A BIOLOGICAL AND SOCIO-ECONOMIC ASSESSMENT OF THE CORAL REEFS AND ASSOCIATED FAUNA OF THE TOBAGO CAYS MARINE PARK AND CANOUAN ISLAND

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Introduction

While coral reefs cover only 0.2% of the ocean floor, it is estimated that they harbour an estimated 1-3 million species; approximately one third of all described marine species (Reaka-Kudla, 2001). This makes coral reefs the world's most bio-diverse marine ecosystem. It is estimated that 850 million people live within 100 km of a coral reef and at least 275 million people live less than 10 km from the coast and within 30 km of reefs (Burke *et al.*, 2011). All these people will derive benefits from the ecosystem services the reefs provide, ranging from food and coastal protection, to economic input via tourism. It is estimated that globally, these ecosystem benefits have an annual value of US$172-375 billion (Fischlin *et al.*. 2007; Martinez *et al.*, 2007).

The threats to coral reefs have been well described, with stressors acting at both the global and local level. The continued increase in global atmospheric carbon dioxide levels is resulting in global stressors such as rising sea temperatures, ocean acidification, and increased storm frequency. Rising sea temperatures can lead to mass bleaching events that often result in significant coral mortality (Eakin *et al.*, 2010), such as the 1998 mass bleaching event which destroyed 16% of the world's coral reefs (Wilkinson, 2004). However the consequences of a change in ocean chemistry leading to acidification, is only just beginning to be revealed. It is causing a reduction in hard coral species' ability to deposit the calcium carbonate skeletons that are essential for reef-building and ultimately the survival of present day coral reef ecosystems (Veron *et al.*, 2009). Fishing both excessively (Jackson *et al.*, 2001) and destructively (Fox and Caldwell, 2006; Wells, 2009), and sedimentation (e.g. Alongi *et al.*, 2005) and pollution (e.g. Reopanichkul *et al.*, 2009) often as a result of poorly managed coastal development, are examples of local pressures which can cause direct physical damage to coral reefs, as well as indirect effects on trophic webs. It is important to note that these stressors will often have a compounding and/or synergistic effect on coral reefs According to the most recent 'Reefs at Risk' report (Burke *et al.*, 2011) 75 percent of all reefs are considered 'threatened' as a result of the stressors described above. Due to the fact that only a very small number of reefs have been monitored over extended periods of time e.g. Australia's Great Barrier Reef, there is limited information on changes in coral cover and condition which is an impediment to effective, sustainable management of coral reefs, both the local and global level.

Protecting coral reefs

In order to protect the valuable resources that coral reefs, and the marine environment as whole, offer, it is essential that they are protected. These protective measures have to take place at both local and global level, similar to the threats, and involve on the ground management, as well as political legislation. The most tangible measure is the Marine Protected Area (MPA) – also known as marine reserves, marine managed areas and marine conservation zones, dependant on their management strategy. MPAs can range enormously in their rationale, size, as well as their effectiveness. MPAs have been shown to be an effective management tool in coastal areas for reducing the impact of fisheries on fish populations, and their associated habitats, by reducing or outright banning fishing on a range of spatial and temporal scales (Cote *et al.*, 2001; Halpern, 2003). While MPAs may not be able to directly protect against global pressures such as climate change and ocean acidification, it has been shown that they can prevent reef degradation on a local level by increasing reef resilience (Seilig and Bruno, 2010). This is very likely due to the fact that the pressures on coral reefs are working synergistically and the reduction of local pressures will mean global pressures are less damaging.

It is estimated that there are 2,679 coral reef MPAs which cover approximately 27% of shallow water coral reefs (Burke *et al.*, 2011). However, there are concerns that many of these may not be managed effectively, so-called 'paper parks', and that MPAs may not always be established where reefs are most at threat. This led Burke *et al* to conclude that 47% of MPAs analysed should be considered 'ineffective'. Further, to put this figure in context, global ocean coverage of all MPAs (including non-coral reef areas) is only 1.42%, of which 0.12% are fully protected no-take MPAs (Dan Laffoley, IUCN, personal communication, 2011).

Caribbean reefs
The term 'Caribbean reefs' is used to loosely describe areas of coral that are bordered by the arc of Islands that runs south from Barbados to the Lesser Antilles along the Western part of the Atlantic, and the land mass of Central America (Figure 1).

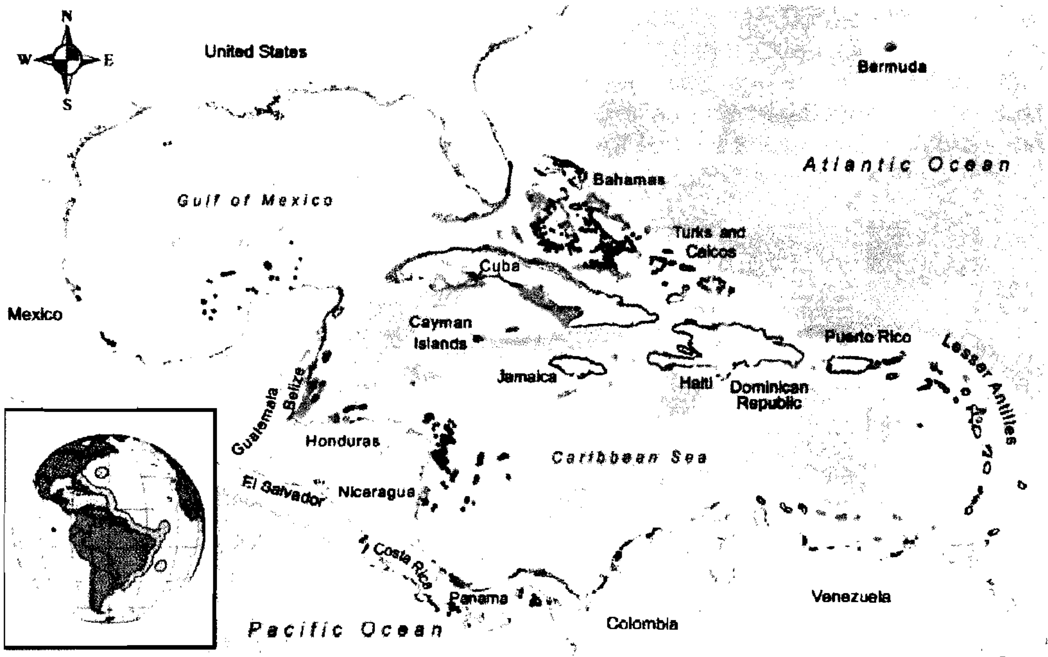

Figure 1. Map of the Caribbean region and its coral reefs (adapted from Burke *et al.*, 2011).

The Caribbean hosts around 65 species of hard corals with well over 90 percent of these, and the associated species of fish, crustaceans, and other fauna being endemic to the region (Eakin et al, 2010). It is estimated that in the Caribbean, hard coral cover has decreased by 80% in only 30 years (Gardner *et al.*, 2003) with a phase-shift to more macro-algal dominated reefs (Hughes, 1994). About 43 million people live within 30 km of a coral reef, and overfishing affects nearly 70% of reefs resulting in some of the lowest fish biomasses in the world – the only healthy populations existing in a handful of well-managed MPAs (Burke *et al.*, 2011). In addition to this human pressure – and that of tourism, which in 2002 was estimated to bring $110 million to the economy of the region (Burke and Maidens, 2004) – disease has had a significant effect on the hard corals in the Caribbean. White-band disease has decimated populations of what were considered the two most prolific reef-building species in the region; *Acropora palmata* (elkhorn coral) and *Acropora cervicornis* (staghorn coral) (Aronson and Precht, 2002).

30% of Caribbean reefs are estimated to be protected by MPAs, of which 40% of these are considered 'ineffective' (Burke *et al.*, 2011). This highlights the problems associated with managing MPAs and encouraging the necessary community buy-in. Indeed, a study in Belize indicated that local pressures are overwhelming local management efforts and that subsequently the MPAs in this area did not seem to be effective (Huntington *et al.*, 2011). Despite this, there is evidence that some MPAs in the Caribbean are proving effective for coral reefs. For example, a study in the Bahamas indicated that the establishment of a marine reserve reduced the exploitation of herbivorous fish, thus decreasing macro-algae cover and allowing hard coral species to grow faster, compared to outside of the MPA (Mumby and Harborne, 2010). This contrast in findings highlights the need for long-term monitoring in the Caribbean, on a range of spatial scales, to facilitate further understanding of the benefits and limitations of MPAs in the region.

St. Vincent and the Grenadines (SVG)

SVG consists of 34 Islands located in the south east of the Caribbean which are bordered by St. Lucia to the north and Grenada to the south. St. Vincent is a relatively young volcanic Island with sporadic coral reefs present on the north and east coasts, and good coral growth on the rocks around headlands on the west coast. To the south of St. Vincent lies the chain of Islands known collectively as the Grenadines which host an abundance of coral reefs (Figure 2).

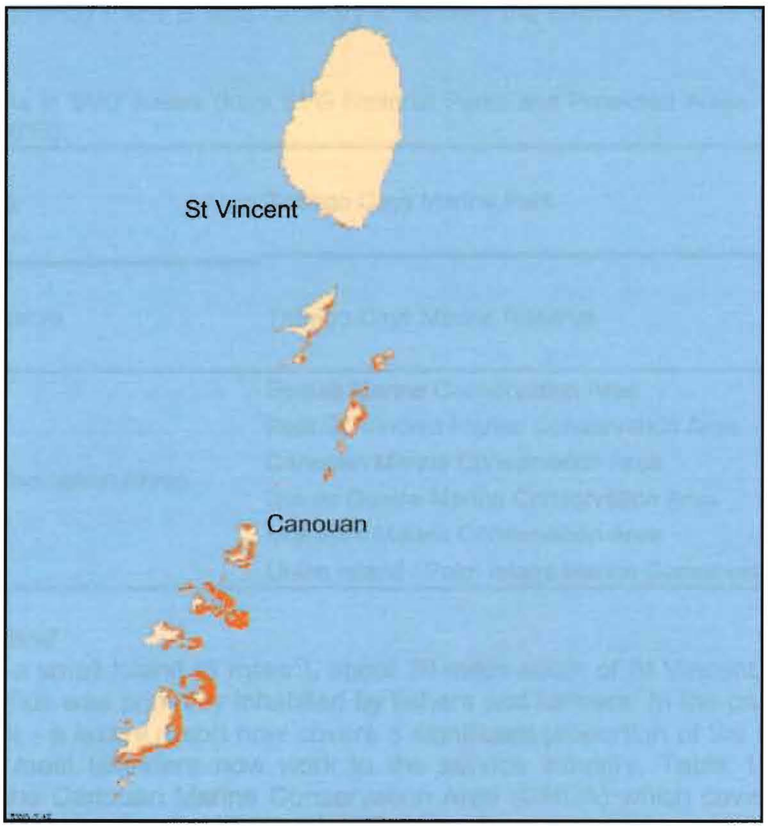

Figure 2. Coral cover in the SVG region (ReefBase ©). Coral cover is highlighted in orange.

The total population of SVG is 109,000 of which ~20% is reliant on agriculture, forestry and fisheries (www.FAO.org, 2011). According to the last assessment in 1999 (www.FAO.org), fish landings in SVG are an estimated 1,120 t of fish/annum, generating ~$ 2.7 million. Small inshore pelagics, such as scad, account for approximately 45% of the total landings, Average annual fish exports amounts to ~175 t of which tuna and lobster account for more than 75%.

The Reefs at Risk in the Caribbean report (Burke and Maidens, 2004) indicated that all the 140 km^2 of reefs within the waters of SVG are at risk from human activities, and predominantly, overfishing. On a broader scale, the following was stated in the 'Fourth National Biodiversity Report of St. Vincent and the Grenadines to the United Nations Convention on Biological Diversity (UNCBD)' (Anonymous, 2010):

Coastal Wetland habitats (including beaches, mangroves, and marshland) are suffering as a result of developments such as hotels and marinas, but also due to illegal removal of beach (and dune) sand for the construction industry, and cutting of mangroves for charcoal production. The fragmentation of habitats and degradation of coastal ecosystems is making the country increasingly vulnerable to the impacts of natural disasters such as hurricanes, tropical storms, storm surges and heavy rains; the effects of which are expected to worsen under climate change. Furthermore, destruction of nursery areas and habitats for fish results in a reduction in fish stocks and a decline in livelihood opportunities in fishing communities.

In response to these threats, the SVG government have designated 11 MPAs in SVG, which are sub-divided into three categories (Table 1) according to the level of protection they are afforded; fishing and removal of any flora and fauna, dredging and construction are not permitted in these areas without special dispensation. However, currently there is little capacity to assess the effectiveness of the MPAs in the SVG.

Table 1. MPAs in SVG waters (from SVG National Parks and Protected Areas System Plan 2010-2014, 2010).

Marine Park	Tobago Cays Marine Park
Marine Reserve	Tobago Cays Marine Reserve
Marine Conservation Areas	Bequia Marine Conservation Area Petit St. Vincent Marine Conservation Area Canouan Marine Conservation Area Isle de Quatre Marine Conservation Area Mustique Marine Conservation Area Union Island / Palm Island Marine Conservation Area

Canouan Island

Canouan is a small Island (5 $miles^2$), about 30 miles south of St Vincent, which until the early 1990s was primarily inhabited by fishers and farmers. In the past 20 years, development - a luxury resort now covers a significant proportion of the Island - has meant that most Islanders now work in the service industry. Table 1 shows the location of the Canouan Marine Conservation Area (CMCA) which covers a lagoon (Godhal Lagoon) to the east of the Island (Figure 3). A report was recently published that assessed the impact Island development on the natural resources of the Godhal Lagoon (Price, 2011) which indicated that the protection of the area was not effective.

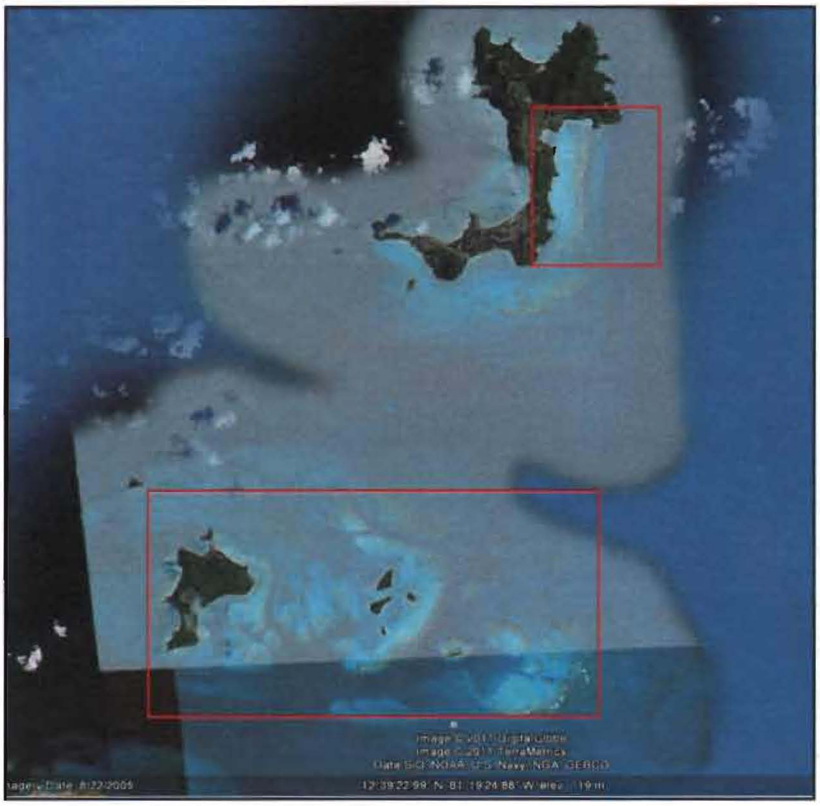

Figure 3. The Canouan Marine Conservation Area (top) and Tobago Cays Marine Park (bottom).

