FINAL REPORT

Fishery independent survey of commercially exploited fish and shellfish populations from mesophotic reefs within the Puertorrican EEZ

by:

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I. Executive Summary

Fishery independent surveys of commercially important fish and shellfish from mesophotic habitats within a 30 – 50 m depth range were performed at reef sites within the Puertorrican EEZ, Abrir la Sierra (ALS), Isla Desecheo (Des), and Bajo de Sico (BDS) during the period of February 2011 thru January 2012. Fish targets included large groupers (red hind, Nassau, yellowfin, black), snappers (mutton, cubera, dog, schoolmaster, yellowtail), large parrotfish (midnight, blue, rainbow), hogfish, queen triggerfish, lionfish, great barracuda, and sharks. Shellfish targets included spiny lobster and queen conch. Mesophotic benthic habitats at sites surveyed included reef tops, slope walls and rhodolith reefs at ALS; slope walls, patch reefs with colonized pavement and rhodolith reefs at Des; and rock reef promontories and rhodolith reef at BDS. The objectives of the study were: 1) to characterize the main species assemblages present from each of the benthic habitats and depths surveyed; 2) analyze variations of the species assemblages between sites; 3) provide rough estimates of population size for target species based on field estimated densities and benthic habitat areas at each site; 3) convey preliminary analysis of the status of the populations within the mesophotic habitats surveyed based on the length frequency data; 4) provide inferences of seasonal variations by species at ALS, with particular interest on queen conch; and 5) produce underwater video and photo documentation of the main benthic habitats and species observed.

A series of eight (8) belt-transects, approximately 250 m long x 6 m wide (1,500 m^2 each) were visually surveyed by rebreather divers from the three main mesophotic benthic habitats at each site. At ALS, three seasonal surveys were performed. The total sampling effort produced a total of 120 transects, covering a total area of 194,438 m^2 of benthic habitat from mesophotic reef sites within the Puertorrican EEZ. Visual (total) length estimates of each fish individual was recorded on each transect surveyed, as well as the cephalothorax length of spiny lobster. Total lengths and shell width (inside the lip) of queen conch were measured with a ruler. Fish/shellfish density data was reported as individuals/1000m^2.

Marked variations in the composition and abundance of several commercially important fish and shellfish populations between sites were noted. Higher abundance of queen conch, large snappers (mutton, dog, cubera) and hogfish were observed from at ALS, as compared to Des and BDS. Given the similarity of benthic habitat types between sites and the habitat plasticity exhibited by most of the aforementioned species, it is proposed that the sharp differences in population size and species composition of commercially important fish and shellfish populations is related to the recruitment enhancement effect provided by the within shelf connectivity between nursery and mesophotic habitats at ALS, compared to the partial isolation imposed by the oceanic barrier of Mona Passage separating Des and BDS from the PR shelf. Several populations evidenced marked preferences for particular benthic habitats. For example: more than 90 % of all queen conchs from all sites were observed from the rhodolith reef. Conversely, spiny lobsters, groupers, hogfishes, lionfishes and snappers, with the exception of mutton snapper, were more abundant at the reef top and slope wall habitats than at the rhodolith reef. Queen conch was more abundant during the August – September survey, coinciding with their peak reproductive season at ALS. Couples of queen conchs were observed engaged in copulation and egg masses discovered buried on the rhodolith habitat at depths ranging between 38 – 45

m (125 – 145 ‘) during the August-September survey season. Based on field density estimates at the various habitat types and the corresponding benthic habitat areas, it is calculated that the population of queen conch within mesophotic habitats of ALS was in the order of 20,000 to 30, 000 individuals during our 2011-12 survey period. As such, queen conch represents the most valuable stock within the PR EEZ area included in this survey. Queen conch stocks from mesophotic habitats at Des and BDS were estimated in the order of several hundred individuals.

Fish and shellfish population size assessments were constrained by the low proportion of the surveyed habitat relative to the total (e.g. 3.6 % at ALS; 4.5 % at BDS; unknown at Des) and the low numbers of individuals sighted, particularly for the large grouper/snapper assemblage. From the available data, stocks of red hind, schoolmaster snapper, lionfish and queen triggerfish were estimated in the low thousands (1,000 – 5,000 Ind) within mesophotic habitats at ALS, and in the low to mid hundreds at BDS. There is no data on benthic habitat areas for Des and thus, population estimates are not yet feasible from our survey data. Stocks of large groupers (Nassau, yellowfin, black) and snappers (cubera, dog, mutton) were estimated in the low to mid hundreds within mesophotic habitats at ALS, and in the low hundreds at BDS. Red hind presented a modal size just above the size at first reproduction, with a relatively low proportion of large individuals, and maximum size well under that reported for the Caribbean Antilles, which may be indicative of high fishing pressure on this species.

Large groupers (Nassau, yellowfin, blackfin) and snappers (cubera, dog, mutton), as well as hogfish and queen triggerfish all presented size distributions well over the length at first reproduction, with some individuals approaching the maximum sizes reported for the Caribbean Antilles, indicative that mesophotic habitats are prime residential, foraging, and reproductive grounds for adult fish and shellfish populations of commercial value within the PR EEZ. Within the constraints imposed by the small sample sizes, these data suggests that these stocks are presently not being overfished within the mesophotic habitats surveyed, and may support an alternative theory of ecosystem low carrying capacity, where in a scenario of relatively low availability of food resources, a few large individuals dominate large foraging areas. The scarcity of sharks evidenced during our surveys tends to support the theory of low carrying capacity that these mesophotic habitats naturally convey for large fish predators. Lionfish (*Pterois volitans*), conversely, exhibited a size distribution encompassing the entire range for the species, from settlement juveniles to maximum size adults, indicative that mesophotic habitats function as recruitment, residential, foraging and perhaps reproductive habitats for this species. The high proportion of large adult individuals in the population may be associated to the virtual lack of fishing pressure on this species.

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II. Introduction

Recent efforts to establish annual catch limits (ACL's) for commercially exploited fish and shellfish populations within the Caribbean EEZ have been constrained by the lack of fishery-dependent information on fishing effort, positive taxonomic identification of species, length data, geographic fishing locations, depths, and benthic habitats (CFMC, 2009). This situation has forced a management approach based on the grouping of species into "stock complexes" (e.g. groupers units, snapper units, parrotfish units) and the use of annual catch data as a proxy of maximum sustainable yield (msy). Within any "stock complex" there are relevant differences in life histories, depth and benthic habitat distribution between species, as well as broad inter-specific variations of catch vulnerability to any particular fishing gear. Seasonal and area fishing closures associated with spawning aggregations, in addition to hurricanes and other climatological hazards have introduced substantial variability into the historic annual catch data base, adding uncertainty into msy considerations. This is because of the significant catch declines associated with reduced or null fishing effort during spawning events when catch vulnerability is typically highest.

While there is an ongoing effort to improve the quality of fishery-dependent data through revised commercial fishermen catch reports, this is expected to contribute for management criteria on middle to long-term basis. Fishery-independent surveys, however, can provide a fast, short term assessment of the status of coral reef associated fishery stocks, their benthic habitat and depth preferences, and at the same time, contribute a much needed evaluation of overfished and/or protected species in closed fishing areas where monitoring assessments have not been possible.

Fishery independent assessments have been performed in Puerto Rico and the US Virgin Islands since 1992 as part of the Southeast Area Monitoring and Assessment Program Caribbean (SEAMAP-C) (Rosario 1994-2006; Jimenez 2006, Cummings et. al., 2007). The fisheries data from SEAMAP-C is largely based on fish trap and hand-line samplings off the west coast of Puerto Rico and south of St. John, USVI. Visual surveys of queen conch were performed, but restricted to shallow insular shelf areas (Marshack, 2007). Recent evaluations by the Southeast Data, Assessment and Review (SEDAR) panel suggest that SEMAP-C program may not be providing managers the information needed for making reliable stock assessment evaluation of

US Caribbean fishery resources (Cummings et. al., 2007). The main limitations are associated with narrow spatial and temporal coverage, lack of information regarding benthic habitats types where fishing effort is being addressed and a general paucity of information regarding large groupers and snappers, including protected species, such as the Nassau grouper (*Epinephelus striatus*) (Cummings et al., 2007). Other commercial targets that are not typically fished with either traps or hook and line remain as well under-sampled by the present SEAMAP-C program. Visual surveys have been recommended by the SEDAR panel as alternatives to supplement the existing fishery independent data from traps and hook and line sampling protocols (Cummings et al., 2007).

Mesophotic coral reef systems within the Puertorrican EEZ are known to function as residential and/or foraging habitats for large groupers and snappers, lobsters, conch and other commercially important species (García-Sais et. al. 2005, 2007, 2010a). The Caribbean Fishery Management Council (CFMC) has seasonally closed Bajo de Sico, Abrir la Sierra and Tourmaline Reefs to fishing in order to protect spawning aggregations of the red hind (*E. guttatus*) in those localities. In addition, permanent closure of the of queen conch (*Strombus gigas*) fishery is in effect at Abrir la Sierra. The CFMC needs to evaluate the role of these mesophotic reefs within the Puertorrican EEZ as critical habitats for coral reef associated fish and shellfish species of commercial value. As part of this undertaking by the CFMC, biological characterizations and/or benthic habitat maps of the sessile-benthic, motile megabenthic and demersal fishes associated with the main benthic habitats down to a depth of 50 m (165') are available for Isla Desecheo, Bajo de Sico, and Abrir La Sierra (García-Sais et. al. 2005, 2007, 2010a).

Because of their relatively low abundance, migratory behaviors and large home ranges, large demersal fishes, such as groupers and snappers, and motile megabenthic invertebrates, such as queen conch and spiny lobsters require large geographical scale survey approaches for population stock assessments. This study provides density and size (length) distribution estimates and seasonal demographic assessments of large demersal fishes and invertebrates associated with different benthic habitats and depths surveyed from mesophotic reefs within the Puertorrican EEZ (Abrir la Sierra, Bajo de Sico, and Isla Desecheo).

III. Study Objectives:

1) Characterize the main species assemblages of commercially important fish and shellfish populations present from each of the benthic habitats and depths surveyed
2) Analyze variations of the species assemblages between sites
3) Provide inferences of seasonal variations by species at ALS, with particular interest on queen conch
4) Produce rough estimates of population sizes for target species based on field estimated densities and benthic habitat areas at each site
3) Covey a preliminary analysis of the status of the commercially important fish and shellfish populations within the mesophotic habitats surveyed based on the length frequency data
5) Produce underwater video and photo documentation of the main benthic habitats and species observed

IV. Research Background

A. Caribbean Mesophotic Reefs – Research Background

Mesophotic coral ecosystems (MCEs) are characterized by the presence of light-dependent corals and associated communities that are typically found at depths between 30 – 150 m in tropical and subtropical regions (Hinderstein et al. 2009). Characterizations of reef habitats and associated sessile-benthic and fish communities from mesophotic reefs are rare in the Caribbean, and mostly available from submersible surveys. Colin (1974; 1976) described the taxonomic composition of reef fishes at depths between 90 – 305 m off the coasts of Jamaica, Belize and the Bahamas as a mixed assemblage of shallow reef (< 30 m) and true “deep-reef” species seldom present shallower than 50 m. Colin (1974) argued that the vertical distribution of some reef fish species was more related to habitat features than depth, and noted ontogenetic trends in the vertical distribution of “deep-reef” species, where juvenile stages were typically observed at shallower depths than adults. In Puerto Rico, the Seward Johnson- Sea Link submersible survey (Nelson and Appeldoorn 1985) provided a qualitative characterization of benthic habitats and associated fishes of the insular slope, encompassing depths between 100 – 1,250 m. Despite observations of a “rich and highly complex” reef fish community associated with the upper insular slope

(30 – 100 m), these habitats were left virtually undescribed by the Seward Johnson - Sea Link survey.

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

García-Sais et al. (2004) performed a survey of non-cryptic reef fish abundance and sessile-benthic substrate cover measurements from Black Jack Reef, a mesophotic coral reef in the south coast of Vieques Island. Most of the 54 fish species observed within a depth range of 30 - 40 m were common shallow (< 30 m) reef species also present within the neritic shelf of Vieques Island (García-Sais et al. 2004). Notable exceptions to the shallow reef assemblage were the presence of adult tiger groupers (*Mycteroperca tigris*) and mutton snappers (*Lutjanus analis*). From diver visual surveys and ichthyocide collections, Dennis et al. (2005) reported 111 fish species from reef sites in Mona Passage, including 32 from depths below 30 m at Mona Island. They proposed that the relatively impoverished ichthyofauna, compared to the mainland Puertorrican shelf reflects the limited habitat diversity of the island, and the “imperfect filtering” effect of the oceanic (Mona) passage on ichthyofaunal connectivity between islands. The assessment of fish richness from mesophotic habitats in Mona Island

must have been influenced by the type of habitat surveyed, since García-Sais et al. (2012) identified a total of 45 non-cryptic fish species off Playa Sardinera at depths between 30 – 40 m during a 30 min dive. Recent surveys of fish communities associated with mesophotic reefs in Puerto Rico have highlighted the relevance of these systems as habitats for large groupers and snappers and proposed management alternatives for their protection (García-Sais et al. 2005, 2007, 2010 a).

B. Study Sites - Research Background

1. Isla Desecheo

Isla Desecheo is an oceanic island in Mona Passage, located approximately nine nautical miles off Rincon, northwest coast of Puerto Rico (Figure 1). The island, which used to be a U. S. Navy shooting range during the Second World War, was designated as a Natural Reserve in 1999. The island is permanently closed to fishing along a 0.5 nautical mile perimeter from its shoreline, but there is very low surveillance and enforcement of fishery regulations. Marine communities at Isla Desecheo are influenced by clear waters, strong currents and seasonally high wave action from North Atlantic winter swells (cold fronts). Coral reefs are established off the west coast at depths between 15 m and (at least) 50 m. Reef stations at 15, 20 and 30 m depths off Puerto Botes and Puerto Canoas are included as part of the Puerto Rico national coral reef monitoring program since 1999 (García-Sais et al. 2010 b).

Mesophotic reef habitats at Isla Desecheo include a series of rock promontories colonized by sponges, corals, turf algae and other reef encrusting biota (colonized pavement habitats) along the shelf-edge in the northwest, north, and northeast section of the island. These mesophotic reef systems have not been quantitatively surveyed. The largest coral reef system is found on the southwest shelf and upper insular slope off Puerto Canoas, where a massive and impressive coral buildup has developed as a series of patch reef promontories separated by coralline sand deposits. Coral promontories are structurally comprised of several large colonies of Boulder Star Coral, *Montastraea faveolata* and other massive, branching and encrusting corals. There are colonies that rise from the seafloor almost four meters and extend horizontally more than five meters, in some instances merging with other large colonies to form

continuous laminar coral formations that are unique in Puerto Rico with live coral cover in excess of 50 %. After the 2005 regional coral bleaching event, live coral cover in this reef has declined more than 60% at depths between 15 – 30 m (García-Sais et al. 2012 and references therein). The shelf-edge used to be the residential habitat of a healthy population of Nassau and Yellowfin groupers (*Epinephelus striatus, Mycteroperca venenosa*) and Yellowtail and dog snappers (*Ocyurus chrysurus, Lutjanus jocu*), but recent snapshot surveys have observed only a few individuals of these demersal predators (García-Sais et al. 2012). Adult queen conchs (*Strombus gigas*) are typically found at depths between 25 – 30 m in the sand channels between reef promontories.

Quantitative surveys of sessile benthos and fish populations associated with reef habitats across a 15 – 50 m depth gradient were performed by direct diver observations using rebreathers at Isla Desecheo, Puerto Rico (Garcia-Sais, 2010c). Statistically significant differences between depths were found for total live coral, total coral species, total benthic algae, total sponges and abiotic cover. Live coral cover was higher at the mid-shelf (20 m) and shelf-edge (25 m) stations, whereas benthic algae and sponges were the dominant sessile-benthic assemblage at mesophotic stations below 25 m. Marked shifts in the community structure of corals and benthic algae were observed across the depth gradient. A total of 119 diurnal, non-cryptic fish species were observed across the depth gradient, including 80 species distributed among 7,841 individuals counted within belt-transects. Fish species richness and abundance were positively correlated with live coral cover. However, the relationship between total fish abundance and live coral was weak. Abundance of several numerically dominant fish species varied independently from live coral cover and appeared to be more influenced by depth and/or habitat type. Statistically significant differences in the rank order of abundance of fish species at euphotic versus mesophotic stations were detected. A small assemblage of reef fishes that included the cherubfish, *Centropyge argi*, sunshine chromis, *Chromis insolata,* greenblotch parrotfish, *Sparisoma atomarium*, yellowcheek wrasse, *Halichoeres cyanocephalus,* sargassum triggerfish*, Xanthichthys ringens,* and the longsnout butterflyfish, *Chaetodon aculeatus* were most abundant and/or only present from stations deeper than 30 m, and thus appear to be indicator species of upper mesophotic habitats.

A preliminary characterization of the main geophysical and biological features of the mesophotic reef zones along the southwest section of Isla Desecheo was provided by García-Sais et al. (2005). The shelf breaks at depths between 27 - 30 m with a steep slope of approximately 45° that ends at a depth of approximately 40 m (SW Wall Reef). The slope is heavily colonized by sponges and fleshy algae, mostly *Lobophora variegata*. A total of 23 scleractinian corals, three hydrocorals and two antipatharians (black corals) were reported for the SW Wall Reef with a mean substrate cover of 8.5 % in transects surveyed (García-Sais et al. 2005). The SW Wall Reef appears to be the residential habitat of red hinds (*Epinephelus guttatus*), spiny lobsters (*Panulirus argus*) and a foraging habitat of yellowfin groupers, cero mackerels, barracudas, reef sharks, jacks, and hawksbill turtles.

The SW Wall Reef ends in a gently sloping terrace of coralline sand with coral rubble that leads towards a vast deposit of rhodolith nodules extensively colonized by encrusting biota, including benthic algae (mostly *L. variegata*), erect and branching sponges and corals, forming a reef named Agelas for the high prominence of tube sponges, *Agelas spp*. This is a live hermatypic reef established at depths between 45 – 70 m on the southwest insular slope of Isla Desecheo (García-Sais et al. 2005; Ballantine et al. 2008). Large branching sponges dominate the benthic landscape with a mean substrate cover of 28 %. A total of 18 species of scleractinian corals, two hydrozoans and one antipatharian were identified from Agelas Reef. The combined mean substrate cover by nine coral species within transects surveyed was 13.1 % (range: 7.4 – 36.4 %). Irregular sheets of laminar coral, *Agaricia spp*. prevailed at depth between 45 – 53 m with a combined cover of 8.9 %. Fish species of commercial value include the red hind, present as juveniles and adults, and adult yellowfin grouper, which appear to forage at this deep mesophotic habitat.

2. Bajo de Sico

Supported by the multi-beam bathymetry survey performed by the R/V Nancy Foster (http://ccma.nos.noaa.gov/ecosystems/coralreef/usvi_nps.aspx), García-Sais et al. (2007) produced a map of benthic habitats at depths between 30 – 50 m at Bajo de Sico (BDS) and provided a baseline quantitative characterization of the sessile-benthic and demersal fish populations associated with the main benthic habitats at those depths. 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 (García-Sais et al. 2007).

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 3.6 % (or 0.4 km^2) is associated with rock promontories and more than 88 % corresponds to a deep shelf platform 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. A species rich and numerous assemblage of small, isolated encrusting colonies that contributed minimal topographic relief characterized growth of scleractinian corals at the reef top. Lettuce corals, mostly *Agaricia lamarcki* and *A. grahamae* 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 macroalgae 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 grew attached to rhodoliths, and were 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 a group of pelagic, highly migratory oceanic predators. Zooplanktivorous schooling fish populations were abundant at BDS and appeared to serve as the main forage for large pelagic and demersal piscivores 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 appeared to be influenced by the availability of microhabitats at the deep rhodolith reef and a small 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 also functions 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 is a foraging area for large migratory pelagic fishes, including the wahoo (*Acanthocybium solanderi*), mahi-mahi (*Coryphaena hippurus*), tunas (*Thunnus spp*.) and marlins (mostly *Makaira nigricans*). BDS is one of the most popular fishing grounds for recreational fishermen in the west coast of Puerto Rico.

3. Abrir La Sierra

Supported by the multi-beam bathymetry survey performed by the R/V Nancy Foster (http://ccma.nos.noaa.gov/ecosystems/coralreef/usvi_nps.aspx), García-Sais et al. (2010a) produced a map of benthic habitats at depths between 30 – 50 m at Abrir La Sierra (ALS) and provided a baseline quantitative characterization of the sessile-benthic and demersal fish populations associated with the main benthic habitats at those depths. ALS is a section of the shelf-edge and upper insular slope that runs north south along a stretch of approximately 6 km off the southwest coast of Puerto Rico (Figure 1). The profile of the study area is highly variable with a continuous ridge at the shelf-edge, and a series of adjacent secondary ridges within a deep outer shelf terrace submerged at depths from 30 - 50 m, extending offshore approximately 0.3 km. In many sections of the outer shelf at ALS, the seafloor rise to relatively narrow ridges of variable vertical and horizontal dimensions. The benthic habitat at the reef top and down the slopes is hard ground or pavement colonized by algae, sponges and some isolated corals that decline in abundance and diversity with increasing depth. At the reef top, red hinds (*Epinephelus guttatus)* are abundant, adult queen conch (*Strombus gigas*) are common, and several large yellowfin and Nassau groupers, hogfishes and dog snappers have been observed. Red Hinds continue being the most abundant grouper down to depths of 50 m, but a healthy population of black groupers (*Mycteroperca bonaci*), that include large, full grown individuals has been consistently observed at the outer slope at depths between 35 – 50 m.

In sections where a ridge is not present, the initial drop of the insular shelf slopes down to about 35 m then rises gradually until it almost flattens out into a gently sloping terrace where crustose algal nodules have accumulated, creating an extensive algal rhodolith deposit. This habitat was classified by NOAA as an algal plain, and was previously described for Isla Desecheo and Bajo de Sico by García-Sais et al. (2005, 2007) as an algal rhodolith reef. Rhodoliths are covered by dense mat of fleshy algae, particularly the encrusting fan alga, *Lobophora variegata*. Erect and branching sponges are also common in this habitat. Rhodolith nodules serve as attachment substrates for sponges and isolated, mostly laminar scleractinian corals (*Agaricia spp*.). This is the habitat where the largest aggregations of adult queen conch have been detected at ALS. A unique assemblage of fishes is present in this habitat. A total of 46 species were identified. Two species represented almost 58 % of the total individuals

within belt-transects; these were the bicolor damselfish (*Stegastes partitus*) and the cherubfish (*Centropyge argi*). In addition to the aforementioned species, the yellowhead jawfish (*Opistognathus aurifrons*), greenblotch parrotfish (*Sparisoma atomarium*), lantern bass (*Serranus baldwini*), yellowhead wrasse (*Halichoeres garnoti*), tobacco fish (*Serranus tabacarius*) and the bluehead wrasse (*Thalassoma bifasciatum*) represented the main fish assemblage in terms of abundance. Large pelagic and/or demersal fish predators were present in low abundance at the algal rhodolith reef habitat. Red hinds (*Epinephelus guttatus*) and queen triggerfish (*Balistes vetula*) appear to be the most common demersal predators, whereas the great hammerhead (*Sphyrna mokarran*) is undoubtedly the main pelagic predator and was also observed to reach to the bottom of the reef.

Coral reef habitats were discovered at depths between 30 – 40 m associated with protected coves in promontories located within the deep basin of Abrir la Sierra. Boulder star coral, *Montastraea annularis* appears to be the main structural reef component and was observed to be in good condition. Gorgonians were observed to be prominent in the reef and contribute substantially to the benthic habitat complexity. Large fishes, mostly snappers, groupers and hogfish tend to concentrate within these deep coral reefs increasing the biodiversity of the habitat.

V. Methods

Fishery independent surveys were performed at Abrir La Sierra, Bajo de Sico, and Isla Desecheo (Figure 1). A series of 8 belt-transects, approximately 250 m long x 6 m wide (1,500 m^2) were visually surveyed by rebreather divers on the three main benthic mesophotic habitats at each site to provide population density estimates of commercially valuable fish and shellfish. Fish targets included large groupers (red hind Nassau, yellowfin, black), snappers (mutton, cubera, dog, yellowtail), large parrotfish (midnight, blue, rainbow), hogfish, lionfish and sharks. Shellfish targets included spiny lobster and queen conch.

