encompassing a variety of benthic habitats, including a bank coral reef, patch coral reefs, rhodolith reefs and colonized pavements. The bank coral reef habitat is an impressive continuous coral formation growing at depths of 33 – 41 m (110 – 135') throughout the northern and eastern sections of the "El Seco" shelf. While the reef's northern boundary remains yet undetermined, it's known surface area of 3.7 km^2 makes it the largest continuous coral reef habitat of Puerto Rico. With a mean substrate cover of 34.2 %, representing 84.4 % of the total cover by scleractinian corals, *Montastraea franksi,* a sibling species of boulder brain coral (*M. annularis*) represented the keystone species of the bank coral reef ecosystem. It's thick and laminar, table-like growth pattern, supported by pedestals of unknown origin and variable heights contributed highly to the overall reef topographic relief and structural complexity, serving as the main protective microhabitat for reef biota. While *M. annularis* (complex) was one of the most vulnerable species of the late 2005 regional coral bleaching event, *M. franksi* exhibited no signs of historically recent bleaching at El Seco, thereby representing a true genetic reservoir for this coral reef building species.

More than 100 fish species were identified from El Seco, including 76 from mesophotic depths (33 – 40 m) at the bank coral reef habitat. Two fish species with highly aggregated or patchy distributions, creole wrasse (*Clepticus parrae*) and masked goby (*Coryphopterus personatus*) accounted for 57.0 % of the total mean abundance within belt-transects. In addition, blue and yellowhead wrasses (*Thalassoma bifasciatum*, *Halichoeres garnoti),* brown chromis (*Chromis multilineata*), princess parrotfish (*Scarus taeniopterus*), bicolor damselfish

(*Stegastes partitus*), and fairy basslet (*Gramma loreto*) comprised the main small demersal fish assemblage of the bank reef habitat. The bank coral reef was observed to function as the residential and/or foraging habitat of several commercially important large demersal reef fish predators, such as schoolmaster, dog and cubera snappers (*Lutjanus apodus, L. jocu, L. cyanopterus*) tiger and yellowfin groupers (*Mycteroperca tigris, M. venenosa*), red hind (*Epinephelus guttatus*), hogfish (*Lachnolaimus maximus*), and nurse shark (*Ginglymostoma cirratum*), all of which were observed to be abundant in this reef habitat. Migratory pelagics, such as dolphinfish (*Coryphaena hippurus*), wahoo (*Acanthocybium solandri*), tunas and mackerels (Scombridae) and marlins (Istiophoridae) forage the bank coral reef.

A discontinuous formation of patch reefs separated by coralline sand channels prevailed at depths of 40 – 45 m at the southern boundaries of the bank coral reef, covering an estimated surface area of 0.8 km^2. Multivariate analyses detected high resemblance of benthic and fish community structure between patch and bank coral habitats at El Seco. Still, substrate cover by *M. franksi* declined markedly at patch reefs, yielding relatively higher contributions to the total reef substrate cover by lettuce corals (*Agaricia* spp) and boulder brain coral (*M. cavernosa*).

Colonized pavement habitat prevailed throughout the reef top area of "El Seco" ridge at depths between 24 – 33 m, covering an area of 1.4 km^2. A highly heterogeneous benthic community structure was observed at this habitat, where spatially scattered rock outcrops colonized by algae, corals, sponges and other reef biota introduced substantial variability to an otherwise flat, depauperate and mostly abiotic seascape. Fish community structure at the colonized pavement habitat was dissimilar to other habitats due to the high relative abundance of bluehead and yellowhead wrasses (*Thalassoma bifasciatum*, *Halichoeres garnoti*) and bicolor damselfish (*Stegastes partitus*) within belt-transects. The high frequency of sightings of red hinds, yellowtail snappers, queen triggerfish, hogfish and queen conch during visual surveys suggests that the colonized pavement is an important residential and/or foraging habitat for these species, particularly in the vicinity of rock outcrops.

A mostly flat and homogeneous benthic habitat characterized by the predominance of crustose algal rhodoliths prevailed along the entire western section of the study area at depths between 35 – 50 m. Algal rhodoliths were colonized by turf and fleshy algae, scleractinian corals, sponges and other encrusting biota. The areal extension of rhodolith reef habitat was estimated at 8.6 km^2, or 57.9 % of the surveyed area. Both the benthic and fish community structure of the rhodolith reef habitat was significantly different than that from other habitats studied at El Seco. A relatively high substrate cover by benthic algae, relatively low cover by scleractinian corals, and the predominance of lettuce coral, *Agaricia undata* over *Montastraea* spp. were the main factors contributing to dissimilarity between benthic habitats. Despite being one of the most similar or uniform habitats in terms of its sessile-benthic components, the rhodolith reef exhibited high spatial variability in terms of its fish community structure. Fishes were found in very low abundance and many species were observed aggregated in the vicinity of sponges, corals or tilefish mounds not uniformly distributed within the reef. The low fish abundance and the patchy distributions of protective microhabitats introduced the potential for high sampling variability within this reef sub-system. The ichthyofauna of rhodolith reefs consists of a unique assemblage of small demersal fishes adapted to use rhodolith deposits as protective microhabitats, and a reduced array of demersal predators of small to moderate size, such as coneys, red hinds and queen triggerfish. The higher relative abundance of bicolor damselfish, cherubfish and masked goby at the rhodolith reef represented the main species contributions to the dissimilarity with patch and bank coral reefs habitats. It is here suggested that the lack of reef structural complexity and associated availability of large protective microhabitats influenced the comparatively low fish species richness and abundance, and the general absence of large demersal predators at the rhodolith reef habitat.

A highly localized section of the patch reef habitat at a depth of 44 m located southeast of "El Seco" ridge near the shelf-edge served as the seasonal spawning aggregation site for tiger grouper, dog snapper and perhaps several other reef fish species observed there in aggregations during the period of February – April 2011. An aggregation of approximately 300 adult dog snappers, *Lutjanus jocu* was observed engaging in active reproductive behavior at noon during February 16, 2011. This aggregation prevailed at the spawning site until February 19. Tiger groupers, initially comprised by 10 males and two females displaying the distinctive reproductive coloration were observed at the spawning site since February 16, 2011. The peak aggregation reached 120 individuals (mostly males) during the full moon of February 18, but no reproductive activity was observed. A small group of 15 males remained at the spawning site until the full moon of April 2011. In addition to aggregations of dog snapper and tiger grouper, other large demersal predators were observed aggregated at the El Seco spawning site during the period between February and April 2011. These included mutton and cubera snappers (*Lutjanus analis, L. cyanopterus*), and white margate (*Haemulon album*). Aggregations of reef pelagics included permits (*Trachinotus falcatus*) and horse-eyed jacks (*Caranx hippos*). No reproductive activity was observed from these species at the spawning site.

Water currents, including the entire water mass over the outer insular shelf at El Seco exhibited a dominant flow towards the southwest, with velocity vectors pointing towards a westerly direction near the surface and rotating to a southerly heading closer to the bottom in response to bathymetric steering during the period between February – April 2011. Under the prevailing water current direction and velocity conditions, it is suggested that fertilized eggs and early larval stages of dog snapper, tiger grouper and/or any other fishes spawning near the shelf edge off southeast Vieques were transported off the shelf towards the southwest, entering the northern Caribbean current. This current system has the southern shelf of the Greater Antilles as its northern boundary, being Puerto Rico the nearest island from the fish larval source at El Seco.

Table of Contents

II. Introduction

El Seco is a mesophotic coral reef system located at the southeastern end of the Vieques shelf that is known as the spawning aggregation site of the tiger grouper, *Mycteroperca tigris*. Sadovy et al. (1994) initially described the tiger grouper spawning aggregation in 1992 and estimated that approximately 4,900 individuals were harvested that year from El Seco. Matos-Caraballo et al. (2006) monitored local fishermen landings between 1995 through 1998 reaching the conclusion that the tiger grouper stock spawning at El Seco did not present signs of overfishing.

From general qualitative observations of the reef benthic habitat, Sadovy et al. (1994) described the fish spawning aggregation site at El Seco as a coral reef formation dominated by a low relief growth form of boulder star coral, *Montastraea annularis* at depths between 35 – 40 m (115 – 132'). This is the prevailing coral formation of the Marine Conservation District (MCD) reef located off the south coast of St. Thomas, U. S. V. I. (Tyler, 2008), which also functions as a spawning aggregation site for the red hind, *Epinephelus guttatus* (Beets and Friedlander, 1997; Nemeth, 2005, Nemeth et al. 2007). A similar coral formation, although from a much smaller coral reef system was previously described for Black Jack Reef at the shelf-edge off south Vieques by García-Sais et al. (2004; 2008 a).

Aside from its relevance as a spawning aggregation site for a commercially important fish species, it is likely that El Seco may be part of the largest and deepest mesophotic coral reef system constructed by boulder star coral in Puerto Rico. This coral, which was the most dominant in terms of percent substrate cover by live corals in many of the best developed reefs of Puerto Rico has suffered an acute degradation in Puerto Rico and the U. S. Virgin Islands after the regional coral bleaching event of 1995 (García et al. 2005 a, 2008 a; Rothenberger et al. 2008). Only two years after the marked degradation of reef live coral cover associated with the bleaching mortality a pronounced decline of the number of fish species present within belt-transects from nine reefs included in the Puerto Rico coral monitoring program has been noted (García-Sais et al., 2008 b.). Evidence of severe reef degradation associated with a disease outbreak affecting *M. annularis* complex from a mesophotic reef system located south of St. John, U. S. V. I. was reported by Menza et al. (2007). Likewise, an extreme disease event that affected 47% of the coral reef basin habitat at the MCD was reported by Smith et al. (2010).

The CFMC through the Coral Reef Conservation Grant Program is working toward the mapping and characterization of mesophotic reef systems in the U.S. Caribbean EEZ. The Magnuson-Stevens Act calls for the description and specifically the mapping of EFH. Research recently completed on Isla Desecheo (García-Sais et al., 2005b), Bajo de Sico (García-Sais et al., 2007), Abrir La Sierra (García-Sais et al., 2009) and the St. Thomas, USVI MCD reef (Nemeth et al. 2008, Smith et al., 2008; Rothenberger et al., 2008) have contributed to the location and mapping of mesophotic reefs, and have demonstrated that these systems represent important residential and foraging habitats, as well as spawning aggregation sites for a variety of commercially important demersal reef fishes that have virtually disappeared from shallow reef systems. In addition, coral species that have been severely impacted and are presently vulnerable to bleaching events associated with increasing water temperatures in shallow reefs, such as *M. annularis* (complex) have been protected from the bleaching effects in mesophotic reefs until present. Thus, mesophotic reefs also represent genetic reservoirs for these coral species and associated biota.

This investigation provides a description of the benthic habitat types, a map of their spatial distribution within a 10 km^2 around El Seco reef, and a quantitative and qualitative characterization of the predominant sessile-benthic and fish community associated to each habitat. A particular focus of this research was initially directed towards an assessment of the tiger grouper, *Mycteroperca tigris* seasonal spawning aggregation, but includes as well observations of other fish species aggregating to spawn at this location concurrent with the tiger grouper aggregation.

The Caribbean Fishery Management Council (CFMC) subcontracted with Principal Investigator Dr. Jorge R. García-Sais and other personnel to carry out the proposed work herewith. Mrs. Maria A. Irizarry and Graciela García-Moliner (both from the CFMC) serve as the study Fiscal Administrator and Point of Contact (POC), respectively.

III. Scientific Background

Characterizations of reef habitats and associated sessile-benthic and fish communities at depths between 30 – 100 m (mesophotic) are rare in the Caribbean, and mostly available from submersible surveys. Colin (1974; 1976) described the taxonomic composition of reef fishes at depths between 90 – 305 m off the coasts of Jamaica, Belize and the Bahamas as a mixed assemblage of shallow reef (< 30 m) and true "deep-reef" species seldom present shallower than 50 m. Colin (1974) argued that the vertical distribution of some reef fish species was more related to local environmental conditions (habitat features) than depth, and noted ontogenetic trends in the vertical distribution of "deep-reef" species, where juvenile stages were typically observed at shallower depths than adults. In Puerto Rico, the Seward Johnson- Sea Link submersible survey (Nelson and Appeldoorn, 1985) provided a qualitative characterization of benthic habitats and associated fishes of the insular slope, encompassing depths between 100 – 1,250 m. Despite observations of a "rich and highly complex" reef fish community associated with the upper insular slope (30 – 100 m), these habitats were left virtually undescribed by the Seward Johnson - Sea Link survey.

Most of the research attention on mesophotic and deeper reef communities in the U. S. Caribbean Economic Exclusive Zone (EEZ) has been focused toward fishery resources. Assessment surveys of the deep sea snapper and grouper fisheries potential were performed during the late 70's and throughout the 1980's by the National Marine Fishery Service in collaboration with the local governments of Puerto Rico, U. S. Virgin Islands and the Caribbean Fishery Management Council (Juhl, 1972; Silvester and Dammann, 1974; Collazo, 1980; NOAA, 1979,1980, 1981, 1982, 1983, 1984, 1985, 1987; Appeldoorn, 1985; Nelson and Appeldoorn, 1985; Rosario, 1986). These surveys consisted of at least 11 cruises, including the Seward Johnson-Sea Link II submersible survey of the insular slope of PR and the U.S. Virgin Islands in 1985. Despite the generalized conclusion from these surveys that deep sea fish stocks were depauperate, deep sea snapper fisheries still represent a main fisheries resource in terms of catch and value in the U. S. Caribbean. Surprisingly, our understanding of the life histories, reproductive biology, feeding ecology and habitat preferences of deep sea snappers and groupers is still very limited and constrains our ability to manage the resource.

The Seward Johnson-Sea Link II submersible survey provided an unprecedented and exceptional insight of our deep-sea reef communities at depths between 100 – 450 meters. Whereas observations about a rich and highly complex reef community near the top of the insular shelf appear in the Seward Johnson-Sea Link II report (Nelson and Appeldoorn, 1985), mesophotic reef communities were left undescribed. Thus, a major gap in our basic knowledge of our mesophotic and deep reef communities on the insular slope still exists and needs to be addressed. Highly valuable reef fish populations, including snappers and groupers undertake massive aggregations and spawn at the shelf-edge. Out of their spawning season, the catchability of these species is drastically reduced possibly due to their migration down the insular shelf. Observations of red hinds, other groupers and reef snappers at these deep reef habitats were made by the Seward Johnson-Sea Link II survey (Nelson and Appeldoorn, 1985). Therefore, the relevance of the mesophotic reef habitat as a refuge for important reef fishery resources deserves further evaluation.

Deep reef sessile-benthic and motile megabenthic communities were studied as part of fishery assessment exploratory surveys performed during the 1980's in Puerto Rico and the Virgin Islands (NOAA, 1980; 1985). The information is mostly limited to taxonomic listings from incidental collections by fish traps, shrimp trawls and coral entanglement devices. Most of the information available on black corals from Puerto Rican reefs goes back to the exploratory work by Goenaga (1977), which included taxonomic descriptions of two new species of *Stichopathes* (Zoantharia: Antipatharia) and observations on their distribution, reproduction and growth. Underwater photographic documentation of deep reef communities is also limited to the Seward Johnson-Sea Link II submersible survey which does not include the upper reef slope communities.

Initial quantitative assessments of reef substrate cover by sessile-benthic communities from mesophotic reef habitats in the Caribbean include the autonomous underwater vehicle (AUV) surveys of the La Parguera shelf-edge (Singh et al., 2004) and the Marine Conservation District (MCD) coral reef system of St. Thomas, USVI (Armstrong et al., 2006). Menza et al. (2007) reported on coral taxonomic composition, percent substrate cover, and recent degradation of a mesophotic coral reef system (MSR-1) dominated by *Montastraea annularis* (complex) on the outer shelf south of St. John, USVI using video and still camera images dropped from the NOAA R/V Nancy Foster. The aforementioned studies identified mayor differences of sessile-benthic community structure associated with the various mesophotic habitat types and depth gradients, but lack inferences about their reef fish communities. Beets and Friedlander (1997) and Nemeth (2005) conducted quantitative surveys of the red hind (*Epinephelus guttatus*) population within the MCD, a known spawning aggregation site for this species. These studies provided a baseline and an assessment of the effectiveness of the closed fishing regulation for the recovery of the red hind population within the MCD, but do not include information on fish - habitat associations for other species. A more general description of the fish community at the MCD from AGRRA surveys is available from Nemeth et al. (2008).

García-Sais et al. (2004) performed a snapshot (one-dive) survey of reef fish abundance and sessile-benthic substrate cover measurements from Black Jack Reef, a mesophotic coral reef in the south coast of Vieques. Most of the 54 fish species observed within a depth range of 35 - 40 m were common shallow (< 30 m) reef species previously reported from reefs systems surveyed by García-Sais et al. (2004) within the neritic shelf of Vieques. Notable exceptions to the shallow reef assemblage were the presence of adult tiger groupers (*Mycteroperca tigris*) and mutton snappers (*Lutjanus analis*). Recent surveys of fish communities associated with mesophotic reefs in Puerto Rico have highlighted the relevance of these systems as habitats for large groupers and snappers, as well as foraging habitats for queen conch (*Strombus gigas*) and proposed management alternatives for their protection (García-Sais et al. 2005 b, 2007, 2009). Quantitative assessments of sessile-benthic, motile megabenthic invertebrate and fish populations from mesophotic reefs in Puerto Rico are limited to the NMFS-CFMC sponsored studies of Isla Desecheo, Bajo de Sico, and Abrir La Sierra (García-Sais et al. 2005 b, 2007, 2009) in Puerto Rico, and the work of Nemeth et al. (2008) and Smith et al. (2010) at the Marine Conservation District (MCD) reef south of St. Thomas, USVI.

Mesophotic reef habitats and associated sessile-benthic and fish assemblages were studied by direct diver observations using rebreathers across a 15 – 50 m depth gradient at Isla Desecheo, Mona Passage (Garcia-Sais, 2010). Statistically significant differences between depths were found for total live coral, total coral species, total benthic algae, total sponges and abiotic cover. Live coral cover was higher at the mid-shelf (20 m) and shelf-edge (25 m) stations, whereas benthic algae and sponges were the dominant sessile-benthic assemblage at mesophotic stations below 25 m. Marked shifts in the community structure of corals and benthic algae were observed across the depth gradient. Star corals, *Montastraea* spp. prevailed down to a maximum depth of 40 m, whereas lettuce corals, *Agaricia* spp, were dominant at 50 m. Turf algae were the dominant assemblage at (euphotic) shelf stations (15, 20, 25 m), but fleshy algae (mostly *Lobophora variegata*) prevailed in terms of reef substrate cover at mesophotic stations (30, 40, 50 m). A total of 119 diurnal, non-cryptic fish species were observed across the depth gradient, including 80 within belt-transects. Fish species richness and abundance were positively correlated with live coral cover, but the relationship between total fish abundance and live coral was weak. Abundance of several numerically dominant fish species including the bluehead wrasse, *Thalassoma bifasciatum* varied independently from live coral cover and appeared to be more influenced by depth and/or habitat type. Statistically significant differences in the rank order of abundance of fish species at euphotic vs. mesophotic stations were detected (Garcia-Sais, 2010). A small assemblage of reef fishes that included the cherubfish, *Centropyge argi*, sunshine chromis, *Chromis insolata,* greenblotch parrotfish, *Sparisoma atomarium*, yellowcheek wrasse, *Halichoeres cyanocephalus, sargassum triggerfish, Xanthichthys ringens,* and the longsnout butterflyfish, *Chaetodon aculeatus* were most abundant and/or only present from stations deeper than 30 m, and thus appear to be indicator species of mesophotic habitats. Mesophotic reefs, particularly rhodolith reef habitats are also known to be prime foraging grounds for the queen conch, *Strombus gigas* (Garcia-Sais et al., 2009).

Smith et al. (2010) mapped the main benthic habitats and described the predominant benthic populations at the MCD, an extensive mesophotic coral ecosystem in St. Thomas, USVI. Two-thirds of the MCD (23.6 km^2) reef substrate cover was found to be continuous growth of boulder star coral, *Montastraea annularis* complex. Other coral reef habitats reported for the MCD by Smith et al (2010) include an extremely flat basin reef, and a highly rugose hillock basin with coral knolls. This reef system is known to support a large population of red hind and other commercially important groupers and snappers, some of which seasonally aggregate to spawn at this reef (Nemeth, 2005; Nemeth et al., 2007; Rothenberger et al., 2008).

IV. Study Objectives:

1) Provide a baseline quantitative and qualitative characterization of the sessile-benthic, motile-megabenthic invertebrate and demersal fish communities associated with the principal mesophotic reef habitats within a depth range of 30 – 50 m at El Seco Reef.
2) Construct a digitized map of the benthic habitats at El Seco Reef based on direct diver observations down to depths of 50 m.
3) Provide a fisheries-independent assessment of the abundance and size frequency distributions of commercially important and transitory fish species associated with mesophotic (30 – 50 m) reef habitats at El Seco
4) Provide an assessment of the tiger grouper (*Mycteroperca tigris*) population during their annual spawning aggregation at El Seco Reef.
5) Prepare a digital photographic and video album of deep reef communities from El Seco Reef

V. Methods

1.0 Study Site

"El Seco" is a submerged promontory, or ridge that rises from a deep outer shelf basin at the southeastern tip of the Vieques shelf, approximately 6 km from Punta del Este. The promontory with an elliptical shape runs along a north-south axis and rises from the basin at depths of 33 – 36 m to a mostly flat hard ground reef top at depths of 23 – 28 m (Figure 1). Approximately 0.93 km to the southeast margin of "El Seco" ridge, the seasonal spawning aggregation of the tiger grouper, *M. tigris* has been reported. Mesophotic reef habitats are distributed all around the "El Seco" ridge within the deep outer shelf of southeastern Vieques. Depth increases towards the shelf-edge to the east and south of the ridge, and decreases towards the north, where an extensive mesophotic coral reef system was discovered. The northern boundary of this reef falls out of our study area and is yet undescribed. The mesophotic coral reef system ends as patch reef spurs separated by coralline sand pools at depths between 40 – 45 m. The deepest sections of the shelf basin at depths between 45 – 53 m were found associated with flat and homogeneous bottom topography to the west and south of the ridge. Exceptionally clear waters prevail at "El Seco" with underwater visibility generally exceeding the 30 - 40 m range.

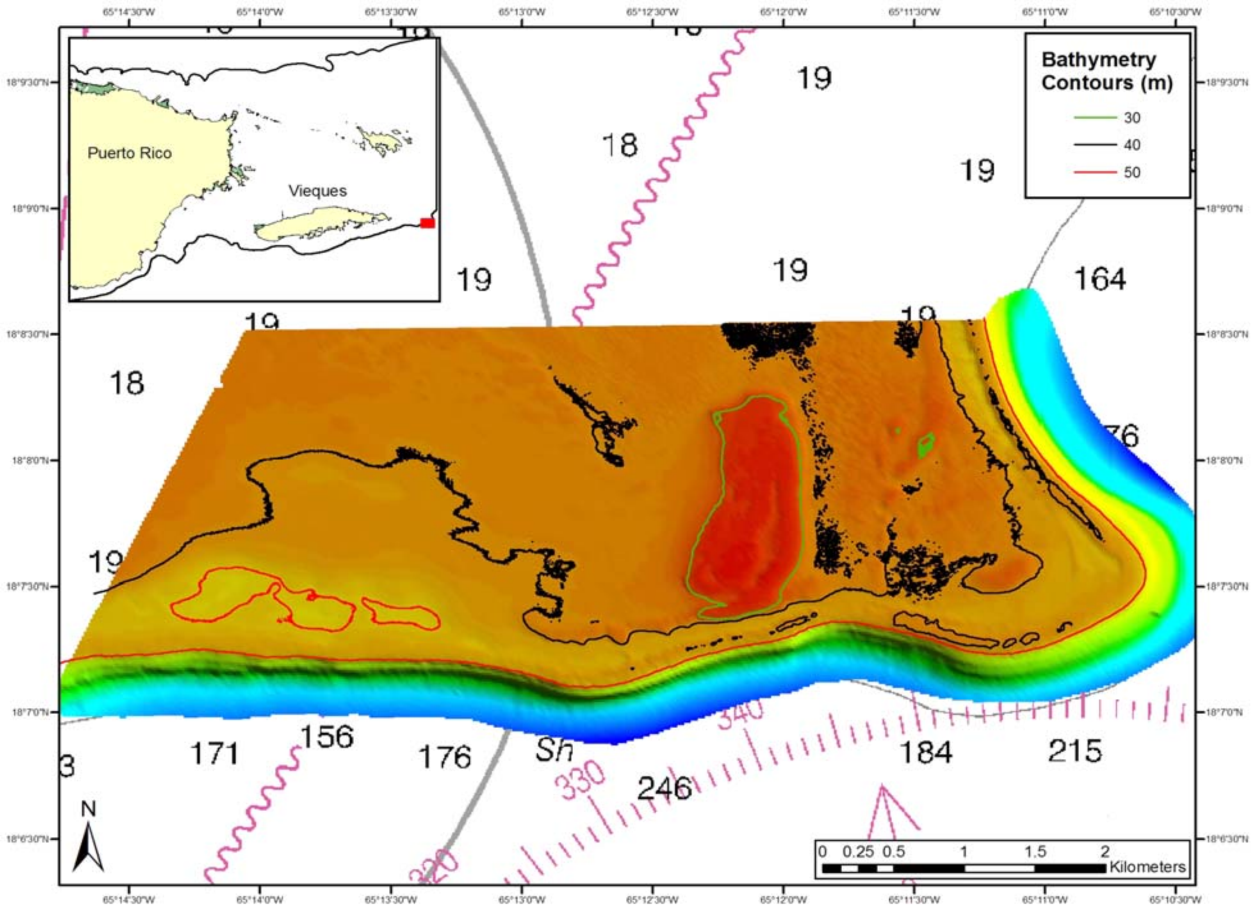


Figure 1. Multibeam bathymetry map of the study area at the southeastern section of the Vieques Island shelf. Multibeam data from NOAA Biogeography Team.

2.0 Benthic Habitat Mapping

The multibeam bathymetric survey of the southeast coast of Vieques prepared by NOAA's Biogeography Team aboard the R/V Nancy Foster (Figure 1) was used as the main footprint in preparation of the benthic habitat map. Benthic habitat transitions at El Seco were generally characterized by particular topographic features of the seafloor recognized from the multibeam bathymetry and derived rugosity values. These included: 1) a ridge with an elliptical shape and a mostly flat reef top extending approximately 1.8 km from north to south along the eastern section of the study area; 2) a zone of continuous corrugated topography around the eastern, northern and northwestern side of the ridge; 3) a diffuse pattern of seafloor topographic discontinuities at the southern edges of the corrugated footprint; and 4) an extensive area of mostly deep, flat and homogeneous bottom topography. The shelf-edge, bordering the eastern and southern sections of the study area was another evident topographic seafloor feature within our study area, and perhaps characteristic of particular benthic habitat type(s), but was found deeper than our maximum diving depth limit of 50 m. A series of exploratory bounce dives were initially scheduled to match the different topographic footprints with benthic habitat types.

Within each field verified habitat type, a series of at least 10 sampling stations were haphazardly selected and transects for quantitative characterizations of the prevailing biota executed at each station. Dives for quantitative biological characterizations were used to supplement the benthic habitat map. Additional bounce dives were specifically georeferenced to verify apparent benthic habitat boundaries and smaller scale topographic anomalies within larger topographic footprints. Due to technical problems with rebreather units during the latter part of the study, additional coverage of the seafloor habitats in support of the benthic habitat mapping efforts were accomplished using a Go-Pro drop camera. Station positions for the drop camera survey were selected to provide a wider geographical coverage of the study area, in particular to verify habitats within the deeper sections. A total of 75 field verifications of benthic habitats within the 10 km^2 study area were executed (Figure 2). The exact station geographic position, depth, habitat type, and additional observations are included in Appendix 1.