Tobago Cays

The Tobago Cays are five small Islands - Petit Rameau, Petit Bateau, Baradal, Petit Tabac and Jamesby – that are believed to have some of the best-developed reefs in the waters surrounding them. Each Island has a fringing reef, bordered by Horseshoe Reef to the east after which is the World's End Reef (Figure 4). The Tobago Cays also offers up a large area of seagrass bed that supports a small green turtle population, and also has the potential to harbour other species such as seahorses.

These uninhabited Islands are the focus for the Marine Park that surrounds them - and also includes the Island of Mayreau where the majority of the local stakeholders reside (Figure 3). This is the largest and arguably the most effective MPA in the region and has been in existence since 1997. However, in 2002, government policy stated that the SVG Coastguard Services only allotted 15 sea days to fisheries surveillance and enforcement (www.FAO.com). There is significant boat traffic in the park which includes cruise ships, yachts, charter boats and diving boats, and as such anchor damage is a concern (Davis, 1977), especially with such poor enforcement coverage.

6. To understand the management of the TCMP and CMCA and provide recommendations to improve their effectiveness.

7. Circulate outcomes to key stakeholders and provide recommendations for *future sustainable development.*

Methodology

Dive site descriptions

Surveys within the TCMP (on Mayreau Gardens and Horseshoe reefs) were carried out from 2nd – 6th September 2011 – one day was lost due to issues with lost luggage which unfortunately meant limited replicate surveys at Mayreau Gardens could be carried out - while surveys around Canouan (on the outer reef and in the lagoon of Canouan marine conservation area, and on Canouan Southern reef) were carried out from 8th – 13th September 2011. Survey sites within the TCMP are marked on Figure 5, and sites in the waters surrounding Canouan are marked on Figure 6. On Canouan, one survey site was located outside the CMCA, Canouan South, with the other three groups occurring within the CMCA –CMCA deep and shallow, and Canouan Lagoon which incorporates the shallow waters to the west of the reef. Deep sites were those that were below 14 metres, while shallow dives were less than 13 metres.

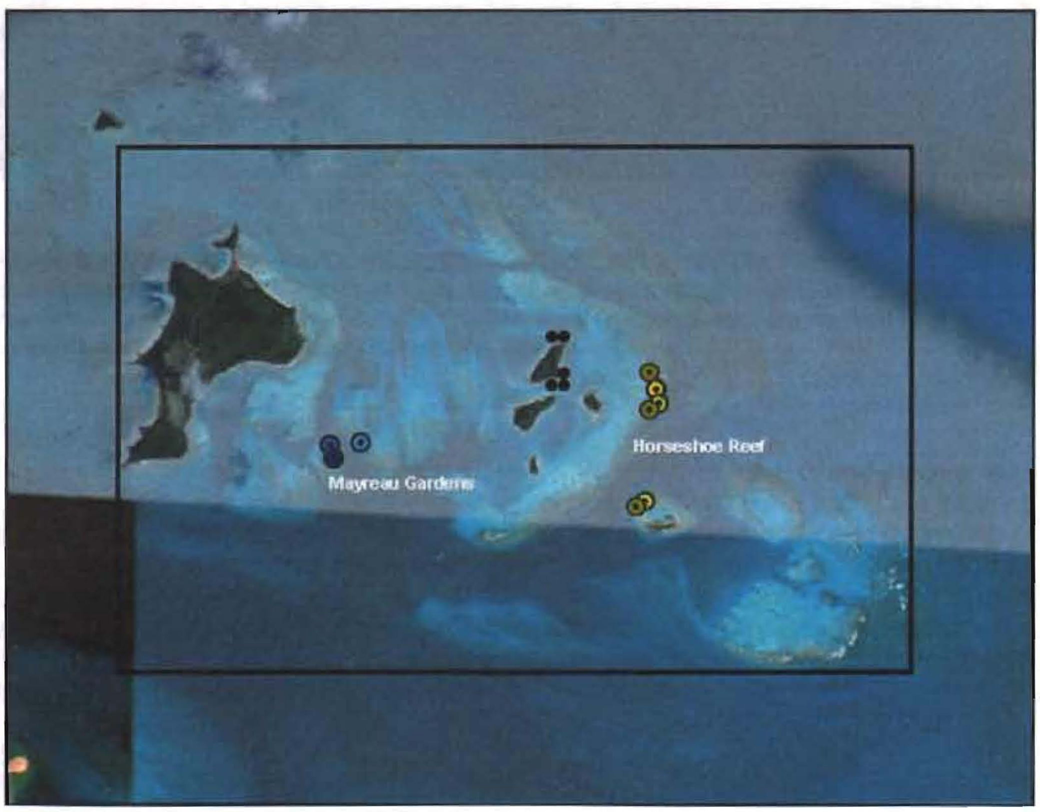

Figure 5. Dive survey sites in the TCMP, dives in Mayreau Gardens are marked in light blue (shallow) and dark blue (deep), while those in Horseshoe Reef are marked in yellow (shallow) and dark yellow (deep). The location of sea grass surveys are denoted by small black dots.

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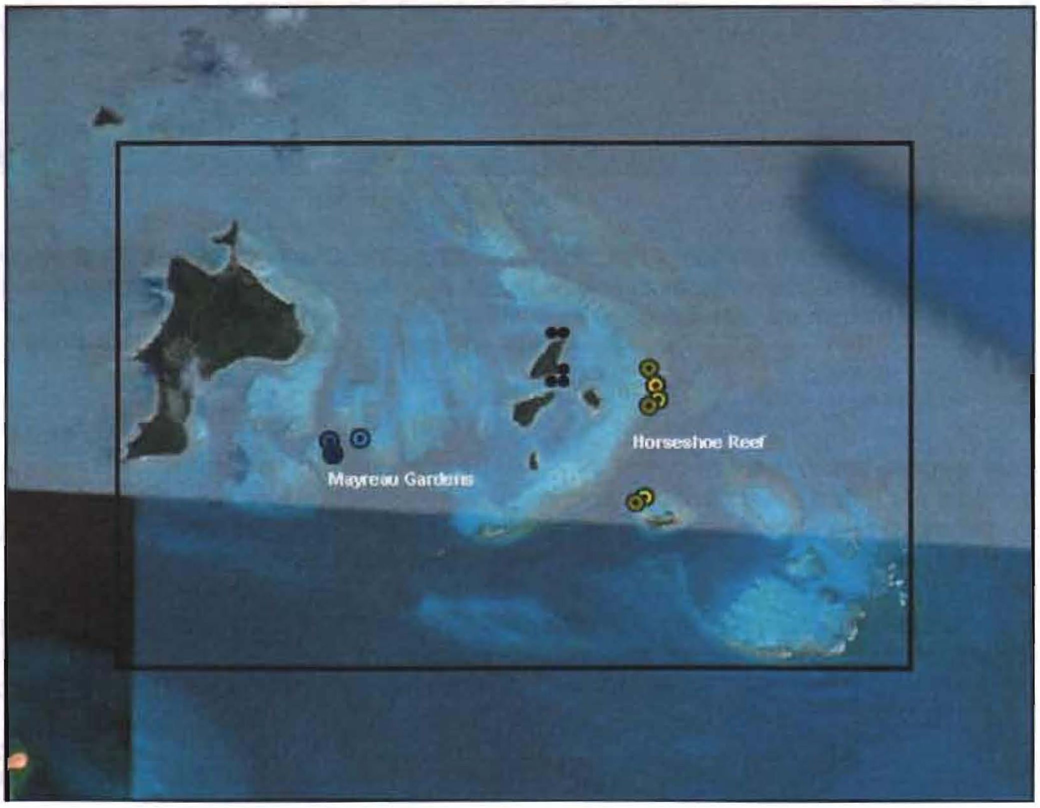

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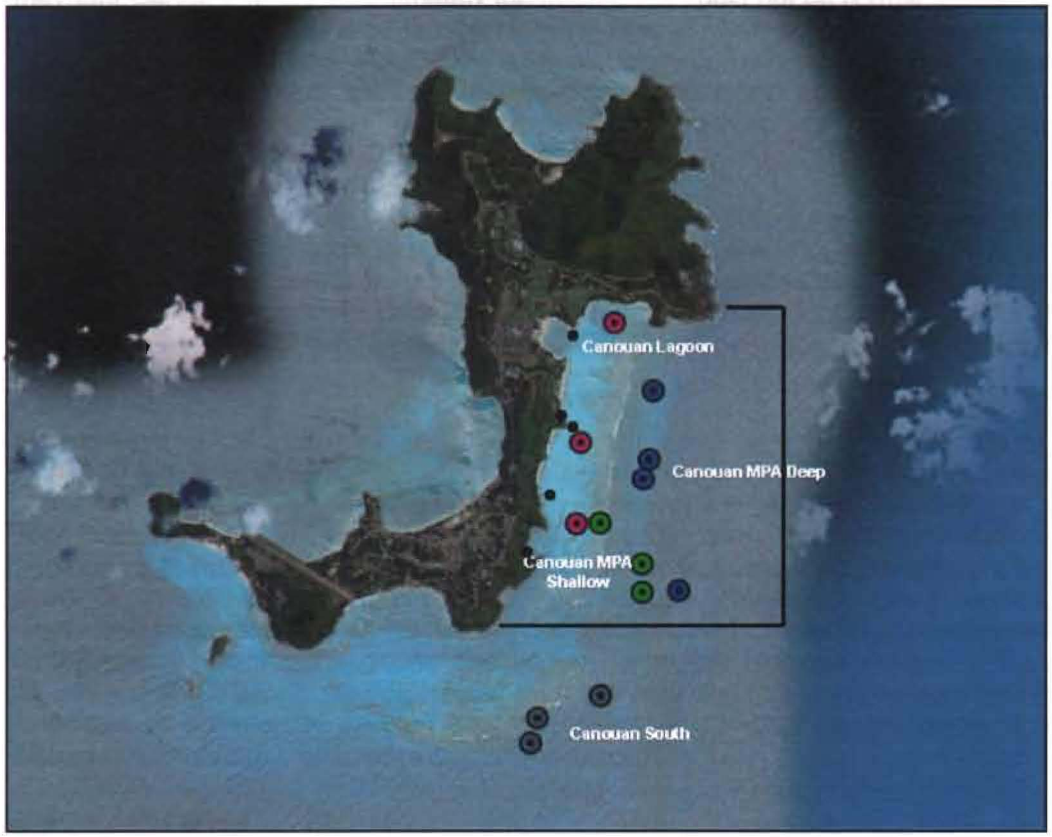

Figure 6. Dive survey sites in Canouan, dives in Canouan Lagoon are marked in pink, dives in deep waters in the CMCA are marked in dark blue, dives in shallow waters in the CMCA are marked in green while those in outside the CMCA (Canouan South) are marked in grey. The location of sea grass surveys are denoted by small black dots.

Manta Tows

An overall impression of both the TCMP and the Canouan Island waters was garnered by manta towing for a day at each location. Two team members wearing snorkelling equipment were towed behind the boat on a 10m rope and estimates of coral cover, depth and reef type was gained. Any incidental observations such as anthropogenic damage, and unusual flora and/or fauna, were also noted. These surveys were used to identify appropriate sites for the dive surveys, which were representative of the reefs in these locations and taking into account logistical considerations such as strong currents.

Surveys

Reef assessments were carried out at the two locations (TCMP and Canouan Island) by a team of four divers (two buddy pairs). Five sites within these two locations were surveyed as a representation of the reefs present: Horseshoe Reef, and Mayreau Gardens in TCMP; and Canouan Outer Reef within the conservation area, Canouan Lagoon within the conservation area, and Canouan Southern Reef. Shallow dives (7-10 m) were carried out at each of the five sites. Further, at sites where conditions allowed – Horseshoe Reef, Mayreau Gardens, and Canouan Outer Reef within the marine park – deep (13-18m) dives were also carried out. Therefore in total eight sites were assessed with three dives at each of the eight sites, with the exception of

Mayreau Gardens where unfortunately the three dives could not be completed due to strong currents and a reduced timeframe (One dive at Mayreau Gardens deep and two dives at Mayreau Gardens shallow were completed). Each replicate was at least 250m from another, and surface GPS readings were taken at the start of each survey. The bottom temperature was recorded during each survey and a Secchi disc reading to assess turbidity was taken after each dive.

During the dive, a transect tape was laid over 50m of reef along the same depth contour during both shallow and deep dives. Depths were kept as consistent as possible throughout; however, topography, weather and ocean state dictated dive locations in some instances. Once the transect tape had been laid, it was left for at least five minutes to let fish populations return to normal behaviour. Several different methodologies were employed as part of the monitoring of the transects:

Fish surveys

Fish species and abundance counts, lasting a standardised 15 minutes, were performed to assess 2.5 m either side of the transect line and 5 m above the sea floor (creating a 250 m^3 tunnel) by one of the buddy pairs. The fish identifications were spilt into two groups: 1) commercial fish species (e.g. snapper, grouper, grunts, parrotfish) and wrasse; 2) demersal fish (e.g. hamlets, damsels, gobies, blennies, moray eels). Lengths of commercial species were estimated into length categories (categories: 0 -5cm, 5.5 – 10cm, and so on) to enable biomass estimates. Fish abundance and diversity was calculated from this data and fish biomass from length estimates of commercial species was calculated, using length:weight conversion factors obtained from Fishbase (www.fishbase.org).

Invertebrate survey

Abundance of macro-invertebrates was assessed along a belt transect adapted from the internationally recognised ReefCheck methodology (www.reefcheck.org). A 1 m swathe either side of the 50 m transect tape – yielding a 100 m^2 area - was surveyed for the presence of macro-invertebrates targeted in the ReefCheck methodology for the region:

Invertebrates in all Regions:

- Banded coral shrimp *Stenopus hispidus*
- Collector urchin *Tripneustes* spp.
- Lobster (spiny and slipper/rock) - Malacostraca (Decapod)
- Long-spined black sea urchin *Diadema* spp.

Invertebrates in the Atlantic specifically

- Flamingo tongue *Cyphoma gibbosum*
- Gorgonians (octocorals including sea fans, sea rods, sea plumes and s whips)
- Pencil urchin *Eucidaris* spp.
- Triton *Charonia variegata*

In addition to this abundance of Queen conch (*Strombus gigas*) were also recorded as they are a local commercial species. Any other macro-invertebrates encountered were noted and identified to as close to species level as possible to be added to species lists for the area. All macro-invertebrates that are identified are reported as a total count within the 100 m^2, and not linked to specific sub-sections within the survey area.

Benthic videography
Videography of the benthos was carried out along the transect line to allow a permanent record of the line transect to be retained for *ex-situ* analysis of the benthic cover. Filming was carried out immediately behind the initial laying of the transect line. The camera was kept approximately 40 cm from and parallel to, the substrate, and a swimming speed of 10 m / min was maintained - surge/current permitting. The camera was held to the right of the transect tape to avoid direct glare. A wide angle lens was attached to the camera, and the zoom was not used. The white-balance of the camera was adjusted prior to each transect to compensate for light attenuation at each depth assessed.

Benthic Quadrats
A quadrat (0.5 m x 0.5 m) was laid and photographed every 5 m (10 per 50 m transect) to record coral degradation and disease frequency, and estimated area of different habitat categories. These were photographed for *ex situ* analysis of:

- Disease occurrence
- Disease type and species on which it occurs
- Width and length of infected colony at widest points
- Bleaching

Seagrass
Assessments of the seagrass beds located within Tobago Cays in the TCMP, and in the lagoons of CMCA (including Godhal Lagoon) were carried out by undertaking five 50 m surveys at both locations parallel to the shoreline (Figures 5 and 6). The GPS location of the start of each survey was recorded. Photographs of a quadrat (0.5 m x 0.5 m) were taken every 5 m along the transect line to allow *ex situ* analysis of important benthic characteristics, percentage sea grass cover and sea grass species composition.

