ATLANTIC AND GULF RAPID REEF ASSESSMENT (AGRRA) PROTOCOL v. 4.0 FIRST IMPLEMENTATION IN THE COMMONWEALTH OF DOMINICA

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General Introduction

Marine biologists agree that there is a general degradation of coral reefs throughout the world (Lewis 2002). Synergistic factors contributing to the declining health of coral reefs vary regionally and globally. Since reef community structure differs among regions throughout the Caribbean, comparable quantitative data is needed. The Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol is a new approach for a region-wide assessment of coral reef conditions. The standardized protocol focuses on stony corals, fishes and algae in order to give a general overview of reef community structure (Ginsburg 2003). The first compilation of AGRRA surveys was published in 2003.

This is the first AGGRA survey to be implemented in Dominica focusing on the west coast (see Fig. 1). Data collected will allow assessment of future changes such as over fishing, mass mortality or changes in community composition. This AGRRA survey adds to previous research that will help in the management of Dominican reefs.

Comprehensive quantitative surveys of Dominica's reefs began in 1999 with the assessment of reef types, their distribution as well as coral community structure and the occurrence of coral disease (see Steiner and Borger 2000, Steiner 2003, Borger 2003, Knuth 2003, Borger and Steiner 2005). A permanent monitoring program of the status of the echinoid *Diadema antillarum* was established in 2001and has received much attention in the works of Williams (2001), Willette (2001), Smith (2002), McKinney (2002), Steiner and Williams (2004, 2005). Surveys of Mohan (2001), Green (2002), Komorsoke (2002), Petterson (2002) and McDonald (2003), focused on determining the species richness and abundance of reef fishes. In some instances special attention was given to grazing species and predators of *Diadema*. Site specific studies have focused Tarou Point (see Lucas 2001, Lehman 2001, Diamond 2001). West and east coast reefs in the region between Salisbury and Hodges Bay, were differentiated in the studies of Alfnes (2004), Ishikawa (2004), Kerr (2004), Davis (2004), and Baird (2004).

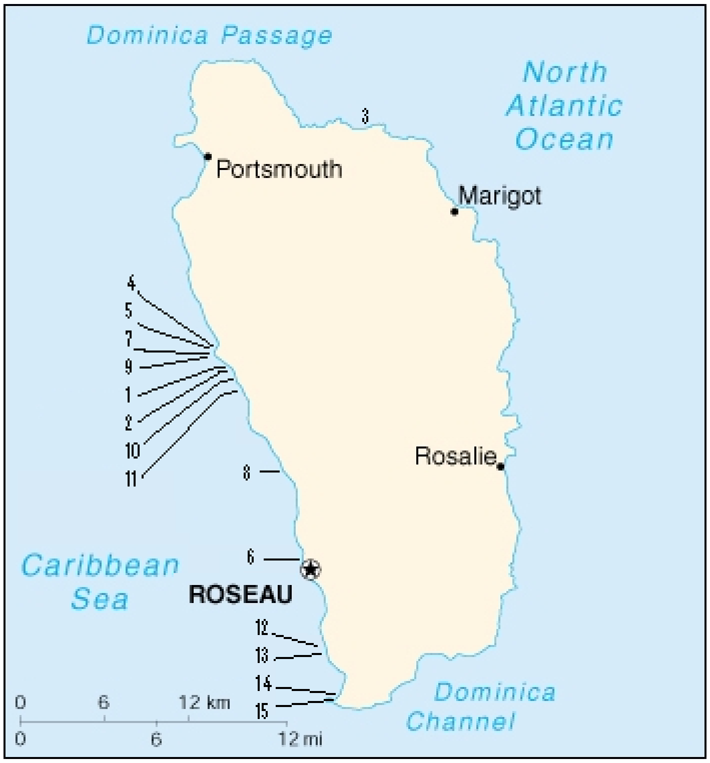

Fig. 1 Map of survey sites for first AGRRA in Dominica.
1. Salisbury East, 2. Salisbury West, 3. Calibishie, 4. Floral Gardens, 5. Batali, 6. Fond Colé, 7. Rena's Reef, 8. Rodney's Rock, 9. Brain Reef, 10. Macoucheri, 11. Berry's Dream, 12. Champange East, 13. Champagne West, 14. Cachacrou SCUBA, 15. Cachacrou snorkel.

References

Borger JL, Steiner SCC (2005) The spatial and temporal dynamics of coral diseases in Dominica, West Indies. Bull Mar Sci 77: 137-154

Green D (2003) Dominica reef fish status 2002: An assessment of the abundance and species composition of Dominican reef fishes. ITME Research Reports 13

Ishikawa M, Kerr J, Alfsnes K (2004) Preliminary surveys of northern reefs of Dominica, West Indies. ITME Student Research Reports 21:1-3. Student Research Reports, Fall Semester 2004

Knuth K (2003) Scleractininan monitoring in Dominica West Indies: species richness, diversity and live coral. ITME Research Reports 19: 3-10

Lucas D, Lehman W, Diamond A, (2001) The marine environment of Tarou Point, Commonwealth of Dominica. ITME Research Reports 6:1-3, Spring Semester 2001

McDonald K (2033) The abundance of herbivorous and predatory fishes in relation to *D. antillarum* along the west coast of Dominica. ITME Research Reports 19: 11-21

Lewis JB (2002) Evidence from aerial photography of structural loss of coral reefs at Barbados, West Indies. Coral Reefs 21: 49-56

Smith Q, McKinney J, Komoroske L, Pettersen L. (2002) Dominica coral reef status 2002: assessment of the sea urchin *Diadema antillarum*, reef fishes and algae. ITME Research Reports 12:1-4. Student Research Reports, Fall Semester 2002.

Steiner SCC, Borger JL (2000) Coral assemblages of Dominica West Indies: An introduction. Reef Encounter 28: 20-23

Steiner SCC (2003) Stony corals and reefs of Dominica. Atoll Res Bull 498

Williams SM, Mohan E, Willette DAS, Lestrade N (2001) Dominica coral reef status 2001: assessment of the sea urchin *Diadema antillaurm*, reef fishes, algae and sponges. ITME Research Reports 9:1-4 Student Research Reports, Fall Semester 2001

Study I: Assessment of Coral Reef Community Structure in Dominica, (Lesser Antilles)

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Abstract The Atlantic and Gulf Rapid Reef Assesment (AGRRA) protocol version 4.0 was used to assess the overall community structure of all hermatypic scleractinian corals and hydrocorals within the genus *Millepora* spp. greater than or equal to 10cm at nine sites in Dominica. Mortality, bleaching and disease was also recorded. Three hundred two coral colonies in 16 species were observed with *P. astreoides* being the most abundant species with 36% of the total number of colonies. The mean species richness for all sites was 8.2 species while the mean diversity expressed as H′ was 1.72. Bleaching was observed at all sites and was recorded in 82.4% of all colonies. The majority (93.2%) of the mortality recorded fell into the “old” category.

Keywords AGRRA, Mortality, Bleaching, Dominica, Community structure, Coral reefs

Introduction

The objective of this study was to examine the community structure of hermatypic scleractinian corals and hydrocorals within the genus *Millepora* larger than or equal to 10.0cm in maximum diameter in Dominica. It also took into account the overall condition of these corals by determining mortality, the occurrence of bleaching and diseases. This study was executed in accordance to the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol version 4.0 (Kramer 2005). The AGRRA protocol provides a standardized quantitative survey of coral reefs that can be quickly applied to assess reef community structure. Information is then pooled into a central database located at the Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Science, University of Miami. This information is made available to the public to be used for comparative evaluation of current reef conditions.

In 1999, comprehensive quantitative studies of Dominica’s reef community began with surveys by Steiner and Borger (2000). Since then, other studies have assessed the coral community structure in Dominica. Steiner (2003) examined 31 sites on Dominica’s north-east and west coasts. Diamond (2003) identified and assessed the scleractinian community at Tarou Point, and Knuth (2003) monitored the species richness, diversity and live cover of scleractinians. Coral diseases and bleaching have also been documented for Dominican reefs. A three year study beginning in 2000 done by Borger and Steiner (2005) addressed the spatial and temporal dynamics of coral diseases in Dominica. Kerr (2004) examined diseases as well as the bleaching of cnidarians on Dominica’s west coast. AGRRA has never been implemented in Dominica before. The data collected in this survey builds on previous research and allows comparison to past conditions and community structure which can be used to evaluate further danger to Dominican reefs.

Coral reefs are a vital part of tropical marine ecosystems. A large variety of microorganisms, invertebrates and fishes live among the corals and algae, making coral reefs one of the most diverse and productive biomes on Earth (Campbell 1993) . Prominent herbivores including snails, sea urchins and fishes feed on and around the reef (Campbell 1993). Predators like octopus, sea stars and carnivorous fishes in turn consume these animals. Coral reefs are extremely delicate communities exerting a tight control on material cycles in an oligotrophic environment. Since corals host endosymbiotic dinoflagellates know as zooxanthellae within their gastrodermis which require light for photosynthesis; the vertical distribution of living reef corals is restricted to the depth of light penetration. Because of this dependence on light, corals require clear water. Thus, coral reefs are found only where the surrounding water contains relatively low amounts of suspended material. Coral reefs are further restricted by water temperature and only occur in areas where the average minimum water temperature never falls below 20 degrees centigrade (Barnes 1987). Because coral reefs are so delicate, determining and monitoring the abundance and condition of the reefs can provide a first indication of changes in community structure.

Two components that are affecting coral mortality are the occurrence of bleaching and the emergence of coral diseases. Bleaching is of particular interest for this study since bleaching events in Dominica have been recorded for 2003 and 2004. Bleaching results in the loss of the zooxanthellae contained within the coral tissue. This may be caused by a wide range of environmental stresses, but is most commonly caused by elevated water temperatures for prolonged periods of time. Corals can also bleach when exposed to extreme changes in salinity, pollution, increased sedimentation, or unusually low temperatures (Humann and Deloach 2002). Without the zooxenthellae, bleached corals are under an increased amount of stress because the zooxenthellae provide the corals with a substantial nutritional component. It is believed that this added stress makes the corals more susceptible to disease (Humann and Deloach 2002). Coral diseases have become a persistent source of mortality on many reefs and thus have the potential to be more damaging to reefs than all other threats combined (Borger and Steiner 2005). There is also evidence suggesting that the emergence of new conditions/diseases is increasing as well as the local and geographic distribution of diseases and host species range (Borger and Steiner 2005).

In Dominica, the coral reefs are very unique; because it is a volcanic island with a narrow steep shelve, coral reef development is spatially limited and true reefs with carbonate build up are only found in the Grande Savane area and northeast parts of the island (Steiner 2003). All other reefs have coral assemblages growing on substrate composed of volcanic rock that has fallen from the sea shore cliffs or pebbles cemented together by rhodophyta and other algae.

Dominica is one of the largest islands in the Lesser Antilles with a low population of under 100 thousand people and historically has had limited large scale development. Although some people do live on the interior parts of the island, the steep mountains and rugged terrain that dominate the landscape make it difficult to build roads and other infrastructure. Traditionally, agriculture has been done on a small scale and agricultural development is based out of river valleys. Also, people traveled by boat in order to move about the island. Because of this, Dominica's population has been concentrated on the coastlines; in particular the west coast. Here, Dominicans can take advantage of natural resources provided by the sea; mainly fish.

Dominica has two large fishing complexes located in Marigot and Roseau built to support pelagic fisheries. Unfortunately, most fisherman do not have the equipment or fishing vessels necessary to fish far from shore. Those fishermen that do fish the pelagic environment view using the fishing complexes as too inconvenient and would much rather sell their catch themselves on the street, making these complexes highly underutilized. Because of this scenario, fishing pressure is focused on the reefs surrounding the island; and the management and regulation of these fisheries is still in its infancy. Local fishermen commonly use fishing gear such as fish pots and seine nets that do not discriminate against what types of fish are caught. These fishing methods combined with the high fishing pressure are removing key herbivores, planktivores and grazers who help keep the reef healthy by removing algae and plankton which reduces the amounts of suspended material in the water. Over fishing these types of fish can lead to reef degradation. Uncontrolled garbage disposal throughout the island seen particularly in close proximity to shore is also threatening reef health.

Due to limited resident personnel capacity, it is very difficult to implement a proper management and enforcement program pertaining to the reefs in Dominica. Since AGRRA provides standardized methods of collecting data it can be used by Dominican officials working in fisheries and marine parks. Results from this study can be used as a benchmark and compared to other AGRRA surveys around the Caribbean basin.

Method and Materials

Nine sites in four regions were examined for this study. Site descriptions are listed in Byrd (2005) and McNeal (2005). Sites were strategically chosen based the AGRRA protocol v. 4.0 and sites characterized by boulder substrates were included because these sites represent common reef types in Dominica (Kramer 2005). For the deep sites (6-15m) SCUBA was used and shallow sites (0-5m) were surveyed by snorkeling. Regions and sites were divided up as follows. For the west/central (deep) region the sites surveyed were, Floral Gardens, Rena's, Brain, Berry's Dream and Salisbury west. For the west/central (shallow) region the site surveyed was Rodney's Rock. The site in the north/east region was Calibishie and the sites in the south region included Cachacrou and Champagne west.

The following amendments were made to the AGRRA protocol to make data collection quicker. Two divers instead of one carried out the benthic survey; know as diver A and diver B. Diver A, laid down the 10m transect line and collected data pertaining to scleractinian corals and *Millepora* spp. greater than or equal to 10cm. Corals were identified *in situ* according to Humann and Deloach (2002). Mortality, bleaching and the presence of Black-Band Disease (BB), White-Band Disease (WB), White Pox Disease (WS), White Plague (WP), Red-Band Disease (RB) and Yellow-Band Disease (YB) was also recorded.

Data for live coral cover were analyzed using one-way ANOVA. Species evenness was calculated using the Pielou index of evenness (Pielou 1966). The Shannon-Wiener diversity index was used to calculate species diversity (Shannon-Wiener 1948).

Results

Coral Community Structure

The mean number of colonies per 10m at each site varied from 3.6% at Calibishie and 15.7% at Brain (Fig. 1). *Porites astreoides* was the most abundant species (34.0 %) while; *Dichocoenia stokesii* and *Acropora palmata* were the least abundant with 0.03% of the total colonies recorded (Fig. 3). *P. astreoides* also had the largest amount of live coral cover with 24% (Fig. 4) Mean species richness for all sites was 8.2 species with the highest species richness occurring at Berry's Dream with 11 species recorded. The mean evenness of species distribution for all sites was 0.83 expressed as J′ (Pielou, 1966) with the highest species evenness being 0.95 at Calibishie. Mean species diversity for all sites was 1.72 expressed as H′ (Shannon-Wiener, 1948) with the highest diversity being 2.19 also at Calibishie (Table 1). The mean surface area per colony was 880.4cm^2, the species with the highest surface area was *A. palmata* with an average of 8250.0 cm^2 (Fig.2).

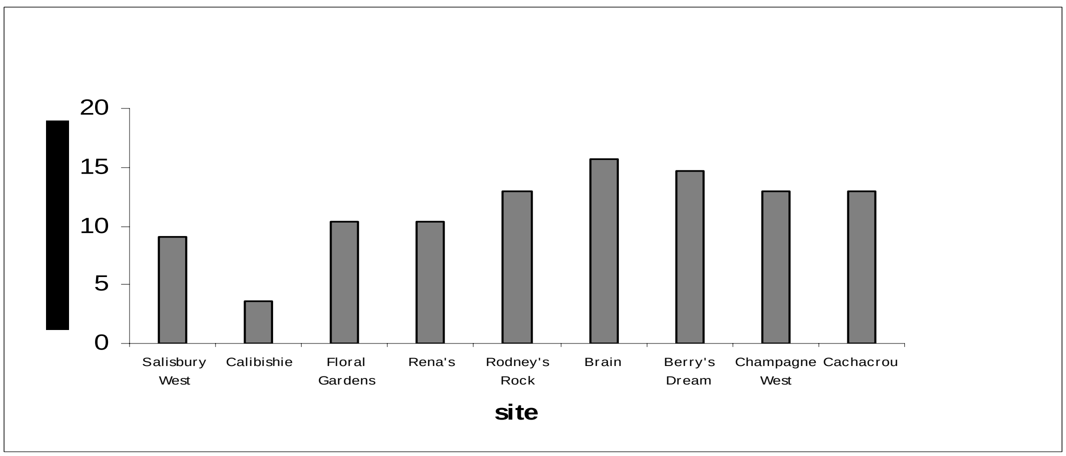

Fig.1 Mean number of colonies per 10m for each site Salibury West (3 transects), Calibishie (5), Floral gardens (3), Renas's (3), Rodney's Rock (4), Brain (3), Berry's Dream (3), Champagne West (3) and Cachacrou (2).

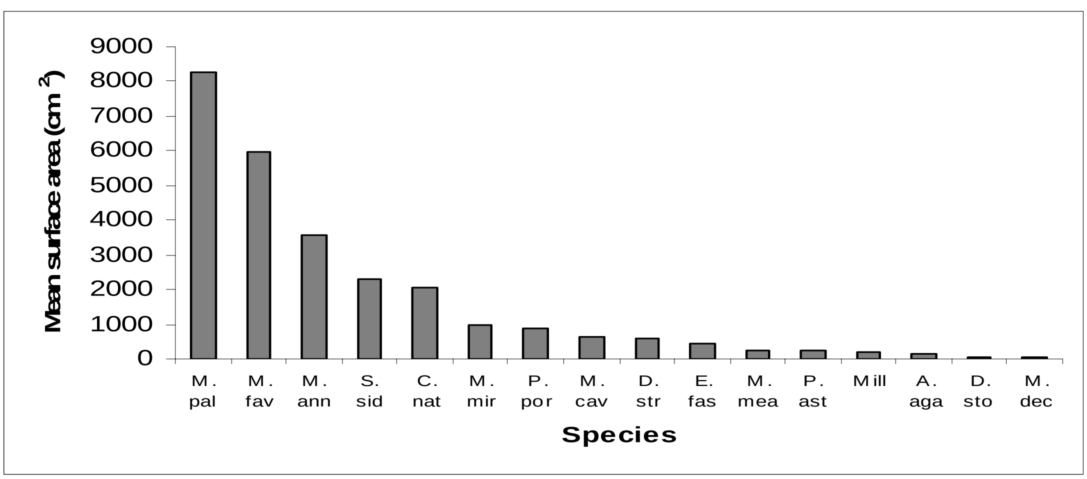

Fig. 2 Mean surface area per species (based on length x width measurements).

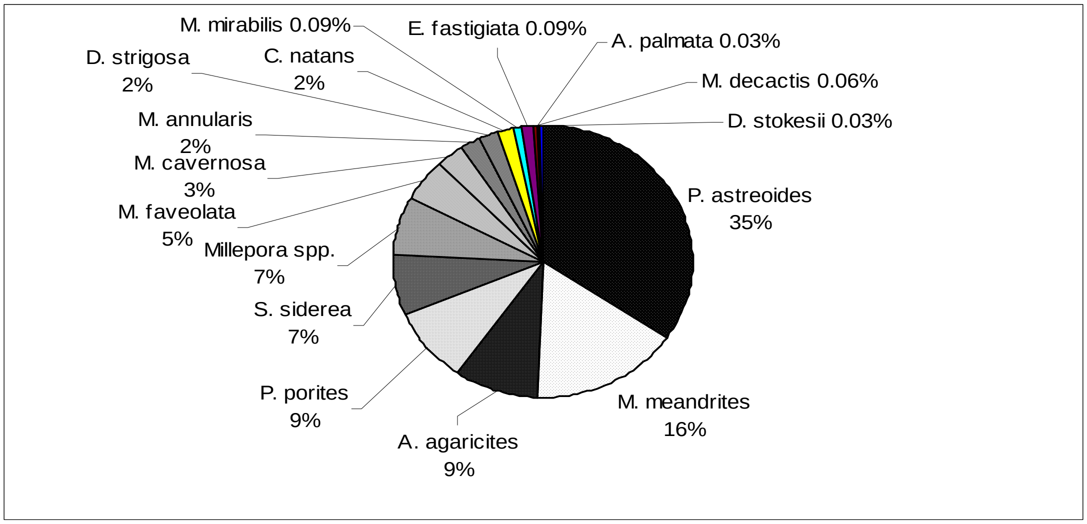

Fig.3 Percentages of species abundance for all sites.

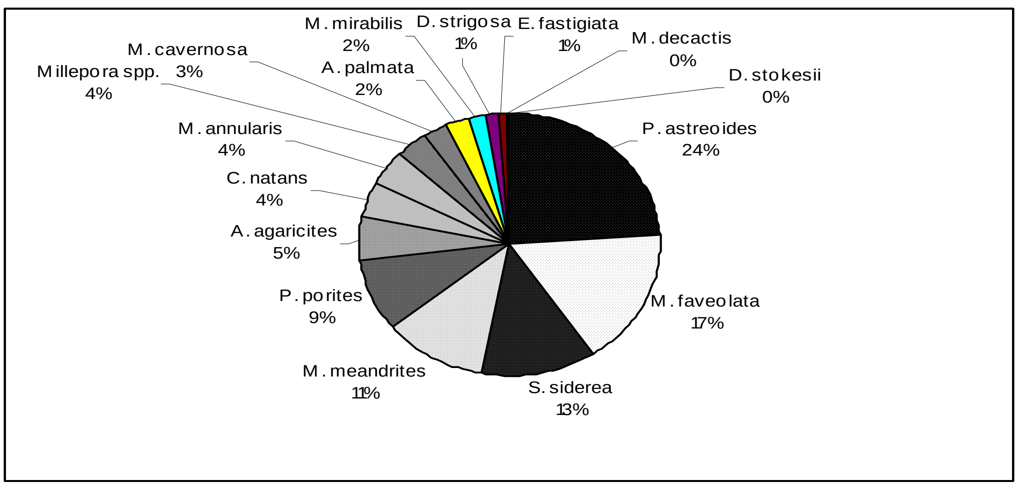

Fig. 4 Percentages of live coral cover for all sites (M. decactis 0.1% and D. stokesii 0.04%)

Table 1 Species richness, species evenness and Shannon-Wiener diversity index for each site

Site	Species Richness (S)	Pielou Species Evenness (J′)	Shannon-Wiener Diversity Index (H′)
Salisbury West	9	0.87	1.91
Calibishie	10	0.95	2.19
Floral Gardens	6	0.84	1.51
Rena’s	7	0.63	1.22
Rodney’s Rock	8	0.89	1.86
Brain	10	0.91	2.09
Berry’s Dream	11	0.79	1.89
Champagne West	9	0.74	1.62
Cachacrou	4	0.83	1.16

Live Coral Cover

The amount of live coral cover varied significantly between the study sites (ANOVA, F = 4.84, P< 0.1). At Salisbury West, the live coral cover under the transect line was 7% composed mostly of *Montastraea. faveolata* with 21.6% (Fig.5). Calibishie had the lowest live coral cover with only 5.4%. *A. palmata* was the dominant species at this site and comprised 22.0% of the live coral cover (Fig.6). Floral Gardens had a total of 14.0% live coral cover with *M. faveolata* taking up 61.7% (Fig.7). Rena's Reef had a live coral cover of 9.0% being dominated by *P. astreoides* which comprised 57.7% (Fig.8). Rodney's Rock had 19.0% live coral cover, 89.5% of which was *Siderastrea. siderea*; this was the highest cover by one species at any particular site (Fig.9). Brain Reef had the highest live coral with 31%; 57.7% of which was *Montastraea annularis* (Fig.10). Berry's Dream had a live coral cover of 19% and was dominated by *P. astreoides* with 61.3% (Fig.11). Champagne West had a 13.3% live coral cover and also was dominated by *P. astreoides* with 84.0% (Fig.12). Cachacrou had a live coral coverage of 27.3%. *M. faveolata* was the dominate species at this site and comprised 54.6% of the live coral coverage (Fig.13).

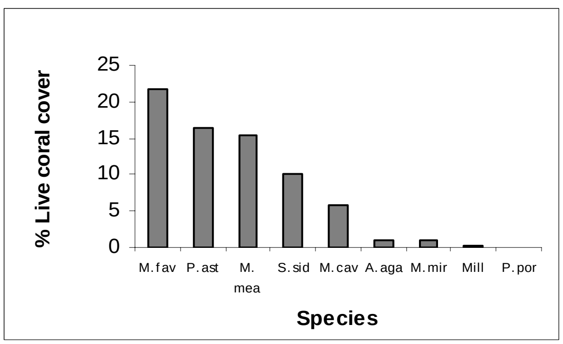

Fig. 5 Percent live coral cover for Salisbury West

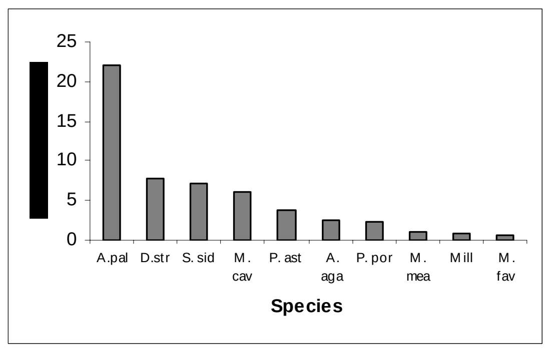

Fig. 6 Percent live coral cover for Calibishie.

Figs. 5-13: P. ast = *Porites astreoides*, M. mea = *Meandrina meandrites*, A. aga = *Agaricia agaricites*, S. sid = *Siderastrea siderea*, Mill = *Millepora sp*., P. por = *Porites porites*, M. fav = *Montastraea faveolata*, M. cav = *Montastraea cavernosa*, M. ann = *Montastraea annularis*, D. str = *Diploria strigosa*, C. nat = *Colpophyllia natans*, M. mir = *Madracis mirabilis*, M. dec = *Madracis decactis*, A. pal = *Acropora palmata*, E. fas = *Eusmillia fastigiata*, D. sto = *Dichocoenia stokesii*.

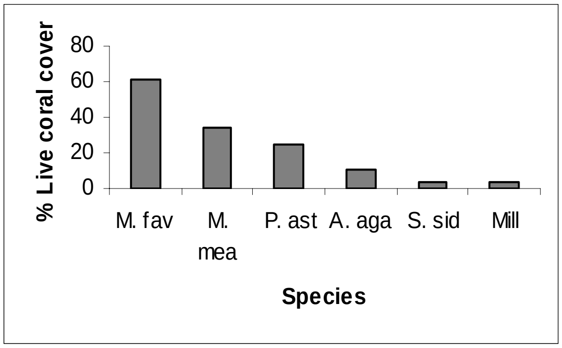

Fig. 7 Percent live coral cover for Floral Gardens.

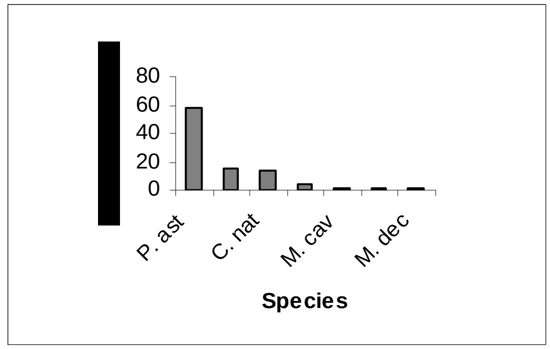

Fig. 8 Percent live coral cover for Rena's Reef.

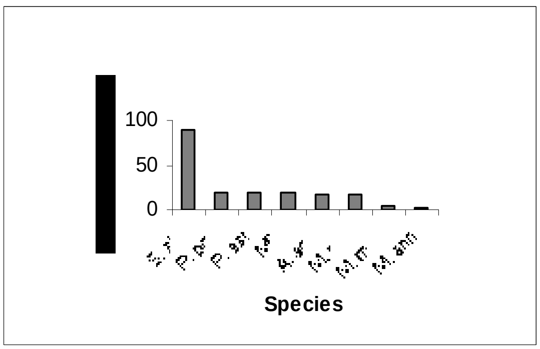

Fig. 9 Percent live coral cover for Rodney's Rock

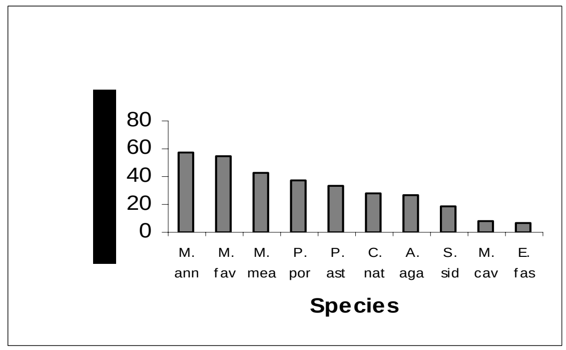

Fig. 10 Percent live coral cover for Brain Reef

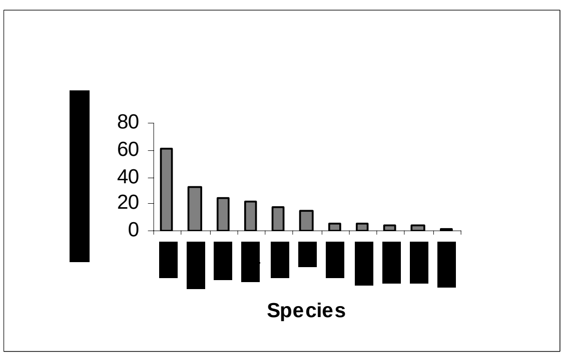

Fig. 11 Percent live coral cover for Berry's Dream.

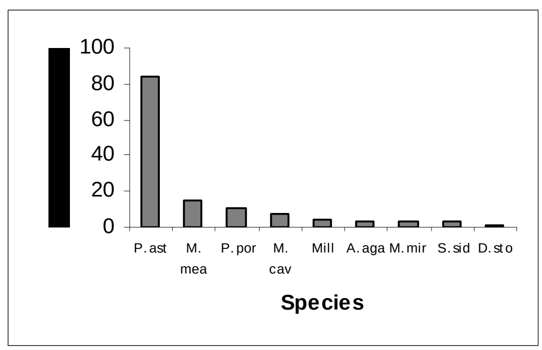

Fig.12 Percent live coral cover for Champagne West.

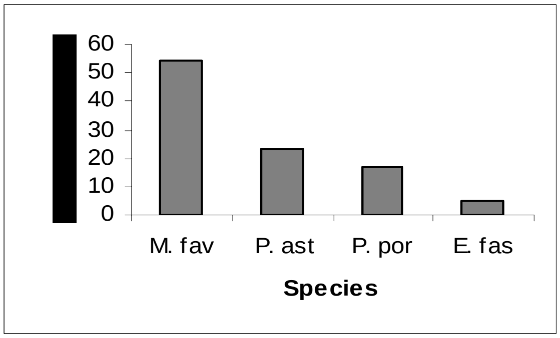

Fig. 13 Percent live coral cover for Cachacrou.

Bleaching

Bleaching occurred at all sites with 82.4% of the total number of colonies exhibiting some bleaching. Rodney's Rock exhibited the highest amount of bleached colonies. Berry's Dream had the most partially bleached colonies and the highest number of pale colonies occurred at Rena's Reef (Fig.14). Bleaching was prevalent in all of the recorded coral species except *Madracis decactis*, *Madracis mirabilis* and *D. stokesii*. *Agaricia agaricites* exhibiting the largest percentage of bleached colonies (Fig.15). Dark spot disease that had infected a *S. siderea* colony at Champagne West was the only disease recorded in this study.

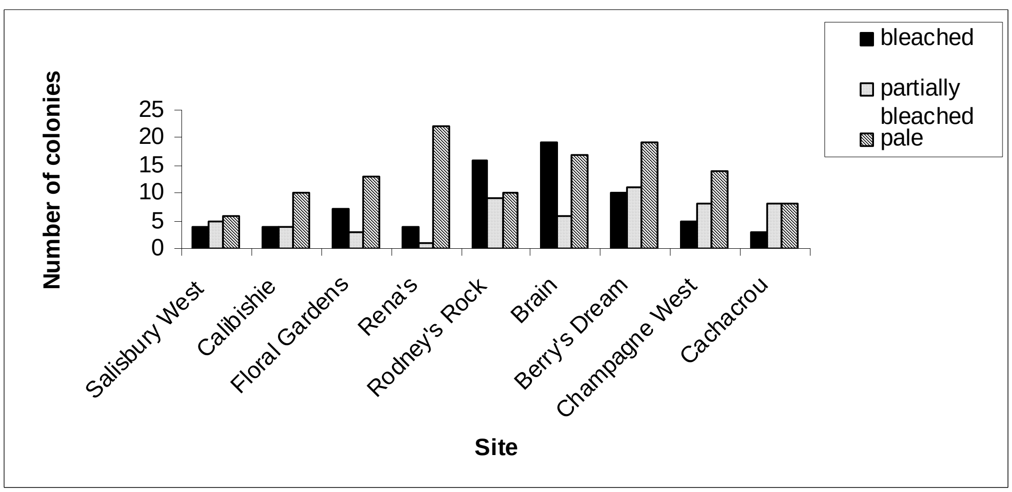

Fig. 14 Total number of bleached, partially bleached and pale colonies at each site.