3.0 Water Currents and Temperature Measurements

In an effort to provide an assessment of potential trajectories of fertilized eggs and early larvae of fish species aggregating to spawn at "El Seco" an RD Instruments 600 KHz Workhorse Sentinel Acoustic Doppler Current Profiler (ADCP) was installed (Plate 1). The ADCP deployment data is shown in Table 1. ADCP location (Figure 3) corresponds to the tiger grouper spawning aggregation geographic coordinates provided by the CFMC. Dives at the spawning site were performed to verify the presence of tiger grouper aggregation before deployment. The duration of the ADCP deployment was from the week before the full moon of February to the week after the full moon of April 2011. A continuous measurement of water temperature near the bottom of the water column (e.g. 47.0 m) was obtained with a Hobo-Temp installed adjacent to the ADCP. The Hobo thermistor recorded temperature during the period between June 14, 2010

Table 1. ADCP current meter deployment data at El Seco, Vieques. Depth in meters relative to MLLW.

Event	Start	End	Lat	Lon	Bottom Depth	Xducer Depth	6% Xducer Depth
VeS01	16-Feb-11	17-Apr-11	18° 7.402'N	65° 11.437'W	42.1 m	41.8 m	2.5 m

and April 18, 2011. Water column profiles of water temperature, salinity and temperature were taken with a Seabird Electronics CTD, Model 1.

The RDI Sentinel ADCP has a beam angle of 20°, which restricts useful data to depths greater than 6% (= 1 – cos (20°) of the transducer depth (Xducer Depth in Table 1). In other words, the ADCP does not provide good data close to the sea surface. There is also a "blank" depth range right above the ADCP transducer, which is documented in Table 2. At a bottom depth of 42 m the 600 kHz ADCP provided usable data in the depth range of 3.7 – 39.7 meters (bin center depths), which by taking into account the bin depth limits becomes 3.2 – 40.2 meters (top of first bin to the bottom of the last bin). The ADCP was configured to sample 45 bins, 37 of which were below the 6% depth level indicative of good velocity data.

Table 2: Sentinel ADCP configuration at El Seco, Vieques.

Bin size	1.0 m
Currents and tide sampling interval	15 minutes
Pings per sampling interval	300
Standard deviation (ADCP only)	1.0 cm/s
Distance to center of deepest bin	2.12 m

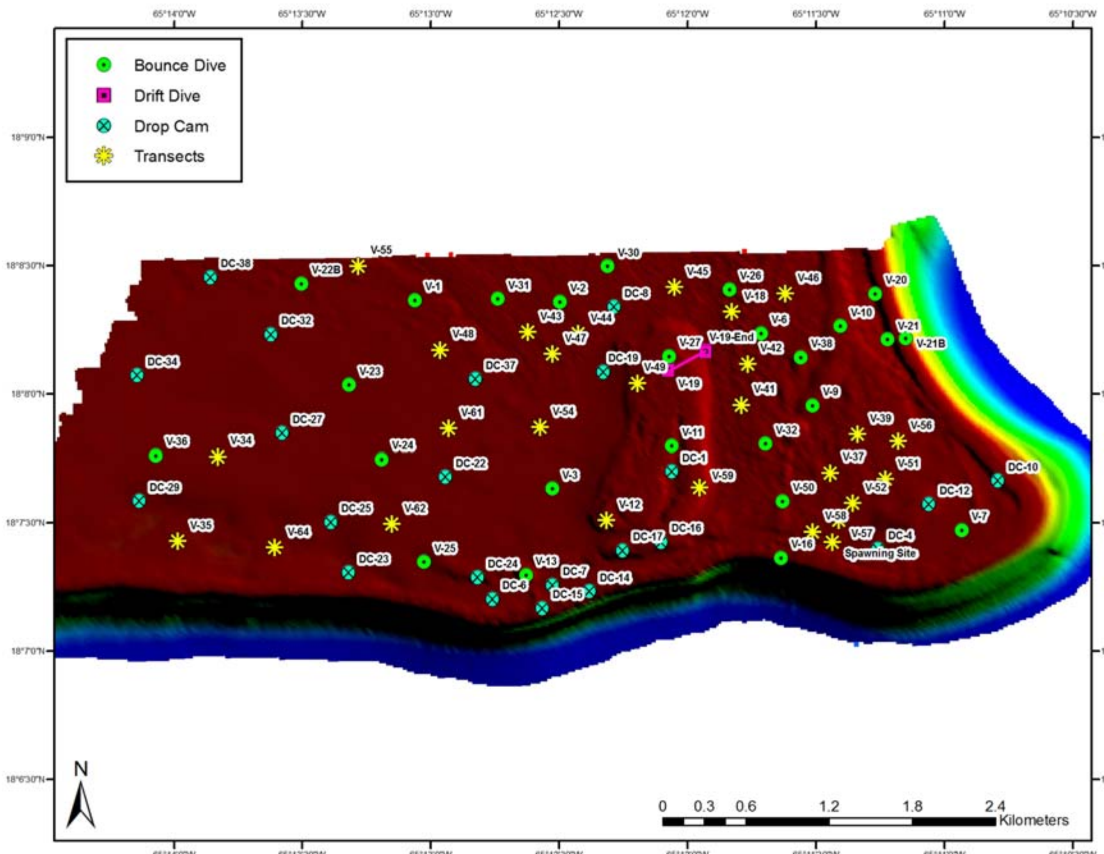


Figure 2. Map of the study area at “El Seco” showing location of sampling stations.

Plate 1. ADCP deployment in the seasonal tiger grouper spawning aggregation site at El Seco, February 2011. Depth: 42.1 m

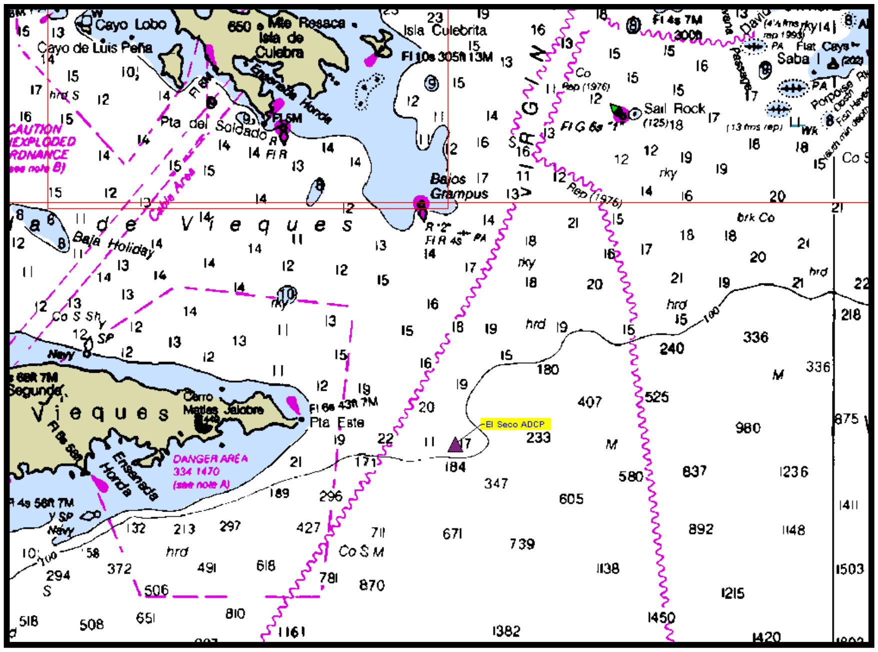


Figure 3. Location of an ADCP meter at the seasonal tiger grouper spawning site, southeast Vieques.

4.0 Biological Characterization of Mesophotic Reef Communities

Benthic habitats within the study area were quantitatively characterized by a series of 10 replicate transects for determination of percent substrate cover by sessile-benthic substrate categories and taxonomic composition and abundance of fishes and megabenthic invertebrates. Qualitative characterizations included identifications of predominant biota outside transects within each station. Location of transects for sessile-benthic substrate categories, invertebrates and fish community characterizations are presented in Figure 2. Additional transect station information has been included as Appendix 1.

4.1 Sessile-Benthic Community

Quantitative determinations of reef substrate cover by sessile-benthic categories were accomplished from analyses of 10 digital images (photos) of the habitat substrate per each 20 m long transect. Each transect was photographed using a Nikon D70 digital camera with an Aquatica housing maintaining a constant distance between the camera and the seafloor. Ten (10) non-overlapping digital photos of each transect were obtained representing each an area of approximately 0.9 m^2. A template of 25 random points was overlaid over each photo image and the proportion of each substrate category over the total number of points determined with the "Coral Point Count" software (Kohler and Gill, 2006). Panoramic photos and videos of the reef habitats were taken to supplement benthic habitat characterizations.

Substrate classifications included the following:

- **Live corals** – reported by species, density of colonies and percent substrate cover, also includes stony hydrocorals and black corals (e.g. *Montastrea cavernosa*, *Stichopathes sp.)*
- **Octocorals** -(soft corals) reported by species, density of colonies and percent substrate cover, includes sea fans, such as *Iciligorgia sp.*, sea whips, and encrusting forms, such as *Erythropodium* sp.)
- **Sponges** –density of colonies and percent substrate cover by species or lowest possible taxon
- **Zoanthids** – density of colonies and percent substrate cover by species or lowest possible taxon
- **Algal Turf** – percent substrate cover reported for a mixed assemblage of short algae intermixed with other small epibenthic biota forming a mat or carpet over hard substrate
- **Calcareous Algae** – percent substrate cover reported for total calcareous algae, or lowest possible taxon
- **Fleshy Algae** – percent substrate cover reported as total fleshy algae, or lowest possible taxon for vertically projected, mostly brown, red and green macroalgae
- **Abiotic Substrate** – percent substrate cover by unconsolidated sediment, bare rock, deep holes, crevices and gaps.

4.2 Characterization of Fishes and Motile Megabenthic Invertebrate

1. Small Demersal Fishes

Demersal non-cryptic reef fish populations and motile megabenthic (> 5 cm) invertebrates were surveyed from 10 m long by 3 m wide (30 m^2) belt-transects centered over the reference line of transects used for sessile-benthic reef characterizations. Location of transects are shown in Figure 2. Fish species saturation curves were constructed from the set of ten transects at each depth. Data and curves for benthic habitats surveyed are presented in Table 3 and Figure 4. For all benthic habitats, the 95% or higher species saturation was reached by the 9^{th} transect.

Each transect was surveyed during ten to twelve (10-12) minutes, subject to the richness and abundance encountered. The initial two minutes focused on elusive and/or transitory species that could swim away of the "belt-transect" area upon detection of a diver (e.g. snappers, large groupers, hogfish, mackerel, large parrotfishes, etc.). During the next two minutes, the diver swam over the center of the transect counting fishes attracted to divers, such as wrasses and butterflyfishes (e.g. *Thalassoma, Halichoeres spp*., *Chaetodon spp*.). Then, fishes that form schooling aggregations at less than 3 meters over the reef (e.g. *Chromis spp., Clepticus parrae, Bodianus*, etc.) and other transitory species were counted as they entered the belt-transect area. Runs over both sides of transects were performed during the last four-six minutes of the survey area in order to enumerate demersal and territorial fishes (e.g. *Stegastes* spp, *Gramma loreto*, squirrelfishes, etc.) that remain within the transect area. Fish species observed outside transect areas were reported to supplement the taxonomic assessment, but were not included in density (abundance) determinations.

2. Large Transitory Fishes

Transitory pelagic and other large demersal but elusive fishes that usually represent the commercially important assemblage are characterized by a series of 10 - 20 m long x 3 m wide (area: 60 m^2) belt-transects centered over the reference line of transects used for sessile-benthic reef characterizations. Survey of these transects preceded any other sampling activities in the reef in order to obtain the most accurate information regarding densities of these large fishes in their natural environment. All fishes of commercial

Table 3. Fish species saturation data from 20m x 3m belt-transect surveys at each benthic habitat

Transects	Patch Reef Spp	%	Coral Reef Spp	%	Colonized Pavement Spp	%	Rhodolith Reef Spp	%
1	21	35.6	17	34.7	13	34.2	3	15.0
2	27	45.8	30	61.2	20	52.6	6	30.0
3	34	57.6	32	65.3	25	65.8	9	45.0
4	41	69.5	39	79.6	26	68.4	10	50.0
5	46	78.0	41	83.7	31	81.6	11	55.0
6	50	84.7	41	83.7	34	89.5	15	75.0
7	50	84.7	42	85.7	35	92.1	17	85.0
8	54	91.5	44	89.8	36	94.7	18	90.0
9	57	96.6	47	95.9	36	94.7	19	95.0
10	59		49		38		20	

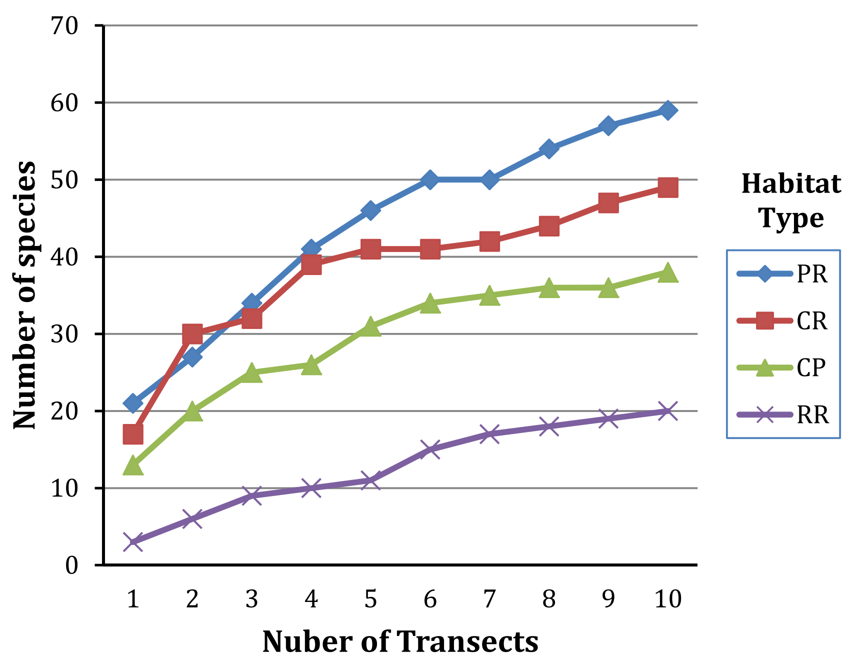


Figure 4. Fish species saturation curves from the series of 10 - 20m x 3m belt-transect surveys at each benthic habitat: Patch Reef (PR); Coral Reef (CR); Colonized Pavement (CP); Rhodolith Reef (RR)

value were targeted by this sampling approach, with particular attention to large demersal reef snappers, groupers and hogfish, but also included reef pelagics, such as sharks, mackerels, jacks, barracudas and others present within three (3) meters above the reef substrate. A size estimate of each fish was made in order to provide size frequency assessments for each species present. Large megabenthic invertebrates of commercial value, such as lobsters and conch were included in the survey.

4.3 Tiger grouper spawning aggregation

In situ observations and video records of the tiger grouper (*Mycteroperca tigris*) aggregation were performed during the full moons of February, March and April, 2011. The schedule of dive observations and sea conditions at the spawning site is shown in Table 4. The main goal was to provide reliable estimates of fish abundance at the aggregation. Direct observations by divers were concentrated within an area of 1 km^2 around the geographic coordinates provided by the CFMC based on previous information of tiger grouper spawning aggregations on that site. The exact position of fish aggregations in the water column was detected with a dual frequency ecosounder on board. A series of reconnaissance dives were executed in the immediate vicinity and similar habitat of the spawning site to verify that no further fish aggregations were taking

Table 4. Schedule of observations at the tiger grouper spawning site and prevailing sea conditions

Date	Moon Phase	Work	Wave height (m)	Wind Speed (km/h)	Wind Gust (km/h)	Wind Direction	Water Temp **°C**
2/16/2011	- 2 days	ADCP, CTD	1	19.3	27.4	ESE	26.26
2/16/2011	- 2 days	Video	1	19.3	27.4	ESE	26.26
2/17/2011	- 1 day	Video/Photos	1	19.3	32.2	East	26.28
2/18/2011	Full Moon	Video	1	11.3	19.3	SE	26.26
2/19/2011	+ 1 day	Video/Photos	1	17.7	27.4	NNE	26.21
3/18/2011	- 1 day	Video/Photos	2	19.3	33.8	North	25.67
3/18/2011	- 1 day	Video	2	19.3	33.8	North	25.67
3/19/2011	Full Moon	Video	2	22.5	40.2	North	25.67
3/20/2011	+ 1 day	Video	3	27.4	46.7	North	25.62
4/19/2011	+ 1 day	Video	1	17.7	29	North	25.94

place in the vicinity of the tiger grouper spawning site. Underwater videos were taken as to fit the entire spawning aggregation in several images and allow enumeration of individuals. Particular attention was addressed to evidencing egg and sperm release from the spawning aggregation. Still digital photos were taken of the fish individuals and fish aggregations at the spawning site.

VI. RESULTS AND DISCUSSION

1.0 Physical measurements

1.1. Water currents

Water current directions and velocities were measured by the ADCP during the period between February 16 and April 17, 2011. Typical winter - spring conditions in the NE Caribbean Sea that include low water temperatures and the arrival of storm swell events associated with North Atlantic cold fronts prevailed in the Anegada Passage during the ADCP deployment period. El Seco is moderately sheltered from northerly swells due to the barrier effect of Culebra to the north, Vieques to the east and St. Thomas to the northeast. Still, maximum wave heights of approx. 3-4 m were experienced during the study period. Mean water current flow measurements are presented in Figures 5 and 6. It must be noted that a 50-day deployment may or may not be representative of long-term current patterns. The mean strength of the flow is best represented by the mean speed (the scalar average) and the 50^{th} percentile (median) profiles, which exhibited speeds in the order of 22-23 cm/s and 21-22 cm/s, respectively. The higher values were measured in the subsurface 4-7 m depth layer. Mean speeds were observed to decline linearly towards the bottom and reached the bottom boundary layer with speeds of 10 cm/s at 40 m. Median speeds were similar (only slightly smaller) to the mean speeds, showing a nearly-symmetrical speed distribution. R/S ratios of ~0.3 over most of the water column, except near the surface, are indicative of both a relatively weak and highly oscillatory (probably tidally and wind-driven) flow.

The entire water mass above detected by the ADCP over the outer insular shelf exhibited a dominant flow towards the southwest, with velocity vectors pointing towards a westerly direction near the surface and rotating to a southerly heading closer to the bottom in response to bathymetric steering. The 90^{th} percentile speeds (Figure 6),

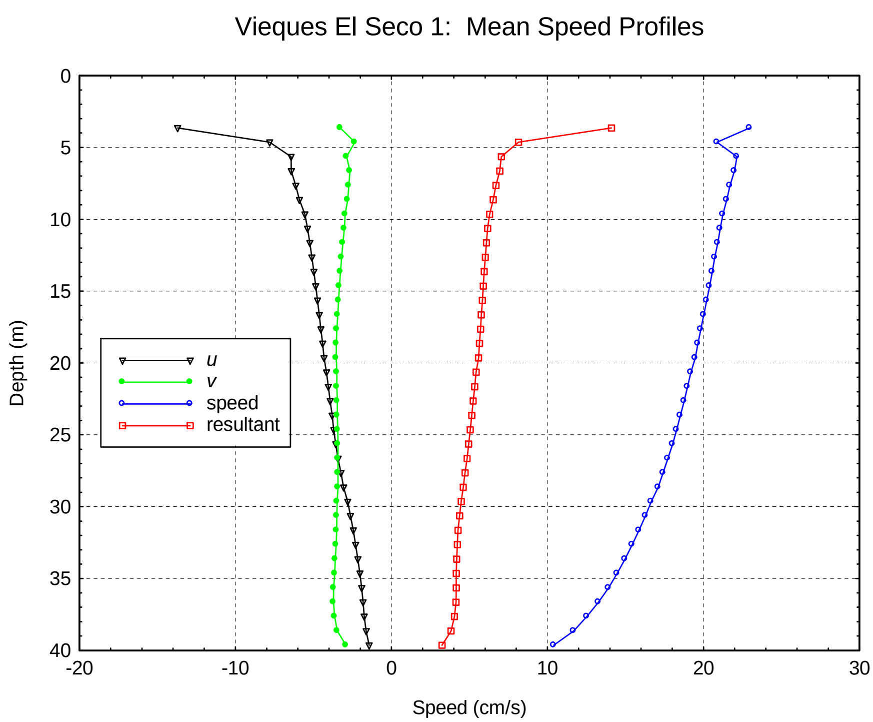


Figure 5. Mean current speed profiles at El Seco, Vieques. February – April, 2011

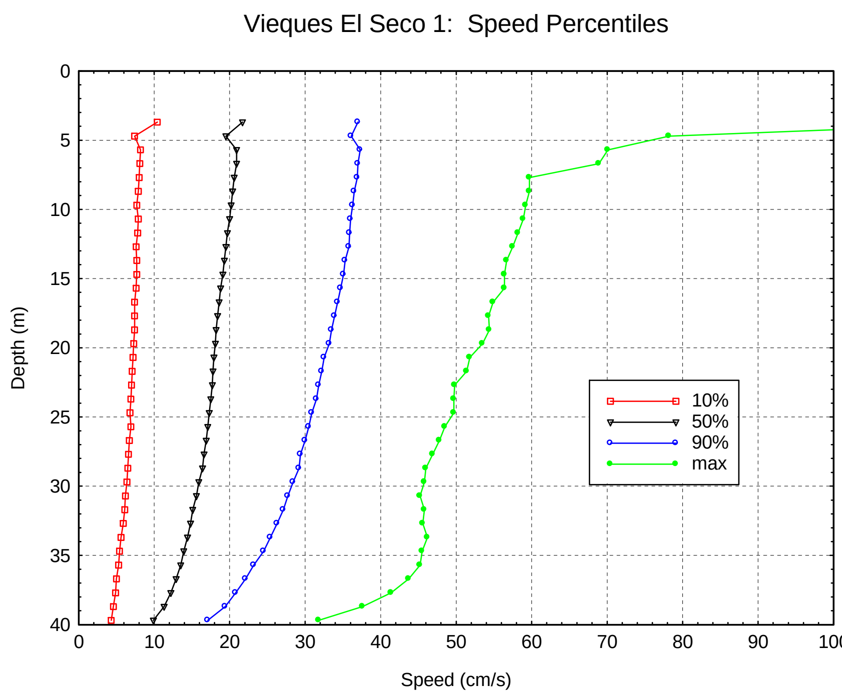


Figure 6. Water current speed percentiles at El Seco, Vieques. February – April 2011

usually resulting from peak tidal or peak sea breeze currents ranged from 37 cm/s in the top bin to 17 cm/s in the deepest bin. Excluding a possibly anomalous value of 125 cm/s in the top layer, the maximum observed speed ranged from 70 cm/s in the upper bins to 32 cm/s in the deepest bin. Compared to other regional observations, El Seco exhibited much lower speeds, roughly half than those measured at Bajo de Sico in Mona Passage (Garcia-Sais et al., 2007), but comparable to observations at Culebra and Humacao (Capella, unpublished data).

The progressive vector (PV) pseudo-trajectories (Figure 7) and the directional transport distributions (Figure 8) provide consistent and complementary views of the mean flow patterns described. A persistent interior southwestward moderate flow, semi-diurnal tidal current oscillations and relatively small vertical gradients were observed. Cross-shelf southerly flows with speeds in the order of one knot were measured during February 19-21. Conversely, cross-shelf northerly flows with speeds in the order of one knot were measured during March 23-25 (Figure 9). On March 26, the flow reversed again and turned towards the dominant southwesterly direction. The spawning aggregation of tiger grouper was monitored between March 17-20 and despite presence of several adult tiger grouper individuals with distinctive reproductive coloration no spawning activity was observed during these dates. A tropical trough that brought up winds of 18-25 knots and waves in excess of 3 m compromised sea conditions after March 20, making further rebreather diving observations unsafe.