Socioeconomic survey
In order to assess the local stakeholder's perception of the marine environment, its benefits, impacts, and overall value, interviews were conducted on Mayreau and Canouan using a set of 28 statement/questions. Statement/questions were paired with initial scaled "strongly agree" to "strongly disagree" statements followed by open-ended questions that allowed interviewees to expand on their views.

Statement/questions were grouped into the following five categories:

1. Benefits the marine environment provides to humans.
2. The health of the marine environment.
3. Protection of the marine environment.
4. Corals and coral reef familiarity and importance.
5. Seahorses/sea grasses familiarity and importance.

Locals were approached and introduced to the work of ZSL, highlighting the Society's work with corals and seahorses. They were given a fact sheet on two ZSL projects: EDGE Corals and Project Seahorse. It was explained that ZSL had been invited to SVG by the National Trust to look at the health of the marine ecosystem and to gain an understanding of how healthy the local population felt SVG marine life was.

During the initial open discussion, interviewees were reassured that the information they provided was not for political purposes and would not be used against their interests. Interviewees were then asked to take part in the detailed survey. Basic information such as name, occupation, age and address were recorded in order to provide a demographic of the people taking part. The structure of the survey was explained with statement responses ringed and open ended questions recorded. Time was allowed after each question to give interviewees a chance to provide any additional comments, in order to keep the discussion informal and to capture any additional information that may have been indirectly related to the survey. Due to the casual structure of the survey there was sometimes more than one person present; in some cases other family members, friends or work colleagues would be present during the interview. In such instances only the responses from the selected interviewee were recorded, although they may have been influenced by others around them.

Data analysis

Abundance, and density of fish (fish per m^3) was assessed at all sites, as was both Simpson's index of family and species richness. Relative frequency of feeding guilds was also assessed for each site. For commercial fish species (Appendix 1) abundance and biomass was calculated from length estimates of commercial species was calculated, using length:weight conversion factors obtained from Fishbase. Density of invertebrate species (individuals per m^2) was calculated for each site from the obtained data, and combining both fish and invertebrate species of commercial interest allowed an assessment of the economic value of species caught at each site. Differences between all the above parameters were tested with one-way analysis of variance (ANOVA) using a Tukey's post-hoc test. A statistically significant difference was one where the p-value ≤ 0.05.

Benthic belt videography transects were analysed using dot grid analysis to obtain % cover of benthic communities and substrates, and % coral cover. Benthic quadrats photographed after fish surveys and videography was complete were analysed to assess the % of diseased and or bleached coral. Both of these methodologies were analysed in relation to the individual sites that were dived, except for Mayreau Gardens due to poor diving conditions and technical issues.

Quadrats photographed during seagrass surveys allowed visual analysis that identified specific categories of substrate. Survey results for each site - CMCA and TCMP - were pooled and the mean values compared.

Results

Fish Surveys

Surveys indicated that the shallow areas of Horseshoe reef (Horseshoe Shallow) in the TCMP had the greatest abundance of fish (Figure 7i), although this was only statistically greater than both the deep sections of Horseshoe reef (Horseshoe Deep) and the Canouan Lagoon. Analysis of both species and family richness (Figure7i and ii) to determine whether there were differences in the range of taxa present at each site varied, indicating that there were no differences between any of the study locations, irrespective of their designation as a protected area, i.e. while some sites may have had a greater number of fish, the diversity of fish was similar across the sites.

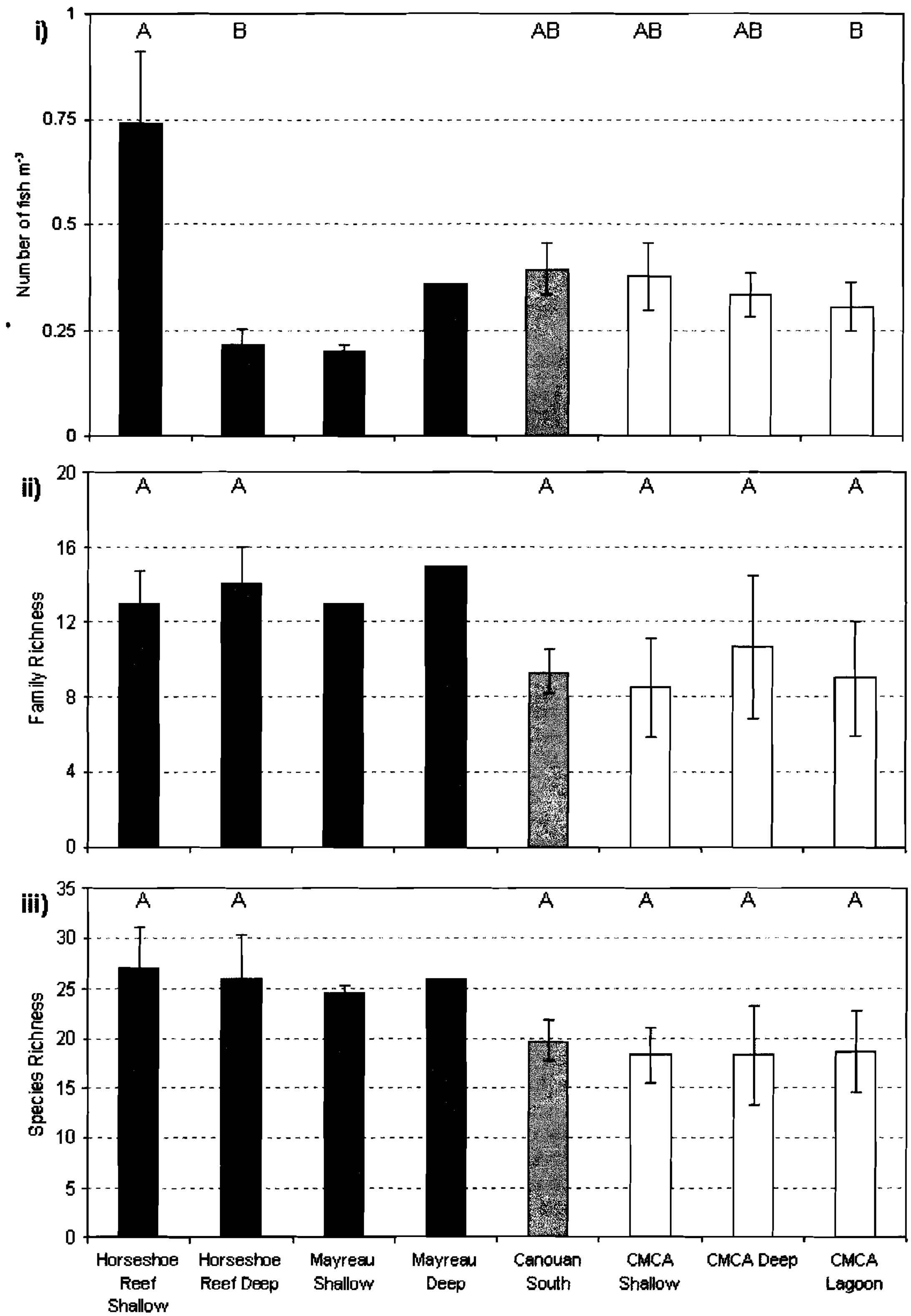

Figure 7. **i)** Mean number of fish (per m^{-3}), **ii)** mean family richness and **iii)** mean species richness across eight sites surrounding Canouan and within the Tobago Cays Marine Park, SVG. Error bars are one standard error of the mean. Mayreau deep and Mayreau shallow were excluded from statistical analysis due them having a limited number of replications (n = 1 and n = 2 respectively. Dissimilar letters indicate a significant difference ($p<0.05$).

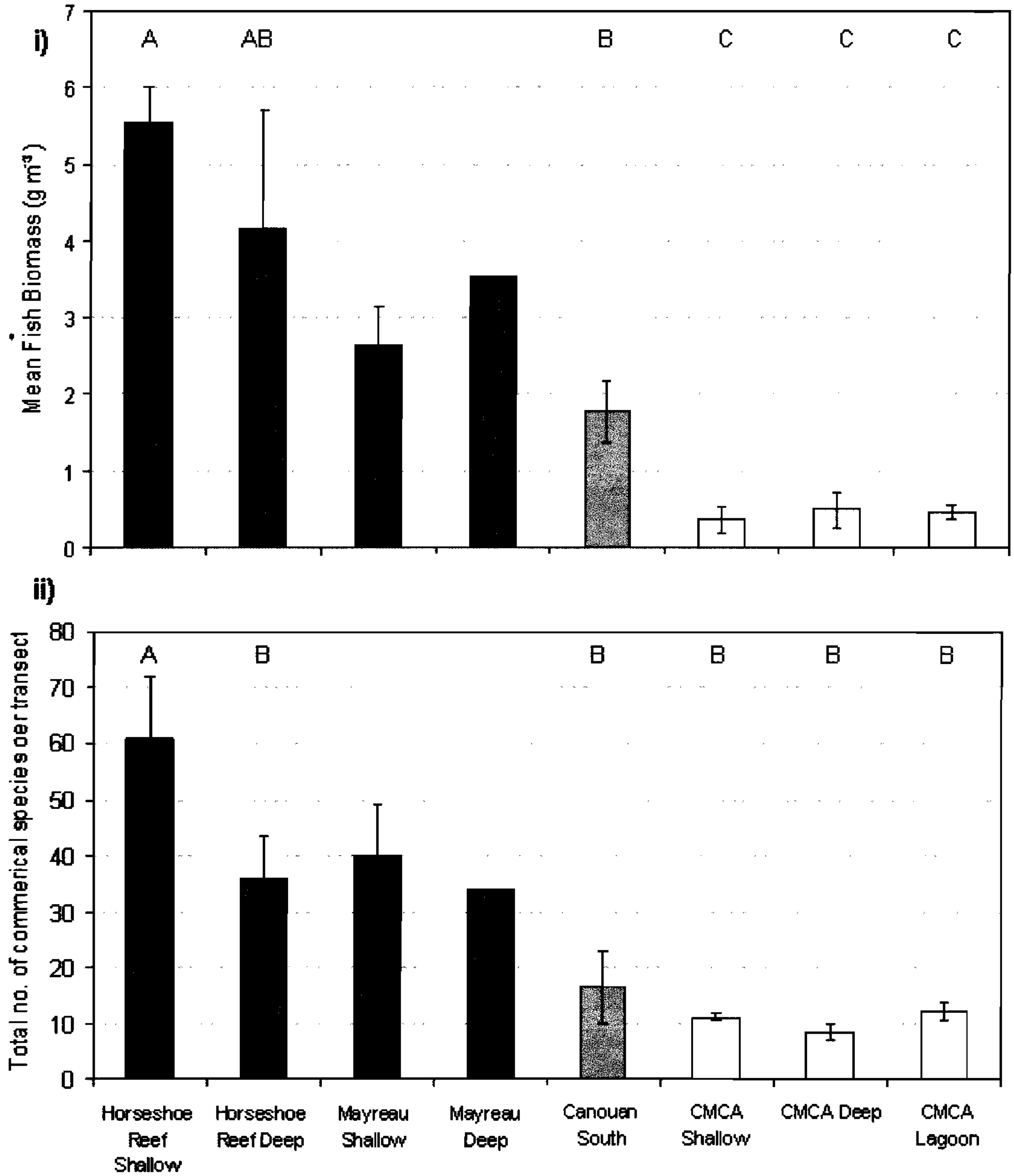

Figure 8. **i)** Mean commercial fish biomass (g m^{-3}) and **ii)** total number of commercial fish, across eight sites surrounding Canouan Island and within the Tobago Cays Marine Park, SVG. Biomasses were calculated through underwater fish length estimates and length:weight ratios obtained from FishBase.org. Error bars are a standard error of the mean. Mayreau deep and shallow were excluded from statistical analysis due a limited number of replicates (n = 1 and n = 2 respectively). Dissimilar letters indicate a significant difference ($p<0.05$).

Both fish biomass and fish counts of commercial species (see Appendix 1 for the species list) exhibited significant differences between sample sites (Figure 8i and ii). The shallow surveys at Horseshoe Reef indicated this was likely the most productive site, exhibiting significantly higher biomass and counts of commercial species than all the sites monitored within the CMCA. Both counts and biomass at all sites within the CMCA were of a similarly low level. The site outside the CMCA ("Canouan South") had lower biomass and counts of fish than the shallow waters of the Horseshoe Reef.

Canouan South had higher numbers and biomass of commercial fish than all the sites within the CMCA, but not statistically so.

Site data by feeding guild is presented in Table 2, and highlights that at all but one of the shallow sites (Canouan Lagoon), herbivorous fish species were the most predominant. While coralivores were noted at all sites, they were generally in low numbers – the shallow site at Mayreau Gardens had the highest numbers. All 90 fish species observed during the surveys are presented in Table 3.

Invertebrate surveys
Due to the low numbers of invertebrates that were identified, only the density of gorgonian species (sea fans, sea rods, and sea plumes) could be analysed statistically (Figure 9). The presence of these octocorals was significantly greater at the deep sites at Horseshoe reef in TCMP compared to all the sites surrounding Canouan, irrespective of their protected status.

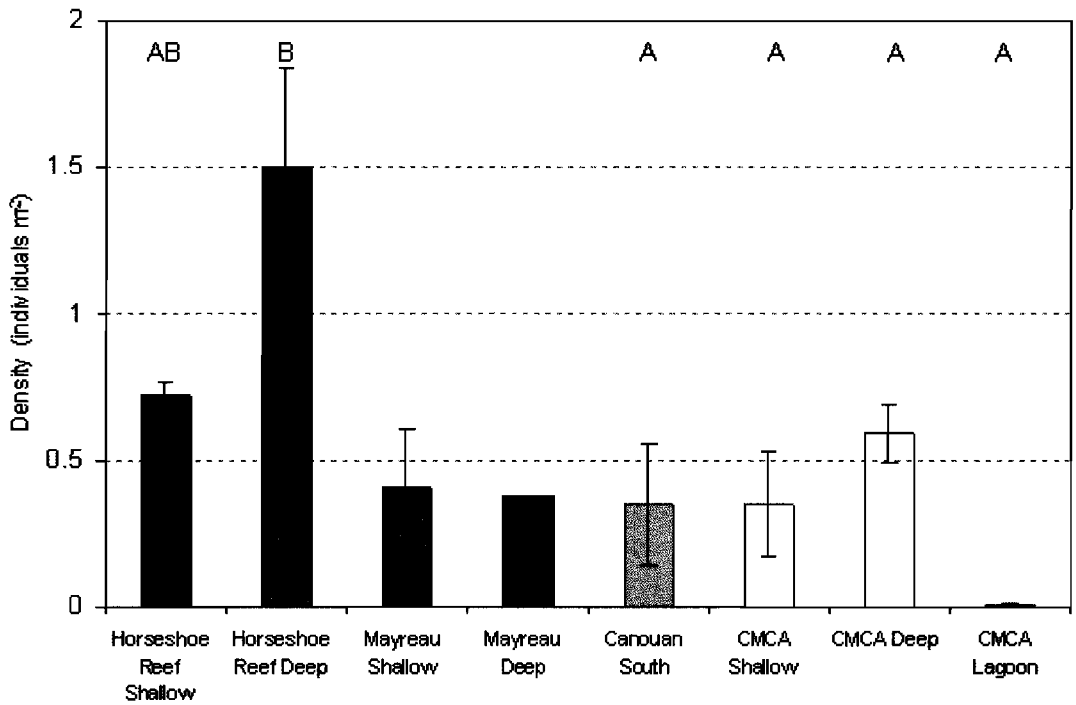

Figure 9. Mean gorgonian density (per m^{-2}) across eight sites surrounding Canouan Island and within the Tobago Cays Marine Park, SVG. Error bars are a standard error of the mean. Mayreau deep and Mayreau shallow were excluded from statistical analysis due them having a limited number of replicates (n = 1 and n = 2 respectively). Dissimilar letters indicate a significant difference ($p<0.05$).

