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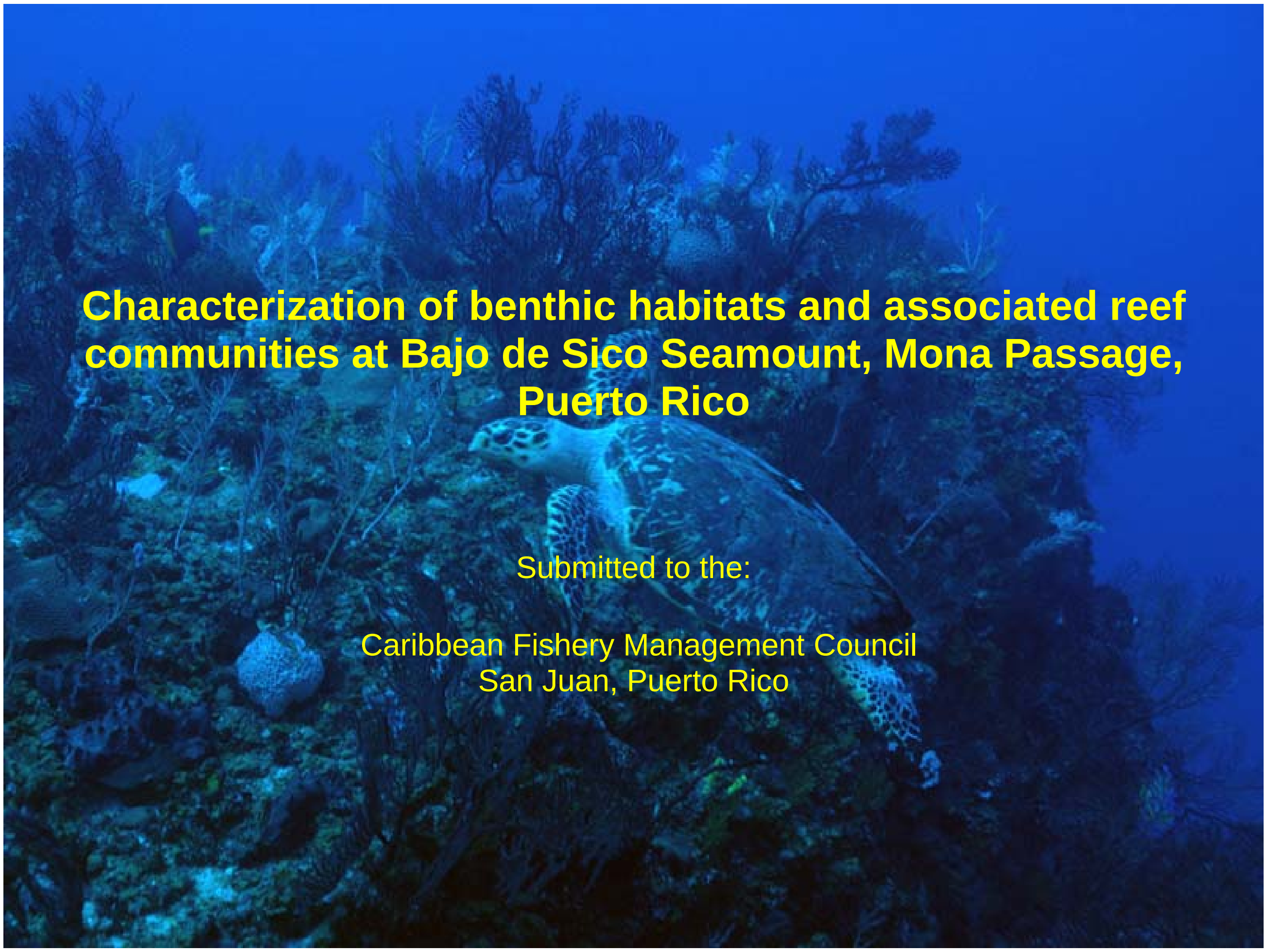

Characterization of benthic habitats and associated reef communities at Bajo de Sico Seamount, Mona Passage, Puerto Rico

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I. Executive Summary

Bajo de Sico (BDS) is a seamount that rises from a deep platform (177 m) of the insular slope in the west coast of Puerto Rico. Reef bathymetry is characterized by a ridge of rock promontories aligned southeast – northwest which rise from a platform at 45 m to a reef top at 25 m, and an extensive, mostly flat, homogeneous and gradually sloping shelf that ends as a vertical (shelf-edge) wall at depths between 90 – 100 m reaching down to depths of 200 – 300 m. Salient oceanographic features of the water column influencing the reef system include a warm mixed surface water mass with a summer thermocline at a depth of 45 – 50 m, strong, persistent northwesterly surface currents, and high water transparency with 1% light penetration reaching depths of almost 80 m.

Benthic habitats that were identified and field verified to a maximum depth of 50 m at BDS include: a reef top and a vertical reef wall associated with rock promontories, colonized pavement and sand channels at the base of promontories, uncolonized gravel and rhodoliths at the reef slope, and a colonized rhodolith reef habitat surrounding the rock promontories at least to a depth of 50 m. Benthic habitats beyond 50 m have not been field verified, but several video images produced by the R/V Nancy Foster detected coral growth down to a maximum depth of 90 m along the deep shelf platform at BDS. From the multi-beam bathymetry survey of the reef produced aboard the R/V Nancy Foster, the total extension of BDS includes a surface area of approximately 11.1, km^2 of which only 3.6 % is associated with rock promontories (0.4 km^2) and more than 88 % corresponds to the deep shelf platform at depths below 50 m.

The sessile-benthic community at the reef top was characterized by a highly diverse assemblage comprised by benthic algae (52%), sponges (26%), scleractinian corals (8%), octocorals (5%) and hydrozoans (3%), with an abiotic cover of less than 1.5%. Scleractinian corals were represented at the reef top by 13 species within transects surveyed, with a mean substrate cover of 8.0% and a mean density of almost 20 colonies/m^2. Growth of scleractinian corals at the reef top was characterized by a species rich and numerous assemblage of small, isolated encrusting colonies that contributed minimal topographic relief. Lettuce corals, mostly *Agaricia lamarki* and *A. grahame* were the dominant assemblage in terms of reef substrate cover and density of colonies. *Tubastrea coccinea, Porites astreoides* and *Montastraea cavernosa* were also common at the reef top. Sponges, represented within transects by at least 12 species were the dominant sessile-benthic invertebrate in terms of reef substrate cover (mean: 26%) at the reef top. Due to their large size and abundance, sponges contributed substantially to the reef topographic relief and served as an important habitat for fishes and invertebrates.

The reef wall habitat was characterized by irregular formations that appear to have been influenced by erosional processes, with deep crevices, undercuts, gaps, ledges and other substrate irregularities. The sessile-benthos of the reef wall habitat resembled the reef top in that it was also highly diverse and taxonomically complex, comprised by sponges (43%), benthic algae (26%), octocorals (14%), scleractinian corals (5.5%), antipatharians (3%) and hydrozoans (2%). Abiotic cover was approximately 4%. Sponges were the most prominent component of the sessile-benthos at the reef wall, with at least 11 species present within transects surveyed and the prevalence of large erect and branching growth forms providing substantial topographic relief and reef substrate complexity. Octocorals (gorgonians), particularly the deep sea fan, *Iciligorgia schrammi* combined with black corals (Antipatharians), mostly the Caribbean bushy coral, *Antipathes caribbeana* to contribute an average reef substrate cover of 17%, adding to the benthic substrate heterogeneity and providing protective habitat for fishes at the reef wall. As in the reef top, scleractinian corals were present as a species rich assemblage of numerous, but small isolated colonies growing encrusted to the hard ground substrate and contributing minimally to the reef topographic relief.

The deep platform rhodolith reef, at least down to the maximum surveyed depth of 50 m, appears to be a vast deposit of crustose algal nodules or rhodoliths overgrown by a dense macroalgal carpet, mostly the encrusting fan-leaf alga, *Lobophora variegata*. The sessile-benthic invertebrate community was characterized by relatively low taxonomic diversity, with virtual absence of gorgonians and antipatharians, low substrate cover and species composition by scleractinian corals and a marked decline of cover and species composition by sponges, relative to the reef top and wall habitats. With few exceptions, scleractinian corals and sponges grow attached to rhodoliths, and are therefore not fixed to the bottom. Lettuce corals, *Agaricia spp*. were the dominant scleractinian taxa in terms of reef substrate cover.

Reef fishes associated with BDS were comprised by a combination of the typical shallow water reef species, a small assemblage of deep reef species, large demersal predators (snappers and groupers), and the group of pelagic highly migratory oceanic predators. Zooplanktivorous schooling fish populations are abundant at BDS and appear to serve as the main forage for large pelagic and demersal piscivorous fishes of the reef. Both fish abundance and species richness declined markedly with increasing depth at the benthic habitats studied. Variations of fish taxonomic composition and abundance between habitats appear to be influenced by the availability only of microhabitats at the deep rhodolith reef and the limited assemblage of species adapted for the vertically oriented habitat of the reef wall.

Reef promontories at BDS represent an important residential and foraging habitat for a group of large, commercially important species of snappers (*Lutjanus cyanopterus, L. jocu*) and groupers (*Epinephelus striatus, Mycteroperca bonaci, M. venenosa, M. interstitialis*) that have virtually disappeared from most reef systems in Puerto Rico. It also represents a spawning aggregation site for red hind (*Epinephelus guttatus*), and possibly other groupers within Mona Passage. The deep rhodolith reef appears to be the residential habitat for the red hind and for an assemblage of fishes that are typical of deep reefs, including some of which are highly valuable for the aquarium trade industry.

The reef system at BDS serves as an important foraging and residential habitat for the endangered hawksbill turtle (*Eretmochelys imbricata*). Its population in the reef promontories is impressive because of the large size and high abundance of individuals. The seamount also functions as a foraging area for large migratory pelagic fishes, including the wahoo (*Acanthocibium solanderi*), mahi-mahi (*Coryphaena hippurus*), tunas (*Thunnus spp*.) and marlins (mostly *Makaira nigricans*).

From the field survey at BDS, the following recommendations are included:

a. A year-round permanent closure for fishing of demersal fish species at the entire reef platform is recommended for the protection of what could be one of the few remaining actively reproducing populations of black, yellowmouth, yellowfin and Nassau groupers in Puerto Rico.

b. Characterization of benthic habitats and associated communities of the deep shelf platform below depths of 50 m using autonomous underwater vehicles (AUV) or similar systems that could provide high resolution images of the reef substrate.

c. The hermatypic and ahermatypic coral assemblage at BDS consists of species that have not been previously reported for coral reef systems in PR, and a more comprehensive characterization will require further exploration and research

d. The Caribbean Fishery Management Council (CFMC) should convey further research attention to the large grouper-snapper populations at BDS, particularly aspects of their reproductive biology, trophic interactions and larval dispersal and recruitment dynamics

II. Introduction

The study of Bajo de Sico (BDS) in Mona Passage represents a pioneer effort towards characterization of benthic habitats and associated deep reef communities on a submerged seamount of Puerto Rico. The work forms part of the research program priorities of the Caribbean Fishery Management Council (CFMC) for scientific documentation of closed fishing areas under Federal jurisdiction in Puerto Rico and the US Virgin Islands (CFMC, 2000). BDS is a known red hind (*Epinephelus guttatus*) spawning aggregation site that was proposed for seasonal closure (December – February) by west coast fishermen as a management strategy for protection of the commercially valuable grouper stock. The reef was officially closed to fishing seasonally on December 7, 1996 (CFMC, 1996).

BDS is a preferred fishing ground for local and international sport fishermen of highly migratory pelagic species, such as wahoo, mahi-mahi, great mackerel, yellowfin, blackfin and skipjack tuna, and the sailfish, white and blue marlin. The reef is fished for its deep sea snappers (silk, queen, wenchman, vermilion) and deep sea grouper (misty grouper) resources by artisanal fishers of the west coast. Also, a small number of spear-fishers hunt the large reef groupers and snappers, including the Nassau, yellowfin, yellowmouth and black groupers, and the cubera, mutton and dog snappers. Thus, the wide variety of pelagic and demersal fishery resources associated with BDS and its undocumented (anecdotal) history of its fishery exploitation conveyed for the scientific characterization of its benthic habitats and associated reef communities.

Because of the inherent logistic and technical constraints, deep hermatypic reef systems, or mesophotic reefs, have received very limited research attention in Puerto Rico and the US Virgin Islands. Sessile-benthic communities associated with the upper insular slope off La Parguera, southwest coast of Puerto Rico were described by Singh et al. (2004) from photo mosaics of the seafloor produced by the SeaBED Autonomous Underwater Vehicle (AUV). A more comprehensive characterization of marine communities associated with a mesophotic reef system off the southwest coast of Isla Desecheo (Agelas Reef) was recently provided by García-Sais et al. (2005) from direct observations by divers using re-breather diving technology. Concurrent with the present research at BDS, a team from the University of the US Virgin Islands, led by Dr. Richard

Nemeth is conducting a biological characterization of the marine communities associated with the outer shelf reef system at the Marine Conservation District (MCD), south of St. Thomas, USVI sponsored by the CFMC/NOAA (Nemeth, personal communication).

The US Caribbean Economic Exclusion Zone (EEZ) lacks information on the location and status of the corals and coral reefs from the insular slope. The National Ocean Service (NOS) benthic maps extend only to State water and only to the very nearshore environments. The CFMC through the Coral Reef Conservation Grant Program is working toward the mapping and characterization of benthic marine habitats in the U.S. Caribbean EEZ. Previous to our survey of BDS, the only available scientific information regarding this reef system was a side-scan sonar survey of the shallow reef section produced by Department of Natural and Environmental Resources (DNER). Bathymetry data, limited to a few depth contours was available from the 25671-NOAA nautical chart. Fishery statistics for the reef were inexistent, except for the anecdotal accounts of the red hind aggregation and its seasonal fisheries by west coast fishermen. Taxonomic inventories of marine flora and fauna, nor descriptions of benthic habitats present had ever been reported for BDS.

III. Study Objectives:

1) Provide a baseline quantitative and qualitative characterization of the benthic habitats and associated sessile-benthic and fish communities at BDS down to a maximum depth of 50 m.
2) Construct a georeferenced map of the main reef benthic habitats field verified down to a maximum depth of 50 m
3) Produce a detailed bathymetric map of BDS down to a maximum depth of 100 m
4) Provide a preliminary assessment of the commercially important grouper and snapper populations associated with BDS down a to depth of 50 meters
5) Contribute a digital photographic documentation of deep reef communities from BDS.

IV. Research Background

Most of the information regarding deep reefs in Puerto Rico and the USVI was produced more than 100 years ago, during the early exploration surveys that included the Voyage of the H. M. S. Challenger in 1873, dredging surveys by the “Blake” during 1878-79, U. S. Commission “Fish Hawk” in 1899, and the Johnson-Smithsonian Expedition aboard the Yacht Caroline in 1933. Taxonomic records and benthic habitat descriptions from these early cruises were reviewed and summarized by García-Sais et al. (2005). After the early explorations directed to describe the species composition and biogeography of deep reef habitats in PR and the USVI, research attention was particularly directed toward fishery resources.

Assessment surveys of the deep sea snapper and grouper fisheries potential were performed during the late 1970’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). Summarized fisheries data from these cruises, including the species composition, catch data, and geographic location of prime deep snapper/grouper fishing grounds along the insular slope habitats of PR and the USVI is available in García-Sais et al. (2005).

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 (García-Sais et al., 2005).

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), the upper slope reef communities were left undescribed. García-Sais et al. (2005) analyzed the depth and habitat distributions of the fish species reported by scientists aboard the Sea Link submersible and noted a high level of plasticity in terms of depth range and habitat of occurrence by numerically prominent populations throughout the insular slope. Such effective connectivity suggests that the insular slope of PR and the USVI represents an integral ecological system (García-Sais et al., 2005).

Quantitative assessments of sessile-benthic communities associated with mesophotic reefs of Puerto Rico and the USVI include observations of the upper insular slope at depths between 20 – 125 m off La Parguera, southwest coast of Puerto Rico by Singh et al. (2004). Data on percent substrate cover by corals and other sessile-benthic categories was obtained from photo mosaics of the seafloor produced by the SeaBED Autonomous Underwater Vehicle (AUV). From these data, Singh et al (2004) noted that scleractinian corals were the dominant sessile-benthic invertebrate down to 30 m, with maximum reef substrate cover (ca. 25%) at the 24 – 30 m depth interval. Below 30m, sponges were the dominant sessile-benthic invertebrate, although with a reef substrate cover not exceeding 10% (Singh et al., 2004). Benthic algae, sand and other abiotic substrate categories prevailed down the insular slope of La Parguera down to a depth of 125 m. Black corals (*Antipathes sp*p.) were reported from the deepest section of the transect (90-100 m). Only one transect perpendicular to the seafloor was produced by the SeaBED AUV. The limited data from the AUV constrains analysis of variability associated with the vertical distribution of sessile-benthic substrate categories at La Parguera.

The SeaBED AUV imaging platform was also used to survey benthic habitats of the Hind Bank in a marine protected area located near the shelf-edge, south of St. Thomas, USVI known as the Marine Conservation District (MCD) (Armstrong et al., 2006). The survey of reef benthic communities encompassed a depth range of 32 to 54 m. Four digital photo-transects provided data on benthic species composition and percent cover of reef substrate. Within the western side of the MCD, a well-developed hermatypic coral reef with 43% mean living coral was found. A flattened growth form of boulder star coral, *Montastraea annularis* (complex) was the dominant taxonomic component of the sessile-benthos at all four sites surveyed. Maximum coral cover found was 70% at depths of 38 - 40 m. Armstrong et al. (2006) reported 10 species of scleractinian corals, 10 gorgonians, one antipatharian, two hydrozoans, 17 sponges and several motile-megabenthic invertebrates and benthic algae within photo-transects surveyed at the MCD. Partial field validation of the SeaBED AUV results in characterization of benthic communities at the MCD were later produced by Nemeth et al. (2004) and Herzlieb et al. (in press).

A smaller, but morphologically similar mesophotic reef formation, known as Black Jack Reef was studied off the south coast of Vieques, PR by García-Sais et al. (2001). The reef is associated with the upper slope of a seamount that rises from a depth of 51 m to a reef top at 30 m. A total of 25 species of scleractinian corals, two antipatharians and one hydrocoral were identified. Live coral cover averaged 28.8% (range 25.0 – 40.4%) within surveyed transect areas. Boulder star coral (*Montastraea annularis* complex) was the dominant coral species in terms of substrate cover (mean: 21.9%), representing 76% of the total live coral cover at depths between 36 – 40 m. As in the MCD, boulder star coral exhibited a laminar or flattened growth with closely spaced colonies of moderate size and low relief. Corals grow from a pedestal of unknown origin, creating protective habitat underneath the coral.

Menza et al. (2007), working off the NOAA R/V Nancy Foster reported on the benthic community structure of a mesophotic reef known as MSR-1, located off the outer shelf south of St. John, USVI at depths between 30 – 40 m. High resolution still images of the seafloor were taken with a Spectrum Phantom S2 remotely operated vehicle (ROV). The reef MSR-1 presented an average live coral cover of 37.8% (SE=4.9%), with maximum cover of approximately 80% at a depth of 34.4 m. As in the MCD and Black Jack reefs, boulder star coral, *Montastraea annularis* complex, including *M. annularis, M. faveolata* and *M. franksi*) were the principal reef building species at MSR-1, with *M. cavernosa, Agaricia lamarki* and *Siderastrea siderea* representing less than 5% of the total live coral cover. Menza et al. (2007) described *Montastraea* colonies forming discrete horizontal plates, where distinct colonies overlapped each other vertically, creating a complex three-dimensional structure with high rugosity. Interestingly, a relatively high percentage of recently dead coral overgrown by turf algae (DCA) was reported for the deepest sections of transects surveyed (Menza et al., 2007).

Mesophotic reefs have also been discovered on the southwest coast of Isla Desecheo (Mona Passage) by García Sais et al. (2005). These include the SW Wall Reef, at depths between 30-40 m, and Agelas Reef, at depths between 45 – 70 m. Substrate cover at the SW Wall Reef was dominated by benthic macroalgae (mostly *Lobophora variegata*), sand, sponges, and massive corals. Sponges were highly prominent (mean surface cover: 17.3%), growing mostly as large erect and branching forms that produced substantial topographic relief and protective habitat for fishes and invertebrates. In many instances, sponges were observed growing attached to stony corals, forming sponge-coral bioherms of considerable size. One of the most common associations involved brown tube (*Agelas conifera, A. sceptrum*) and row pore sponges (*Aplysina spp*.) with star corals (*Montastraea cavernosa, M. annularis*-complex). A total of 25 scleractinian corals, three hydrocorals and two antipatharian (black coral) species were present along the SW Wall Reef. Star corals (*M. cavernosa, M. annularis* complex) were the dominant species of scleractinian corals at the SW Wall Reef (García-Sais et al., 2005).

Agelas Reef (45 – 70 m) appears to be a depositional zone of crustose (calcareous) algal rhodoliths densely colonized by encrusting brown algae (*Lobophora variegata*), large erect and branching sponges (*Agelas conifera, Agelas spp., Aplysina spp*.) and lettuce corals (*Agaricia lamarki, A. grahamae, Agaricia spp.*). Sessile-benthic biota grows over a vast deposit of rhodolith nodules loosely anchored to the bottom. The reef has very low topographic relief as it lies over an essentially flat platform and massive corals do not contribute significantly to its rugosity. A total of 18 species of scleractinian corals, two hydrozoans (*Millepora alcicornis* and *Stylaster roseus*) and the antipatharian black wire coral (*Stichopathes lutkeni*) were identified from Agelas Reef. The combined mean substrate cover by the nine species of scleractinian corals within transects surveyed was 13.1% (range: 7.4 – 36.4 %). Irregular sheets or laminar growth by lettuce corals (*Agaricia spp*.) prevailed at depths between 45 and 53 m (148 – 175'), with a combined substrate cover of 8.9%, representing 70% of the total cover by scleractinian corals. Lamark's sheet coral (*Agaricia lamarki*) appeared to be the main species present (García-Sais et al., 2005).

A total of 70 fish species were identified from depths beyond 30 m at Isla Desecheo. An assemblage of 10 species accounted for 85.4% of the total fish abundance at 30m. The blue chromis (*Chromis cyanea*) was the numerically dominant species with a study mean abundance of 79.2 Ind/30 m^2, representing 31.5% of the total fish abundance within belt-transects. The creole wrasse (*Clepticus parrae*), bicolor damselfish (*Stegastes partitus*), fairy basslet (*Gramma loreto*), bridled, masked, peppermint and sharknose gobies (*Coryphopterus glaucofraenum, C. personatus, C. lipernes, Gobiosoma evelynae*), brown chromis (*C. multilineata*) and the blue-head wrasse (*Thalassoma bifasciatum*) comprised the rest of the numerically dominant assemblage at the SW Wall Reef at 30 m (García-Sais et al., 2005). At a depth of 40 m, an assemblage of seven species accounted for 82.5% of the total individuals surveyed within belt-transects at the SW Wall Reef. The blue chromis was the numerically dominant species, representing 32.6% of the total fish abundance within transects, followed by the masked goby, creole fish, sunshine chromis (*C. insolata*), bridled goby, bicolor damselfish and fairy basslet, among others. Only a few species not typical of shallow reefs, such as the cherubfish (*Centropyge argi*), longsnout butterflyfish (*Chaetodon aculeatus*) and the Sargassum triggerfish (*Xanthichthys ringens*) were common at the SW Wall Reef (García-Sais et al., 2005). At 50 m on Agelas Reef, an assemblage of five species accounted for almost 80% of the total individuals surveyed within belt-transects by García-Sais et al. (2005). The bicolor damselfish was the most abundant, followed by the blue chromis, peppermint goby, sunshine chromis and the cherubfish.

In general, the ichthyofauna from depths between 30 – 50 m at reefs studied in Isla Desecheo was dominated by zooplanktivorous taxa, suggesting that planktonic food webs are most relevant in these mesophotic reef habitats (García-Sais et al., 2005). These reefs are also the natural habitats of many exploited commercially important food fishes, such as large groupers (Nassau, yellowfin, red hind) and snappers (dog, cubera) and target species of the aquarium trade (blue chromis, fairy basslet, cherubfish, butterflyfishes, jawfishes and hawkfishes, among others). The deeper habitats (below 100 m) of the reef slope at Isla Desecheo, are well known fishing grounds for “deep sea” snappers, such as, silk snapper (*Lutjanus vivanus*), blackfin snapper (*L. buccanella*), vermilion snapper (*Rhomboplites aurorubens*), queen snapper (*Etelis oculatus*) and wenchman (*Pristipomoides macrophthalmus*). Also, the particularly high abundance of post-settlement juveniles of coneys (*Cephalopholis fulva*), blue chromis and fairy basslet reported for the deep reefs of Isla Desecheo (García-Sais et al., 2005) suggests that these mesophotic reefs may also function as prime recruitment sites for these and other reef fish populations.

From the initial exploratory surveys of the recently discovered mesophotic reefs of Puerto Rico and the USVI (including this study), it is evident that there are at least two main reef formations. One type is found associated to hard ground platforms and biologically dominated by a flattened morphotype of boulder star coral, *Montastraea annularis* complex. Such reef formation appears to be typical of the south coast outer shelf USVI region (e.g. MCD, MSR-1; Armstrong et al., 2006; Menza et al., 2007) and southeast Puerto Rico (e.g. Vieques Island; García-Sais et al, 2004). The other type of mesophotic reef formation is associated with extensive algal rhodolith deposits and dominated by benthic algae (e.g. *Lobophora variegata*), sponges and lettuce corals of the *Agaricia lamarki/grahame* combination. These reefs appear to be typical of oceanic islands and seamounts in Mona Passage, such as Desecheo Island (García-Sais et al., 2005) and Bajo de Sico (this study).

Extensive mesophotic reef systems, such as Pulley Ridge, Flower Banks (East and West) and Sherwood Forest Reef (Dry Tortugas) are found in the Gulf of Mexico and the Florida shelf. Pulley Ridge, regarded as the deepest coral reef in the United States extends over 200 km along the western margin of the south Florida shelf at depths between 58 – 75 m (Halley et al. 2003; http://coastal.er.usgs.gov/pulley-ridge/). The reef grows over a relatively flat deep terrace where hermatypic (symbiotic) lettuce corals, mostly *Agaricia spp*. and *Leptoseris spp*. cover as much as 60% of the reef substrate in some localities (Halley et al. 2003). Fleshy brown, red and calcareous macroalgae, including *Lobophora variegata*, *Halimeda tuna* and *Andaymonene menzeii* are also reported to be highly abundant at certain regions of the reef forming “lettuce fields growing in the dusk”, but also reported to occupy reef surfaces between corals, along with sponges and octocorals (Halley et al. 2003; http://coastal.er.usgs.gov/pulley-ridge/). Interestingly, vast deposits of coralline algal nodules (rhodoliths) and cobble zones surround much of the ridge in deeper water (>80 m). The flat terrace reef geomorphology, with high abundance of lettuce corals (*Agaricia spp. Leptoseris spp*), fleshy macroalgae and sponges, and the presence of rhodolith deposits at Pulley Ridge convey some relevant physical and biological similarities with the recently discovered mesophotic reefs of Isla Desecheo and Bajo de Sico in Mona Passage (García-Sais et al., 2005, this study).

More than 60 species of fishes have been identified from the Pulley Ridge reef system. The fish assemblage is comprised by a mixture of shallow water and deep species. Commercial species include *Epinephelus morio* (red grouper) and *Mycteroperca phenax* (scamp). Typical shallow-water tropical species include *Thalassoma bifasciatum* (bluehead), *Stegastes partitus* (bicolor damselfish), *Cephalopholis fulva* (coney), *Lachnolaimus maximus* (hogfish), *Malacanthus plumieri* (sand tilefish), *Pomacanthus paru* (French angelfish), and *Holacanthus tricolor* (rock beauty). The deepwater fauna is represented by *Chaetodon aya* (bank butterflyfish), *Sargocentron bullisi* (deepwater squirrelfish), *Bodianus pulchellus* (spotfin hogfish), *Pronotogrammus martinicensis* (roughtongue bass), and *Liopropoma eukrines* (wrasse bass).

The reef system at the Flower Gardens Banks National Marine Sanctuary (FGBNMS), located in the northwestern Gulf of Mexico, approximately 192 km southeast of Galveston Texas was described by Rezak et al. (1985), Gardner et al. (1998) and Hickerson and Schmahl (2005) (see also http://flowergarden.noaa.gov/about/facts.html). At least six of these banks harbor important populations of scleractinian coral, these include the larger East Flower Garden Banks (EFGB) and West Flower Garden Banks (WFGB), the West Bright Bank, Sonnier Bank, Geyer Bank, and McGrail Bank. Most of the biological characterization and coral reef monitoring work has been limited to the reef top, at depths between 18 – 25 m. Within this depth range, reef substrate cover by live corals averaged 53.9% and 48.8% at the EFGB and the WFGB reefs, respectively. In both reef systems, the dominant coral species was boulder star coral, *Montastraea annularis* (complex). Symmetrical brain coral (*Diploria strigosa*) and mustard-hill coral (*Porites astreoides*) were also prominent species of the coral assemblage at both reef sites (Hickerson and Schmahl, 2005). More recent investigations of deeper reef zones at McGrail Bank revealed that blushing star coral (*Stephanocoenia intersepta*) covers up to 30% of the reef substrate at depths between 45 – 60 m (Schmahl and Hickerson, in press).