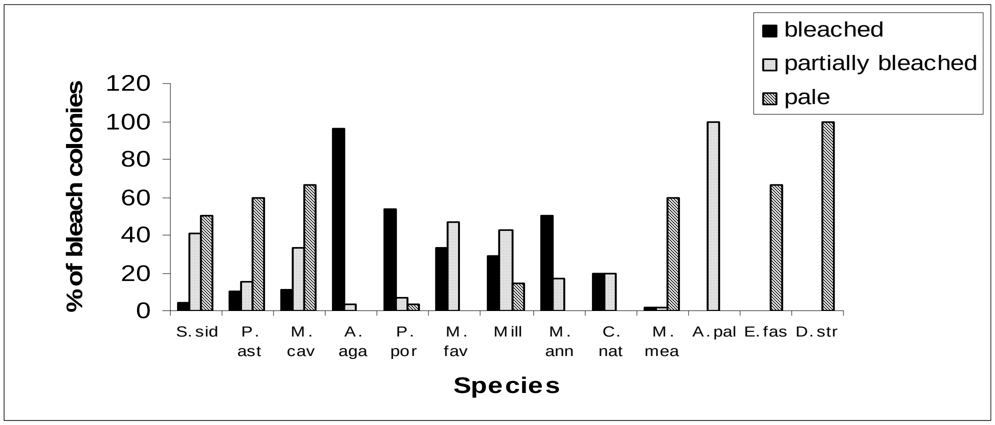

Fig. 15 The percentage of bleached, partially bleached and pale colonies for each species.

Mortality

Coral mortality was recorded at all sites. Most of the mortality recorded was "old" and had dense algal cover. Although there was recent mortality recorded at Cachacrou, Champagne West, Salisbury West, Berry's Dream, Rena's Reef and Floral Gardens all of the values added up to less than 1% at each site. Floral Gardens had the most mortality with 50.5% of the total number of colonies being old dead coral; while Salisbury West exhibited the least amount of mortality with 14.8% of the total number of colonies being old dead coral (Fig.17). All coral species except for *Millepora sp.* and *D. stokesii* showed some mortality. Most of the mortality recorded for each species was also old mortality. The only species recorded with recent mortality were *P. astreoides* (2.4%) and *Porites Porites* (4.7%) *P. porites* also exhibited the largest overall percentage of coral mortality with 53.9% (Fig.16).

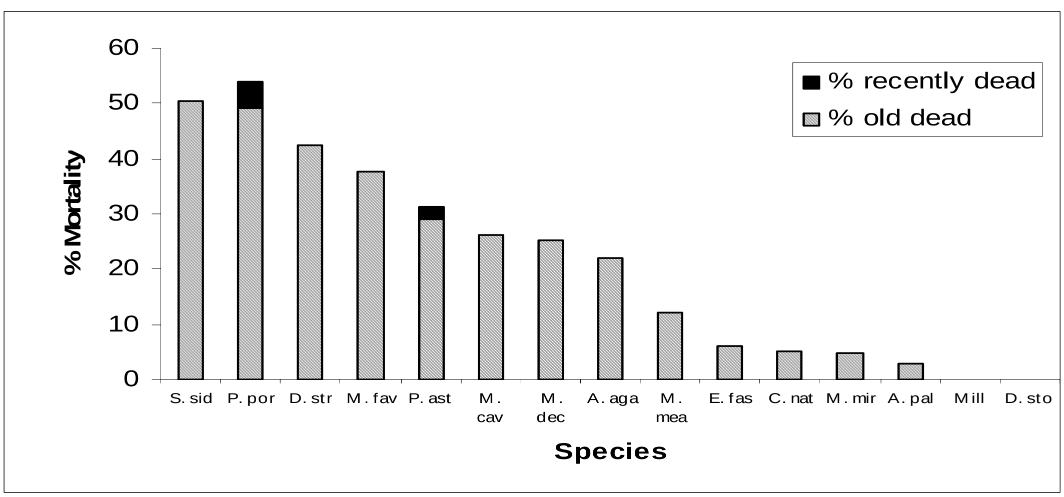

Fig.16 Percentage of old and recent mortality for each species.

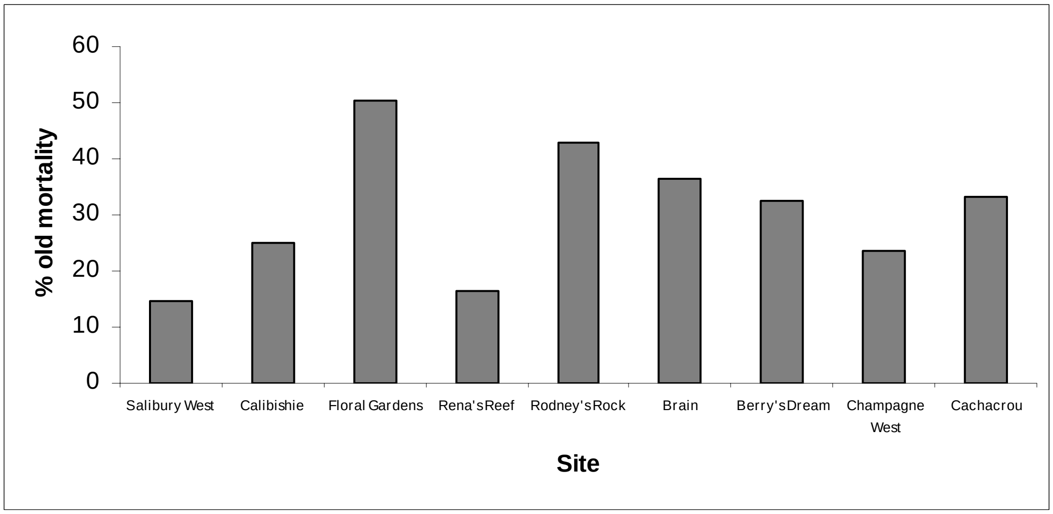

Fig. 17 Percentage of old mortality recorded for each site.

Discussion

Three hundred two coral colonies and 16 different coral species were recorded in this study. The majority of coral colonies (79.3%) consisted of "weedy" species dominated by *P. astreoides* this same result was also recorded by Knuth (2003) and Steiner (2003). "Weedy" species usually grow in a wide variety of habitats and can act as fillers of space on many reefs. Large framework builders only comprised 20.7% of all colonies recorded but covered more surface area than the rest of the colonies combined. These framework builders are extremely important in the building of reefs; their paucity in this study could be due to the spatial limitations presented by Dominica's topography or due to poor recruitment by these species. Only one live *A. palmata* colony was recorded in this study and it covered the most surface area out of any recorded colony. Acroporids have been the main framework builders in high turbulence reefs of the Caribbean. Because *A. palmata* is a branching coral, has substantial size and grows quickly (5-6in per year under optimum conditions) it provides a suitable substrate for many sessile organisms to settle on and habitat for vagile organisms as well. Because of this, transplantation of *A. palmata* to reefs on Dominica's east coast can be used in order to encourage reef growth and proliferation. Even though many of the sites were made up of the same coral species, the amount of live coral varied significantly between study sites, this represents the heterogeneity of Dominican reefs.

The high occurrence of bleaching is most likely due to a prolonged increase in average water temperature, which during this study averaged 30-31°C. Global stresses like climate change can synergistically degrade reefs and increase the occurrence of bleaching. In Dominica, pollution is prevalent on the reefs and in the water column and fishing pressure of important reef fishes is high, this could place added stress on corals weakened by the bleaching event. Although Dominicans cannot control natural global occurrences, having better control over stresses caused by humans like improper waste disposal can help lower the mortality of bleached corals. The species most affected by bleaching was *A. agaricites* since almost 100% of the colonies were completely bleached. This corresponds to what was reported by Kerr (2004) where *A. Agaricites* colonies were bleached at all sites except Champagne. The least affected species was *Meandrina meandrites.* Even though many of the colonies were pale, there was only one partially bleached colony and one completely bleached colony. This shows a difference in the susceptibility to bleaching between different coral species. Buddemeir and Fautin (1993) suggest that bleaching might be adaptive rather than pathological, providing and opportunity for recombining hosts with alternative algal types to form symbioses that are better adapted to altered circumstances. In support of this theory, there are small differences between temperatures that occur at regular intervals with no effect and some that induce bleaching; Veron (1995) reported that one taxon of zooxanthellae can replace another. This may be the reason why there are differences pertaining to bleaching between species. Kerr (2004) recorded *M. meandrites* as being the first species affected by bleaching, and in this study there was a low occurrence of bleached *M. meandrites* colonies. It could be that after the previous years bleaching event a new taxon of zooxanthellae entered this species and in turn, it became better adapted to the higher water temperatures. Although there was only one disease recorded in this study, it should be noted that during general reef observations dark spot disease was seen frequently; mostly occurring on *S. siderea* colonies. Black-band disease was also observed on many of the *Diploria* spp. and at Calibishie white-band disease was seen on many of the *A. palmata* colonies.

The high occurrence of old mortality in this study could be explained by chronic or large disturbances in recent decades. The fact that large framework builders such as *S. siderea* and *M. faveolata* had some of the highest mortality percentages should be of some concern because of their importance in forming substrate on coral reefs and low recruitment numbers shown by Wallover (2005) in which only eight recruits of framework building corals were recorded from a total of 10 sites. While the mortality of some of the “weedy” species such as *P. astreoides* should not be of major concern because of their large abundance and their role as space fillers on reefs.

Acknowledgments

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References

Barnes R (1987) Invertebrate Zoology. CBS College Publishing SaundersCollege Publishing Holt, Rinehart and Winston The Dryden Press pp. 149-150

Borger J and SC Steiner (2005) The Spatial and Temporal Dynamics of Coral Diseases in Dominica, West Indies. Bull Mar Sci 77(1): 137-138

Buddemeir RW and Fautin DG (1993) Coral bleaching as an adaptive mechanism Boscience 43: 320-326

Byrd K (2005) Study V: A Rapid Assessment of the Stony Corals and Algae in Dominica, Lesser Antilles. ITME Reports 23 (I-VII):53-63

Campbell N (1993) Biology The Benjamin /Cummings Publishing Company Inc. pp.1068-1069

Deloach N and Humann P (2002) Reef Coral Identification 2nd ed. Florida Caribbean Bahamas New World Publications Jacksonville Star Standard Publications Inc. Singapore

Kerr, J (2004) Coral Disease and Coral Bleaching Along the North and West Coasts of Dominica, West Indies. ITME Research Reports 21 (1-3) 10-19

Knuth K (2003) Scleractinian monitoring in Dominica, West Indies: species richness, diversity, and live cover. ITME Research Reports 19 (1-2) 3-10

Kramer P and Lang J (2003) The Atlantic and Gulf Rapid Reef Assessment (AGRRA) Protocols: Former Version 2.2 In: Lang J (ed) Status of Coral Reefs in the Western Atlantic: Results of Initial Surveys, Atlantic and Gulf Rapid Reef Assessment (AGGRA) Program. National Musuem of Natural History Smithsonian Institution Washington D.C. Atoll Res Bull 496 vii-x

Kramer *et al.* (2005) AGRRA Methodology v. 4.0 Atlantic and Gulf Rapid Reef Assessment v. 4.0 1-14

McNeal J (2005) Study IV: Atlantic and Gulf Rapid Reef Assessment of *Diadema antillarum*, coral recruits and algal cover on Dominican reefs. ITME Research Reports 23 (I-VII):43-52

Pielou EC (1966) The measurement of diversity in different types of biological collections. J Theor Biol 13: 131-144

Shannon CE and W. Wiener (1948) The mathematical theory of communication. Univ. Illinois Press, Urbana, Illinois. 117p

Steiner SCC (2003) Stony corals and reefs of Dominica Atoll Res Bull 498: 1-12

Veron JEN (1995) Corals in space and time the biogeography and evolution of the scleractinia. Australian Institute of Marine Science Cape Ferguson, Townsville, Queensland Southwood Press Pty Ltd , Australia pp. 95-96

Wallover N (2005) Study III: Rapid benthis assessment of reefs of Dominica, West Indies ITME Research Reports 23 (I-VII):32-42

Study II: Rapid Assessment of Stony Coral Community Structure in Dominica, West Indies

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Abstract This study is a rapid assessment of Dominica's benthic coral community structure including Scleractinian species and the hydrocoral *Millepora* spp. It was done by measuring stony coral and *Millepora* spp. of 10 cm or greater diameter and surveying their condition. The Atlantic and Gulf Rapid Reef Assessment (AGRRA) Protocol version 4.0, along with several modifications, was implemented for research. This study was completed in October and November 2005 and included 10 sites, predominately boulder fields and reef assemblages on the western coast of Dominica. Seven deep sites, 5-14 m depth, were surveyed on SCUBA and the remaining three, 0-5 m depth, were surveyed snorkelling. Nineteen coral species were recorded in the surveys. *Porites astreoides* was the overall dominant coral, ranking most abundant in eight of ten individual sites. Species richness at sites varied between 4 and 14 species, diversity between H'=0.96 and H'=2.28, and evenness between E=0.69 and E=0.92. Live coral cover of colonies greater than 10 cm ranged from 7.9%-35.5% under the transects. Old mortality was more prominent than recent mortality over all sites surveyed, and was most prevalent in the framework builder *Montastraea cavernosa*. Bleaching affected corals at all sites, the majority of species exhibiting more colonies affected by bleaching that not. The data from this study can also be used to put the condition of Dominican corals into context with research done on the reef community of the greater Caribbean area.

Keywords Scleractinian, AGRRA, Coral bleaching, Dominica

Introduction

Coral reefs throughout the Caribbean are unarguably undergoing recent changes as result of growing human influences such as increased sedimentation from road development and chemical run-off from agriculture. The Atlantic and Gulf Rapid Reef Assessment (AGRRA) was created to provide method for this baseline quantitative data collection to quantify and monitor these widespread changes (Lang 2003). The AGRRA protocol is a standard survey method that focuses on three aspects of reef community: stony corals, algae, and fishes (Lang 2003). This particular study focuses on the presence, size, and condition of scleractinian corals and the hydrocoral *Millepora* spp.

Coral presence and size data is important in determining whether a reef phase shift from coral-dominated to algal-dominated is taking place in Dominica, or over the greater Caribbean area. The presence or absence of certain coral species gives insight into the extent at which different species tolerate stress factors such as increased water temperatures, sedimentation, and direct human disturbance. The data also aids in determining depths at which certain coral species thrive. The relationship between mortality, sites and species studied provided information on the extent corals are suffering from stresses.

The rise of bleaching associated with elevated water temperatures is contributing to these reef changes (Humann and Deloach 2002) (Steiner 2003a). Bleaching studies have been especially relevant since the large bleaching event of 1998 which was known to affect most common reef building corals in the Caribbean (Yap 2000). Cases of coral bleaching have been recorded in Dominica for the past three years. At the time of this study, coral bleaching was so widespread that is was difficult, in many cases, to observe a healthy colony of susceptible species, such as the hermatypic coral *Siderastrea siderea* or *Porites astreoides* (pers. observation). The weakened state in which bleached corals exist puts them at high risk of mortality by other stresses, such as bacterial diseases (Fitt and Warner 1995). The extent to which bleaching was affecting various corals in Dominica, and which coral species it was affecting was investigated. Disease occurrence and species that diseases affected was also recorded to give a more complete picture of overall reef health.

Dominica is a 751 km^2 country in the Lesser Antilles (Honychurch 1995). Due to the island's recent formation and volcanic origin, it has a narrow underwater shelf. Within the shelf zone, only approximately 150 km^2 lie in the photic zone (depth of 50 m or less) where symbiotic relationships between zooxanthellae and corals can exist (Steiner 2003b). The narrow zone suitable for coral growth creates drastic differences between reefs of Dominica and reef systems in areas characterized by long wide shelves. Boulder fields (coral growing on rocks rather than calcium carbonate accumulation), wall assemblages, and various patch reefs, along with some true fringing reef in Dominica characterize the island's benthic habitat (Willette 2001). The mountainous forests of Dominica surround many rivers that carry terrestrial sediment into the oceans and affect the range of corals. The island's ecosystems and weather patterns are greatly affected by the prevailing trade winds, which lead to heavy surge and more rain at sites on the eastern, windward coast of the island. The condition variations between windward and leeward coasts create notably different habitats.

The approximately 70,000 inhabitants are concentrated on the coast of the islands, as the interior has rough, mountainous terrain. Resource use of the majority of the population in close proximity to the reef habitat is reason for concern. The local economy of artisanal fishing is widespread and demersal with 1934 registered fisherman in the small island nation (Guiste pers. com.). Anthropogenic impacts on the reef from fishing industry, though local, very likely extend beyond the damage to the targeted reef fishes. Anchor dragging and fish pot presence on the reef contribute to destruction of stony coral communities. Also, over-fishing causes the breakdown of fish guilds vital to reef maintenance. The much-encouraged tourism economy could also exacerbate current stress levels and prove detrimental to coral reefs of the area. Direct damage of snorkelers and divers on reefs, deforestation attributed to improved tourist amenities, and agriculture will add sediment to the reefs, blocking light from and possibly suffocating corals. Quantitative data from this study can be used to aide in decisions of officials on possible limitations needed on terrestrial development and fishing.

The coral communities of Dominica have been the subject of very little quantified research, with published studies beginning less than ten years ago (Steiner 1999, 2001, 2003b, Williams *et al.* 2001, Smith *et al.* 2002, Green *et al.* 2002, Knuth *et al.* 2003, Ishikawa *et al.* 2004, Borger 2005, Borger and Steiner 2005). A baseline quantification of coral species, size class, and condition of reefs in Dominica was necessary in order to monitor reef changes and effects of anthropogenic influences in the future. This study creates such a baseline for Dominica. Furthermore, it contributes to the quantified knowledge base allowing further research on issues such as bleaching, coral disease, reef phase shifts, and coral diversity/abundance to be studied in context with data from Dominica.

Method and Materials

The AGRRA Protocol version 4.0 was implemented in this study, with a few modifications. Each transect was surveyed by a pair of divers rather than one, and each diver focused on a specific aspect of the reef composition along the transect. Data collected in this study pertains to the coral community structure, which is described as the second benthic transect pass in the AGRRA protocol. Sites were selected strategically, but not all were carbonate systems as described in the AGRRA protocol. Due to Dominica's geography and coral community, coral assemblages on boulder fields were included. No data was collected on Damselfishes. Corals were identified *in situ* according to Humann and Deloach (2002). Species diversity was calculated using Shannon-Weiner Diversity Index and evenness was calculated using J' (Shannon-Weiner 1948) (Pielou 1966). Out-of-water consistency training was done, as was in-water data collection practice. The results of these two training sessions were compared between researchers to ensure consistent data measurements/observations.

This study was conducted by surveying a minimum of 2 transects in each of the following sites (a minimum of 6 other transects for complete AGRRA data were surveyed on each of the same sites by different teams of researchers) (Table 1). Site descriptions and maps for SCUBA sites can be seen in McNeal 2005 and for snorkel sites in Byrd 2005. AGRRA protocol was followed for transect placement with the exception of Cachacrou where transects were placed on a wall edge due to SCUBA time limitation. Sites 0-5 m were done snorkelling and 5-14 m sites were done on SCUBA.

Table 1 Sites (name, coast location, reef type), depth, and survey method.

Site Name	Coast of Dominica	Depth	Number Transects	Reef Type (as stated for AGRRA data)
Salisbury West	West	7.9-9 m	4	Pavement area of deep fringing reef
Calibishie	East	3-4 m	5	Reef crest of deep fringing reef
Battalie	West	12-13 m	3	Spur and Groove Reef
Fond Cole	West	2-4 m	3	Coral on consolidated pebbles
Rena's Reef	West	9.5-11.5 m	3	Offshore fringing reef
Rodney's Rock	West	3-5 m	3	Coral on rock
Brain Reef	West	12.8-13.7 m	2	Forereef slope of fringing reef
Berry's Dream	West	10.5 m	3	Coral on rock
Champagne	West	6-9 m	3	Coral on rock
Cachacrou	West	3-7.5 m	4	Fringing reef

Results

Community Structure of Colonies Greater than 10 cm

A total of 18 scleractinians and the hydrocoral *Millepora* spp. (not identified past genus) were quantified in the survey. Fond Colé had the lowest species richness (4 species) and Salisbury West had the highest (14 species) (Table 2). Mean species richness was 8.60 (±2.99) species per site. *P. astreoides* was the dominant coral species comprising 33.78 % of the total colonies counted. *Meandrina meandrites* was second most common taxon, with 13.56 % of the total colonies counted (Fig. 1). Six coral species (*P. astreoides, M. meandrites, Agaricia agaricites, S. siderea, Porites porites* and *Millepora* spp.) made up > 77.00% of all coral colonies counted. *Diploria labyrinthiformis* and *Madracis decactis* (one colony each) and *Acropora palmata* and *Isophyllia sinuosa* (two colonies each) had the lowest abundance over all sites surveyed (Fig. 1). *P. astreoides* was present at every site. It was the most abundant coral at eight of the ten sites, and the second most abundant at the remaining two sites. *D. labyrinthiformis* was seen only at Salisbury West, and *I. sinuosa* only at Rena's Reef. *A. palmata* was completely absent from all sites on the west coast, occurring only at Calibishie (Fig. 2-11).

Salisbury West had the highest diversity index (H'=2.28) and Fond Colé had the lowest (H'= 0.96) (Table 2). Mean diversity was H'=1.75 (±0.36). Species evenness was highest at Calibishie, J'=0.92, and lowest at Fond Colé, J'=0.69 (Table 2). Mean evenness over all sites was J'=0.83 (±0.08).

Average live coral cover under the transect line varied from 7.90% at Calibishie to 35.50% at Brain Reef (Fig. 12). Mean live coral cover of deeper (SCUBA) sites was 22.38%, and shallower (snorkel) sites, 14.65%. On average, there was also a higher count (16.64 ±4.95 colonies per 10 m) of coral colonies per 10 m transect line at SCUBA sites than at snorkelling sites (9.78 ±4.18 colonies per 10 m) (Table 3).

Mean surface area of colonies was lowest at Rena's Reef (426 cm^2 ±427.47) and 9406.4 cm^2 (±30383.05) at Cachacrou, the site with the highest mean surface area (Fig. 13). Overall, SCUBA sites had higher mean surface area of corals than snorkel sites.

Table 2 Diversity, Species Richness, Evenness (including averages) for each site surveyed.

Site	Shannon-Weiner Diversity Index (H')	Species Richness (S)	Species Evenness (J'=H'/lnS)
Salisbury West	2.28	14.00	0.86
Calibishie	1.65	6.00	0.92
Floral Gardens	1.53	6.00	0.85
Fond Colé	0.96	4.00	0.69
Rena's Reef	1.87	11.00	0.78
Rodney's Rock	1.74	7.00	0.89
Brain Reef	2.07	11.00	0.87
Berry's Dream	1.93	10.00	0.84
Champagne	1.57	9.00	0.72
Cachacrou	1.87	8.00	0.90
AVERAGE	1.75	8.60	0.83

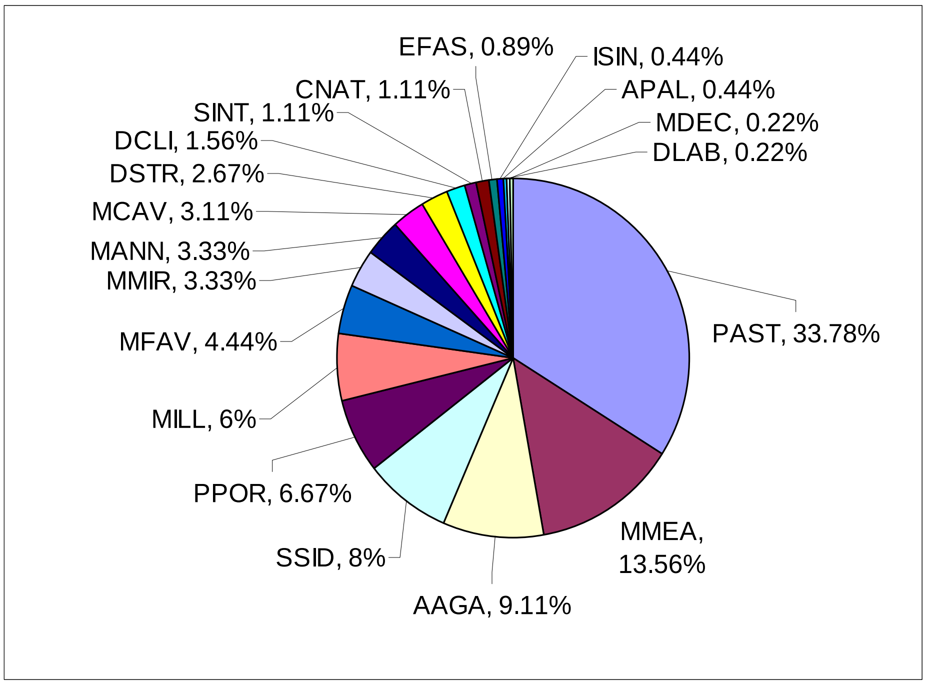

Fig. 1 Percent Species Abundance over all Sites.

Fig. 1, 2-11, 13, 14, and 16 PAST=*Porites astreoides,* MMEA=*Meandrina meandrites,* AAGA=*Agaricia agaricites,* SSID=*Siderastrea siderea,* PPOR=*Porites porites,* MILL=*Millepora* spp.*,* MFAV=*Montastraea faveolata,* MMIR=*Madracis mirabilis,* MANN=*Montastraea annularis,* MCAV=*Montastraea cavernosa,* DSTR=*Diploria strigosa,* DCLI=*Diploria clivosa,* SINT=*Stephanocoenia intersepta,* CNAT=*Colpophyllia natans,* EFAS=*Eusmilia fastigiata,* ISIN=*Isophyllia sinuosa,* APAL=*Acropora palmata,* DLAB=*Diploria labyrinthiformis*, MDEC=*Madracis decactis.*

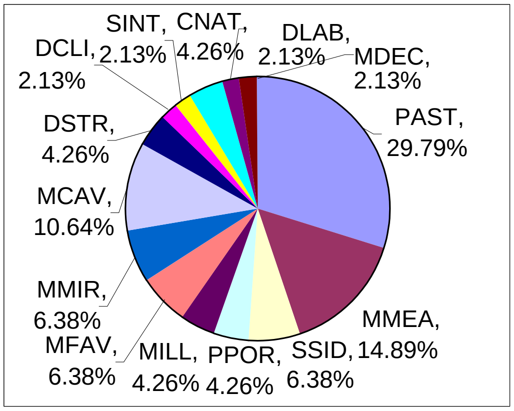

Fig. 2 Species composition at Salisbury West (SCUBA).

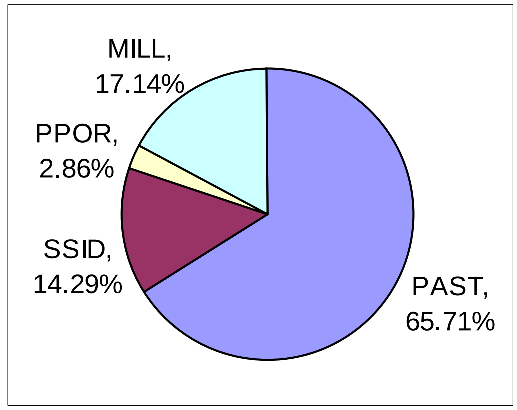

Fig. 5 Species composition at Fond Cole (snorkel).

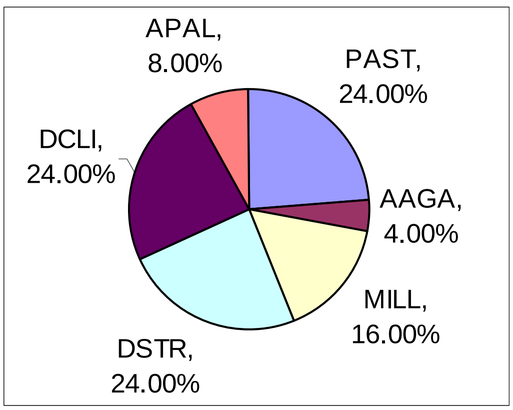

Fig. 3 Species composition at Calibishie (snorkel).

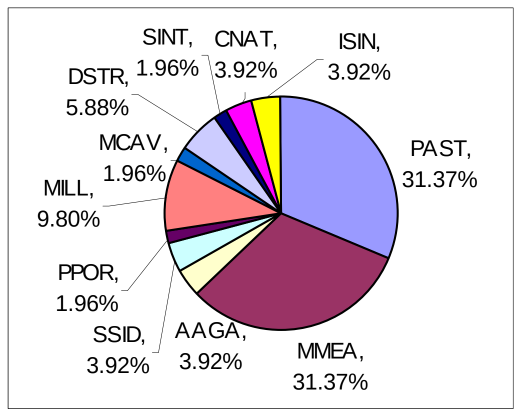

Fig. 6 Species composition at Rena's Reef (SCUBA).

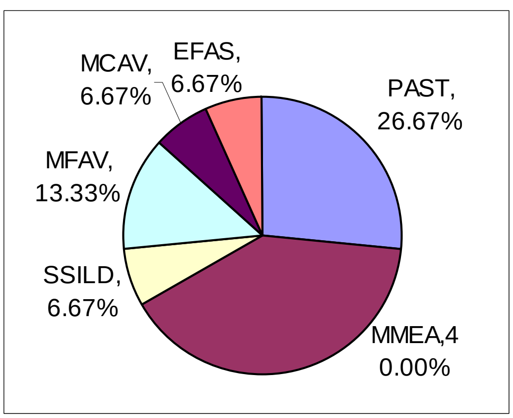

Fig. 4 Species composition at Floral Gardens (SCUBA).

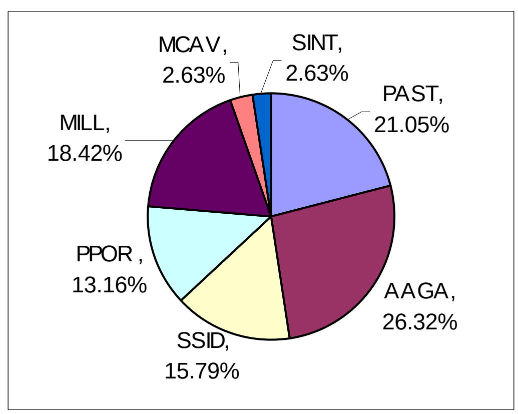

Fig. 7 Species composition at Rodney's Rock (snorkel).

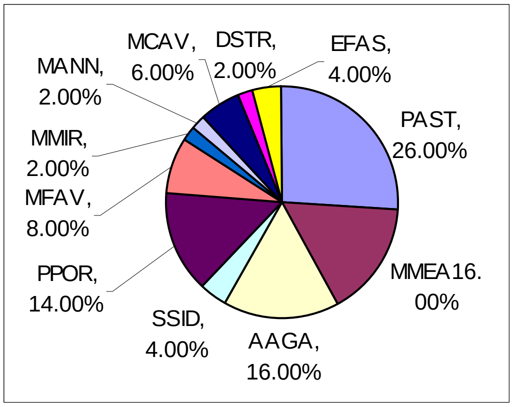

Fig. 8 Species composition at Brain Reef (SCUBA).

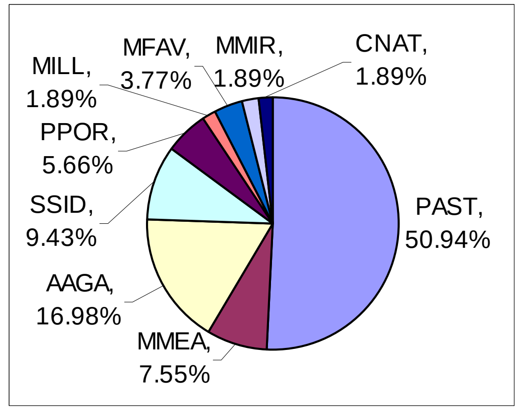

Fig. 10 Species composition at Champagne (SCUBA).