Due to low numbers, the three sea urchin species groups (long-spined, collector and pencil) were grouped (Figure 10). While no statistical analysis was possible, the Canouan lagoon site had a much higher density of urchins compared to any of the other sites that were surveyed. The site outside of the CMCA, Canouan South, also had relatively high levels of urchins, which exceeded all sites within the TCMP and the two shallow sites in the CMCA. No urchins were observed at deep dive sites. Conch, an economically important species in the region, were observed more frequently in the CMCA – particularly at the deep site - when compared to the TCMP, where they were only observed at shallow sites (Figure 11).

Table 2. Relative frequency (%) of all reef fish grouped by feeding guild, across eight sites surrounding Canouan and within the Tobago Cays Marine Park, SVG. Figures highlighted in red are one standard error of the mean. Mayreau deep has no standard errors as only one transect was run at this site.

	Mayreau Shallow	Mayreau Deep	Horseshoe Reef Shallow	Horseshoe Reef Deep	CMCA Shallow	CMCA Deep	CMCA South	CMCA Lagoon
Herbivorous	49.59 (18.82)	46.24	18.87 (6.48)	49.29 (15.61)	42.59 (8.95)	27.69 (1.08)	38.84 (5.43)	36.01 (10.28)
Herb/Coralivores	13.86 (3.61)	6.19	7.57 (3.53)	11.57 (3.33)	2.64 (0.85)	1.62 (0.14)	2.60 (1.15)	3.24 (1.18)
Herb/Zoobenthos	1.90 (1.52)	0.00	-	0.14 (0.14)	-	-	-	0.26 (0.26)
Piscivorous	1.04 (0.67)	1.33	0.61 (0.27)	1.55 (0.30)	0.65 (0.49)	0.44 (0.14)	0.63 (0.30)	0.35 (0.04)
Pisc/Zoobenthos	1.20 (0.08)	0.44	0.79 (0.19)	2.17 (0.63)	0.70 (0.45)	3.17 (3.17)	0.47 (0.26)	-
Planktivorous	21.34 (20.97)	39.82	42.12 (22.21)	17.65 (16.40)	25.81 (14.85)	27.27 (12.80)	19.37 (6.78)	12.53 (9.74)
Sponge	-	0.00	-	0.44 (0.25)	-	0.11 (0.11)	-	-
Zoobenthos	11.08 (0.82)	5.97	30.00 (25.13)	16.80 (4.78)	27.61 (5.21)	39.58 (9.35)	38.09 (3.86)	47.55 (3.92)
Zoo/Detritivore	-	0.00	0.03 (0.03)	0.39 (0.06)	-	0.11 (0.11)	-	0.06 (0.06)

Table 3. Fish species identified during the dive surveys.

Family	Latin name	Common name
Angelfish	*Holacanthus ciliaris*	Queen angel
	Holacanthus tricolor	Rock beauty
Blenny	*Acanthemblemaria spinosa*	Spinyhead blenny
	Hypleurochilus bermundensis	Barred blenny
	Malacoctenus triangulatus	Saddled blenny
	Ophioblennius atlanticus	Red lip blenny
Butterflyfish	*Chaetodon capistratus*	4 eye butterfly
	Chaetodon ocellatus	Spotfin Butterfly
	Chaetodon striatus	Banded butterfly
Damselfish	*Abudefduf saxatilis*	Sergeant major
	Chromis cyanea	Blue chromis
	Chromis multilineata	Yellow edge chromis
	Microspathodon chrysurus	Yellowtail damsel
	Stegastes diencaeus	Longfin damsel
	Stegastes dorsopunicans	Dusky damsel
	Stegastes partitus	Bicolor damsel
	Stegastes planiforns	Threespot damsel
	Stegastes variabilis	Cocoa damsel
Elasmobranch	*Dasyatis americana*	Southern ray
	Ginglymostoma cirratum	Nurse Shark
Goby	*Coryphopterus glaucofraenum*	Bridled goby
	Gnatholepis thompsoni	Goldspot Goby
	Gobiosoma evelynae	Sharknose Goby
Grouper/ Seabass	*Epinephalus adscensionis*	Rock Hind Grouper
	Epinephalus fulvus	Coney Grouper
	Epinephelus cruentatus	Graysby Grouper
	Epinephelus guttatus	Red Hind Grouper
	Mycteroperca bonaci	Black Grouper
	Mycteroperca interstitialis	Yellowmouth Grouper
	Paranthias furcifer	Creole Fish

Family	Latin name	Common name
Grouper/ Seabass (cont.)	*Rypticus saponaceus*	Greater Soapfish
	Rypticus subbifrenatus	Spotted Soapfish
	Serranus baldwini	Lantern bass
	Serranus tabacarius	Tobbacofish
	Serranus tigrinus	Harlequin bass
Grunts	*Haemulon aurolineatum*	Tomtate
	Haemulon flavolineatum	French Grunt
Jacks/Scad	*Caranx bartholomaei*	Yellow Jack
	Caranx crysos	Blue Runner
	Caranx ruber	Bar Jack
	Scomberomorus regalis	Cero
	Selar crumenopthalmus	Big eye scad
Parrotfish	*Scarus croicensis*	Striped Parrotfish
	Scarus taeniopterus	Princess Parrotfish
	Scarus vetula	Queen Parrotfish
	Sparisoma atomarium	Greenblotch Parrotfish
	Sparisoma aurofrenatum	Redband Parrotfish
	Sparisoma radians	Bucktooth Parrotfish
	Sparisoma viridae	Stoplight Parrotfish
Snapper	*Heteropriacanthus cruentatus*	Glasseye snapper
	Lutjanus analis	Mutton Snapper
	Lutjanus griseus	Gray Snapper
	Lutjanus mahogoni	Mahogany Snapper
	Ocyrus chrysurus	Yellowtail Snapper
Squirrelfish	*Acanthurus bahianus*	Ocean Surgeonfish
	Acanthurus chirurgus	Doctorfish
	Acanthurus coeruleus	Blue tang
	Holocentrus adscensonsis	Squirrelfish
	Holocentrus marianus	Longjaw Squirrelfish
	Holocentrus rufus	Long-spine Squirrelfish

Family	Latin name	Common name
Wrasse	*Hemipteronotus martinicensis*	Rosy razor
	Bodianus rufus	Spanish Hogfish
	Clepticus parrae	Creole Wrasse
	Doratonotus megalepis	Dwarf Wrasse
	Halichoeres bivittatus	Slippery Dick Wrasse
	Halichoeres cyanocephalus	Yellowcheek Wrasse
	Halichoeres garnoti	Yellowhead Wrasse
	Halichoeres maculipinna	Clown Wrasse
	Halichoeres radiatus	Puddingwife
	Haliochoeres pictus	Rainbow Wrasse
	Haliochoeres poeyi	Blackear Wrasse
	Hemipteronotus splendens	Green Razorfish
	Thalassoma bifasciatum	Bluehead Wrasse
Other	*Amblycirrhitus pinos*	Redspotted hawkfish
	Apogon maculatus	Flamefish
	Aulostomus maculatus	Trumpetfish
	Canthigaster rostrata	Sharpnose puffer
	Equetus lanceolatus	Jackknife fish
	Gymnothorax miliaris	Goldentail moray
	Gymnothorax moringa	Spotted moray
	Hypoplectrus chlorurus	Yellowtail hamlet
	Hypoplectrus puella	Barred hamlet
	Lactophrys triqueter	Smooth trunkfish
	Malacanthus plumieri	Sand tilefish
	Mulloidichthys martinicus	Yellow goatfish
	Myrichthys breviceps	Sharptail eel
	Priacanthus arenatus	Bigeye
	Pseudupeneus maculatus	Spotted goatfish
	Scorpaena plumieri	Spotted scorpion
	Synodus intermedius	Sand diver

Lobsters were observed in relatively low densities in the CMCA deep and shallow sites, but not in the Lagoon or the site outside the CMCA (Figure 12). Higher densities were observed at two sites within the TCMP - Horseshoe reef deep and Mayreau Gardens shallow.

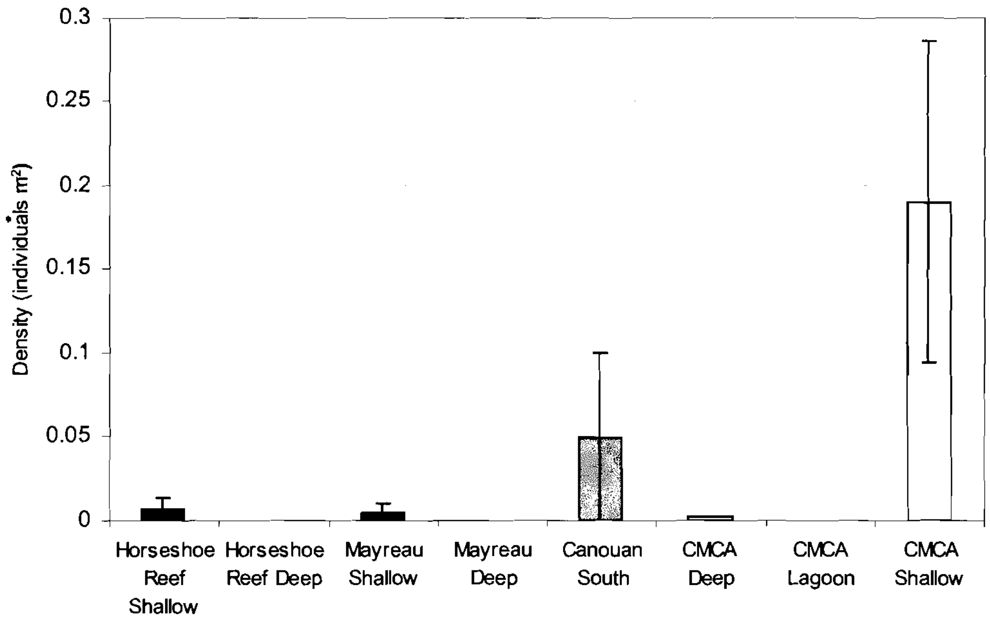

Figure 10. Mean sea urchin density (per m^{-2}) across eight sites surrounding Canouan Island and within the Tobago Cays Marine Park, SVG. Error bars are a standard error of the mean.

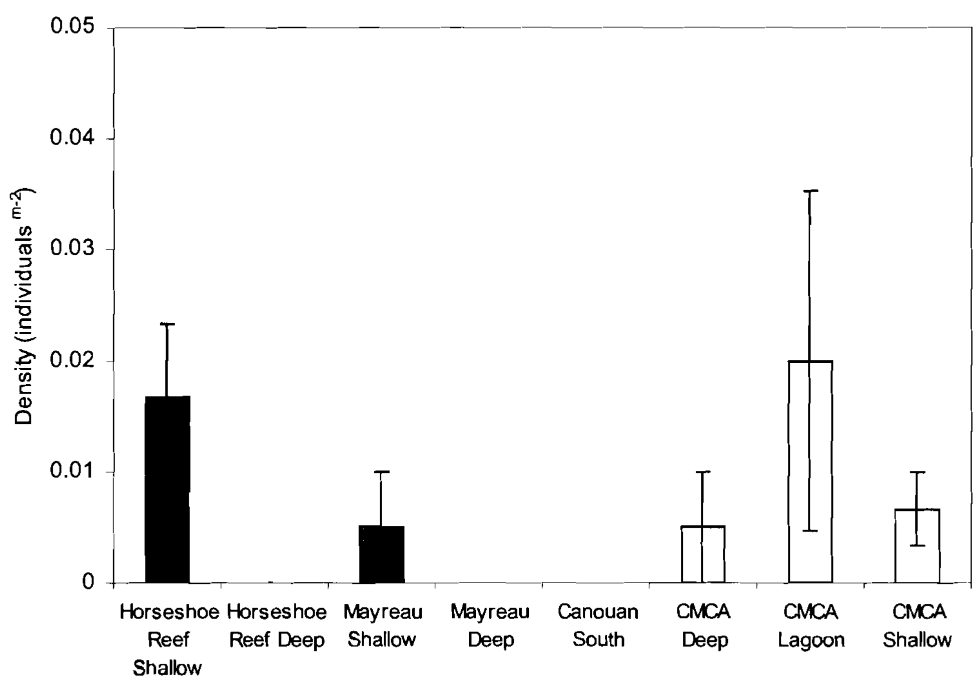

Figure 11. Mean conch density (per m^{-2}) across eight sites surrounding Canouan Island and within the Tobago Cays Marine Park, SVG. Error bars are a standard error of the mean.

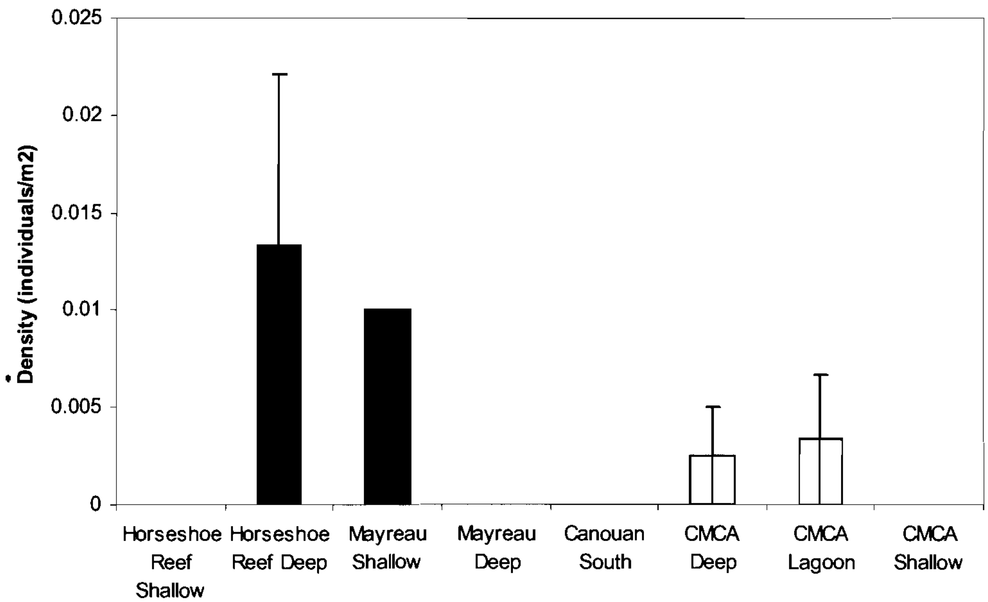

Figure 12. Mean lobster density (per m^{-2}) across eight sites surrounding Canouan Island and within the Tobago Cays Marine Park, SVG. Error bars are a standard error of the mean.