Over 170 species of fish are known to inhabit the Flower Garden Banks Reef system. Fishes of the families Labridae, Pomacentridae and Serranidae were the most abundant during coral reef monitoring surveys at depths between 18 – 25 m, with densities ranging between 6.9 Serranids per 100 m^2 at the EFGB in 2002 to 70.4 Labrids per 100m^2 at the EFGB in 2003. Pomacentridae, Serranidae and Labridae were also the three most specious fish families with 12, 10, and 6 species present, respectively (Hickerson and Schmahl, 2005).

V. Methods

Geographic location of Bajo de Sico

Bajo de Sico (BDS) is located in Mona Passage, about 27 kilometers off Mayagüez in the west coast of Puerto Rico (Figure 1). It is part of a ridge, known as the great southern Puerto Rico fault zone (Glover, 1967; Garrison and Buell, 1971), a submerged section of the Antillean ridge that extends across the entire Mona Passage, connecting Puerto Rico with La Hispaniola. The ridge rises from a depth of approximately 3,500 m and includes the islands of Mona, Monito and Desecheo, as well as submerged seamounts that reach depths of less than 100 m, such as BDS, Bajo Esponjas and Bajo Pichincho in PR, and Cabo Engaño, partially within Dominican Republic waters. The seamount promontories at BDS rise from a submerged platform that extends out to the north from the insular slope of western Puerto Rico.

Bathymetric Map

An initial bathymetric map of BDS consisting of approx. 13,000 single beam (echosounder) data points was prepared for the seamount reef top. A grid of 73 planned lines within an area of approximately 0.5 km x 1.5 km was prepared in Hypack Software. The bathymetry line grid was georeferenced over an existing side-scan sonar TIF image file of BDS prepared by DNER. A Garmin Model 2006 GPS unit with an integrated echosounder was used to navigate over the planned lines. The GPS/echosounder unit was interfaced to an on-deck computer and the data stored and processed by Hypack Software to produce an XYZ data set. The XYZ data points were limited by the range of

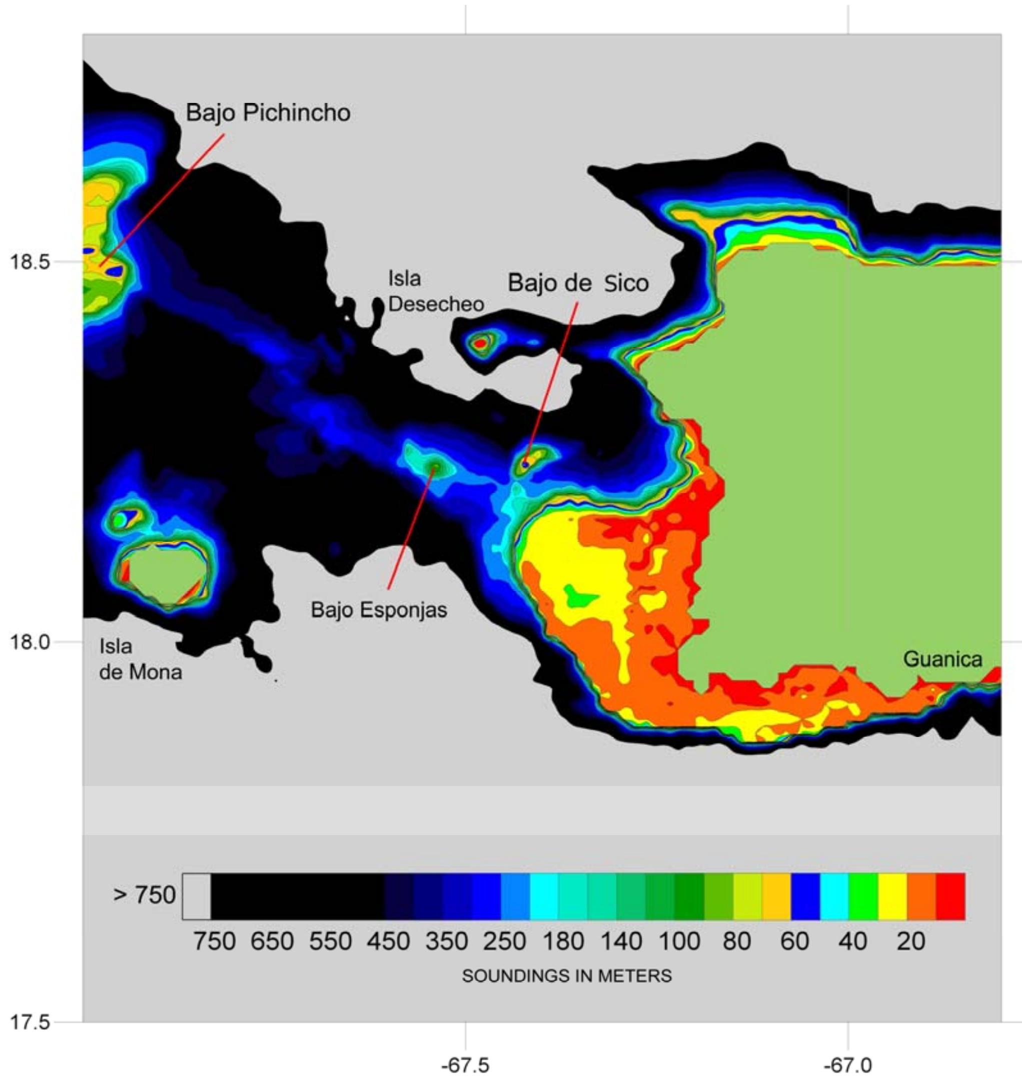

Figure 1. Location of Bajo de Sico in Mona Passage

the echosounder to a depth of approximately 100 m. The final bathymetry contours over the BDS reef top were plotted using Golden Software Surfer v.8 (Figure 2).

The bathymetry survey of BDS was expanded to the entire reef platform and the resolution significantly enhanced by the multi-beam mapping provided by the R/V Nancy Foster in April 2007. Multibeam data was collected with a hull-mounted Simrad EM 1002 and a hull-mounted Reson 8124 multibeam SONAR and were processed by a NOAA contractor using CARIS HIPS/SIPS v.6.1 software.

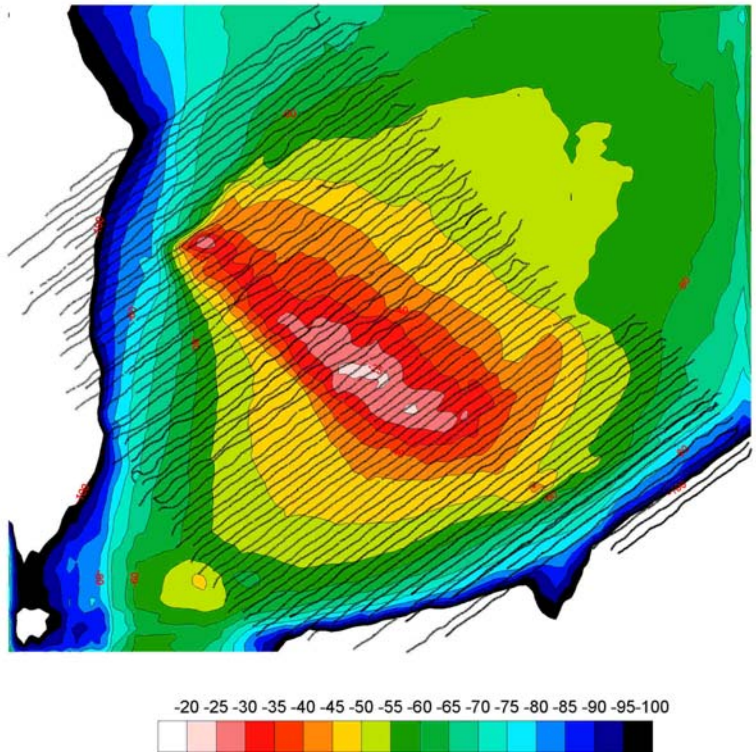

Figure 2. Bathymetry contours of the BDS reef top produced from a single beam echosounder and the corresponding surveyed lines

Benthic Habitat Map

A digitized benthic habitat map of Bajo de Sico was produced down to a depth of 50 m (165 feet). An initial (preliminary) blueprint of reef promontories and other salient topographic features of BDS were constructed from a side-scan sonar mosaic image file provided by the DNER. The bathymetric and backscatter data produced by the multibeam survey of the reef by the R/V Nancy Foster of NOAA (http://ccma.nos.noaa.gov/products/biogeography/usvi_nps/data.html) was used to prepare the final blueprint of the reef benthic habitats. Field verification of the main reef bathymetric features and benthic habitats was produced by divers using Inspiration re-breathers. Field verification of benthic habitats included a combination of exploratory drift dives across the reef, bounce (point) dives at strategic locations, and dives for biological assessment (Figure 3). The final benthic habitat map was prepared in Arc-View software with NOAA Habitat Digitizer extension.

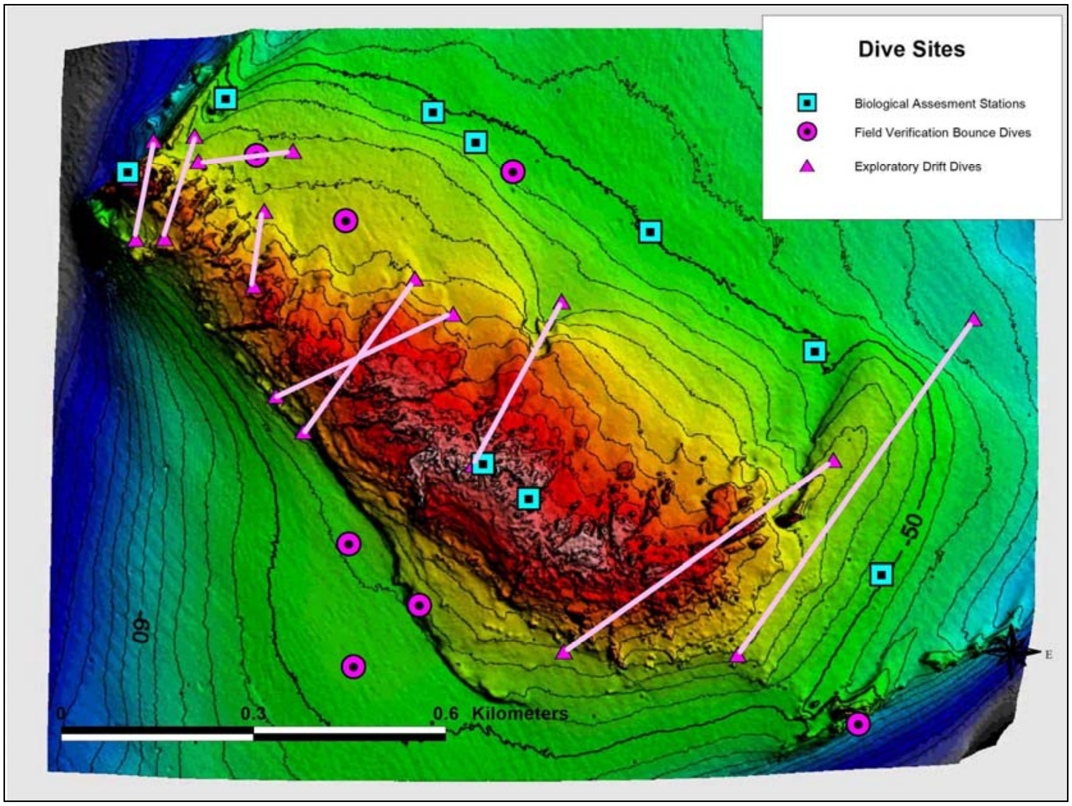

Figure 3. Field verification dives performed for validation of benthic habitat map of BDS to 50 m depth.

Physical Oceanographic Data

<u>CTD Profiles</u>

Profiles of the water column temperature and salinity were obtained with a Seabird Electronics CTD (Model SBE19). Water column profiles were taken to a depth of 60 m during June, July, August and September, 2007. Hobo temperature data loggers were installed at depths of 30 and 50 m in Bajo de Sico on February 23, 2007. Data loggers were programmed to record water temperature at one hour intervals for a duration of 12 months. Hobo's were retrieved on September 26, 2007. The unit at 30 m depth recorded temperature until May 23, 2007. After this date the unit stopped recording, apparently due to battery malfunction. The Hobo installed at a depth of 50 m flooded and returned no data.

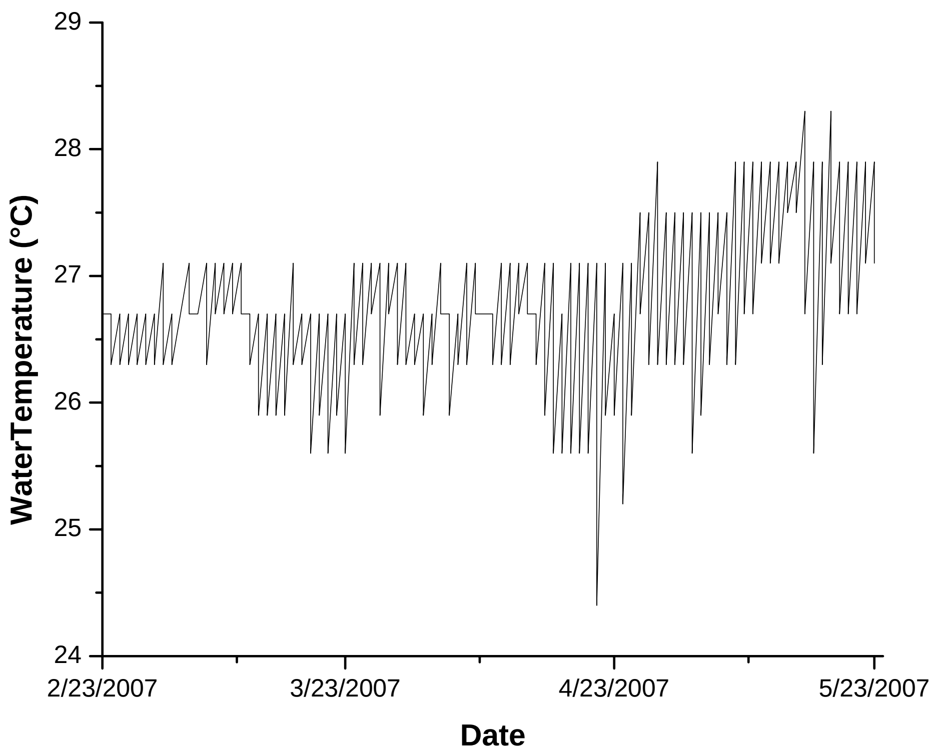

Figure 4. Water temperature data from Hobo data logger at 30 m depth

Water Currents

Water current velocities and directions from depths between 2.3 m and 38.4 m were measured at Bajo de Sico using an Acoustic Doppler Current Profiler (ADCP) during a 10 week period between February 23 and May 9, 2007. Geographic coordinates, depths and other statistics of the ADCP deployment (BS01) are summarized in Table 1.

Table 1. ADCP deployment at Bajo de Sico. Depth in meters (feet) relative to MLLW.

Event	Start	End	Lat (N)	Lon (W)	Bottom Depth	Xducer Depth	6% Xducer Depth
BS01	23-Feb-07	9-May-07	18° 13.808	67° 25.786	38.8 (127)	38.4 (126)	2.3 (7.6)

Table 2: Sentinel ADCP configuration.

Bin size	1.0 m (3.28 ft)
Currents and tide sampling interval	30 minutes
Pings per sampling interval	300
Standard deviation (ADCP only)	0.35 cm/s
Distance to center of deepest bin	2.12 m (6.95ft)

An RD Instruments 600 KHz Workhorse Sentinel ADCP was used in this study. The BS01 ADCP configuration parameters are listed in Table 2. The ADCP was bottom mounted near the top of the reef promontory at the biological benchmark survey station BDS-1 (Figure 5). Bottom contours at BDS-1 are oriented along a north-south axis, sloping down towards the west. The center depths and depth limits of the ADCP data bins are provided in Table 3. 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). Considering these limitations, at a bottom depth of 38.8 m the 600 kHz ADCP provided usable data in the depth range of 3 – 36 m (bin center depths), which by taking into account the bin depth limits becomes 2.79 – 36.79 m (top of first bin to the bottom of the last bin, see Table 3). The ADCP was configured to sample 40 bins, 34 of which were below the 6% depth level indicative of good velocity data (Table 3).

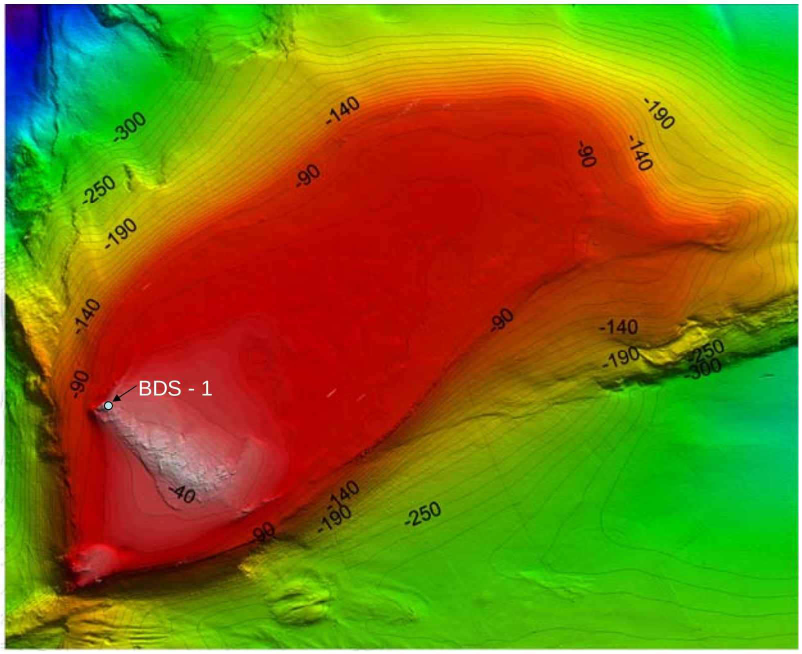

Figure 5. Location of ADCP current meter at benchmark station BDS-1.

<u>Optical Measurements</u>

Planar downwelling irradiance Ed (watts per meter) was measured at noon with the Underwater Irradiance Meter LI -1400 at 5 m and 10 m in an area where the water column was hit directly by the sun. Seven to eight readings where taken at each depth over Bajo de Sico. The diffuse attenuation coefficient Kd (inverse meters) was calculated using the equation:

$$K_d = 1/(z_1 - z_2) * \ln E_d(z_1)/Ed(z_2)$$

where E_d (watts per square meter) is planar downwelling irradiance and z (in meters) is depth positive downward from the sea surface. K_d is an indicator of the penetrative component of solar radiation. The euphotic zone is defined as the depth at which E_d decreases to 1% of the E_d value just underneath the surface. The depth of the euphotic zone (Z_{eu}) was calculated using the equation:

$$Z_{eu} = 4.6/K_d$$

Table 3. MR01 bin placement. Center Height is the distance measured from the transducer to the center of a bin. Center Depth is the depth from the sea surface to the center of a bin. Top and Bottom are the depth from the sea surface to the top and bottom of a bin. Distances in meters (first row for each bin) and feet (second row). Bin numbers from the bottom (first row), from the top (second row). Bins corresponding to 10%, 50% and 90% depths, are indicated in bold.

Bin	Center Height	Center Depth	Bin Top	Bin Bottom	Bin	Center Height	Center Depth	Bin Top	Bin Bottom
34	35.12	3.29	2.79	3.79	17	18.12	20.29	19.79	20.79
1	115.19	10.81	9.17	12.45	18	59.43	66.57	64.93	68.21
33	**34.12**	**4.29**	**3.79**	**4.79**	16	17.12	21.29	20.79	21.79
2	**111.91**	**14.09**	**12.45**	**15.73**	19	56.15	69.85	68.21	71.49
32	33.12	5.29	4.79	5.79	15	16.12	22.29	21.79	22.79
3	108.63	17.37	15.73	19.01	20	52.87	73.13	71.49	74.77
31	32.12	6.29	5.79	6.79	14	15.12	23.29	22.79	23.79
4	105.35	20.65	19.01	22.29	21	49.59	76.41	74.77	78.05
30	31.12	7.29	6.79	7.79	13	14.12	24.29	23.79	24.79
5	102.07	23.93	22.29	25.57	22	46.31	79.69	78.05	81.33
29	30.12	8.29	7.79	8.79	12	13.12	25.29	24.79	25.79
6	98.79	27.21	25.57	28.85	23	43.03	82.97	81.33	84.61
28	29.12	9.29	8.79	9.79	11	12.12	26.29	25.79	26.79
7	95.51	30.49	28.85	32.13	24	39.75	86.25	84.61	87.89
27	28.12	10.29	9.79	10.79	10	11.12	27.29	26.79	27.79
8	92.23	33.77	32.13	35.41	25	36.47	89.53	87.89	91.17
26	27.12	11.29	10.79	11.79	9	10.12	28.29	27.79	28.79
9	88.95	37.05	35.41	38.69	26	33.19	92.81	91.17	94.45
25	26.12	12.29	11.79	12.79	8	9.12	29.29	28.79	29.79
10	85.67	40.33	38.69	41.97	27	29.91	96.09	94.45	97.73
24	25.12	13.29	12.79	13.79	7	8.12	30.29	29.79	30.79
11	82.39	43.61	41.97	45.25	28	26.63	99.37	97.73	101.01
23	24.12	14.29	13.79	14.79	6	7.12	31.29	30.79	31.79
12	79.11	46.89	45.25	48.53	29	23.35	102.65	101.01	104.29
22	23.12	15.29	14.79	15.79	5	6.12	32.29	31.79	32.79
13	75.83	50.17	48.53	51.81	30	20.07	105.93	104.29	107.57
21	22.12	16.29	15.79	16.79	4	5.12	33.29	32.79	33.79
14	72.55	53.45	51.81	55.09	31	16.79	109.21	107.57	110.85
20	21.12	17.29	16.79	17.79	3	4.12	34.29	33.79	34.79
15	69.27	56.73	55.09	58.37	32	13.51	112.49	110.85	114.13
19	20.12	18.29	17.79	18.79	**2**	**3.12**	**35.29**	**34.79**	**35.79**
16	65.99	60.01	58.37	61.65	**33**	**10.23**	**115.77**	**114.13**	**117.41**
18	**19.12**	**19.29**	**18.79**	**19.79**	1	2.12	36.29	35.79	36.79
17	**62.71**	**63.29**	**61.65**	**64.93**	34	6.95	119.05	117.41	120.69

The remote sensing attenuation coefficient was obtained by accessing the NASA ocean color web page. For the BDS site using SEADAS software the level 2 product from both MODIS Terra and Aqua where processed using the K490 algorithm in order to obtain higher spatial and temporal resolution. A digital value for K490 was obtained for the exact location where field measurements where taken at BDS.

Biological Characterization of Reef Communities

Quantitative assessments of the predominant sessile-benthic and motile-megabenthic and fish populations were performed at the main reef benthic habitats down to a maximum depth of 50 m at BDS. Location of sampling stations is shown in Figures 5 and 6. The benthic habitats studied included 1) reef top promontories at depths between 26 – 31 m, 2) vertical wall promontories at depths between 32 – 40 m, and 3) deep rhodolith reef at depths between 46 – 53 m. Communities at the reef top were surveyed from the benchmark station BDS-1 and another location near the center of the promontories' ridge (Figure 6). Transects for characterization of the reef wall were studied from three different locations within BDS-1 (Figure 7). The deep rhodolith reef community was studied from transects established in (replicate) pairs at five different locations along the northern section of the BDS platform.

At each benthic habitat, a total of 10, 10-meter long transects were established for biological assessments. A fiberglass tape measure was stretched between two points to mark the transects. Sessile-benthic communities at the deep rhodolith reef and at the vertical wall promontories habitats were quantitatively characterized by photo transects. The reef top promontories were characterized by a combination of five video-transects and five photo-transects. Initially all data for sessile-benthic characterizations was collected using video-transects, but lack of resolution caused by poor illumination at the deep rhodolith reef habitat, and the irregular three-dimensional features (gorgonians and antipatharians) of the vertical wall habitat rendered video images useless for taxonomic identifications. Collection of photographic and visual data on reef communities at BDS were produced by divers using closed circuit (Inspiration) rebreathers.

A total of ten non-overlapping digital images (still photos or video frames) from each transect were analyzed using the Coral Point Count software v.3.2. A template of 25

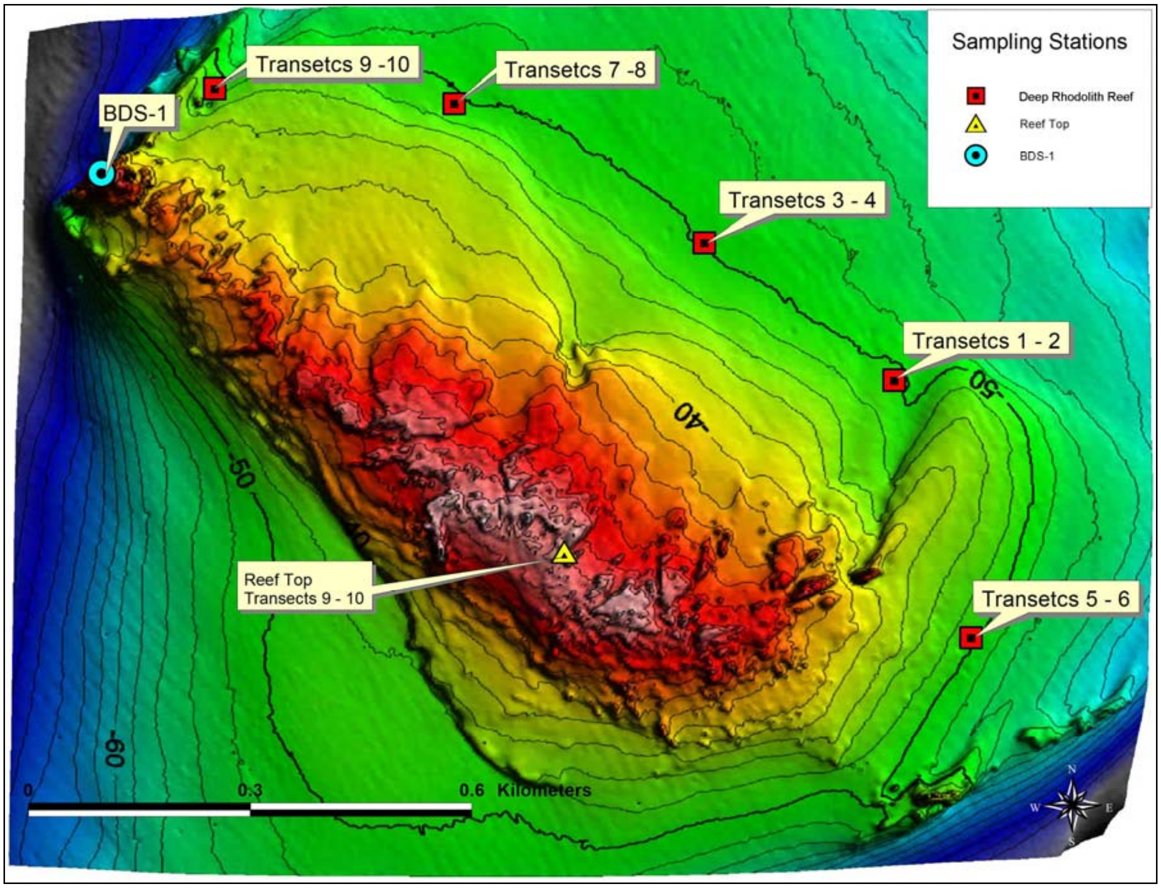

Figure 6. Location of sampling stations over each benthic habitat

random points was overlaid on each image and the substrate categories under each point identified. The cumulative number of points over each substrate category in the ten images analyzed per transect was divided by the total number of points overlaid per transect (e.g. 25 points per image x 10 transects = 250 points) and reported as the percent reef substrate cover for that transect. The total number of scleractinian, hydrozoan and antipatharian colonies present in all images analyzed were identified to the lowest possible taxon and enumerated for determination of coral colony density (in colonies per square meter). The area of the reef included in each image was calculated from the tape measure included as a "scale" in each image. The reef substrate area encompassed in video and still images ranged between 0.85 and 1.0 m^2, respectively. A greater area (1.3 m^2) was captured on the reef wall habitat in order to include entire colonies of gorgonians and antipatharians projecting outward from the wall.