1.2. Water Temperature and Density Profiles

The bottom (40 m depth) temperature time series recorded by the Hobo thermistor installed at the tiger grouper spawning site depict a pattern of increasing water temperatures between the end of July thru November 2010, with a peak temperature of 29.3°C recorded September 1, 2010 (Figure 10). Periods of sustained water temperatures above 29°C were recorded during the last week of June, and during the period between September and the first week of November, 2010. Decreasing temperature periods were recorded between mid June and the end of July 2010, and then after November 2011. Bottom temperatures reached a minimum of 25.5 - 25.6 °C during the week of March 17-23, 2011. The minimum water temperature recorded by

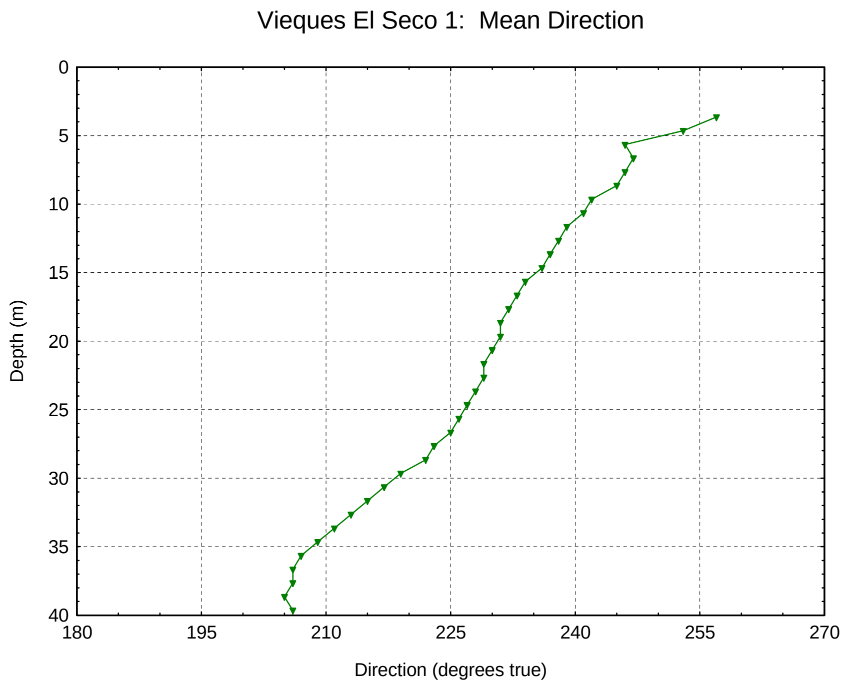


Figure 7. Progressive vectors pseudo-trajectories measured at El Seco, Vieques. February-April 2011

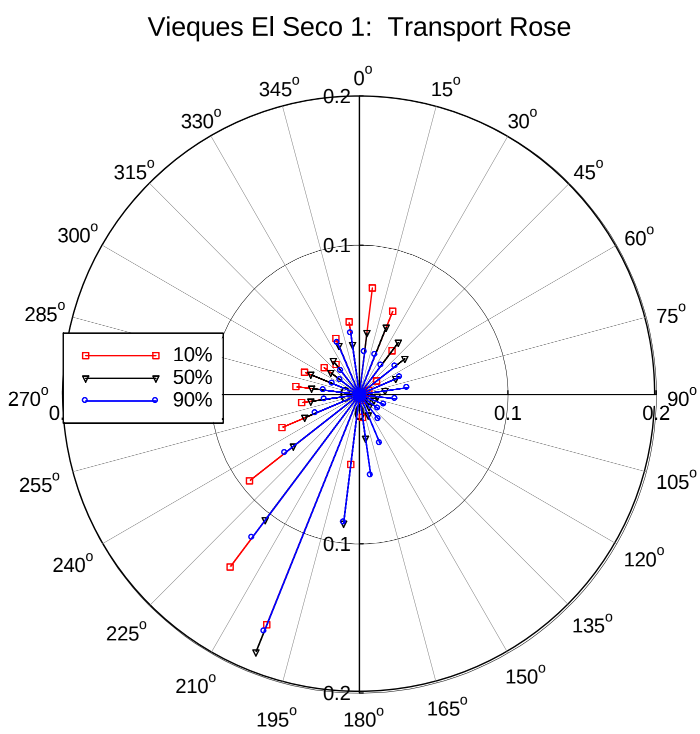


Figure 8. Water currents flow transport rose, showing the directional percent of flows during February – April, 2011 at El Seco, Vieques

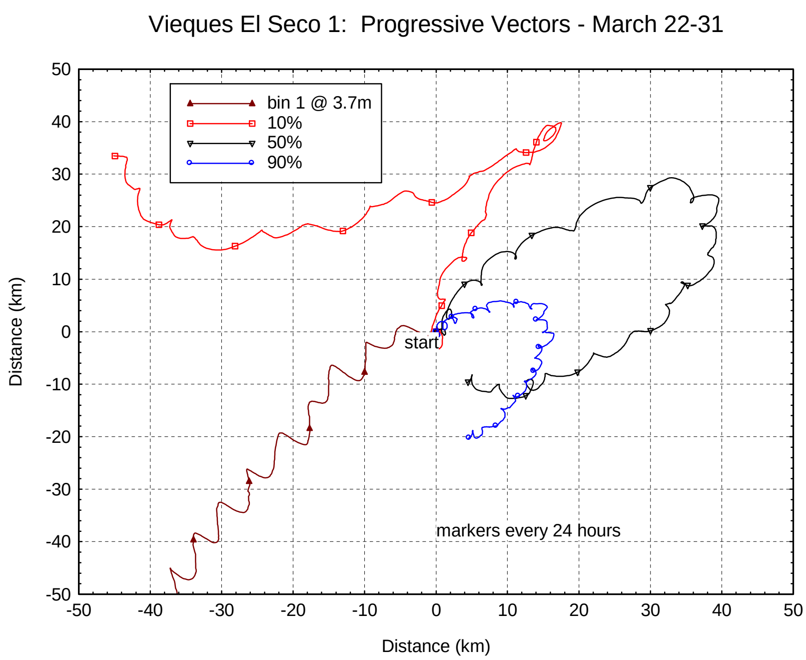


Figure 9. Progressive vectors of current direction measured at the tiger grouper spawning site, southeast Vieques during March 22 – 31, 2011

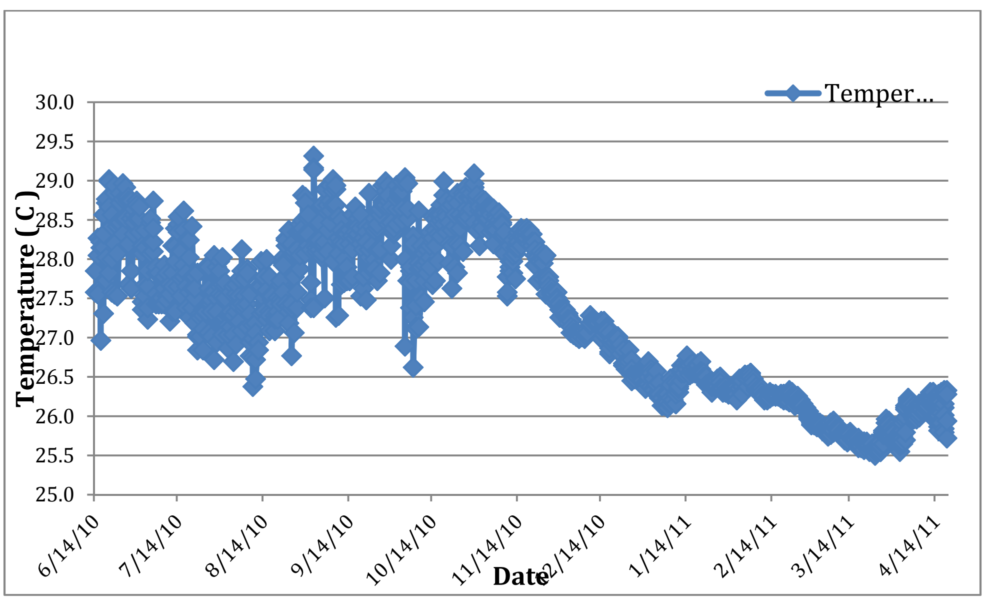


Figure 10. Water temperature time-series recorded by the Hobo thermistor at a depth of 40 m during the period between June 2010 and April 2011 at the tiger grouper spawning site in El Seco, southeast, Vieques

the Hobo was of 25.50°C on March 23, 2011. Daily temperatures at 40 m fluctuated between 0.1°C - 0.2°C.

Under the prevailing water current direction and velocity conditions, it is suggested that fertilized eggs and early larval stages of tiger grouper and any other fishes spawning near the shelf edge off southeast Vieques were transported off the shelf towards the southwest, entering the northern Caribbean current system. This current system has the southern shelf of the Greater Antilles as its northern boundary, being Puerto Rico the nearest island from the fish egg/larval source spawned at El Seco. Northerly current reversals associated with semi-diurnal tidal excursions were of short duration in relation to the time required for fish larvae to develop directional swimming skills. Thus, neritic retention of fish larvae spawning at El Seco is not supported by our data. Nevertheless, the largest current anomaly detected, a strong northerly flow that prevailed during two days (March 23-25) was measured right after the minimum water temperature was measured at the spawning site during March 23, 2011. Since such minimum water temperatures have been associated with grouper spawning activity (Ojeda, 2002), it can be suggested that if any fish spawning activity occurred during March 23, dispersal towards the Vieques shelf would have been favored. Still, it would be expected that the reestablishment of the prevailing southwesterly current would have transported the early preflexion (non-swimming) larvae off the shelf.

Conductivity, temperature and density (CTD) profiles were taken on November 2010 (Figure 11) and February 2011 (Figure 12). During November 2010, the CTD profile exhibited a well mixed water column with essentially homogeneous temperature and salinity from the surface down to a depth of 31 m, where a more dense water mass was detected down to the bottom. The water mass on the lower 9 m was warmer than the overlying surface layer, but was denser because of the higher salinity. The origin of this water mass is unknown, but given its warmer and more saline signature may have been formed at the surface and sank to density equilibrium below the less saline (and lighter) surface layer. The density profile taken on February 2011 (Figure 12) depicts a more typical mixed surface layer with a monotonically increasing density from surface to bottom associated with small increments of salinity and a gently decreasing water temperature with an overall weak gradient of 0.2°C from surface to bottom at 40 m. The greatest change of temperature with depth was associated with the surface layer.

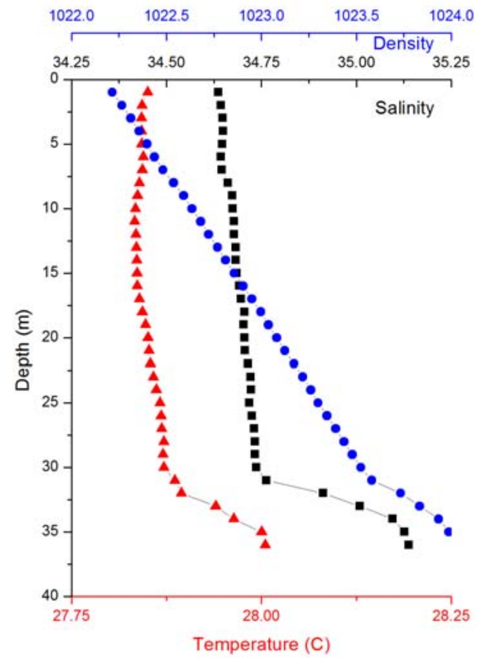


Figure 11. CTD profiles taken at the spawning site of El Seco, southeast Vieques, November 2010.

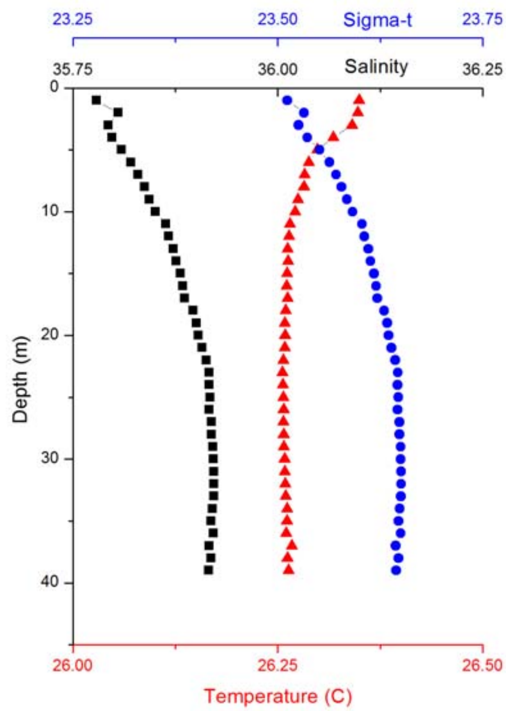


Figure 12. CTD profiles taken at the spawning site of El Seco, southeast Vieques, February 2011.

2.0 Benthic habitat map

The outer shelf of southeast Vieques is an extensive mesophotic ecosystem that includes a variety of benthic habitat types and associated communities. The benthic habitat mapping effort in this study includes a total surface area of 14.8 km^2, extending 6.2 km from the eastern shelf-edge towards the west and 2.4 km from the southern shelf-edge towards the north (Figure 13). Four predominant benthic habitat types were observed within the study area at the outer shelf of southeast Vieques; these include a continuous coral reef bank; a discontinuous or patch coral reef; a rhodolith reef; and a colonized pavement habitat.

a. Bank coral reef. The bank coral reef habitat is an impressive continuous formation of scleractinian corals growing at depths of 33 – 41 m (110 – 135’) throughout the northern and northeastern sections of the study area (Figure 13). The total surface area of the coral reef bank within the study area was estimated as of 3.7 km^2, or 25 % of the total area surveyed (Table 5). The northern boundary of our study area is the limit of the multi-beam bathymetry survey produced by NOAA on the outer shelf of southeast Vieques. The areal extension of the bank coral reef to the north of the study area remains undetermined. The bank coral reef habitat is largely (almost a biotope) of *Montastraea franksi*, a sibling species of *M. annularis* growing as laminar planks of up to 1 m of diameter, supported by pedestals of unknown origin and variable heights (Plate 2).

b. Patch coral reef. At a depths of about 40 and extending down to 44 m the bank coral reef system breaks down to a discontinuous formation of patch reefs separated by coralline sand channels and pockets. The patch reef benthic habitat prevailed at the southern boundaries of the coral reef bank formation to the southeastern and northwestern sides of the “El Seco” ridge (Figure 13), covering an estimated surface area of 0.8 km^2, representing 5.4 % of the surveyed area (Table 5). Patch reefs appear to be of sedimentary origin, with variable and relatively lower contributions of recent biological carbonate (e.g. scleractinian coral) deposition, compared to the coral reef bank formation. Laminar growth of *M. franksi* declined markedly at the patch reef habitat, yielding relatively higher dominance to lettuce corals (*Agaricia* spp) and boulder brain coral (*M. cavernosa*). Scleractinian corals were observed to occur mostly as encrusting growth forms, with minor contributions to the overall underwater reef topography. Patch reefs were found increasingly interspersed with increasing depth down to about 45 m, merging with algal rhodolith deposits in the northwestern and southeastern side of the "El Seco" (Figure 13).

c. Rhodolith reef. A mostly flat, homogeneous benthic habitat characterized by the predominance of algal rhodoliths prevailed along the entire western and southeast section of the study area at depths between 35 – 50 m (Figure 13). Algal rhodoliths were observed to be colonized by turf and fleshy algae, scleractinian corals, sponges and other encrusting biota. The areal extension of rhodolith reef habitat was estimated at 8.6 km^2, or 57.9 % of the surveyed area (Table 5).

A small area south of the Rhodolith Reef habitat bordering the shelf edge was found to be a transition between a rhodolith reef habitat and a colonized pavement. The area was classified as "scattered coral rock in algal rhodoliths" and represents only 1% of the total area (Table 5). The habitat contained scattered and less colonized algal rhodoliths over a patchy colonized pavement.

d. Colonized pavement. Hard-bottom, with interspersed rocky outcrops and sand patches prevail throughout the reef top area of "El Seco" ridge at depths between 24 – 38 m (Figure 13). This is a highly heterogeneous seafloor characterized by extensive areas of low relief hard bottom colonized by turf algae and interspersed basket sponges and the occurrence of rocky outcrops colonized by scleractinian corals, gorgonians and other coral ref biota. There are also essentially flat hard bottom areas colonized mostly by gorgonians and turf algae with some scleractinian corals growing as encrusting isolated colonies that contributed minimally to the overall underwater topographic relief. The estimated areal cover by the colonized pavement habitat was 1.0 km^2, or 7.3 % of the surveyed area (Table 5).

Another colonized pavement habitat but with far more sand coverage and thus less colonization overall was observed bordering the west and east side of "El Seco" reef top including some deep pools along the top. This area was classified as "Colonized pavement with sand channels" and represents only 0.3 km^2, or 2.3 % of the surveyed area (Table 5).

e. Uncolonized bottom habitats. Deep sandy habitats were found in the vicinity of the shelf-edge along the southern margin of the study area and between patch reefs at depths from 42 – 50 m (Figure 13). The map does not represent or quantify the presence of sand between patch reefs due to its small and highly fragmented distribution. Nevertheless, a more extensive and easily discernable extension of uncolonized pavement with sand was found at the southeastern slope of the study area. It is estimated that this uncolonized habitat area within the 50 m depth limit of our survey was 0.16 km^2, or 1.1 % of the surveyed area (Table 5).

Table 5. Benthic habitat classifications and areal coverage at "El Seco", southeast Vieques

Habitat Type	Area (km2)	Area (Hectares)	%
Rhodolith Reef	8.56	856.2	57.9
Bank Coral Reef	3.68	368.2	24.9
Colonized Pavement	1.08	108.3	7.3
Patch Coral Reef	0.80	79.9	5.4
Colonized Pavement with Sand Channels	0.34	33.9	2.3
Uncolonized Pavement with Sand Channels	0.16	16.5	1.1
Scattered Coral/Rock in Algal Rhodoliths	0.15	15.4	1.0
	14.78	**1478.4**	**100**

Plate 2. Bank coral reef habitat

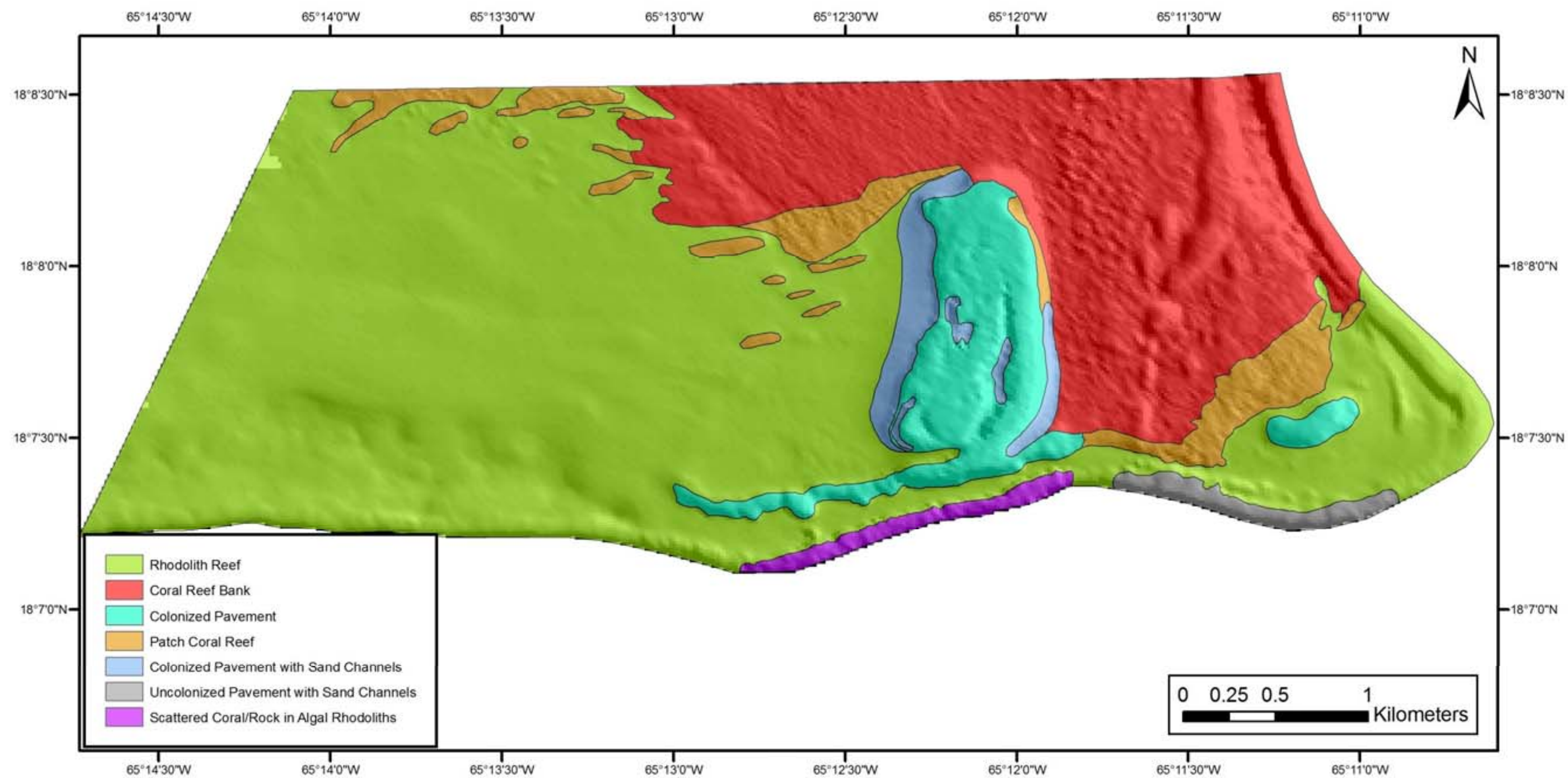


Figure 13. Benthic habitat map of the study area down to 50 m depth at "El Seco", Vieques.

3.0 Biological characterization of mesophotic habitats

3.1 Colonized Pavement

3.1.1 Sessile-benthic community

The relative composition by substrate categories from the set of 10 transects surveyed at the colonized pavement habitat is shown in Figure 14. Benthic algae dominated substrate cover with a combined mean of 71.3 % (range: 61.3 – 78.0 %). Turf algae, a mixed assemblage of short filamentous algae growing as a carpet over hard bottom and packed with fine sediments was the dominant component of the benthic algae averaging 55.9 % (Table 6). Photographic documentation of the colonized pavement habitat at "El Seco" ridge is presented as Photo Album 1. Fleshy algae, comprised by several species, but mostly the encrusting fan alga, *Lobophora variegata* were present in all transects averaging 14.4 %. Abiotic substrates particularly sand overlying uncolonized hard bottom ranked second in terms of percent cover with a mean of 8.1 % (range: 1.3 – 15.3 %). In many sections of the colonized pavement habitat, compacted sand bottom was colonized by reddish cyanobacteria growing as a slimy film over the substrate. Cyanobacteria was observed in seven transects with a mean cover of 4.1 % (range:0 – 9.3 %).

Among sessile-benthic invertebrates, sponges were the dominant component, averaging 7.3 % of the reef substrate cover and were present in all transects surveyed. A total of 38 species of sponges were identified from the colonized pavement habitat (Appendix 2). The most common was the basket sponge, *Xestospongia muta,* which was present in five transects with a mean cover of 0.8 % (Table 6), and due to its large size and erect growth contributed substantially to the habitat topographic complexity and relief. Sponges, particularly *X. muta* function as important microhabitats for small reef fishes and invertebrates including brittle stars and spider crabs, *Stenorhinchus seticornis*. Octocorals (or gorgonians), represented by at least 16 species (Appendix 2) were present in nine transects with a mean cover of 2.0 %. Sea plumes (*Pseudopterogorgia* spp) were the most common. Due to their vertical projections and branching growth, octocorals contributed markedly to the habitat topographic relief and complexity, also serving as protective habitat for fishes.

Stony corals, represented by 19 species within transects (including the hydrocoral *Millepora alcicornis*) presented a mean cover of 6.9 % (range: 3.3 – 14.7 %). Great star coral, *Montastraea cavernosa* was the dominant species in terms of substrate cover with a mean of 1.7 % and was present in all transects (Table 6). Boulder star coral, *M. annularis* complex, Mustard-hill coral, *Porites astreoides*, symmetrical brain coral, *Diploria strigosa*, and lesser starlet coral, *Siderastrea siderea* were present in at least six transects and along with *M. cavernosa* and *M. alcicornis* comprised the most common stony coral assemblage of the colonized pavement habitat. Coral exhibited mostly encrusting and/or mound shaped growth in the extensive flat hard bottom of the pavement and typically occurred as isolated colonies of small to moderate size. Within the rocky outcrops of the pavement however, corals were more abundant and in some areas several coral species were observed growing together, forming a biologically complex system with substantial contributions to the overall structural topographic relief. It can be argued that in many rocky outcrops of the pavement habitat, coral growth has significantly increased the value and function of these habitats as protective structures for fish and invertebrate species, which is more consistent with their classification as small coral reef habitats.

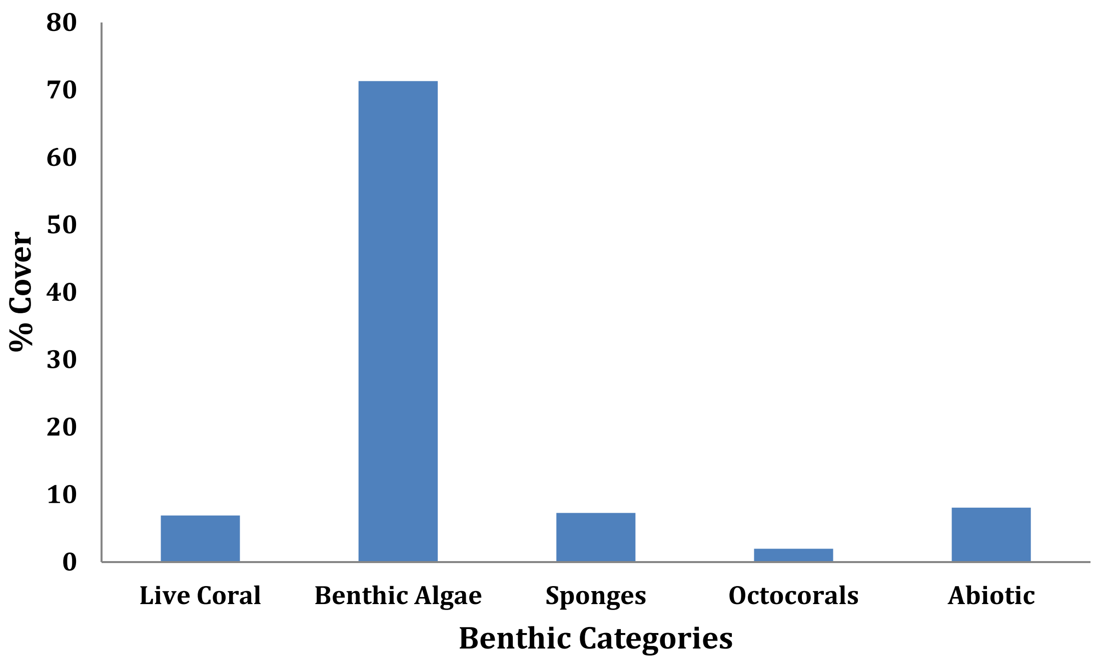


Figure 14. Colonized pavement. Relative composition of substrate categories based on the mean of 10 photo transects surveyed.

Table 6. Percent substrate cover by sessile-benthic categories at the Colonized Pavement habitat, El Seco, Vieques. 2010 -11. Depths: 24.5 – 30.3 m

Substrate Categories	12a	12b	12c	12d	49a	49b	58a	58b	59a	59b	Mean % Cover
Benthic algae											
Algal turf	67.0	65.3	61.5	60.7	45.3	56.7	43.3	52.7	51.3	55.7	**55.9**
Red Coralline Algae					0.3		1.7	0.7	0.3	0.7	**0.4**
Rhipocephalus sp.			0.4								**0.0**
Turbinaria sp.			0.4								**0.0**
Amphiroa sp.								0.3			**0.0**
Fleshy algae			0.4	0.3	0.3		2.0		0.7	1.0	**0.5**
Lobophora sp.	4.7	2.7	5.8	0.3	18.7	13.3	18.0	33.0	24.7	20.7	**14.2**
Padina sp.							1.3				**0.1**
Dictyota sp.							0.3	0.3	0.3		**0.1**
Total benthic algae	**71.7**	**68.0**	**68.4**	**61.3**	**64.7**	**70.0**	**66.7**	**87.0**	**77.3**	**78.0**	**71.3**
Sponges											
A. lacunosa									1.7	2.0	**0.4**
A. fistularis					0.7						**0.1**
I. strobilina	0.3										**0.0**
C. vaginalis						0.3				0.3	**0.1**
C. plicifera					0.3						**0.0**
Unident sponge	6.0	9.0	4.0	10.0	3.7	7.3	6.3	4.7	5.0	2.7	**5.9**
X. muta		3.0		2.0	0.7	1.7			1.0		**0.8**
Total Sponges	**6.3**	**12.0**	**4.0**	**12.0**	**5.3**	**9.3**	**6.3**	**4.7**	**7.7**	**5.0**	**7.3**
Octocorals											
E. caribaeorum								0.3	0.3		**0.1**
Unident. Gorgonian	4.3	2.3	3.3	1.0	1.0	0.7			2.3	2.0	**1.7**
Pseudopterogorgia sp.			0.4	0.3						0.7	**0.1**
Eunicea sp.					0.3				0.3		**0.1**
Total octocorals	**4.3**	**2.3**	**3.6**	**1.3**	**1.3**	**0.7**	**0.0**	**0.3**	**3.0**	**2.7**	**2.0**
Abiotic											
Rubble					0.3		1.0				**0.1**
Sand	10.0	4.7	11.6	7.0	13.3	15.3	5.0	1.3	5.0	6.0	**7.9**
Total abiotic	**10.0**	**4.7**	**11.6**	**7.0**	**13.7**	**15.3**	**6.0**	**1.3**	**5.0**	**6.0**	**8.1**
Cyanobacteria	**2.3**	**9.3**	**7.6**	**8.7**	**6.7**	**0.3**	**6.0**				**4.1**
Ascidian									**0.3**		**0.0**
Unidentified	**0.3**	**0.3**		**0.7**	**0.3**		**0.3**		**0.7**	**1.0**	**0.4**
Scleractinian Corals											
Montastrea cavernosa	1.0	0.3	1.8	2.3	2.3	0.3	6.0	0.3	1.7	1.0	**1.7**
Montastrea annularis				0.7	1.0	0.7		3.7	2.0	1.0	**0.9**
Porites astreoides	1.7	1.3	0.7		0.3		2.0	0.3	0.7	1.7	**0.9**
Diploria strigosa	0.7		0.4	1.0	0.7	1.0	3.3			1.0	**0.8**
Millepora alcicornis	0.7	0.7	0.7	2.3	0.7	0.3	0.7		0.3	0.3	**0.7**
Siderastrea radians			0.4	0.3	0.7	0.7	1.0	0.3	0.3	0.7	**0.4**
Diploria clivosa		0.3			2.0						**0.2**
Isophyllia sinuosa	0.3		0.4	0.3				0.3		0.7	**0.2**
Agaricia agaricites		0.3	0.4	0.3		0.7					**0.2**
S. intersepta	0.3			0.7	0.3			0.3			**0.2**
Unidentified coral							0.7	0.3	0.3	0.3	**0.2**
Diploria labyrinthiformis						0.7	0.7				**0.1**
M. meandrites				0.7					0.3		**0.1**

Table 6. continued.

