Results of a coral reef survey of the North Sound of Antigua

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EXECUTIVE SUMMARY

The following is a report documenting the results of a coral reef survey conducted in the North Sound region of Antigua between August 1st and 5th, 2005. This survey was supported by the Stanford Development Corporation and was conducted using the benthic and fish surveying methods of the Atlantic and Gulf Rapid Reef Assessment (AGRRA) program. These methods were designed to allow a comparison of similar reef zones across the Caribbean by using standardized procedures for the collection of data on commonly recognized indicators of reef health. Data from this survey are presented here for the purposes of describing the composition and distribution of benthic and fish communities in the North Sound region. These North Sound communities are then compared to reef sites within the AGRRA database, a collection of survey data from over 25 regions and 400 reef sites within the Caribbean area.

Results of the survey in the North Sound show a relatively healthy benthic community but an unhealthy and disturbed fish community. In comparison to other Caribbean sites in the AGRRA database, indicators of reef health of the benthic community of the North Sound rank relatively high. Live coral cover was high, the abundance of macroalgae (competitors with coral) was low, and the abundance of a major herbivore, the long-spined sea urchin (*Diadema antillarum*) was the second highest recorded in the AGRRA database. When compared to deeper sites located farther from shore on the west and southwest bank of Antigua, the habitat complexity of the North Sound would predict a more diverse and abundant fish community however, the opposite result was found. Overall, total fish abundance ranks comparatively high as well, but this is due to the relatively high abundance of very small herbivores on these reefs. Carnivores, specifically piscivores, and large herbivores were almost entirely absent from surveys, indicating a severely depleted and disturbed fish community.

Despite the presence of large reef areas of the North Sound dominated by coral rubble and standing dead colonies, indicating significant mortality of coral in the past, all indicators of reef health from our survey suggest a healthy and diverse re-colonizing benthos with the potential for future recovery and growth. However, the fish community is severely under-populated relative to the potential provided by the amount of available habitat in the North Sound area. These low abundances could be due to multiple factors, including increased adult mortality due to fishing pressures, as well as potentially a lack of larval fish supply from nearby reef areas. To address these issues, more information is needed on the oceanographic conditions and demographics of fishing effort in this region. In addition, documentation of the distribution and composition of both the benthic and fish communities within the entire Antigua-Barbuda shelf system is needed to properly assess the condition of these populations, and assess the extent and potential for recovery in the Sound and elsewhere. There were reef areas where seaweed levels were not as excessive as on reefs in some other countries, possibly indicating low nutrient levels. However, upcoming changes to the watersheds make it vital that a thorough understanding of nutrient processes affecting the reefs be attained, particularly given the increased sensitivity to nutrient loading often associated with a disturbed fish community.

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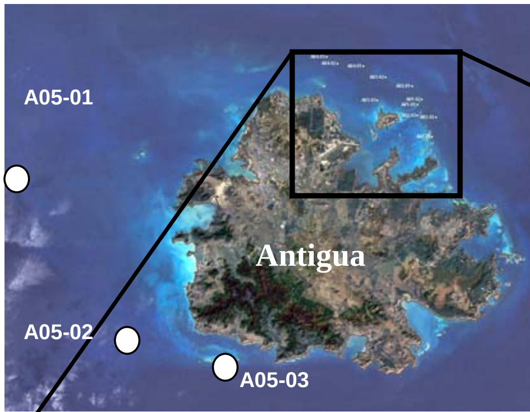

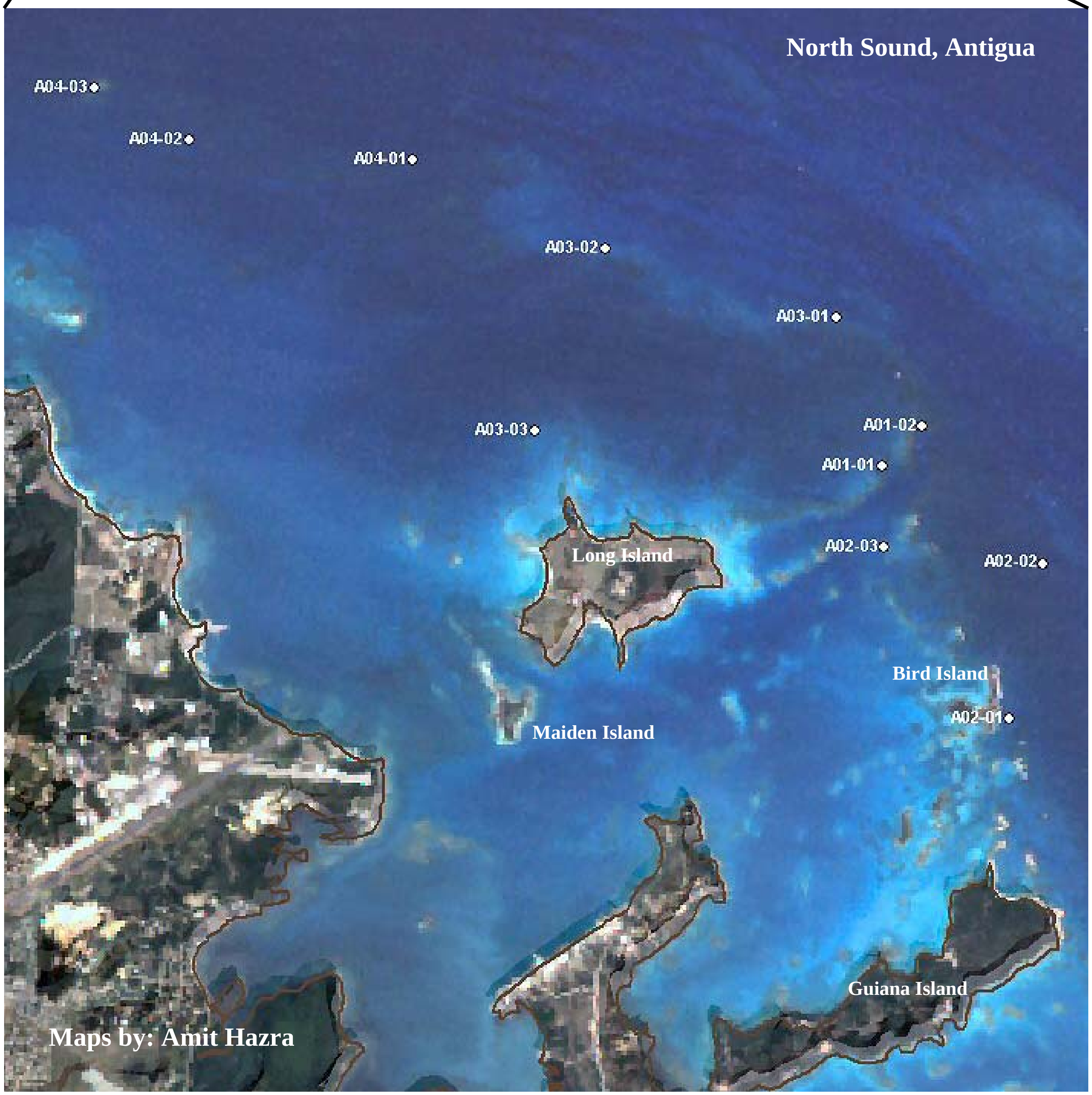

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1. Introduction

1.2 The Survey Team

What follows are the results of a coral reef survey conducted in the North Sound area of Antigua that took place from August 1st to 5th, 2005. The survey team was from the Rosenstiel School of Marine and Atmospheric Science at the University of Miami located in Miami, Florida, USA. The survey method used was the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol, version 4.0 that can be download from the following website: http://www.agrra.org/method/methodology.html. With the exception of one, all team members were previously trained in the AGRRA method and had participated in data collection on at least two previous AGRRA survey missions. On the first day, consistency training was carried out to assess and minimize variability between data collection by team members.

The survey team was operating under the auspices of the National Center for Coral Reef Research (NCORE), a center within the Rosenstiel School of Marine and Atmospheric Science, directed by Dr. John McManus. NCORE was founded in response to the need for critical information on how to best assess and manage coral reefs, and focuses on the analysis and prediction of coral reef resilience in order to improve the scientific and socioeconomic basis of coral reef management. Funding for this specific survey was provided by the Stanford Development Corporation.

1.3 Purpose of Survey

NCORE's purpose in performing the survey was to quantitatively describe the fish and coral communities of the North Sound of Antigua and to compare the status of several indicators from the coral reefs found there to other reefs throughout the Caribbean basin surveyed with identical methods. This information will be disseminated to the stakeholders of Antigua and will serve as a preliminary database for the selection of potential monitoring sites and protected areas within the region.

2. Methods

2.2 Site Identification

Fourteen reef sites were surveyed in all: eleven sites spanning the reef development from Bird Island to Horseshoe Reef off the northeast quadrant of Antigua, and three sites to the west and southwest of Antigua (Map of study region, Table 1). The eleven sites in the North Sound area, hereafter presented as NE Antigua in the results and discussion, were chosen as representative of the area based on geomorphologic structure inferred from nautical charts, preliminary snorkel surveys by Professor John McManus, and expert opinion by locals John Birk and Ashton Williams. The three sites to the west and southwest of Antigua, hereafter presented as W-SW Antigua, were chosen for comparison to the NE reefs based on suggestions from John Birk.

Four different reef zones were surveyed (presented here as a progression from seaward to landward): (1) the fore reef, representing the area from the seaward edge of the shallow reef crest sloping into deeper water; (2) the reef crest, representing the shallow area of reef growth between the fore reef and back reef; (3) the back reef, representing the area between the seaward edge of a lagoon floor and the landward edge of a reef crest; and (4) coral patches, representing relatively small areas of distinct and unconnected reef growth within the lagoonal area. The reef crest was primarily not emergent, but clearly served to reduce wave energy between what are considered here to be the reef slope and back reef areas.

2.3 Benthic Surveys

Six 10m-long benthic transect surveys were performed at each site to assess: (1) the density of the long-spined sea urchin *Diadema antillarum*; (2) the size and condition of coral individuals; (3) the percent cover of the major benthic components; and (4) the macroalgae height, reef relief, and recruitment of stony corals.

2.3.1 The long-spined sea urchin, *Diadema antillarum*

To assess the density of the long-spined sea urchin *Diadema antillarum*, a diver counted the total number of individuals within 0.5m of each side of the transect line (total area per transect = $10m^2$). Juveniles were recorded as any individual with black and white markings on the spines, while adults were recorded as those individuals with only black coloration on the spines.

2.3.2 Coral size and condition

To assess the corals in each transect, the diver recorded information on each coral colony more than 10cm in diameter located directly beneath the transect line, including: species name; depth; size (diameter and height perpendicular to the axis of growth); substrate type; percent living under the transect line, "recently dead" (corallite structure identifiable to genera), or "long dead" (corallite structure non-identifiable or covered thickly by organisms); disease type if infected (identification of diseases based on the Coral Disease Identification and Information webpage found in the NOAA Coral Health and Monitoring Program website, http://www.coral.noaa.gov/coral_disease); percent bleached if affected; and the total number of damselfish gardens and damselfish per coral head (for *Stegastes diencaeus*, *S. fuscus*, *S. planifrons*, and *S. variabilis*).

2.3.3 Percent cover of major benthic components

The percent cover was estimated for each of the major benthic components directly under the transect line, including: sand, live coral, crustose coralline algae, fleshy macroalgae, calcareous macroalgae, and any other sessile benthic animals (e.g., gorgonians, sponges, zoanthids, tunicates, etc.). To determine the percent cover, the diver recorded and tallied the total length (in cm) of each benthic component directly under the transect tape as they progressed from the beginning to the end of the transect line.

2.3.4 Macroalgae height, reef relief, and recruitment

To assess the macroalgae height, reef relief (i.e. rugosity), and recruitment, the diver re-swam the transect and placed a 25x25cm quadrat every 2 meters along the transect line (at 1, 3, 5, 7, and 9m marks), directly under the meter mark. For each quadrat, the diver recorded (1) the substratum (pavement, live coral, dead coral, rubble, or sand); (2) the approximate average canopy height (in cm) of all fleshy macroalgae, using a plastic ruler; (3) the approximate average canopy height (cm) of all calcareous macroalgae; (4) the maximum reef relief (cm), measured as the height of the tallest coral or reef rock above the lowest point in the underlying substratum within the quadrat; and (5) the total number of stony coral recruits (≤2cm), and the genus or species identification for each recruit.

2.4 Fish Surveys

The fish surveys consisted of two distinct methods: (1) a 30m belt transect survey to assess fish density and size; and (2) a roving diver census to assess fish presence/absence and relative abundances. Method 1 was used to gain a quantitative and standardized measurement of fish density, while Method 2 was used to gain a qualitative assessment of the species diversity and abundance. For Method 1, the divers conducted ten haphazardly-positioned belt transect counts, each 30x2x2m in size, and at least 5m laterally away from previous counts. For each transect, a diver swam the 30m distance within 5-8 minutes, counting all fish from a pre-determined list (Table 2) within an imaginary 2 meter wide area extending 2m up from the benthic floor. The fish species counted (Table 2) represent common species likely affected by human impacts. Fish were assigned to one of six size categories (<5cm, 5-10, 10-20, 20-30, 30-40, and >40cm) using a 1m "T-bar" with 5cm increments to help in assessing sizes. Juvenile grunts and parrotfish were not counted if <5cm, since species identification can be difficult within this size category. For Method 2, a diver swam haphazardly for approximately 30minutes, recording all fish species observed and the relative abundance of each species as single (1 fish), few (2-10), many (11-100), or abundant (>100 fishes), following the methodology of the Reef Environmental Education Foundation (REEF, http://www.reef.org/).

3. Results

Four reef "zones" were sampled during the course of the survey; the fore-reef, reef crest, back-reef, and lagoonal coral patch zones. In most cases, the coral populations of the fore-reef, back-reef, and lagoonal coral patch zones were diverse and healthy. Though there was rubble evidence of a significant loss of populations of *A. palmata, A. cervicornis,* and *A. prolifera* (pic 1), in general there were sizeable healthy populations of these species along with diverse assemblages of the massive coral species (pics 2-3). However, the reef crest zone was dominated by *A. palmata* rubble and was generally absent of live coral with the exceptions of some scattered live colonies of young *A. palmata*, fire coral, and small brain corals.

3.2 Fore-reef Zone

Five fore-reef sites in the NE and three fore-reef sites in the W-SW were visited during the course of the survey (Map, Table 1). Average depth at the NE fore-reef sites ranged between 6.4 and 10.1m (Table 1). In the NE, this zone contained spur and groove formations of reef development that ranged from low to medium relief and the average relief of the substrate was 75cm (Table 3). The carbonate "spurs" appeared to be built primarily by rubble of the branching coral *Acropora palmata* and also by the massive coral species complex that includes *Montastrea annularis, M. faveolata,* and *M. franksi.* The spurs were separated by sand "grooves" or, in some cases, by a lower relief of the rubble and coral heads giving the appearance of a completely continuous reef structure. The spurs and grooves were oriented perpendicular to the reef crest which slopes up from the seafloor but was not always not emergent from the water and was generally only marked by breaking waves.

In the three W-SW fore-reef sites, the substrate was found to be large areas of continuous low relief hard-bottom scattered with numerous small coral heads and a high abundance of gorgonians. These platforms of reef structure were separated by equally large areas of rippled sand. Average depths at these sites were deeper than the NE fore-reef sites, ranging from 10.2 to 13.7 meters (Table 1). Little relief or structural complexity due to hard substrate was noted and the average reef relief at these sites was 34cm, a considerably lower number than the average for the NE sites indicating a large difference between the structure of the substrate of the two areas (Table 3).

3.2.1 Coral

Overall, a total of 31 transects were carried out with a resulting 310m^2 of reef assessed and 327 coral colonies evaluated in the fore-reef zone of the NE Antigua area (Table 3). Sixteen species of scleratinian coral from eight genera were identified within this zone along with three species of hydrocorals of the genera *Millepora*. Of the genera identified, species of *Acropora*, *Montastrea*, and *Porites* were the most abundant comprising a respective 22%, 31%, and 24% (Total of 77%) of the coral colonies assessed (Fig. 1). As shown in Table 3, live coral cover in this zone ranged from 11 to 41% with an average of 21% for the NE area (i.e. on average, live coral covered 21% of the available substrate). The highest coral cover in the fore-reef zone was found at site A04-02, the most northwesterly of the fore-reef sites. Also in Table 3, on average, colonies exhibited 16% old mortality (i.e. no corallite structure identifiable) and 0.6% recent mortality (i.e. corallite structure still identifiable or covered by a thin layer of filamentous algae). Of the colonies assessed, 0.4% was recorded as standing dead meaning that the entire colony was dead. Of the colonies assessed, 4.6% were noted to be experiencing some type of disease. Also, while the survey was taking place, a fairly substantial amount of bleaching was occurring and on average, 36.9% of corals in the fore-reef zone of the North Sound exhibited some type of bleaching (e.g. partial bleaching, paling or complete bleaching).

Three fore-reef sites, two on the western bank and one near Cades Reef were assessed as well for comparison to the northeastern area (Map: Sites A05-01, A05-02, A05-03; Table 1). At these sites 18 transects were carried out and thirteen species of scleractinian coral belonging to nine genera were identified and one species of hydrocoral was recorded. The most common species of corals recorded at these three sites belonged to the genera *Diploria* (27%), *Porites* (19%), and *Montastrea* (19%) making up a total of 65% of the corals encountered (Fig. 1). The average live coral cover in these three areas was 10% with the lowest coral cover, 6%, occurring at site A05-03, near Cades Reef. Colonies assessed exhibited an average of 17% old mortality and 0.2% recent mortality. Disease was rare and found on an average of 0.5% of corals sampled. Less bleaching was occurring on these reefs versus the NE however it was still a large percentage (16.6%, Table 3).

3.2.2 Algae

Algal abundance was evaluated at each fore-reef site and also for each fore-reef area (Table 4, Fig. 2). Crustose coralline algal abundance ranged from 1 to 15% considering all the sites separately. The North Sound fore-reef in general had a higher cover of crustose corallines at 10% versus the W-SW fore-reef which had only 3%. Most of the calcareous and fleshy macroalgal cover reported here are composed of *Halimeda* spp. and *Dictyota* spp., respectively. Four sites, on average, had no calcareous macroalgae, with three of them comprising the W-SW fore-reef sites. The highest calcareous macroalgal cover observed in the fore-reef sites was 11%. Fleshy macroalgal cover ranged from 1 to 51%. There was a distinct difference in fleshy macroalgal abundance between the NE and W-SW fore-reefs, where the latter had higher cover (30% vs 10%). A05-02 a W fore-reef site exhibited the greatest fleshy macroalgal cover at 51%. Apart from having greater fleshy macroalgae, the W fore-reef sites also had on average lower crustose coralline cover (3%) and zero calcareous macroalgae compared to the NE fore-reef sites (10% crustose coralline and 6% calcareous macroalgae). For the NE fore-reef sites, the percent covers of the three algal types were quite close.

3.2.3 Fish

When all fish are combined, the average total density of target fish (Table 2) in the fore-reef zone for the northeastern area of Antigua is 136 fish /100m^2 (Table 5). By far the most commonly encountered fish families were Parrotfish (average density 73/100m^2) and Surgeonfish (average density 57/100m^2) (Table 6), both of which are targeted by the AGRRA method because they are major herbivorous groups on the reef. Together, these two families composed 96% of the fish recorded in transects (Fig 3). Despite their abundance however, individuals of these families were, on average, extremely small (Parrotfish average size 11cm, Surgeonfish average size 7cm, Table 7) and so when size and abundance are combined to estimate biomass (g/100m2), these estimates were low (Table 8). All other fish families except Angelfish comprised the other 4% of fish recorded. These families include all piscivorous fish families, feeding exclusively on other fish, and those fish considered "commercially significant" (See * Table 2). These fish families were encountered rarely, their sizes were typically small (<30cm, Table 7), and the estimate of biomass was extremely low (Table 8). Angelfish were not recorded in any fore-reef transects or during the rover diver survey. Only 16 of the 63 fish species targeted by the AGRRA fish method were seen at the NE fore-reef sites (Table 5). During the rover diver survey, a total of 35 species were recorded at fore-reef sites.

In comparison, fore-reef sites on the western bank and southwestern area of Antigua had an overall average fish density of 73/100m^2 (Table 5). At these sites, Parrotfish were also the most abundant family (average density 25/100m^2) however, Grunts (Haemulidae) represented the second most abundant family (average density 22/100m^2) and Surgeonfish were third (average density 16/100m^2) (Table 6). Parrotfish were also on average small in this area (average size 12cm) however Surgeonfish were generally larger (average size 15cm) as were all other family groups (Table 7). With the exception of the Grunt family, carnivorous fish families and fish species considered commercially significant were also encountered rarely and when recorded, were typically small (Tables 6, 7) however the situation was not as extreme as in the NE area. This is evidenced in the considerably higher biomass estimates for all families of the W-SW fore-reef sites in comparison to all of the NE reef zones (Table 8). Additionally, double the number of target fish species were identified in S-SW transects versus NE and 15 more fish species than in the NE were identified in roving surveys (Table 5). All of this suggests that fish communities of the fore-reef zone of S-SW Antigua are more species rich and abundant than those found in the NE.

3.3 Reef Crest Zone

The reef crest zone of the NE area appeared to extend from south of Bird Island to as far as Beggar's Point in the northwest section. The only apparent emergent part of this reef crest was Horseshoe Reef although a more extensive survey would be required to fully characterize this habitat. The reef crest appeared to be built almost entirely of *Acropora palmata* rubble (Pic 1). On top of the *A. palmata* rubble, some small thickets of live *A. palmata* were occasionally encountered as well as some scattered clusters of mound coral.

3.3.1 Coral

Two sites, A01-02 and A02-01 were classified as reef crest zone sites and six transects were carried out at each site. Very little coral was found in this zone and therefore only 85 colonies were assessed (Table 3). These 85 colonies belonged to twelve scleractinian coral species from six genera and two hydrocoral species. The most dominant genus was by far *Acropora*, comprising 48% of all corals encountered in this zone. *Diploria* (19%) and *Porites* (19%) were also often found (Fig. 4). Live coral cover averaged 10% and the average old and recent mortality found on coral colonies was 16% and 0.4% respectively (Table 3). The average proportion of diseased and bleaching corals at these two sites were 0.0 and 26.9% respectively.

3.3.2 Algae

The two reef crest sites were very similar. They had the highest crustose coralline cover observed in all the sites at 19% (18 and 19% for the individual sites) (Table 4, Fig. 2). On average as well, the reef crest had the lowest fleshy macroalgal cover (5%) out of all the sites. Calcareous macroalgal average cover was 6% with 4 and 9% for the individual sites.

