PRELIMINARY SURVEYS OF NORTHERN REEFS OF DOMINICA, WEST INDIES

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Introduction

Dominica is a young volcanic island (26 million years old) in the central Lesser Antilles. The potential habitat for coral reefs is limited to the island's narrow shelf. Therefore, Dominica's corals grow close to shore and must endure associated stresses including sediment and fresh water runoff, coastal fishing pressure, and deleterious effects of coastal development.

Detailed quantitative studies of Dominica's coral reefs have only recently been carried out. Most of the sites studied were on the West coast of the island while only a few were on the East and Northeast coasts. The examination of northern reefs has thus far been limited to qualitative data. The following three studies aimed at providing insights into the reef communities of northern coastal areas. Unfortunately, the weather/sea conditions during the time allotted for these studies made it impossible to obtain quantitative data from Toucari Bay and Thibaut. Therefore, two West coast reefs were included in the studies in order to provide a preliminary comparison of North coast and West coast reefs. This report serves as a reference point for future investigations of Dominica's northern reefs.

In the first study, scleractinian species richness and relative abundances were assessed. Data collected was compared to previous studies done along the western and eastern coasts in order to illuminate differences in community structure. The second study was a census of six coral diseases, the species infected by each disease, and the size classes of colonies infected. The third study addressed the population density of *Diadema antillarum,* and its relation to algal cover and species richness.

Study Sites

Location 1: "Guyana Quartz" is located on the southern shore of the Cabrits National Park in Prince Rupert Bay. The shore is lined by quartz boulders, which are part of a man-made sea defense wall. A natural boulder field characterizes the benthos, which is interspaced by sand to about 30 meters off shore. Coral growth was noted throughout the first 20 meters from shore at a depth of approximately two meters, but reef accretion was virtually absent.

Location 2: Douglas Bay North is located to the North of Cabrits National Park, lined by a pebble beach and cliffs towards the North. There were boulders at two meters depth with limited coral growth.

Location 5: The site Capucin is located below the village of Capucin near the fisheries complex. A pebble beach marked the shoreline, which transitioned into a boulder-dominated benthos. Following the modest coral growth there was a transition to a few large boulders with higher coral growth 30 meters from shore surrounded by large areas of sand.

Location 6: Anse Soldat is located between Anse du Me and Calibishie, and is composed of a fringing reef which shelters a shallow sea grass bed (*Thallasia testudinum*). The northern end of the sea grass bed gradually transitioned into an area characterized of turf algae and the *Echinometra viridis*, followed by a pavement of old reef accretion (*Acropora palmata*). One hundred meters from shore large mats of *Polythoa caribeorum* and *Millepora* dominated the substrate in transition to the fore reef where *Diploria clivosa* and intermittent smaller colonies of *Diploria strigosa* cover most of the available substrate. In the shallow breaking zone the substrate was largely composed of small living colonies and large skeletons of recently killed *A. palmata* are at five meters depth.

Location 7: Hodges Bay is located between Calibishie and Woodford Hill. The bay was partially protected by a series of small islands on the eastern side. Directly off shore there was a progression from a sandy beach to an 80-meter wide sea grass bed primarily composed of *Syringodium filiforme* and *Thalassia testudinum*. The examined fringing reef was located 175 meters off shore on the leeward side of the islands. The reef crest was at one-meter depth and was made up of patchy assemblages of *Porites astreoides* and larger colonies of *Siderastrea siderea,* near the reef peripheries.

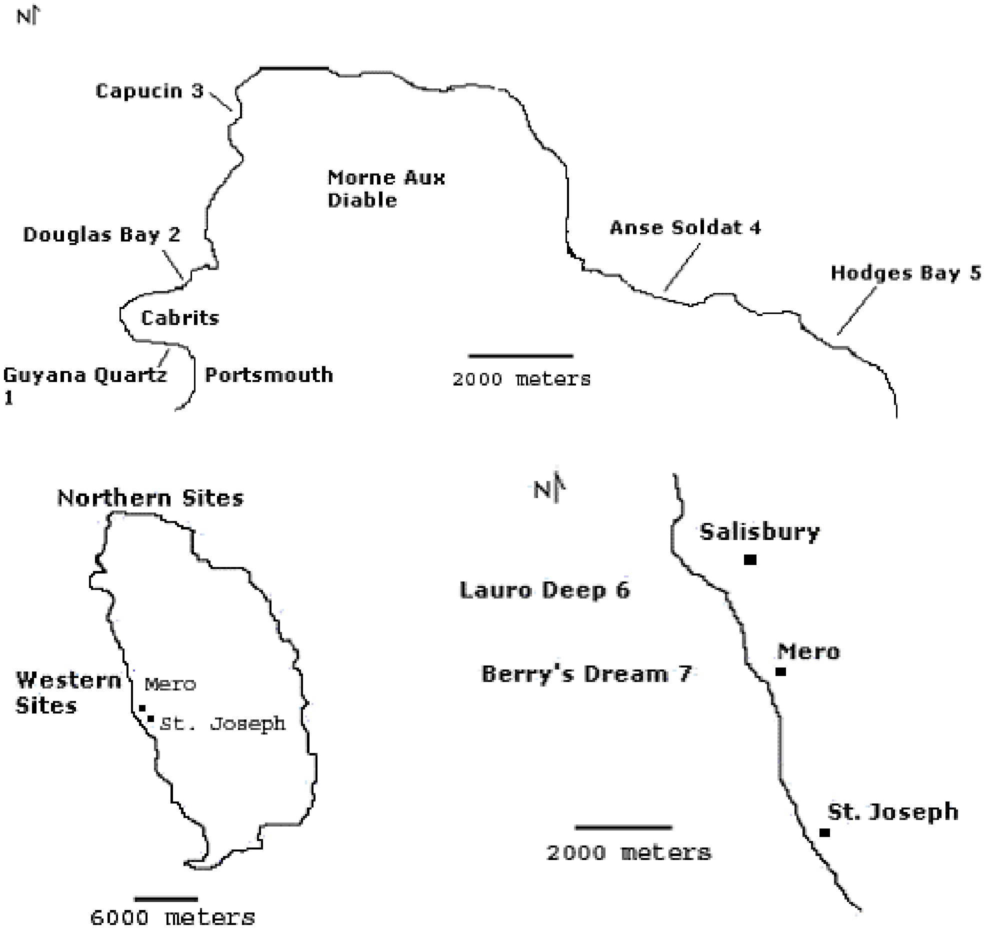

Fig. 1 Location of study sites, map by Shannon Baird, 2004

Study I: Coral Species Richness and Abundance of Northern Dominica

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Abstract The North coast of Dominica has not been previously studied in regards to coral community structure. In order to attain a more complete perspective of Dominica's reef systems five sites along the North coast (depths from 1 m to 2 m) were examined for scleractinia species richness, colony abundance, and live cover. Species richness varied from 6 to 15, percent cover varied from 0.6% to 38.6% m^{-2}, and species diversity varied from H'=1.15 to H'=2.04. A general trend reflected reefs dominated by *Porites astreoides* and *Siderastrea siderea*.

Keywords Coral reefs · community structure · species richness · northern Dominica

Introduction

Dominica is a relatively young volcanic island (26 million years) in the Lesser Antilles, and its mountainous terrain has only partially eroded and flattened out. The result has been a narrow coastal shelf, which provides limited substrate for coral settlement and formation (S Steiner, pers. com.). Despite Dominica's lack of extensive reef habitats, use of the reef environment as a resource is high. Inshore reef fishing by local fishermen is excessive, and ecotourism attractions such as snorkling and scuba diving are becoming a growing part of the Dominican economy. In addition, reefs are affected by chronic impacts related to terrain runoff (heavy rains) and coastal development. Because the reef environment is a limited resource, yet so important to the livelihood of Dominicans, it is critical to assess exactly what coral species are present and in what abundances so that reefs can be better defined and managed. This study is an assessment of species richness and live cover of scleractinians along the North coast of Dominica.

Coral reefs are important in terms of maintaining biodiversity in the marine environment (Lewis, 1960). Coral reefs provide reef fishes with habitat and resources they need to survive, and create an area that larger pelagic species utilize as a nursery. A multitude of invertebrate marine species make their living off of the reef, and corals provide shelter, suitable substrates, and resources that many species utilize for survival. Additionally, large marine animals such as turtles forage along reef, and depend on the environment that coral reefs provide. By surveying reefs, coral cover and abundance can be assessed more clearly and the biodiversity of an area can be monitored more carefully.
The data from this study can facilitate the identification of areas that need to be regulated in order to conserve the coral community in Dominica. Conservation of reefs is an integral part of utilizing it in a sustainable way, either as a fishing or tourism resource. Therefore, it is important for Dominica to have a thorough coral community structure census done throughout the entire island.

Because the northern coast of Dominica has had little work done quantifying the coral community present it is important that this area be surveyed. A baseline study of the

North will facilitate more in depth biological studies of the region that can be compared to the East and West coasts, thus providing a more complete picture of coral reef diversity and percent cover along Dominica's coasts.