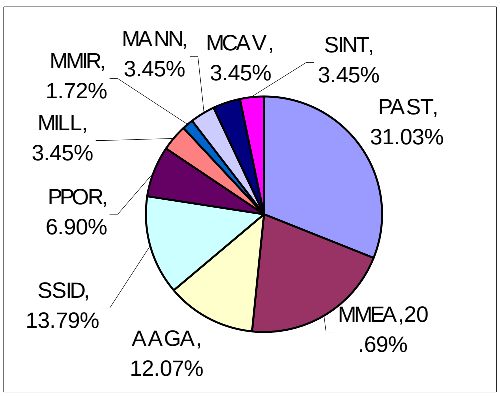

Fig. 9 Species composition at Berry's Dream (SCUBA).

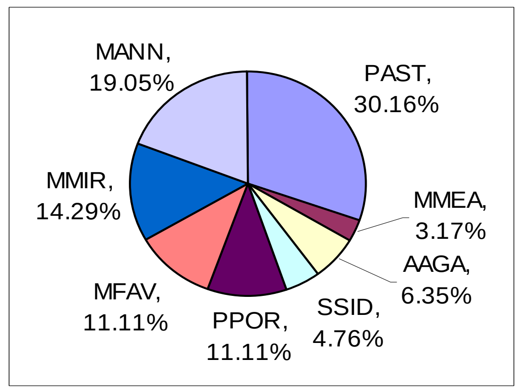

Fig. 11 Species composition at Cachacrou (SCUBA).

Table 3 Average number of colonies counted per 10 m at each site surveyed.

Site	Mean Colonies per 10 m
Salisbury West	11.75
Floral Gardens	10.00
Rena's Reef	17.00
Brain Reef	25.00
Berry's Dream	19.33
Champagne	17.67
Cachacrou	15.75
Average SCUBA Sites	16.64
Calibishie	5.00
Fond Colé	11.67
Rodney's Rock	12.67
Average snorkel Sites	9.78

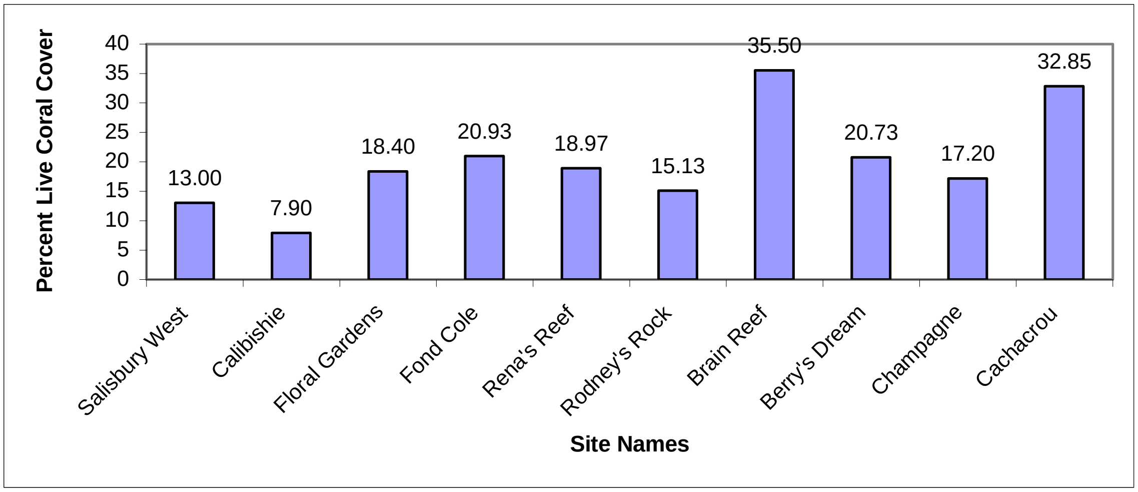

Fig. 12 Percent live coral cover of colonies under the transect line at each site surveyed.

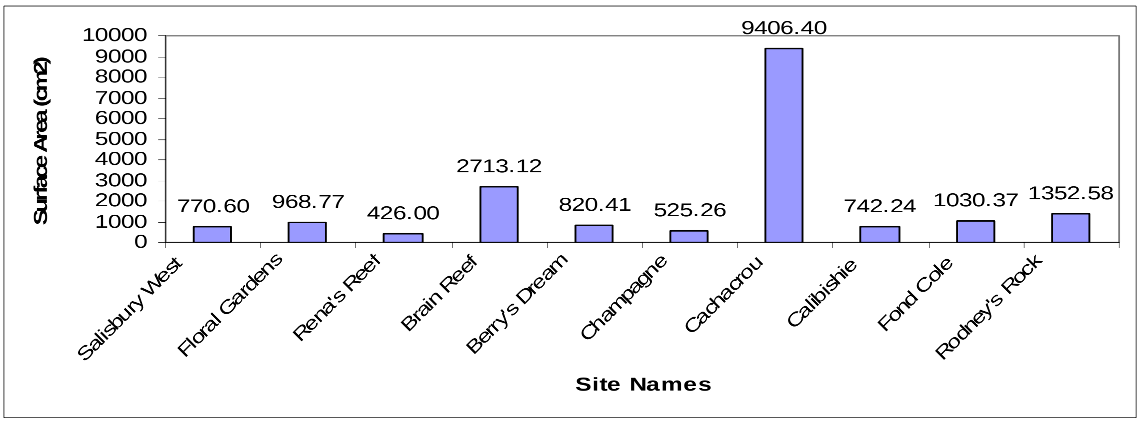

Fig. 13 Average surface area of coral colonies at each site surveyed.

Coral Mortality

Percent old mortality was the highest in *Montastraea cavernosa* with 62.52% old dead. M. *cavernosa* had no recent mortality, but was still the only species to show a higher percent dead than live tissue. *D. labyrinthiformis, I. sinuosa,* and *A. palmata* each had 0.00% mortality, but comprised a very small percent of the total colonies counted (0.22%, 0.44%, and 0.44% respectively). *Montastraea faveolata* exhibited the highest percentage of recent mortality (18.30%) and had only slightly more old mortality (21.79%) (Fig. 14).

Berry's Dream had the highest percentage of old mortality (40.00%), and Champagne had the highest recent mortality (1.86%). Combined mortality was the most widespread at Berry's Dream. Old mortality was more prevalent in all sites that exhibited both old and recent death. All sites exhibited more live than dead coral (Fig. 15).

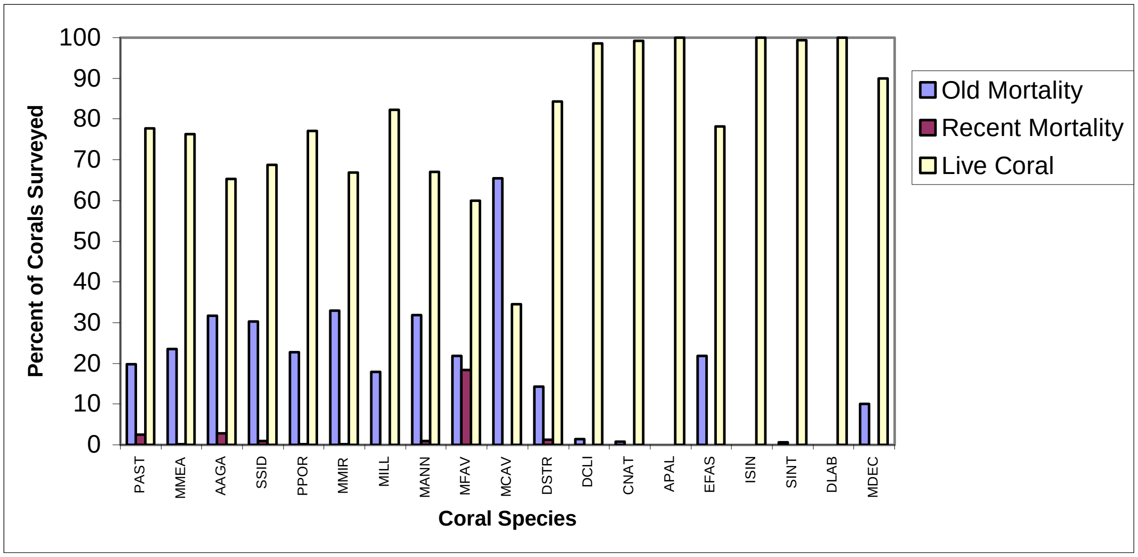

Fig. 14 Percent old mortality, recent mortality and live coral of colony surfaces in each species surveyed.

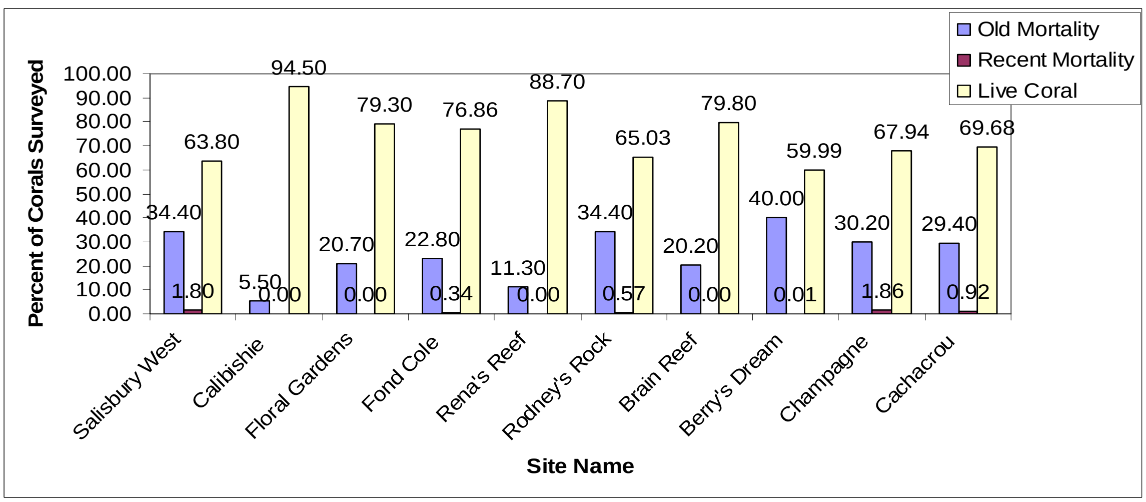

Fig. 15 Percent old mortality, recent mortality and live coral of colony surfaces at each site surveyed.

Coral Bleaching

Bleaching was seen in all species except *M. decactis* and *D. labyrinthiformis,* both of which had a sample size of only one colony. Every surveyed *M. faveolata, A. palmata, Stephanocoenia intersepta,* and *I. sinuosa* was affected by bleaching, although *M. faveolata* was the only one with a sample size greater than five. Both colonies of *A. palmata* recorded were partially bleached. On average, more colonies were pale than were unaffected, partially or completely bleached. *S. siderea, M. meandrites, Montastraea annularis*, *Madracis mirabilis,* and *S. intersepta* exhibited paleness and partial, but never complete, bleaching (Fig. 16).

Calibishie had the most (36.00%) corals unaffected by bleaching. Alternately, only 2.63% of corals surveyed at Rodney's Rock were unaffected. Overall, 82.90% of corals surveyed showed bleaching symptoms. Pale colonies were more abundant than partially bleached, bleached, or unaffected colonies over all sites (Fig. 17).

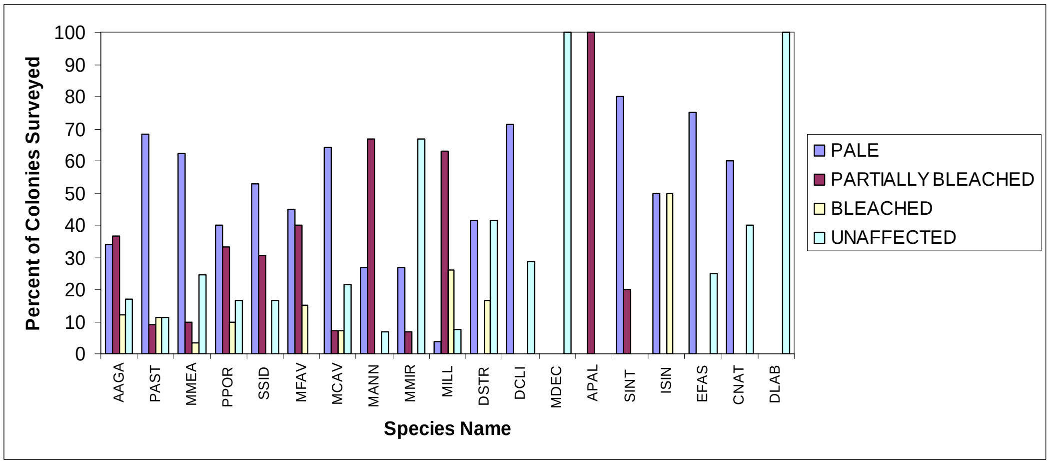

Fig.16 Percent pale, partially bleached, bleached, and unaffected of each surveyed coral species.

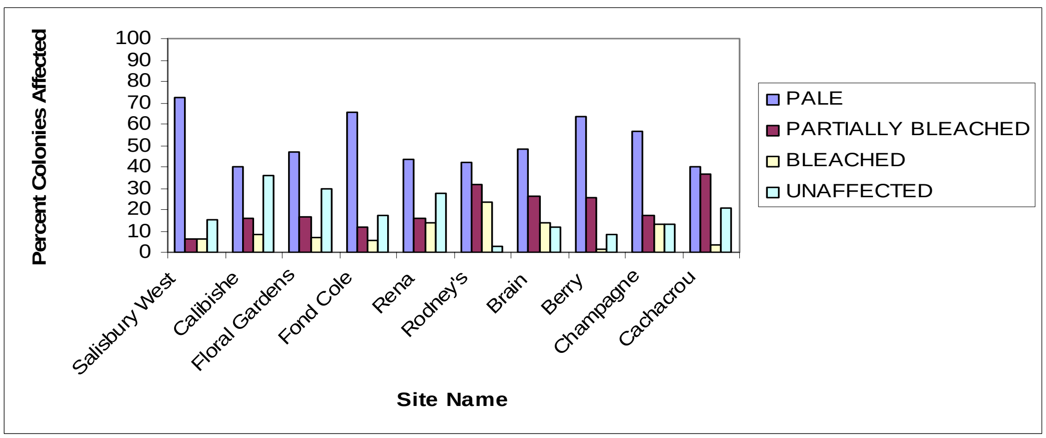

Fig. 17 Percent pale, partially bleached, bleached, and unaffected (by bleaching) of each site surveyed.

Disease

Black Band Disease was present in one colony of *S. siderea* at Berry's Dream, one colony of *A. agaricites* at Champagne, and one colony of *Diploria strigosa* at Salisbury West. *S. siderea* was recorded in two instances with Dark Spots Syndrome at Champagne. One case of White Plague was noted at Champagne in a colony of *M. faveolata*.

Discussion

The range of species richness between sites is explained by comparisons with reef habitats. Corals at Fond Colé, the site with lowest species richness, grew on isolated assemblages of rock in shallow water. Alternately, corals surveyed at Salisbury West were part of a deep fringing reef. Factors such as decreased wave action, higher levels of dissolved oxygen, or less space competition than is seen in reefs on patchy rock assemblages, make fringing reef condition more favorable for stony coral growth. Rena's Reef and Brain Reef, both having the second highest richness, were also part of fringing reef systems, supporting the above analysis. In the case of Salisbury West, the absence of nearby rivers causing terrestrial runoff may also contribute to the high richness. The low richness at Calibishie may be in part due to the increased wave action of the east coast limiting the larval settlement of many coral species. This natural selection is also documented in Knuth (2003).

The higher mean species richness at SCUBA sites can be explained in part by analyzing species composition. *Millepora* spp. composes more than 16.00% coral cover at each snorkel site, whereas it makes up no more than 9.80%, if even present, at SCUBA sites. *Millepora* spp. is a robust hydrocoral which grows well in shallow areas. Its presence at snorkel sites limits possible substrate available for other growth (Knuth 2003).

By comparing the species composition at each site, inferences can be made about characteristics of various species. The data, showing *P. astreoides* at every site, supports that the species is a generalist, able to adapt to a wide range of conditions. *A. palmata* was present on the east coast because of its known tolerance of increased wave action. The overall composition of reefs in Dominica, dominated by six species: *P. astreoides, M. meandrites, A. agaricites, S. siderea, P. porites* and *Millepora* spp.*,* indicates a trend within the coral community. It shows that reefs are mainly composed of smaller, nonhermatypic coral species. The widespread presence of patchy reef substrates insufficient in supporting large colonies, for example, boulder assemblages rather than true fringing reefs, support this analysis.

Species diversity mirrored species richness with the highest diversity being seen at Salisbury West and the lowest at Fond Colé. Species were distributed most evenly at Calibishie, a site which also exhibited relatively low species richness (6 species). Evenness may be due to the fact that transects at Calibishie were not placed on the reef crest. Rather, they were in a shallow fore-reef that most likely had lower nutrient content, decreased oxygen, and warmer water. These conditions, in addition to large areas of reef substrate created by *A. palmata* accretion, lead to little competition at Calibishie. With low interspecific competition between corals, certain species are less likely to become overwhelmingly dominant.

Generally higher live coral cover at SCUBA sites suggests that conditions are more favorable for scleractinian growth in deeper areas. This could be due to a variety of factors including nutrients present, water temperatures, substrate available, or suitable water turbulence at such sites. The intermediate live coral cover percentages are fairly even over both SCUBA and snorkel sites. The difference in depth zones, however, can be seen in diversity values. SCUBA areas with high diversity show live coral cover comprised of many species due to more favorable conditions and high interspecies competition. The intermediate live coral percentages from snorkel sites correspond to a lower average diversity and much of the live coral comprised of just a few species. The differences in diversity, although noticeable, are quite small. This can be attributed to the narrow shelf of Dominica homogenizing deep and shallow sites, making both equally susceptible to terrestrial disturbances, such as sedimentation, pollution, and freshwater input. Also, the space limitation across all sites on a narrow shelf creates similarities. Cachacrou had substantially the highest mean surface area of colonies (9406.40 cm^2 ±30383.050). The presence of many large framework builders (e.g. *M. annularis*, *M. faveolata*) and "weedy" corals that grow near the substrate, but span large areas (e.g. *P. porites*, *M. mirabilis*) contribute to this high average. These huge colonies, with substantially smaller colonies interspersed among them give rise to the very large standard of deviations for mean surface area. Lower surface area values, ranging between 426.00 cm^2 at Rena's Reef and 1352.58 cm^2 at Rodney's Rock, again show that reefs of Dominica are predominately comprised of small species, such as *P. astreoides* and *M. meandrites.*

Much more old mortality was recorded than recent mortality. This is consistent with the fact that dead tissue is only present as recent mortality for a short time before it is colonized by sponges or algae. The absence of recent death shows that no mass mortalities had recently affected or were affecting the reefs of Dominica up to the end point of the study. It also shows that although bleaching was very widespread, fatality due to the season's bleaching had not currently occurred. *M. cavernosa* was the only species to show a higher percent of dead coral than live coral. As an important framework builder, this high occurrence of dead *M. cavernosa* could be detrimental to reef communities. With few live framework builders, fewer recruits of those species will be started, hence reefs in the future may lack the substrate that framework builders provide. A simultaneous study surveying the same sites for algae, recruits and *Diadema antillarum,* reports no *M. cavernosa* recruits (McNeal 2005). In fact, there was an overall paucity in constructional hermatypic recruits, with only *S. siderea* reported (4.90% of recruits seen) (McNeal 2005). The fact that recent death and old death percentages in *M. faveolata* were nearly even indicates that this species may not be tolerating stress as well as other species. This highlights the need for conservation of sites inhabited by healthy colonies.

Bleaching was extremely widespread over all sites, possibly due to the time of year that this study was done: directly following the warmest months, and within the rainy season. The seasonal effects caused increased water temperatures and high levels of sedimentation on the reef, both of which contribute to bleaching. Every sampled colony of *M. faveolata, A. palmata, S. intersepta,* and *I. sinuosa* exhibited bleaching. It is hard to make assumptions due to the low sample size of the latter three, but this further supports the mortality data suggesting that *M. faveolata* has a low tolerance to stress. *S. siderea, M. meandrites, M. annularis*, *M. mirabilis,* and *S. intersepta* showed pale coloration and partial bleaching, but very little or no complete bleaching. This indicates that these species are better adapted to withstand high water temperatures and/or sedimentation levels. The presence of a completely bleached individual of any of the five species could be an indicator of poor reef health. The differences between species' bleaching symptoms agrees with studies done showing that different types of zooxanthellae respond differently to environmental conditions (Kinzie *et al.* 2001).

Calibishie (east coast) showed the highest percentage of corals unaffected by bleaching. This may be due to the shallow water having daily temperature fluctuations as a result of differing day and night air temperatures. The nightly cooling would limit coral exposure to temperatures in which bleaching occurs. The high percentage of corals affected by bleaching at Rodney's Rock fits with the assumption that bleaching would be more prevalent in shallow sites due to high water surface temperatures. However, Brain Reef, Berry's Dream, and Champagne also showed high percentages of affected corals. This may be due to the prolonged presence of warm water in some deep sites that do not benefit from the cooling effects of rain, river input, or cooler air temperature at night. In addition to this data, observations were made that even in very close proximity to one another, corals of the same colony showed very different degrees bleaching. This supports Buddemeier (2003) in that some zooxanthellae may react differently within the same species, and that corals of the same species may host different symbiotic algae.

Data shows that diseases are indeed a present threat to corals of Dominica. All disease seen occurred at SCUBA sites, which were generally farther from shore than snorkel sites. This perhaps indicates that diseases arrive in Dominica from the open ocean, initially affecting corals nearest the edge of the shelf. Two cases of Dark Spot Syndrome (DSS) were seen, both on colonies of *S. siderea.* This agrees with Borger (2005), who states that it was the only species in Dominica to exhibit DSS lesions. Low numbers of DSS recorded in this study, in comparison to that of Borger, support the theory that DSS is a general stress response rather than a coral disease. Personal observations of the diseases Yellow Blotch and White Band show that the diseases are rare, but present in Dominica. A lack of experience in distinguishing disease from other coral problems may account for a lack of disease data.

The paucity of constructional species and low coral cover percentages highlight the need for conservation of coral reef habitats. Future monitoring of reef diversity and species composition is necessary for keeping the reefs in their current condition. The extent to which bleaching and disease are present over reefs in Dominica is reason for concern. As human development continually adds to stresses on reefs, corals will become less able to recover and persist. Measures must be taken to ensure that widespread bleaching and disease symptoms do not lead to widespread mortality in the future.

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References

Borger JL (2005) Dark Spot Syndrome: a scleractinian coral disease or a general stress response? Coral Reefs 24 (1): 139-144

Borger JL, Steiner SCC (2005) The Spatial and Temporal Dynamics of Coral Diseases in Dominica, West Indies. Bull Mar Sci 77(1):137-154

Buddemeier RW 2003 Coral Bleaching as an Adaptive Mechanism. Bioscience 43(5):320-327

Byrd K (2005) Study V: A Rapid Assessment of the Stony Corals and Algae in Dominica, Lesser Antilles. ITME Reports 23 (I-VII):53-63

Fitt WK, Warner ME (1995) Bleaching Patterns of Four Species of Caribbean free Corals. Biological Bulletin 189:298-307

Green D (2002) Dominica Coral Reef Status: An Assessment of the Abundance and Species Composition of Dominican Reef Fishes. ITME Research Reports 13(1)

Honychurch L (1995) The Dominica Story: A History of the Island. Macmillan Education Ltd: London and Oxford

Humann P, Deloach N (2002) Coral Reef Identification: Florida, Caribbean, Bahamas. New World Publications, Inc.: Jacksonville, Fl, USA

Ishikawa M, Kerr J, Alfsnes C (2004) Preliminary Surveys of Northern Reefs of Dominica, West Indies. ITME Research Reports 21(1-3)

Kinzie RA, Takayama M, Santos SC, Coffroth MA (2001) The Adaptive Bleaching Hypothesis: Experimental Tests of Critical Assumptions. Biological Bulletin 200: 51-58.

Knuth K, McDonald K (2003) ITME Research Reports 19(1-2)

Kramer P, Lang J, Marks K, Garaza-Perez R, Ginsburg R (2005) AGRRA Methodology v. 4.0, June 2005

Lang J (2003) Status of Coral Reefs in the Western Atlantic. Atoll Res Bull 496

McNeal J (2005) Study IV: Atlantic and Gulf Rapid Reef Assessment of *Diadema antillarum*, coral recruits and algal cover on Dominican reefs. ITME Research Reports 23 (I-VII):43-52

Pielou, EC (1966) The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13: 131-144

Shannon, CE and Wiener W (1948) The mathematical theory of communication. University of Illinois Press: Urbana, Illinois: 117

Smith Q, McKinney J, Komoroske L, Pettersen L (2002) Dominica Coral Reef Status 2002: Assessment of the Sea Urchin *Diadema antillarum,* Reef Fishes, and Algal Cover. ITME Research Reports 12(1-4)

Steiner SCC (2003a) Development and its Effects on Dominica's Stony Corals. In: Koudman Issues in Development: The Environment and National Development 10(1): 26-27

Steiner SCC (2003b) Stony Corals and Reefs of Dominca, Lesser Antilles. Atoll Res Bull 498

Willette DAS (2001) Algal Cover versus grazing Fish Abundance of Shallow and Mid-Depth Coral Reefs of Dominica, West Indies. ITME Research Reports Fall Semester 2001:19-25

Williams S, Mohan E, Willette D, Lestrade N (2001) Dominica Coral Reef Status 2001: Assessment of the Sea Urchin *Diadema antillarum*, Reef Fishes, Algae, and Sponges. ITME Research Reports 9(1-4)

Yap HT (2000) The Case for Restoration of Tropical Coastal Ecosystems. Ocean and Coastal Management 43:841-85

Study III: Rapid Benthic Assessment of Reefs of Dominica, West Indies

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Abstract In Fall 2005, the Atlantic and Gulf Rapid Reef Assessment (AGRRA) survey was performed on the small volcanic island of Dominica, West Indies. Scleractinians <10 cm, scleractinian recruits, *Diadema antillarum, Strombus gigas* and *Panulirus argus,* algae, sessile invertebrates, and substrate composition were included in the study. Deep and shallow sites were surveyed on the west coast, and one shallow site on the east coast. Twelve species of scleractinian colonies <10 cm were identified, and constituted 6.9% of total benthic cover. Scleractinian recruitment was dominated by *Agaricia agaricites* and *Porites porites. D. antillarum* were observed at every site on the west coast, with a density of $1.0 \cdot m^{-2}$. Algal cover was dominated by filamentous algae and low growing *Dictyota* spp. This study can be used as a baseline for future surveys of reef status in Dominica.

Keywords Dominica, *Diadema antillarum,* coral recruitment, Scleractinian density

Introduction

The Atlantic and Gulf Rapid Reef Assessment (AGRRA) methodology is designed to observe and assess the present condition of Caribbean coral reefs using a standardized protocol. Collection and submission of data from numerous islands can be easily cataloged and referenced with other surveyed reef systems. This will provide for a larger picture of the current health of the Caribbean reef system than currently exists (Lang 2003).

The volcanic island of Dominica consists of 750 km^2 in the Windward Isles of the West Indies between Martinique and Guadeloupe. It is bordered on the windward east coast by the Atlantic Ocean. The west coast borders the Caribbean Sea, and is an important resource to both fisheries and recreational diving industries. Dominica's highest peak is 4,747 ft, and the island still boasts 60% coverage by undisturbed tropical vegetation (National Development Corp 2005). Eco-tourism is among Dominica's developing sources of revenue, with much of the emphasis on hiking and natural attractions within the mountainous terrain. An increasing interest in snorkeling and diving is taking place on the reefs of the calm west coast, where marine reserves have been established. These are the Scott's Head Marine Reserve, created in 2000 at the southernmost point, at the Cabrits National Park in the northwest corner of the island, created in 1986. The island's narrow shelf includes roughly 150 km^2 above 50 meters depth, much less than wide shelves of calcium carbonate islands such as the Turks and Caicos Islands (Steiner pers. com. 2005, Diamond 2003). Within this area, sediment and freshwater input limits coral settlement. Narrow shelf area offers little protection for reef accretion by hermatypic scleractinians. Reef accretion is limited to west coast sites sheltered by coves (Scott's Head), or depth (Grand Savane), and northeast fringing reefs. (Steiner 2003).

The east coast reefs are constructed of old dead *Acropora palmata* complexes. Corals are also found on rocky substrates throughout the island. Two thirds of Dominica's 65,000 live along the coasts, increasing stresses on the reef. Anthropogenic factors affecting the reefs include residential development, increasing sediment and waste input, and over harvesting of economically important fishes, which have naturally low populations on Dominica (Diamond 2003).

The AGRRA survey was implemented for the first time in Dominica in order to define the current benthic coral reef communities along the west and northeast coast. This included coral recruitment, as successful recruitment by hermatypic corals is especially important as large colonies have little protection from disturbances on the narrow shelf. AGGRA includes a quantification of *Diadema antillarum*, an important bioeroder that suffered a severe Caribbean wide die off in the 1980's due to disease (Miller *et al.* 2003). Little is known about the effects of this disease in Dominica, as no surveying was done on *D. antillarum* in Dominica during the die off, or in years immediately following. Recent studies done within the last five years have found the population of *D. antillarum* on the island have found densities higher than reported elsewhere in the Caribbean system (Williams 2001). The distribution and density of the herbivore *D. antillarum* directly impacts the spatial substrate availability for coral recruits by limiting macrophytic algae growth, which will out-compete recruits for substrate.

Methods

Field research was completed over 4 weeks in late autumn. Surveying was done according to the protocol set forth in AGRRA Methodology v. 4.0. (Kramer *et al.*). This involved performing 10 m benthic transects, each including five 25x25 quadrats, at 9 sites along the west coast, and one on the northeast coast. SCUBA was used at sites between 5 and 10 m, and snorkeling at sites above 5 m. Descriptions of each SCUBA site location can be found in McNeal (2005), and snorkel site locations in Byrd (2005). In order to be time efficient, two researchers carried out each survey designated as either diver A or B and each was responsible for several aspects of the benthic survey. This report focuses on the aspects of AGRRA performed by diver "B". The protocol was amended to include the following alterations.

The duties of the benthic diver B included the Line Intercept Information portion of the survey, which records the linear coverage directly under the transect line. This included the linear cover of corals less than 10cm in diameter, calcareous and fleshy algae, crustose coralline algae, and sand. An "Other" category included sponges, soft corals and other sessile invertabrates. Coral recruits were considered all individuals less than 2 cm. Reefs of Dominica are patchy in size and distribution, so sites with rock and pavement (limestone) substrates were included, as they would otherwise be excluded by AGRRA as areas that "lack a framework constructed of reef building corals"(Kramer *et al*). "Rock" was also included as a substrate category in the Quadrat section, which also included recruitment identification, maximum relief, and a measurement algal height for both fleshy and calcareous algae. The survey sites were chosen strategically based on local knowledge to represent reef communities of Dominica, and transects were laid at each site in areas which best characterized the reef. Care was taken to avoid reef edges, however this could not be avoided at some sites, which had limited suitable survey area. Gorgonian coverage was considered as the measurement of the base. All *D. antillarum* individuals with any part of the body (test), not including the spines within the belt transect were counted. *D. antillarum* were classified as adults or juvenile based on size. Prostrate growth of macro algae was considered turf, thus not included in the survey. All benthic organisms will be identified in *situ* according to Humann (2005). The Pearson's product moment correlation test of *D. antillarum* and algae (excluding Calibishie), and algae and coral recruitment, were done using Sigmastat.

Results

A total of thirty three 10m transects and one hundred sixty five 25x25cm quadrats were done at 10 sites on the island

Algae

Algal growth was dominated by filamentous turf with prostrate *Dictyota* spp. at all sites, with a few patches of *Lobophora variegata* at Champagne. Champagne and Cachacrou, both near shore sites which were surveyed near the reef crest, consistently had the highest density of all algae classes. Fleshy macroalgae were most abundant at Cachacrou, where it dominated the substrate with 37.2% (± 21.4 StDev) coverage (Fig. 1). No measurable fleshy macro algae were observed at Calibishie, Fond Colé, or Rodney's Rock. Coverage at Brain, Berry's Dream, and Champagne were similar, between 4.6% and 6.3%. The tallest average fleshy algal height recorded was 5.7 cm (± 2.8), and found at Cachacrou. Floral Gardens and Rena's Reef were the only other sites to have algal heights above 3cm (Table 1).