Diploria clivosa										0.7	**0.1**
Madracis decactis								0.7			**0.1**
Siderastrea siderea				0.3				0.3			**0.1**
Dichocoenia stokesi	0.3	0.3									**0.1**
Porites porites									0.3		**0.0**
Scolymia cubensis							0.3				**0.0**
Total living coral	**5.0**	**3.3**	**4.7**	**9.0**	**8.0**	**4.3**	**14.7**	**6.7**	**6.0**	**7.3**	**6.9**

3.1.2 Fish/Invertebrate community

A total of 52 fish species, including 33 within belt-transects were identified from the colonized pavement habitat. A complete list of fish species observed from the different benthic habitats surveyed is included as Appendix 2. Reef fishes at the colonized pavement habitat were typically observed aggregated at rocky outcrops interspersed within an otherwise low relief and homogeneous hard ground substrate with many sand pockets. Within the flat pavement, the reef community was depauperate and fishes were mostly concentrated in small microhabitats created by substrate discontinuities, crevices and/or associated with basket sponges, gorgonians and isolated coral heads. The composition of fish species and abundance within 10 m x 3 m belt-transects is shown in Table 7. Mean abundance within belt-transects was 36.8 Ind/30m^2 (range: 17 – 54 Ind/30m^2). Mean species richness was 9.9 spp/30m^2 (range: 6 – 14 spp/30m^2).

The bluehead wrasse, *Thalassoma bifasciatum* and the bicolor damselfish, *Stegastes partitus* were present in the 10 transects surveyed and accounted for 70.0 % of the total mean abundance within belt-transects (Table 7). Five additional species were present in lower abundance in at least five out of the 10 transects surveyed and along with the aforementioned species appear to form part of the small resident demersal fish assemblage of the colonized pavement habitat. These include the wrasses *Halichoeres garnoti, H. maculipinna*, harlequin bass, *Serranus tigrinus*, squirrelfish, *Holocentrus rufus*, and the doctorfish, *Acanthurus chirurgus*. Medium sized demersal reef fish carnivores, such as the queen triggerfish, *Balistes vetula*, hogfish, *Lachnolaimus maximus,* yellowtail snapper, *Ocyurus chrysurus*, red hind, *Epinephelus guttatus*, coney, *E. fulva* and graysbe, *E. cruentatus* were observed to be common or abundant. Their density and size distribution within the 10 – 60 m^2 belt-transects surveyed is presented in

Table 7. Colonized pavement habitat. Taxonomic composition and abundance of fishes within 10 m x 3 m belt-transects.

	Station										
	12a	12b	12c	12d	49a	49b	59a	59b	58a	58b	
SPECIES	(Ind/30m²)										**Mean**
Thalassoma bifasciatum	11	6	8	19	27	33	8	8	14	6	**14**
Stegastes partitus	18	33	19	18	12	6	2	1	3	4	**11.6**
Halichoeres garnoti	2	2	1	0	3	2	1	1	3	2	**1.7**
Acanthurus chirurgus	1	1	0	2	0	2	0	5	1	0	**1.2**
Halichoeres maculipinna	4	0	2	2	1	0	0	0	0	0	**0.9**
Holocentrus rufus	0	1	1	2	1	1	1	1	1	0	**0.9**
Serranus tigrinus	1	0	0	0	1	3	0	1	1	0	**0.7**
Sparisoma radians	2	1	0	1	0	3	0	0	0	0	**0.7**
Chromis cyanea	1	0	3	1	0	0	0	0	0	0	**0.5**
Paranthias furcifer	0	0	4	0	0	0	0	0	0	0	**0.4**
Acanthurus coeruleus	0	0	2	0	0	0	1	0	0	0	**0.3**
Balistes vetula	0	1	0	0	1	0	1	0	0	0	**0.3**
Canthigaster rostrata	1	0	1	0	0	0	1	0	0	0	**0.3**
Chaetodon aculeatus	1	1	1	0	0	0	0	0	0	0	**0.3**
Coryphopterus glaucophraenum	0	1	1	1	0	0	0	0	0	0	**0.3**
Chaetodon capistratus	0	0	0	0	2	0	0	0	0	0	**0.2**
Chaetodon sedentarius	0	0	0	0	2	0	0	0	0	0	**0.2**
Epinephelus cruentatus	0	1	0	0	1	0	0	0	0	0	**0.2**
Epinephelus fulva	0	0	0	0	1	0	0	0	0	1	**0.2**
Epinephelus guttatus	0	0	0	0	0	1	0	1	0	0	**0.2**
Pseudupeneus maculatus	0	0	0	0	0	0	1	0	0	1	**0.2**
Lactophrys triqueter	0	1	0	1	0	0	0	0	0	0	**0.2**
Xanthichthys ringens	0	0	0	0	1	0	0	0	0	1	**0.2**
Acanthurus bahianus	0	0	1	0	0	0	1	0	0	0	**0.2**
Caranx crysos	0	0	1	0	0	0	0	0	0	0	**0.1**
Chaetodon striatus	0	0	0	0	0	1	0	0	0	0	**0.1**
Holacanthus tricolor	0	0	0	0	0	0	0	0	0	1	**0.1**
Malacanthus plumieri	0	0	0	0	0	0	0	0	0	1	**0.1**
Melichthys niger	0	0	1	0	0	0	0	0	0	0	**0.1**
Ocyurus chrysurus	0	0	0	0	1	0	0	0	0	0	**0.1**
Scarus taeniopterus	0	0	0	1	0	0	0	0	0	0	**0.1**
Sparisoma viride	0	0	0	0	0	0	0	1	0	0	**0.1**
Sphyraena barracuda	0	0	0	0	0	1	0	0	0	0	**0.1**
Total Individuals	**42**	**49**	**46**	**48**	**54**	**53**	**17**	**19**	**23**	**17**	**36.8**
Total Species	**10**	**11**	**14**	**10**	**13**	**10**	**9**	**8**	**6**	**8**	**9.9**

Table 8. Queen triggerfish and hogfish were the most abundant with densities in the order of 7 and 6 Ind/600, respectively. These densities must be evaluated with caution due to the fact that both of these two fish species tend to be attracted to divers. Density of red hind was estimated in the order of 4 Ind/600m^2. Large demersal predators, such as nurse shark, *Ginglymostoma cirratum*, dog snapper, *Lutjanus jocu*, and Nassau grouper, *E. striatus* were present within and outside transects surveyed from several stations. Large mid-water predators, such as the reef shark, *Carcharhinus perezii,* great barracuda*, Sphyraena barracuda*, rainbow runner, *Elagatis bipinnulata* and the cero Mackerel, *Scomberomorus regalis* were also present (Table 8). One of the two lionfish. *Pterois volitans* observed during our study at El Seco was observed in the colonized pavement habitat.

Queen conch, *Strombus gigas* was observed to be present although patchily distributed within certain areas of the colonized pavement habitat. It was most abundant at station V-12, a hard ground bottom with scattered sand patches colonized by turf algae, gorgonians, sponges and isolated coral heads. A total of 29 adult conch ranging in carapace length from 26 – 30 cm were observed within an area of 4,000 m^2 , equivalent to 7 conchs per 1000 m^2. Over all stations surveyed, its density within belt-transects was calculated in the order of 3 Ind/600m^2, or 5 conchs per 1000 m^2. A total of four spiny lobsters, all females with eggs, were observed outside transects. Long-spined urchin, *Diadema antillarum* and the cleaner shrimp, *Periclimenes pedersoni* were present within belt-transects (Table 9).

Table 8. Colonized pavement habitat. Taxonomic composition, density and size of fishes and invertebrates within 20 m x 3 m belt-transects.

	Stations									
	12a	12b	12c	12d	49a	49b	59a	59b	58a	58b
SPECIES	(Ind/60m²) - fork length (cm)									
Fishes										
Epinephelus guttatus			1-30	1-28				1-33		1-25
Epinephelus cruentatus		1-20		1-20	1-18		1-15			
Epinephelus fulva			1-20		1-22, 1-16					1-20
Lutjanus jocu		1-50								
Lachnolaimus maximus	1-80		2-60		1-70			1-55		1-45
Ocyurus chrysurus		2-50		1-30	2-30	1-25				
Balistes vetula	1-30			1-32		2-35	1-20	2-25		
Invertebrates										
Strombus gigas	1-28	1-27		1-30		1-28				

Fishes Outside	Stations									
Transects	V-12a	V-12b	V-12c	V-12d	V-49a	V-49b	V-59a	V-59b	V-58a	V-58b
Ocyurus chrysurus	10-40	2-50	4-30	6-25, 1-30	4-25, 2-30	3-25	10-40	2-50	4-30	6-25, 1-30
Epinephelus striatus									1-76	
Balistes vetula		1-45	1-30			2-35, 3-38	20, 27, 30	4-25, 2-30		
Epinephelus cruentatus						3-38				
Lachnolaimus maximus		3-70		3-45						
Epinephelus guttatus						2-30, 3-38				
Scomberomorus regalis	80			90						
Ginglymostoma cirratum								1-180		
Carcharhinus perezii			1-150							

Table 9. Colonized pavement habitat. Taxonomic composition and abundance of motile-megabenthic invertebrates within 10 m x 3 m belt-transects.

	Station										
	12a	**12b**	**12c**	**12d**	**49a**	**49b**	**59a**	**59b**	**58a**	**58b**	
SPECIES	**(Ind/30m²)**										**Mean**
Periclimenes pedersoni	1	1									**0.2**
Diadema antillarum				1							**0.1**
Strombus gigas	1	1		1		1					**0.4**
Total Individuals	**2**	**2**	**0**	**2**	**0**	**1**	**0**	**0**	**0**	**0**	**0.7**
Total Species	**2**	**2**	**0**	**2**	**0**	**1**	**0**	**0**	**0**	**0**	**3**

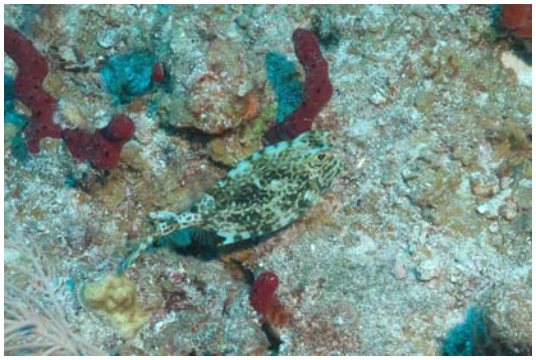
Photo Album 1. Colonized Pavement















3.2 Bank Coral Reef

3.2.1. Sessile-benthic community

Live scleractinian coral was the dominant sessile-invertebrate taxa in terms of substrate cover at the coral reef bank with an average of 40.5 % (range: 20.0 – 49.7 %, Figure 15). Coral cover was observed to be virtually a biotope of *Montastraea franksi,* a sibling species of boulder star coral, *M. annularis* growing in table shaped colonies side by side, sometimes slightly overlapping and producing an impressive continuous live mesophotic coral system resembling that described by Smith et al. (2009) for the MCD Hind Bank in St. Thomas, USVI (see Photo Album 2). This coral reef ecosystem is unique in Puerto Rico and represents an important discovery of the CFMC essential fish habitat assessment program. Mean substrate cover by *M. franksi* was 34.2 % (range: 13.7 – 44.4 %), representing 84.4 % of the total live coral cover within transects (Table 10). Another 14 scleractinian corals and one hydrocoral were intercepted by transects. Mustard-hill coral, *Porites astreoides* with a mean cover of 1.8 %, and whitestar sheet coral, *Agaricia lamarcki* with 1.3 % were present in all transects surveyed. Other scleractinian corals that were shown to comprise the predominant coral assemblage include lettuce coral, *A. agaricites*, symmetrical brain coral, *Diploria strigosa* and dimpled sheet coral, *A. grahamae* (Table 10). No bleached corals, or recent coral mortality was observed during our survey at the coral reef bank in southeast Vieques.

Octocorals (gorgonians) were observed in very low abundance and mostly occurring as isolated colonies interspersed at the coral reef bank. Their average substrate cover within transects was measured as 0.2 %, with presence of erect colonies in only 2 of the 10 transects surveyed (Table 10). A total of 13 species were identified from the coral reef bank outside transects (Appendix 2). Evidently, scleractinian corals exhibiting laminar growth outcompete the vertically projected octocorals for limiting space at the coral reef bank. Likewise, sponges were also observed to play a minor function in terms of reef community structure at the coral reef bank with an average substrate cover of 3.9 % (range: 1.0 – 9.7 %). Sponge growth was mostly constrained to the vertically projected substrates of the coral pedestals and the reef framework underneath the scleractinian coral bank, particularly comprised by *M. franksi*. A total of 24 species of sponges were identified (Appendix 2).

Table 10. Coral Reef Bank Habitat. Percent substrate cover by sessile-benthic categories at El Seco, Vieques, 2010-11. Depth 33 – 38 m.

	STATIONS										Mean
Substrate categories	**18a**	**18b**	**37**	**39**	**41**	**42**	**43**	**45**	**46**	**48**	**% Cover**
Benthic algae											
Algal turf	25.8	30.7	27.7	24.0	29.0	26.3	32.3	34.7	28.3	35.7	**29.5**
Red Coralline Algae	4.3	4.7	6.0	2.7	4.3	11.3	5.0	5.0	10.7	4.7	**5.9**
Calcareous Green Algae											
Halimeda sp.		0.2					0.3	0.3			**0.1**
Fleshy Brown Algae											
Lobophora sp.	13.5	7.3	14.0	13.0	5.7	12.3	9.0	5.7	8.0	14.0	**10.3**
Total benthic algae	**43.7**	**42.8**	**47.7**	**39.7**	**39.0**	**50.0**	**46.7**	**45.7**	**47.0**	**54.3**	**45.7**
Total Sponges	**1.7**	**4.5**	**1.0**	**2.3**	**5.0**	**1.0**	**4.0**	**4.7**	**4.7**	**9.7**	**3.9**
Total octocorals	**0.7**	**0.0**	**0.0**	**1.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.3**	**0.2**
Abiotic											
Sand	1.3	1.7	2.3	0.3	0.3	1.0	3.0	1.0	2.3	8.3	**2.2**
Total abiotic	**1.3**	**1.7**	**2.3**	**0.3**	**0.3**	**1.0**	**3.0**	**1.0**	**2.3**	**8.3**	**2.2**
Cyanobacteria	**6.8**	**5.8**	**8.7**	**5.0**	**5.3**	**5.7**	**6.3**	**6.0**	**5.3**	**6.0**	**6.1**
Unidentified	3.0	0.7	2.7	3.3	0.7	1.7	0.7	1.3		1.3	**1.5**
Stony corals											
Montastraea franksi	37.2	37.7	34.0	40.3	44.3	37.3	31.0	31.7	34.7	13.7	**34.2**
Porites astreoides	2.0	1.8	2.0	2.0	1.3	1.0	2.3	0.3	2.3	2.7	**1.8**
Agaricia lamarcki	1.2	2.3	0.7	1.7	2.3	0.3	2.3	0.7	0.7	0.7	**1.3**
Agaricia agaricites	0.2	0.8		0.3	0.7	1.3	1.0	0.7	0.3	0.7	**0.6**
Diploria strigosa		0.3					0.7	3.7	0.7		**0.5**
Agaricia grahamae	0.3	0.7	0.7		0.3	0.3	1.0	1.0		1.0	**0.5**
Montastraea cavernosa	0.8	0.2		1.7			0.3	1.0	1.0	0.3	**0.5**
Unidentified coral	0.5		0.3	0.7				1.0	0.3	0.3	**0.3**
Siderastrea siderea	0.2	0.3		0.3	0.7			0.3		0.3	**0.2**
Porites furcata	0.3			0.7							**0.1**
Agaricia fragilis		0.2				0.3	0.3				**0.1**
Madracis decactis		0.2					0.3			0.3	**0.1**
Millepora alcicornis	0.2			0.3				0.3			**0.1**
S. intersepta								0.3	0.3		**0.1**
Colpophyllia natans									0.3		**0.0**
Scolymia cubensis								0.3			**0.0**
Total stony corals	**42.8**	**44.5**	**37.7**	**48.0**	**49.7**	**40.7**	**39.3**	**41.3**	**40.7**	**20.0**	**40.5**

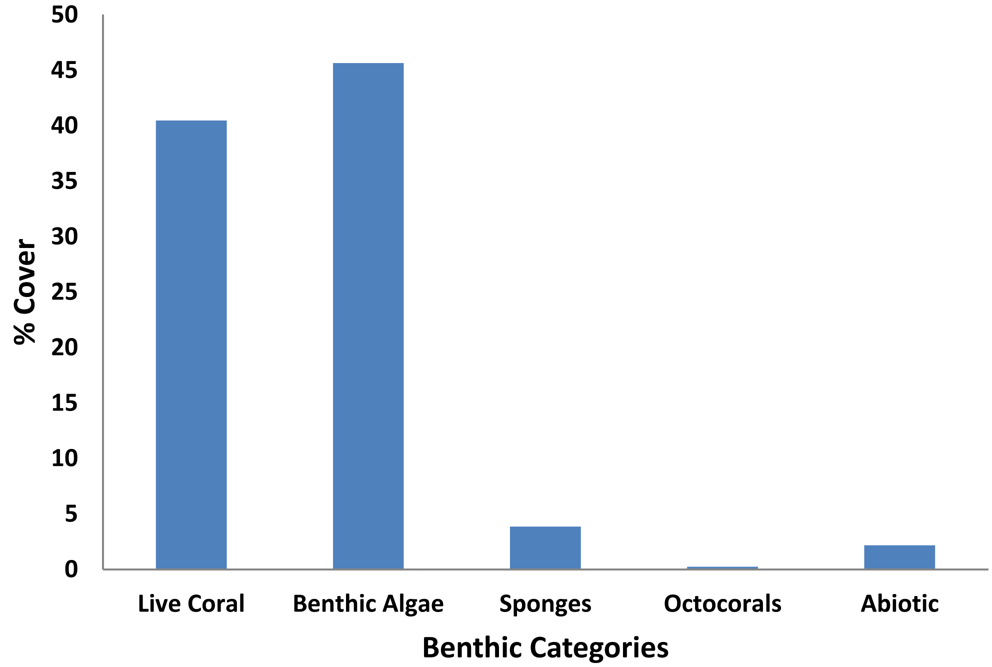


Figure 15. Coral Reef Bank. Relative composition of substrate categories based on the mean of 10 photo transects surveyed.

Minor components of the sessile-benthic community structure at the coral reef bank included the encrusting zoanthid, *Palythoa caribaeorum* and the black corals, *Antipathes caribbeana* and *Stichopathes lutkeni*. An unidentified white encrusting zoanthid was observed overgrowing small dead coral sections at the reef.

3.2.2. <u>Fish/Invertebrate community</u>

A total of 76 fish species, including 47 within belt-transects were identified from mesophotic depths (34 – 40 m) at the coral reef bank (Table 11). A complete list of fish species observed from the different benthic habitats is included as Appendix 2. Mean abundance within belt-transects was 75.0 Ind/30m^2 (range: 37 - 216 Ind/30m^2). Mean species richness was 14.2 spp/30m^2 (range: 8 – 19 spp/30m^2). Fish species composition and abundance estimates from this reef must be evaluated with caution due to the high rugosity and labyrinth dimensions that constrain visual access of the reef seascape and full microhabitats range to divers.

Two fish species with highly aggregated or patchy distributions, creole wrasse, *Clepticus parrae* and masked goby, *Coryphopterus personatus* accounted for 57.0 % of the total mean abundance within belt-transects (Table 11). Seven additional species were present in lower abundance in at least five out of the 10 transects surveyed and along with the aforementioned species appear to form part of the small resident demersal fish assemblage of the bank coral reef. These include the blue and yellowhead wrasses *Thalassoma bifasciatum*, *Halichoeres garnoti,* brown chromis, *Chromis multilineata,* princess parrotfish, *Scarus taeniopterus,* bicolor damselfish, *Stegastes partitus,* masked goby, *C. glaucofraenum* and fairy basslet, *Gramma loreto*. A total of 17 species were only observed in one out of the ten transects surveyed.

The bank coral reef was observed to function as the residential habitat of several commercially important medium and large demersal reef fish predators, such as red hind, *Epinephelus guttatus*, hogfish, *Lachnolaimus maximus,* schoolmaster, dog and cubera snappers, *Lutjanus apodus, L. jocu, L. cyanopterus*, tiger grouper, *Mycteroperca tigris* and nurse shark, *Ginglymostoma cirratum*. Their densities and size distributions within the 10 – 60 m^2 belt-transects surveyed is shown in Table 12. Cubera snapper was the most abundant within belt-transects due to the passing of one school of over 80 adult individuals through one of our belt-transects at station V-39. While this aggregated behavior leads to a biased overestimate of the overall density for this species (e.g. 83 Ind/600 m^2), it must be stressed that large adult cubera snappers were observed to be common and frequently sighted outside transects at the coral reef bank (see Table 12). A similar situation with a school of schoolmaster snappers (19 Ind/600 m^2) was also encountered at station V-18a. Conversely, the actual densities of red hind and tiger grouper estimated as of 7 and 4 Ind per 600 m^2 may have been underestimated due to the semi-cryptic behavior of these species and the high availability of secretive microhabitats at this reef. Hogfishes were observed either within or outside transects at five of the 10 stations surveyed. Mutton snappers were also observed outside transects at the reef bank. The largest demersal predator of the reef at size distributions ranging between 150–250 cm appears to be the nurse shark, which was present outside transects in 6 of the 10 stations surveyed. Nurse sharks appear to be common in the reef and were typically attracted to divers during our survey of the reef bank.

The pelagic reef community at the bank reef was depauperate, compared to other mesophotic reefs studies, such as Bajo de Sico, Isla Desecheo and Abrir la Sierra (Garcia-Sais et al., 2005, 2007, 2010). In addition to ballyhoo and flying-fishes (Exocoetidae) only small schools of mackerel scad, *Decapterus macarelus* and creole wrasse, *Clepticus parrae* were observed in mid-water to serve as potential forage species for the larger pelagic predators. Among these, divers observed cero mackerels, *Scomberomorus regalis*, great barracuda, *Sphyraena barracuda*, and sailfish, *Istiophorus albicans*. It is highly expected that other typical components of the large migratory pelagic predators of mesophotic reefs including dolphinfish, *Coryphaena hippurus*, wahoo, *Acanthocybium solandri*, marlins (Istiophoridae) and tunas (Scombridae) also forage at this reef. Several large hawksbill turtles, *Eretmochelys imbricata* were present at the bank reef. No megabenthic invertebrates were observed within belt-transects.

Table 11. Coral Reef Bank Habitat. Taxonomic composition and abundance of fishes within 30 m^2 belt-transects. El Seco, Vieques, 2010-11

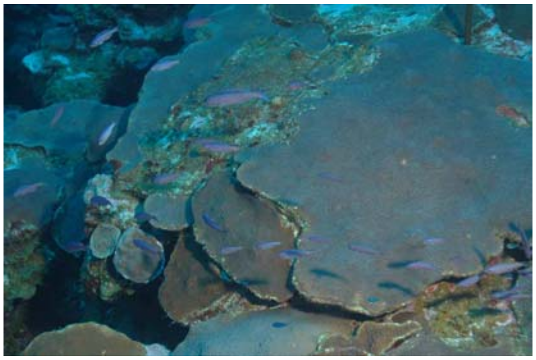
	Stations										
	18a	**18b**	**42**	**43**	**46**	**48**	**45**	**41**	**39**	**37**	
SPECIES	**(Ind/30m²)**										**Mean Abundance**
Clepticus parrae	154	75	0	0	0	0	0	0	0	0	**22.9**
Coryphopterus personatus	25	37	20	0	33	8	23	1	36	13	**19.6**
Thalassoma bifasciatum	5	13	4	5	7	3	1	1	1	3	**4.3**
Chromis cyanea	12	10	1	0	0	0	2	10	2	0	**3.7**
Scarus taeniopterus	0	1	0	10	0	3	2	0	15	3	**3.4**
Stegastes partitus	6	5	2	2	1	1	4	2	0	3	**2.6**
Coryphopterus glaucofraenum	0	0	0	0	5	0	0	15	0	3	**2.3**
Coryphopterus lipernes	0	0	0	3	0	4	1	0	2	8	**1.8**
Gramma loreto	1	7	0	1	3	0	1	3	0	2	**1.8**
Halichoeres garnoti	1	1	2	3	2	1	1	0	0	4	**1.5**
Myripristis jacobus	2	0	0	0	0	8	0	0	0	0	**1.0**
Bodianus rufus	0	2	0	2	1	0	0	1	0	1	**0.7**
Chaetodon capistratus	0	1	2	0	0	0	0	2	2	0	**0.7**
Hypoplectrus chlorurus	0	1	2	1	0	1	0	0	1	1	**0.7**
Holocentrus rufus	0	0	0	1	0	5	0	0	0	0	**0.6**
Scarus iserti	1	0	5	0	0	0	0	0	0	0	**0.6**
Sparisoma aurofrenatum	0	2	0	1	0	1	0	1	0	1	**0.6**
Decapterus macarelus	5	0	0	0	0	0	0	0	0	0	**0.5**
Epinephelus guttatus	0	1	0	1	0	1	0	0	1	1	**0.5**
Sparisoma radians	0	0	0	2	0	0	0	0	0	3	**0.5**
Canthigaster rostrata	0	1	2	0	0	0	0	1	0	0	**0.4**
Epinephelus cruentatus	0	1	0	0	0	2	0	0	0	1	**0.4**
Epinephelus fulva	0	0	0	1	0	2	0	1	0	0	**0.4**
Chaetodon aculeatus	1	0	0	1	0	1	0	0	0	0	**0.3**
Gobiosoma evelynae	0	1	0	0	0	0	0	0	0	2	**0.3**
Neoniphon marianus	1	0	0	0	0	1	0	0	0	1	**0.3**
Stegastes leucostictus	0	0	0	1	0	0	1	1	0	0	**0.3**
Haemulon flavolineatum	0	0	0	1	0	1	0	0	0	0	**0.2**
Hypoplectrus indigo	0	0	0	0	1	0	0	1	0	0	**0.2**
Pomacanthus arcuatus	0	1	0	0	0	0	0	1	0	0	**0.2**
Acanthurus bahianus	0	0	1	0	0	0	0	0	0	0	**0.1**
Acanthurus coeruleus	0	0	1	0	0	0	0	0	0	0	**0.1**
Chaetodon sedentarius	0	0	0	0	0	0	0	0	0	1	**0.1**
Chromis insolata	1	0	0	0	0	0	0	0	0	0	**0.1**
Chromis multilineata	0	1	0	0	0	0	0	0	0	0	**0.1**
Haemulon sciurus	0	0	0	0	0	1	0	0	0	0	**0.1**
Holacanthus tricolor	0	0	0	0	0	1	0	0	0	0	**0.1**
Hypoplectrus unicolor	0	0	0	0	0	0	1	0	0	0	**0.1**
Hypoplectrus puella	0	0	0	0	0	0	0	0	0	1	**0.1**
Hypoplectrus sp.	0	0	0	1	0	0	0	0	0	0	**0.1**
Kyphosus sectatrix	0	0	0	0	0	0	0	0	1	0	**0.1**
Liopropoma rubre	0	0	0	0	0	0	0	0	1	0	**0.1**
Lutjanus cyanopterus	0	1	0	0	0	0	0	0	0	0	**0.1**
Lutjanus jocu	0	0	0	0	0	0	0	0	1	0	**0.1**
Pterois volitans	0	0	0	0	0	1	0	0	0	0	**0.1**
Sparisoma atomarium	0	0	0	0	0	0	0	1	0	0	**0.1**
Sparisoma viride	1	0	0	0	0	0	0	0	0	0	**0.1**
Total Individuals	**216**	**162**	**42**	**37**	**53**	**46**	**37**	**42**	**63**	**52**	**75.0**
Total Species	**14**	**19**	**11**	**17**	**8**	**19**	**10**	**15**	**11**	**18**	**14.2**