Methods and Materials

Five sites along the Northern coast of Dominica (Guyana Quartz, Anse Soldat, Capucin, Douglas Bay and Hodges Bay) were surveyed for scleractinian presence and abundance. Sites were first visually inspected using snorkling equipment, and qualitative observations were made in order to determine the dimensions and orientation of the reef system. A 20 m transect line was laid parallel to shore on the central portion of the reef and a 1 m^2 quadrat was used to estimate the percent coral cover and the number of individual colonies for each coral species found within the quadrats. This was repeated at each site except Guyana Quartz (20 m^{-2}) resulting in a total surveyed area of 40 m^{-2} per site.

Scleractinian colonies of the same species that were approximately 4 cm apart were considered separate and counted independently. Additionally, coral species that made up less than 0.5% of the total area in a quadrat were marked as being present, but not included in the total cover. Shannon-Wiener Diversity Index based on colony occurrence was used to express species diversity (Shannon and Wiener, 1948).

At Capucin massive boulders with much more coral growth than the surrounding area were found intermittently along the coast. It was estimated that the boulders took up 10% of the reef area, and that the non-boulder area took up 90% of the reef area. The first transect was broken up into two 10 m lines, which were laid along two separate boulders. The second transect line was laid in the non-boulder area. In order to reduce a "boulder bias" in the data received, the data from the "boulder zone" and the "non-boulder zone" were partitioned in a 1:9 ratio respectively.

Results

Guyana Quartz had a mean coral cover of 12.9% m^{-2}, and a mean number of colonies of 14.0 m^{-2}. *Siderastrea siderea* dominated the site with a mean cover of 4.7% m^{-2}, and *Agaricia agaricites* was the most common coral having a mean number of colonies of 7.8 m^{-2}. Species diversity was H'=1.61.

Anse Soldat had the highest mean coral cover m^{-2} out of all sites surveyed (38.6% m^{-2}), and a mean number of colonies of 8.3 m^{-2}. *Diploria clivosa* dominated the reef with a mean cover of 29.6% m^{-2}, and in terms of number of colonies *Diploria clivosa* (3.8 colonies m^{-2}) and *Porites astreoides* (3.1 colonies m^{-2}) were prevalent. Species diversity was H'=1.22.

Capucin had the lowest coral cover (0.6% m^{-2}), and also had the lowest number of colonies (3.1 m^{-2}). *Porites astreoides* dominated the site in terms of coral cover (0.3% m^{-2}), and *Siderastrea radians* (1.8 m^{-2}) and *Porites astreoides* (0.7 m^{-2}) composed most of the individual colonies. Species diversity was H'=1.15.

Douglas Bay had a mean coral cover of 3.8% m^{-2}, and a mean number of colonies of 5.5 m^{-2}. *Siderastrea siderea* (1.4% m^{-2}) and *Porites astreoides* (1.0% m^{-2}) composed most of the coral cover, and *Porites astreoides* (1.8 m^{-2}) and *Siderastrea radians* (1.1 m^{-2}) made up most of the individual colonies. Species diversity was H'=2.04.

Hodges Bay had a mean coral cover of 5.7% m^{-2}, and the highest mean number of colonies (15.8 m^{-2}). *Porites astreoides* (3.2% m^{-2}) and *Siderastrea siderea* (1.4% m^{-2}) dominated in terms of coral cover, and *Porites astreoides* (9.4 m^{-2}) made up most of the individual colonies. Species diversity was H'=1.17.

Table 1 Species richness, species evenness, and Shannon-Wiener Diversity Index by site

Site	Species Richness (S)	Species Evenness (H'/lnS)	Shannon-Wiener Diversity Index (H')
Guyana Quartz	15.0	0.59	1.61
Anse Soldat	8.0	0.58	1.22
Capucin (boulder)	13.0	0.70	1.80
Capucin (non-boulder)	6.0	0.60	1.08
Capucin (partitioned)	6.7	0.61	1.15
Douglas Bay	14.0	0.77	2.04
Hodges Bay	9.0	0.53	1.17

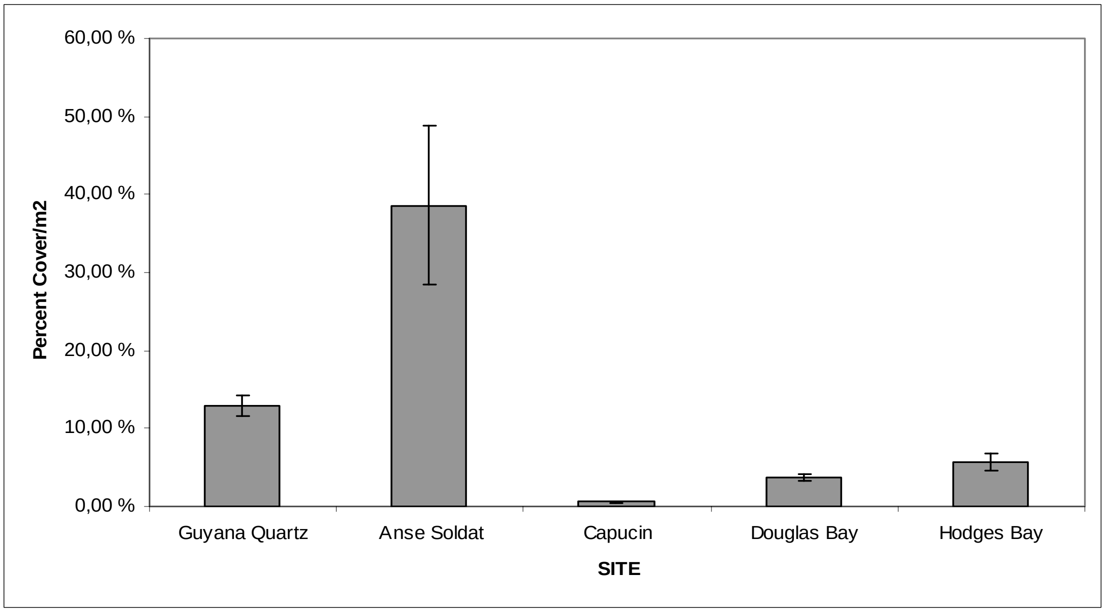


Fig. 1 Mean coral cover per m^{-2} by site

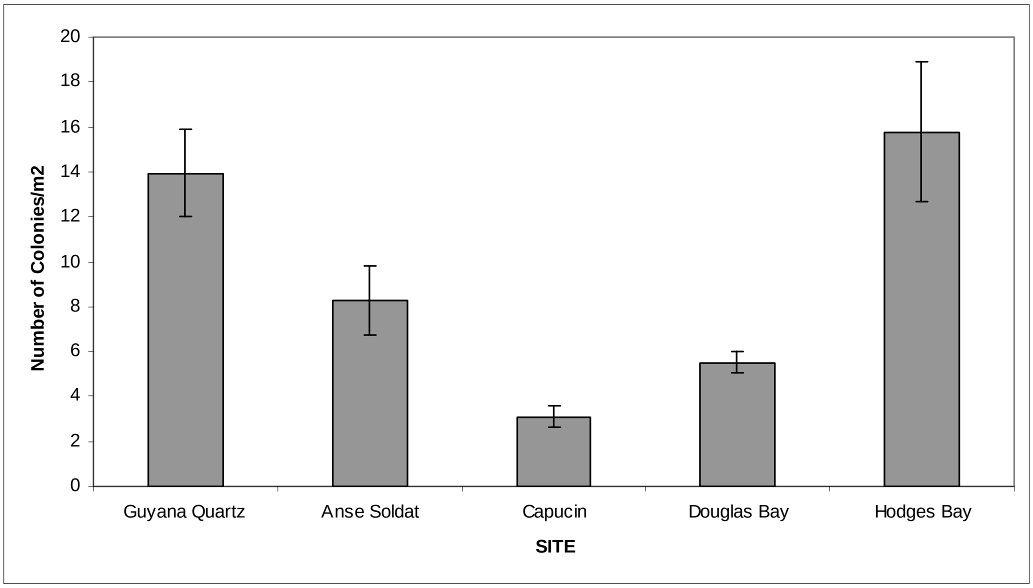


Fig. 2 Mean number of colonies per m^{-2} by site

Figs. 3-12: S.S. = *Siderastrea siderea*, M.A. = *Montastraea annularis*, M.C. = *Montastraea cavernosa*, A.A. = *Agaricia agaricites,* D.S. = *Diploria strigosa*, D.C. = *Diploria clivosa*, A.P. = *Acropora palmata*, M.F. = *Montastraea faveolata*, P.A. = *Porites astreoides*, P.P. = *Porites porites*, D.L. = *Diploria labyrinthformis*, M.D. = *Madracis decactus*, M.M. = *Madracis mirabilis*, S.R. = *Siderastrea radians*, F.F. = *Favia fragum*, M.M. (2) = *Meandrina meandrites*, D.S. (2) = *Dichocoenia stokesii*, I.S. = *Isophyllia sinuosa*, and C.N. = *Colpophyllia natans.*

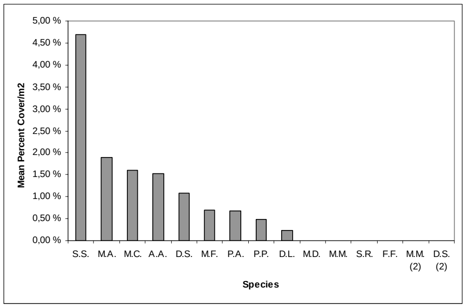


Fig. 3 Coral cover at Guyana Quartz
All corals less than 0.5 % in all quadrats were marked as present.

