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Observations on five coral diseases and coral bleaching along the north and west coasts of Dominica, West Indies : a capstone project ...

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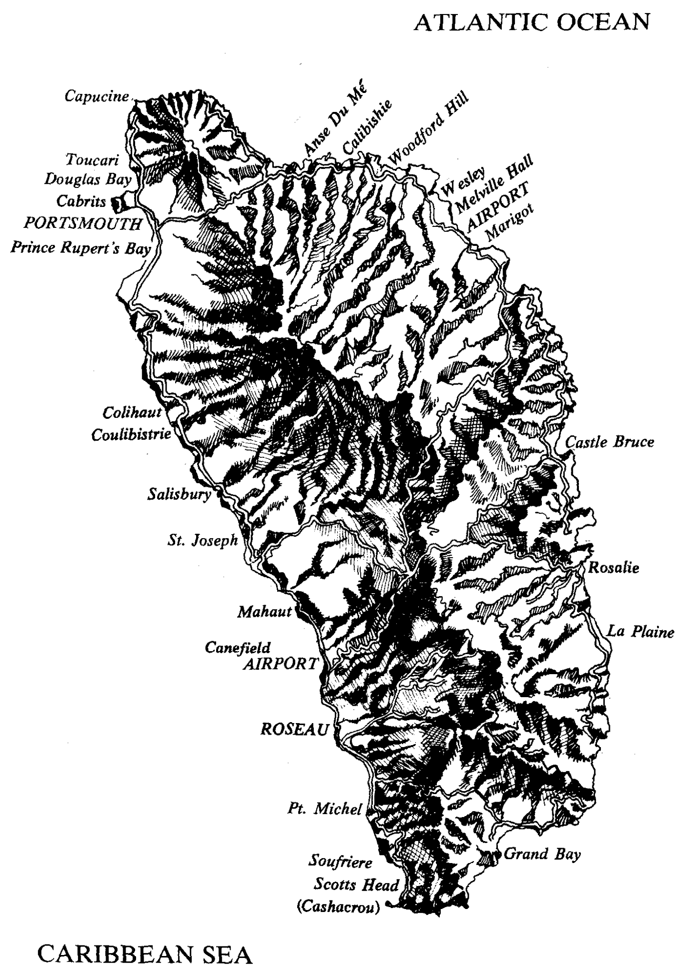
Observations on Five Coral Diseases and Coral Bleaching along the North and West Coasts of Dominica, West Indies



A Capstone Project
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by

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Abstract

Scleractinian diseases and bleaching have been studied for about 30 years. And yet, very little is known about the vectors, pathogens, and long-term effects of coral disease and coral bleaching. In the 1990s, the reported number of coral diseases escalated significantly. 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 are from the north and west shores of the island, previously unstudied areas. Height, widest diameter, disease symptoms, percent of diseased coral tissue, and the color differences between diseased and healthy coral tissue are recorded *in situ* within a 3-meter radius circle at each of 6 locations. Data collection begins the last week of October 2004 and ends the third week of November 2004. Eighteen zooxanthellate species suffer from coral bleaching. Yellow Blotch Disease infections are found in *Montestraea faveolata* and *Montestraea annularis* colonies. *Siderastrea siderea* is found infected by Dark Spot Syndrome and White Plague. Black Band Disease infections are rare. *Gorgonia* spp. are possibly infected by Aspergillosis. In future studies, incidence and occurrence of coral diseases and coral bleaching in framework building species *Montestraea faveolata*, *Montestraea annularis*, and *Siderastrea siderea* should be monitored to reduce overall reef degradation. Incidence and occurrence of coral disease and coral bleaching in non-framework species *Agaricia agaricites* and *Porites asteroides* should be monitored as possible indicators of an impending bleaching event.

Keywords · Dominica · Scleractinian · Coral Disease · Coral Bleaching

Tropical coral reefs and their associated habitats provide vital resources to Earth's inhabitants. Coral reef accretion provides habitat for 25% of all marine species and protects shoreline from storm events and wave action. Fisherman, SCUBA divers, the ecotourism industry, and coastal communities rely on these ecosystems as a source of food, economic opportunity, and aesthetic pleasure. Coral reef ecosystems respond to environmental changes and may be used as an indicator of the oceans' health. Global and local stresses are causing reef degradation of coral reef habitats. The decline in health of coral reefs around the world is a serious threat and a cause for concern.

Coral reef degradation involves many natural and anthropogenic environmental factors. Natural factors include hurricanes, fresh water run off, sedimentation, ocean currents, UV light exposure, erosion, pest populations, water temperature, seawater chemistry, sea level, coral diseases, and coral bleaching (McClanahan, 2002). Anthropogenic factors contributing to reef degradation are pollution, fishing practices, physical damage, tourism, land use practices, vessel groundings, coastal development, green house gases, unsuccessful management policies, and a lack of environmental education (McClanahan, 2002). These natural and anthropogenic factors work synergistically to affect the coral reef community.

Coral diseases and coral bleaching are natural factors contributing to reef degradation. These natural factors can be greater sources of coral mortality than hurricanes or storms events (Borger, 2003). Coral diseases, such as Black Band Disease (BBD), White Band Disease (WBD), White Plague (types I, II, and III) (WP), Yellow Blotch Disease (YBD), Dark Spot Syndrome (DSS), Aspergillosis (ASP), and Red Band Disease (RBD) have been observed infecting either stony or soft coral colonies in the Atlantic Ocean, Indian Ocean, the Pacific Ocean, the Caribbean Sea, and the Red Sea (Deloach, 2002). Coral bleaching is a stress response resulting in the loss of symbiotic algae (zooxanthellae), or the reduction of the photosynthetic pigments of zooxanthellae (Deloach, 2002). Coral diseases and coral bleaching contribute to reef degradation by weakening and killing healthy coral tissue; which can induce a phase shift from coral domination to algal domination of the reef (Borger, 2003; DeLoach, 2002; Steiner, pers. comm.). A phase shift affects the nutrient flow, the food web, and the habitat within a coral reef and the surrounding ecosystems; therefore, it is necessary to understand the vectors, pathogens, and virulence or coral diseases and coral bleaching.

The first description of BBD (Antonius, 1973) began the study of coral diseases. BBD is a slimy, dark maroon to black colored band that moves across the surface of the coral colony. The band consists of a microbial community, which includes *Phormidium corallyticum*, *Beggiatoa* spp., and *Desulfovibrio* spp. The bacterial 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. Other opportunistic organisms such as *Hermodice carunculata*, *Coralliophilia* spp., protozoans, flatworms, nematodes, fungal filaments, and small crustaceans have been observed feeding on the dead or diseased tissue (DeLoach, 2002). In the Western Atlantic, 16 species of massive and plating corals and several gorgonians have been identified with this disease (Deloach, 2002; Goreau, 1998).