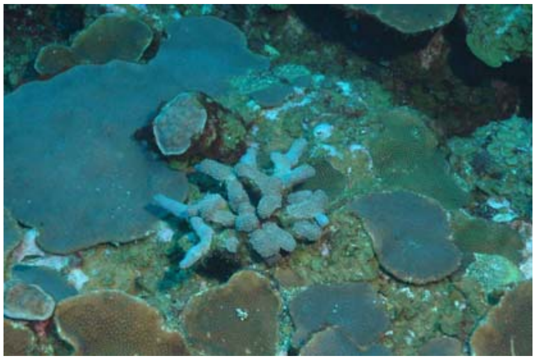
Table 12. Coral Reef bank Habitat. Taxonomic composition, density and size of fishes and invertebrates within 20 m x 3 m belt-transects. El Seco, Vieques, 2010-11

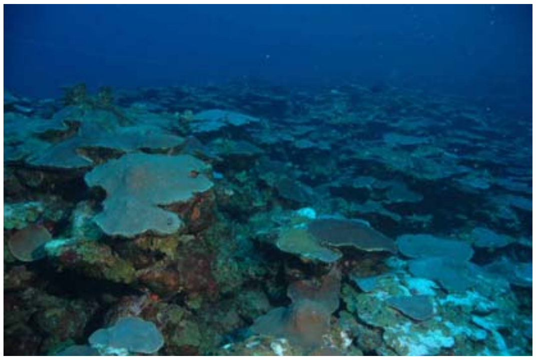
	Stations									
	18a	**18b**	**42**	**43**	**46**	**48**	**45**	**41**	**39**	**37**
SPECIES	**Ind/60m²- length in cm**									
Epinephelus guttatus		1-30, 1-35		1-38		2-40			1-38	1-38
Lutjanus jocu	2-60				2-76				1-60	
Mycteroperca tigris	1-70	1-55			1-55		1-60			
Lutjanus apodus	15-30	3-40			1-45					
Epinephelus fulva										
Lutjanus cyanopterus		1-71							82(60-90)	
Mycteroperca venenosa		1-35				1-60				
Lachnolaimus maximus	2-50	1-60								

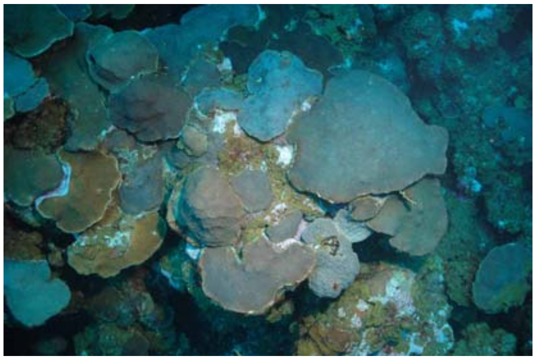
Fishes Outside Transects	**Station**									
Transects	**V-18a**	**V-18b**	**V-42**	**V-43**	**V-46**	**V-48**	**V-45**	**V-41**	**V-39**	**V-37**
Lutjanus cyanopterus	1-80		1-60, 1-70			1-70		2-80		2-90
Lutjanus analis				50, 55		1-55				
Lutjanus apodus			1-30			1-30				
Epinephelus guttatus				1-28						1-30
Ocyurus chrysurus						1-30	1-30			1-20
Ginglymostoma cirratum	1-190	1-200	1-180			1-250		1-180	1-200	
Lachnolaimus maximus				1-45	1-40				1-50	
Istiophorus albicans								1-15		

Photo Album2. Bank Coral Reef



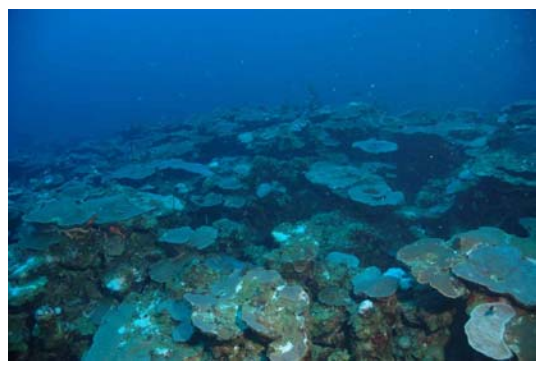
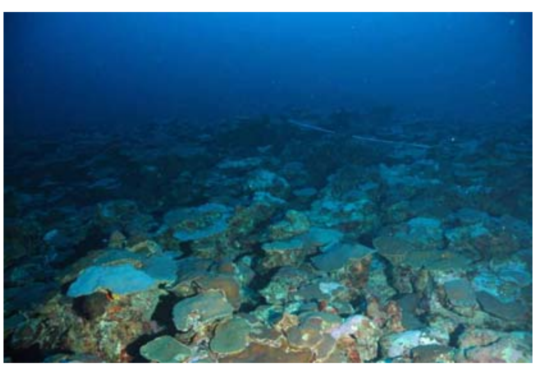











3.3 Patch Coral Reef

3.3.1 Sessile-benthic community

Patch coral reefs of variable dimensions were found interspersed on a sandy bottom at depths of 40 – 45 m at the southern limit of the coral reef bank formation (see benthic habitat map on Figure 13). Substrate cover by sessile-benthic categories from transects surveyed over the coral patch reef habitat is presented in Table 13. The combined assemblage of benthic algae, comprised by turf, fleshy brown, and coralline red algae was the dominant category in terms of percent cover with a combined (total benthic algae) mean of 64.0 % (range: 39.0 – 77.5 %). The encrusting fan alga, *Lobophora variegata* was the main (algal) component in terms of reef substrate cover with an average of 30.7 %, representing 48.0 % of the total benthic algae. Turf algae, a mixed taxonomic array of short filamentous algae were present in all transects with a mean cover of 28.7 % (Table 13). An assemblage of *Lobophora* intermixed with y-twig alga, *Dictyota* sp. and turf algae were observed growing encrusted as a carpet over hard reef substrates of apparently sedimentary origin. There was very limited algal overgrowth of relict or recently dead coral at this habitat. Red coralline algae was observed as a reddish and/or violet thin crustose layers overlying hard reef substrates. Cyanobacteria patches were present as a slimy thin films over hard and sandy bottom in nine transects with a mean cover of 3.0 % (range: 0 – 7.0 %). It was most common overlying deeper sections of sandy bottom at the base of the patch reefs.

Live scleractinian coral was the dominant sessile-benthic invertebrate in terms of substrate cover at the patch coral reef habitat with an average of 17.9 % (range: 6.0 – 46.0 %, Figure 16). Scleractinian corals were observed to contribute substantially to the reef structural framework, rugosity and habitat complexity, but not to the extent observed at the coral bank. With few exceptions (e.g. stations 51 and 52), coral growth at the patch reefs was more variable from reef to reef and largely discontinuous, with moderate to small boulder and encrusting colonies interspersed over the hard bottom not forming a quasi-continuous layer as in the coral bank. Boulder star coral, *Montastraea franksi* was the dominant species in terms of substrate cover in all transects with a mean of 11.5 % (range: 1.5 – 46.0 %), representing 65.0 % of the total live coral cover within transects (Table 13). Another 12 scleractinian corals and two hydrocorals (*Millepora* spp.) were intercepted by transects. Mustard-hill coral, *Porites astreoides* and whitestar sheet

Table 13. Patch Coral Reef Habitat. Percent substrate cover by sessile-benthic categories at El Seco, Vieques, 2010-11. Depth 40 – 45 m.

Substrate categories	4a	4b	4c	4d	51	52	54	55	56	57	Mean % Cover
Benthic algae											
Turf Algae	14.0	24.0	19.5	25.5	21.7	30.3	36.7	23.0	52.0	40.0	**28.7**
Red Coralline Algae	0.5	0.5			1.0	3.3	2.0	3.3	2.7	3.7	**1.7**
Brown Fleshy algae						0.7			0.3	0.3	**0.1**
Lobophora sp.	54.0	47.5	52.5	46.5	22.7	16.0	12.7	12.7	18.3	24.0	**30.7**
Padina sp.	0.5										**0.1**
Dictyota sp.	5.0	5.5	3.0	5.0	0.3	2.0	1.3		1.0	4.7	**2.8**
Total benthic algae	**74.0**	**77.5**	**75.0**	**77.0**	**45.7**	**52.3**	**52.7**	**39.0**	**74.3**	**72.7**	**64.0**
Sponges											
A. fistularis						0.3					**0.0**
Unident sponge	3.0	3.0	4.5	3.5	3.7	4.7	4.7	5.3	3.7	4.0	**4.0**
Total Sponges	**3.0**	**3.0**	**4.5**	**3.5**	**3.7**	**5.0**	**4.7**	**5.3**	**3.7**	**4.0**	**4.0**
Octocorals	0	0	0	0	0.6	0.6	1.4	0	0	0	**0.3**
Abiotic											
Rubble	0.5	1.0		3.0				33.0			**3.8**
Sand	3.5	4.5	8.0	3.5	1.7	5.3	19.0	1.3	9.3	7.3	**6.3**
Total abiotic	**4.0**	**5.5**	**8.0**	**6.5**	**1.7**	**5.3**	**19.0**	**34.3**	**9.3**	**7.3**	**10.1**
Cyanobacteria	**6.0**	**7.0**	**5.5**	**6.0**	**2.7**	**0.7**	**1.0**		**0.3**	**1.0**	**3.0**
Stony Coral											
Montastraea franksi	5.5	1.5	3.5	1.5	34.3	21.7	13.7	16.0	9.3	8.3	**11.5**
Agaricia lamarcki	4.0	1.5	0.5	1.0	4.3	0.3	1.7		1.0	1.0	**1.5**
Porites astreoides			0.5	1.0	4.3	3.7	1.7	1.0		2.3	**1.5**
Montastraea cavernosa	1.0	1.0		0.5		2.7	0.7	1.0	1.3	1.7	**1.0**
Agaricia agaricites				0.5	1.3	1.0		3.0		0.3	**0.6**
Siderastrea siderea	0.5			1.5	1.3	0.3	2.0			0.3	**0.6**
Agaricia grahamae		2.0	0.5			0.7	0.3	0.3			**0.4**
unidentified coral	1.0						0.7			0.7	**0.2**
Millepora alcicornis			1.5			0.3	0.3				**0.2**
Siderastrea radians				0.5	0.3						**0.1**
Agaricia fragilis						0.3				0.3	**0.1**
Colpophyllia natans							0.3				**0.0**
D. labyrinthiformis							0.3				**0.0**
Madracis decactis						0.3					**0.0**
Millepora squarrosa						0.3					**0.0**
Diploria strigosa				0.5							**0.1**
Total stony coral	**12.0**	**6.0**	**6.5**	**7.0**	**46.0**	**31.7**	**21.7**	**21.3**	**11.7**	**15.0**	**17.9**

coral, *Agaricia lamarcki*, each with a mean cover of 1.5 %, and great star coral, *M. cavernosa* with 1.0 % were present in at least seven transects and comprised along with boulder star coral the main scleractinian coral assemblage of the patch reef habitat. Neither bleached corals, nor widespread recent coral mortality was observed during our survey at the patch reef habitat in southeast Vieques.

Octocorals (gorgonians) were present in very low abundance and mostly as isolated colonies widely scattered at the patch reef habitat. Their average substrate cover within transects was measured as 0.3 %, with presence of erect colonies in only 3 of the 10 transects surveyed (Table 13). A total of 10 species were identified from the patch reef habitat outside transects (Appendix 2). Sponges were present in all transects surveyed at the patch reef habitat with an average substrate cover of 4.0 % (range: 3.0 – 5.3 %). Sponge growth was mostly observed as branching (e.g. *Aplysina* spp., *Agelas* spp.), barrel shaped (*Xestospongia muta*) and encrusting (*Cliona* sp.) over the hard ground bottom. A total of 18 species of sponges were identified (Appendix 2). Abiotic substrates, particularly sand and coral rubble were present on the 10 transects surveyed with an average cover of 10.1 % (range: 1.7 – 34.3 %), reflecting the discontinuous nature of the patch reef hard ground structure.

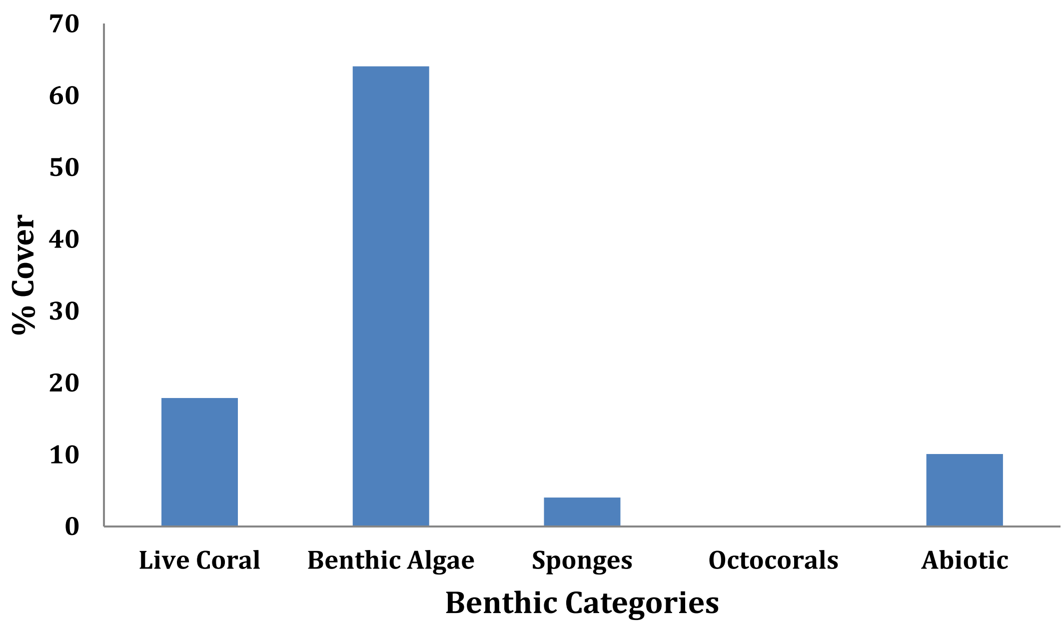


Figure 16. Patch Coral Reef Habitat. Relative composition of substrate categories based on the mean of 10 photo transects surveyed. Depth 40 – 45 m

3.3.2 Fish/Invertebrate community

A total of 62 fish species, including 50 within belt-transects were identified from patch coral reef habitats at depths of 40 – 45 m (Table 14). The complete list of fish species observed from the different benthic habitats is included as Appendix 2. Mean abundance within belt-transects was 40.5 Ind/30m^2 (range: 18 - 64 Ind/30m^2). Mean species richness was 15.0 spp/30m^2 (range: 7 – 20 spp/30m^2). Small territorial fish species were not observed from the patch coral reefs as numerically dominant assemblages. Blue chromis, *Chromis cyanea* was the most abundant species with 6.3 Ind/30 m2, representing only 15.5 % of the total individuals. The top six species accounted for 51.8 % of the total individuals within belt-transects. Nine species were present in at least six of the 10 transects and appear to comprise the main small territorial demersal fish assemblage. These include *Chromis cyanea, Coryphopterus personatus, Halichoeres garnoti, Stegastes partitus, Thalassoma bifasciatum, Scarus taeniopterus, Myripristis jacobus, Bodianus rufus* and *Sparisoma aurofrenatum* (Table 14).

Abundance of reef fishes has been shown to decline with increasing depth (Garcia- Sais 2010, Garcia-Sais et al, 2005, 2007, 2010). This is probably related to lack of food resources and predation pressure. Patch coral reefs are prime foraging areas for large demersal and pelagic reef fish predators, including reef and nurse sharks, cubera, mutton and dog snappers, red hinds, tiger and yellowfin groupers, large barracudas, permits, blue and black jacks, very large hogfishes, queen triggerfishes and giant green morays. Large demersal and pelagic predators of commercial value observed within and outside transects at patch reefs surveyed are presented along with their size distributions in Table 15. In addition, we observed during this study that patch reefs are the preferred habitat for spawning aggregations of tiger groupers, mutton and dog snappers. The predation pressure exerted by such aggregations of top reef predators, although potentially very high, has not been yet documented. The fact that spawning aggregations are intensively fished is evidence that these fish are actively feeding during their pass through these reproductive habitats and may be responsible, or at least may be influencing the relatively low abundance of small territorial fishes associated with patch coral reefs in southeast Vieques.

Table 14. Patch Reef Habitat. Taxonomic composition and abundance of fishes within belt-transects. El Seco, Vieques 2010-11

	Stations										
	4a	**4b**	**V-44**	**47**	**52**	**51**	**57**	**55**	**56**	**54**	
SPECIES					**(Ind/30m²)**						**Mean**
Chromis cyanea	17	9	3	6	0	0	2	2	3	21	**6.3**
Coryphopterus personatus	15	0	15	5	0	11	5	0	1	10	**6.2**
Halichoeres garnoti	0	1	2	4	4	5	4	1	2	1	**2.4**
Stegastes partitus	0	0	11	0	3	4	2	1	1	1	**2.3**
Thalassoma bifasciatum	1	3	2	0	0	7	0	5	0	3	**2.1**
Scarus taeniopterus	1	0	4	0	0	3	0	4	4	1	**1.7**
Scarus iserti	0	0	2	12	0	0	0	0	0	0	**1.4**
Gramma loreto	1	3	0	0	0	5	0	3	0	1	**1.3**
Myripristis jacobus	2	3	1	1	3	2	0	0	0	1	**1.3**
Mulloidichthys martinicus	0	0	0	0	0	12	0	0	0	0	**1.2**
Clepticus parrae	0	10	0	0	0	0	0	0	0	0	**1.0**
Paranthias furcifer	5	2	0	1	0	0	0	1	0	0	**0.9**
Canthigaster rostrata	0	0	0	1	4	0	1	0	1	1	**0.8**
Holocentrus rufus	4	0	1	2	0	0	1	0	0	0	**0.8**
Sparisoma aurofrenatum	1	1	1	3	0	1	0	0	0	1	**0.8**
Bodianus rufus	1	2	0	1	0	1	0	0	1	1	**0.7**
Chaetodon aculeatus	0	0	1	0	0	4	0	1	1	0	**0.7**
Gobiosoma evelynae	3	0	0	1	0	1	0	0	0	2	**0.7**
Acanthurus bahianus	0	0	0	1	0	0	1	3	1	0	**0.6**
Coryphopterus glaucophraenum	0	0	0	6	0	0	0	0	0	0	**0.6**
Epinephelus cruentatus	2	1	0	0	0	0	1	0	1	0	**0.5**
Hypoplectrus chlorurus	0	0	2	0	0	1	1	0	1	0	**0.5**
Chaetodon capistratus	0	0	0	3	0	1	0	0	0	0	**0.4**
Coryphopterus lipernes	0	0	3	0	0	0	0	0	0	1	**0.4**
Epinephelus fulva	0	0	1	0	0	1	1	0	0	1	**0.4**
Haemulon flavolineatum	1	1	0	2	0	0	0	0	0	0	**0.4**
Neoniphon marianus	0	1	0	1	0	0	1	0	1	0	**0.4**
Caranx latus	3	0	0	0	0	0	0	0	0	0	**0.3**
Holacanthus tricolor	2	0	0	1	0	0	0	0	0	0	**0.3**
Lactophrys triqueter	1	1	0	0	0	0	0	0	0	1	**0.3**
Ocyurus chrysurus	0	0	0	0	2	0	0	1	0	0	**0.3**
Chromis insolata	1	0	0	0	0	0	0	0	0	1	**0.2**
Epinephelus guttatus	0	0	0	1	0	0	0	0	0	1	**0.2**
Ginglymostoma cirratum	2	0	0	0	0	0	0	0	0	0	**0.2**
Lutjanus analis	0	0	0	0	0	0	0	0	2	0	**0.2**
Lutjanus apodus	0	0	1	1	0	0	0	0	0	0	**0.2**
Pseudupeneus maculatus	0	0	0	0	0	0	0	2	0	0	**0.2**
Acanthurus coeruleus	1	0	0	0	0	0	0	0	0	0	**0.1**
Chaetodon sedentarius	0	1	0	0	0	0	0	0	0	0	**0.1**
Chaetodon striatus	0	0	0	0	1	0	0	0	0	0	**0.1**
Gymnothorax funebris	0	0	0	0	0	0	0	0	0	1	**0.1**
Hypoplectrus niger	0	0	0	0	0	0	0	1	0	0	**0.1**
Lutjanus cyanopterus	0	0	0	0	1	0	0	0	0	0	**0.1**
Ophioblennius atlanticus	0	0	0	0	0	0	0	0	1	0	**0.1**
Opistognatus aurifrons	0	0	0	0	0	0	0	1	0	0	**0.1**
Pomacanthus arcuatus	0	0	0	0	0	0	0	1	0	0	**0.1**
Pomacanthus paru	0	0	0	0	0	0	0	0	0	1	**0.1**
Serranus tigrinus	0	0	0	1	0	0	0	0	0	0	**0.1**
Sparisoma viride	0	0	0	0	0	1	0	0	0	0	**0.1**
Synodus intermedius	0	0	0	0	0	1	0	0	0	0	**0.1**
Total Individuals	**64**	**39**	**50**	**54**	**18**	**61**	**20**	**27**	**21**	**51**	**40.5**
Total Species	**19**	**14**	**15**	**20**	**7**	**17**	**11**	**14**	**14**	**19**	**15.0**

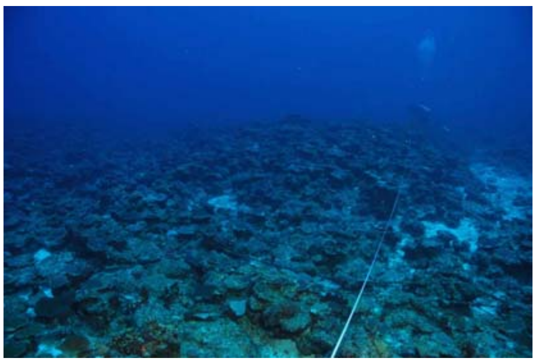
Table 15. Patch Reef Habitat. Taxonomic composition, abundance and size distribution of commercially important fishes and shell fishes within 20m x 3m belt-transects. El Seco, Vieques 2010-11

	Station									
SPECIES	**4a**	**4b**	**44**	**47**	**52**	**51**	**57**	**55**	**56**	**54**
					(Ind/60m²)					
Epinephelus guttatus	1-40		1-40	1-20		1-35		1-30		1-25
Lutjanus jocu			1-60							
Mycteroperca tigris					1-60	2-50				
Lutjanus apodus		5-40			1-30					
Epinephelus fulva				7-15						
Lachnolaimus maximus		1-45		2-15				1-38		
Lutjanus cyanopterus								1-90		
Haemulon album						1-40				
Lutjanus analis									1-70	
Ocyurus chrysurus									1-30	
Sphyraena barracuda	81, 91									

	Stations									
Fishes/Invertebrates Outside Transects	**4a**	**4b**	**44**	**47**	**52**	**51**	**57**	**55**	**56**	**54**
Fishes										
Epinephelus guttatus	1-35	1-40	1-25, 1-30, 1-35		1-30, 1-35	1-25		1-40	1-30	1-30; 1-40
Carcharhinus perezii	1-150									
Trachinotus falcatus		25(50-60)								
Lachnolaimus maximus				2-50		1-60	1-40	1-40, 1-50		
Gymnothorax funebris										1-140
Lutjanus analis	6(50-60)	8(40-50)			1-40, 1-50			2-40, 1-50		1-55
Lutjanus jocu	300(40-50)					2(40-50)				
Lutjanus cyanopterus	2-80	15(50-80)		2-60		3-70, 1-90		27 (50-60); 3-70;	9(50-60)	2-50; 1-60
Mycteroperca venenosa							1-45			
Ginglymostoma cirratum	1-150		1-120			1-120			1-150	
Mycteroperca tigris	95(50 - 60)	12(50-60)			1-70	3-60		1-50		
Ocyurus chrysurus						3-20, 4-30				
Invertebrates										
Strombus gigas	2-26	1-27		2-27			1-26, 2-27		1-26	

Photo Album 3. Patch Coral Reef








3.4 Rhodolith Reef

3.4.1 Sessile-benthic community

The rhodolith reef habitat occupies an extensive section of the outer Vieques shelf. It consists of crustose algal nodules deposited over an otherwise flat, homogeneous and gently sloping shelf. Almost the entire hard bottom is covered by rhodoliths, which in turn are colonized by benthic algae, sponges, corals and other encrusting biota. The percent substrate cover data for sessile-benthic categories in transects surveyed at the rhodolith reef habitat are presented in Table 16. Benthic algae were the dominant category in terms of substrate cover in all transects surveyed with an average of 72.5 % (range: 56.6 – 88.0 %). Turf algae and brown fleshy algae, mostly the encrusting fan alga, *Lobophora variegata* were the main components of the benthic algal assemblage. Crustose coralline algae overgrowing rhodolith nodules were also present in all transects with an average cover of 7.8 % (range: 2.0 – 12.0 %). At least 13 species of macroalgae were identified from the rhodolith reef habitat. Cyanobacteria, growing as a slimy film overlying mostly abiotic substrates, but also overgrowing macroalgae were present in all transects with a mean cover of 3.3 %.

Branching, erect and encrusting sponges were present in all transects with a mean cover of 13.3 % (range: 4.7 – 30.8 %) and comprised the most prominent benthic invertebrate taxa in terms of substrate cover (Figure 17). Branching (*Agelas* spp., *Aplysina* spp.) and encrusting sponges grew attached to rhodolith nodules, whereas the larger erect sponges (e.g. *Xestospongia muta*) appeared to be attached to the primary hard ground bottom. Both branching and erect sponges were the main biological components contributing topographic relief at the rhodolith reef and thus, represented the main structure providing protective habitat for fishes and motile invertebrates.

Scleractinian corals were represented by 15 species within transects at the rhodolith reef habitat with a mean cover of 3.4 % (range: 0.3 – 11.0 %). A total of 18 coral species were identified (Appendix 2). Lettuce corals, comprised by at least three species (*A. undata*, *A. lamarcki*, *A. grahame*) were the most prominent coral assemblage with individuals present in all transects and a combined mean cover of 2.2 %, representative of 64.7 % of the total scleractinian coral cover in transects surveyed. Scleractinian corals grew mostly attached to algal rhodoliths and were generally of small to very small sizes, contributing minimally to the overall reef topographic relief and rugosity. Corals were also observed to serve as attachment surfaces for sponges, forming small coral-sponge bioherms that appear to function as important recruitment microhabitats for reef fishes. Reef substrate cover by the lettuce coral, *Leptoseris cailleti* was probably underestimated by the photo image method due to its cryptic branching growth intermixed and camouflaged in the brown fleshy algal mat.

