Annual Report and Plan 2006

April D. Ridlon & Bryan Bugler, Marine Biologists

2006 Annual Report and Plan Table of Contents

1. Introduction

Reef Conservation International Ltd. (ReefCI) is a small not for profit organisation that use volunteers and guests to assist in conservation research in the Sapodilla Cayes Marine Reserve, Southern Belize. ReefCI has established a basis of regular monitoring and surveying of the general health of the reefs and the specific health of certain marine species, collaborating with local entities and consulting with scientists on survey techniques and needs.

During the first year of operating, ReefCI employed three survey techniques. Reef Check and two population monitoring techniques for Queen Conch, *Strombus gigas* and Caribbean Spiny Lobster, *Panulirus argus*. To expand the baseline date, these surveys were continued during 2006.

The objective stated in the 2005 Annual report, to establish a baseline of data that can be shared with local entities and stakeholders and used for comparison in future years, still applies. As with any monitoring projects in their early stages, the data that ReefCI has collected during the first two years serves more to shape the remainder and future direction of these projects than to draw definitive conclusions from. Having this baseline of data to start from is however, extremely valuable in modifying the study design for efficiency and accuracy, seeing early signs of possible trends or abnormalities, and creating a focused plan for future monitoring projects.

Wherever possible, we have mentioned in this report any potential trends or notes of importance within each data set, (with the understanding that proper statistical analysis is not yet possible), identified some strengths and weaknesses in study design, implementation, and/or data collection for each project, and stated future plans for modification or continuance of the monitoring involved.

In addition, from this initial work, it has become apparent that some new monitoring projects and/or data collection of finer resolution on existing projects would be very valuable. We have outlined our plans to implement these changes over the next year (2006-2007).

It is worth noting the unique way in which ReefCI operates, and how ReefCI contributes to the Sapodilla Cayes Marine Reserve (SCMR). Engaging guests who come to the Sapodilla Cayes from around the world in our research efforts financially helps to sustain ReefCI and provides essential human resource needed to conduct the research. It also serves to educate an international audience about the conservation work being done in the park. ReefCI are uniquely positioned to provide very complete seasonal data throughout the SCMR because we maintain operations on a year-round basis, sending divers out daily to both established and new sites. ReefCI has already contributed in significant ways by collecting new and unexpected data, such as the discovery of three new spawning aggregations and of a deep water conch aggregation within the park.

.

2. Reef Check Monitoring Project

Reef Check is a simple data collection methodology designed to obtain a snap shot of the condition of the coral reefs world wide. Its simple design is intentional, with the goal of engaging recreational divers in the work, ensuring a level of accuracy in the data, and being able to compare data on key species populations and other indicators of general reef health in various locations around the globe. To this end, the data collected for fish are presence/absence and number of individuals for key species only, categorized at the family level. The invertebrate data are presence/absence and number of individuals for key species only, recorded at the species level. The substrate data is collected in even more broad categories (see below for key), and taken by point-line intercept method. Bleaching, coral diseases, and human impacts on the reef (termed "impacts" in this report), are noted, and percent cover of bleached/affected colonies is taken.

ReefCI monitored four sites using the Reef Check methodology during 2006: Vigilance, Ragged, Bungee Backside, and Lime Caye Wall. Each site was originally selected for surveying using the Reef Check criteria, and was monitored twice during the year.

It should be noted that the number of sites monitored in 2006 is reduced from those monitored in 2005, and that at each site the surveys were done with more consistent frequency than the previous year. This was a conscious decision made as a part of ReefCI's intention to streamline and focus our research efforts so that we are collecting data at fewer sites that are of a higher quality.

Also of note is the exclusion of the Bungee Backside site from any year to year comparisons in the Reef Check data. This is due to the fact that the only Reef Check monitoring done at BBS before 2006 was done in December of 2004. While this data was included in the 2005 report because each monitoring year ranges from December to December, the single sample size and length of time between collection of the data make it illogical to do temporal comparisons with the 2006 data.

All data collected at these sites were recorded, entered and submitted regularly in accordance with the Reef Check protocol. (For more information, about Reef Check's site selection criteria, methods and/or data analysis techniques, please visit (www.reefcheck.com)

2.1 Substrate Type Data

The intent of Reef Check's substrate surveying is to capture any changes in the amount and types of living coral on the reef as compared to sponges, algae, and other non-living substrates. It is generally agreed upon that a "healthy" reef will have a high abundance of living coral in comparison to other substrate, especially algae, which makes these distinctions important. In addition, the Reef Check methodology specifically includes recording recently killed coral as a different substrate type, in order to capture the ratio between living and dead coral at a given site and any changes in that ratio.

Reef Check uses the point-line intercept method along four 20m transects. Each transect is laid to maintain a relatively constant depth and topography. A plum line dropped every 50cm along each transect determines which substrate is identified and recorded. The first substrate that the plum line touches when dropped is the substrate recorded

The abbreviations of the substrate categories recorded are as follows:

HC – hard coral
SC – soft coral
SD – sand
RKC – recently killed coral
NIA – nutrient indicator algae
RB – rubble
SP – sponge
RC – rock (including algae cover)
SI – silt
OT – other

Results

Substrate results for the four sites sampled in 2006 show that rock/algae, hard coral, sand, rubble and other (generally gorgonian species), are the five most frequently recorded substrate types at all sites (see Table1). In particular, there was a higher frequency of rock/algae than any other substrate type at all sites with the exception of Vigilance, at which the hard coral cover exceeds rock/algae. The Ragged Caye site showed the highest frequency of hard coral as compared with the other sites, followed by Vigilance, Bungee Backside and Lime Caye Wall in that order (See Charts 1,2, 3, & 4 -for a comparison of coral frequency between sites). These results match those from 2005, and as noted in the 2005 Annual Report, it seems that the sites further from the continental shelf have a higher frequency of hard coral, possibly indicating higher deleterious impacts or environmental conditions that affect coral tolerance limits in areas of close proximity to the wall. This could be influenced by fresh water effluent from Honduras and Guatemala, although it would not account for the same fresh water effluent from mainland Belize itself. Water quality testing planned for the 2007 monitoring year, including pH and salinity profiles of the water column, turbidity and temperature readings, and the possible instalment of sediment traps for more in-depth analysis may enhance the understanding of water quality trends within the cayes and their possible affects on the reefs in these areas.

The two least frequent substrates recorded at all sites were silt (SI) and nutrient indicator algae (NIA), with the exception of Bungee backside, at which soft coral (SC) had a lower recorded frequency than NIA. While silt (defined by Reef Check as any sediment fine enough to stay in suspension when disturbed) can settle on live coral and stress or potentially kill it, algae blooms have the potential to overgrow or out-compete live coral, and NIA blooms can also indicate high levels of nutrients in the water. The near absence of both of these substrate types at nearly all sites is an indication of good health for these reefs. The increased frequency of NIA at Bungee Backside is almost definitely due to a change in Reef Check's 2006 definition of NIA to include more algae

species, which ReefCI began using only in December of 2006. This seeming increase in NIA, then, cannot be taken to reflect a true increase of the NIA populations at this site. As ReefCI continues to use the expanded definition of NIA in the 2007 monitoring year, the frequencies at all sites are expected to increase, and will become more reflective of the NIA populations at each site.

Tables

Substrate Type	Vigilance	Bungee Backside	Lime Caye Wall	Ragged
RC	9.1	14.4	17.5	14
SD	4.5	8.0	7.9	1.5
HC	10.3	6.2	3.1	12.8
OT	6.4	3.8	4.1	5
RB	6.6	3.4	3.6	3.8
NIA	0	1.9	0.0	0
SP	2.1	1.1	2.6	1
RKC	0.4	0.5	0.3	1.1
SC	0.5	0.0	0.9	0.9
SI	0	0.0	0.0	0

Table 1: Shows the mean substrate frequencies recorded at all sites in 2006.