Another disease found to affect plating and massive corals is WP. Outbreaks of WP have occurred in the last 3 decades. At least 17 scleractinian species in the Caribbean Sea and Western Atlantic have been identified as being infected by WP, including *Siderastrea* spp., *Mycetophyllia* spp., *Dichocoenia stokesii*, and *Colpophyllia natans*. WP begins at the base of a colony and spreads upwards in a semicircular pattern. 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 affliction occurs mostly in *Siderastrea siderea* and *Stephanocoenia intersepta* and has been reported in *Montestraea annularis* complex. Spots on *S. siderea* 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. annularis* and *Montestraea faveolata* colonies. This affliction begins as a yellow spot that becomes a yellow band as it slowly progresses over the infected colony. A filamentous alga is commonly found colonizing the exposed coral skeleton. 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 are not indicative of the presence of Aspergillosis. Verification of this disease depends on the presence of white fungal filaments; however, these are hard to observe *in situ* (Deloach, 2002; Goreau, 1998; Nagelkerken, 1997). In Dominica, *A. sydowii* has been isolated from Sahara dust carried over the Atlantic Ocean by trade winds (Y Deterés, *pers comm*).

Bleached corals may be more susceptible to coral disease because of a lack of an essential symbiotic partner. Coral bleaching has been observed for over 100 years, but only in the last 3 decades have detailed observations been recorded. Bleaching events, multiple colonies of different coral species are observed bleached, can be caused by periods of temperatures 1°C higher than average for 3-4 weeks (Winter, 1998). Increased ultraviolet radiation, sedimentation, pollution, or changes in water chemistry may also induce bleaching (Deloach, 2002; Fitt, 1995; Robert, 2001; Buddemeier, 1993). Global warming and El Nino Seasonal Oscillations (ENSO) are two atmospheric factors that can induce coral bleaching. 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. Repeated coral bleaching events are a chronic stress on coral reefs which cause deterioration of the health of coral reef. The decline in the reefs' health concerns human interests.

Fisherman, coastal communities, SCUBA divers, the biomedical industry, and the tourism industry have economic interests in coral reefs. The development of successful coral reef resource management policies and monitoring procedures will preserve the economic survival of fisherman and coastal communities, preserve pristine environments for SCUBA divers and tourists, and provide a valuable resource for the development of new medicines. Therefore, it is important to understand the full extent of coral diseases and coral bleaching. In Dominica, West Indies little is known about the effects of coral disease and coral bleaching on local coral reefs.

Dominica, a volcanic island, is located in the arc of islands known as the Lesser Antilles in the Eastern Caribbean Sea (see Figure 1). The island is about 29 miles long, 16 miles wide, and about 300 square miles (Honychurch, 1984; S Steiner, *pers comm*) with a steep island shelf. Currently, a human population of about 72,000 people resides on the island. The two largest cities, Roseau and Portsmouth, are located along the west coast of the island. The capital of Roseau has a population of about 30,000 people, while the city of Portsmouth has a population of about 20,000. In recent years, people have migrated from inland areas towards these coastal cities, thereby, increasing fishing pressure on coral reefs. .

Figure 1: Map of the Eastern Caribbean Sea.

In Dominica, the loss of coral reefs will affect two important economic activities: tourism and fishing. Tourists SCUBA dive and snorkel in coral reefs along the west coast of the island. Fishermen and local communities rely on corals reefs as a protein source. Today, more people rely on coral reef fisheries for food than ever before. The Dominican government is promoting the conservation of coral reef fisheries by pushing a shift from near shore fishing (of coral reefs) to oceanic fishing utilizing fish aggregating devices (FADs). However, a lack of technology, education, and money is slowing this process down.

Current near shore fishing practices in Dominica can inadvertently lead to coral disease. The coral reef fisheries of Dominica are currently overexploited (S Stiener, *pers comm*; H Guiste, *pers comm*). Most fishing on the island is performed near shore with seine nets, fish pots (Z-traps), gill nets, spear guns, or a hook and line. Fishermen unintentionally damage the reef by dropping anchors, stones, and fish traps on top of coral colonies. Lost fish pots, or ghost traps, deplete coral reef resources by trapping fish, smothering sessile marine organisms, and inflicting physical damage to corals and sponges until the trap degrades. Coral colonies exposed to these fishing practices can become stressed and weakened; thereby, becoming more susceptible to coral diseases. These fishing practices will continue into the foreseeable future; therefore, it is important to understand the impacts of coral diseases on Dominica's coral reefs before making policy decisions regarding coral reef resources in the near future.

Scientific data on Dominica's coral reefs are limited, beginning in 1999 with the establishment of the Institute for Tropical Marine Ecology (ITME). Researchers at ITME have studied coral community structure, species diversity, algal cover, population size and density of *Diadema antillarum*, and cataloguing fish species, coral species, and other invertebrate species So far, thirty-six Scleractinia species have been identified around Dominica, with the species *M. faveolata*, *S. siderea*, and *M. annularis* considered important framework builders (Steiner, *pers comm*). BBD, WP, DSS, YBD, and coral bleaching have been observed by ITME researchers since May 2000.

Coral diseases and coral bleaching are present in the coral reefs of Dominica (Borger, 2003), and will continue to exist in the foreseeable future. These coral afflictions are important factors in coral reef degradation. Despite their potential influence, there has been little research into the incidence, occurrence, and effects of these coral afflictions on coral reefs around the island. Scientists must fully understand the pathogens, vectors, and the biological, chemical, meteorological, geologic, hydrological, oceanographic, and anthropogenic factors contributing to coral diseases and coral bleaching if successful coral reef management policies addressing these two natural factors are to be developed.

Project Goals

This project aims to answer three questions:

1) What coral diseases are present in the coral reefs of Dominica?

2) Which scleractinian species are being infected?
3) Did a bleaching event occur in fall 2004?

In order to answer questions 1 and 3, I will identify different coral afflictions, such as parrotfish scaring, algal overgrowth, death due to sedimentation, coral diseases, coral bleaching, and physical damage. Dr. Sascha Steiner, Director of ITME, is able to show me the physical signs of these different afflictions *in situ* before research begins. In order to identify these specific coral diseases I compare field observations with published descriptions (Deloach, 2002; Goreau, 1998). In order to answer question 2, I will identify 24 coral species known to be found in the coastal waters of Dominica.