Octocorals were present in very low abundance and diversity at the rhodolith reef habitat. Only two colonies were observed within transects, for a mean cover of 0.1 %. Wire coral, *Stichopathes lutkeni* (Antipatharia) was observed at the rhodolith habitat but in very low abundance. Abiotic substrates, consisting largely of sand pockets and rhodolith rubble mounds were common with an average cover of 5.1 %. Rhodolith mounds of up to 0.5 m in height were constructed by sand tilefishes, *Malacanthus plumieri*, which use the structure as protective habitat. These mounds were observed to function as microhabitats for other small fishes as well and contributed some topographic relief to the otherwise flat seascape.

Table 16. Rhodolith Reef Habitat. Percent substrate cover by sessile-benthic categories at El Seco, Vieques, 2010-11. Depth 43 – 50 m.

	Stations										Mean Substrate
Substrate Categories	**34a**	**34b**	**34c**	**35a**	**35b**	**35c**	**61**	**62a**	**62b**	**64**	**Cover (%)**
Benthic algae											
Turf Algae	30.5	35.5	33.5	19.6	15.7	21.2	41.7	34.3	43.7	30.7	**30.6**
Red Coralline Algae	10.5	12.0	11.5	6.8	6.8	11.6	2.0	3.7	3.3	9.7	**7.8**
Amphiroa sp.				0.8				1.3	0.3		**0.2**
Green Calcar Algae											
Halimeda sp.	2.5	3.0	0.5	0.8	2.0	0.4	0.7	1.3	0.7	2.0	**1.4**
Brown Fleshy algae				0.4	0.4		0.7			1.0	**0.2**
Lobophora	26.0	25.0	21.5	36.4	31.3	38.8	33.7	36.7	28.3	24.7	**30.2**
Dictyota sp.					0.4		8.7	1.7	5.0	2.3	**1.8**
Total benthic algae	**69.5**	**75.5**	**67.0**	**64.8**	**56.6**	**72.4**	**88.0**	**79.0**	**81.3**	**70.3**	**72.5**
Sponges											
Unident sponges	8.0	7.5	11.5	29.2	27.3	24.0	4.7	5.7	4.0	4.7	**12.7**
A. clathrodes	1.0	0.5									**0.2**
A. conifera		1.0	0.5								**0.2**
I. strobilina			0.5					0.3	0.3		**0.1**
X. muta				1.6					0.3		**0.2**
Total Sponges	**9.0**	**9.0**	**12.5**	**30.8**	**27.3**	**24.0**	**4.7**	**6.0**	**4.7**	**4.7**	**13.3**
Octocorals	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.7	0.0	0.0	**0.1**
Abiotic											
Rubble	2.0	3.0	5.0	0.4	4.0			1.3	1.7	5.3	**2.3**
Sand	4.5	4.0	4.0	0.4	4.0	0.8	5.0	0.7	1.3	3.3	**2.8**
Total abiotic	**6.5**	**7.0**	**9.0**	**0.8**	**8.0**	**0.8**	**5.0**	**2.0**	**3.0**	**8.7**	**5.1**
Cyanobacteria	**6.5**	**2.5**	**3.0**	**1.2**	**2.0**	**0.8**	**1.7**	**6.7**	**5.3**	**3.3**	**3.3**
Ascidian		**0.5**	**0.5**						**0.3**		**0.1**
Scleractinian Corals											
Agaricia undata	4.0									5.0	**0.9**
Agaricia grahamae	0.5	0.5		0.8					0.3	5.3	**0.7**
Agaricia lamarcki		0.5	0.5	1.2	2.0			0.7	1.0	0.3	**0.6**
Leptoseris cailleti			1.0		2.0						**0.3**
Montastraea franksi		0.5			0.8		0.3	0.3	1.0		**0.3**
Unident. Coral					0.4			0.7			**0.1**
Agaricia agaricites			0.5					0.3			**0.1**
Scolymia cubensis									0.3	0.3	**0.1**
Madracis decactis			0.5								**0.1**
Siderastrea siderea			0.5								**0.1**
Leptoseris cucullata						0.4					**0.0**
Montastraea cavernosa						0.4					**0.0**
Siderastrea radians						0.4					**0.0**
Meandrina meandrites								0.3			**0.0**
Porites astreoides									0.3		**0.0**
Total scleractinian coral	**4.5**	**1.5**	**3.0**	**2.0**	**5.2**	**1.2**	**0.3**	**2.3**	**3.0**	**11.0**	**3.4**

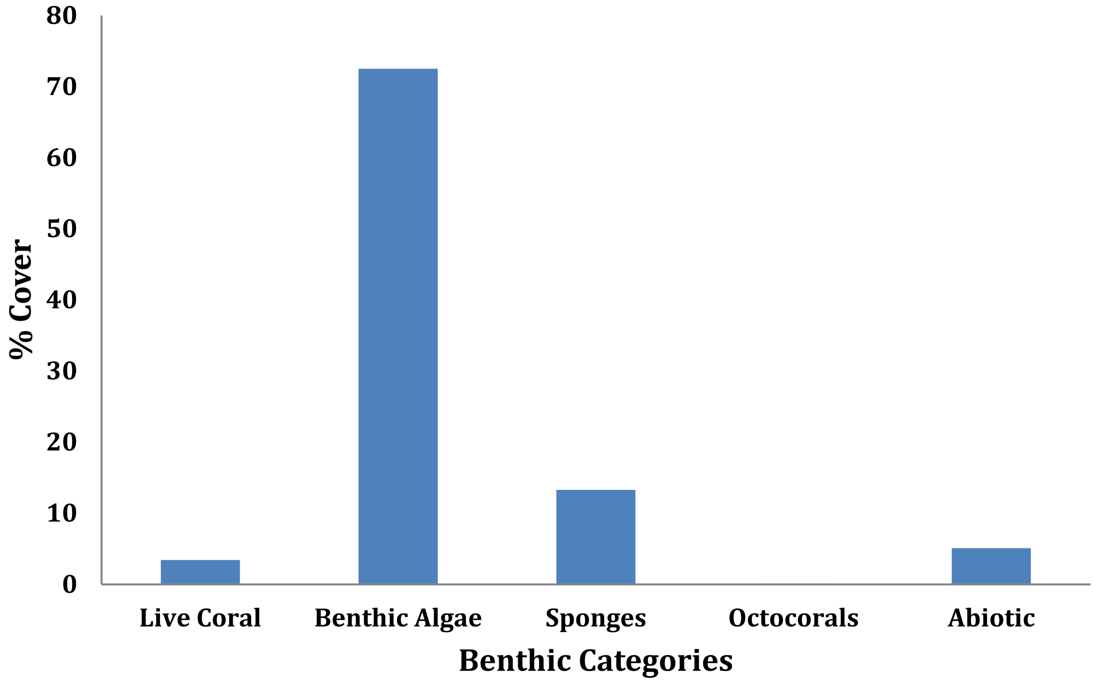


Figure 17. Rhodolith Reef Habitat. Relative composition of substrate categories based on the mean of 10 photo transects surveyed. Depth 43 – 50 m

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3.4.2 Fish/Invertebrate community

A total of 48 fish species, including 20 within belt-transects were identified from rhodolith reef habitats at depths of 43 – 50 m (Table 17). The complete list of fish species observed from the different benthic habitats is included as Appendix 2. Mean abundance within belt-transects was 10.6 Ind/30m^2 (range: 3 - 26 Ind/30m^2). Mean species richness was 4.2 spp/30m^2 (range: 3 – 5 spp/30m^2). Small territorial fish species were the most commonly observed from the rhodolith reef habitat. An assemblage of three species accounted for 69.8 % of the total individuals. The most abundant species was the bicolor damselfish, *Stegastes partitus* with 4.6 Ind/30m^2, followed by cherubfish, *Centropyge argi* with 1.8 Ind/30m^2 and masked goby, *Coryphopterus personatus* with 1.0 Ind/30m^2 (Table 17).

The fish community structure of the rhodolith reef habitat in southeast Vieques was found to be depauperate, with a reduced assemblage of small territorial fishes present in very low abundance and a correspondingly low abundance of demersal and pelagic predators. Opportunistic carnivores of small benthic invertebrates were the most prominent trophic group represented by a wide assemblage of basslets (*Serranus* *baldwini, S. tortugarum, S. tigrinus, S. tabacarius, S. annularis*), wrasses (*Thalassoma bifasciatum, Halichoeres garnoti*), hamlets (*Hypoplectrus chlorurus*), sand tilefish, *Malacanthus plumieri* and gobies (*C. personatus*) among others. Herbivorous taxa included *C. argi, Sparisoma atomarium, S. viride* and *Acanthurus chirurgus*. The main demersal predators resident at the rhodolith habitat were the red hind, *Epinephelus guttatus,* coney*, Epinephelus fulva* and the queen triggerfish, *Balistes vetula*. The generally small size of red hind individuals suggest that the rhodolith reef may be functioning as a recruitment or nursery site for this species, since all individuals present were smaller (< 25 cm) than individuals observed from other mesophotic habitats studied in southeast Vieques (Table 18).

Table 17. Rhodolith Reef Habitat. Taxonomic composition and abundance of fishes within belt-transects. El Seco, Vieques 2010-11

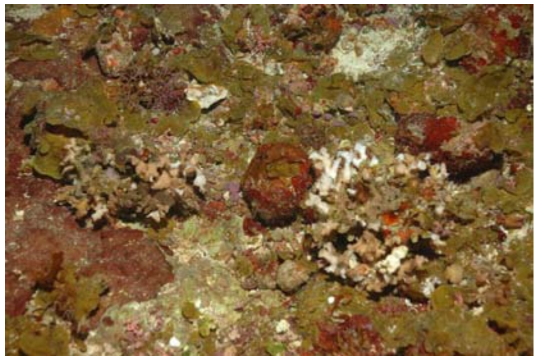
	Station										
	35a	**35b**	**35c**	**34a**	**34b**	**34c**	**62a**	**62b**	**61**	**64**	
SPECIES					**(Ind/30m²)**						**Mean**
Stegastes partitus	1	1	6	4	5	0	18	4	7	0	**4.6**
Centropyge argi	0	1	3	0	3	0	5	3	3	0	**1.8**
Coryphopterus personatus	0	0	0	0	10	0	0	0	0	0	**1.0**
Serranus baldwini	0	0	1	0	0	0	0	0	4	0	**0.5**
Hypoplectrus chlorurus	0	0	0	1	1	0	0	0	0	2	**0.4**
Halichoeres garnoti	0	1	0	1	0	0	0	1	0	0	**0.3**
Chromis insolata	0	0	0	0	0	0	1	0	0	2	**0.3**
Chromis cyanea	0	0	1	1	0	0	0	0	0	1	**0.3**
Thalassoma bifasciatum	0	1	0	0	0	0	1	0	0	0	**0.2**
Sparisoma atomarium	0	0	1	0	0	1	0	0	0	0	**0.2**
Serranus tortugarum	0	0	0	0	0	0	0	1	0	0	**0.1**
Serranus tigrinus	1	0	0	0	0	0	0	0	0	0	**0.1**
Serranus tabacarius	0	0	0	0	0	0	0	0	1	0	**0.1**
Serranus annularis	1	0	0	0	0	0	0	0	0	0	**0.1**
Seriola rivoliana	0	0	0	0	0	0	0	0	0	1	**0.1**
Liopropoma rubre	0	0	0	0	0	1	0	0	0	0	**0.1**
Holocentrus rufus	0	0	0	0	0	1	0	0	0	0	**0.1**
Epinephelus guttatus	0	0	0	0	0	1	0	0	0	0	**0.1**
Epinephelus fulva	0	0	0	0	0	0	1	0	0	0	**0.1**
Chaetodon aculeatus	0	0	0	0	0	1	0	0	0	0	**0.1**
	3	**4**	**12**	**7**	**19**	**5**	**26**	**9**	**15**	**6**	**10.6**
	3	**4**	**5**	**4**	**4**	**5**	**5**	**4**	**4**	**4**	**4.2**

The pelagic fish community was comprised by several species of flying fishes (Exocoetidae), mackerel scad (*Decapterus macarelus*) and ballyhoo (*Hemiramphus brasiliensis*). The latter assemblage appears to serve as forage for large predators that include great barracuda, *Sphyraena barracu*da, Almaco Jack, *Seriola rivoliana*, and cero mackerel, *Scomberomorus regalis*. Although not observed during our survey, it would be expected that many other pelagic reef predators, such as tunas, wahoo, marlins, jacks and dolphinfish also forage the water column above the rhodolith reef habitat.

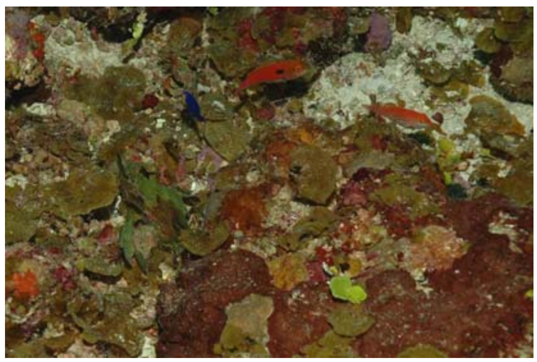
Table 18. Taxonomic composition, abundance and size distribution of commercially important fishes within 20m x 3m belt-transects. El Seco, Vieques 2010-11

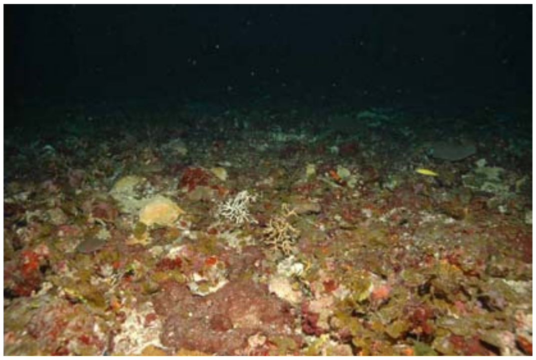
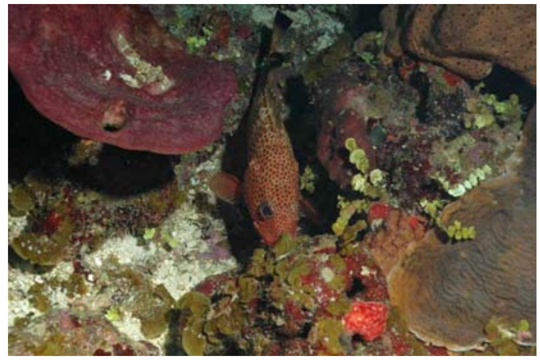
SPECIES					**Stations**					
	35a	**35b**	**35c**	**34a**	**34b**	**34c**	**62a**	**62b**	**61**	**64**
					Ind/60m²– length (cm)					
Epinephelus fulva							1-20		1-16	
Epinephelus guttatus	1-18					1-18				1-20
					Stations					
	35a	**35b**	**35c**	**34a**	**34b**	**34c**	**62a**	**62b**	**61**	**64**
Fishes/Invertebrates Outside Transects										
Seriola rivoliana										1-80
Epinephelus guttatus	2-20				1-18			1-22		
Sphyraena barracuda					1-70					
Scomberomorus regalis		1-60								

Photo Album 4. Rhodolith Reef

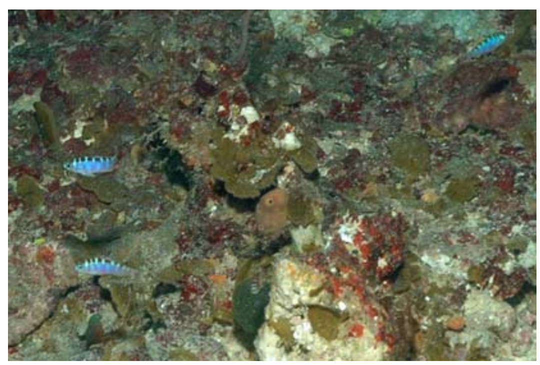











4.0 Patterns of sessile-benthic and fish community structure

4.1 Benthic Community

Measurements of the percent substrate cover by sessile-benthic categories from transects surveyed at benthic habitats were used to construct a multidimensional scaling (MDS) diagram of community structure similarities (resemblance) based on Bray-Curtis Euclidean distances. Three distinct habitat clusters (rhodolith reef, colonized pavement, coral reef and patch reef) emerged from the resemblance matrix with similarities of community structure above 65 % within each group (Figure 18). Statistically significant differences were found between transects at the bank coral reef and the rhodolith reef (ANOSIM, $r = 0.996$; $p < 0.001$) and between the bank coral reef and colonized pavement habitats (ANOSIM, $r = 0.941$; $p < 0.001$). Also, significant differences resulted between patch reef and rhodolith reef habitats (ANOSIM, $r = 0.902$; $p < 0.001$). Differences between the bank coral reef and patch reef, and between the colonized pavement and the patch reef habitats were not statistically significant. Pairwise analyses

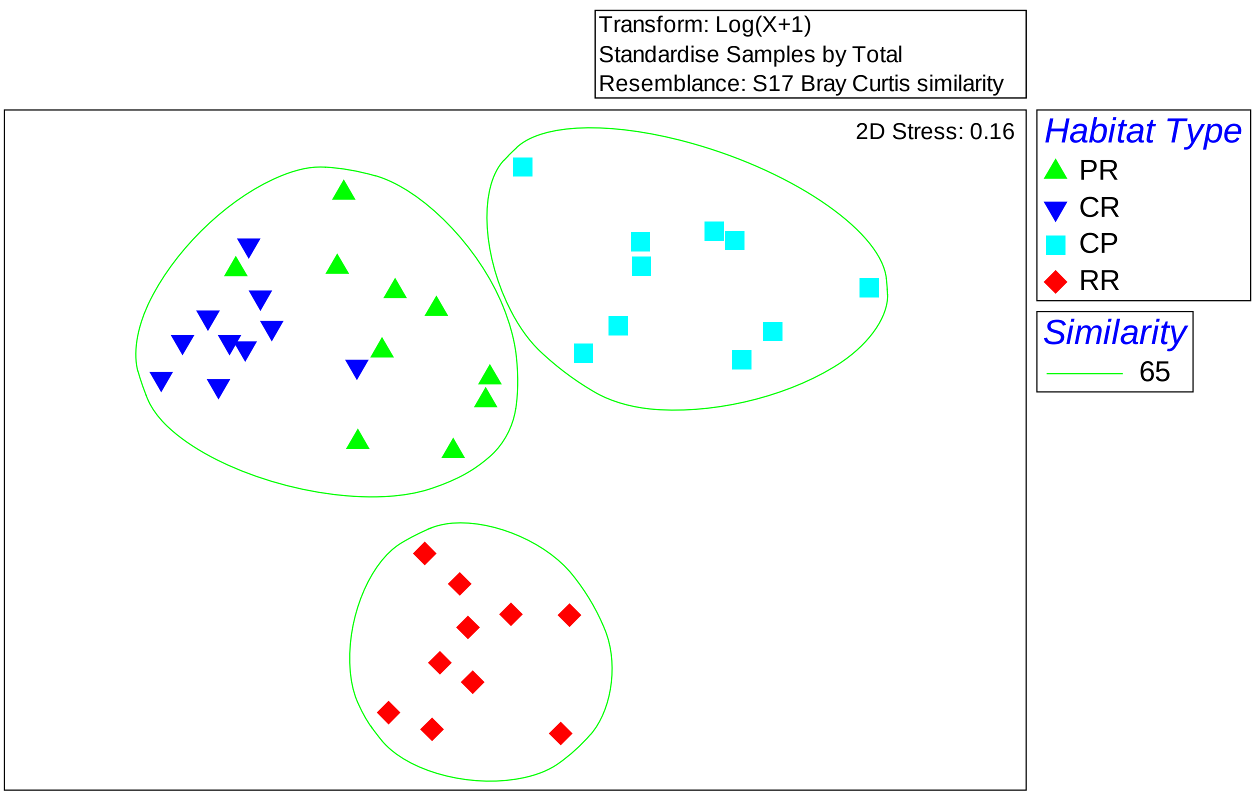


Figure 18. Multidimensional scaling plot of Bray-Curtis similarities between benthic habitats based on the data of percent substrate cover by sessile-benthic categories on photo-transects at El Seco, southeast Vieques. 2010-11

of similarities (ANOSIM) between benthic habitats are included in Appendix 3.

The highest similarity of sessile-benthic community structure within any given habitat was observed for the bank coral reef with 85.0 % (Table 19). The lowest average similarity resulted for transects surveyed at the colonized pavement (75.3 %). Community structure similarities at the bank coral reef and patch reef habitats were driven by the contributions of turf algae, *Lobophora variegata* and *Montastraea franksi* to the cumulative similarity within both habitats. The aforementioned variables ranked on the top four in terms of percent contributors to similarity, accounting for more than 50 % to the cumulative similarity within each habitat (Table 19). Substrate cover by turf algae, sponges and abiotic categories contributed more than 60% to the similarity at the colonized pavement habitat, whereas sponges, turf algae and *L. variegata* contributed 66.6 % of the cumulative similarity at the rhodolith reef habitat (Table 19).

The relative contributions of substrate categories to dissimilarity between benthic habitats are presented in Table 20. Dissimilarities were highest between the coral reef and rhodolith habitats, and between the coral reef and the colonized pavement habitats. Substrate cover by boulder star coral, *M. franksi* was the main factor contributing to dissimilarity of community structure between benthic habitats at El Seco. *Montastraea franksi* was the dominant invertebrate in terms of percent substrate cover at the coral reef and patch reef habitats with averages of 34.2 % and 11.5 %, representing 84.4 % and 64.3 % of the total cover by live scleractinian corals, respectively. Conversely, *M. cavernosa* and *Agaricia undata* were the dominant scleractinian coral taxa at the colonized pavement and rhodolith reef habitats, respectively.

Despite its high structural complexity and rugosity the bank coral reef was the most uniform habitat in terms of the relative composition and spatial arrangement of its biological components. This was strongly influenced by the fact that the system is essentially a biotope of boulder star coral, *M. franksi*. The mean coefficient of variation (stdev/mean*100) on measurements of substrate cover by *M. franksi* at the bank coral reef was 24.0 %. Open horizontal reef space not covered by laminar growth of *M. franksi* was typically colonized at the reef base by turf algae growing intermixed with the encrusting fan alga, *L. variegata*. Mean cover by these three substrate categories was 80.3 % of the total cover at the bank coral reef. Conversely, the most heterogeneous habitat was the colonized pavement which prevailed at the El Seco ridge, where spatially scattered rock outcrops colonized by benthic algae, corals, sponges and other reef biota introduced substantial variability to an otherwise flat, depauperate and mostly abiotic seascape. Abiotic substrate (mostly sand) was also prominent at the patch reef habitat, although not strongly evidenced by the data because transects were placed over coral reef promontories. Nevertheless, sand pockets were present and contributed substantially to the average substrate cover (e.g. 11.5%). If transects would have been randomly arranged at the patch reef habitat the contribution by sand would have been a numerically dominant category. The rhodolith reef habitat was second only to the coral reef bank in terms of homogeneity of benthic community structure. The combined cover by benthic algae and sponges represented on the average more than 85 % of the total cover at the reef with a coefficient of variation between transects of only 8.1 %. Dominance of substrate cover by benthic algae and sponges over coral appears to be influenced by the increased depth distribution of the rhodolith reef (> 40 m) and the lack of coral attachment substrates. Scleractinian corals appeared to grow with limited success and constrained to small sizes using mostly algal rhodoliths as attachment substrates.

Differences of benthic community structure associated with depth were linked to the different habitats present across the 25 – 50 m depth gradient studied. Distinct habitats and associated benthic communities were found occupying relatively narrow depth ranges. For example, the colonized pavement habitat was only observed at the reef top platform of the El Seco ridge, which is essentially flat and varied in depth only between 25 – 30 m (80 – 100’). The bank coral reef rises from a gently sloping terrace, with depth fluctuating mostly between 35 – 40 m (115 – 132’). Patch reefs were found at the deeper margin of the coral reef bank at depths of 40 – 45 m (135 – 148’), while the rhodolith reef habitat was distributed at depths of 45 – 50 m (145 – 165’). Because of the limited depth ranges exhibited by these habitats, depth related differences of benthic community structure within any given habitat were insignificant. Differences were perhaps visually evident at the margins of each habitat and associated with substrate transitions or interfaces.

Table 19. SIMPER. Contributions to similarity percentages by substrate categories within benthic habitats surveyed at El Seco, southeast Vieques. 2010-11 (Parameters: Resemblance: S17 Bray Curtis; Cut off for low contributions: 90.0%)

Benthic Habitats	Av.Abund	Av.Sim	Sim/Sd	Contrib%	Cum.%
Bank Coral Reef (Average similarity: 85.0)					
Algal turf	17.88	17.38	33.58	20.44	20.44
Montastrea franksi	18.58	17.16	7.04	20.18	40.62
Lobophora	12.48	11.29	7.55	13.28	53.90
Cyanobacteria	10.25	9.69	21.87	11.40	65.29
Red Coralline Algae	9.80	8.58	7.70	10.09	75.38
Sponges	7.51	5.99	2.97	7.04	82.43
Porites astreoides	5.16	4.41	2.67	5.19	87.62
Abiotic	5.03	3.47	2.02	4.08	91.70
Rhodolith Reef (Average similarity: 81.0)					
Sponges	22.49	20.98	13.88	25.97	25.97
Algal turf	17.73	16.59	8.87	20.53	46.50
Lobophora	17.97	16.23	9.62	20.09	66.59
Red Coralline Algae	10.81	8.91	3.69	11.03	77.62
Abiotic	8.22	6.46	2.42	8.00	85.62
Cyanobacteria	6.82	5.53	3.97	6.84	92.46
Patch Reef (Average similarity: 76.2)					
Algal turf	17.79	16.62	16.06	21.82	21.82
Lobophora	17.81	15.62	5.68	20.50	42.32
Abiotic	11.53	9.28	3.62	12.19	54.51
Montastrea franksi	11.61	8.97	2.51	11.77	66.28
Sponges	8.56	8.09	16.54	10.62	76.90
Dictyota sp.	6.17	3.98	1.27	5.23	82.13
Cyanobacteria	6.14	3.55	1.06	4.67	86.80
Agaricia lamarcki	4.27	2.60	1.36	3.41	90.20
Colonized Pavement (Average similarity: 75.3)					
Algal turf	25.33	23.69	9.78	31.45	31.45
Sponges	12.93	11.42	6.71	15.16	46.62
Abiotic	12.85	10.88	4.03	14.45	61.06
Lobophora	14.90	10.82	1.91	14.37	75.43
Octocorals	6.00	3.97	1.37	5.27	80.70
Cyanobacteria	7.36	3.67	0.75	4.87	85.56
Montastrea cavernosa	5.15	3.54	1.90	4.70	90.26

Table 20. SIMPER. Contributions to dissimilarity percentages by substrate categories between benthic habitats surveyed at El Seco, southeast Vieques. 2010-11
(Parameters: Resemblance: S17 Bray Curtis; Cut off for low contributions: 60.0%)
Habitats: Patch Reef (PR), Bank Coral Reef (CR) ; Colonized Pavement CP), Rhodolith Reef RR)

Substrate Categories	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Groups CR & RR (Average dissimilarity = 38.3%)						
	Group CR	**Group RR**				
Montastrea franksi	18.58	1.14	8.72	6.40	22.78	22.78
Sponges	7.51	22.49	7.49	4.26	19.56	42.34
Lobophora	12.48	17.97	2.77	1.63	7.25	49.58
Porites astreoides	5.16	0.14	2.51	3.39	6.55	56.13
Abiotic	5.03	8.22	2.10	1.53	5.47	61.61
Groups PR & CR (Average dissimilarity = 28.0%)						
	Group PR	**Group CR**				
Montastrea franksi	11.61	18.58	3.64	1.65	12.98	12.98
Abiotic	11.53	5.03	3.39	1.66	12.10	25.08
Dictyota sp.	6.17	0.00	3.08	1.75	11.01	36.09
Lobophora	17.81	12.48	2.79	1.51	9.96	46.05
Red Coralline Algae	4.38	9.80	2.73	1.51	9.76	55.81
Cyanobacteria	6.14	10.25	2.39	1.34	8.55	64.35
Groups PR & CP (Average dissimilarity = 35.8)%						
	Group PR	**Group CP**				
Montastrea franksi	11.61	3.33	4.36	1.80	12.18	12.18
Algal turf	17.79	25.33	3.82	2.37	10.68	22.86
Lobophora	17.81	14.90	3.21	1.32	8.98	31.84
Cyanobacteria	6.14	7.36	3.05	1.45	8.54	40.38
Dictyota sp.	6.17	0.54	2.87	1.68	8.04	48.42
Octocorals	0.54	6.00	2.79	1.75	7.79	56.21
Sponges	8.56	12.93	2.19	1.74	6.12	62.33
Groups CR & CP (Average dissimilarity = 40.9%)						
	Group CR	**Group CP**				
Montastrea franksi	18.58	3.33	7.62	3.53	18.63	18.63
Red Coralline Algae	9.80	1.56	4.12	2.95	10.06	28.69
Abiotic	5.03	12.85	3.96	2.01	9.68	38.38
Algal turf	17.88	25.33	3.72	2.62	9.10	47.48
Lobophora	12.48	14.90	2.99	1.42	7.30	54.78
Cyanobacteria	10.25	7.36	2.79	1.48	6.81	61.59
Groups PR & RR (Average dissimilarity = 36.4%)						
	Group PR	**Group RR**				
Sponges	8.56	22.49	6.96	5.26	19.12	19.12
Montastrea franksi	11.61	1.14	5.24	2.36	14.39	33.51
Red Coralline Algae	4.38	10.81	3.30	1.64	9.05	42.55
Dictyota sp.	6.17	3.27	2.57	1.52	7.06	49.62
Abiotic	11.53	8.22	2.23	1.24	6.12	55.74
Cyanobacteria	6.14	6.82	2.05	1.73	5.63	61.37
Groups CP & RR (Average dissimilarity = 40.4%)						
	Group CP	**Group RR**				
Sponges	12.93	22.49	4.78	2.73	11.82	11.82
Red Coralline Algae	1.56	10.81	4.62	2.60	11.43	23.25
Algal turf	25.33	17.73	3.80	2.28	9.40	32.65
Lobophora	14.90	17.97	3.06	1.24	7.57	40.22
Cyanobacteria	7.36	6.82	2.87	2.10	7.11	47.32
Octocorals	6.00	0.47	2.82	1.75	6.97	54.30
Abiotic	12.85	8.22	2.60	1.43	6.43	60.72

4.2 Fish Community Structure

A multivariate data matrix based on the relative abundance of fishes surveyed within belt-transects was used to construct the multidimensional scaling (MDS) plot of Bray Curtis similarities shown in Figure 19. As for the benthic community structure MDS, transects surveyed at the bank coral reef and patch reef habitats showed the highest similarities of fish community structure and statistically significant differences between them were not found (ANOSIM, $r = 0.063$; $p > 0.01$). Pairwise analyses of similarities (ANOSIM) of fish community structure between benthic habitats are included in Appendix 4. Statistically significant differences were found between the bank coral reef and the colonized pavement (ANOSIM, $r = 0.875$; $p < 0.001$), and between the bank coral reef and the rhodolith habitat (ANOSIM, $r = 0.659$; $p < 0.001$). Fish community structure at the patch reef was different than that at the colonized pavement (ANOSIM, $r = 0.757$; < 0.001), but not different than that at the rhodolith reef. Differences between colonized pavement and rhodolith reef were not significantly different either (ANOSIM, $r = 0.573$; $p < 0.001$).

Despite being one of the most similar or uniform habitats in terms of its sessile-benthic components, the rhodolith reef showed that its fish community was not. Fishes were found in very low abundance and many species were observed associated to sponges, corals or tilefish mounds not uniformly distributed within the reef. Also, there were sections of the habitat in which territorial and numerically dominant species were absent. The low fish abundance and the patchy distributions of protective microhabitats introduce a potential for high sampling variability within this system. Out of the 10 transects surveyed, two of them were dissimilar from the rest in terms of fish community structure (Figure 19). The high sampling variability introduced by these two transects at the rhodolith reef increased the “stress” of the multivariate statistical analysis, reducing its ability to detect what appeared to be real differences, or dissimilarities of fish community structure relative to other benthic habitats. In both transects, the top two species in terms of mean abundance and frequency of occurrence, bicolor damselfish (*Stegastes partitus*) and cherubfish (*Centropyge argi*) were not observed. These transects also differed from each other in that they presented unique species found in no other transect surveyed within this habitat. The data from these transects could be interpreted as outliers, but they seem to reflect the true nature of fish distributions at this particular habitat. It is clear that due to the depauperate nature of fish distributions at the

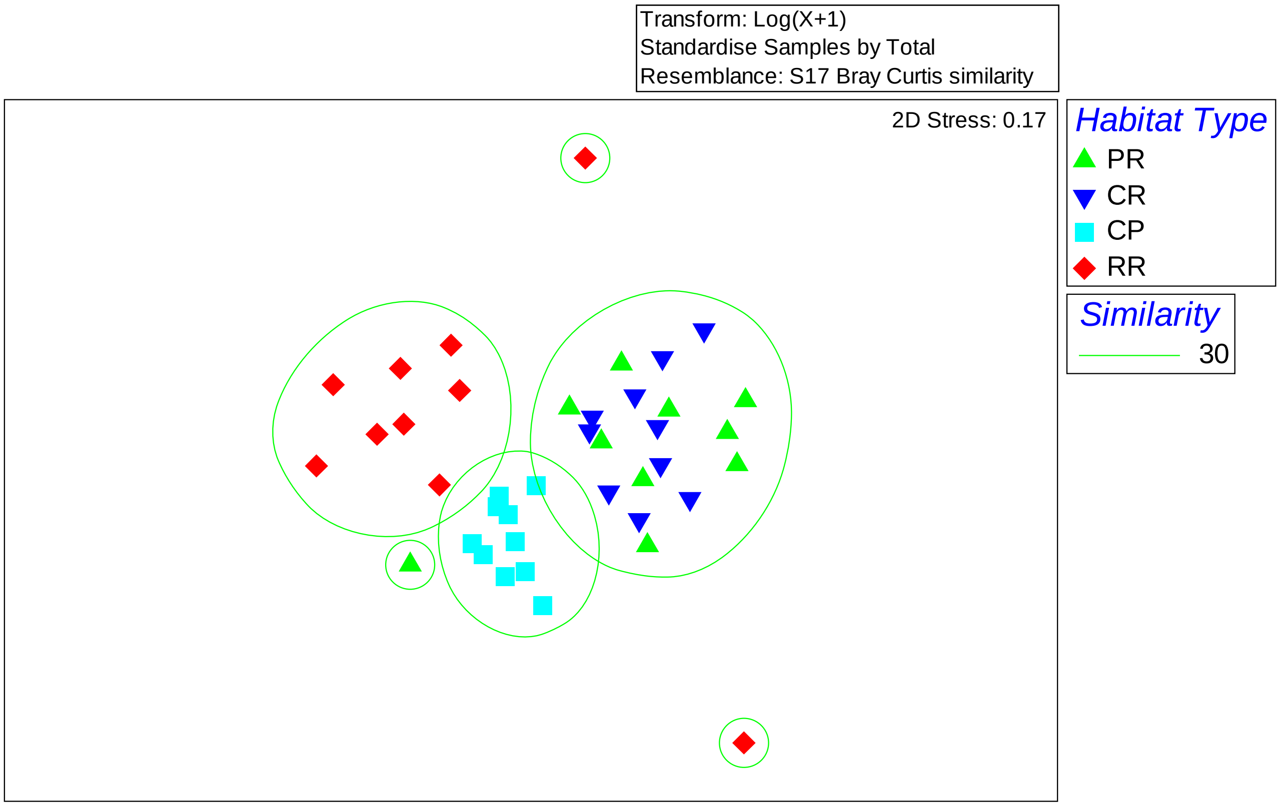


Figure 19. Multidimensional scaling plot of Bray-Curtis similarities of fish community structure between benthic habitats surveyed by 10 x 3 m belt-transects at El Seco, southeast Vieques. 2010-11

rhodolith reef, the effectiveness of 10 m long transects for characterization of small demersal territorial fish assemblages was compromised and longer transects would have been more appropriate.

The colonized pavement presented the highest similarity of small demersal fish community structure (52.8 %) within any given habitat (Table 21). This was strongly influenced by the presence of the two numerically dominant species, bluehead wrasse (*Thalassoma bifasciatum*) and bicolor damselfish (*Stegastes partitus*) in all 10 transects, and the presence of the third numerically dominant species, yellowhead wrasse (*Halichoeres garnoti*) in nine out of the ten transects surveyed. Nevertheless, this data must be interpreted with caution because both wrasse species are attracted to divers and their densities within belt-transects may have been somewhat biased by the presence of the surveyor.

The bank coral reef and patch reef habitats shared the same top five fish species in terms of their individual contributions to the within habitat similarity, but in different rank order (Table 21). These included the blue chromis (*Chromis cyanea*), bluehead and yellowhead wrasses, bicolor damselfish and masked goby (*Coryphopterus personatus*). The bank coral reef and patch reef habitats are physically contiguous systems, but patch reefs are distributed deeper by 5 -10 m. Variations of both sessile-benthic and fish community structure were insignificant despite such depth difference. Fish species contributions to dissimilarity between coral reef and patch reef habitats are presented in Table 22. Only two species contributed more than 5 % to the average dissimilarity between habitats, none of which exceeded 10 %. Prevalence of boulder star coral, *M. annularis* as the dominant coral contributing substrate cover and topographic relief both at the bank coral reef and patch reefs provides an important habitat continuity for the fish community across a relatively small and apparently insignificant depth gradient.

Below 45 m the physical features of the seafloor changed drastically relative to that observed at the bank coral reef and patch reef habitats, particularly in terms of structural complexity and topographic relief. Influenced by the absence of *M. annularis* and other massive reef building corals, only small and scattered protective microhabitats were available at the rhodolith reef. It is here suggested that the lack of reef structural complexity and associated availability of protective microhabitats influenced the sharp decline of fish species richness and the general absence of large demersal predators at the rhodolith reef habitat. The ichthyofauna of rhodolith reefs consists of a unique assemblage of small demersal fishes adapted to use rhodolith deposits as protective microhabitats, and a reduced array of demersal predators of small to moderate size, such as coneys (*Epinephelus fulva*), red hinds (*E. guttatus*) and queen triggerfish (*Balistes vetula*). Differences in the relative abundance of bicolor damselfish, cherubfish and masked goby represented the main species contributions to the dissimilarity between patch and bank coral reefs and the rhodolith reef habitat (Table 22).

Table 21. SIMPER. Contributions to similarity percentages by fish species within benthic habitats surveyed at El Seco, southeast Vieques. 2010-11
(Parameters: Resemblance: S17 Bray Curtis; Cut off for low contributions: 90.0%)

Fish Species	**Av.Abund**	**Av.Sim**	**Sim/Sd**	**Contrib**	**Cum.%**
Colonized Pavement (Average similarity: 52.8%)					
Thalassoma bifasciatum	23.56	19.94	4.39	37.78	37.78
Stegastes partitus	18.62	15.24	3.56	28.87	66.65
Halichoeres garnoti	8.85	6.23	1.71	11.80	78.45
Holocentrus rufus	5.48	3.52	1.16	6.67	85.12
Acanthurus chirurgus	5.93	2.26	0.68	4.28	89.40
Serranus tigrinus	3.82	1.36	0.50	2.57	91.97
Coral Reef (Average similarity: 39.8%)					
Coryphopterus personatus	16.17	10.18	1.32	25.56	25.56
Thalassoma bifasciatum	8.62	6.46	3.42	16.23	41.79
Stegastes partitus	6.69	4.69	1.73	11.78	53.57
Halichoeres garnoti	4.80	2.78	1.02	6.99	60.56
Chromis cyanea	5.85	2.55	0.66	6.40	66.96
Gramma loreto	4.68	2.28	0.83	5.73	72.69
Scarus taeniopterus	5.98	2.07	0.59	5.21	77.90
Coryphopterus lipernes	4.05	1.61	0.52	4.05	81.94
Hypoplectrus chlorurus	2.62	1.10	0.68	2.76	84.70
Bodianus rufus	2.40	0.89	0.52	2.24	86.93
Sparisoma aurofrenatum	1.92	0.79	0.53	1.98	88.92
Epinephelus guttatus	1.83	0.69	0.52	1.73	90.65
Patch Reef (Average similarity: 33.8%)					
Chromis cyanea	9.03	5.79	1.20	17.15	17.15
Halichoeres garnoti	7.79	4.61	1.48	13.65	30.80
Coryphopterus personatus	8.28	4.40	0.85	13.02	43.81
Stegastes partitus	6.23	2.82	0.80	8.36	52.17
Thalassoma bifasciatum	4.77	1.98	0.63	5.86	58.04
Myripristis jacobus	4.56	1.91	0.86	5.66	63.70
Scarus taeniopterus	4.69	1.75	0.60	5.18	68.88
Sparisoma aurofrenatum	2.44	1.14	0.69	3.38	72.25
Bodianus rufus	2.57	1.12	0.68	3.32	75.58
Gramma loreto	3.37	1.08	0.47	3.20	78.78
Canthigaster rostrata	3.82	0.93	0.50	2.75	81.53
Epinephelus cruentatus	2.16	0.63	0.39	1.88	83.41
Holocentrus rufus	2.25	0.62	0.38	1.83	85.24
Acanthurus bahianus	2.54	0.61	0.37	1.80	87.04
Chaetodon aculeatus	2.18	0.60	0.38	1.78	88.82
Hypoplectrus chlorurus	2.15	0.60	0.37	1.77	90.59
Rhodolith Reef (Average similarity: 31.6%)					
Stegastes partitus	28.25	19.6	1.26	1.98	61.98
Centropyge argi	15.47	7.98	0.70	25.25	87.23
Halichoeres garnoti	5.96	1.12	0.26	3.54	90.77

Table 22. SIMPER. Contributions to dissimilarity between benthic habitats by fish species at El Seco, southeast Vieques. 2010-11
(Parameters: Resemblance: S17 Bray Curtis; Cut off for low contributions: top 5 spp)
Habitats: Patch Reef (PR), Bank Coral Reef (CR); Colonized Pavement CP), Rhodolith Reef RR)

Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Groups PR & CR (Average dissimilarity = 64.5)						
	Group PR	**Group CR**				
Coryphopterus personatus	8.28	16.17	5.61	1.37	8.69	8.69
Chromis cyanea	9.03	5.85	3.29	1.35	5.10	13.80
Scarus taeniopterus	4.69	5.98	3.16	1.18	4.90	18.69
Thalassoma bifasciatum	4.77	8.62	2.86	1.41	4.43	23.12
Stegastes partitus	6.23	6.69	2.66	1.41	4.13	27.25
Groups PR & CP (Average dissimilarity = 76.5)						
	Group PR	**Group CP**				
Thalassoma bifasciatum	4.77	23.56	9.39	2.50	12.28	12.28
Stegastes partitus	6.23	18.62	6.39	1.80	8.36	20.64
Coryphopterus personatus	8.28	0.00	4.14	1.32	5.41	26.05
Chromis cyanea	9.03	1.96	3.95	1.56	5.16	31.21
Acanthurus chirurgus	0.00	5.93	2.96	0.91	3.88	35.09
Groups CR & CP (Average dissimilarity = 75.4)						
	Group CR	**Group CP**				
Coryphopterus personatus	16.17	0.00	8.09	1.69	10.73	10.73
Thalassoma bifasciatum	8.62	23.56	7.52	2.21	9.97	20.70
Stegastes partitus	6.69	18.62	6.04	1.93	8.01	28.72
Acanthurus chirurgus	0.00	5.93	2.96	0.91	3.93	32.65
Scarus taeniopterus	5.98	0.55	2.96	0.93	3.93	36.58
Groups PR & RR (Average dissimilarity = 86.8)						
	Group PR	**Group RR**				
Stegastes partitus	6.23	28.25	12.25	2.04	14.12	14.12
Centropyge argi	0.00	15.47	7.73	1.20	8.91	23.03
Coryphopterus personatus	8.28	3.82	5.22	1.15	6.02	29.05
Halichoeres garnoti	7.79	5.96	4.57	1.53	5.27	34.31
Chromis cyanea	9.03	5.09	4.41	1.63	5.08	39.39
Groups CR & RR (Average dissimilarity = 86.7)						
	Group CR	**Group RR**				
Stegastes partitus	6.69	28.25	12.12	2.22	13.98	13.98
Coryphopterus personatus	16.17	3.82	8.38	1.72	9.67	23.65
Centropyge argi	0.00	15.47	7.73	1.20	8.92	32.57
Thalassoma bifasciatum	8.62	3.52	4.43	1.91	5.11	37.68
Halichoeres garnoti	4.80	5.96	3.94	1.29	4.55	42.23
Groups CP & RR (Average dissimilarity = 77.4)						
	Group CP	**Group RR**				
Thalassoma bifasciatum	23.56	3.52	10.33	2.45	13.35	13.35
Stegastes partitus	18.62	28.25	8.58	2.28	11.09	24.45
Centropyge argi	0.00	15.47	7.73	1.20	10.00	34.44
Halichoeres garnoti	8.85	5.96	4.78	1.88	6.17	40.61
Acanthurus chirurgus	5.93	0.00	2.96	0.91	3.83	44.44

The presence of large demersal predators, including adult cubera, mutton, dog, yellowtail and schoolmaster snappers, adult tiger, yellowfin and red hind groupers, hogfish and nurse sharks was a common feature of the bank coral reef and patch reef habitats at El Seco. More pelagic reef fish activity was observed at the patch reef system, but this may have been associated with the presence of large aggregations of snappers and groupers at the tiger grouper spawning site, which is within the patch reef habitat. With the notable absence of tiger grouper and cubera snappers, large demersal predators were observed also at the colonized pavement habitat, but in much lower abundances. The colonized pavement habitat appears to be a prime foraging habitat for many of these demersal predators, whereas the bank coral reef appears to function as the main residential habitat for most of them. As for the small demersal fish assemblage, most of the contributions to dissimilarity between the patch and coral reef habitats and the colonized pavement habitat were related to the higher mean and relative abundance of bluehead wrasse, bicolor damselfish and doctorfish at the colonized pavement, and the higher abundance of masked goby at the coral reef and patch reef habitats (Table 22).

A population of queen conch, *Strombus gigas* was found patchily distributed within the southwest margin of the colonized pavement habitat at El Seco ridge. Several adult individuals were also observed over sandy bottom at a depth of 45 m in the vicinity of patch reefs. A total of four (4) spiny lobsters, *Panulirus argus* were present in the rock promontories of the colonized pavement habitat, but not seen elsewhere within our study area.

4.3 Fish spawning aggregations

Located on the southeastern corner of the Vieques outer shelf, at approximately 250 m north and 150 m west of the shelf edge (18.12376 N; 65.19061 W) the reported seasonal spawning aggregation of tiger grouper was investigated. A total of eight visits to the spawning aggregation site were made, including one previous to the spawning season in which quantitative baseline observations of fish abundance were established. Fish abundance surveys were performed during June 2010 and then during the full moons of February, March and April 2011. The benthic habitat corresponded to that previously described for patch reefs within a depth range of 42 - 44 m (138 – 147'). A series of low relief rock promontories colonized by benthic algae, mostly *Lobophora sp.*, corals and sponges and separated by wide expanses of sand characterized the spawning aggregation site.

Fish community structure at the spawning site during the June 2010 baseline survey was characterized by the typical demersal fish assemblage previously described in this report for the patch reef habitat (see section 3.3.2). Fish species of commercial value observed out of transects, but within the spawning site patch reef habitat included three (3) red hinds (*Epinephelus guttatus*) and two (2) mutton snappers (*Lutjanus analis*). One adult nurse shark (*Ginglymostoma cirratum*) and several horse-eye jacks (*Caranx hippos*) were also present during our baseline survey. The fish community was largely concentrated over the patch reef promontories. Several queen conch (*Strombus gigas*) were observed at the sand bottom close to the patch reefs. Fish aggregations were not observed during the June 2010 survey at the spawning site except for a small aggregation of approximately 25 small smooth trunk fish (*Lactophrys triqueter*) (Plate 3).

During our second survey of the spawning site, three days prior to the full moon of February 2011 (February 16 – 18) a spawning aggregation of approximately 300 adult dog snappers (*Lutjanus jocu*) were present (Plate 4, Video 1). Swarms of 40 – 60 individuals were initially observed, but in some instances converged into one large mass of dog snappers swirling over the reef, rising to about 20 m from the bottom. The entire dog snapper aggregation was confined within an estimated area of approximately 50-60 m^2. Active spawning of dog snapper was observed once, close to noon, involving at least 20 individuals swimming up to the water column and releasing gametes. The dog snapper aggregation remained at the spawning site during consecutive days between February 16 and full moon (February 18, 2011). No further observations were made after full moon in February 2011. Three large cubera snappers (*L. cyanopterus*) and five mutton snappers (*L. analis*) were observed intermixed in the dog snapper aggregation and swimming in and out of it, but staying within the patch reef spawning site.

Plate 3. Aggregation of smooth trunk fish during June 2010

Plate 4. Aggregation of dog snapper during February 2011

A group of 12 tiger groupers (*Mycteroperca tigris*), including 10 males and two females were present during February 16, 2011. All males were observed with distinctive reproductive coloration in black and white holding territories near the edges of the patch reef promontories (Plate 5). There was a progressive increment of adult tiger groupers at the spawning site, mostly males, until the full moon of February 18, when the largest aggregation was observed at about 120 individuals.

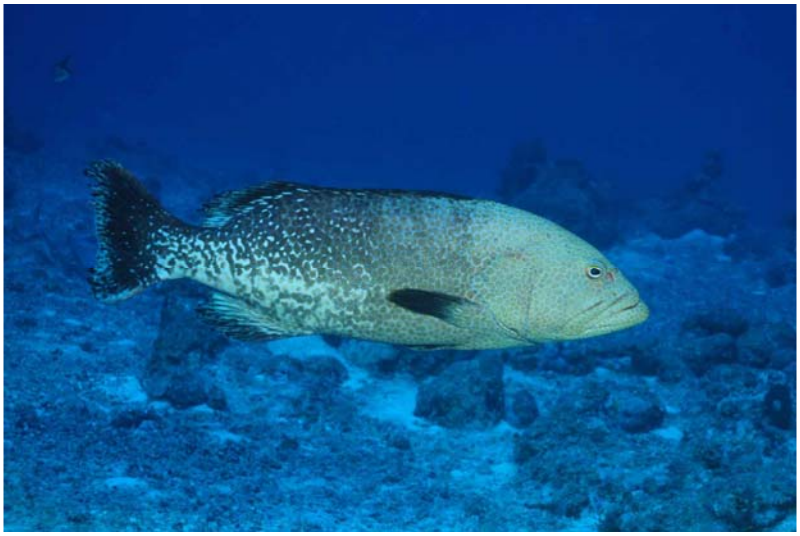


Plate 5. Male tiger grouper

Tiger groupers exhibiting the distinctive reproductive coloration were distributed close to the patch reef promontories not forming any packed, vertically oriented swirling aggregation (Video 2). Males represented more than 85 % of the total population at the spawning site at that time. Mating behavior involving upward swimming in the water column and release of gametes was not seen. Three adult yellowfin groupers (*Mycteroperca venenosa*) were observed within the tiger grouper aggregation. A school of approximately 80 permits (*Trachinotus falcatus*) and another larger school of approximately 200 horse-eye jacks (*Caranx hippos*) were observed at the spawning site during February 17 (Video 3).

A set of fish traps was deployed by local fishermen at the spawning site during the night before the full moon of February (February 17). Direct diver observations of the fish traps confirmed that only pair of angelfishes (*Pomacanthus sp*.) were trapped. One 36 foot commercial fishing boat from Palmas del Mar anchored and had divers in the water during late afternoon on March 19 at a location approximately 200 m south of the spawning site. Only one person was observed on deck. Sea conditions made any attempt to get close to the ship unsafe. Aside from these events, neither commercial nor recreational fishing was observed at the spawning ground.

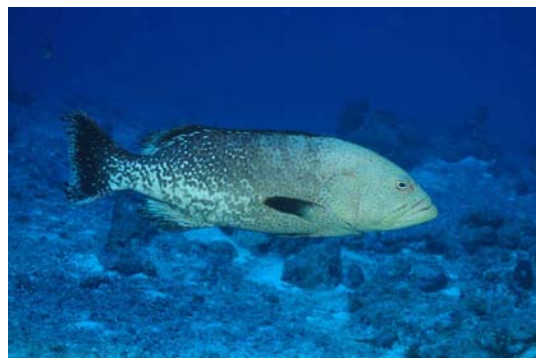
During the full moon of March 2011 (March 19) and during the next two days (March 20-21) the tiger grouper aggregation declined to only eight individuals, all males. No further reproductive activity of tiger grouper was noted. An aggregation of 18 large (40-50 cm) adult white margates (*Haemulon album*) was observed at the spawning site on March 20, 2011 (Plate 6). Coloration was normal, but individuals remained aggregated at the spawning site. Sea conditions deteriorated after March 21 making further observations at the spawning site unsafe for rebreather diving operations.

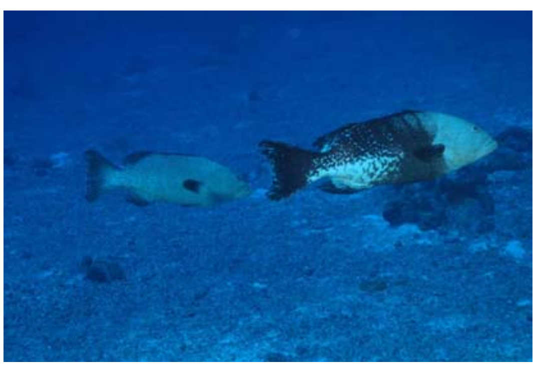
Plate 6. Aggregation of white margates during March 2011

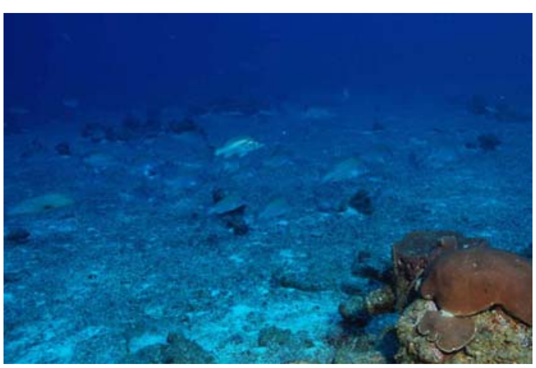
During the full moon of April 2011 divers observed an aggregation of approximately 60 cubera snappers (*L. cyanopterus*) at the tiger grouper spawning site (Video 4). Reproductive behavior of cubera snappers was not observed during this time. Cubera snapper schools were noted during several dives within the patch reef habitat, particularly during the February - April 2011 season. A small group of eight tiger groupers, all males, with the distinctive reproductive coloration were also observed at the spawning site during the full moon of April 2011.