Mesophotic benthic habitats at sites surveyed included reef tops, slope walls and rhodolith reefs at ALS; slope walls, patch reefs with colonized pavement and rhodolith reefs at Des; and rock reef promontories and rhodolith reef at BDS. Surveys were performed once during the year at each of the main benthic habitats in BDS and Des. At ALS, a series of (3) quarterly surveys were conducted at each benthic habitat for evaluation of seasonal abundance patterns and demographic characterization of a large population of queen conch (*Strombus gigas*) at this site. The total sampling effort produced a total of 120 transects, covering a total area of 194,438 m^2 of benthic habitat from mesophotic reef sites within the Puertorrican EEZ managed by the Caribbean Fishery Management Council. The surveyed area represented 3.63 % and 4.56 % of the total mesophotic areas within the 30 – 50 m depth range at ALS and BDS sites, respectively. There is at present no benthic habitat map for Isla Desecheo. Visual (total) length estimates of each fish individual was recorded on each transect surveyed, as well as the cephalothorax length of spiny lobster. Total lengths and shell width (inside the lip) of queen conch were measured with a ruler. Fish/shellfish density data was reported as individuals/1000m^2.

Belt-transects were performed by a pair of rebreather divers drifting with the current. Transect location and geographic position at the point of entry was predetermined based on the information of benthic habitat location and depth available from benthic habitat maps (Garcia-Sais et al. 2007, 2010a) and multibeam bathymetry surveys (NOAA 2007). An effort was made to conduct drift dive surveys within a continuous benthic habitat, with the provision of achieving the most complete geographical.

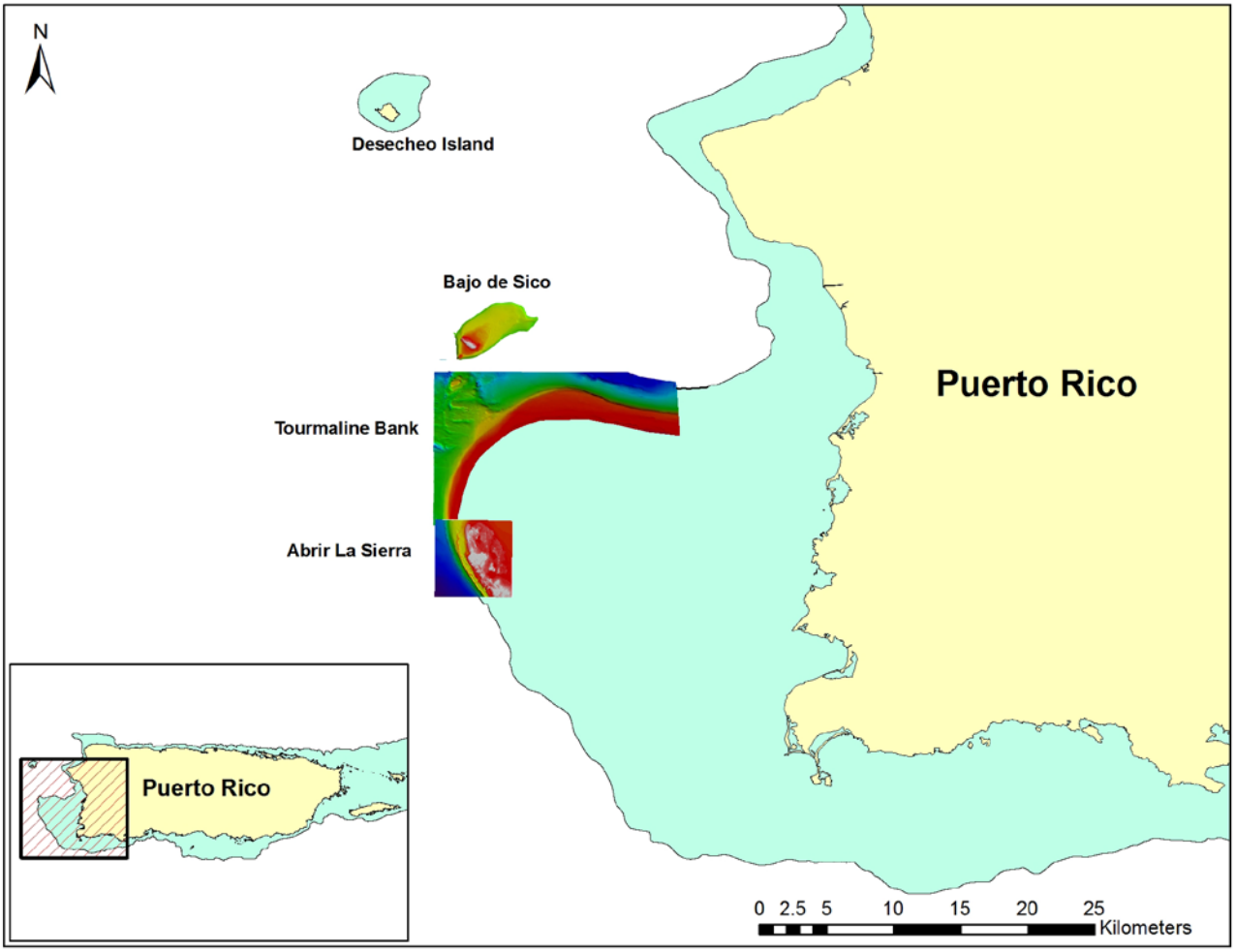


Figure 1. Location of proposed study sites, Abrir La Sierra, Bajo de Sico, and Isla Desecheo in Mona Passage, within the Puertorrican EEZ.

coverage of the main benthic habitats at each site. Transect ending positions were signaled by divers pulling down a surface buoy several times, followed by the support vessel recording of the GPS position where the buoy sank. Transect paths at ALS are shown in Figure 2. Information on geographic position, date of survey, area covered, habitat type, and depth for each of the 72 transects surveyed during the three seasons at each of the three main benthic habitats of ALS (reef tops, insular slope wall, rhodolith reef) are shown in Table 1.

Table 1. Geographic positions, depth and habitat supporting data for transects surveyed at Abrir la Sierra. 2011-12

			Start		End		Dist.	Area	Depth	
Trans	**Date**	**Seas**	**Lat (N)**	**Long (W)**	**Lat (N)**	**Long (W)**	**(m)**	**(m²)**	**(m)**	**Habitat**
1	2/2/11	1	18.07525	-67.42764	18.07175	-67.42547	450	3,600	30 - 35	Reef Top
2	2/2/11	1	18.07056	-67.42492	18.06987	-67.42416	110	880	30 - 35	Reef Top
3	2/2/11	1	18.07518	-67.42715	18.07693	-67.42686	215	1,720	30 - 35	Reef Top
4	2/2/11	1	18.07693	-67.42686	18.07807	-67.42696	125	1,000	30 - 35	Reef Top
5	2/3/11	1	18.07525	-67.42764	18.06777	-67.42261	985	7,880	30 - 35	Reef Top
6	2/3/11	1	18.06777	-67.42261	18.06528	-67.42117	315	2,520	30 - 35	Reef Top
7	2/3/11	1	18.06683	-67.42186	18.06528	-67.42117	185	1,480	30 - 35	Reef Top
8	2/3/11	1	18.06362	-67.41965	18.06106	-67.41781	345	2,760	30 - 35	Reef Top
40	9/1/11	2	18.06312	-67.41950	18.06502	-67.42100	265	2,120	30 - 35	Reef Top
41	9/1/11	2	18.06646	-67.42169	18.06853	-67.42328	285	2,280	30 - 35	Reef top
46	9/30/11	2	18.09652	-67.43501	18.09442	-67.43461	235	1,880	30 - 35	Reef Top
47	9/30/11	2	18.09301	-67.43438	18.09160	-67.43354	180	1,440	30 - 35	Reef Top
48	9/30/11	2	18.09463	-67.43421	18.09303	-67.43409	180	1,440	30 - 35	Reef Top
49	9/30/11	2	18.10018	-67.43466	18.09880	-67.43440	155	1,240	30 - 35	Reef Top
50	9/30/11	2	18.09995	-67.43311	18.10115	-67.43256	145	1,160	30 - 35	Reef Top
51	9/30/11	2	18.10337	-67.43422	18.10354	-67.43331	100	800	30 - 35	Reef Top
53	12/2/11	3	18.09625	-67.43312	18.09838	-67.43282	238	1,904	30 - 35	Reef Top
55	12/2/11	3	18.08632	-67.43328	18.08590	-67.43296	57	456	30 - 35	Reef Top
64	1/15/12	3	18.06422	-67.42014	18.06568	-67.42116	194	1,552	30 - 35	Reef Top
66	1/15/12	3	18.05893	-67.41603	18.06252	-67.41808	450	3,600	30 - 35	Reef Top
69	1/20/12	3	18.07410	-67.42700	18.07647	-67.42695	262	2,096	30 - 35	Reef Top
71	1/20/12	3	18.08265	-67.43172	18.08467	-67.43180	223	1,784	30 - 35	Reef Top
72	1/21/12	3	18.08757	-67.43282	18.08552	-67.43271	227	1,816	30 - 35	Reef Top
10	3/31/11	1	18.07834	-67.42694	18.07955	-67.42690	135	1,080	40 - 42	Rhodolith
12	3/31/11	1	18.08212	-67.42814	18.08372	-67.42827	180	1,440	40 - 42	Rhodolith
14	4/1/11	1	18.06820	-67.42215	18.06950	-67.42274	160	1,280	45 - 48	Rhodolith
16	4/1/11	1	18.07452	-67.42534	18.07601	-67.42497	170	1,360	36 - 40	Rhodolith
17	4/9/11	1	18.09134	-67.43065	18.09063	-67.43028	90	720	36 - 40	Rhodolith
19	4/9/11	1	18.08861	-67.43035	18.09055	-67.43057	215	1,720	36 - 40	Rhodolith
21	4/14/11	1	18.05870	-67.41444	18.05986	-67.41432	130	1,040	43 - 45	Rhodolith
23	4/14/11	1	18.06389	-67.41816	18.06525	-67.41803	150	1,200	45 - 50	Rhodolith
30	8/10/11	2	18.09134	-67.43065	18.09286	-67.43046	170	1,360	40 - 42	Rhodolith
31	8/10/11	2	18.08861	-67.43035	18.09012	-67.43033	165	1,320	40 - 42	Rhodolith
32	8/10/11	2	18.08632	-67.43021	18.08754	-67.42997	135	1,080	40 - 42	Rhodolith
33	8/10/11	2	18.08790	-67.43087	18.08871	-67.43068	90	720	40 - 42	Rhodolith
34	8/12/11	2	18.10056	-67.43214	18.10010	-67.43278	85	680	33 - 35	Rhodolith
35	8/12/11	2	18.09802	-67.42906	18.09712	-67.43035	170	1,360	33 - 35	Rhodolith
36	8/12/11	2	18.09980	-67.43185	18.09985	-67.43145	40	320	33 - 35	Rhodolith
37	8/12/11	2	18.09885	-67.43195	18.09917	-67.43256	75	600	33 - 35	Rhodolith
38	9/1/11	2	18.06901	-67.42260	18.06853	-67.42278	60	480	45 - 50	Rhodolith

Table 1. Continued

42	9/2/11	2	18.06437	-67.41890	18.06427	-67.41759	140	1,120	45 - 50	Rhodolith
44	9/2/11	2	18.06800	-67.42189	18.06824	-67.42238	60	480	45 - 50	Rhodolith
52	12/2/11	3	18.09381	-67.43309	18.09689	-67.43249	347	2,776	40 - 42	Rhodolith
54	12/2/11	3	18.09944	-67.43190	18.10324	-67.43107	430	3,440	36 - 40	Rhodolith
65	1/15/12	3	18.06559	-67.41903	18.06975	-67.42003	280	2,240	40 - 42	Rhodolith
67	1/15/12	3	18.06086	-67.41545	18.06204	-67.41616	150	1,200	40 - 42	Rhodolith
68	1/20/12	3	18.07556	-67.42579	18.07649	-67.42592	104	832	40 - 42	Rhodolith
70	1/20/12	3	18.07119	-67.42428	18.07274	-67.42435	171	1,368	40 - 42	Rhodolith
73	1/21/12	3	18.07926	-67.42743	18.08030	-67.42788	125	1,000	40 - 42	Rhodolith
9	3/31/11	1	18.07652	-67.42845	18.07823	-67.42919	205	1,640	38 - 40	Wall
11	3/31/11	1	18.07834	-67.42960	18.08017	-67.43007	210	1,680	38 - 40	Wall
13	4/1/11	1	18.06517	-67.42112	18.06646	-67.42169	155	1,240	40 - 43	Wall
15	4/1/11	1	18.06823	-67.42320	18.06967	-67.42393	175	1,400	40 - 43	Wall
18	4/9/11	1	18.09273	-67.43489	18.09524	-67.43494	280	2,240	36 - 40	Wall
20	4/9/11	1	18.08981	-67.43432	18.09214	-67.43483	265	2,120	36 - 40	Wall
22	4/14/11	1	18.05988	-67.41709	18.06104	-67.41762	140	1,120	40 - 42	Wall
24	4/14/11	1	18.06259	-67.41916	18.06520	-67.42054	325	2,600	40 - 42	Wall
25	8/9/11	2	18.07707	-67.42688	18.07686	-67.42814	205	1,640	33 - 40	Wall
26	8/9/11	2	18.07538	-67.42783	18.07775	-67.42909	295	2,360	33 - 40	Wall
27	8/9/11	2	18.08054	-67.43076	18.08299	-67.43205	305	2,440	33 - 40	Wall
28	8/9/11	2	18.08299	-67.43205	18.08550	-67.43269	285	2,280	33 - 40	Wall
29	8/9/11	2	18.07056	-67.42492	18.07358	-67.42669	385	3,080	33 - 40	Wall
39	9/1/11	2	18.06127	-67.41796	18.05976	-67.41704	195	1,560	40 - 43	Wall
43	9/2/11	2	18.07053	-67.42324	18.07101	-67.42375	75	600	40 - 43	Wall
45	9/2/11	2	18.06962	-67.42233	18.07035	-67.42228	80	640	40 - 43	Wall
56	12/8/11	3	18.07525	-67.42764	18.07706	-67.42880	235	1,880	36 - 40	Wall
57	12/8/11	3	18.06716	-67.42249	18.06866	-67.42352	199	1,592	40 - 42	Wall
58	12/8/11	3	18.07049	-67.42277	18.07244	-67.42390	247	1,976	36 - 40	Wall
59	12/8/11	3	18.07327	-67.42669	18.07549	-67.42769	268	2,144	36 - 40	Wall
60	12/9/11	3	18.06108	-67.41791	18.06246	-67.41904	194	1,552	36 - 40	Wall
61	12/9/11	3	18.06392	-67.41991	18.06515	-67.42091	172	1,376	36 - 40	Wall
62	12/9/11	3	18.07901	-67.42998	18.08056	-67.43078	191	1,528	36 - 40	Wall
63	12/9/11	3	18.08163	-67.43136	18.08339	-67.43217	213	1,704	36 - 40	Wall

Surveys at BDS were intended to characterize three benthic habitat types as previously reported (e.g. reef tops, wall and rhodolith reef), but the relatively small horizontal extension of reef tops and wall habitats within the rock promontories formation relative to the length of transects (Figure 3) and the evident continuity of the reef top and wall habitat for many large demersal and pelagic fishes led to the merging of the data from transects surveyed at these two later habitats within the main rock promontories. In total, 24 transects were surveyed at BDS, eight (8) corresponding to rhodolith reef and 16 corresponding to the reef top/reef wall habitat considered as one continuous habitat (Table 2). Reef habitats shallower than 30 m were not surveyed at BDS.

The main benthic habitats surveyed at Isla Desecheo included rhodolith reefs, patch coral reefs with sand channels, and reef tops. A benthic habitat map for Isla Desecheo is unavailable at present and somewhat limited our ability to characterize fish and shellfish populations associated with the main benthic habitats. A total of 24 transects were surveyed at Isla Desecheo (Table 3). Transect paths at Isla Desecheo are shown in Figure 4.

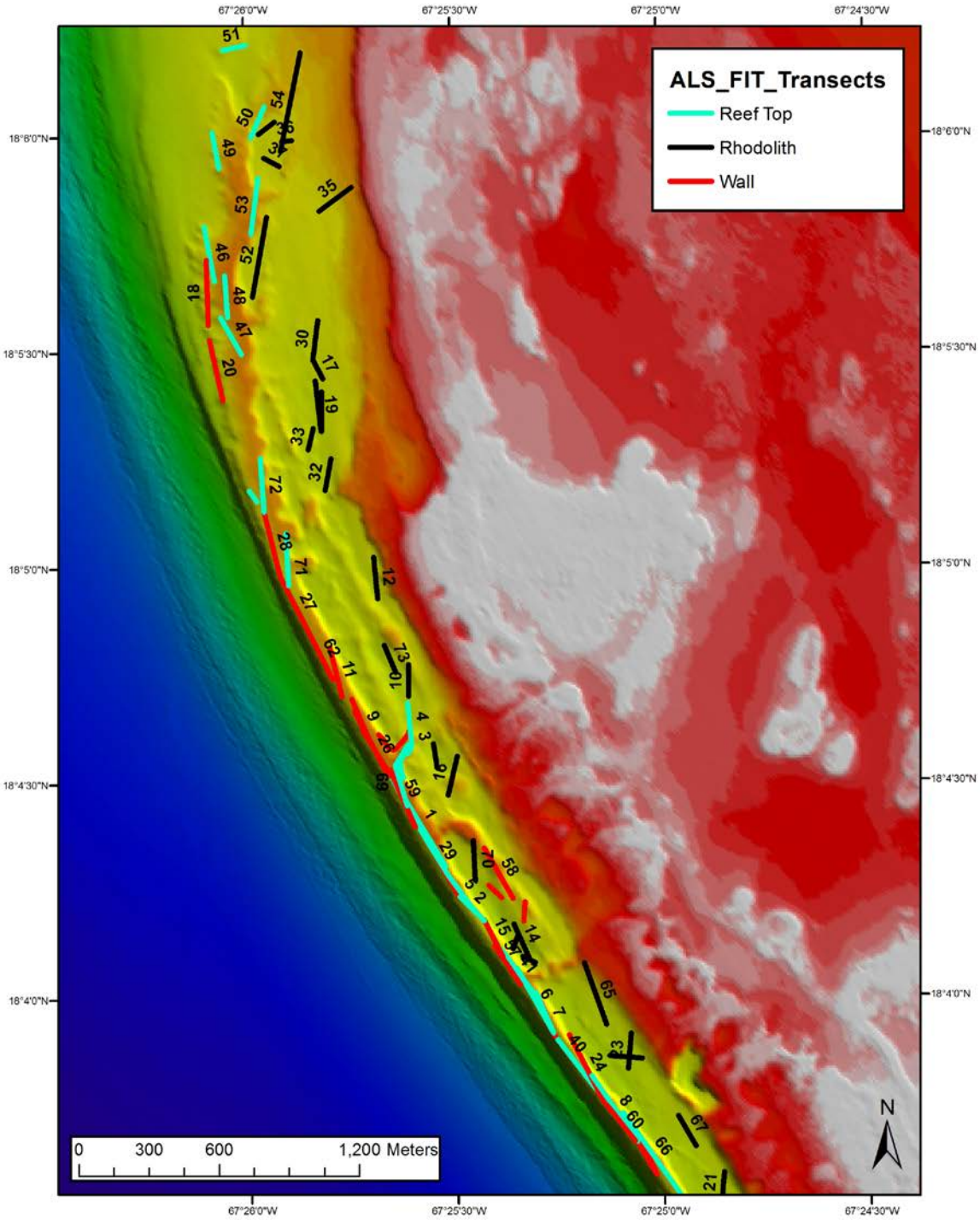


Figure 2. Paths of belt-transects surveyed at the main benthic habitats in Abrir la Sierra, 2011-12. Benthic habitat map from Garcia-Sais et al. (2010a)

Table 2. Geographic positions, depth and habitat supporting data for transects surveyed at Bajo de Sico, May - November 2011.

		Start		End		Dist.	Area	Depth	
Trans	**Date**	**Lat (N)**	**Lon (W)**	**Lat (N)**	**Lon (W)**	**(m)**	**(m²)**	**(m)**	**Habitat**
1	5/21/11	18.224	-67.423	18.225	-67.421	234.4	1,875.0	40-42	Rock Reef
2	5/21/11	18.225	-67.423	18.226	-67.421	257.7	2,061.7	33-36	Rock Reef
3	5/21/11	18.228	-67.429	18.227	-67.427	248.2	1,985.4	30-33	Rock Reef
4	5/21/11	18.227	-67.427	18.225	-67.425	301.0	2,407.7	30-33	Rock Reef
5	5/24/11	18.231	-67.430	18.232	-67.430	224.3	1,794.6	30-33	Rock Reef
6	5/24/11	18.231	-67.430	18.231	-67.430	113.6	908.7	30-33	Rock Reef
7	5/24/11	18.231	-67.431	18.231	-67.430	159.1	1,273.0	30-33	Rock Reef
8	5/24/11	18.229	-67.428	18.229	-67.426	233.3	1,866.2	36-40	Rock Reef
9	5/26/11	18.226	-67.423	18.228	-67.423	153.4	1,226.9	36-40	Rock Reef
10	5/26/11	18.226	-67.421	18.228	-67.420	192.3	1,538.5	36-40	Rhodolith
11	5/26/11	18.228	-67.426	18.229	-67.425	204.8	1,638.1	36-40	Rock Reef
12	5/26/11	18.229	-67.427	18.230	-67.425	184.4	1,474.9	36-40	Rock Reef
13	11/2/11	18.229	-67.429	18.231	-67.428	276.6	2,213.1	36-40	Rhodolith
14	11/2/11	18.230	-67.428	18.232	-67.426	294.4	2,355.1	36-40	Rhodolith
15	11/2/11	18.227	-67.424	18.227	-67.423	183.1	1,465.1	40-42	Rock Reef
16	11/2/11	18.229	-67.424	18.230	-67.424	148.0	1,184.2	40-42	Rhodolith
17	11/2/11	18.230	-67.430	18.232	-67.430	187.1	1,497.0	40-42	Rock Reef
18	11/3/11	18.228	-67.426	18.230	-67.425	155.6	1,245.2	40-42	Rock Reef
19	11/3/11	18.224	-67.428	18.226	-67.426	290.3	2,322.3	48-50	Rhodolith
20	11/3/11	18.224	-67.424	18.226	-67.422	320.7	2,565.9	36-40	Rock Reef
21	11/3/11	18.223	-67.425	18.226	-67.422	420.0	3,360.4	48-50	Rhodolith
22	11/10/11	18.231	-67.429	18.232	-67.431	225.8	1,806.6	36-40	Rhodolith
23	11/10/11	18.227	-67.426	18.229	-67.429	395.2	3,161.7	30-33	Rock Reef
24	11/10/11	18.223	-67.426	18.226	-67.427	288.5	2,308.2	36-40	Rhodolith

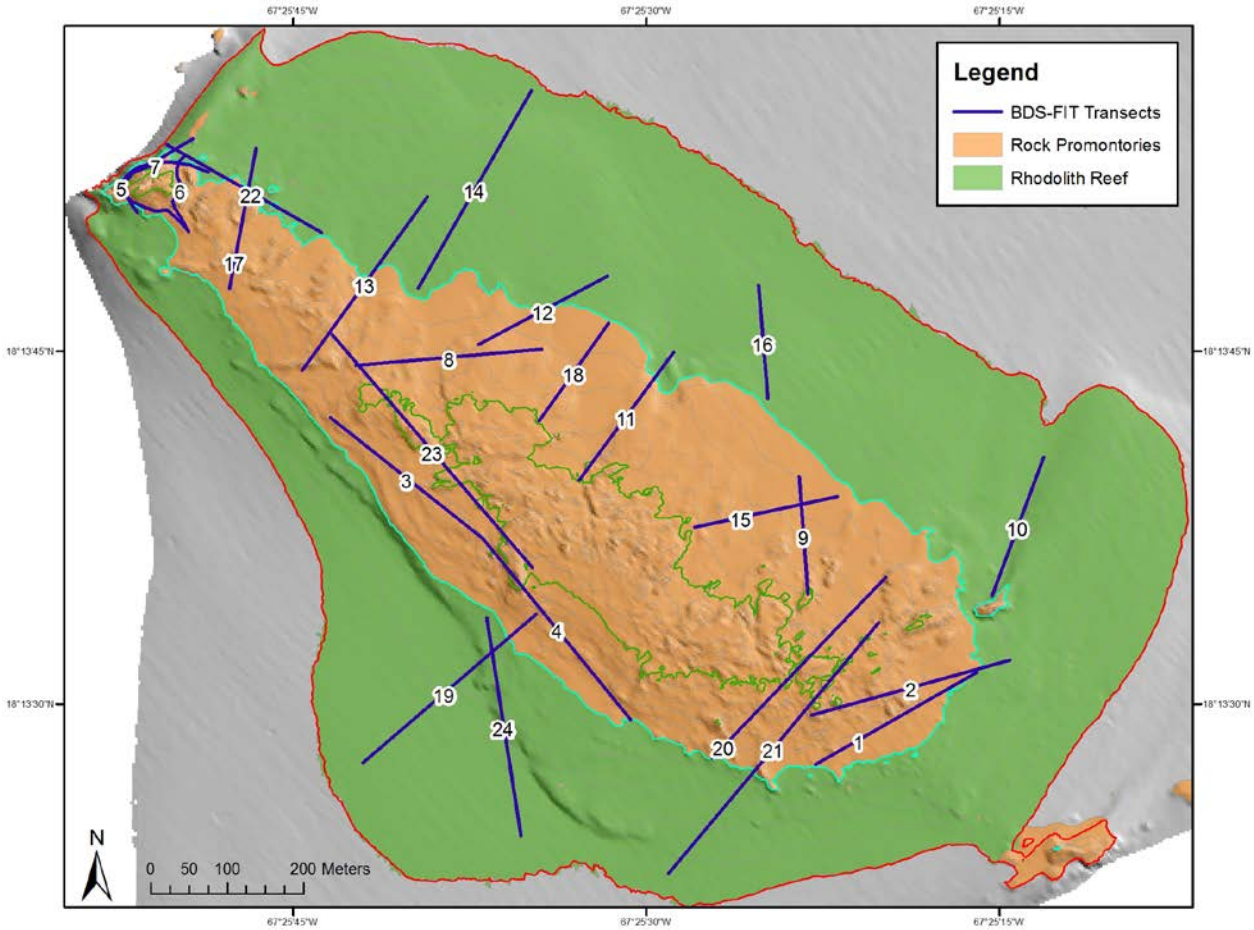


Figure 3. Paths of belt-transects surveyed at the main benthic habitats in Bajo de Sico. Benthic habitat map modified from Garcia-Sais et al. (2007). The dark green, light green, and red lines represent 30, 40 and 50 m depth contours.