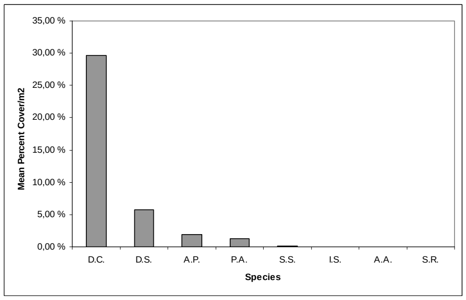


Fig. 4 Coral cover at Anse Soldat
All corals less than 0.5 % in all quadrats were marked as present.

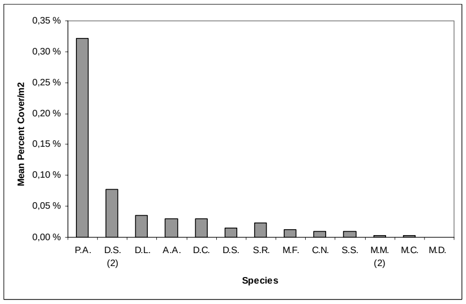


Fig. 5 Coral cover at Capucin
All corals less than 0.5 % in all quadrats were marked as present.

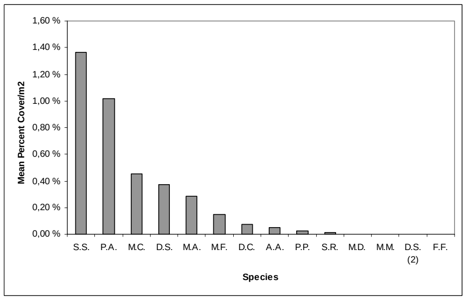
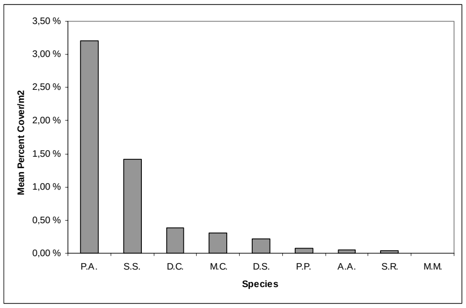


Fig. 6 Coral cover at Douglas Bay
All corals less than 0.5 % in all quadrats were marked as present.



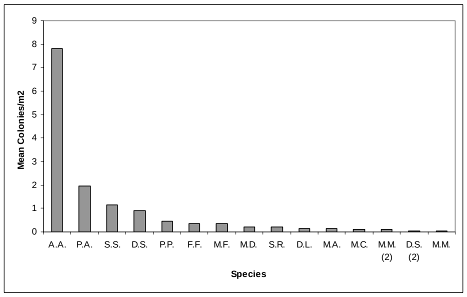
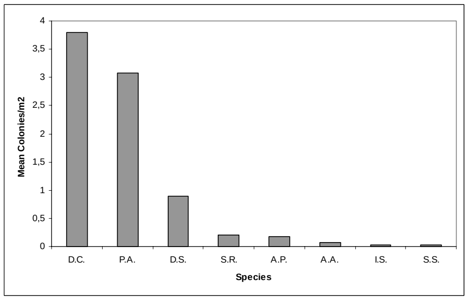


Fig. 7 Coral cover at Hodges Bay
All corals less than 0.5 % in all quadrats were marked as present.

Fig. 8 Coral colonies at Guyana Quartz



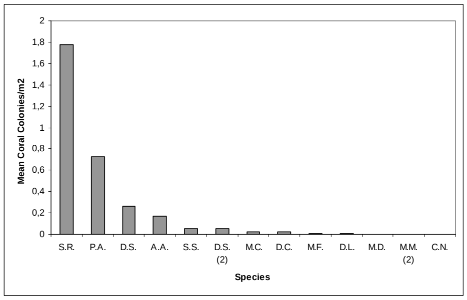
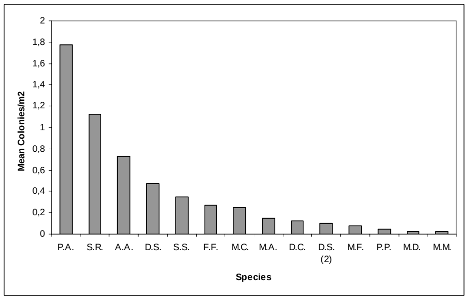


Fig. 9 Coral colonies at Anse Soldat

Fig. 10 Coral colonies at Capucin



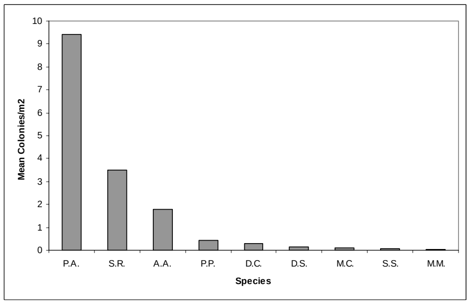


Fig. 11 Coral colonies at Douglas Bay

Fig. 12 Coral colonies at Hodges Bay

Discussion

There is a high variability in the coral cover along the North coast of Dominica. Sites such as Anse Soldat, where there is a well established fringing reef, there is high coral cover (38.6% m^{-2}). In contrast, sites like Capucin (0.6% m^{-2}) also exist where only small patchy reefs with little coral cover occur due to a lack of suitable substrate.

Species diversity also varied from site to site, but for the most part remained low (ranging from H’=2.04 to H’=1.15). Douglas Bay had the highest diversity (H’=2.04), and Capucin had the lowest (H'='1.15). Important to note is that a higher diversity did not coincide with either a high coral cover or a large number of colonies. Although Douglas Bay was the most diverse site, it did not have a high coral cover (3.8% m^{-2}) or many individual coral colonies (5.5 m^{-2}) in comparison to other sites surveyed. This brings into question what categories should best be used to define the health of a reef since diversity cannot simply be used as the sole criterion.

Porites astreoides or *Siderastrea siderea* consistently had high coral cover at all sites except Anse Soldat. At Guyana Quartz *S. siderea* had the highest cover, at Capucin *P. astreoides* had the highest cover, and at Douglas Bay and Hodges Bay both of them together made up most of the cover. Both of these corals together made up 55.4% of the total coral cover at all of the sites excluding Anse Soldat.

Overall *P. astreoides* was the most abundant coral colony. Although *P. astreoides* is the most abundant coral in only two sites (Douglas Bay and Hodges Bay), it is the second most abundant coral in the other three sites. The fact that *P. astreoides* made up much of the percent cover (22.8% of total coral cover excluding Anse Soldat) in all but one site, and also had many colonies at all sites is a testament to its nature as a generalist. *P. astreoides* is able to grow in a wide range of habitats, and withstand stressful conditions which makes for a hardy coral that seems to grow well in the North coast of Dominica (S Steiner, pers. com., 2004).

The North coast of Dominica may reflect some similarities to South Caicos Island, located in the southeastern Bahamian archipelago. South Caicos Island is a carbonate island with a wider shelf than Dominica, and was found to support forty different scleractinian species, of which *P. astreoides*, *S. siderea*, and *Dichocoenia stokesii* were the most abundant in all depth ranges (Steiner, 1999). Similar to South Caicos Island, *P. astreoides* and *S. siderea* were the most abundant corals along the North coast of Dominica, although *D. stokesii* was only found in small abundances. This finding suggests that these two coral species (*P. astreoides* and *S. siderea*) are characterized by a high level of plasticity, and are able to add substantially to reefs in different geographic ranges on both volcanic and carbonate islands.

Dominica's West and East coast reefal habitats have an overall live coral cover of 14.6%, and the most common coral found is *P. astreoides* comprising 29.7% of the total live cover. Along the West coast *Madracis mirabilis* and *Porites porites* are among the major reef builders and sometimes form mono- and bi-specific assemblages (Steiner, 2003), although *P. astreoides*, *S. siderea*, and *Montastraea faveolata* are the largest contributors to live coral cover (Knuth, 2003). The East coast has been discovered to be composed primarily of *Acropora palmata* frameworks, and reflect significantly lower live cover (9.25%) than the West coast (16.68%). Additionally, the East coast has a much lower coral diversity than the West coast (Steiner, 2003).

Anse Soldat was an interesting site that stood out from the rest of the areas surveyed. A well-established fringing reef was present that was mostly composed of large colonies of *Diploria clivosa* and *Diploria strigosa*, and spotted throughout the reef were large *A. palmata* colonies. Anse Soldat had the highest mean coral cover (38.6% m^{-2}), but a relatively low species diversity (H'=1.22). Similar to the East coast, this site reflected a fringing reef structure well adapted to shallow turbulent waters and was also the only site where *A. palmata* was found. The lower species diversity observed at Anse Soldat, and other East coast sites, may be due to the turbulent environment that these reef systems are exposed to allowing fewer species to survive. Anse Soldat may share some similarities with East coast sites since it is also exposed to the increased wave action from Atlantic waters. Although Hodges Bay was also located on the Northeastern shoreline of Dominica it was a more protected area (small islands along the peripheries of the bay) and may have provided a microhabitat more favorable for *S. siderea* and *P. astreoides* (Figure 7) rather than *D. clivosa*, *D. strigosa*, and *A. palmata*.