3.3.3 Fish

In the reef crest zone, the average density of all target fish was higher than in the fore-reef zone (Table 5, average density 175/100m^2), however, nearly all of the fish encountered were either Parrotfish (102/100m^2) or Surgeonfish (67/100m^2) (Table 6, Fig 3) and they were all extremely small (Table 7, average size 12cm Parrotfish and 8cm Surgeonfish). Biomass estimates by fish family for this zone versus the fore-reef are higher for Parrotfish, Surgeonfish and "Other" (Table 8). "Other" in this case represents an abundance of the Yellowtail Damselfish, an herbivorous fish species known to create algal "gardens" on areas of dead and live coral. Other targeted fish families were either rarely seen (Grouper, Butterflyfish) or not seen at all (Grunt, Snapper, Angelfish, Triggerfish) (Table 6, 8). Only ten target fish species were identified in reef crest transects and only 23 fish altogether were identified in the roving diver surveys making the reef crest zone the least fish species rich zone of all the zones surveyed (Table 5).

3.4 Back-Reef Zone

Two back reef sites were examined during the survey, A01-01 and A04-03. These sites differed from each other in that they were distinguished by their structure and coral composition. At site A01-01, located near the southeastern area of the lagoon by Bird Island and close to the channel, the back reef sloped gently down to a sandy bottom that was populated by diverse clusters of large coral heads and gorgonians. Site A04-03 was located behind Horseshoe Reef in the very northeast section of the area. Here, the crest fell sharply down to the substrate and was dominated by large clusters of primarily *M. annularis* colonies and thickets of *Acropora cervicornis*.

3.4.1 Coral

Six transects were surveyed at each of the two sites within the back-reef zone and a total of 138 coral colonies were assessed (Table 3). At these sites 15 scleratinian coral species from 8 genera and one hydrocoral species were recorded. The most abundant species belonged to the genera *Montastrea* (61%), *Porites* (18%), and *Acropora* (7%, Fig 5). The average of live coral cover for the back-reef zone sites was 20% and coral colonies were found to exhibit an average of 20%old mortality and 0.1% recent mortality (Table 3). On average 4.2% of corals were diseased and 12.6% of corals were bleached at these sites.

3.4.2 Algae

The two back reef sites had slightly higher calcareous macroalgal cover (11%) followed by fleshy macroalgae at 9% and crustose corallines 6% (Table 4). Similar to the NE fore-reefs, the algal cover distribution is quite even between these three types (Fig 2).

3.4.3 Fish

In the back reef, fish were found at an average density of $109/100m^2$ (Table 5). Parrotfish and Surgeonfish dominated with average densities of 73 and $57/100m^2$ respectively and all other families were rarely seen or not seen at all as in the case of Snappers, Angelfish and Triggerfishes (Table 6, Fig 3). For those groups where fish were recorded, fish sizes were small, all groups being on average less than 20cm (Table 7). This lead to low biomass estimates for all fish groups (Table 8). Similar to the other coral reef zones in the NE, the backreef zone had few fish species with only 17 target fish species identified in transects and 39 fish species identified in roving diver surveys (Table 5).

3.5 Coral patch Zone

Two coral patch sites, A02-03 and A03-03, were surveyed over the course of the five day survey including one site in the southeast section of the area and one north of Long Island (Map, Table 1). Overall, 143 coral colonies were recorded and evaluated in this zone (Table 3). In the central parts of the lagoon (e.g. the shallow areas north of Long Island and northwest of Bird Island) large, mounded coral patches were found dominated by thickets of *A. palmata, A. prolifera,* and *A. cervicornis.* The mounds range from 10-20 meters in diameter.

3.5.1 Coral

Six transects were performed at each of the two coral patch sites. Within these transects, 10 species of scleractinian coral from 5 genera and 1 species of hydrocoral (*Millepora alcicornis*) were identified (Table 3). At these sites, *Montastrea* (32%), *Acropora* (31%), and *Porites* (23%) species were the most commonly encountered (Fig 6). Average live coral cover was 20 % and colonies were recorded with an average old mortality of 29% and recent mortality of 0.6% (Table 3). On average, 1.2% of corals were diseased and 22.3% of corals were bleached.

3.5.2 Algae

Fleshy macroalgae had a slightly higher cover (12%) in the coral patches, followed by calcareous macroalgae (10%) but only 4% for crustose corallines (Table 4, Fig 2).

3.5.3 Fish

The back reef and coral patch zones had similar densities and composition of fish families. The coral patch average fish density was 111/100m^2 (Table 5) and was again comprised mostly of Parrotfish and Surgeonfish (57 and 49/100m^2, Table 6, Fig 3). The main difference between the zones was that Grunts were seen slightly more frequently in the coral patches versus the back reef (5/100m^2 vs. 1/100m^2). Fish sizes were small, all groups less than 20cm on average (Table 7) and therefore biomass estimates were also low (Table 8). Again, the number of fish species found at these sites was low, only 18 identified in transects and 36 in roving surveys (Table 5).

3.6 Coral Recruits

Coral recruitment was measured as number of coral recruits per 0.25m^2 and then expanded to estimate the number per square meter. A total number of 70 recruits were identified in 424 quadrats assessed during the survey, 48 recruits at sites in the NE area and 32 at sites in the W-SW. The overall average number of coral recruits per square meter for the NE was 3.1 and for the W-SW was 4.6 (Table 3). Recruits were found at a average density of 2.2/m^2 in the reef crest zone, 1.3/m^2 in the back reef zone and 1.6/m^2 in the coral patch zone (Table 3).

In both areas, the two most commonly found genera of coral recruits were *Porites* and *Agaricia*, both of which include species of fast-growing corals that often settle in high densities. These two genera represented a respective 51% and 17% of the recruits identified in quadrats. Other individuals identified included those belonging to the genera *Favia* (9%), *Millepora* (4%), *Siderastrea* (3%), *Acropora* (3%), *Diploria* (2%), *Scolymia* (2%), *Dichocoenia* (1%), *Isophyllia* (1%), and *Manicina* (1%). Few of these recruits belong to massive genera (*Diploria* and *Siderastrea*) and no recruits were of the *Monastrea* species complex, species which are considered the common Caribbean framework builders. This is not necessarily surprising as the method by which these different genera reproduce leads to different patterns of recruit density. For instance, *Porites spp* and *Agaricia spp* are brooders whose larvae are able to settle immediately after being released from the parent colony, typically leading to high densities of recruits. Meanwhile, *Montastrea spp* are broadcast spawners which must develop for several days before becoming capable of settling and are therefore subject to more oceanographic influences that may increase their mortality.

3.7 Coral Diseases

Sclearactinian coral diseases have recently been recognized as a major source of mortality of corals and therefore a potential reason for the recent drastic decline of Caribbean coral reefs (Porter & Meier 1992, Harvell et al. 1999, Porter et al. 2001, Aronson & Precht 1997, 2001, Porter et al. 2002). During the survey, four characterized coral diseases were identified to be affecting corals in the area including Yellow Blotch, Black-band, Dark Spots and White Band diseases. In recent decades, these four syndromes have become common on Caribbean reefs and it was therefore not surprising to discover them affecting Antiguan corals as well.

As mentioned in previous sections, the average proportion of coral colonies affected by disease was generally low at each site. In some cases, however, disease was locally abundant. For example at site A04-02 an average of 22% of corals recorded in transects were diseased. In this case, Yellow blotch and Black-band diseases were locally abundant at this site and were the reason for the high proportion of diseased corals. Coral cover at this site was also the highest recorded during the survey. It may be, therefore, that the abundance of corals (i.e. potential hosts for pathogens) has allowed these diseases to persist at a higher prevalence than would be found at a lower density site. However, more work on the spread and distribution of diseases in the varying habitats should be conducted before any conclusions are drawn.

Yellow blotch was the most abundant disease found affecting corals. The etiology (i.e. description of the causal agent) is not known for this disease but it commonly affects the massive *Montastrea annularis* species complex and causes slow mortality over a period of several years. This disease is identified as an area or line of yellowed tissue (Pic 4). Within the transects,Yellow blotch was found to be affecting 13 colonies belonging to the *M. annularis* species complex. Although this only comprised 1.6% of all of the coral colonies surveyed, it represented 5.3% of all *M. annularis* species complex individuals surveyed. Yellow blotch affected colonies were found at four sites, one NE fore-reef site as mentioned previously (A04-02), one W-SW fore-reef site (A05-01), one back-reef site (A04-03) and one patch-reef site (A03-03). Of the 13 affected colonies recorded, only one affected coral was identified at each of sites A03-03 and A05-01. The two sites, A04-02 and A04-03, where the majority of affected colonies were found were sites with high coral cover estimates and coral family compositions largely dominated by *Montastrea* species. Also mentioned previously, it may therefore be likely that the high number of affected colonies was related to the abundance of available hosts.

Black-band disease was the second most commonly encountered coral disease during the course of the survey. This disease has been extensively characterized and is known to be caused by a consortium of bacteria dominated by the cyanobacteria *Phormidium corallyticum* (Richardson *et al.* 1997, Kuta & Richardson 2002). The disease appears as a thick black line on the coral colony marking the intersection of healthy tissue and dead white skeleton (Pic 5). Five Black-band affected colonies were recorded during the survey, all of them occurring in locations in the northwest of the NE survey area. Three were reported from the fore-reef site, A04-02, and two at the back-reef site, A04-03. Clustering of Black-band affected colonies has been indicated elsewhere in the Caribbean (Bruckner & Bruckner 1997) and it has been postulated that this is because it may be highly contagious.

Dark Spots syndrome and White Band disease were each recorded to be affecting one coral colony during the survey. Dark Spots disease is commonly found occurring on species of the genera *Siderastrea* and *Agaricia* and may be a generalized stress response of a coral (Borger 2004). White Band disease attacks only branching coral species of the genera *Acropora* and is likely responsible for the demise of this genera in the Caribbean (Aronson & Precht 2001). It is important, therefore, to note that both of these diseases, despite an abundance of hosts, were not commonly found throughout the course of this survey.

3.8 Long-spined sea urchin (Diadema antillarum) populations

Diadema individuals were present at 33% of the $10m^2$ transects surveyed in NE Antigua, and 11% of transects surveyed in W Antigua. The highest density recorded for a single transect was $3/m^2$, located at A02-02, where a total of 89 individuals were counted within the six transects surveyed. The average number per transect differed markedly among the sites and reef zones (Table 9), where *Diadema* were most prevalent in the fore reef zones of NE Antigua. Although not surveyed, the reef crest and back reef area of Cade's reef supported a healthy population with high densities (Picture 6), suggesting a patchy, heterogeneous distribution of individuals across the whole of Antigua.

4. Discussion

4.2 Comparison to other Caribbean regions (AGRRA database sites)

There was little published information available on the reefs of Antigua, especially in the NE area of the island. This survey represents the first known comprehensive survey of both the benthic and fish communities of this area. With no basis for comparison to previous studies, it is difficult to say whether what was recorded represents a baseline for the area or if this system has experienced significant changes in recent decades like other Caribbean coral reef systems. However, it is possible to compare some standard indicators of reef health to other reefs around the Caribbean surveyed using the AGRRA methodology in similar reef zones.

Comparisons were made between results from this survey and results from other surveys in other countries completed with identical methods and reported in the AGRRA database (Country Key Table 10). Zones targeted by the AGRRA method include fore-reef, reef crest and coral patches. The majority of information in the AGRRA database is for the fore-reef zone, however, there is some available information for the reef crest and coral patches. Unfortunately, there is no available information for the back-reef zone and therefore, no comparisons are made for this zone. Values for comparison were obtained from the AGRRA summary products website, released in August, 2005.

4.2.1 Coral

The average coral cover for all NE fore-reef sites was 21% versus an average for all other Caribbean fore-reef sites recorded in the AGRRA database of 20% (Fig 7). With this value, the North Sound of Antigua lies in the upper half of regions surveyed using the AGRRA method between 1999 and 2003. In contrast, the average coral cover of the west and southwest Antigua fore-reef sites was 10%, half of the Caribbean average and in the lower quarter of regions surveyed.

Average coral cover recorded on the NE coral patch sites was the highest of the four coral patch zones recorded in the AGRRA database (20%) and was nearly twice the average (12%, Fig 8). The average coral cover recorded in the NE reef crest zone however, was 10% putting it in the lower quarter of those regions recorded in the AGRRA database and also placing it well below the Caribbean average (18%, Fig 9). There was no information available for comparison to the North Sound back reef however the average coral cover for this zone was 20% which is comparable to the fore-reef and coral patch sites.

When the community composition of coral families in the North Sound is compared to that of an average for all Caribbean sites, it differs significantly in the types of coral families that dominate (Fig 1). Whereas in most of the Caribbean *Montastrea* is largely the most dominant coral family, in the fore-reef zone of North Sound, *Montastrea*, *Porites*, and *Acropora* were all equally dominant coral families. Today, *Acropora* is rarely seen in the fore-reef zone of Caribbean reefs, due primarily to the demise of this genus by White Band disease in the last two decades (Aronson & Precht 2001). Within the AGRRA database, on average *Acropora* comprises only 3% of the corals found in fore-reef zones. This is compared to the North Sound average of 22% where, although there was much evidence of a significant loss of *Acropora* based on the abundance of rubble and standing dead, there were still large, healthy populations remaining of all three species (*Acropora palmata, A. cervicornis,* and *A. prolifera*, Pic 2). Sites surveyed in the W-SW followed more closely the Caribbean trend where *Acropora* individuals were scarce (representing only 3% of colonies recorded) and the coral community was dominated by mounding corals; in this case *Montastrea, Diploria*, and *Porites* (Fig 1).

The community composition of corals found in the reef crest zone of North Sound was comparable to the average for other reef crest sites in the Caribbean (Fig 4). The main exception was the absence of *Siderastrea* species and that *Acropora* and *Porites* seemed more abundant in this area than elsewhere.

Although it is not possible to compare its composition to that of another Caribbean sites, the coral family composition of the NE back reef zone was similar to that of the Caribbean average fore-reef zone, meaning it was dominated largely by *Montastrea* (Fig 5).

The community composition of the NE coral patches differed strikingly from the average of other coral patch zones in the Caribbean (Fig 6) and this was mostly due to the abundance of *Acropora*. Similar to the fore-reef zone, most Caribbean coral patches recorded in the AGRRA database are dominated by *Montastrea* individuals and *Acropora* is rarely encountered. In NE Antigua, this is not the case and *Acropora* and *Montastrea* are equally as dominant in this zone.

In terms of coral recruit density, for the purposes of comparison, averages were calculated for each habitat type and then judged against those values for equivalent habitats within the AGRRA database. The average number of recruits per square meter in the fore-reef zone of the NE was slightly less than the average for all fore-reef sites within the AGRRA database (Fig 10). However, the average for the three W-SW fore-reef sites was slightly higher than average. The differences are slight and overall, both areas appear to have a fairly average rate of recruitment of juvenile corals. Similarly, recruit densities in the coral patch and reef crest zones of the North Sound were comparable to the average for those zones within the AGRRA database and the values fell in the middle of those for other countries (Figs 11 and 12).

4.2.2 Macroalgae

The dominant macroalgae found in all the sites came from the two genera of *Halimeda* and *Dictyota*. *Halimeda* spp. are calcareous macroalgae that contribute to reef sediment and are commonly found in coral reefs and seagrass ecosystems worldwide. *Dictyota* spp. are considered fleshy macroalgae that can grow fast but are relatively more ephemeral, i.e., they experience large changes in cover usually peaking in the summer then declining markedly (Lirman and Biber 2000).There were differences in the abundances of the three algal groups, crustose, calcareous and fleshy, between the various sites and habitat types. The habitat types had differing orders for the algal group covers (as discussed in the Results section) although these were not quantitatively large differences except for the W-SW fore-reef sites where the fleshy macroalgae were obviously dominant. Of note was the distinct difference between the NE and W-SW fore-reef sites reflected as well in the algal cover. Not only did the W-SW fore-reef sites have the highest fleshy macroalgal cover, but also had the lowest crustose algae and zero calcareous.

AGRRA uses a macroalgal index that is a product of the macroalgal cover and height, to help characterize the dominance of macroalgae in sites. Unfortunately, AGRRA had recently changed the methods to measure macroalgal cover, thus it is difficult to compare this Antigua data to those from other regions in the Caribbean. However, the method to obtain fleshy and calcareous macroalgal heights was still the same and this was used to investigate if the patterns obtained with algal heights were similar to the indices and therefore the cover. When the fleshy and calcareous macroalgal heights from Antigua were compared to other Caribbean regions with similar data, these exhibited similar patterns as those using the cover and indices. This gives more confidence in the between country comparison results.

The NE fore-reef and reef crest sites of Antigua exhibited the lowest fleshy macroalgal index out of twelve and ten countries, respectively (Figures 13 and 14). The coral patch data could only be compared to macroalgae cover from the Florida Keys, U.S.A., and Antigua fleshy macroalgal index was also lower than the Florida Keys index (Figure 15). Deviating from this pattern, the W fore-reef was closer to the average fleshy macroalgal index for 12 Caribbean countries (Figure 13). The fleshy macroalgal index taken with other benthic cover data, potentially indicates the availability of space in the reefs and possibly the capacity of coral larvae to recruit onto the substrate. Thus, it is a good sign for the NE fore-reef and reef crest that they have very low fleshy macroalgal indices.

4.2.3 Long-spined sea urchin (*Diadema antillarum*) populations

During 1983 and 1984, greater than 93% of the entire Caribbean population of *Diadema* died in a mass mortality event that rapidly spread throughout the Caribbean basin in a pattern consistent with water currents (Lessios 1988, Lessios 2005). Although the exact cause of this mortality remains unknown, the lethality, specificity, and pattern of spread strongly suggest the effects of a water-borne pathogen (Lessios 1988). Although many Caribbean reefs had previously been overfished by this date, leading to reduced numbers of herbivores capable of grazing the seaweeds on reefs (Jackson et al. 2001), the mass mortality of *Diadema* represented the loss of the last major herbivore for many Caribbean reef sites, leading to a fast increase in the dominance of seaweed on many sites within a few years. This synchronized increase in seaweed abundances demonstrated the significance and importance of *Diadema* as a keystone grazer within Caribbean reefs.

Jamaica is a classic example of the effects of this mass mortality on the health of reefs, where the synergistic impacts of a hurricane strike prior to the mass mortality event and the later loss of *Diadema* led to the decrease in coral cover from 52% to 3% and increase in seaweed abundances from 4 to 92% between 1977 and 1993 (Hughes 1994). Even now after 20 years, population densities remain low throughout the Caribbean (Figure 17), which before reached values as high as 71 per square meter (Knowlton 2001). These relatively low densities could be the result of continual localized outbreaks of disease as populations recover, or an extremely slow but prevalent recovery rate.

By the mid-1990's, a few sites throughout the Caribbean have noticed increases in their *Diadema* populations (Barbados: Hunt and Younglao 1988; Jamaica: Edmunds and Carpenter 2001; St. Croix: Miler et al. 2003). The recent recovery of *Diadema* populations in Jamaica has been christened the "best news to emerge from Caribbean reefs in decades" from one author (Knowlton 2001). Recovery of this population has had a strong ecosystem-level effect through a reduction in seaweeds from grazing, thereby providing bare substrate for the successful recolonization of corals.

The average density of *Diadema* in the NE fore-reef zone is the highest recorded density within the AGRRA database and is more than 13 times the average (Fig 16). Overall, the population of *Diadema* within the NE reefs of Antigua represents the second highest abundances within the Caribbean (Figs 17), sometimes as high as 30 individuals per $10m^2$. In addition, extremely high densities of *Diadema* were noted while snorkeling the back reef and reef crest at Cade's Reef on the SW side of the island, where densities may have reached dozens per square meter (Picture 6). These localized populations of high density, in addition to the overall presence of individuals in 33% and 11% of the transects surveyed in the NE and W-SW reefs, respectively, suggest a very healthy population of *Diadema* within Antigua. Although the population of *Diadema* prior to 1983 within Antigua is unknown, it likely suffered a substantial decline, as all known populations within the Caribbean were affected (Lessios 1998). Therefore, we conclude that the current presence of *Diadema* within Antigua represents a significant sign of recovery for this population. With this species keystone role in overall ecosystem health, specifically with respect to their control of seaweed dominance, this apparently healthy population of *Diadema* within Antigua may provide an increased potential for successful recruitment and recovery of corals, as previously found in Jamaica (Edmunds and Carpenter 2001).

4.2.4 Fish

Overall average fish density, including all families, for NE fore-reef sites was the highest recorded in the Caribbean (Fig. 18). However, as mentioned previously, this number primarily represents the high abundance of very small Parrotfish and Surgeonfish (Fig 6). When total average biomass is calculated (based on abundance and size combined), the NE fore-reef zone is approximately even with the average for all sites within the AGRRA database (Fig 19). In contrast, the average density of fish in the W-SW fore-reef zone is significantly lower than the NE fore reef though the average total biomass of these sites is much higher than that of the NE (Figs 18, 19).

When average densities and biomass for the North Sound fore reef are broken down into groups and compared to other Caribbean countries within the database, values for carnivorous and piscivorous fish families (i.e. Groupers, Grunts, and Snappers) and all species considered commercially significant compare poorly with other countries (Figs 20-25). Values for these groups are either the lowest recorded or are in the lower quarter of countries surveyed and well below the average. In contrast, densities of herbivorous fish families (i.e. Parrotfish and Surgeonfish) are the highest recorded and biomass estimates are in the upper quarter and above average (Figs 26-29). All density and biomass values for fish families in the W-SW Antigua fore reef zone fell in the upper third of countries recorded in the database (Figs 20-29).

Similar situations were found in the reef crest and coral patch zones where fish densities and biomass were high compared to the other AGRRA sites (Figs 30-33) but these populations were dominated by herbivorous fish families (data not shown).

In general, these data would suggest that although the density of fish is high and the biomass estimates are average for the NE, these values do not represent a healthy fish population. Only the herbivorous fish families were present in any quantifiable amount and these families were composed of only small individuals. Other fish families appeared rarely and were generally small as well. Typically, a fish community should be composed of equal proportions of herbivorous and carnivorous fish families however; in NE Antigua the carnivorous group is nearly absent.

4.3 Summary

Based on this survey and in comparison to other similar surveys in the Caribbean region, the benthic communities of the North Sound appear to be in a relatively healthy condition while the fish communities appear to be in a relatively unhealthy and disturbed condition, as evidenced by the almost complete lack of carnivores and piscivores. The complexity of the substrate provided by a healthy population of branching corals would generally predict a high abundance and diversity of fish. However, different factors may be causing carnivorous fish populations to be depressed. Although it appears that there was a severe loss of coral as evidenced by a large amount of rubble and standing dead, indicators such as the abundance of coral recruits, the quantity of the herbivore *Diadema antillarum*, the absence of excessive macroalgae overgrowth, and the high percentage of live, healthy coral cover suggests that these reefs have significant potential for recovery.