Table 3. Geographic positions, depth and habitat supporting data for transects surveyed at Isla Desecheo, April - December 2011.

Trans	Date	Start Lat (N)	Lon (W)	Finish Lat (N)	Lon (W)	Dist (m)	Area (m2)	Depth (m)	Habitat
1	4/15/11	18.3781	-67.4868	18.3787	-67.4872	74.7	597.8	34-40	Wall
2	4/15/11	18.3781	-67.4868	18.3775	-67.4859	114.2	913.6	34-40	Wall
3	4/15/11	18.3775	-67.4859	18.3779	-67.4865	74.0	592.4	45-50	Rhodolith
4	5/20/11	18.3859	-67.4938	18.3864	-67.4935	64.8	518.4	45-50	Patch Reef
5	5/20/11	18.3930	-67.4911	18.3914	-67.4923	216.0	1,728.0	30-33	Sand/Col Pave
6	5/20/11	18.3828	-67.4913	18.3816	-67.4907	149.3	1,194.6	35-40	Wall
7	5/30/11	18.3858	-67.4693	18.3863	-67.4695	63.3	506.3	42-45	Sand
8	5/30/11	18.3873	-67.4699	18.3872	-67.4704	51.7	413.5	120ft	Patch Reef
9	6/7/11	18.3889	-67.4724	18.3886	-67.4723	30.1	240.9	35-40	Patch Reef
10	6/7/11	18.3941	-67.4763	18.3959	-67.4779	260.6	2,085.1	35-40	Coral Reef
11	6/7/11	18.3965	-67.4813	18.3958	-67.4853	433.1	3,464.9	30-33	Col Pave
12	6/9/11	18.3748	-67.4757	18.3767	-67.4731	348.1	2,784.5	35-40	Col Pave
13	6/9/11	18.3798	-67.4689	18.3819	-67.4672	292.3	2,338.2	45-50	Rhodolith
14	6/9/11	18.3913	-67.4728	18.3896	-67.4732	201.2	1,609.7	35-40	Patch Reef
15	6/9/11	18.3907	-67.4743	18.3921	-67.4754	193.9	1,551.3	30-33	Coral Reef
16	6/9/11	18.3940	-67.4770	18.3943	-67.4766	54.1	433.1	30-33	Coral Reef
17	11/11/11	18.3838	-67.4687	18.3822	-67.4695	200.1	1,601.0	45-50	Col Pave
18	11/11/11	18.3850	-67.4703	18.3828	-67.4692	270.3	2,162.4	30-33	
19	11/11/11	18.3981	-67.4796	18.3988	-67.4800	85.2	681.6	35-40	Patch Reef
20	11/11/11	18.3962	-67.4824	18.3973	-67.4832	150.7	1,205.5	30-33	
21	12/1/11	18.3782	-67.4870	18.3792	-67.4877	124.6	997.2	45-50	
22	12/1/11	18.3792	-67.4878	18.3798	-67.4894	176.5	1,411.7	35-40	Sand/Rhodolith
23	12/1/11	18.3852	-67.4940	18.3868	-67.4939	172.0	1,375.8	45-50	
24	12/1/11	18.3772	-67.4839	18.3786	-67.4850	196.3	1,570.0	30-33	

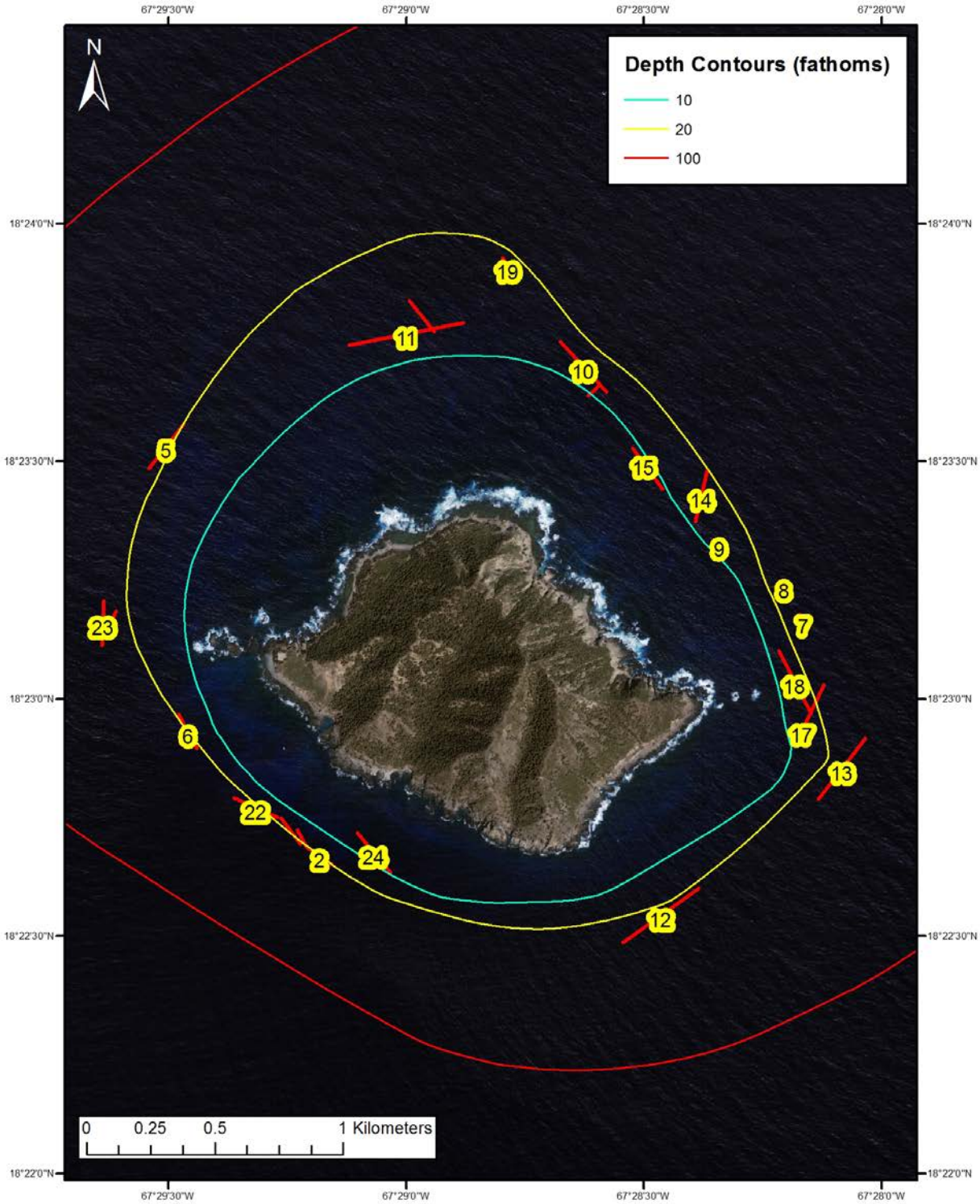


Figure 4. Paths of belt-transects surveyed at Isla Desecheo during 2011.

VI. Results and Discussion

A. Population estimates and benthic habitat distributions of commercially important fish and shellfish at study sites within the US-PR EEZ: Abrir la Sierra, Bajo de Sico and Isla Desecheo.

1. Abrir la Sierra (ALS)

A total of 932 fish and 681 shellfish individuals, comprised by 18 species of fish and two (2) of shellfishes were identified during three (3) seasonal surveys of mesophotic habitats at ALS (Table 4). Three main reef benthic habitats within the 30 – 50 m depth range were surveyed, including reef tops (30 – 35 m), shelf-edge walls (40 – 50 m), and rhodolith reef banks (35 – 50 m). Quantitative and qualitative characterizations of predominant sessile-benthic and demersal-territorial fish assemblages from these benthic habitats were previously reported by Garcia-Sais et al. (2010a). The total surface area of benthic habitats surveyed by 72 belt-transects at ALS was 116,926 m^2, which represents approximately 3.63% of the total surface area at this site within the 30 – 50 m depth range. The mean area covered per transect was 1,624 m^2. Surveys at reef tops (42,318 m^2) and shelf-edge walls (42,392 m^2) covered a larger area than at rhodolith reefs (32,216 m^2) due to the higher density of queen conch at this later habitat, which required direct shell measurements by divers drifting along belt-transects.

The most abundant target species found from mesophotic habitats at ALS was the queen conch (*Strombus gigas*). A total of 672 individuals were observed within belt-transects during the three seasonal surveys at ALS, of which 628 or 93.4 % were from the rhodolith reef habitat (Figure 5). Queen conchs were observed throughout the 30 – 50 m mesophotic depth range at ALS, but were more abundant within the 35 -50 m depth that encompasses the rhodolith habitat at ALS (Table 4). The rhodolith reef habitat at ALS is distributed throughout the basin of a false shelf drop-off that characterizes the south and central sections of ALS, encompassing the 35 – 50 m depth range (Garcia-Sais et al. 2010a). Rhodoliths were heavily colonized by benthic macroalgae and other encrusting biota. Although queen conch were observed throughout the habitat, it was noted that the higher concentrations were associated with a sandy interface at the edge of the inner walls of the rhodolith basin at depths of 35 – 38 m.

Table 4. Total numbers of fish and shellfish individuals sighted at mesophotic benthic habitats from Abrir la Sierra during 2011

Abrir La Sierra	**Season 1**			**Season 2**			**Season 3**			
	Reef			Reef			Reef			
Habitat	**Top**	**Wall**	**Rhod**	**Top**	**Wall**	**Rhod**	**Top**	**Wall**	**Rhod**	**TOTALS**
T. Area Surveyed (m2)	15,954	14,040	9,840	11,060	14,600	9,520	15,304	13,752	12,856	**116,926**
Fish Species										
Epinephelus guttatus	69	56	21	40	45	9	24	20	12	**296**
Pterois volitans	41	54	2	23	39		52	17	4	**232**
Lutjanus apodus	140									**140**
Balistes vetula	5	4		7	3	3	18	4	10	**54**
Lutjanus analis	2	7	4	7	3	6	1	1	9	**40**
Elagatis bipinnulata	11				1			12		**24**
Sphyraena barracuda	2	1		3	6		2	4	4	**22**
Lactophrys spp.	2	5	2	3			5		2	**19**
Lachnolaimus maximus		2	2	6	2		3		2	**17**
Scomberomorus regalis				1	12		2	1	1	**17**
Mycteroperca venenosa	2	1		2	7		3	1		**16**
Lutjanus cyanopterus	4	2			7		1	1		**15**
Lutjanus jocu	5				1		6	1		**13**
Ginglymostoma cirratum	1	1	1	4			1	1		**9**
Ocyurus chrysurus				6					2	**8**
Epinephelus striatus	1	1					3			**5**
Mycteroperca bonaci					1		3			**4**
Sphyrna mokarran							1			**1**
Shellfish Species										
Strombus gigas	7	5	129	8	9	307	15		192	**672**
Panulirus argus		3		1	1		2	2		**9**

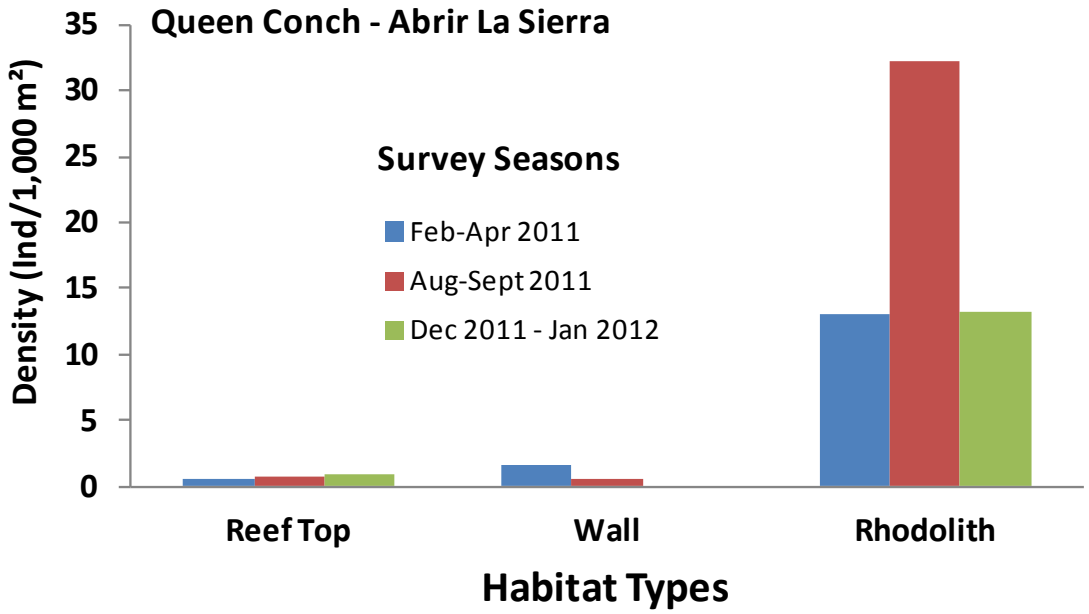


Figure 5. Distribution of queen conch, *Strombus gigas* from mesophotic benthic habitats (30 – 50 m) surveyed at Abrir La Sierra during 2011.

During September 2011 queen conch were observed engaged in copulation and eggs masses buried in the rhodolith habitat were discovered at depths 38-40 m. Peak density of queen conch (32.2 Ind/1000 m^2) was recorded at the rhodolith habitat during the August-September 2011 survey season (Figure 5).

Mean abundances and population size estimates of queen conch and other fish and shellfish targets of the commercial trade in Puerto Rico are presented in Table 5. Based on the population densities at the different habitats surveyed and the surface area of each habitat it is here estimated that at the time of our survey the population size of queen conch from mesophotic habitats in ALS was in the order of 29,092 individuals, of which 95.8 % were residents of the rhodolith reef habitat at depths of 35 – 50 m. We believe this to be a conservative estimate given the cryptic condition of queen conch in the rhodolith habitat heavily camouflaged with algae, sponges and other encrusting biota, which undoubtedly influenced some level of escape from diver's visual detection during surveys. Relatively large colonies of the fire hydrocoral, *Millepora alcicornis* (typically found in shallow reef areas) growing on the shell of several queen conchs observed from the rhodolith habitat during this survey suggest

Table 5. Estimates of density and population size of commercially important fish and shellfishes from belt-transects surveyed at Abrir la Sierra during 2011

	Reef					
Habitat	**Top**	**%**	**Wall**	**%**	**Rhod**	%
T. Area Surveyed (m^2)	42,318	2.6	42,392	29.4	32,216	2.3
T. Area Habitat (10^3m^2)	1,643.0		144.0		1,430.2	
	Mean	**Total**	**Mean**	**Total**	**Mean**	**Total**
Fish Species	**Ind/10^3m^2**	**Ind/habitat**	**Ind/10^3m^2**	**Ind/habitat**	**Ind/10^3m^2**	**Ind/habitat**
Epinephelus guttatus	3.14	5,164	2.85	411	1.30	1,865
Pterois volitans	2.74	4,504	2.59	374	0.19	266
Lutjanus apodus	3.31	5,436	0.00	-	0.00	-
Balistes vetula	0.71	1,165	0.26	37	0.40	577
Lutjanus analis	0.24	388	0.26	37	0.59	843
Elagatis bipinnulata	0.26	427	0.31	44	0.00	-
Sphyraena barracuda	0.17	272	0.26	37	0.12	178
Lactophrys spp.	0.24	388	0.12	17	0.12	178
Lachnolaimus maximus	0.21	349	0.09	14	0.12	178
Scomberomorus regalis	0.07	116	0.31	44	0.03	44
Mycteroperca venenosa	0.17	272	0.21	31	0.00	-
Lutjanus cyanopterus	0.12	194	0.24	34	0.00	-
Lutjanus jocu	0.26	427	0.05	7	0.00	-
Ginglymostoma cirratum	0.14	233	0.05	7	0.03	44
Ocyurus chrysurus	0.14	233	0.00	-	0.06	89
Epinephelus striatus	0.09	155	0.02	3	0.00	-
Mycteroperca bonaci	0.07	116	0.02	3	0.00	-
Sphyrna mokarran	0.02	39	0.00	-	0.00	-
						-
Shellfish Species						-
Strombus gigas	0.71	1,165	0.33	48	19.5	27,879
Panulirus argus	0.07	116	0.14	20	0.00	-

that these conch individuals were residents of shallower habitats during previous stages of their life cycle. A small population of queen conch was associated with the colonized pavement with sand habitat of the reef top (1,165 Individuals, or 0.7 Ind/1000 m^2). Queen conchs were present, but in very low density (0.3 Ind/1000 m^2) at the vertically projected habitat of the slope walls.

The spiny lobster, *Panulirus argus*, the other shellfish species of commercial value targeted by our belt-transect surveys were observed at the reef top and slope wall habitats in very low densities (e.g. 0.07 and 0.14 Ind/1000 m^2, respectively), yielding a population estimate in the order of only 136 individuals (Table 5). Spiny lobsters were not observed from the rhodolith habitat, where there was no protective habitat for them. In general, mesophotic habitats at ALS were not characterized by the high availability of protective habitat, such as coral reef buildups or any sedimentary origin reef structure contributing underwater topographic relief. Perhaps, basket sponges, *Xestospongia muta* represented the most important agent contributing topographic relief from mesophotic habitats at ALS. Therefore, the lack of spiny lobsters and fishes that require protective structures as residential habitat is probably associated with the generally flat and low rugosity seafloor features that prevail at ALS in the 30 – 50 depth range. Aside from the limited habitat availability, spiny lobsters could be under severe predation pressure by nurse sharks, *Ginglymostoma cirratum*, a known top predator of spiny lobsters that was observed to be present at the reef top of ALS.

Among fish species of commercial value, the red hind, *Epinephelus guttatus* was the species observed in highest densities from mesophotic habitats of ALS. Red hinds were present from all three benthic habitats surveyed, but were observed in higher densities at the reef top (3.1 Ind/1000 m^2) and slope wall (2.8 Ind/1000 m^2) habitats (Figure 6). Density of red hinds was consistently higher during the February thru April survey season at all three mesophotic benthic habitats surveyed (Figure 7). Such peak densities coincided with their known spawning aggregations at ALS. It is possible that the higher densities respond in part to migrations of additional individuals from shallower sections of the insular shelf, since it is evident from these data that mesophotic habitats at ALS are natural residential grounds for red hind. Another possibility is that red hinds become more active during their reproductive season and are therefore more visible to divers performing visual surveys.

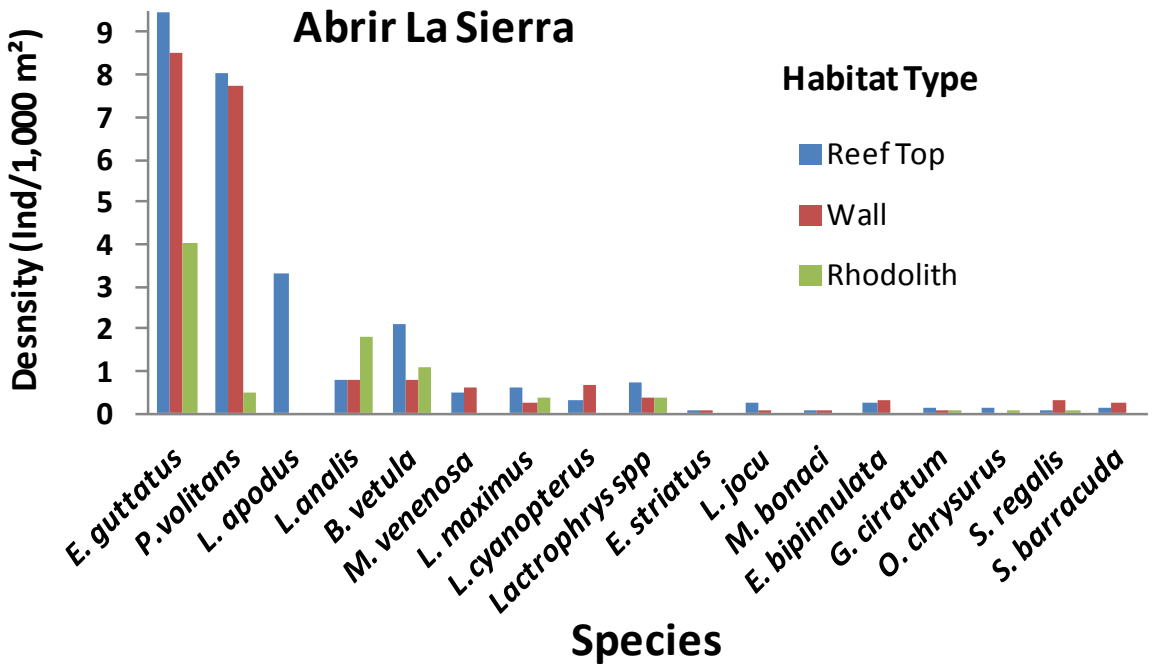


Figure 6. Distribution by mesophotic benthic habitat of fish individuals surveyed by belt-transects at Abrir La Sierra during 2011.