Comparing the West and East coasts to the North, *P. astreoides* was still observed to be the most common coral in many areas. The North coast sites surveyed, excluding Anse Soldat, had a mean coral cover of 5.7 % ± 5.2 %, and were most similar to West coast reefs in composition (*S. siderea* and *P. astreoides* most common). Although similar species were found in the North and the West, the North coast has a lower cover of corals.

In conclusion, the Northern coast of Dominica has a diverse array of reefs and coral habitats. Some areas have well established fringing reefs where true reef accretion occurred (Anse Soldat), and other areas are impoverished with corals and have only small patchy reefs (Capucin). Species diversity (H') does not seem to correlate with either coral cover or the number of colonies, and therefore cannot be used as the sole tool in determining the reefal health of an area. Despite the high variance observed from site to site, *P. astreoides* and *S. siderea* dominate the North, which reflects similarities to previous surveys done in the West.

References

Knuth K (2003) Scleractinian Monitoring in Dominica, West Indies: Species Richness, Diversity, and Live Cover. ITME Research Reports 19:3-10

Lewis JB (1960) The Coral Reefs and Coral Communities of Barbados, West Indies. Ca J Zool 38:1133-1145

Steiner SC (1999) Species Presence and Distribution of Scleractinia (Cnidaria: Anthozoa) From South Caicos, Turks and Caicos Islands. Bull Mar Sci 65(3): 861-871

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

Shannon CE Wiener W (1948) The Mathematical Theory of Communication. Univ Illinois Press, Urbana, Illinois, pp 117

Study II: Coral Disease and Coral Bleaching along the North and West Coasts of Dominica, West Indies

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Abstract Scleractinian diseases and bleaching have been studied for about 30 years. Black Band Disease, White Plague, Dark Spot Syndrome, Yellow Blotch Disease, Aspergillosis, and Coral Bleaching events have been identified and reported in the coral reef ecosystems of Dominica since 2000. This study aims to add to the knowledge base of these coral afflictions around Dominica. The data collected in this survey is from the north and west shores of the island. Height, widest diameter, disease symptoms, percent of diseased coral tissue, and the color differences between diseased and healthy coral tissue were recorded *in situ* within 113.10 m^2 at each of 6 locations. Data collection began in the last week of October 2004 and ended the third week of November 2004. Eighteen zooxanthellate species suffered from coral bleaching. Yellow Blotch Disease infections were found in *Montestraea faveolata* and *Montestraea annularis* colonies. *Siderastrea siderea* was found infected by Dark Spot Syndrome and White Plague. Black Band Disease infections were rare. *Gorgonia* spp were possibly infected by Aspergillosis.

Keywords Dominica · Scleractinia · Coral Disease · Coral Bleaching

Introduction

A disease is defined as interruption, cessation, or disorder of body functions, systems, or organs (Borger, 2003). Coral bleaching is the loss of symbiotic algae (zooxanthellae) or the reduction of the photosynthetic pigments of zooxanthellae (Deloach, 2002). Coral disease and coral bleaching can be greater sources of coral mortality than storm or hurricane events (Borger, 2003). Black band disease (BBD), dark spot syndrome (DSS), white plague (WP), yellow blotch disease (YBD), Aspergillosis (ASP), and coral bleaching (BLCH) events have all been identified as affecting scleractinians along the west coast of Dominica (Borger, 2003). Three major coral reef framework builders (*Montestraea faveolata*, *Montestraea annularis*, and *Siderastrea siderea*) have been identified as suffering from BBD, DSS, YBD, WP, or BLCH (Deloach, 2002; Goreau, 1998). All zooxanthellate species are susceptible to coral bleaching. The loss of major framework builders can cause phase changes within a reef ecosystem, or even complete loss of the coral reef community. Therefore, it is important to understand the distribution, causes, temporal dynamics, and virulence of coral diseases and coral bleaching as they represent an added stress factor on reefs already affected by local disturbances such as sedimentation, pollutants, and physical damage.

Research on coral reef diseases began in 1973 with the first description of BBD (Antonius, 1973). This affliction is a slimy, dark maroon to black band that moves across the surface of the coral colony. The band is made of a microbial community, which includes *Phormidium corallyticum*, *Beggiatoa* spp, *Desulfovibrio* spp, and other opportunistic organisms. In the Western Atlantic, 16 species of massive and plating corals and several gorgonians have been identified with this disease (Deloach, 2002; Goreau, 1998). It is believed that the consortium kills coral tissues by creating an oxygen-sulfur gradient, with high levels of oxygen near the coral tissue and high levels of sulfur near the bare skeleton.

Another disease that affects plating and massive corals is WP. Outbreaks of WP have occurred in the last 3 decades. At least 17 scleractinian species have been identified as being infected by WP, including *Siderastrea* spp, *Mycetophyllia* spp, *Dichocoenia stokesii*, and *Colpophyllia natans*. This affliction begins at the base of a colony and spreads upwards. A line of bleached tissue separates healthy tissue from bare skeleton. Two types of WP (I and II) have been identified. A bacterium in the genus *Sphingomonas* has been identified to cause WP type II (Deloach, 2002; Goreau, 1998).

Little is known about the cause of DSS. This disease appears as dark spots on the surface of the colony. This affliction occurs mostly in *S. siderea* and *Stephanocoenia intersepta* and has been reported in *M. annularis* complex. Spots on *S. siderea* may appear as pink, purple, blue, or brown. This condition was first reported in the 1990s and has since been identified throughout the Caribbean (Deloach, 2002; Goreau, 1998).

In 1994, YBD was first reported. YBD is known to infect *M. faveolata* and *M. annularis* colonies. This affliction begins as a yellow spot that becomes a yellow band as it slowly progresses over a colony. Bare skeleton is usually not found because of the slow spread of the infection. An YBD infection can last for several years. The cause of YBD has not yet been identified (Deloach, 2002; Goreau, 1998).

Aspergillosis is a common disease of *Gorgonia* spp. caused by the soil fungus *Aspergillus sydowii*. The symptoms appear as a dark purple discoloration. Nodules or tumors, called galls, may also form, but they are not indicative of the presence of Aspergillosis. Verification of this disease depends on the presence of white fungal filaments, but these are hard to observe *in situ* (Deloach, 2002; Goreau, 1998; Nagelkerken, 1997). In Dominica, *Aspergillus sydowii* has been isolated from Sahara dust carried over the Atlantic Ocean by trade winds (Y Deterés, pers comm).

Coral bleaching has been observed for over 100 years, but only in the last 3 decades has it been recorded. Coral bleaching occurs when the symbiotic zooxanthelle is expelled from the coral polyp. Since 1979, 6 major bleaching events have been recorded. Bleaching events can be caused by periods of temperatures 1°C higher than average for 3-4 weeks (Winter, 1998). Increased ultraviolet radiation, sedimentation, or changes in salinity and pollution may also cause bleaching (Deloach, 2002; Fitt, 1995; Robert, 2001; Buddemeier, 1993). In 2003, researchers at the Institute of Tropical Marine Ecology (ITME) recorded a bleaching event (S Steiner, pers comm) in which 25 species exhibited symptoms of bleaching. Bleached corals may be more susceptible to coral disease because of a lack of an essential symbiotic partner.

Thirty-six scleractinian species have been identified around Dominica. The species *M. faveolata*, *S. siderea*, and *M. annularis* are considered important framework builders, all of which have been identified as being affected by multiple coral diseases. In a study along the western shore of Dominica beginning in March 2000 and ending in August 2001, DSS and BBD both infected *S. siderea*. Coral diseases may thus induce the weakening or death of these framework species.

The effects of coral diseases can be increased by a synergistic combination of natural and anthropogenic stresses. Coastal development, sedimentation, pollution, eutrophication, changes in water temperature, physical damage, storm events, and poor land use also contribute to the mortality of scleractinians. All of these factors can be found to affect the corals reefs of Dominica. Dominica receives high amounts of rainfall, which imports sediment, pollutants, and excess nutrients from agriculture into the coral reef ecosystem. The development of a tourism industry is increasing coastal development and chronic physical damage. Fishing practices (e.g. fish pots, seine nets) lead to physical damage and overexploitation of reef fishes (H. Guiste).

In Dominica, the tourism industry and the fishing industry both rely on the presence and health of coral reefs. The government of Dominica is promoting the growth of a tourism industry, which includes the construction of hotels, increasing SCUBA diving, and increasing cruise ship calls. The government is promoting the growth of pelagic fishing; however, the fishing industry is mainly restricted to near shore fisheries due to a lack of technology and training for pelagic fishing.

Coral diseases affect the community structure of coral reefs. In Florida, an epidemic of White Band Disease caused a phase change from branching corals to foliose corals. Changes in community structure can affect the human populations that rely on the coral reefs for economic purposes. In Dominica, coral diseases have been identified along the west coast of the island (Borger, 2003), but very little research of any kind has been done along the northern shore. This study provides the first data on the occurrence of BBD, DSS, WP, YBD, and WP and coral bleaching along the north coast, and additional on the west coast.

Methods and Materials

Six sites along the northern and western shores of Dominica (Anse Soldat – 2 m depth, Capucin – 4 m depth, Douglas Bay North – 4 m depth, Hodges Bay - < 1 m depth, Barry's Dream - 9 m depth, and Lauro Club – 9 m depth) were quantitatively surveyed for coral disease occurrence. Four additional sites along the west coast (Champagne - 5 m depth, Brain Reef - 15m depth, and Maggie's Point - 15 m depth) and one site along the northwest coast (Guyana Quartz - 4 m depth) were also qualitatively examined for coral disease presence. All sites with depth greater than 5 m were surveyed or examined by SCUBA diving.

