A Comparative Study of Dominican Coral Reef Health and Influencing Factors

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Abstract:

Multiple factors are known to affect the health of coral reefs, yet their correlations are not commonly studied. Following the Atlantic and Gulf Rapid Reef Assessment (AGRRA) Protocols Version 5.4, we analyzed the benthic cover, and fish and *Diadema* populations of Scott's Head Bay and Champagne Bay in Dominica. We expected to find more live coral in areas with more algae-grazers and less algae-farmers. Champagne Bay had a significantly higher percentage of algal cover than Scotts Head. A positive correlation was also found between algae-farming damselfish populations and algal density. Of concern, there were no adult Diadema found in transects at Scott's Head. Of greater concern, live coral cover at both sites were less than 5%, much lower than the 17-21% observed in 2001.

Introduction:

Coral reefs around the world include some of the most diverse ecosystems on earth and the Caribbean is a global hotspot of biodiversity (Conservation International 2007). Unfortunately, coral reefs worldwide are being affected by a combination of threats including "bleaching, fishing, pollution, waste disposal, coastal development, sedimentation, SCUBA diving, anchor damage, predator outbreaks, invasive species and epidemic diseases" (Grimsditch and Salm 2005).

Coral recruitment is limited by the amount of available substrate for colonization (Davis 2006). Bare substrate, however, is rare on coral reefs, which have many fast growing and invasive species of algae that rapidly colonize any available space. A variety of factors influence live coral cover including the physical conditions of the site, coral recruitment, density of algal grazers, such as *Diadema antillarum*, and algal grazing fish.

There are scientific claims that because damselfish are aggressively territorial, they sometimes inhibit coral grazing by other fish, thus leading to higher algal biomass (Foster 2005). Since damselfish farm algae that grow on dead coral, the damselfish often kill the coral to allow the algae to grow (Harris 2009). This is usually balanced by damselfish predation from larger fish such as Grouper and Snapper. As human fishing pressure increases the number of predatory fish are being decreased enough to destabilize this system. This results in more damselfish and therefore more dead coral (Burke and Maidens 2004). There are multiple species of damselfish in Dominica but certain ones do not farm algae and instead feed on plankton or other small organisms (Humann 1999). These species were recorded in our data but not categorized as "harmful" to coral since their actions do not directly affect coral health negatively. *Diadema* are known to graze algae on reefs and thus provide additional area for the colonization of corals. Though *Diadema* typically graze on algae growing on dead coral, they do sometimes eat live coral, contributing to bioerosion (Birkeland 1997).

Dominica, the "Nature Island of the Caribbean" is located in the Lesser Antilles between the islands of Martinique and Guadeloupe at roughly 15.25˚N 61.20˚W (Greenwich2000 2010). Dominica is home to many coral reefs surrounding the island and is known as one of the Caribbean's top diving destinations (Delphis 2010). Though Dominica only has approximately 70 km^2 of coral reef (Burke and Maidens 2004) it serves as an excellent location to study coral reef environments and interactions.

This study attempts to determine the relative effects and inter-relationships between the physical environment, density of Diadema, damselfish density, abundance of fish that prey on damselfish, and human fishing pressure on the benthic cover in Dominican coral reefs. Our studies were confined to the coral reefs of two different locations in southwestern Dominica, Champagne Bay and Scott's Head (Figure 1). These sites are relatively close to each other but may differ in fishing intensity. Champagne is the most heavily touristed marine area on the island and resides in a fish nursery zone, a core area of the (name of the Marine Reserve). Scott's Head is at the southwestern tip of the island adjacent to the waters of the Atlantic. We used the Atlantic and Gulf Rapid Reef Assessment (AGRRA) Protocols as a basis for our studies (Lang 2010). We compared the two sites using data collected on the physical environment, benthic cover, *Diadema* abundance, damselfish abundance, and overall fish abundance.

Materials and Methods:

Physical Environmental Data Collection

Weather information was collected using a Kestrel 3500 Pocket Weather Meter, in a clear, open area. Water quality data was measured with a Hydrolab Quanta Water Quality Monitoring System. Four HOBO U22 Water Temp Pro v2 Loggers were placed under rocks to continuously record water temperature. One was installed in 1 m water depth and one was installed in 3 m water depth in both Scott's Head and Champagne. When the loggers were retrieved, data was downloaded and plotted using HOBOware Pro v2.7 software.

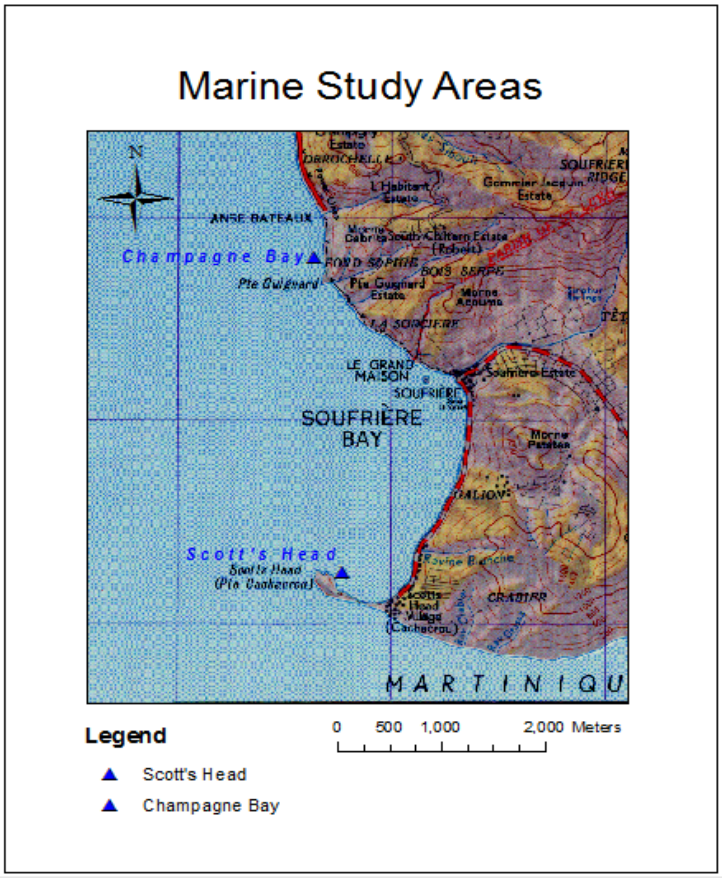


Figure 1: Locator map of Dominica in the Eastern Caribbean showing the location of study sites at Champagne and Scott's Head.

For the transect, we used a 50 meter underwater transect tape, rope, and surrounding rocks we found on the shore (weights can be substituted). For underwater data collection, slates with pencils were used. Snorkels, masks, wetsuits, and fins were used throughout our data collection. In order to keep track of transect points, a Garmin GPSmap 76 was used. An Olympus Stylus Tough 8010 underwater camera was taken to facilitate the gathering of our data.

We used a 1 m x 1 m quadrat made from ½ inch diameter PVC pipe that had holes drilled, 10-cm apart, large enough to run a rope through. The quadrat contained 100 equal-sized squares of 10 cm^2. A 1-m long PVC pipe to use as a guide bar and prepared our transect lines by tying rocks to the tape to weigh it down.

Biological Data Collection

We set up our transects parallel to the shore. The fish and damselfish transects were 30-m long by 2-m wide. The transects for benthic cover data were 10-m long by 1-m wide, with quadrats placed every 2 meters. To get more variability in our data, we only took one benthic cover transect per fish transect. After lowering the rock-tied end of the transect tape to the bottom, we swam thirty meters and placed the end of the tape on the ocean floor. We set our second transect tape at the end of the first transect and laid it another 30 meters. As soon as both tapes were in place we did our counts. The first surveyor counted the general fish along the transect, the second followed a few meters behind while counting damselfish, and the last pair of surveyors collected benthic cover data. While swimming along the transects, we recorded our data on the underwater slates and took occasional pictures with our cameras.

To minimize human error, only three transects were conducted per day. This process was repeated every two days for each site. A total of twelve transects, six at each site were taken. Before deploying the transects we conducted a day of reconnaissance at each site for familiarization of the region and to find a practical location to place them. This process was repeated at Scotts Head except with one minor adjustment, due to a short reef two out of the final three transects were placed parallel to each other and perpendicular to the shore ten meters apart. The final transect was placed along a reef connected a rock wall fifteen meters to the west of transect two and perpendicular to the shore. The data were input to a Microsoft Excel spreadsheet to calculate the standard deviation by individual species.

The algae farming Damselfish species that we recorded data for include: *Stegastes fuscus* (Dusky Damselfish), *Stegastes leucostictus (*Beaugregory), *Stegastes diencaeus* (Longfin Damselfish), *Stegastes planifrons* (Threespot Damselfish), *Microspathodon chrysurus* (Yellowtail Damselfish), *Eupomacentrus mellis* (Honey Damselfish), *Abudefduf taurus* (Night Sergeant), *Abudefduf saxatilis* (Sergeant Major), and *Stegastes variabilis* (Cocoa Damselfish). The non-algae farmers that we recorded include: *Stegastes partitus* (Bicolored Damselfish), *Chromis multilineata* (Brown Chromis), and *Chromis cyanea* (Blue Chromis).

Following the AGRRA Protocol, we collected data on the percentage of benthic coverage as divided into the following categories: live coral, algae, sand, and bare rock. The count for algae included algae-covered rock. After we placed the quadrat down on the transect line, we floated above it and calculated the number of each dominant substratum. Once we were finished with the benthic coverage data, we swam back to the start of the transect line and counted *Diadema antillarum*, Spiny lobsters, Queen Conch, and Lionfish for 10-m forward and 1-m wide**.**

Results and Discussion:

<u>Biological data</u>

Champagne Bay had a higher mean, 81.5% (SD= 26.9), of algae than Scott's Head Bay 92.3% (SD=6.4) (Table 1, Figure 2). To test the statistical significance of observed differences in benthic cover between the two sites, we used a nested ANOVA.

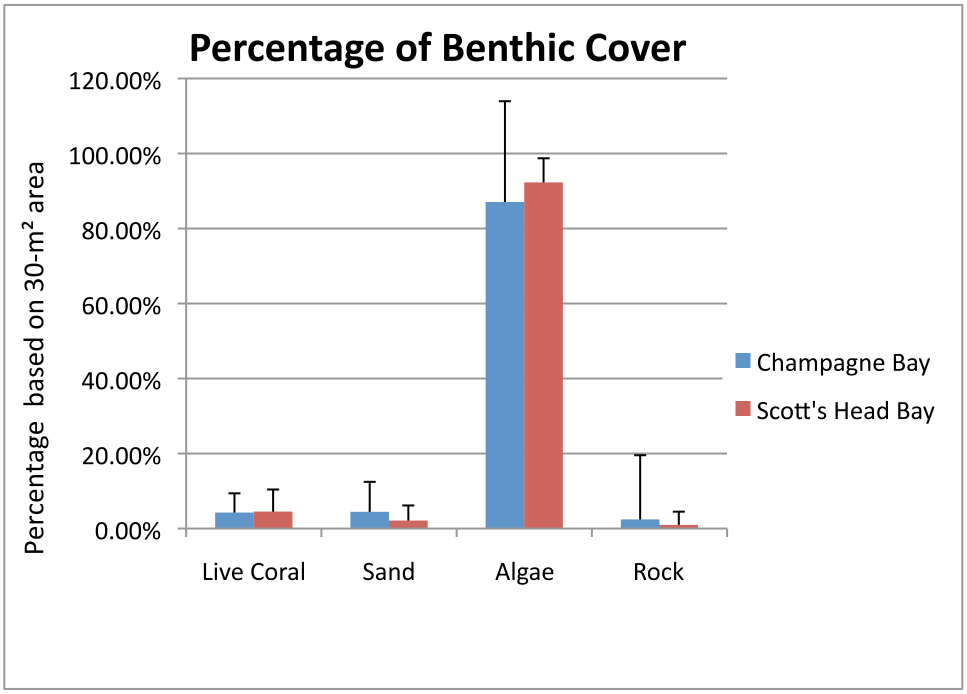


Figure 2: Benthic Coverage: Scott's Head Bay vs. Champagne Bay

There was no statistical significance between live coral, rock, and sand at the two sites (Table 1, Figure 2). Though sand was marginally non-significant, Champagne Bay's mean, 4.5% (SD=5.0), was higher than the mean for Scott's Head, 2.1% (SD=4.0%) (Table 1). Though Scott's Head did have more live coral present there, with 4.5% versus 4.3%, the data regarding live coral was found to be statistically insignificant. Scott's Head Bay had a reported live coral cover of 20.7% in 2003 and Champagne Bay had a reported live coral cover of approximately 17.0% (Steiner, 2003). If both sets of data are accurate, there has been a large decline in coral cover in both locations between 2001 and 2010.

A positive correlation was seen between the percent of algae and the percent of live coral. Scott's Head Bay contained both more live coral cover, 4.5% (SD=5.9), and more algae, 92.3% (SD=6.4), than Champagne Bay which had less algal cover, 81.5% (SD=26.9), and less live coral cover, 4.3% (SD=5.1). The proportion of live coral to algae is not consistent with prior studies, as corals cannot tolerate an excess of algae (Birkeland 1997).

Table 1: Nested ANOVA: Testing the effects of site and transect on benthic cover.

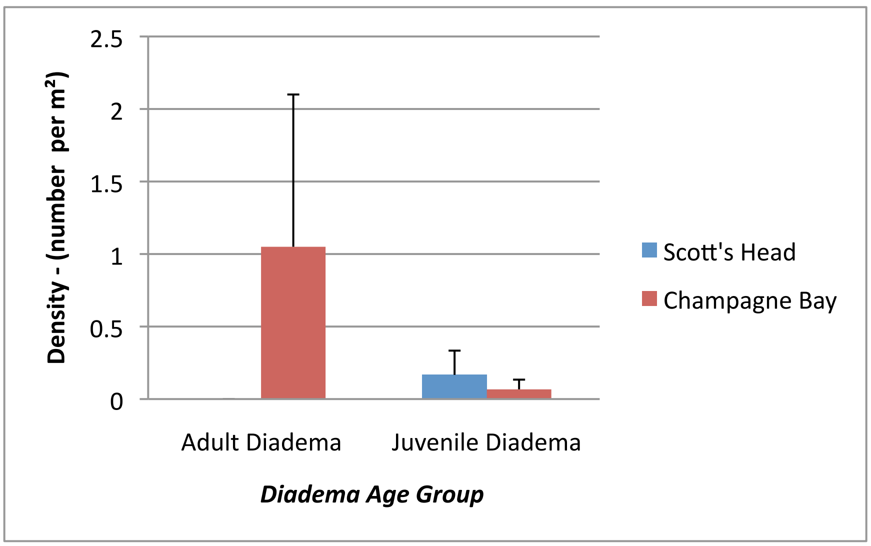
	Wald Chi-Square	df	p-value
Live Coral			
Site	0.045	1	0.833
Transect	13.733	5	0.017
Sand			
Site	3.016	1	0.082
Transect	25.71	5	0
Algae			
Site	5.547	1	0.019
Transect	10.735	5	0.057
Rock			
Site	1.75	1	0.186
Transect	9.054	5	0.107

Table 2: Significant Means for Benthic Cover

Significant Means in m^{-2}		
	Sand	Algae
Scott's Head	2.1%	81.5%
Champagne	4.4%	92.3%

Champagne Bay had a larger density of adult *Diadema antillarum*, 1.05 m^{-2} (SD=1.6), than Scott's Head Bay, which had none in our transects (Figure 1). In July 2004, Champagne Bay had a reported *Diadema* density of 1.38 m^{-2} (SD=0.9). Scott's Head had a reported *Diadema* density of 2.3 m^{-2} (SD=0.8) (Steiner 2006). Scott's Head had a marginally larger density of juvenile *Diadema* with 0.167 m^{-2} as opposed to 0.067 m^{-2} in Champagne Bay. Personal observations of our surveyors showed that other parts of Scott's Head did have *Diadema*, though there were few in the area where the transects were laid. Nonetheless, it is worth noting the possible decline in Diadema at Scott's Head. These should be re-surveyed in the future.

Figure 3: Density of *Diadema antillarum* by age group and location

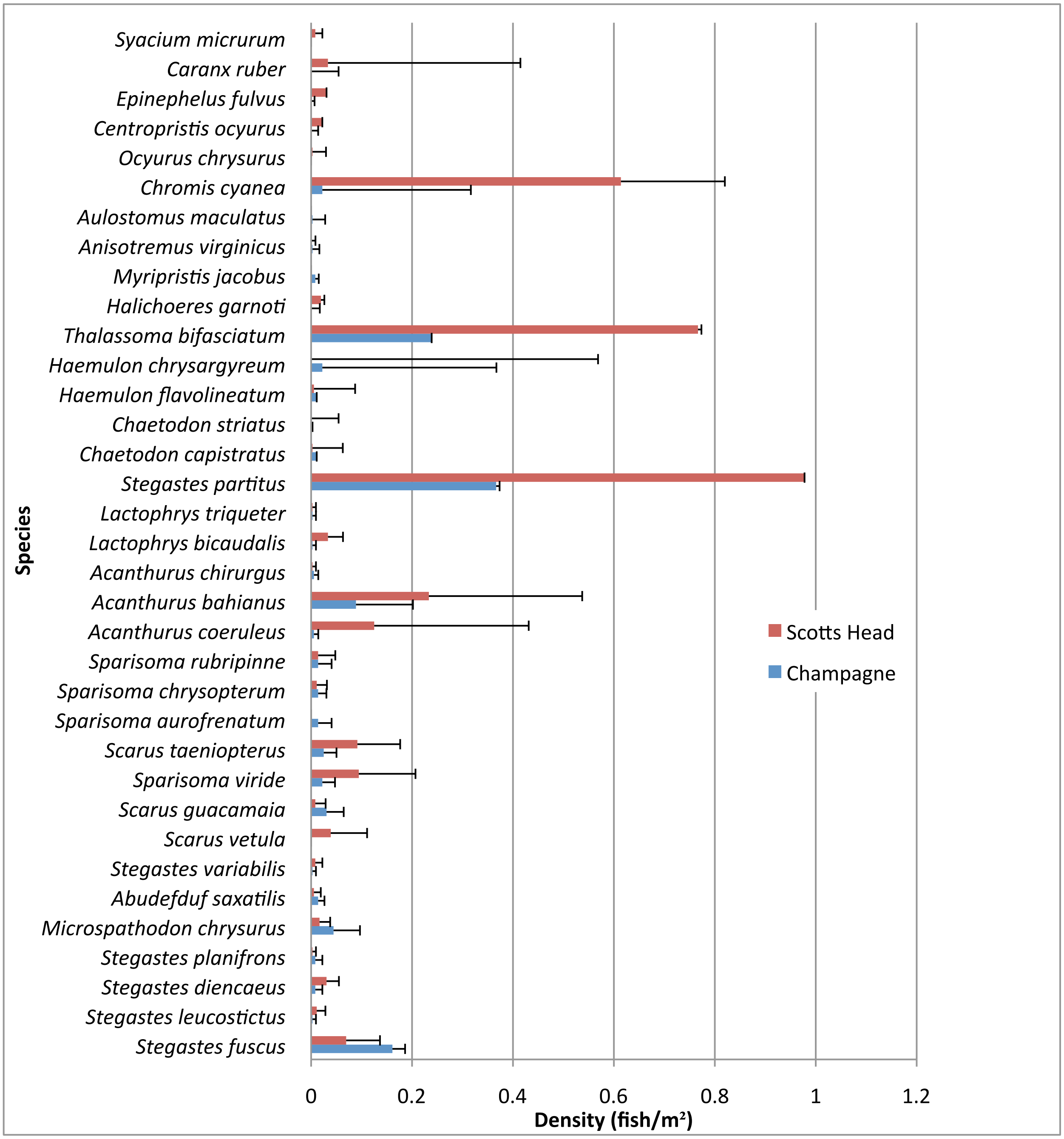


Both Scotts Head and Champagne had a similar number of fish species. The locations were very similar in species richness, Champagne having a species richness of 28 and Scotts Head having a species richness of 29. Several species were scared away at the Scott's Head site that is not expressed in the data below. Over the three day period of observations along the Champagne transects 28 different species were observed, *Pomacanthus paru* (French Angelfish) and *Ablennes hian* (Flat Needlefish) were observed in the area but not along the transects at Champagne. Over the three day period in Scotts Head 29 different species were observed along the six transects. *Ablennes hian* (Flat Needlefish) and *Clepticus parrae* (Creole Wrasse) were observed at Scotts Head in areas away from the transects. Many of the same species were observed along the transects at both locations throughout the study. However, *Myripristis jacobus, Anisotremus virginicus, Haemulon chrysargyreum, Chaetodon striatus, Aulostomis maculates,* and *Sparisoma aurofrenatum* were observed along the transects at Champagne Reef but not at Scotts Head, while *Scarus vetula, Epinephelus fulvus, Centropristis ocyurus, Caranx ruber, Ocyurus chrysurus, Halichoeres garnoti,* and *Syacium micrurum* were observed at Scotts Head, but not at Champagne Reef. Species evenness was calculated for each site using Simpsons Index; $D = \sum (n/N)^2$, where n represents the total number of fish of a particular species and N represents the total number of fish of all species. Species evenness was also calculated for each site, Champagne had an evenness of 0.17 indicating a high amount of diversity. The species evenness at Scotts Head was 0.19 which also indicates a high amount of diversity but less than that recorded at Champagne.

Figure 4 represents the density of each species (number of fish/m^2). This was calculated by taking the total number counted for each species and dividing by the area in meters covered by the transects. In this study, each of the six transects accounted for sixty square meters of reef. Therefore, 360 square meters were covered at each site and this was used as the denominator in our equation. Fish per m^2 = Total counted by species/360. The majority of the species had less than 0.2 fish/ m^2. The only two species at Champagne with a higher density were *Stegastes partitus,* with 0.37 ± 0.34 fish/ m^2, and

Thalassoma bifasciatum, with 0.24 ± 0.29 fish/ m^2 (Figure 4). Density for most species was higher at Scott's Head. The four species at Scott's Head with a density greater than 0.2 fish per meter squared were *Stegastes partitus* (0.98 ± 0.57), *Thalassoma bifasciatum* (0.77 ± 0.2), *Chromis cyanea* (0.61 ± 0.38), and *Acanthurus bahianus* (0.23 ± 0.3) (Figure 4).

Figure 4: Fish density in Champagne Bay and Scott's Head Bay



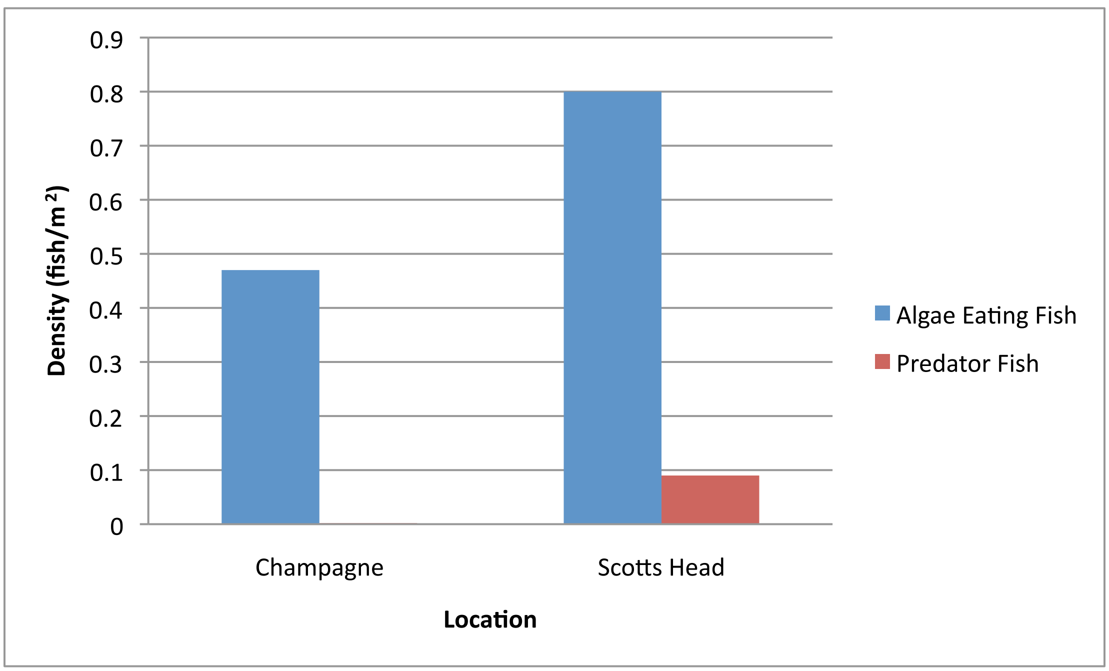
The data show clear differences in the abundance and diversity of the two sites. Several observations however were not reflected in the data. This is because of the behaviors of the fish, in part as a response to our surveyors. The fish in Scott's Head were noticeably more skittish, definitely affecting our data. The fish observed at Scott's Head were also larger in size as they became adults. The bigger fish also tended to be more abundant in the deeper water than the smaller fish perhaps due to the threat of predators lurking near the drop off.

The results shown in Figure 5 represent the number of algae eating fish observed compared to the number of fish observed that prey on other fish at each location. At Champagne Reef there was a smaller number of fish observed but the algae eating fish faced little threat since only one predatory fish was observed in the area. The numbers are significantly higher for both categories at Scott's Head; this was in part due to a larger number of fish present but also due to habitat. An increased number of fish will result in a larger number of predators as well as the surrounding habitat. At Scott's Head a drop off approximately 200 meters deep at the edge of the reef provided a habitat more suiting to predatory fish allowing them to lurk in the darker deep water and make occasional passes through the edge of the shallows to feed on the smaller fish.

Figure 5 shows the number of fish/m^2 based on algae eaters and predatory fish. Scott's Head had a little under double the number of algae eating fish/m^2 than Champagne. However, Scott's Head had ten times as many predators/m^2 compared to Champagne. Champagne had 0.5 algae eaters/m^2 ± 0.04 and 0.002 predators/m^2 ± 0.0. Scott's Head had 0.8 algae eaters/m^2 ± 0.06 and 0.09 predators/m^2 ± 0.02 (Figure 5).

The first implementation of the Atlantic and Gulf Rapid Reef Assessment v4.0 was conducted in the Commonwealth of Dominica from October through November 2005 (Steiner, 2005). The results of my survey show 0.47 herbivorous fish/m^2, an increase of 0.14 herbivorous fish/m^2 in Champagne compared to 0.33/m^2 in 2005. This could be the result of the decline of predator fish in the area from 0.05/m² in 2005 to 0.002/m² today (Klarman, 2005). This same assessment showed 0.13 herbivorous fish/m² and 0.05 predator fish/m² at Cachacrou (Klarman, 2005). My survey at Scotts Head, 100 meters south, showed 0.8 herbivorous fish/m² and 0.09 predatory fish/m². This suggests that the increase in predator fish was a result in the large increase of herbivorous fish for them to feed on.

Figure 5: Density of Algae-eating v. Predator Fish



The fish species with the highest density at Champagne Bay was *S. partitus*, with a density of 0.37 m^{-2}; and *S. fuscus* had the second highest density with 0.16 m^{-2}. Both *Stegastes leucostictus* and *Stegastes diencaeus* had a density of 0.00 m^{-2}. In Scott's Head, *S. fuscus* had a considerably smaller density with only 0.07 m^{-2}. *Stegastes partitus*, on the other hand, had a considerably higher density, with 0.98 m^{-2}. Scott's Head had multiple damselfish with densities close to 0. Champagne had a higher algae-farming damselfish population, 87 fish, which is consistent with the higher algae density, 8.7 m^{-2} (SD=2.7), found at the location. However, Scott's Head had a lower algal density, 5.7 m^{-2} (SD=0.6), and a lower algae-farming damselfish population, 52 fish. The data demonstrates a positive correlation between algal density and algae-farming damselfish population.

Physical data analysis

We took basic physical environment data for comparison at Champagne Bay and Scott's Head Bay (Tables 3, 4, 5; Figures 5, 6).

Table 3: Kestrel 3500 Pocket Weather Meter Data for Champagne Bay and Scott's Head Bay

	Champagne Bay:		Scott's Head Bay:	
	5/30/2010	6/1/2010	6/3/2010	6/5/2010
Windspeed:	7.2 mph	4.7 mph	4.6 mph	10.9 mph
Relative Humidity:	69.20%	74.90%	49%	76.20%
Dewpoint:	75.4	76.2	69.8	79.2
Barometric Pressure (Hg):	29.93	30.10	30.01	29.94
Temperature:	86.8 F	84.8 F	91.4 F	86.6 F

Table 4: Water quality data collected for Champagne Bay.

Champagne Bay Hydrolab Data	
Temperature	28.94°C
Specific Conductance	54.6 mS/cm
D.O.	6.98 mg/L
pH	8.07
Depth	2.1 m
D.O.%	89.5% SAT
Oxidation Reduction Potential	80 mV
Turbidity	0.5 NTU

Table 5: Water quality data collected by Hydrolab Quanta Monitoring System for Scott's Head Bay.

Scott's Head Hydrolab Data	
Temperature	29.74 °C

Specific Conductance	56.6 mS/cm
D.O.	7.50 mg/L
pH	8.21
Depth	2.6 m
D.O.%	98.2% Sat
Oxidation Reduction Potential	73 mV
Turbidity	0 NTU

Figure 5a: Temperature range of the shallow water in Champagne Bay from 05/30/10-06/08/10

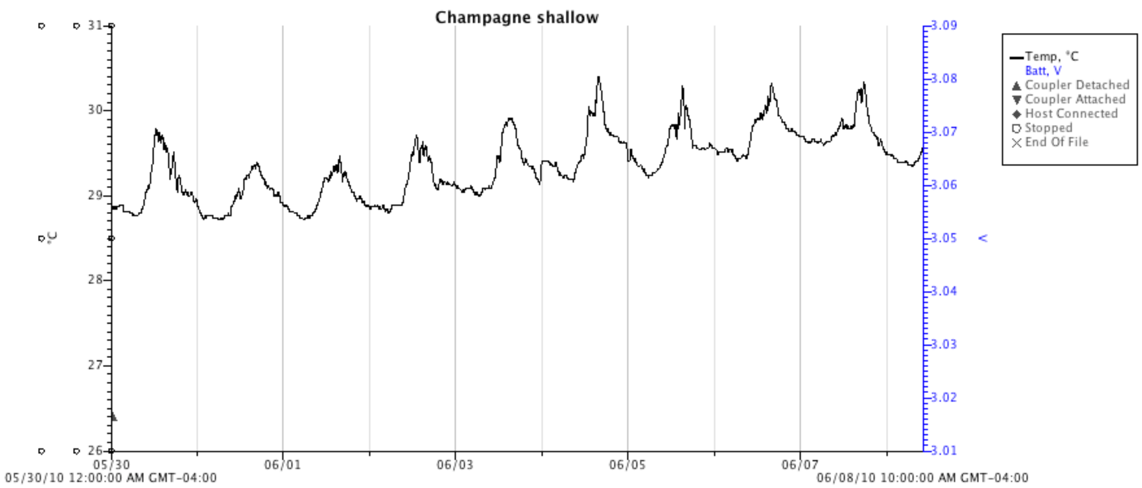


Figure 5b: Temperature range of the deep water in Champagne Bay from 05/30/10-06/08/10

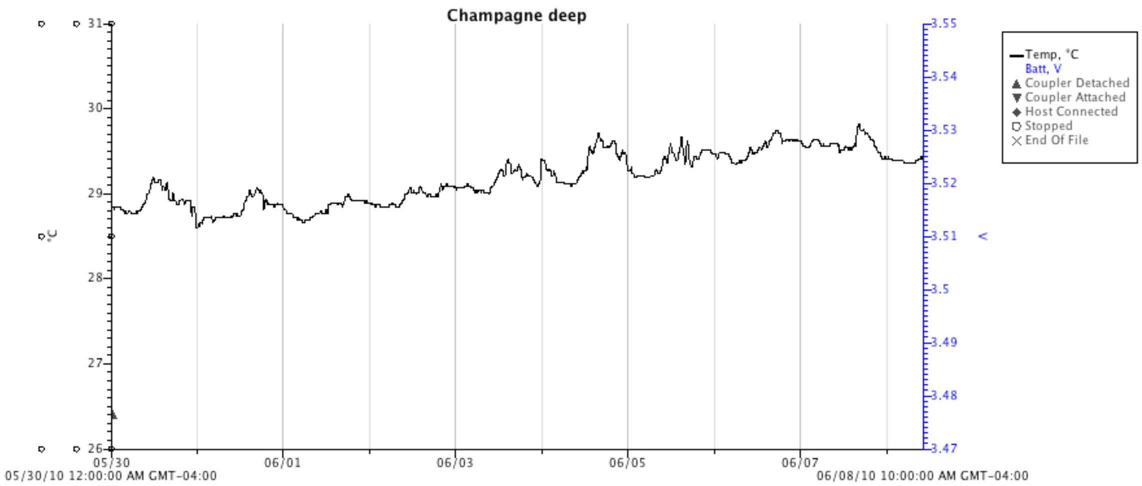
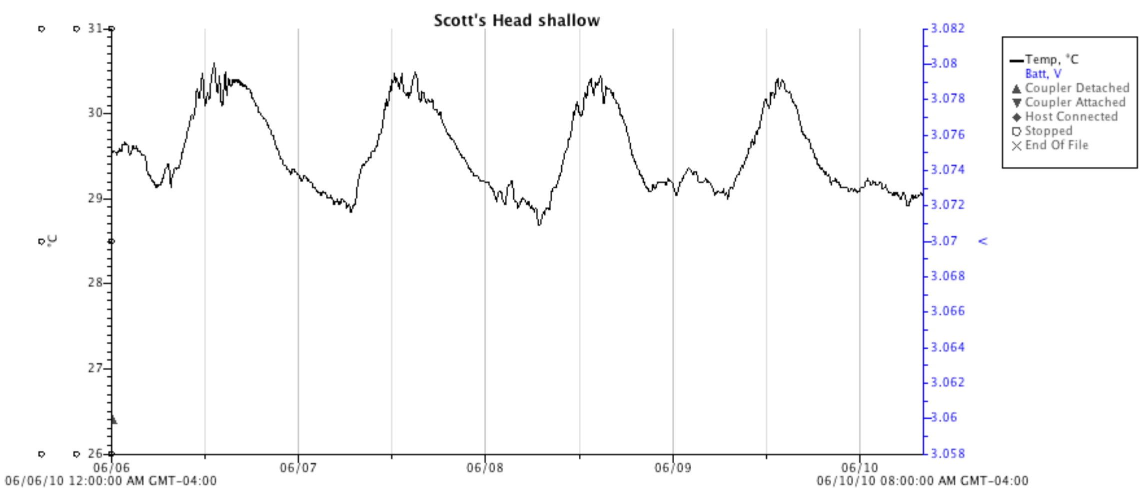


Figure 6: Temperature range of Scott's Head Bay from 06/06/10-06/10/10



Conclusions:

In order to more efficiently collect data, it would be beneficial to plan further ahead. Having fish identification cards would also be helpful, as it was often difficult to determine which fish was which. A study of more sites along the coast of Dominica would result in a more accurate picture of Dominican coral reefs. As to a more effective use of the quadrat, we recommend that future surveyors tie ropes to it, in order to help lower it down to areas deeper than diving allows. Placing the HOBO loggers on the same day in both sites would allow for more consistent data.

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