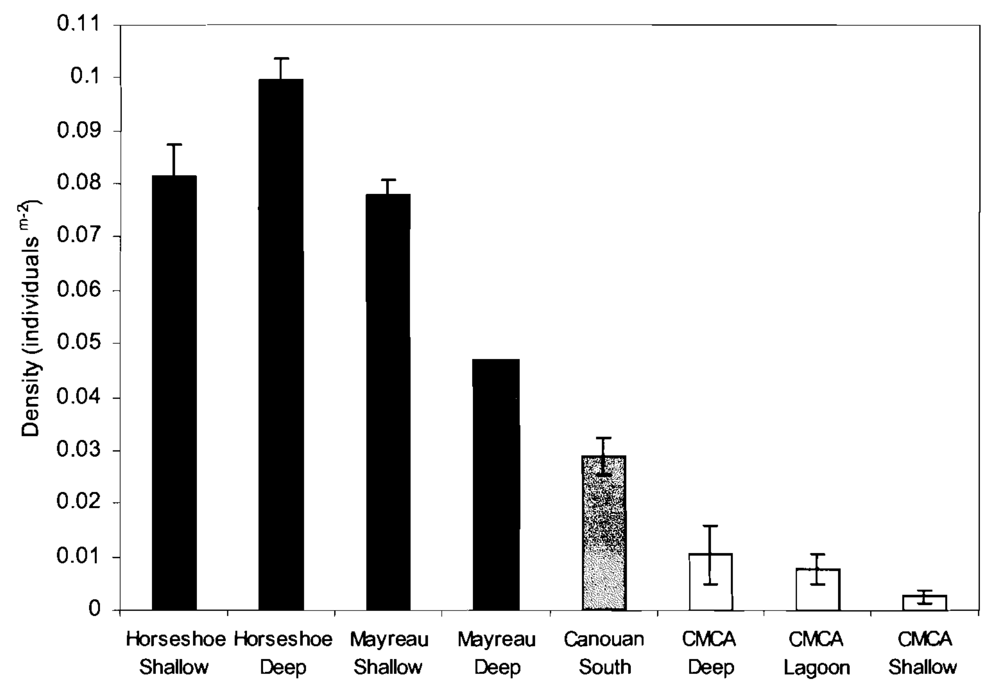

Figure 13. **i)** Mean economic value of commercially important organisms (EC$ m^{-3}) across eight sites surrounding Canouan Island and within the Tobago Cays Marine Park, SVG. For the purposes of this analysis, only groupers, grunts, snappers, parrotfish and lobsters were included. Information from local fisherman provided us with values per lb for grunts, snappers and grouper (EC$8, parrotfish (EC$5) and lobsters (EC$15). Weights in lbs were converted from the fish biomass (g) calculated previously. Lobster length was not measured and therefore length:weight ratios could not be utilised. Therefore a conservative estimate of 2lb for each lobster was used. Error bars are a standard error of the mean. Mayreau deep and shallow were excluded from statistical analysis due to limited number of replicates (n = 1 and n = 2 respectively). Dissimilar letters indicate a significant difference ($p<0.05$).

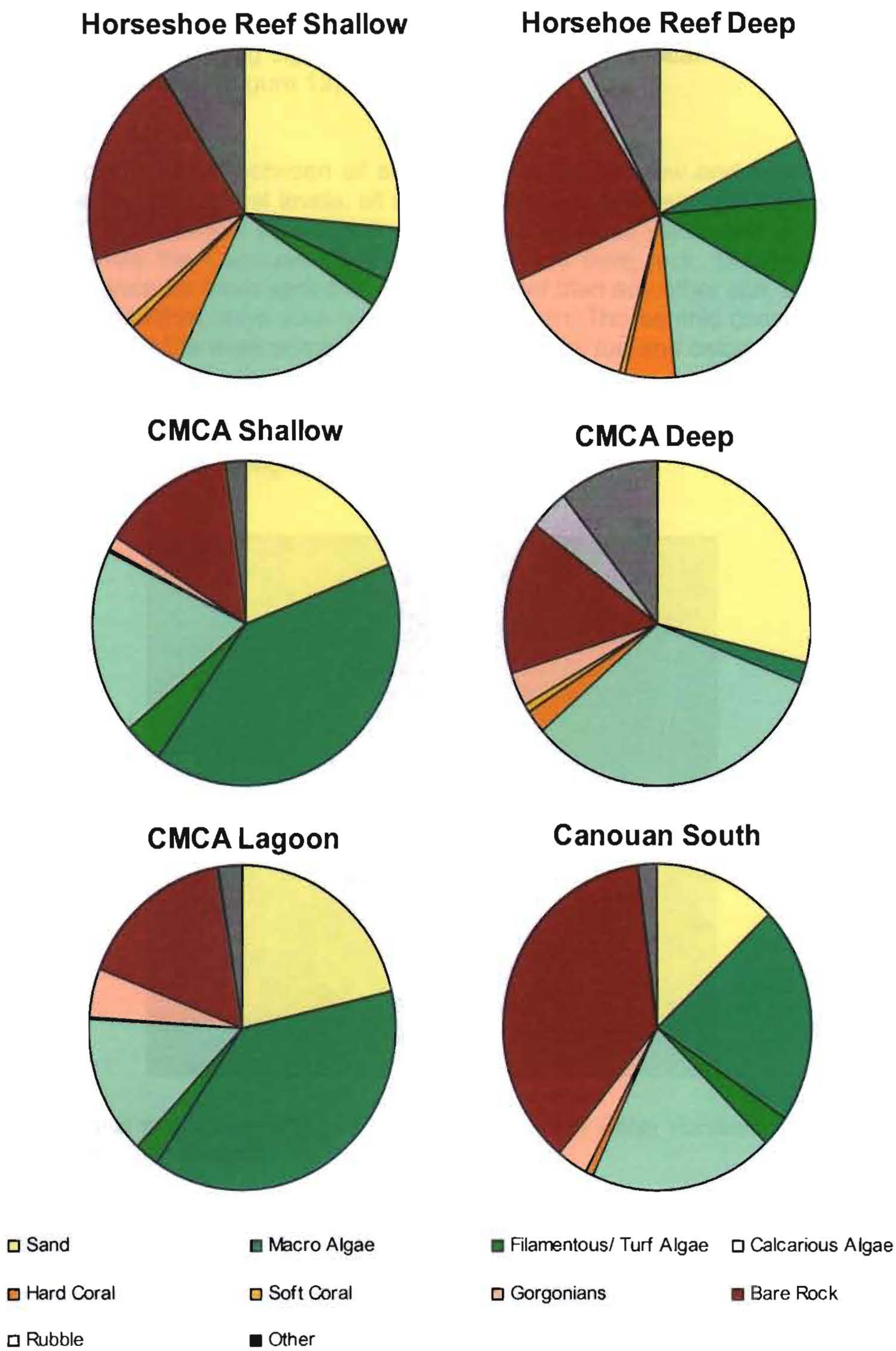

Figure 14. Reef cover assessed by videography. Each category is graphed as a proportion of the whole image that was analysed.

Commercial species
Assessing the results in economic terms, there was a clear split between the sites within the TCMP, and those off Canouan Island, with both the deep and shallow Horseshoe reef sites being significantly greater than the Canouan sites irrespective of their level of protection (Figure 13).

Videography
Hard coral cover varied between all sites with both the shallow and deep Horseshoe reef sites having the highest levels; all sites on Canouan had very little hard coral cover. At the two CMCA shallow sites (shallow and Lagoon) algae was found in the greatest proportion, while the Canouan South site was more bare rock. Overall the benthic communities were far more varied at Horseshoe reef than any other site, indicating that they are in a healthier state than all sites in Canouan. The benthic communities of all sites in Canouan sites were dominated by algae (macro, turf and calcareous).

Benthic surveys
Digital photograph quadrat analyses across all sites highlighted only one bleached colony (Figure 15) and no signs of coral disease.

Figure 15. Digital photograph of a quadrat at a shallow site within Horseshoe Reef showing evidence of bleaching (circled).

Seagrass surveys
Analysis of the quadrats that were photographed during seagrass surveys within the two protected areas indicates marked differences between the two sites (Figures 16i and ii). The TCMP sites were 59.5% sand/gravel, with only 23.1% of the cover being seagrass of any species – 19.2% of this was Manatee grass (*Syringodium filiforme*). Interestingly, other photosynthetic organisms, in the form of algae, accounted for a similar coverage of 15.4%. In comparison, the CMCA, exhibited a much higher seagrass coverage with Turtle grass (*Thalassia testudinum*) being solely responsible for 49.1%, and seagrasses generally accounting for 55.8%. In relation to seagrass-associated fauna, juvenile parrotfish and wrasse, and collector urchins were observed but not in numbers that warranted further analysis. These low numbers observed were not necessarily due to low numbers of associated species but partly due to high

turbidity in some sites obscuring observational ability, and also due the camouflaged nature of many fish species making fish counts very difficult.

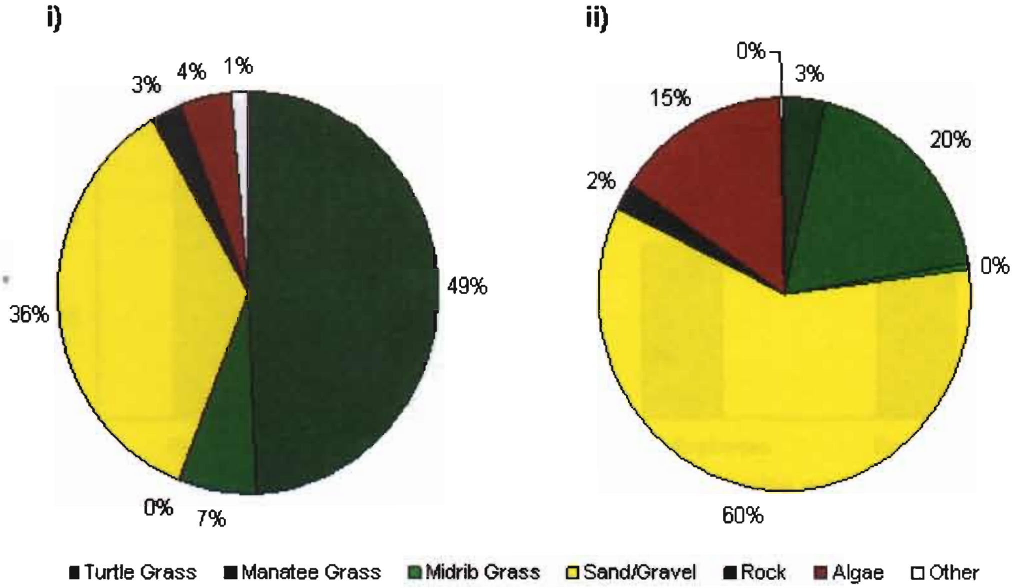

Figure 16. Proportions of seagrass survey quadrats defined as specific categories in **i)** Tobago Cays **ii)** Canouan. Both areas had five surveys carried out and results were pooled to provide the results above.

<u>Socioeconomic surveys</u>

A total of 17 interviews were conducted during the survey in Mayreau and Canouan; 14 on Mayreau and three on Canouan. In some cases interviewees recorded their domicile address from other Islands (Union, St. Vincent, and Bequia) but that they either worked or temporarily lived on Mayreau or Canouan. Interviewees represented a variety of occupations including hoteliers, restaurateurs, fishermen, vendors, dive operators, teachers, boat operators and one park ranger. In some cases more than one occupation was held (teacher/shop owner, fisherman/dive operator).

Benefits of the marine environment
All interviewees recognised that there were benefits provided by the marine environment, with 60% strongly agreeing that the marine environment was of importance. When asked who most benefitted from the marine environment the majority of respondents said fishermen with a large number also saying that tourists and those residents working in the tourist sector were benefitting from the marine environment (Figure 17). Only a third of respondents stated that everyone benefitted equally from the marine environment.

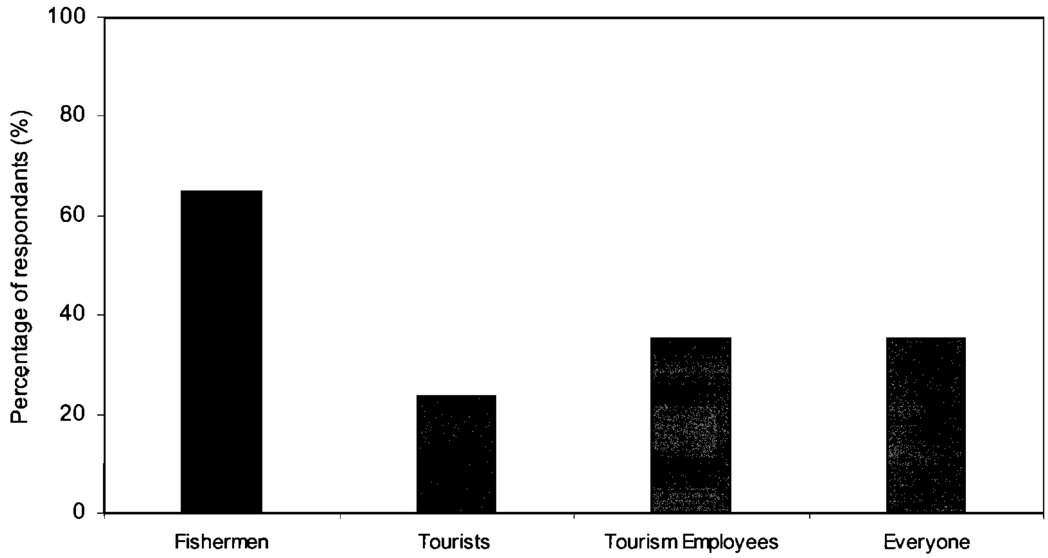

Figure 17. Survey responses in relation to who benefits from the marine environment. The dark grey bars represent extractive processess. Note that some respondants may have provided more than one reponse while others chose to abstain.

When specifically asked whether they agreed that there are many things people in SVG gain from the marine environment, 94% believed this was the case. Only one respondent didn't think there were many benefits gained; surpisingly this was a fisherman. Participants were then asked to list the top three benefits of the marine environment, in no particular order of importance. Responses varied greatly, with some people giving very general answers and others elaborating in detail or giving specific species that were important (Figure 18). Generally fishermen listed those species they most financially benefitted from such as fish, conch or lobsters. Those not employed in the fishing sector were more likely to give general answers such as "employment." However, nearly everyone included fish or fishing in their top three benefits.

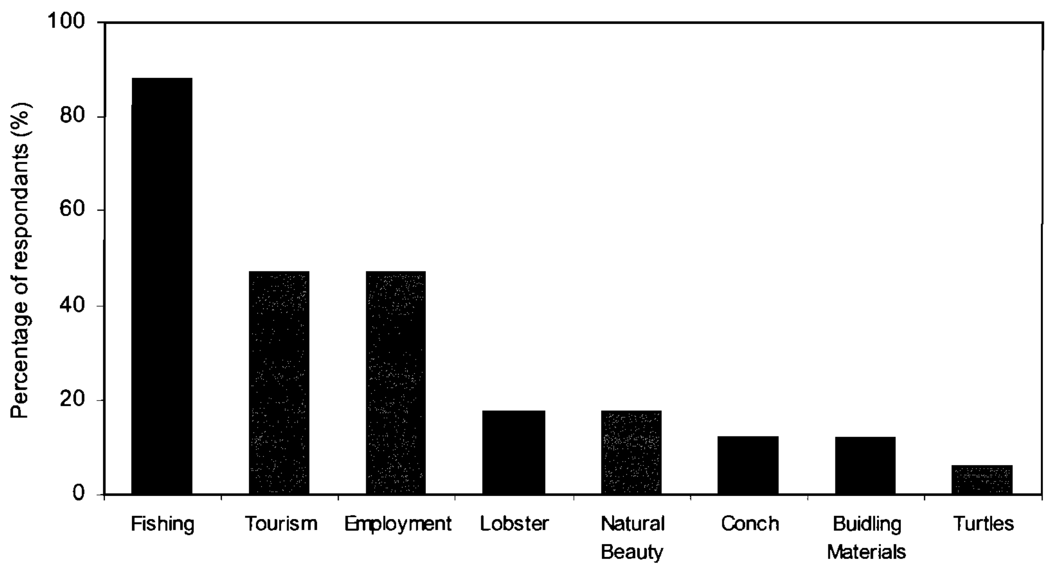

Figure 18. Survey responses in relation to ranking top 3 specific benefits of the marine environment. The dark grey bars represent extractive processess. Note that some respondants may have provided more than one reponse while others chose to abstain.

When asked whether products such as seafood and sandy beaches were important to the people of SVG, all those interviewed agreed or strongly agreed (eight and nine respectively) that there were economic benefits derived from the sea. When asked what things from the sea provided specifc economic benefits the responses were similar to general benefits received (Figure 19). Fish and fishing was considered to provide the most important economic benefit with tourism secondary. Some respondents specified high value species such as lobster or conch as a key economic benefit and indicated that selling these seafood products to hotels and restaurants or to tourists was a significant livelihood. The selling of curios such as shells and coral was also considered an economic benefit for those in the tourist industry.