Four surveys were carried at Capucin, Douglas Bay North, Hodges Bay, and Barry's Dream providing a study area of 113.10 m^2 for each location. A central point was chosen at random, and three concentric circles centered on the chosen point with increasing radii of 1, 2, and 3 meters were used to determine an area of 28.27 m^2. Only 3 sets of circles were performed at Anse Soldat, providing a study area of 84.82 m^2. At Lauro Club, due to time constraints, only 2 sets of circles (56.54 m^2) were carried out. For each scleractinian colony exhibiting disease or bleaching symptoms within the study area, the following was recorded: (a) widest diameter, (b) height, (c) disease symptoms exhibited, (d) an estimation of diseased surface area, (e) an estimation of algal overgrowth, (f) an estimation of bare skeleton exposed, (g) color of healthy and diseased coral tissues

A coral colony had to be entirely within the circle to be included. Color was determined by comparison with the Coral Watch bleaching color chart (Jennings, 2003). Other anthozoans (i.e. *Palythoa carribaeroum, Gorgonia* spp) displaying signs of disease within the study area were included.

After quantitative surveys were completed, a random swim was performed. Coral colonies or other anthozoans (i.e. *Palythoa carribaeroum, Gorgonia* spp) outside of the study area that exhibited disease symptoms were noted. Qualitative surveys were also performed at western reefs Champagne, Maggie's Point, Guyana Quartz, and Brain Reef.

Diagnosing each disease in the field was difficult. The color of the diseased tissue, the presence of bare skeleton, the presence of algal overgrowth on a colony, and the percent of dead tissue were all used to diagnose a disease. In the field, diseases were identified based on published reports (Deloach, 2002; Goreau, 1998; Nagelkerken, 1997).

Results

This study identified 14 scleractinian species, 3 other anthozoans, and 1 hydrozoan affected by one or more diseases. The total number of infected colonies measured within the study area was 141. BLCH, YBD, WP, and DSS were all identified along the northwestern shore of Dominica. BBD was identified in one *S. siderea* colony. ASP may have been present in Hodges Bay. Identification of ASP *in situ* is difficult, and microbiological testing must be performed to positively identify its presence.

Within the study areas, *Agaricia agaricites* had the highest number of diseased colonies (n = 45, 39.0%). Bleached colonies of *A. agaricites* were found at all sites except Champagne. Diseased colonies of *M. faveolata* (n = 7, 5.0%), *Porites porites* (n = 13, 9.2%), *S. siderea* (n = 15, 10.6%), *Meandrina meandrites* (n = 5, 3.5%), and *Porites asteroides* (n = 15, 10.6%) were found at 8, 8, 7, 6, and 6 sites, respectively. All diseased *Gorgonia* spp were found in Hodges Bay.

Bleaching was observed at all sites, affecting a total of 17 cnidarian species (Table 1). Bleaching affected the area of colonies facing the surface of the ocean, areas that are exposed to the most sunlight.

Along the west coast of Dominica, YBD infections of *M. faveolata* and *M. annularis* were found. Infections of YBD were found in study areas deeper than 5m, except for Champagne. Some colonies infected with YBD were also suffering from coral bleaching.

S siderea is the only scleractinian species to exhibit either DSS or WP. The DSS symptoms observed were dark purple spots of various sizes interspersed across the surface of a colony. In Hodges Bay, one *S. siderea* colony was observed within the study area. Larger spots appeared pink in the middle, with a small amount of coral growth in the middle of larger spots. Smaller spots appeared purple, and mucus was present.

In Hodges Bay, all *Gorgonia* spp. within the study area had a dark purple discoloration or purple notches, or galls. The gastropod *Cyphoma gibbosum* was found on the discolored portions of some *Gorgonia* spp colonies. The rough conditions of the site prevented the identification of white fungal filaments; therefore, a positive identification of ASP was not possible. A similar purple coloring was noted on one *S radians* colony and one bleached colony of *Millepora* sp.

Table 1 Diseased coral species by type of disease and site found. (Note: P = present)

	BLCH	YBD	DSS	WP	BBD	ASP
Anse Soldat	*P. asteroides (3)* *A. agaricites (9)* *P. porites (1)* *S. siderea (1)* *M. faveolata (P)* *P. carribaeorum (5)*					
Capucin	*P. asteroides (4)* *A. agaricites (12)* *P. porites (P)* *M. annularis (P)* *D. labyrinthiformus (P)* *P. carribaeorum (1)* *Millepora spp. (P)*					
Douglas Bay	*P. asteroides (5)* *A. agaricites (14)* *P. porites (3)* *M. annularis (7)* *D. stokesii (P)* *Millepora spp (P)*		*S. siderea (1)*	*S. siderea (1)*		
Lauro Club	*P. asteroides (1)* *A. agaricites (3)* *P. porites (2)* *S. siderea (5)* *M. faveolata (3)* *M. meandrites (1)* *D. labyrinthiformus (P)* *E. fastigiata (P)* *Mycetophyllia sp. (P)* *C. gigantea (P)*					
Brain Reef	*A. agaricites (P)* *M. meandrites (P)*	*M. faveolata (P)*				
Maggie's Point	*A. agaricites (P)* *P. porites (P)* *S. siderea (P)* *M. meandrites (P)*	*M. faveolata (P)*				

Champagne	*P. porites (P)* *M. annularis (P)* *M. faveolata (P)* *M. meandrites (P)* *M. cavernosa (P)*	*M. faveolata (P)*				
Barry's Dream	*P. asteroides (2)* *A. agaricites (10)* *P. porites (7)* *S. siderea (6)* *M. annularis (1)* *M. faveolata (4)* *M. meandrites (4)* *D. labyrinthiformus (2)* *D. strigosa (1)* *Colpophyllia natans (P)* *Millepora spp. (P)*	*M. faveolata (P)* *M. annularis (P)*			*S. siderea (1)*	
Hodges Bay	*P. asteroides (P)* *A. agaricites (7)* *M. faveolata (P)* *Millepora spp. (P)*		*S. siderea (1)*	*S. siderea (1)*		*Gorgonia spp. (13)*
Guyana Quartz	*A. agaricites (P)* *P. porites (P)* *M. annularis (P)* *M. faveolata (P)* *M. meandrites (P)* *D. stokesii (P)* *M. mirabilis (P)*		*S. siderea (P)*	*S. siderea (P)*		

Photographs of BLCH (*A. agaricites, P. porites, S. siderea, M. annularis, M. faveolata, M. meandrites, D. labyrinthiformus, D. strigosa, Mycetophyllia sp., C. gigantea*), YBD (*M. faveolata, M. annularis*), WP (*S. siderea*), and BBD (*S. siderea*) can be found in Appendix A.

Discussion

Coral diseases can affect the species composition of a coral reef community. In the Florida Keys, USA, White Band Disease destroyed 95% of living branching corals, inducing a phase shift from branching corals to foliose corals. In Dominica, 4 diseases (YBD, DSS, WP, BBD) and BLCH were identified in November 2004. It is possible that another disease (ASP) may also be present along the north coast of the island. The virulence of coral diseases appears to be influenced by abiotic factors (i.e. water temperature, wave action) (Deloach, 2002; Borger, 2003).

The seasonal fluctuation of water temperatures appears to influence the occurrence of BBD. Borger (2003) found BBD to infect 6 species of scleractinian during March, June, and August of 2000, 2001, and 2002. However, only one BBD infection was found in November of 2004. Generally, the months of October and November have cooler water temperatures than the study times of Borger (2003). Thus, cooler water temperatures may reduce the virulence of BBD. The fact that coral bleaching also occurred in November 2004, and may have been induced by temperatures of 30º+ C, indicates that factors other than temperature can possibly induce BBD.

DSS infections were found in areas of less than 5 m depth and only in *S siderea* colonies. Borger (2003) also found DSS only in *S siderea* colonies; she suggests that the east Caribbean region differs in species susceptibility characteristics. DSS may be a stress reaction to biotic factors (i.e. algal overgrowth, settlement and/or predation by polychaetes) or abiotic factors (i.e. high water temperatures, high UV exposure). DSS may also make colonies more susceptible to other diseases. In November 2004, WP was found on colonies suffering from DSS.

YBD slowly kills coral colonies due to a slow progression rate and infections that may last for years (Deloach, 2002). In Dominica, YBD was found to affect only *M. annularis* and *M. faveolata*, two reef framework builders. Both of these species were also found bleached, with some colonies suffering from both bleaching and YBD. Bleaching may weaken a coral colony and make that colony more susceptible to other diseases, such as YBD. The presence, progression, and effects of YBD on Dominica's coral reefs should be monitored over a multi-year period to determine its exact effect on community structure.

ASP has been isolated from African dust brought to Dominica by trade winds. Hodges Bay is influenced by Atlantic trade winds. ASP may be present in Hodges Bay. *Gorgonia* spp. was found with purple discolorations similar to ASP. A purple discoloration was also found on one colony of *Millepora* spp. and one colony of *S. radians*. *Cyphoma gibbosum* was found feeding on diseased gorgonian tissue. *C. gibbosum* could be a possible vector for the spread of *A. sydowii* (Nagelkerken, 1997). A positive identification of ASP was impossible *in situ*. Microbiologic tests must be performed to conclude the presence of ASP.