Figures

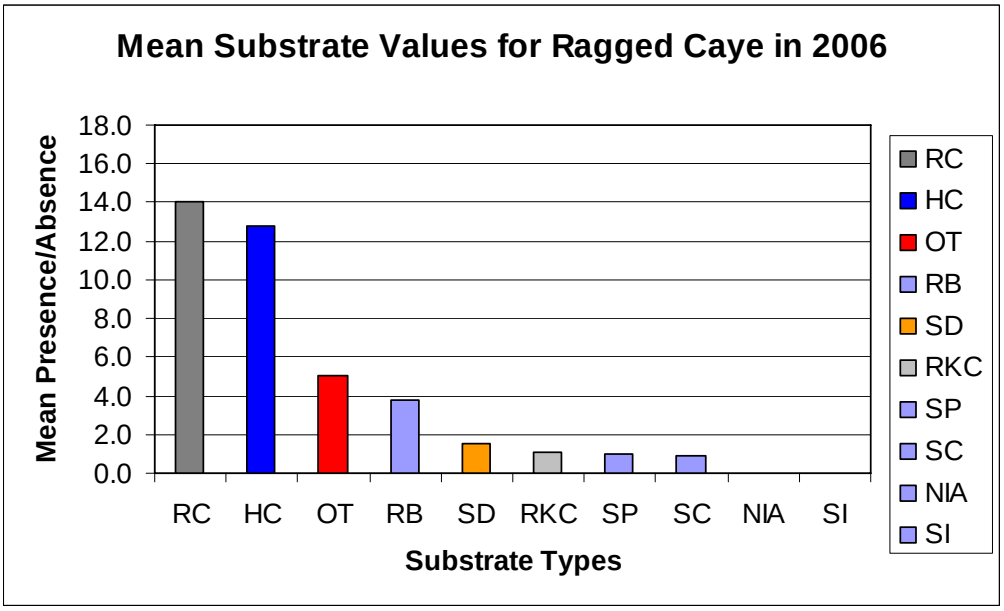

Figure 1 shows the mean substrate frequencies recorded at Ragged Caye in 2006. Values are ordered by frequency from highest to lowest value.

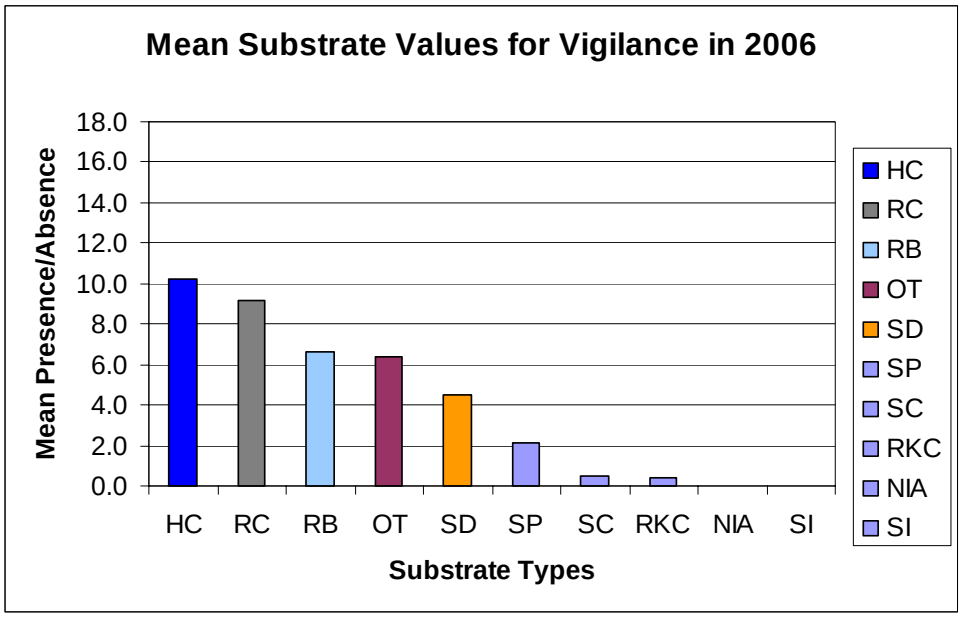

Figure 2 shows the mean substrate frequencies recorded at Vigilance Caye in 2006. Substrate types are ordered from the highest frequency value to the lowest value.

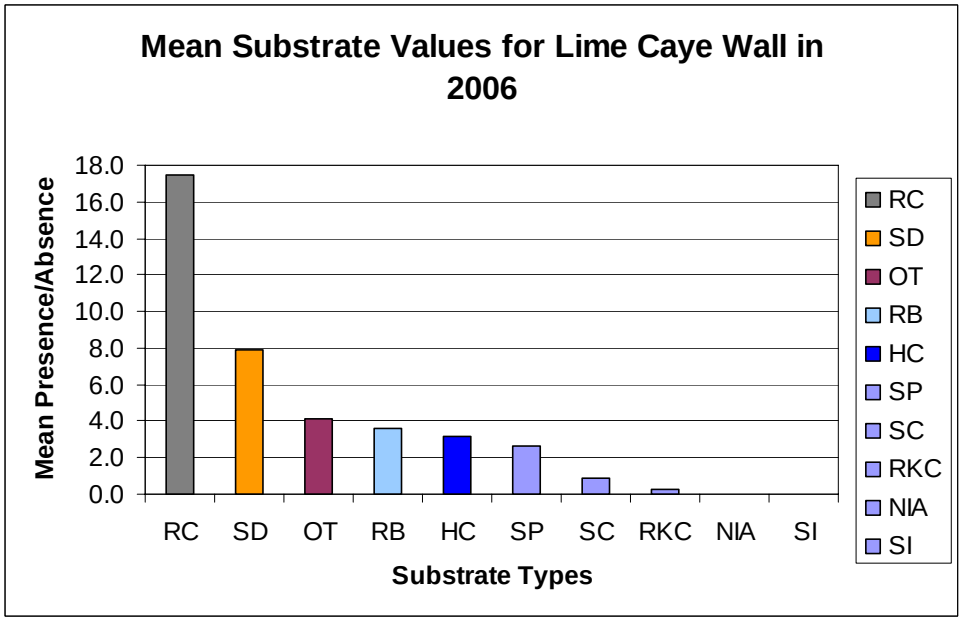

Figure 3 shows the mean substrate frequencies recorded at Lime Caye Wall in 2006. Values are ordered by frequency from highest to lowest value.

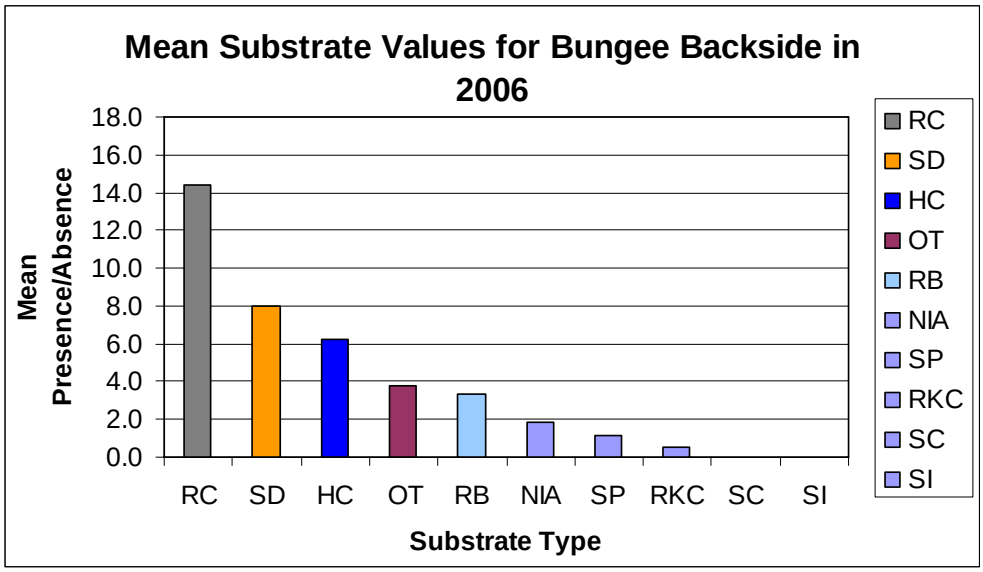

Figure 4 shows the mean substrate frequencies recorded at Bungee Backside in 2006. Values are ordered by frequency from highest to lowest value.

2.2 Fish Data

The Reef Check methodology includes counting individuals from specific families of fish that serve as indicators of over fishing (from both local and commercial fisheries), or over harvesting for the aquarium trade. The families monitored include parrotfish, grunts, snappers, groupers, butterflyfish and moray eels. Only one fish is identified to species: *Epinephalus striatus,* the Nassau Grouper.

In the Sapodilla Cayes, harvesting for the aquarium trade is rare. As a result, the major concern for fish populations remains over fishing. Since ReefCI conducts specific population monitoring for two of the major non-fish commercial fisheries in the cayes (lobster and conch), the data collected as part of the Reef Check methodology serves to round out our understanding of the health of the reef by providing population data for fish.