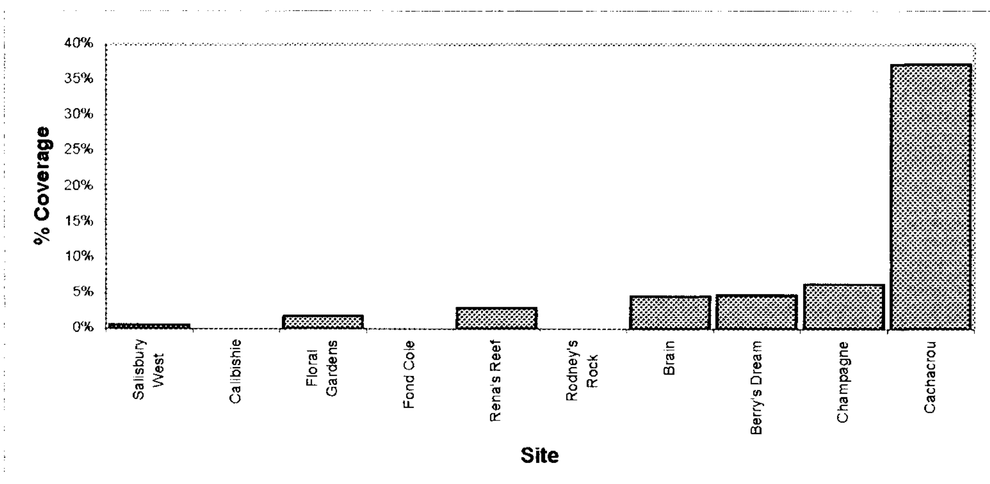

Fig. 1 Fleshy Macro Algae Density (Salisbury West, 0.5%; Calibishie, 0%; Floral Gardens, 1.8%; Fond Colé, 0%; Rena's Reef, 2.9%; Rodney's Rock, 0%; Brain, 4.6%; Berry's Dream, 4.8%; Champagne, 6.3%; Cachacrou, 37.2%)

Table 1 Abundance of Sand and other*(includes sponges, gorgonians, soft corals, and *Psuedopterogorgia)*, Fleshy Macro Algal Height, Recruit Density, and Relief.

Site	Surveyed Area (m^2)	Relative Abundance (%) Other*	Sand	Fleshy Macro Algae Height (cm)	Recruit Density (#/.0625m^2)	Relief (cm)
Salisbury West	20	4.4±3.9	4.2±3.8	0.8±0	0.3±0.1	18.8±1.8
Calibishie	50	22.3±13.7	-	-	0.4±0.1	34.7±4.9
Floral Gardens	30	6.8±4.4	28.3±21.8	3.4±0.5	0.5±0.2	53.5±27.5
Fond Cole	30	5.9±1.9	1.1±1.9	-	0.4±0.1	29.2±2.9
Rena's Reef	30	17.4±5.0	-	3.0±0.1	0.6±0.3	27.2±5.3
Rodney's Rock	40	9.9±7.7	-	-	0.7±0.4	147.5±49.5
Brain	30	9.5±4.5	-	2.±0	0.3±0.1	58.6±12.1
Berry's Dream	30	5.2±1.1	4.3±4.0	1.9±0.2	0.6±0.3	53.8±11.9
Champagne	30	14.2±6.6	-	1.6±0.3	0.2±0.2	39.3±9.7
Cachacrou	30	0.3±0.5	11.8±9.7	5.5±2.8	0.1±0.1	78.1±31.2

Calcareous macro algae was limited to four sites, and composed exclusively of *Halimeda* spp. and *Galaxaura* spp. It was most abundant at Cachacrou (mean 4.5%(±4.7) cover). Champagne and Berry's Dream had 0.5% (± 1.5) and 0.7% (± 1.2) respectively. Calibishie had the lowest density of calcareous algae with 0.3% (± 0.3). No calcareous algae lay within any quadrats, so no height measurements were taken.

Porolithon spp. was the only crustose coralline algae identified, and was seen at all sites with the exception of Calibishie. It was most abundant at Champagne, composing a mean of 23.8% of the transect (±13.9) (Fig. 2). Cachacrou and Berry's Dream had 18.6% (±19.6) and 17.6% (±3.2) *Porolithon* spp. respectively, and Rena's Reef had 14.4%(± 14.1) cover. Salisbury West, Floral Gardens, Fond Colé, and Brain all had coverage below 5%.

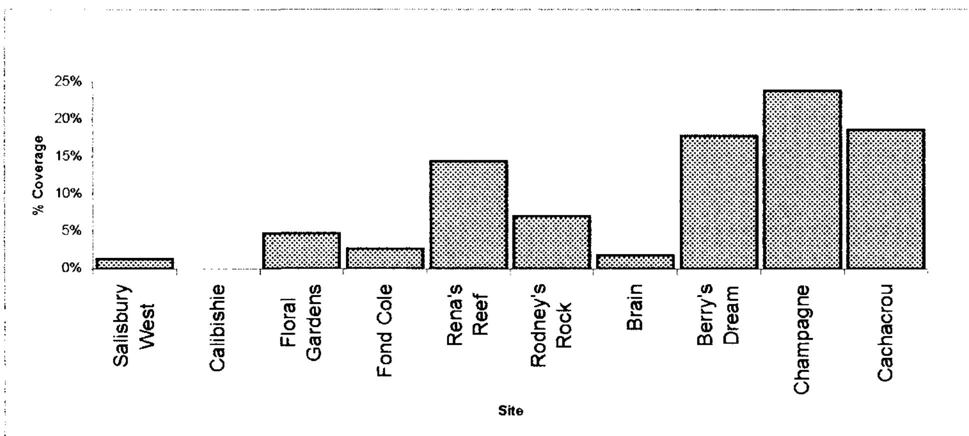

Fig. 2 Crustose Coralline Algae Diversity (Salisbury west, 1.3%; Calibishie, 0%; Floral Gardens, 4.67%; Fond Colé, 2.7%; Rena's Reef, 14.4%; Rodney's Rock, 7.0%; Brain, 1.8%; Berry's Dream, 17.8%; Champagne, 23.8%; Cachacrou, 18.6%)

Diadema antillarum

D. antillarum were abundant at all sites, with the exception of Calibishie on the east coast, where no individuals were observed (Fig. 3). In total, 327 individuals were counted, including 20 juveniles with an overall density of 1.0/m^{2}. Overall density including adults and juveniles were highest at Berry's Dream and Fond Colé (2.7·m^{-2}, 2.6·m^{-2})(Fig. 3). The lowest density recorded was 0.3·m^{-2} at Cachacrou. No *D. antillarum* were recorded at Calibishe, although *Echinometra* spp. was present. No significant relationship was found between *D. antillarum* density and fleshy algal coverage ($r = -0.33$, $P>0.05$). Berry's Dream also had the highest density of juvenile *D. antillarum* with 0.2·m^{-2}, followed by Fond Colé and Rodney's Rock, with 0.1·m^{-2} at each. The mean density of *D. antillarum* at sites below 5m was .987·m^{-2} (±0.867). Data collection done concurrently at 8 near-shore sites above 5m observed a mean *D. antillarum* density of 1.60·m^{-2}. No juveniles were observed at Rena's Reef, Cachacrou, or Calibishie. No significant relationship was found between juvenile and adult densities ($r=0.37$, $P>0.05$).

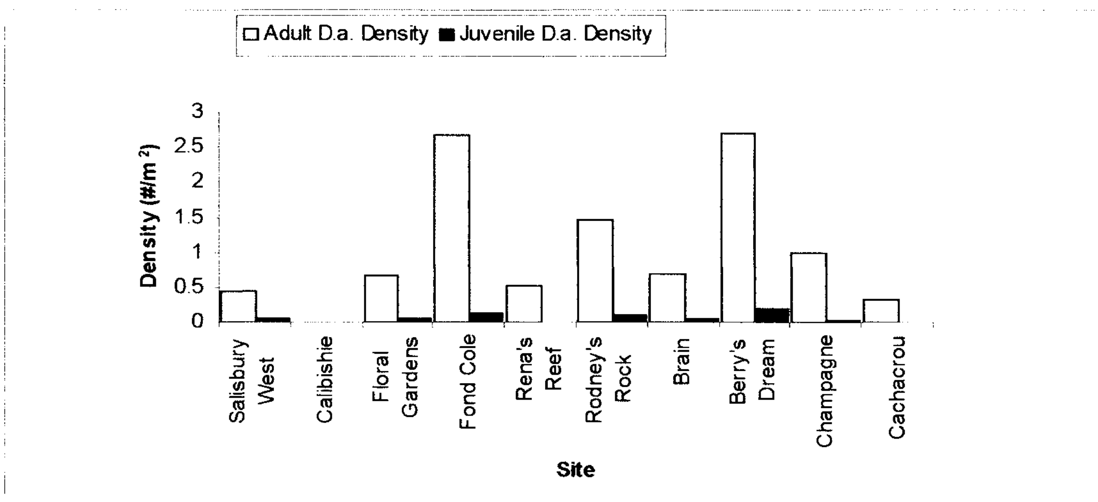

Fig. 3 Density of *D. antillarum* adult and juveniles

Colonies <10cm

Four hundred eigth scleractinian colonies smaller than 10 cm were counted, totaling 21.5 m of linear cover. Rodney's Rock had both the highest percent coverage by colonies <10 cm with 11.2% (±1.3), and the highest density of colonies <10 cm with a mean of 1.8·m within the 10 m linear transect (Fig. 4, Fig. 5). Results were similar at Berry's Dream, which had 9.7% coverage (±2.7), and mean colony density of 1.8·m. Six of the ten sites had colony densities between 1.0·m and 1.5·m. Calibishie and Cachacrou had the lowest coral cover and densities with 3.4%(±1.2) and 0.64·m at Calibishie, and 2.4% (±1.2) cover and 0.5·m at Cachacrou.

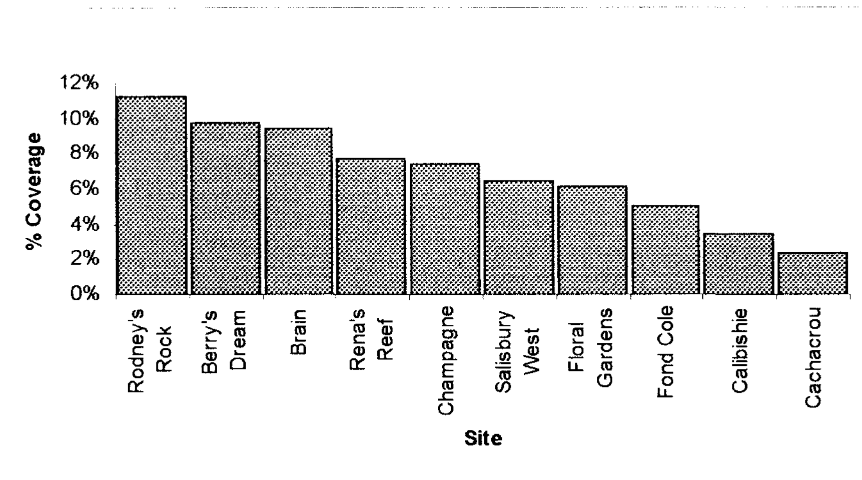

Fig. 4 Scleractinian coverage by colonies <10 cm

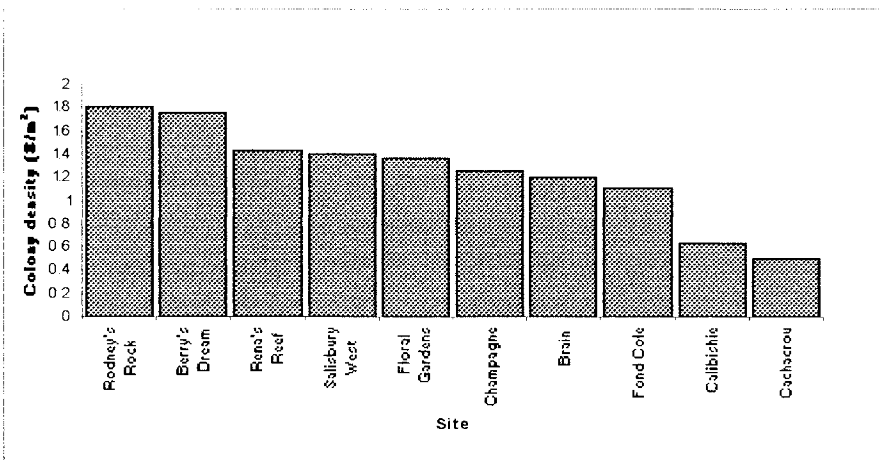

Fig. 5 Density of scleractinian colonies <10 cm

In total, 12 scleractinian species were identified. Species richness was relatively uniform at all sites, and dominated by "weedy" species such as *Agaricia agaricites* and *Porites astreoides* (Fig. 6). Colonies of *Meandrina meandrites, Siderastrea siderea*, and *Porites porites* were observed at 8 sites. Colonies of *Madracis decactis, Siderastrea radians*, and *Madracis mirablis* were recorded at 7, 5, and 4 sites respectively. *Dichocoenia stokesii* was only recorded at one site. The hermatypic species *Montastraea faveolata, Montastraea cavernosa*, and *Montastraea annularis* were observed at 6 sites, although no more than two species occurred at any one site. Salisbury West had the highest richness with 10 species, Brain Reef and Champagne had a total of 8 species each. Rodney's Rock and Fond Colé, the two shallow west coast sites, had the lowest species richness. The mean richness for all surveyed reefs was 7.2 (±1.4). Calibishie, the only other shallow site also had low species richness.

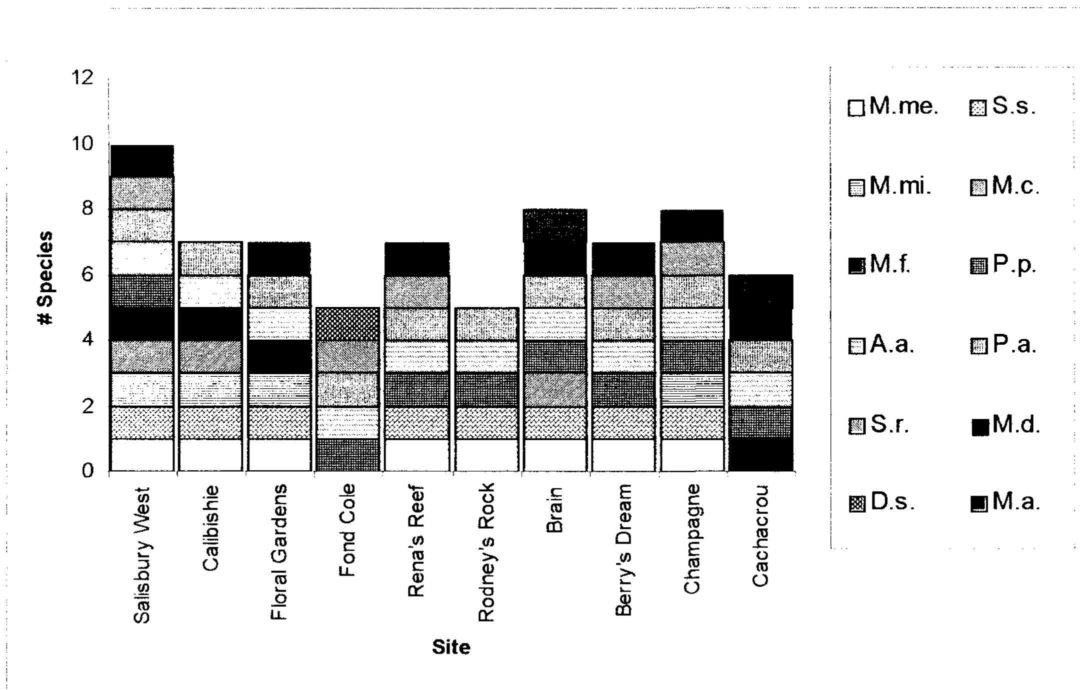

Fig. 6 Scleractinian colonies <10 cm Species richness at each site (M.me.=*Meandrina meandrites*; M.mi.=*Madracis mirabilis*; M.f.= *Montastraea faveolata;* A.a.= *Agaracia agaricites*; S.r.=*Siderastrea radians*; D.s.=*Dichocoenia stokessi*; S.s.=*Siderastrea siderea*; M.c.= *Monastraea cavernosa*; P.p.= *Porites porites*; P.a.= *Porites astreoides*; M.d.=*Madracis decactis*; M.a.= *Montastraea annularis;* uk=unknown)

Recruitment

One hundred thirty five recruits and ten species were counted. *A. agaracites* and *P. astreoides* constituted 71% of all recruitment (Fig. 7) This reflects the established scleractinian community. Only five recruits of the hermatypic genus *Montastraea* were observed, three of which were found at Salisbury West. Rodney's Rock was highest in both recruit density ($0.7 \cdot .0625m^{-2}$) (± 0.4), and recruit species richness with 6 (Fig. 7). Rena's Reef and Berry's Dream each had recruit densities of $0.6 \cdot .0625m^{-2}$ and recruit species richness of 4 and 5 respectively. Cachacrou had the lowest of both measures, with a density of $0.1 \cdot .0625m^{-2}$ (±0.1) and richness of two.

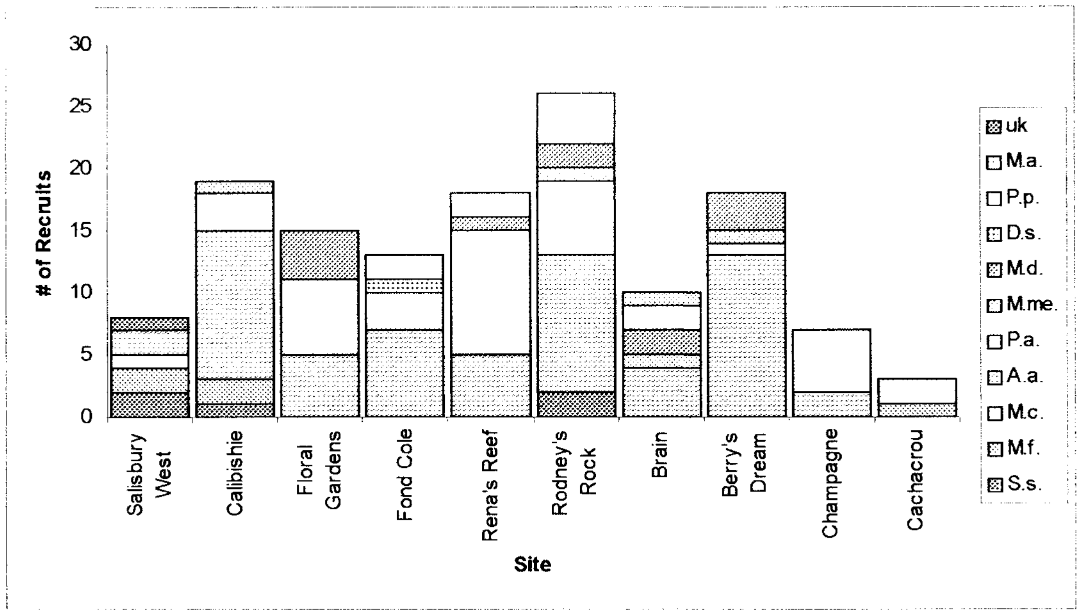

Fig. 7 Scleractinian recruits and species richness (see fig. 6 for key)

Relief and Sand

The highest relief of 147.5 cm (± 49.5) was recorded at Rodney's Rock, a near shore boulder field (Table 1). The relief at Cachacrou, Floral Gardens, Rena's Reef, and Brain was dominated by large scleractinian bioherms. Berry's Dream was characterized by a series overhangs and crevices.

Sand coverage at Floral Gardens was almost triple that of any other site (Table 1). Cachacrou was the second highest with 11.8% (± 9.7), which was more than double that of Berry's Dream, Fond Colé, and Salisbury West. The reefs at Calibishie, Rena's Reef, Rodney's Rock, Brain, and Champagne had no sand. Although sand cover limits the availability of substrate for algae, recruits, and *D. antillarum*, no relationship was seen between sites.

Other

Gorgonia sp., *Callyspongia vaginalis, Pseudoptergorogia* sp., *Xestospongia muta, Ircinia strobilina* and *Palythoa caribaeorum*, were all common within the 10 sites. Other encrusting sponges were measured, but not identified. *Pseudoptergorgia sp. and X. muta* were abundant at the deep sites in the Grand Savane area comprising 9.5% (± 5.7) of the total cover (Table 1). Only 0.3% (± 0.5) coverage was observed at Cachacrou. *Gorgonia* spp., small tube sponges, and encrusting sponges occurred more often in the shallow sites.

Two adult *Panulirus agrus* were found on the reef at Floral Gardens, but were not included as they were found outside the transects. No *Strombus gigas* were observed at any site.

Discussion

Calibishie was the only site on the northeast coast that could be surveyed in the time allotted. However, it is thought to be generally representative of the shallow reefs of the northeast coast, although much of the coast remains unstudied. High wave action and water turbulence may have a role in the lack of *D. antillarum* and macro algae, as well as the low coral recruitment. The lack of macrophytic algae could also be contributed to the large population of *Echinometra* spp., another herbivore, which was observed on the reef crest.

On the west coast, filamentous turf algae was common at all sites. *Dictyota* spp., a prominent macrophytic fleshy algae in Dominica, was often found within the turf complex in a low lying prostrate growth form. However, it was not included in algal cover, as turf is excluded from AGRRA surveys. The omission of *Dictyota* spp. in this form may have weakened the expected relationships between fleshy algal cover, *D. antillarum*, and coral recruitment. Previous studies in Dominica have found turf algae cover to be anywhere between 16.9% and 69.6% at sites on the west coast (McKinnley 2002). Although a significant correlation could not be made between algal cover and *D. antillarum* populations, it was apparent though personal observation at several sites that high *D. antillarum* seemed densities limit algal coverage. This was especially evident at Fond Colé, where *D. antillarum* densities where high, but no fleshy macro algae was observed, and at Cachacrou, where *D. antillarum* density was the lowest observed, and fleshy macro algae was the highest of all sites. Likewise, the correlation between algal cover and recruitment could not be significantly related. However, personal observations from each site agree support with the accepted ecological principle that profuse algae cover limits successful recruitment by dominating rock and coral substrate suitable for recruit settlement (Edmunds 2001).

D. antillarum was present at all sites on the west coast. Densities were consistently greater in shallow sites than deep sites sites. This observation was supported by the findings at other shallow sites surveyed by researchers during the same period. Fond Colé and Rodney's rock, two of the shallow sites, had the first and third highest densites of adults, and the two highest densities of juveniles observed. Shallow sites may serve as better feeding areas for *D. antillarum* in that sunlight, as well as nutrients from terrestrial runoff promote algal growth. The high density at Berry's Dream may be due to the rugged topography of the reef, including overhangs and crevices, which offer easily available shelter for *D. antillarum.*

The Grand Savane area had a large population of *Pseudoptergorgia* spp. and *X. muta*. These were the deepest sites surveyed, with a max depth of 17 m. The deeper environment is not susceptible to turbulent waters, which prohibit growth in shallow water. In addition, more nutrients may be available at deeper sites through upwelling along the narrow shelf. Calibishie and other shallow sites were characterized by *Gorgonia* spp. and encrusting sponges, which are physically adapted to the stronger currents and water movement, benefit from the constant supply of nutrients and particulate organic material.

Rodney's Rock, a shallow site, had the highest coral cover, density of both established and recruit corals, recruit species richness, and the third highest *D. antillarum* density. However, it had the lowest species richness for established colonies, suggesting that most colonization was limited to weedy species, which can tolerate the conditions of shallow sites. It is unclear why Rodney's Rock was so heavily colonized, although it was by far the most rugose site, which offers much more substrate, as well as protection from turbulence when attached between rocks. Rodney's Rock is generally considered a disturbed site due to sedimentation from recent land development (Steiner pers. com. 2005). Increased nitrification, especially farm runoff from the Belfast River, may cause occasional algal blooms, which may explain the high *D. antillarum* density (Williams 2001).

Species richness of stony corals was highest in deep sites near the shelf edge, where conditions are favorable, and reefs are generally larger and provide more substrate than narrow near shore shallow sites. Recruit richness was highest at Rodney's Rock and Calibishie. This was unexpected since species richness at these two sites was among the lowest recorded. It seems possible that larvae dispersed by other reefs or deeper areas of the same reef, may be settling these reefs, but cannot succeed in the conditions at reef crest.

The lack of *S. gigas* and *P. argus* in any transect was likely due to a number of factors. The narrow shelf system does not allow for a high population of either species as seen in calcium carbonate islands. The naturally low population is especially sensitive to disturbances. Over harvesting may have eliminated an appreciable amount of the reproductively mature individuals on the reef for both species.

The reefs on the narrow shelf of Dominica are constantly threatened by natural disturbances. Increasing anthropogenic threats, especially sedimentation and resource extraction, are increasing stresses on all members the reef community structure. The aspects of this AGRRA survey helped to produce a baseline understanding of the current status of the reefs in Dominica, as well as the Caribbean system, which can be used to compare to future conditions.

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References

Byrd K (2005) Study V: A Rapid Assessment of the Stony Corals and Algae in Dominica, Lesser Antilles. ITME Reports 23 (I-VII):53-63

Diamond A (2003) Identification and Assessment of Scleractinians at Tarou Point, Dominica, West Indies. Coastal Management 31:409-421

Dominica Division of Tourism (2005) Dominica: Nature isle of the Caribbean. (Pamphlet) National Development Corporation, Dominica

Edmunds P, Carpenter R (2001) Recovery of *Diadema antillarum* reduces macroalgal cover and increases abundance of juvenile corals on a Caribbean reef. PNAS 99: 5067-5071

Humann P, Deloach N (2002). Reef coral identification, Florida, Caribbean, Bahamas, 3rd edtion. New World Publications, Inc. Jacksonville, Florida

Kramer P, Lang J, Marks K, Garza R, Ginsburg R (2005) AGRRA methodology v. 4.0: 9-10

Lang J (2003) Status of Coral Reefs in the Western Atlantic. Atoll Res Bull 496

McKinnley J (2002) Algal cover versus *Diadema antillarum* abundance along the west coast of Dominica, West Indies. ITME Student Research Reports 12(2): 10-14

McNeal J (2005) Study IV: Atlantic and Gulf Rapid Reef Assessment (AGRRA) of *Diadema antillarum*, coral recruits, and algal cover on Dominican reefs (Lesser Antilles). ITME Research Reports 23(I-VII):43-52

Steiner SCC (2003) Stony Corals and Reefs of Dominca, Lesser Antilles. Atoll Res Bull 498

Williams S (2001) Abundance and size distribution of *Diadema antillarum* along the west coast of Dominica, West Indies. ITME Student Research Reports 9(1):3-9

Study IV: Atlantic and Gulf Rapid Reef Assessment (AGRRA) of *Diadema antillarum*, coral recruits, and algal cover on Dominican Reefs (Lesser Antilles)

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Abstract The coral reefs surrounding Dominica have comprehensively and quantitatively been studied since 1999. These reefs are very important as a source of food and income through fishing and tourism. The status of *Diadema antillarum* densities, algal coverage, live coral cover <10cm, and abundance of coral recruits were assessed through the Atlantic and Gulf Rapid Reef Assessment protocol for the first time on Dominican reefs. Nine west coast sites and one east coast site were surveyed in depths ranging from 3-14m. On the west coast sites mean *D. antillarum* densities ranged from 0 - 3.7·m^{-2} and were negatively correlated to macroalgal cover while mean *D. antillarum* densities were positively correlated to coral recruit abundance. No significant correlations were found on the east coast. *Agaricia agaricites* and *Porites astreoides* were the most abundant coral recruit species.

Keywords Dominica, AGRRA, *Diadema antillarum,* Coral recruits

Introduction

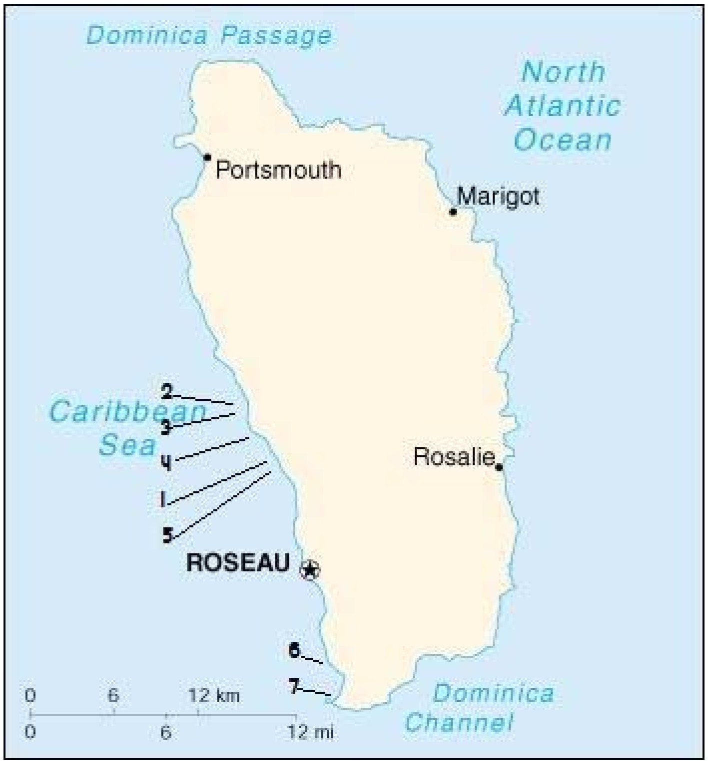
Dominica, located in the Windward Islands, is a volcanic island with a narrow shelf harboring little room for reefs to form (150 km^2). In this setting near shore reefs on Dominica's west coast have developed on boulders and rocks lining the island. In contrast, reefs built on carbonate frame works are also found on the west coast in the Grande Savane area (Fig. 1). The east coast reefs are built by *Acropora palmata* frameworks although there is a low cover today (Steiner 2003). Even though the reefs surrounding Dominica cover a small area, they are very important to the Dominican economy. The reefs support fishermen who fish them daily to supply the local demand of fresh fish. Green and red algae (sea moss) are harvested and used as agar in a locally made beverage. The growing tourist economy also includes SCUBA diving and snorkeling on the reefs of Dominica. Although the reefs have always been an important component to life on Dominica, quantitative research on them has only begun in 1999 (S Steiner pers. com.).

Previous studies conducted on Dominican reefs assess the coral community structure on the north and north east coasts (Steiner 2003) and the spatial and temporal dynamics of coral diseases (Borger and Steiner 2005). Relating studies are about organism diversity and percent cover of sessile organisms, composition of substrate, and abundance of *Diadema antillarum* (Lehman 2001), algal cover versus *D. antillarum* abundance along the west coast of Dominica (McKinney 2002), and *D. antillarum* and its grazing effect on algal richness and cover on coral habitats (Alfsnes 2004). This study continues Dominican coral reef research through the Atlantic and Gulf Rapid Reef Assessment, (AGRRA), protocol which is a standardized quantitative assessment of reef communities. This is to provide a database for comparative evaluation of current reef community structure and conditions (Lang and Ginsberg 2003). This study assesses the abundance of the echinoid *D. antillarum*, the crustacean *Panulirus argus*, the mollusc *Strombus gigas*, scleractinian recruits, and macroalgal cover. *D. antillarum* is a long-spined sea urchin and one of the most important animals in controlling macroalgae populations in coral aggregations (Szmant 2001). It does this by grazing on macroalgae which in turn opens substrate for coral recruits to settle on. Without *D. antillarum* and herbivorous fishes, coral reef communities would collapse due to the overgrowth of macroalgae. This study aims to asses the current relationship between *D. antillarum*, macroalgal cover, and coral recruitment.

By addressing these topics and implementing the AGRRA protocol for the first time, this study intends to encourage continued AGRRA research on Dominican reefs. Implementing the AGRRA protocol is a straightforward and time efficient way to generate a database of the benthic community structure of reefs. This database can be used by the Fisheries Division in Dominica to monitor the reefs health and watch for phase shifts on the reefs as human pressure on these resources increases. It can also serve as a reference point to assess future mass mortalities of keystone species such as the one that took place in 1983 affecting *D. antillarum* (Lessios *et al*. 1984).