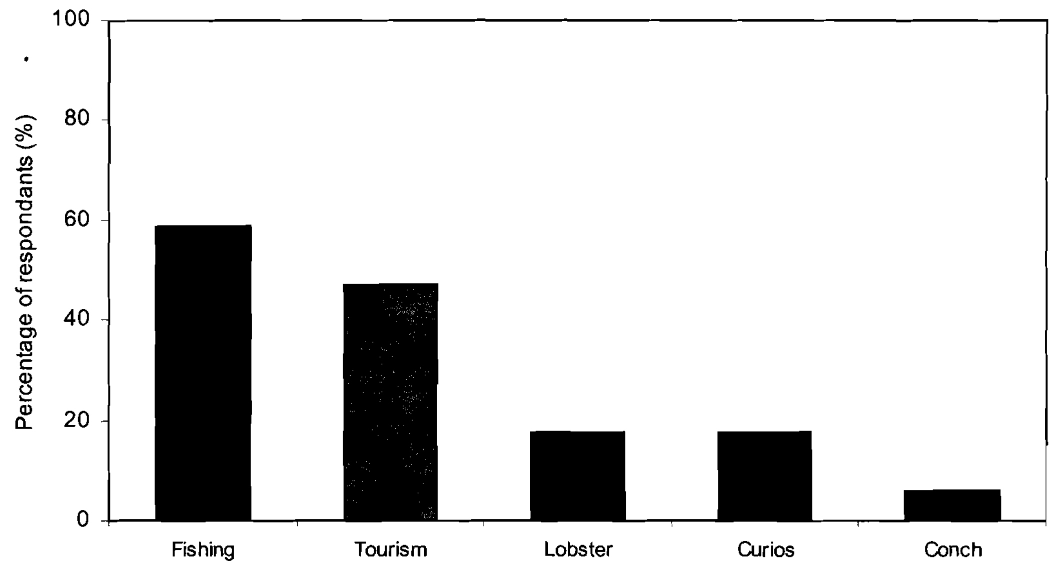

Figure 19. Survey responses in relation to economic benefits of the marine environment. The dark grey bars represent extractive processess. Note that some respondants may have provided more than one reponse while others chose to abstain.

The health of the marine environment

Participants were given four statement/questions related to the changes in the health of the marine environment and the human impact on it. The majority (n=12 / 71%) of responses indicated a perception of a downward trend in the health of the marine environment. Fishermen and dive operators in particular cited fewer fish and pollution as indicators of this downward trend. Some participants working in the tourism sector did not believe there was a downward trend, perhaps due to a lack of direct contact with the sea or because a negative response in the questionnaire would be seen to impact tourism.

Of the 12 participants that indicated a downward trend in the health of the marine environment a number of observations were given as evidence including the loss or damage of coral reefs, fewer fish, yacht/anchor damage, mangrove loss, hurricane damage and pollution. Of those that thought the marine environment was as healthy now, or healthier than previously, most cited the increase in numbers of fish in the protected area and the enforcement of laws protecting marine life as reasons.

When asked whether humans have had a negative impact on the marine environment, 65% of participants thought they had. When asked to list impacts that humans had on the marine environment they suggested activities such as littering and development. Those that felt humans didn't have a negative impact used the creation of the marine park as evidence; one participant said the boundary of the park was too large, suggesting a positive impact of humans on the environment which then adversely affected the local human population.

Protection of the Marine Environment

Ten statements/questions addressed the protection of the marine environment in SVG. Participants were asked about their awareness of laws, their effectiveness, specific protection measures for certain species and about their familiarity with the marine protected areas in SVG and its effectiveness at conserving species and habitats. Participants were divided nearly equally between those that thought there was adequate protection for the marine environment and those that didn't (47% agreed; 47% disagreed) with only one person strongly feeling that there was adequate protection (6%). All but one of those that felt there was inadquate protection of the marine environment were employed in land-based professions. The majority of those that felt the sea was adequately protected were fishermen and boat operators.

All participants agreed that MPAs were beneficial for protecting marine life, with three strongly agreeing. When asked whether there were any MPAs in SVG, all 17 participants said yes and cited Tobago Cays (TCMP) as the protected area. Some participants listed additional sites such as Mayreau Gardens (an area included withinthe bounds of the TCMP) and suggested there may be more on other Islands near to St. Vincent that they were unaware of. None of the participants were familiar with the different designations of Marine Parks, Marine Reserves, Marine Conservation Areas and Protected Landscapes/Seascapes. When asked if they thought there was any protection designation in place in Canouan, none of the participants believed this to be the case. Some participants said that the boundaries of the TCMP were unclear and because it was not delineated clearly with markers some people overlooked and perhaps ignored the boundaries.

When asked which activities were allowed and which were prohibited in MPAs, every participant could provide a list of activities in each category. Of those activities allowed, swimming, snorkelling and picnicking were all listed. Of the restricted activities fishing was always listed, with some participants citing specific fishing methods (e.g. spear-fishing). Damaging the reef or corals and harrassing the turtles also featured on the list of prohibited activities of several participants. A few participants indicated a double standard in place, with tourists being allowed to undertake activities that locals were not allowed to do, such as taking away shells.

Most participants thought there were sufficient laws in place to protect marine life in SVG (88%) but their familiarity with laws varied considerably. In most cases participants cited restrictions on fishing or seasons on lobster, turtles and conch as the key laws protecting marine life. When asked whether the laws protecting marine life were adequately enforced all but four of the particpants agreed that they were. The list of enforcement methods included patrolling, fines and jail sentences. Of those that felt there was inadequate enforcement the primary reason was a lack of sufficient or regular patrolling in the TCMP. Most participants also felt that the laws in place were doing an adequate job of protecting marine species and habitats. All but three agreed there was adequate protection and all but two participating could provide a list of species that received protection by law.

Species that are harvested for food such as turtles, lobsters and conch were most frequently cited as receiving some form of protection (Figure 20). Interestingly despite known no-take zones for fish in MPAs, fewer respondents recognised fish as being protected by law. Only one participant recognised coral as being protected, perhaps due to a lack of recognition of coral as an animal or due to a limit in its percieved importance for collection and use.

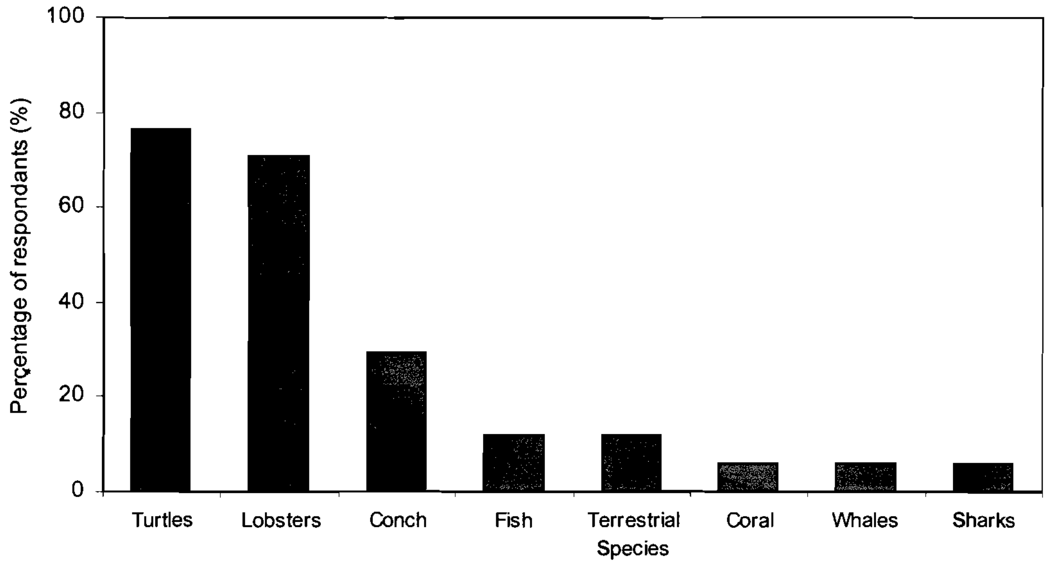

Figure 20. Number of respondents citing specific species that are legally protected in SVG. Note that some respondants may have provided more than one reponse while others chose to abstain.

Coral and coral reef familiarity and importance

Participants were given four statement/questions relating specifically to coral reefs. All those taking part in the questionnaire recognised coral as a component of the marine environment. All but 6% of respondents agreed that it was important in some way to the livelihoods of the people living in SVG, however the reasons for its importance varied. Many participants recognised coral reefs as important attractants for tourists and as a home or nursery for fish (Figure 21). Fewer participants saw aesthetic value in coral and only three recognised the reef's value in protecting the coastline. Nearly all participants mentioned hurricanes during the interviews at some point yet the direct connection between coastline protection from reefs during storms was not included in the list of values for reefs among most participants.

When asked whether there were unique species of coral found in the Caribbean and if some of these species were threatened many participants agreed. Only two disagreed but three did not know either way. This could be due to a lack of understanding of what was meant by "threatened" as many participants asked for this question to be repeated and specifially what was meant by "threatened". When asked what human activities had a negative impact on coral reefs a variety of answers were given, often connected to first hand experience based on their own livelihoods. For example, fishermen often cited net damage or fishing activities whereas boaters cited waste disposal and anchorage (Figure 22).

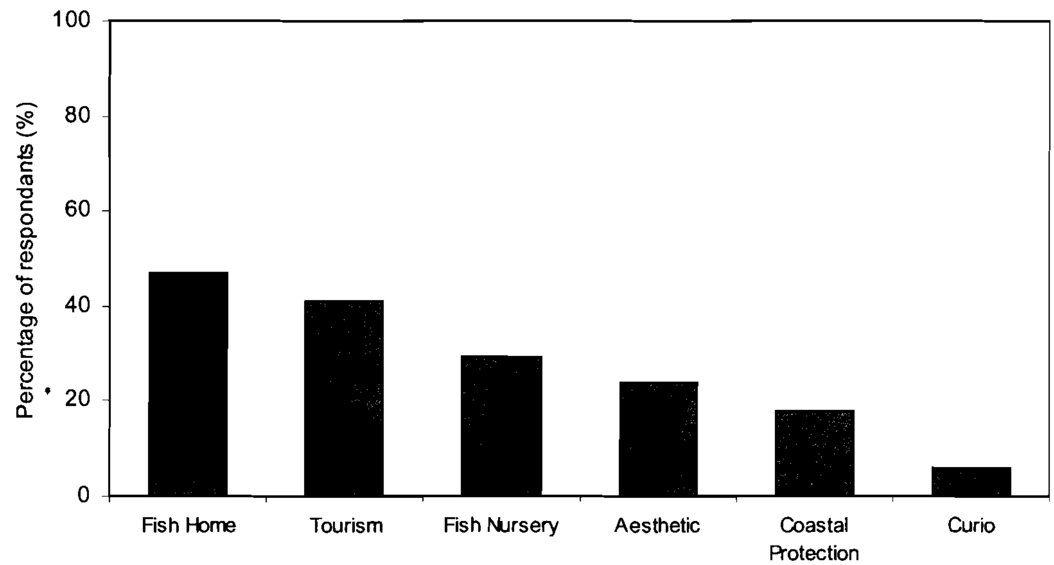

Figure 21. Number of respondents citing specific livelihoods that coral reefs benefited. Note that some respondants may have provided more than one reponse while others chose to abstain.

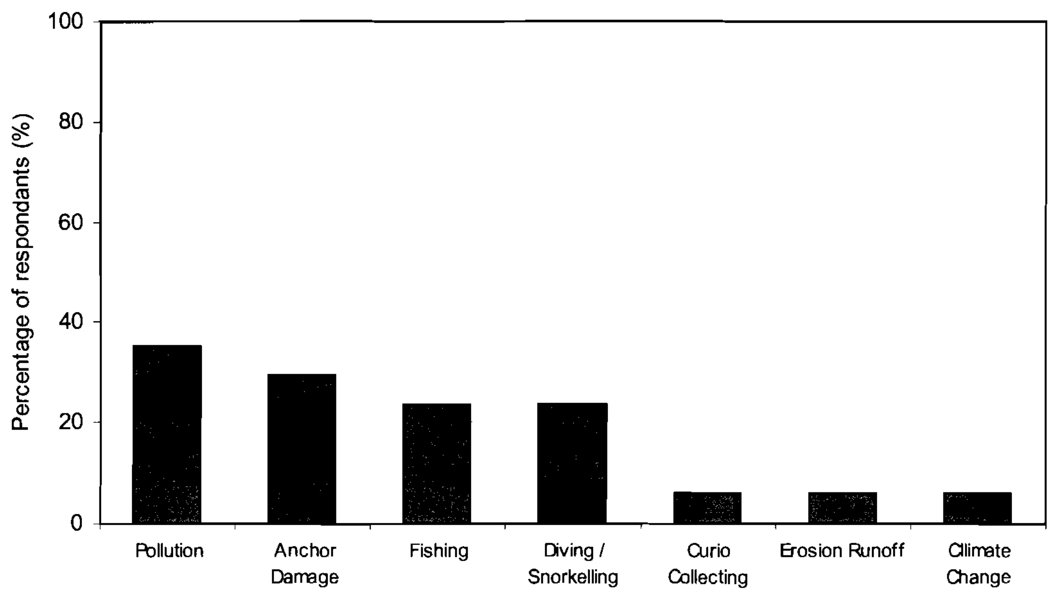

Figure 22. Number of respondents citing specific human activities that negatively affected coral reefs. Note that some respondants may have provided more than one reponse while others chose to abstain.

Seagrasses and seahorse familiarity and importance

Seagrass bed importance and familiarity was assessed through two statement/questions, followed by two statement/questions about seahorse occurance in SVG. In general although people knew of the existance of seagrasses there was some confusion with sea moss, a marine algae used to make a drink. When the question was clarified people often couldn't see any importance of seagrasses specifically, although some responses indicated an understanding of it as a habitat or food for turtles, fish or conch.

Using the photographs of seahorses from the Project Seahorse factsheet, participants were asked two questions about the occurance of seahorses in SVG. When participants were asked whether they thought seahorses were often found in the waters around SVG nearly half said they disagreed. Those that said they agreed usually said they had seen them, either alive or dead but not very often; only one or two times in their lifetime. Three participants, all fishermen, gave more detailed information about where they saw seahorses. One said they were found on fish pots and traps, one said on gorgonians and the third said in deeper water, below 30 metres. None of the participants that had seen seahorses said they were found in sea grasses.

Discussion

The main aim of this study is to provide baseline data on the local coral reefs and sea grass beds of Canouan Island - including Canouan Marine Conservation Area (CMCA) - and Tobago Cays Marine Park (TCMP) - including Mayreau Gardens and Tobago Cays - to inform their conservation management. It is important to bear in mind that this was an initial study carried out in a two-week timeframe, and so although the results show some clear patterns and allow us to make reliable recommendations, this study should also be used to guide more focussed and in depth endeavours. The data from both the biological and socioeconomic assessment have yielded some extremely interesting findings that add weight to the need for further sustainable management of the marine environment in the region. There is a particular need for more sustainable management of land based activities, particularly by the coast, which have an impact on the marine environment, for instance through sedimentation, integrated watershed management.

Biological surveys

The TCMP, particularly the shallow regions of the Horseshoe reef, have the highest fish biomass, this may indicate that protection is working to an extent. Other sites surveyed were found to have lower fish abundance and biomass to varying degrees, but there was not a concurrent decrease in species diversity. This is encouraging because it suggests that the ecosystem, though degraded, is still intact and therefore continued and increased sustainable management of these areas can lead to an increase in fish biomass across all trophic levels and a healthier ecosystem. In Bonaire, Dutch Antilles, which has a long established marine protected area, fish populations are relatively abundant despite anthropogenic impacts on the habitat (Stokes *el al* 2010). It is also encouraging to see the presence of a top predator, nurse sharks, at Mayreau Gardens, their presence here indicates a healthy ecosystem and increases the importance of these reefs for conservation. Unfortunately time limitations and strong currents meant the survey team was unable to gain enough survey replicates for statistically analysis from Mayreau Gardens but observational data and the limited data set collected suggests higher fish abundances and coral cover than any other area surveyed. Strong currents are known to be a regular occurrence here (personal communications with dive operators), and maybe partially responsible for the healthier reefs as strong currents would act to wash nutrient pollution and sedimentation away from the reefs at Mayreau. Lack of coastal development on Mayreau likely also plays a role.