Dominica has experienced bleaching events in 2003 and 2004. In 2003, 25 species were recorded bleached. This event was first recorded in mid October. Water temperature was 30º+ C up to depths of 10 m. In 2004, 18 species were recorded bleached, beginning with *M. meandrites* in early October. The water temperature ranged from 27º C in early October to 30º+ C in mid November.

One field observation made was that bleaching did not occur uniformly over entire colonies of *A. agaricites, C. natans, D. labyrinthiformus, D. stokesi,i M. faveolata, M. annularis, P. asteroides,* and *P. porites*. The top portion, which was exposed to the most sunlight, was bleached. No temperature gradient could be found between the exposed and shaded areas of colonies. Therefore, a combination of water temperature and UV light probably induced this bleaching event. This coincides with a report by Fitt (1995). In a 2-day laboratory experiment, a combination of natural UV levels and elevated water temperatures induced bleaching in *M. annularis* and *A. agaricites*. The UV levels used by Fitt were below the UV levels found at 14 – 16 m depth, and water temperatures ranged from 26º to 36º C. In 2 days, bleaching occurred in colonies incubated at water temperatures ≥32º C. In the current study, *M. faveolata*, *M. annularis*, and *A. agaricites* were found bleached in depths ≤ 10 m with water temperatures of 27º to 30º+ C over the course of 8 weeks.

The coral reefs of Dominica are subject to local stresses (i.e. pollutants, fishing practices) and global stresses (i.e. global warming, spores carried in dust by trade winds). Local and global stresses can synergistically degrade coral reef ecosystems. Coral colonies can become more susceptible to coral diseases and coral bleaching as both local and global stresses increase. Global stresses are beyond the control of Dominicans; however, action can be taken to reduce local stresses. Actions to control the impact of local stresses will help preserve the coral reefs of Dominica; helping to ensure an important resource for future generations.

Coral diseases and coral bleaching occur in Dominica and will likely occur in the foreseeable future. Coral diseases contribute to the weakening and death of corals, including reefs framework builders. The loss of framework builders, such as *M. faveolata, M. annularis,* and *S. siderea*, can lead to the structural degradation of coral reefs around Dominica. Monitoring the factors contributing to the presence, distribution, and temporal dynamics of coral diseases and coral bleaching around Dominica is an important tool in managing the reef resources.

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References

Borger J (2003) The spatial and temporal dynamics of coral diseases in Dominica, West Indies. (in press)

Buddemeier RW, Fautin DG (1993) Coral Bleaching as an adaptive mechanism. Bioscience 43(5):320-326

Deloach N, Humann P (2002) Reef Creature Identification: Florida Caribbean Bahamas New World Publications Jacksonville Star Standard Publications Inc Singapore

Fitt WK, Warner ME (1995) Bleaching Patterns of Four Species of Caribbean Reef Corals. Biol Bull 189:298-307

Goreau TJ *et al.* (1998) Rapid Spread of diseases in Caribbean coral reefs. Rev Biol Trop 46(5):157-171

Jennings K (2003) Coral Watch VTHRC The University of Queensland, QLD 4072 Australia www.CoralWatch.org

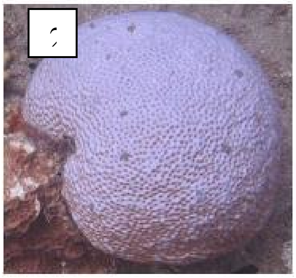
Nagelkerken I *et al*. (1997) Widespread disease in Caribbean Sea fans: II. Patterns of infection and tissue loss. Mar Ecol Prog Ser 160:255-263

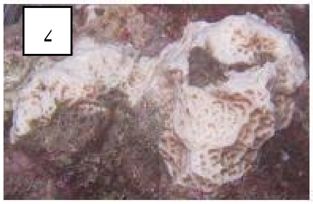
Robert A *et al*. (2001) The Adaptice Bleaching Hypothesis: Experimental Tests of Critical Assumptions. Biol Bull 200:51-58

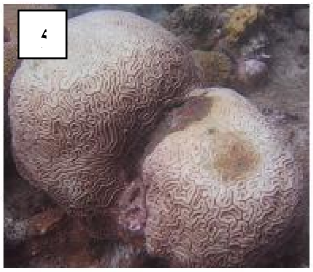
Warner ME, Fitt WK, Schmidt GW (1999) Damage to Photosystem II in Symbiotic Dinoflagellates. A Determinant of Coral Reef Bleaching Proc Natl Acad Sci USA 96:8007-8012

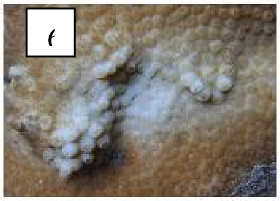
Winter A et al. (1998) Sea surface temperature and coral reef bleaching off La Parguera, Puerto Rico (northeastern Caribbean Sea). Coral Reefs 17:377-382

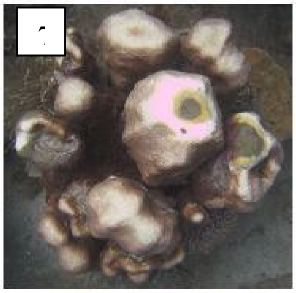
Appendix A

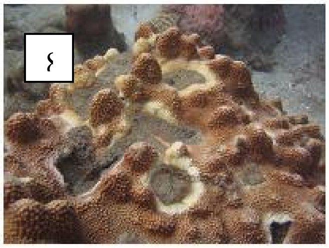


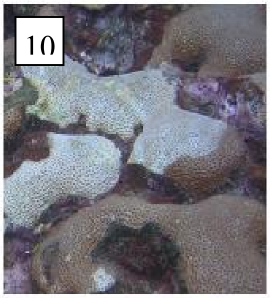


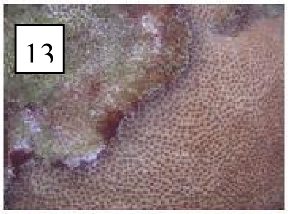












From left to right, top to bottom: 1. Bleaching *D. Strigosa*; **2.** Bleaching *S. siderea*; **3.** Bleaching *P. porites*; **4.** Bleaching *A. agaricites*; **5.** Bleaching *D. labyrinthiformus*; **6.** Close up of bleaching *M. faveolata*; **7.** Bleaching *M. annularis* with YBD infection; **8.** *M. faveolata* with YBD infection; **9.** Bleaching *M. meandrites*; **10.** *S. siderea* with WP infection; **11.** Close up of *M. faveolata* with YBD infection; **11.** Bleaching *Condylactis gigantea*; **12.** *S. siderea* with BBD infection; **13.** Bleaching *M. annularis*; **14.** Bleaching *Mycetophyllia* sp.

Study III: *Diadema antillarum* and its Grazing Effect on Algal Richness and Cover on Coral Habitats of Dominica

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Abstract The long-spined black sea urchin, *Diadema antillarum* is one of the most important herbivore on modern reefs in the Caribbean. After it faced a mass-die off in 1983 many reef systems collapsed being overgrown algae, as herbivorous fishes had already been overfished. Two types of reefs were encountered on the north coast of Dominica, fringing reefs on the eastern side and non-reef coral habitats on the western side. *D. antillarum* was absent on fringing reefs, but was found in variable densities on more sheltered sites on the western side. Algal cover was negatively correlated with density of *D. antillarum*, while algal species richness was positively correlated with density of *D. antillarum*. Effects of *D. antillarum* on the substrate composition may be overlapping with other interactions, such as competition between coral and algae and herbivore fishes. The presence of invertebrates showed no correlation with various densities of *D. antillarum*.

Keywords *Diadema antillarum* · herbivory · grazing · Dominica

Introduction

The long-spined black sea urchin, *Diadema antillarum* Philippi is a keystone herbivore echinoid in Caribbean coral reef ecosystems. In Jamaica *D. antillarum* is found to be most abundant on shallow reefs, between 1-7 m depth on back reefs, reef crests and fore reefs (Moses and Bonem, 2001). They are also major contributors to the bioerosion of the reefs and have been observed eating live corals (Moses and Bonem, 2001).

Both algae and corals compete for space, a limiting resource on reefs, but because algae are fast growing they tend to exclude the slower growing corals. Herbivore grazers reduce the growth and recruitment of algae and allow for the corals to settle and grow. *D. antillarum* was observed to have the highest impact on the algae density and diversity on the Caribbean coral reef ecosystem (Sammarco *et. al.*, 1973), but other invertebrates (e.g. *Tripneustes ventricosus*) and fishes like scarids and acanthurids also have an effect on algal density and diversity. Up to 40-60% of the available substrate can be kept in a cropped state by a healthy herbivorous fish population (Williams and Polunin, 2001). Scleractinian corals (Cnidaria, Anthozoa) are positively affected by the presence of herbivores, and typically increase in abundance and diversity where herbivores are abundant.

Due to a massive *D. antillarum* die-off event in 1983, populations were reduced by 87-100% on various Caribbean islands. This caused some reefs to go through a so-called phase-shift, where the lack of fish herbivory associated to overfishing causes the macro-algae to overgrow the reef and eventually dominating and excluding scleractinian corals. The die-off had a long-term effect on *D. antillarum* populations, studies done 10 years later showed little or no recovery (Lessios, 1995).