Method and Materials

This study quantified coral recruits, macroalgal cover, and *D. antillarum* population by following the Atlantic and Gulf Rapid Reef Assessment protocol version 4.0 (Kramer *et al.,* 2005). The sites for this study were strategically chosen to best fit the AGRRA guidelines of sampling. Coral assemblages growing on rock (without significant carbonate accretion) were also included because they are representative reef resources in Dominica. Three shallow sites (<5m), Calibishie, Fond Colé, and Rodney's Rock, were surveyed using snorkel gear, see Byrd (2005) for site descriptions and map. Seven deep sites (>5m) located on the west coast (Fig. 1) were surveyed using SCUBA gear.



1. Salisbury West
2. Floral Gardens
3. Rena's Reef
4. Brain Reef
5. Berry's Dream
6. Champagne
7. Cachacrou

Fig. 1: Map of Dominica numbered with deep sites that were surveyed by SCUBA diving.

1. Salisbury West (15˚ N 26.315' 61˚ W 26.738') is located in the Grand Savane area north of the village of Salisbury. The area surveyed was approximately 300 meters SW of Grande Savane, and 120 m from shore. Water depth was 9 m. It is a deep fringing reef with mid-relief (mean 53cm) composed of pavement and rock substrates. *Pseudopterogorgia* spp. and *Xestospongia* spp. were abundant. Live scleractinian cover was approximately 10%.

2. Floral Gardens is located in the Grand Savane area, 1km south of the village of Batali on the west coast (15˚ N 26.89', 61˚ W 27.032'). The area surveyed was approximately 125 m from shore and in 14 m water. The site is a spur and groove formation with limestone substrate, and was of mid-relief (mean 46cm). The reef was characterized by *Xestospongia* spp. and several species of tube sponge. Live scleractinian cover was approximately 15%.

3. Rena's Reef (15˚ N 26.48', 61˚ W 27.211') is located in the Grand Savane area north of the village of Salisbury (approximately 200 m south of the Floral Gardens site). The area surveyed was approximately 300 m off shore with water depth of 9-14 m. It is an offshore fringing reef with a substrate of boulders and minimal coral accretion. The site was characterized by *Pseudopterogorgia* spp. and *Xestospongia* spp. and had mid-relief (mean 43cm). Live scleractinian cover was approximately 20%.

4. Brain Reef (15˚ N 26.292', 61˚ W 26.822') is located north of Salisbury. The study area was approximately 300 m from shore and 15.5 m deep. The reef is located on the fore reef slope portion of the Grand Savane reef with a limestone substrate. The site exhibited high relief (mean 77cm), and was dominated by corals over 10 cm. Live scleractinian cover was approximately 50%.

5. Berry's Dream (15˚ N 25.040', 61˚ W 26.008') is located offshore, about 250 m, from the village of Mero. The study area was in approximately 10.5 m of water. The reef substrate was composed of boulders and rocks cemented together (generally with *Porolithon* spp.). It is of high relief (mean 63cm) and exhibits uneven topography with large rocky ridges. The site was characterized by *Pseudopterogorgia* spp. and *Xestospongia* spp. Live scleractinian cover was approximately 15%.

6. Champagne (15˚ N 14.67', 61˚ W 22.42') is located 2 km south of Point Michele, on the southern end of the Champagne beach. The study area was in approximately 7.5-9 m of water. The reef was built on top of rock and had mid to high relief (mean 59cm). Live scleractinian cover was approximately 20%

7. Cachacrou (15˚ N 12.90' 61˚ W 22.30') is located off shore approximately 100 m north of the Scott's Head peninsula. The surveyed area was at the top of the fringing reef wall at a water depth of 6-7.5 m. It was dominated by large framework building corals and exhibited a high relief (mean 69 cm). Live scleractinian cover was approximately 50%.

Transect lines were placed parallel to shore and approximately at the same depth to avoid assessing different organism communities within one line. Two days were used for consistency training in which the use of line transects were practiced on land and in water to ensure that measurements and species identifications were accurate. All animal and algal identifications were based on Humann and Deloach (2002). During this training several modifications were made to the protocol. The protocol says a single surveyor is to swim over a 10m transect line three times to collect all benthic data. This was amended so that the transect work be split between two people. The task of measuring the benthic composition (sand, live coral cover <10cm, crustose coralline, macroalgal cover, calcareous algal cover and other sessile benthic animals) was taken from the second pass or swim and added as a separate fourth pass. As a clarification to the first pass in which the *D. antillarum*, *P. argus*, and *S. gigas* were counted; *D. antillarum* was only counted when all or part of the test was within an area of 50 cm of either side of the transect line. The alga, *Ventricaria ventricosa*, was included in algal measurements. Low lying (prostrate growth) *Dictyota* spp. were not assessed, but instead noted in the comments section.

A Pearson Product Moment Correlation was performed using the Sigma Stat program on mean *D. antillarum* densities in relation to total fleshy macroalgal cm and coral recruit abundance for each transect. Data from the east coast site of Calibishie was not included in the analysis of this correlation. Data of corals >10cm was taken from Zuercher (2005) for use in presenting the line intercept data for each site (Fig. 3).

Results

Within the surveyed habitats dead coral and rock were the most frequently observed substrates (Table 1). The highest mean relief, 77 (±13.37 StDev) cm at Brain Reef, and lowest mean relief, 43 (±20.32) cm at Rena's Reef, were both found on deep sites of 9-14m.

Table 1: Site features including mean macroalgal heights.

Site Name	Depth (m)	Reef Type/Substrate	Mean Max Relief cm	Mean Macroalgal Height (cm)	Mean Calcareous Algal Height (cm)
Salisbury West	7-9	deep fringing/pavement	53 (±19.82)	0.84 (±1.00)	0
Calibishie	3-4	fringing reef crest/pavement	52 (±26.56)	0	0
Floral Gardens	12-13	spur & groove/dead & live coral, coral rubble, sand	46 (±14.53)	2.08 (±1.67)	0
Fond Colé	3-4	consolidated pebbles/rock	53 (±47.84)	0	0
Rena's Reef	9-11.5	fringing reef/dead coral	43 (±20.32)	2.47 (±1.32)	0
Rodney's Rock	3-4.5	coral on rock/rock	47 (±23.05)	0.28 (±0.39)	0.15 (±0.33)
Brain Reef	13-14	forereef slope/dead coral, sand	77 (±13.37)	2.33 (±1.35)	0.27 (±0.57)
Berry's Dream	11	coral on rock/ dead & live coral, rock	63 (±23.11)	0.70 (±0.56)	0.13 (±0.35)
Champagne	7.5-9	rock/rock, dead coral	59 (±33.21)	0.73 (±0.53)	0.13 (±0.35)
Cachacrou	6-7.5	fringing/rock, dead & live coral, coral rubble	69 (±45.31)	3.43 (±2.04)	0.23 (±0.49)

Three hundred and five *D. antillarum* were counted within 310 m^2 of 31 transects at 11 sites. Fond Colé had the highest mean *D. antillarum* density with $3.7 \cdot m^{-2}$ (Fig. 2). Calibishie (north east coast) had no *D. antillarum* (Fig. 2). On the west coast Champagne and Cachacrou had the lowest mean *D. antillarum* densities with $0.20 \cdot m^{-2}$ and $0.23 \cdot m^{-2}$ (Fig. 2). No *P. argus* or *S. gigas* were seen on the transects.

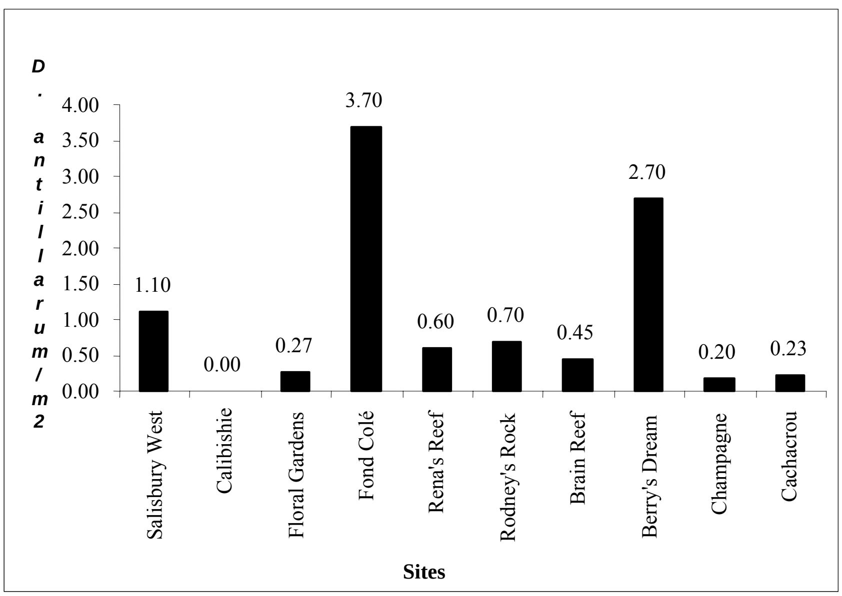


Fig. 2: Mean *D.antillarum* densities for each site surveyed.

Although not quantified, prostrate algae and turf algae were more common than fleshy and calcareous macroalgae. *Dictyota* spp. and *Galaxaura* spp. were the two most common macroalgae identified. *Lobophora varegiata*, *Caulerpa* spp., and *V. ventricosa* were also observed. Cachacrou had the highest mean fleshy macroalgal cover with 20.60% while Fond Colé had the lowest with no macroalgae (Fig. 3). Calcareous macroalgae cover was rare and only quantified on three sites (Fig.3). Both fleshy and calcareous macroalgae were relatively short (Table 1). The mean fleshy macroalgal height at Cachacrou was the tallest at all sites with 3.43 (±2.04) cm and Brain Reef had the tallest calcareous macroalgae height with 0.27 cm and a large variance of ±0.35. The only identified crustose coralline algal species was *Porolithon* spp. The three highest mean percents of crustose coralline algae seen were on reefs that were composed of rock (Table 1 and Fig. 3).

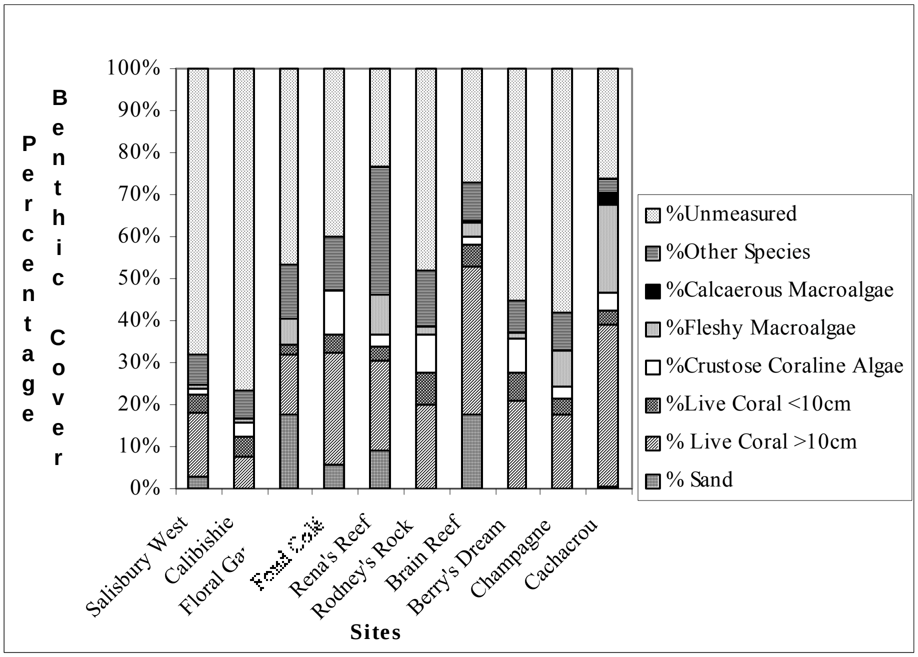


Fig. 3: Benthic composition for each site. Area measured at each site: Salisbury West (40 m), Calibishie (50 m), Floral Gardens (30 m), Fond Colé, Rena's Reef (30 m), Rodney's Rock (30 m), Brain Reef (20 m), Berry's Dream (30 m), Champagne (30 m), Cachacrou (30m). % Unmeasured represents turf algae and bare rock that were not quantified in this study.

A total of 1373 cm of live coral <10 cm was counted with the mean percent across all sites being 4.42%. Berry's Dream had the highest mean live coral cover <10cm with 6.37% and Rena's Reef had the lowest with 2.93% (Fig. 3). A total of 163 coral recruits among 11 species were counted. *Agaricia agaricites* was the most prevalent coral recruit (Fig. 4). The mean abundance of coral recruits at each site were 4 (±1.63) Salisbury West, Calibishie 4.4 (±1.81), Floral Gardens 3.6 (±1.52), Fond Colé 9 (±8.71), Rena's Reef 2.6 (±2.60), Rodney's Rock 7 (±3.60) Brain Reef 5 (±1.41) Champagne 4.33 (±4.04), and Cachacrou 0.

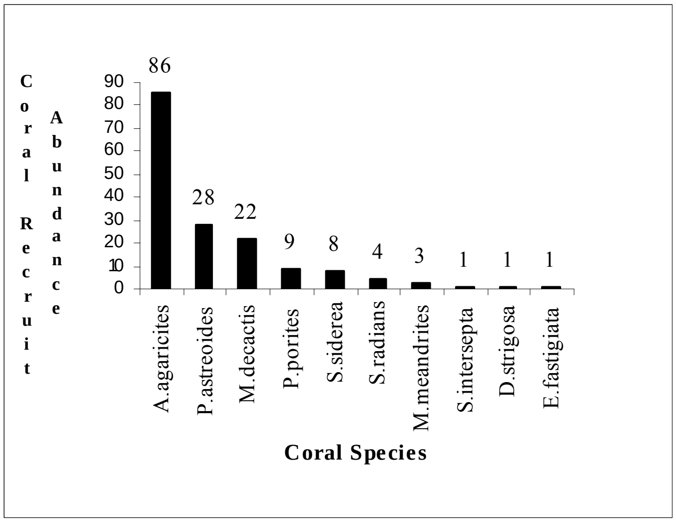


Fig. 4: Mean abundance of coral recruits.

Mean *D. antillarum* densities and fleshy macroalgal cm of the west coast transects were found to have a significant negative relationship (r = -0.45, p= 0.02, n=27) (Fig. 5). Mean *D. antillarum* densities and coral recruit abundance of the west coast transects were found to have a significant positive relationship (r = 0.73, p= 0, n=27) (Fig. 6).

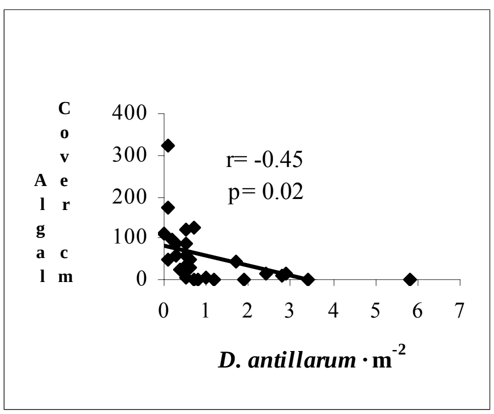


Fig. 5: Relationship between *D. antillarum* densities and total fleshy macroalgal cover of all west coast transects.

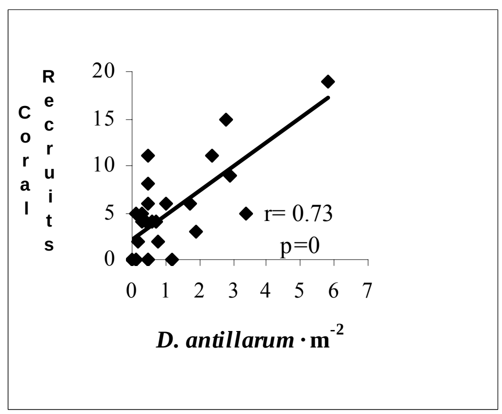


Fig. 6: Relationship between mean *D. antillarum* densities and coral recruit abundance of all west coast transects.

Discussion

The overall mean density found ($1.00 \cdot m^{-2}$) in this study is lower than the overall mean density recorded by Williams (2001) ($1.35 \cdot m^{-2}$). This is most likely due to the difference in location of areas that were surveyed. Calibishie, Rodney's Rock, and Cachacrou were surveyed in this study but were not included in Williams' (2001) study. Calibishie, where no *D. antillarum* were recorded, and Cachacrou, that had the third lowest recorded density ($0.23 \cdot m^{-2}$), were factors in causing this study to have a lower mean density than Williams' (2001) study. Despite the differences in overall mean densities Fond Colé was found to have the highest density in both this study ($3.70 \cdot m^{-2}$) and Williams' (2001) study ($1.93 \cdot m^{-2}$) showing that *D. antillarum* densities are increasing at this site.

Depth and relief were not found to be major factors of *D. antillarum* densities in this study. An increase in *D. antillarum* densities is generally seen with decreasing depth but Floral Gardens, Fond Colé, Champagne, and Cachacrou were the only sites to follow this trend. This trend was not seen at Salisbury West, Rena's Reef, Brain Reef, or Berry's Dream where increased depth showed an increase in *D. antillarum* density. Rodney's Rock did not follow this trend either but instead showed a decrease in density with a decrease in depth when compared to the other sites.

The west coast sites exhibited a significant negative relationship ($r = -0.45$, $p = 0.02$, $n=27$) between mean *D. antillarum* densities and total fleshy macroalgal cm. This means that as *D. antillarum* densities increase fleshy macroalgal cm should decrease, showing that *D. antillarum* is an important grazer in the reef community. A slight decrease in overall mean *D. antillarum* densities of all sites was noted when this study was compared to Williams' (2001). This is most likely due to this site having more deep sites and William's (2001) study having more shallow sites. If the density of *D. antillarum* continues to decrease Dominican reefs could become susceptible to a phase shift from reefs dominated by scleractinian species to ones dominated by macroalgal growth (Carpenter 1990). When coral reefs become overgrown with macroalgae the corals become covered and die, which in turn alters the entire community structure.

D. antillarum was not seen on the east coast site of Calibishie. The lack of *D. antillarum* at Calibishie may be due to the high wave action this reef receives. McIntyre (2005) found that *D. antillarum* only inhabited the leeward side of a seawall off the south coast of Barbados because the windward side received high wave action. Even though there were no *D. antillarum* reported for this site, a low amount of macroalgae was recorded (1.02%) and could possibly be explained by the observed presence of the grazing sea urchin, *Echinometra* sp.

Another way through which *D. antillarum* grazing is important to the reef community, is that it clears substrate for coral recruits to settle on (Edmunds and Carpenter 2001). This study found a significant positive relationship ($r = 0.73$, $p = 0$, $n=27$) between *D. antillarum* densities and coral recruit abundance for west coast sites. Where high mean densities of *D. antillarum* were reported, low total fleshy macroalgal cm and high abundances of coral recruits were observed. Edmunds and Carpenter (2001) found similar results and stated that an increase in density of sea urchins was associated with a decrease in macroalgal cover and an increase in the density of coral recruits. This may infer that *D. antillarum* aids in the proliferation of coral species in Dominica.

A. agaricites and *P. astreoides* were the two most abundant coral recruit species reported. The reefs surveyed exhibited a wide range of reef type and depth (3-14m) showing that *P. astreoides* and *A. agaricities* are easily adaptable to a variety of habitats. *P. astreoides* also had the highest overall abundance of corals >10 cm with 33.78% and *A. agaricites* had the third highest overall abundance with 9.11% (Zuercher 2005). Although *P.*

astreoides and *A. agaricites* are abundant and can live in a variety of reef habitats, they are not framework building corals. Framework building coral species common to the Caribbean Sea are *Siderastrea siderea, M. annularis, M. faveolata,* and *Montastraea cavernosa*. Of these species *S. siderea* was the only one to have coral recruits. Zuercher (2005) found the abundance of these framework building species (8.00% *S. siderea,* 4.40% *M. faveolata,* 3.33% *M. annularis,* 3.11% *M. cavernosa*) to be low compared to those of *P. astreoides* and *A. agaricites*. Since these framework building species exhibit low abundance and coral recruitment, the colonies currently living on Dominican reefs are vital to reef growth.

The lack of *P. argus* is most likely due to over harvesting (commonly seen caught by spearfishermen – Steiner pers. com.). No *S. gigas* were seen in this study because they inhabit sea grass beds and sand flats (Human and Deloach 2002).

Future studies could assess the same topics on east coast reefs and compare their findings with data from this study. Another topic that could be addressed is to quantify turf and prostrate algae in relation to *D. antillarum* and other reef grazers.

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References

Alfsnes K (2004) *Diadema antillarum* and it Grazing Effect on Algal Richness and Cover on Coral Habitats of Dominica. ITME Research Reports 21: 20-26

Borger J, Steiner SCC (2005) The Spatial and Temporal Dynamics of Coral Diseases in Dominica, West Indies. Bullof Mar Sci 77 (1): 137-154

Byrd K (2005) Study V: A Rapid Assessment of the Stony Corals and Algae in Dominica, Lesser Antilles. ITME Reports 23 (I-VII):53-63

Carpenter R C (1990) Mass Mortality of *Diadema antillarum*. I. Long-term effects on sea urchin population-dynamics and coral reef algal communities. Marine Biology 104: 66-77

Edmunds P, Carpenter R C (2001) Recovery of *Diadema antillarum* reduces macroalgal cover and increases abundance of juvenile coral on a Caribbean reef. PNAS 98: 5067-5071

Humann P and Deloach N (2002) Reef Coral Identification: Florida, Caribbean, Bahamas. New World Publications, INC. Jacksonville, Florida.

Humann P and Deloach N (2002) Reef Creature Identification: Florida, Caribbean, Bahamas. New World Publications, INC. Jacksonville, Florida.

Kramer P, Lang J, Marks K, Garaza-Perez R, Ginsburg R. (2005) Atlantic and Gulf Reef Assessment Revised Rapid Assessment Protocol

Lang CJ and Ginsburg NR (2003) Status of Coral Reefs in the Western Atlantic: Results of Initial Surveys, Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program. Atoll Res. Bull. NO. 496. In: Lang CJ (ed) Forward. pp vii-xiii

Lehman W (2001) Organism Diversity and Percent Cover of Sessile Organisms; Composition of Substrate; Abundance of *Diadema antillarum*. ITME Research Reports 6: 12-18

Lessios HA, Robertson DR, Cubit JD (1984) Spread of *Diadema* mass mortality through the Caribbean. Science 226: 335-337

Macintyre IG, Glynn PW, Hinds F (2005) Evidence of the role of *Diadema antillarum* in the promotion of coral settlement and survivorship. Coral Reefs 24: 273.

Mckinney J (2002) Algal Cover versus *Diadema antillarum* Abundance along the West Coast of Dominica, West Indies. ITME Research Reports 12: 10-14

Steiner, SCC (2003) Stony Corals and Reefs of Dominica. Atoll Res Bull No. 498

Szmant AM (2001) Introduction to the special issue of Coral Reefs on: Coral Reef Algal Community Dynamics. Coral Reefs 19: 299-302

Williams S (2001) Abundance and Size Distribution of *Diadema antillarum* Along the West Coast of Dominica, West Indies. ITME Research Reports 9: 3-9

Zeucher R (2005) Study III: Rapid Assessment of Stony Coral Community Structure in Dominica, West Indies. ITME Research Reports 23 (I-VII): 17-31

Study V: A Rapid Assessment of Shallow Reefs in Dominica, Lesser Antilles.

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Abstract Dominica is a volcanic island in the Lesser Antilles with a narrow shelf leaving little space for coral reef development. This limited resource is currently being exploited by human activities such as heavy artisanal fishing. The Atlantic and Gulf Rapid Reef Assessment (AGRRA) is a standardized quantitative protocol. It was developed as a result of coral reef degradation throughout the Caribbean to measure the stony corals, algae, and fishes of a reef. This study paper reports the findings of the first AGRRA survey in Dominica. Shallow reefs were dominated by *Porites astreoides* colonies (197) which also had the highest number of recruits (49). Most species (78%) were experiencing some form of bleaching. The overall density of *Diadema antillarum* was $1.6 \cdot m^{-2}$ and had a significant negative relationship with fleshy macroalgae and stony coral recruits. There was no significant relationship between the abundance of recruits and algal cover. The overall low diverse system was experiencing high mortality percentages for species (14) which may possibly be due in part to bleaching that has been taking place over several years in addition to other chronic stresses.

Keywords AGRRA, Dominica, Coral community structure, Coral condition, *Diadema antillarum*

Introduction

Dominica is a small (751 km^2) tropical island in the Lesser Antilles south of Guadaloupe and north of Martinique. The volcanic island is characterized by tall mountains in the interior and a narrow shelf (Honychurch 1995) of only 150 km^2 above 50 m depth (Steiner pers.com.). Coral reefs are three-dimensional shallow water structures dominated by stony corals (Bellwood *et al.* 2004). Reefs are therefore very close to shore. The west coast reefs are comprised mainly of coral assemblages on boulders with areas of reef accretion predominately located in the Grand Savane region. The shelf is wider in the northeast allowing true fringing reefs made of *Acropora palmata* frameworks, currently with a low live cover (Steiner 2003). Reefs offer protection from storms and hurricanes by dissipating wave energy. They also provide habitats, food, and nurseries for fishes and marine invertebrates. Tourism related industries rely on natural wonders like reefs for snorkeling and SCUBA activities (White *et al.* 2000). Coral reef ecosystems are an important but limited resource in Dominica.

Coral reefs endure natural stresses such as terrestrial run-off, the presence of bioeroders such as *Diadema antillarum*, bleaching, and pathogens. The human population of Dominica is exacerbating natural disturbances with anthropogenic stresses. During heavy rains, the natural terrestrial run-off deposits sediment into the ocean as well as solid waste and chemicals that have been put in the rivers by humans. Developments of roads and homes as well as quarries along the west coasts also contribute to this. When the water accumulates too much sediment, primary producers in the water column and endosymbiotic zooxanthellae in stony corals do not receive enough light for photosynthetic processes. Heavy artisanal fishing and local fishing methods also damage the reef. Forgotten wire fish pots do not break down and cause physical damage when dropped or dragged on the reef. The pot is not harvested and continues to "fish" the reef catching some that have not yet had a chance to reproduce (Guiste pers.com.). An increasing number of ecotourists are going to local snorkeling and SCUBA areas and causing, whether purposeful or accidental, coral fragmentation. With limited reef resource in Dominica, it is important to quantify the benthic composition and its condition as a primary tool in devising conservation measures.

Coral reef degradation throughout the Caribbean was cause for development of the Atlantic and Gulf Rapid Reef Assessment (AGRRA). It is a protocol to standardize data collection for reefs in the Greater Caribbean, Gulf of Mexico, and South Atlantic (Ginsberg 2003). The study quantifies three main elements of reef ecosystems: stony corals, algae, and fishes (Ginsberg 2003). The methodology of the protocol can be used to periodically monitor reef systems. Dominica has never before participated in a standardized study like this. The objective of this study was to implement AGRRA by defining the stony coral community structure. The abundance of stony coral recruits was compared to the *D. antillarum* and macroalgae. *Panulirus argus* and *Strombus gigas* were also quantified.

Methods and Materials

Benthic surveys according to AGRRA protocol v. 4.0 (Kramer *et al.* 2005) were conducted in 10 days over a 26 day period in October and November at eight sites (Fig. 1) chosen strategically to best fit the protocol while still representing Dominica's coral assemblages which include of boulder fields:

Site 01 Salisbury East (15N 26.333, 61W 26.681) was located in northern Salisbury 45 m west of shore and 200 m north of the Lauro Hotel. The rocky substrate was 2 m below the surface of the water was classified as a patch reef. It was surrounded by sand 1 m below.

Site 02 Calibishie (15N 35.668, 61W 20.743) is located just south of the village of Calibishie. The site is 175 m offshore where the water is 3-4 m deep. Large seas grass beds (*Thalassia testudinum* and *Syringodium filiforme*) extend 100 m from shore to where the reef crest begins. The reef which is constructed of mostly dead *Acropora palmata* was dominated by an encrusting brown sponge and *Gorgonia* spp.

Site 03 Batali Boulder Field (15N 26.869, 61W 27.032) was located south of Batali Beach, 100 m south of the Batali river and 10 m offshore. Depths at this site ranged from 2-4 m. At a distance of 20 m offshore the shelf drops off steeply. The substrate was comprised of large boulders and rock rubble.

Site 04 Fond Colé (15N 19.238, 61W 23.671) was located south of Canefield and north of Fond Colé. The site is 15 m offshore and consists of consolidated rubble with a high level of rugosity. Depths varied from 0.5-3 m. The shallow areas had a high abundance of *Gorgonia* spp. and the southern portion of the site consisted of large colonies of *Sidestraea siderea.*

Site 05 Rodney's Rock (15N 22.837, 61W 24.692) was located just north of the village of Jimmit and south of the village of Tarou. The site is located north of Rodney's Rock, at a distance of 20 m from shore.

Depths at this site ranged from 4-7 m. The substrate consists of large boulders and areas of large *Sidestraea siderea* colonies.

Site 06 Macoucheri Reef was located in the village of Salisbury and 100 m northwest of the Macoucheri River. Depths at this site were 5-6 m. The substrate was comprised of patch reefs characterized by many sponge species. It was surrounded by sand.

Site 07 Champagne East (15N 14.67, 61W 22.42) was located south of Sibouli and 500 m north of Point Guignard. It was in the northernmost area in the Soufriere/Scott's Head Marine Reserve (SSMR). The depths 50 m west of shore ranged from 2-3 m. The rock substrate was surrounded by sand. Shallow water thermal vents were to the north of the site among algae covered rocks.

Site 08 Cachacrou (15N 12.90, 61W 22.30) was located in the Soufriere Bay. It was in the southernmost area of the SSMR. 100 m east of shore depths ranged from 2-4 m and the substrate was mostly coral rubble surrounded by sand. 10 m south of the rubble depths ranged from 2.5-4 m and the substrate was a ledge made of rock. The area was characterized by large amounts of *Dictyota* spp. in the coral rubble. It also had drop-offs in the middle of the bay to depths greater than 50 m.

Fig. 1 Surveyed sites locations

Surveys were completed by snorkeling. All species were identified *in situ* according to Humann and Deloach (2003). The following modifications to the protocol were:

If the reef had limited structure and/or coral growth, subsequent transects were not placed laterally 2 m apart, but placed either end to end (Batali-Boulder, 1 m apart) or directly in areas where coral colonies were observed (Salisbury East, Cachacrou).

In Kramer *et al.* (2005), a 10-m transect line was laid out and swum (passed) over four times. On the first pass, when only the spines (not the test) of *D. antillarum* were in the surveyed area the urchin was not counted. In order to simplify logistics, the second pass as defined by AGRRA was divided into two separate passes the following way: On the second pass, all scleractinians (stony corals) and *Millepora* spp colonies greater than or equal to 10 cm were measured. Dark Spot Syndrome (DSS) (Borger 2005) was considered a disease and recorded when observed. Damselfish and their respective gardens were not recorded. On the third pass, the remaining sessile invertebrates, sand patches, and algae directly under the line were quantified. On the fourth pass, *Ventricaria ventricosa* was included in the fleshy macroalgae. When *Dictyota* spp had prostrate growth it was considered turf and not quantified yet noted in the comment area. Due to the topography of Dominica, rock was included as a substrate category.

All statistics were calculated using a Pearson correlation with the SigmaStat software program. Species diversity was calculated using Shannon-Weiner Diversity Index (Shannon 1948) and evenness was calculated using J′ (Pielou 1966).

Results

A total of 433 stony coral colonies were counted along 38 transects in Dominica. Seventeen species were identified throughout the surveyed sites (Table 1). Macoucheri had the highest species richness with 14 and Salibury East had the lowest with 4 (Table 2). Macoucheri also had the highest species diversity (H′=2.20) (Table 2) and percent live coral cover (28.6%) (Fig. 2). Calibishi had the highest evenness (J′=0.90) and the species diversity was H′=1.69 (Table 2). Though it had the highest evenness and the second highest diversity index, it had the lowest percent live coral cover (11.4%) out of all sites (Fig. 2). The lowest species diversity (H′=0.95) was at Batali-Boulder and the lowest evenness of species (J′=0.49) was at Fond Colé (Table 2). The most abundant corals were *Porites astreoides, Sidestraea siderea*, and *Millepora* spp. (Fig.3). *S. siderea* also had the highest average surface area per 10 m over other present species at Macoucheri, Cachacrou, Champagne East, and Rodney’s Rock (Fig. 4-11). *P. astreoides* and *Millepora* sp. also had high surface area in addition to their abundance.