In comparison, sites surveyed on the west bank and southwest area of Antigua contained diverse and abundant fish populations. The substrate in this area consisted of a generally flat continuous reef populated by numerous small mound corals and gorgonians. When comparing the North Sound to these sites, again one would predict that the North Sound would contain a much more abundant and diverse fish community based on the characteristics of the substrate. However, this was not at all the case. Besides substrate characteristics, the major differences between the W-SW fore-reef sites and the North Sound fore-reef sites were depth and distance from shore.

There may be many factors influencing the differential abundance and composition of fish communities in the North Sound versus the west and southwest shelf. Two factors in particular may be separately or synergistically acting in these two areas, mortality and larval fish supply. Factors influencing larval fish supply are largely oceanographic (e.g. currents, water temperature) and there is a paucity of information on the oceanography of the Antigua area. Fishing pressure is likely the most influential factor on fish mortality, particularly given the scarcity of highly marketable species of snappers and grunts. Harvest levels of these species are difficult to quantify given the lack of accurate estimates of spatially-explicit fishing pressure in the area. The west-southwest sites were deeper and generally farther from shore than the North Sound sites. Differences in the amounts and sizes of fish, particularly carnivorous fish, may have something to do with differential fishing pressure.

In order to understand how these factors may be influencing the composition and abundance of fish populations in the North Sound, more information is needed on the oceanography of the area, its relationship to processes of fish and coral recruitment, and the fishing effort. Also, a more thorough documentation of the coral reefs of the entire Antigua-Barbuda shelf area should also be undertaken in order to gain a complete understanding of the distribution of the benthic and fish communities and their recovery status. Low amounts of seaweed in some reef areas may indicate that excessive nutrient loading is not widespread. However, given the increasing rates of development within adjacent watersheds, it is critical to better understand nutrient processes which may become problematic in the future, especially given the fact that reductions in the fish community generally increase the sensitivity of reef ecosystems to these stressors.

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Table 1:

Region	Date Surveyed	Site	Avg. Depth (m)	Latitude	Longitude	Reef Type
NE Antigua	8/1/2005	A01-01	2.9	N17.16402	W61.73284	Back reef
NE Antigua	8/1/2005	A01-02	2.3	N17.16723	W61.72954	Reef Crest
NE Antigua	8/2/2005	A02-01	5.0	N17.14432	W61.72247	Reef Crest
NE Antigua	8/2/2005	A02-02	9.4	N17.15646	W61.71973	Forereef
NE Antigua	8/2/2005	A02-03	2.4	N17.15774	W61.73266	Coral Patch
NE Antigua	8/3/2005	A03-01	6.4	N17.17564	W61.73652	Forereef
NE Antigua	8/3/2005	A03-02	7.3	N17.18114	W61.75529	Forereef
NE Antigua	8/3/2005	A03-03	4.6	N17.16683	W61.76107	Coral Patch
NE Antigua	8/4/2005	A04-01	8.2	N17.18800	W61.77090	Forereef
NE Antigua	8/4/2005	A04-02	10.1	N17.18958	W61.78912	Forereef
NE Antigua	8/4/2005	A04-03	7.9	N17.19374	W61.79682	Back reef
W Antigua	8/5/2005	A05-01	13.7	N17.11684	W62.01280	Forereef
W Antigua	8/5/2005	A05-02	11.7	N17.01834	W61.93518	Forereef
SW Antigua	8/5/2005	A05-03	10.2	N17.00369	W61.86499	Forereef

Table 2:

Common Name	Scientific Name	Common Name	Scientific Name
Angelfishes		***Groupers***	
Queen	*Holacanthus ciliaris*	Rock Hind*	*Epinephelus adscensionis*
Rock Beauty	*Holacanthus tricolor*	Graysby	*Epinephelus cruentatus*
Gray	*Pomacanthus arcuatus*	Coney*	*Epinephelus fulvus*
French	*Pomacanthus paru*	Red hind*	*Epinephelus guttatus*
Butterflyfishes		Nassau*	*Epinephelus striatus*
Longsnout	*Chaetodon aculeatus*	Black*	*Mycteroperca bonaci*
Foureye	*Chaetodon capistratus*	Yellowmouth*	*Mycteroperca interstitialis*
Spotfin	*Chaetodon ocellatus*	Tiger*	*Mycteroperca tigris*
Reef	*Chaetodon sedentarius*	Yellowfin*	*Mycteroperca venenosa*
Banded	*Chaetodon striatus*	***Snappers***	
Grunts		Mutton*	*Lutjanus analis*
Black Margate*	*Anisotremus surinamensis*	Schoolmaster*	*Lutjanus apodus*
Porkfish	*Anisotremus virginicus*	Cubera*	*Lutjanus cyanopterus*
White Margate*	*Haemulon album*	Gray*	*Lutjanus griseus*
Tomtate	*Haemulon aurolineatum*	Dog*	*Lutjanus jocu*
Caesar	*Haemulon carbonarium*	Mahogany*	*Lutjanus mahogoni*
Smallmouth	*Haemulon chrysargyreum*	Lane*	*Lutjanus synagris*
French*	*Haemulon flavolineatum*	Yellowtail*	*Ocyurus chrysurus*
Spanish	*Haemulon macrostomum*	***Surgeonfishes***	
Sailors choice	*Haemulon parra*	Ocean	*Acanthurus bahianus*
White	*Haemulon plumieri*	Doctorfish	*Acanthurus chirurgus*
Bluestriped	*Haemulon sciurus*	Blue Tang	*Acanthurus coeruleus*
Parrotfishes		***Leatherjacket***	
Midnight	*Scarus coelestinus*	Scrawled Filefish	*Aluterus scriptus*
Blue	*Scarus coeruleus*	Queen triggerfish	*Balistes vetula*
Striped	*Scarus croicensis*	Whitespotted filefish	*Cantherhines macroceros*
Rainbow	*Scarus guacamaia*	Orangespotted filefish	*Cantherhines pullus*
Princess	*Scarus taeniopterus*	Ocean triggerfish*	*Canthidermis sufflamen*
Queen	*Scarus vetula*	Black Durgon	*Melichthys niger*
Greenblotch	*Sparisoma atomarium*	Sargassum triggerfish	*Xanthichthys ringens*
Redband	*Sparisoma aurofrenatum*	***Other fishes***	
Redtail	*Sparisoma chrysopterum*	Spanish Hogfish	*Bodianus rufus*
Redfin	*Sparisoma rubripinne*	Bar Jack*	*Caranx ruber*
Stoplight	*Sparisoma viride*	Hogfish	*Lachnolaimus maximus*
		Yellowtail Damselfish	*Microspathodon chrysurus*
		Great Barracuda	*Sphyraena barracuda*
*Fishery importance of species is defined as "commercially significant" by FishBase			

Table 3:

Coral Summary																					
Site Information												Colony Information									
Region	Site	Zone	Total # Colonies Surveyed	Avg. Live Coral Cover	±	Avg. Coral Density	±	Avg.# coral recruits / m2	±	Avg. Relief (cm)	±	Avg. Old Partial Mortality	±	Avg. Recent Partial Mortality	±	% of Colonies that were 100% dead	±	Avg. % Diseased	±	Avg. % Bleached	±
NE Antigua	A01-01	Back reef	60	15%	3	1.0	0.4	1.6	3	100	39	16%	13	0.1%	0	0.0%	0	1.4%	3	18.8%	29
NE Antigua	A01-02	Reef crest	36	7%	9	0.6	0.4	0.5	1	103	42	14%	16	0.7%	1	6.3%	15	0.0%	0	32.3%	38
NE Antigua	A02-01	Reef crest	49	13%	4	0.8	0.2	3.7	4	73	27	17%	12	0.3%	1	0.0%	0	0.0%	0	21.5%	16
NE Antigua	A02-02	Fore-reef	84	20%	12	1.4	0.7	1.6	3	50	19	13%	7	0.2%	0	1.9%	5	1.0%	2	35.3%	34
NE Antigua	A02-03	Coral patch	57	24%	17	1.0	0.4	1.1	2	63	20	28%	21	0.9%	1	0.0%	0	0.0%	0	17.8%	19
NE Antigua	A03-01	Fore-reef	49	12%	9	0.8	0.4	6.4	7	46	12	11%	7	1.1%	2	0.0%	0	0.0%	0	36.1%	80
NE Antigua	A03-02	Fore-reef	46	11%	4	0.8	0.4	1.6	2	58	28	11%	6	0.2%	0	0.0%	0	0.0%	0	66.6%	52
NE Antigua	A03-03	Coral patch	86	16%	8	1.4	0.4	2.1	2	137	46	30%	13	0.3%	1	6.3%	15	2.4%	6	26.8%	39
NE Antigua	A04-01	Fore-reef	65	20%	11	1.1	0.6	4.3	4	130	67	15%	13	0.3%	1	0.0%	0	0.0%	0	35.4%	54
NE Antigua	A04-02	Fore-reef	83	41%	16	1.4	0.5	1.6	3	94	17	26%	11	0.9%	2	0.0%	0	22.1%	26	11.1%	14
NE Antigua	A04-03	Back reef	78	25%	14	1.3	0.7	1.1	2	99	20	20%	13	0.1%	0	0.0%	0	7.1%	12	6.4%	8
W-SW Antigua	A05-01	Fore-reef	60	12%	4	1.0	0.4	3.7	4	38	6.3	13%	9	0.3%	0	0.0%	0	1.4%	3	19.3%	29
W-SW Antigua	A05-02	Fore-reef	55	10%	3	0.9	0.4	4.3	5	28	4.9	8%	6	0.0%	0	0.0%	0	0.0%	0	18.1%	31
W-SW Antigua	A05-03	Fore-reef	47	6%	2	0.8	0.4	5.9	4	37	7.8	26%	6	0.3%	1	0.0%	0	0.0%	0	12.5%	14
		NE Fore-reef	327	21%	14	1.1	0.6	3.1	7	75	36	16%	23	0.6%	4	0.4%	2	4.6%	11	36.9%	25
		NE Reef Crest	85	10%	6	0.7	0.3	2.2	7	88	21	16%	28	0.4%	2	3.1%	11	0.0%	0	26.9%	16
		NE Back Reef	138	20%	11	1.2	0.6	1.3	10	99	0.5	20%	26	0.1%	1	0.0%	0	4.2%	6	12.6%	15
		NE Coral patch	143	20%	14	1.2	0.5	1.6	5	100	52	29%	34	0.6%	3	3.1%	11	1.2%	4	22.3%	15
		W Fore-reef	162	10%	4	0.9	0.4	4.6	5	34	5.5	17%	25	0.2%	1	0.0%	0	0.5%	2	16.6%	9

Table 4:

Macro-algae Summary															
Site/ Habitat	**Reef Type**	**Live Coral (%)**	**±**	**Crustose (%)**	**±**	**Fleshy (%)**	**±**	**Calc (%)**	**±**	**Turf/ Bare (%)**	**±**	**Fleshy Macro Ht (cm)**	**±**	**Calc Macro Ht (cm)**	**±**
A01-01	Back reef	15	3	7	3	18	16	14	6	31	7	2.5	0.6	4.5	1.8
A01-02	Reef crest	7	7	19	14	4	8	9	12	59	11	0.7	0.3	1.8	0.8
A02-01	Reef crest	13	4	18	13	7	5	4	3	45	18	1.6	1	3.7	1.9
A02-02	Fore-reef	20	12	15	8	4	3	10	8	47	12	1.4	0.6	4.3	1.3
A02-03	Coral patch	24	17	4	3	14	11	16	16	38	20	2.8	0.7	6.3	1.4
A03-01	Fore-reef	12	9	6	3	18	8	5	5	54	7	2.5	0.5	4.5	0.6
A03-02	Fore-reef	11	4	8	13	19	15	11	13	48	7	2.5	1.2	4.2	2
A03-03	Coral patch	16	8	4	6	9	5	5	4	57	14	3	0.9	5.1	1.8
A04-01	Fore-reef	20	11	14	10	14	8	0	0	43	29	0.9	0.4	0.6	0.2
A04-02	Fore-reef	41	16	5	5	1	2	6	3	27	14	0.7	0.3	6.1	1.6
A04-03	Back reef	25	14	5	7	0	0	8	5	40	16	0.6	0.2	7.1	1.7
A05-01	Fore-reef	12	4	2	2	24	13	0	0	43	13	3.2	1	0.2	
A05-02	Fore-reef	10	3	1	1	51	10	0	0	27	10	4.3	0.6	0.4	
A05-03	Fore-reef	6	2	7	10	16	14	0	0	61	19	3.1	0.3	0.4	0.2
NE Fore-reef		21	14	10	9	11	11	6	8	94		1.7	1.4	3.9	2.7
NE Reef Crest		10	4	3	6	30	19	0	0	94		3.5	1.4	0.1	0.4
NE Back Reef		10	6	19	13	5	7	6	8	95		1.1	1	2.9	3
NE Coral patch		20	11	6	5	9	14	11	6	94		1.5	1.5	5.8	3.2
W Fore-reef		20	14	4	4	12	8	10	13	95		2.9	1.8	5.7	2.5

Table 5:

Fish Summary								
Region	**Site**	**Zone**	**No. of Target Spp.**	**No. of Spp. (Roving)**	**Total No. of Ind.**	**Density (#/100m2)**	**Avg. Biomass (g/100m2)**	**±**
NE Antigua	A01-01	Back reef	17	31	536	89	4201	2141
NE Antigua	A01-02	Reef crest	9	22	873	146	11446	4741
NE Antigua	A02-01	Reef crest	10	23	1228	205	6956	3348
NE Antigua	A02-02	Fore-reef	16	26	969	162	6428	3348
NE Antigua	A02-03	Coral patch	18	28	560	93	5534	2571
NE Antigua	A03-01	Fore-reef	11	35	453	76	3359	3200
NE Antigua	A03-02	Fore-reef	15	30	880	147	3734	1635
NE Antigua	A03-03	Coral patch	18	36	811	135	6659	4179
NE Antigua	A04-01	Fore-reef	13	26	1156	193	8771	3974
NE Antigua	A04-02	Fore-reef	13	29	619	103	5390	2298
NE Antigua	A04-03	Back reef	14	39	766	128	7739	1386
W-SW Antigua	A05-01	Fore-reef	20	44	472	79	10966	10050
W-SW Antigua	A05-02	Fore-reef	23	49	563	94	11766	8908
W-SW Antigua	A05-03	Fore-reef	23	50	283	47	5016	2672
		NE Fore-reef	16	35	4077	136	5536	2195
		NE Reef Crest	10	23	2101	175	9201	3175
		NE Back Reef	17	39	1302	109	5970	2502
		NE Coral patch	18	36	811	135	6097	795
		W Fore-reef	23	50	1318	73	9249	3688

Table 6:

Average Density by Family (#/100m2)

Region	Site	Zone	Surgeonfish (Acanthuridae)	±	Parrotfish (Scaridae)	±	Grunt (Haemulidae)	±	Snapper (Lutjanidae)	±	Grouper (Serranidae)	±	Commercially Significant	±
NE Antigua	A01-01	Back reef	26	15	61	21	1	2	0		0		2	3
NE Antigua	A01-02	Reef crest	61	32	78	63	0		0		0		2	3
NE Antigua	A02-01	Reef crest	74	29	126	53	0		0		0		0	1
NE Antigua	A02-02	Fore-reef	44	17	108	34	0		1	1	0		1	1
NE Antigua	A02-03	Coral patch	45	44	37	18	9	21	1	2	0		5	9
NE Antigua	A03-01	Fore-reef	52	18	22	15	0		0		0		0	1
NE Antigua	A03-02	Fore-reef	57	13	83	38	0		1	1	0		5	13
NE Antigua	A03-03	Coral patch	53	11	78	40	1	2	1	1	0		1	3
NE Antigua	A04-01	Fore-reef	99	37	84	31	0		0		0		6	16
NE Antigua	A04-02	Fore-reef	36	13	66	23	0		1	1	0		1	1
NE Antigua	A04-03	Back reef	38	14	86	24	1	1	0		1	1	1	2
W-SW Antigua	A05-01	Fore-reef	19	6	24	11	30	62	0		2	1	4	5
W-SW Antigua	A05-02	Fore-reef	15	6	32	11	35	82	0		1	1	9	7
W-SW Antigua	A05-03	Fore-reef	16	8	19	10	3	4	1	3	5	4	6	4
		NE Fore-reef	57	25	72	32	0	0	0	0	0	0	3	2
		NE Reef Crest	67	9	102	34	0	0	0	0	0	0	1	1
		NE Back Reef	32	9	73	18	1	0	0	0	1	0	2	1
		NE Coral patch	49	6	57	29	5	5	1	0	0	0	3	3
		W Fore-reef	16	2	25	7	22	17	1	1	3	2	6	3

Region	Site	Zone	Angelfish (Pomacanthidae)	±	Butterflyfish (Chaetodontidae)	±	Triggerfish (Balistidae)	±	Other	±
NE Antigua	A01-01	Back reef	0		1	1	0		1	2
NE Antigua	A01-02	Reef crest	0		0		0		8	8
NE Antigua	A02-01	Reef crest	0		0		0		5	3
NE Antigua	A02-02	Fore-reef	0		0		0		9	3
NE Antigua	A02-03	Coral patch	0		1	1	0		1	2
NE Antigua	A03-01	Fore-reef	0		1	1	0		1	2
NE Antigua	A03-02	Fore-reef	0		0		0		6	13
NE Antigua	A03-03	Coral patch	0		1	1	0		1	2
NE Antigua	A04-01	Fore-reef	0		1	2	0		9	15
NE Antigua	A04-02	Fore-reef	0		1	1	0		0	
NE Antigua	A04-03	Back reef	0		2	3	0		0	
W-SW Antigua	A05-01	Fore-reef	1	1	2	2	1	1	1	2
W-SW Antigua	A05-02	Fore-reef	1	1	4	2	4	7	3	4
W-SW Antigua	A05-03	Fore-reef	0		1	2	0		2	2
		NE Fore-reef	0	0	1	0	0	0	5	4
		NE Reef Crest	0	0	0	0	0	0	6	2
		NE Back Reef	0	0	1	1	0	0	0	1
		NE Coral patch	0	0	1	0	0	0	1	0
		W Fore-reef	0	0	2	1	2	2	2	1

Table 7:

Average fish size (cm)

Region	Site	Zone	Surgeonfish (Acanthuridae)	±	Parrotfish (Scaridae)	±	Grunt (Haemulidae)	±	Snapper (Lutjanidae)	±	Grouper (Serranidae)	±
NE Antigua	A01-01	Back reef	9	3	12	2	14	2	16 (N=1)		16 (N=1)	
NE Antigua	A01-02	Reef crest	8	2	14	3	N/A		N/A		N/A	
NE Antigua	A02-01	Reef crest	8	2	10	2	N/A		N/A		21 (N=1)	
NE Antigua	A02-02	Fore-reef	6	1	10	1	21 (N=1)		21	7	16 (N=1)	
NE Antigua	A02-03	Coral pach	9	2	12	3	19	6	12	5	N/A	
NE Antigua	A03-01	Fore-reef	6	1	13	4	26 (N=1)		N/A		N/A	
NE Antigua	A03-02	Fore-reef	6	2	10	1	N/A		16	0	N/A	
NE Antigua	A03-03	Coral pach	9	1	11	2	20	5	17	12	N/A	
NE Antigua	A04-01	Fore-reef	9	2	11	1	16 (N=1)		36 (N=1)		31 (N=1)	
NE Antigua	A04-02	Fore-reef	9	1	12	2	12 (N=1)		13	4	43 (N=1)	
NE Antigua	A04-03	Back reef	10	2	13	2	22	6	N/A		20	5
W-SW Antigua	A05-01	Fore-reef	14	3	14	3	22	5	43		24	2
W-SW Antigua	A05-02	Fore-reef	14	3	13	2	22	5	31		27	8
W-SW Antigua	A05-03	Fore-reef	15	2	10	4	21	5	22	6	23	7
		NE Fore-reef	7	2	11	1	18	6	21	10	30	14
		NE Reef Crest	8	0	12	3	N/A		N/A		21 (N=1)	
		NE Back Reef	9	1	13	1	18	6	16 (N=1)		18	3
		NE Coral patch	9	0	11	1	20	1	14	4	N/A	
		W Fore-reef	14	0	12	2	22	1	32	10	25	2.3

Region	Site	Zone	Angelfish (Pomacanthidae)	±	Butterflyfish (Chaetodontidae)	±	Triggerfish (Balistidae)	±	Other	±
NE Antigua	A01-01	Back reef	N/A		8	0	N/A		14	3
NE Antigua	A01-02	Reef crest	N/A		N/A		N/A		18	3
NE Antigua	A02-01	Reef crest	N/A		8 (N=1)		N/A		16	1
NE Antigua	A02-02	Fore-reef	N/A		8 (N=1)		N/A		16	3
NE Antigua	A02-03	Coral patch	8 (N=1)		8 (N=1)	0	N/A		16	0
NE Antigua	A03-01	Fore-reef	N/A		12	4	N/A		10	4
NE Antigua	A03-02	Fore-reef	N/A		8 (N=1)		21 (N=1)		16	7
NE Antigua	A03-03	Coral patch	N/A		8	0	N/A		18	5
NE Antigua	A04-01	Fore-reef	N/A		8	0	N/A		15	3
NE Antigua	A04-02	Fore-reef	N/A		8	0	N/A		N/A	
NE Antigua	A04-03	Back reef	N/A		7	1	N/A		N/A	
W-SW Antigua	A05-01	Fore-reef	26	0	14	3	26	7	23	8
W-SW Antigua	A05-02	Fore-reef	12	5	11	3	25	2	19	7
W-SW Antigua	A05-03	Fore-reef	N/A		13	4	21		18	4
		NE Fore-reef	N/A		9	2	21 (N=1)		14	3
		NE Reef Crest	N/A		8 (N=1)		N/A		17	1
		NE Back Reef	N/A		8	0	N/A		14	
		NE Coral patch	8 (N=1)		8	0	N/A		17	2
		W Fore-reef	19	10	13	2	24	3	20	3

Table 8:

Average Biomass (g/100m2)