In the aftermath of this event it is important to monitor the presence of *D. antillarum* and other herbivores within the same functional group (Bellwood *et.al.*, 2004), e.g. herbivore fishes such as acanthurids and scarids, both in reference to fisheries management and coral reef conservation. Dominica is a young volcanic island in the Lesser Antilles, the island shelf is narrow because of its short geological history and coral growth is limited to certain locations around the island (primarily along the western and northern coast). The most important herbivorous reef fishes are heavily overfished in Dominica (M. Guiste, pers. com.) and the importance of *D. antillarum* on these reefs can not be ignored (Steiner and Williams, in prep.). Studies on the community structure and interactions are needed to increase our understanding of *D. antillarum* and herbivore fishes and their impact on reefs. To examine the relations of grazing by *D. antillarum* in coral reef communities, a comparison between the densities of *D. antillarum*, algae and coral cover and richness were done. Data on herbivorous fishes (Baird, 2004) from the same sites were also included, and compared with substrate composition and presence of *D. antillarum*. These data were used to identify and isolate the interactions (e.g. grazing, competition) between corals, algae, herbivorous fishes and *D. antillarum*, and in what direction they work and where they are strongest.

Methods and Materials

On arrival at the sites preliminary studies were executed and approximate dimensions, extent and orientation of the reef was mapped. Using the map; two 20 meters transect lines were laid out in the centre of the reef, 5 meters apart from each other and parallel to the shore. Along the lines 20 m^2 belt transects were surveyed by using a 1 m^2 pvc-quadrat. Within the belt transects all occurrences of *D. antillarum*, algae (species richness and percent live cover) and other invertebrates (e.g. sponges, octocorals or zooanthids) were recorded. Algae were divided in two categories; turf, including filamentous algae and all algae less then 2 cm and macro algae, including all algae larger then 2 cm. General observations of the substrate were also noted, but not quantified. On fringing reef settings the transect lines were put down on the fore reef (where reef accretion is the highest) or where corals were predominant, on non-reef coral habitat the transect lines were put in the centre of the area dominated by corals. The findings from the two transect were treated indiscriminately on all sites, except for the data from Capucin. At this site a high variability in algae and coral cover was evident between the two transects. The first transect was dominated by corals while the second by algae, the former being present in about 10% of the area, while the latter composing about 90% of the area. Algae cover data from the first transect at Guyana Quartz only included macro algae, and was excluded from further analysis.

Results

D. antillarum were only found at 3 out of 5 sites studied on the northern coast, but at both western sites, Lauro Club and Berry’s Dream. The areas with *D. antillarum* were generally more sheltered and more rugose then where they were absent. The substrate at the studied areas at Guyana Quartz, Capucin, Douglas Bay, Lauro Club were all dominated by rocks and boulders, a possible requirement for *D. antillarum* to thrive. The reefs at both Anse Soldat and Hodges Bay were highly exposed to wave currents and turbulence, and a less complex structure then the non-reef coral habitats. A shallow, pavement-like substrate composed of old *Acropora palmata* colonies and mat-forming coral growth were found at both reefs, but Hodges Bay were more rugose than Anse Soldat.

The mean density of *D. antillarum* from all sites was found to be 0.72 m^{-2} ±1.43, mean density at sites with *D. antillarum* present was 1.19 m^{-2} ±1.69 (Fig. 1).

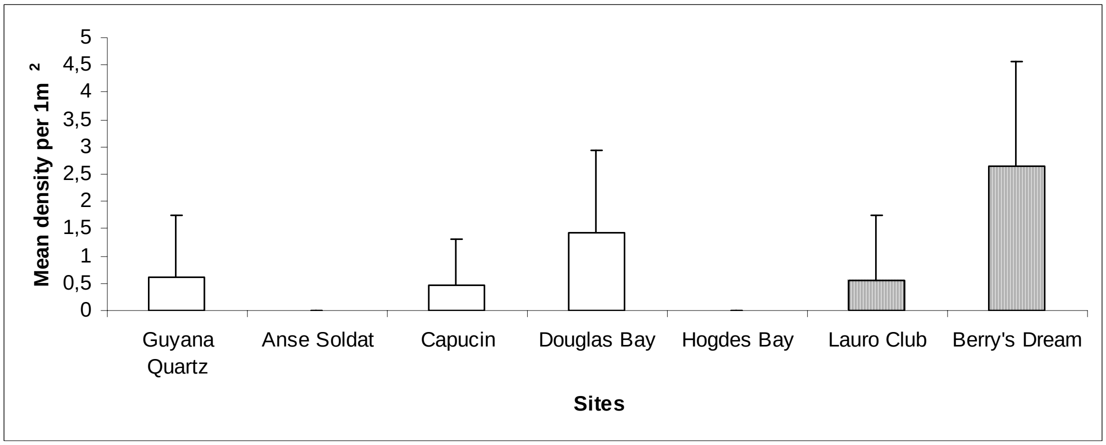

Fig. 1 Mean density of *D. antillarum* with positive standard deviation from all locations. Blank bars indicate non-reef habitats and bars with horizontal lines indicate patch reefs.

Few other echinoderms were found at sites with *D. antillarum*. *Echinometra viridis* was present at Capucin, Hodges Bay and Lauro Club, predominantly in shallower water. *Eucidaris tribuloides* was only encountered once. At sites lacking *D. antillarum*, *Tripneustes ventricosus* were abundant, usually found in shallower water (sea grass beds in the back reef area). There was more than 10 *T. ventricosus* m^{-2} at some sites in Anse Soldat, but their distribution was patchy. Estimates of *T.* ventricosus were hard to make in Hodges Bay due to low visibility. No *T. ventricosus* were noted on any site with *D. antillarum*. Sponges, *Pseudopterogorgia* and *Millepora spp.* were only found at sites with *D. antillarum* present, and highly variable within each site. *Millepora spp.* and *Porolithon* seemed to competitively excluding the other, but accurate data on *Porolithon* was lacking and no analysis could be done.

There was no relation between mean algae cover seem and the presence of *D. antillarum* (Regression, $p>0.05$, $n=5$). Mean algal cover of all sites (except Guyana Quartz) was 49.63 % m^{-2} ±34.53 (Fig. 2). Turf and filamentous algae dominated most sites, but some macro algae were found at two locations, Guyana Quartz and Hodges Bay. Macro algae and sea grass were however noted at shallower depths on all locations, especially the fringing reefs, Anse Soldat and Hodges Bay. At Guyana Quartz and Douglas Bay the macro algal cover were recorded <2 %, in Douglas Bay it only accounted for 1.35 % of the total algal cover, while in Hodges Bay it accounted for 13.76 % of the total algal cover (Fig. 2).

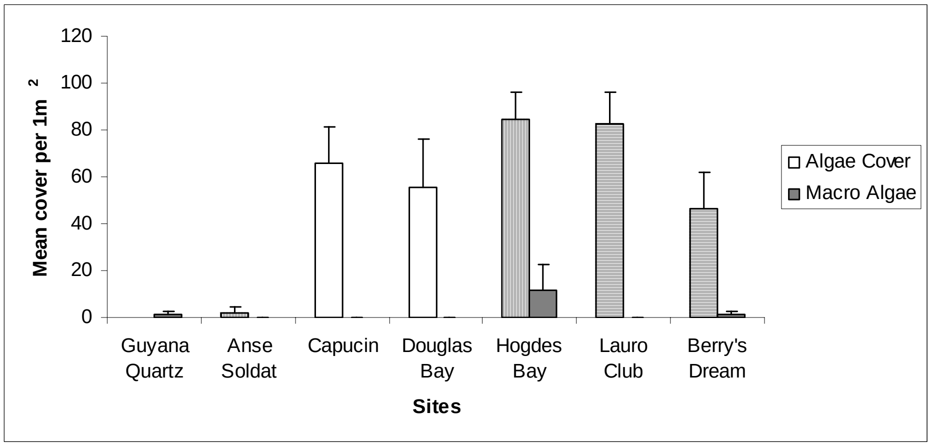

Fig. 2 Mean algae cover (all algae) and macro algae (algae >2 cm) from all locations with positive standard deviation, only macro algae cover data from Guyana Quartz included. Blank bars indicate non-reef coral habitats, bars with vertical lines indicate fringing reefs and bars with horizontal lines indicate patch reefs.

Mean algal species richness recorded from all sites was 2.00 % m^{-2} ±1.16 (Fig. 3). A negative yet not significant relationship was found between algal cover and species richness.