Physical aspects and disease symptoms for each diseased colony are recorded *in situ*. This study provides the first data on the occurrence of BBD, DSS, YBD, ASP, WP, and coral bleaching along the north coast.

Methods

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 - are quantitatively surveyed for coral disease occurrence (Figure 2). Three 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 - are also qualitatively examined for coral disease presence (Figure 2). Sites with depth greater than 5 m are examined by SCUBA diving.

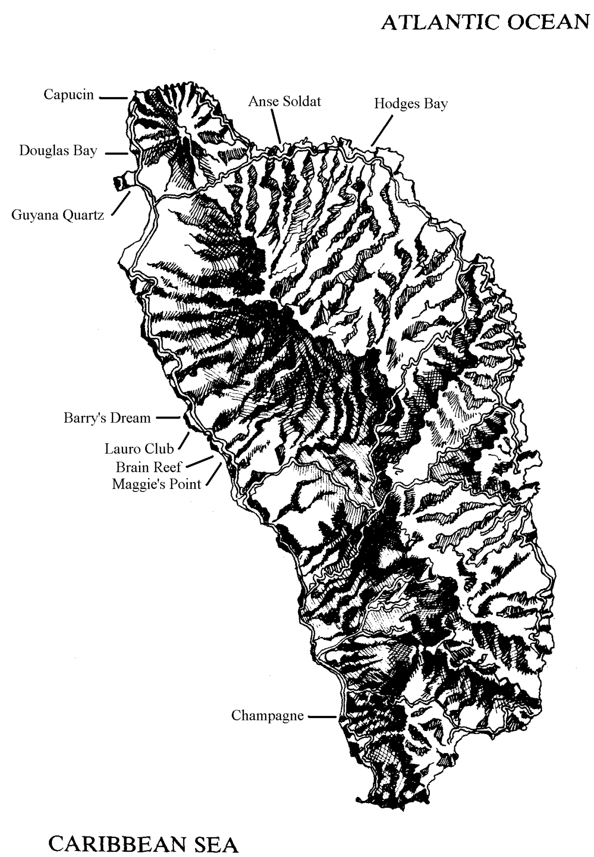

Figure 2: Locations of Study Sites

Site Descriptions

Hodges Bay (HB) (<1 m depth): Located between Calibishie and Woodford Hill. A series of small islands in the northeast protect this bay from the Atlantic Ocean. The shore progresses from a sandy beach to an 80-meter wide sea grass bed primarily composed of *Syringodium filiforme* and *Thalassia testudinum*. The examined fringing reef is located 175 meters off shore on the leeward side of the aforementioned islands. The reef crest (1 m depth) is mostly composed of patchy assemblages of *Porites asteroides, large* colonies of *S. siderea,* and *Gorgonia* spp.

Anse Soldat (ASD) (2 m depth): Located between Anse du Mé and Calibishie. A fringing reef composed of *Acropora palmata* skeleton shelters a shallow sea grass bed of *T. testudinum*. The sea grass bed gradually transitions into turf algae, with a high abundance of *Echinometra viridis*. One hundred meters from shore large mats of *Polythoa caribeorum* and *Millepora* spp. dominate the substrate in transition to the fore reef where *Diploria clivosa* and intermittent smaller colonies of *Diploria strigosa* cover most of the available substrate. Substrate in the shallow break zone (between 1-5 m) is dominated by small living colonies and dead stands of *A. palmata*.

Guyana Quartz (GQ) (4 m depth): 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. The benthos is characterized by a boulder field interspaced by sand to about 25 meters off shore. Coral heads ranging from less than 10 cm (coral recruits) to over 1.5 m in diameter are found throughout the first 20 meters from shore at a depth up to 4 meters. Although true reef accretion is virtually absent, colonies of *A. agaricites, S. siderea, P. porites, M. annularis, M. faveolata,* and *Montestraea cavernosa* are present.

Douglas Bay North (DB) (4 m depth): A collection of coral heads located north of Cabrits National Park. The shoreline consists of a cobblestone beach transitioning into a boulder field, which then transitions into a sea grass bed 30 m from shore. Coral heads of *A. agaricites, P. asteroides, P. porites, M. annularis*, and *Millepora* spp. range from less than 10 cm (coral recruits) to 1 m in diameter.

Capucin (Cap) (4 m depth): Another collection of coral heads located below the village of Capucin, near a fisheries complex. A pebble beach transitions into a boulder field, and a medium to strong current flows north. Growth of *A. agaricites*, *P. asteroides*, *M. faveolata*, and *Siderea radians* colonies occur on and around large boulders. Very few coral colonies larger than 50 cm in diameter are found. Humans use this area for recreation and fishing.

Champagne (Cha) (5 m depth): Located near Pointe Michelle, north of Soufriere Bay. A popular tourist destination, the shoreline consists of cobblestone transitioning into a boulder field interspaced with sand. Bubbles, due to volcanic activity, trickle from the sea floor to the surface at about 10 m offshore. Colonies of *M. annularis, M. faveolata*, and *M. cavernosa* with diameter greater than 4 m can be found 30-70 m from shore. This is the only location in Dominica where the stony coral *Tubastraea coccinea* is found.

Lauro Club - Deep (LC) (9 m depth): Located north of Salisbury. From shore, the benthos is composed of a sandy bottom interspersed with boulders. About 100 m from shore, true reef accretion begins at a depth of 10 m. Colonies of *M. cavernosa*, *M. faveolata*, and *P. asteroides* dominate the coral community.

Barry's Dream (BD) (9 m depth): Located 150 m offshore of the Village of Mero. A patch reef surrounded by sand and sea grass beds. The bottom of the reef is 20 m deep, and the reef stands 10 m tall. All research is performed on the top of the reef at 10 m depth. *A. agaricites, M. annularis, M. faveolata, P. porites, P. asteroides, C. natans, S. siderea, Diploria labyrinthiformis,* and *Meandrina meandrites* are coral species common to this location.

Brain Reef (BR) (15 m depth): Located north of Salisbury. A mix of primary substrate, secondary substrate, and sand characterize the benthos of this patch reef. Coral heads of *M. faveolata, P. asteroides*, and *M. meandrites* grow close to the sea floor. At least one colony of *P. asteroides* is found to suffer partial mortality due to burial by sediment.

Maggie's Point (MP) (15 m depth): Located south of Mero. A bi-specific assemblage of *Madracis mirabilis* and *Porites porites* colonies creates a spur and groove zone with depth ranging from 10 m to 15 m. *Ventricaria ventricosa*, *Meoma ventricosa*, *Udotea* sp., *Caulerpa* sp., *Dictyota* sp., and *Sargassum* sp. are algae species found in the sand surrounding the reef accretion. Fish traps and a mooring line for SCUBA boats indicate the recreational and economic usage of this reef by humans.

The survey area is determined by creating replicate survey circles with a radius of 3 meters (area of circle = 28.27 m^2). For each circle, the center point is chosen in a haphazard manner. All scleractinian, gorgonians, and hydrocorals within the survey circle exhibiting signs of coral disease or coral bleaching are recorded. Only colonies exhibiting symptoms of disease or bleaching are included in this study. To avoid recording colonies more than once, the circle is divided into 3 smaller areas (See Figure 3). Based on the distance from the center point, the first area ranges from 0 to 1 meter away (white circle), the second area from 1 to 2 meters away (light gray circle), and a third area from 2 to 3 meters (dark gray area). Replicate survey circles are examined at each study site.

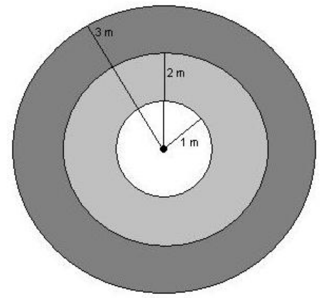

Figure 3: Diagram of survey area.

Four replicate survey circles are performed at Capucin, Douglas Bay North, Hodges Bay, and Barry's Dream providing a total study area of 113.10 m^2 for each location. Only 3 replicate survey circles are performed at Anse Soldat, providing a study area of 84.82 m^2. At Lauro Club, due to time constraints, only 2 replicate survey circles (56.54 m^2) are carried out. For each scleractinian colony exhibiting disease or bleaching symptoms within the study area, the following is 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 must be entirely contained within the outer 3-meter circle to be included in the data set. Color is determined by comparison with the Coral Watch bleaching color chart (Jennings, 2003). Other anthozoans (i.e. *Palythoa carribaeroum, Gorgonia* spp.) found within the study area that display signs of disease are included.

After quantitative surveys are complete, a random swim is performed. Data from random swims include occurrences of coral diseases and coral bleaching too rare to be observed within the survey circles. Coral colonies and other anthozoans (i.e. *Palythoa carribaeroum, Gorgonia* spp) outside of the study area that exhibited disease symptoms are noted. A random swim is performed at Champagne, Maggie's Point, Guyana Quartz, and Brain Reef while circular surveys are not.

In the field, coral diseases are identified based on published reports (Deloach, 2002; Goreau, 1998; Nagelkerken, 1997). 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 are all symptoms used to diagnose diseases.

In order to compare the occurrence of coral disease and coral bleaching across study sites, standard values are calculated or estimated. Mean density of diseased and bleached corals is calculated. Using the widest diameter *d*, measured *in situ*, a circular area *a* is estimated for each coral colony. The total area *T* represented by sampled colonies is then calculated with these values. Values for percent cover of sampled colonies and percent cover of diseased and bleached tissue are then estimated using the percent of diseased tissue, estimated *in situ*, and the area values for each colony. Estimated percent of tissue infected in the 6 most commonly observed species is then calculated.

Results

This study identifies 14 scleractinian, 3 other anthozoans, and 1 hydrocoral species affected by one or more coral disease or coral bleaching (Tables 1 and 2). In the study circles, a total of 139 colonies exhibiting symptoms of disease or bleaching are examined (Table 1). Bleaching is the most common coral affliction (n = 123, 88.5% of examined colonies). BBD, DSS, and WP combined infect approximately 2.2% (n = 3) of the sampled population. Possible ASP infections are observed in approximately 7.2% (n = 13) of the sample population. Cases of YBD are found only on random swims (Table 2).

A. agaricites is the coral species most commonly observed (n = 55, 40.0% of bleached colonies) (Figure 4). Other commonly observed species include *P. asteroides* (n = 15, 10.8%), *S. siderea* (n = 15, 10.8%), *P. porites* (n = 13, 9.8%) (Figure 4), *M. annularis* (n = 8, 5.8%), and *M. faveolata* (n = 7, 5.0%) (Figure 5).

Bleaching is observed at all sites, affecting a total of 17 cnidarian species. The highest density of bleached colonies per m^2 is found at Barry's Dream (.336 bleached colonies per m^2), followed by Lauro Club (.248 bleached colonies per m^2) and Douglas Bay (.248 bleached colonies per m^2). Hodges Bay has the lowest density of bleached colonies (.061 bleached colonies per m^2). These values are compared with the overall mean coral density of each site as described by Ishikawa (2004) (Figure 6).

Observed colonies of *M. annularis* are estimated to have 30.45% of coral tissue afflicted with coral disease or coral bleaching, the highest percent of the 6 most commonly observed species (Figure 7). *S. siderea* and *M. faveolata* are found to have the lowest percentages of afflicted tissue with 0.73% and 2.77%, respectively. The three non-framework builders *A. agaricites* (11.34%), *P. porites* (15.68%), and *P. asteroides* (16.26%) all have similar percents of diseased or bleached tissue.

For all sites, the mean estimated percent cover of observed colonies is 1.19%, and the mean estimated percent cover of afflicted tissue is 0.15% (Figure 8). The highest estimated percent cover of observed colonies is found in Barry's Dream (2.62%), and the lowest estimated percent is found in Hodges Bay (0.17%). Douglas Bay has the highest estimated percent cover of afflicted tissue with 0.4%, while Capucin has the lowest with 0.04%.

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

S. siderea is the only scleractinian species to exhibit BBD, DSS, or WP. The DSS symptoms observed are dark purple spots of various sizes interspersed across the surface of a colony. Larger spots appear pink in the middle, with a small amount of algal growth in the center. Smaller spots appear purple, and mucus was present.

In Hodges Bay, all *Gorgonia* spp. within the study area have a dark purple discoloration or purple notches, or galls. The gastropod *Cyphoma gibbosum* is found on the discolored portions of some *Gorgonia* spp. colonies. Identification of ASP *in situ* is difficult, and microbiological testing must be performed to positively identify its presence. The rough conditions of the site prevent the identification of white fungal filaments; therefore, a positive identification of ASP is not possible. A similar purple coloring is noted on one *S. radians* colony and one bleached colony of *Millepora* sp.

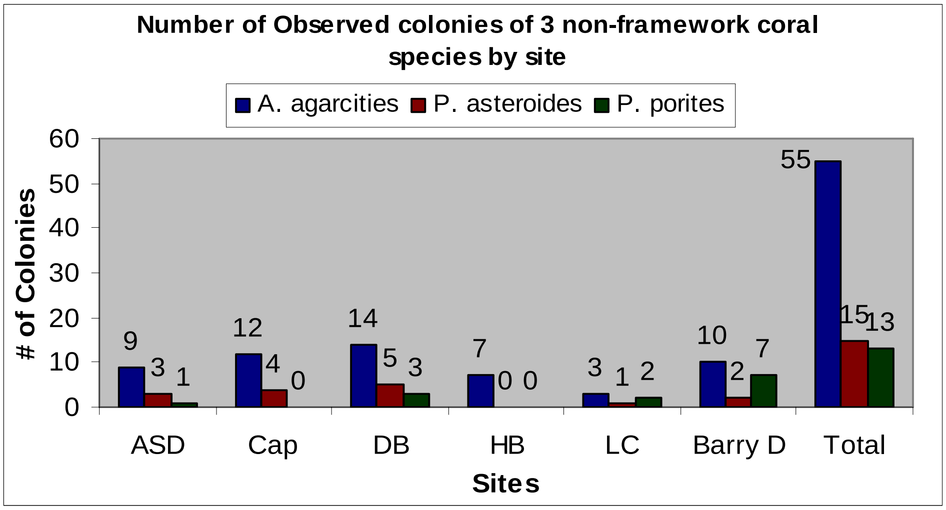

Figure 4: Comparison of the number of 3 non-framework coral species found within study circles at 6 locations.

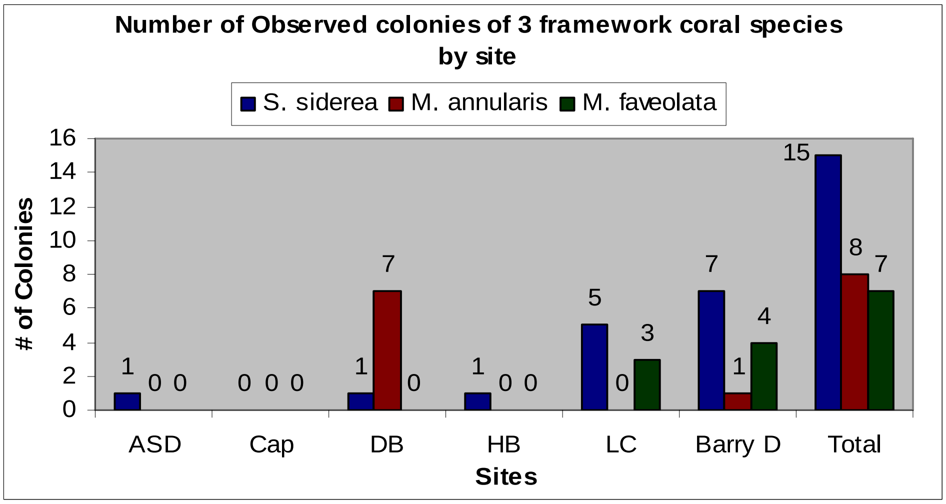

Figure 5: Comparison of the number of 3 framework coral species found within study circles at 6 locations.

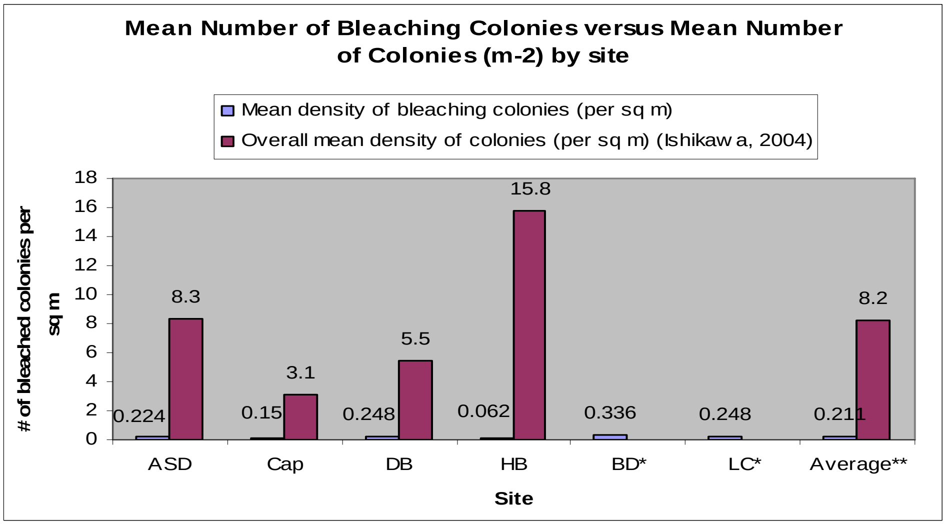

Figure 6: Mean density of observed corals compared with mean density of coral as described by Ishikawa (2004). Ishikawa did not provide information on BD and LC.

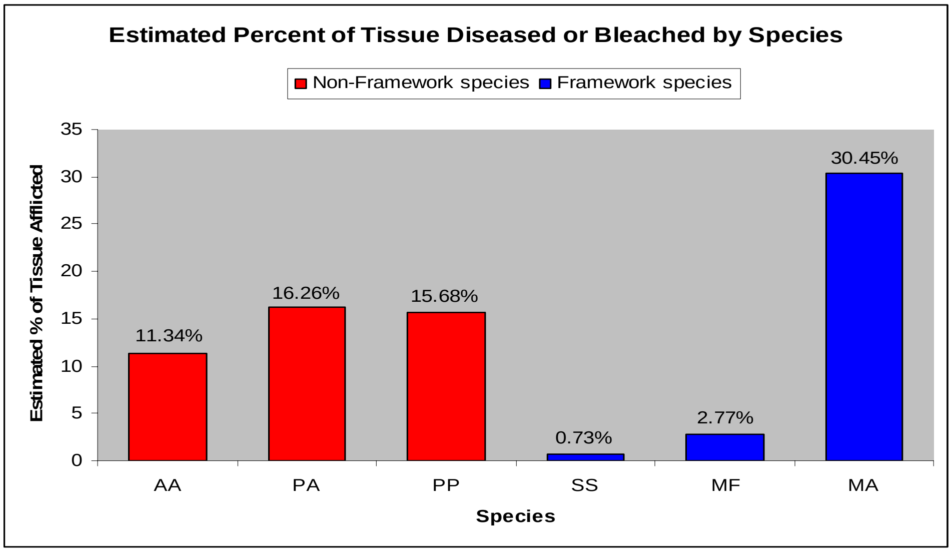

Figure 7: Overall Estimated Percent of Diseased and/or Bleaching Tissue of 6 Commonly Observed Species.