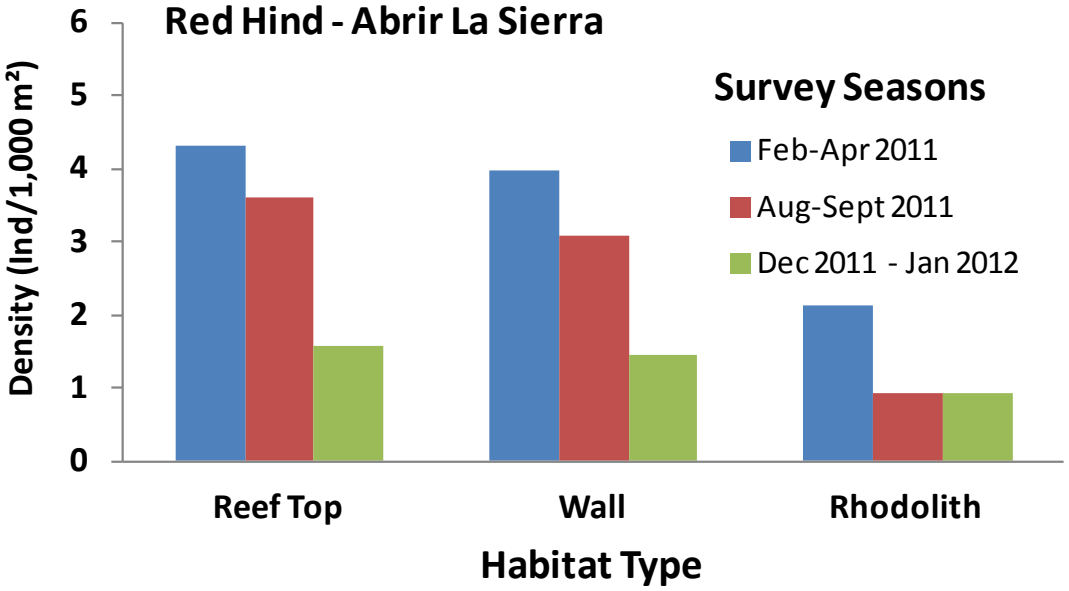


Figure 7. Seasonal variations of red hind, *Epinephelus guttatus* density at mesophotic benthic habitats of Abrir La Sierra surveyed during 2011

From the specific densities at each habitat surveyed and the surface area of each habitat, it is here estimated that the population size of red hinds within the mesophotic habitats of ALS was in the order of 7,440 Individuals, of which 5,160 Individuals or 69.4 % were associated with the reef top (Table 5). Although density of red hinds at the rhodolith reef were the lowest recorded, the total population within this habitat represented 25.0 % of the total, due to the higher surface area of the rhodolith habitat (1,430 x $10^3 m^2$) relative to the surface area of the slope wall (144 x $10^3 m^2$).

Larger grouper populations, such as the yellowfin, black (*Mycteroperca venenosa, M. bonaci*) and Nassau (*Epinephelus striatus*) were present within mesophotic habitats of ALS. These were observed mostly from the reef top and slope wall habitats (Table 4). Yellowfin grouper, with 16 individuals observed was the most abundant of the large groupers at ALS (Figure 6), with average densities over the three seasonal surveys ranging between 0.17 and 0.21 Ind/1000 m^2 at the reef top and slope wall habitats. Peak density was observed off the insular slope wall during the August – September period, but marked seasonal patterns of higher density, nor reproductive aggregations were evident for *M. venenosa* at mesophotic habitats of ALS (Figure 8). Yellowfin groupers were seen mostly swimming in pairs apparently foraging the areas, since in most instances, there was no protective reef structure to serve as residential habitat. Based on the average densities of the three seasonal surveys on each habitat, the population of yellowfin grouper within mesophotic habitats of ALS, largely the reef top and wall of the insular shelf is estimated in the order of 300 individuals (Table 5).

Only five (5) Nassau groupers were observed within mesophotic habitats at ALS during the three seasons surveyed (Table 4). Nassau groupers were observed to be more common on coral reef habitats typically distributed above the mesophotic depths of our study area, mostly in the 20-28 m range. Black groupers were represented by only four (4) individuals in our three seasonal surveys of mesophotic habitats in ALS (Table 4). These were mostly seen at the outer edge of the reef top, but most individuals were observed below our diving depth of 50 m on deeper sections of the slope wall. Although very few individuals were observed within our belt-transect areas, their presence outside transects suggests that the insular slope wall represents the prime residential habitat of black groupers at ALS. Their population size within our study area was estimated in the order of 119 individuals (Table 5).

The lionfish*, Pterois volitans* ranked as the second most abundant fish species of (potential) commercial value within mesophotic habitats of ALS (Table 4). A total of 232 individuals were observed during the three (3) survey seasons at ALS. Lionfish were present from all mesophotic habitats (Figure 6), but in much higher densities (2.7 and 2.6 Ind/1000 m^2) at the reef top and slope wall than at the rhodolith reef (Figure 9). No clear seasonal density variations were noted at any of the mesophotic benthic habitats surveyed. Lionfishes were typically observed in small to moderate aggregations of 2 – 10 individuals associated with protective habitats of the reef top and slope wall. They were rare at the rhodolith reef (0.4 Ind/1000 m^2), where there were no protective structures available, but a few individuals were present out in the open seafloor. Lionfishes were present at the wall down to the maximum depth surveyed of 50 m. Their total population from mesophotic habitats at ALS was estimated in the order of 5,144 individuals (Table 5).

Snappers (Lutjanidae) were represented by four (4) species of commercial value within mesophotic habitats of ALS. The most abundant was the schoolmaster snapper, *Lutjanus apodus* with a total of 140 individuals observed during the three seasonal surveys (Figure 6). All schoolmasters here reported correspond to one large school that was detected during one dive at a depth of 32 m on the reef top of ALS. Schoolmasters were more typically observed within coral reef habitats of the neritic shelf. Mutton snapper, *L. analis* were observed from all mesophotic benthic habitats, throughout the 30 – 50 m depth range, and across the three seasonal surveys conducted at ALS without depicting any marked seasonal pattern (Figure 10). A total of 40 individuals were observed, of which 19 were present within the rhodolith reef habitat. Average densities over the three seasonal surveys ranged between a minimum of 0.2 Ind/1000 m^2 at the reef top, and a maximum of 0.6 Ind/1000 m^2 at the rhodolith reef. Based on the specific habitat densities and the habitat areas, it is estimated that the total population from mesophotic habitats of ALS during our study was in the order of 1,268 individuals (Table 5). Because of the higher densities of mutton snapper at the rhodolith reef and the larger habitat surface area, it is estimated that 66.5 % of mutton snappers from mesophotic habitats correspond to the rhodolith reef. Mutton snappers appear to be most of the time in transition between mesophotic habitats at ALS and may have been attracted to divers. When divers fish for queen conch at the

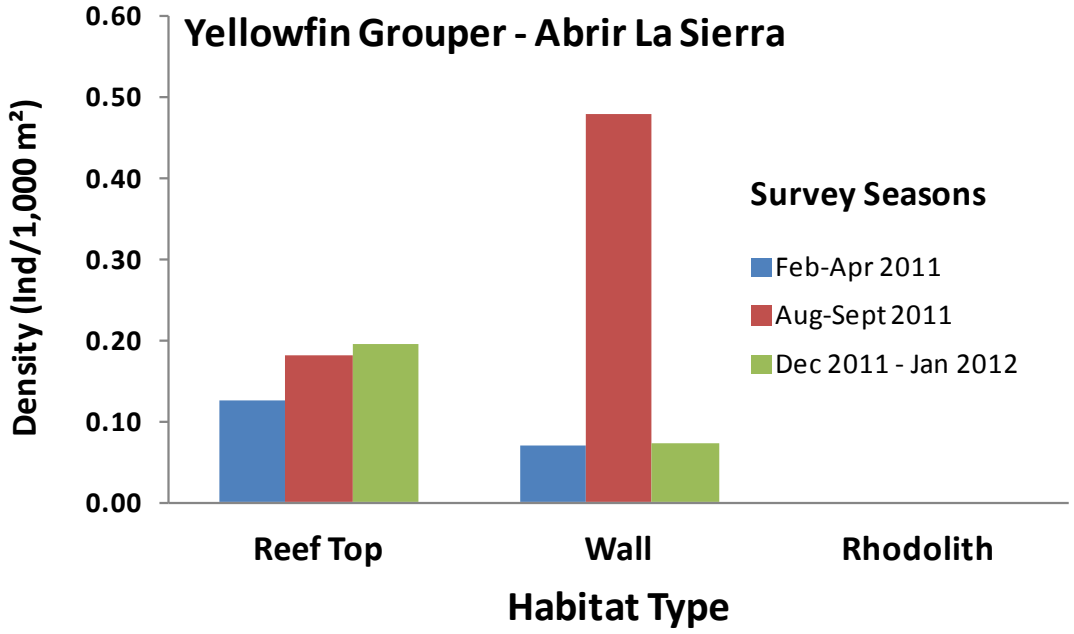


Figure 8. Seasonal variations of yellowfin grouper, *Mycteroperca venenosa* density at mesophotic benthic habitats of Abrir La Sierra surveyed during 2011

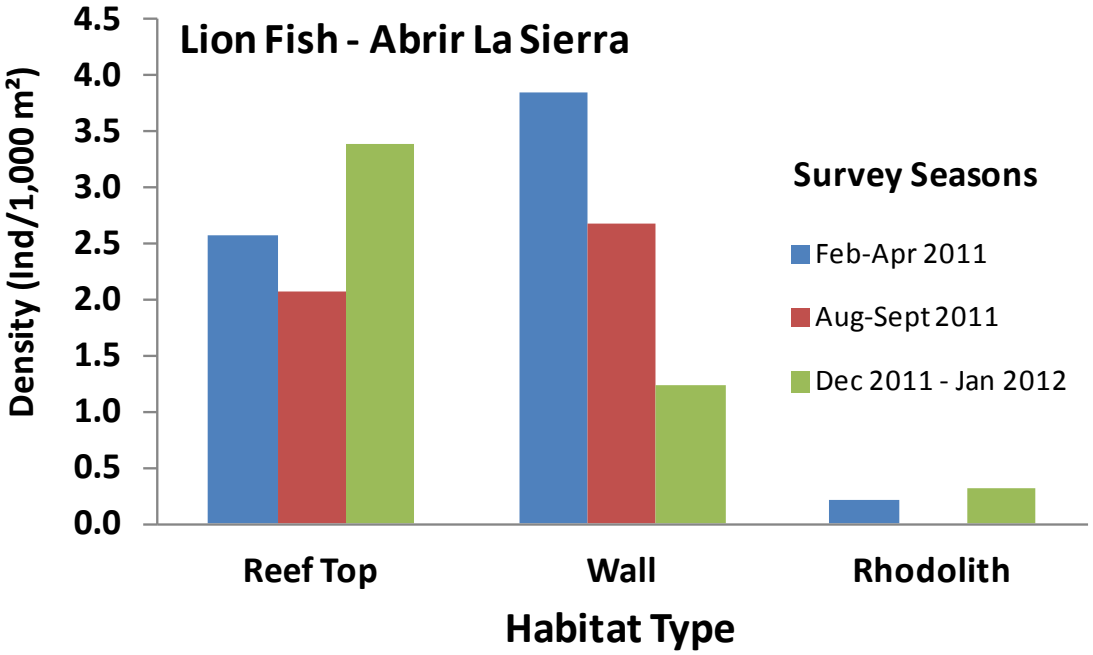


Figure 9. Seasonal variations of lionfish, *Pterois volitans* density at mesophotic benthic habitats of Abrir La Sierra surveyed during 2011

rhodolith reef and extract the animal from the shell underwater, mutton snapper feed on the gut and remains of the queen conch. Thus, mutton snappers, as well as other benthic predators, including nurse, reef and hammerhead sharks seem to associate divers with feeding on conch remains at ALS.

Cubera snappers, *L. cyanopterus* were observed at the reef top and wall habitats of ALS (Table 4). A total of 15 individuals were observed, 10 of which were present at the wall (Figure 6). Based on average densities over the three seasonal surveys of 0.1 and 0.2 Ind/1000 m^2 at the reef top and slope wall habitats, it is estimated that the total population of cubera snappers within mesophotic habitats of ALS was in the order of 228 individuals at the time of our survey (Table 5). Dog snapper, *L. jocu* were also sighted only from the reef top and slope wall habitats, but with 11 out of 13 total individuals observed from the reef top (Table 4). Dog snappers are known to form spawning aggregations at depths of 40 – 45 m over horizontal habitats of sand and patch reefs at El Seco, southeast Vieques (Garcia-Sais et al. 2011). Thus, their sharp decline of abundance below 35 m at ALS may be more related to the acute slope and benthic habitat features of the insular slope wall than to depth proper. Nevertheless, peak abundances of dog snappers at El Seco were reported to occur from mesophotic coral reef habitats within the 35 – 45 m depth range (Garcia-Sais et al. 2011). Based on survey densities of 0.3 and 0.05 Ind/1000 m^2 at the reef top and slope wall habitats, it is estimated that the total population of dog snappers within mesophotic habitats of ALS was in the order of 434 individuals at the time of our survey (Table 5). Yellowtail snappers (6 individuals) were observed during one dive at the reef top of ALS. These appeared to be more common at the shelf-edge and tended to stay in mid-water, above mesophotic zones.

Queen triggerfish, *Balistes vetula* were present from all mesophotic habitats surveyed at ALS (Figure 6). A total of 54 individuals were observed, of which 28 or 51.8 % were from the reef top (Figure 11). Average density of queen triggerfish over the three seasonal surveys was also highest at the reef top (0.7 Ind/1000 m^2) and lowest at the insular shelf wall (0.3 Ind/1000 m^2). Peak densities were observed during the December 2011 – January 2012 survey at reef top and rhodolith habitats (Figure 11).

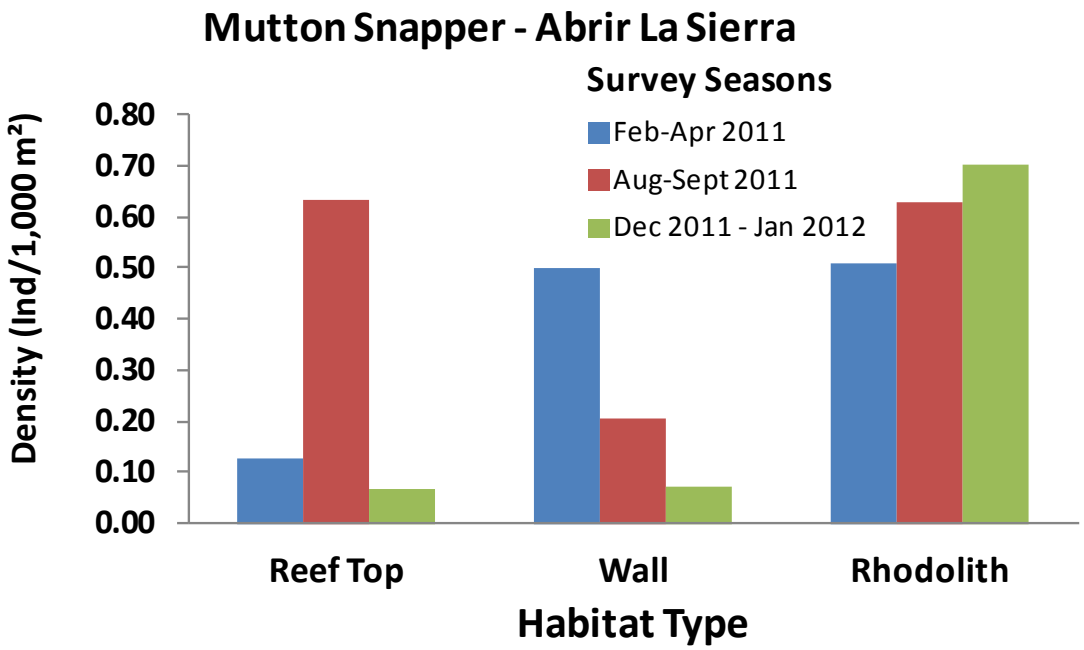


Figure 10. Seasonal variations of mutton snapper, *Lutjanus analis* density at mesophotic benthic habitats of Abrir La Sierra surveyed during 2011

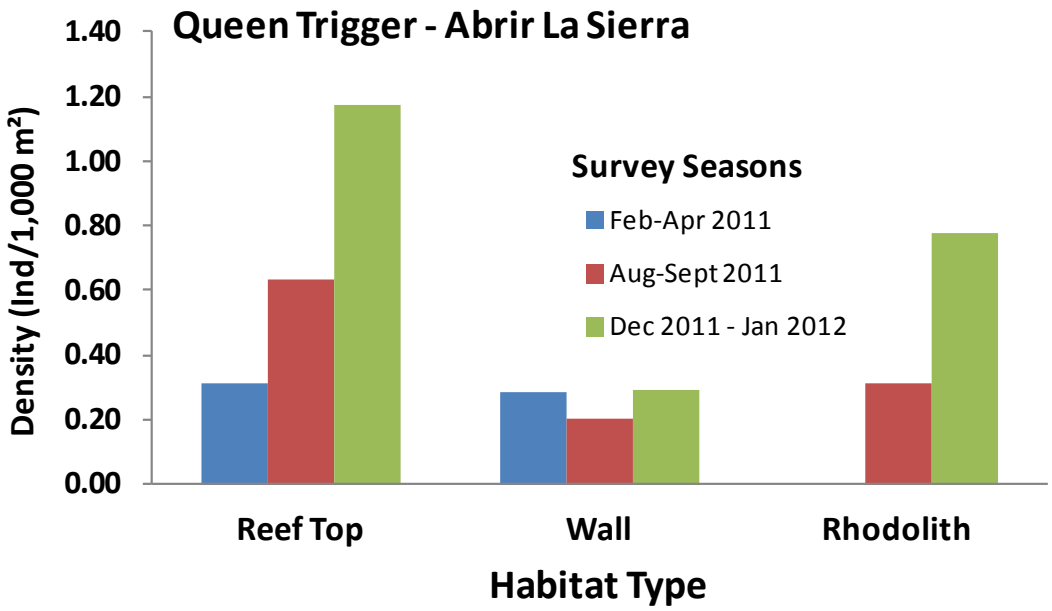


Figure 11. Seasonal variations of queen triggerfish, *Balistes vetula* density at mesophotic benthic habitats of Abrir La Sierra surveyed during 2011

At the rhodolith reef habitat, queen triggerfishes were common and appeared to represent one of the top demersal carnivores. Based on average densities per habitat over the three seasonal surveys, it was estimated that the total population of queen triggerfish from mesophotic habitats at ALS was in the order of 1,779 individuals during the study period (Table 5). It must be noted that queen triggerfishes seem to be attracted to divers as well as to any kind of seafloor disturbances. Thus, it is possible that queen triggerfishes were overestimated in our visual surveys because of their behavior.

A total of 17 hogfishes, *Lachnolaimus maximus* were observed from all mesophotic habitats at ALS, but nine, or 53 % were from the reef top (Figure 12). Hogfishes appeared to be always transient, foraging for benthic prey on the reef or semi-buried in the sand or rubble. Hogfish were observed across the 30 – 50 m depth range at ALS. No clear seasonal signal for hogfish abundance emerged from these data except for the relatively lower sightings during the February thru April season, when only two (2) individuals were detected at the slope wall. Based on the average densities per habitat over the three seasonal surveys, the population size of hogfish within the 30 – 50 m mesophotic zone of ALS was estimated as of 541 individuals (Table 5).

Among large pelagic predators present from mesophotic habitats surveyed at ALS the most abundant was the great barracuda, *Sphyraena barracuda* (Figure 6). A total of 22 individuals were sighted, of which 11, or 50% were associated with the slope wall without any distinct seasonal pattern (Figure 13). Great barracudas are common at open water transition zones, such as the shelf-edge and the outside wall of ALS. Barracudas were curious and followed divers down to the maximum diving depth limit of 50 m off the slope wall of ALS. The largest pelagic predator at ALS was the hammerhead shark, *Sphyrna mokarran*. Only one individual was sighted during this study at the reef top, but several more were previously reported by Garcia-Sais et al. (2010a) from mesophotic habitats of ALS. Nurse sharks, *Ginglymostoma cirratum* were the most common shark species at ALS. Six out of the nine individuals sighted were associated with the reef top (Table 4).

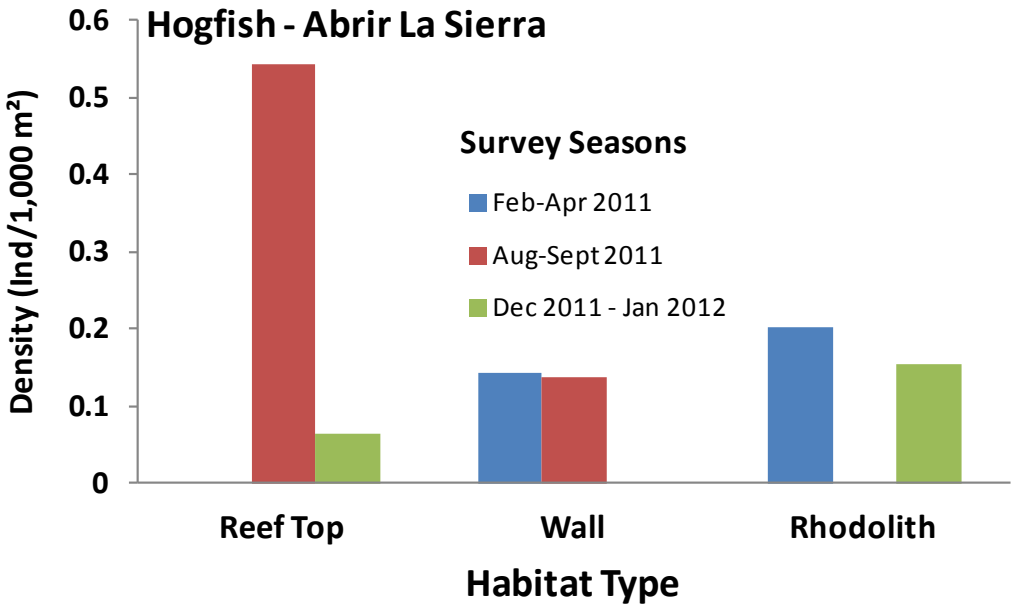


Figure 12. Seasonal variations of hogfish, *Lachnolaimus maximus* density at mesophotic benthic habitats of Abrir La Sierra surveyed during 2011

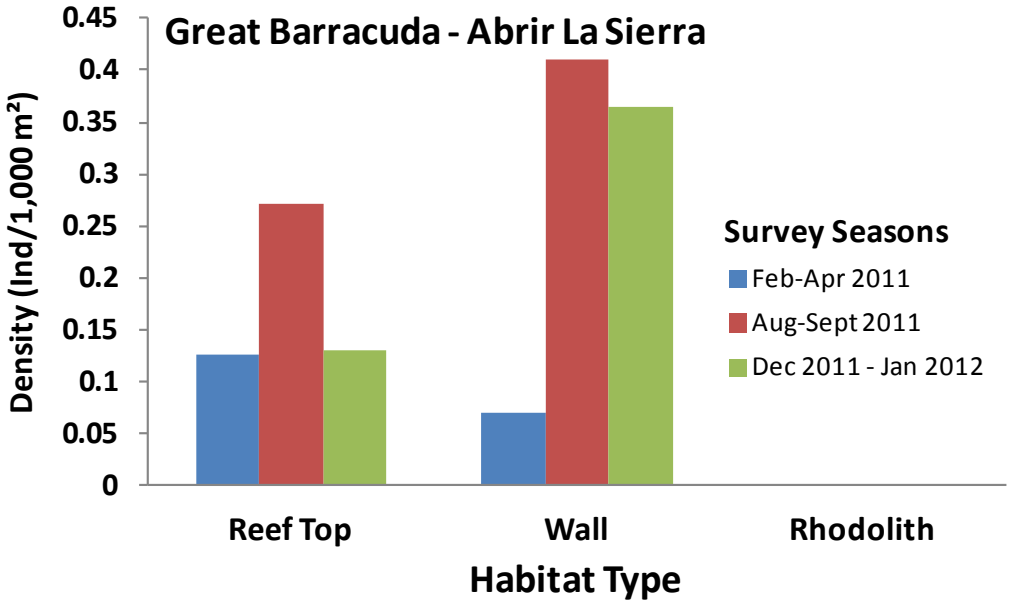


Figure 13. Seasonal variations of great barracuda, *Sphyraena barracuda* density at mesophotic benthic habitats of Abrir La Sierra surveyed during 2011

2. Bajo de Sico

The rock reef habitat combines reef top and slope wall physiographic zones present within the irregular rock promontories system of Bajo de Sico (BDS). Because of the extensive survey areas and the irregular reef formation, both reef physiographic zones were inevitably crossed by belt-transects. Thus, surveys within reef promontories reflect the combined observations of reef tops and walls, previously described for benthic habitat characterizations as two distinct benthic habitats (Garcia-Sais et al. 2007). Fish and shellfish individuals observed within belt-transects from mesophotic (30 – 50 m) benthic habitats at BDS during 2011 are shown in Table 6.

Queen conch, *Strombus gigas* was present from both rock and rhodolith reef benthic habitats at BDS (Table 6). They appeared to be more abundant at depths of 40 - 45 m (130 – 145 ') at the base of the rock reef walls, where an unconsolidated substrate of coarse sand and rubble prevailed, forming channels and pools that separated rock promontories. Large aggregations of queen conch were not observed in either habitat. The highest density (0.7 Ind/1000 m^2) corresponded to the rock reef habitat (Table 6). Spiny lobsters, *Panulirus argus* were rare at mesophotic benthic habitats of BDS. Only one lobster was observed at the reef rock promontories within the 30 – 50 m depth range (Table 6). The rhodolith habitat was completely devoid of topographic anomalies or any structure that could serve as protective habitat for spiny lobsters and thus, none was found there. Conversely, substantial protective habitat for spiny lobsters was available at the rock reef promontories, yet their low abundance may respond to the lack of adequate recruitment habitat and/or high predation pressure by large groupers and snappers.

A total of 79 groupers, distributed into five species were surveyed from mesophotic benthic habitats at BDS (Table 6). Red hind, *Epinephelus guttatus* was the most abundant, with densities of 1.2 and 0.6 Ind/1000 m^2 at the rhodolith and rock reef habitats, respectively (Figure 14). Given the larger areal extension of the rhodolith reef and higher densities of red hind, it is here estimated that about 75 % of the nearly 1,000 red hinds present at BDS within the 30 – 50 m depth range are associated with

Table 6. Total numbers of fish and shellfish individuals sighted at mesophotic benthic habitats from Bajo de Sico during 2011

BDS

Survey Dates: 2/2/2011 - 4/14/2011

Habitat		**Rock Reef**		**Rhodolith**		
Habitat Area (x10^3 m^2)		**371.2**		**628.0**		
T. Survey Area (m^2)	**27,627**	**Density**	**Estimated**	**17,909**	**Density**	**Estimated**
	# Ind. Obs.	**Ind/1000m^2)**	**Pop. Size**	# Ind. Obs.	**Ind/1000m^2)**	**Pop. Size**
Species						
Balistes vetula	6	0.217	81	9	0.503	316
Elagatis bipinnulata	4	0.145	54	8	0.447	281
Epinephelus guttatus	18	0.652	242	21	1.173	736
Epinephelus striatus	14	0.507	188	2	0.112	70
Ginglymostoma cirratur	4	0.145	54			
Lutjanus apodus	170	6.153	2,284			
Lutjanus cyanopterus	11	0.398	147			
Lutjanus jocu	1	0.036	13			
Mycteroperca bonaci	9	0.326	121			
Mycteroperca venenosa	7	0.253	94	2	0.112	70
Mycteroperca tigris	6	0.217	81			
Negaprion brevirostris	2	0.072	27			
Pterois volitans	41	1.484	551			
Scarus guacamaia	3	0.109	40			
Scomberomorus cavalla	1	0.036	13			
Scomberomorus regalis	6	0.217	81			
Sphyraena barracuda	9	0.326	121	5	0.279	175
Shellfish Species						
Panulirus argus	1	0.036	13			
Strombus gigas	20	0.724	269	5	0.279	175

the rhodolith reef (Table 6). It must also be noted that because of their semi-cryptic behavior and available hiding features of the rock reef habitat, the density of red hinds could have been underestimated.

Nassau groupers, *E. striatus* were mostly present at the rock reef, although a couple of individuals were found associated with a large boulder at a depth of 145 m on the rhodolith reef. Their density at mesophotic habitats of BDS was estimated at 0.5 and 0.1 Ind/1000 m^2 for the rock reef and rhodolith reef habitats, respectively. The combined abundance yielded a population estimate of approximately 258 individuals (Table 6). This is well below a previous estimate of nearly 1,000 individuals provided by Garcia-Sais et al. (2007) for BDS. It must be considered that during the original survey at BDS, reef top sections of the seamount shallower than 30 m were surveyed and Nassau grouper densities at these depths were included in population estimates. Nassau groupers appeared to be concentrated at the reef top of the rock promontories, and surveys performed within this shallower habitat may have overestimated the stocks of this species for the entire seamount. Conversely, our present stock assessment for Nassau grouper in this survey underestimates their population because it did not include the habitat above 30 m that appears to be most important for this species. It is here proposed that an estimate in the order of 400-500 individuals may be more realistic for Nassau grouper at BDS.

Individuals of yellowfin, black and tiger groupers (*Mycteroperca venenosa, M. bonaci, M. tigris*) were observed fro mesophotic habitats at BDS. Black and tiger groupers were only observed at the rock reef promontories (Figure 14), whereas a couple of yellowfin groupers were sighted in transition over the rhodolith reef. Population estimates for these species are here estimated in the order of 164, 121 and 81 for yellowfin, black and tiger grouper, respectively (Table 6), with the core of their populations associated with the rock promontories as their main residential and foraging habitat.

Snappers were represented by three species within the 30 – 50 m depth range at BDS, all sightings associated with rock promontories (Table 6). Schoolmaster snapper, *Lutjanus apodus* represented more than 94 % of all individuals observed. Most of the 170 schoolmaster individuals observed were from a single aggregation associated with

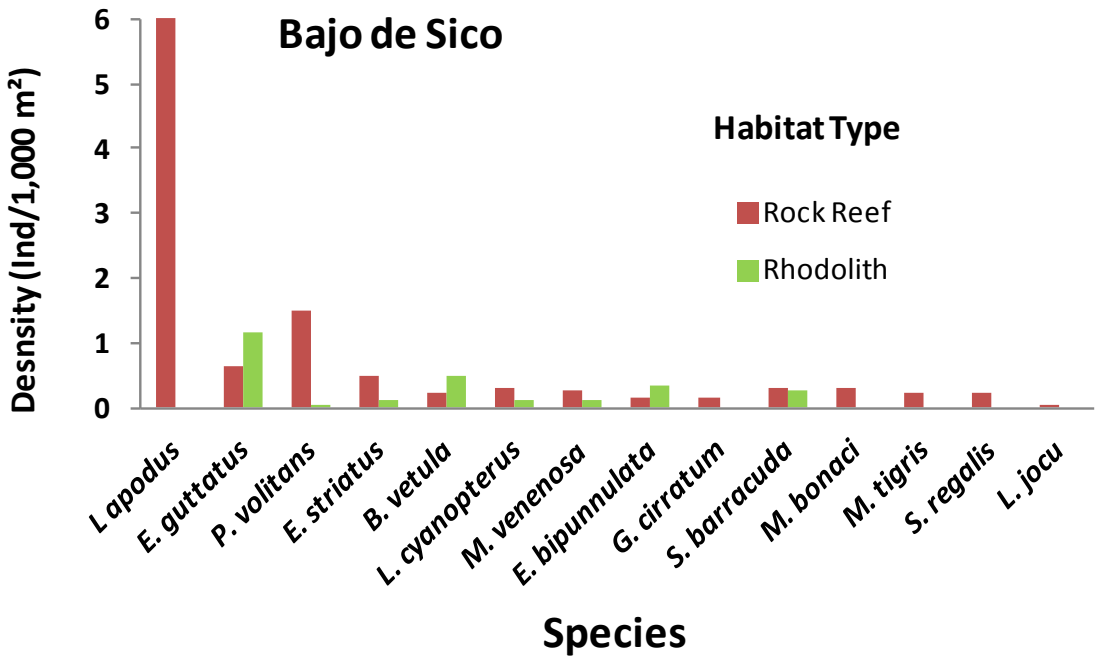


Figure 14. Distribution by mesophotic benthic habitat of fish individuals surveyed by belt-transects at Bajo de Sico during 2011

the rock reef promontory (Figure 14). The school was initially seen on the reef top, at depths between 25 – 28 m and then moved into the mesophotic zone to use the slope wall as shelter against a swift current. Based on a density of 6.2 Ind/1000 m^2, it is estimated that the population size of schoolmaster snapper within the 30 – 50 m depth range in BDS was in the order of 2, 284 individuals during 2011. This estimate needs to be evaluated with caution because of the high intrinsic variability inherent to the aggregation behavior of this species at BDS. Because reef top sections above 30 m were not surveyed, it is uncertain if more "schools" of schoolmaster snapper were present in the shallower sections of the seamount.

Eleven (11) cubera snappers, *L. cyanopterus* were present within the rock reef habitat of BDS (Table 6). These large demersal predators were typically observed alongside the promontory slope walls and at the base of the rock promontories, where an interface with a sandy/rubble bottom was found. Based on a density of 0.4 Ind/1000 m^2 it is here estimated that the population of cubera snappers from BDS was in the order

of 147 individuals during 2011. One dog snapper, *L. jocu* was observed within belt-transect areas during our surveys and a few others were observed outside transect areas. Likewise, Mutton snapper, *L. analis* were observed outside transects along the sandy/rubble bottom at the base of the rock reef slope walls and in transition at the rhodolith reef, but they were not common at BDS during our survey. Yellowtail snapper, *Ocyurus chrysurus* was observed over the reef top out of transects at depths above 30 m.

Queen triggerfish, *Balistes vetula* were present at the rock reef and rhodolith reef habitats at BDS (Figure 14). A total of 15 individuals were observed. Density was higher at the rhodolith reef with 0.5 Ind/1000 m^2 (Table 6). The main population of queen triggerfish, estimated at about 400 individuals was largely associated with the rhodolith reef habitat, where they appeared to be one of the top demersal predators. As previously mentioned for stock estimates from ALS, it must be noted that queen triggerfishes are attracted to divers and to any kind of seafloor disturbance. Thus, it is possible that queen triggerfishes were overestimated in our visual surveys because of their behavior.

With a total of 41 individuals sighted in 24 belt- transects, the lionfish*, Pterois volitans* ranked as the second most abundant fish species of (potential) commercial value within mesophotic habitats of BDS. Lionfishes were only present at the rock reef habitat (Figure 14), particularly within crevices and below ledges protected from water currents. Their density within the rock reef habitat was 1.5 Ind/1000 m^2 yielding a population size estimate of 550 individuals present within mesophotic habitats (30 – 50 m) at BDS (Table 6).

Other demersal species of large size and/or of potential commercial value at BDS include a family of three (3) large adult rainbow parrotfishes, *Scarus guacamaia*. The group was observed at a depth of 41 m on a sand pool at the base of the rock reef promontories. Several nurse sharks, *Ginglymostoma cirratum* were present over the reef top and at the base of the rock reef promontories.

Pelagic fishes of commercial value that were observed within belt-transects include the king and cero mackerels, *Scomberomorus cavalla* and *S. regalis*, the great barracuda,

Sphyraena barracuda and the reef shark, *Negaprion brevirostris*. The most abundant within belt-transects was the great barracuda with 9 individuals at the rock reef (0.33 Ind/1000 m^2) and 5 individuals at the rhodolith reef (0.3 Ind/1000 m^2) (Figure 14). Based on these densities, it is estimated that approx. 300 great barracudas were present at mesophotic habitats in the 30 – 50 m depth range from BDS (Table 6). This estimate should be analyzed with caution because barracudas are attracted to divers and may have been overestimated due to their behavior. Other migratory pelagic species, such as wahoo, *Acanthocybium solandri* and dolphinfish, *Coryphaena hippurus* were observed outside transects. Several hawksbill turtles, *Eretmochelys imbricata* were observed at the top of the reef promontories, but none were present within belt-transects.

3. Isla Desecheo

The types of benthic habitats surveyed at Isla Desecheo within the 30 – 50 m depth range included a slope wall at depths of 30 – 40 m, a rhodolith reef at depths between 40 – 50 m, and a mixed patch reef/colonized pavement habitat that was observed within the entire 30 – 50 m depth range. A benthic habitat map is not yet available for Isla Desecheo, but a preliminary characterization of mesophotic communities associated with the wall and rhodolith reef mesophotic habitats was prepared by Garcia-Sais et al. (2005). The slope wall and rhodolith reef habitats were surveyed at the west and southwest sections of Isla Desecheo. A habitat of discontinuous patch reefs of variable dimensions surrounded by either colonized hard bottom (pavement), or hard bottom covered by sand prevailed throughout the northern, southeastern and eastern sections of the island.

Queen conch, *Strombus gigas* were observed from the rhodolith and patch reef/colonized pavement habitats at similar densities of 2.4 and 2.3 Ind/1000m^2, respectively (Table 7). They typically presented scattered distributions, except for small aggregations observed over a sandy/colonized pavement bottom separating a series of patch reef promontories at the northeast section of Desecheo within the 30 – 40 m depth range. Spiny lobsters, *Panulirus argus* were present on all benthic habitat types surveyed with densities varying between 0.3 – 0.7 Ind/1000m^2

Table 7. Total numbers of fish and shellfish individuals sighted at mesophotic benthic habitats in Isla Desecheo during 2011.

Desecheo
4/15/2011 - 6/9/2011

Habitat	**Wall**		**Rhodolith**		**Patch Reef/Col Pavement**	
Total Area (m2)	**2,706**	**Density (Ind/10^3m^2)**	**7,794**	**Density (Ind/10^3m^2)**	**21,477**	**Density (Ind/10^3 m^2)**
Fish Species						
Epinephelus guttatus	7	2.59	21	2.69	74	3.45
Pterois volitans	12	4.43	16	2.05	54	2.51
Mycteroperca venenosa	4	1.48	2	0.26	5	0.23
Epinephelus striatus			5	0.64		
Sphyraena barracuda	3	1.11	2	0.26	8	0.37
Scomberomorus cavalla	1	0.37				
Seriola rivoliana			1	0.13	4	0.19
Balistes vetula			3	0.39	16	0.74
Lutjanus jocu			1	0.13	2	0.09
Lactophrys polygonia			4	0.51	2	0.09
Eretmochelys imbricata					1	0.05
Ginglymostoma cirratum					2	0.09
Lutjanus apodus					366	17.04
Elagatis bipinnulata					4	0.19
Scomberomorus regalis					5	0.23
Negaprion brevirostris			1	0.13	1	0.05
Shellfish Species						
Panulirus argus	2	0.74	2	0.26	7	0.33
Strombus gigas			19	2.44	49	2.28

(Table 7). Spiny lobsters were observed associated with crevices and holes on the slope wall and below coral ledges and other secretive microhabitats of the patch reefs. On the colonized pavement habitat that is typically flat and devoid of protective structures, spiny lobsters were observed inside large basket sponges, *Xestospongia muta* attached to the hard bottom. Due to their cryptic behavior, spiny lobsters were most likely underestimated by our survey, particularly in highly irregular habitats with plenty of protective structures, such as the patch reefs.

Schoolmaster snapper, *Lutjanus apodus* was the fish species of commercial value observed in highest density (17.0 Ind/1000m^2) from mesophotic benthic habitats at Isla Desecheo during 2011 (Figure 15). As their common name suggests, schoolmasters were present in several large schools of more than 50 - 100 individuals associated with patch reef habitats at depths of 30 – 35 m.
Three dog snappers, *L. jocu* were observed in transition over the rhodolith reef and at the patch reefs. Several yellowtail snappers, *Ocyurus chrysurus* were observed outside transects, near the surface to mid-water over mesophotic benthic habitats at Desecheo. Aside from the schoolmaster, snappers were not common at Desecheo.

Commercially important groupers observed from mesophotic habitats of Desecheo included the red hind, *Epinephelus guttatus*, Nassau grouper, *E. striatus* and the yellowfin grouper, *Mycteroperca venenosa*. Red hinds were the most abundant of the grouper assemblage with a total of 102 out of a total of 118 individuals sighted within 24 belt-transects (Figure 15). Densities varied from a maximum of 3.4 Ind/1000m^2 at the patch reef/colonized pavement habitat to 2.6 Ind/1000m^2 at the wall habitat (Table 7). Yellowfin groupers were sighted at the three mesophotic benthic habitats of Desecheo, but presented peak densities of 1.5 Ind/1000m^2 at the wall (Figure 15). Nassau groupers were concentrated on the patch reefs, at depths not exceeding 35 m. It has been noted that the largest population of Nassau groupers from Desecheo was associated with a system of patch coral reefs on the southwestern section of the insular shelf within a depth range of 25 – 30 m (Garcia-Sais et al. 2012 and references therein).

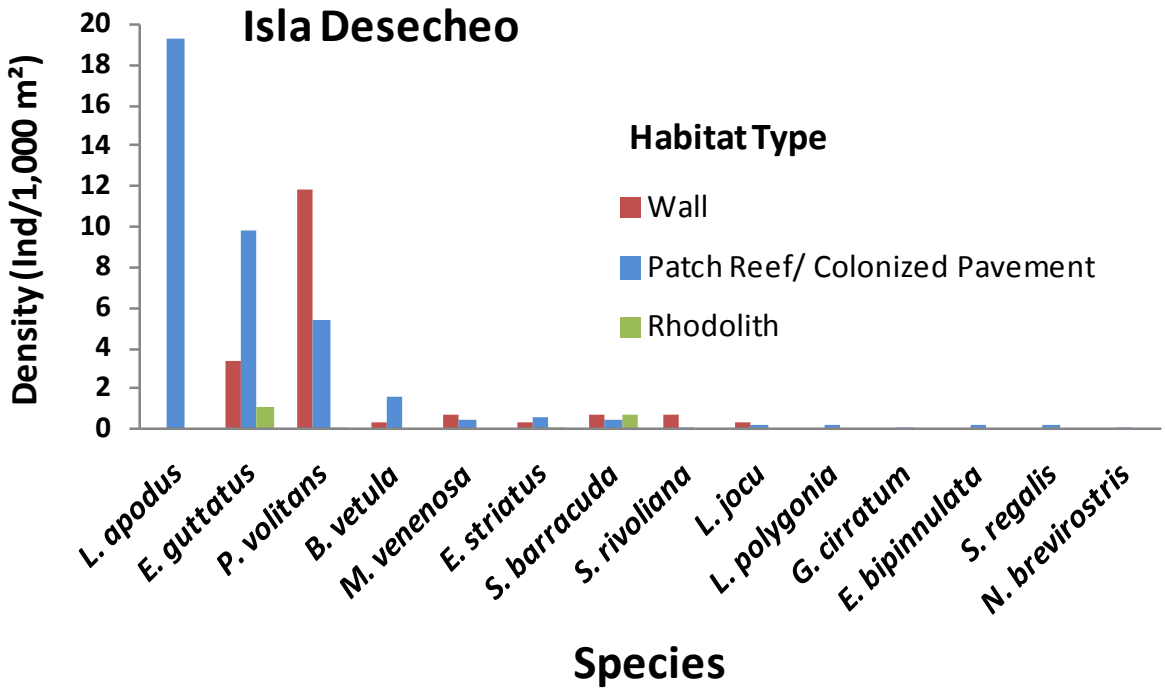


Figure 15. Distribution by mesophotic benthic habitat of fish individuals surveyed by belt-transects at Isla Desecheo during 2011

A total of 16 queen triggerfishes, *Balistes vetula* were observed within belt-transects at Isla Desecheo. Most individuals (13/16) were sighted at the patch reef/colonized pavement habitat (Figure 15), resulting in a density estimate of 0.7 Ind/1000 m^2 for that particular habitat (Table 7). Several individuals were also present outside transects at the rhodolith habitat. As previously mentioned for density estimates of queen triggerfish at mesophotic habitats from ALS and BDS, queen triggerfishes are attracted to divers and to any kind of seafloor disturbance and thus, their densities may have been overestimated due to their behavior.

Lionfishes, *Pterois volitans* were present from all mesophotic benthic habitats at Desecheo (Figure 15), with densities ranging between a maximum of 4.4 Ind/1000 m^2 at the wall to a minimum of 2.0 Ind/1000 m^2 at the rhodolith reef (Table 7). Their spatial distribution appeared to be strongly influenced by the availability of protective habitats, which were less available at the rhodolith reef. Other demersal species of large size and/or of potential commercial value include nurse sharks, *Ginglymostoma cirratum,*

which appeared to be mostly associated with the coral reef system over the insular shelf, but followed divers as they reached mesophotic habitats in Desecheo.

Pelagic fishes of commercial value that were observed within belt-transects include the king and cero mackerels, *Scomberomorus cavalla* and *S. regalis*, the great barracuda, *Sphyraena barracuda* and the reef shark, *Negaprion brevirostris*. The most abundant within belt-transects was the great barracuda with 13 individuals sighted in a total of 24 belt-transects surveyed. Great barracudas were present from the three benthic habitats surveyed (Figure 15). Densities ranged between a maximum 1.1 Ind/1000 m^2 at the wall to a minimum of 0.3 Ind/1000 m^2 at the rhodolith habitat (Table 7). This estimate should be analyzed with caution because barracudas are attracted to divers and may have been overestimated due to their behavior. Other pelagic species observed in low numbers include the great amberjack, *Seriola rivoliana* and the rainbow runner, *Elagatis bipinnulata* (Table 7). Juveniles of the rainbow runner appear to serve as forage for adult wahoo, *Acanthocybium solandri* observed near the wall outside transects. One hawksbill turtle, *Eretmochelys imbricata* was observed within transects at the patch reef/colonized pavement habitat.

B. Size-frequency distributions of commercially important fish and shellfish species from mesophotic benthic habitats at sites within the US-PR EEZ: Abrir la Sierra, Bajo de Sico and Isla Desecheo.

Summarized and density standardized length-frequency data of commercially important fish and shellfish species visually surveyed by divers within belt-transects is presented per site and mesophotic (30 – 50 m) benthic habitat type as Appendices 1, 2 and 3 for Abrir La Sierra (ALS), Bajo de Sico (BDS) and Isla Desecheo (Des), respectively. Length data are pooled standardized observations from replicate transects surveyed within the most prevalent benthic habitat types at each site, with the total number of (fish/shellfish) individuals at each length category divided by the total area surveyed from that particular habitat. An additional information layer of three seasonal surveys is included for ALS. Table 8 presents a synthesis of life history and fisheries length data for selected fish and shellfish species included in this study.

Table 8. Life history data for commercially important fish and shellfish species observed from mesophotic habitats of the Puertorrican EEZ, Abrir La Sierra (ALS); Bajo de Sico (BDS), and Isla Desecheo (Des) during 2011. (modified from Froese and Pauly 2005)

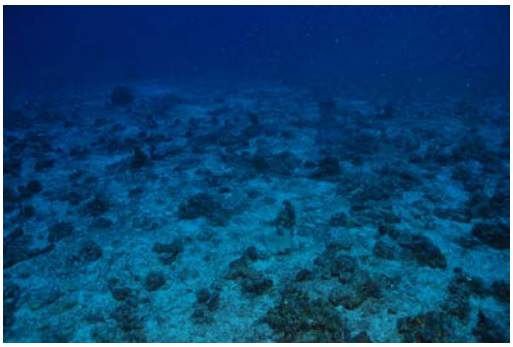
Species	**Common Name**	**Fish Base Lmax (cm)**	**Caribb Antilles Lmax (cm)**	**This Study Lmax (cm)**	**Fish Base Common Length (cm)**	**Fish Base Length at 1st Reprod Lm (cm) (cm)**	**Reported Max Weight (kg)**	**Max Age (yrs)**
Strombus gigas	Queen conch	30.4	n/d	30.0	n/d	24.0*	2.3	40
Panulirus argus	Spiny lobster	60.0	n/d	45.0	20	5.4	n/d	n/d
Epinephelus guttatus	Red hind	76.0	54.5	41	40	25.0	25.0	17
Epinephelus striatus	Nassau grouper	122.0	82.0	80	n/d	48.0	25.0	29
Mycteroperca bonaci	Black grouper	150.0	132.0	90	70	58 - 95	100.0	n/d
Mycteroperca venenosa	Yellowfin grouper	100.0	92.0	80	50	51.0	18.5	n/d
Mycteroperca tigris	Tiger grouper	101.0	74.0	60	40	46.0	10.0	n/d
Lutjanus analis	Mutton snapper	94.0	77.0	60	50	41.0	15.6	29
Lutjanus apodus	Schoolmaster	67.2	46.4	40	35	25.0	10.8	n/d
Lutjanus cyanopterus	Cubera snapper	160.0	109.0	90	90	n/d	57.0	n/d
Lutjanus jocu	Dog snapper	128.0	77.0	55	60	32.0	28.6	n/d
Ocyurus chrysurus	Yellowtail snapper	86.3	59.0	50	40	23.7	4.1	14
Lachnolaimus maximus	Hogfish	91.0	70.4	60	35	n/d	11.0	11
Balistes vetula	Queen triggerfish	60.0	54.6	45	30	23.0	5.4	n/d
Scarus guacamaia	Rainbow parrotfish	120.0	85.0	70	70	n/d	20.0	n/d
Pterois volitans	Lionfish	38.0	n/d	30	n/d	16.0	n/d	10
Sphyraena barracuda	Great barracuda	200.0	114.0	100	140	58.0	50.0	n/d

1. Queen Conch (*Strombus gigas*)

Length-frequency distributions of queen conch standardized by the total area surveyed during three seasonal surveys at ALS are presented in Figure 16. The higher densities at most queen conch lengths were observed during the August – September survey period. It is uncertain if the higher densities during the August – September season were influenced by migrations from neritic to mesophotic areas, or that conch individuals become less cryptic and/or more aggregated during what appears to be a period of high reproductive activity at this site. Queen conchs were observed engaged in copulating behavior during the August – September 2011 survey season at ALS, particularly on the rhodolith reef habitat within a 38 – 42 m depth range. Eggs masses were detected under queen conch individuals partially buried on the sandy bottom below the rhodolith layer. Schools of large adult blue runners, *Carangoides crysos* were observed to dive into the rhodolith deposit as to dig out the conch eggs masses to feed on them.

Queen conch length distributions from mesophotic habitats of ALS show that large adults, with a minimum component of smaller adults, or juveniles in the 12 – 19 cm range comprised the main population (Figure 16). More than 95% of the entire population of queen conch surveyed from mesophotic habitats at ALS were measured in the 20 – 28 cm length range. The maximum length reported for queen conch in this study at 30.0 cm is close to the maximum reported for the species at 30.4 cm (Table 8). Queen conch growth is deterministic, with maximum length attained at sexual maturity, corresponding to the formation of the flared lip of the shell (McCarthy, 2008). All conch individuals at ALS were observed to have flared lips at lengths of 20 cm or larger, which is indicative that the queen conch population from mesophotic habitats at ALS is mostly comprised by adult and reproductively active population. Lip thickness (LT) increases with age and has been used to estimate adult conch growth since maturation (Appeldoorn, 1988).

Lip thickness (LT) distribution of queen conch from ALS measured in situ by divers is presented in Figure 17. LT ranged from 0.5 cm to 3.0 cm, with a mean of 2.1 cm. The distribution of LT was strongly skewed to the right, with 72% of the total conch population with LT's between 2.0 and 3.0. Interestingly, the largest LT mode is at 3.0



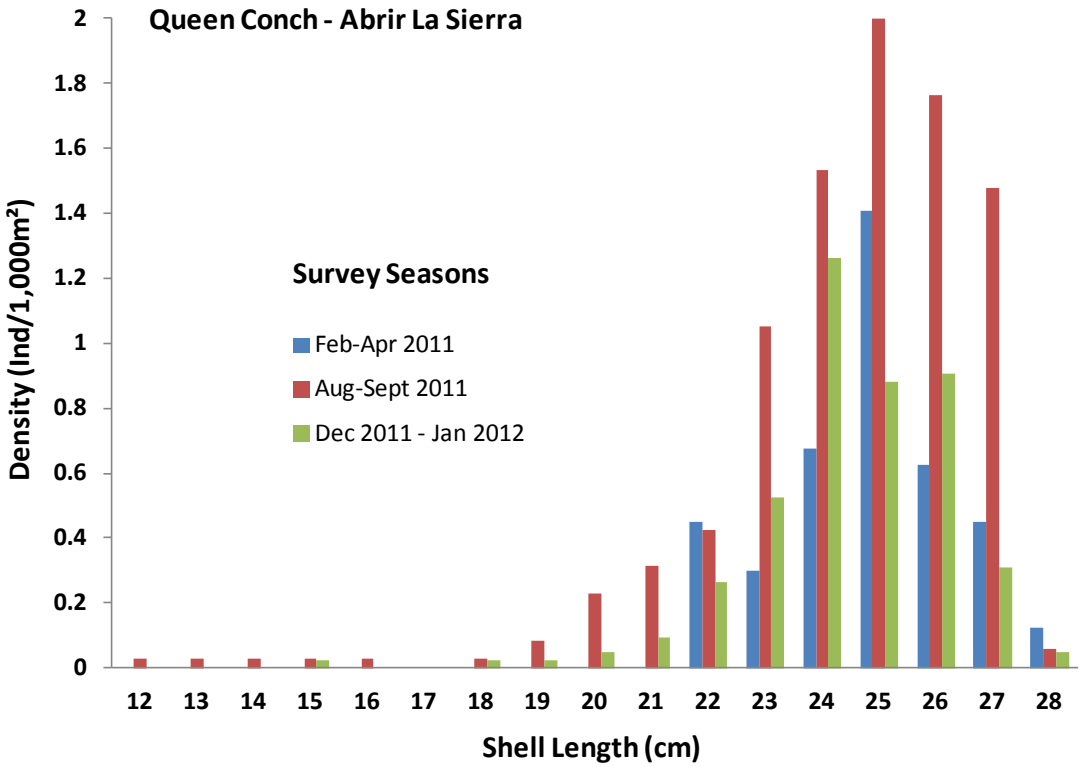


Figure 16. Queen conch, *Strombus gigas* shell length frequency distributions during seasonal surveys of mesophotic habitats at Abrir la Sierra, 2011-12

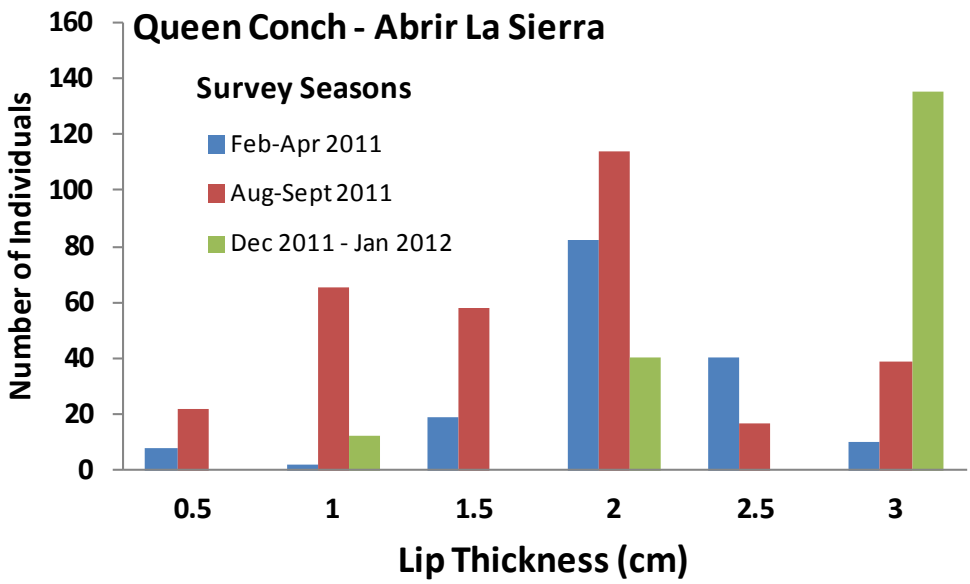


Figure 17. Queen conch, *Strombus gigas* shell thickness field measurements from mesophotic habitats at Abrir la Sierra during 2011-12.

cm, suggesting that at LT=3.0 queen conch from this environment reach a maximum size and then probably erode back to a smaller LT size. Determinations of age, growth, mortality, and age at first reproduction of queen conch from La Parguera were provided by Appeldoorn (1988) applying the von Bertalanffy growth function to measurements of shell lengths and/or lip thickness. Total instantaneous mortality in adults was reported as 1.66 $year^{-1}$ with a natural mortality of 0.52 $year^{-1}$. Appeldoorn (1988) proposed an age at first reproduction for queen conch of approximately 4 years based on observations that the average adult size of 24 cm in shell length from individuals in La Parguera was reached in 3.2 yrs, plus at least a 5-month period between the beginning of lip formation and production of ripe gonads. Appeldoorn (1988) warned that because of the scarcity of data on thick-lipped and deep-water specimens, such as those prevailing in our study of mesophotic habitats, age and growth predictions for these large sized individuals would be less reliable.

Queen conch shell lengths from all mesophotic habitats and sites surveyed (e.g. ALS, BDS, Des) consistently depicted large adult specimens, with the bulk of individuals in the 24 – 27 cm TL range (Figure 18). It is also evident that queen conch populations at mesophotic habitats of ALS were much more abundant than those from Bajo de Sico and Desecheo. This may be strongly influenced by the direct, within shelf habitat connectivity at ALS, since deep oceanic barriers separate both BDS and Des from the insular shelf of Puerto Rico (PR), where seagrass nurseries for queen conch are plentiful. It is also interesting that despite the absence of such nursery habitats and the oceanic barrier physically separating BDS and Des from PR, small adult populations of queen conch thrive at these oceanic sites. This suggests that although such preferred recruitment and nursery habitats may support larger populations of queen conch, they are not indispensable for their survival. Juvenile queen conchs were not observed at BDS or at Des. Thus, life history strategies of queen conch at these oceanic islands and seamounts remain unknown and deserve further research attention.

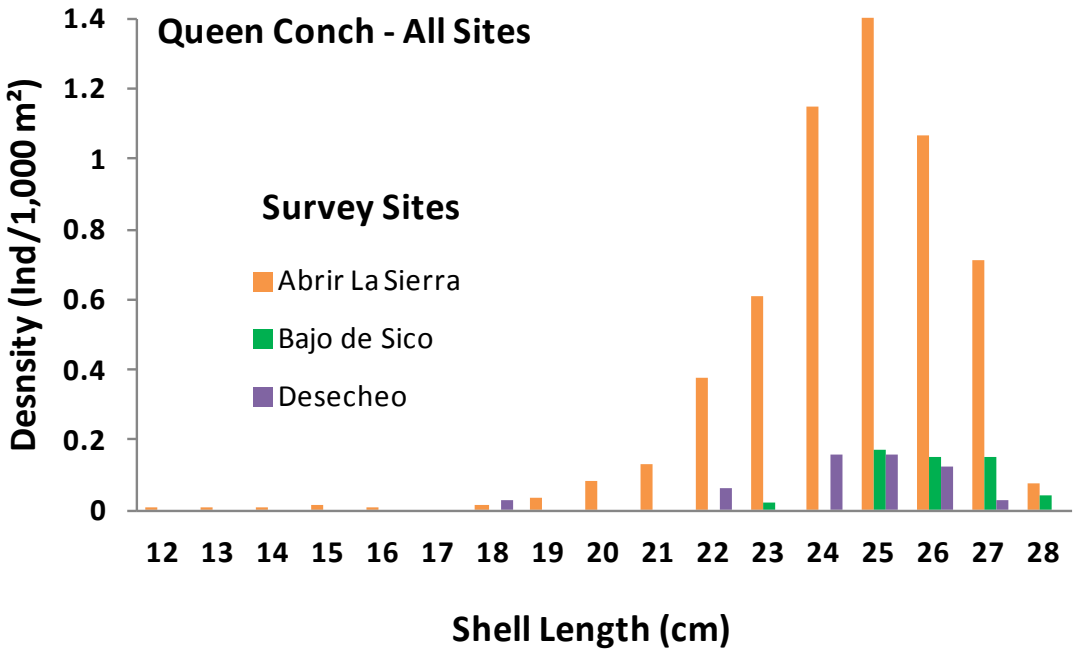


Figure 18. Shell length distribution of Queen conch, *Strombus gigas* at mesophotic sites surveyed during 2011-12

2. Spiny Lobster (*Panulirus argus*)

Spiny lobsters were not highly abundant at any of the mesophotic habitats surveyed within the PR EEZ. A total of 21 individuals were observed from all three sites, with more frequent sightings at Isla Desecheo. The cephalothorax length distribution of the total individuals shows that mostly large adult, reproductively active spiny lobsters prevailed in mesophotic habitats (Figure 19). Only one specimen was smaller than 10 cm cephalothorax length, and one very large specimen of 20 cm cephalothorax length and weighting more than 10 pounds was observed. The maximum reported total length of spiny lobster is 45 cm (Table 8), but data on cephalothorax length for this specimen was not reported. The lack of recruitment and nursery habitats, combined with the strong predation pressure exerted by the presence of large groupers and nurse sharks makes mesophotic habitats not an ideal place for small lobsters, but once they reach a certain size that minimizes predation mortality large sizes may be attained perhaps due to relatively low fishing mortality imposed by depth and/or closed fishing regulations.

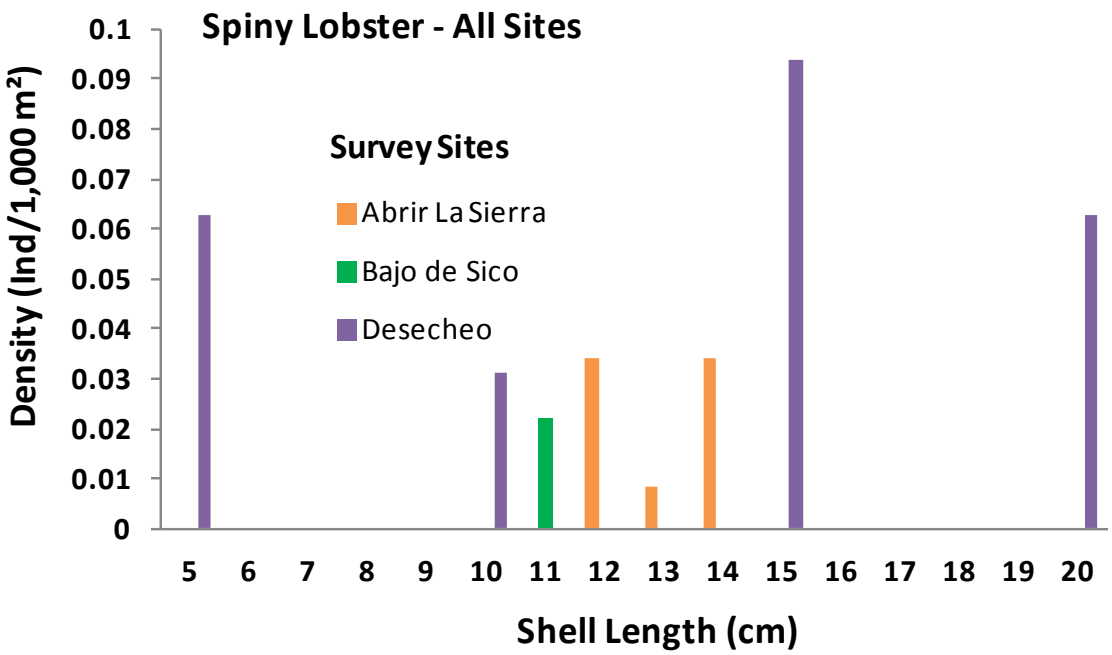


Figure 19. Spiny lobster, *Panulirus argus* cephalothorax length frequency distribution at mesophotic sites surveyed during 2011-12

3. Red Hind (*Epinephelus guttatus*)

Among fish species of commercial value, red hind was the most abundant from mesophotic habitats surveyed within the PR EEZ. Although red hinds were present from all benthic habitat types, depths and seasons surveyed at ALS, higher densities were observed during the February – April 2011 survey period, coinciding with its peak reproductive season (Figure 20). Still, massive spawning aggregations were not observed. Modal length was consistent at 30 cm (TL) during the three seasonal surveys at ALS. More than 95 % of the total individuals observed at ALS were at or larger than 25 cm TL, which is the reported length at first reproduction (Table 8). The maximum length of red hind from this study at 40 cm is well below the maximum length reported of 76.0 cm, but is closer to the maximum length reported for the Caribbean Antilles at 54.5 cm (Table 8). Juvenile red hinds (< 25) were present from all study sites (Figure 21), but were more common at ALS. Several individuals smaller than 10 cm were observed at the reef top of ALS, but it seems that recruitment into these mesophotic habitats is more frequent at about 15 cm.

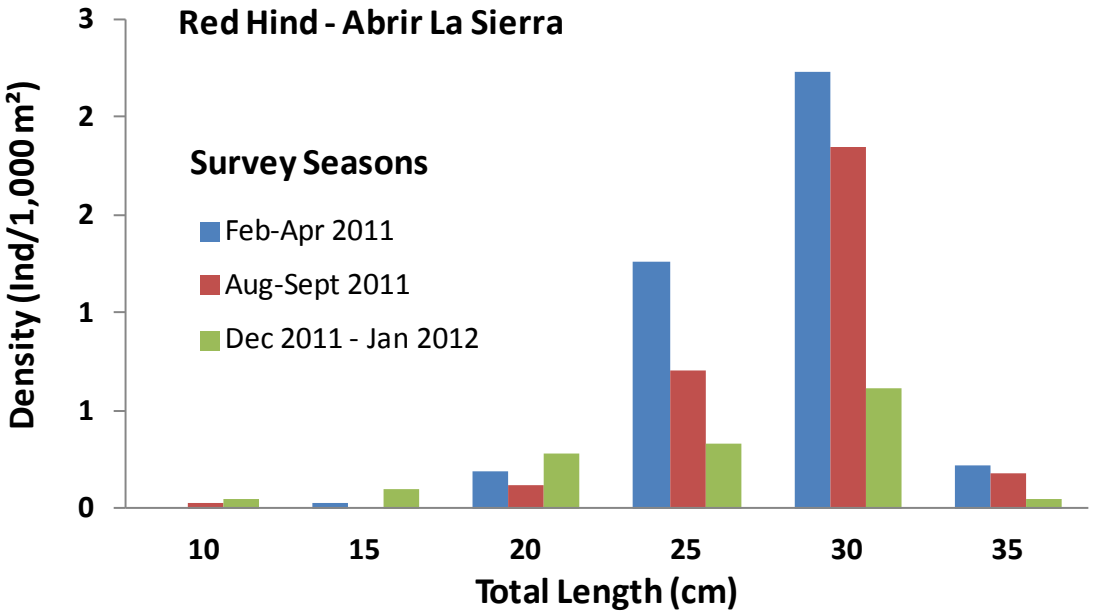


Figure 20. Red Hind (*Epinephelus guttatus*) length frequency distributions during seasonal surveys of mesophotic habitats at Abrir la Sierra, 2011-12

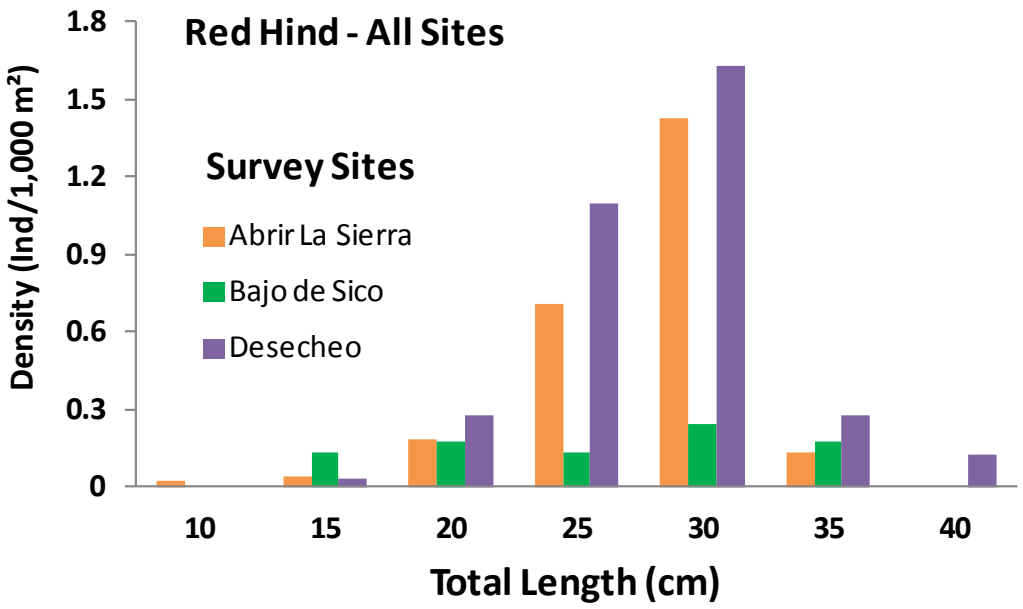


Figure 21. Length frequency distributions of red hind, *Epinephelus guttatus* at mesophotic sites surveyed during 2011-12

4. Yellowfin Grouper (*Mycteroperca venenosa*)

A total of 36 yellowfin groupers were observed within belt-transects during visual surveys at mesophotic habitats of PR EEZ sites. Individual's total lengths varied from 40 to 90 cm, with a mode at 70 cm (Figure 22). Length at first reproduction of yellowfin grouper has been reported at TL= 51.0 cm (Table 8). Thus, approximately 86 % (31/36) of the yellowfin population present at the sites studied within the PR EEZ correspond to full adult, reproductively active individuals. The maximum (total) length observed from yellowfin individuals was at 90 cm, which is close to the maximum reported for the Caribbean Antilles (e.g. 92 cm). Juvenile yellowfin were present both at ALS and Desecheo and appeared to recruit into mesophotic habitats at a length of approximately 40 cm. Only adult individuals with a minimum length of 60 cm were observed from BDS (Figure 22).

Yellowfin groupers were observed from mesophotic habitats of ALS during the three seasonal surveys without any distinct period of higher abundance. Spawning aggregations were not detected at any sites surveyed.

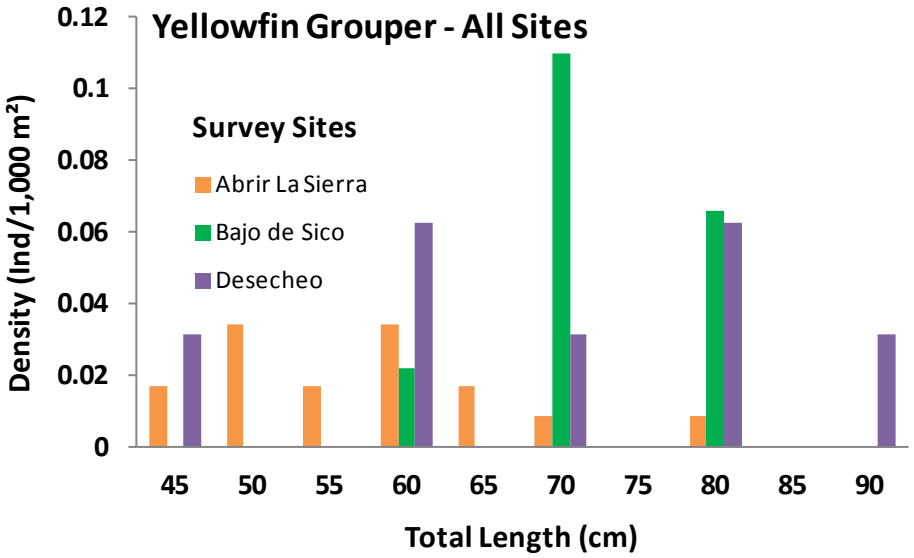
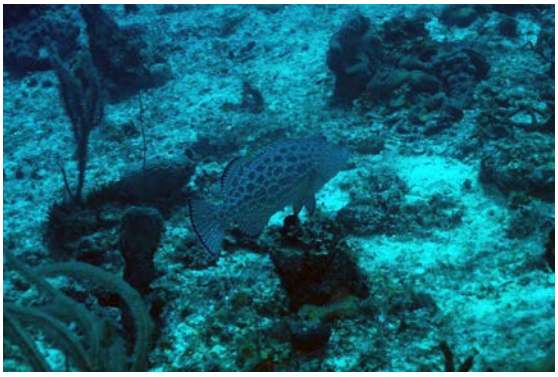


Figure 22. Length frequency distributions of yellowfin grouper, *Mycteroperca venenosa* at mesophotic sites surveyed during 2011-12



5. Nassau Grouper (*Epinephelus striatus*)

A total of 26 Nassau groupers were sighted in a total of 120 belt-transects surveyed from mesophotic habitats at the three sites, 16 of which were from BDS. Individual total lengths varied from 40 – 80 cm, with a mode at 60 cm. Nassau groupers become reproductively active at approximately 48 cm (Table 8). Thus 23 out of the 26 individuals included in our survey, or 88.5 % were adults. The maximum length for Nassau grouper has been reported at 122.0 cm (Table 8). Our two largest individuals were estimated at a total length of 80 cm, which is very close to the largest reported for the Caribbean Antilles (e.g. 82 cm). From our observations, Nassau groupers appear to recruit to mesophotic habitats at sizes close to adulthood, at lengths of 40 cm.

The higher abundance of Nassau groupers from mesophotic habitats at BDS, as compared to Des and ALS may be related to the higher rugosity, geographic extension and deeper range of the coral reef habitat. The depth limit of the coral reef habitat at both ALS and Des was close to 28 m. A reduction of rugosity and habitat complexity is associated with the shift of coral reef to pavement habitat at Des and ALS. It was noted that Nassau groupers were more associated to the coral reef habitat, and horizontal seascapes in the 25 – 28 m depth range than to pavement habitats below 30 m and on sloping, shelf-edge walls. Despite perhaps deeper penetration of the coral reef habitat at BDS, it was still evident that higher abundance of Nassau groupers prevailed within the 25 – 30 m zone.

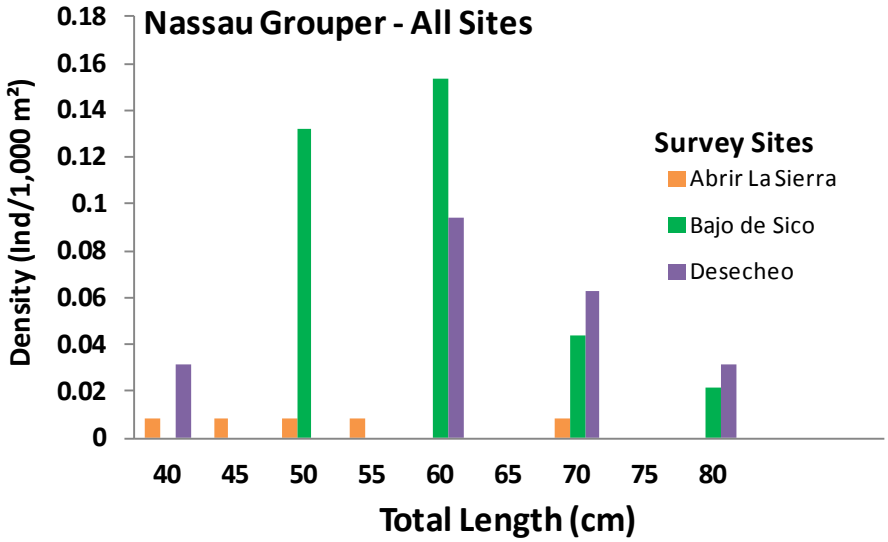


Figure 23. Length frequency distributions of Nassau grouper, *Epinephelus striatus* at mesophotic sites surveyed during 2011-12

6. Black Grouper (*Mycteroperca bonaci*)

Black groupers were observed from BDS and ALS within a size range of 40 – 90 cm TL (Figure 24). Only 13 individuals were sighted within belt-transects, nine (9) of which were sighted at BDS. Black groupers were observed to be residents of slope walls, both at BDS and ALS and to have a normal depth range starting at about 30 m to depths well below 50 m on slope walls. The maximum length of black groupers surveyed from BDS at 90 cm is below the maximum length reported of 150 cm and of 130 cm for the Caribbean Antilles (Table 8). However, the full depth range for this species was not covered in our survey due to our gear depth limit of 50 m. Our data shows that juvenile black groupers recruit to mesophotic habitats of ALS at a size of 40 cm, which is almost 20 cm below their size at first reproduction (Table 8). To our knowledge there is no active fishery for black grouper in Puerto Rico.

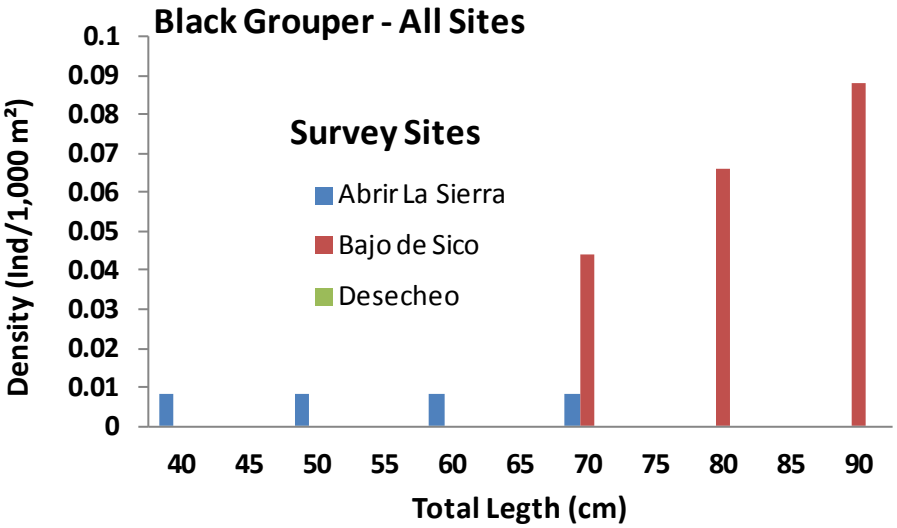


Figure 24. Length frequency distributions of black grouper, *Mycteroperca bonaci* at mesophotic sites studied during 2011-12

7. Tiger Grouper (*Mycteroperca tigris*)

Tiger groupers were only observed from BDS. The six (6) specimens ranged in total length form 40 to 60 cm, with only one specimen (46 cm TL) below the length at first reproduction (Table 8). The maximum reported total length for tiger grouper is 101.0 cm and the maximum length reported for the Caribbean Antilles is 74.0 cm (Table 5).

8. Mutton snapper (*Lutjanus analis*)

Mutton snappers were observed from all mesophotic benthic habitat types, depths, and seasons at ALS within a size range of 25 – 60 cm TL (Figure 25). Modal length was at 50 cm (TL). The reported length at first reproduction for mutton snapper is 41.0 cm (Table 8). Thus, 25 % of the total individuals observed at ALS (30/40) were juveniles. The maximum length of mutton snapper visually estimated during our surveys at 60 cm is well below the maximum length reported of 94.0 cm, but closer to the maximum length reported for the Caribbean Antilles at 74.0 cm (Table 8).

Mutton snappers were not observed either at BDS or Desecheo. There are previous reports of mutton snappers both from Des and BDS (Garcia-Sais et al. 2005, 2007), but their occurrence at these oceanic sites was rare. The wide plasticity of habitat types in which mutton snappers occur at ALS suggests that their virtual absence from Des and BDS is not habitat related, but perhaps more related to larval dispersal dynamics and/or to the lack of connectivity with their neritic recruitment and nursery habitats, which are present at ALS and not so at oceanic sites.

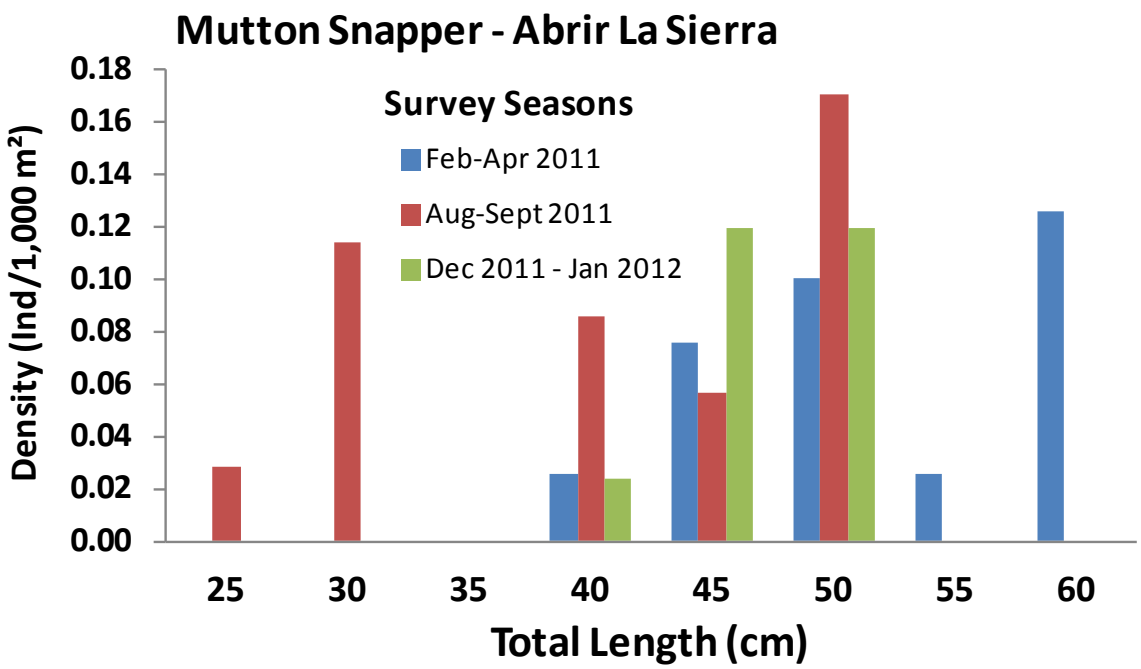


Figure 25. Length frequency distributions of mutton snapper, *Lutjanus analis* during seasonal surveys of mesophotic habitats at Abrir la Sierra, 2011-12

9. Schoolmaster snapper (*Lutjanus apodus*)

Schoolmaster snappers were present on all three survey sites associated with hard bottom habitats at the upper limit of mesophotic depth (e.g. 30 m). They presented a size distribution range between 20 and 40 cm, with dense aggregations in the 25 - 30 cm TL range (Figure 26). Schoolmasters are reported to mature at a length of 25 cm (Table 8). Therefore, most of the populations present in the mesophotic habitats of sites surveyed appear to be comprised by adult individuals. Schoolmasters were observed mostly above 30 m, but penetrated mesophotic depths apparently to gain protection against strong currents. Their occurrence in high numbers at oceanic sites, such as BDS and Des without neritic connectivity to mangroves and seagrass nursery habitats is indicative of effective replenishment via larval dispersal or by floating objects supporting large numbers of post-settlement juveniles. It is interesting, nonetheless that such post-settlement juveniles were not observed within the mesophotic habitats surveyed. Another possibility to be considered is the transport of schooling adults from neritic areas, perhaps during storms and/or other extreme events.

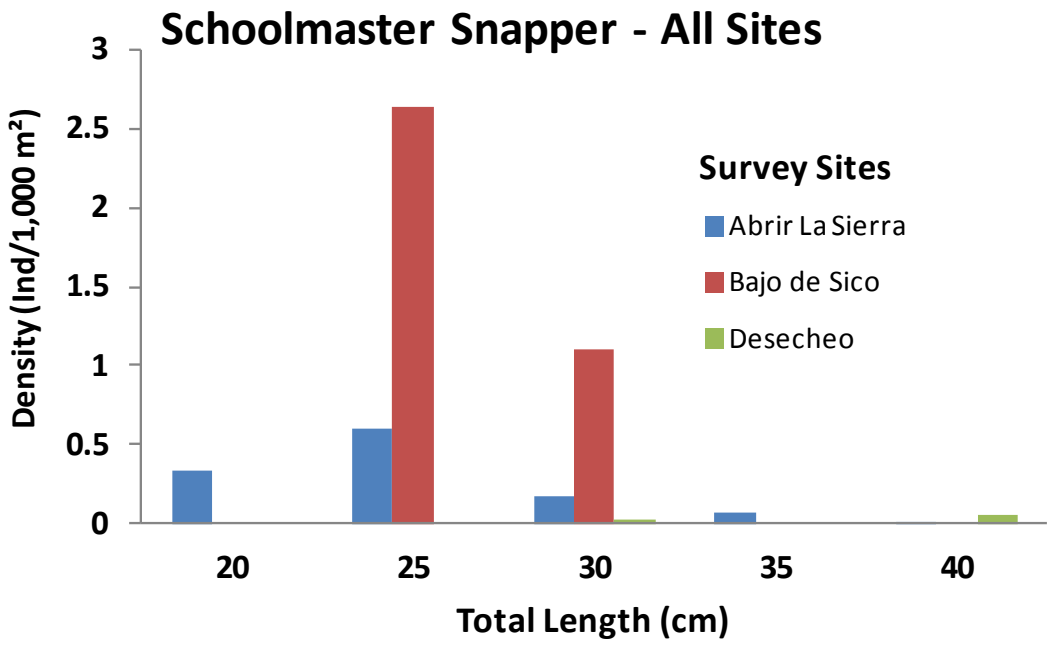
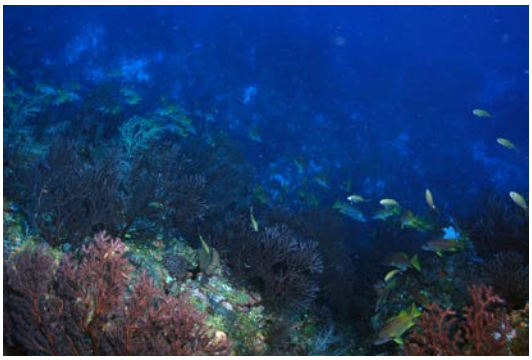


Figure 26. Length frequency distributions of schoolmaster snapper, *Lutjanus apodus* at mesophotic sites surveyed during 2011-12



10. Cubera snapper (*Lutjanus cyanopterus*)

A total of 26 cubera snappers were observed within mesophotic habitats at BDS and ALS within the size range of 25 – 90 cm (Figure 27). Data on length at first reproduction (Lm) for cubera snappers is not available, but since it is a larger and perhaps, longer lived species than its congener *L. jocu* which has a Lm = 32.0 (Table 8), it must be assumed that it's Lm is larger than 32 cm. The size distribution of cubera snappers shows that mostly adult individuals prevailed at mesophotic habitats from ALS and BDS, but there was a small component of juvenile individuals from both populations (Figure 27). Modal length was 60 cm at both sites. Maximum length of cubera snappers has been reported at 160 cm, which is almost twice the maximum size (visually estimated) from our sites in Puerto Rico (e.g. 90 cm), which in turn, is very close to the maximum size reported for the Caribbean Antilles (e.g. 109.0 cm; see Table 8). Cubera snappers were present on all three seasonal surveys at ALS without evidencing any distinct peak of abundance. Cubera snappers represent one of the top demersal predators of shelf-edge habitats, where they are transient between outer neritic and upper insular slope domains. They seem to have wide foraging areas with ample depth range. Their absence from Isla Desecheo is consistent with the pattern shown as well for mutton and dog snappers (*Lutjanus analis, L. jocu*) at Desecheo, and may be related to the lack of connectivity with recruitment and/or nursery habitats and/or to larval dispersal dynamics.

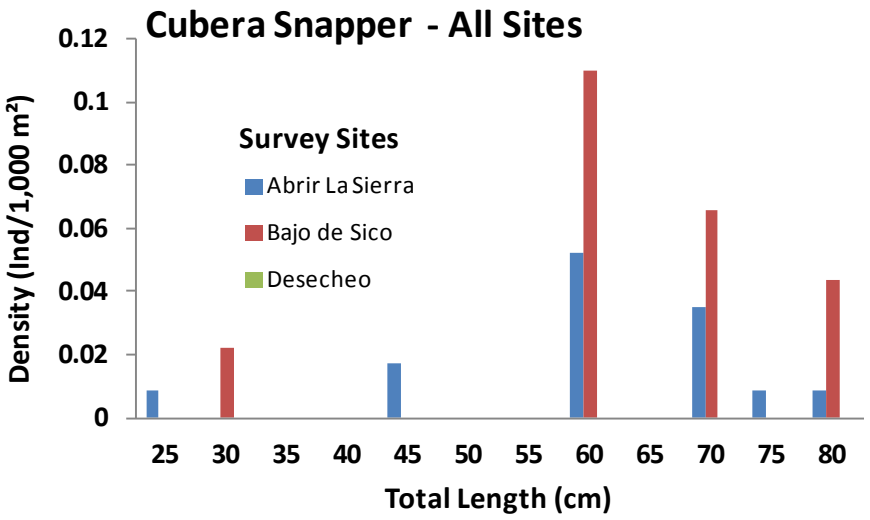


Figure 27. Length frequency distributions of cubera snapper, *Lutjanus cyanopterus* at mesophotic sites surveyed during 2011-12

11. Queen Triggerfish (*Balistes vetula*)

Queen triggerfish were observed from all mesophotic habitats, sites and depths surveyed within a size range of 20 to 45 cm (FL), with a mode at 30 cm (FL) (Figure 28). Age at first reproduction of queen triggerfish has been reported as 23 cm (Table 8). Thus, more than 95 % of the entire population observed from mesophotic habitats was comprised of adult individuals. Maximum length reported for queen triggerfish is 60 cm, with the maximum reported for the Caribbean Antilles at 54.6 cm. Thus, our maximum length estimate of 45 cm is close to the maximum length reported for the species. Recruitment of juvenile queen triggerfish to mesophotic habitats at oceanic sites, such as Isla Desecheo and BDS require further research attention. Juveniles less than 20 cm (FL) were not observed from either oceanic site. The late juvenile to adult size range presented by queen triggerfish on all three sites suggests that an effective replenishment mechanism for recruitment of this species at mesophotic habitats of oceanic sites is in place. Again, it is possible that recruitment as adults is associated with floating materials or dispersal from neritic areas during storms or other extreme events.

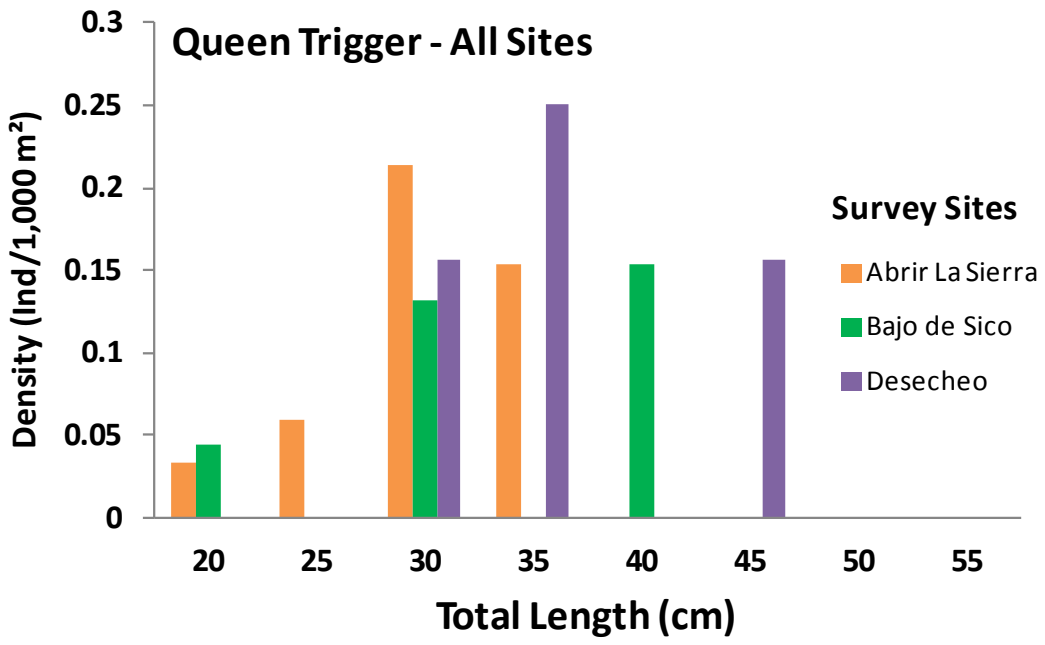


Figure 28. Length frequency distributions of queen triggerfish, *Balistes vetula* at mesophotic sites surveyed during 2011-12

12. Hogfish (*Lachnolaimus maximus*)

Hogfishes were only observed at ALS. They ranged in length from a minimum (FL) of 25 cm to a maximum (FL) of 60 cm (Figure 29). There is presently no information on length at first reproduction for hogfish (Table 8), but from a total of 17 individuals sighted, only two (c.a. 12%) were below 40 cm. Modal size was at 50 cm, with the maximum size visually estimated at 60 cm. The maximum size reported for hogfish is 91.0 cm, and the maximum size reported for the Caribbean Antilles is 70.0 cm (Table 8). Thus, most of the individuals observed from mesophotic habitats within the PR EEZ approach the maximum size reported for the Caribbean Antilles and were presumably adults. Hogfishes were observed from all benthic habitats, seasons and depths at ALS. Given such habitat plasticity, it is improbable that their absence from mesophotic habitats at oceanic sites surveyed be habitat related. Their sole distribution at ALS suggests that the physical connectivity to recruitment and/or nursery habitats within the insular shelf, which applies for ALS, is a critically important aspect of their life strategy. Larval dispersal is not likely to be a factor limiting recruitment to nearby oceanic sites within Mona Passage because larval Labridae are known to have oceanic distributions (Ramirez and Garcia 2003).

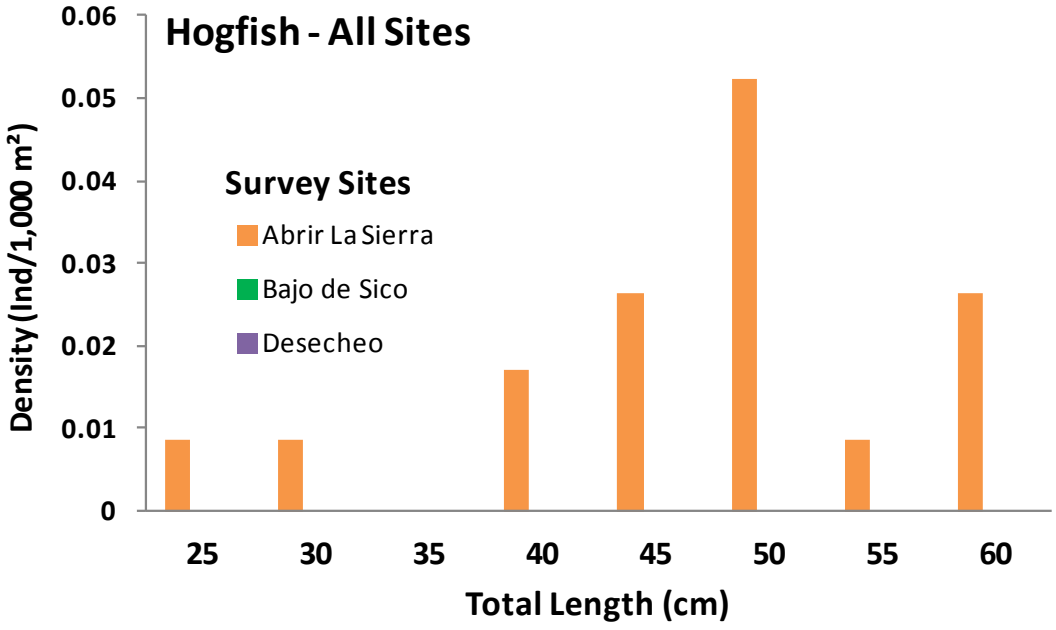
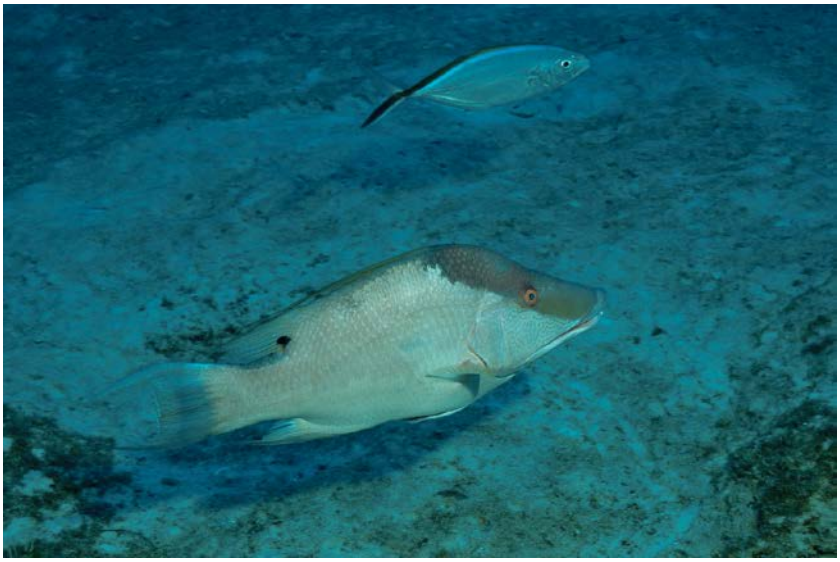


Figure 29. Length frequency distributions of hogfish, *Lachnolaimus maximus* at mesophotic sites surveyed during 2011-12



13. Lionfish (*Pterois volitans*)

Lionfishes were observed from all mesophotic habitats, sites, depths, and seasons surveyed. Their (total) length frequency distribution, ranging from 5 to 30 cm suggests that lionfishes have adapted to lifetime residence at mesophotic habitats within the PR EEZ (Figure 30). Their relatively high abundance within mesophotic habitats at oceanic sites, such as at BDS and Desecheo implies that effective larval dispersal mechanisms, as well as appropriate early juvenile recruitment adaptations to mesophotic habitats are operational for this species. Lionfishes were visually estimated to reach 30 cm TL, which is close to the maximum 38 cm TL reported (Table 8). Modal length was at 25 cm. The relatively high amount of individuals at maximum length (e.g. 30 cm) is indicative that lionfishes are reaching their full development at mesophotic habitats and perhaps experiencing low fishing mortality. From a total 355 lionfishes sighted at the three sites, 81 (or 22.8 %) were juveniles. Relative to other commercially targeted fishes included in this survey, the high proportion of juveniles to adults may be indicative of low predation pressure on the juvenile stages.