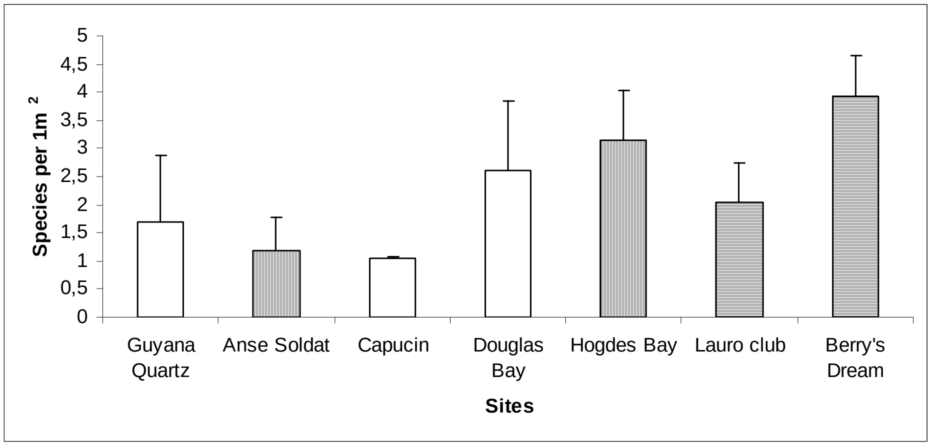

Fig. 3 Algal species richness with positive standard deviation. Blank bars indicate non-reef coral habitats, bars with vertical lines indicate fringing reefs and bars with horizontal lines indicate patch reefs.

A significant correlation between density of *D. antillarum* and algal species richness was found (Regression, $p<0.05$, $n=7$) (Fig. 4).

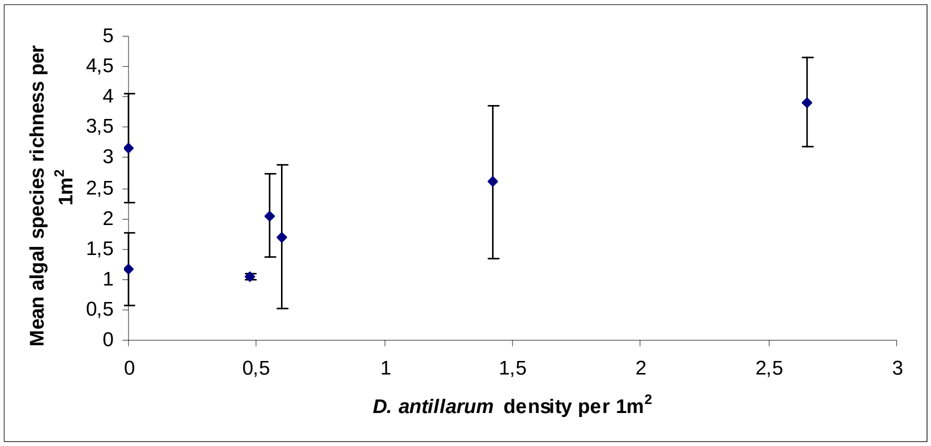

Fig. 4 Mean densities of *D. antillarum* and algal species richness, with standard deviation of the mean algal species richness. Blank bars indicate non-reef coral habitats, bars with vertical lines indicate fringing reefs and bars with horizontal lines indicate patch reefs.

Discussion

The reefs on the north coast can roughly be divided into two categories, fringing reef systems on the windward eastern side and non-reef coral habitats on the leeward sheltered western side. Dominican fringing reefs are characterized by distinct zonations from fore reef to back reef. *A. palmata* frameworks form the fore reef which is usually flat, turbulent and shallow. The back reef is composed of a higher diversity of corals and invertebrates and is shallower and more convoluted. Sandy areas and sea grass beds are the transitions between the back reef and the shore.

The other category, non-reef coral habitat, is usually formed in sheltered sites, and is composed of coral growth on big boulders and rocks originating from the shore. There is usually a 5 meter wide "grey-area" between the shore and the boulders where algae dominate the substrate and only certain corals such as *Porites astreoides* and *Siderastrea radians* (Ishikawa, 2004) grow amidst the algae. Boulders and rocks further out from shore at 2-3 meters depth have higher coral cover and densities of *D. antillarum*, but these areas only compose a fraction of the total substrate. Most transect were laid in an intermediate zone between the "grey-area" and the boulders, except at Capucin.

Two fringing reef systems were included in the study, Anse Soldat and Hodges Bay, but the reef morphologies found differed substantially (see Fig. 2 and 3). In addition to a significant difference in algae cover and algal species richness, the mean percent coral cover was also considerably different between the two sites, 39.48 % m^{-2} ±23.96 at Anse Soldat and 6.33 % m^{-2} ±10.10 at Hodges Bay (Ishikawa, 2004). Could the differences be caused by competition between algae and corals or do other factors influence the algae and coral ratio? Recorded herbivore fish densities were similar at both sites, but slightly lower on Anse Soldat (0.60 m^{-2}) compared to Hodges Bay (0.70 m^{-2}) (Baird, 2004). The lack of a clear relation between herbivore fish densities and algal cover may indicate that the fish populations have no significant importance. The important echinoid grazer, *D. antillarum*, were absent on both reefs, but large populations of *T. ventricosus* were noted in the sea grass areas on both sites. Differences in herbivory on the two sites do not seem to correlate with the difference in algal cover (Fig. 2). Herbivore fish were most abundant where the algal cover was highest, while *D. antillarum* were absent from both reefs. No quantitative data was collected on densities of *T. ventricosus*, but the densities on Anse Soldat seemed to be higher than Hodges Bay (pers. obs.). Even though the difference in density of *T. ventricosus* is slight, their grazing pressure may be a factor in the substantial difference in algal cover at these two sites. The absence of *D. antillarum* makes it seem unlikely that they influence the algae and coral cover on fringing reef systems. A significant difference in algal species richness was recorded between the fringing reef sites (Anova Single-factor, $p<0.05$, n=40) and could possibly be due to less herbivory in Hodges Bay (but see later). Despite the lack of herbivores at Hodges Bay, the more rugose reef could be the reason for a high algal richness

Guyana Quartz, Capucin and Douglas Bay were characterized as non-reef coral habitats; they had a "grey-zone" with a low coral cover the first 5 meters off shore, following a narrow belt with coral growth and findings of *D. antillarum* between the grey zone and the sandy areas further out. Coral cover was highly clumped and irregular, recorded percent cover at Guyana Quartz, Capucin and Douglas Bay were as follow; 13.5 % m^{-2} ±14.25, 1.15 % m^{-2} ±1.21 and 4.48 % m^{-2} ±8.75 (Ishikawa, 2004). Algal cover varied between sites (Anova Single-factor, p=0,057, n=40), and the recorded mean percent cover was higher at Capucin then at Douglas Bay (Fig. 2). The study showed positive, yet not significant, relationships between *D. antillarum* density and coral cover and diversity (Ishikawa, 2004) and algal richness (Fig. 3). Interestingly the recorded herbivore fish density was also highest at Douglas Bay, followed by Guyana Quartz and Capucin. The study showed a negative, yet not significant, relationship between density of *D. antillarum* and algal cover on the non-reef coral habitats. It is possible that grazing pressure by *D. antillarum* limit the growth of the most competitively algae species and therefore allow for higher algal species richness and reduces the competition with corals. The increased grazing by *D. antillarum* in Douglas Bay may increase the rate of scleractinian settlement and diversity. According to L. Davis (2004) densities of coral recruits (<2 cm) were 4.00 m^{-2} at Capucin and 8.03 m^{-2} at Douglas Bay, while diversity (H') of the recruits were 0.79 at Capucin and 0.83 at Douglas Bay supporting the theory that grazing by *D. antillarum* increases recruitment densities and diversity (Williams & Polunin, 2001).

Two studies were done on deeper reefs on the west coast for comparison. A similar pattern to what was recorded on the non-reef coral habitats was found on these two reefs, where Berry's Dream had the lowest algal cover, and the highest algal richness and density of *D. antillarum* (Fig. 1, 2 and 3). Difference in *D. antillarum* densities may explain this pattern, and as herbivorous fish density was the highest at Berry's Dream (Baird, 2004) this supports the above.

The study will benefit fisheries management and in turn future generations of fishermen on Dominica, in terms of the interactions between the echinoderms and the coral reefs (which directly influence the abundance of fishes). It will also benefit conservation management, in that sites that are vulnerable to overfishing can be efficiently identified and put aside for alternative use, e.g. ecotourism (snorkelling or SCUBA-diving), and can prove to be both profitable for the local tourism industry and spared from overexploitation.

Future studies should focus on interactions such as competition between *T. ventricosus* and *D. antillarum* and physical parameters required for *D. antillarum* to thrive. Studies need to compass more data, both temporally and spatially distributed on the north coast. Future studies should also measure complexity (rugosity) of the reef structure and tie these finding to experiments with *D. antillarum* under different levels of turbulence and available shelter. Size distribution and population structure should also be included in light of the die-off two decades ago.

References

Baird S (2004) The density of grazing fishes along the northern coast of Dominica, ITME Student Paper, Fall 2004

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

Davis L (2004) Recruitment of scleractinian corals in northern Dominica, ITME Student Paper, Fall 2004

Ishikawa M (2004) Coral community structure and species richness of northern Dominica, ITME Research Reports 21:3-9

Lessios HA (1995) *Diadema antillarum* 10 years after mass mortality: still rare, despite help from a competitor. R Soc Lond 259:331-337

Sammarco PW, Levinton JS Ogden JC (1973) Grazing and control of coral reef community structure by *Diadema antillarum* Philippi (Echinodermata: Echinoidea): A preliminary study. J Mar Res 32: 47-53

Steiner SCC and Williams SM (2004) *Diadema antillarum* of Dominica (Lesser Antilles): 2001-2004 (in prep.)

Williams ID Polunin NVC (2001) Large-scale associations between macroalgal cover and grazer biomass on the mid-depth reefs in the Caribbean. Coral Reefs 19:358-366