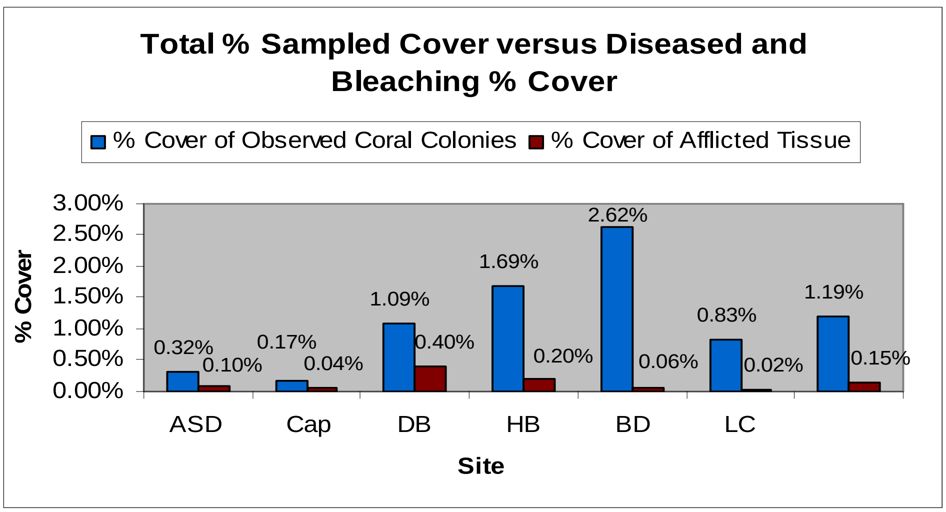

Figure 8: Estimated percent cover of observed colonies and the estimated percent cover of diseased and/or bleached tissue at 6 locations.

Table 1: Type of disease, species infected, and number of infected colonies found within study circles at each site (*= colony observed with two or more afflictions)

	BLCH (124)	YBD (*)	DSS (2)	WP (2)	BBD (1)	ASP (13)
Anse Soldat (19)	*P. asteroides (3)* *A. agaricites (9)* *P. porites (1)* *S. siderea (1)* *P. carribaeorum (5)*					
Capucin (17)	*P. asteroides (4)* *A. agaricites (12)* *P. carribaeorum (1)*					
Douglas Bay (30)	*P. asteroides (5)* *A. agaricites (14)* *P. porites (3)* *M. annularis (7)*		*S. siderea* (1)*	*S. siderea* (1)*		
Lauro Club (15)	*P. asteroides (1)* *A. agaricites (3)* *P. porites (2)* *S. siderea (5)* *M. faveolata (3)* *M. meandrites (1)*					
Barry's Dream (38)	*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)*				*S. siderea (1)*	
Hodges Bay (21)	*A. agaricites (7)*		*S. siderea* (1)*	*S. siderea* (1)*		*Gorgonia spp. (13)*

Table 2: Type of disease and species of infected colonies found on haphazard swim at each site (*= colony observed with two or more afflictions)

	BLCH	YBD	DSS	WP	BBD	ASP
Anse Soldat	*M. faveolata*					
Capucin	*P. porites* *M. annularis* *D. labyrinthiformus* *Millepora spp.*					
Douglas Bay	*D. stokesii* *Millepora spp*					
Lauro Club	*D. labyrinthiformus* *E. fastigiata* *Mycetophyllia sp.* *C. gigantea*					
Barry's Dream	*Colpophyllia natans* *Millepora spp.*	*M. faveolata* *M. annularis*				
Hodges Bay	*P. asteroides* *M. faveolata* *Millepora spp.*					
Brain Reef	*A. agaricites* *M. meandrites*	*M. faveolata*				
Maggie's Point	*A. agaricites* *P. porites* *S. siderea* *M. meandrites*	*M. faveolata*				
Champagne	*P. porites* *M. annularis* *M. faveolata** *M. meandrites* *M. cavernosa*	*M. faveolata**				
Guyana Quartz	*A. agaricites* *P. porites* *M. annularis* *M. faveolata* *M. meandrites* *D. stokesii* *M. mirabilis*		*S. siderea**	*S. siderea**		

Discussion

In Dominica, Yellow Blotch Disease (YBD), Dark Spot Syndrome (DSS), White Plague (WP), and Black Band Disease (BBD), and coral bleaching (CB) are identified in November 2004. Aspergillosis (ASP) may be present along the east coast of the island. Both coral diseases and coral bleaching infect the framework builders *M. annularis*, *M. faveolata*, and *S. siderea*.

This study records the number diseased and bleached colonies, but not the total number of colonies within the study circles. Instead, a mean density (per m^2) and estimated percent cover of diseased and bleached colonies are calculated. Past reports on coral disease, such as AGGRA, compare locations by percent of total sampled colonies exhibiting disease and bleaching, making it difficult to compare the data. In regards to area and percent cover values, each coral colony is assumed to be flat and a perfect circle. Of course, these two assumptions are not true, but due to time constraints for field work, they are necessary. These two assumptions allow for estimates and comparisons between sites to be made. Despite the shortcomings of the data, the research does indicate certain conclusions.

A bleaching event occurs in Dominica in the year 2004. Approximately 88.5% of colonies observed and 18 zooxanthellate species are found bleached. The first species observed exhibiting signs of bleaching is *M. meandrites* in early October. The water temperature ranges from 27º C in early October to 30º+ C in mid November. In 2003, 25 species were recorded as bleached. This event was first recorded in mid October. Water temperature was 30º+ C up to depths of 10 m. These consecutive bleaching events indicate chronic stress on Dominica's coral reefs. The most obvious stress factor contributing to these bleaching events is water temperature; however, other natural factors could be inducing these bleaching events.

Field observations provide clues to the cause of the 2004 bleaching event. One field observation is that bleaching did not occur uniformly over entire colonies of *A. agaricites, C. natans, D. labyrinthiformus, D. stokesii, M. faveolata, M. annularis, P. asteroides,* and *P. porites*. The top portion of the colony, which is exposed to the most sunlight, is bleached. No temperature gradient can be found between the exposed and shaded areas of colonies. Therefore, a combination of water temperature and UV light may be inducing this bleaching event. A report by Fitt (1995) determined that UV light can induce coral bleaching when combined with high water temperatures. 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. The current study finds *M. faveolata*, *M. annularis*, and *A. agaricites* bleached in depths ≤ 10 m with water temperatures of 27º to 30º+ C over the course of 8 weeks.

The non-framework builder *A. agaricites* is the species most commonly found bleached; however, it has the third lowest estimated percent of afflicted tissue. *P. asteroides* and *P. porites* exhibit slightly higher percents of afflicted tissue, yet when combined; they represent a smaller portion of the observed colonies than *A. agaricites*. Ishikawa (2004) found *P. asteroides*, but neither *A. agaricites* nor *P. porites*, to be a main contributor to live coral percent cover at any study locations. Shallow areas contain more colonies of bleaching *A. agaricites* and *P. asteroides* than deeper areas. *P. porites* is more often found in deeper areas. This difference in distribution is the result of differences in community structure between deep and shallow reefs. As evidence, *P. porites* forms mono- and bi-specific (with *Madracis mirabilis*) assemblages in deep areas along the West coast of Dominica, unlike *A. agaricites* and *P. asteroides*. These three coral species may be used as indicator species for future bleaching events.

Framework building species are affected slightly differently than non-framework builders. *M. annularis* is found to have the highest percent of afflicted tissue. Out of the 6 most commonly observed species, this species has the second lowest number of examined colonies, with 87.5% found at Douglas Bay. *M. faveolata* and *S. siderea* exhibit the lowest amount of afflicted percent of coral tissue. Afflicted colonies of these two species are found more often in deeper areas. Therefore, *M. annularis* may be more susceptible to coral bleaching than other framework corals. Haphazard swims suggest all three framework builders are susceptible to coral diseases such as YBD, BBD, DSS, and WP.

Results from Ishikawa (2004) and AGGRA (2003) found an overall mean coral cover of 14.8% and 18% for shallow reefs, respectively. For the Caribbean Sea, AGGRA results show live coral cover between 3% and 38%. Thus, Dominica is similar to the rest of the Caribbean in live coral cover.

A comparison between live coral cover percent, as described by Ishikawa (2004), and estimated percent cover of afflicted tissue shows Capucin, Hodges Bay, and Douglas Bay may be more impacted by coral disease and coral bleaching (Figure 9). Anse Soldat does not seem impacted by coral diseases and coral bleaching. No determination can be made for the deep sites of Lauro Club and Barry's Dream because Ishikawa (2004) does not provide information for these locations. The data in this study indicate Barry's Dream has the highest density of diseased and bleached corals. Deep reef sites often have higher live coral cover and live coral density than other sites (S Steiner, *pers comm*). Personal field observations at Barry's Dream suggest a higher live coral cover than other sites. Thus, it seems reasonable that Barry's Dream has a higher density of diseased corals.

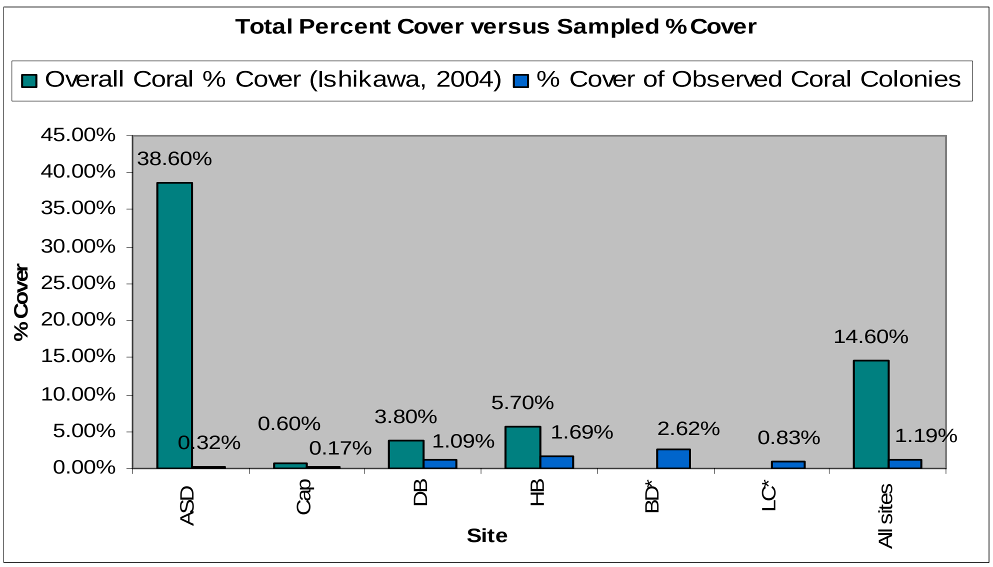

Figure 9: Comparison of estimated percent cover of observed corals with overall percent cover as described by Ishikawa (2004) at 6 locations

Anse Soldat has the highest live coral cover (38%) and the second lowest estimated percent of afflicted coral tissue (0.32%). This does not follow the trends of the other locations. The possible reasons for this are community structure, location, and reef type. Ishikawa (2004) found *Diploria clivosa* and *P. asteroides* to dominate this fringing reef, unlike other locations where *P. asteroides* and *S. siderea* were dominant. The difference in community structure may affect susceptibility of a coral reef to disease and bleaching because different coral species may have a different tolerance ranges for factors contributing to infection.

A comparison of the results of this study and AGGRA results is not possible. The current study estimates percentage of tissue afflicted by coral disease and bleaching and mean density of bleached corals per m^2, while AGGRA reports only the percentage of total coral colony population exhibiting coral disease and/or coral bleaching (6% of all coral colonies). Borger (2003) suggests percent of tissue mortality is more relevant to policy than percent of colonies afflicted. The research present in this report supports this idea. Although *A. agaricites* is most commonly found afflicted by coral disease and coral bleaching, *M. annularis* exhibits a greater percent of afflicted tissue.

YBD slowly kills coral colonies due to a slow progression rate and infections that may last for years (Deloach, 2002). YBD is only found affecting *M. annularis* and *M. faveolata*. In the Caribbean, AGGRA (2001) found both of these species and *M. franski* to commonly be infected with YBD. Colonies of *M. annularis* and *M. faveolata* are also found suffering from a combination of bleaching and YBD. If bleaching does make corals more susceptible to coral diseases, then, in Dominica, *M. faveolata* and especially *M. annularis* may be at higher risk of degradation from these two afflictions.

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 is 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.

DSS infections are 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). In November 2004, WP is found on colonies suffering from DSS. Therefore, DSS may also make colonies more susceptible to other coral diseases.