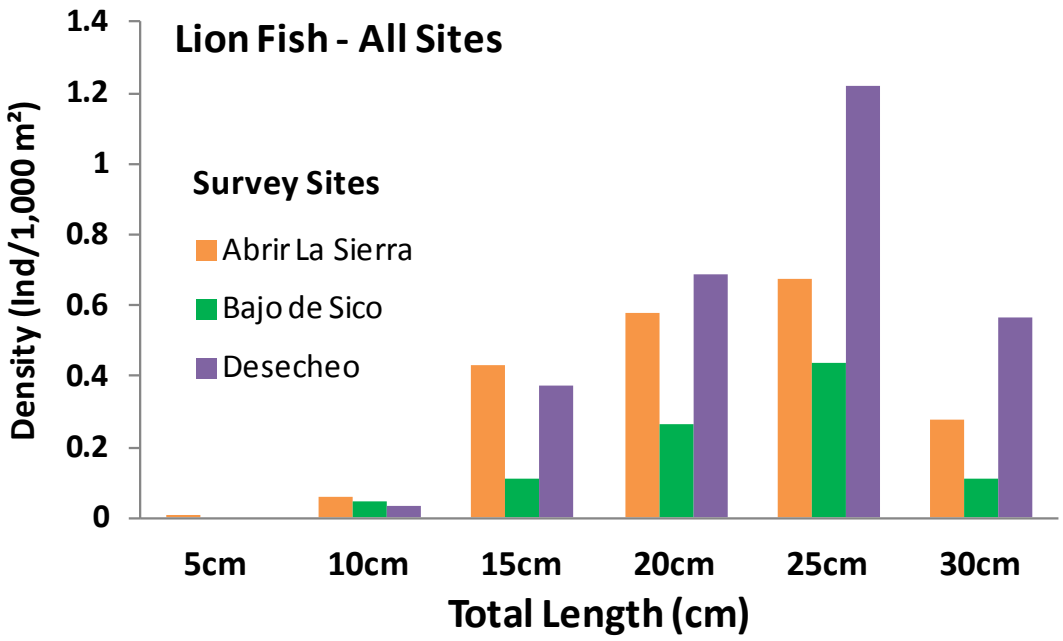


Figure 30. Length frequency distributions of lionfish, *Pterois volitans* at mesophotic sites surveyed during 2011-12

14. Great Barracuda (*Sphyraena barracuda*)

With a total of 49 individuals sighted, great barracuda was the most numerically dominant pelagic type fish present from mesophotic habitats within the PR EEZ. Great barracuda presented a size range of 60 – 100 cm (TL) (Figure 31). Maximum length estimated from individuals in this survey was close to the maximum reported for the Caribbean Antilles at 114 cm (Table 8). Great barracudas recruited to mesophotic habitats at a length of 60 cm, which is about their size at first reproduction (Table 8). Beyond the recruitment size, barracudas were observed throughout their mature size range at all sites surveyed. Modal (total) length was 90 cm., influenced by several very large individuals sighted at Desecheo, but large individuals were observed also from BDS and ALS (Figure 31). Since a permanent ban for sale of barracuda is in effect in PR, it is possible that fishing pressure for this species has reached a point that is allowing individuals to grow towards their maximum potential.

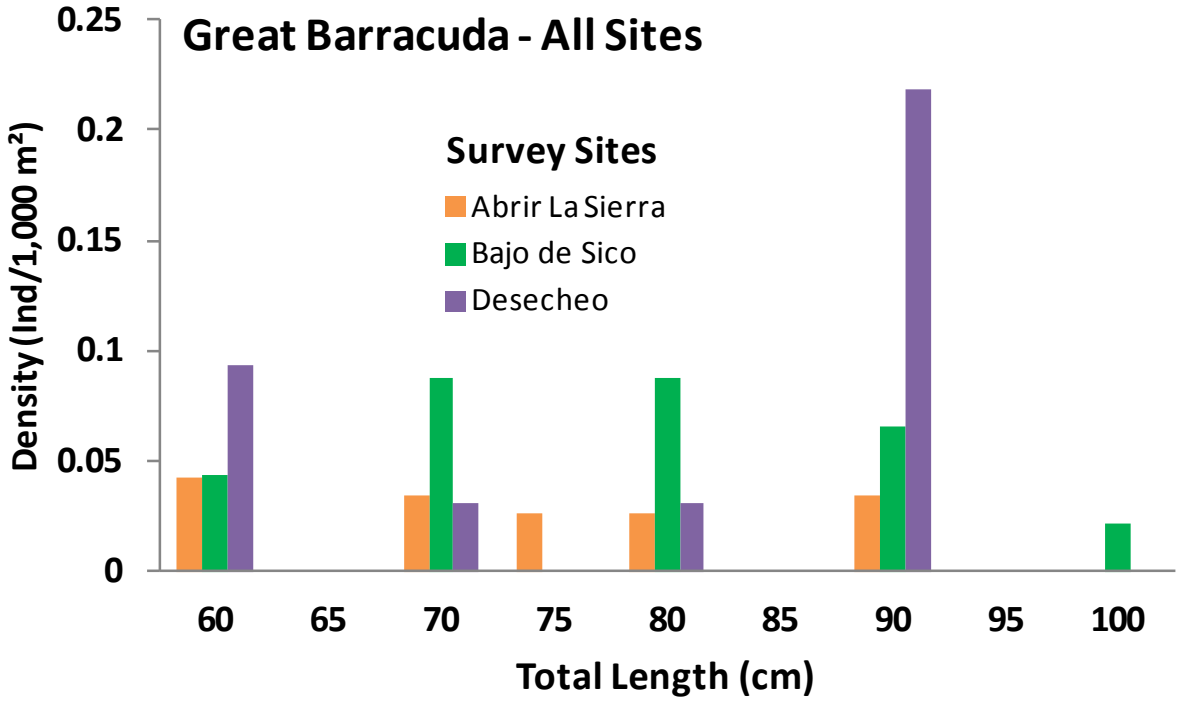


Figure 31. Length frequency distributions of great barracuda, *Sphyraena barracuda* at mesophotic sites surveyed during 2011-12

VII. Conclusions

1) Mesophotic benthic habitats at sites surveyed within the PR EEZ included reef tops, slope walls and rhodolith reefs at Abrir la Sierra (ALS), slope walls, patch reefs with colonized pavement and rhodolith reefs at Isla Desecheo (Des), and rock reef promontories and rhodolith reefs at Bajo de Sico (BDS).
2) These mesophotic habitats represent prime residential, foraging and spawning habitats for a diverse assemblage of commercially important fish and shellfish populations in their late juvenile and adult life stages.
3) Marked variations in the composition and abundance of several commercially important fish and shellfish populations between sites were noted. Higher abundance of queen conch, large snappers (mutton, dog, cubera) and hogfish were observed from at ALS, as compared to Des and BDS.
4) Given the similarity of benthic habitat types between sites and the habitat plasticity displayed by snappers, hogfish and queen triggerfish, it is proposed that the sharp differences in size and composition of the aforementioned species assemblage is related to the recruitment enhancement effect provided by the within shelf connectivity of recruitment and/or nursery with mesophotic habitats at ALS, compared to the isolation imposed by oceanic barriers separating Desecheo and Bajo de Sico from the PR shelf.
5) Several populations evidenced marked preferences for particular benthic habitats. For example: more than 90 % of all queen conch from all sites was observed from the rhodolith reef at ALS. Conversely, spiny lobsters, groupers, hogfishes, lionfishes and snappers, with the exception of mutton snapper, were more abundant at the reef top and slope wall habitats than at the rhodolith reef.
6) Queen conch was more abundant during the August – September survey, coinciding with their peak reproductive season at ALS. Couples of queen conchs were observed engaged in copulation and egg masses discovered from the rhodolith habitat at depths ranging between 38 – 45 m (125 – 145 ‘) during the August-September survey season.
7) Based on density estimated by visual surveys at the various habitat types and the corresponding benthic habitat areas, it is estimated that the population of queen conch within mesophotic habitats of ALS was in the order of 20,000 to 30, 000 individuals during our 2011-12 survey period. As such, queen conch represents the most valuable stock within the PR EEZ area included in this survey. Queen conch stocks from mesophotic habitats at Desecheo and Bajo de Sico were estimated in the order of several hundred individuals.
8) Stocks of red hind, schoolmaster snapper, lionfish and queen triggerfish were estimated in the low thousands (1,000 – 5,000 Ind) within mesophotic habitats at ALS, and in the low to mid hundreds at Bajo de Sico. There is no data on benthic habitat areas for Isla Desecheo and thus, population estimates are not feasible from our survey data.
9) Stocks of large groupers (Nassau, yellowfin, black) and snappers (cubera, dog, mutton) were estimated in the low to mid hundreds within mesophotic habitats at ALS and in the low hundreds at Bajo de Sico.
10) Groupers and snappers, as well as hogfish and queen triggerfish all presented size distributions with most individuals over the length at first reproduction, indicative that mesophotic habitats serve largely as residential habitats for adult fish populations.

11) Red hind presented a modal size just above the size at first reproduction, with relatively low proportion of large individuals, and maximum size well under that reported for the Caribbean Antilles, which may be indicative of high fishing pressure on this species.
12) Large groupers with the exception of red hind, and snappers, as well as hogfish and queen triggerfish all presented size distributions well above the length at first reproduction, encompassing the entire adult size range up to, or close to the maximum sizes reported for the Caribbean Antilles. This is inconsistent with the notion of these stocks being presently overfished (within the mesophotic habitats surveyed) and may support an alternative theory of low carrying capacity, where in a scenario of relatively low availability of food resources, a few large individuals dominate large foraging areas.
13) The scarcity of sharks detected during our surveys tends to support the theory of low carrying capacity that these mesophotic habitats naturally convey for large fish predators.
14) Lionfish (*Pterois volitans*) exhibited size distributions encompassing the entire range for the species, from settlement juveniles to maximum size adults, indicative that mesophotic habitats function as recruitment, residential, foraging and perhaps reproductive habitats for this species. The high proportion of large adult individuals in the population conveys the virtual lack of fishing pressure on this species.

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IX. Appendices

Appendix 1a. Length data for fish and shellfish at Abrir la Sierra (ALS) – Season 1

February – April, 2011

ALS - Season1		**Season 1**	
Habitat	**Reef Top**	**Wall**	**Rhodolith**
Total Survey Area (m2)	15,954	14,040	9,840
Species			
Balistes vetula	2 - 30cm	1 - 25cm	
	3 - 35cm	2 - 30cm	
		1 - 35cm	
Elagatis bipinnulata	11 - 35cm		
Epinephelus guttatus	1 - 15cm	1 - 20cm	2 - 25cm
	6 - 20cm	23 - 25cm	9 - 28cm
	22 - 25cm	30 - 30cm	7 - 30cm
	37 - 30cm	2 - 35cm	3 - 33cm
	3 - 35cm		
Epinephelus striatus	1 - 40cm	1 - 70cm	
Ginglymostoma cirratum	1 - 140cm	1 - 200cm	1 - 180m
Lachnolaimus maximus		2 - 60cm	1 - 25cm
			1 - 41cm
Lactophrys spp.	1 - 36cm	1 - 38cm	1 - 25cm
	1 - 15cm	3 - 41cm	1 - 28cm
		1 - 46cm	
Lutjanus analis	1 - 50cm	3 -51cm	1 - 40cm
	1 - 60cm	1 - 55cm	3 - 45cm
		3 - 60cm	1 - 60cm

Lutjanus apodus	40 - 20		
	70 - 25		
	20 - 30		
	8 - 35		
	2 - 40cm		
Lutjanus cyanopterus	2 - 45cm	1 - 60cm	
	2 - 60cm	1 - 70cm	
Lutjanus jocu	1 - 20cm		
	2 - 50cm		
	2 - 55cm		
Mycteroperca venenosa	1 - 45cm	1 - 65cm	
	1 - 50cm		
Pterois volitans	1 - 10cm	1 - 10cm	2 - 25cm
	30 - 15cm	3 - 15cm	
	10 - 20cm	13 - 20cm	
		25 - 25cm	
		12 - 30cm	
Sphyraena barracuda	1 - 75cm	1 - 80cm	
	1 - 80cm		

Shellfish Species		**Season 1**	
	Reef Top	**Wall**	**Rhodolith**
Panulirus argus		1 - 13cm	
		2 - 14cm	
Strombus gigas	5 - 25cm	2 - 24cm	17 - 22cm
	1 - 27cm	1 - 25cm	12 - 23cm
	1 - 28cm	1 - 26cm	20 - 24cm
		1 - 27cm	47 - 25cm
			18 - 26cm
			13 - 27cm
			2 - 28cm

Appendix 1b. Length Data for fish and shellfish at Abrir la Sierra (ALS) – Season 2
August – September, 2011

ALS-2 August – September, 2011		**Season 2**	
Habitat	**Reef Top**	**Wall**	**Rhodolith**
Total Survey Area (m2)	11,060	14,600	9,520
Species			
Balistes vetula	4 - 20cm	1 - 30cm	2 - 30cm
	1 - 25cm	2 -35cm	1 - 35cm
	1 - 30cm		
	1 - 35cm		
Elagatis bipinnulata		1 - 50cm	
Epinephelus guttatus	1 - 20cm	2-20cm	1 - 10cm
	6 - 25cm	14-25cm	1 - 20cm
	29 - 30cm	27-30cm	3 - 25cm
	4 - 35cm	2-35cm	4 - 30cm
Ginglymostoma cirratum	4 -150cm		
Lachnolaimus maximus	3 - 45cm	1 - 50cm	
	2 - 50cm	1 - 60cm	
	1 - 55cm		
Lactophrys spp.	2-35cm		
	1-50cm		
Lutjanus analis	1 - 25cm	2 - 40cm	3 - 30cm
	1 - 30cm	1 - 50cm	1 - 40cm
	5 - 50cm		2 - 45cm
Lutjanus cyanopterus		3 - 60cm	
		3 - 70cm	
		1 - 75cm	
Lutjanus jocu		1 - 50cm	
Mycteroperca bonaci		1 - 70cm	

Mycteroperca venenosa	1 - 50cm	2 - 50cm
	1 - 65cm	3 - 60cm
		1 - 70cm
		1 - 80cm
Ocyurus chrysurus	2 - 25cm	
	2 - 30cm	
	1 - 40cm	
	1 - 50cm	
Pterois volitans	5 - 20cm	1 - 10cm
	11 - 25cm	4 - 15cm
	7 - 30cm	7 - 20cm
		20 - 25cm
		7 - 30cm
Scomberomorus regalis	1-55cm	2 - 25cm
		2 - 30cm
		4 - 45cm
		3 - 50cm
		1 - 55cm
Sphyraena barracuda	2 - 75cm	3 - 60cm
	1 - 90cm	2 - 70cm
		1 - 90cm

Shellfish Species		**Season 2**	
	Reef Top	**Wall**	**Rhodolith**
Panulirus argus	1 - 14cm	1 - 14cm	
Strombus gigas	1 - 23cm	3 - 24cm	1 - 12cm
	1 - 25cm	3 - 25cm	1 - 13cm
	6 - 26cm	3 - 26cm	1 - 14cm
			1 - 15cm
			1 - 16cm
			1 - 18cm
			3 - 19cm
			Rhodolith
Strombus gigas			8 - 20cm

			11 - 21cm
			15 - 22cm
			36 - 23cm
			51 - 24cm
			70 - 25cm
			53 - 26cm
			52 - 27cm
			2 - 28cm

Appendix 1c. Length Data for fish and shellfish at Abrir la Sierra (ALS) – Season 3
December 2011 – January 2012

ALS-3			**Season 3**
Habitat	**Reef Top**	**Wall**	**Rhodolith**
Total Survey Area (m2)	15,304	13,752	12,856
Species			
Balistes vetula	10 - 30cm	1 - 25cm	4 - 25cm
	8 - 35cm	2 - 30cm	5 - 30cm
		1 - 35cm	1 - 35cm
Elagatis bipinnulata		6 - 30cm	
		3 - 40cm	
		3 - 50cm	
Epinephelus guttatus	1 - 15cm	2 - 10cm	2 - 15cm
	3 - 20cm	1 - 15cm	4 - 20cm
	4 - 25cm	4 - 20cm	5 - 25cm
	15 - 30cm	4 - 25cm	1 - 30cm
	1 - 35cm	8 - 30cm	
		1 - 35cm	
Epinephelus striatus	1 - 45cm		
	1 - 50cm		
	1 - 55cm		
Ginglymostoma cirratum	1 - 150cm	1 - 180m	

Lachnolaimus maximus	1 - 30cm		1 - 40cm
	2 - 50cm		1 - 50cm
Lactophrys spp.	2 - 15cm		1 - 20cm
	1 - 30cm		1 - 30cm
	2 - 40cm		
Lutjanus analis	1 - 50cm	1 - 45cm	1 - 40cm
			4 - 45cm
			4 - 50cm
Lutjanus cyanopterus	1 - 90cm	1 - 25cm	
Lutjanus jocu	4 - 35cm	1 - 50cm	
	1 - 40cm		
	1 - 50cm		
Mycteroperca bonaci	1 - 40cm		
	1 - 50cm		
	1 - 60cm		
Mycteroperca venenosa	1 - 45cm	1 - 60cm	
	2 - 55cm		
Ocyurus chrysurus			2 - 30cm
Pterois volitans	1 - 5cm	1 - 10cm	1 - 10cm
	2 - 10cm	2 - 15cm	3 - 25cm
	10 - 15cm	7 - 20cm	
	24 - 20cm	6 - 25cm	
	10 - 25cm	1 - 30cm	
	5 - 30cm		
Scomberomorus regalis	1 - 45cm	1 - 55cm	1 - 50cm
	1 - 50cm		
Sphyraena barracuda	2 - 90cm	2 - 60cm	2 - 60cm
		2 - 70cm	1 - 70cm
			1 - 80cm

Sphyrna mokarran	1 - 300cm		

Shellfish Species		**Season 3**	
	Reef Top	**Wall**	**Rhodolith**
Panulirus argus	2 - 12cm	2 - 12cm	
Strombus gigas	4 - 23cm 5 - 24cm 3 - 25cm 3 - 26cm		1 - 15cm 1 - 18cm 1 - 19cm 2 - 20cm 5 - 21cm 11 - 22cm 18 - 23cm 50 - 24cm 53 - 25cm 34 - 26cm 13 - 27cm 3 - 28cm

Appendix 2. Length Data for fish and shellfish at Bajo de Sico (BDS)

BDS				
2/2/2011 - 4/14/2011			**Totals**	
Habitat	**Rock Reef**	**Rhodolith**	**Rock Reef**	**Rhodolith**
Total Survey Area (m2)	**27,627**	**17,909**		
Species				
Balistes vetula	3 - 30cm	2 - 20cm	6	9
	3 - 40cm	3 - 30cm		
		4 - 40cm		
Elagatis bipinnulata	2 - 50cm	5 - 50cm	4	8
	2 - 60cm	3 - 70cm		
Epinephelus guttatus	1 - 15cm	5 - 15cm	18	21
	1 - 20cm	7 - 20cm		
	2 - 25cm	4 - 25cm		
	7 - 30cm	4 - 30cm		
	7 - 35cm	1 - 35cm		
Epinephelus striatus	6 - 50cm	1 - 60cm	14	2
	6 - 60cm	1 - 80cm		
	2 - 70cm			
Ginglymostoma cirratum	1 - 130cm		4	
	3 - 180cm			
Lutjanus apodus	120 - 25cm		170	
	50 - 31cm			
Lutjanus cyanopterus	1 - 30cm	2 - 60cm	11	
	3 - 60cm			
	3 - 70cm			
	2 - 80cm			
Lutjanus jocu	1 - 50cm		1	
Mycteroperca bonaci	2 - 70cm		9	
	3 - 80cm			
	4 - 90cm			

Mycteroperca venenosa	1 - 60cm 5 - 70cm 1 - 80cm	2 - 80cm	7	2
Mycteroperca tigris	1 - 40cm 2 - 50cm 3 - 60cm		6	
Negaprion brevirostris	1 - 81cm 1 - 185cm		2	
Pterois volitans	5 - 15cm 11 - 20cm 20 - 25cm 5 - 30cm	2 - 10cm 1 - 20cm	41	
Scarus guacamaia	2 - 60cm 1 - 70cm		3	
Scomberomorus cavalla	1 - 121cm		1	
Scomberomorus regalis	3 - 40cm 2 - 50cm 1 - 60cm		6	
Sphyraena barracuda	1 - 60cm 2 - 70cm 3 - 80cm 2 - 90cm 1 - 100cm	1 - 60cm 2 - 70cm 1 - 80cm 1 - 90cm	9	5

Shellfish Species

Panulirus argus	1 - 11cm		1	
Strombus gigas	1 - 23cm 8 - 25cm 6 - 26cm 5 - 27cm	1 - 26cm 2 - 27cm 2 - 28cm	20	5

Appendix 3. Length Data for fish and shellfish at Isla Desecheo (Des)

Desecheo
4/15/2011 - 6/9/2011

Habitat **Depth Contour** **Station** **Distance (m)**	**Totals** **Wall**	**Totals** **Rhodolith**	**Totals** **patch/hrd grd**
Fish Species			
Epinephelus guttatus	3 - 30cm	1 - 15cm	9 - 25cm
	2 - 35cm	2 - 20cm	31 - 30cm
	2 - 38cm	5 - 25cm	30 - 35cm
		11 - 30cm	4 - 38cm
		2 - 35cm	
Pterois volitans	1 - 15cm	1 - 15cm	3 - 10cm
	4 - 20cm	1 - 20cm	12 - 15cm
	5 - 25cm	12 - 25cm	15 - 20cm
	2 - 30cm	2 - 30cm	21 - 25cm
			3 - 30cm
Mycteroperca venenosa	1 - 45cm	1 - 60cm	1 - 60cm
	1 - 60cm	1 - 70cm	1 - 70cm
	2 - 80cm		3 - 80cm
Epinephelus striatus			3 - 60cm
			1 - 70cm
			1 - 80cm
Sphyraena barracuda	3 - 90cm	1 - 80cm	3 - 60cm
		1 - 90cm	1 - 70cm
			1 - 80cm
			3 - 90cm
Scomberomorus cavalla	1 - 90cm		
Seriola rivoliana		1 - 80cm	4 - 60cm
Balistes vetula			2 - 30cm
			5 - 35cm
			8 - 40cm
			2 - 45cm

Lutjanus jocu		1 - 60cm	1 - 40cm
			1 - 50cm
Lactophrys polygonia		2 - 15cm	1 - 30cm
		2 - 20cm	1 - 40cm
Ginglymostoma cirratum			2 - 100cm
Lutjanus apodus		1 - 20cm	7 - 15cm
		7 - 25cm	5 - 20cm
			230 - 25cm
			120 - 30cm
			4 - 35cm
Elagatis bipinnulata			1 - 25cm
			2 - 40cm
			1 - 50cm
Scomberomorus regalis			1 - 40cm
			4 - 70cm
Negaprion brevirostris			1 - 225cm
		1 - 100cm	
Shellfish Species			
Panulirus argus	2 - 15cm	2 - 10cm	4 - 10cm
			2 - 15cm
			1 - 18cm
Strombus gigas		1 - 18cm	13 - 25cm
		2 - 22cm	24 - 26cm
		5 - 24cm	7 - 27cm
		5 - 25cm	5 - 28cm
		4 - 26cm	
		2 - 27cm	
Sea Turtles			
Eretmochelys imbricata			1 - 90cm