Table 1. Stony coral species seen at each site*.

	MA	CAC	CE	CAL	BB	FC	RR	SE
Porites astreoides (PAST)	●	●	●	●	●	●	●	●
Millepora spp (MILL)	●		●	●	●	●	●	●
Sidestraea siderea (SSID)	●	●	●	●	●	●	●	
Agaricia agarcites (AAGA)	●	●	●		●		●	
Porites porites (PPOR)	●	●	●			●	●	
Montastraea faveolata (MFAV)	●	●	●	●			●	●
Diploria strigosa (DSTR)			●	●	●	●		●
Madracis mirabilis (MMIR)		●	●					
Montastraea cavernosa (MCAV)	●			●	●			
Colpophyllia natans (CNAT)	●	●				●		
Meandrina meandrites (MMEA)	●	●		●				
Montastraea annularis (MANN)	●	●						
Diploria labyrinthiformis (DLAB)	●			●				
Stephocoenia intersepta (SINT)	●							
Dichocoene ia stokesii (DSTO)	●							
Eusmilia fastigiata (EFAS)		●						
Manicina areolata (MARE)	●							

* Site abbreviations: MA=Macoucheri, CAC=Cachacrou, CE=Champagne East, CAL=Calishie, BB=Batali-Boulder, FC=Fond Colé, RR=Rodney's Rock, SE=Salisbury East

Table 3. Number and type of stony coral recruits

AAGA	30
SSID	22
SRAD	46
MMEA	4
PAST	49
DIPL	4
DSTR	8
DSTO	3
MDEC	6
FFAV	1
PPOR	6
ISIN	4
SINT	3
CNAT	1
MMIR	20

Table 2. Stony coral species richness, diversity, and evenness of distribution

Site	Species Richness (n)	Shannon-Weiner Diversity Index (H′)	Species Evenness of Distribution (J′)
MA	14	2.20	0.83
SE	4	0.95	0.67
RR	6	1.26	0.70
CAC	10	1.53	0.66
BB	6	0.95	0.53
FC	6	0.87	0.49
CE	8	1.75	0.84
CAL	8	1.87	0.90

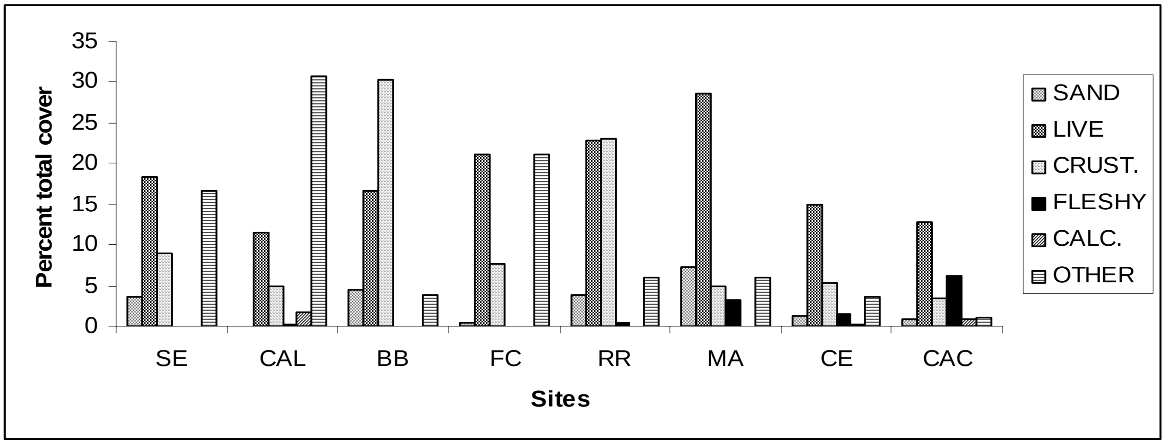

Fig. 2 Total percent cover under the line of key categories

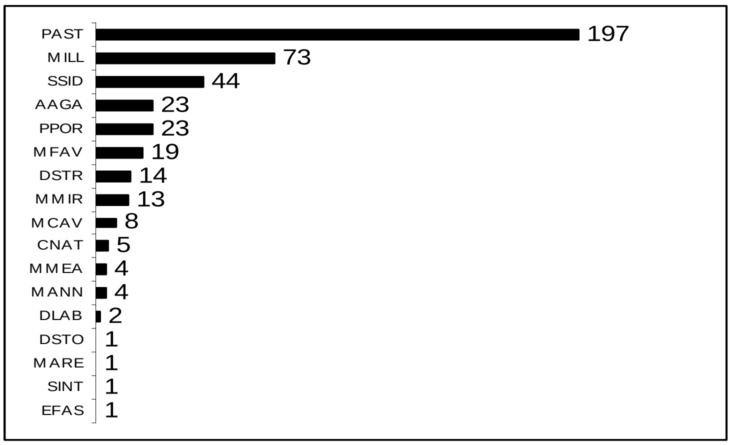

Fig. 3 Total number of colonies of all stony corals identified

Bleaching was seen at every site. *P. astreoides* had the highest number of colonies (178) affected and the majority of those were considered pale (Fig. 12). The highest partially bleached (63%) was experienced by *Millepora* sp. and the highest bleached (95.7%) was seen in *Agaricia agarcites* (Fig. 12). Disease was seen at three sites on four colonies, one *P. astreoides* and three *S. siderea.* The symptoms afflicting *P. astreoides* were unknown. The remaining three were Dark Spot Syndrome (DSS) and affected 6.8% of total *S. siderea.* Mortality was seen in 14 of the 17 identified species (Fig. 13). Fond Colé had the highest amount of old mortality (83.3%) followed by Champagne East (81.4%), Rodney's Rock (80.4%), Batali-Boulder (79.6%), Salisbury East (72.8%), Macoucheri (70.4%), Cachacrou (66%), and Calibishie (63.6%). Champagne had the highest recent mortality (25.4%) followed by Cachacrou (7.6%), Rodney's Rock (2.0%), Macoucheri (1.4%) and Salisbury East (1.2%).

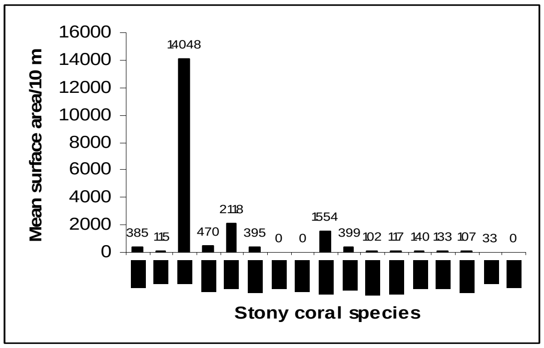

Fig. 4. Mean surface area of each species at Macoucheri

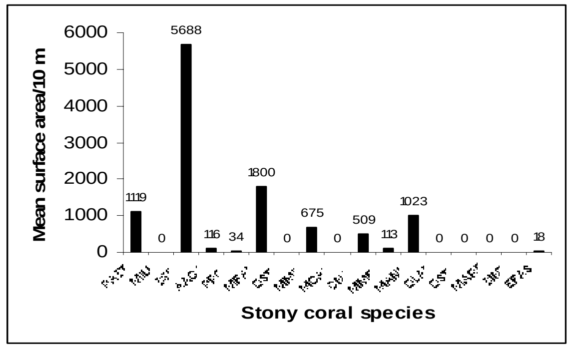

Fig. 5. Mean surface area of each species at Cachacrou

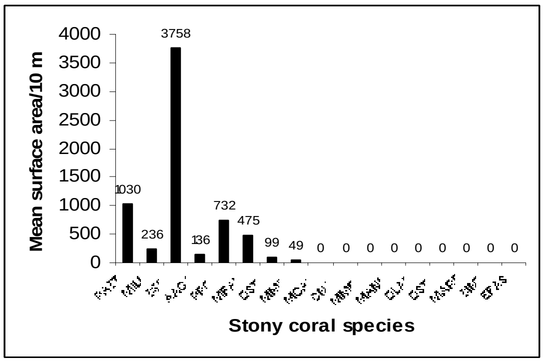

Fig.6 Mean surface area of each species at Champagne East

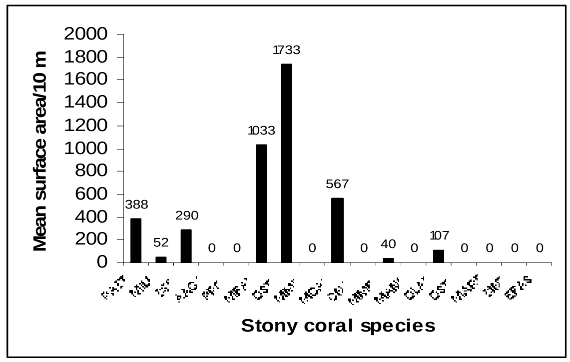

Fig. 7. Mean surface area of each species at Calibishie

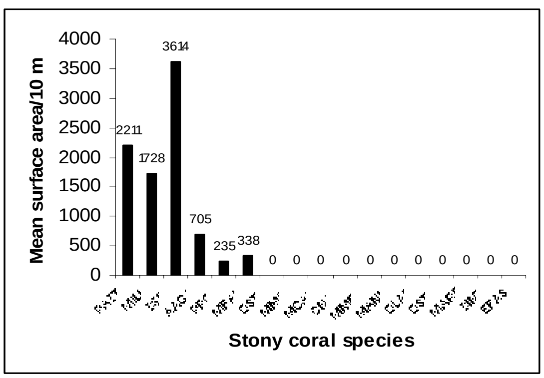

Fig. 8 Mean surface area of each species at Rodney's Rock

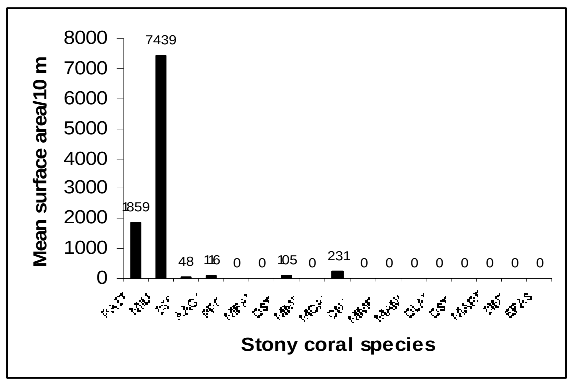

Fig. 9 Mean surface area of each species at Batali-Boulder

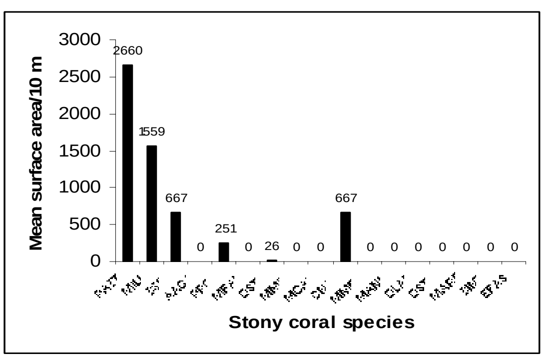

Fig. 10 Mean surface area of each species at Fond Colé

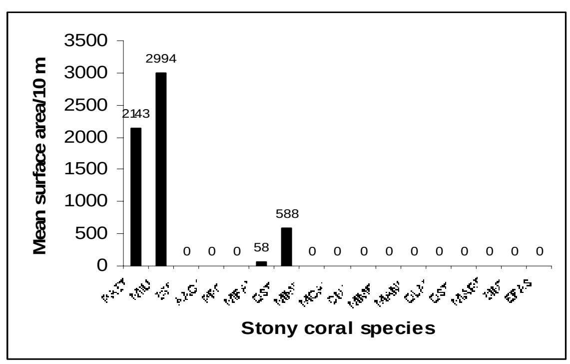

Fig. 11 Mean surface area of each species at Salisbury East

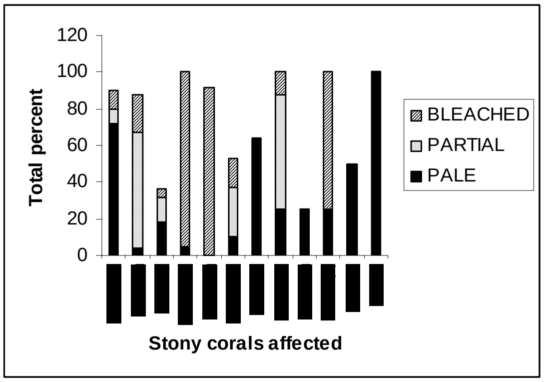

Fig. 12 Percents of stony corals affected by each stage of bleaching (Actual colony number in parentheses)

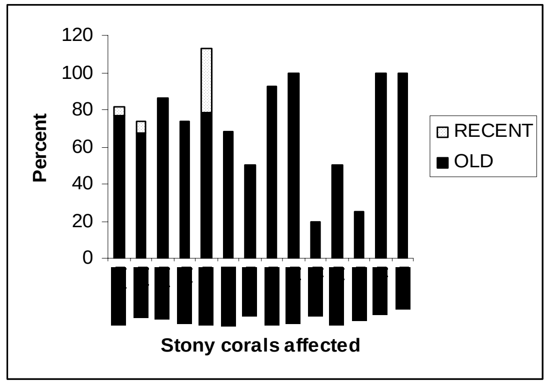

Fig. 13 Percent of stony corals affecting by old and recent mortality (Actual colony numbers in parentheses)

There were 14 species of recruits identified (Table 3). In the *Diploria* genus, 4 could not be identified to species. *P. astreoides*, *M. mirabilis,* and *Sidestraea radians* had the highest number of recruits (Table 3). *S. siderea* had 22 recruits total which was the highest number for large mound building colonies. There was no significant relationship between the number of recruits with macroalgae ($R=0.20$, $p>0.05$) or crustose coralline algae ($R=0.18$, $p>0.05$). There was a significant relationship between recruits and *Diadema antillarum* ($R= -0.32$, $p<0.05$)

No *P. argus* or *S. gigas* were seen at any site. The overall density of *D. antillarum* was 1.6 $\cdot m^{-2}$. The average density for each of the sites was: 2.0$\cdot m^{-2}$ (Salisbury East), 0$\cdot m^{-2}$ (Calibishie), 4.5$\cdot m^{-2}$ (Batali-Boulder), 3.9$\cdot m^{-2}$ (Fond Colé), 2.2$\cdot m^{-2}$ (Rodney's Rock), 0.3$\cdot m^{-2}$ (Macoucheri), 1.3$\cdot m^{-2}$ (Champagne East) and 0.2$\cdot m^{-2}$ (Cachacrou). Fleshy algae cover was highest at Cachacrou and was not seen at Salibury East, Batali-Boulder, and Fond Colé (Fig. 2). There was a significant negative correlation between the amount of fleshy macroalgae and the density of *D. antillarum* ($R= -0.47$, $p<0.05$).

Discussion

The overall community structure in shallow water consisted of small, "weedy" stony corals such as *P. astreoides* and *A. agarcites* rather than large framework builders such as *Montastraea faveolata*. *P. astreoides* is a coral that can take on different growth forms to adapt to turbulent waters (Humann 2003). *Millepora* spp. also had a large surface area in several sites as well as the second highest abundance of colonies. This hydrocoral species thrives in shallow surge waters (Knuth 2003) where it thinly encrusts the substrate. When both *Millepora* spp. and *P. astreoides* were present with large surface areas the diversity index of colonies was low. This is evident in comparing the sites Batali-Boulder with Macoucheri. The highly diverse Macoucheri had low surface area of the two species and high surface area of large *S. siderea*. The least diverse site was dominated by *P. astreoides* and *Millepora* spp. These weedy corals settle in high numbers yet leave sufficient room for other species to settle. However, the low numbers of these other species suggest they are not adaptable to the turbulent shallow water.

Only few framework builders (*Montastraea annularis, Montastraea cavernosa, M. faveolata,* and *S. siderea*) were seen. It is the framework builders that provide habitat and structure for the reef. In Cachacrou, there was one colony of *M. faveolata* but it had the second highest surface area. *P. astreoides* had the most abundant colonies (19) at the site yet had a low surface area. Macoucheri had the highest number of *M. faveolata* and *S. siderea* creating a different reef structure than other sites. This may have contributed to the high diversity and evenness calculated for the site.

If water temperatures exceed the average annual temperature by 1.7ºC for 3-4 continuous weeks a bleaching event may occur (Steiner pers.com.). When an event occurs the endosymbiotic zooxanthellae leave the coral polyp which puts it in a weakened state. The warm water temperature increases the proliferation of phytoplankton in the water column. A bleaching event was ongoing during the survey. Most species were only pale and not completely bleached. Water temperatures had begun to decrease from the beginning (30.5º) of the surveys to the end (29.5ºC) (Steiner pers.com.). The increase in recent mortality at Champagne and Cachacrou which could be due to the fact that these were the last two sites surveyed. Without the endosymbiotic partnership perhaps many coral colonies were unable to take any additional stresses such as the increased amount of phytoplankton. Bleaching events had also taken place in 2003 and 2004 (Steiner pers.com.). Bleaching may have accounted for part of the high rates of old mortality. Recovery from these events takes approximately 6-7 months and may go well into the reproductive/spawning months of the next year. While in a weakened state, gametogenisis may have been suspended (Pomerance 1999) in previous years causing a small number of recruits in this year.

Recruits tend to not settle in areas of high macroalgae cover and do preferentially settle on crustose coralline algae (Riegl *et al.* 2003). This survey did not substantiate either of these observed tendencies. *D. antillarum* also tends to have a relationship with coral recruitment. Since it feeds on macroalgae, a high density of *D. antillarum* should mean a low cover of the algae which hinders recruitment. Though there was a not a significant relationship between recruits and algae there was a relationship between recruits and *D. antillarum*. Bioerosion by *D. antillarum* open up space for recruits to settle contributing to this correlation. Bleaching from the previous years, 2003 and 2004 (Steiner pers. com.), may have decreased the number of recruits settling thus disrupting relationship cycles with algal growth. Coral recruits recorded were mainly of small species. *P. astreoides* was the most abundant (49) followed by *S. radians* (46). Large colony recruits were less abundant. *S. siderea* had the only recruits (22) for the large coral forms.

The negative relationship between fleshy macroalgae and *D. antillarum* was evident. Community dominance from corals shifts to macroalgae when the urchin is not present (Lessios 2004). The site with the highest density of *D. antillarum* (Batali-Boulder) had no fleshy macroalgae present. The site with the highest amount of macroalgae (Cachacrou) had low numbers of the urchin. *S. gigas* inhabit sea grass beds and sand flats near or around fringing reefs (Humann 2003) which are not typical of Dominica and explains their absence. *P. argus* hide in deep recesses or caves around the reef (Humann

2003) and when present are overexploited by fishing. They may have been out of sight but more than likely the majority have been fished out.

Currently, Dominica's shallow reefs are weakened and are subject to constant anthropogenic stresses. As heavy fishing, coastal development, tourism and increased sedimentation from humans intensify, the reef systems continue to be stressed. Shallow reefs are predominately made up of small coral communities. Large structural colonies that form necessary habitats are limited and do not seem to be reproducing as rapidly as the small ones. Monitoring the composition of the reef is essential in managing reefs usage. Implementing AGRRA periodically provides the information necessary for such initiatives.

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References

Bellwood DR, Hughes TP, Folke C, Nystrōm M (2004) Confronting the coral reef crisis. Nature 429:827:832

Borger J, Steiner SCC (2005) The Spatial and Temporal Dynamics of Coral Diseases in Dominica, West Indies. Bull of Mar Sci 77(1): 137-154

Ginsberg R, Lang J (2003) Status of Coral Reefs in the Western Atlantic: Results of Initial Surveys, Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program. Natural Museum of Natural History Smithsonian Institution: Washington, D.C.

Honychurch L (1995) The Dominica Story. MacMillian Education Ltd, London and Oxford, 317 pp

Humann P, Deloach N (2002) Reef Coral Identification: Florida Caribbean Bahamas. New World Publications, Jacksonville, Florida 278 pp

Knuth K (2003) Scleractinian Monitoring in Dominica, West Indies: Species Richness, Diversity, and Live Cover. ITME Research Reports 19:3-9

Kramer P *et al.* (2005) AGRRA Methodology v. 4.0

Lessios H (2004) *Diadema antillarum* populations in Panama twenty years following mass mortality. Coral Reefs 24:125-127

Pielou, EC (1966) The measurement of diversity in different types of biological Collections. J Theor Biol 13:131-44

Pomerance R (1999) Coral Bleaching, Coral Mortality, and Global Climate Change. Bureau of Oceans and International Environmental and Scientific Affairs

Riegl B, Manfrino C, Hermoyian C, Brandt M, Hoshino K, (2003)Assessment of the coral reefs of the Turks and Caicos islands (Part 1: Stony Corals and Algae). Atoll Res Bull 496:461-473

Shannon CE, Weiner W (1948) The mathematical theory of communication. Univ. Illinois Press, Urbana, Illinois 117

Steiner SCC (2003) Stony Corals and Reefs of Dominica. Atoll Res Bull 498

White A, Vogt H, Arin T (2000) Philippine Coral Reefs Under Threat: The Economic Losses Caused by Reef Destruction. Marine Pollution Bull 40:598

Study VI: Abundance, Size Distribution and Species Richness of Key Reef Fishes in Dominica

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Abstract In October and November of 2005 eight reef sites located off the northeastern and western coasts of the island of Dominica were surveyed using the Atlantic and Gulf Rapid Reef Assessment, AGRRA, protocol v. 4.0. Data regarding abundance, size distribution and species richness of commercially and economically important reef fishes was assessed. Twenty-two percent of all fishes surveyed were predators, of these over ninety percent were under 20 cm in length. Seventy-eight percent of all fish surveyed were herbivores, ninety percent of which were under 20 cm in length. Species richness was greatest at two sites situated inside a marine reserve. Results of this study indicate that Dominica's reefs are over fished and the data can be used to assist in the development of a reef management plan.

Keywords Herbivorous fishes, Predatory fishes, AGRRA, Dominica, Species richness

Introduction

Dominica is a small (750 km^2) volcanic island located between the islands of Guadeloupe and Martinique in the Lesser Antilles. It is characterized by a steep island slope and a very small shelf, approximately 150 km^2 above 50 m in depth (Steiner pers. com.). As a result, reef habitats are located close to shore where there is adequate light and suitable substrate. The reefs of Dominica are extremely vulnerable to the anthropogenic disturbances of fishing and terrestrial run-off containing pollutants, such as solid wastes and chemicals, due to their proximity to coastal populations.

Currently, the fishing effort in Dominica is artisanal (Guiste pers. com.). There are 1,934 local fishermen who hold fishing licenses but it is estimated that around 3,000 people are actually fishing off the shores of Dominica (Guiste pers.com.). Fishing technology is limited to a single modern longline vessel with an inboard motor, all other fishing is done with vessels less than 30 feet, from which fishermen use methods such as fish pots, hook and line, or seine nets (Guiste pers.com.). Neighboring islands with more advanced fishing industries are encroaching on Dominica's exclusive economic zone (Guiste pers. com.). Due to an increase in coastal development, the marine environment is experiencing more stress and disturbance. This, along with exhaustive fishing on reefs has the potential to alter the entire ecosystem because it removes the larger consumers and herbivorous fishes. A decreased fish population would not have the capacity to perform all necessary ecosystem functions. Ecosystem functions that would be affected range from the management of the amount of algae by herbivorous grazers to the introduction of particulate organic matter through excretion which is necessary for the continuous cycle of nutrients within reef ecosystems.

It is important to look at reef fish assemblages when monitoring benthic reef environments as a whole because fishes play vital roles in the ecosystem as predators and grazers through their interactions with corals, algae, and other herbivores (Kramer 2003). Although there may be benthic organisms present that perform similar ecological functions, removal of fishes will inevitably cause an impact on the reef community. For example, the herbivore *Acanthurus coeruleus* and the urchin *Diadema antillarum* both act as herbivorous grazers but *D. antillarum* is also a destructive bioeroder and can cause reef damage (Bellwood 2004). The relative abundance of *A. coeruleus* to the abundance of *D. antillarum* will impact which type of grazing, destructive or non-destructive, predominates on the reef.

The quantification of size and number of top fish predators gives insight into reef health in terms of population size of benthic organisms that these fish prey upon. For example, the assembly of *Bodianus rufus* which are *D. antillarum* predators can be an indicator of urchin abundance (Behrents 1984). Although there are many other factors that tie into the relationship between fishes and benthic community structure, the study of fish assemblages is an essential link in examining the entire reef ecosystem. Another connection between the fish and benthic communities is control of the algae abundance by herbivorous fishes. The populations of herbivorous fishes prevent phase shifts from occurring between coral habitats to fleshy macro algae habitats (Scheffer 2001).

This study had two main objectives which were to record the abundance and size classes of key reef species as well as overall species richness at each site. Kramer (2005) defines key reef fishes as being either ecologically or commercially important. For example, members of the Lutjanidae family were included in the survey due to their commercial significance in fisheries and as a local food source. Acanthuridae and Scaridae families, among others, were considered for their ecologically significant functional role as herbivorous grazers.

These objectives were met by implementing the Atlantic and Gulf Rapid Reef Assessment, AGRRA, v. 4.0 protocol, a standardized quantitative survey method (Kramer 2005). Development of the AGRRA program started in 1993 with the goal of quickly evaluating the conditions of the world's reefs by gathering quantitative data concerning the three fundamental elements of reef ecosystems: stony corals, fish and algae. Never before has an AGRRA study been conducted on the reefs surrounding Dominica. Data from this study can be used to compare different sites in the Caribbean or it can be used to compare the same sites over a period of time. These comparisons will be important to assess recent changes and the resilience to both natural and anthropogenic disturbances as well as the health and stability of Dominica's reefs.

Methods and Materials

Data for this study was collected using the AGRRA v. 4.0 protocol (Kramer *et al*. 2005). Methods for fish data collection were a rover diving census (RDC) and the use of belt transects to quantify the abundance of commercial and ecological target fish species (Table 1) and their size classes.

In October and November 2005 a total of eight reef sites were surveyed along the western and northern coasts of the island. For site descriptions and site locations see Byrd 2005. These sites were strategically selected based on site location guidelines set by AGRRA also including boulder fields which are representative coral reefs in Dominica. When it was not possible for transects to be oriented 5 m apart laterally due to space constraints, they were laid down radially (four transects all starting at the same point running in different directions) or end to end. Ten transects (30m x 2m) ranging in depth from 3-5 m were surveyed at each site with the exception of Rodney's Rock (8 transects) and Fond Colé (5 transects). The size classes of 0-5 cm and 6-10 cm were combined into one 0-10 cm size class. Data collection took place during the mid-morning using snorkeling gear. The rover diver census lasted 30 minutes at each site. All fish species were identified *in situ* with reference to Humann and Deloach (2002).

Results

Belt Transects

During this study a total of 73 belt transects at eight sites were surveyed, encompassing an area of 4,380 m^2. Nineteen of the possible 26 AGRRA species were actually observed in transects during the surveys. Only three of these species (*Acanthurus bahianus*, *A. coeruleus*, and *Microspathodon chrysurus*) were seen at all eight sites. Salisbury East had the highest fish density (52.67 individuals/100 m^2) where as Macoucheri had the lowest fish density (18.67 individuals/100 m^2) (Fig. 1). Cachacrou was the site where the most AGRRA fish species were observed (16 species) followed by Champagne (13 species) (Fig. 2).

Acanthurids was the most common family represented among fish surveyed at all eight sites combined (56.9% of total fish observed) (Fig. 3) followed by the Lutjanids (15.6%), Pomacentridae (10.5%) and the Scarids (9.9%). Acanthurids were dominant at each of the eight sites. With the exception of Batali, Acanthuridae density was close to double that of the second most abundant family at each site (Fig. 4). Lutjanids, which had the second highest percentage of total fish, were observed in high densities compared to other families at Salisbury East and Batali. High densities of members of the Scaridae family were observed at Champagne and Cachacrou which contributed significantly to its ranking as the family with the fourth highest percentage of total fish.

Herbivores had a greater density than predators at all sites surveyed (Fig. 5). In particular, Calibishie and Fond Colé had considerably different densities of herbivores compared to predators (43: 0.17 individuals/100 m^2 and 14.5: 0.67 individuals/100 m^2 respectively). Majority of fishes surveyed were found in the 11-20 cm size class (Fig. 6), with 55% of all herbivores and 52% of all predators recorded as being 11-20 cm in length. There was a higher percentage of predators than herbivores in the smallest size class. In all other size classes there were more herbivores than predators. No predators were observed above 30 cm and no fishes above 40 cm in length were observed in any transect throughout the survey. When the density of fish in each size class was compared between the eight different sites, Champagne and Cachacrou had higher densities of fish in the 21-30 cm and 31-40 cm size classes (Fig. 7).

Species Richness

A total of four hours were devoted to RDCs for all sites. During the RDCs 53 different species were observed. Cachacrou exhibited the highest species richness with 42 different species and the lowest species richness was found at Calibishie with 20 different species (Fig.8). The average number of species found at each site was 27 species (SD ± 7). Ten species were seen at all 8 sites (Table 2). Of these 10 most frequently sighted species, seven were on the AGGRA list of target species. Only 2 species (*Chromis multilineata* and *Stegastes partitus*), both of which were not on the AGRRA target species list were observed to be abundant at more than one site. Pomacentridae was the most represented family during the RDCs with eight species followed by the Labridae and Scaridae families (6 species each).

Table 1 List of fish species included in the AGGRA survey.

Family Name	**Common Name**	**Species**
Pomacanthidae	French Angelfish	Pomacanthus paru
	Rock Beauty	Holacanthus tricolor
Chaetodontidae	Foureye Butterflyfish	Chaetodon capistratus
Scaridae	Princess Parrotfish	Scarus taeniopterus
	Queen Parrotfish	Scarus vetula
	Redband Parrotfish	Sparisoma aurofrenatum
	Stoplight Parrotfish	Sparisoma viride
	Striped Parrotfish	Scarus iserti
Serranidae	Coney	Epinephelus fulvus
	Graysby	Epinephelus cruentatus
	Black	
Lutjanidae	Mahogany Snapper	Lutjanus mahogoni
	Schoolmaster	Lutjanus apodus
	Yellowtail Snapper	Ocyurus chrysurus
	Mutton Snapper	Lutjanus analis
Acanthuridae	Blue Tang	Acanthurus coeruleus
	Doctorfish	
	Ocean Surgeon	Acanthurus bahianus
Balistidae	Black Durgon	Melichthys niger
Pomacentridae	Yellowtail Damselfish	Microspathodon chrysurus
Labridae	Hogfish	Lachnolaimus maximus
	Spanish Hogfish	Bodianus rufus
Sphyraenidae	Great Barracuda	Sphyraena barracuda
Carangidae	Bar Jack	Caranx ruber

Table 2 List of fish species and abundance for each site (Salisbury East-1, Calibishie-2, Batali-3, Fond Colé-4, Rodney's Rock-5, Macoucheri-6, Champagne-7, Cachacrou-8 (S-single(1), F-few(2-10), M-many(11-100), A-abundant(101+))).