In accordance with Reef Check's methodology, ReefCI monitors fish populations by conducting a timed count of the target families and species found within each of four belt transects measuring 5 meters wide and 20 meters long. One diver stops every 5 meters, hovers slightly behind the 5 meter mark and observes and records the numbers of individuals, while a second diver times the monitoring, so that each count is 1 minute, 30 seconds.

Since ReefCI submits all Reef Check data directly to Reef Check, where it is analysed in relationship to reefs worldwide, the results shown in this report are a summary, including highlights and points of particular interest.

Results

The family of fish with the highest abundance for all sites was Parrotfish, with the family rating the lowest abundance being Grouper (see Table 2). Although Moray Eels, and to a lesser extent Butterfly fish, had relatively low abundances at all sites in 2006, this cannot be attributed to harvesting for the aquarium trade, and neither species represent a major fisheries in the cayes.

Most notably, zero Grouper other than Nassau Grouper were found at all sites in 2006, and no Grouper species at all, including Nassau, were recorded at Lime Caye Wall. Although global Reef Check data does show similarly low abundances of Grouper at reefs worldwide, the low numbers of Grouper recorded with the methodology may not to be a clear indication of their populations. There are three main reasons for this: first, most Grouper species, especially those that are large in size at maturity, inhabit water deeper than that in which the Reef Check monitoring takes place. Secondly, many Grouper species cover a large range, so that the limited area of Reef Check fish counts, paired with the shallow depth does not accurately represent their typical habitat. Thirdly, Grouper tend to be extremely shy and easily disrupted, making it likely that they would be disturbed from the area as the transect is laid out and therefore not present for fish counts. In the Sapodilla Cayes, accurately monitoring Grouper species' populations is are particularly important, due to the yearly formation spawning aggregations within the park, three of which ReefCI discovered and is currently monitoring (see Spag Project). In addition, Grouper are fished within the park, and a seasonal closure and size limit for fishing Nassau Grouper is enforced. In the 2007 monitoring year, ReefCI will be exploring alternative methodologies for more accurately surveying Grouper populations.

In terms of spatial variation of the fish data, Vigilance had the highest abundance of all fish species (total 115, mean 16.4) followed by Bungee Backside, (total 96, mean 13.7), (see Table 3) and at both of these sites the Snapper and Grunt families were far more abundant than at Lime Caye Wall and Ragged Caye. When taken with the substrate data, a seeming trend for Lime Caye Wall may be emerging. Again, Lime Caye Wall is the most exposed site included in the Reef Check project, and that with the lowest frequency of hard coral substrate. Both of these factors may contribute to smaller fish populations. Ragged Caye, which had the greatest frequency of hard coral substrate, is also a relatively exposed site, suggesting that extent of exposure may influence fish populations at both of these sites. Future water quality testing may increase ReefCI's ability to analyse these data in more detail with respect to environmental conditions at these sites that may impose a limitation on fish populations.

Tables

Fish Families	Vigilance	Bungee Backside	Lime Caye Wall	Ragged
Parrotfish	6.00	4.63	4.25	3.38
Grunts	3.88	3.88	1.25	0.75
Butterfly fish	3.00	2.38	1.00	0.50
Snapper	1.13	0.63	0.13	0.13
Grouper	0.00	0	0.00	0.00
Moray eel	0.13	0.25	0.00	0.00
Nassau Grouper	0.25	0.25	0.00	0.13

Table 2: Shows the mean frequencies at all sites for all families and Nassau Grouper.

	Vigilance	Bungee Backside	Lime Caye Wall	Ragged
Total Number	115.0	96.0	53.0	39.0
Mean number of Fish	16.4	13.7	7.6	5.6

Table 3: Shows the total and mean numbers of fish counted at each site

2.3 Invertebrate Data

Reef Check methods call for a specific set of marine invertebrates to be counted; some of these are identified to family and some are identified down to species level. As is the case with the fish families and species monitored, the invertebrates selected are considered indicator organisms because fluctuations in their population numbers can indicate over fishing for food or over harvesting for the aquarium and/or curio trades.
Included in the invertebrates identified and recorded by Reef Check methods are Lobster spp. And Gorgonian spp. (both identified to family), *Stenopus hispidus* (Banded Coral Shrimp), *Charonia variegata* (Tritons), *Cyphoma gibbosum* (Flamingo tongue), *Diadema antillarium* (Long-spined Black Sea Urchin), *Tripneustes* spp (Sea Egg) *Eucidaris spp.*(Slate Pencil Urchin).

At each site, two ReefCI divers, each monitoring one side of the 5 meter by 20 meter transect, swim in an S-shaped pattern looking in crevasses, holes, and all potential habitat for the invertebrates listed above. Individuals of each type of invertebrate are counted and their numbers recorded.

Harvesting invertebrates for the purposes of aquarium and curio trade in the Sapodilla Cayes is extremely rare, so that the populations of invertebrates found in the park are not likely to be effected by such practices.
However, since invertebrates are especially correlated with substrate type, some of the invertebrate data is analysed with respect to the types and abundances of substrates found at different sites, and other potential influences on invertebrate populations are discussed in “Results” below.

Results

At all sites, Gorgonian species were by far the most abundant invertebrate recorded in 2006, numbering in the hundreds at each site. This was true for the 2005 data, and in comparison to other reef systems, the Sapodilla Cayes have a relatively high abundance of Gorgonians. *S. hispidus* (Banded Coral Shrimp), *D. antillarium* (Long-spined Black Sea Urchin), and *C. gibbosum* (Flamingo Tounge) in that order show the highest abundances for invertebrates beside Gorgonians (see Table 4). The fact that the aquarium and curio trades are virtually non-existent in the park probably plays a significant role in the relatively high abundances of these species.

Those invertebrate species with the lowest abundances include *C. variegata* (Triton) and *Tripneustes* spp. (Sea Egg). As discussed above with Grouper species, the low numbers of these invertebrates may be reflective of the methodology and habitat selected for monitoring as opposed to being an accurate representation of their populations. Both of these species prefer sandy and sea grass habitats to reefs, and in the case of *C.variegata,* individuals tend to bury themselves in sandy substrate, (DeLoach & Humann,

2003) accounting for the fact that the only sites at which *C.variegata* were found were the two with the highest recorded frequency of sand substrate: Bungee Backside and Lime Caye Wall.

Spatially, the highest abundances of all recorded invertebrate families and species were found at Vigilance (total= 566.6, mean=70.8), followed by Bungee Backside (total=480, mean=60.1). However, the high total abundance for invertebrate species at Vigilance is confined to only 5 families/species, of which Gorgonians contribute the highest number. In terms of diversity of invertebrate species, then, the Vigilance data shows the lowest diversity of all sites. Of the sites at which all eight invertebrate families/species are represented, Bungee Backside again shows the highest total abundances for these families/species, with the exception of *C. variegata* (see Table 5). Because ReefCI conducts separate and more detailed population surveys for Lobster species within the cayes, we do not extensively analyse the Lobster data collected with the Reef Check methodology (see Lobster Population Monitoring Project for those data).

Of particular interest to ReefCI and scientists worldwide is the population numbers for *D. antillarium*. Because it grazes primarily on algae species, *D. antillarium* plays a significant role in maintaining the balance between living coral and algae abundances, and therefore significantly contributes to the overall health of the reef. In areas where *D. antillarium* populations exceed the abundance of algae available for their diet, individuals will begin to graze instead on live corals. Conversely, in areas where their population numbers are low, algae species may grow unchecked and overgrow or out-compete coral species. For these reasons, ReefCI analyses the *D. antillarium* data spatially, temporally and with respect to substrate types.

As chart 5 shows, there seems to be some correlation between the abundances of *D. antillarium* and hard coral species at all sites, possibly indicating that those sites with the highest abundances of *D. antillarium* also have higher abundances of hard coral due to the grazing effect explained above. Since ReefCI had been recording non-nutrient indicator algae as rock (as is indicated in the Reef Check methodology), the rock substrate is also charted for comparison. In the future, ReefCI will be using Reef Check's new definition of NIA, (see Substrates), and can expect to have more detailed data on the relationship, if any, between algae populations and *D. antillarium* populations at all sites and over time.

When compared to the 2005 data as shown in table 6, it appears that *D. antillarium* populations are comparable at all sites in 2006, with the notable exception of Lime Caye Wall. The nearly eight-fold difference in mean abundance for this species between 2005 and 2006 is substantial. Careful monitoring of this species at Lime Caye, along with the additional projects suggested throughout the report, will be carried out to gain a better understanding of the effect of this population reduction has on the reef at Lime Caye Wall, and any potential causes of such a population crash at this site.