ASP has been isolated from African dust brought to Dominica by trade winds. *Gorgonia* spp. is found with purple discolorations similar to ASP. A purple discoloration is also found on one colony of *Millepora* spp. and one colony of *S. radians*. *C. gibbosum* is observed 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 is impossible *in situ*. A picture of *Gorgonia* sp., taken by S. Steiner in the Scottshead/Soufriere Marine Reserve, displays similar symptoms to the *Gorgonia* spp. of Hodges Bay including the presence of *C. gibbosum* (Appendix A).

Future research should focus on different aspects for each disease. Infection rates in reef framework builders *M. annularis*, *M. faveolata*, and *S. siderea* should be studied further. The presence, progression, and effects of BBD, DSS, WP, and YBD on Dominica's coral reefs should be monitored over a multi-year period to determine their infection rates, their progression rates over the colonies' surface, and the rate of recovery of the colonies. Future studies focusing on BBD should be performed between early March and late August. Studies of YBD should be focused in deeper areas and examining its effects on *M. annularis* and *M. faveolata*. Microbiological tests should be performed on *Gorgonia* spp. to determine the presence of ASP.

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 reef 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.

It is important to reduce the occurrence of coral diseases and coral bleaching to ensure the sustainability of coral reef resources. 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 synergistically degrade coral reef ecosystems. Coral colonies 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, actions can be taken to reduce local stresses. Actions to control the impact of local stresses include reducing agricultural and urban pollution, converting from near-shore to pelagic fishing, and developing more efficient waste disposal systems. These actions will help preserve the coral reefs of Dominica; helping to ensure an important resource for future generations.

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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

Ecological Society of America (2000) *Coral Reefs*. Washington, DC www.esa.org

Feldman, AF (2000) *An Assessment of Coral Reef Management Programs: Towards a Community Based Approach*. (CSUMB Capstone Project)

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

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

Lang, JC (2003) *Atoll Research Bulletin Status of Coral Reefs in the Western Atlantic: Results of Initial Surveys, Atlantic Reef Assessment and Gulf Rapid Reef Assessment (AGGRA) Program*. National Museum of Natural History Smithsonian Institute Washington, DC

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

McClanahan, TR (2001) *The near future of coral reefs*. Environmental Conservation 29 (4): 460-483

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

Nugues, MN, Roberts, CM (2003) Coral Reefs 22:507-516

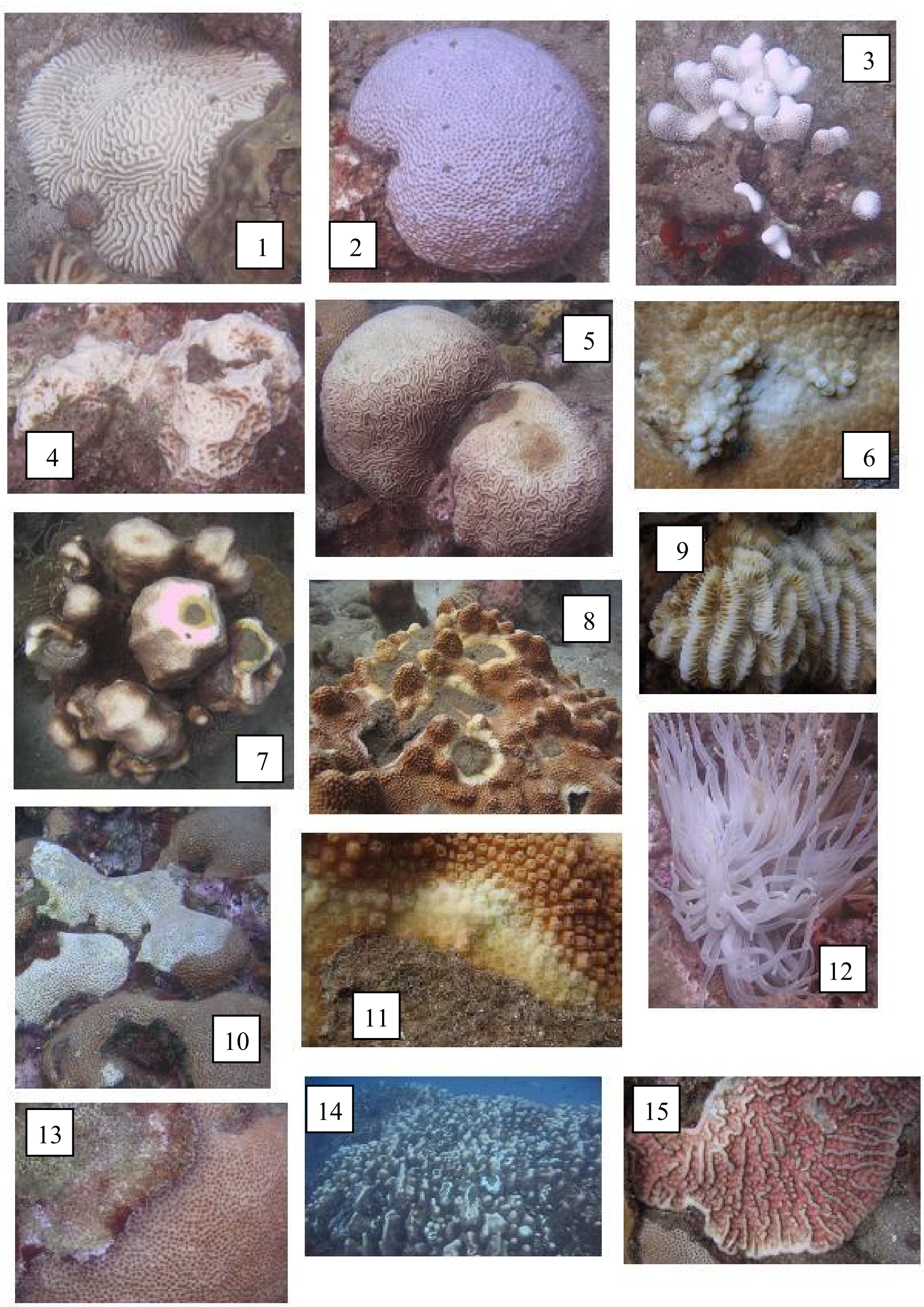
Robert A *et al*. (2001) *The Adaptive Bleaching Hypothesis: Experimental Tests of Critical Assumptions*. Biol Bull 200:51-58

Szmant, AM (2002) *Nutrient Enrichment on Coral Reefs: Is It a Major Cause of Coral Reef Decline*? Estuaries 25 (4b): 743-766

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; **12.** Bleaching *Condylactis gigantea*; **12.** *S. siderea* with BBD infection; **13.** Bleaching *M. annularis*; **14.** Bleaching *Mycetophyllia* sp.