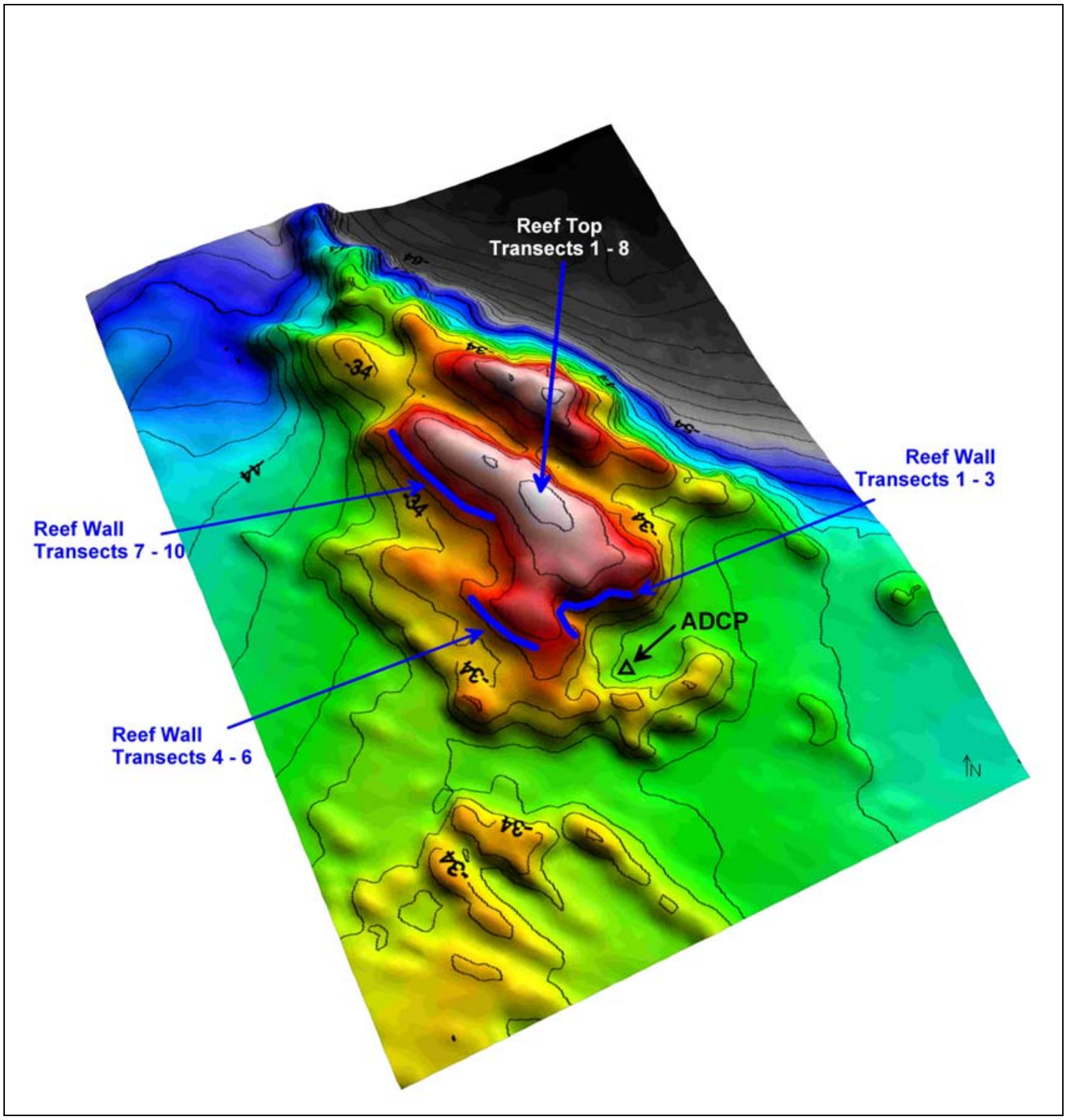

Figure 7. Detailed map of benchmark station BDS-1 indicating the location of characterization transects

Common names and coral taxonomy followed Veron (2000) and Humann and Deloach (2003)

Sessile-benthic reef categories included in the photographic image analysis included the following:

Scleractinian corals – percent cover and density of colonies per transect reported by species. Both hermatypic (e.g. *Montastraea cavernosa*) and ahermatypic (e.g. *Tubastrea coccinea*) taxa included.

Octocorals - (soft corals) percent cover and density of colonies per transect reported by species; or lowest identifiable taxon; includes vertically projected colonies, such as *Iciligorgia schrammi* and encrusting colonies, such as *Erythropodium caribaeorum*)

Antipatharians – (black corals), percent cover and density of colonies per transect reported to the lowest identifiable taxon;

Hydrocorals – (fire and lace corals), percent cover and density of colonies per transect reported by species; or lowest identifiable taxon; includes vertically projected colonies, such as *Stylaster roseus,* and encrusting colonies, such as *Millepora spp*.

- **Sponges** – percent cover reported by species, or lowest possible taxon
- **Algal Turf** – consisting of a mixed assemblage of short articulate coralline algae, intermixed with red, brown macroalgae and other small epibenthic biota forming a mat or carpet over hard substrate
- **Calcareous Algae** – reported as total calcareous algae, or lowest possible taxon
- **Fleshy Algae** – vertically projected, mostly brown, red and green macroalgae reported as total fleshy algae, or lowest possible taxon (e.g. *Lobophora variegata*)
- **Abiotic Substrate** – includes unconsolidated sediment, bare rock, deep holes and gaps.

Characterization of Fishes and Motile Megabenthic Invertebrates

Densities of demersal (non-criptic) reef fish populations and motile megabenthic invertebrates were estimated from a total of 10 – 3 m wide by 10 m long (30 m^2) belt-transects surveyed per benthic habitat (e.g. reef top promontories, vertical wall and deep terrace reef). Belt-transects were centered along the reference line of transects used for sessile-benthic reef characterizations. A more detailed description of this survey method was given in García-Sais et al. (2005).

Large, elusive fish populations, which include many commercially important and recreationally valuable populations were surveyed using an Active Search Census (ASEC). This is a non-random, fixed-time method designed to optimize information of the species and numbers of fish individuals present at the main reef habitats, providing simultaneous information on taxonomic composition, size frequency distributions and population density estimates. Because of the wide home ranges and relatively high mobility of large fishes associated with the reef promontories at BDS, the reef top and vertical wall sections of the promontories were considered as one habitat for ASEC surveys. A total of five ASEC surveys were performed at the promontories reef top/wall habitat to provide assessments of large fish populations within one short-acre (ca. 4,000 m^2) of the reef at the benchmark station BDS-1. Areal cover by ASEC surveys was estimated from the markings in the GPS as the boat captain followed a marker buoy from divers executing the survey. Due to the lack of underwater topographic relief or substrate discontinuities, ASEC surveys at the deep rhodolith reef were performed along 50 m long by 3 m wide line transects. Five ASEC surveys were performed at the deep rhodolith reef for a total areal coverage of 750 m^2. Common names of reef fishes were taken from Humann and Deloach (2006).

VI. Results and Discussion

1.0 Physical Oceanography Data

1.1 CTD Water Column Profiles

Water temperature and salinity profiles of the top 50 m at BDS during June, 2007 are presented in Figure 8. Water temperature ranged between 28.85 °C at the surface and 27.30°C at a depth of 52 m. A sub-surface thermocline of gradual temperature decline encompassing depths between 8 – 13 m was registered. Water temperature remained virtually constant down to a depth of 42 m, and then declined sharply along a thermocline at depths between 45 – 50 m. A corresponding increment of salinity (halocline) was associated with the thermocline at 45 m, suggesting the influence of different water masses. The density profile essentially followed the salinity profile, but appeared to be more strongly influenced by the temperature variations in the 40 – 50 m range. From this data it is apparent that the deep rhodolith reef communities were living just below the early summer thermocline, whereas the reef top and reef wall communities were living within the surface mixed layer during June, 2007.

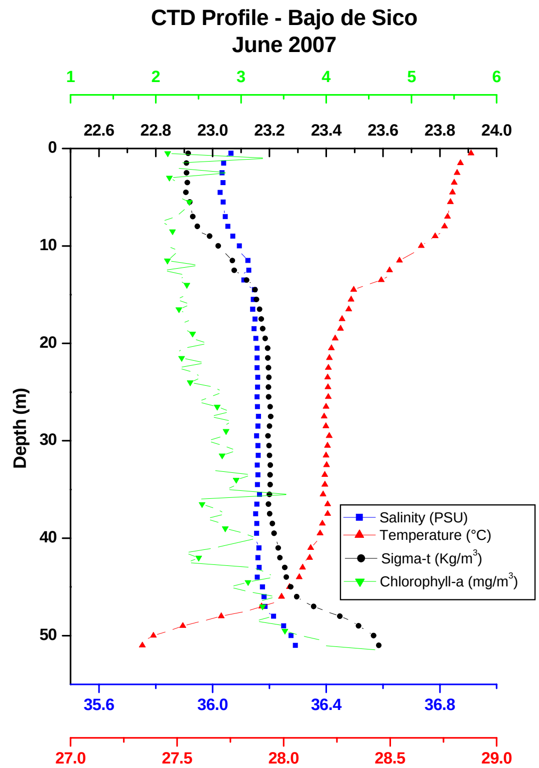

Figure 8. Water temperature and salinity profile taken with a CTD at Bajo de Sico

1.2 Water Currents

Mean flow estimates of the 75 day ADCP deployment at BDS are presented in Table 4 and Figures 9 and 10. The mean strength of the flow is represented by the mean speed (the scalar average) and the 50th percentile (median) profiles which exhibited relatively high speeds in the order of 41 cm/s and 38 cm/s (1 knot = 51 cm/s), respectively, with the higher values observed in the subsurface 5 -15 m depth layer (Figure 9). Mean speeds decreased markedly with increasing depth. Both surface and bottom boundary layers were evident. Median speeds were similar to the mean speeds indicating a nearly-symmetrical speed distribution (Figure 9). R/S ratios of ~0.5 are indicative of both a strong mean flow and highly oscillatory (probably tidally and wind-driven) flow. Below a depth of approximately 4 m the mean (resultant) flow was directed northward, a heading of 0°. Closer to the surface, in the wind-driven surface boundary layer, the mean flow rotated westward, while the bottom boundary layer flowed towards the southeast along bottom contours. The 90th percentile speeds (Figure 10), usually resulting from peak tidal or peak sea breeze currents were in the order of 70-74 cm/s (1.4-1.5 kt). Maximum observed speeds were in excess of 122 cm/s (2 kts).

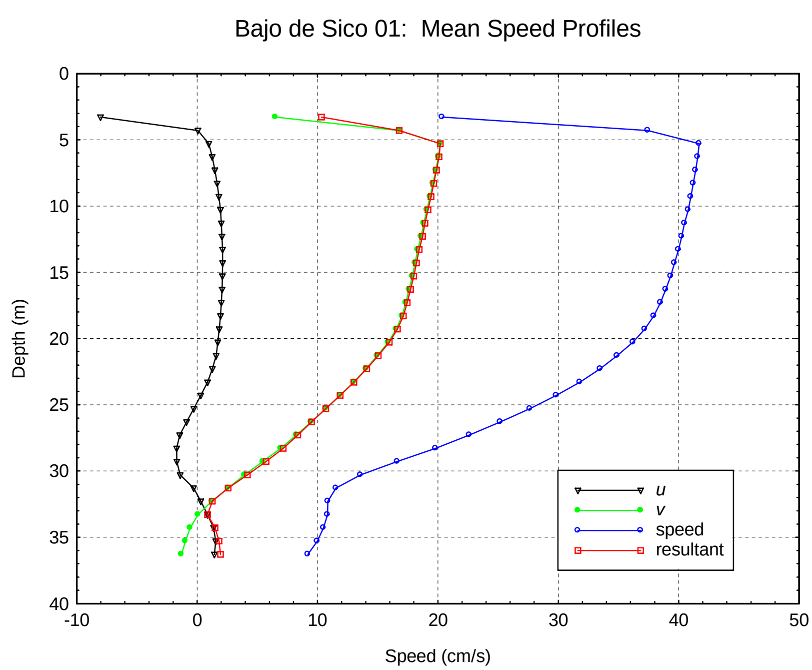

Figure 9. Mean water current speed profiles of the top 38 m at Bajo de Sico during the period between February 23 and May 9, 2007.

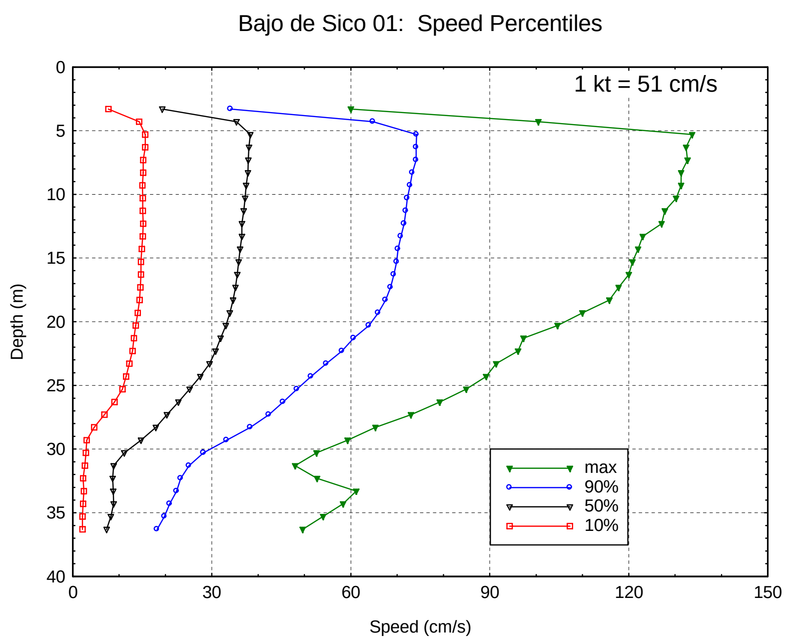

Figure 10. Water current speed percentile profiles of the top 38 m at Bajo de Sico during the period between February 23 and May 9, 2007.

The progressive vector (PV) pseudo-trajectories shown in Figure 11 and the directional transport distributions in Figure 12 show the prevalence of a persistent interior northward flow, semidiurnal tidal current oscillations and more rectified flow near the bottom.

Full record, tidally smoothed, *v* (north-south component) time series are presented in Figure 13. Near surface and mid-water currents displayed a similar pattern in both amplitude and phase, while the near-bottom currents were much weaker. Flow variability at multiple time scales was evident. Despite a very prominent northward mean flow, periods of sustained southward flow were observed in the 75-day record. Southward mean flow prevailed during February 24-28, and later over a one week period during April 7-14. The Punta Ostiones tidal current predictions maintained a near-zero mean across several tidal cycles, whereas the observed flow at BS01 exhibited a persistent northward mean flow (Figure 14). A strong northward mean flow of more than 1 kt prevailed over a three-day period, decreasing to a near-zero mean by the time the ADCP was recovered.

Table 4. BS01 mean statistics and percentiles. Depth in meters and speeds in cm/s. **Scalar**=scalar speed average, **Res**=magnitude of the resultant vector, **Dir**=direction of the resultant vector, **R/S**=**Res/Scalar** ratio, **u**=average of the *u* component, **v**=average of the *v* component. Data at 10%, 50% and 90% depth are highlighted in bold.

Depth	Scalar	Res	Dir	R/S	u	V	10	50	90	max
3.30	20.4	10.3	309	0.51	-8.0	6.5	7.7	19.3	34.0	60.0
4.30	**37.4**	**16.8**	**0**	**0.45**	**0.1**	**16.8**	**14.3**	**35.3**	**64.8**	**100.5**
5.30	41.7	20.2	3	0.48	1.0	20.2	15.6	38.3	74.2	133.7
6.30	41.6	20.1	4	0.48	1.2	20.1	15.6	38.0	74.1	132.4
7.30	41.4	19.9	4	0.48	1.5	19.8	15.2	37.9	74.1	132.7
8.30	41.2	19.7	5	0.48	1.7	19.6	15.2	37.8	73.3	131.3
9.30	41.0	19.4	5	0.47	1.8	19.3	15.0	37.4	72.8	131.3
10.30	40.8	19.2	6	0.47	1.9	19.1	15.1	37.2	72.2	130.2
11.30	40.5	18.9	6	0.47	2.0	18.8	15.1	36.9	71.9	127.8
12.30	40.3	18.7	6	0.46	2.1	18.6	15.2	36.5	71.5	127.1
13.30	40.0	18.4	7	0.46	2.1	18.3	15.1	36.5	70.8	123.0
14.30	39.7	18.2	7	0.46	2.1	18.1	14.9	36.1	70.2	122.0
15.30	39.3	18.0	7	0.46	2.1	17.9	14.7	35.8	69.9	120.8
16.30	38.9	17.7	7	0.46	2.1	17.6	14.7	35.5	69.3	120.0
17.30	38.5	17.5	7	0.45	2.0	17.3	14.6	35.1	68.6	117.8
18.30	37.9	17.1	7	0.45	1.9	17.0	14.4	34.6	67.5	115.8
19.30	**37.2**	**16.6**	**6**	**0.45**	**1.8**	**16.5**	**14.0**	**33.9**	**65.9**	**110.0**
20.30	36.2	16.0	6	0.44	1.7	15.9	13.6	33.0	63.9	104.6
21.30	34.9	15.0	6	0.43	1.6	15.0	13.2	31.9	60.6	97.3
22.30	33.5	14.1	5	0.42	1.3	14.0	12.9	30.8	58.1	96.1
23.30	31.8	13.0	4	0.41	0.9	13.0	12.2	29.5	54.7	91.4
24.30	29.8	11.9	1	0.40	0.3	11.9	11.5	27.5	51.4	89.2
25.30	27.7	10.7	358	0.39	-0.3	10.7	10.7	25.2	48.4	84.9
26.30	25.2	9.5	355	0.38	-0.9	9.5	9.0	22.8	45.4	79.2
27.30	22.6	8.4	350	0.37	-1.4	8.2	6.8	20.3	42.3	73.0
28.30	19.8	7.1	346	0.36	-1.7	6.9	4.6	17.9	38.3	65.3
29.30	16.6	5.7	343	0.34	-1.7	5.5	3.0	14.7	33.2	59.3
30.30	13.6	4.2	340	0.31	-1.4	3.9	2.8	11.1	28.2	52.6
31.30	11.5	2.6	353	0.22	-0.3	2.6	2.6	8.8	25.1	48.0
32.30	10.9	1.3	15	0.12	0.3	1.2	2.2	8.6	23.3	52.7
33.30	10.8	0.9	84	0.08	0.9	0.1	2.4	8.7	22.4	61.2
34.30	10.5	1.5	113	0.14	1.4	-0.6	2.2	8.8	20.9	58.3
35.30	**10.0**	**1.8**	**122**	**0.18**	**1.5**	**-1.0**	**2.1**	**8.2**	**19.8**	**54.0**
36.30	9.2	1.9	132	0.21	1.4	-1.3	2.1	7.3	18.2	49.6

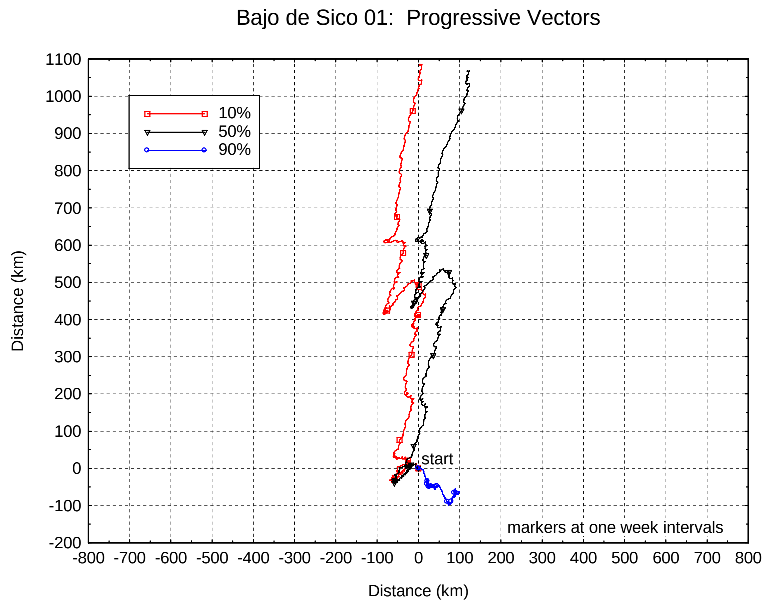

Figure 11. Water current progressive vector pseudo-trajectories at BDS during the period between February 23 and May 9, 2007.

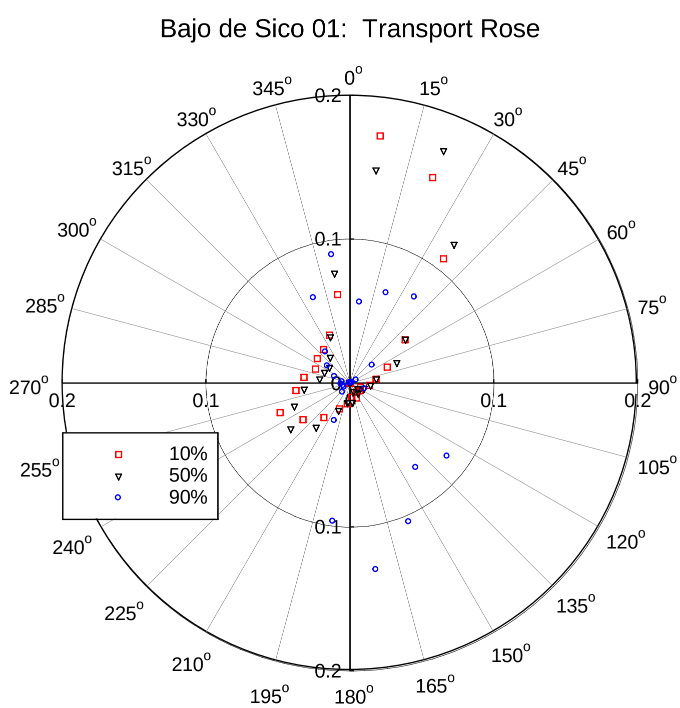

Figure 12. Water current directional transport rose at BDS during the period between February 23 and May 9, 2007. The radial position of each depth marker represents the percentage of the total transport that lies in any given 15° bin. Each radial division indicates 10% of the total transport

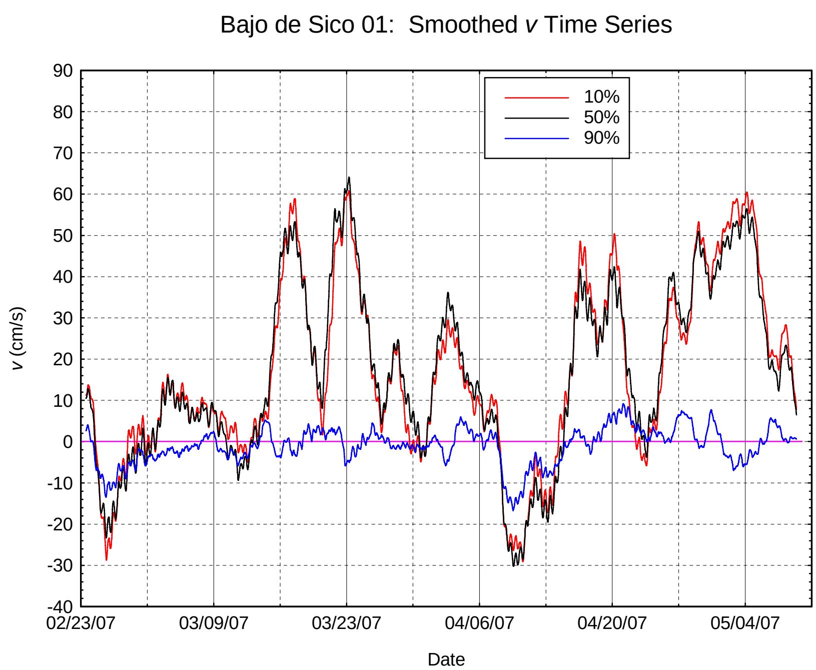

Figure 13. Full record, smoothed *v* time series at 10%, 50% and 90% depths during Feb 23 – May 9, 2007

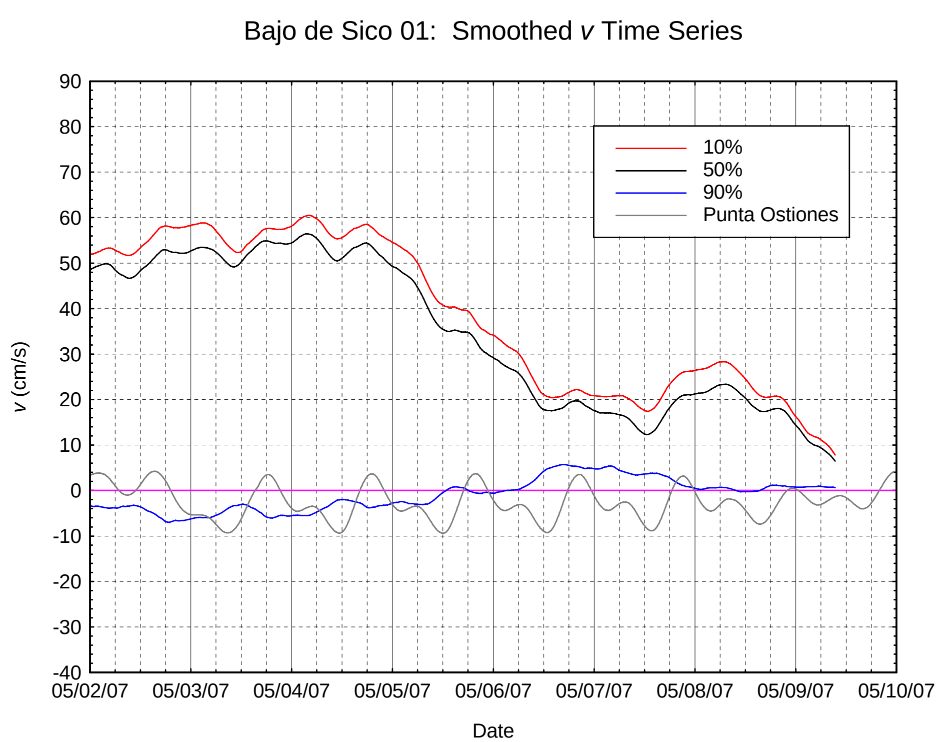

Figure 14. Punta Ostiones predicted tide (NOAA) and *v* time series at 10%, 50% and 90% depths during May 2-10, 2007.

1.3 Water Column Optical Data

The diffused attenuation coefficient K_d and the depth of the euphotic zone are shown in Figure 15. Optical field measurements contain inherent sources of error due to light refraction by surface waves, cloud cover, boat shadow, and instrument shadow. During the BDS sampling date weather conditions were close to ideal and consequently the remote sensing attenuation coefficient K490 was the most similar to the corresponding K_d field measurements. The depth of the euphotic zone calculated from the satellite data for the same date and time of field measurements was less than 7.0 m shallower than the 70.39 m euphotic zone (1% incident light) given by the field measurements. The site was visited during early September, which falls in the middle of the Caribbean hurricane season. This is probably the time when the attenuating effect of terrigenous sediments is most felt in the adjacent shelf waters as can be seen in the satellite image.

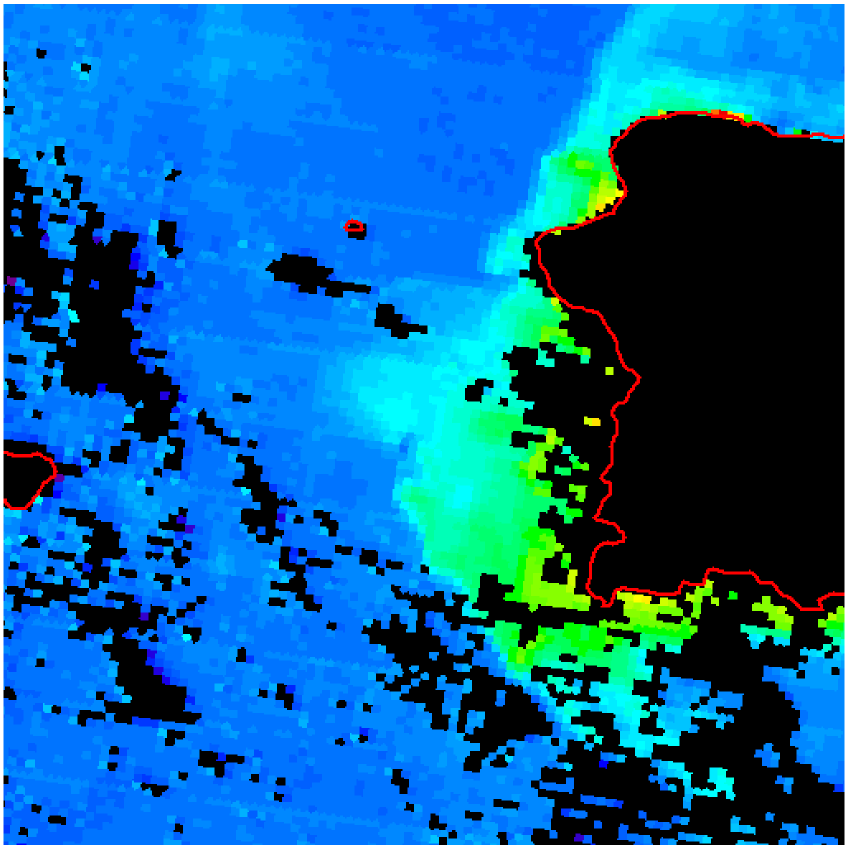

Figure 15. MODIS-K 490 satellite image of the Mona Channel (9/7/07) and depth of the euphotic zone for field measured Kd and remote sensed K490

2.0 Bathymetry of Bajo de Sico

BDS seamount has a maximum length of approximately 6.0 km along its southwest to northeast axis, and a maximum width of approximately 2.5 km across the northwest to southeast axis. The total surface area of the seamount within the 100 m depth contour is of approximately 11.1 km^2. BDS is connected to the insular shelf of Puerto Rico by the deepest and widest of a series of hard ground platforms that extend west and north towards Mona Passage at about 28 km due west off Punta Guanajibo in the Cabo Rojo platform (Figure 16). The deep shelf platform of BDS rises gradually from a depth of 190 m towards the north reaching a minimum depth of 24 m at the top of the seamount. The edge of the deep shelf platform at BDS is found at depths that range between 90 – 115 m. The slope of the seamount is an abrupt, almost vertical wall towards the bottom at depths that increase sharply from 200 m in the southern margin to depths of more than 300 m in the northern margin of the seamount.

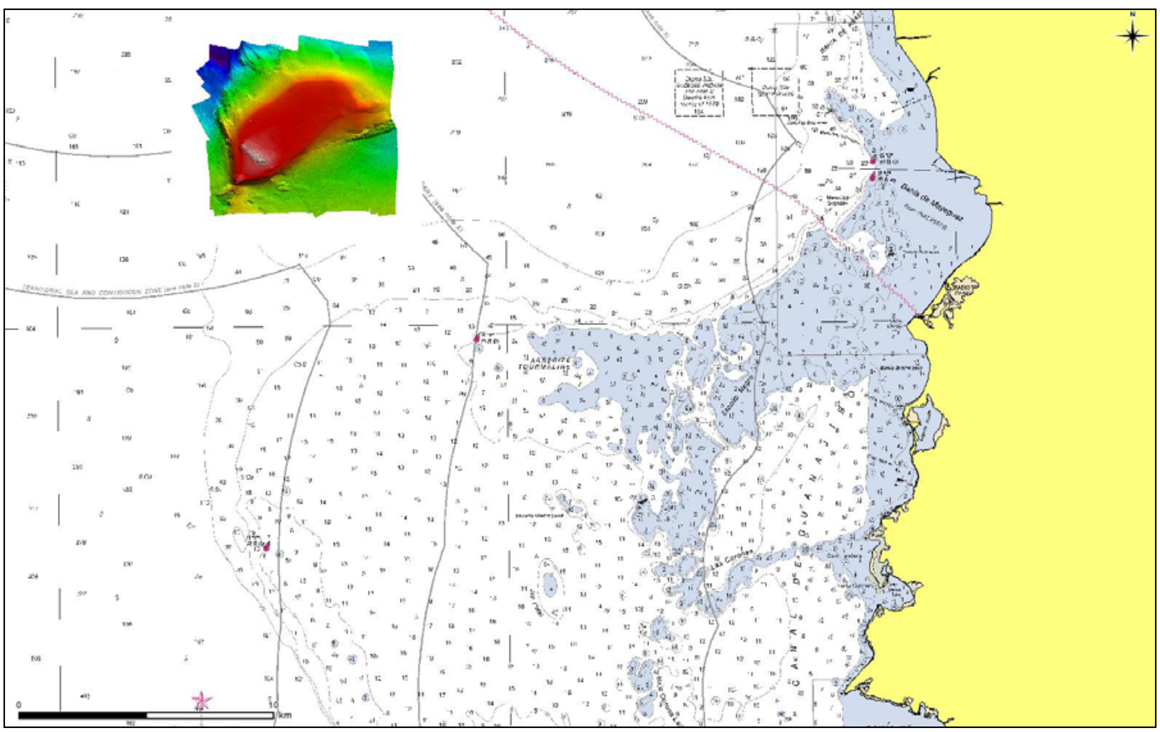

Figure 16. Nautical chart of the west coast of Puerto Rico (NOAA 25671) showing bathymetric features of the west coast insular slope and the Bajo de Sico seamount.

The most salient bathymetric feature of BDS is a series of promontories located at the southwest margin of the seamount. Promontories rise from a basal depth of approximately 40 m and extend along a southeast to northwest axis, occupying a surface area of approximately 0.4 km^2, or 3.6% of the total seamount surface area within the 100 m depth contour (Figures 17 and 18). Depth increases gradually along a series of mostly flat homogeneous platforms oriented towards the northeast, the larger of which sits within the 60 – 70 m depth contours and occupies a surface area of approximately 2.84 km^2, or 25.5% of the total BDS shelf surface area. Table 5 provides area estimates of the various depth provinces at BDS.

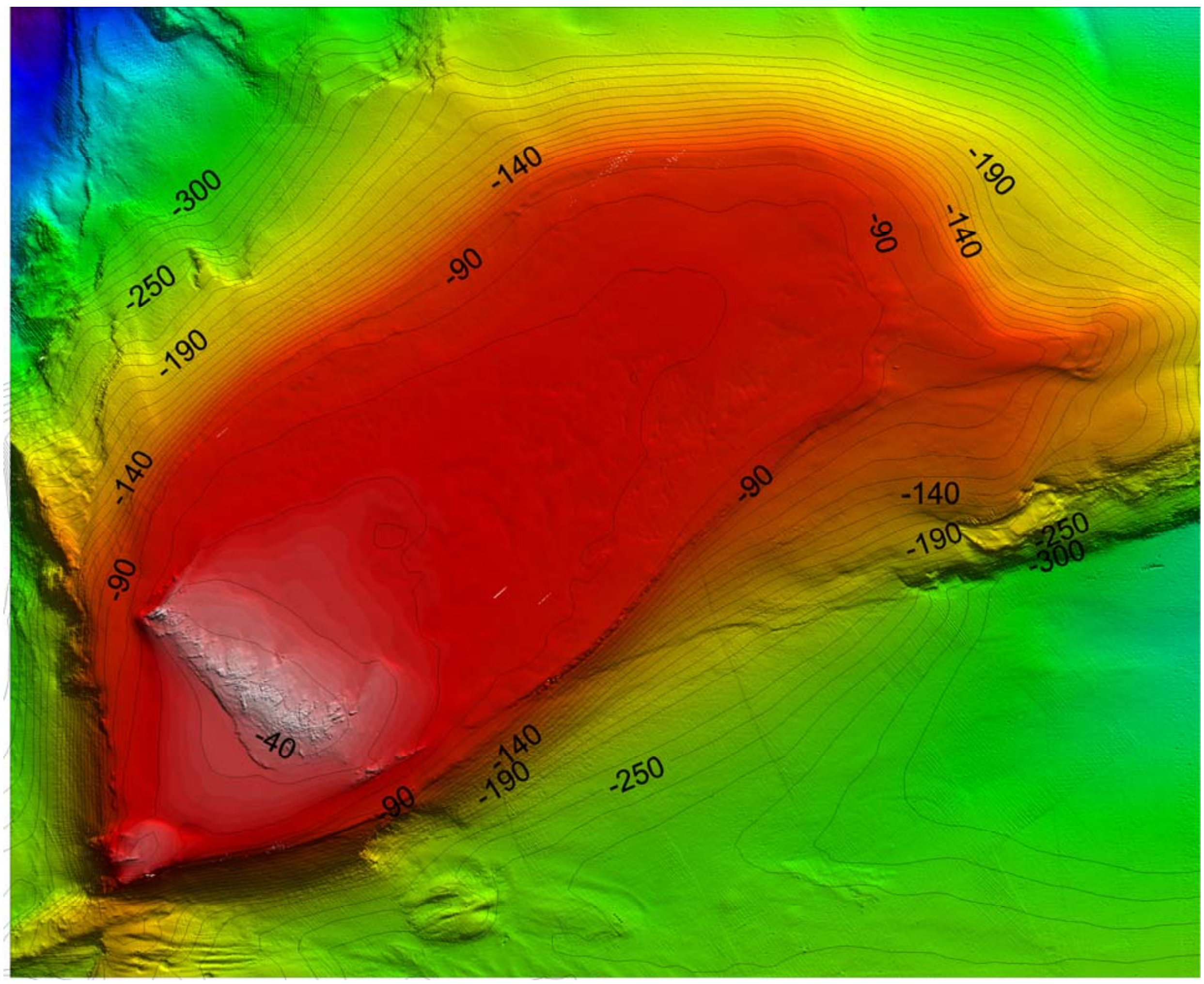

Figure 17. Bathymetry of Bajo de Sico viewed from the top to show the main reef platforms oriented along a southwest to northeast axis.

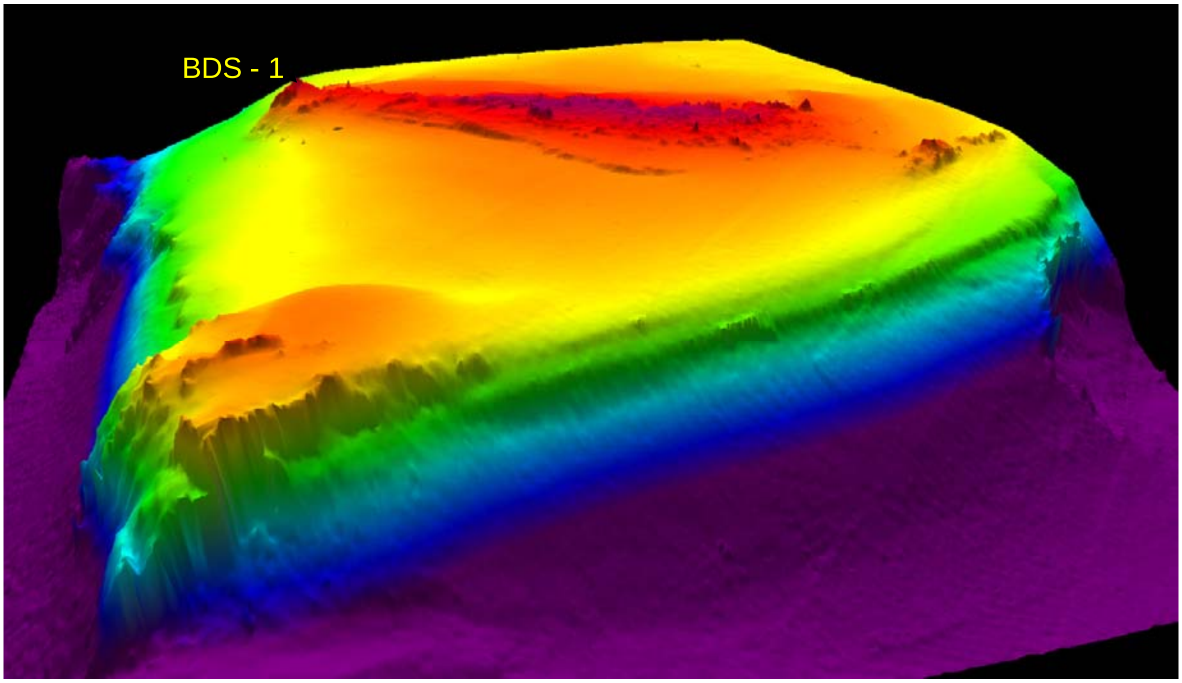

Figure 18. Bathymetry of Bajo de Sico viewed from the side to show the main reef promontories

Table 5. Estimates of surface area covered by depth provinces within 100 m at Bajo de Sico

Depth Province (m)	Estimated Surface Area (Km2)	% Total Area
25 - 40	0.40	3.6
41 - 50	0.90	8.1
	1.30	**11.7**
51 - 60	1.74	15.6
61 - 70	2.84	25.5
71 - 80	1.04	9.3
81 - 90	1.90	17.1
91 - 100	2.30	20.7
	11.12	**96.3**

3.0 Benthic Habitat Map

Five main benthic habitats distributed within a depth range of 23.5 to 50.0 m were field verified by direct diver observations at BDS. The total area within the 50 m depth contour was 1.3 km^2, or 11.7% of the total seamount's surface area (e.g. 11.1 km^2). The distribution of the main benthic habitats at BDS is presented in Figure 19. A ridge of rock promontories aligned southeast to northwest located on the southern section of the seamount is the main topographic feature of BDS. Promontories rise from a hard ground platform at a depth of 40 – 45 m up to a minimum depth of 23.5 m on the north-western margin of the ridge. There is an additional promontory that stands as a solitary mount rising to a depth of 27.0 m at the southern tip of the seamount (Figure 19).

Rock promontories exhibited two main benthic habitats, the reef top and the reef wall. The reef top habitat was highly irregular, with many substrate discontinuities, outcrops, holes, crevices and the rugosity contributed by large erect sponges and some massive corals. It is a horizontally projected, well illuminated hard ground surface characterized by a distinct assemblage of reef biota dominated in terms of substrate cover by benthic algae and sponges. Scleractinian corals presented their highest substrate cover at the reef top.

The reef wall is a vertically projected, highly irregular habitat, with caves, gaps and holes at the wall's face, and undercuts near the base. Light declines rapidly with increasing depth down the reef wall, and instead of benthic algae, the substrate at the wall is dominated by sponges. Instead of scleractinian corals, gorgonians and black corals are prominent at the reef wall. Also, benthic algae were less prominent at the reef wall, compared to the reef top. The total surface area of the reef promontories (including the reef top and wall habitat) was calculated as 0.40 km^2, representative of 3.6% of the total seamount area (Table 5). Due to the vertical projection of the reef wall, its surface area was underrepresented on the benthic habitat map, and mostly unaccounted in terms of areal distribution by benthic habitats at BDS.

A highly heterogeneous benthic habitat of colonized pavement and sand was found on channels separating adjacent promontories, and surrounding the ridge at its base within a depth range of 40 – 45 m. Isolated coral heads, sometimes associated with sponges, gorgonians, colonial hydrozoans and benthic algae colonized the hard ground between and around promontories. Coarse sand and rubble prevailed at the channels separating promontories, whereas the habitat surrounding the rock promontories presented uncolonized gravel and small rhodoliths dispersed over a compacted sandy substrate that gradually sloped down to the main platform of the seamount. An array of rock promontories generally smaller than the ones found within the main ridge colonized by benthic algae and encrusting biota, including scleractinian corals were present interspersed within the slope.

An extensive hard ground platform that extends north of the main seamount ridge was found at depths between 45 – 90 m. The total surface area of the deep platform below 50 m was estimated at 9.82 km^2, representing 88.2% of the seamount surface area. The shelf edge is an abrupt vertical wall mostly throughout the seamount, except along the southeast section where the seamount appears to be connected to the main island of Puerto Rico by a horizontal displacement of the insular slope forming a deep terrace at a depth of 177 m.

The deep shelf platform of BDS, down to the maximum surveyed depth of 50 m was found to be mostly covered by a vast deposit of algal rhodoliths. Two main benthic habitats can be discerned from this deep platform section of BDS. At the northern section of the platform, rhodoliths and other relict carbonate materials are densely overgrown by benthic algae, mostly the encrusting alga, *Lobophora variegata*, sponges, and scleractinian corals. Although of low topographic relief, the sharp increment in biotic cover and biodiversity relative to the adjacent slope environment serve as criteria to classify this habitat as a mesophotic reef system. South of the main ridge and at the western and eastern edges of the ridge, extensive rhodoliths deposits were also found. In contrast to the northern section, rhodolith nodules were mostly uncolonized by encrusting reef biota and appeared to be in a more dynamic state, as suggested by ripple formations observed in some areas.

There is at present very little information of the habitat features of the deep shelf platform beyond 50 m. During its multi-beam bathymetry survey of BDS, the R/V Nancy Foster was able to obtain video images of the seafloor along the deep platform beyond 50 m. From the limited resolution of the images, scleractinian corals could be discerned down to a maximum depth of 90 m along the northern section of the seamount's deep platform. Backscatter data from the R/V Nancy Foster multi-beam bathymetry survey was used in an effort to differentiate benthic habitats at BDS. The map of backscatter data differentiates substrates types between the main ridge and the deep platform (Figure 19), but does not provide enough resolution to discern benthic habitat differences (e.g. live reef vs abiotic) within the deep platform.

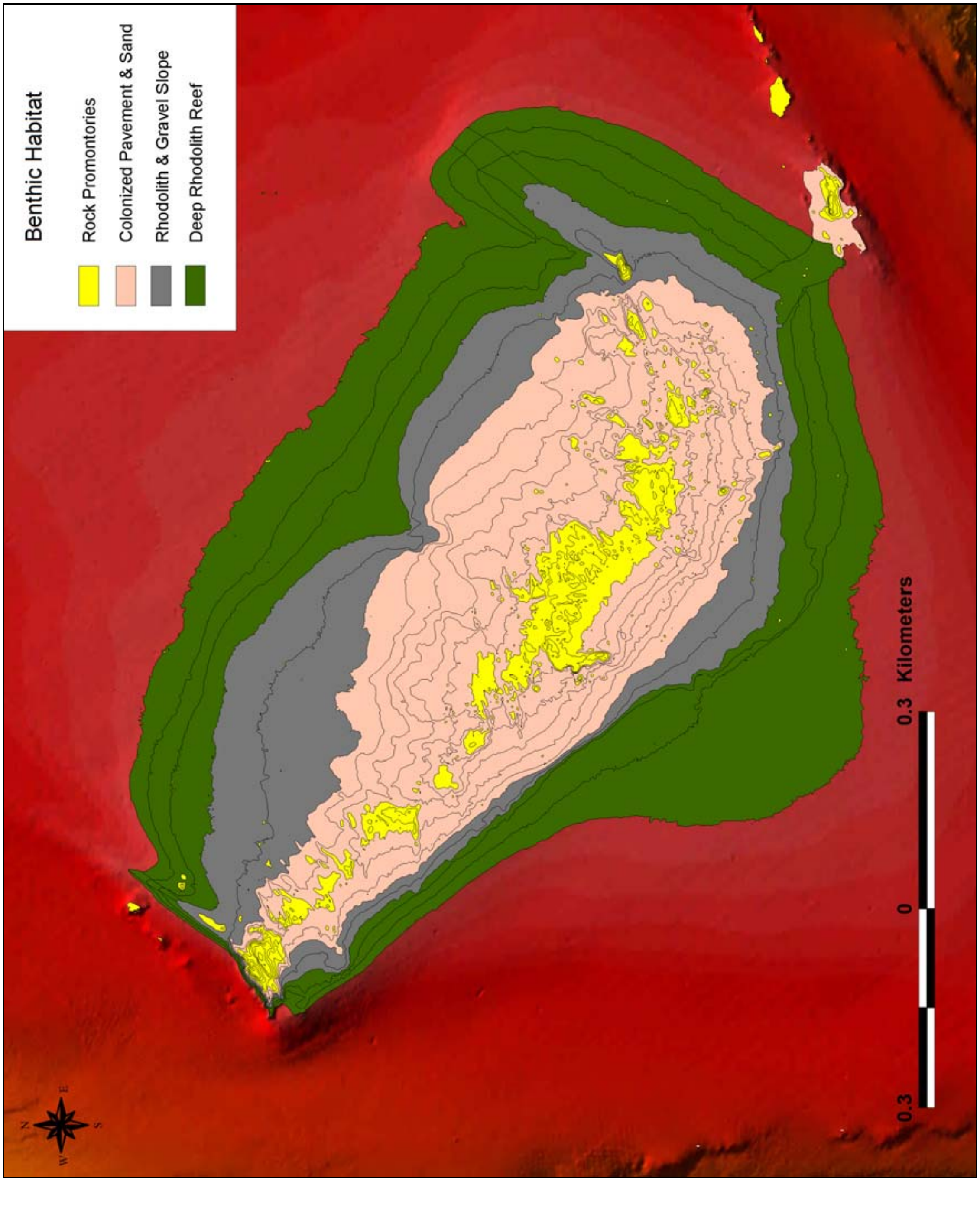

Figure 19. Benthic habitat map of Bajo de Sico up to a maximum depth of 50 m

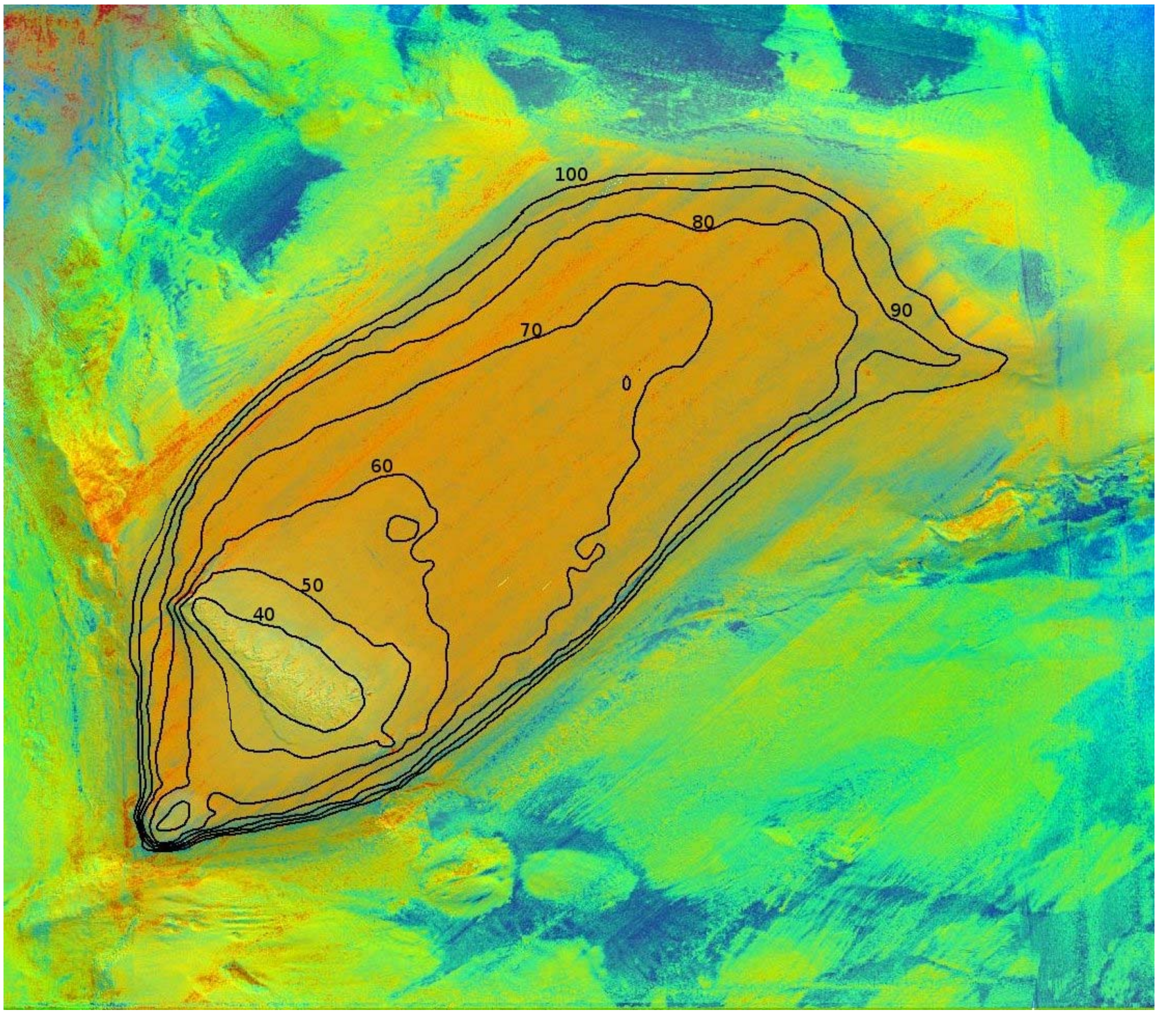

Figure 20. Backscatter data of Bajo de Sico produced by the R/V Nancy Foster multibeam survey on April 2007.

4.1 Biological characterization of marine communities associated with the main benthic habitats at Bajo de Sico

4.1 Sessile-benthic Community

4.1.1 Reef Top

The sessile-benthic community at the reef top of BDS was studied from a set of 10 permanent transects established on top of two reef promontories at depths between 26 – 30 m (for location see Figure 6). Turf algae, a mixed assemblage of short red and brown macroalgae was the dominant sessile-benthic category with an average reef substrate cover of 27.6% (range: 12.4 – 47.6%). Turf algae were observed growing as a carpet over hard abiotic substrates at the reef top habitat. encrusting fan-leaf algae, *Lobophora variegata* was the most prominent species of benthic macroalgae at the reef top of BDS. It was present in all ten transects surveyed with a mean cover of 22.1% (range: 17.6 – 28.8%). *Lobophora* was observed growing in large patches over hard substrates, sometimes intermixed with turf algae. Tufts of calcareous algae, including *Halimeda sp*. and encrusting coralline red macroalgae were present in eight out of the ten transects surveyed at the reef top with a mean cover of 2.3%. *Halimeda sp*. was observed in substrate depressions and at the base of coral heads. The leafy flat blade alga, *Stypopodium zonale* (Phaeophyta), the Y-twig alga, *Amphiroa sp.* (Rhodophyta) and a red coralline encrusting alga were also common. The total reef substrate cover by the combined assemblage of benthic algae at the reef top of BDS was 52.0% (Table 6). Views of the reef top at BDS habitat and associated sessile-benthic communities are shown in Appendix 1.

Sponges, represented within transects by at least 12 species were the dominant sessile-benthic invertebrate in terms of reef substrate cover at the reef top of BDS with a mean of 26.5% (range: 17.2 – 40.4%). Rope sponges (*Agelas clathrodes, A. dispar* and *A. conifera*) and the basket sponge (*Xestospongia muta*) were the most abundant within transects among identified species. Basket sponges were observed to reach a very large size, acting as an important protective microhabitat for several species of invertebrates and fishes. Spiny lobsters (*Panulirus argus*) and red hind groupers (*Epinephelus guttatus*) were observed inside sponges during our survey of the reef top.

Table 6. Percent substrate cover by sessile-benthic categories at Bajo de Sico, Reef Top habitat. Depth: 26 – 30 m

	TRANSECTS										
SUBSTRATE CATEGORY	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**MEAN**
Abiotic	0.4	0.4	0.0	0.4	0.0	0.4	3.6	0.8	0.8	4.4	**1.1**
Unidentified	0.0	0.4	0.4	0.8	1.4	5.2	10.0	7.2	2.4	1.6	**2.9**
Benthic algae											
Algal Turf - mixed assemblage	39.0	41.4	47.6	23.6	25.6	12.4	14.8	14.8	29.2	27.6	**27.6**
Lobophora variegata	24.4	18.8	17.6	20.0	27.2	24.4	15.2	19.6	25.2	28.8	**22.1**
Calcareous/Coralline algae	3.6	3.6	5.2	0.8	4.0	0.0	0.0	2.8	2.0	0.8	**2.3**
Total Benthic Algae	67.0	63.8	70.4	44.4	56.8	36.8	30.0	37.2	56.4	57.2	**52.0**
Hydrozoa											
Plumaria (habereri)	0.2	0.8	0	0	0	0.4	0.8	0.8	3.2	2.0	**0.8**
Millepora alcicornis	0.4	4.4	0.8	12.8	2.0	0	0	0	0	0	**1.7**
Total Hydrozoa	0.6	5.2	0.8	12.8	2.0	0.4	0.8	0.8	3.2	2.0	**2.9**
Octocorals											
Iciligorgia schrammi	0	0	0	0	0	0	0	6.0	0	0	**0.6**
Pseudopterogorgia sp.	4.0	6.4	4.4	4.0	8.8	2.8	2.8	0.4	1.2	0	**3.2**
Total Octocorals	4.0	6.4	4.4	4.0	8.8	2.8	2.8	6.4	1.2	0.0	**4.8**
Scleractinian Corals											
Agaricia spp.	0.0	0.8	0.0	0.0	0.0	6.4	6.4	5.6	3.6	1.2	**2.4**
Porites astreoides	0.4	1.6	2.8	0.4	0.4	0.8	1.6	2.8	1.2	0.8	**1.3**
Montastraea cavernosa	0	0	0.4	0.0	0.0	0.8	0.8	1.2	3.2	4.8	**1.1**
Meandrina meandrites	4.4	0	0.0	0.4	0.0	1.2	0.0	1.2	2.0	1.6	**1.1**
Tubastrea coccinea	0	0	0.0	1.2	0.4	2.4	0.4	2.8	0.4	0.0	**0.8**
Eusmilia fastigiata	0.4	0	0.0	0.0	0.0	0.8	0.4	0.0	0.8	0.4	**0.3**
Madracis decactis	0	0	0	0	0	0.8	0.8	0.4	0.0	0.0	**0.2**
Montastraea annularis	0	0	0	0	0	0.0	1.6	0.0	0.0	0.0	**0.2**
Siderastrea siderea	0	0	0	0	0	0.0	0.0	0.0	1.2	0.4	**0.2**
Unid. coral	0.8	0.4	0.0	0.0	0.0	0.o	0.0	0.0	0.0	0.0	**0.1**
Colpophyllia natans	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.4	0.0	0.0	**0.1**
Diploria sp.	0	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	**0.1**
Isophyllia rigida	0	0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	**0.1**
Total Stony Corals	6.4	7.2	4.0	16.4	2.8	14.0	12.8	14.8	12.4	9.2	**8.0**
Sponges											
unidentified sponges	5.6	12.0	5.2	8.8	14.8	14.4	12.4	11.2	7.2	7.6	**8.9**
Agelas clathrodes	0	0	0	0	0	9.6	7.2	4.4	4.0	5.2	**3.4**
Xestospongia muta	10.0	0.8	4.4	6.0	4.0	4.4	5.2	2.8	8	4	**5.0**
Agelas dispar	0	2.0	4.0	4.0	4.4	4.0	3.2	2.8	0.8	6.0	**3.1**
Agelas conifera	0	0	0	0	0	1.2	7.6	6.0	0.4	0.8	**1.6**
Verongula gigantea	0	0	3.6	1.2	4.0	0	0	0	0	0	**0.9**
Plakortis angulospiculatus	2.4	0	0	1.2	0	6.0	2.4	3.6	0.8	0.0	**1.6**
A. crassa	0.8	0.4	0	0	0.4	0	0	0	0	0	**0.2**
Callyspongia vaginalis	0.4	1.2	0.4	0	0	0	0	0	0	0	**0.2**
Ircinia sp.	2.8	0.4	2.4	0.8	0.4	0.4	0.8	0.8	0.4	1.2	**1.0**
Neofibularia nolitangere	0	0	0	0	0	0.0	0.0	0.0	1.6	1.2	**0.3**
Aplysina cauliformis	0	0	0	0	0	0.4	0.0	0.0	0.4	0.0	**0.1**
Verongula rigida	0	0	0	0	1.6	0.0	0.0	0.8	0.0	0.0	**0.2**
Total Sponges	22.0	17.2	20.0	22.0	29.6	40.4	38.8	32.4	23.6	26.0	**26.5**

These organisms seem to use the sponge “basket” as a protective hideout from the strong currents that prevail at the reef top.

An assemblage of 13 species of scleractinian corals combined for a mean reef substrate cover of 8.0% (range: 2.8 – 16.4%) within transects at the reef top of BDS. Lettuce corals, *Agaricia spp*., mostly the *lamarki/grahame* species combination were the numerically dominant taxa in terms of substrate cover with a mean of 2.4%. Mustard hill coral, *Porites astreoides* ranked second in terms of reef substrate cover with only 1.3%, but was present in all transects surveyed. Great star coral, *Montastraea cavernosa*, maze coral, *Meandrina meandrites*, and the ahermatypic orange cup coral, *Tubastrea coccinea* were present in six out of the 10 transects surveyed, but with very low substrate cover (< 1.2%). The *Agaricia spp*. combination, orange cup coral, mustard hill coral and great star coral were the dominant scleractinian coral taxa in terms of density of colonies within photo-transects (Table 7). Their combined density represented 84.3% of the total coral colonies. The *Agaricia spp*. combination, with an average of 75.8 col/10 m^2 was the dominant taxa. A total of nine species of scleractinian corals were present in all five transects surveyed for coral density determinations.

Table 7. Density of scleractinian coral colonies at the reef top habitat of Bajo de Sico, Depth: 26 – 30 meters (photo transects 6 – 10).

	TRANSECTS					
CORAL SPECIES	**6**	**7**	**8**	**9**	**10**	**MEAN**
Agaricia spp.	95	81	101	59	43	**75.8**
Tubastrea coccinea	75	29	80	24	7	**43.0**
Porites astreoides	28	29	46	9	17	**25.8**
Montastrea cavernosa	15	18	21	31	32	**23.4**
Eusmilia fastigiata	6	6	3	23	3	**8.2**
Madracis decactis	15	14	6	1	2	**7.6**
Meandrina meandrites	2	3	4	7	9	**5.0**
Siderastrea siderea	0	2	1	3	8	**2.8**
Isophyllia rigida	5	4	1	1	1	**2.4**
Montastraea annularis	1	2	3	1	5	**2.4**
Diploria sp.	4	0	0	1	1	**1.2**
Colpophyllia natans	0	2	2	0	0	**0.8**
Isophyllia sinuosa	2	0	1	0	0	**0.6**
Mycetophyllia aliciae	1	0	0	0	0	**0.2**
TOTALS	249	190	269	160	128	**199.2**

In general, scleractinian corals were mostly present as a species rich assemblage of small isolated encrusting colonies not forming massive buildups at the reef top of BDS. Even species that commonly form massive structures, such as *Montastraea cavernosa, M. annularis* and *Colpophyllia natans* were present as rather small, low relief colonies. The relatively low substrate cover of boulder star coral, *M. annularis* from the reef top at BDS is in sharp contrast with previous observations of reef community structure at similar depths (Garcia-Sais et al., 2005), where this species complex generally represents one of the dominant taxa. For example, in the west coast of Puerto Rico, *M. annularis* complex was the dominant species at Isla Desecheo in two reefs studied within the 25 – 30 m depth range (García-Sais et al., 2005), and also at Tourmaline Reef in the shelf-edge off Mayagüez Bay (García-Sais et al., 2007). At Puerto Canoas (Isla Desecheo), *M. annularis* complex averaged a reef substrate cover of 16.0%, representing 54% of the total substrate cover by scleractinian corals within the 25-30 m depth (García-Sais et al., 2007). Also from Isla Desecheo, in the SW Wall Reef, the *M. annularis* complex presented the highest cover (tied with *M. cavernosa*) among scleractinian corals at a depth of 30 m (García-Sais et al., 2005).

Recent observations of substrate cover from reefs on the east coast of PR and the USVI within the 25 - 30 m depth range highlight the fact that *Montastraea annularis* complex is the main reef builder and predominant scleractinian coral in terms of reef substrate cover. This includes reports of Black Jack Reef, on the south coast of Vieques by García-Sais et al. (2004) where *M. annularis* complex accounted for 76% of the total cover by live coral at depths between 36 – 40 m. At the MCD Reef system south of St. Thomas, USVI, Armstrong et al. (2006) estimated maximum cover by *M. annularis* as of approximately 70% at depths of 38 – 40 m. Likewise, Menza et al. (2007) identified a flattened growth form of *M. annularis* complex as the dominant coral structuring the MSR-1 Reef, located off the south coast of St. John, USVI.

The limited development of *Montastraea annularis* complex at the reef top of BDS may be related to a combination of factors, such as the prevailing heavy surge associated with wave action and currents and/or the competition for space from other sessile-benthic components that appear to have more favorable growth conditions, such as benthic algae, sponges and/or lettuce corals. We suggest that the lack of larval availability would not be expected to be a limiting factor because small colonies of *M.*

annularis are present throughout the reef top at BDS. A few relatively large flattened colonies of *M. annularis* were observed at the reef top promontories during reconnaissance dives for benthic habitat mapping. But over large (habitat) spatial scales, the pattern was of prevalence of the small encrusting coral colonies and relatively low incidence of the large colonies of boulder star coral and other massive coral species.

During November 2005, a massive coral bleaching was observed at the reef top of BDS (Plate 1). The coral bleaching event preceded our quantitative observations of percent reef substrate cover by live corals and other sessile-benthic biota at the reef top. Thus, it is uncertain if the estimates of live coral cover presented in this report reflect a significant mortality impact associated with the massive bleaching event. Nevertheless, recently dead coral colonies were not evident during our quantitative assessment of the reef top habitat at BDS-1. Qualitative field observations of bleached coral species included boulder star and great star corals (*Montastraea annularis* complex; *M. cavernosa*), mustard-hill coral (*Porites astreoides*), lettuce coral (*Agaricia spp*), maze coral (*Meandrina meandrites*), and fire corals (*Millepora spp.*). Bleached corals were observed down to a maximum depth of 42.5 m.

Soft corals (gorgonians), were represented by only two species at the reef top with a combined cover of 4.8%, but the sea whip, *Pseudopterogorgia* sp. was common at the reef top with colonies in all of the 10 transects surveyed. The deepwater fan, *Iciligorgia schrammi* was only present in one transect. The latter was observed to attain a fairly large size (height up to a meter), whereas colonies of *Pseudopterogorgia* sp. were generally small (up to 30-40 cm. *Plumaria (haberi)*, a vertically projected colonial hydrozoan growing as a small (up to 30 cm), black shrub was ubiquitous over the reef top, contributing an average of 1.4% to the reef substrate cover. An unidentified colonial hydrozoan was observed growing (encrusted) over standing dead black coral colonies (dead *Antipathes caribbeana*). Antipatharians (black corals) were present at the reef top, but were not abundant. One colony of the bushy black coral, *A. caribbeana* (Opresco) was observed within transects at the reef top.

The substrate at the reef top was mostly consolidated, without sand pockets and/or other unconsolidated sediments. The abiotic categories averaging less than 1.5% within transects surveyed were associated with holes and gaps in the rock promontories.

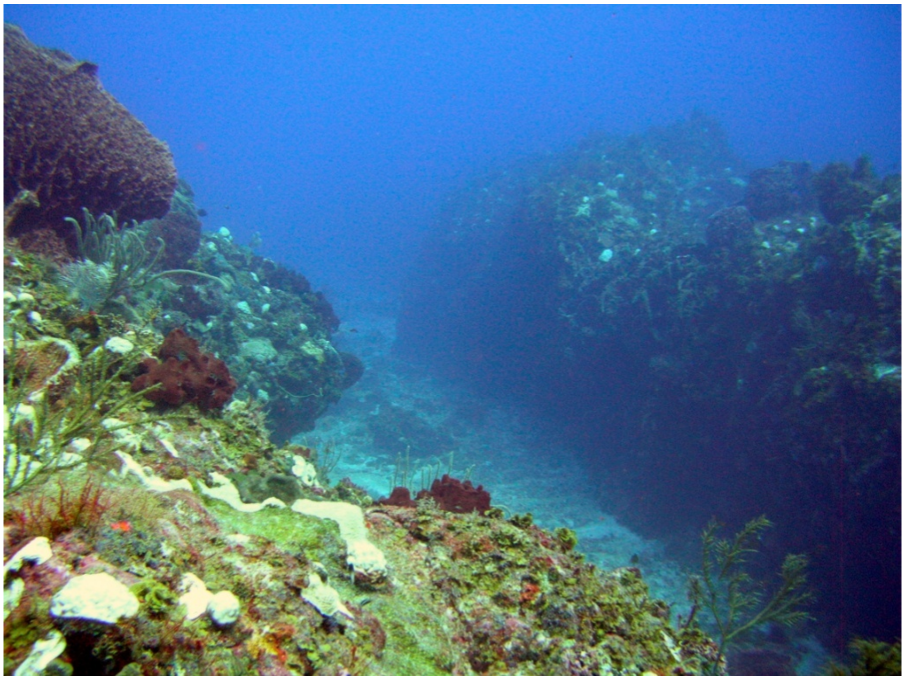

Plate 1. Reef promontories at BDS. Note the prevalence of small encrusting coral colonies bleached during November, 2005.

4.1.2 Reef Wall

Most reef promontories at BDS end laterally with abrupt slopes that create almost vertical walls down to the base of the reef, a sandy channel with scattered rocks and rubble (Plate 1). Reef walls are typically irregular formations that appear to have been influenced by erosional processes, with deep crevices, undercuts, gaps, ledges and other substrate discontinuities (Plate 2). The depth range of the wall habitat associated with reef promontories was typically found between 30 – 45 m. Reef walls that slope down vertically from the reef top promontories to more than 200 m depths are found in the southwest section of BDS. Deep wall habitats are also associated with the edge of the reef at depths from approximately 90 – 300 m (see Figures 6-7). Our survey of the reef wall habitat was performed at depths between 30 – 40 m at the benchmark station BDS-1. A total of 10 line transects were surveyed from three sites within BDS-1 (for location see Figure 7). Panoramic views of the reef wall habitat are presented as Appendix 2.

Plate 2. Reef wall habitat at BDS showing irregular formations with deep crevices, undercuts and other substrate discontinuities.

Sponges were the dominant sessile-benthic category at the reef wall habitat in terms of substrate cover with a mean of 43.1% (range: 22.4 – 64.4%). At least 11 species were present within surveyed transects (Table 8). *Agelas conifera, Plakortis angulospiculatus, A. clathrodes, A. dispar,* and *Xestospongia muta* combined for a mean reef substrate cover of 19.9%, representing the main assemblage of sponges at the reef wall. All these sponges presented erect and/or branching growth forms, typically reaching large sizes. Their structure contributed significantly to the reef topographic relief and represented an important protective habitat for fishes and invertebrates (Plate 3). Sclerosponges (possibly *Ceratoporella nicholsoni*) were commonly found growing as spherical colonies underneath ledges, and on the wall and ceiling of deep crevices. Sclerosponges were also observed growing as encrusting colonies in exposed sections of the wall habitat. Sponges are the main food source of the hawksbill turtle, *Eretmochelys imbricata* (Diez, 2002, León and Bjorndal, 2002) and may explain the exceptionally large adult population of these turtles at BDS. Branching sponges at the wall were observed to function as a recruitment habitat for several species of reef fishes, such as the blue and sunshine chromis, *Chromis cyanea* and *C. insolata*. They are also the main food source of angelfishes (*Holacanthus ciliaris, H. tricolor, Pomacanthus spp*) (Randall, 1967).

Table 8. Percent substrate cover by sessile-benthic categories at station BDS-1. Bajo de Sico. Reef Wall 30 - 40 m

	TRANSECTS										
SUBSTRATE CATEGORY	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**MEAN**
Abiotic	4.0	4.0	6.8	4.0	7.6	0.0	2.8	2.8	5.6	4.0	**4.16**
Benthic algae											
Turf-mixed assemblage	2.8	5.2	6	8.8	8	5.2	13.2	6	6.8	13.5	**7.55**
Lobophora variegata	30.8	33.6	26.4	7.6	4.8	3.2	20	19.6	18	15	**17.9**
Halimeda spp.	0	0	0	0.4	0	0.8	0	0.4	0	0	**0.16**
Total Benthic Algae	33.6	38.8	32.4	17	13	9.2	33.2	26	24.8	28.5	**25.61**
Hydrozoa											
Unid. colonial hydrozoan	0	1.2	1.2	3.2	3.2	11.2	1.2	0.4	0	0	**2.16**
Millepora alcicornis	0	0	0	0	0	0	0	0.8	0	0	**0.08**
Antipatharians	1.2	3.2	2.0	20.0	0	0	0	1.2	1.6	1.0	**3.02**
Octocorals											
Iciligorgia schrammi	14	6.4	0	8.8	9.2	5.2	4.8	32.0	30.0	15.0	**12.54**
Pseudopterogorgia sp.	0	0	1.2	0	0	0	0.4	0.8	0	0.5	**0.29**
Unid. Gorgonian	0.8	0.4	1.6	1.6	1.2	0	0.8	0	0	0.5	**0.69**
Total Octocorals	14.8	6.8	2.8	10	10	5.2	6	32.8	30	16	**13.52**
Scleractinian Corals											
Montastrea cavernosa	0	2.4	3.2	0.8	0	0	3.2	1.6	0.8	5	**1.7**
Agaricia spp.	2	2.8	0.4	2	0.8	0.4	3.2	0.8	2.4	0	**1.48**
Tubastrea coccinea	0.8	1.2	0	1.2	0	0	1.2	3.2	1.2	1.5	**1.03**
Porites astreoides	0.8	1.6	0.4	0	0	0	0.4	0	0.4	0	**0.36**
Montastrea annularis	0	1.2	0	0	0	0	0	0.4	0	0.5	**0.21**
Madracis decactis	0	0.8	0	0	0	0	0	1.2	0	0	**0.2**
Diploria labyrinthiformis	0	2	0	0	0	0	0	0	0	0	**0.2**
Leptoseris cucullata	0	0.4	0.8	0	0	0	0	0	0	0	**0.12**
Meandrina meandrites	0	1.2	0	0	0	0	0	0	0	0	**0.12**
Eusmilia fastigiata	0	0	0	0	0	0		0.8	0	0	**0.08**
Siderastrea siderea	0	0	0	0	0	0	0.4	0	0	0	**0.04**
Total Scleractinian Corals	3.6	13.6	4.8	4	0.8	0.4	8.4	8	4.8	7	**5.54**
Sponges											
unidentified sponges	10	5.2	20.4	22	38	37.2	17.2	16.4	15.2	26.5	**20.81**
Agelas conifera	15.6	6.8	9.6	12	9.6	2.4	4	7.2	6.8	9	**8.3**
Plakortis angulospiculatus	8.4	6.4	14.8	2.4	6.4	6.8	5.6	1.2	1.6	3.5	**5.71**
Agelas clathrodes	0.4	1.6	1.6	2.8	4.4	2.4	5.2	1.6	2	2	**2.4**
Agelas dispar	0.8	1.2	0.4	1.6	4.8	3.6	4.4	0.8	0.4	1	**1.9**
Xestospongia muta	0	0	0	0	0	2.4	9.2	0	4.8	0	**1.64**
Callyspongia fallax	0.4	0.4	0	0	1.2	2.8	0	0	1.6	1	**0.74**
Ircinia sp.	0.8	0.8	0.8	0.8	0.4	2.4	1.6	0.4	0.4	0	**0.84**
Callyspongia plicifera	0.8	0	0.4	0	0	1.6	0	0	0.4	0.5	**0.37**
Callyspongia vaginalis	0.8	0	0	0	0	0	0.8	0	0	0	**0.16**
Aplysina cauliformis	0	0	0	0	0	0	0	0	0.4	0	**0.04**
Svenzea zeai	0	0	2	0	0	0	0	0	0	0	**0.2**
Total Sponges	38	22.4	50	42	64	61.6	48	27.6	33.6	43.5	**43.11**

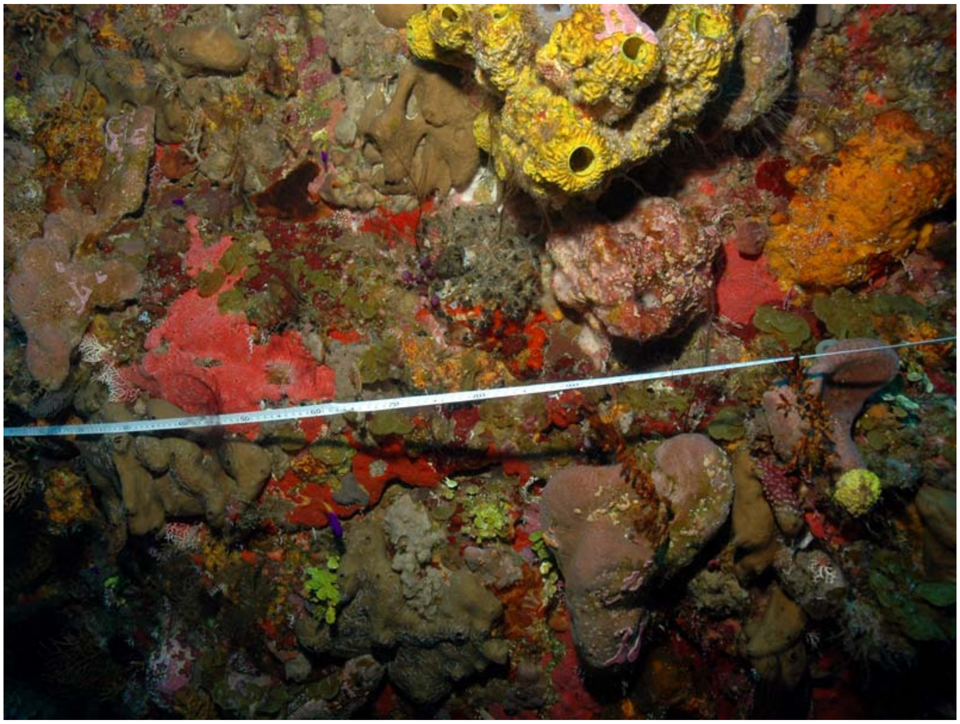

Plate 3. Sponge dominated reef wall habitat

Benthic algae, comprised mostly by the encrusting fan-leaf algae, *Lobophora variegata* (mean cover: 17.9%) and to a lesser extent by turf (mean cover: 7.6%) and calcareous macroalgae (mean cover: 0.2%) ranked second in terms of reef substrate cover at the wall habitat with a combined mean of 25.6% (range: 9.2 – 38.8%) (Table 8). The vertical inclination of the wall habitat with its undercuts, ledges and crevices tend to reduce illumination of the reef substrate, providing perhaps a competitive advantage to sponges, gorgonians and black corals that grow out of the wall towards the water column.

The deepwater fan, *Iciligorgia schrammi* was one of the most prominent features of the wall habitat sessile-benthos, with a mean reef substrate cover of 12.5% (range: 0 – 32.0%), representing more than 95% of the total cover by gorgonians (octocorals) at the wall habitat (Table 8). Substrate cover by the deepwater fan is probably underestimated by the fact that it grows perpendicular to the wall, and therefore, the angle of the photograph used for quantitative determinations of substrate cover provides only a fraction of its total surface extension. This gorgonian grows to a relatively large size (more than one meter) and generally presented aggregated (patchy) distributions in the wall (Plate 4). It is a rigid, branching skeleton and its patchy distribution creates a complex structure that adds substantial topographic relief and serves as protective micro habitat for reef organisms. In addition to the deepwater fan, the sea plume, *Pseudopterogorgia sp*., the long sea whip, *Ellisella sp*. and an unidentified bright red gorgonian were the octocoral species observed at the wall habitat.

Black corals (Antipatharians) were present in seven out of the 10 transects surveyed at the wall habitat with a mean substrate cover of 3.0% (range: 0-20%). At least five species were present within surveyed transects (Appendix 5), but the bushy black coral, *Antipathes caribbeana* was the dominant species because of its much larger size and abundance relative to other species of black corals in the wall of BDS. At present, black coral specimens are under taxonomic evaluations involving molecular analyses and the final taxonomy of the other species will be reported elsewhere. As with the deepwater fan, due to their considerably large size and branching growth, black corals create topographic relief in the reef, and thereby protective microhabitat for fishes. Black corals displayed a highly aggregated distribution, as inferred by the wide range of substrate cover in transects surveyed (Table 8). Black corals were most abundant at the southern

Plate 4. Deep sea fan, *Icilligorgia schrammi* at the reef wall habitat on BDS

walls, where they grow in patches as moderate to large colonies. The southern walls are regions that are fully exposed to the prevailing northerly directed current flow (see section 1.1). Growth of black corals may be favored by environments with strong water currents due to the advantage of increased flow for feeding upon zooplankton. As in the reef top habitat, a small (unidentified) branching colonial hydrozoan was ubiquitously distributed at the reef wall of BDS. Its mean cover within surveyed transects was 2.16% (range: 0 – 11.2%).

Scleractinian corals were represented by a total of 11 species within transects at the reef wall of BDS with a mean cover of 5.5% (range: 0.8 – 13.6%). An additional 11 scleractinian coral species were observed outside transects at the wall (Appendix 4). Great star coral, *Montastraea cavernosa* and lettuce corals, *Agaricia spp*. (mostly the *lamarki/grahame* combination) were the dominant taxa in terms of substrate cover, but with means of only 1.7% and 1.5%, respectively. As in the reef top, scleractinian corals were present mostly as a specious rich assemblage of small isolated colonies growing encrusted on the substrate without contributing significantly to the reef topographic relief. Scleractinian corals appear to be out competed for space by heterotrophic taxa, such as sponges and have the additional competition of the deepwater fan and black corals at the wall. Nevertheless, scleractinian corals contribute, along with black corals (3.0%), hydrozoans (2.2%) and octocorals (13.6%) to a combined reef substrate cover by cnidarians of almost 25% at the reef wall of BDS. The high amount of scleractinian coral species represents also an important contribution to the biodiversity of the reef.

Orange cup coral, *Tubastrea coccinea* was the most abundant scleractinian coral at the reef wall habitat, representing 53.1% of the total density of coral colonies within transects with a mean of 52.7 colonies/10m^2 (range: 3 – 139 colonies/10m^2). This is an aposymbiotic species that forms rather small hemispherical colonies attached to hard reef substrates. It was present in all seven transects analyzed for determinations of coral density at the reef wall habitat (Table 9). Lettuce corals, *Agaricia spp*., great star coral, *Montastrea cavernosa,* mustard- hill coral*, Porites astreoides* and ten-ray star coral, *Madracis decactis* combined for an additional 42% of the total density of coral colonies and comprised, along with orange cup coral, the main species assemblage of scleractinian corals in terms of coral densities at the wall.

Table 9. Density of coral colonies within photo transects 4 – 10 at the reef wall of BDS-1. Bajo de Sico. Depth 30 – 40 m.

SCLERACTINIAN CORALS	TRANSECTS							
	4	**5**	**6**	**7**	**8**	**9**	**10**	**MEAN**
Tubastrea coccinea	31	3	9	62	139	56	69	**52.7**
Agaricia spp.	19	9	7	95	29	20	11	**27.1**
Montastrea cavernosa	5	0	0	20	14	11	14	**9.1**
Porites astreoides	2	0	0	11	4	1	2	**2.9**
Madracis decactis	0	0	0	8	8	1	1	**2.6**
Siderastrea siderea	0	0	0	2	0	0	7	**1.3**
Eusmilia fastigiata	0	0	0	3	6	0	0	**1.3**
Meandrina meandrites	0	0	0	2	1	4	1	**1.1**
Montastrea annularis	0	0	0	1	3	0	1	**0.7**
Diploria labyrinthiformis	0	0	0	1	0	0	0	**0.1**
Dichocoenia stokesi	0	0	0	1	0	0	0	**0.1**
Diploria sp.	0	0	0	0	1	0	0	**0.1**
Isophyllia rigida	0	0	0	0	1	0	0	**0.1**
Totals	57	12	16	206	206	93	106	**99.4**
HYDROCORALS								
Millepora alcicornis	0	0	0	0	1	0	0	**0.1**
Stylaster roseus	11	26	94	8	4	17	12	**17.2**
OCTOCORALS								
Iciligorgia schrammi	16	16	12	13	70	72	33	**33.1**
Pseudopterogorgia sp.	4	0	0	2	5	3	3	**2.4**
Ellisella sp.	0	0	1	3	0	0	0	**0.6**
unidentified gorgonian	0	0	0	0	0	0	2	**0.3**
Totals	20	16	13	18	75	75	38	**36.4**
ANTIPATHARIANS	17	6	4	2	5	4	2	**5.7**

Among octocorals, the deepwater fan, *Iciligorgia schrammi* was present from all photo transects analyzed for densities of coral colonies with a mean of 33.1 colonies/10m^2 (range: 12- 72 colonies/10m^2). A few colonies of the long sea whip, *Ellisella sp*. and of the sea plume, *Pseudopterogorgia sp*. were present within transects surveyed at the wall. Black corals (Antipatharians), particularly the bushy black coral, *Antipathes caribbeana* were present in all seven transects with a mean density of 5.7 colonies/10m^2 (range: 2 – 17 colonies/10m^2). The rose lace coral, *Stylaster roseus* was the most abundant hydrocoral with a mean density of 17.2 colonies/10m^2. It is perhaps one of the most abundant sessile-benthic invertebrate components of the reef wall, but it's small colony size and typically cryptic growth within crevices, holes and other substrate irregularities undermines its quantitative characterization from photo images.

4.1.3 Deep Rhodolith Reef

The deep rhodolith reef was surveyed by a total of 10 transects, distributed in sets of two (replicate) transects at five different stations within the northern shelf of BDS. Location of sampling stations is shown in Figure 6. Benthic algae, comprised by an assemblage of turf, fleshy and calcareous macroalgae were the dominant component of the sessile-benthos at all transects surveyed with a mean substrate cover of 65.0% (range: 51.6 – 71.6%). Table 10 shows the percent cover by sessile-benthic categories at transects surveyed from the deep rhodolith reef. The encrusting fan-leaf alga, *Lobophora variegata* was the most prominent component of the benthic algae assemblage with a mean cover of 42.0% (range: 26.4 – 66.0%). *Lobophora* was observed growing as a carpet over extensive sections of the deep rhodolith reef. Its cover of the reef substrate was interrupted only by scattered growth of erect and branching sponges, isolated coral colonies and a few abiotic patches. *Lobophora* appears to be the main stabilizing agent of a vast deposit of mostly unconsolidated sediments, comprised by rhodoliths, coarse sand and what appear to be relict coral fragments. Small tufts of calcareous macroalgae, mostly *Halimeda spp*. were observed growing intermixed with *Lobophora*, averaging a reef substrate cover of 8.7%. An additional 37 species of benthic algae were identified from the deep rhodolith reef (Appendix 4). Panoramic views of the deep rhodolith reef are included as Appendix 3.

Sponges, represented within transects by an assemblage of at least 10 species were the main invertebrate taxa in terms of substrate cover at the deep rhodolith reef with a mean cover of 20.2% (range: 8.8 – 32.8%). Among the identified species of sponges within transects, *Aplysina cauliformis, Agelas clathrodes, A dispar* and the basket sponge, *Xestospongia muta* presented the highest mean substrate cover (Table 10). Sponges grow from an essentially flat and homogeneous seafloor at the deep rhodolith reef and thereby, are the most prominent structures providing topographic relief. The basket sponge grows attached to the hard ground reef platform, but most other sponges were observed growing from rhodoliths and/or other unidentified carbonate structures lying unattached over the seafloor.

