Scleractinian Monitoring in Dominica, West Indies:
Species Richness, Diversity, and Live Cover
By Kim Knuth

The Abundance of Herbivorous and Predatory Fishes in Relation to *Diadema antillarum* Along the West Coast of Dominica
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Introduction

The coral reefs of Dominica represent a vital yet limited and threatened natural resource. Historically, reefs have provided for the livelihood of fishermen and their families at an artisinal level. Presently, new user groups are emerging such as recreational divers. Simultaneously, urban migration is leading to coastal sprawl coupled with increased terrestrial runoff and pollution.

Dominica's young volcanic topography is characterized by a narrow shelf. The potential coral reef areas are less than 20 percent than that of the total area (750 km^2) of the island. Therefore, conservation of coral reefs is crucial in maintaining a sustainable use of its resources.

One of the tools used in conservation is the assessment and regular monitoring of resources. In the first study (pages 3-10) a permanent Scleractinian coral monitoring system was established along the West coast. This study serves a reference point for the detection of phase shifts (species richness, size classes and percentage of live coral cover). The second study (pages 11-21) is a continuation of previous research on fish predators of *Diadema antillarum*. In addition, this study assesses the relationship between grazing fishes, algal abundance and *D. antillarum* densities. Information generated from these studies will assist in the future conservation of economic and ecological functions of Dominica's coral reefs.

These studies were carried out at 7 reef sites on the West coast of Dominica. The sites are listed in order from north to south.

Location 1: Tabby Bay- Directly offshore on the northern most point of Secret Bay, with a depth of 1-4 m. This site is comprised of coral aggregations on large boulders surrounded by sand flats and generally characterized by high macroalgal cover and low visibility due to the river north of this location.

Location 2: Salisbury West- 150 m offshore and 200 m north of the Lauro Club, 10-15 m in depth. The reefal compostition consists of flat carbonate buildup containing large corals and sponges.

Location 3: Salisbury East- Located 30 m offshore and directly east of Salisbury West. Depth ranged from 2-4 m. A pair of reefs formed from a solidified beach, incorporated with sand flats. Substrate is characterized by low coral diversity and small nonreef building corals.

Location 4: Macoucheri- Approximately 100 m southwest of the Macoucheri River, ranging in depth from 5-10 m. A patch reef characterized by high coral and structural diversity that is surrounded by sand flats and *Syringodium filiforme* beds.

Location 5: Champagne- 40 m south of the point at the southern end of Champagne beach, 30 m from the shore, in a shallow cove 2-5 m in depth. Substrate was composed of boulder fields and coral aggregations. This site is the northern most boundary of the Soufriere / Scott's Head Marine Reserve (SSMR).

Location 6: Scott's Head- The site was located 30m north of the Scott's Head peninsula on a shallow (2-5m) flat shelf with coral assemblages. This benthic composition is shaped by its exposure to turbulent waters at the convergence of the Atlantic Ocean and Caribbean Sea. This site is in the southern area of the SSMR.

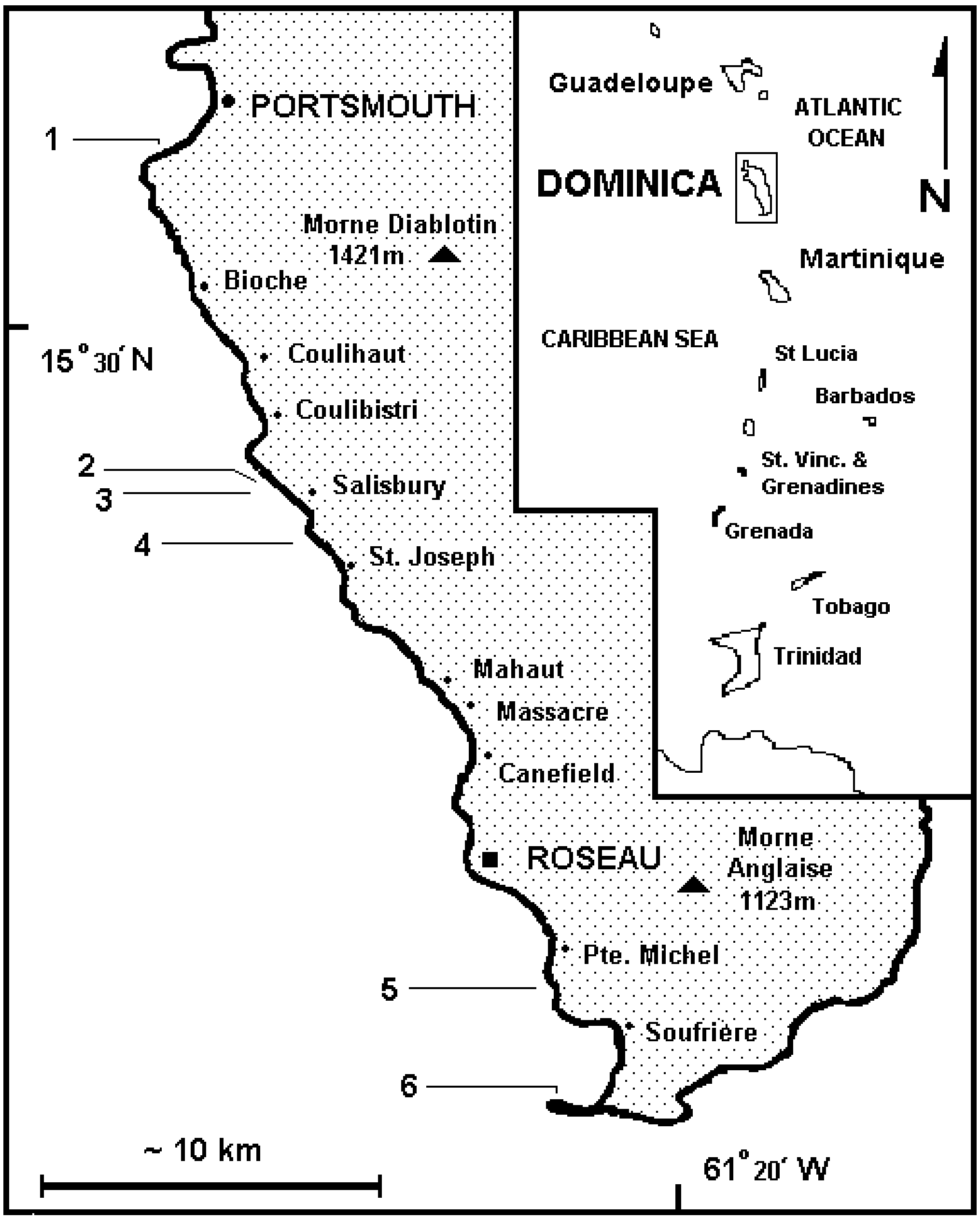

Fig. 1 Survey locations along the West Coast of Dominica

25 November 2003 Kim Knuth and Kimberly McDonald

Study I: Scleractinian Monitoring in Dominica, West Indies: Species Richness, Diversity and Live Cover.

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Abstract Four permanent scleractinian monitoring sites were established along the western coast of Dominica. Each site was surveyed for species richness, species diversity and live cover. Among the eighteen species identified, colonies of *Porites astreoides*, *Agaricia agaricites*, and *Siderastrea siderea* were the most abundant. Salisbury West and Macoucheri displayed the highest species richness (13). Salisbury West had the highest scleractinian species diversity ($H' = 2.12$) and evenness of distribution ($J' = 0.42$). In contrast, Salisbury East displayed both the lowest species diversity ($H' = 0.785$) and evenness ($J' = 0.174$). Scleractinian species *S. siderea*, *P. astreoides* and *Montastraea faveolata* were found to be the largest contributors of live tissue cover on the reef. Currently, a scleractinian monitoring system does not exist to record and monitor long term changes in reef composition. This project serves as a reference to quantitatively record changes in scleractinian structure and benthic cover.

Keywords Scleractinia · Species richness · Species diversity · Live cover · Dominica

Introduction

There is a general consensus among coral reef biologists that there has been a worldwide degradation and decline of reefs and related ecosystems over the past several decades (Lewis 2002). Coral reefs provide many important ecological and economic benefits, such as: providing habitat and nurseries for reef fishes, protecting the shoreline from erosion, decreasing storm damage by reducing wave energy, and attracting tourists (White et al. 2000). Therefore, a decline in reef structure and area can have serious consequences. Small islands with limited reef resources, such as Dominica, which rely heavily upon artisanal fishing and tourism are particularly vulnerable to losing these benefits.

Due to Dominica's young volcanic origin, the island is characterized by a steep terrestrial topography and narrow coastal shelf (Honychurch 1995). Since corals are limited by depth due to endosymbiotic photosynthetic zooxanthellae. The absence of a wide euphotic zone limits coral growth and the corresponding benefits these organisms provide. In addition to light, a narrow range of tolerance to other critical environmental factors including nutrient poor waters, salinity, temperature (16-28 degrees Celsius) and a stable substrate for attachment are essential for the development of coral reefs (Humann and Deloach 2002). Since coral formations are naturally limited around the island, additional problems associated with coastal sprawl, such as increased sedimentation and urban pollution, can have a drastic impact on coral abundance and structure.

Monitoring coral reefs is necessary in providing environmental data that can be applied to reef conservation. Since historical records of disturbance do not exist for most coral reefs (Aronson et al. 1994), the establishment of a permanent monitoring program will be vital to detecting and recording any changes taking place in Dominica. In the following study, a permanent monitoring system was established along the western coast of the island. Four survey sites were selected between Soufriere and Salisbury. At each site, species richness, diversity and live cover were recorded along permanent transects. This information will be used as a reference point to identify any future structural changes on Dominica's reefs.

Method and Materials

Four coral reef monitoring sites were selected along the west coast of Dominica (Fig. 1, Knuth and McDonald 2003). Salisbury West (10-14 m) and Macoucheri (6-7 m) were surveyed using SCUBA; Champagne (2-3 m) and Salisbury East (3 m) were surveyed using snorkeling gear. The locations of each permanent transect per site are illustrated in Figure 2.

Four permanent, 25 m transects were laid out at each site. The transects at Macoucheri were placed perpendicular to each other (forming a large cross), while transects at Champagne, Salisbury East and Salisbury West were placed north to south avoiding large sand patches. Metal nails were used to permanently mark the end of each transect. The nails were marked with flagging tape for future reference. A 25 m transect line was temporarily anchored to the nails while the survey was conducted. All scleractinian colonies directly below the transect line were identified *in situ* (Humann and Deloach 2002), then measured (longest and shortest diameter) using a measuring tape. The percent of dead vs. live tissue was visually estimated. However, scleractinian species smaller than 9cm^2 are often misidentified *in situ* and were not included. Areas where the transect line included patches of sand or anemones (*Stichodactyla helianthus)* were measured to be considered in calculations of live cover per meter. Species diversity expressed as (H′) and evenness as (J′) were calculated using Shannon-Weiner (1948).

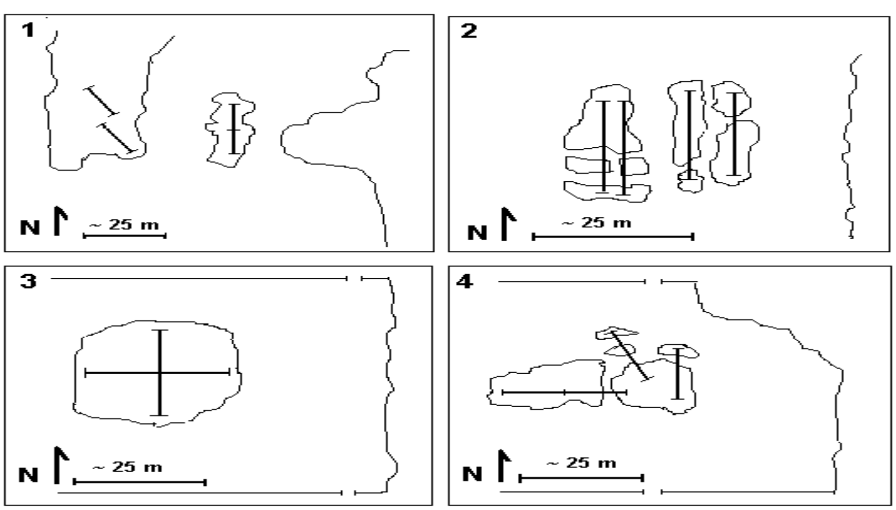

Fig. 2 Transect positions for each survey site: Champagne (1), Salisbury East (2), Salisbury West (3) and Macoucheri (4)

Results

Eighteen scleractinian species were identified along the western coast (Table 1). However, species richness varied per site. Nine species were identified at Champagne, 10 at Salisbury East and 13 at both Salisbury West and Macoucheri (Table 2).

Colonies of *Porites astreoides*, *Agaricia agaricites* and *Siderastrea siderea* had the highest overall abundance (Fig. 3). However, *S. siderea*, *P. astreoides* and *Montastraea faveolata* contributed the highest amount of live tissue cover to the reefs (Fig. 4). At Champagne and Salisbury East, *P. astreoides* was both the dominant scleractinian species and the highest contributor of live tissue cover (Figs. 5-6). In contrast, at Salisbury West and Macoucheri, *P. astreoides* was most abundant but the majority of live tissue was contributed by *M. faveolata* and *S. siderea* (Figs. 6-7).

The highest scleractinian species diversity (H′ = 2.12) and evenness of species distribution (J′ = 0.42) occurred at Salisbury West. In contrast, Salisbury East had both the lowest species diversity (H′ = 0.785) and the lowest evenness of distribution (J′ = 0.174). The sites located at Champagne and Macoucheri had a species diversity of H′ = 1.143 and H′ = 1.87. Evenness of scleractinian distribution was higher at Macoucheri (J′ = 0.368) than Champagne (J′ = 0.23) (Table 2).

Table 1 Total scleractinian species identified in Dominica

Porites astreoides (PA)	*Diploria strigosa* (DS)	*Diploria labyrinthiformis* (DL)
Agaricia agaricites (AA)	*Montastraea cavernosa* (MC)	*Siderastrea radians* (SR)
Meandrina meandrites (Mme)	*Isophyllia sinuosa* (IS)	*Madracis decactis* (MD)
Porites porites (PP)	*Colpophyllia natans* (CN)	*Favia fragum* (FF)
Madracis mirabilis (Mmi)	*Stephanocoenia intersepts* (SI)	*Acropora palmata* (AP)
Montastraea faveolata (MF)	*Dichocoenia stokesii* (D Sk)	*Siderastrea siderea* (SS)

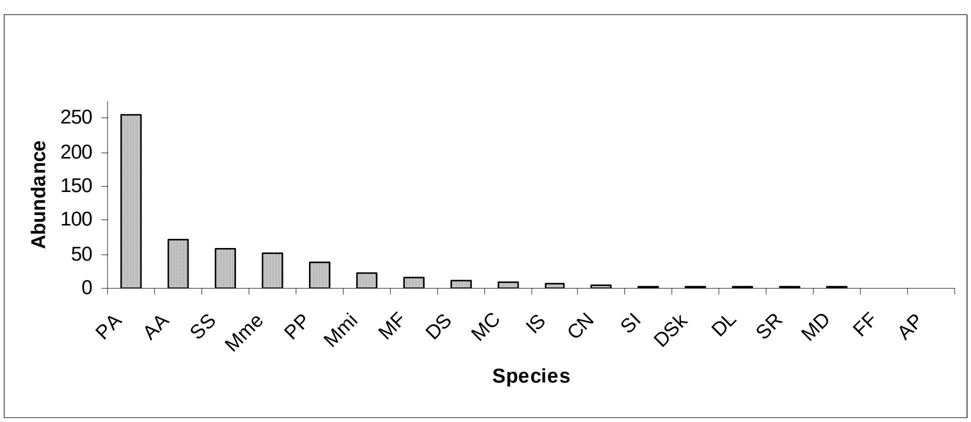

Fig. 3 Total scleractinian abundance

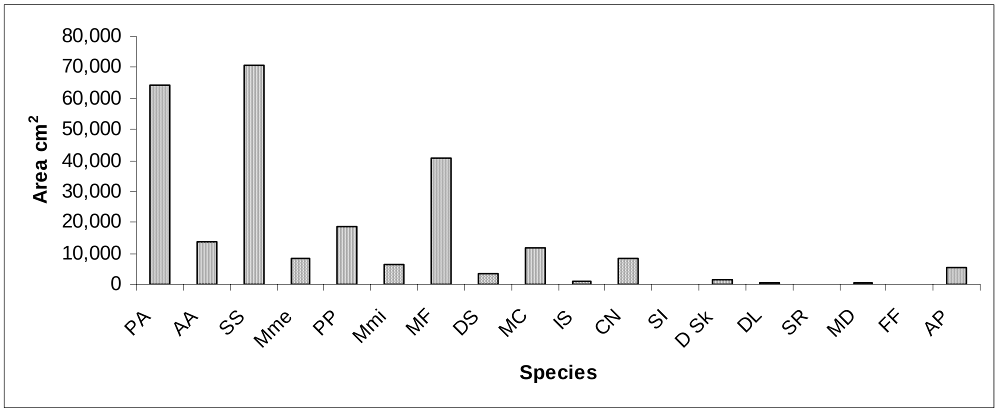

Fig. 4 Total scleractinian live tissue

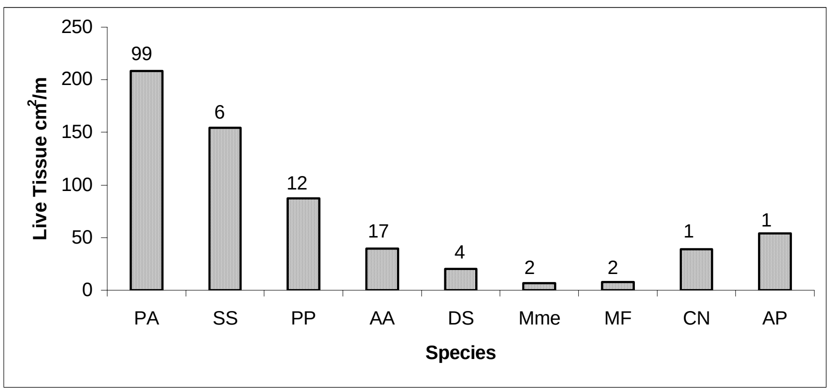

Fig. 5 Scleractinian live tissue cover and abundance (listed above bars) at Champagne

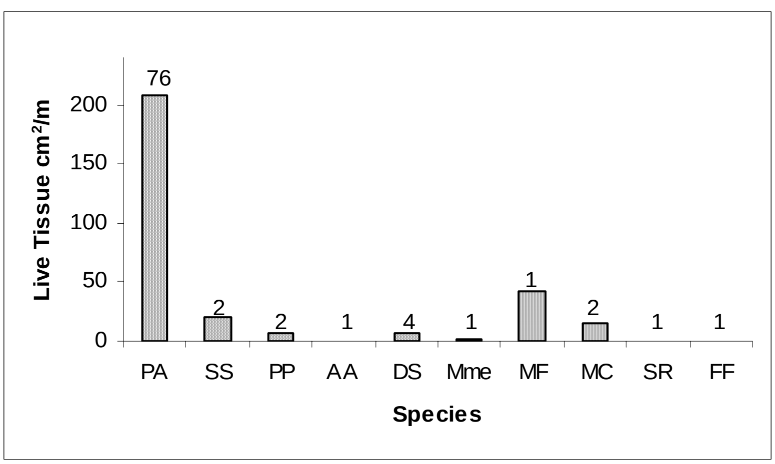

Fig. 6 Scleractinian live tissue cover and abundance (listed above bars) at Salisbury East

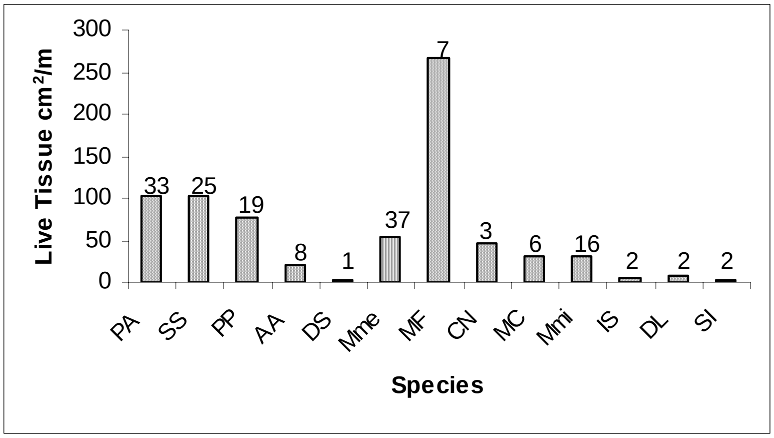

Fig. 7 Scleractinian live tissue cover and abundance (listed above bars) at Salisbury West

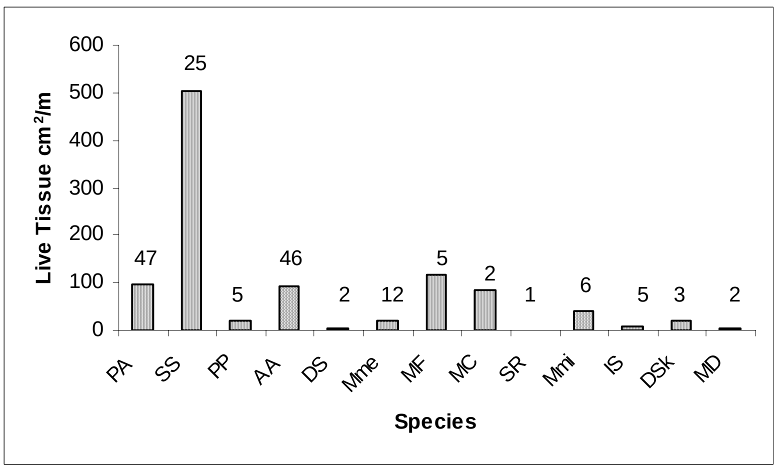

Fig. 8 Scleractinian live tissue cover and abundance (listed above bars) at Macoucheri

Table 2 Scleractinian species richness (n), diversity (H′) and evenness of distribution (J′) at study sites

Site	n	H′	H′ Max	J′
Champagne	9	1.143	4.97	0.23
Salisbury East	10	0.785	4.5	0.174
Salisbury West	13	2.12	5.09	0.42
Macoucheri	13	1.87	5.08	0.368

Discussion

Champagne had a low species diversity and evenness of distribution. Only nine scleractinian species were identified at this site (Table 2). This number is relatively low when compared to previous studies that identified 32 species along Dominica's western coast (Steiner and Borger 2000). The permanent transects for this site are located in shallow water (2-3 m deep). Due to their close proximity to the surface, this site is subject to constant wave energy that could limit larval settlement. In addition, this site has a high occurrence of *Millepora spp. Millepora* is a Hydrocoral that is very common in shallow surge zones and is rarely found in depths beyond 10 m (Humann and Deloach 2002). The high occurrence of Hydrocorals in shallow water limits available substrate for attachment and contributes to a low diversity and evenness of scleractinian species.

The dominant scleractinian species at Champagne was *P. astreoides.* As a result of its high abundance (99), this species also contributed the largest amount of live tissue cover on the reef (Fig. 5). However, *S. siderea* was also a major contributor of live cover despite its low abundance (6). In addition, Champagne was the only site were *Acropora palmata* was present. At this site, the lack of massive reef builders limit habitat for reef fishes and benthic organisms. Champagne is also a popular recreational reef for SCUBA diving and snorkeling. Therefore, monitoring scleractinian colonies that have already been established is necessary in detecting future changes, such as coral diseases, bleaching or mass mortality, that could impact its available habitat for reef organisms and the income generated by eco-tourism.

Salisbury East had the lowest species diversity and evenness of distribution for all four sites (Table 2). Only ten scleractinian species were identified. This site is characterized by shallow waters (below 3 m) with high wave energy and a high occurrence of *Millepora spp.* For that reason, it is comparable to Champagne in terms of larval settlement and limited substrate for attachment.

P. astreoides is the dominant scleractinian species (76) present at Salisbury East (Fig. 6). Due to the lack of framework builders, it is also the main contributor of live tissue cover found at this reef. In addition, Salisbury East was the only site were *Favia fragum* was identified. *F. fragum* is a common species and was probably present at other sites however; it was not included if less than 9 cm^2. Despite the absence of large, structurally complex species, such as *Montastraea annularis* which provide habitat, this site is economically important for artisanal fishing of the Salisbury community.

The scleractinian species richness at Salisbury West was 13. This site had both the highest species diversity and evenness of distribution (Table 2). This reef is located approximately 150 m offshore at a depth of 10-14 m (Fig. 1, Knuth and McDonald 2003). Depth related factors including increased larval settlement (less turbulence), the reduction of Hydrocorals (increased substrate) and higher levels of dissolved oxygen (cooler water) contribute to the high diversity and evenness found here. Due to its distance from shore and the lack of nearby rivers, this reef remains less affected by disturbances caused by terrestrial runoff (sedimentation).

Salisbury West was dominated by *Meandrina meandrites* (37) (Fig. 7). *M. meandrites* is a polymorphic species capable of forming hemispherical heads or flattened plates. In addition, it is often found in areas with coral rubble or sand and does not need to be firmly attached to the substrate (Humann and Deloach 2002). This species abundance can be attributed to its ability to exploit different types of substrate and alter its growth form to maximize light absorption. Due to the oceanic parameters at Salisbury West conducive to coral growth (see above), there was a high occurrence of other species including *P. astreoides* (33), *S. siderea* (25) and *Porites porites* (19) (Fig. 7). However, despite these abundances, the majority of live tissue was contributed by *M. faveolata.* Colonies of *M. faveolata* grow in massive mounds that can reach up to 3 m (Humann and Deloach 2002). Despite its infrequent occurrence (7), this species is an important framework builder that provides habitat for many benthic organisms. This is an important site for scleractinian monitoring due to its high species diversity (Table 2) and the presence of framework builders. This site provides habitat and could possibly be a dispersal site for larval recruits downstream.

Thirteen scleractinian species were identified at Macoucheri. The species diversity and evenness were slightly lower than those found at Salisbury West (Table 2). This reef is approximately 6-7 m deep and is located 100 m SW from the Macoucheri River (Fig. 1, Knuth and McDonald 2003). It is periodically affected by high amounts of sedimentation from heavy rainfall due to its close proximity to the river.

P. astreoides is the dominant scleractinian species (47), though *S. siderea* contributes the largest amount of live tissue cover (Fig. 8). *S. siderea* is not only abundant at a variety of depths, it is also a massive reef builder whose colonies can grow up to 2 m (Humann and Deloach 2002) thus being a large contributor to reefal structure (habitat) and live tissue coverage. There was also a high abundance of *A. agaricites* (46). This species can adapt to many environments by altering its growth forms to optimize light absorbency. This reef is also frequented by SCUBA divers. Scleractinian monitoring will be useful to detect changes that could result in the loss of habitat (fisheries) and local revenue (tourism).

Overall, the dominant scleractinian species was *P. astreoides* (255) (Fig. 3). This species is a small, polymorphic coral commonly found forming mounds or encrusting a rocky substrate. It was present at all permanent transects which ranged in depth from 2-13 m. The occurrence of *P. astreoides* in turbulent waters, and areas of increased sedimentation combined with its ability to take on different growth forms to capture sufficient light indicate that it is very robust. In contrast, *S. siderea* was found to be the largest contributor of live tissue cover due to its massive size (up to 2 m) despite its infrequent occurrence (58) (Fig. 4).

As human activity continues to increase along Dominica's western coast, i.e. recreational divers and coastal sprawl, conservation issues must be addressed to mitigate structure and habitat loss. Permanent scleractinian monitoring is an essential tool in recording future changes in reefal structure and benthic composition. Other factors that could facilitate future surveying include attaching more nails to stabilize the transect lines and documenting reefal conditions using underwater photography. Performing biannual surveys of selected reefs and providing this information to local governmental agencies would be helpful in managing areas of recreational use and artisanal fishing. In addition to the four sites established along the western coast, other areas should be included, i.e. Scott's Head and Tarou Point.

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Study II: The Abundance of Herbivorous and Predatory Fishes in Relation to *Diadema antillarum* Along the West Coast of Dominica

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Abstract Six sites off the West coast of Dominica were surveyed to determine the density of herbivorous fishes and abundance of fish predators in relation to the keystone grazer *Diadema antillarum*. Thirty square meter belt transects and roving diver surveys were used to obtain density and abundance data. Density of herbivorous fishes was relatively even across all six sites ranging from Scott's Head (2.33 fish/m^2) to Tabby Bay (1.30/ fish/m^2). Herbivorous fishes tended to occur in high densities in areas of greater turf algal cover and low densities in areas of greater macroalgal cover. Nine species of *D. antillarum* fish predators were identified. Over 50% of the individuals identified were in the family Haemulidae. Other commonly observed predators included the sharpnose puffer and the puddingwife. The greatest abundance of predators was found at Salisbury East and the least at Scott's Head. *D. antillarum* densities from the same sites were compared to data collected during surveys yielding no significant relationships, although there is evidence that both herbivorous fishes and predators help shape the occurrence of *D. antillarum* through competition and predation pressure.

Keywords Herbivorous fishes · Predators of *Diadema antillarum* · Dominica

Introduction

Marine herbivores are estimated to consume 50 to 100 percent of the primary production on shallow forereefs (Deloach 1999). Herbivorous fishes (families Pomacentridae, Labridae, Scaridae, and Acanthuridae) are found on Dominica's West coast (Green 2002) and can be competitors for food resources to *Diadema antillarum* (Echinodermata; Echinoidea), which also feeds on seagrass, algae, and detritus (Randall 1964). The grazing activities of *D. antillarum* can markedly influence the structure of the shallow-water epibenthic coral reef community (Sammarco et al. 1974). Studies from Panama have shown that after the pathogen-induced mass die off of *D. antillarum* in 1983, there was a great increase in abundance of soft algae and herbivorous fishes (Robertson 1991). Removal of these grazers can result in amplified benthic algal growth, resulting in species composition shifts on reef communities. For example, Caribbean reefs that were formerly dominated by scleractinian corals and diminutive algal turfs have become overgrown by macroalgae (Edmunds and Carpenter 2001).

D. antillarum is more abundant on Dominica's West coast than elsewhere in the Caribbean (Quinn 2002). Due to their high abundance on Dominican reefs, it is assumed that *D. antillarum* is responsible for controlling a majority of the algal growth over other reef dwellers such as herbivorous fishes. It is still unclear if there is a correlation between the abundance of herbivorous fishes and *D. antillarum* in Dominica, and whether or not these fish play a role in shaping the occurrence of *D. antillarum* through competition for algal resources.

Eight families of fishes known to prey on *D. antillarum*: Haemulidae, Sparidae, Carangidae, Balistidae, Labridae, Ostraciidae, Diodontidae, and Tetraodontidae (Behrents 1984; Randall et al. 1964) are also found on Dominica's West coast (Green 2002). As predators, these fishes may play a role in controlling the abundance of *D. antillarum*, which could otherwise reduce coral recruitment from intensive urchin grazing. By acting as an urchin population control, these families may also play a role in maintaining the health and balance of reef ecosystems.

The main objectives of this study were to survey the density and size classes of herbivorous fishes, as well as the presence and abundance of known urchin predators at permanent monitoring sites on the West coast of Dominica. These surveys were then used to determine if a relationship exists between the densities of herbivorous fishes, algae and *D. antillarum*. In addition, predator abundance was also examined in relationship to *D. antillarum* density.

Methods and Materials

This study was carried out at six reef sites on the West coast of Dominica during the months of October and November 2003. From North to South these sites are Tabby Bay (TB), Salisbury East (SE), Salisbury West (SW), Macoucheri (MC), Champagne (CP), and Scott's Head (SH) (Fig. 1, Knuth and McDonald 2003). All sites were surveyed using snorkeling gear with the exception of Salisbury West and Macoucheri that required SCUBA. Fishes were identified *in situ* according to Humann and Deloach (2002). Species selected for the survey are known to commonly occur in Dominica (Green, 2002).

Herbivore Survey

At each site four 2 m wide, 30 m long, belt transects were conducted from a central starting point, and surveyed North, East, West, South. The weighted end of a transect tape was dropped and the observer swam at a constant speed (approximately 3 m/minute) for 30 m recording the number of individual species of grazing fish and their respective size classes (<5cm, 5-10, 10-15, 15-20, 20-25, >25 cm). A one-meter T-bar was carried ahead of the observer to standardize the sample size. Species on either side, underneath, above or entering in front of the observer were recorded. Where alignment of transects was not possible (Tabby Bay and Scott's Head), transects were run parallel to one another at least 5 m apart and/or end to end.

The following is list of species counted during this survey.

Family Name	**Common Name**	**Species**
Pomacentridae	Damselfish, Yellowtail	*Microspathodon chrysurus*
	Damselfish, Dusky	*Stegastes adustus*
	Damselfish, Bicolor	*Stegastes partitus*
	Damselfish, Threespot	*Stegastes planifrons*
Labridae	Wrasse, Yellowhead	*Halichoeres garnoti*
	Puddingwife	*Halichoeres radiatus*
	Slippery Dick	*Halichoeres bivittatus*
	Wrasse, Bluehead	*Thalassoma bifasciatum*

Scaridae	Parrotfish, Yellowtail	*Sparisoma rubripinne*
	Parrotfish, Stoplight	*Sparisoma viride*
	Parrotfish, Redband	*Sparisoma aurofrenatum*
	Parrotfish, Princess	*Scarus taeniopterus*
	Parrotfish, Queen	*Scarus vetula*
	Parrotfish, Striped	*Scarus iserti*
Acanthuridae	Ocean Surgeonfish	*Acanthurus bahianus*
	Blue Tang	*Acanthurus coeruleus*

Predator Survey

After completing the belt transects, a roving diver census based on the Roving Diver technique (Atlantic & Gulf Rapid Reef Assessment Project, 1999) was conducted (30 minutes) in the same general area. Density of predators was visually estimated and a category assigned as follows:

0 = None (no individuals seen during the survey)
1 = Single (1 fish)
2 = Few (2-10 fishes)
3 = Many (11-100 fishes)
4 = Abundant (>100)

The following is a list of species that was estimated during this survey.

Family Name	Common Name	Species
Haemulidae	Grunt, Cesar	*Haemulon carbonarium*
	Grunt, French	*Haemulon flavolineatum*
	Grunt, White	*Haemulon plumierii*
	Grunt, Bluestriped	*Haemulon sciurus*
	Black Margate	*Anisotremus surinamensis*
Labridae	Spanish Hogfish	*Bodianus rufus*
	Puddingwife	*Halichoeres radiatus*
	Slippery Dick	*Halichoeres bivittatus*
Balistidae	Triggerfish, Queen	*Balistes vetula*
	Triggerfish, Ocean	*Canthidermis sufflamen*
Ostraciidae	Trunkfish, Spotted	*Lactophrys bicaudalis*
Diodontidae	Porcupine fish	*Diodon hystrix*
Tetraodontidae	Puffer, Bandtail	*Sphoeroides spengleri*
	Puffer, Sharpnose	*Canthigaster rostrata*

D. antillarum and algal cover densities used to complement fish surveys were collected as part of regular monitoring by the Institute for Tropical Marine Ecology (ITME). Current *D. antillarum* density data for Salisbury West was not available, so data from fall 2002 was substituted for general analysis. An ANOVA test was performed on herbivorous fishes size class and site data. Pearson correlation was performed on herbivorous fishes, algae and *D. antillarum* data, as well as predator and *D. antillarum* data.

Results

Herbivores

Overall, the most abundant family of herbivorous fishes was Pomacentridae of which 85% were bi-color damselfish, most frequently occurring in the 5-10 cm size class (Fig. 1, Table 1). The next most abundant family was Labridae of which 97% were juvenile bluehead wrasses most commonly observed in the less than 5 cm size class. Together these two families comprised 84% of the total fishes observed in this study. Acanthuridae mainly represented by ocean surgeonfish (71%), occurred most frequently in the 10-15 cm and 20-25 cm size classes and comprised 9% of the total fish observed. Scaridae were 69 % redband and striped parrotfish generally observed in the 5-10 cm and 10-15 cm sizes classes, representing 7% of the total fish observed during this study.

Density of herbivorous fishes was relatively even at all six sites (Fig. 2) and tended to be higher where turf algal cover was higher ($r = 0.836$, $\alpha = 0.05$) and macroalgal cover was lower ($r = -0.586$, $\alpha = 0.05$) (Fig. 3). In addition, *D. antillarum* densities were higher where fish densities were higher ($r = 0.419$, $\alpha = 0.05$), with the exclusion of Tabby Bay (Fig. 4). None of these relationships were significant.

There was a significant difference between the size classes at each site ($F = 1.95$, $p = 0.01$). For example, Scott's Head had notably more juveniles (< 5 cm) than any other site (Fig. 5), but also had the greatest number of larger fishes (20-25 cm and >25 cm) yielding the greatest overall density. Champagne was one of the only other sites well represented in the larger size classes (15-20 cm, and 20-25 cm). Individuals at Salisbury West were concentrated in the < 5 cm and 5-10 cm size classes, and Tabby Bay had no fishes larger than 15 cm and had the overall lowest density.

Predators

No predators were abundant at any of the sites sampled according to the ranking system used (Table 2). Over 50% of the predators observed were french grunts, which are also one of the larger sized predators in this survey (adults observed up 30 cm). The next two most abundant predators were the sharpnose puffer (33) and puddingwife (31). Other predators observed were the cesar grunt (21), slippery dick (21), spanish hogfish (5), spotted trunkfish (5), queen triggerfish (2), and porcupinefish (1). White and bluestriped grunts, black margates, and ocean triggerfish were not seen at any sites during the surveys or time spent in the water. Two bandtail puffers were seen at Macoucheri, although not during the survey period.

Predator abundance in comparison to *D. antillarum* abundance showed a non-significant negative relationship ($r = -0.481$). However, it was observed that where the abundance of predators was higher, the number of *D. antillarum* was lower (Fig. 6). Salisbury East had the most individual *D. antillarum* predators (83). Seventy percent of predators observed at this site were french grunts. Macoucheri had the greatest diversity of fish predators composed of 61 individuals. The 3rd most predator abundant site was Champagne with 40 individuals of which 70% were grunts. Tabby Bay and Salisbury West had 26 and 25 individual predators respectively. However, Tabby Bay was marked by a greater diversity of predators than Salisbury West where 92% of predators observed were grunts and sharpnose puffers. Only 8 individuals were observed at Scott's Head, making it the least abundant predator site.

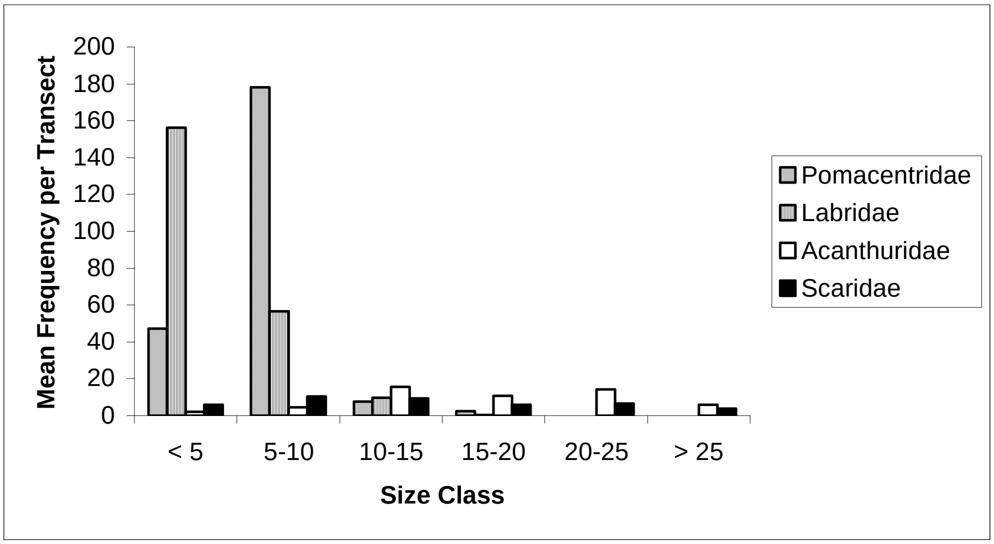

Fig. 1 Size class frequency of herbivorous fish families surveyed

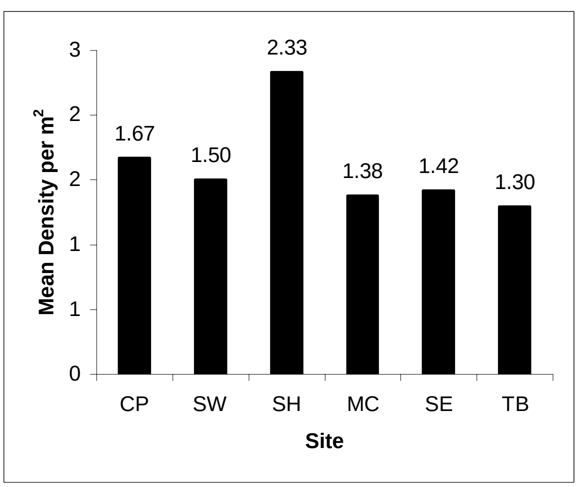

Fig. 2 Density of herbivorous fishes (all families combined) observed at each site

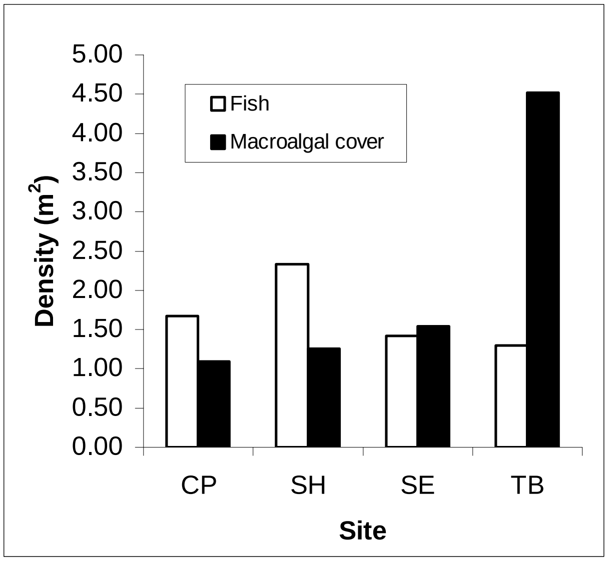

Fig. 3 Herbivorous fishes and macroalgal cover (% cover / m^2) at each site surveyed

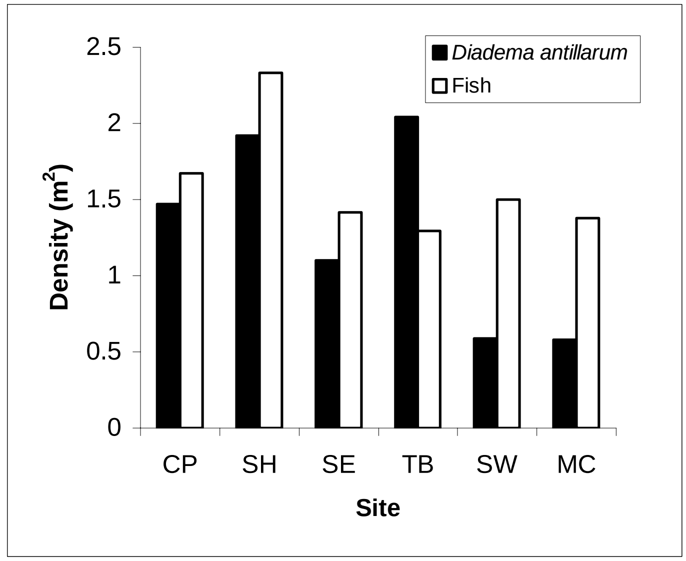

Fig. 4 Density of *D. antillarum* and herbivorous fishes at each site surveyed

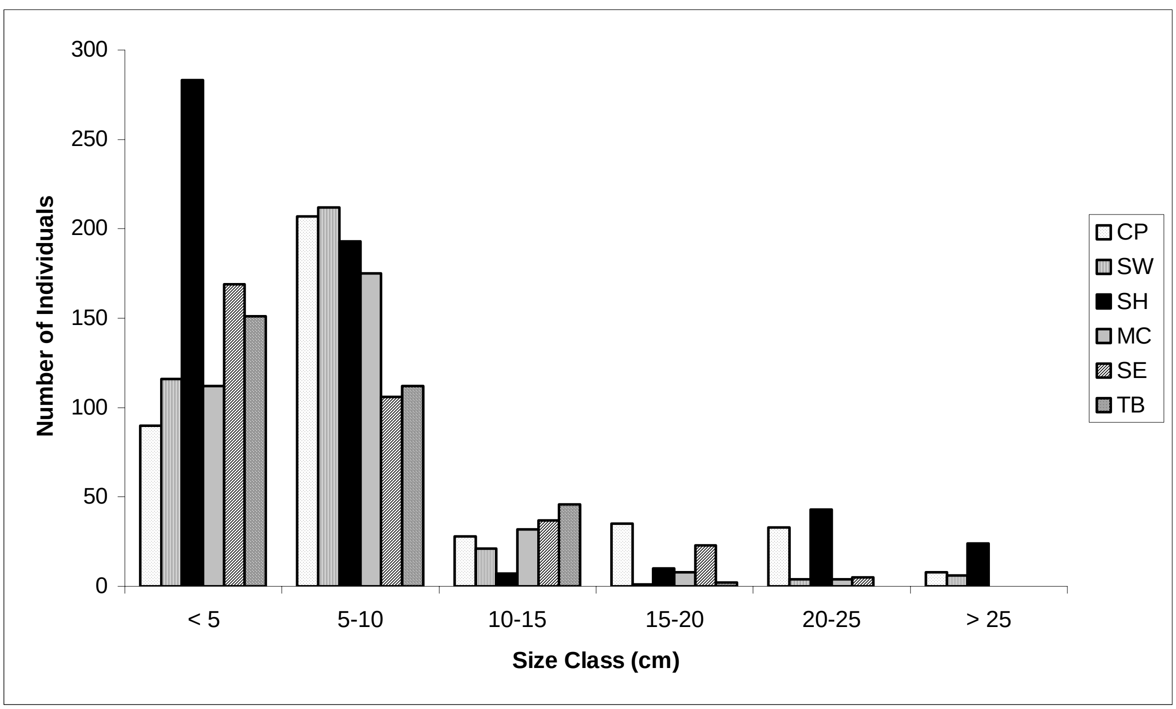

Fig. 5 Size class abundance at each site with all herbivorous fish families combined

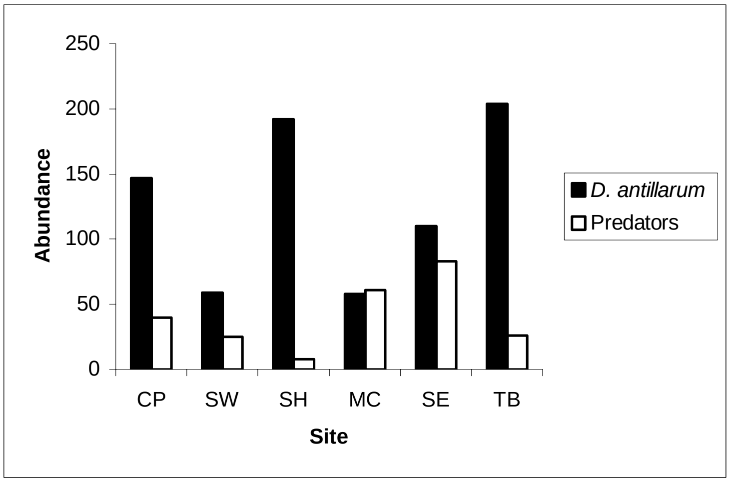

Fig. 6 Abundance of Predators and *D. antillarum* at each site surveyed

Table 1 Abundance of herbivorous species observed grouped into respective families

	Site						
Species	CP	SW	SH	MC	SE	TB	**Total**
Damselfish, Bicolor	162	230	219	154	89	23	877
Damselfish, Yellowtail	10	0	22	0	4	4	40
Damselfish, Dusky	30	0	0	0	3	79	112
Damselfish, Threespot	1	0	0	0	0	0	1
Wrasse, Yellowhead	0	5	1	0	0	0	6
Wrasse, Bluehead	119	83	242	95	165	156	860
Puddingwife	3	0	2	0	4	6	15
Slippery Dick	0	2	0	0	3	5	10
Surgeonfish, Ocean	28	0	30	25	47	21	151
Blue Tang	8	0	30	3	7	14	62
Parrotfish, Princess	3	9	4	5	0	0	21
Parrotfish, Stoplight	5	0	0	10	5	2	22
Parrotfish, Redband	10	16	8	22	11	0	67
Parrotfish, Yellowtail	2	1	0	0	0	1	4
Parrotfish, Queen	1	0	0	0	0	0	1
Parrotfish, Striped	19	14	2	17	2	0	54

Table 2 Summary of predator observations in assigned categories

Family	Species	MC	SE	CP	SW	SH	TB
Haemulidae	Grunt, Cesar	Many	Single	Single	None	Few	Single
	Grunt, French	Many	Many	Many	Many	None	Few
	Grunt, White	None	None	None	None	None	None
	Grunt, Bluestriped	None	None	None	None	None	None
	Black Margate	None	None	None	None	None	None
Labridae	Spanish Hogfish	None	None	None	None	None	Few
	Puddingwife	Few	Few	Single	None	Few	Few
	Slippery Dick	Few	Few	Few	None	None	Few
Balistidae	Triggerfish, Queen	Single	None	None	None	None	Single
	Triggerfish, Ocean	None	None	None	None	None	None
Ostraciidae	Trunkfish, Spotted	Single	None	Few	Few	None	None
Diodontidae	Porcupine fish	Single	None	None	None	None	None
Tetraodontidae	Puffer, Bandtail	None	None	None	None	None	None
	Puffer, Sharpnose	Many	Few	None	Many	None	None

Discussion

Only 16% of the fishes observed during these surveys (Acanthuridae and Scaridae) are recognized for their significant grazing pressure on reefs due to their body size and large territories (Robertson 1991; Deloach 1999). Data from Komoroske (2002) also concluded that Scaridae and Acanthuridae had a low frequency of occurrence in comparison to Pomacentridae and Labridae, which were most frequently less than 10 cm. In addition, 51% of Acanthuridae and Scaridae combined were in smaller sized initial phases (< 15 cm). It is unknown as to how much each size class of fishes contributes to grazing pressure and competition for algae in Dominica. Greater numbers of small fishes may contribute to grazing as much as lower numbers of larger fishes. For example, bicolor damselfish were the most abundant species, but are known for their maintenance and defense of algal gardens rather than their overall rate of herbivory (Deloach 1999). Swarms of bluehead wrasses (the second most abundant species) observed at all sites are known to be efficient in feeding on reefs due to their overwhelming numbers (Deloach 1999).

It is possible that the steep shelves and/or paucity of reefs in Dominica do not provide enough habitat for large fishes to thrive, so small fishes are dominant and non competitors of *D. antillarum* for algal resources. However, Scaridae and Acanthuridae combined are more abundant in Scott's Head and less abundant in Tabby Bay, which are sites currently found to have the greatest and least density of *D. antillarum* respectively. Although this relationship was not significant, it was found that sites with a greater density of herbivorous fishes also had a greater density of *D. antillarum*. A positive correlation may exist due to both animals' preference for turf algae, which would imply some level of competition between the two exists in Dominica despite the smaller size classes. A larger number of samples may more clearly represent and define this relationship between *D. antillarum* and herbivorous fishes.

A low abundance of predators during this study was expected due to the limited available habitat and high fishing pressure (Williams, personal comment). Two of the most abundant predators were french grunts and puddingwifes. This is significant because they both grow to be larger than 20 cm (Humann and Deloach 2002) and are known to directly feed on *D. antillarum* (Randall et al. 1964) rather than foraging opportunistically. Komoroske (2002), also observed a low abundance of predatory fish at the same sites, identifying sharpnose puffers and french grunts as the most frequent predators respectively. With a large enough predator abundance it is possible that these fishes could exert enough predation pressure to limit the occurrence of *D. antillarum*.

Looking exclusively at total number of predators or predator diversity may be misleading when defining potential predation pressure at surveyed sites. For example, even though Macoucheri had fewer individual predators than Salisbury East, there is evidence that *D. antillarum* experience the greatest potential predator pressure at this site. There was greater predator diversity at Macoucheri, and when visiting the site after the survey, predators not observed during the survey ranged from few to many, in addition to an increased abundance of previously observed predators. *D. antillarum* density is lowest at this site and second lowest at Salisbury East (excluding the 2002 data from Salisbury West) indicating that a higher number of individual predators alone may not define potential predation pressure accurately at these two sites, or that Macoucheri was under-represented during this study.

Scott's Head had the fewest predators, but the second highest *D. antillarum* density to Tabby Bay, which had a larger number and greater diversity of predators. One reason for this occurrence could be that a majority of the predators observed at Tabby Bay were smaller Labridae and Haemulidae (5-15 cm) that are opportunistic feeders, and/or are not yet selectively feeding on benthic invertebrates (Deloach 1999), thus exerting little potential predation pressure on *D. antillarum*. In comparison, the shallow site at Scott's Head is surrounded by deeper water where large fishes reside during the day, so predators may not have been counted due to limitations of snorkeling, thus under-representing the potential predation pressure at this site.

Tabby Bay is a shallow and turbulent site composed of rock slabs with crevices that provide good shelter for *D. antillarum*. These parameters may not be ideal for herbivorous or predator fishes to thrive. In their absence *D. antillarum* have neither competition nor predation pressure to limit their population size, which may explain why this site has the highest density of *D. antillarum*. The high cover of both turf and macroalgae may be due to high levels of disturbance and nutrient input from the river 35 m north. Research shows that dominance of reefs by macro-fleshy algae appears to reduce the abundance of herbivorous fishes that prefer palatable turf-forming algae (McClanahan et al. 1999), which was observed during this survey as well. Champagne had both the lowest cover of macro and turf algae. A low cover of macroalgae at this site has allowed for the turf to grow, which attracts herbivorous fishes. High densities of herbivorous fishes and *D. antillarum*, which are experiencing little predation pressure, have collectively grazed turf algae to a low cover. These are good examples of how direct relationships between variables within dynamic communities may be difficult to identify and may not accurately represent how multiple factors collectively shape marine environments. Greater numbers of samples may better identify factors shaping the occurrence of *D. antillarum*, as well as the implications of a phase shift within this system.

Without herbivores to harvest the rapidly growing algae, coral reefs could not exist in their present form (Deloach 1999). For example, a massive die off of *D. antillarum* in Dominica could allow algae to grow over coral reefs. Presently, overfishing has reduced the abundance of herbivores that could potentially keep algal cover down, which means a great amount of live coral reef could be lost if a phase shift were to occur. This would be a significant loss for Dominica due to the low presence of coral reefs to begin with. People of Dominica rely on fishing at an artisinal level. A loss of coral reefs is a loss of fish habit and nurseries for already stressed fish populations. As a result there would be even fewer fish to support the fishing industry in Dominica. The better this system and its interactions are understood the better the fishing resources of Dominica can be managed and conserved.

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