Species	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Scientific Name	Common Name								
Acanthuridae	**Surgeonfishes**								
Acanthurus bahianus	Ocean Surgeonfish	A	M	M	M	M	M	M	M
Acanthurus coeruleus	Blue Tang	M	F	M	M	F	F	M	M
Acanthurus chirurgus	Doctorfish	F							
Aulostomidae	**Trumpetfishes**								
Aulostomus maculatus	Trumpetfish	M		M	F		S	F	M
Balistidae	**Triggerfishes**								
Melichthys niger	Black Durgon	F						S	F
Balistes vetula	Queen Triggerfish	S							
Blenniidae	**Blennies**								
Opioblennius macclurei	Redlip Blenny	F	F		F			F	
Bothidae	**Lefteye Flounders**								
Bothus lunatus	Peacock Flounder	S						S	
Carangidae	**Jacks**								
Caranx ruber	Bar Jack	F			M			F	S
Chaetodontidae	**Butterflyfishes**								
Chaetodon ocellatus	Spotfin Butterfly	S							
Chaetodon striatus	Banded Butterflyfish		S			S	F	F	
Cirrhitidae	**Hawkfishes**								
Amblycirrhitus pinos	Red-spotted Hawkfish								S
Haemulidae	**Grunts**								
Haemulon cardonareum	Caesar Grunt							F	
Haemulon flavolineatum	French Grunt	M	F	F	F	M	M	M	M
Haemulon chrysargyreum	Smallmouth Grunt	M	M	M	F	M	M	M	M
Holocentridae	**Squirrelfishes**								
Holocentrus adscensionis	Squirrelfish	F	S	F	F		F		S
Myripristis jacobos	Blackbar Soldierfish			F	F			M	
Labridae	**Wrasses**								
Halichoeres radiatus	Pudding Wife			S		S		F	M
Thallasoma bifisciatum	Bluehead Wrasse	M	M	M	M	M	F	M	M
Halichoeres garnoti	Yellowhead Wrasse	M	M	M		M	F	M	M
Halichoeres bivittatus	Slippery Dick	S	M	M	F			M	M

Species	Site	1	2	3	4	5	6	7	8
Halichoeres maculipinna	Clown Wrasse	F	M	F	F			M	M
Bodianus rufus	Spanish Hogfish	S	F				F		F
Lutjanidae	**Snappers**								
Lutjanus mohogoni	Mahogany Snapper	M		M		M	F	M	F
Ocyurus chrysurus	Yellowtail Snapper	M		F	S	F	M	M	M
Malacanthidae	**Tilefishes**								
Malacanthus plumieri	Sand Tilefish								S
Monacanthidae	**Filefishes**								
Cantherhines pullus	Orange Spotted Filefish	F		F	F	F		F	
Mullidae	**Goatfishes**								
Meulloidichthys martinicus	Yellow Goatfish	M	F	F		F		F	M
Pseudopeneus maculatus	Spotted Goatfish	F		F		M	M	F	F
Ostraciidae	**Boxfishes**								
Lactophrys triqueter	Smooth Trunkfish	F		S				F	F
Pomacanthidae	**Angelfishes**								
Holocanthus tricolor	Rock Beauty					F			F
Pomacentridae	**Damselfishes**								
Abudefduf saxatilis	Sergeant Major	M	M	M	M	M	M	M	M
Stegastes partitus	Bicolor Damsel	M	M	A	M	A	M	M	A
Stegastes variabilis	Cocoa Damsel	F					S	S	F
Stegastes adustus	Dusky Damsel	M	M	M	F	F		M	M
Chromis multilineata	Brown Chromis	A		A	M	A	A	M	A
Chromis cyanea	Blue Chromis	F		F	F		F		A
Stegastes planifrons	Three Spot Damselfish								F
Microspathedon chrysurus	Yellowtail Damsel	M	M	M	M	M	M	M	F
Scaridae	**Parrotfishes**								
Sparisoma aurofrenatum	Redband Parrotfish	M	F	F	F	M	M	M	M
Sparisoma rubripinne	Yellowtail Parrotfish	F	F			F		F	M
Scarus vetula	Queen Parrotfish							F	F
Scarus taeniopterus	Princess Parrotfish	S				M	F	M	M
Scarus iserti	Striped Parrotfish	S			S		F	M	M
Sparisoma viride	Stoplight Parrotfish	F	S	F	F	M	M	M	M
Sciaenidae	**Drums**								
Equetus punctatus	Spotted Drum								S

Species	Site	1	2	3	4	5	6	7	8
Serranidae	**Seabasses**								
Cephalopholis cruentatus	Graysby			F		F	F		F
Serranus tigrinus	Harlequin Bass						F	S	M
Hypoplectrus guttavarius	Shy Hamlet								S
Cephalopholis fulva	Coney			S	S	S			S
	Silversides	A						M	
Synodontidae	**Lizardfishes**								
Synodus intermedius	Lizardfish				S	S	S		
Tetraodontidae	**Puffers**								
Canthigaster rostrata	Sharpnose Puffer			F	S	F			S

Table 3 Species seen at all sites during Rover Diver Censuses.

Species	
Scientific Name	Common Name
Abudefduf saxatilis	Sergeant Major
Stegastes partitus	Bicolor Damsel
Microspathedon chrysurus	Yellowtail Damsel
Sparisoma aurofrenatum	Redband Parrotfish
Acanthurus bahianus	Ocean Surgeonfish
Thallasoma bifisciatum	Bluehead Wrasse
Acanthurus coeruleus	Blue Tang
Sparisoma viride	Stoplight Parrotfish
Haemulon flavolineatum	French Grunt
Haemulon chrysargyreum	Smallmouth Grunt

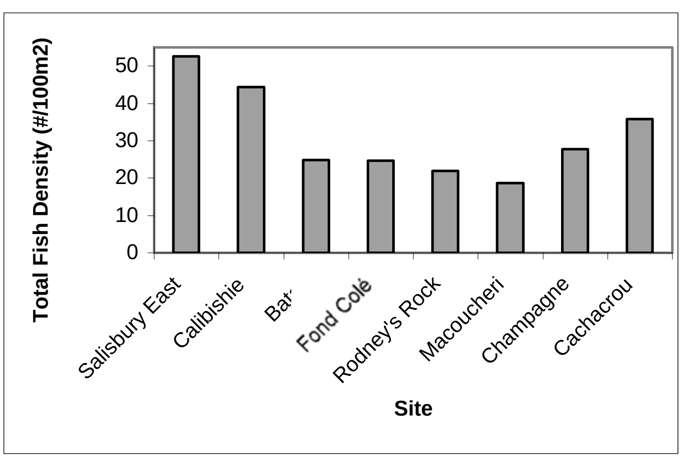

Fig. 1 Total fish density at each site.

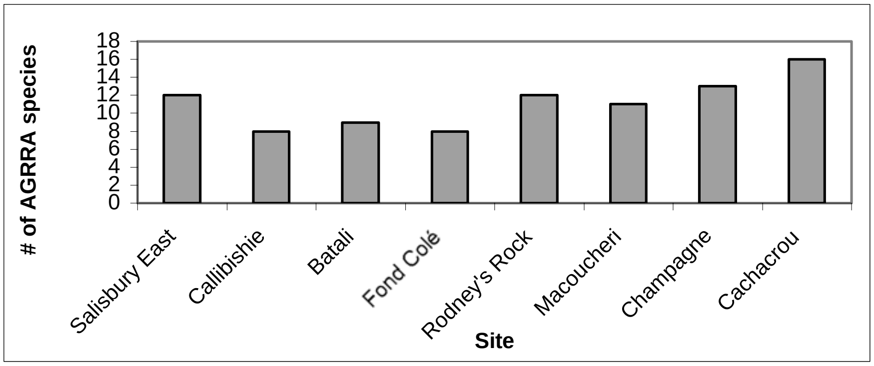

Fig. 2 Number of AGRRA species observed at each site.

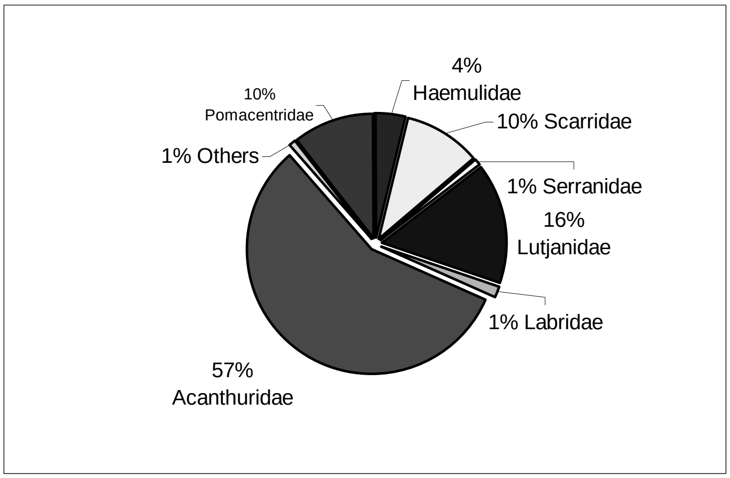

Fig. 3 Percentages of all AGRRA fishes (other includes Pomacentridae, Balistidae and *Caranx ruber*).

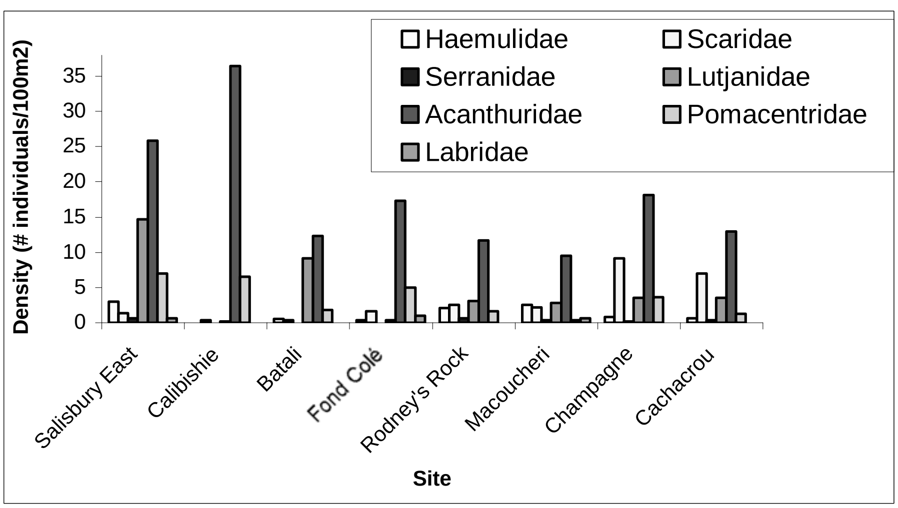

Fig. 4 Density of AGRRA fishes at all sites.

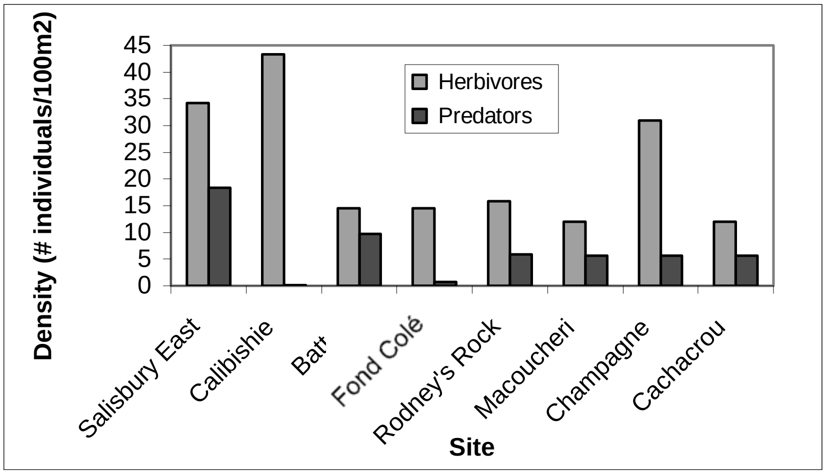

Fig. 5 Density of herbivores (Acanthuridae, Scarridae, Microspathodon chrysurus) and predators (Lutjanidae, Serranidae, Haemulidae) at all sites.

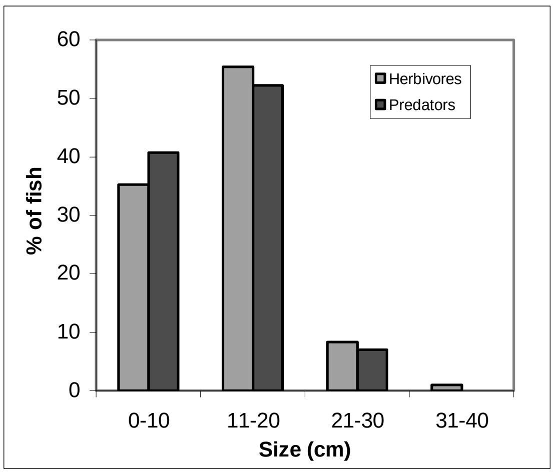

Fig. 6 Percentage of total herbivores (Acanthuridae, Scarridae, *Microspathodon chrysurus*) and predators (Lutjanidae, Serranidae, Haemulidae) categorized by size class at all sites.

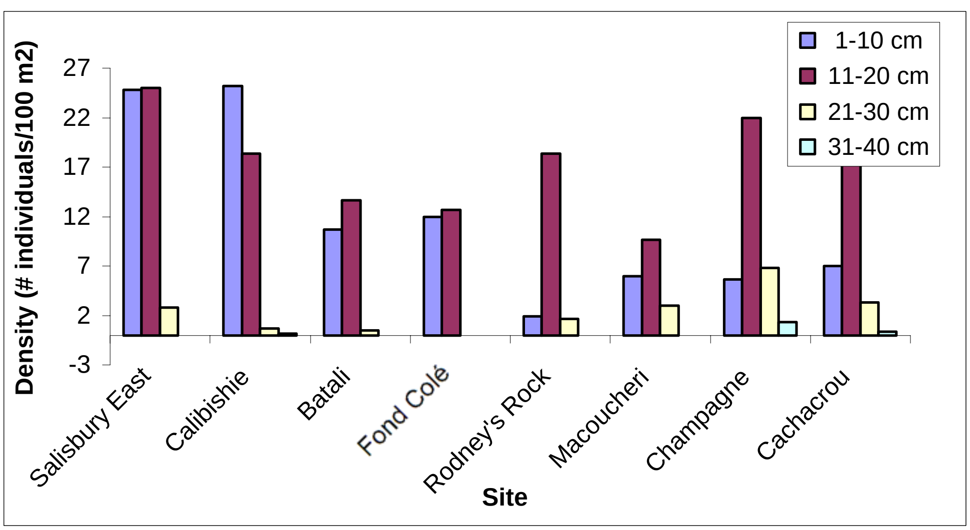

Fig. 7 Density of all fishes observed in each size class at all sites.

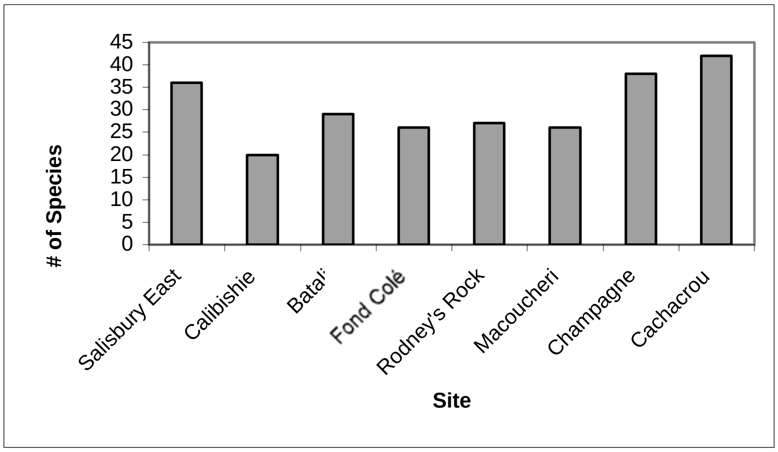

Fig. 8 Total number of species recorded at all sites.

Discussion

It is important to consider the fact that only 19 of the 26 target fish species were observed during the transect portion of this study. Five of the absent species fall under the commercially significant category and two of the species are ecologically important. However, all but three of these species (*Lachnolaimus maximus, Sphyraena barracuda* and *Centropristis striata*) were seen during RDCs completed in this survey and that of Lowe (2005). Lowe's RDCs were conducted using SCUBA at greater depths than those conducted in this study suggesting these key species are not absent from Dominica's reefs, but inhabit deeper waters.

Fewer predators than herbivores, 22%: 78% were recorded in this study. Of the few predators that were observed, the majority were likely juveniles due to their small size. Ninety percent of *Ocyurus chrysurus* observed were only one third of their maximum length, 60 cm (Deloach 2003). Four of the five *Cephalopholis fulva* recorded were less than half their maximum length, 40 cm, which is just barely reaching their sexually mature size of 20 cm (Deloach 2003). An AGRRA study conducted in the windward Netherland Antilles, including Saba with similar reef structure to that of Dominica, reported the highest proportion of predators in the 21-30 cm size class (Klomp 2003). This suggests that the predatory fishes in Dominica are smaller when compared to those found in reefs on other islands. Although numbers are low and sizes are small, it is evident that populations of predators do exist in Dominican reefs but just not as large adults. It is likely that the fishes are not reaching their full size because humans are removing them as a source of food early on in their life stages. At Salisbury East and Champagne spear fishermen were seen within 25 m of the transect area and 2 fish pots containing fish were also observed at Salisbury East. This extraction is especially detrimental to the future of fishing if the population is not allowed to reach sexual maturity.

Herbivores consisted of 77% of fish surveyed. This is a higher percentage than was reported by Kramer (2003) comparing 20 sites across the Caribbean that showed 60% of total fishes were herbivores. Herbivorous fishes naturally occur in greater numbers than predators due to the structure of the tropic pyramid. However, in Dominica this occurs to a greater extent. The high proportion of herbivores was consistent across all eight sites demonstrating this is representative of Dominican fish assemblages. Batali was the exception where lower numbers of Acanthurids and higher numbers of Lutjanids were observed. Not only was the abundance of herbivores relatively high but some of the smaller herbivorous species were also slightly above average in length. For example, *Microspathedon chrysurus* usually range in size between 10-15 cm (Deloach 2003) and in this survey 75% of them were above 10 cm. Most of the larger herbivorous fishes were average or slightly below average in length. *Scarus vetula* can reach a maximum length of 61cm (Deloach 2003), however all *S. vetula* observed in this study were less than 40 cm in length. A plausible explanation for this is the larger herbivores such as *S. vetula* are being fished along with the predators, decreasing the competition for resources such as food and space between other herbivores. This allows the smaller herbivores like *M. chrysurus* to grow to above average lengths.

Pomacentridae play a big role in the make up of reef fish assemblages, shown by its representation during the RDCs regarding its abundance, number of species, and frequency observed. Pomacentrids can easily adapt to different habitats (Deloach 2003) and their function as herbivores, which naturally exist in greater numbers, explains their presence on Dominican reefs. Acanthurids, which eat a wide variety of plants, regularly graze for food over sandy patches and seagrass beds up to 15 m from the reef's perimeter (Deloach 2003). Macoucheri, Cachacrou, and Calibishie all had seagrass within the immediate vicinity and all eight sites included sandy patches ideal for surgeonfish grazing. These habitat factors, in addition to the fact that Acanthurids are a common reef fish (Deloach 2003) explain the family's dominance in Dominica's fish assemblage.

It was interesting to note that the greatest species richness, both recorded during RDCs and during belt transects, was located at the two sites (Cachacrou and Champagne) situated inside the Soufriere and Scotts Head Marine Reserve (SSMR). These two sites only exhibited the third and fourth highest fish densities. However, the density of fishes in the two larger size classes (21-30 cm and 31-40 cm) was noticeably greater at the two SSMR sites. It is likely that two variables contributing to these sites' unique fish populations in terms of richness and size are habitat and inclusion in a marine reserve. Both Cachacrou and Champagne have more extensive reef habitats than most of the other six sites surveyed. The substrate was less fragmented by sandy regions and it covered a greater area than at other sites surveyed. Cachacrou had a seagrass bed nearby and was bordered by a deep bay, ~1000 m deep. This type of complex structure allows for more microhabitats and thus a more diverse range of species can occupy the space. A result of the area's designation as a marine reserve is that fishing is regulated to a certain extent by the allocation of a specific zone for fishing, which may explain why the fish observed here were larger than at other sites.

Due to the volcanic nature of Dominica, the island has a limited area of reef environment. It is possible that the type of reef system that exists on Dominica contributed to the small size of the majority of predators and some of the herbivores observed in this study. However, it is evident that over-fishing plays a large role in the composition of Dominica's fish assemblages. Data collected in this study is a first step in assessing what type of management plan should be implemented to sustain Dominica's reef fishes. A potentially interesting aspect to investigate in the future would be whether the sites in the SSMR continue to exhibit high species richness and larger size classes of certain species. The Scott's Head area was only recently designated as a marine reserve in 2001. Comparing the data in this survey to data collected in the future may indicate the effectiveness of the marine reserve.

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References

Behrents K (1984) The influence of fish predators on the distribution and abundance of *Diadema antillarum*.

Bellwood D, Hughes, T, Folke C, Nystrom M (2004) Confronting the coral reef crisis. Nature 429:827-832

Byrd K (2005) Study V: A Rapid Assessment of the Stony Corals and Algae in Dominica, Lesser Antilles. ITME Reports 23 (I-VII):53-63

Deloach N, Humann P (2003) Reef fish behavior Florida Caribbean Bahamas, New World Publications Inc.: Jacksonville FL

Humann P, Deloach N (2002) Reef coral identification Florida Caribbean Bahamas, New World Publications Inc.: Jacksonville FL

Klomp K, Kooistra D (2003) A post-hurricane, rapid assessment of reefs in the Windward Netherlands Antilles (Stony Corals, Algae and Fishes). In: Lang J (ed) Status of Coral Reefs in the Western Atlantic: Results of Initial Surveys, AGRRA program. Smithsonian Institutions Press Washington D.C., pp 405-432

Kramer P, Lang J, Marks K, Garza R, Ginsburg R (2005) Atlantic and Gulf Rapid Reef Assessment protocol v. 4.0

Kramer P (2003) Synthesis of Coral Reef Health Indicators For The Western Atlantic: Results of The AGGRA Program (1997-2000). In: Lang J (ed) Status of Coral Reefs in the Western Atlantic: Results of Initial Surveys, AGRRA program. Smithsonian Institutions Press Washington D.C., pp 1-58

Lowe A (2005) Study VII: A rapid assessment of coral reef fishes in Dominica, West Indies. ITME Reports 23 (I-VII):77-91

Scheffer M, Carpenter S, Foley J, Folkes C, Walker B (2001) Catastrophic Shifts in Ecosystems. Nature 413:591-596

Study VII: A rapid assessment of coral reef fishes in Dominica, West Indies.

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Abstract

Coral reef fish assemblages were assessed at 10 sites in Dominica, an island in the Lesser Antilles. The sites were located in three regions of Dominica: North/East, West/Central and South. Surveys were conducted according to the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol version 4.0. At each site, ten 30 m belt transects were completed to quantitatively assess the abundance and size-frequency distribution of ecologically and commercially important species. Additionally, a 30 minute rover diver census was done in the same area as the transects to determine the species richness and relative abundance of fish on Dominican reefs. 106 species of fish from 32 families were observed in the rover diver census. A significant positive correlation was seen between live coral cover and species richness ($r = 0.653$, $p < 0.01$). Pomacentridae was the most abundant family. Size-frequency distributions of ecologically and economically important species showed high frequencies of small individuals in all families, especially in Lutjanidae, Serranidae, Scaridae and Haemulidae. The paucity of large individuals from all families indicates a high level of fishing pressure on Dominican reefs. This was the first AGRRA survey conducted in Dominica. It provided valuable information to the AGRRA database as well as serving as a baseline of reef fish community structure for future studies in Dominica.

Keywords Rapid Reef Assessment, Reef Fish, Dominica, Over-fishing

Introduction

Dominica is a small volcanic island, approximately 751 km^2, in the Lesser Antilles (Honychurch 1995). It is characterized by tall, steep mountains and a narrow coastal shelf. The coral reefs growing around the island are greatly affected by the topography of the shelf. Rapid increases in depth restrict corals to shallow, near-shore areas where the light necessary for photosynthesis is available. Coral assemblages growing near shore are more susceptible to natural and anthropogenic disturbances because there is little buffer area to protect them. Wave energy from storms hits the reefs and displaces corals. Displaced corals are likely to be washed ashore or into deeper water where they cannot re-grow. Seasonal rains also affect the reefs through run-off that carries large amounts of sediment into the water. Zooxanthellae, the symbiotic algae living within the coral polyps, are shaded by the sediment and cannot photosynthesize, resulting in slow growth and recovery from damage. Due to the high frequency of disturbance reefs are subjected to in Dominica, coral accretion is restricted to only a few sites around the island, the largest of which occurs in the Grand Savane area on the west coast. Other reef types are typically small coral assemblages on slabs of rock or boulders that have fallen from the cliffs.

Human development in Dominica is concentrated along the west coast. The two main ports for cruise and cargo ships are located there, along with most of the population. Development of the coast increases the amount of pollutants entering the water. These pollutants include silt from road construction and quarries, hazardous materials like bleach and garbage, and pesticides from farms. People's direct physical interaction with the reef increases in the form of swimming, SCUBA diving tourism and fishing. Increasing anthropogenic disturbances can act to exacerbate natural disturbances and degrade the reef ecosystem.

Reef fishes depend on the coral reefs for food and shelter. Dominica has naturally low populations of fish because the limited reefs cannot support a large biomass of individual species (Mohan 2001; McDonald 2003). Reef fish are an important and inexpensive source of protein for Dominicans. Fishing in Dominica is mainly artisanal, the fish is either sold or consumed the same day it is caught. While the demand is low, over-fishing is still a concern for Dominicans because of the naturally low abundances of fish. The local fishing techniques, which include beach seines, fish traps and spearfishing, concentrate effort on near-shore fishes. Species targeted by fishermen are lutjanids (snappers), serranids (seabass), scarids (parrotfishes), haemulids (grunts) and acanthurids (surgeonfishes). These fish are a vital component of the coral reef ecosystem. It is estimated that herbivorous fishes consume between 50 and 100 percent of the primary production in tropical reef environments (Deloach and Humann 2003). Grazing clears areas for new settlement and greatly influences the types, abundances and biomass of algae on reefs (Deloach and Humann 2003; Ginsburg and Lang 2003), while the predatory fish act to control herbivore populations. Removal of herbivorous and predatory fishes has been linked to community phase shifts from coral to algae dominated systems (McCook 1999). When macroalgal cover increases due to reduction in grazing, it can suppress the abundance of herbivorous fish and corals (McClanahan et al. 1999). This would result in the loss of economically important species like parrotfish, surgeonfish and the larger predators, such as snappers, that Dominican fishermen rely on.

Evidence of the declining health of reefs worldwide called for a standardized survey that enabled a quantitative comparison of different regions (Kramer 2003). The development of the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol addressed this need. Originally designed to assess coral community structure and health, the protocol was later amended to include quantitative observations on algal functional groups, fish densities and herbivory.

This study implemented the AGRRA protocol for the first time in Dominica. The goal of this study was, first, to quantify the reef fish community structure by recording all species seen and estimating the relative abundance of each and secondly, to assess the status of economically and ecologically important species by quantifying abundance and estimating size-frequency distributions of families. This data presents a picture of the current fish community on Dominican reefs that can be compared to AGRRA data from other areas in the Western Atlantic. Within Dominica, the data will be important for management and future monitoring of this sensitive resource.

Methods

A total of 10 sites were surveyed in Dominica between 18 October and 13 November 2005 to assess the reef fish assemblage. The sites were located in 3 regions of Dominica: North/East, West/Central, and South (McNeal 2005). All sites shallower than 5 m were surveyed by snorkeling, while sites deeper than 5 m used SCUBA. Exceptions were Rodney's Rock, where snorkeling transects exceeded 5 m depth, and Batali, Champagne and Cachacrou, where SCUBA transects were shallower than 5 m. Site descriptions for SCUBA sites (Salisbury west, Rena's Reef, Brain, Berry's Dream, Champagne and Cachacrou) can be found in McNeal (2005). Snorkel site descriptions for Calibishie, Fond Colé and Rodney's Rock are in Byrd (2005). All fish were identified *in situ* according to Humann and Deloach (2002). The surveys were conducted in accordance to the AGRRA protocol v. 4.0 (Kramer et al. 2005).

A single diver swam the 30 m belt transect and counted all target species (Table 1) within 1 meter of either side of the transect line. Size was estimated in classes: 0-5 cm, 6-10 cm, 11-20 cm, 21-30 cm, 31-40 cm and >41 cm. Sites were surveyed by conducting parallel transects 5 m apart, each at a constant depth. At all sites except Batali, Fond Colé, Rena's Reef and Berry's Dream, end-to-end transects were implemented to fit transects in the available reef area. Ten transects were run at each site for a total of 6000 m^2 of surveyed area.

A 30 minute rover diver census was conducted in the same area the transect survey took place. The diver identified all species seen using logarithmic categories to estimate their abundance. The categories of abundance were: Single (1 fish), Few (2-10 fish), Many (11-100 fish) and Abundant (>100 fish). Due to limited time while SCUBA diving, all of the rover diver censuses at the dive sites were done by a second diver. This data was submitted to Reef Environmental Education Foundation (REEF) database.

The rover diver census data was used to estimate the species richness and relative abundance for each site individually and all sites combined. Densities of target species listed in Table 1 were recorded. Size-frequency distributions of the 5 most abundant families (Scaridae, Acanthuridae, Haemulidae, Serranidae and Lutjanidae) and the species yellowtail damselfish (*Microspathodon chrysurus*) were used to characterize the fish communities of all sites. The distributions were also used to compare deep (greater than 7 m average transect depth) and shallow (less than 7 m average transect depth) communities. One-way analysis of variance (ANOVA) was used to compare average species richness between deep and shallow sites and between the two sites in the Scott's Head/ Soufriere Marine Reserve (SSMR) and all other sites combined (Larson and Farber 2000). Correlations between live coral cover, rugosity and species richness were tested using the Pearson correlation (Gravetter and Wallnau 2000). Benthic community parameters came from Jordan (2005), McNeal (2005), Wallover (2005) and Zuercher (2005).

Results

Rover Diver Census

106 species of fish representing 32 families were observed in 5 hours of rover censuses. Species richness ranged from 26 at Calibishie to 63 at Berry's Dream (Table 1). Deep sites had an average 53 species compared to 44 at shallow sites (ANOVA, F-value= 1.37, $p>0.05$). SSMR had an average 61 species, while all other sites combined had an average 48.1 species (ANOVA, F-value= 2.62, $p>0.05$). There was a significant positive

correlation between live coral cover and species richness ($r = 0.653$, $p < 0.01$). The correlation between rugosity and species richness was not significant ($r = 0.295$, $p > 0.05$).

Families with the highest number of species seen were serranids (15 identified, plus hamlet hybrids), pomacentrids (10 species), scarids (8 species), haemulids (7 species), labrids (7 species) and holocentrids (7 species) (Table 1). The most abundant family on Dominican reefs was Pomacentridae, with 7 of the 10 observed species were present at greater than or equal to 70% of the sites. Species with the highest estimated abundance were brown chromis (*Chromis multilineata*), bicolor damselfish (*Stegastes partitus*) and bluehead wrasse (*Thallasoma bifisciatum*) (Table 1). Of the 20 most commonly observed species, 10 were defined by AGRRA to be economically and ecologically important species. Scarids and acanthurids were most prevalent, followed by haemulids and the species yellowtail damselfish (*Microspathodon chrysurus*) (Fig. 1).

Belt Transects

1835 individuals of economically and ecologically important species were counted during 100 belt transects. The most abundant families were Scaridae, Acanthuridae, Haemulidae (Fig. 1). Members of Lutjanidae, Serranidae and the yellowtail damselfish were common, but in lower densities. Pomacanthids, chaetodontids, Balistids and individuals of the species Spanish Hogfish (*Bodianus rufus*) and Bar Jack (*Caranx ruber*) were rare. The largest proportion of each family was in the 11-20 cm size class (Fig. 2).

Sites with the highest fish density were Brain (54.17 fish/ 100 m^2), Champagne (45 fish/ 100m^2) and Cachacrou (35.67 fish/ 100 m^2) (Fig. 3). The high density of fish at Brain was primarily composed of haemulids, though scarids and lutjanids were also seen in relatively high densities (Fig. 4). Many of the sites were dominated by one family. The deep sites (Salisbury West, Rena's Reef, Brain, Berry's Dream and Cachacrou) were largely dominated by scarids, while the shallow sites (Calibishie, Batali, Fond Colé, Rodney's Rock and Champagne) had the highest densities of acanthurids (Fig. 4). Haemulids, scarids, lutjanids and acanthurids were seen in higher densities in the two SSMR sites (Fig. 6, 7). SSMR also had higher densities of a wider range of families and size classes (Fig. 4). Cachacrou and Champagne were the only sites in which individuals over 31 cm were seen (Fig. 6).

Differences in fish densities and size classes were seen between depths (Fig. 5). Deep sites had more individuals from all families, excluding Acanthuridae, in the 6-10 cm and 11-20 cm size classes. There were also slightly higher densities of individuals from Haemulidae, Scaridae, Serranidae, Lutjanidae and Acanthuridae in the 21-30 cm size class at deep sites. Yellowtail damselfish in the 11-20 cm and 21-30 cm size classes were observed in higher densities at shallow sites.

Table 1 List of all species observed in rover diver censuses and their respective abundance at each site. Asterisks indicate species defined by AGRRA to be economically and ecologically important. Sites are: 1- Salisbury West, 2- Calibishie, 3- Batali, 4- Fond Colé, 5- Rena's Reef, 6- Rodney's Rock, 7- Brain, 8- Berry's Dream, 9-Champagne, 10- Cachacrou. Species richness is listed at the bottom of each column.