Scleractinian corals were represented within transects by an assemblage of eight species with a mean substrate cover of 4.9% (range: 0 – 14.0 %). Reef substrate cover by scleractinian corals was below 1.5% in two out of the five sampling stations

Table 10. Percent substrate cover by sessile-benthic categories at the deep rhodolith reef. Bajo de Sico. Depth: 48 -53 m

	TRANSECTS										
SUBSTRATE CATEGORY	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**MEAN**
Abiotic	6.4	5.2	2.4	3.2	2.4	2.0	0.0	2.0	2.4	6.8	**3.28**
Unidentified	0.4	5.6	3.6	3.6	6.4	1.2	6.0	4.8	2.0	0.4	**3.4**
Benthic algae											
Turf-mixed assemblage	0.0	0.0	15.2	10.4	10.4	26.0	10.0	16.4	18.0	25.6	**13.2**
Fleshy Algae											
Lobophora variegata	66.0	52.4	49.6	46.4	34.8	38.8	38.0	37.2	30.4	26.4	**42.0**
Codium sp.	0.0	0.0	4.4	4.4	0.0	0.0	0.4	0.0	0.0	0.0	**0.9**
Sargassum histrix	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.2**
Calcareous algae											
Halimeda spp.	2.4	4.8	2.4	9.2	6.4	2.8	22.8	12.4	15.6	8.8	**8.7**
Total Benthic Algae	70.0	57.2	71.6	70.4	51.6	67.6	71.2	66.0	64.0	60.8	**65.0**
Hydrozoa	0	0	0	0	2.4	4.4	0	0	4.0	4.4	**1.9**
Live Stony Corals											
Agaricia spp.	3.6	7.6	4.8	2.8	0.8	0.4	4.8	4.4	0.0	0.4	**2.96**
Montastrea annularis	0	0	0.0	0.0	0.0	0.0	6.0	0.8	0.0	0.0	**0.68**
Porites astreoides	0.8	0	0.8	0.4	0.0	0.0	2.0	0.4	0.0	0.8	**0.52**
Leptoseris cailleti	1.6	1.2	1.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	**0.48**
Eusmilia fastigiata	0	0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.0	**0.08**
Montastrea cavernosa	0	0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	**0.04**
Meandrina meandrites	0	0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	**0.04**
Unid. coral	0.4	0	0	0	0	0	0	0	0	0	**0.04**
Colpophyllia natans	0	0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	**0.04**
Total Stony Corals	6.4	8.8	6.8	4.0	1.2	0.4	14.0	6.0	0.0	1.2	**4.88**
Sponges											
unidentified sponges	18	10	5.6	8	16.4	14.8	4.8	10.4	17.6	12.0	**11.8**
Aplysina cauliformis	nd	nd	5.6	6.4	10.8	4.0	0.0	0.0	2.0	0.8	**3.7**
Xestospongia muta	0	0	0.4	0.8	0.4	4.4	0.8	3.2	2.8	5.6	**1.8**
Agelas clathrodes	nd	nd	0	1.6	1.6	0.0	2.0	2.8	2.4	4.0	**1.8**
Agelas dispar	nd	nd	1.6	1.2	1.2	0.0	1.2	4.0	0.8	0.0	**1.3**
Aiolochroia crassa	nd	nd	0.8	0	0	0.0	0.0	0.0	0.0	2.8	**0.5**
Agelas conifera	nd	nd	0	0.4	0.8	0.4	0.0	0.0	0.0	1.6	**0.4**
Verongula gigantea	nd	nd	0	0	0	0.4	0.0	0.8	1.6	0.0	**0.4**
Plakortis angulospiculatus	nd	nd	0	0	1.2	0.0	0.0	0.0	0.0	0.0	**0.2**
Verongula rigida	nd	nd	0	0.4	0.4	0.0	0.0	0.0	0.0	0.0	**0.1**
Aplysina lacunosa	nd	nd	0	0	0	0.4	0.0	0.0	0.4	0.0	**0.1**
Total Sponges	18.0	10.0	14.0	18.8	32.8	24.4	8.8	21.2	27.6	26.8	**20.2**

surveyed, which included the sets of paired transects 5-6 and 9-10. These sets of transects correspond to the eastern and western margins of the northern shelf of BDS, and thus, may well represent the lateral boundaries of scleractinian coral development within the 50 m depth range. Bounce and drift dives performed along the eastern, western and southern shelf of BDS at depths between 40 – 50 m confirmed the virtual absence of coral development along these shelf sections, characterized by extensive coverage of benthic algae along the eastern and western shelf sections, and by vast deposit of algal rhodoliths and lightly colonized pavement throughout most of the southern shelf.

Lettuce corals, *Agaricia spp*. (mostly the *A. lamarki/grahame* combination) were the most prominent scleractinian taxa within transects surveyed at the deep rhodolith reef. The mean substrate cover of lettuce corals was 3.0% (range: 0 – 7.6%) and were present in nine out of the 10 transects surveyed (Table 10). The *A. lamarki/grahame* combination was also the dominant taxa in terms of density of colonies with a mean of 23.2 colonies/10m^2 (range: 1 – 45 colonies/10m^2). Boulder star coral, *Montastraea annularis* complex exhibited variable growth forms at the deep rhodolith reef with a mean substrate cover of 0.7% (range: 0 – 6.0%) and a mean density of 1.3 colonies/10m^2 (Table 11). Colonies of boulder star coral were present in only two of the ten transects surveyed. Flattened colonies of up to 0.5 m diameter were observed growing from a short pedestal attached to the hard ground reef platform, but encrusting growth over rhodoliths and other unidentified substrates was also observed. Mustard-hill coral, *Porites astreoides* was present in 9 out of the 10 transects surveyed with a mean substrate cover of 0.5% (Table 10), and a mean density of 5.2 colonies/10m^2 (Table 11). At the deepest transects surveyed, the lacy lettuce coral, *Leptoseris cailleti* was common, with substrate cover and densities at transects 1- 4 ranging between 0.8 – 1.6%, and 5 – 14 colonies/10m^2, respectively (Tables 10 and 11). Due to its cryptic growth intermixed with benthic algae; substrate cover by this coral was most likely underestimated. Likewise, the diffuse ivory coral, *Oculina sp*. (*vericosa*) was impossible to discern from photos due to its cryptic growth intertwined with sponges and benthic algae.

Table 11. Density of scleractinian coral colonies within photo transects at the deep rhodolith reef. Bajo de Sico. Depth: 50 m.

	TRANSECTS										
CORAL SPECIES	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**MEAN**
Agaricia spp.	14	23	45	44	3	1	34	60	4	4	**23.2**
Porites astreoides	4	0	4	3	2	0	26	11	1	1	**5.2**
Leptoseris cailleti	6	5	14	13	0	0	0	2	0	0	**4.0**
Montastrea annularis	0	0	0	0	0	0	9	4	0	0	**1.3**
Montastrea cavernosa	0	0	1	2	1	0	1	1	0	0	**0.6**
Meandrina meandrites	0	0	1	0	0	0	2	0	1	0	**0.4**
Eusmilia fastigiata	0	0	0	0	0	0	1	1	0	0	**0.2**
Unid. coral	2	0									**0.2**
Colpophyllia natans	0	0	0	0	0	0	1	0	0	0	**0.1**
Dichocoenia stokesi	0	0	0	0	0	0	1	0	0	0	**0.1**
TOTALS	**12**	**5**	**20**	**18**	**3**	**0**	**41**	**19**	**2**	**1**	**12.1**

Perhaps with the exception of boulder star coral, species comprising the main scleractinian coral assemblage at the deep rhodolith reef of BDS (*Agaricia spp, Leptoseris cailleti, Porites astreoides*) exhibited highly aggregated or patchy distributions. This may be related to physical factors influencing availability of substrates for attachment, but may also respond to limitations imposed by larval dispersion associated with sexual reproduction.

4.2 Fish and Motile Mega-benthic Invertebrate Communities

4.2.1 Reef Top

A total of 80 species of reef fishes were identified at the reef top of BDS, including 53 species within belt transects surveyed at depths between 25 – 30 m. Mean abundance within belt-transects was 247.7 Ind/30m^2 (range: 128 – 362 Ind/30m^2). The mean number of species within transects was 19.8 (range: 17 – 25). The combined abundance of three species, bicolor damselfish (*Stegastes partitus*), bluehead wrasse (*Thalassoma bifasciatum*) and brown chromis (*Chromis multilineata*) accounted for 83.1 % of the total fish abundance within transects (Table 12). The aforementioned species and two additional species, the coney (*Cephalopholis fulva*) and the squirrelfish (*Holocentrus rufus*) were the only fishes present in all ten transects surveyed.

Table 12. Taxonomic composition and abundance of fishes within belt-transects at Bajo de Sico (BDS). 2005-07. reef top: 25 - 30 m

BELT – TRANSECTS (Area: 30 m^2)

SPECIES	COMMON NAME	**T-1**	**T-2**	**T-3**	**T-4**	**T-5**	**T-6**	**T-7**	**T-8**	**T-9**	**T-10**	**MEAN**
Stegastes partitus	bicolor damselfish	132	171	73	91	80	130	126	42	152	202	**119.9**
Thalassoma bifasciatum	bluehead wrasse	57	79	80	35	16	28	17	15	45	73	**44.5**
Chromis multilineata	brown chromis	17	66	45	3	1	115	130	35	2	3	**41.7**
Cephalopholis fulva	coney	3	5	6	1	5	4	2	2	5	4	**3.7**
Paranthias furcifer	creole fish				3	2	2		26		1	**3.4**
Amblycirrhitus pinos	red-spotted hawkfish	3	3	4		2	8	5	3	1		**2.9**
Clepticus parrae	creole wrasse	3	6	18		1						**2.8**
Halichoeres maculipinna	clown wrasse	3	3	6		1				4	8	**2.5**
Holocentrus rufus	squirrelfish	4	1	5	4	1	2	3	2	1	2	**2.5**
Chromis cyanea	blue chromis	4					3	7	3	3	4	**2.4**
Scarus iserti	stripped parrotfish	1	6	4	2	1			1	6		**2.1**
Melichthys niger	black durgon	2	3	1	1	2		1	6	1		**1.7**
Halichoeres garnoti	yellowhead wrasse	5	3	1	1	2			1	3		**1.6**
Acanthurus chirurgus	doctorfish	1	4	3	1		1	1		1	2	**1.4**
Caranx crysos	blue runner				10	4						**1.4**
Bodianus rufus	spanish hogfish	1		3	2	2	1	1		1	1	**1.2**
Acanthurus coeruleus	blue tang	1	1	2	2	1	1	1	1	1		**1.1**
Sparisoma radians	bucktooth parrotfish		1			1	2	3	2	1	1	**1.1**
Chaetodon capistratus	four-eye butterflyfish		2	2	2				1	2		**0.9**
Cephalopholis cruentatus	graysbe	1	4					2	1			**0.8**
Gramma loreto	fairy basslet						4	3				**0.7**
Scarus taeniopterus	princess parrotfish								7			**0.7**
Acanthurus bahianus	ocean surgeon	1		1	1	3						**0.6**
Caranx ruber	bar jack	4		1	1							**0.6**
Chaetodon striatus	banded butterflyfish	2						2	1			**0.5**
Sparisoma viride	stoplight parrotfish		1				3	1				**0.5**
Canthigaster rostrata	caribbean puffer	2				1			1			**0.4**
Epinephelus guttatus	red hind					2	1				1	**0.4**
Coryphopterus lipernes	peppermint goby								3			**0.3**
Elagatis bipinnulata	rainbow runner				3							**0.3**
Holacanthus tricolor	rock beauty						1		1		1	**0.3**
Sparisoma aurofrenatum	parrotfish	1		1					1			**0.3**
Cantherhines pullus	tail-light filefish		1						1			**0.2**
Gobiosoma evelynae	sharknose goby		1								1	**0.2**
Holacanthus ciliaris	queen angelfish	1					1					**0.2**
Microspathodon chrysurus	yellowtail damselfish					1	1					**0.2**
Pomacanthus paru	french angelfish										2	**0.2**
Scarus vetula	queen parrotfish	1		1								**0.2**

Table 12. Continued

Anisotremus surinamensis	black margate									1		**0.1**
Anisotremus virginicus	porkfish						1					**0.1**
Caranx lugubris	black jack								1			**0.1**
Centropyge argi	cherubfish		1									**0.1**
Chaetodon ocellatus	spotfin butterflyfish	1										**0.1**
Coryphopterus glaucofraenum	bridled goby										1	**0.1**
Sparisoma atomarium	greenblotch parrotfish								1			**0.1**
Halichoeres cyanocephalus	wrasse									1		**0.1**
Holocentrus coruscus	reef squirrelfish								1			**0.1**
Sparisoma chrysargyreum	redtail parrotfish										1	**0.1**
Serranus baldwini	lantern bass							1				**0.1**
Sphyraena barracuda	great barracuda										1	**0.1**
Halichoeres radiatus	puddinwife			1								**0.1**
Scomberomorus regalis	cero mackerel										1	**0.1**
	TOTAL SPECIES	**24**	**20**	**20**	**17**	**19**	**19**	**17**	**25**	**18**	**19**	**19.8**
	TOTAL INDIVIDUALS	**251**	**362**	**258**	**163**	**129**	**309**	**306**	**159**	**231**	**310**	**247.8**

The bicolor damselfish was numerically dominant at the reef top with a mean abundance of 119.9 Ind/30 m^2 (range: 42 – 202 Ind/30m^2), representing 48.4% of the total fish abundance. Its abundance variance to mean ratio (e.g. 48.7) (Table 13) reflects a moderately aggregated spatial distribution. The coefficient of variation between transects for the bicolor damselfish was the lowest among the top 10 most abundant fishes (40.6%), indicative of low abundance variability between transects in relation to its (high) mean abundance. It was the most abundant fish in eight out of the ten transects surveyed. The squirrelfish and the coney presented the lowest abundance variance to mean ratios among the top ten most abundant fishes, indicative of near random spatial distributions at the reef top. Relative to their mean abundance within transects, their coefficient of variation was moderately low as well. Three fishes that were present in at least eight out of the ten transects (e.g. spanish hogfish, blue tang, and doctorfish) presented abundance variance to mean ratios below 1, indicative of spatially uniform distributions. Schooling fishes that live closely associated to the reef benthos, such as the creole wrasse (*Clepticus parrae*), creole fish (*Paranthias furcifer*), brown and blue chromis (*Chromis multilineata, C. cyanea*) presented both a high abundance coefficient of variation and high variance to mean ratios, indicative of highly aggregated or patchy spatial distributions.

Table 13. Descriptive statistics of fish abundance for the numerically dominant species within belt-transects at the reef top. Bajo de Sico (BDS). Depth: 25 - 30 m

Species	**Common Name**	**Mean**	**StDev**	**Var**	**Var/X**	**Coeff. Variation %**
Stegastes partitus	Bicolor Damselfish	119.9	48.7	2373.7	48.7	40.6
Thalassoma bifasciatum	Bluehead Wrasse	44.5	26.3	691.2	26.3	59.1
Chromis multilineata	Brown Chromis	41.6	48.5	2351.7	48.5	116.6
Cephalopholis fulva	Coney	3.7	1.6	2.7	1.6	44.2
Paranthias furcifer	Creole Fish	3.4	8.0	64.3	8.0	235.8
Clepticus parrae	Creole Wrasse	2.8	5.7	32.4	5.7	203.3
Halichoeres maculipinna	Clown Wrasse	2.5	2.8	8.1	2.8	113.5
Holocentrus rufus	Squirrelfish	2.5	1.4	2.1	1.4	57.3
Chromis cyanea	Blue Chromis	2.4	2.4	5.6	2.4	98.6
Scarus iserti	Stripped Parrotfish	2.1	2.4	5.7	2.4	113.2

The reef promontories at BDS, including the reef top and reef wall appear to function as one large residential and foraging habitat for a varied assemblage of top reef demersal predators, such as the Nassau, black, yellowmouth and yellowfin groupers (*Epinephelus striatus, Mycteroperca bonaci, M. interstitialis, M. venenosa*) and the cubera and dog snappers (*Lutjanus cyanopterus, L. jocu*). These species, all of which are of high commercial value, were observed mostly in their upper range of adult sizes (Table 14). Juvenile stages were not observed for any of the aforementioned species. Nassau groupers were generally observed inside hideouts near the top of the promontories, whereas yellowfin, black and yellowmouth groupers were typically observed swimming at or near the base of the promontory and along the sand channels in the deeper sections of the reef.

Table 14 includes standing stock estimates for large, commercially important reef fishes based on the number of individuals observed during Active Search (ASEC) surveys at station BDS-1. These numbers are only from fishes observed during daytime surveys, and because of bottom time limitations and the highly complex habitat of reef promontories at BDS-1 a comprehensive, all inclusive scan of the study area was not achieved. Therefore, the numbers of individuals reported in Table 14 represent a conservative, minimum estimate of the stocks from an area of approximately 1 acre (0.004 km^2) comprised within the geographic boundaries of station BDS-1. The surface area of station BDS-1 (0.004 km^2) represents approximately 1 % of the total surface area of reef promontory habitat at BDS (e.g. 0.4 km^2). During our benthic habitat mapping effort, many of the commercially important fish species reported in Table 14 were also observed in reef promontories outside BDS-1, suggesting that despite the inherent variability in depth and size dimensions of reef promontories, these reef structures appear to function as a cohesive and continuous residential and foraging habitat for commercially exploited large demersal and pelagic fishes, lobsters and sea turtles at BDS.

Intermediate sized demersal predators at the reef promontories include the red hind (*E. guttatus*), the schoolmaster and yellowtail snappers (*L. apodus, Ocyurus chrysurus*) and the queen triggerfish (*Balistes vetula*). These were also present as adults, including very large individuals, particularly red hinds (Table 14). Schoolmaster snappers were always observed as one very large school of approximately 50 individuals in the face of a wall at BDS-1. Red hinds were observed in relatively low numbers (7), considering that BDS is a known spawning aggregation site for this species. Most of the red hinds were observed in the promontories during the surveys of August through October. Red Hinds spawn at BDS during late December through January, but it was not possible to survey the reef promontories of BDS during the winter season because of rough sea conditions. Thus, from our observations at BDS-1 and other reef promontory sites surveyed during benthic habitat mapping activities, it was perceived that the reef promontories are not the main residential habitat for red hinds at BDS. Red hinds may be undertaking a migration from unidentified habitats within or outside BDS, and gradually build-up a spawning aggregation at the shallow reef promontories during the winter. Red hinds were observed in much higher densities at the deep rhodolith reef habitat of BDS surveyed down to a maximum depth of 53 m. It is unknown if red hinds inhabit the entire deep shelf platform down to depths of 100 m or more down the reef slope, but anecdotal information from local fishermen suggests that they are distributed at least to the 90 m range of the shelf at BDS.

Table 14. Size-frequency distribution of large and/or commercially important reef fishes identified during ASEC surveys at Bajo de Sico, BDS - 1

Depth : 25 - 40 m

SPECIES	**COMMON NAME**	**Numbers -Total Length (Inches)**			**Total Stock**
Acanthocybium solanderi	wahoo	1-60	3 (60-90)		4
Balistes vetula	queen triggerfish	1-12	2-15	1-18	4
Caranx crysos	blue runner	3-12	2-16	1-20	6
Caranx latus	horse-eye jack	25-15	7-20		32
Caranx lugubris	black jack	3-16	1-20	3-(24-30)	7
Carcharhinus perezii	reef shark	1-36	1-42	1-50	3
Dasyatis americana	southern stingray	1-32	1-56		2
Elagatis bipinnulata	rainbow runner	10-20	12-30		32
Epinephelus guttatus	red hind	2-12	3-15	2 - 18	7
Epinephelus striatus	Nassau grouper	3-20	4-26	5-(30-32)	12
Euthynnus alletteratus	little tuna	n/d			
Lutjanus apodus	schoolmaster	50-(15-20)			50
Lutjanus cyanopterus	cubera snapper	1-28	1-32	1-36	3
Lutjanus jocu	dog snapper	1-15	1-20		2
Lutjanus mahogany	mahogani snapper	1			1
Mycteroperca bonaci	black grouper	3–(28–32)			3
Mycteroperca interstitialis	yellowmouth grouper	1-22	1-28		2
Mycteroperca venenosa	yellowfin grouper	2-20	3-24	2-30	7
Ocyurus chrysurus	yellowtail snapper	30-15	15-18	5-20	50
Scarus guacamaia	rainbow parrotfish	1-32			1
Scomberomorus cavalla	great mackerel	2-34			2
Scomberomorus regalis	cero mackerel	1-18	1-28	1-34	3
Sphyraena barracuda	great barracuda	1-24	1-28	1-32	3
Invertebrates					
Panulirus argus	spiny lobster	3- (4-5 lb)			3
Strombus gigas	queen conch	1-14			1
Mithrax spinosissimus	channel clinging crab				
Sea Turtles					
Chelonia midas	green sea turtle			1-36	1
Eretmochelys imbricata	hawksbill turtle	5-(26-30)	2-30	2-36	9

Others
Thunnus albacores, Amblycirrhitus pinos, Pomacanthus arcuatus, Pomacanthus paru, Mulloides martinicus, Kyphosus bermudensis, Cantherhines macrocerus, Hemiramphus brasiliensis, Decapterus macarellus, Ablennes hians,Tylosurus crocodilus, Chaetodipterus faber, Canthidermis sufflamen, Xanthichthys ringens, Chaetodon aculeatus, Anisotremus surinamensis, Gymnothorax funebris, Coryphaena hippurus, Caranx bartholomaei

Pelagic reef predators are abundant in the water column above the reef promontories at BDS. Schools of horse-eye, black jacks and blue runners (*Caranx latus, C. lugubris, Carangoides crysos*) remain throughout the year at BDS, were they are the most prominent assemblage because of their high abundance. Large schools of more than 20 individuals of rainbow runners (*Elagatis bipinnulata*) were observed during late summer and fall (August – October), which coincided with the visit of Wahoo (*Acanthocybium solanderi*) and dolphinfish (*Coryphaena hippurus*). At least three reef sharks (*Carcharhinus perezii*) are year-round residents of the reef promontories at BDS-1, since they were observed throughout our field survey at this station. No other sharks were observed during our field survey. Great barracudas (*Sphyraena barracuda*) were common throughout the year over the reef. Large schools of little tunny and blackfin tuna (*Euthynnus alletteratus, Thunnus albacores*) were observed during the summer (June - August) feeding close to the surface in the periphery of BDS-1. Great and cero mackerels (*Scomberomorus cavalla, S. regalis*) were also observed during the summer at BDS, although cero mackerel were present throughout the year. Ocean triggerfish (*Canthidermis sufflamen*) and black durgon (*Melichthys niger*) both maintained large year-round populations associated with the reef promontories at BDS-1. The ocean triggerfish typically occupied the upper water column, whereas black durgons were generally observed closer to the reef. Billfishes are commonly fished over the reef at BDS, but none were observed during our field survey.

A varied assemblage of schooling zooplanktivorous fishes serves as forage for the rich and abundant community of piscivorous fish populations at the reef promontories of BDS. Mackerel scad (*Decapterus macarellus*), ballyhoo (*Hemiramphus brasiliensis*), flat needlefish (*Ablennes hians*), and flying fishes (Exocoetidae) appear to be the main food for large pelagic fishes that feed near the surface, such as wahoo, dolphinfish, blackfin tuna, great mackerel, and billfishes. Large schools of creole wrasse (*Clepticus parrae*), creole fish (*Paranthias furcifer*) and brown chromis (*Chromis multilineata*) were observed closer to the reef and may be more important as prey for demersal reef predators and pelagic fishes that feed closer to the reef, such as great barracuda, jacks, cero mackerel and the large groupers and snappers previously mentioned. Given the very large biomass associated with the high abundance and size of demersal and pelagic fish predators and their close feeding association with zooplanktivorous fish populations, it is evident that plankton food webs are of outmost relevance in the trophic structure of BDS.

Small opportunistic carnivores, such as wrasses (Labridae), gobies (Gobiidae), squirrelfishes (Holocentridae), sea basses (Serranidae), basslets (Grammatidae), trunkfishes (Ostraciidae) and puffers (Tetraodontidae) represent a highly specious and abundant assemblage at the reef promontories and may function as keystone food sources for juvenile stages of piscivorous fishes, as well as for the small demersal predators.

The herbivorous fish assemblage, mostly represented by doctorfishes (Acanthuridae) and parrotfishes (Scaridae) was comprised by a few species present in relatively low abundance. The combined abundance of doctorfishes and damselfishes (excluding the bicolor damselfish) represented only 3.2% of the total abundance of fishes within belt-transects at the reef top. Sea turtles, mostly hawksbill (*Eretmochelys imbricata*) maintain an impressive population at the promontories of BDS. At least seven large individuals were observed within station BDS-1 (Table 14), but many more were seen basking at the surface throughout the reef. One green turtle (*Chelonia midas*) was also observed.

Motile megabenthic invertebrates were present in very low abundance and species richness at the reef promontories of BDS. The most common were the arrow crab (*Stenorhynchus seticornis*) and the pederson cleaner shrimp (*Periclimenes pedersoni*), which were present in three and two of the 10 transects surveyed (respectively) (Table 15). Several large spiny lobsters (*Panulirus argus*) were present outside transects. One adult queen conch (*Strombus gigas*) was observed at the sandy interface of the reef promontories. According to reports by local fishermen, an adult queen conch population has been harvested from depths of 30 – 40 m in BDS, but we did not detect any aggregation of queen conch in the vicinity of the reef promontories, nor at any other habitat during our field survey.

Table 15. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Bajo de Sico (BDS). 2005-07. Reef Top: 25 - 30 m

SPECIES	COMMON NAME	T-1	T-2	T-3	T-4	T-5	T-1	T-2	T-3	T-4	T-5	MEAN
Stenorhynchus seticornis	Arrow Crab				1			1	3			**0.5**
Periclimenes pedersoni	Pederson Cleaner Shrimp			1			1					**0.2**
Stenopus hispidus	Banded Coral Shrimp					1						**0.1**
Ophiocoma sp.	Sponge Brittle Star					12						**1.2**
	TOTAL SPECIES	**0**	**0**	**1**	**1**	**2**	**1**	**1**	**1**	**0**	**0**	**0.7**
	TOTAL INDIVIDUALS	**0**	**0**	**1**	**1**	**13**	**1**	**1**	**3**	**0**	**0**	**2.0**

4.2.2 Reef Wall

A total of 52 species of reef fishes were identified at the reef wall of BDS, including 41 species within belt transects surveyed at depths between 30 – 45 m. Mean abundance within belt-transects was 99.1 Ind/30m^2 (range: 42 – 165 Ind/30m^2). The mean number of species within transects was 13.8 (range: 11 – 16). The combined abundance of five species, fairy basslet (*Gramma loreto*), bicolor damselfish (*Stegastes partitus*), brown and sunshine chromis (*Chromis multilineata, C. insolata*), and bluehead wrasse (*Thalassoma bifasciatum*) accounted for 74.4% of the total fish abundance within transects (Table 16). The fairy basslet was the numerically dominant species (mean : 33.6 Ind/30m^2) and the only species present in the 10 transects surveyed. The bicolor damselfish, brown chromis, yellowhead wrasse, creole fish and the squirrelfish were present in at least seven transects.

Both fish abundance and species richness declined sharply at the reef wall relative to the reef top habitat. Abundance declined almost 2.5 fold and the number of species/transect declined 30%. A total of 11 fish species, or 27.6% of the total species within transects were only represented by one individual at the reef wall. Only 12 species were present in at least five of the 10 belt-transects surveyed. The banded coral shrimp (*Stenopus hispidus*) was the only motile megabenthic invertebrate observed within belt-transects at the reef wall (Table 18). One large spiny lobster (*Panulirus argus*) was present outside transects.

Table 16. Taxonomic composition and abundance of fishes within belt-transects at the reef wall of Bajo de Sico (BDS-1).

BDS 1. Reef Wall

SPECIES	COMMON NAME	T-1	T-2	T-3	T-4	T-5	T-6	T-7	T-8	T-9	T-10	MEAN
	Depth	117	120	130	111	107	103	112	117	114	125	
Gramma loreto	fairy basslet	43	19	19	14	5	16	112	87	12	9	33.6
Stegastes partitus	bicolor damselfish	25	14	7	10	0	56	4	5	24	30	17.5
Chromis multilineata	brown chromis	0	0	8	28	12	30	8	4	4	6	10.0
Chromis insulata	sunshine chromis	5	32	26	0	0	0	0	0	0	0	6.3
Thalassoma bifasciatum	bluehead wrasse	3	0	4	17	4	32	3	0	0	0	6.3
Coryphopterus personatus	masked goby	0	0	27	0	0	0	0	0	3	0	3.0
Paranthias furcifer	creole fish	2	0	14	6	0	1	1	1	1	4	3.0
Halichoeres garnoti	yellowhead wrasse	0	3	3	3	3	3	9	0	3	1	2.8
Bodianus rufus	spanish hogfish	0	1	1	0	3	2	2	12	0	0	2.1
Clepticus parrae	creole wrasse	1	0	0	0	4	10	1	3	0	0	1.9
Holocentrus rufus	squirrelfish	2	3	0	2	1	2	1	0	3	3	1.7
Cephalopholis fulva	coney	2	2	5	2	1	0	0	0	2	0	1.4
Sparisoma radians	bucktooth parrotfish	1	5	3	0	0	0	0	0	0	0	0.9
Coryphopterus lipernes	peppermint goby	0	0	0	0	0	0	2	0	0	6	0.8
Canthigaster rostrata	caribbean puffer	2	1	1	0	1	0	1	0	0	0	0.6
Acanthurus coeruleus	blue tang	0	0	1	1	0	3	0	1	0	0	0.6
Cephalopholis cruentatus	graysby	1	0	0	0	0	2	0	1	1	1	0.6
Gramma linki	yellow-cheek basslet	0	0	0	0	0	0	6	0	0	0	0.6
Chromis cyanea	blue chromis	0	0	0	0	0	0	0	3	0	3	0.6
Melichthys niger	black durgon	0	1	0	2	1	1	0	0	0	0	0.5
Chaetodon capistratus	four-eye butterflyfish	0	0	2	1	0	0	0	1	1	0	0.5
Chaetodon aculeatus	longsnout butterflyfish	1	1	0	0	0	0	1	2	0	0	0.5
Flammeo marianus	longspine squirrelfish	0	0	0	1	0	0	1	1	1	0	0.4
Lutjanus apodus	schoolmaster snapper	0	0	0	0	3	0	0	0	0	0	0.3
Carangoides crysos	blue runner	0	0	0	0	0	3	0	0	0	0	0.3
Amblycirrhitus pinos	redspotted hawkfish	0	0	0	0	0	2	0	0	0	1	0.3
Apogon sp.	cardinalfish	0	0	0	0	0	0	3	0	0	0	0.3
Lactophrys triqueter	smooth trunkfish	1	1	0	0	0	0	0	0	0	0	0.2
Mulloides martinicus	yellowtail goatfish	0	0	0	0	2	0	0	0	0	0	0.2
Chaetodon striatus	banded butterflyfish	0	0	0	0	0	0	2	0	0	0	0.2
Acanthurus bahianus	ocean surgeon	1	0	0	0	0	0	0	0	0	0	0.1
Acanthurus chirurgus	doctorfish	0	0	0	0	1	0	0	0	0	0	0.1
Holacanthus ciliaris	queen angelfish	0	0	0	1	0	0	0	0	0	0	0.1
Holacanthus tricolor	rock beauty	0	0	1	0	0	0	0	0	0	0	0.1
Ocyurus chrysurus	yellowtail snapper	0	0	0	1	0	0	0	0	0	0	0.1
Sparisoma viride	stoplight parrotfish	0	0	0	0	1	0	0	0	0	0	0.1
Scarus taeniopterus	princess parrotfish	0	0	0	0	0	1	0	0	0	0	0.1
Gobiosoma evelynae	sharknose goby	0	0	0	0	0	1	0	0	0	0	0.1
Sparisoma aurolineatum	redband parrotfish	0	0	0	0	0	0	0	1	0	0	0.1
Aulostomus maculatus	trumpetfish	0	0	0	0	0	0	0	0	0	1	0.1
Coryphopterus sp.	goby	0	0	0	0	0	0	0	0	0	1	0.1
	TOTAL SPECIES	**14**	**12**	**15**	**15**	**14**	**16**	**16**	**13**	**11**	**12**	**13.8**
	TOTAL INDIVIDUALS	**90**	**83**	**122**	**89**	**42**	**165**	**157**	**122**	**55**	**66**	**99.1**

Table 17. Descriptive statistics of fish abundance for the numerically dominant species within belt-transects at the reef wall habitat. Bajo de Sico (BDS).

SPECIES	COMMON NAME	MEAN	STDEV	Var	Var/X	Variat Coeff
Gramma loreto	fairy Basslet	33.6	36.7	1344.0	36.7	109.1
Stegastes partitus	bicolor damselfish	17.5	16.9	284.5	16.9	96.4
Chromis multilineata	brown chromis	10.0	10.7	113.8	10.7	106.7
Chromis insulate	sunshine chromis	6.3	12.1	147.6	12.1	192.8
Thalassoma bifasciatum	bluehead wrasse	6.3	10.4	107.3	10.4	164.5
Coryphopterus personatus	masked goby	3.0	8.5	72.0	8.5	282.8
Paranthias furcifer	creole fish	3.0	4.3	18.4	4.3	143.2
Halichoeres garnoti	yellowhead wrasse	2.8	2.5	6.4	2.5	90.4
Bodianus rufus	spanish hogfish	2.1	3.6	13.2	3.6	173.1
Clepticus parrae	creole wrasse	1.9	3.2	10.1	3.2	167.3

Table 18. Taxonomic composition and abundance of motile megabenthic invertebrates within belt-transects at Bajo de Sico (BDS). 2005-07. Reef wall:30 - 40 m

SPECIES	COMMON NAME	T-1	T-2	T-3	T-4	T-5	T-6	T-7	T-8	T-9	T-10	MEAN
Stenopus hispidus	banded coral shrimp		1		3	2			0			**0.6**
	TOTAL SPECIES	**0**	**1**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**1**
	TOTAL INDIVIDUALS	**0**	**1**	**0**	**3**	**2**	**0**	**0**	**0**	**0**	**0**	**0.6**

4.2.3 Deep Rhodolith Reef

A total of 47 species of fishes, including 23 within belt-transects were identified from depths of 45 – 53 m at the deep rhodolith reef habitat of BDS. The bicolor damselfish (*Stegastes partitus*) was the numerically dominant species with a mean abundance of 47.9 Ind/30m^2 (range: 17 - 79 Ind/30m^2), representing 61.4% of the total fish abundance within the 10 belt-transects surveyed. An assemblage of five species, including the bicolor damselfish, blue chromis (*Chromis cyanea*), cherubfish (*Centropyge argi*) and the bluehead and yellowhead wrasses (*Thalassoma bifasciatum, Halichoeres garnoti*) represented 91.9% of the total fish abundance within belt-transects. The bicolor damselfish and the bluehead wrasse were the only species present in all transects surveyed. The blue chromis, cherubfish, coney and yellowhead wrasse were present in at least seven of the 10 transects. A total of nine (9) species were only observed in one transect (Table 19).

Among the top ten most abundant fish species at the deep rhodolith reef, the bicolor damselfish, blue chromis and cherubfish presented aggregated or patchy spatial distributions (var/mean > 1.0), whereas both the bluehead and yellowhead wrasses presented mostly random distributions (var/mean ~ 1.0) (Table 20). The random distribution of wrasses at the deep rhodolith reef is in sharp contrast to the aggregated distributions that are typical for these species in shallow reefs, where they often form harems and swim about reefs in schools. The maximum number of bluehead wrasse individuals observed in a belt-transect was five, but most of the sightings were of one or two individuals per transect, indicative that their typical reproductive behavior consisting of one male and the female harem is not common at the deep rhodolith reef. Cherubfish typically live in pairs or small groups composed of a large male and female and several smaller, possibly immature individuals (Deloach and Humann, 1999), thereby influencing their patchy distribution at the deep rhodolith reef. The coney (*Cephalopholis fulva*) presented a highly uniform spatial distribution at the deep rhodolith reef (var/mean < 1.0). It was present in seven transects with abundance ranging between 0 – 2 individuals per transect and a total of six transects with one individual. The uniform distribution may be a density dependent condition associated with food resources and/or habitat spatial limitations at the deep rhodolith reef.

Table 19. Taxonomic composition and abundance of fishes within belt-transects at the deep rhodolith reef. Bajo de Sico. 2005-07. Depth: 45 - 53 m

Species	**Common Name**	**T-1**	**T-2**	**T-3**	**T-4**	**T-5**	**T-6**	**T-7**	**T-8**	**T-9**	**T-10**	**Mean**
Stegastes partitus	bicolor damselfish	60	17	40	34	63	71	44	79	41	30	**47.9**
Chromis cyanea	blue chromis	3	17	9	0	5	36	30	2	27	8	**13.7**
Centropyge argi	cherubfish	23	0	0	2	5	4	6	6	6	0	**5.2**
Thalassoma bifasciatum	bluehead wrasse	2	5	3	1	1	3	2	1	1	3	**2.2**
Halichoeres garnoti	yellowhead wrasse	3	0	0	3	1	2	3	2	2	0	**1.6**
Chromis insolata	sunshine chromis	0	0	0	2	0	8	1	0	0	0	**1.1**
Coryphopterus lipernes	peppermint goby	0	0	3	0	0	0	0	0	0	7	**1.0**
Cephalopholis fulva	coney	1	1	0	2	0	1	1	1	0	1	**0.8**
Sparisoma radians	bucktooth parrotfish	1	1	0	0	4	1	0	0	0	0	**0.7**
Sparisoma atomarium	greenblotch parrotfish	0	0	0	0	0	0	1	1	2	3	**0.7**
Holocentrus rufus	squirrelfish	0	1	1	4	0	0	0	0	0	0	**0.6**
Halichoeres cyanocephalus	yellowcheek wrasse	1	1	0	1	1	1	0	0	0	0	**0.5**
Amblycirrhitus pinos	redspotted hawkfish	0	1	1	0	0	0	0	0	1	0	**0.3**
Paranthias furcifer	creole fish	0	0	0	0	3	0	0	0	0	0	**0.3**
Serranus tigrinus	harlequin bass	1	1	0	0	1	0	0	0	0	0	**0.3**
Scarus iserti	striped parrotfish	0	0	2	0	0	0	0	0	0	0	**0.2**
Chaetodon aculeatus	longsnout butterflyfish	0	0	0	0	0	1	0	0	0	1	**0.2**
Cephalopholis cruentata	graysby	0	0	0	0	0	0	0	0	0	2	**0.2**
Sparisoma aurofrenatum	redband parrotfish	0	1	0	0	0	0	0	0	0	0	**0.1**
Serranus annularis	orangeback basslet	0	0	0	1	0	0	0	0	0	0	**0.1**
Flammeo marianus	longspine suirrelfish	0	0	0	0	0	0	0	0	0	1	**0.1**
Gobiosoma evelynae	sharknose goby	0	0	0	0	0	0	0	0	0	1	**0.1**
Epinephelus guttatus	red hind	0	0	0	0	0	0	0	0	0	1	**0.1**
	Total Species	**9**	**10**	**7**	**9**	**9**	**10**	**8**	**7**	**6**	**11**	**8.6**
	Total Abundance (Ind/30m2)	**95**	**46**	**59**	**50**	**84**	**128**	**88**	**92**	**80**	**58**	**78**

Large demersal fishes were rare at the deep rhodolith reef. A protective, residential habitat is not available for them, since the bottom is essentially flat and without any significant topographic relief. The deep rhodolith reef may represent a foraging habitat for large groupers and snappers, but none were observed during our daytime surveys. The only relatively large (> 90 cm) demersal fish observed at the deep rhodolith reef was a nurse shark (*Ginglymostoma cirratum*) (Table 21). Queen triggerfish (*Balistes vetula*), red hinds (*Epinephelus guttatus*) and coneys (*Cephalopholis fulva*) appear to act as the main residential demersal predators of the reef. Smaller opportunistic carnivores were represented by squirrelfishes (*Holocentrus rufus, H. adscensionis, Flammeo marianus*)

Table 20. Descriptive statistics of fish abundance for the numerically dominant species within belt-transects at the deep rhodolith reef habitat. Bajo de Sico (BDS). Depth: 45 – 53 m

Species	**Common Name**	**Mean Abundance (Ind/30m2)**	**StDev**	**Var**	**Var/X**	**Variation Coeff.**
Stegastes partitus	Bicolor Damselfish	47.9	19.6	385.4	8.0	41.0
Chromis cyanea	Blue Chromis	13.7	13.0	168.9	12.3	94.9
Centropyge argi	Cherubfish	5.2	6.8	45.7	8.8	130.1
Thalassoma bifasciatum	Bluehead Wrasse	2.2	1.3	1.7	0.8	59.8
Halichoeres garnoti	Yellowhead Wrasse	1.6	1.3	1.6	1.0	79.1
Chromis insolata	Sunshine Chromis	1.1	2.5	6.3	5.7	228.6
Coryphopterus lipernes	Peppermint Goby	1	2.3	5.3	5.3	230.9
Cephalopholis fulva	Coney	0.8	0.6	0.4	0.5	79.1
Sparisoma radians	Bucktooth Parrotfish	0.7	1.3	1.6	2.2	178.8
Sparisoma sp. (atomarium)	(Greenblotch) Parrotfish	0.7	1.1	1.1	1.6	151.3

Table 21. Size-frequency distribution of large and/or commercially important reef fishes identified during ASEC surveys at the deep rhodolith reef habitat. Bajo de Sico, BDS – 1. 2005 – 07. Depth : 25 - 40 m

SPECIES	**COMMON NAME**	Numbers -Total Length (Inches)		
Acanthocybium solanderi	wahoo	3-70		
Balistes vetula	queen triggerfish	1-15	3-18	
Caranx crysos	blue runner	3-(15-18)		
Caranx lugubris	black jack	2-20	1-24	
Elagatis bipinnulata	rainbow runner	30-(15-20)	20-(21-30)	
Epinephelus guttatus	red hind	6-(8-10)	9-(11-15)	
Epinephelus striatus	Nassau grouper	1-20		
Decapterus macarellus	mackerel scad	n/d		
Euthynnus alletteratus	little tuna	n/d		
Ginglymostoma cirratum	nurse shark	1-(48)		
Scomberomorus regalis	cero mackerel	2-18	1-24	
Sphyraena barracuda	great barracuda	1-24	2-30	1-36

<u>Others</u>: *Scarus taeniopterus, Priacanthus sp., Serranus annularis, Serranus tabacarius, Malacanthus plumieri, Opistognathus aurifrons, Xanthichthys ringens, Haemulon adscensionis, Acanthurus chirurgus, Acanthurus bahianus, Clepticus parrae, Canthigaster rostrata, Chaetodon striatus, Bodianus rufus, Malacoctenus triangulatus, Holacanthus ciliaris*

and wrasses (*Thalassoma bifasciatum, Halichoeres garnoti, H. cyanocephalus*). Zooplanktivorous fish species, including the bicolor damselfish, blue and sunshine chromis (*Chromis cyanea, C. insolata*) accounted for 80.4% of the total fish abundance within transects and thus, may represent important forage for the larger demersal predators. Despite the exceptionally high reef substrate cover by benthic algae at the deep rhodolith reef (>60%), herbivorous fishes presented a combined abundance of only 9% within belt-transects. These were mostly represented by the cherubfish (*Centropyge argi*) and several species of small parrotfishes (*Sparisoma radians, S. aurofrenatum, S. atomarium, Scarus taeniopterus, S. iserti*). Large pelagic fishes, including wahoo, great barracuda, black jacks, rainbow runners and cero mackerels were observed at the deep rhodolith reef (Table 21), but appeared to be foraging on water column prey, such as mackerel scad and ballyhoo.

Both fish abundance and species richness declined at the deep rhodolith reef relative to the reef wall habitat, establishing a well defined pattern of decreasing fish abundance and richness with increasing depth (Figure 21). A similar observation was reported by Garcia-Sais et al (2005) for Agelas Reef, a mesophotic reef system studied at Isla Desecheo. The absence of substrate heterogeneity and topographic relief constrains fish diversity at the deep rhodolith reef because of the limited kinds of microhabitats available. Also, the low substrate cover by live corals may be also limiting fish diversity because of the direct and indirect relationships between reef fishes and stony corals. This condition is exacerbated by the limited availability of black corals and gorgonians at the deep rhodolith reef. Structures that provide topographic relief at the deep rhodolith reef include large branching and erect sponges, such as *Agelas spp*. and *Xestospongia muta*. Branching *Agelas spp*. serve as a recruitment habitat for post-settlement and early juvenile *Chromis spp* (e.g. *Chromis insolata, C. cyanea*). Large basket sponges (*X. muta*) are used by red hinds as shelter.

Two fish species showed a marked increment of abundance at the deep terrace reef, relative to other shallower habitats studied at BDS, these were the cherubfish and the blue chromis. The orangeback bass (*Serranus annularis*), the tobacco fish (*Serranus tabacarius*), the greenblotch parrotfish, *Sparisoma atomarium*) and the nurse shark (*Ginglymostoma cirratum*) were only observed from the deep rhodolith reef at BDS.

The deep rhodolith reef appears to be a residential habitat of red hind (*Epinephelus guttatus*). A total of 15 individuals, ranging in size between 20 – 38 cm were observed during ASEC surveys within an estimated reef surface area of 700 m^2, or about 2 Red Hinds per 100 m^2 of reef at depths between 45 - 53 m.

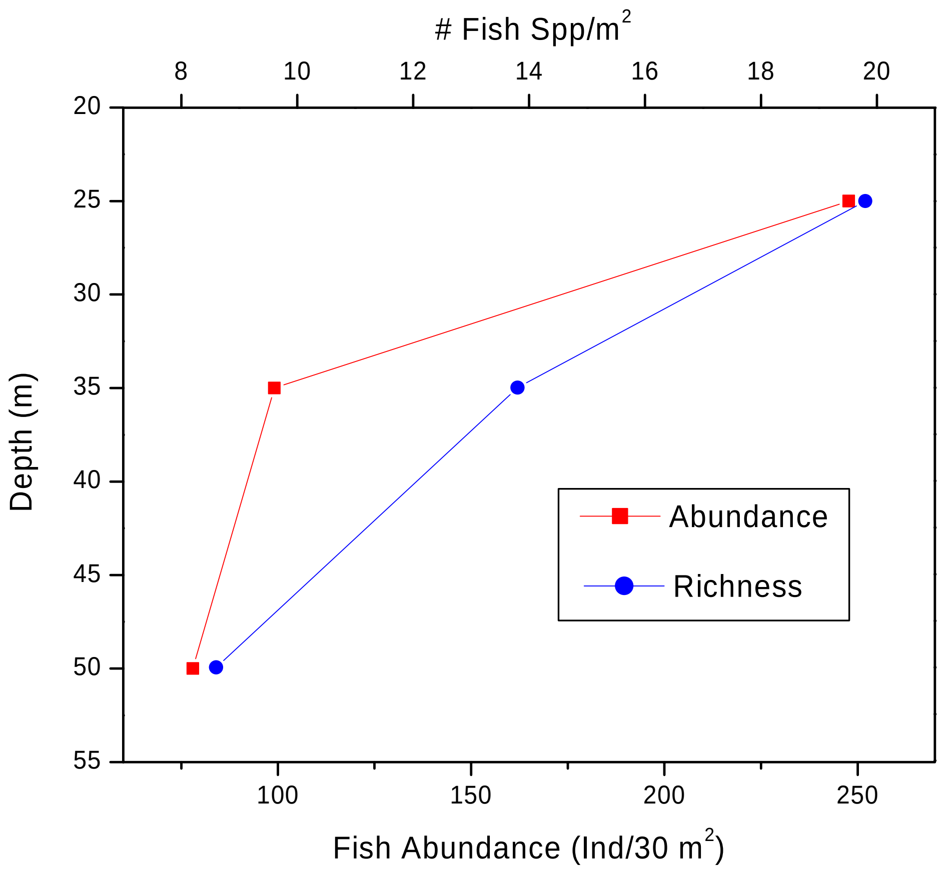

Figure 21. Variations of fish abundance and species richness with increasing depth at benthic habitats surveyed in Bajo de Sico. 2005 – 07. Data are means of 10 10 x 3 m belt-transects at the reef top (25 – 30 m), reef wall (30 – 40 m), and the deep rhodolith reef habitat (45 -53 m).

VII. Conclusions and Recommendations

1. Bajo de Sico is a seamount that rises from a deep platform of the insular slope in the west coast of Puerto Rico

2. The reef bathymetry is characterized by a ridge of rock promontories aligned southeast – northwest which rise from a platform at 45 m to a reef top at 25m, and an extensive, mostly flat, homogeneous and gradually sloping deep rhodolith reef that ends as a shelf-edge wall at depths between 90 – 100 m reaching down to depths of 200 – 300 m.

3. Salient oceanographic features of the water column influencing the reef system include a warm mixed surface water mass with a summer thermocline at a depth of 45 – 50 m, strong, persistent northwesterly surface currents, and high water transparency with 1% light penetration reaching to depths of almost 80 m.

4. At least five (5) main benthic habitats have been identified and field verified to a maximum depth of 50 m, these include a reef top and a vertical reef wall associated with rock promontories; colonized pavement with sand channels at the base of promontories; uncolonized rhodoliths and gravel at the reef slope; and a colonized rhodolith mesophotic reef.

5. From the multi-beam bathymetry survey of the reef, the total extension of Bajo de Sico includes a surface area of approximately 11.1 square kilometers, of which only 3.6 % is associated with the rock promontories (0.4 km^2) and more than 88 % corresponds to a deep shelf platform at depths between 45 - 100 m.

6. The sessile-benthic community at the reef top was characterized by a highly diverse assemblage comprised by benthic algae (52%), sponges (26%), scleractinian corals (8%), octocorals (5%) and hydrozoans (3%), with an abiotic cover of less than 1.5 %.

7. Scleractinian corals were represented at the reef top by an assemblage of 13 species within transects surveyed, with a mean substrate cover of 8.0 % and a mean density of almost 20 colonies per square meter.

8. Growth of scleractinian corals at the reef top was characterized by a species rich and numerous assemblage of small, isolated encrusting colonies that contributed minimal topographic relief.

9. Lettuce corals, mostly *Agaricia lamarki* and *A. grahame* were the dominant assemblage in terms of reef substrate cover and density of colonies. *Tubastrea coccinea, Porites astreoides* and *Montastraea cavernosa* were also common at the reef top.

10. Sponges, represented within transects by at least 12 species were the dominant sessile-benthic invertebrate in terms of reef substrate cover (mean: 26 %) at the reef top. Due to their large size and abundance, sponges contributed substantially to the reef topographic relief and served as habitat for fishes and invertebrates.

11. The reef wall habitat was characterized by irregular formations that appear to have been influenced by erosional processes, with deep crevices, undercuts, gaps, ledges and other substrate discontinuities

12. The sessile-benthos of the reef wall habitat resembled the reef top in that it was also highly diverse and taxonomically complex, comprised by sponges (43%), benthic algae (26%), octocorals (14 %), scleractinian corals (5.5%), antipatharians (3%) and hydrozoans (2%). Abiotic cover was 4%.

13. Sponges were the most prominent component of the sessile-benthos at the reef wall, with at least 11 species present within transects surveyed and the prevalence of large erect and branching growth forms providing substantial topographic relief and reef substrate complexity.

14. Octocorals (gorgonians), particularly the Deep Sea Fan, *Iciligorgia schrammi* combined with black corals (Antipatharians), mostly the Caribbean Bushy Coral, *Antipathes caribbeana* contributed an average reef substrate cover of 17 %, adding to the benthic substrate heterogeneity and providing protective habitat for fishes at the reef wall.

15. As in the reef top, scleractinian corals were present as a species rich assemblage of numerous, but small isolated colonies growing encrusted to the hard ground substrate and contributing minimally to the reef topographic relief.

16. The deep rhodolith reef habitat of BDS, at least down to a maximum surveyed depth of 50 m, appears to be a vast deposit of algal rhodoliths. At the northern section of the platform rhodoliths are overgrown by a dense macroalgal carpet, mostly the encrusting fan-leaf alga, *Lobophora variegate*, sponges and scleractinian corals.

17. The sessile-benthic invertebrate community at the deep rhodolith reef was characterized by relatively low taxonomic diversity, with virtual absence of gorgonians and antipatharians, low substrate cover and species composition by scleractinian corals and a marked decline of cover and species composition by sponges, relative to the reef top and wall habitats. Nevertheless the sharp increment in biotic cover and biodiversity compared to the adjacent slope environment serves as criteria to classify this habitat as a mesophotic reef system.

18. With few exceptions, scleractinian corals and sponges grow attached to rhodoliths, and are therefore not fixed to the bottom. Lettuce corals, *Agaricia spp*. were the dominant scleractinian taxa at the deep rhodolith reef in terms of reef substrate cover.

19. Reef fishes associated with BDS were comprised by a combination of the typical shallow water reef species assemblage, a group of deep reef species, large demersal predators (snapper s and groupers), and a species rich and abundant assemblage of reef and oceanic pelagic predators.

20. Zooplanktivorous schooling fish populations are abundant at BDS and appear to serve as the main forage for large pelagic and demersal piscivorous fishes of the reef.

21. Both fish abundance and species richness declined markedly with depth at the benthic habitats studied at BDS. Variations of taxonomic composition and abundance appear to be associated with the low availability of protective habitat at the deep rhodolith reef and the limited assemblage of species adapted for the vertically oriented habitat of the wall.

22. Reef promontories at BDS represent an important residential and foraging habitat for a group of large, commercially important species of snappers (*Lutjanus cyanopterus, L. jocu*) and groupers (*Epinephelus striatus, Mycteroperca bonaci, M. venenosa, M. interstitialis*) that has virtually disappeared from most reef systems in Puerto Rico. It also represents a spawning aggregation site for red hind (*Epinephelus guttatus*), and possibly other groupers within Mona Passage.

23. The deep rhodolith reef appears to be the residential habitat for the red hind, as higher densities of this species were observed relative to the reef top and wall habitats. It is possible that the smaller habitats of the deep rhodolith reef and the strong competition by larger groupers at the reef promontories influence the distribution of red hinds at the deep rhodolith reef.

24. The reef system at Bajo de Sico (BDS) serves as an important foraging and residential habitat for the endangered Hawksbill turtle (*Eretmochelys imbricata*). Its population at BDS is impressive because of the large size and high abundance of individuals.

25. The seamount serves as a foraging area for large migratory pelagic fishes, including the Wahoo (*Acanthocibium solanderi*), Mahi-Mahi (*Coryphaena hippurus*), Tunas (*Thunnus spp*.) and Marlins (mostly *Makaira nigricans*)

26. From the field survey at Bajo de Sico, the following recommendations are proposed:

   e. A year-round permanent closure for fishing of demersal fish species at the entire reef platform is recommended for the protection of what could be one of the few remaining actively reproducing populations of Black, Yellowmouth, Yellowfin and Nassau groupers in Puerto Rico.

   f. Characterization of the benthic habitats and associated communities at the deep shelf platform below depths of 50 m using Autonomous Underwater Vehicles (AUV) or similar systems that could provide high resolution images of the reef substrate.

   g. The hermatypic and ahermatypic coral assemblage of the deep shelf platform at BDS consists of species that have not been previously reported for coral reef systems in PR, and a more comprehensive characterization will require further exploration and research

   h. The CFMC should convey further research attention to the large grouper-snapper populations at BDS, particularly aspects of their reproductive biology, trophic interactions and larval dispersal and recruitment dynamics

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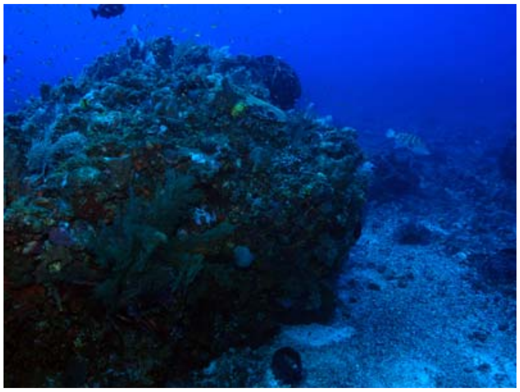
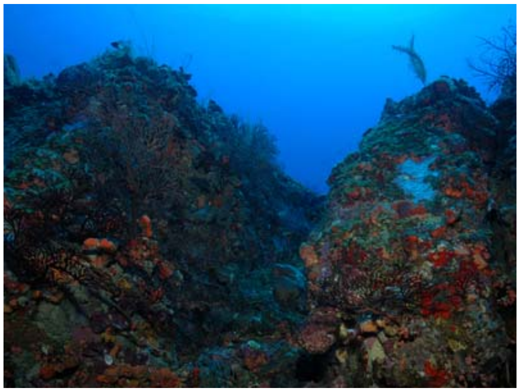
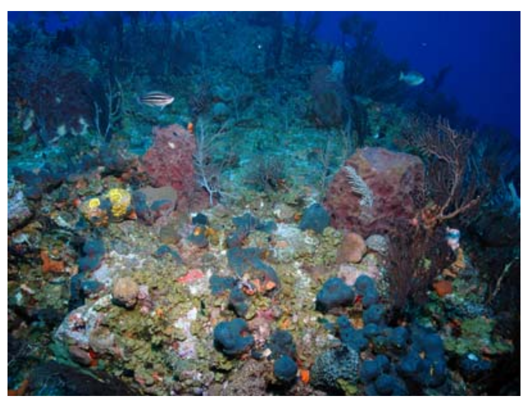
IX. Appendices

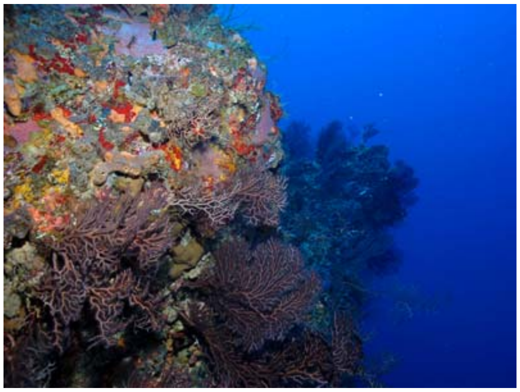
Appendix 1. Photo Album Reef Top





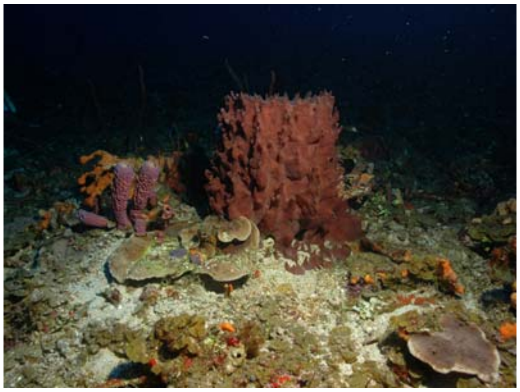
Appendix 2. Photo Album Reef Wall

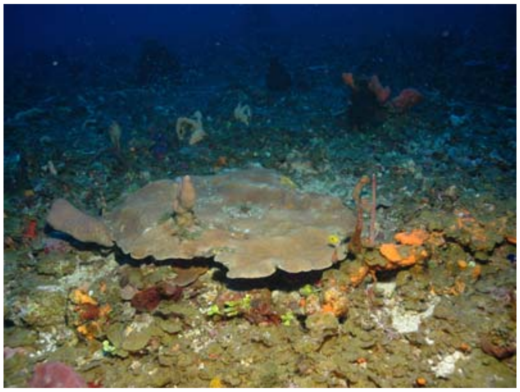




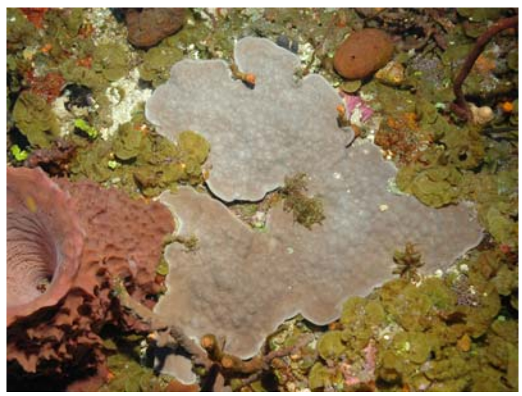
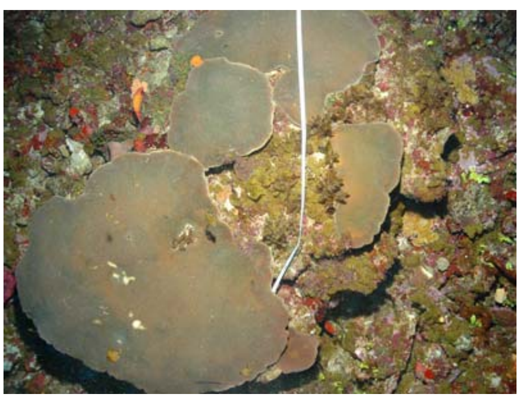
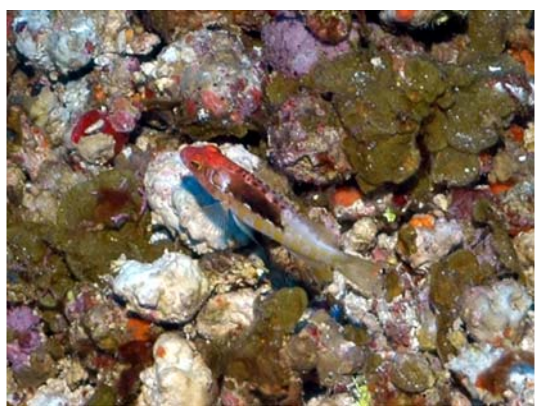



Appendix 3. Photo Album Deep Terrace Reef







Appendix 4. Master species list

				Reef Top	Wall	Deep Terrace
Cnidaria	Anthozoa	anemone	*Ricordea florida*			X
Cnidaria	Anthozoa	anemone	*unident. Anemone*			X
Chordata	Ascidiacea	ascidian	*Ascidiacea (colonial ascidian)*			X
Cnidaria	Anthozoa	black coral	*Antipatharia*		X	
Cnidaria	Anthozoa	black coral	*Stichopathes*	X	X	
Bryozoa		bryozoan	*Bryozoa*		X	X
Cnidaria	Anthozoa	coral	*Agaricia agaricites*	X	X	X
Cnidaria	Anthozoa	coral	*Agaricia grahamae*	X	X	X
Cnidaria	Anthozoa	coral	*Agaricia lamarcki*	X	X	X
Cnidaria	Anthozoa	coral	*Colpophyllia natans*	X	X	X
Cnidaria	Anthozoa	coral	*Dichocoenia stokesi*		X	X
Cnidaria	Anthozoa	coral	*Diploria labyrinthiformis*		X	
Cnidaria	Anthozoa	coral	*Diploria strigosa*	X	X	
Cnidaria	Anthozoa	coral	*Eusmilia fastigiata*	X	X	X
Cnidaria	Anthozoa	coral	*Isophyllia rigida*	X	X	
Cnidaria	Anthozoa	coral	*Isophyllia sinuosa*	X	X	
Cnidaria	Anthozoa	coral	*Leptoseris cailleti*			X
Cnidaria	Anthozoa	coral	*Leptoseris cucullata*		X	
Cnidaria	Anthozoa	coral	*Madracis decactis*	X	X	X
Cnidaria	Anthozoa	coral	*Meandrina meandrites*	X	X	X
Cnidaria	Anthozoa	coral	*Montastrea aliciae*		X	
Cnidaria	Anthozoa	coral	*Montastrea annularis*	X	X	X
Cnidaria	Anthozoa	coral	*Montastrea cavernosa*	X	X	X
Cnidaria	Anthozoa	coral	*Mycetophyllia aliciae*	X	X	X
Cnidaria	Anthozoa	coral	*Mycetophyllia lamarckiana*	X		X
Cnidaria	Anthozoa	coral	*Oculina (varicosa)*			X
Cnidaria	Anthozoa	coral	*Porites astreoides*	X	X	X
Cnidaria	Anthozoa	coral	*Scolymia cubensis*	X		
Cnidaria	Anthozoa	coral	*Siderastrea siderea*	X	X	
Cnidaria	Anthozoa	coral	*Stephanocoenia michelini*		X	
Cnidaria	Anthozoa	coral	*Tubastrea coccinea*		X	X
Cnidaria	Anthozoa	coral	*unident. Coral*			X
Crustacea	Arthropoda	crab	*Stenopus hispidus*	X		X
Crustacea	Arthropoda	crab	*Stenorhynchus seticornis*	X		
Crustacea	Arthropoda	crab	*Xanthidae*			X
Echinodermata	Crinoidea	crinoid	*unident. Crinoid 1*		X	
Echinodermata	Crinoidea	crinoid	*unident. Crinoid 2*		X	
Protozoa	Foraminifera	foraminifera	*Homotrema rubens*			X
Cnidaria	Anthozoa	gorgonian	*Ellisella sp.*		X	
Cnidaria	Anthozoa	gorgonian	*Eunicea laxispica*	X		
Cnidaria	Anthozoa	gorgonian	*Iciligorgia schrammi*	X	X	X
Cnidaria	Anthozoa	gorgonian	*Pseudopterogorgia acerosa*	X		
Cnidaria	Anthozoa	gorgonian	*Pseudopterogorgia sp.*		X	X
Cnidaria	Anthozoa	gorgonian	*Pterogorgia citrina*	X		
Cnidaria	Anthozoa	gorgonian	*unident. Gorgonian*		X	

Echinodermata	Holothuroidea	holothuroid	*Holothuria sp.*	X		
Cnidaria	Hydrozoa	hydrozoa	*Hydrozoa*	X	X	X
Cnidaria	Hydrozoa	hydrozoa	*Millepora alcicornis*	X	X	
Cnidaria	Hydrozoa	hydrozoan	*Stylaster roseus*		X	X
Crustacea	Arthropoda	lobster	*Panulirus argus*		X	
Echinodermata	Ophiuroidea	ophiuroid	*Ophiuroidea*			X
Annelida	Polychaeta	polychaete	*Serpulidae*		X	X
Annelida	Polychaeta	polychaete	*Sabellidae*		X	
Crustacea	Arthropoda	shrimp	*Periclimenes swensoni*	X		
Crustacea	Arthropoda	shrimp	*Periclimenes pedersoni*	X		
Porifera	Demospongia	sponge	*Agelas clathrodes*	X	X	X
Porifera	Demospongia	sponge	*Agelas conifera*	X	X	X
Porifera	Demospongia	sponge	*Agelas dispar*	X	X	X
Porifera	Demospongia	sponge	*Agelas sp.*			X
Porifera	Demospongia	sponge	*Aiotochroia crassa*			X
Porifera	Demospongia	sponge	*Aplisina cauliformis*	X	X	X
Porifera	Demospongia	sponge	*Aplisina fistularis*		X	X
Porifera	Demospongia	sponge	*Aplisina insularis*		X	X
Porifera	Demospongia	sponge	*Aplisina lacunosa*		X	
Porifera	Demospongia	sponge	*Aplisina sp.*			X
Porifera	Demospongia	sponge	*Callispongia fallax*		X	X
Porifera	Demospongia	sponge	*Callispongia plicifera*		X	X
Porifera	Demospongia	sponge	*Callispongia vaginalis*		X	X
Porifera	Demospongia	sponge	*Ectyoplasia sp.*		X	
Porifera	Demospongia	sponge	*Halisarca caerulea*		X	X
Porifera	Demospongia	sponge	*Ircinia felix*		X	X
Porifera	Demospongia	sponge	*Ircinia sp.*	X		X
Porifera	Demospongia	sponge	*Ircinia strobilina*		X	
Porifera	Demospongia	sponge	*Monanchora sp.*		X	
Porifera	Demospongia	sponge	*Neofibularia nolitangere*	X		
Porifera	Demospongia	sponge	*Niphates erecta*		X	X
Porifera	Demospongia	sponge	*Plakortis angulospiculauts*	X	X	X
Porifera	Demospongia	sponge	*Aiolochroia crassa*			X
Porifera	Demospongia	sponge	*Pseudoceratina sp.*			X
Porifera	Demospongia	sponge	*Scopolina ruetzleri*		X	X
Porifera	Demospongia	sponge	*Siphonodictyon sp*		X	
Porifera	Demospongia	sponge	*Svensea zeaii*		X	X
Porifera	Demospongia	sponge	*Verongia sp.*		X	
Porifera	Demospongia	sponge	*Verongula gigantea*		X	X
Porifera	Demospongia	sponge	*Verongula reiswige*		X	X
Porifera	Demospongia	sponge	*Verongula rigida*	X		
Porifera	Demospongia	sponge	*Xestospongia muta*	X	X	X
Porifera	Sclerospongia	sclerosponge	*Ceratoporella sp.*		X	
Annelida	Polychaeta	worm	*Sabellids*		X	
Annelida	Polychaeta	worm	*Serpulids*		X	X
Heterokontophyta		brown algae	*Dictyota recurvata*			X
Heterokontophyta		brown algae	*Dictyota sp.*		X	
Heterokontophyta		brown algae	*Lobophora variegata*	X	X	X
Heterokontophyta		brown algae	*Padina sp.*		X	

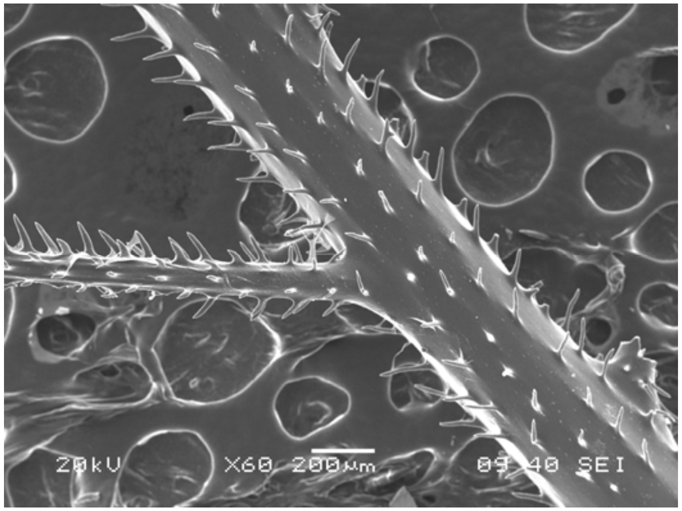
Heterokontophyta	brown algae	*Sargassum hystrix*			X
Heterokontophyta	brown algae	*Stypopodium zonale*	X		
Chlorophyta	green algae	*Anadyomene stellata*			X
Chlorophyta	green algae	*Caulerpa racemosa var. peltata*			X
Chlorophyta	green algae	*Codium sp.*			X
Chlorophyta	green algae	*Halimeda discoidea*	X	X	X
Chlorophyta	green algae	*Halimeda tuna*			X
Chlorophyta	green algae	*Rhipocephalus phoenix*		X	X
Chlorophyta	green algae	*Udotea sp.*			X
Chlorophyta	green algae	*Valonia sp.*			X
Chlorophyta	green algae	*Ventricaria ventricosa*		X	X
Rhodophyta	red algae	*Amphiroa sp.*	X	X	X
Rhodophyta	red algae	*Galaxaura sp.*	X	X	
Rhodophyta	red algae	*Peyssonnelia sp.*			X
Cyanophyta	cyanobacteria	*Schyzothrix sp.*			X

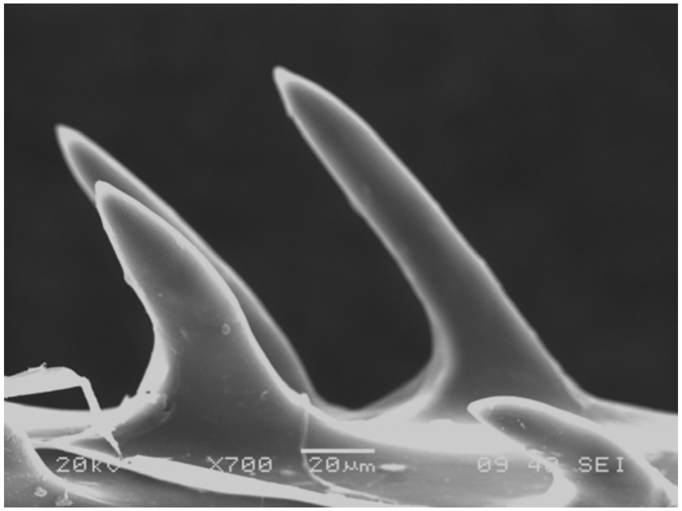
Other algae

Heterokontophyta	brown algae	*Dictyota cervicornis*
Heterokontophyta	brown algae	*Dictyota hamifera*
Heterokontophyta	brown algae	*Dictyota humifusa*
Heterokontophyta	brown algae	*Dictyota pulchella*
Heterokontophyta	brown algae	*Sargassum sp.*
Heterokontophyta	brown algae	*Stypopodium sp.*
Chlorophyta	green algae	*Anadyomene sp.*
Chlorophyta	green algae	*Caulerpa macrophysa*
Chlorophyta	green algae	*Caulerpa webbiana*
Chlorophyta	green algae	*Halimeda copiosa*
Chlorophyta	green algae	*Halimeda cuneata*
Chlorophyta	green algae	*Halimeda discoidea*
Rhodophyta	red algae	*Amphiroa rigida*
Rhodophyta	red algae	*Ceramium bisporum*
Rhodophyta	red algae	*Crouania sp.*
Rhodophyta	red algae	*Galaxaura lapidescons*
Rhodophyta	red algae	*Gloiocladia atlantica*
Rhodophyta	red algae	*Herposiphonia sp.*
Rhodophyta	red algae	*Hypoglossum cologlossoides*
Rhodophyta	red algae	*Hypoglossum rhizophora*
Rhodophyta	red algae	*Nitophyllum adherens*
Rhodophyta	red algae	*Peyssonnelia flavescens*
Rhodophyta	red algae	*Polysiphonia gorgoniae*

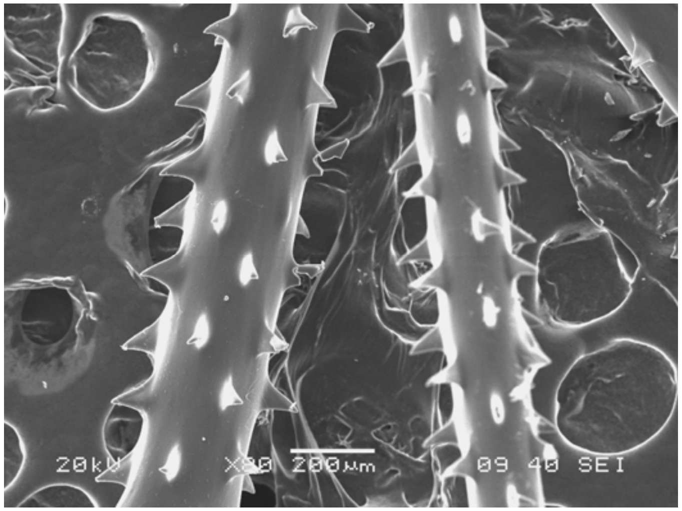
Appendix 5. Antipatharians

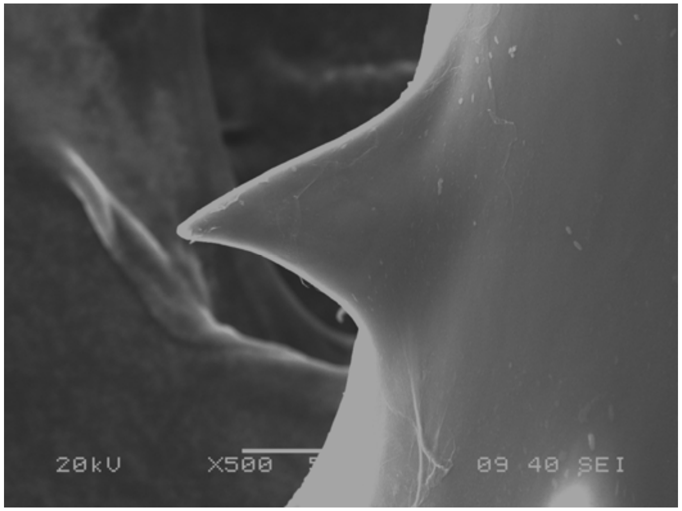
2.1 *Plumapathes*-like, or a related species



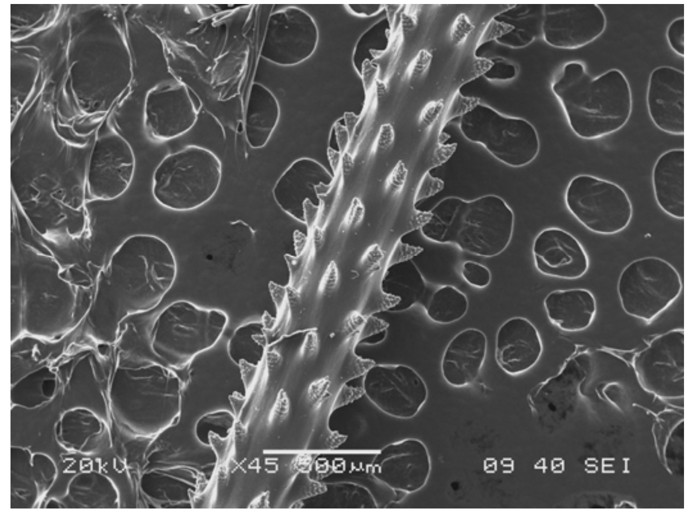


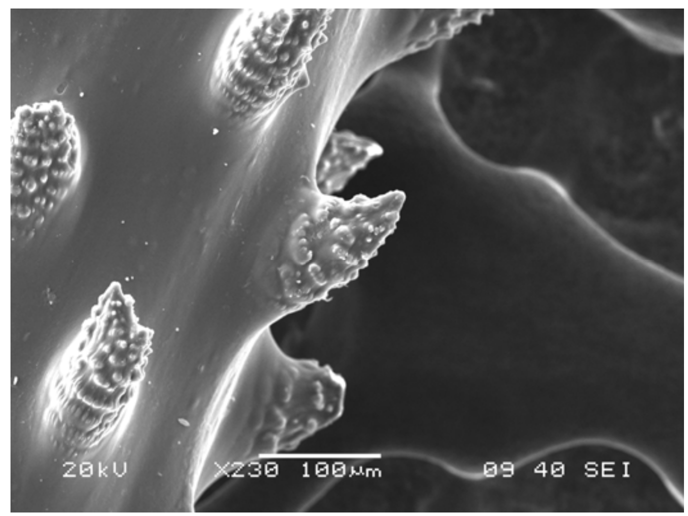
2.2 Variant of *Antipathes atlantica / gracilis*



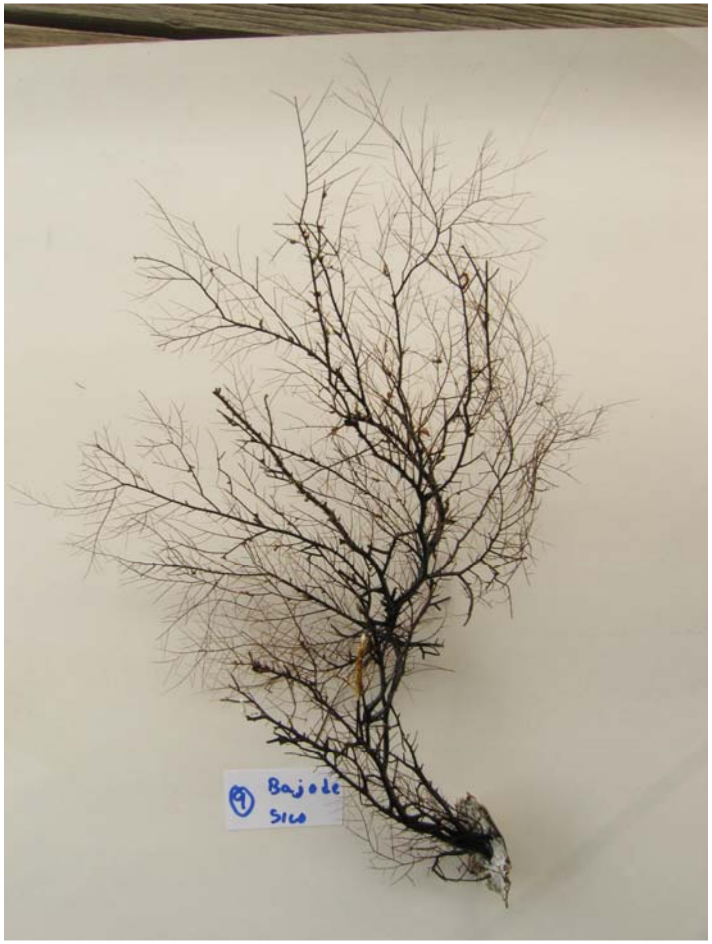


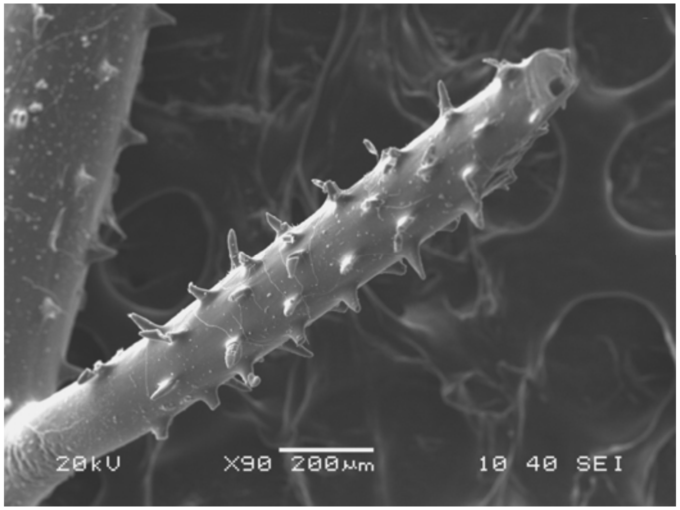
2.3 Variant of *Antipathes caribbeana*

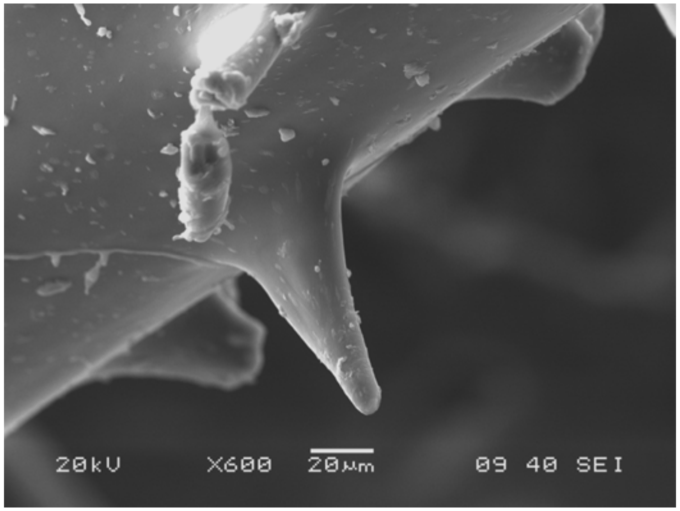




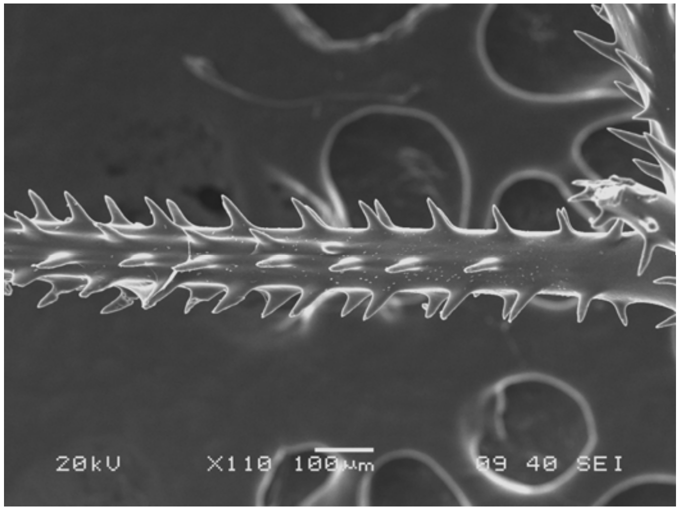
2.4 Close to *Antipathes atlantica/gracilis*

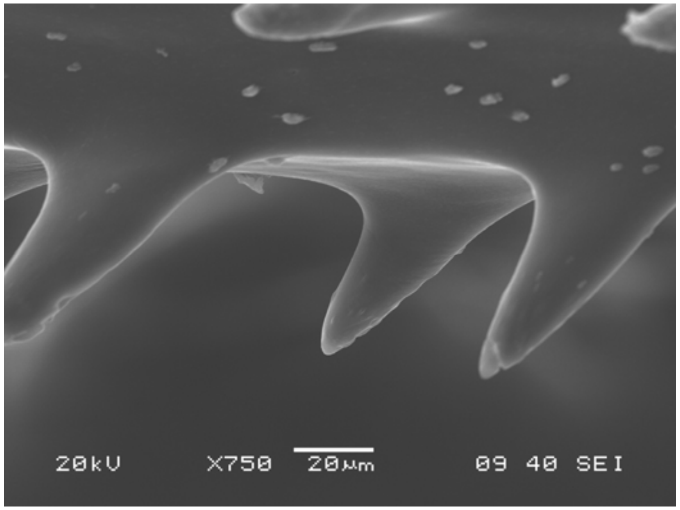




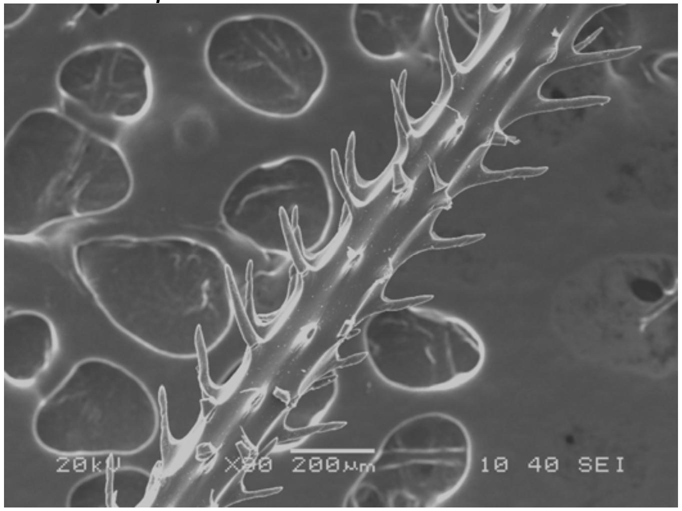


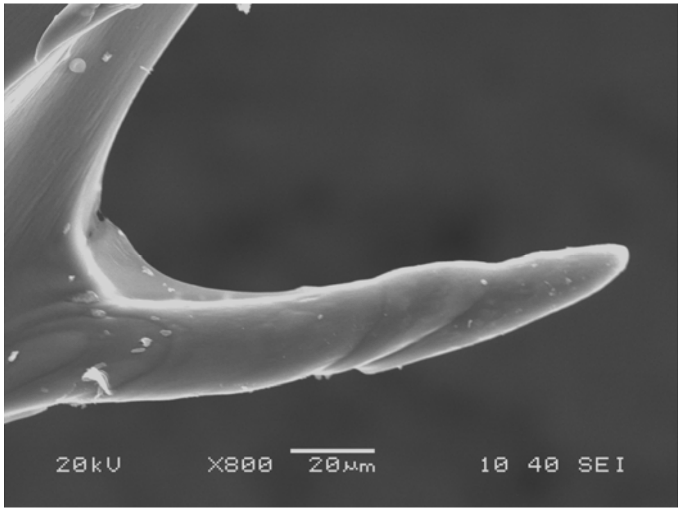
2.5 *Myriopathes*-like





2.6 *Plumapathes*-like





2.7 *Plumapathes*, *Tanacetipathes* or *Myriopathes*-like