The coral cover at sites surveyed in Canouan waters was much lower than at sites in TCMP and we would describe much of the Canouan reefs as having undergone a phased shift from a coral dominated state to an algae dominated state. This has been described on many reefs in the Caribbean in recent years (Hughes, 1994). It is hard to pin point the exact causes of this phrase shift especial when no baseline data is available on the state of the reefs in previous years, but causes of phase-shifts are well documented in other areas on the Caribbean (Hughes *et al* 2010). The structure of the Canouan reefs are still relatively complex in places and dead skeletons of branching and massive corals were clearly observed suggesting this area once was a thriving coral reef. It is likely that the decline in coral cover is due to a variety of global and direct human factors acting together. Sedimentation from the documented dredging of the lagoon area (Price 2011), as well as from coastal development, has almost certainly settled on the substrate smothering the corals, which leads to coral mortality. Pollution from land-based activities, particularly from pesticides and fertilizers used on the golf course, that is located right on the beach, can lead to increased nutrients in the water column and consequently increased algae growth (Stokes *et al* 2010). On the outer Canouan reef coral rubble synonymous with hurricane damage was also observed and personal communications with local people also indicated this was likely (Mallela and Crab 2009). Further it has been suggested that the close proximity of algae to coral due to the increase in abundance of the former may well be toxic (Rasher and Hay, 2010) may well have exuberated the coral decline. The higher abundance of sea urchins, a taxa known to graze on algae, within the Canouan lagoon, may be explained by the high algae cover found in the lagoon.

In comparison coral cover on TCMP reefs was significantly higher and more in keeping with the average coral cover for reefs in the region. However the manta tow also revealed large areas of algae –dominated reefs along Horseshoe (observation only). A low level of coral bleaching and disease was observed across all sites, with only one colony found to be partially bleached in the quadrat assessments. This is encouraging considering the high prevalence of both disease and bleaching in some sites in the Caribbean (e.g. Miller *et al.*, 2006, Muller *et al.*, 2008, Wilkinson *et al.*, 2008), and a low level of bleaching and disease is naturally reported to occur on reefs (Suggett and Smith 2011). It should be noted that many Sea fans were observed to have aspergilousis disease during dives but this was not quantified in these assessments.

However it may be the case that bleaching and disease have already wiped out a large percentage of the hard corals, for instance it is know that a region wide mass bleaching event took place in 2005 (Wilkinson, 2008), and that it is the corals with some level of resistance that remain. In which case the corals that remain may have a higher chance of surviving future bleaching events and therefore the area's continued management is worthwhile. A high percentage of bare rock was also recorded at all sites, this is important because it indicates that there is available substrate for coral recruits to settle and subsequent coral growth and potential recovery. Few branching corals were observed, with exception of Millepora a well known hardy reef coral.

Comparison of species of economic value (commercial fish and commercially important invertebrates) across all sites shows a clear difference between those sites within the TCMP compared to the Canouan sites. This indicates that the TCMP is having a positive effect on the fauna within its boundaries. However, there does appear to be social issues related to the TCMP, which are discussed below. Sites within the CMCA were generally in poorer health, i.e. fish abundance and coral cover indices, compared to the TCMP, which would indicate that the CMCA is not effective as a protected area. Worryingly not all of the local residents that were interviewed knew of the existence of the CMCA, and therefore harmful activities may well be occurring in this protected area, not with intent but out of poor knowledge. Price (2011) specifically focussed his study on the Godhal Lagoon – the site we define as Canouan Lagoon in our analysis – due to concern that development, particularly dredging, had negatively impacted the area. During the surveys we came across a large area of coral rubble, where the rubble pieces were unusually uniform in shape suggesting that this may have been created by anthropogenic activity, such as dredging, rather than natural causes (Figure 23). Generally, the Canouan lagoon (Godhal Lagoon) was found to be the least productive site that was studied, with the lowest coral cover and low numbers of fish and invertebrates likely due to lack of suitable habitat. Therefore despite the protection afforded this site of the CMCA, it appears to be in poor health compared to other sites within the CMCA, the site outside of the CMCA (Canouan South) and the sites in the TCMP, irrespective of depth.

Figure 23. Coral rubble in the Canouan Lagoon site.

To determine whether the CMCA was effective, an area outside of its boundaries was surveyed for comparison (Canouan South). In many of the parameters that were assessed, the Southern reef had similar or even higher values than the sites within the CMCA, which would indicate that it is at least as healthy as many of the sites within the MPA and should be considered for incorporation to the CMCA.

Dendrogyra cylindrus, *Dichocoenia stokesii* and remnant colonies of *Acropora palmata* were all observed in Canouan South but *Dendrogyra cylindrus and Acropora palmata* were not identified at any other survey sites, a*nd Dichocoenia stokesii* was only seen in low abundance at other sites in Canouan waters. None of these three species were observed in the TCMP. All three of these hard coral species are Evolutionarily Distinct and Globally Endangered (EDGE) species (Figure 24A and B). Developed by the Zoological Society of London (ZSL) and based on work by Issac *et al.* (2007), the EDGE of Existence Program (www.edgeofexistence.org) is a highly innovative conservation initiative that seeks to conserve EDGE species that are unique in the way they look, live and behave, and are by definition, highly threatened. A large healthy stand of *Acropora palmata* (Figure 24C) was identified on the southern reef during the manta tows. This coral species has historically been key in reef building in the Caribbean as a whole, but is now a rarity due to the impact of bleaching and disease (Aronson and Precht, 2002).

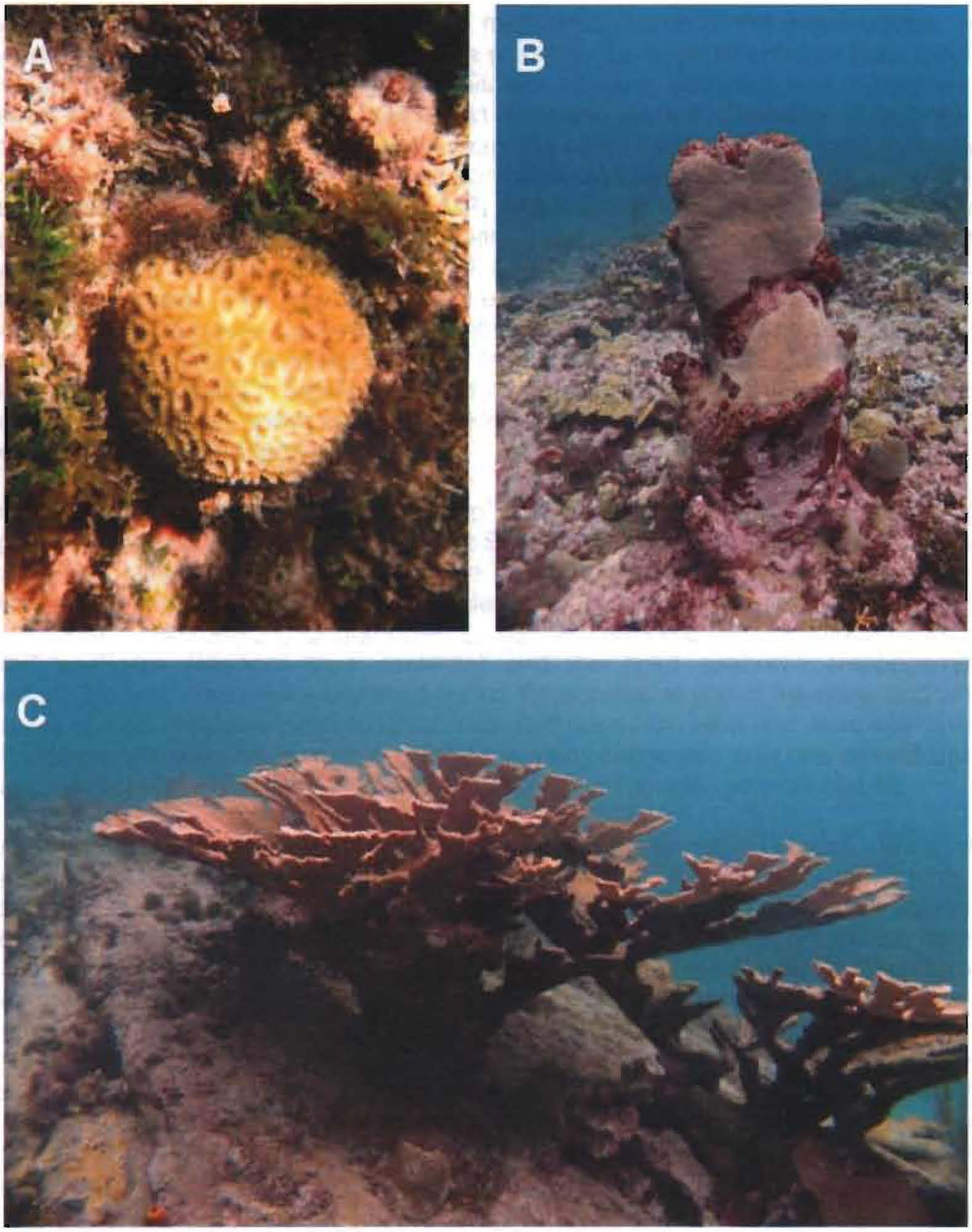

Figure 24. Photographs of the three Caribbean EDGE Coral species present within SVG. A) A small *Dichocoenia stokesii* colony found within the CMCA at a depth of ~2 metres, B) A large colony of *Dendrogyra cylindrus* located on the Southern Canouan reef at a depth of around ~8 metres, and C) A healthy *Acropora palmata* colony found during a manta tow to the South of Canouan Island at a depth of approximately 4 metres.

Seagrass beds were surveyed within both TCMP and CMCA, and in contrast to the coral cover, the Canouan sites had a higher cover of sea grass than TCMP and a significantly higher cover of turtle grass, the species of sea grass eaten by green turtles. Numerous green turtles (*Chelonia mydas*) were observed in the area within the TCMP where the seagrass sites were located. Whereas no turtles were seen in Canouan waters, and although the resulting low grazing pressure may account for the high sea grass cover in Canouan waters the situation is likely more complex than this. A very low abundance of young seagrass shoots was observed in Canouan seagrass beds, and it is these young shoots that are the main food source of the green turtles. The absence of young seagrass in Canouan is possibly due to sedimentation from coastal development smothering the seagrass. This lack of young seagrass shoots maybe the reason for the lack of turtles observed in Canouan waters. Therefore it is hard to identify the causal relationship between seagrass cover and turtle presence. In relation to seagrass-associated fauna, juvenile parrotfish and wrasse, and collector urchins were observed both at CMCA and TCMP, which was similar to other studies in the Caribbean (e.g. Ogden, 1976). However, while Ogden (1976) found fish and invertebrates to be abundant, the present study identified very few associated fauna during the surveys. This maybe reflect the effects of human activity nearby – most seagrass beds that were surveyed were within 20m of the shore – and is of concern as seagrass is recognised as being a nursery habitat for some species (Nagelkerken *et al.*, 2001) and may highlight damage to ecosystem connectivity in the region. It is also probably due to high water turbidity making presence of associated fauna hard to observe during surveys (see results).

Another key objective of the study was to identify the presence of seahorses in the region, due to ZSL's close links to Project Seahorse. While these fish are often linked closely with seagrass, they are found in a range of habitats which also include coral reefs (Lourie *et al.*, 1999). The three species that are associated with Caribbean reefs and seagrass beds are the long-snouted or slender seahorse (*Hippocampus reidi*), the dwarf seahorse (*Hippocampus zosterae*) and the lined seahorse (*Hippocampus erectus*). No seahorses were identified during the surveys at any of the sites, and while surveys of local residents indicated that some had seen both alive and dead specimens, discussions with the dive team that guided the study suggested only one site off Union Island had regular sighting so seahorses, though which species was not stated.

SVG has a number of different categories for protecting its natural places. Within the marine environment there are three main designations that provide some form of protection. Designations for marine sites were created from several different agencies historically and often were created to protect a specific species or restrict certain activities (Mattai and Mahon 2006). The complexity of the existing network of protected sites makes coordination between agencies difficult and could hinder the protection of some sites in particular where there is confusion about what each designation means. The NP & PASP is the result of consultation between various government sectors and the National Trust. The proposed Plan aims to change the status of several marine protected areas and clarify the level of protection each site receives. The proposed plan classifies SVG's protected areas under the IUCN protection categories used internationally.

Classifying SVG's marine protected areas under IUCN's will allow better management for each site and clarify for SVG residents which activities are allowed or prohibited. This should strengthen biodiversity protection by using an internationally recognised system that will promote better international support.

Under the proposed plan, some sites in SVG will receive improved protection. For example, reclassifying a site from Marine Conservation Area to Marine Reserve gives provision to intervene for the conservation of specific species.

Canouan's existing designation is "**Marine Conservation Area**" This falls under IUCN classification category VI (Managed Resource Protection Area) which means it is "a protected area managed mainly for the sustainable use of natural systems." Specifically: "*Area containing predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community* *needs."*

- The proposed designation for Canouan changes it to "**Marine Reserve"** This falls under IUCN classification category IV (Habitat/Species Management Area) which means it is "protected area managed mainly for conservation through management intervention." Specifically: "*Area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species."*
- The NP&PASP states that: "The term Marine Conservation area although widely used by the Fisheries Division in publications and public awareness campaigns is not prescribed by law."
- The Fisheries Act, No. 8 of 1986 includes in Part II: Marine Reserves and Conservation Measures and states that "the Fisheries Minister may declare any area of the fishery waters and possibly land in the vicinity to be a **marine reserve**" and goes on to say: "Generally prohibited activities are fishing or attempting to fish, taking or destroying any flora or fauna, dredging or removing any sand or gravel, discharging harmful substances, polluting or otherwise damaging the natural environment."

In 1990 the SVG government created the Canouan Resorts Development Limited Act. This additional legal protection granted by the Act has done little to protect the island's marine habitats. The coral reefs, mangroves and seagrass beds have all been heavily impacted by human activities on the eastern side of the island.

- The Canouan Resorts Development Limited Act of 1990 states in section c (ii): "*(the Lessee agrees) not to interfere with the reefs on the eastern side of the Premises, or conduct or permit dredging operations therein; (iii) to import all sand to be used for development purposes; and (iv) not to remove sand from any beach on the Island to be transferred elsewhere."* However evidence shows that the main lagoon on the eastern side of the island has suffered greatly from dredging both historically and very recently. Damage done to the fringing reef was evident in the survey and siltation from on-going land development in the resort area is likely to be interfering with the coral's ability to survive here.

Socioeconomic surveys

Bunce et al. (1999), highlighted the value of stakeholder engagement in relation to marine protection, in the context of a Caribbean MPA. Consequently, from it's inception, the present study was geared towards both a biological and socio-economic assessment of the region. However, as this was a pilot study carried out over a short period of time, it should be highlighted that there were some limitations to the surveys that were carried out. The sample size was small; this was largely due to difficulties in finding people that were willing to be interviewed. A number of people that were approached did not want to be interviewed, and often interviews needed to be scheduled in advance and in some cases people didn't turn up for the interview. Some of the interviewees were unfamiliar with the interview structure and this meant some questions were not immediately understood. After explanation however, answers were received for all but a few questions. Prior to this survey taking place, it is our understanding that there were no other detailed assessments such as this that have taken place in Mayreau and Canouan. Sustainable Grenadines, carried out a Grenadines-wide socio-economic and environmental awareness assessment that addressed a small section of the present survey (Lee *et al.*, 2007), however, it did not specifically address marine protection and coral reefs as the present study does.