Scientific Name	Common Name	1	2	3	4	5	6	7	8	9	10
Serranidae	**Seabasses**										
Cephalopholis fulva *	Coney	F	F	F	F	F	F	F	F	F	F
Hypoplectrus nigricans	Black Hamlet	F						S	F		S
Hypoplectrus chlorurus	Yellowtail Hamlet	F		S				F	F	S	F
Epinephalus guttatus	Red Hind	S							F	S	F
Serranus tigrinus	Harlequin Bass	M		M		M	S	M	M	M	M
Hypoplectrus puella	Barred Hamlet	F		F			S	M	M		F
Epinephalus adscensionis	Rock Hind			F			S		S		F
Hypoplectrus gummigutta	Golden Hamlet								S		
Cephalopholis cruentatus *	Graysby	F		F		F	F	F		F	F
Hypoplectrus guttavarius	Shy Hamlet							S		S	
Hypoplectrus unicolor	Butter Hamlet							S			
Serranus tabacarius	Tobaccofish	F		F		F					
Hypoplectrus indigo	Indigo Hamlet			S							
Rypticus saponaceus	Greater Soapfish			S							
Paranthias furcifer	Creolefish	F									
	Hamlet hybrid								F		F
Pomacentridae	**Damselfishes**										
Chromis multilineata	Brown Chromis	A		A	A	M	A	A	A	A	A
Stegastes adustus	Dusky Damselfish		M	M	M		F	F	F	M	M
Stegastes planifrons	Threespot Damselfish	F		F			S	M	F	F	M
Stegastes variabilis	Cocoa Damselfish	S	S	S					F	F	M
Stegastes partitus	Bicolor Damselfish	A	M	A	M	A	M	A	M	A	A
Chromis cyanea	Blue Chromis	M		M		M	M	A	M	M	M
Abudefduf saxatilis	Sergeant Major	M	F	M	M	A	M	F	M	A	M
Microspathedon chrysurus *	Yellowtail Damselfish	F	M	M	M	M	M	F	M	F	F
Stegastes diencaeus	Longfin Damselfish									S	
Stegastes leucostictus	Beaugregory									S	F
Scaridae	**Parrotfishes**										
Scarus taeniopterus *	Princess Parrotfish	M		F	F	F	F	M	F	M	M
Scarus iserti *	Striped Parrotfish	M		F	F	M	F	M	F	M	M
Sparisoma aurofrenatum *	Redband Parrotfish	F	S	F	F	M	M	M	F	M	M
Sparisoma chrysopterum	Redtail Parrotfish		F	F				S	F	F	
Sparisoma rubripinne	Yellowtail Parrotfish		F	F					F	F	F
Sparisoma viride *	Stoplight Parrotfish	M	F	F	F	S	M	F	M	M	M
Scarus coerulus	Blue Parrotfish	F						S			
Scarus vetula *	Queen Parrotfish						F	S	S	F	F

Scientific Name	Common Name	1	2	3	4	5	6	7	8	9	10
Labridae	**Wrasses**										
Bodianus rufus *	Spanish Hogfish		M	F			F		F		F
Clepticus parrae	Creole Wrasse	M		F		F	M	A	M	M	A
Thallasoma bifisciatum	Bluehead Wrasse	M	A	M	M	M	F	M	M	M	M
Halichoeres garnoti	Yellowhead Wrasse	M		M		M	S	M	M	M	M
Halichoeres radiatus	Pudding Wife		F	F	F				S	S	
Halichoeres bivittatus	Slippery Dick		M							S	F
Halichoeres maculipinna	Clown Wrasse		M			F				F	F
Haemulidae	**Grunts**										
Haemulon flavolineatum *	French Grunt	M		M	M	F	F	M	M	M	M
Haemulon plumierii	White Grunt	S						F	M		
Haemulon chrysargyreum	Smallmouth Grunt	F		M	M	F	M	M	M	M	M
Haemulon cardonareum	Caesar Grunt				F			F			
Haemulon macrostomum	Spanish Grunt				F		S	S			
Haemulon sciurus *	Bluestriped Grunt				F						
Haemulon striatum	Striped Grunt			F							
Holocentridae	**Squirrelfishes**										
Sargocentron bullisi	Deepwater Squirrelfish							S			
Myripristis jacobos	Blackbar Soldierfish	M		M	M	S	M	M	M	A	M
Holocentrus rufus	Longspine Squirrelfish	F							M	F	M
Neoniphon marianus	Longjaw Squirrelfish							F			
Sargocentron vexillarum	Dusky Squirrelfish	S	S		F			F			
Holocentrus adscensionis	Squirrelfish	F	F	M	M	F	F	M	M	F	M
Sargocentron coruscum	Reef Squirrelfish										S
Chaetodontidae	**Butterflyfishes**										
Chaetodon aculeatus	Longsnout Butterflyfish					F		F	F	F	F
Chaetodon capistratus *	Foureye Butterflyfish					F		S	F	F	
Chaetodon striatus	Banded Butterflyfish	F	S		S		F			F	
Chaetodon sedentarius	Reef Butterflyfish			S							F
Chaetodon aya	Bank Butterflyfish	F		S							F
Lutjanidae	**Snappers**										
Lutjanus analis *	Mutton Snapper						M	M		M	S
Ocyurus chrysurus *	Yellowtail Snapper	F					F		F	F	M
Lutjanus mohogoni *	Mahogany Snapper	F	F	M	F		F	M	F	M	M
Lutjanus apodus *	Schoolmaster							S			
Tetraodontidae	**Puffers**										
Sphoeroides spengleri	Bandtail Puffer					F			F		
Canthigaster jamestyleri	Goldface Toby	F									
Canthigaster rostrata	Sharpnose Puffer	M		F	F	M	F	M	M	M	M
Coryphopterus ;i[ernes	Masked/ Glass Goby									M	
Acanthuridae	**Surgeonfishes**										
Acanthurus coeruleus *	Blue Tang		F	M	M	F	F	M	M	M	M
Acanthurus bahianus *	Ocean Surgeonfish	F	M	M	M	M	M	M	M	M	M
Acanthurus chirurgus *	Doctorfish		M	M	F				M		M
Pomacanthidae	**Angelfishes**										
Holocanthus tricolor *	Rock Beauty	S		S			S	S	F	S	S
Pomacanthus paru *	French Angelfish						F				
Holocanthus ciliaris	Queen Angelfish						S				

Scientific Name	Common Name	1	2	3	4	5	6	7	8	9	10
Ostraciidae	**Boxfishes**										
Lactophrys triqueter	Smooth Trunkfish	F		F		M		F	F	F	F
Acanthostracion polygonia	Honeycomb Cowfish	S			S	S			S	F	
Lactophrys bicaudalis	Spotted Trunkfish								S		
Diodontidae	**Porcupinefishes**										
Dionon holocanthus	Balloonfish	S					S		S		
Chilomycterus antillarum	Web Burrfish					S			S		
Diodon hystrix	Porcupinefish				S						
Balistidae	**Triggerfishes**										
Melichthys niger *	Black Durgon	F		F		M		S	F	M	
Balistes vetula	Queen Triggerfish								S		
Mullidae	**Goatfishes**										
Pseudopeneus maculatus	Spotted Goatfish	F	S	M	F	F	F	F	M	F	M
Meulloidichthys martinicus	Yellow Goatfish			M	F		F	M	M	M	F
Sciaenidae	**Drums**										
Pareques acuminatus	Highhat								F		
Equetus punctatus	Spotted Drum	S				S			F	S	S
Monacanthidae	**Filefishes**										
Cantherhines pullus	Orange Spotted Filefish		S	F	F	F	F		F	F	F
Aluterus scriptus	Scrawled Filefish									S	
Blenniidae	**Blennies**										
Opioblennius macclurei	Redlip Blenny		M	F	F						
Starksia nanodes	Dwarf Blenny									S	
Exocoetidae	**Halfbeaks**										
Hemiramphus brasiliensis	Ballyhoo						M				
Hemiramphus balao	Balao										M
Aulostomidae	**Trumpetfishes**										
Aulostomus maculatus	Trumpetfish	F	S	M	M	M	F	M	M	F	M
Synodontidae	**Lizardfishes**										
Synodus intermedius	Lizardfish			S		S	S	S	F	S	F
Cirrhitidae	**Hawkfishes**										
Amblycirrhitus pinos	Red-spotted Hawkfish			S		F			S	S	
Bothidae	**Lefteye Flounders**										
Bothus lunatus	Peacock Flounder			S		S		S			
Muraenidae	**Morays**										
Gymnothorax miliaris	Goldentail Moray					S	S			F	
Malacanthidae	**Tilefishes**										
Malacanthus plumieri	Sand Tilefish			F							F
Priacanthidae	**Bigeyes**										
Heteropriacanthus cruentatus	Glasseye Snapper							F			
Congridae	**Conger Eels**										
Heteroconger longissimus	Garden Eels			M							
Dasyatidae	**Stingrays**										
Dasyatis americana	Southern Stingray								S		
Kyphosidae	**Chubs**										
Kyphosus sectatrix/ incisor	Chub										M
Opisthognathidae	**Jawfishes**										
Opisthognathies aurifrons	Yellowhead Jawfish										F
Species Richness	**106**	**47**	**26**	**54**	**34**	**40**	**44**	**55**	**63**	**62**	**60**

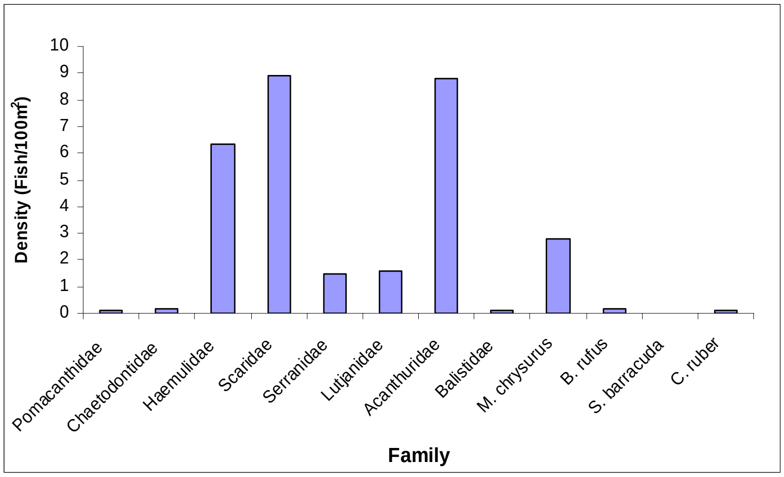

Fig. 1 Density of economically and ecologically important species at all sites combined.

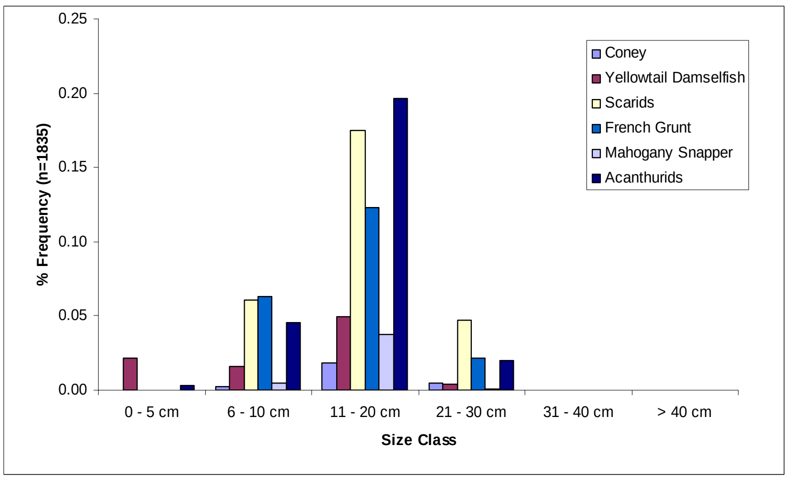

Fig. 2 The most frequently observed ecologically and economically important species. Four species of parrotfish are grouped as parrotfishes: redband parrotfish (*Sparisoma aurofrenatum*), stoplight parrotfish (*S. viride*), princess parrotfish (*Scarus taeniopterus*) and striped parrotfish (*S. iserti*). Ocean surgeonfish (*Acanthus bahianus*) and blue tang (*A. coeruelus*) were grouped as surgeonfishes.

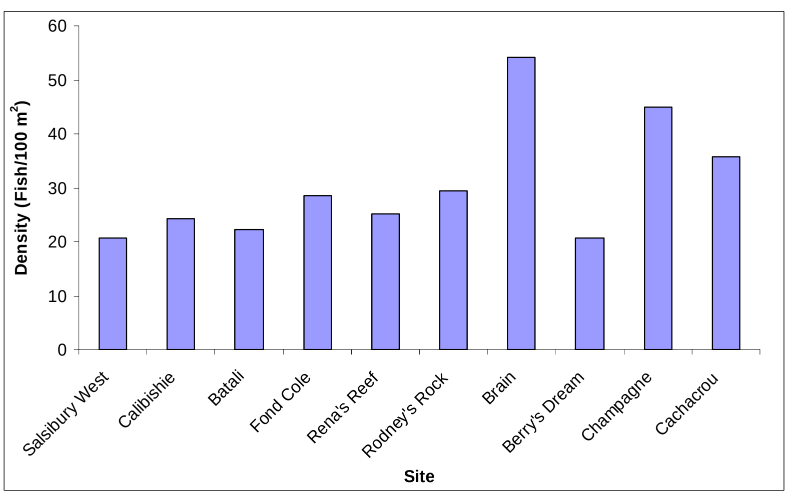

Fig. 3 Mean density of all target species counted at each site.

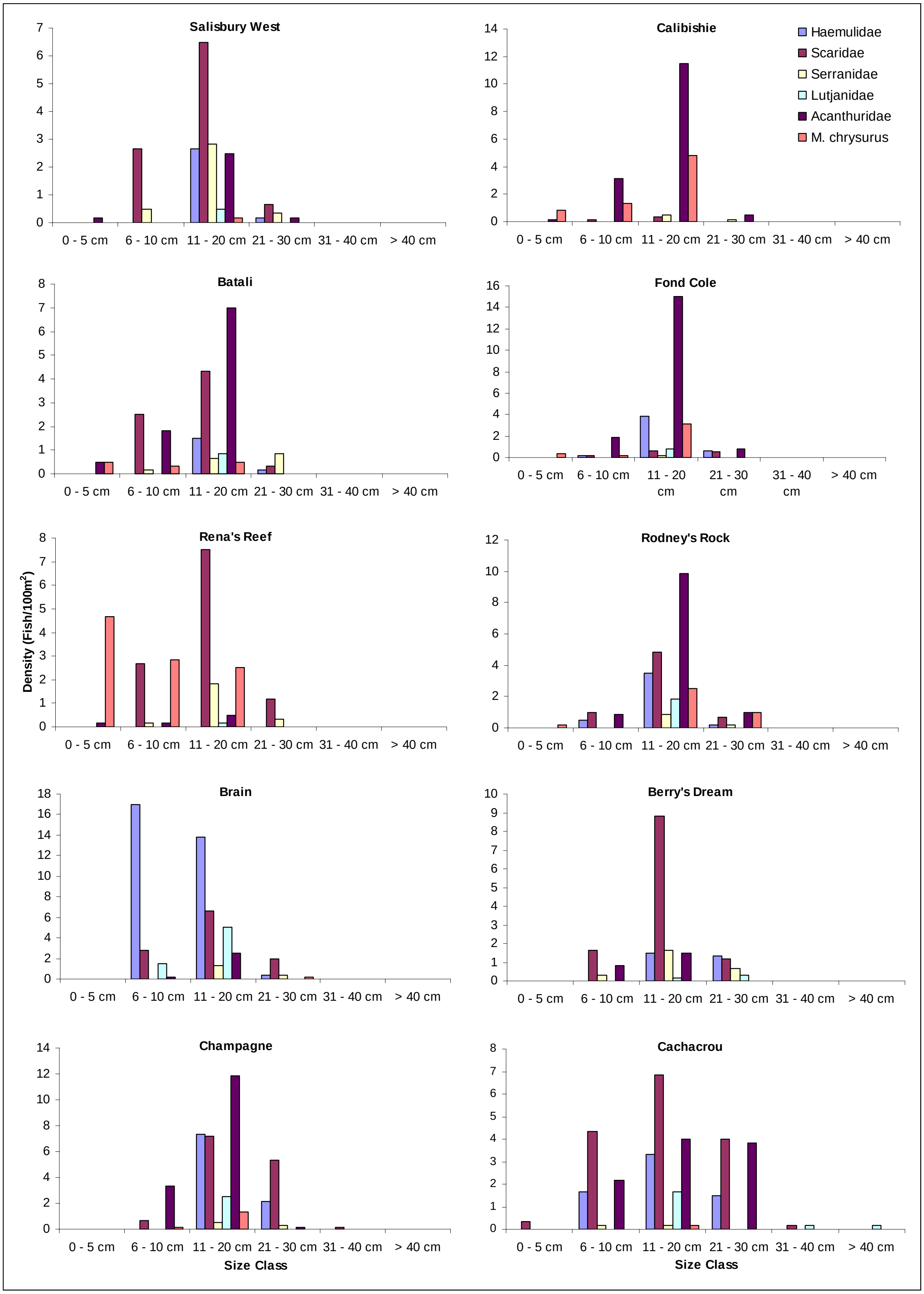

Fig. 4 Density of the 6 most abundant families of economically and ecologically important fish. Values are shown for all ten sites. Note varying scale on y-axis.

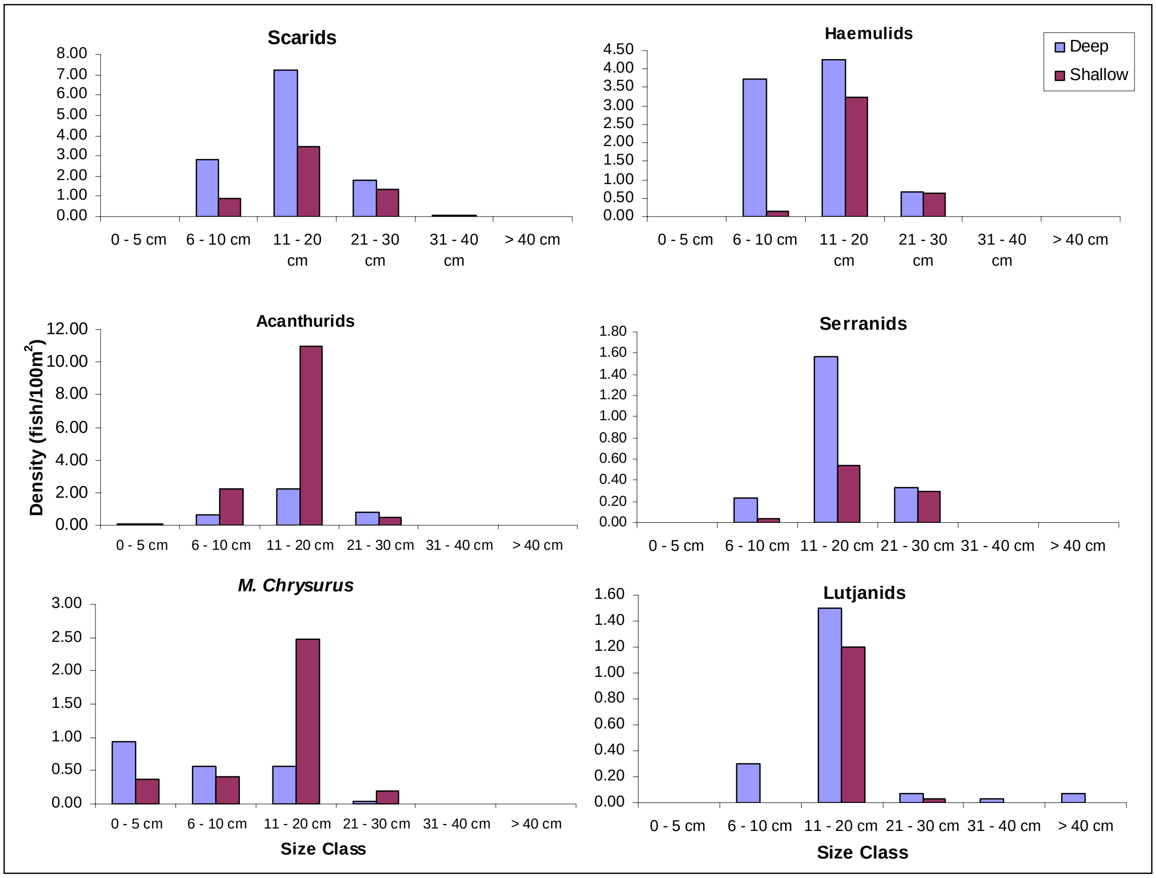

Fig. 5 Density of Herbivores (scarids, acanthurids, *M. chrysurus*) and Carnivores (haemulids, serranids and lutjanids) between deep and shallow sites. Note varying scale on y-axis.

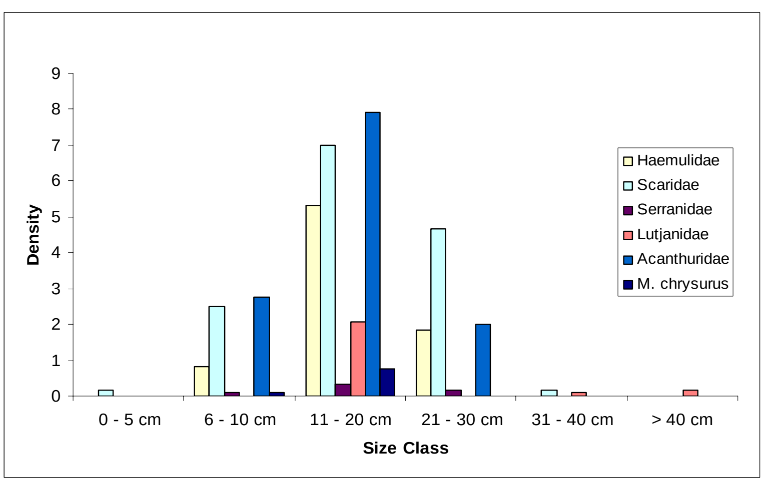

Fig. 6 Mean densities of important herbivores and carnivores at Scotts Head/ Soufriere Marine Reserve (SSMR) sites, Champagne and Cachacrou.

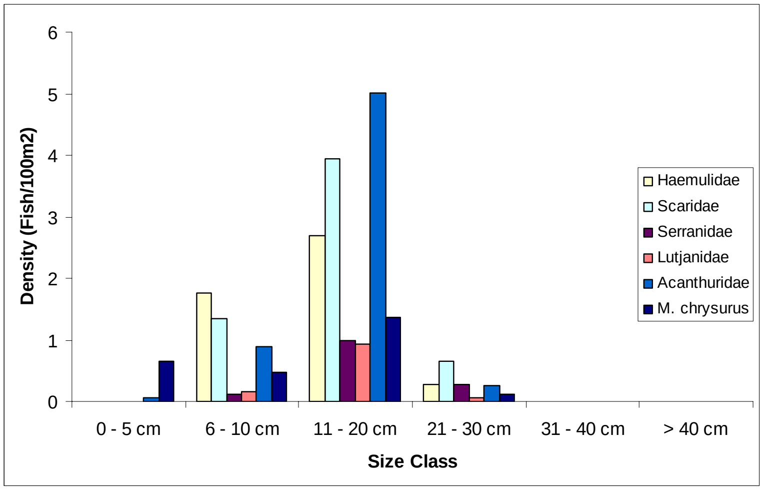

Fig. 7 Mean densities of important herbivores and carnivores at all sites excluding the SSMR sites.

Discussion

Corals reefs in Dominica have a relatively high species richness when compared to other young volcanic islands. A species richness of 81 was recorded in St. Vincent (Deschamps et al. 2003) and 142 for 4 islands in the windward Netherland Antilles (Klomp and Kooistra 2003). Many of the species observed in Dominica were in low abundance (Table 1). The variability of reef types in Dominica allows exploitation of different habitats, yielding high species richness, but the limited area of reefs keeps abundance low. Species that occurred in high abundances were planktivorous (brown chromis, sergeant major, creole wrasse) and herbivorous fishes (bluehead wrasse, acanthurids) that can move about the reefs, thus utilizing a larger area to feed. In a typical trophic pyramid, primary consumers are expected to be more abundant than tertiary consumers and predators. Low densities of predators on Dominican reefs may not exert enough predation pressure to control herbivores, resulting in the relative abundance of so many herbivorous species (Table 1). Interestingly, the most commonly abundant predator in roving surveys was the trumpetfish (*Aulostomus maculata*). Trumpetfish are not targeted by fishermen, and their long, slender body makes them less vulnerable to by-catch in fish traps and nets. Fishing reduces both competition between other predators and predation by larger fish, such as lutjanids, thus allowing trumpetfish to thrive (Deschamps *et al*. 2003).

Populations of economically and ecologically important species in Dominica are naturally low due to limited resources such as space and food. The concentrated fishing pressure has further reduced their numbers. Target species observed in this study were seen to have lower densities in Dominica than in other areas. Scarids had the highest densities in Dominica, but densities were much lower than those seen in St. Vincent and the Archipeliego de los Roques National Park in Venezuela (Deschamps *et al*. 2003; Posada *et al*. 2003). However, it is difficult to compare results between these studies as only a subset of all the species listed by AGRRA as economically and ecologically important were considered in the present study. The higher abundances noted in these protected areas could also be a result of fishing and usage restrictions, and overall reduced human impact. Klomp and Kooistra (2003) conducted a survey of reefs in Saba, an island with similar physical characteristics to Dominica. The main difference between the economically and ecologically important species observed in Saba and those seen in Dominica was their relative size-frequency distributions. The largest percentage of individuals from Scaridae, Serranide, Lutjanidae and Haemulidae observed in Saba fell in the 21-30 cm size class, while the majority of the individuals from these families seen in Dominica were in the 11-20 cm size class, with very few individuals over 21 cm. The reduction of larger size classes is an indicator of over-exploitation. Larger species are usually the first to be extracted, they have a greater response to exploitation due to life history characteristics, such as slow growth and time it takes to reach maturation (Graham *et al*. 2005).

The deeper sites in this study had higher densities of scarids, haemulids, lutjanids and serranids than the shallow sites (Fig. 5). Food availability is probably the determining factor in the abundances of acanthurids and yellowtail damselfish at the shallow sites (Lawson et al. 1999). Acanthurids and yellowtail damselfish both feed on the filamentous algae that grow in abundance in the shallows (Deloach and Humann 2003). It is interesting to note the abundance of small fish at the deep sites (Fig. 5). The paucity of small fish at the shallow sites could be due to indiscriminate harvest of fish by nets and fish traps. The deeper sites might offer refuge from these types of fishing pressure.

Many of the deeper sites were located on the true reef system around Grand Savane. High rugosity increases reef metabolism, and therefore the amount of energy available for higher trophic levels (Miller and Gerstner 2002). A weak correlation between rugosity and species diversity suggests this is not a major driving factor in reef fish community composition in Dominica. Deeper sites also had more live coral cover, which was positively correlated with species richness, indicating live coral cover is an important factor in habitat selection. The SSMR sites were seen to have higher densities, as well as a higher proportion of bigger individuals, than the other sites (Fig. 5, 6). Cachacrou and Champagne are part of a large reef system that can support higher abundances of fish. Located adjacent to a 900 m drop-off, these sites also have a deepwater refuge below the depth limits of common fishing techniques. Many lutjanids and carangids come from deeper water and the pelagos to feed over the reefs. The reduction in fishing pressure is a likely factor in the higher densities, especially the high densities seen across many familes, observed in SSMR.

While other natural factors are partially responsible for the low densities of fish seen on Dominican reefs, the lack of large, economically important species indicates over-fishing. The coral reefs in Dominica are an important, yet sensitive, resource. Correlation of species richness to live coral cover illustrates the interconnectedness between different components of the coral reef ecosystem. Successful management of this resource will require a comprehensive approach to protect of all of these components.

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References

Byrd K (2005) Study V: A Rapid Assessment of the Stony Corals and Algae in Dominica, Lesser Antilles. ITME Reports 23 (I-VII):53-63

Deschamps A, Desrochers A, Klomp KD (2003) A rapid assessment of the Horseshoe Reef, Tobago Cays Marine Park, St. Vincent, West Indies (stony corals, algae and fishes) In: Lang J (ed) Status of the coral reefs in the Western Atlantic: results of the initial surveys, Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program. (2003) Atoll Research Bulletin 496: 438-459

Deloach N, Humann P (2003) Reef fish behavior, 1st edition. New World Publications, Inc. Jacksonville, Florida

Ginsburg RN, Lang J (2003) Introduction. In: Lang J (ed) Status of the coral reefs in the Western Atlantic: results of the initial surveys, Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program. (2003) Atoll Research Bulletin 496: vii-xiii

Graham NAJ, Dulvy NK, Jennings S, Polunin NVC (2005) Size-spectra as indicators of the effects on coral reef fish assemblages. Coral Reefs 24: 118-124

Gravetter FJ, Wallnau LB (2000) Statistics for the behavioral sciences. Wadsworth/ Thomson Learning. 10 Davis Drive, Belmont, California

Honychurch L (1995) The Dominican Story: a history of the island. MacMillan Education LTD, London and Oxford, England.

Humann P, Deloach N (2002). Reef fish identification, Florida, Caribbean, Bahamas, 3rd edtion. New World Publications, Inc. Jacksonville, Florida

Jordan M (2005) Study I: Assessment of the coral reef community dtructure in Dominica, (Lesser Antilles). ITME Research reports 23(I-VII):5-16

Klomp KD, Kooistra DJ (2003) A post hurricane, rapid assessment of reefs in the windward Netherland Antilles (stony corals, algae and fishes). In: Lang J (ed) Status of the coral reefs in the Western Atlantic: results of the initial surveys, Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program. (2003) Atoll Research Bulletin 496: 404-437

Knuth K, McDonald K (2003) Introduction. ITME Research Reports 19 (2): 1-2

Kramer PA (2003) Synthesis of coral reef health indicators for the Western Atlantic: results of the AGRRA program (1997-2000). 1-55

Kramer P, Lang J, Marks K, Garza R, Ginsburg R (2005) AGRRA methodology v. 4.0: 9-10

Larson R, Farber B (2000) Elementary statistics: picturing the world. Prentice-Hall, Inc. Upper Saddle River, New Jersey 07458

Lawson GL, Kramer DL, Hunte W (1999) Size-related habitat use and schooling behavior in two species of surgeonfish (*Acanthurus bahianus* and *A. coeruleus*) on a fringing reef in Barbados, West Indies. Environmental Biology of Fishes 54: 19-33

McClanahan TR, Hendrich V, Rodrigues MJ, Polunin NVC (1999) Varying responses of herbivorous and invertebrate-feeding fishes to macroalgal reduction on a coral reef. Coral Reefs 18 (3): 195-203

McCook LJ (1999) Macroalgae, nutrients and phase shifts on corals reefs: scientific issues and management consequences for the Great Barrier Reef. Coral Reefs 18 (4): 357-367

McDonald K (2003) The abundance of herbivorous and predatory fishes in relation to *Diadema antillarum* along the west coast of Dominica. ITME Research Reports 19 (2): 11-21

McNeal J (2005) Study IV: Atlantic and Gulf Rapid Reef Assessment (AGRRA) of *Diadema antillarum*, coral recruits, and algal cover on Dominican reefs (Lesser Antilles). ITME Research Reports 23(I-VII):43-52

Miller MW, Gerstner CL (2002) Reefs of an uninhabited Caribbean island: fishes, benthic habitat, and opportunities to discern reef fishery impact. Biological Conservation 106: 37-44

Mohan E (2001) Fish species composition and size class distribution of Dominica, West Indies. ITME Research Reports 9 (2): 10-18

Posada JM, Villamizar E, Alavarado D (2003) Rapid assessment of coral reefs in the Archipielago de los Roques National Park, Venezuela (part 2: fishes). In: Lang J (ed) Status of the coral reefs in the Western Atlantic: results of the initial surveys, Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program. (2003) Atoll Research Bulletin 496: 530-543

Wallover N (2005) Study III: Rapid benthic assessment of reefs of Dominica, West Indies. ITME Research Reports(I-VII):32-42

Zuercher R (2005) Study II: Rapid assessment of stony coral community structure in Dominica, West Indies. ITME Research Reports 23(I-VII):17-31