Based on our observations, it is uncertain if tiger groupers massively spawned at the reported aggregation site at El Seco. The highest aggregation, approximately 120 individuals was observed during the full moon on February 18, but no reproductive behavior involving release of gametes was observed, nor the numbers in the aggregation were consistent with previous reports of thousands of individuals participating in the spawning aggregation (Matos Caraballo, 2001, 2006; Sadovy 1994). Several geographic coordinates have been reported for the seasonal tiger grouper spawning aggregation at El Seco and it is possible that the core of the spawning population was meeting elsewhere. The status of the tiger grouper population at El Seco is difficult to assess due to their cryptic behavior in an environment characterized by high rugosity, such as the bank coral reef. Nevertheless, based on the small sample size of fish densities within belt-transects surveyed at their preferred habitats of the bank coral and patch reefs, we estimate the present status of the adult population in the order of 20,000 – 30,000 individuals. Sadovy (1994) reported landings of tiger grouper of approximately 5,000 – 10,000 individuals from El Seco during the period between 1991 - 1993. Therefore, estimates in the order of tens of thousands tiger grouper individuals within our study area at the southern Vieques shelf may not be unreasonable.

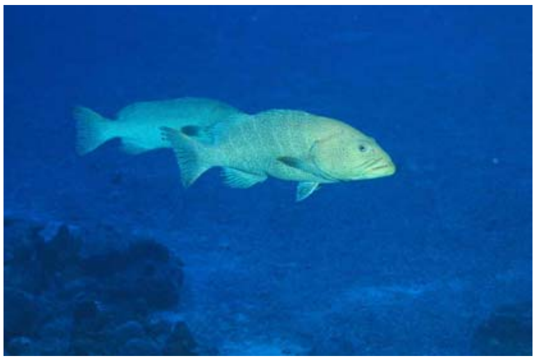
Photo Album 5. Fish Spawning Aggregation Site







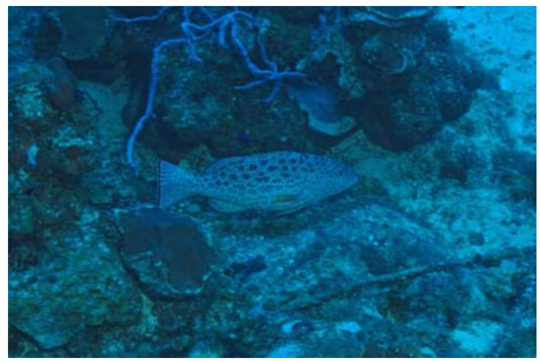












VII. CONCLUSIONS

1) The outer shelf of southeast Vieques, including the area known as “El Seco” is an extensive mesophotic ecosystem encompassing a variety of benthic habitats, including a bank coral reef, patch coral reefs, rhodolith reefs and colonized pavements.
2) The bank coral reef habitat is an impressive continuous coral formation established at depths of 33 – 41 m (110 – 135’) throughout the northern and northeastern sections of the “El Seco” shelf. While the reef’s northern boundary remains yet undetermined, it’s known surface area of approximately 3.68 km^2 makes it the largest continuous coral reef habitat of Puerto Rico.
3) *Montastraea franksi,* a sibling species of boulder brain coral, *M. annularis* is the keystone species of the bank coral reef ecosystem. It’s thick and laminar growth pattern, supported by pedestals of unknown origin and variable heights contributes highly to the overall reef topographic relief and structural complexity, serving as the main protective microhabitat for reef biota.
4) *Montastraea franksi* exhibited no signs of historically recent bleaching at El Seco, thereby representing a true genetic reservoir for this coral reef building species.
5) The bank coral reef system functions as the residential and/or foraging habitat of several commercially important large demersal reef fish predators, such as schoolmaster, dog and cubera snappers, *Lutjanus apodus, L. jocu, L. cyanopterus*, tiger and yellowfin groupers, *Mycteroperca tigris, M. venenosa,* red hind, *Epinephelus guttatus*, hogfish, *Lachnolaimus maximus,* and nurse shark, *Ginglymostoma cirratum*, all of which were observed to be abundant in this reef habitat.
6) Comprised by at least 96 diurnal, non-cryptic species and including healthy populations of large demersal and pelagic predators, the upper mesophotic (30 – 50 m) fish community at El Seco can be regarded as highly biodiverse, well balanced in terms of its trophic components and an important reservoir of commercially exploited coral reef fishes.
7) The relatively long distance from large population centers, mesophotic depths, rugged bottom topography, high prevalence of ciguatera, high wave energy and high abundance of nurse sharks act as relevant deterrents to fishing effort and may explain the relatively pristine nature of the reef ichthyofauna at El Seco.
8) The southeast Vieques shelf near “El Seco” also functions as the seasonal spawning aggregation site for tiger grouper, dog snapper and perhaps several other reef fish species observed there in aggregations during the period of February – April 2011.
9) Fish community structure at the highly heterogeneous benthic habitat of the colonized pavement was dissimilar to other habitats due to the high relative abundance of bluehead and yellowhead wrasses (*Thalassoma bifasciatum*, *Halichoeres garnoti*) and bicolor damselfish (*Stegastes partitus*) within belt-transects. The high frequency of sightings of red hinds, yellowtail snappers, queen triggerfish, hogfish and queen conch during visual surveys suggests that the colonized pavement is an important residential and/or foraging habitat for these species, particularly when in the vicinity of rocky outcrops.
10) The rhodolith reef was found to be the most geographically extensive, yet biologically depauperate benthic habitat of the mesophotic realm at the southeast Vieques shelf.

11) The ichthyofauna of rhodolith reefs consists of a unique assemblage of small demersal fishes adapted to use rhodolith deposits as protective microhabitats and a reduced array of demersal predators of small to moderate size, such as coneys, red hinds and queen triggerfish. The higher relative abundance of bicolor damselfish, cherubfish and masked goby at the rhodolith reef habitat represented the main species contributions to the dissimilarity when compared to patch and bank coral reefs habitats.
12) It is suggested that the lack of reef structural complexity and associated availability of large protective microhabitats influenced the comparatively low fish species richness and abundance, and the general absence of large demersal predators at the rhodolith reef habitat.
13) Under the prevailing water current direction and velocity conditions, it is suggested that fertilized eggs and early larval stages of dog snapper, tiger grouper and/or any other fishes spawning near the shelf edge off southeast Vieques were transported off the shelf towards the southwest, entering the northern Caribbean current.
14) The water current trayectories measured at El Seco during the seasonal spawning aggregations of commercially important fish species evidence the function of this reef as an exceptionally important source of fish larvae for mainland Puertorrican reefs and perhaps other systems downcurrent.
15) The nearly pristine condition of the reef ecosystem at El Seco, with its extensive live coral resources and wide array of healthy reef fish populations, including several of high commercially value, deserves special management considerations.

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Appendix 1. Station coordinates, depths with notes on habitat type

Name	Latitude	Longitude	Habitat	Work	Transects	Depth (m)
Spawning Site	18.123760	-65.190610	Patch Reef	Transects	5	44
V-1	18.139428	-65.217704	Coral Reef	Bounce Dive	0	35
V-2	18.139327	-65.208281	Coral Reef	Bounce Dive	0	38
V-3	18.127221	-65.208784	Rhodolith Reef	Bounce Dive	0	36
V-6	18.137281	-65.195235	Coral Reef	Bounce Dive	0	35
V-7	18.124538	-65.182224	Rhodolith Reef	Bounce Dive	0	44
V-9	18.132586	-65.191882	Coral Reef	Bounce Dive	0	35
V-10	18.137751	-65.190105	Coral Reef	Bounce Dive	0	33
V-11	18.129971	-65.201037	Hard Ground	Bounce Dive	0	24
V-12	18.125175	-65.205262	Hard Ground	Transects	5	24
V-13	18.121620	-65.210460	Hard Ground	Bounce Dive	0	35
V-16	18.122733	-65.193943	Uncol.Slope	Bounce Dive	0	39
V-18	18.138690	-65.197140	Coral Reef	Transects	5	36
V-19	18.134900	-65.201260	Hard Ground	Drift Dive	0	24
V-19-End	18.136130	-65.198840	Coral Reef	Drift Dive	0	33
V-20	18.139840	-65.187830	Coral Reef	Bounce Dive	0	45
V-21	18.136880	-65.187050	Coral Reef	Bounce Dive	0	48
V-21B	18.136960	-65.185840	Coral Reef	Bounce Dive	5	50
V-22B	18.140500	-65.225050	Rhodolith Reef	Bounce Dive	0	38
V-23	18.133932	-65.221959	Rhodolith Reef	Bounce Dive	0	39
V-24	18.129113	-65.219841	Rhodolith Reef	Bounce Dive	0	39
V-25	18.122467	-65.217099	Rhodolith Reef	Bounce Dive	0	41
V-26	18.140121	-65.197286	Coral Reef	Bounce Dive	0	35
V-27	18.135791	-65.201193	Hard Ground	Bounce Dive	0	26
V-30	18.141629	-65.205185	Coral Reef	Bounce Dive	0	38
V-31	18.139512	-65.212334	Coral Reef	Bounce Dive	0	38
V-32	18.130106	-65.194946	Coral Reef	Bounce Dive	0	35
V-34	18.129296	-65.230496	Rhodolith Reef	Transects	3	50
V-35	18.123823	-65.233100	Rhodolith Reef	Transects	3	41
V-36	18.129360	-65.234510	Rhodolith Reef	Bounce Dive	3	0
V-37	18.128243	-65.190762	Coral Reef	Transects	0	39
V-38	18.135718	-65.192657	Coral Reef	Bounce Dive	0	36
V-39	18.130735	-65.188972	Coral Reef	Transects	0	35
V-41	18.132630	-65.196517	Coral Reef	Transects	0	39
V-42	18.135297	-65.196096	Coral Reef	Transects	0	37
V-43	18.137367	-65.210377	Coral Reef	Transects	0	39
V-44	18.137262	-65.207097	Patch Reef	Transects	0	38
V-45	18.140279	-65.200868	Coral Reef	Transects	0	39
V-46	18.139858	-65.193674	Coral Reef	Transects	0	38
V-47	18.135937	-65.208791	Patch Reef	Transects	0	39
V-48	18.136193	-65.216076	Coral Reef	Transects	0	39
V-49	18.134047	-65.203270	Hard Ground	Transects	2	26
V-50	18.126401	-65.193857	Coral Reef	Bounce Dive	0	41
V-51	18.127850	-65.187169	Patch Reef	Transects	1	38
V-52	18.126293	-65.189282	Patch Reef	Transects	1	38
V-54	18.13118585	-65.209590	Patch Reef	Transects	1	38
V-55	18.14165804	-65.221390	Patch Reef	Transects	1	38
V-56	18.13028712	-65.186340	Patch Reef	Transects	1	41
V-57	18.12516825	-65.190208	Patch Reef	Transects	1	41

V-58	18.12442582	-65.191888	Hard Ground	Transects	2	27
V-59	18.12731739	-65.199235	Hard Ground	Transects	2	26
V-61	18.1311077	-65.215529	Rhodolith Reef	Transects	1	41
V-62	18.1249338	-65.219202	Rhodolith Reef	Transects	2	42
V-64	18.12340986	-65.226783	Rhodolith Reef	Transects	1	50
DC-1	18.12833335	-65.201032	Hard Ground	Drop Cam	0	N/A
DC-4	18.12329264	-65.187668	Rhodolith Reef	Drop Cam	0	N/A
DC-6	18.12004938	-65.212676	Rhodolith Reef	Drop Cam	0	N/A
DC-7	18.12094812	-65.208769	Rhodolith Reef	Drop Cam	0	N/A
DC-8	18.13900091	-65.204783	Coral Reef	Drop Cam	0	N/A
DC-10	18.12774722	-65.179892	Rhodolith Reef	Drop Cam	0	N/A
DC-12	18.12622328	-65.184347	Hard Ground	Drop Cam	0	N/A
DC-14	18.12055736	-65.206385	Trans	Drop Cam	0	N/A
DC-15	18.11946325	-65.209433	Trans	Drop Cam	0	N/A
DC-16	18.12376154	-65.201735	Hard Ground	Drop Cam	0	N/A
DC-17	18.12321449	-65.204236	Hard Ground	Drop Cam	0	N/A
DC-19	18.13478078	-65.205487	Hard Ground	Drop Cam	0	N/A
DC-22	18.12798167	-65.215724	Rhodolith Reef	Drop Cam	0	N/A
DC-23	18.1217687	-65.222015	Rhodolith Reef	Drop Cam	0	N/A
DC-24	18.1214561	-65.213653	Hard Ground	Drop Cam	0	N/A
DC-25	18.12505103	-65.223149	Rhodolith Reef	Drop Cam	0	N/A
DC-27	18.1307951	-65.226314	Rhodolith Reef	Drop Cam	0	N/A
DC-29	18.12641866	-65.235575	Rhodolith Reef	Drop Cam	0	N/A
DC-32	18.13720345	-65.227056	Rhodolith Reef	Drop Cam	0	N/A
DC-34	18.13454633	-65.235731	Rhodolith Reef	Drop Cam	0	N/A
DC-37	18.13431188	-65.213771	Patch Reef	Drop Cam	0	N/A
DC-38	18.14091561	-65.230964	Patch Reef	Drop Cam	0	N/A

Appendix 2. Master species list of organisms identified at El Seco reef, Vieques

	Taxa	Coral reef	Colonized pavement	Patch reef	Rhodolith
Ascidia	*unident. Ascidian*	X	X		X
Black Coral	*Antipathes caribbeana*	X		X	
Black Coral	*Stichopathes lutkeni*	X		X	
Brown algae	*Dictyopteris sp.*				X
Brown algae	*Dictyota spp.*	X	X	X	X
Brown algae	*Lobophora variegata*	X	X	X	X
Brown algae	*Padina sp.*		X	X	
Brown algae	*Sargassum polyceratium*				X
Brown algae	*Sargassum sp.*				X
Brown algae	*Stipopodium sp.*			X	X
Brown algae	*Turbinaria sp.*		X		X
Coral	*Acropora cervicornis*		**X**		
Coral	*Agaricia agaricites*	X	X	X	X
Coral	*Agaricia fragilis*	X	X	X	
Coral	*Agaricia grahamae*	X		X	X
Coral	*Agaricia lamarcki*	X	X	X	X
Coral	*Agaricia tenuifolia*		X		
Coral	*Agaricia undata*				X
Coral	*Colpophyllia natans*	X	X	X	X
Coral	*Dendrogyra cylindrus*		X		
Coral	*Dichocoenia stokesi*		X	X	
Coral	*Diploria clivosa*		X		
Coral	*Diploria labyrinthiformis*	X	X	X	
Coral	*Diploria strigosa*	X	X	X	
Coral	*Eusmilia fastigiata*	X	X	X	
Coral	*Isophyllia rigida*	X	X	X	
Coral	*Isophyllia sinuosa*	X	X	X	
Coral	*Leptoseris cailleti*				X
Coral	*Leptoseris cucullata*			X	X
Coral	*Madracis decactis*	X	X	X	X
Coral	*Madracis formosa*	X			
Coral	*Madracis pharensis*	X	X		
Coral	*Meandrina meandrites*	X	X		X
Coral	*Montastraea faveolata*	X	X		
Coral	*Montastrea annularis*	X	X	X	X
Coral	*Montastrea cavernosa*	X	X	X	X
Coral	*Mussa sp.*	X			
Coral	*Mycetophyllia aliciae*	X	X	X	
Coral	*Mycetophyllia ferox*	X			
Coral	*Mycetophyllia lamarckiana*	X			
Coral	*Porites astreoides*	X	X	X	X

Coral	*Porites divaricata*	X	X	X	
Coral	*Porites furcata*	X			
Coral	*Porites porites*	X	X		X
Coral	*Scolymia cubensis*	X	X	X	X
Coral	*Siderastrea radians*	X	X	X	X
Coral	*Siderastrea siderea*	X	X	X	X
Coral	*Siderastrea stellata*				X
Coral	*Stephanocoenia intersepta*	X	X	X	X
Coral	*unidentified Coral*	X		X	X
Crab	*Mithrax sp.*				X
Crab	*Periclimenes pedersoni*	X			
Crab	*Stenorhynchus seticornis*				X
Crinoid	*Crinoid*	X			X
Cyanobacteria	*Cyanobacteria*	X	X	X	X
Gastropod	*Cyphoma gibbosum*		X		
Gastropod	*Strombus gigas*	X		X	
Gorgonian	*Briareum asbestinum*		X		X
Gorgonian	*Ellisella barbadensis*	X		X	
Gorgonian	*Ellisella elongata*		X		
Gorgonian	*Erythropodium caribaeorum*	X	X	X	
Gorgonian	*Eunicea asperula*		X		
Gorgonian	*Eunicea sp.*		X		
Gorgonian	*Eunicea tourneforti*	X	X		
Gorgonian	*Gorgonia mariae*	X	X		
Gorgonian	*Gorgonia ventalina*	X	X	X	
Gorgonian	*Muriceopsis flavida*	**X**		**X**	
Gorgonian	*Plexaura kuekenthali*	X	X	X	
Gorgonian	*Plexaurella dichotoma*	X			
Gorgonian	*Plexaurella nutans*		X		
Gorgonian	*Pseudoplexaura flagellosa wagenaari*	X	X	X	
Gorgonian	*Pseudoptergorgia americana*	X	X	X	
Gorgonian	*Pseudoptergorgia bipinatta*	X			
Gorgonian	*Pseudopterogorgia acerosa*	X	X	X	
Gorgonian	*Pseudopterogorgia sp.*	X	X	X	
Gorgonian	*Ptergorgia anceps*		X		
Gorgonian	*unident. Gorgonian*	X	X	X	X
Green algae	*Halimeda discoidea*				X
Green algae	*Halimeda sp.*			X	X
Green algae	*Rhypocephalus sp.*		X		X
Green algae	*Udotea sp.*		X		X
Hydrozoa	*Hydrozoa*				X
Hydrozoa	*Millepora alcicornis*	X	X	X	X
Hydrozoa	*Millepora complanata*		X		
Hydrozoa	*Millepora squarrosa*	X	X	X	

Hydrozoa	*Stylaster roseus*	X			X
Nudibranch	*Phyllidiopsis papilligera*				X
Pelecypod	*Pectinidae*				X
Red algae	*Amphiroa sp.*		X		X
Red algae	*Encrusting calcareous algae*	X	X	X	X
Red algae	*Wrangelia bicuspidata*	X		X	
Sponge	*Agelas cauliformis*	X		X	
Sponge	*Agelas citrina*		X		
Sponge	*Agelas clathrodes*	X		X	X
Sponge	*Agelas conifera*	X	X	X	X
Sponge	*Agelas dispar*	X	X	X	
Sponge	*Agelas tubulata*	X			
Sponge	*Aiolochroia crassa*	X	X		
Sponge	*Amphimedon compressa*	X	X	X	
Sponge	*Aplysina archeri*		X		
Sponge	*Aplysina cauliformis*	X			
Sponge	*Aplysina fistularis*	X	X	X	
Sponge	*Aplysina fulva*	X	X	X	
Sponge	*Aplysina lacunosa*	X	X	X	
Sponge	*Aplysina sp.*	X		X	
Sponge	*Black erect sponge*		X		
Sponge	*CalliSpongegia plicifera*		X		
Sponge	*Callispongia vaginalis*	X	X	X	
Sponge	*Callyspongia plicifera*		X		
Sponge	*Chondrilla nucula*	X	X	X	
Sponge	*Chondrosia collectrix*		X		
Sponge	*Cinachyrella spp.*		X		
Sponge	*Cliona caribbaea*	X	X	X	
Sponge	*Cliona delitrix*	X	X	X	
Sponge	*Cliona tenius*	X			
Sponge	*Cynachyra sp.*		X		X
Sponge	*Desmapsamma anchorata*		X		
Sponge	*Ectyoplasia ferox*		X		
Sponge	*Geodia neptuni*		X		
Sponge	*Hyrtois cavernosus*		X		
Sponge	*Ircinia compana*		X		
Sponge	*Ircinia felix*		X		
Sponge	*Ircinia strobilina*	X	X	X	X
Sponge	*Monanchora arbuscula*		X		
Sponge	*Neofibularia nolitangere*		X		
Sponge	*Niphates caycedoi*		X		
Sponge	*Niphates digitalis*		X	X	
Sponge	*Niphates erecta*	X		X	
Sponge	*Petrosia pellasarca*	X		X	

Sponge	*Plakortis halichondriodes*	X			
Sponge	*Pseudoceratina crassa*			X	
Sponge	*Pseudoceratina sp.*		X		
Sponge	*Ptilocaulis walpersi*		X		
Sponge	*Scoplina ruetzleri*		X		
Sponge	*Spirastrella coccinea*		X		
Sponge	*Suberea spp.*		X		
Sponge	*Svenzea zeai*	X			
Sponge	*unident. Sponge*	X	X	X	X
Sponge	*unknown black sponge, looks like eggs*		X		
Sponge	*Verongula gigantea*		X		
Sponge	*Verongula rigida*		X		
Sponge	*Xestospongegia muta*	X	X		X
Worm	*Sabellidae*		X	X	X
Worm	*Spirobranchus sp.*			X	
Zonathid	*Palythoa caribaeorum*	X	X		
Fish	*Amblycirrhitos pinnos*				x
Fish	*Acanthosybium solandri*				
Fish	*Acanthurus bahianus*	x	x	x	x
Fish	*Acanthurus chirurgus*	x	x		x
Fish	*Acanthurus coeruleus*	x	x	x	x
Fish	*Apogon pillionatus*				x
Fish	*Balistes vetula*		x	x	x
Fish	*Bodianus rufus*	x	x	x	x
Fish	*Calamus calamus*	x			
Fish	*Carcharhinus perezii*			x	x
Fish	*Canthidermis sufflamen*	x	x		x
Fish	*Canthigaster rostrata*	x	x	x	
Fish	*Caranx crisos*		x		
Fish	*Caranx latus*	x		x	
Fish	*Caranx ruber*	x		x	x
Fish	*Centropyge argi*				x
Fish	*Coryphaena hippurus*				
Fish	*Epinephelus cruentatus*	x	x	x	
Fish	*Epinephelus fulva*	x	x	x	x
Fish	*Exoceetidae*				
Fish	*Chaetodipterus faber*	x		x	
Fish	*Chaetodon acuelatus*	x	x	x	x
Fish	*Chaetodon capistratus*	x	x	x	
Fish	*Chaetodon sedentarius*	x	x	x	x
Fish	*Chaetodon striatus*	x	x	x	
Fish	*Chromis cyanea*	x	x	x	x
Fish	*Chromis insolata*	x		x	x
Fish	*Chromis multilineata*	x			

Fish	*Clepticus parrae*	x		x	
Fish	*Coryphopterus glaucophraenum*	x	x	x	
Fish	*Coryphopterus lipernes*	x		x	
Fish	*Coryphopterus pesonatus*	x		x	x
Fish	*Decapterus macarelus*	x			
Fish	*Epinephelus guttatus*	x	x	x	x
Fish	*Ginglymostoma cirratum*	x		x	x
Fish	*Gymnothorax funebris*			x	
Fish	*Gobiosoma evelynae*	x		x	
Fish	*Gramma loreto*	x		x	
Fish	*Hemiramphlus brasiliensis*				
Fish	*Haemulon album*			x	
Fish	*Haemulon plumierii*	x		x	
Fish	*Haemulon flavolineatum*	x		x	x
Fish	*Haemulon sciurius*	x			
Fish	*Halichoeres garnoti*	x	x	x	x
Fish	*Halichoeres radiatus*	x			
Fish	*Halichoeres maculipina*	x	x		x
Fish	*Holacanthus ciliaris*	x	x	x	
Fish	*Holocantus tricolor*	x	x	x	
Fish	*Holocentrus rufus*	x	x	x	x
Fish	*Hypoplectrus unicolor*	x			
Fish	*Hypoplectrus chlorurus*	x	x	x	x
Fish	*Hypoplectrus niger*	x		x	
Fish	*Hypoplectrus puella*	x	x		
Fish	*Istiophorus albicans*	x			
Fish	*Kyphosus sectatrix*	x			
Fish	*Lachnolaimus maximus*	x	x	x	
Fish	*Lactophrys polygonia*				
Fish	*Lactophrys bicaudalis*		x		
Fish	*Lactophrys triqueter*	x	x	x	
Fish	*Lipropoma rubre*	x	x		x
Fish	*Lutjanus analis*	x	x	x	x
Fish	*Lutjanus apodus*	x	x	x	
Fish	*Lutjanus cyanopterus*	x	x	x	
Fish	*Lutjanus jocu*	x	x	x	
Fish	*Monacanthus tuckeri/ciliatus*				x
Fish	*Mulloidicthys martinicus*	x			
Fish	*Malacanthus plumieri*		x		x
Fish	*Melichthys niger*		x	x	
Fish	*Microspathodon chrysurus*	x			
Fish	*Micteroperca venenosa*	x			
Fish	*Miripristis jacobus*	x	x	x	x
Fish	*Mycteroperca tigrinus*	x		x	

Fish	*Negaprion brevirostris*	x		x	
Fish	*Neoniphon marianus*	x		x	
Fish	*Ocyurus chrysurus*	x	x	x	x
Fish	*Ophioblenus atlanticus*			x	
Fish	*Paranthias fucifer*	x	x	x	x
Fish	*Pocamanthus arcuatus*	x	x	x	x
Fish	*Pomacanthus paru*			x	
Fish	*Pterois volitans*	x			
Fish	*Pseudopeneus maculatus*	x	x	x	
Fish	*Seriola rivoliana*				x
Fish	*Serranus tabacarius*		x		x
Fish	*Scarus iserti*	x		x	
Fish	*Scarus taeniopterus*	x	x	x	x
Fish	*Scarus vetula*	x	x	x	
Fish	*Scomberomorus cavalla*	x			
Fish	*Scomberomorus regalis*	x	x		
Fish	*Serranus annularis*				x
Fish	*Serranus baldwini*				x
Fish	*Serranus tigrinnus*	x	x	x	x
Fish	*Sparisoma atomarium*	x			x
Fish	*Sparisoma aurofrenatum*	x	x	x	x
Fish	*Sparisoma radians*	x	x		x
Fish	*Sparisoma rubripinne*		x		
Fish	*Sparisoma viride*	x	x	x	
Fish	*Sphyraena barracuda*	x	x	x	
Fish	*Stegastes leuocostictus*	x			
Fish	*Synodus intermedius*			x	
Fish	*Stegastes partitus*	x	x	x	x
Fish	*Trachinotus falcatus*		x		
Fish	*Thalassoma bifasciatum*	x	x	x	x
Fish	*Xanthichthys ringens*		x		x

Appendix 3. Pairwise analyses of similarities (ANOSIM) between benthic habitats.

ANOSIM

Analysis of Similarities

One-Way Analysis

Resemblance worksheet
Name: Resem1
Data type: Similarity
Selection: All

Factor Values
Factor: Habitat Type

Global Test
Sample statistic (Global R): 0.863
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
PR, CR	0.644	0.1	92378	999	0
PR, CP	0.743	0.1	92378	999	0
PR, RR	0.902	0.1	92378	999	0
CR, CP	0.941	0.2	92378	999	1
CR, RR	0.996	0.1	92378	999	0
CP, RR	0.939	0.1	92378	999	0

Appendix 4. Pairwise analyses of similarities (ANOSIM) of fish community structure between benthic habitats.

ANOSIM

Analysis of Similarities

One-Way Analysis

Resemblance worksheet
Name: Resem1
Data type: Similarity
Selection: All

Factor Values
Factor: Habitat Type
PR
CR
CP
RR

Global Test
Sample statistic (Global R): 0.63
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
PR, CR	0.094	3.7	5200300	999	36
PR, CP	0.776	0.1	2496144	999	0
PR, RR	0.671	0.1	1144066	999	0
CR, CP	0.907	0.1	2496144	999	0
CR, RR	0.748	0.1	1144066	999	0
CP, RR	0.611	0.1	352716	999	0