The majority of people surveyed indicated a strong connection to the sea, either directly or indirectly, which is not uncommon and has been cited elsewhere (e.g. Johannes, 2002). They recognise that the livelihoods of most Grenadine inhabitants is dependent on the sea, whether through fishing activities or the tourist trade. Other socio-economic activities such as agriculture are largely absent and many products are imported therefore the dependence on marine resources for food and to earn money is significant. In contrast, less obvious benefits from the sea such as coastal protection, were not readily recognised by the majority of the participants, although most mentioned recent hurricanes during the interviews. Coral and coral reefs were known by all of the participants but the benefits of reefs was only partially understood. For example, the connection between coral reefs and sandy beaches was not made by any of the participants, despite it being included in one of the questions in the survey. Many people were unaware of the uniqueness of coral reefs in the Caribbean or the wider threats that reefs are facing such as climate change and ocean acidification.

Many people recognised that there were problems with the marine environment and noticed a downward trend in the health of the sea but opinions about why this was so varied, which was indicated in a more negative outlook compared to the results of Lee *et al.,* (2007). Interviewees cited a variety of factors including pollution and the destruction of coral reefs, the former of which again mirrors the results of Lee *et al.*, (2007), who found that residents of Canouan and Mayreau both felt pollution was the greatest threat to the marine environment. Everyone surveyed was familiar with the TCMP and the regulations that applied there, and felt that it was beneficial for increasing the number of fish, turtles and lobsters within it's boundaries. However, people generally felt that the park was put in place for tourists and not for the benefit of local people, for example, those that worked in the tourist sector were more positive about the TCMP than those who didn't. This is not necessarily a surprising opinion as in fragmented, Island nations/communities, with numerous stakeholders and little available biological and socioeconomic data, there are often conflicts of interest (Fernandes *et al.,* 1999). Several fishermen believed that occasional harvesting of certain species within the park should be allowed. They cited the harvesting of abundant, short lived bait fish as an activity that would not affect the park or its other wildlife. There didn't appear to be an understanding of how a marine park could increase numbers of fish outside of the park's boundaries, but our analysis of commercially important species (Figure 13), would indicate that there is a benefit to protection that would likely result in 'spillover' as has been observed elsewhere (e.g. Harmelin-Vivien *et al.,* 2008). Again, as stated above, the protection of marine resources, for purposes beyond the obvious, short-term economic gains, could be highlighted with environmental education.

While interviewees were aware of the TCMP, there was a very poor understanding of what other MPAs existed in the region e.g. CMCA, and that there were different designations of MPAs. However, it was the case that the laws and regulations of the TCMP were understood to varying degrees by those surveyed; restrictions on activities and the penalties were listed by everyone. Participants were divided about whether there was sufficent enforcement of protection for marine resources - only one patrol boat and a small crew operating only in daylight hours. Enforcement is regularly highlighted as a key facet of successful, sustainable marine protection, irrespective of the scale, and also an area of management that due to logistal and financial constraints, affects the ecological effectiveness of MPAs (Agardy, 2000). In the present study, a percieved lack of interest by government or regulating agencies was regularly suggested as a cause of the ineffective enforcement. On a wider scale, people in Mayreau and Canouan said a lack of communication and support from decision makers in St. Vincent meant that their interests weren't being addressed.

It appears that a number of previous initiatives have had an impact in educating local people about their environment and the laws protecting it. Key species such as sea turtles were widely recognised as a partially protected species and a few people talked in detail about the regulations on turtle protection. Widecast, a Caribbean-wide sea turtle programme, had worked in SVG and the evidence for this was apparent through publications and posters. However, antedotal evidence from dive operators suggested that poaching of turtles within TCMP still occurs and there are concerns that this is increasing. Other NGOs and initiatives such as Sustainable Grenadines and Friends of Tobago Cays were also mentioned if not by direct name, then through being described by their activities.

Recommendations

As stated previously, this study is an initial assessment of the region, both in biological and socioeconomic terms. However, it was clear from this intensive pilot study that a number of short and longer-term measures could be implemented that would significantly benefit both the marine environment, and the local stakeholders.

- Patrols and enforcement in both MPAs would benefit from increased and better resources. More patrol boats, better equipment, and more rangers would help to ensure that poaching and other illegal activities, such as dredging, are not occurring and the rules of the MPAs are being adhered to. It is evident that damaging activities have taken place within the CMCA, and increased enforcement could prevent this. As a consequence, this would help prevent further reef degradation caused by direct human activities, and in doing so increase their resilience to changes in global environmental conditions.

- Clarification is needed on the differences between the different protection designations such as marine reserve and marine park and what activities are allowed or prohibited in these different areas, in order to increase compliance particularly in CMCA. The boundaries of the protected zones need to be delineated and clearly marked to ensure that stakeholders are aware of them. It is vital that this information should be disseminated to all stakeholders in order that these MPAs are effective.

- Public engagement is essential when developing marine protection, as the effects of closing areas to certain activities will almost certainly affect those that live nearby. Improved communication links are needed between all stakeholders, from local fishermen and hotel managers, to environmental NGOS and government agencies, through activities such as regular stakeholder meetings. This would benefit those people engaged in marine livelihoods, and help improve the effectiveness of the MPAs.

- There is evidence that environmental education initiatives work well in SVG. Previous initiatives have had an impact in teaching local people about turtles, terrestrial wildlife and to some extent coral reefs. This work needs to be expanded to show the ecosystem services that the marine environment provides, and the benefits of marine protected areas and how they work. Simple activities such as information leaflets have been shown to be highly effective and are very cost-effective. Key people within the community could be identified to help lead such educational initiatives. Also formal education in the local primary schools could be supplemented with stand alone, regular topic-specific programmes for adults. Those working in the tourist sector should be targeted to get key messages across that can be passed onto visitors to the Island.

- There is currently an unused purposed-built research station on the east coast of Canouan which has the potential to make an ideal base for further monitoring, education initiatives, and/or as a base for enforcement of the CMCA. We strongly recommend that this facility be utilised.

- The importance of mangrove and seagrass beds should be recognised and protected in TCMP and in and around Canouan. Removal of both habitats should be immediately halted. These ecosystems are an integral part of the marine ecosystem providing nursery grounds for fish and important commercial invertebrate species, and they act as buffer systems from storms and to sediment and polluting chemicals reaching the coral reefs.

- Observational data from this study suggests that Mayreau Gardens is one of the healthiest reefs in the region. This reef can act as a larvae base for coral and fish to replenish other more degraded reefs in the area. As such it should be strongly protected both from marine based activities and the effects of coastal development on Mayreau, which unless managed very carefully, will result in sedimentation and pollution and therefore degradation of Mayreau Gardens reefs. Unfortunately due to time constraints a full assessment of Mayreau Gardens was not possible in this report but we believe protection of this area should be prioritised.

- We advocate increasing the boundaries of the CMCA to include the Southern coast of Canouan, including the reef section that was monitored in the present study. In many of the parameters that were assessed, the Southern reef exhibited similar or even higher values than the sites within the CMCA. Further, a large stand of *Acropora palmata*, a species that has historically been key in reef building in the region but is now a rarity, was also identified along the Southern coast of Canouan. However, it should be noted that the priority should be to enforce the current CMCA in an effort to increase its effectiveness, perhaps in conjunctions with extending the boundaries, as simply extending an ineffective MPA is pointless.

- This study highlighted that while the TCMP was relatively effective as a MPA, the CMCA was not. Baseline assessments similar to the present study should be carried out at all MPAs in SVG, as these assessments are essential to measuring the effectiveness of the MPAs. These surveys should be undertaken with the view to compare the effectiveness of MPAs, and also to sites nearby that are not protected to ensure that MPA boundaries are appropriate.

- Long term monitoring is an essential part of assessing the effectiveness of MPAs and sustainable management actions. In light of the information that has been gathered in this study, it would seem wise to continue monitoring key parameters at the sites to identify significant changes over time and guide marine management in the long term.

- Canouan is currently a Marine Conservation Area but there is a proposal to make it a Marine Reserve. Its current designation does little to protect is from any activity apart from spear-fishing. However the Canouan Act specifically states that the reefs of Canouan's eastern shore should not be interfered with or dredged. Changing Canouan's status to Marine Reserve would improve the protection of its remaining reefs and seagrasses, provided enforcement is undertaken.

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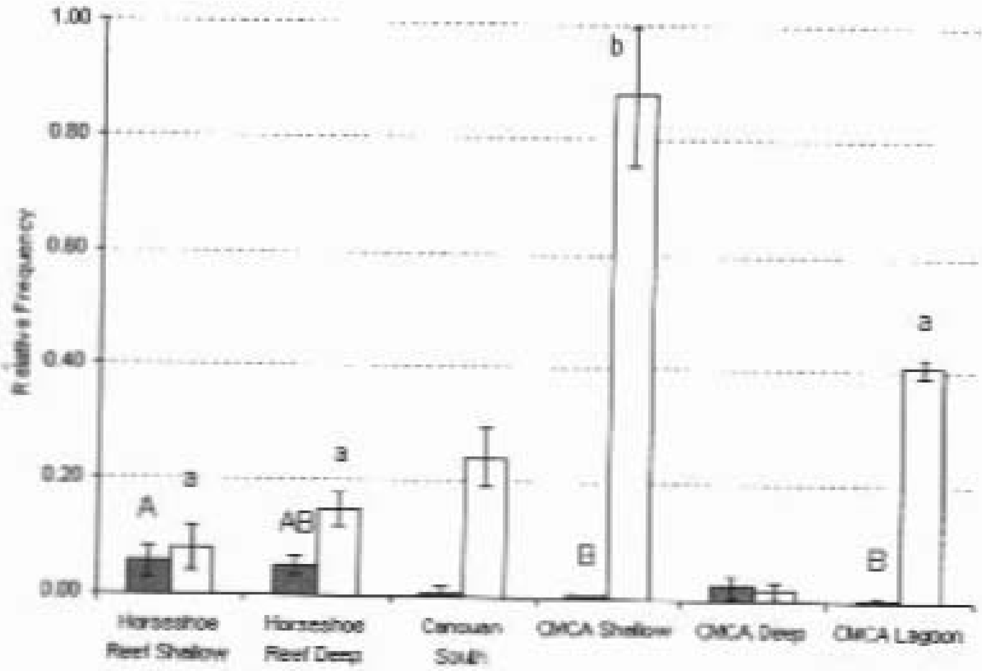

Figure XX. Relative frequency of hard coral (grey bars) and combined algae (white bars) across six sites. Combined algae includes macro algae and turf algae but calcerous algae has been excluded. Error bars represent 1 stand error of the mean. Within these analyses; n = 2 for CMCA Deep and Canouan South and were therefore excluded from statistical analyses. For all other site n = 3 except CMCA shallow whereby n = 4.

Appendices

Appendix 1 - Commercial fish species and conversion ratios

Latin Name	Common Name	Weight
Caranx bartholomaei	Yellow Jack	W=0.0259*L^2.90800
Caranx crysos	Blue Runner	W=0.0318*L^2.94900
Caranx ruber	Bar Jack	W=0.0180*L^2.99000
Epinephalus adscensionis	Rock Hind Grouper	W=0.0125*L^3.22400
Epinephalus fulvus	Coney Grouper	W=0.0188*L^2.97300
Epinephelus cruentatus	Graysby Grouper	W=0.0121*L^3.08200
Epinephelus guttatus	Red Hind Grouper	W=0.0106*L^3.0990
Ginglymostoma cirratum	Nurse Shark	W=0.0106*L^2.29200
Haemulon aurolineatum	Tomtate	W=0.0143*L^3.14000
Haemulon flavolineatum	French Grunt	W=0.0232*L^3.00000
Lutjanus analis	Mutton Snapper	W=0.0158*L^3.03400
Lutjanus griseus	Gray Snapper	W=0.0207*L^2.91500
Lutjanus mahogoni	Mahogany Snapper	W=0.0428*L^2.71900
Mycteroperca bonaci	Black Grouper	W=0.0082*L^3.14000
Mycteroperca interstitialis	Yellowmouth Grouper	W=0.0009*L^3.58200
Ocyrus chrysurus	Yellowtail Snapper	W=0.0382*L^2.75900
Paranthias furcifer	Creole Fish	W=0.0135*L^3.04300
Scarus croicensis	Striped Parrotfish	W=0.0166*L^3.02000
Scarus vetula	Queen Parrotfish	W=0.0250*L^2.9214
Scarus taeniopterus	Princess Parrotfish	W=0.0135*L^3.00000

Sparisoma atomarium	Greenblotch Parrotfish	W=0.0121*L^3.02800
Sparisoma aurofrenatum	Redband Parrotfish	W=0.0129*L^3.11000
Sparisoma radians	Bucktooth Parrotfish	W=0.0179*L^3.0348
Sparisoma viridae	Stoplight Parrotfish	W=0.0250*L^2.92100

Appendix 2 - Socio-economic Questionnaire

Name:
Occupation: Age:
Address (local, regional or tourist):
Questions:

1. The marine environment of SVG is important to everyone that lives here or visits.
    a. Strongly agree b. Agree c. Disagree d. Strongly disagree
2. Who are the groups of people that most benefit from the marine environment in SVG?

3. There are many things that the people of SVG gain from the marine environment.
    a. Strongly agree b. Agree c. Disagree d. Strongly disagree

4. List the three most important benefits that people in SVG gain from the marine environment.

5. Products such as seafood and sandy beaches are important to the people of SVG.
    a. Strongly agree b. Agree c. Disagree d. Strongly disagree

6. What are the most important economic benefits that people of SVG receive from the marine environment?

7. The marine environment of SVG is as healthy as or healthier than it was previously (tailor timeframe to interviewee).
    a. Strongly agree b. Agree c. Disagree d. Strongly disagree

8. What changes have you noticed in the marine environment of SVG over time (tailor timeframe to interviewee)?

9. Humans have had a negative impact on the marine environment of SVG.
    a. Strongly agree b. Agree c. Disagree d. Strongly disagree

10. List the three main impacts humans have had on the marine environment of SVG.

11. SVG has adequate protection of its marine environment. .
    a. Strongly agree b. Agree c. Disagree d. Strongly disagree

12. Are there MPAs in SVG and if so, where are they?

13. The marine protected areas in SVG are beneficial for protecting the marine environment

a. Strongly agree b. Agree c. Disagree d. Strongly disagree

14. What activities are allowed in SVG marine protected areas? What activities are prohibited?

15. There are sufficient laws protecting marine life in SVG.
    a. Strongly agree b. Agree c. Disagree d. Strongly disagree

16. What laws are used to protect marine species and habitats in SVG?

17. The laws protecting marine life in SVG are adequately enforced.
    a. Strongly agree b. Agree c. Disagree d. Strongly disagree

18. How are the laws protecting marine life enforced in SVG?

19. The laws protecting marine life in SVG are adequately protecting marine species and habitats.
    a. Strongly agree b. Agree c. Disagree d. Strongly disagree

20. What marine species or habitats are protected by law in SVG?

21. Coral reefs are important to the livelihoods of people in SVG.
    a. Strongly agree b. Agree c. Disagree d. Strongly disagree

22. What benefits do the people of SVG receive from coral reefs?

23. There are many coral species in the reefs around SVG that are unique to the Caribbean and some that are threatened.
    a. Strongly agree b. Agree c. Disagree d. Strongly disagree

24. What human activities have a negative impact on coral reefs?

25. Sea grasses are important to the livelihoods of people in SVG.
    a. Strongly agree b. Agree c. Disagree d. Strongly disagree

26. What benefits do the people of SVG receive from sea grasses?

27. Seahorses are often found in the waters around SVG.
    a. Strongly agree b. Agree c. Disagree d. Strongly disagree

28. Have you ever seen a seahorse, living or dead, in SVG? If so, where and when?