Region	Site	Zone	Surgeonfish (Acanthuridae)	±	Parrotfish (Scaridae)	±	Grunt (Haemulidae)	±	Snapper (Lutjanidae)	±	Grouper (Serranidae)	±	Commercially Significant	±
NE Antigua	A01-01	Back reef	898	745	3163	1626	51	92	23	73	19	40	101	119
NE Antigua	A01-02	Reef crest	2236	2996	7239	5213	N/A	0	N/A	0	N/A	0	558	1615
NE Antigua	A02-01	Reef crest	2523	2523	3740	3740	N/A	0	N/A	0	54	54	54	169
NE Antigua	A02-02	Fore-reef	768	1045	4287	1446	66	169	157	456	11	34	181	450
NE Antigua	A02-03	Coral patch	1851	2886	2991	2885	572	738	37	110	N/A	0	326	348
NE Antigua	A03-01	Fore-reef	650	480	2522	2862	59	185	N/A	0	N/A	0	59	185
NE Antigua	A03-02	Fore-reef	774	402	2403	1471	N/A	0	35	78	N/A	0	299	683
NE Antigua	A03-03	Coral patch	1583	578	4474	3729	306	487	102	315	N/A	0	193	563
NE Antigua	A04-01	Fore-reef	4150	3097	3654	1837	12	37	110	349	167	399	507	1232
NE Antigua	A04-02	Fore-reef	1065	430	3795	1932	14	43	25	48	483	1526	520	1514
NE Antigua	A04-03	Back reef	1534	776	5842	1091	222	501	N/A	0	119	166	132	176
W-SW Antigua	A05-01	Fore-reef	1803	1436	2414	1809	4650	9288	390	1234	366	285	1128	1767
W-SW Antigua	A05-02	Fore-reef	1419	1732	3049	2486	4136	5879	184	435	460	509	2351	1662
W-SW Antigua	A05-03	Fore-reef	1332	659	1169	1331	595	851	357	938	999	921	1255	1270
		NE Fore-reef	1482	1500	3332	829	30	30	65	66	132	208	313	202
		NE Reef Crest	2379	203	5489	2474	0	0	0	0	27	38	306	357
		NE Back Reef	1216	449	4502	1894	136	121	12	16	69	71	116	22
		NE Coral patch	1717	189	3732	1048	439	189	69	46	0	0	260	94
		W Fore-reef	1518	251	2211	957	3127	2208	310	111	608	342	1578	672

Region	Site	Zone	Angelfish (Pomacanthidae)	±	Butterflyfish (Chaetodontidae)	±	Triggerfish (Balistidae)	±	Other	±
NE Antigua	A01-01	Back reef	N/A	0	8	19	N/A	0	38	70
NE Antigua	A01-02	Reef crest	N/A	0	N/A	0	N/A	0	1972	2729
NE Antigua	A02-01	Reef crest	N/A	0	3	3	N/A	0	637	637
NE Antigua	A02-02	Fore-reef	N/A	0	3	8	N/A	0	1137	494
NE Antigua	A02-03	Coral patch	3	9	8	13	N/A	0	72	125
NE Antigua	A03-01	Fore-reef	N/A	0	66	134	N/A	0	63	123
NE Antigua	A03-02	Fore-reef	N/A	0	5	11	84	225	432	688
NE Antigua	A03-03	Coral patch	N/A	0	19	23	N/A	0	175	281
NE Antigua	A04-01	Fore-reef	N/A	0	11	27	N/A	0	666	789
NE Antigua	A04-02	Fore-reef	N/A	0	8	13	N/A	0	N/A	0
NE Antigua	A04-03	Back reef	N/A	0	22	43	N/A	0	N/A	0
W-SW Antigua	A05-01	Fore-reef	224	360	209	293	471	770	439	600
W-SW Antigua	A05-02	Fore-reef	39	113	179	177	1561	2684	740	1280
W-SW Antigua	A05-03	Fore-reef	N/A	0	135	293	71	184	359	544
		NE Fore-reef	0	0	18	27	17	38	460	467
		NE Reef Crest	0	0	1	2	0	0	1305	944
		NE Back Reef	0	0	15	10	0	0	19	27
		NE Coral patch	1	2	14	8	0	0	124	73
		W Fore-reef	87	120	175	37	701	771	512	201

Table 9:

Diadema antillarum Summary Avg. # juvenile & adult individuals per 10m2				
Site	Zone	Juvenile	Adult	Total
A01-01	Back reef	0	0	0
A01-02	Reef crest	0	1.83	1.83
A02-01	Reef crest	0	0	0
A02-02	Fore-reef	4.5	10.33	14.83
A02-03	Patch reef	0	0	0
A03-01	Fore-reef	0.33	5.83	6.17
A03-02	Fore-reef	0.43	5.71	6.14
A03-03	Patch reef	0	0	0
A04-01	Fore-reef	0.17	0.33	0.5
A04-02	Fore-reef	0	0	0
A04-03	Back reef	0.17	0	0.17
A05-01	Fore-reef	0.17	0.17	0.33
A05-02	Fore-reef	0	0	0
A05-03	Fore-reef	0	0	0
NE Fore-reef		1.06	4.48	5.55
NE Reef Crest		0	0.92	0.92
NE Back Reef		0.08	0	0.08
NE Coral patch		0	0	0
W Fore-reef		0.06	0.06	0.11

Table 10:

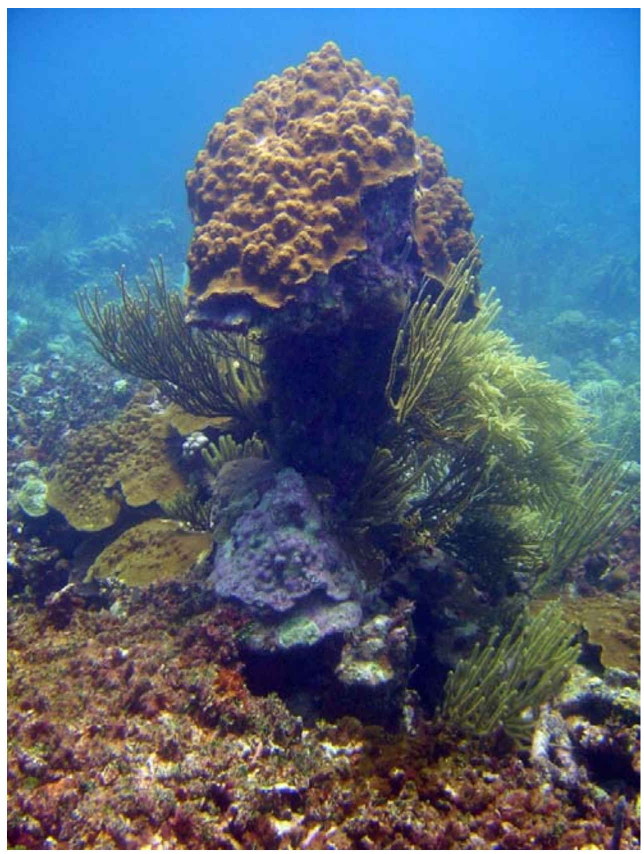
AGRRA Country Key	
Bahamas-1997	Andros Island, Bahamas
Bahamas-1998A	San Salvador Island, Bahamas
Bahamas-1998B	Andros Island, Bahamas
Bahamas-1999	Abaco Islands, Bahamas
Belize-1999A	Northern and south-central barrier reef, Belize
Belize-1999B	Lighthouse Atoll, Belize
Belize-2000	Turneffe Atoll, Glovers Reef & barrier reef, Belize
Brazil-2000	Abrolhos Reefs, eastern Brazil
Cayman-1999	Little Cayman & Grand Cayman, British West Indies
Cayman-2000	Cayman Brac, British West Indies
CostaRica-1999	Cahuita National Park, Costa Rica
Cuba-1999	María la Gorda, southeast Ensenada de Corrientes, Cuba
Cuba-2001A	Batabanó, Cuba
Cuba-2001B	Sabana-Camagüey, Cuba
Cuba-2001C	Jardines de la Reina, Cuba
Jamaica-2000	Northern, northwestern, western and southwestern reefs, Jamaica
México-1999A	Akumal & Xcalak, Quintana Roo, México
México-1999B	Veracruz Reef System, México
México-1999C	Central-southern coast, Quintana Roo, México
México-2000	Chinchorro Banks, Quintana Roo, México
NethAnt-1998	Curaçao, Netherlands Antilles
NethAnt-1999A	Bonaire, Netherlands Antilles
NethAnt-1999B	Saba, Saba Bank, St. Eustatius, St. Marten, Windward Netherlands Antilles
NethAnt-2000	Curaçao, Netherlands Antilles
Nicaragua-2003	Big and Little Corn Islands, Nicaragua
Panamá-2002	Bocas del Toro & Comarca de Kuna Yala (San Blas Islands), Panama
PuertoRico-2003	Culebra, Vieques & Cayos de la Cordillera, Puerto Rico
StVincent-1999	Horseshoe Reef, Tobago Cays Marine Park, Grenadines, St. Vincent, West Indies
TurksCaicos-1999	Caicos, Turks & Mouchoir Banks, Turks & Caicos Islands
USA-1999	Flower Garden Banks National Marine Sanctuary, Gulf of Mexico
USA-2003	Biscayne Bay National Park & Florida Keys National Marine Sanctuary, Florida
Venezuela-1999	Archipiélago de los Roques National Park, Venezuela
VirginIslands-1998	USVI (St. Thomas)
VirginIslands-1999	USVI (St. Croix, St. Thomas) & BVI (Guana)
VirginIslands-2000	USVI (St. Thomas, St. John) & BVI (Anegada, Virgin Gorda)

Appendix 2: Pictures

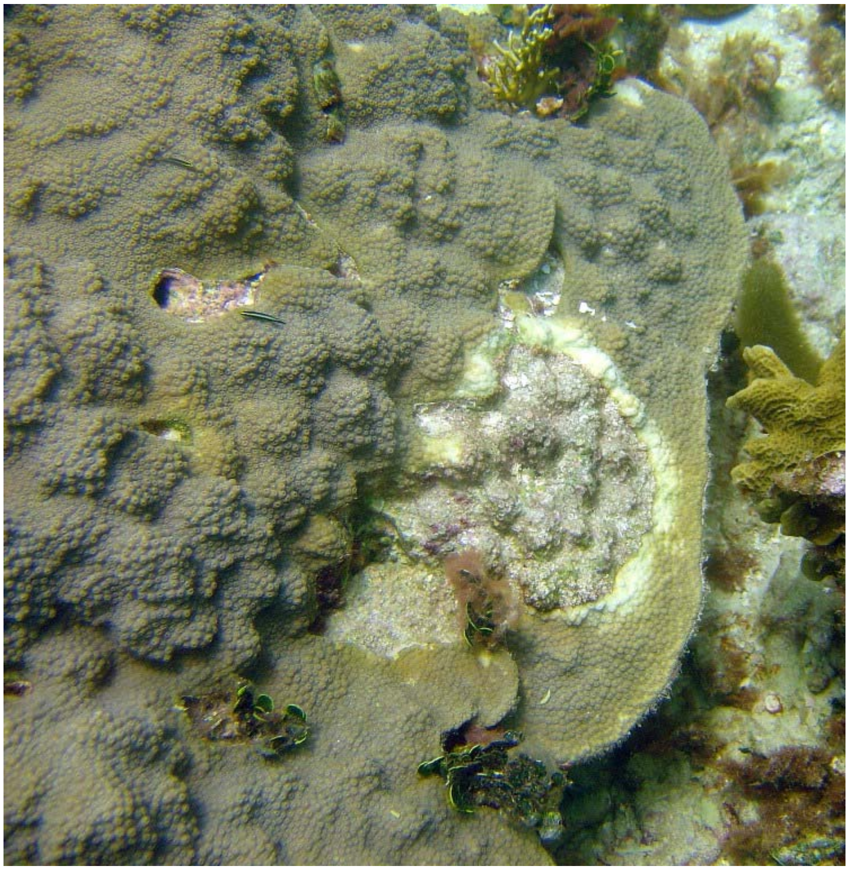
Picture 1:

Picture 2:

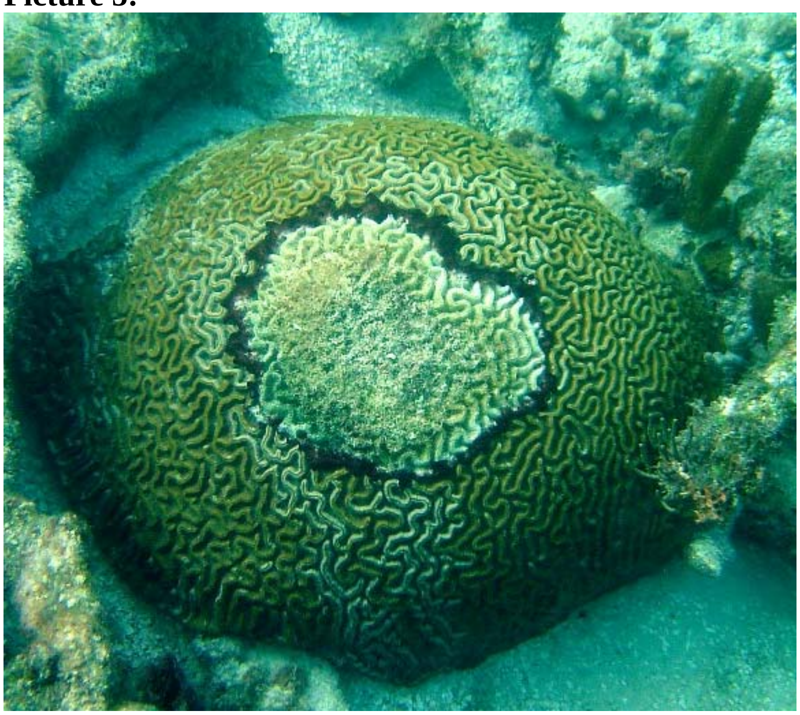
Picture 3:



Picture 4:



Picture 5:



Picture 6:

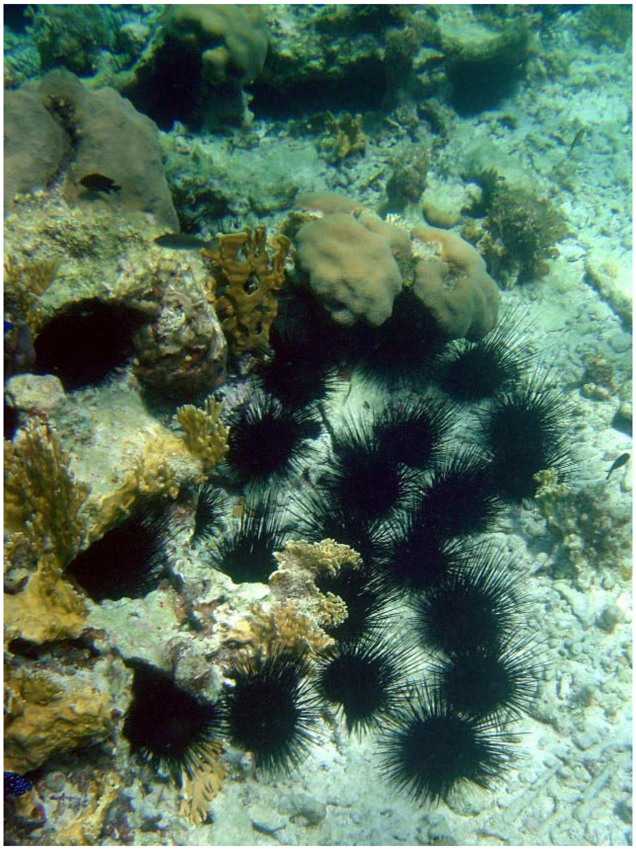


Figure 1:

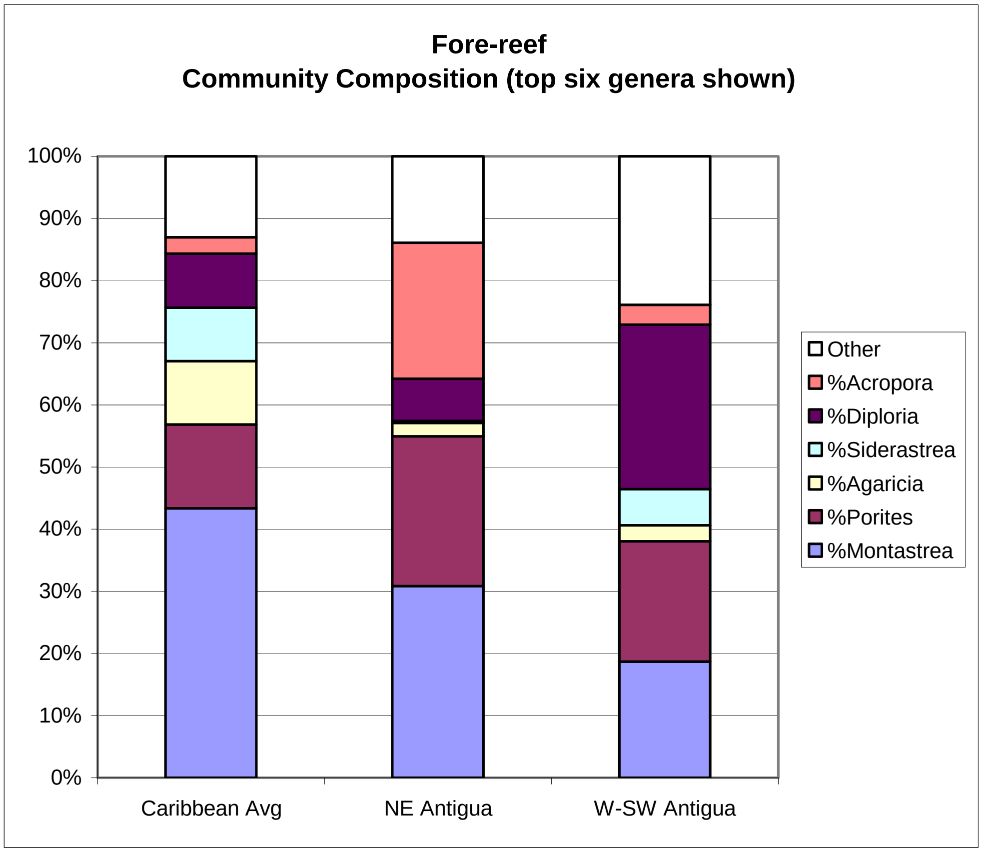


Figure 2:

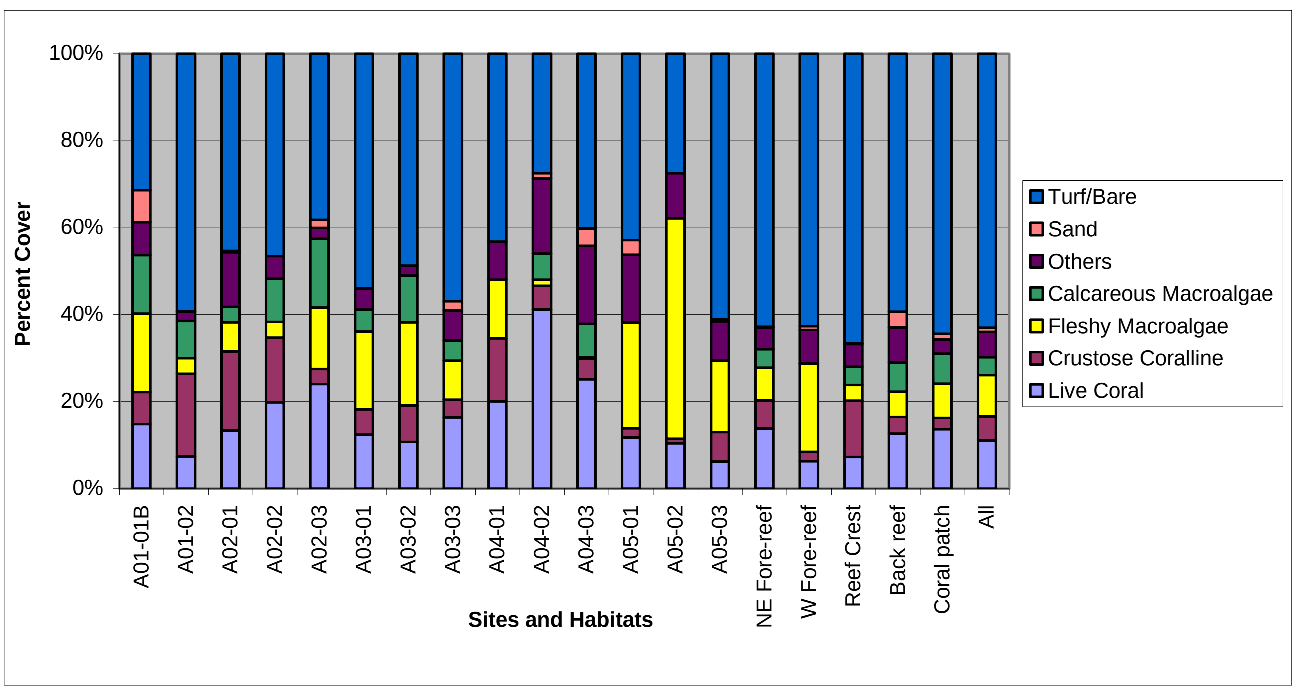


Figure 3:

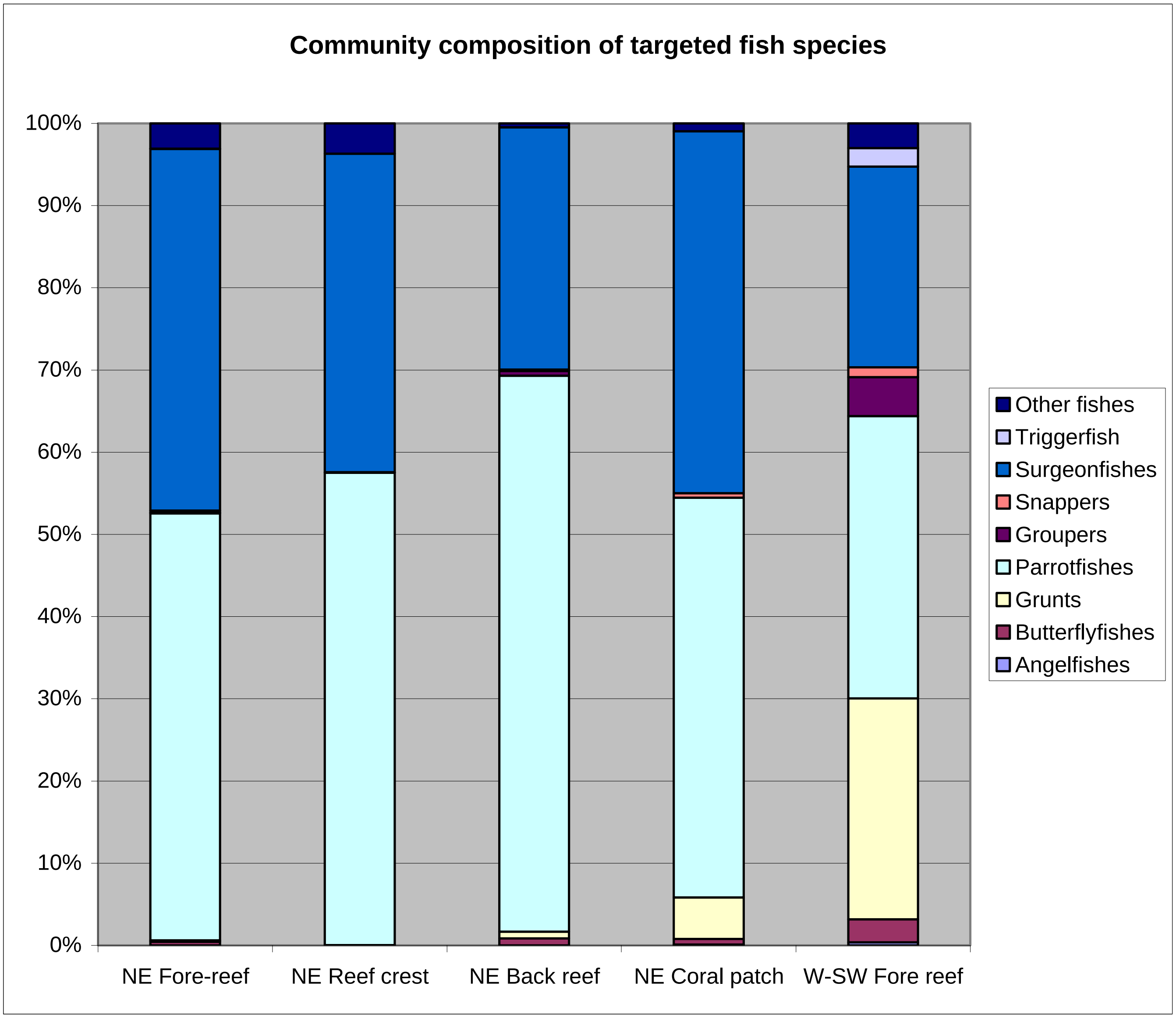

Community composition of targeted fish species
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
NE Fore-reef
NE Reef crest
NE Back reef
NE Coral patch
W-SW Fore reef
Other fishes
Triggerfish
Surgeonfishes
Snappers
Groupers
Parrotfishes
Grunts
Butterflyfishes
Angelfishes