Tables

Invertebrate Families	Vigilance	Bungee Backside	Lime Caye Wall	Ragged
Gorgonian spp.	556.1	469.4	459.0	285.5
Stenopus hispidus	3.8	5.0	1.4	1.9
Diadema antillarum	4.3	1.9	0.3	3.3
Cyphoma gibbosum	2.0	1.3	0.9	1.4
Eucidaris spp.	0.5	2.6	1.6	0.3
Lobster spp.	0.0	0.4	0.1	0.3
Charonia variegata	0.0	0.1	0.3	0.0
Tripneustes spp.	0.0	0.1	0.1	0.0

Table 4: Shows mean abundances of invertebrate families and species by site in 2006

	Vigilance	Bungee Backside	Lime Caye Wall	Ragged
Total Count	566.6	480.8	463.6	292.5
Mean Number in Invert	70.8	60.1	57.9	36.6

Table 5: Shows total and mean number of invertebrates counted at each site in 2006

Year	Vigilance	Bungee Backside	Lime Caye Wall	Ragged
2005	3	Not Monitored	8	3.5
2006	4.25	1.88	0.25	3.25

Table 6: Shows the mean frequency of *D.antillarium* at sites in 2005 and 2006.

Figures

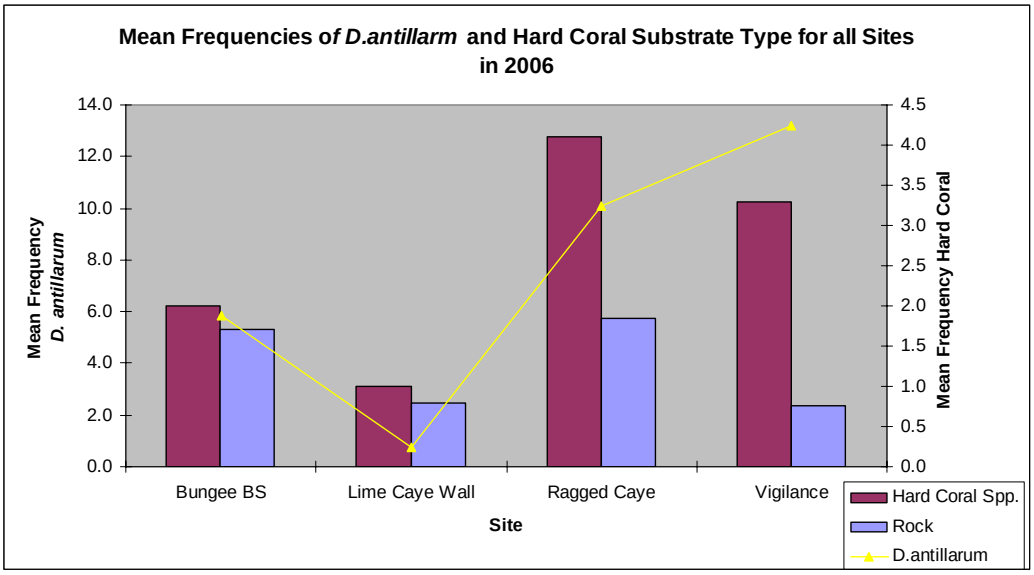

Chart 5 shows the mean frequency of *D. antillarium* (displayed linearly) and both rock and hard coral substrate type frequencies at each site.

2.4 Impacts

Arguably one of the most important measures involved in the Reef Check methodology, particularly for a marine protected area (MPA) such as the SCMR, is the data on coral bleaching, coral diseases, trash, anchor or boat damage, and other noticeable signs of negative impacts on the reef system. For the purposes of ease of reporting these data, and of seeing their potentially collective effects on the reef, ReefCI has grouped these measurements together and termed them Impacts. ReefCI collects these data in accordance with the Reef Check methodology, and has made no other changes to the data besides presenting them together.

Reported in this section are all data on coral bleaching, coral disease, all types of trash (nets, general), and all types of coral damage (boat, anchor, dynamite, other). Coral bleaching is measured by percentage cover of each colony bleached and percent cover of total coral colonies present. Coral diseases are noted and identified when present, along with the species (where possible) of coral effected. All types of trash and coral damage are rated as the following: None (0), Low (1) one piece/damage per transect, Medium (2) two to four pieces/damage per transect, or High (3) more than four pieces/damage per transect.

Results

As was the case in 2005, all sites in 2006 showed a low frequency of trash, and a relatively low frequency of anchor/boat damage to the reef, with Bungee Backside rating a “medium” (mean=2.1) amount of anchor damage and Ragged Caye rating a “low” amount (mean=1.5). Although the data shows that there is not a high degree of anchor damage (see Table 7) at any of the Reef Check sites, as tourism to the SCMR is increasing, installing mooring buoys in areas of higher boat traffic could help to prevent anchor damage from becoming a significant negative impact on the reefs within the park.
Coral diseases were virtually unrecorded at all sites in 2006, with the highest mean presence of coral disease at Lime Caye Wall being 2.13 % of the total coral population (see Figure 6).

The percent cover of coral bleaching was also very low at all sites, with the highest mean percent of bleaching of the total coral population at any one sute being below 5% (mean=4.75 at BBS). While the percentage bleached of the total coral population at all sites are very low (see chart 7), it is worth noting that for two sites, the percentage of each colony that was bleached is higher. For example, at Vigilance the total mean percentage of bleached colonies is only 2%, but of those colonies, the mean percentage bleached is over 50% (see Figure 8). This suggests that the colonies that experienced bleaching at Vigilance were considerably affected. This may be due to Vigilance’s shallow topography and/or the particular coral species that bleached at that site and their associated tolerance limits.

To gather more rigorous bleaching data at all Reef Check sites, ReefCI has begun, as of November of 2006, to identify the affected coral colonies to genus and where possible, species. Also, since percentage cover is a relatively more subjective, and therefore more variable method of measurement (as compared to counting the number of individuals of fish and/or invertebrates),

this data will always be taken by a ReefCI staff member who has been thoroughly trained in this method, which may show an initial seeming increase or decrease in percentage bleached of individual colonies for 2007.

The abundance of recently killed coral at all sites is also very low, with the highest mean abundance being 1.1 at Ragged Caye, and the 2006 numbers are decreased from 2005 (see table 8), with the exception of a negligible increase at Vigilance.

Overall, then, the impacts on the reefs in the Sapodilla Cayes as measured by Reef Check methods, are very low. At sites where coral disease and/or bleaching are comparatively higher, ReefCI plans to implement water quality testing in the 2007 monitoring year, with hopes that more detailed data on the causes of these impacts will emerge.

Tables

Impact	Vigilance	BBS	Lime Caye Wall	Ragged
Mean Bleaching (% of coral population)	2.0	4.8	3.6	1.1
Mean Bleaching (% colony)	51.5	3.3	3.3	16.2
Mean Coral Disease (Yes/No & %)	0.4	1.0	2.1	0.6
Mean Coral damage: Boat/Anchor	0.5	2.1	0.5	1.5
Coral damage: Dynamite	0.0	0.0	0.0	0.0
Coral damage: Other	1.0	0.8	1.5	1.3
Trash: Fish nets	0.0	0.0	0.4	0.0
Trash: General	0.0	0.1	0.0	0.0

Table 7: Shows mean values for all impact types measured at each site in 2006.

Year	Vigilance	Bungee Backside	Lime Caye Wall	Ragged
2005	3	Not Monitored	8	3.5
2006	4.25	1.88	0.25	3.25

Table 8: Shows the mean frequency of recently killed coral in 2005 & 2006

Figures

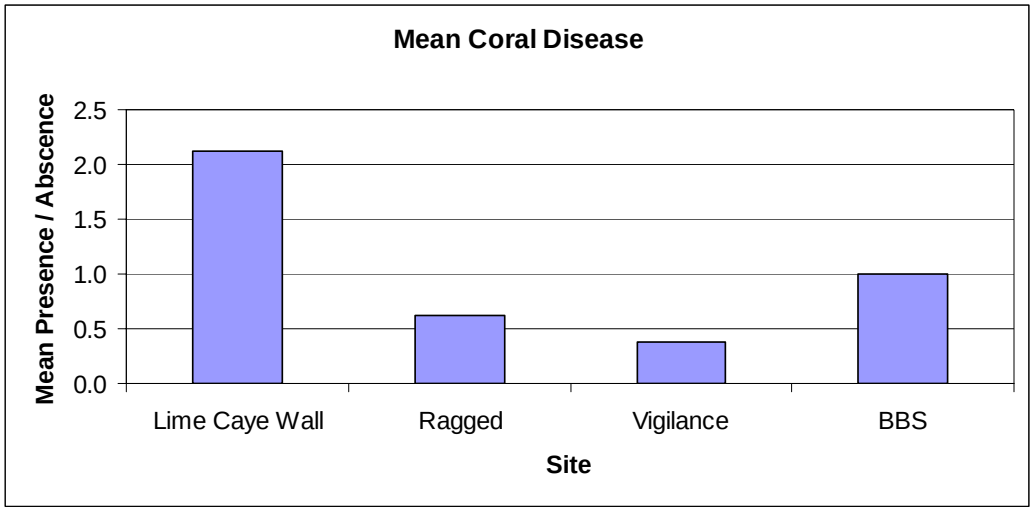

Figure 6 shows the mean frequency of coral disease recorded at each site in 2006

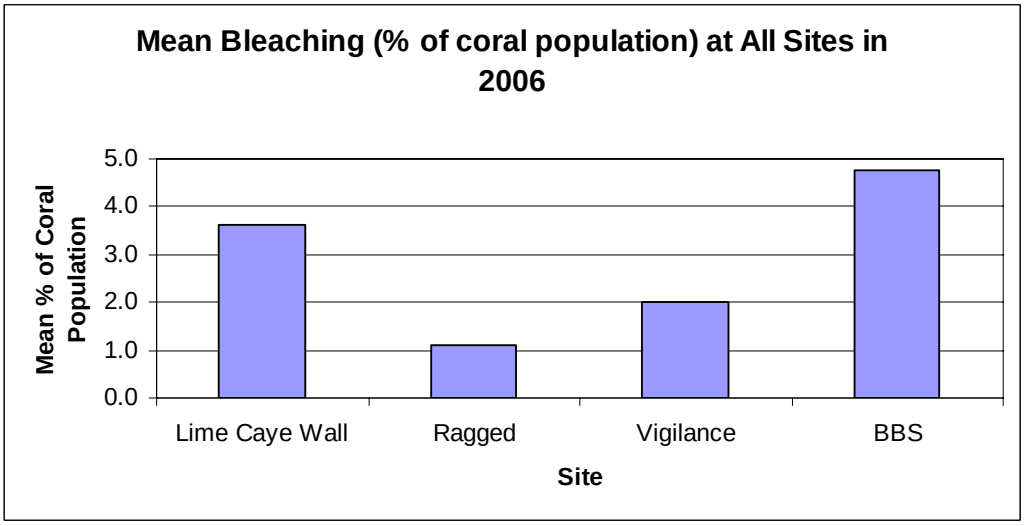

Figure 7 shows the mean percentage bleached of the total coral population at each site in 2006

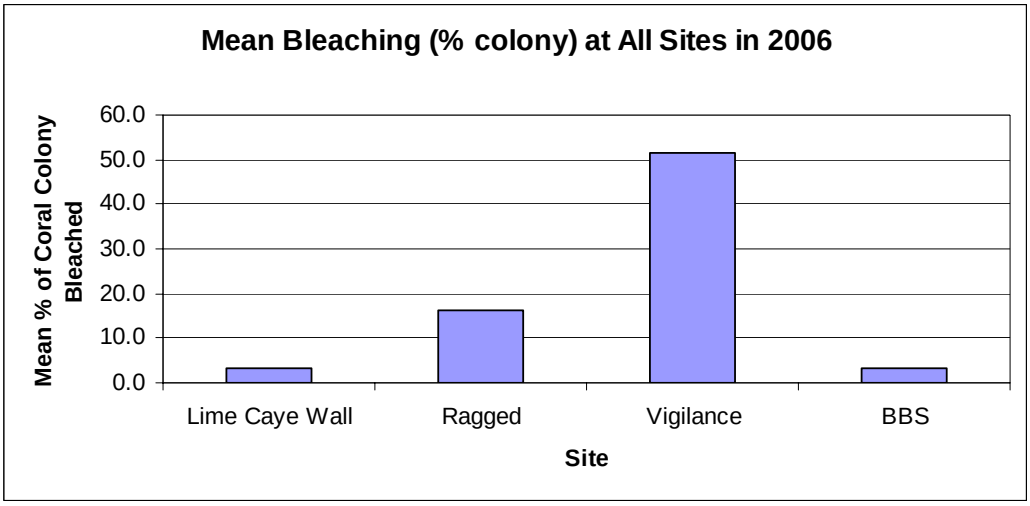

Figure 8 shows the mean percentage bleached of individual coral colonies at each site in 2006

2.5 2007 Reef Check Modifications and Plan

In order to build upon our strong baseline of Reef Check data, to answer new ecological questions, and to gain a finer resolution of some types of data we are collecting using the Reef Check methodology, some significant and minor modifications will be made in the 2007 monitoring year. These changes include:

- **The establishment of a at least one new Reef Check site located outside of the park**. In order to measure the effectiveness of the management of the Sapodilla Cayes Marine Reserve (SCMR) in relation to the human impacts upon the reef system, it is important to have a reserve vs. non-reserve comparison of sites. Taking into consideration time and resource constraints, ReefCI will initially establish one non-reserve site to compare with our established reserve sites for which we already have historical data. This may or may not require a minimization of the number reserve sites sampled in the 2007 monitoring year.
- **The establishment of permanent Reef Check transects** at all sites. Although there are benefits to both random and permanent transects, in order to enable direct year-to-year comparisons (temporal data) of data at each site, permanent transects are needed. The data collected on permanent transects is also more precise, since the data is taken from very nearly the same place on the reef each time it is collected (minimizing spatial variations within each site). Since ReefCI is able to conduct surveys repeatedly and year-round at designated sites, permanent transects will enhance the quality of our data.
- **The continuation/refinement of a regular, year round monitoring schedule for all Reef Check sites**. Setting a regular, rotating monitoring schedule for all of the sites will enable us to provide more consistent and analysis-friendly data both to Reef Check and to the SCMR. In addition, consistent year-round monitoring should minimize seasonal variations between sites sampled only in certain seasons (i.e. comparing sites sampled only in the spring and fall to sites sampled only in the winter and summer), and may also show seasonal variations in

the data at each site. The monitoring schedule goal for 2007 is to sample each site a minimum of 4 times per year, ideally within several weeks of one another for each season.

- **Modifying the Substrate Type data collected to include Reef Check's expanded definition (2006 Manual) of Nutrient Indicator Algae.** In 2006, Reef check expanded its definition of Nutrient Indicator Alga (NIA) to include some species known to inhabit the reefs within the SCMR and formerly not distinguished by the protocol. ReefCI will accordingly adjust our methods to include categorizing these species, whenever found present on the transect line, as NIA. This may create a seemingly sudden increase in 2007 in the mean presence of NIA at some or all Reef Check sites, but will in the long term create a more detailed and accurate database.
- **Refining the methodology for collecting data on coral bleaching** (part of Impacts) to include the identification of all bleaching colonies within the belt transect to genus and preferably to species (when possible). Some recent studies on coral bleaching are finding differences among hard coral species in their tolerances to the environmental factors that cause bleaching, and have noted a shift in the abundance of more tolerant coral species on impacted reefs, perhaps marking an ecologically significant shift for these reefs. In order to track these changes, ReefCI will take more detailed data with respect to coral bleaching, noting the genus and species of each effected colony along with the percent cover of bleached coral. In addition, ReefCI will estimate the percent cover data for each individual colony affected in order to calculate the mean percent cover of bleaching for colonies in each 20M belt transect. This greater attention to detail will probably also result in increased accuracy for the total percent cover of bleached colonies for the entire transect.
- **Refining the recording of anchor damage** (part of Impacts) to include not only presence or absence and a general rating (as is called for the Reef Check methodology), but an estimation of percent cover anchor damage with respect to total hard coral within each 20M belt transect. Since the established Reef Check sites within the reserve show relatively low anchor damage, this refinement will provide more accurate data for year-to-year (temporal) comparison and comparison with the non-reserve site(s).
- **Analysing the number of Individuals of (*Diadema antillarium)* Long-Spined Sea Urchins** found within each 20M belt transect to estimate not only abundance, but also the population density at each site. Because *D. antillarium's* feeding habits support a balance between algae and hard coral cover on reefs (see above) their populations are widely considered an early indicator of potential coral and reef health decline. Since the Reef Check data already includes the recording of presence/absence and number of individuals of *D. antillarium* within the belt transect, ReefCI will simply analyse this existing data differently with respect to both mean hard coral presence/absence and mean nutrient indicator algae presence absence data for 2007.

In addition to implementing these changes over the next year, ReefCI will continue to provide the SCMR with our raw data as requested and will continue to provide the SCMR with our analysis of the data via our 2007 Annual Report and Plan.

3.0 Queen Conch (*Strombus gigas*) Population Monitoring Project

The Queen Conch (*Strombus gigas*) is a commercially important species that may be in serious threat of being over harvested by current fishing practices in the Sapodilla Cayes. Despite recent seasonal closures, managers and scientists alike are concerned with the seeming lack of shallow water aggregations of sexually mature adults within the park, which are necessary in order to support the population. While shallow-water aggregations of juveniles and deeper water aggregations of mature adults have been recorded, more data collection is needed to determine the status of adult populations of conch in shallow habitats. In order to contribute to a better understanding of how to manage the Queen Conch fishery for optimal sustainability, ReefCI began this past year to greatly expand our effort in monitoring their populations within and around the reserve.

The key shift in ReefCI's Queen Conch population monitoring project in 2006 revolved around the strengthening of a collaboration with Dr. John Cigliano, a Principal Investigator with the EarthWatch Institute. Dr. Cigliano, who has monitored *S.gigas* populations throughout the Caribbean, is currently conducting research within and around the SCMR in order to determine the effectiveness of the reserve with respect to managing the species' populations. By collaborating with Dr. Cigliano and contributing to his research, ReefCI will augment the frequency and type of data collection for the project, and Dr. Cigliano will provide the study design and implementation expertise, review of methodologies, and statistical analysis for the data. In this way. ReefCI will be contributing to a much larger project than we would be capable of maintaining ourselves, while at the same time providing crucial resources that the project is currently lacking. Since Dr. Cigliano's results will in turn be directly reported to the SCMR (in addition to limited analysis appearing in ReefCI's Annual Report) this collaboration will enable us to directly and significantly contribute to the data being used as the basis of the management of the Queen Conch fishery within the SCMR.

Under the direction of Dr. Cigliano, ReefCI began in May of 2006 to modify the methodologies and content of the data collected for our existing Queen Conch population project. In addition to these modifications, ReefCI and Dr. Cigliano have identified three research goals that ReefCI have already begun to contribute to. They include:

1. Locating and mapping *S.gigas* aggregations and habitat within the reserve and surrounding areas
2. Modifying the parameters recorded to conform with data taken by the Belize Fisheries Department and TASTE as well as by Dr. Cigliano the following way: In addition to the basic data collected in 2005/2006 (Date, Site, Depth, Tag Number, Relative Location within Site, Other Observations/Reproductive Activity), ReefCI now records the Shell Length (cm), Lip Thickness (mm), Maximum Spire Width (cm), Relative

Maturity (OA- Old Adult, YA- Young Adult, JV- Juvenile), Morph (D-Dark, N-Normal), and Habitat Type (Sand, Rubble, Sea Grass, etc.) for all individuals sampled. (see below)

3. Locating deep-water aggregations of Queen conch (10-30 M+), tagging individuals within these aggregations and monitoring their locations within the park to determine any migration patterns and/or reproductive activity

ReefCI uses the "rover diver" technique to locate individual conch. Once an individual is found, the above measurements are taken, a numbered tag is affixed around its spire, and it is returned. Included in the new parameters measured in 2006, Lip Thickness (measured in mm) Shell Length (measured in cm), and Relative Maturity (categorized as OA- Old Adult, YA- Young Adult, JV- Juvenile), serve to estimate the age the individual conch. The Habitat Type (Sand, Rubble, Sea Grass, etc.) specifies which habitat that the conch are found in and may provide insight into their uses of different sites. Morph (D-Dark, N-Normal), refers to variations in shell coloration, namely a darker shell (as opposed to the normal white/pink) as has been recorded in the Turks and Caicos (personal observation Cigliano & Bugler, 2003). Maximum Spire Width (cm) is a measurement of the distance between the top spire to the tip of apex on the conch. This measurement is included in the methodology used by the Belizean Fisheries Department, and ReefCI records it in order to standardize our data with theirs. Any mating behaviour (mating or egg masses observed) is also recorded. Previously tagged conch are also measured for all of the above parameters and the tag number is recorded to capture growth and possible migration data.

In addition to tagging conch at various sites, ReefCI's 2005 discovery of and 2005-2006 monitoring at a *S.gigas* aggregation at "The Stadium", a sandy-bottomed site at approximately 30M depth, is of particular note and importance, since *S.gigas* were rarely previously found to aggregate in deep water habitats (DeLoach & Humann 2003). Since the site is at such a depth, monitoring any mating and migratory behaviour of these individuals may prove extremely valuable in developing new understandings of *S. gigas* behaviour, natural history and/or reproductive strategy. In addition, the site itself may prove to be an integral and crucial part of the management of the reserve for *S. gigas*, since the individuals aggregated there enjoy protection from all legal fishing pressure (from fisherman using the "free-dive" method).

Results

During the 2005 monitoring year, ReefCI tagged 200 individual *S. gigas* using the "rover diver" technique at sites throughout the reserve. The primary intent of this project was to locate the migratory paths and breeding grounds of *S.gigas* in order to augment the population monitoring being done by the SCMR.

Using the new Cigliano/Acosta methodology and numbered tags provided by Earthwatch, ReefCI tagged 191 conch at three different sites in 2006. For each individual tagged, ReefCI also recorded the parameters listed above.

Due to the objectives and developments outlined above, ReefCI focused our *S. gigas* population monitoring efforts in 2006 by more intensively sampling at two sites: The Stadium and Nicholas Cut. Nicholas Cut, the cut between Nicholas and Hunting Cayes, is a sand/algae habitat with a mean depth of about 16 meters. The individuals inhabiting this moderately-deep site may be resident or may be transitory, as Nicholas Cut could serve as a migratory route of adult individuals to deeper-water habitats. The Stadium, our deep-water aggregation site, these unique data, raw as they are, are important to share with all interested parties as early as possible. Certainly ReefCI will continue to monitor this site with interest and use these initial data to build upon our understanding of the use by and usefulness of the site for the *S.gigas* population of the SCMR.

The data given under the site name of Frank's Jetty represent a small number of conch that were caught by a fisherman during closed season. ReefCI staff persuaded the fisherman to voluntarily release these individuals, and took the opportunity to tag and measure them before returning them. Despite the fact that the individuals included in these data originated elsewhere, ReefCI has observed *S.gigas* individuals (mostly juveniles) utilizing this area. Frank's Jetty is a shallow, near-shore habitat, where one might expect to find juvenile (lip thickness of < 4 mm) and young adult conch, and is situated directly between a juvenile aggregation identified by Cigliano in July of 2006 (Frank's North) and Frank's Cut (the cut between Frank's Caye and Nicholas Caye). It is possible that juvenile and young adult *S.gigas* use the Frank's Jetty area as a migratory site between the nearby juvenile aggregation and the sand/algal plains found in Frank's Cut. Further investigations of these areas in 2007 may support this idea, and will be carried out as part of ReefCI's monitoring of potential *S.gigas* migratory routes

Because of the additional and more detailed parameters ReefCI began to record for all individuals in May of 2006, while we have begun to establish a baseline of more useful data, we are obviously unable to directly compare the data taken in 2005 to that taken in 2006. However, we can show limited data and initial findings with the understanding that proper statistical analysis is not yet possible.

As Table 9 shows, the sample size at each of the three sites varied considerably. This may be a result of the frequency with which each site was visited, and can't be taken to represent the population sizes or densities at these sites. Specifically, Nicholas Cut was the most frequently sampled (6 times over 4 months), and has the highest sample size, followed by The Stadium (4 times over 3 months), and finally Frank's Jetty (sampled once), has the smallest. A consistent monitoring schedule at all sites should minimize this bias of the data in 2007.

As chart 9 illustrates, there is no apparent difference in mean shell length between sites, suggesting that individuals at all sites are relatively the same size. However, there does seem to be a noticeable difference between mean lip thickness at Frank's Jetty and the other two sites (see chart 10). These two data parameters taken together indicate that the individuals transported to Frank's Jetty are younger, and therefore have not developed the fully-flared, thicker lips that are characteristic of older adult conch and that have been recorded at both The Stadium and Nicholas Cut.

Tables

Site	Mean Shell Length (cm)	SD Shell Length (cm)	Mean Lip Thickness (mm)	SD Lip Thickness (mm)	Mean Depth (M)	Sample Size
Franks Jetty	26.6	1.9	6.0	3.8	1.08	12
Nicholas Cut	25.5	2.2	17.0	6.3	16.4	149
The Stadium	25.8	1.8	16.3	5.3	27.6	29

Table 9 shows the mean values for all measurements taken at sites along with the sample sizes in 2006.

Figures

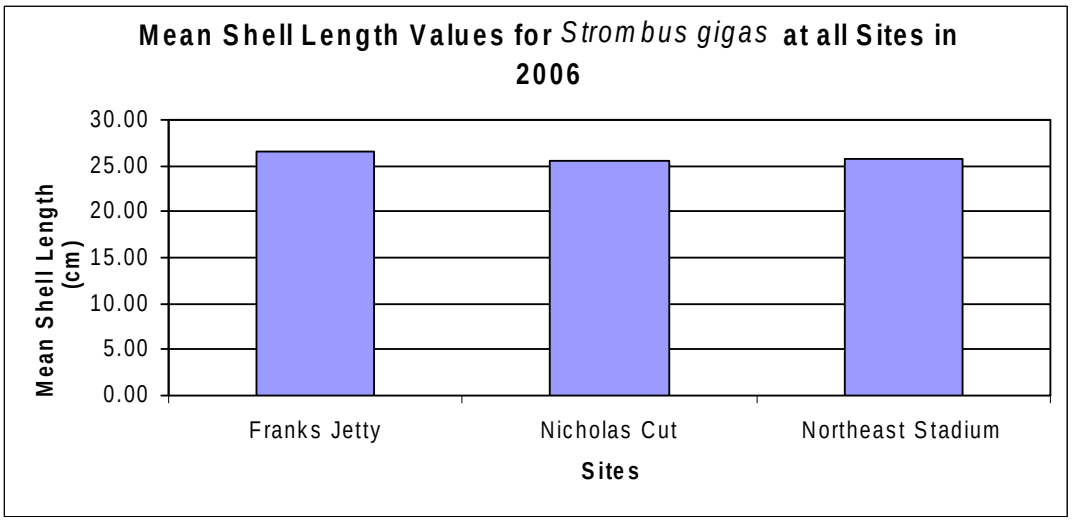

Figure 9 shows the mean shell lengths for *S.gigas* individuals each site in 2006

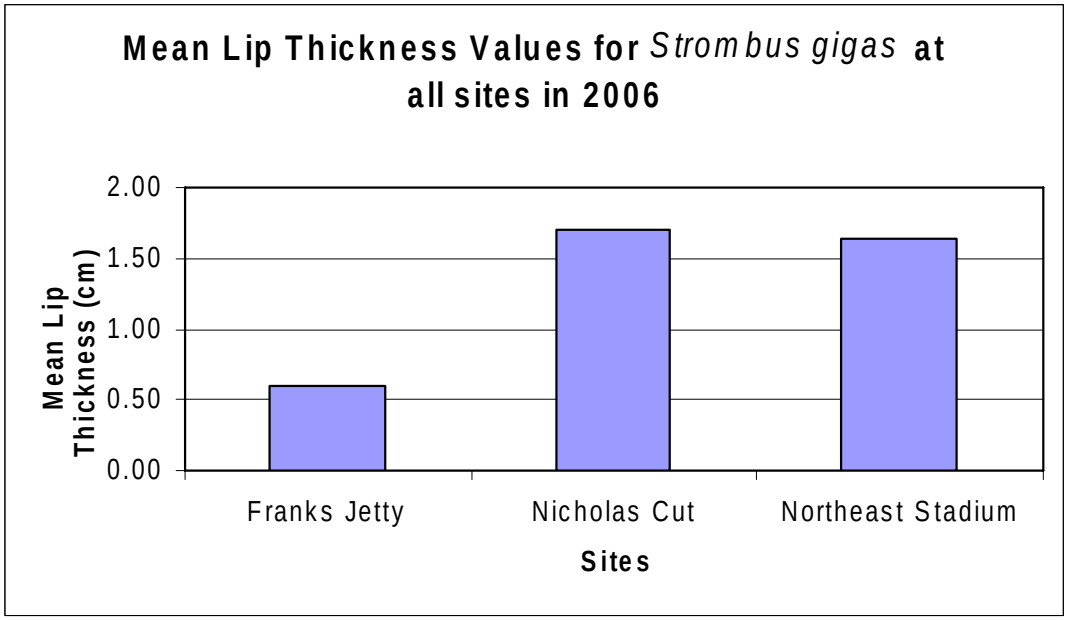

Figure 10 shows the mean lip thickness values for *S.gigas* individuals at each site in 2006

3.1 2007 Queen Conch Population Monitoring Modifications and Plan

In addition to the research goals ReefCI has begun to assist Dr. Cigliano with during 2006, there are other simple modifications to the data collection methods and additional data collection that ReefCI can undertake in the 2007 monitoring year to further enhance the *S. gigas* population monitoring within and around the SCMR. They include:

- **Establishing a regular, year-round monitoring schedule for Queen Conch populations at key sites within and around the reserve.** Taking into consideration natural seasonal variations in any population, and especially the seasonal management closures to the conch fisheries within the reserve, ReefCI will establish and maintain a regular monitoring schedule that ideally includes multiple sampling events within each season/closure at each selected site. ReefCI will continue to tag any new individuals found as well as monitor the location and reproductive activity of previously tagged conch. This will provide valuable data on seasonal variation, reproductive activity, and possibly the effectiveness of seasonal closures.
- **Collecting "recapture" data.** Using the system of reward for tags returned established by Dr. Cigliano and the Earthwatch institute, ReefCI will assist in collecting recapture data by recording the tag number, and location taken of individuals that have been harvested in the area (using information from fisherman that bring the tags to Frank's Caye). In any case where tags are brought to Frank's Caye, ReefCI will provide the above information to Dr. Cigliano directly and either deliver the tags to the Earthwatch office in Punta Gorda or direct the fisherman to do so.
- **Locating and monitoring any *S. gigas* migration routes, particularly any to/from the deep water aggregation(s).** As part of the expanding

effort to understand the natural history and reproductive activity of the Queen Conch, and to better understand the unusual use of deep water sites by individuals within the reserve, ReefCI will actively and frequently search the areas surrounding the deep water aggregation at "The Stadium" (and any additional deep-water sites found) to locate the migration route to/from this site. Location of the route is crucial since it will obviously need to be protected from fishing pressures in order to support the population's use of the site.

4.0 Caribbean Spiny Lobster (*Panulirus argus*)Population Monitoring

The Caribbean Spiny lobster *Panulirus argus* is one of the most commercially important species in Belize, and represents a major fishery in the Sapodilla Cayes. Considering this species' high economic value to Belize, managers have established seasonal closures to protect the population during the height of breeding activity. In order to maintain a sustainable *P.argus* fishery, regular monitoring of the population within the park is necessary. Two data parameters taken by ReefCI in 2006 are of particular usefulness to determining the state of the population within the park and the effectiveness of current management strategies. Recording the ratio of males to females within the population will show the reproductive potential for the population. Recording the number and time of year of any females carrying eggs provides information about the breeding activity of the species relative to closures. In addition, ReefCI also records the size of each individual (as measured by tail, carapace, and total length in cm) as an indirect indicator of relative maturity. The above measurements were taken for each individual found by "rover diver" technique at five sites: Lime Caye Wall, Northeast Wall, Northeast Bouy, Tom Owens Wall and Seal Caye Wall. When a lobster was found, the diver assessed the gender (by noting the shape of the fifth legs and spacing of the swimmerettes), and in the case of females, noted whether or not eggs are present. The diver then removed the lobster from its crevasse by gently tapping the back of its tail with a stick, and length measurements were taken with the stick which is marked in centimetres

Results

A total of 98 *P. argus* individuals were measured by ReefCI at four sites throughout the reserve and one outside the reserve (Tom Owens Wall) in 2006. Of the sites at which *P. argus* individuals were found, divers measured an average of 5 lobsters per dive for a mean of 0.5/100m2 for all individuals recorded.

The site with the highest mean abundance per 100m2 for *P.argus* in 2006 is Northeast Wall (mean= 0.6/100m2), with the lowest mean abundance at Seal Caye Wall, where no individuals were found (mean=0/100m2). The sample sizes for these populations are not equal due in large part to the frequency with which sites were sampled (see Table 10). Because of this, more regular monitoring of these sites, as is planned for the 2007 year, should begin to clarify whether or not these data show actual differences in lobster abundances between sites. However, in the case of Seal Caye Wall, this is a

site locally known to have lower biodiversity and density of fish species, and it is suspected that the absence of lobsters from the data is a reflection of low invertebrate biodiversity there as well. As individuals were recorded at Seal Caye Wall in 2005, ReefCI will continue to more regularly monitor this site.

At all sites where *P. argus* individuals were recorded, females exceeded males in number, with Lime Caye Wall showing the highest difference between females and males. In fact, female individuals represented 69% of the population at Lime Caye Wall, suggesting positive potential growth of the population in that area. Northeast Wall showed similar population numbers and male to female ratios (see Table 10). Tom Owens Wall, ReefCI's only site outside of the SCMR, shows the lowest female to male ratio, but with gender numbers approaching 50/50, this suggests at least a stable population in that area.

One potential bias of these data is that the higher numbers of female *P.argus* at these wall sites may be reflective of a gender-specific behaviour instead of an actual difference in gender ratio of the population. Many females of various species of lobster migrate to walls to release their eggs, and if *P.argus* females are engaging in this behaviour in the Sapodillas, their comparatively increased numbers on the walls may be attributed to it. Since lobsters regularly molt and are highly mobile, tagging individuals and tracking their movements can be complicated and is presently outside the scope of ReefCI's research resources and goals. However, consistent seasonal monitoring of these sites, along with year-round observations of *P.argus* mating behaviour, can help ReefCI to make inferences about both genders' use of these sites.

Tables

SITE	Males	Females	Difference	Number of times sampled
Lime Caye Wall	31%	69%	38	6
Northeast Bouy	47%	53%	6	5
Northeast Wall	36%	64%	28	4
Tom Owens Wall	43%	57%	14	2
Seal Caye Wall	0	0	0	2

Table 10 shows the percentages of males and females at each site in 2006

Figures

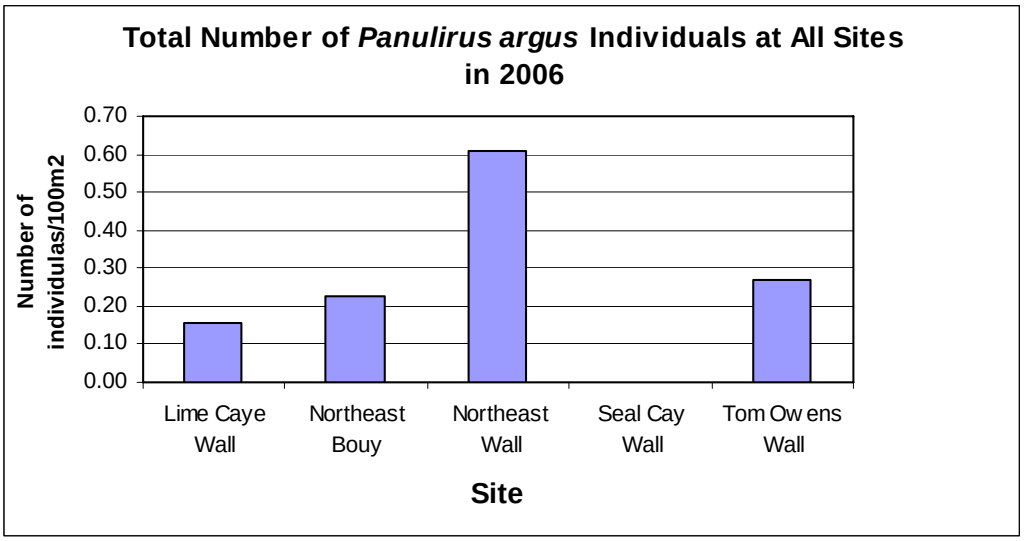

Figure 11 shows the number of total *P. argus* at each site in 2006 per 100m2

4.1 2007 *Panulirus argus* (Caribbean Spiny Lobster) Population Monitoring Modifications and Plan

In order to enhance the baseline data established by the past two years of *P.argus* monitoring, ReefCI has identified the following goals for the 2007 monitoring year:

- **Establishing a regular, year-round monitoring schedule for *P.argus* populations at key sites within and around the reserve.** In order to have more complete data on *P. argus* population fluctuations, especially taking into consideration natural seasonal variations in any population, and the seasonal management closures to the lobster fisheries within the reserve, ReefCI will establish and maintain a regular monitoring schedule that ideally includes multiple sampling events within each season/closure at each selected site. Collecting the data in this manner will better allow ReefCI to analyse the data with respect to closures, breeding behaviour and sites within the park versus those outside.
- **Modifying the methodology used to collect the data to conform with Acosta (REFERENCE HERE)**- doing belt transects at known depths etc.
- **Modifying the parameters recorded to include the depth** at which each individual is found. The depth at which individuals are found could indicate a difference of fishing pressures between sites, and/or give a general indication of overfishing within the park, since the main legal form of fishing for lobsters is the free diving technique. One would expect that as fishing pressures increase in shallow waters, the highly mobile *P.argus* would migrate to deeper habitats.

5.0 Spawning Aggregation (SPAG) Monitoring Project

Spawning aggregations (SPAG) are large collections of individual fish who come together for the express purpose of mating at a specific time of the year and/or month, which is usually correlated to phases of the moon. ReefCI has observed a variety of fish species employing this behaviour in the Sapodilla Cayes, including Black Grouper, Yellowtail Snapper and Dog Snapper. Based on our observations in these areas along with research that shows that many SPAG sites support a number of different species at different times of the year (MBRS et. all, 2005), it is likely that more species of fish, particularly Grouper are forming SPAGs in the Sapodilla Cayes.

During 2005 ReefCI found a total of 3 new spawning aggregation sites; a Dog snapper aggregation at Tom Owens Wall, a Yellowtail Snapper aggregation at Hunter's Mount, and a Black Grouper aggregation at a site called Honeymoon. During the 2006 monitoring year, ReefCI continued to monitor these sites, concentrating our efforts around dates surrounding the full moon.

For the 2007 monitoring year, ReefCI plans to take more rigorous SPAG data, by modifying the methodology set out in the Reef Fish Aggregation Monitoring Protocol for the Mesoamerican Reef and the Wider Caribbean (MBRS, 2005) to match with our present resources and capabilities.

Figure 15 showing the spawning aggregation of Dog Snappers at Tom Owens Wall.

6.0 Conclusion

ReefCI is a small organization within the first few years of operation. ReefCI has already identified the key research projects and associated methodologies for which we are uniquely suited, and which will contribute to conservation and management within the SCMR. By focusing primarily on commercially important and indicator species, ReefCI are creating several potentially long-term baseline monitoring programs involving numerous different species.

By continuing to dive regularly in the Sapodilla Cayes, ReefCI staff and guests have the opportunity to see changes or anomalies in the reef system and report them to the appropriate organizations, which can serve to help safeguard the health of the reef system within the park.

It is the goal of ReefCI to continue to operate in this way, collaborating with the SCMR, Belizean Fisheries Department, the Toledo Association for Sustainable Tourism and Empowerment (TASTE), and the Earthwatch Institute, together with other interested parties to contribute to the research and conservation management in the Sapodilla Cayes.

Finally, because ReefCI trains and utilizes guests from around the world to assist in the research, we are educating a global audience about the need for conservation of reef systems and the specific work being done by ReefCI and the other organisations within the SCMR. This provides us with the opportunity to both contribute to local conservation efforts by providing resources and data to interested parties and to educate the local and international public about the value of the SCMR and the importance of protecting it.

7.0 Appendix

Site Names with GPS Readings

Bungee Backside	GPS :16Q 0356886 UTM 1787655
Franks Cay Inner	Unavailable
Honeymoon	N16°07.120 W088°13.781
Hunters Mount	N16°06.287 W088°15.571
Lime Cay Wall	N16°05.622 W088°16.336
Nicholas Cut	N16°06.712 W088°15.932
Northeast Buoy	N16°07.781 W088°15.012
Northeast Stadium	N16°07.304 W088°15.064
Northeast Wall	N16°08.562 W088°14.556
Ragged Cay	N16°05.385 W088°17.940
Seal Cay Wall	N16°10.005 W088°20.179
Tom Owens Wall (SPAG)	N16°12.359 W088°12.119
Tom Owens Wall	N16°10.262 W088°13.298
Vigilance	N16°07.120 W088°16.