Figure 4:

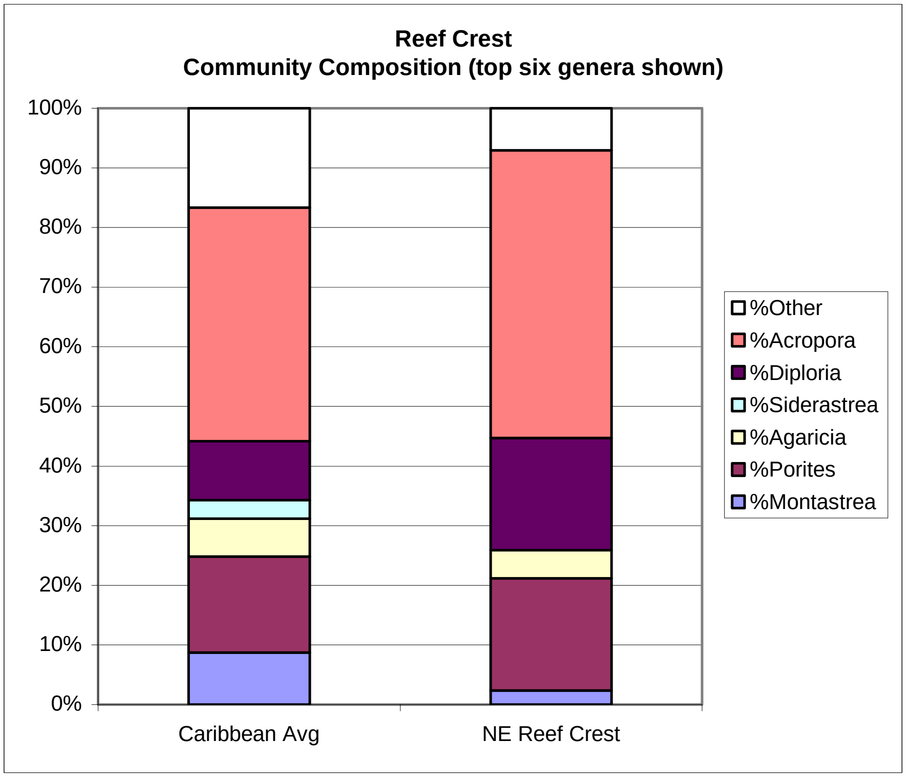


Figure 5:

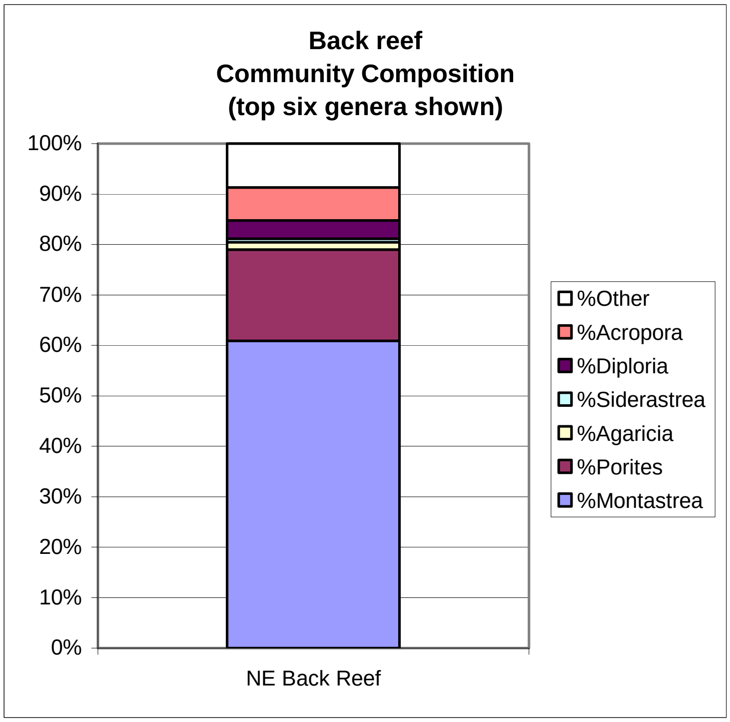
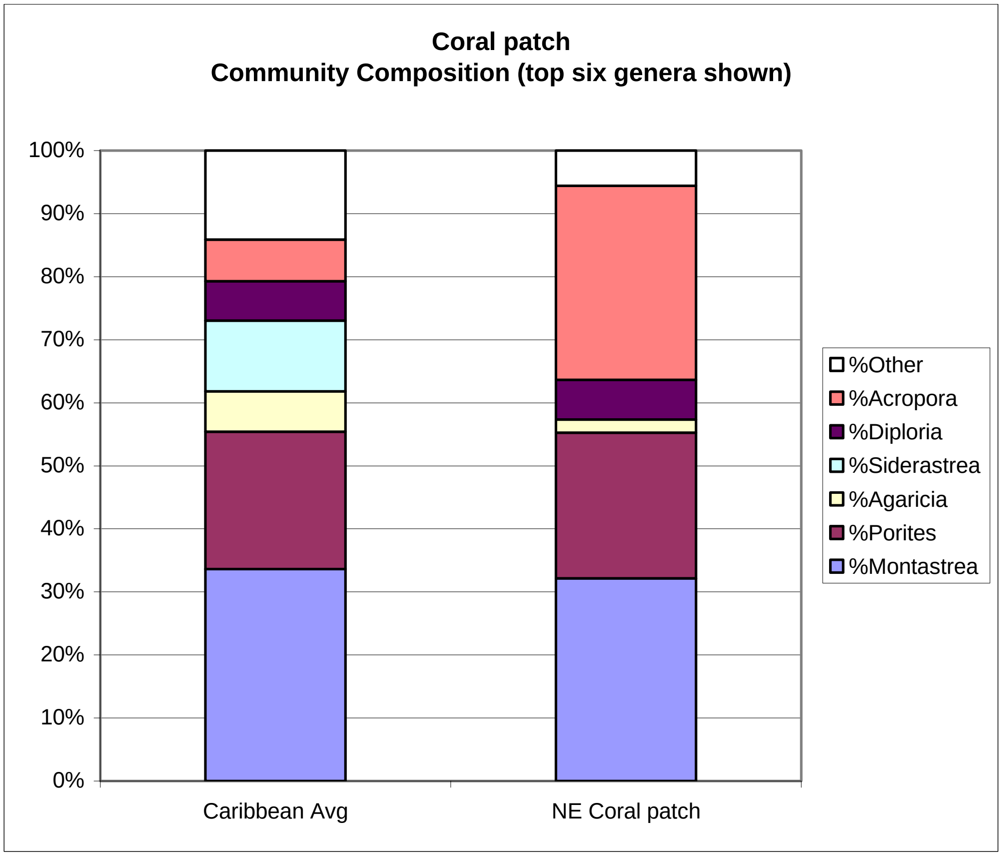


Figure 6:


Coral patch
Community Composition (top six genera shown)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Caribbean Avg
NE Coral patch
%Other
%Acropora
%Diploria
%Siderastrea
%Agaricia
%Porites
%Montastrea

****All bars represent ± 5% standard deviation.**

Figure 7:

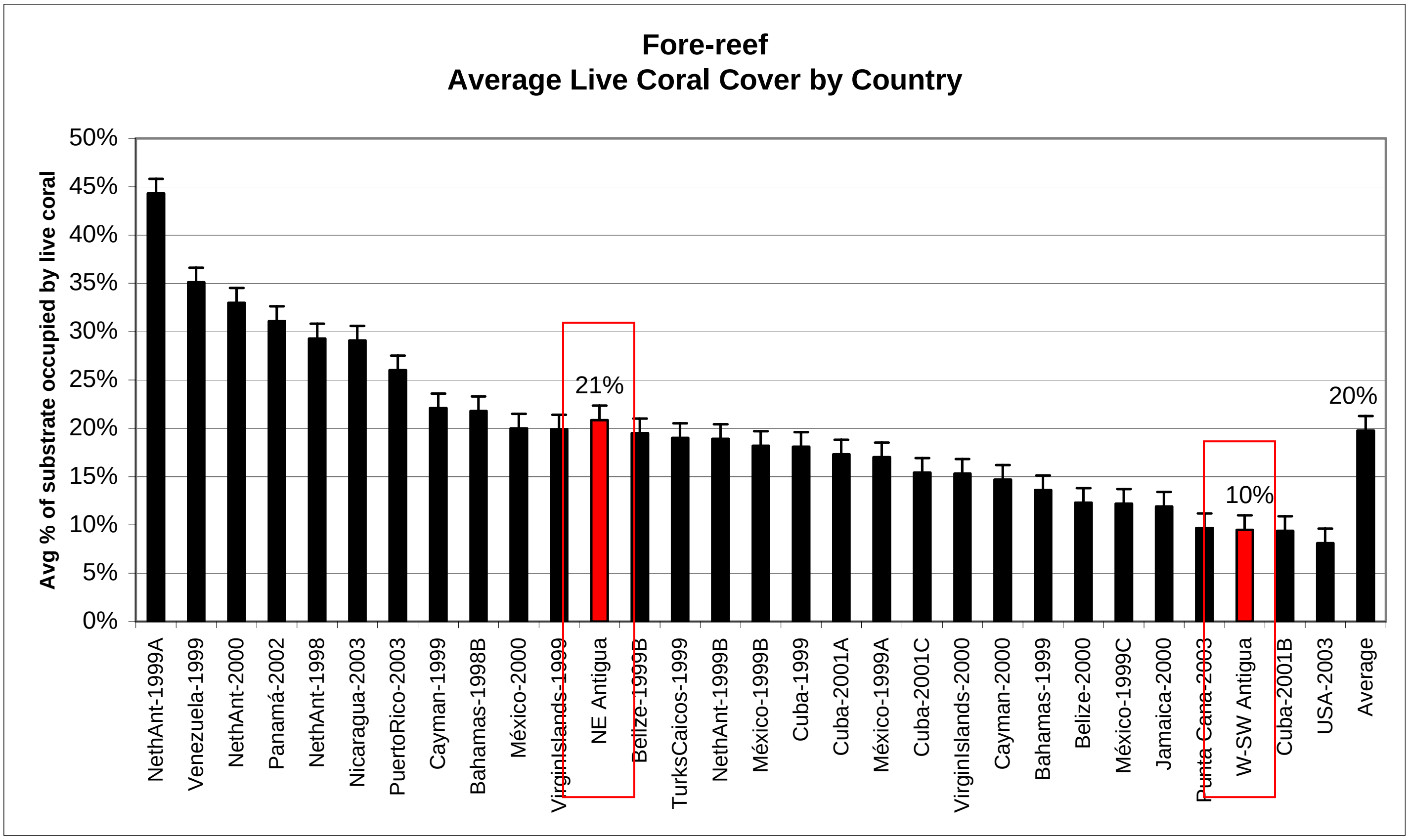


Figure 8:

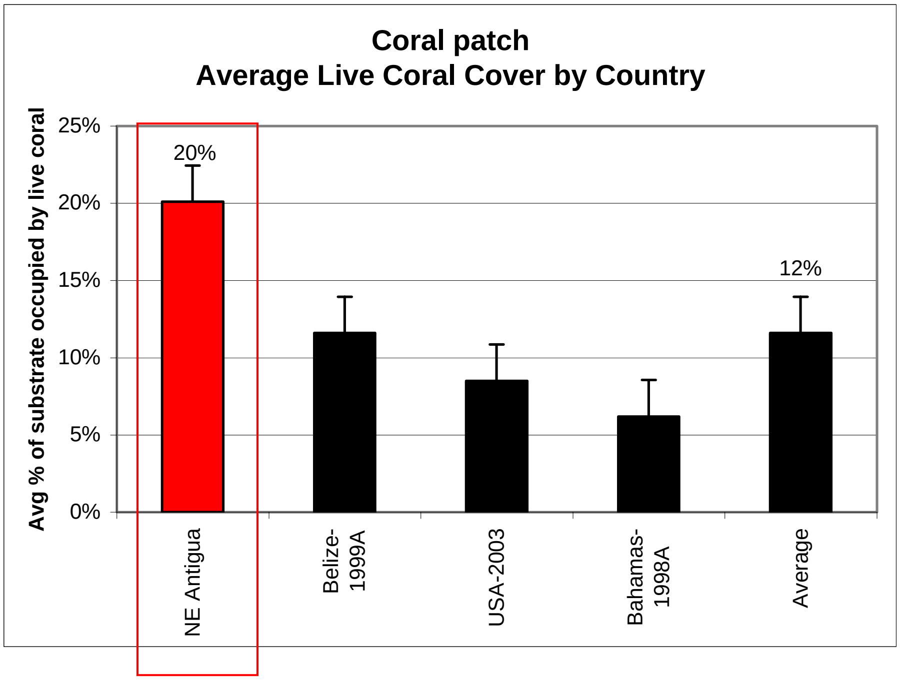


Figure 9:

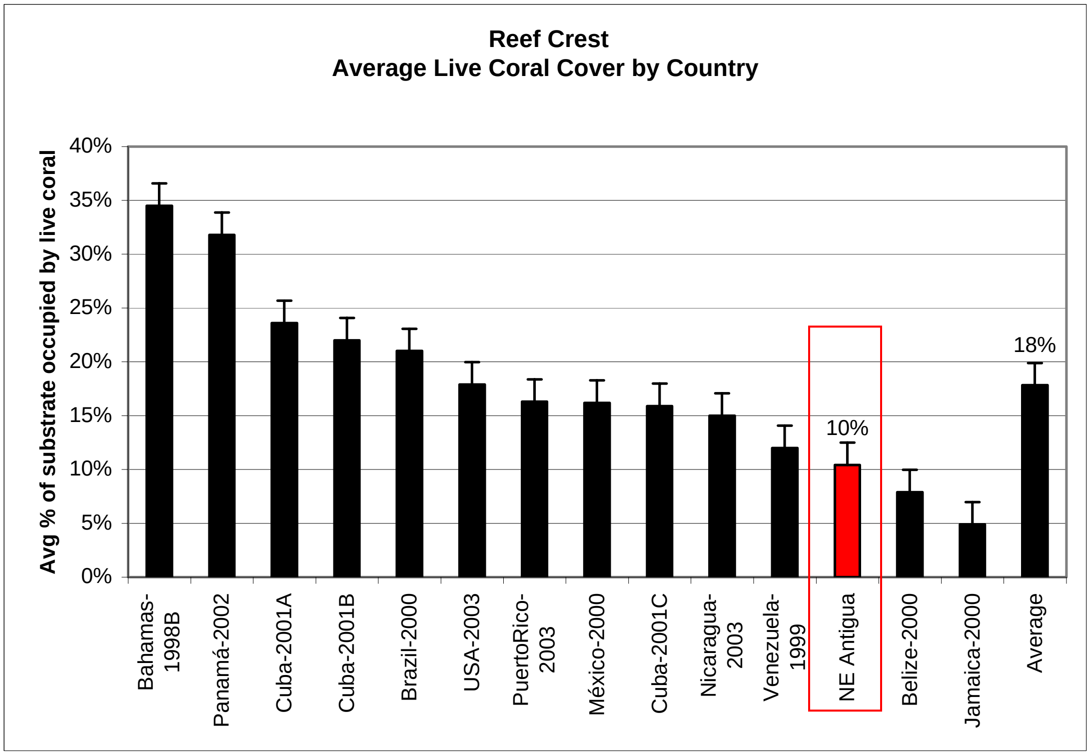


Figure 10:

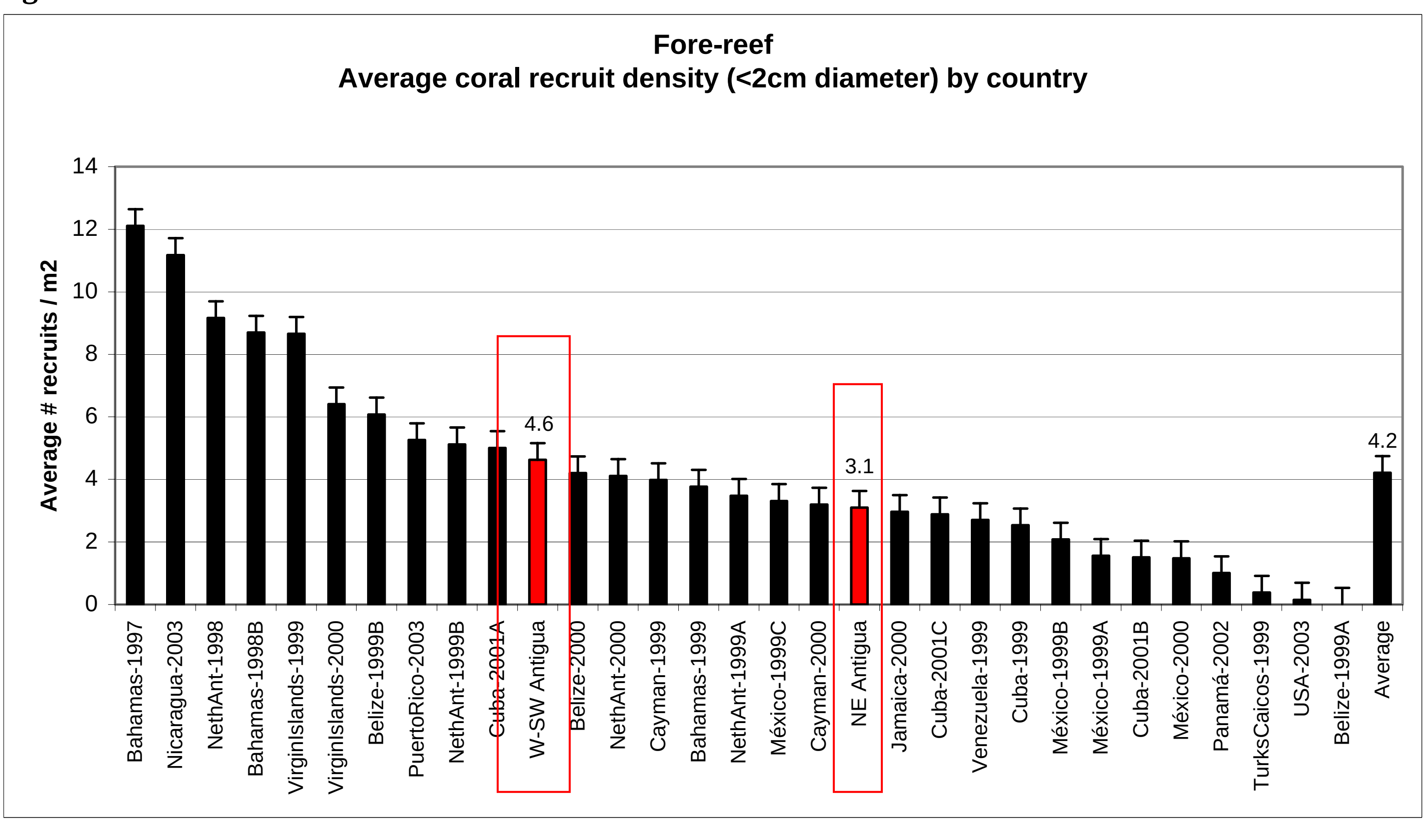


Figure 11:

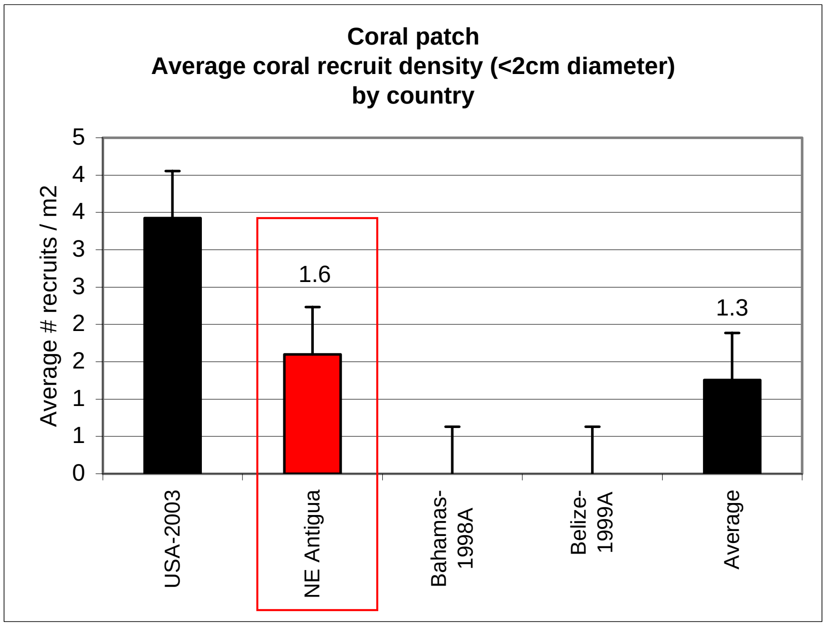


Figure 12:

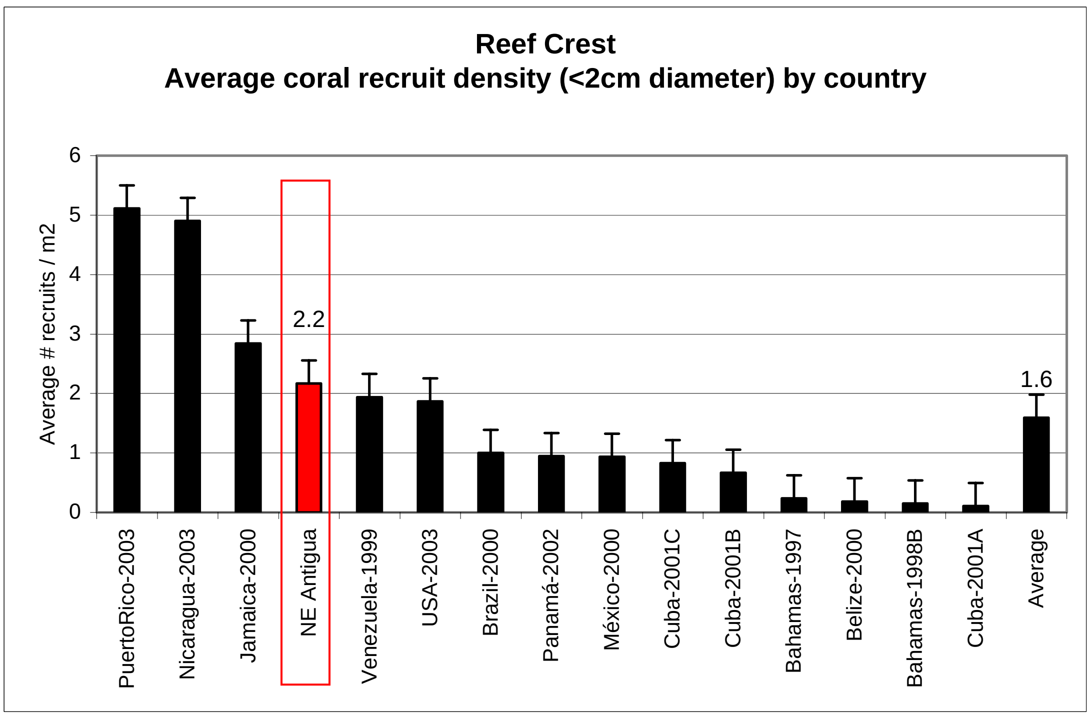


Figure 13:

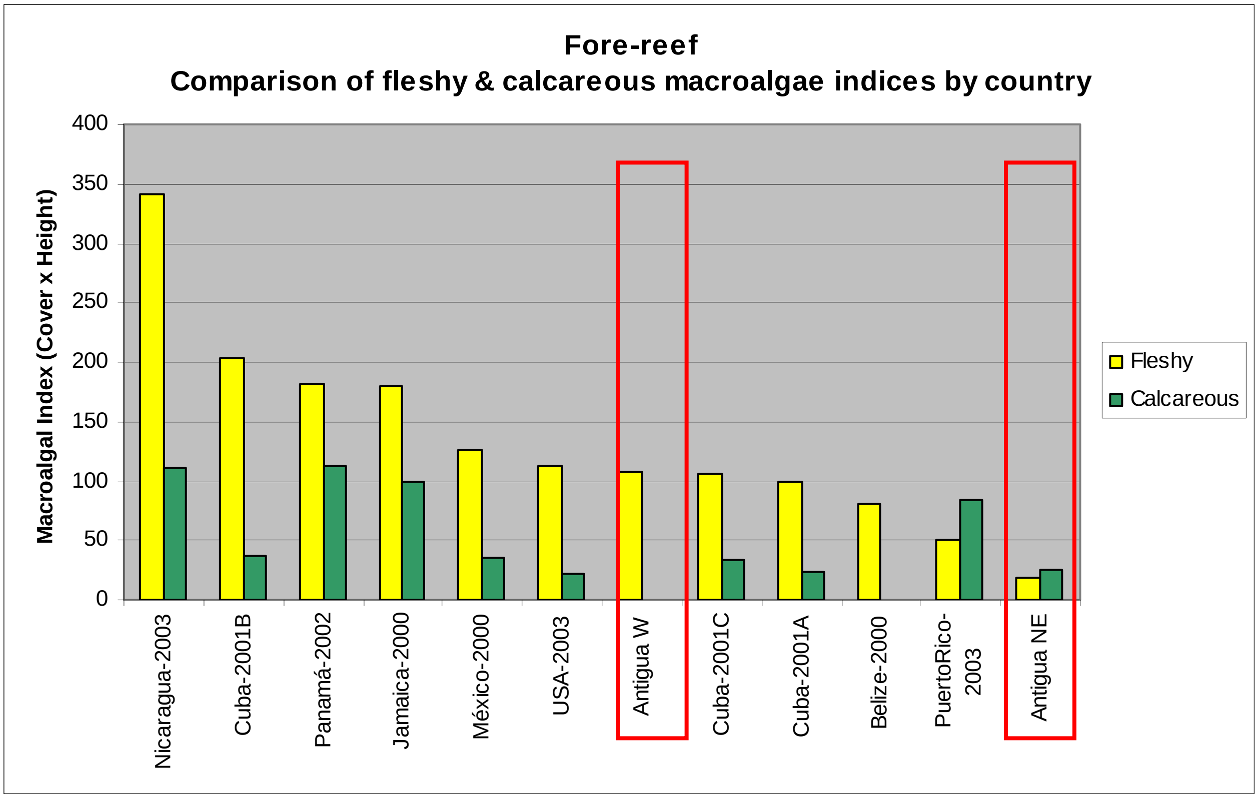


Figure 14:

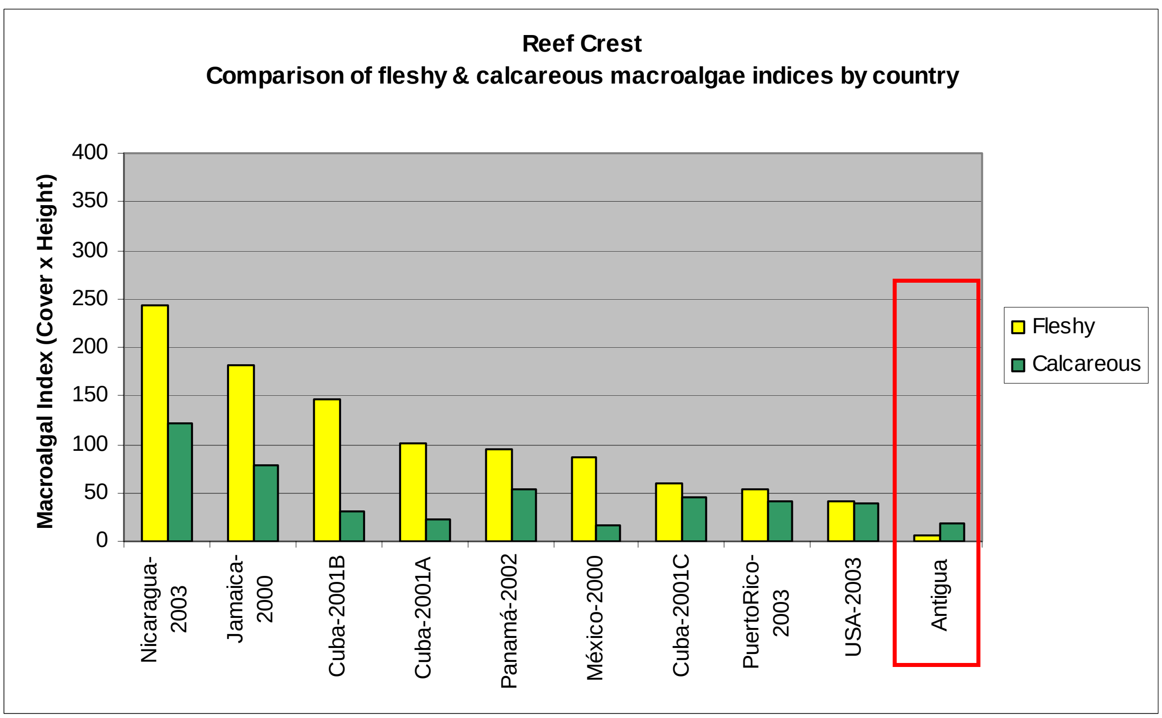


Figure 15:

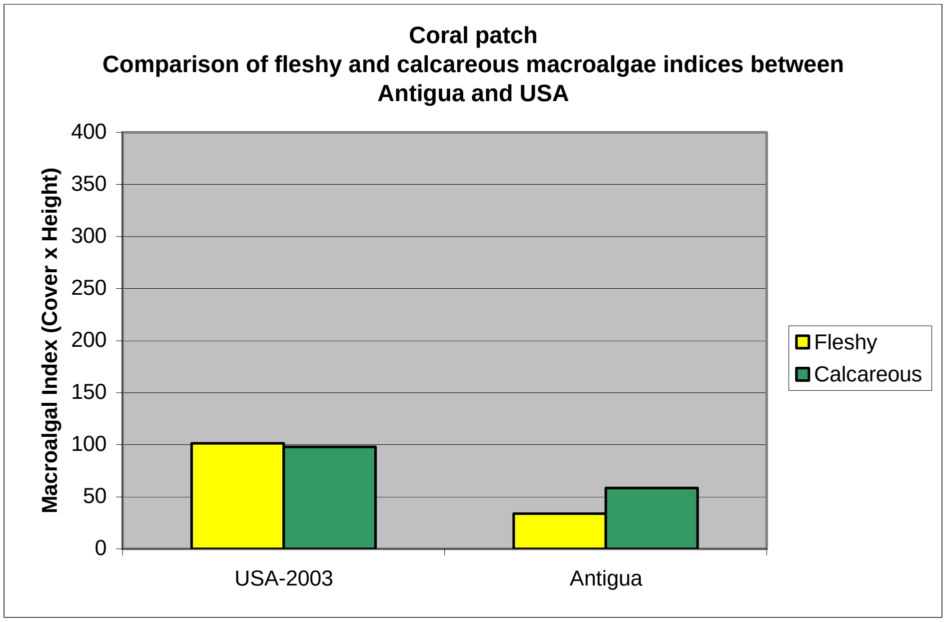


Figure 16:

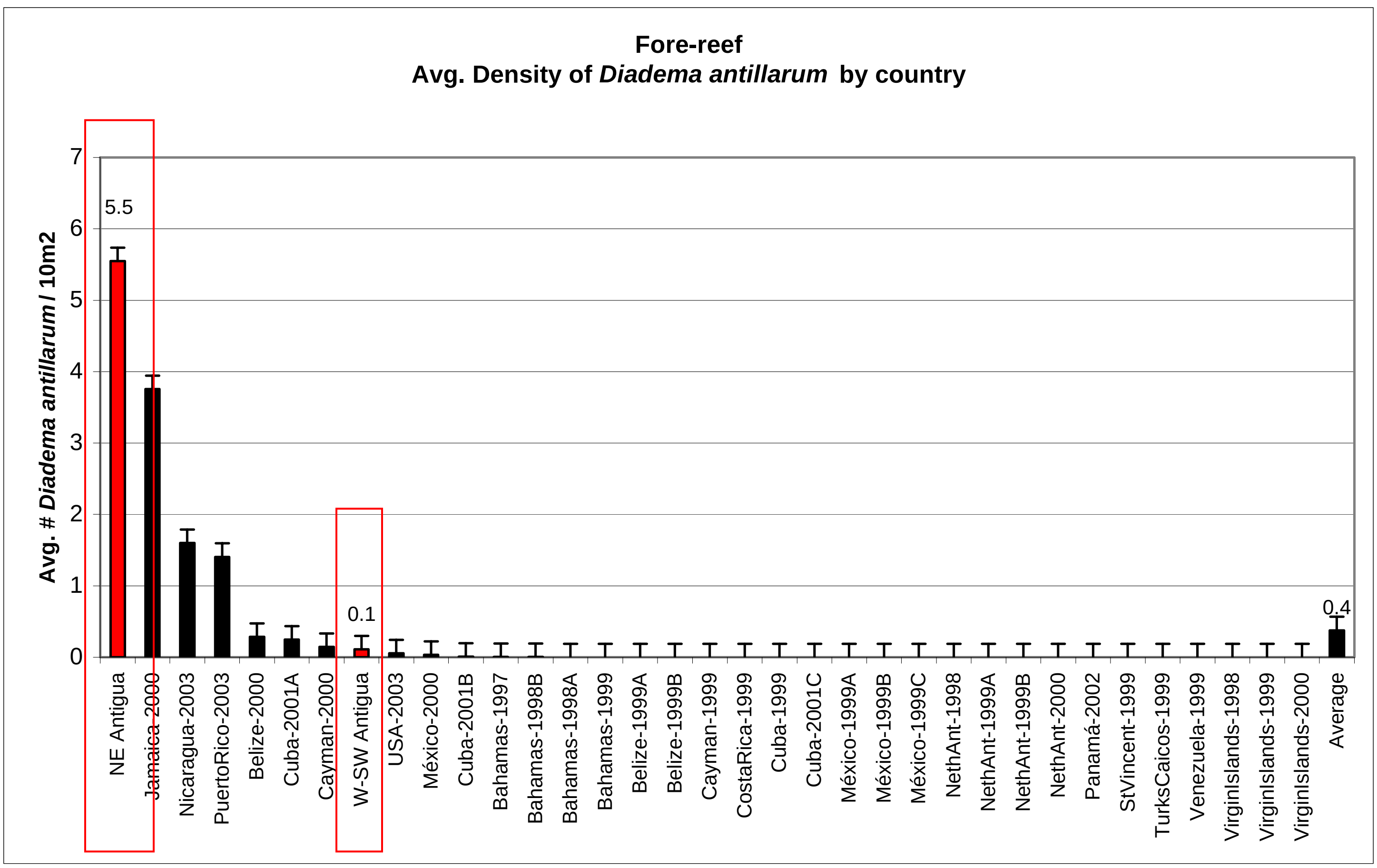
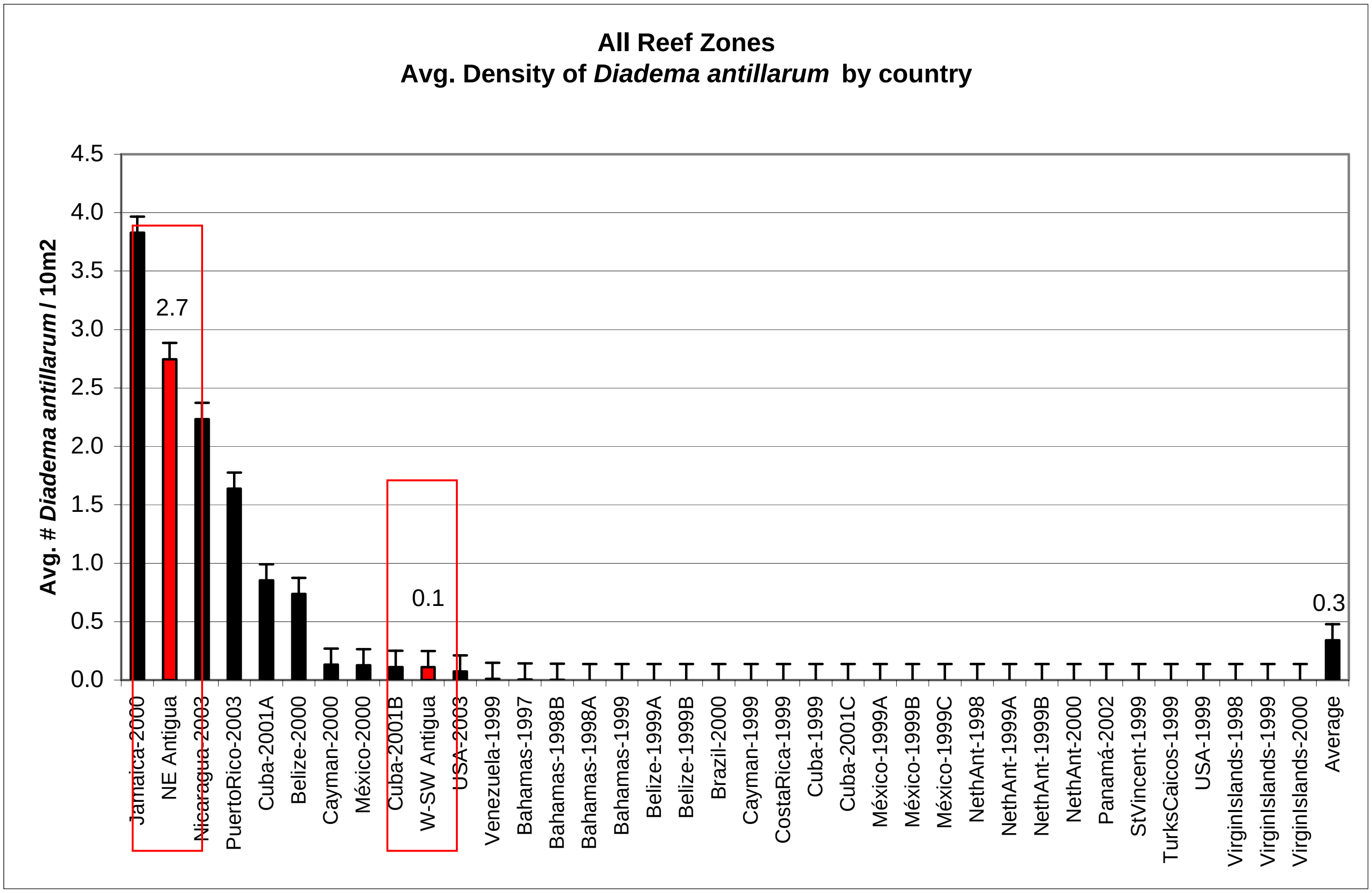


Figure 17:



All Reef Zones
Avg. Density of *Diadema antillarum* by country
Avg. # *Diadema antillarum* / 10m2
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2.7
0.1
0.3
Jamaica-2000
NE Antigua
Nicaragua-2003
PuertoRico-2003
Cuba-2001A
Belize-2000
Cayman-2000
México-2000
Cuba-2001B
W-SW Antigua
USA-2003
Venezuela-1999
Bahamas-1997
Bahamas-1998B
Bahamas-1998A
Bahamas-1999
Belize-1999A
Belize-1999B
Brazil-2000
Cayman-1999
CostaRica-1999
Cuba-1999
Cuba-2001C
México-1999A
México-1999B
México-1999C
NethAnt-1998
NethAnt-1999A
NethAnt-1999B
NethAnt-2000
Panamá-2002
StVincent-1999
TurksCaicos-1999
USA-1999
VirginIslands-1998
VirginIslands-1999
VirginIslands-2000
Average

Figure 18:

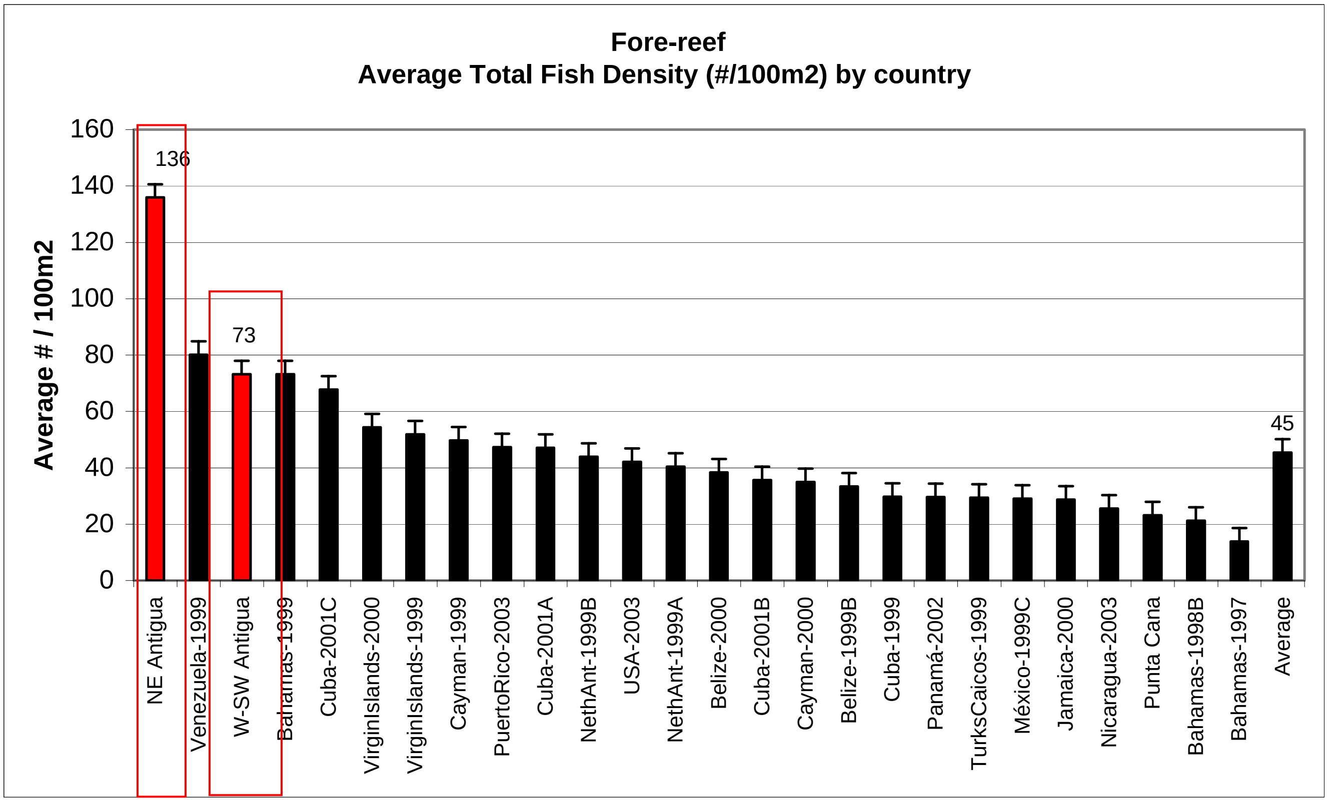


Figure 19:

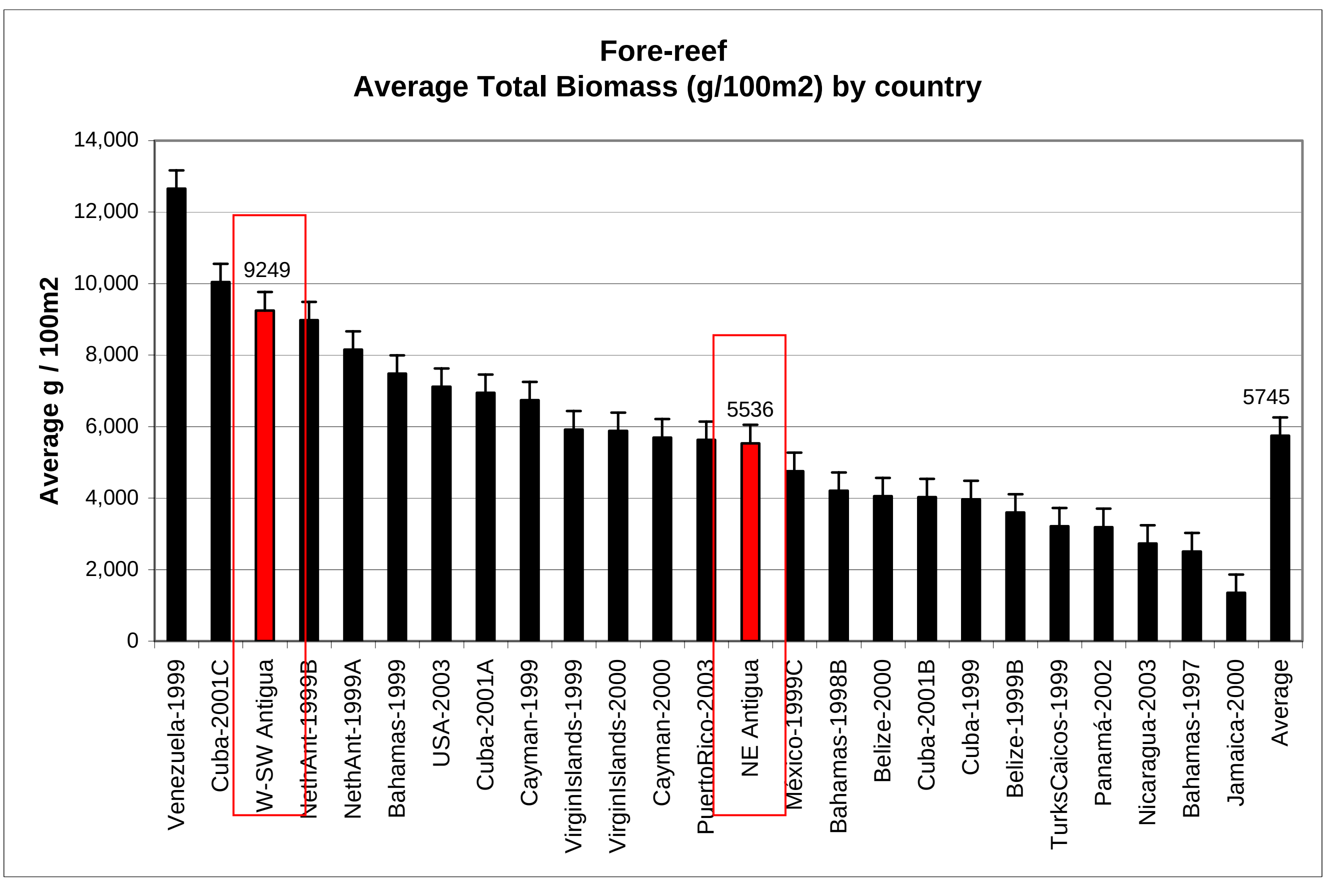


Figure 20:

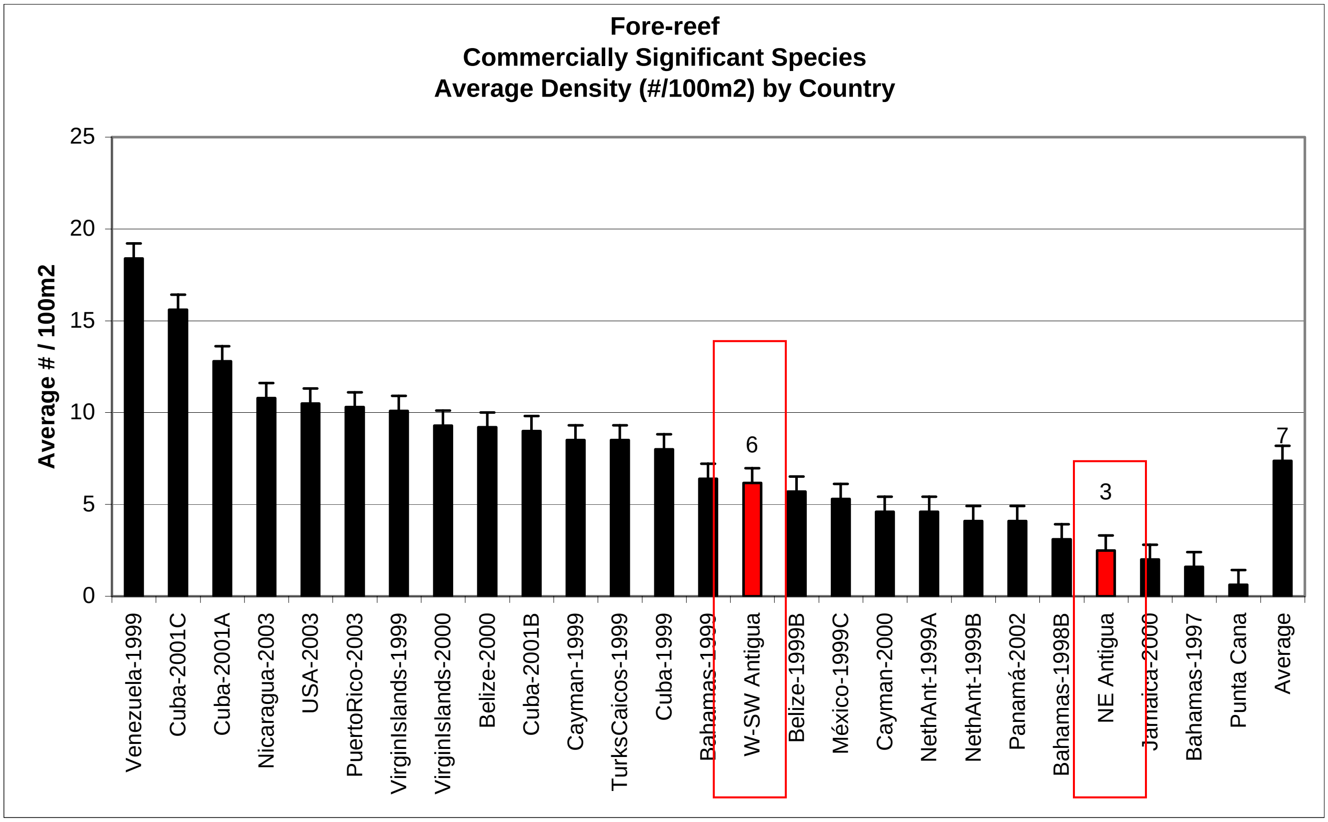


Figure 21:

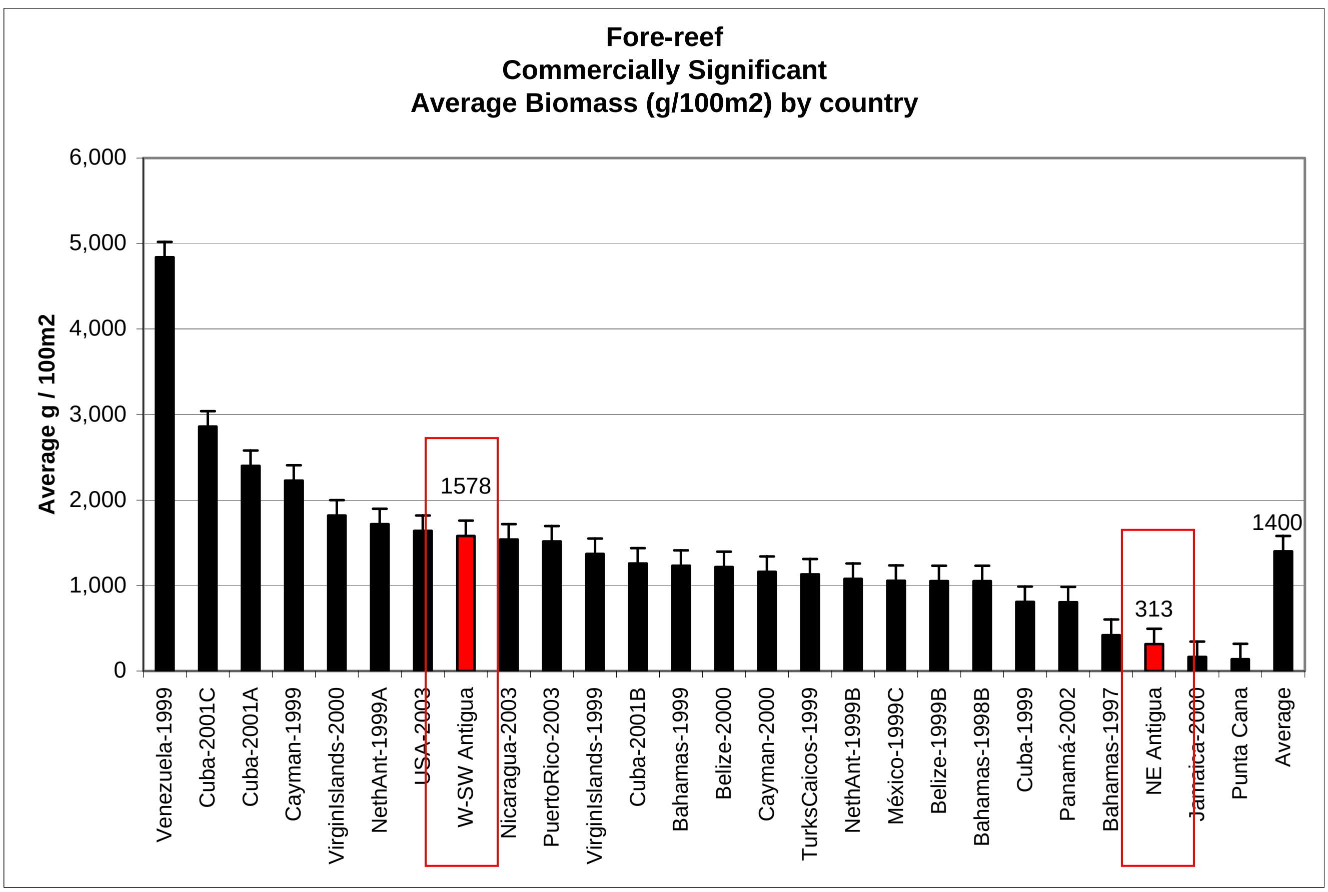


Figure 22:

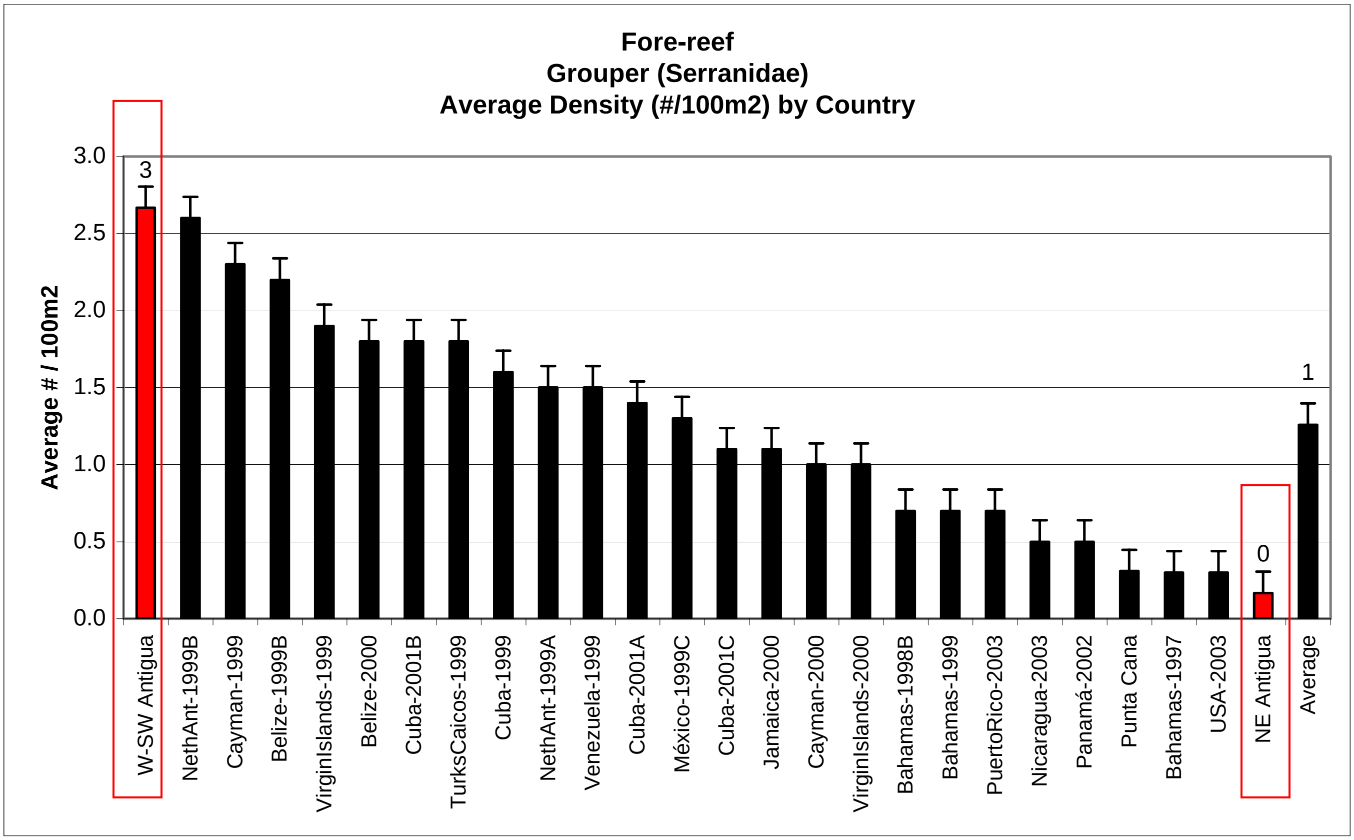
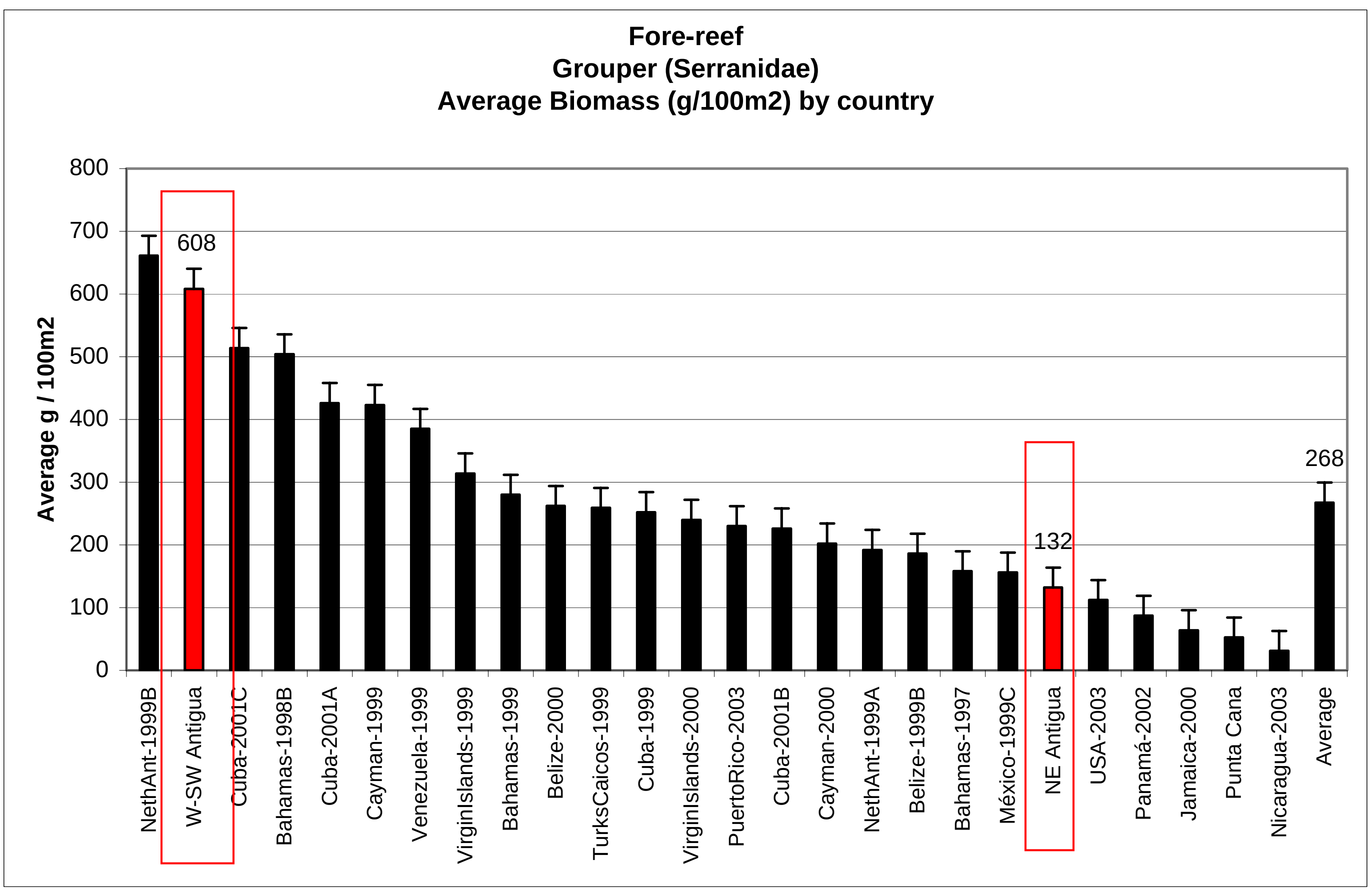


Figure 23:



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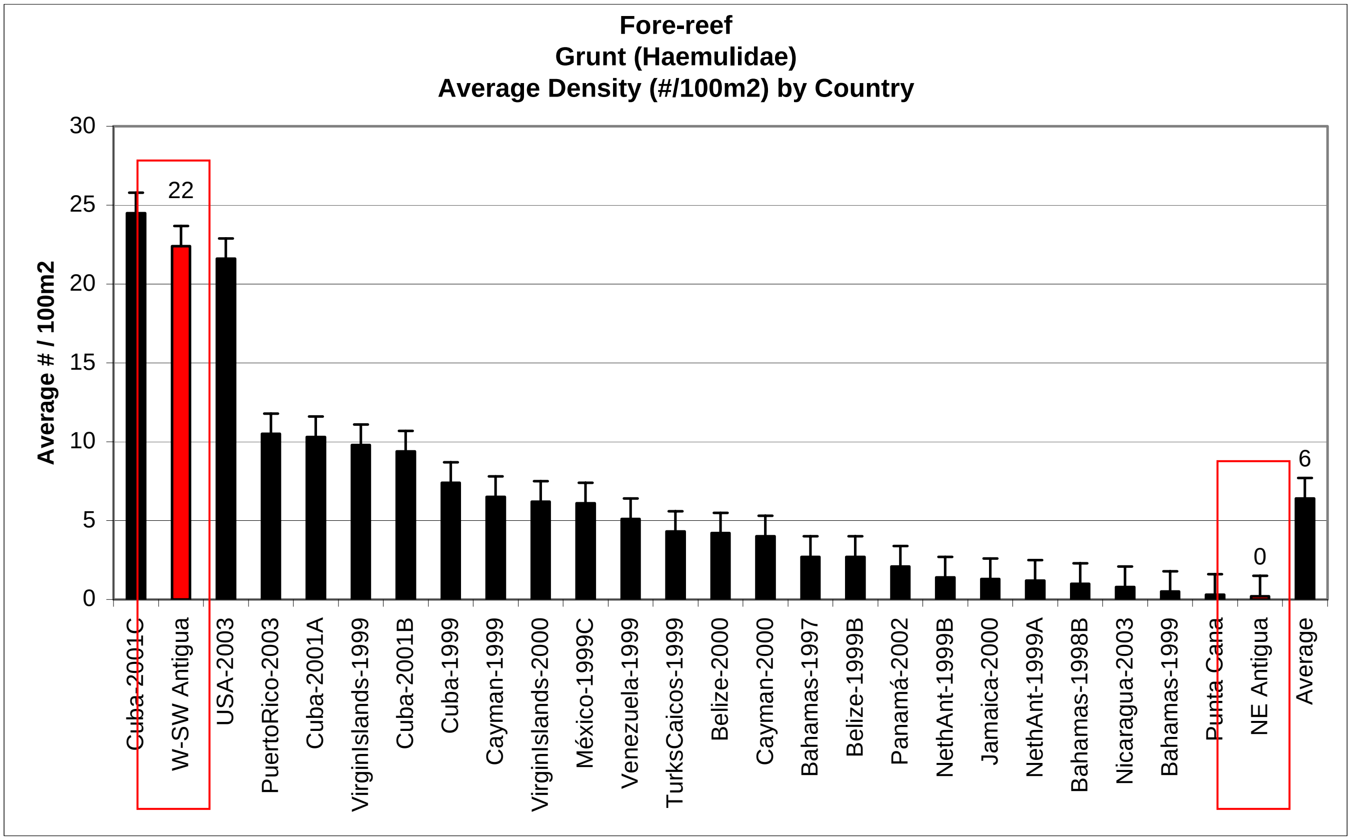


Figure 25:

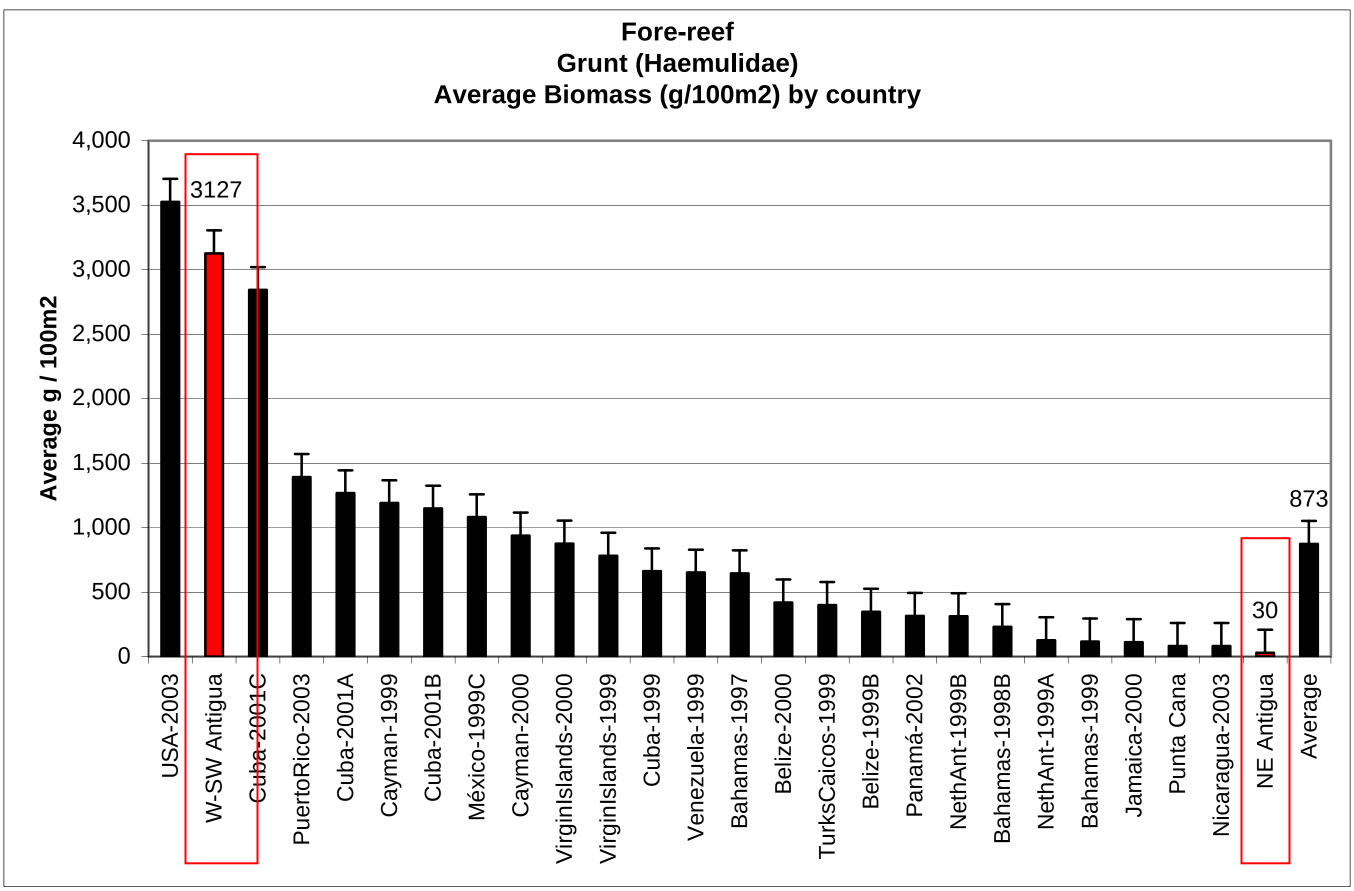


Figure 26:

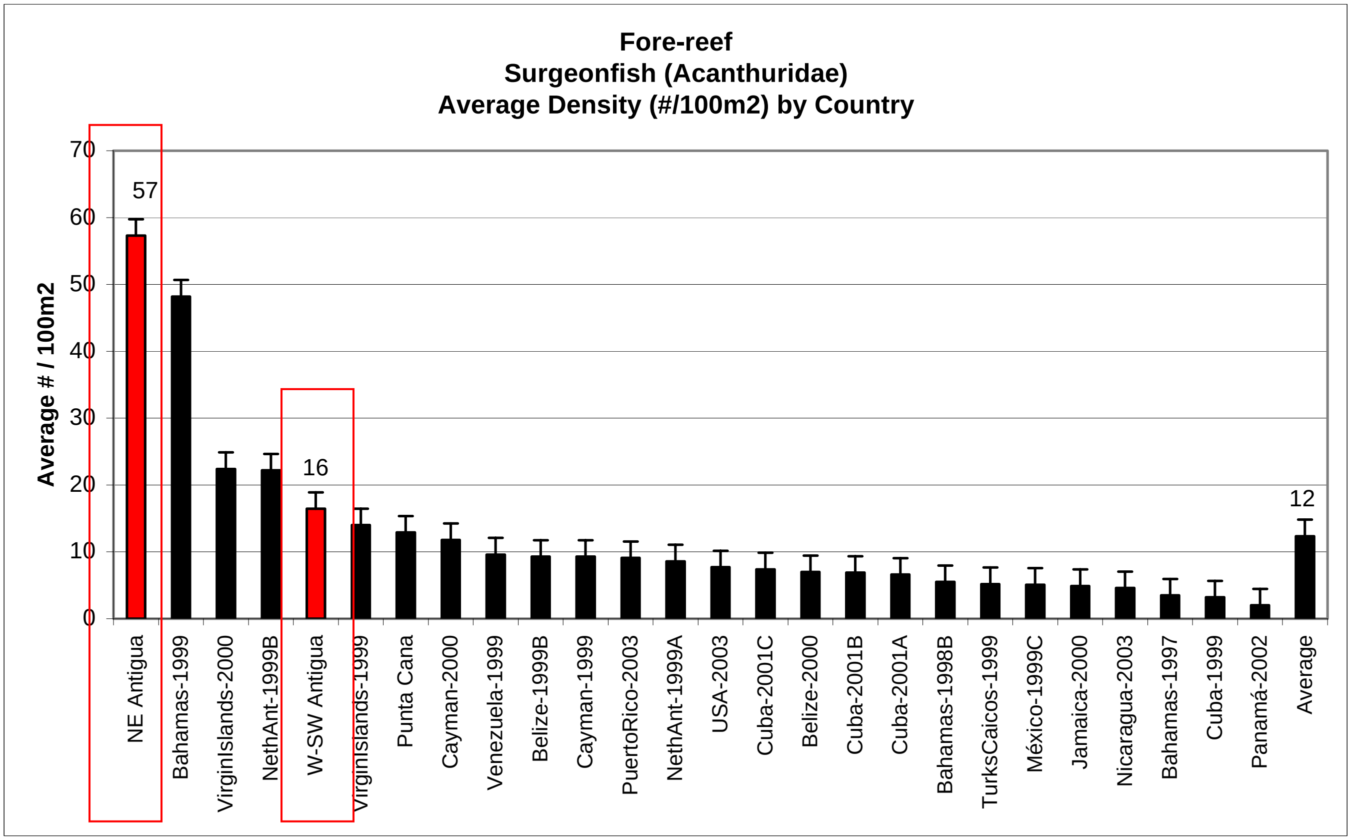
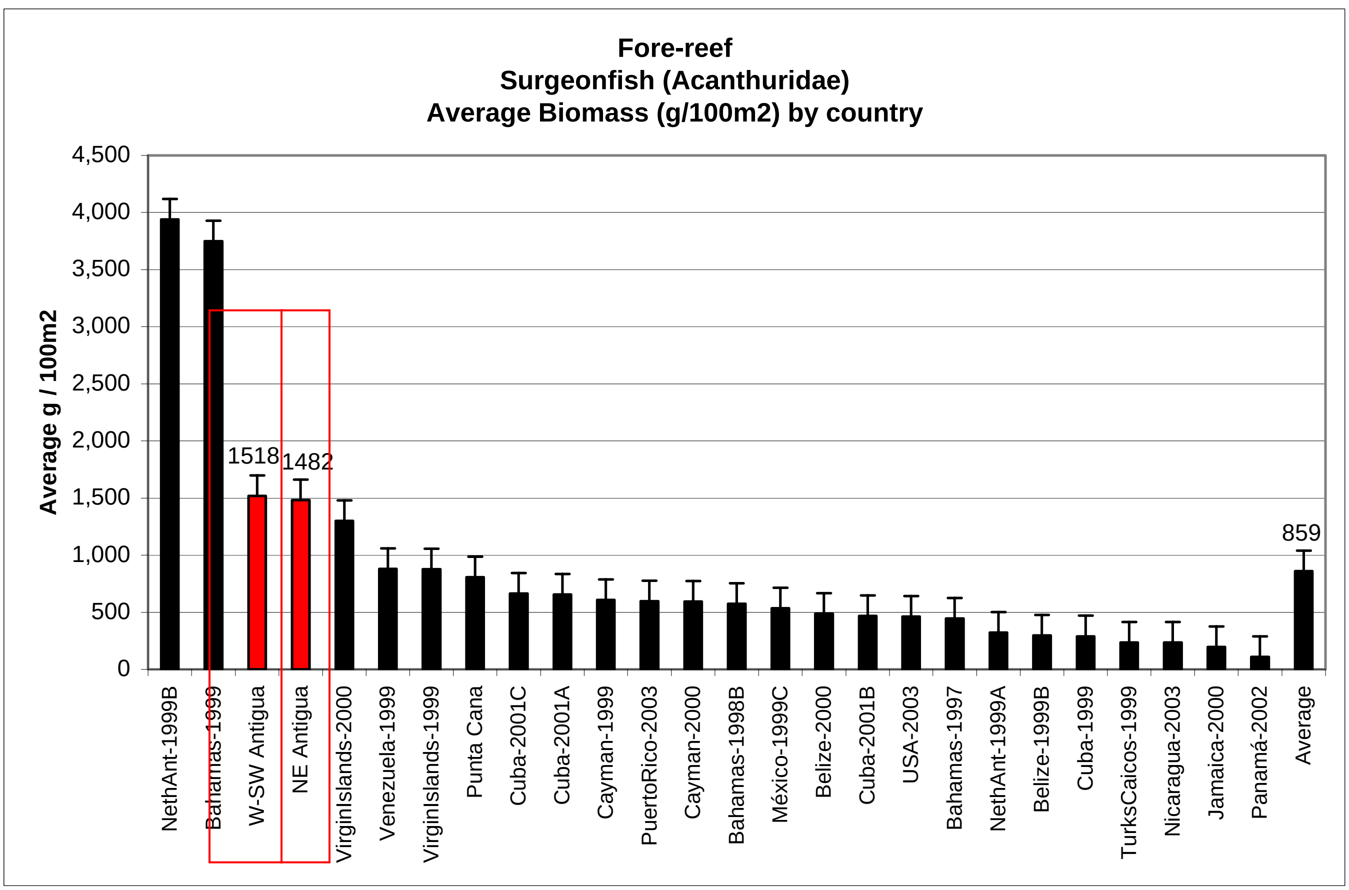


Figure 27:



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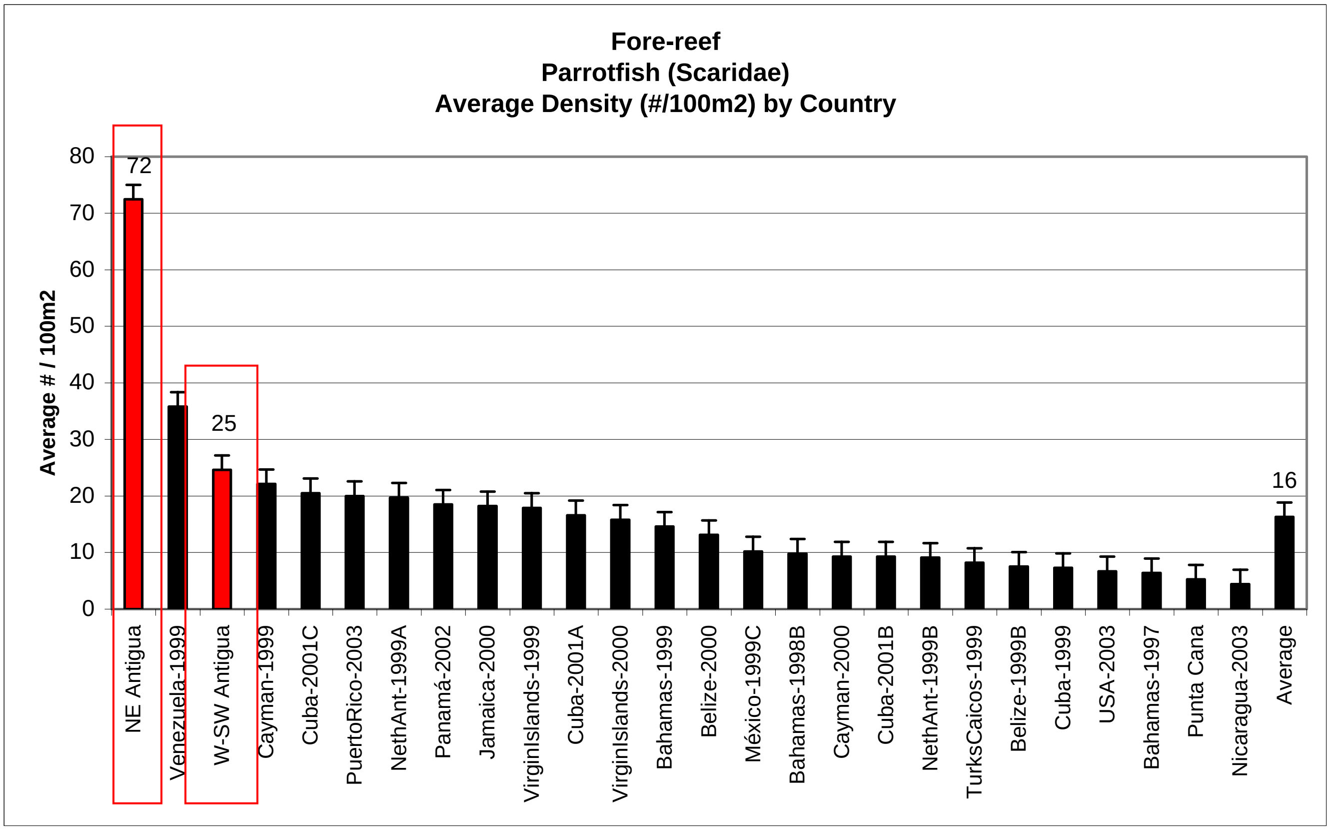
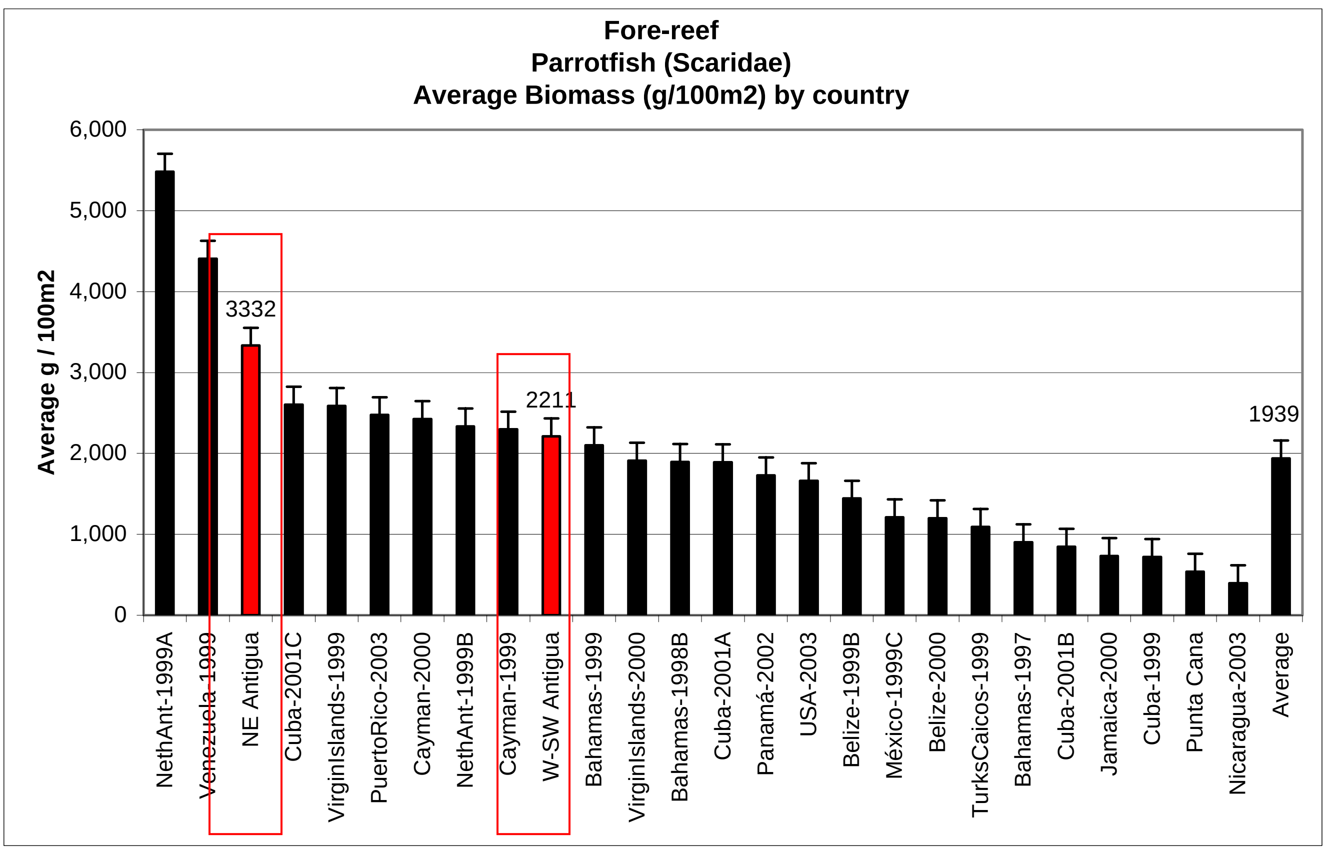


Figure 29:



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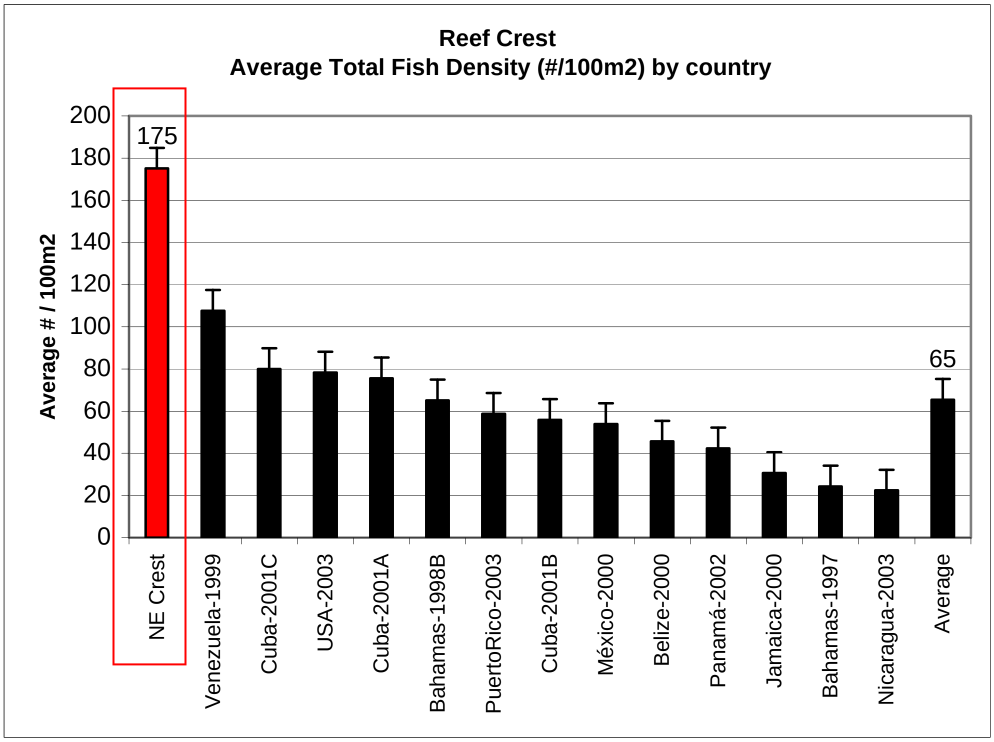

Figure 31:

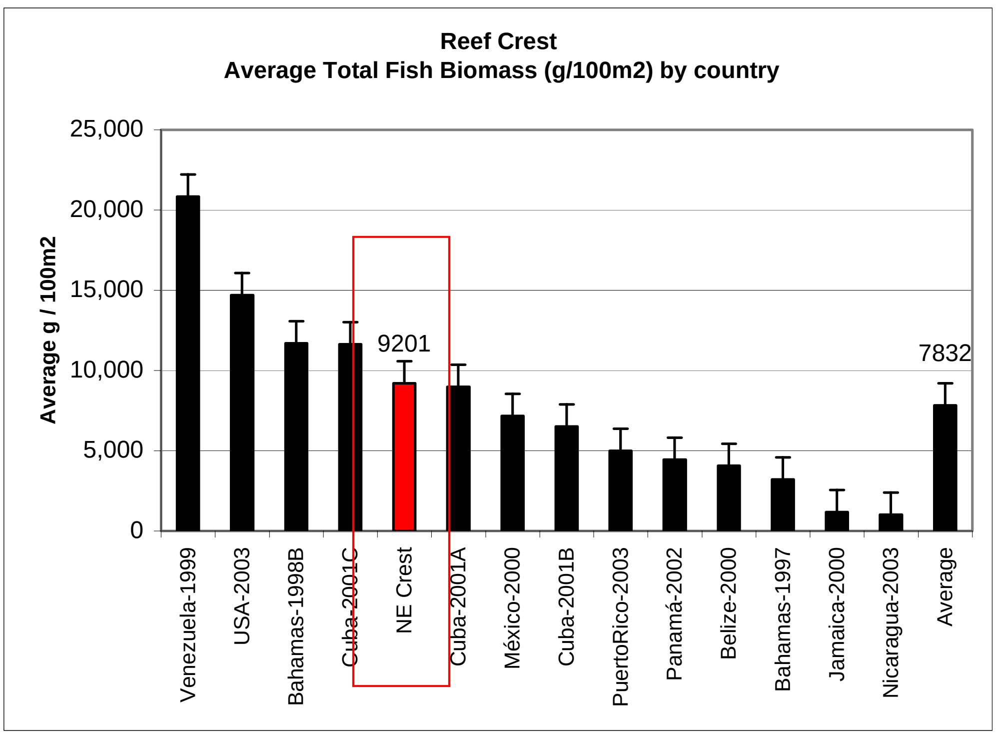

Figure 32:

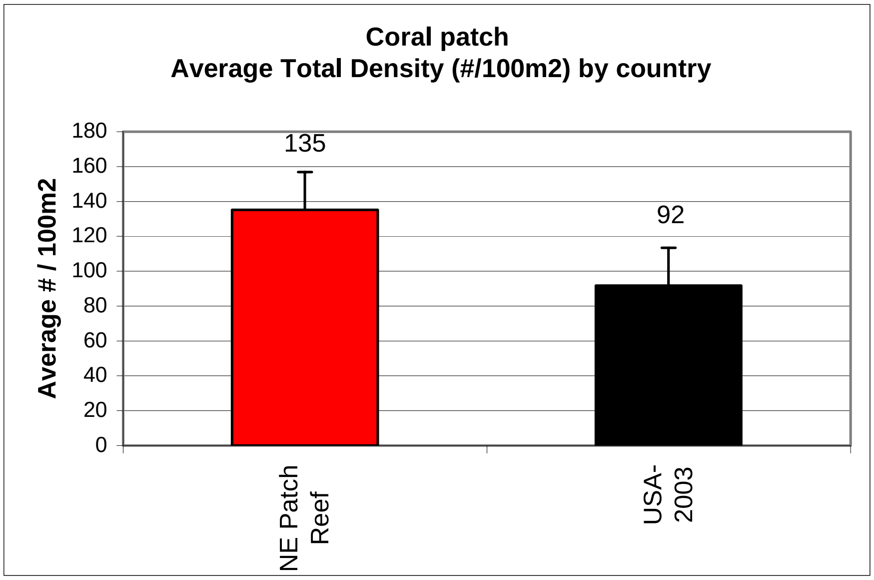

Figure 33: