

# Transboundary Coral Reef Monitoring for the Grenadines Network of Marine Protected Areas

## Monitoreo de la Red Transfronteriza de Áreas Marinas Protegidas en el Banco de Grenada

### Suivi d'un Réseau Transfrontalier D'aires Marines Protégées dur la Banque Grenade

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#### ABSTRACT

Transboundary conservation is defined by the IUCN as “a process of cooperation to achieve conservation goals across one or more international boundaries”, involving regular communication, information sharing, prior consultation and joint planning and implementation of management decisions. Monitoring and evaluation is critical to the success of any such effort, and must be customised to reflect the specific needs of the collaborative arrangement (Vasilijevic, et al. 2015). The Grenadines Network of Marine Protected Areas (MPAs) is a network of MPA managers from the neighbouring small island developing states of Grenada and St. Vincent. Their objectives are to improve site level and transboundary management of MPAs and marine spaces through collaborative capacity building and implementation of best practices.

At their annual meeting in June 2014, the Grenadines Network of Marine Protected Areas set short-term goals to train at least one staff member from each of the six participating MPAs in coral reef monitoring, and to establish one long-term coral reef monitoring site in each of the MPAs in the coming year (2014 - 2015). The Network selected the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol for reef ecosystem monitoring. Small grants under a U.S. National Fish and Wildlife Foundation project were used to sponsor an AGRRA coral reef monitoring training workshop and the first Grenadines-wide field work expedition by and for members of the Grenadines Network of Marine Protected Areas.

We will present findings about the condition of coral reefs across two countries and six biologically-connected MPAs and highlight lessons learned for MPA management in this and other locations in the Caribbean. All except for one site exhibited high coral cover and low fleshy macro algal cover relative to the Caribbean regional averages reported by AGRRA. Several MPAs have the potential to tip the balance back towards coral dominated reefs if herbivores are brought back (e.g. by protecting parrot and other fish). Fish biomass, particularly of commercially important species such as groupers and snappers, was found to be significantly lower in the Grenadines MPAs than Caribbean regional averages, indicating strategic directions for education and outreach, enforcement and ongoing monitoring.

KEY WORDS: MPA, monitoring, transboundary, AGRRA, biomass, Eastern Caribbean, Grenada Bank

#### INTRODUCTION

##### The Grenada Bank

The Grenada Bank is a submarine shelf extending some 120 km in the South Eastern Caribbean. An archipelago of thirty nine volcanic islands and cays, known as the Grenadine Island Chain, sits atop the Grenada bank and is divided between the small island developing states (SIDS) of St. Vincent and the Grenadines (32 northern islands and cays) and Grenada (seven southern islands and cays) (Baldwin and Mahon 2014). The two SIDS, as a result, are entitled to extensive marine jurisdictions which provide an array of socio-economic and ecological services, especially in the tourism and fisheries dependent islands of the Grenadines. There is a large amount of connectivity between habitats due to the proximity of the islands. However, the marine resources of both territories have found themselves under threat from unsustainable fishing, coastal development and waste management practices.

##### Sustainable Grenadines Inc. (SusGren) and the Grenadines Network of MPAs (GNMPA)

Public sector efforts to manage these threats have typically taken the form of conventional top-down approaches guided by a limited pool of biophysical and socio-economic information (Baldwin 2012). However, there have been many efforts within the last ten years to enhance the pool of available information on status and usage patterns of coastal and marine resources and to empower stakeholders to participate in the management of these resources. Many of these efforts took place under the auspices of the Sustainable Grenadines Project, an initiative of the Centre for Resource Management and Environmental Studies of the University of the West Indies. The project, which ended in 2009, was succeeded by an NGO of the same name which has continued to lead efforts to build capacity for stakeholder participation in coastal and marine resource management. One of their most significant collaborative activities occurred in 2011, when Sustainable Grenadines Inc., the management authorities of three MPAs, as well as relevant government and civil society stakeholders from both SVG and Grenada came together to establish a Grenadines Network of Marine Protected Areas (GNMPA). This initiative was intended to promote best practices and collaborative capacity building for MPA management across national borders.

With no formal cooperative management guidelines, nor institutional structure, GNMPA was established on the back of a strong willingness for collaboration that was expressed by the three founding MPAs and the related government agencies in both countries. Each year, the networking meeting has included a facilitated process to assist the MPAs with defining their priority needs and identifying those of GNMPA. SusGren champions the network and strives to match needs with opportunities for expertise and funding for a process of strategic planning and opportunistic implementation. While SusGren takes a facilitating role, accountability for implementation is shared by the MPA partners. SusGren facilitated the signing of a formal agreement between the MPAs “to collaborate together, to ensure effective MPA management and to promote the

conservation and sustainable use of marine resources”.

The GNMPA is a significant establishment as one of only two transboundary MPA networks in the Gulf and Caribbean Region; the other being the significantly larger network between the countries of the Meso-American Reef System (Belize, Honduras, Guatemala and Mexico).

### Transboundary Monitoring Framework

In June 2014, at the time of the Fourth Annual Networking Meeting, the GNMPA had grown to include six marine protected areas, three from each country including two MPAs in Grenada (Molinière-Beauséjour MPA (MBMPA) and Woburn/Clarke’s Court MPA (WCCMPA)) and three in St. Vincent and the Grenadine (Sandy Island Oyster Bed MPA (SIOBMPA), Mustique Marine Conservation Area, and South Coast Marine Management Area (SCMMA) (Table 1). Past meetings in 2011, 2012, and 2013 addressed fundamental MPA management topics including governance, management planning and standard operating procedures for law enforcement. In response to calls for more substantive collaboration on MPA monitoring the previous year at the third annual GNMPA meeting, the group of six member MPAs designed and agreed upon a draft framework for MPA monitoring embodying ecological, socioeconomic and administrative goals in 2014 (Table 2). This framework will act as an evolving standard against which the member MPAs can assess and improve their individual monitoring regimes, facilitate cooperation between Network resources, and allow the Network to progress towards a standardized trans-boundary monitoring archive. In terms of biophysical monitoring, the Network set a short-term goal to train at least one member from each of the six MPAs and establish one long-term coral reef monitoring site in each of the six MPAs in 2014. This effort was

intended to use limited funds for a pilot study of biophysical characteristics at the Network level to highlight gaps in the monitoring framework, collective resources, capacity and collaborative paradigms. The Network selected the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol for reef ecosystem monitoring as they agreed it provided the most rigorous and reliable approach to data collection, would facilitate data sharing among the MPAs and Caribbean-wide, and would provide useful information for MPA adaptive management decision-making. The existence of past AGRRA data from some of the MPAs of the Grenadines was also felt to provide an important historical reference in interpreting current data.

### Objectives

In this paper, we will demonstrate the application of the MPA monitoring framework to the results of the transboundary AGRRA monitoring pilot study. The framework was used to produce recommendations for management prioritisation, as well as communications tools and reference materials for MPA managers. We will also highlight lessons learned, resource and capacity building needs, and plans for further development of the Grenadines Network of MPAs with respect to monitoring.

## METHODS

### Fieldwork

Long term monitoring sites for each MPA were strategically selected for the pilot effort after group deliberation for varying reasons, including:

- i) To fill existing data gaps,
- ii) To coincide with or complement sites with historic data,

**Table 1.** Members of the Grenadines Network of MPAs

Country	MPA	Principal Management Authority
St. Vincent and the Grenadines	South Coast Marine Management Area	SVG Fisheries Division
	Mustique Marine Conservation Area	The Mustique Company Ltd.
	Tobago Cays Marine Park	The Tobago Cays Marine Park
Grenada	Sandy Island/Oyster Bed Marine Protected Area	Ministry of Carriacou/Petit Martinique Affairs
	Moliniere Beausejour Marine Protected Area	Grenada Fisheries Division/Grenada MPAs Department
	Woburn Clarks Court Marine Protected Area	Grenada Fisheries Division/Grenada MPAs Department

**Table 2.** Grenadines Network of MPAs - Monitoring Framework

Ecological Indicators			Socio-economic/Participation Indicators			Administrative Indicators	
(effective protection of natural resources, species, critical habitat and ecological balance to ensure ecosystem services)			(Mechanisms for stakeholder engagement/participation)			(Efficient and effective MPA coordination and administration)	
Coastal and Marine Ecosystems	Key Biodiversity	Water Quality	Stakeholder Compliance	Stakeholder participation	Education & Communication programs	Site-level long-term monitoring schedule & programs	Effective Adaptive management
Reef Benthos; Reef Fish; Diadema; Mangroves	Sea Turtles; Queen Conch; Migratory/ Shore Birds	Turbidity; Temperature; Bacteria	Enforcement officer presence; Warnings/ Arrests	Meeting frequency/ regularity; Active partnerships; Volunteerism	Public awareness & outreach; Youth programmes		

- iii) To address a management issue such as high tourism or fisheries allowances,
- iv) To inform management decisions regarding a specific threat, and
- v) To help to provide baseline data for developing management plans.

Reefs selected represent one reef type and may not be representative of the variety of reef types within the MPA, but they do provide a starting point for the managers to begin to track conditions over time. The sites were plotted in advance using Google Earth. They were then ground-truthed by the field team to ensure their placement on appropriate reef habitat; any deviation from the planned dive site was recorded using a handheld GPS. Permanent transects at the sites were marked underwater using a rebar stake and flagging tape.

Representatives of each of the six Network MPAs with varying levels of reef monitoring experience were trained over the course of three days in the AGRRA Fish and Benthic Protocols (v5.4). The coral protocol was not used for this effort, as the benthic protocol provided a satisfactory assessment of live coral cover for the purposes of the monitoring framework. At least six divers were used for each dive, and were split evenly between the benthic or fish protocol. Each diver was tasked with completing three to four transects at each site on a single dive for a maximum of 12 transects for either protocol. Transects were performed randomly in the general vicinity of the site marker on reef substrate. Three video transects were also recorded for each site using a GoPro Hero 3+.

### GNMPA Monitoring Framework – Biophysical Indicators for Understanding Reef Health

Indicators are “metrics of an ecosystem that help translate the complex concept of ecosystem health into tangible, rigorously defined quantities by which changes in condition can be assessed over time” (McField and Kramer 2007). Five key indicators (mean live coral cover, mean fleshy macroalgal cover, herbivorous fish biomass, commercially important fish biomass, *Diadema antillarum* density) were selected to provide a more easy-to-understand summary of the overall condition of the coral reefs surveyed. These indicators were presented within the context of a Reef Health Index (Table 3); a tool pioneered by the Healthy Reefs Initiative. The Healthy Reef Initiative was one of the first efforts globally to develop measurable ranking criteria for indicators of coral reef health and a combined index to provide a “big picture” snapshot of reef health (The Healthy Reefs Initiative 2008).

Each of the five indicators selected was given a score of critical, poor, fair, good or very good based on the criteria and thresholds developed by HRI (The Healthy Reefs Initiative 2008). The scores or ranks represent a compromise between grading for the ideal “pristine” reef conditions and what we can realistically hope to achieve in modern times and reef conditions based on actual data from the AGRRA.org database for the Wider Caribbean (The Healthy Reefs Initiative 2012).

While these indicators are the focus of the Reef Health Index, a full complement of AGRRA benthic and fish survey data is used to support biophysical assessment and reporting.

## RESULTS

### Moliniere Beausejour MPA, Mainland Grenada

The Moliniere-Beausejour Marine Protected Area (MBMPA) is situated on the western side of Grenada five kilometres north of the capital, St. George’s. The primary uses of the site are recreational (both local and tourism-centric); however, commercial and recreational fishing activities also occur in the fishing priority areas of the site. Primary threats include illegal selective fishing methods (i.e. spearfishing), land based development and sediment and nutrient pollution (Roby 2010).

The permanent monitoring site, established in Flamingo Bay within the fishing priority area of the MPA, exhibited 27% mean live coral cover; considered good by the metrics of the Reef Health Index. However, mean fleshy macroalgae cover was much greater at 34.3% and rated critically high. Herbivorous fish biomass was rated poor at 1130 g/100 m<sup>2</sup> and commercially important fish biomass was critically low at 283 g/100 m<sup>2</sup>. No black sea urchins (*Diadema antillarum*) were observed on any transect.

Past AGRRA data did not exist for this reef site. While mean live coral cover was considered good, it is likely to be lower than historic values based on regional trends. The abundant fleshy macroalgae was observed to actively compete with corals, causing coral mortality. The combined mean cover of turf and fleshy macroalgae was more than 50%, while combined mean live coral and crustose coralline algae cover was only ~37%. Management efforts should prioritise the increase of herbivory as well as the reduction of land-based nutrients to decrease macroalgal cover and allow the corals to reclaim benthic cover. Efforts to reduce land-based nutrient pollution are underway through a number of participatory initiatives in the watershed by the management authority. The importance of these efforts is highlighted by the prevalence

**Table 3.** Grenadines Network of MPAs - Reef Health Index

Indicators	Critical	Poor	Fair	Good	Very Good
Mean Live Coral Cover (%)	<5.0	5.0 - 9.9	10.0 – 19.9	20.0 – 39.9	>39.9
Mean Live Fleshy Macroalgal (%)	>25.0	12.1 – 25	5.1 – 12.0	1.0 – 5.0	0.0 – 0.9
Key Herbivorous Fish Biomass (g/100m <sup>2</sup> ) (parrotfish and surgeonfish only)	<960	960 – 1919	1920 – 2879	2880 – 3479	>3479
Key Commercial Fish (g/100m <sup>2</sup> ) (snappers and groupers only)	<420	420 – 839	840 – 1259	1260 – 1679	>1679
<i>Diadema antillarum</i> density (#/m <sup>2</sup> ) (long-spined sea urchin)	<0.25	0.25 – 0.49	0.5 – 1.0	1.1 – 2.5	>2.5 (and <7)

of algae.

Herbivory at the site may be considered to be very low, as no *Diadema antillarum* were captured in any transect. Herbivorous fish (parrotfish and surgeonfish) biomass was also very low on this reef, with parrotfish size composition skewed towards small sized (mean 12.8cm) fish. *Diadema antillarum* populations may recover naturally in the advent of increased water quality and decreased macro algal presence, but transplant may be a viable management action for consideration.

Commercially important fish (grouper and snapper) biomass was even lower, with populations considered to be in critical condition. Neither large groupers nor snappers were observed, and the average size of grouper and snapper populations were found to be 11.4 and 12.3 cm, respectively.

High relief, complex reef structure was a key feature of this site, and was observed to provide habitat for other key species such as lobster, which were found in abundance. This site characteristic bodes well for potential fish stock recovery, as it implies that there is a large quantity of high quality fish habitat with high carrying capacity.

#### **Woburn/Clark's Court MPA, Mainland Grenada**

Woburn/Clarke's Court Marine Protected Area (WCCMPA) is located on the southwest coast of Grenada within the parish of St. George. The area includes a fishing community and two islands, extensive mangroves, seagrass beds and coral reefs which serve as a crucial habitat for many species (Pascal, Pena and Blackman 2013). However, the MPA has not yet been officially launched and many of the programmes in existence for MBMPA (including regular patrol by rangers) have not yet been implemented there. The area is heavily used by yachts and fishers, and a marina is currently being developed within the park boundaries. This development has caused the destruction of a large swathe of mangrove habitat.

The permanent monitoring site was placed on a shallow offshore reef crest. Mean live coral cover was good at 21.8%, while fleshy macroalgae cover was rated as 'fair' at 7.5%. Both commercially important and herbivorous fish species biomass were critically low at 32 and 709 g/100 m<sup>2</sup> respectively. *Diadema antillarum* abundance was found to be very good, with mean densities of 2.35 individuals/m<sup>2</sup>. *Diadema antillarum* were presumed to be the primary herbivores at this site, maintaining the low fleshy macroalgal cover, limiting turf algae cover to moderate levels (21.8% mean cover) and creating ideal conditions for the growth of extensive crustose coralline algal cover (34.3%) and juvenile coral recruitment. Herbivorous fish biomass, however, did not match *Diadema* abundance. Parrotfish and surgeonfish biomass was extremely low due to a size composition dominated by small individuals (~5cm). Commercially important fish populations were almost non-existent, with only five moderately sized (10 - 20cm) groupers and snappers observed in the fish transects. Fishing pressure and anthropogenic impacts from coastal communities, extensive development and yachting activity are believed to threaten fish populations in the MPA.

The operationalization of the MPA is expected to significantly improve ecosystem conditions; however, this will be contingent on the extent of fishing restrictions, the advent of effective enforcement and stakeholder compliance programmes, and the effectiveness of attempts to reduce watershed and coastal development impacts and preserve key adjacent nursery and population replenishment habitat (i.e. mangroves and seagrass beds).

#### **Sandy Island/Oyster Bed MPA, Carriacou, Grenada**

The Sandy Island Oyster Bed Marine Protected Area (SIOBMPA) is located on the southwest of Carriacou and spans a total area of approximately 787 hectares. The area includes four bays, at least three coastal communities, and extends seaward beyond Sandy Island, Mabouya Island, and the Sister Rocks to encompass extensive areas of mangrove, seagrass and coral reef habitat. It is managed by the Ministry of Carriacou and Petite Martinique Affairs (The Nature Conservancy, The Grenada Fisheries Division 2007).

The permanent monitoring site was placed at Lighthouse Reef just offshore of Sandy Island, a sandbar and popular tourist attraction/yacht mooring area within the MPA. Mean live coral cover was considered good at 34.7%. The area experienced significant mean fleshy macroalgal cover as well, rated critical at 28.9%. Herbivorous and commercially important fish biomass was critically low at 674 and 291 g/100 m<sup>2</sup> respectively, and *Diadema* density was poor at 0.02 individuals/m<sup>2</sup>.

Mean live coral cover was high, although it is likely to be lower than in previous years following significant loss of live coral due to Hurricanes Ivan & Emily and the 2005 coral bleaching event (Kramer and Dowksza 2005). Fleshy macroalgae was also abundant, and was observed to be overgrowing live corals. Cyanobacteria cover was very high at 9.5%, and sedimentation over corals was also observed.

*Diadema* were present but not common, and herbivorous fish biomass was critically low at this site, indicating weak herbivory which may be a contributing factor to the high macroalgae cover; a premise supported by low mean turf algae cover (5.1%). As with other reefs, commercially important fish biomass was even lower. While it must be noted that the site exhibited the second highest number of fish of any site in the pilot study, the size composition was skewed towards smaller individuals such that the biomass remained low. Very few large parrotfish and no large groupers were observed. The biomass of herbivorous species was slightly higher than that reported in 2005, but commercially important species biomass was lower by almost 50%.

Despite ranger presence on this reef since 2010, illegal fishing still occurs within the MPA. The reefs are also susceptible to land-based pollution and sedimentation from the adjacent commercial/residential coastal settlements and anchor damage from yachts. The decline in ecosystem quality and species biomass may also be linked to the loss of mangroves and increased sedimentation due to an ongoing marina development which has moved within park boundaries to degrade critical nursery habitat. There are no initiatives underway to mitigate these land based impacts.

### **Tobago Cays Marine Park, St. Vincent and the Grenadines**

The Tobago Cays Marine Park (TCMP), located in the Southern Grenadines, is a 66 km<sup>2</sup> no-take MPA which encompasses five uninhabited islands and Mayreau, the smallest inhabited island in the Grenadines. TCMP has been managed by a statutory body of the same name under the Ministry of National Security since it was operationalised in 2007, and is considered to be a key tourism destination in the Grenadines, particularly for visiting yachts, cruise ships and day visitors. Unfortunately, the habitats within the marine park have not been considered to be at optimal condition for many years due to a number of factors including storm damage, waste and anchor damage from boating activity, recreational over-use, historic overfishing and coral disease (Creary 2010).

The permanent monitoring site was established on Horseshoe Reef, a 4km semi-circular narrow fringing reef which partially encircles the uninhabited islands of the park. Coral cover at the site was fair at 14.7%. There were many colonies encountered which were partially or entirely dead. Mean fleshy macroalgal cover was found to be fair at 9.3% and composed mostly of *Halimeda sp.*, a genus often avoided by herbivorous fishes. Herbivorous fish biomass was very good (4172 g/100 m<sup>2</sup>), while commercial fish biomass remained poor at 620 g/100 m<sup>2</sup>. *Diadema* abundance was critically low at 0.02 individuals/m<sup>2</sup>.

This site exhibited the lowest coral cover of all the monitoring sites. The 2014 value was ~50% the value reported by the 1999 assessment of the same area of Horseshoe Reef (Deschamps, Desrochers and Klomp 2003). This decrease may have occurred as a result of storm damage and the 2005 and 2010 coral bleaching events. However, the prevalence of crustose coralline algae cover (29.2%), low fleshy macroalgal cover, moderate turf algal cover (18.3%) and the observation of a number of coral recruits suggests that there is potential for increasing live coral cover in future. Cyanobacteria cover was relatively high (6.5%), indicating that there may be impacts to water quality linked to yacht and day tourism in the MPA.

Few *Diadema* were observed; however, the abundance was a slight improvement on 1999 reported values, where none were reported. Herbivorous fish biomass was similar to values reported in 1999. More fish were counted in 2014 than 1999 (922 fish in 2014 vs 240 in 1999), but surprisingly the average size of the fish was smaller (10 cm in 2014 vs 16cm in 1999). Despite this, herbivory by fish in TCMP may still be considered substantial.

A similar pattern was observed in commercial fish biomass, where more fish were seen in 2014 than 1999 (32 vs. 8 fish), but the fish seen in 2014 were, on average, less than half the size of those observed in 1999 (~12 cm in 2014 vs ~30 cm in 1999). Grouper and snapper biomass has greatly increased since 1999 and was the highest reported at any MPA site in this pilot study. However, the average size of individuals from these families remains small, with average grouper size at 12.2 cm and average snapper size at 14.5cm.

The long term protection of TCMP and effectiveness of ranger presence has likely contributed to increasing fish

populations; however, the rarity of large sized fish in TCMP is still a concern. Illegal fishing of larger fish could be responsible for this observation. It is possible that the enforcement presence in the park may be allowing fish populations to grow, but not achieving complete protection.

### **Mustique Marine Conservation Area**

The Mustique Marine Conservation Area is managed by the Mustique Company Ltd., the organisation which has privately owned the island since 1979. Encompassing the island to a distance of 1000 yards from shore, this no-take MPA is patrolled by the island's security force and protects the natural marine diversity for the benefit of the Mustique shareholders.

The permanent monitoring site was placed on the leeward coast on a low relief reef system roughly 1 km from shore known as Plantain Reef. Mean live coral cover was considered good at 24.2%. Mean fleshy macroalgal cover was only slightly lower at 21.8%. Herbivorous and commercially important fish biomass were critically low at 565 g/100 m<sup>2</sup> and 42 g/100 m<sup>2</sup>, respectively. *Diadema antillarum* mean abundance was fair at 0.93 individuals/m<sup>2</sup>.

While fleshy macroalgae were observed to compete with the reef corals for space, the percentages of live coral, fleshy macroalgae and turf algae cover on the reef were very similar; a balance presumably maintained by significant herbivory by *Diadema antillarum*. Reef fish herbivory at the site is not believed to be as effective, with a low biomass made up almost entirely of juvenile parrotfish and surgeonfish 10cm in length or smaller. However, the relatively moderate CCA cover (13.1%) bodes well for coral recruitment. As in the case of the herbivorous fish species, grouper and snapper biomass at the site was also made up entirely of individuals less than 10cm; a state of affairs which suggests impacts of overfishing. Increasing average reef fish size (and consequently, biomass) is a key management priority for this reef; it must be noted; however, that regular enforcement patrols only began in 2014. As such, fish populations may not have had time to recover from previous fishing pressure.

Levels of fleshy macroalgae and cyanobacteria cover and observations of sedimentation suggest possible wastewater-related nutrient pollution and sediment pollution. Initiatives are currently underway to assess watershed dynamics and formulate plans for mitigation of land-based pollution of the marine environment.

### **South Coast Marine Management Area**

The South Coast Marine Management Area (SCMMA) is the only designated Marine Conservation Area on mainland St. Vincent, encompassing five communities and four bays with large expanses of coral reefs, seagrass beds, and mangroves (Lockhart, et al. 2013). It is scheduled to be operationalised in 2016, and has no special enforcement or stakeholder compliance measures in place at present. The primary management agency responsible for the area is the SVG Fisheries Division, though substantial support is received from the National Parks, Rivers and Beaches Authority.

The permanent monitoring site was established on a shallow nearshore reef known as Ray's Place. Key features

of the site include high sedimentation from a nearby river outflow, a monotypic stand of *Porites*, a high density of sponges and extensive turf algal sediment on the bottom. Mean live coral cover was good at 26.8%, while mean fleshy macroalgae cover was fair at 6.7%. Herbivorous and commercially important fish biomass were critically low at 869 g/100m<sup>2</sup> and 15 g/100 m<sup>2</sup>, respectively. *Diadema* mean abundance was fair at 0.48 individuals/m<sup>2</sup>.

Past AGRRA data were available from surveys in 2008 in the same area. Coral cover has declined slightly since 2008, but is still fairly abundant. While the ratio of coral cover to fleshy macroalgae seems positive, there was also a large amount of new dead coral smothered by sediment (20%) and sediment laden turf algae (15%), which can overgrow corals and prevent the settlement of coral recruits. This pattern of smothering by sediment can eventually lead to the loss of reef structure.

*Diadema* populations on the site were in better relative condition than herbivorous reef fish. Mean parrotfish size was 6.8 cm, while mean surgeonfish size was 7.4 cm; an indication of the fishing pressure exerted on these species, especially parrotfish, in the area. Commercial populations were almost non-existent, with no snappers and only six groupers less than 10cm in length (among them Harlequin Bass *Serranus tigrinus*) captured by the transect data.

The reefs have potential to improve with management actions to reduce sedimentation and increase fish biomass.

## DISCUSSION

### Patterns in Reef Ecosystem Condition

The overarching observation to be made about reef ecosystem condition throughout the Grenadines Network of MPAs is that despite several differences, the reef health index indicates a significant overlap in management priority actions throughout the Network (Table 4). Key limitations of the pilot study included:

- i) Different locations and individual reef character at each permanent monitoring site, making it difficult to truly compare MPAs,
- ii) The use of single sites at each MPA for the purposes of this pilot study, limiting representativeness of the data, and
- iii) Varying levels and styles of enforcement and management.

While coral cover is considered good (green) at all sites with the exception of Horseshoe Reef in TCMP, the biomass of key herbivores and commercially important fish is considered critical to poor (orange to red). Commercially important fish are of particular concern at the network level, as there are sites where grouper and snapper populations were found to be almost non-existent (> 50g/100 m<sup>2</sup>), and no groupers or snappers > 40 cm were encountered on any site.

The effects of enforcement programs were noticeable particularly at TCMP, which has had daily ranger presence for the past eight years and strict no-take rules. TCMP exhibited greater fish biomass by a large margin than all other MPAs. TCMP (enforced since 2007), MBMPA (enforced since 2010) and SIOBMPA (enforced since 2010) all had more parrotfish larger than 10 cm than the other MPAs, and were the only sites where groupers > 20 cm were encountered. However, despite herbivore biomass at TCMP being rated very good by the metrics of the RHI, the biomass is made up of a large number of juvenile fish. *Diadema* populations were at acceptable levels at the two low relief sites (Mustique and Woburn Clarks Court), but were poor to critical at all others.

Information collected on water quality monitoring programs throughout the Network indicated that while water quality is cited as a threat to all the MPAs, only SCMMA and Mustique were conducting regular water quality monitoring before the establishment of the Monitoring Framework in June 2014. The TCMP and MBMPA have begun monitoring in 2015, but only MBMPA has established programmes which attempt to decrease marine pollution. The prevalence of fleshy macroalgae and observations of sedimentation and cyanobacteria impacts support the fact that that wastewater and sedimentation pollution is a management priority at the site and Network level.

### Comparison of GNMPA with Regional Values

The sites assessed during the pilot study had low macroalgal cover and high live mean coral cover in comparison with other Caribbean reefs by a significant margin (Figure 1). The Caribbean mean coral cover was less than the pilot study mean by ~8%, while the Eastern Caribbean mean fleshy macroalgae cover exceeded the pilot study mean by ~13%. While the reefs are under stress, most of the sites exhibit higher coral cover than macroalgal

**Table 4.** Reef Health Index Scores - Pilot Reef Survey Efforts

Indicator	Moliniere Beausejour	Woburn/ Clarks Court	Sandy Island/ Oyster Bed	Tobago Cays	Mustique	South Coast	GNMPA Mean
Mean Live Coral Cover (%)	27	21.8	34.7	14.7	24.2	26.8	24.9
Mean Live Fleshy Macroalgae Cover (%)	34.3	7.5	28.9	9.3	21.8	6.7	18.1
Key Herbivorous Fish biomass (g/100m <sup>2</sup> )	1130	709	674	4172	565	869	1353.2
Key Commercial Fish biomass (g/100m <sup>2</sup> )	283	32	291	620	42	15	213.8
<i>Diadema antillarum</i> density (#/m <sup>2</sup> )	0	2.35	0.02	0.02	0.93	0.48	0.6

cover (which is not a trend exhibited in the Caribbean means) and the positive gap between coral and algal cover is likely to increase as herbivore biomass and water quality improve within the MPAs.

Fish biomass in the Grenadines was found to be significantly lower in terms of total, herbivorous and commercially important fish relative to wider Caribbean mean AGRRA values (Figure 2). Species composition in the Grenadines also did not significantly resemble that of the wider Caribbean, where herbivorous fish biomass is exceeded by commercially important fish biomass. However, the composition paradigm seen in the Grenadines was reflected in the species composition observed in St. Kitts, also in the Eastern Caribbean, indicating possible adherence to a regional pattern.

### Indicators of Success

The collection of this data allowed the GNMPA to set reef ecosystem condition baselines for all the MPAs in one year, and provided a pool of data on which to test the first iteration of the MPA monitoring framework. A number of edits were made, including the modification of metrics and targets, with input from stakeholders and international experts, to be more accessible and/or useful in the context of these MPAs. The data was combined with the output of rigorous literature review and extensive consultation to generate a number of communication and reference tools for management, including:

- i) Indicator reference cards for managers based on the second iteration of the monitoring framework, with modified indicators, targets, metrics, background and best practices outlined on a single sheet,

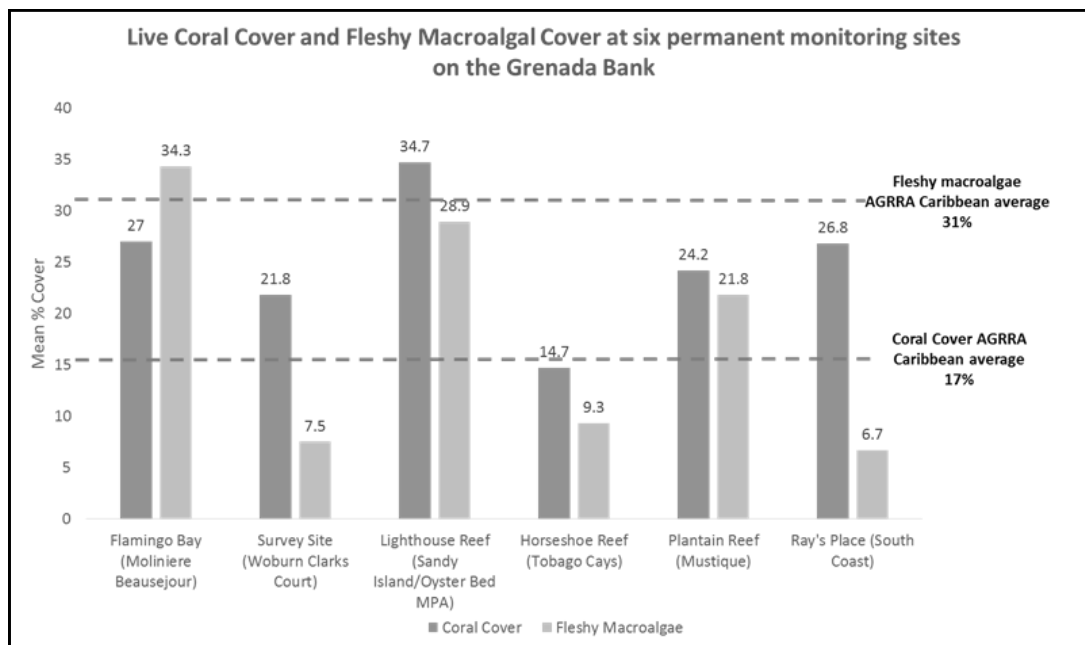
- ii) The first ever collection of monitoring profiles for the Grenadines MPAs, outlining the monitoring framework and the progress of each MPA towards realizing its targets. The report includes relevant past and present management actions, statistics where available, a list of references, and presents management recommendations for each MPA (in development), and
- iii) A series of reference posters indicating individual and overall management priorities for 2015-2016 (under review), intended to be used to communicate the challenges faced by each MPA and the Network overall.

The activity also allowed park management staff to be exposed to and appreciate reef types, ecosystem threats and management approaches outside the context of their own MPA.

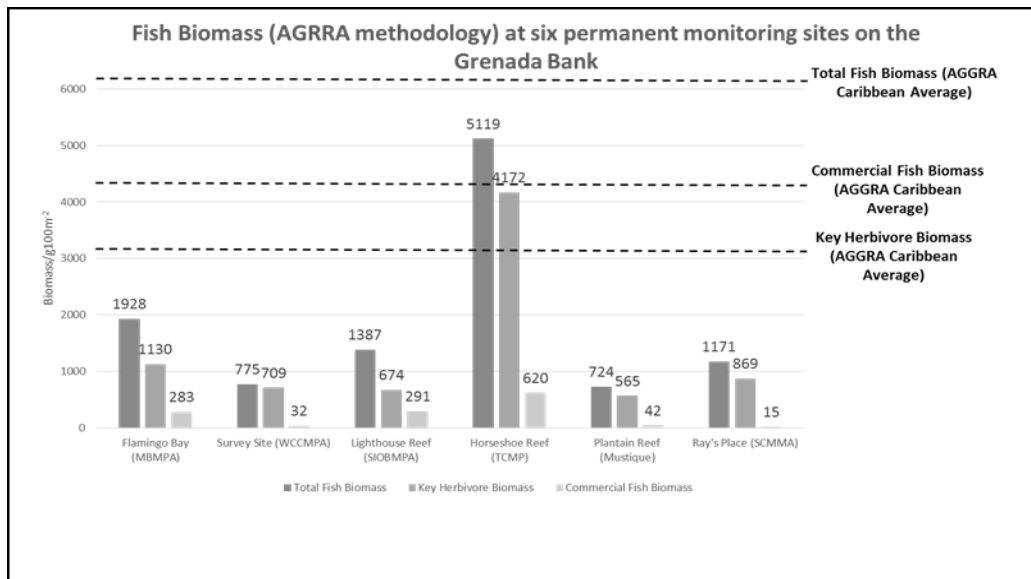
### Lessons Learned: Framework Gaps

The experience of working with the monitoring framework in its first year has presented challenges, come with inherent limitations and highlighted a number of areas for improvement.

Specifically in terms of conducting biophysical monitoring in coral ecosystems, there is a need for more representative data-sets from each MPA. While the permanent monitoring sites will allow managers to observe change at specific locations, larger AGRRA monitoring efforts at a broader spatial scale will allow assessors to capture the true diversity of ecosystem condition and character within each MPA to better inform management actions and future iterations of management decision support and reference tools.



**Figure 1.** Live Coral Cover and Fleshy Macroalgal Cover at six permanent monitoring sites on the Grenada Bank



**Figure 2.** Fish Biomass at six permanent monitoring sites on the Grenada Bank

While it is envisioned to continue to use a roving team of local assessors for reef monitoring, the level of capacity for conducting monitoring is not evenly distributed throughout the MPAs. The Grenada MPAs have made significant strides towards forming a capable team on mainland Grenada, and all of the MPAs have personnel who have been at least exposed to conducting AGRRA and/or ReefCheck. However, it is believed that to truly realize a scenario where local biophysical monitoring capacity is sufficiently high and well distributed to yield robust data at the Network level, training cannot be conducted on an ad hoc, crash course basis. Regular (perhaps annual) training courses would provide sufficient opportunity for park management staff and stakeholders to grasp the scientific knowledge and diving skills necessary to provide reliable data. They would also provide the opportunity for calibration of data collection technique to ensure more uniformity in reporting.

#### **Lessons Learned: Management Gaps**

Many of the MPAs are also not in a position to immediately address the detrimental factors impacting their reef ecosystems, for reasons associated with lack of funding, lack of capacity, local support and political will. In most of the MPAs, monitoring activities are not included in operational costs, and are carried out using grant funding from external sources. This sometimes leaves them in the position where they must choose between prioritizing the allocation of funds to monitoring or other management needs. Insufficient funding for monitoring programs causes monitoring to remain *ad hoc*.

There is also a need for harmonization of MPA capacity building and monitoring schedules. The MPAs still act independently, conducting their activities on their own schedules. However, this limits the effectiveness of collaborative efforts, as differing human resource and financial availability stymy ad hoc attempts to bring

management staff together. A calendar of monitoring activities at the Network level could allow timely pursuit and/or dedication of resources to regular site-level (where required) and Network activities and facilitate training and exchange opportunities. Sustainable Grenadines Inc. is a key partner to the GNMPA in terms of securing funding for MPA operations, and the implementation of such a program would fall under the portfolio of their Monitoring Coordinator.

Enforcement and compliance in particular is an area with many gaps in the context of the Grenadines MPAs, and while efforts have been made to assess existing paradigms, inform management and train personnel, some areas retain ineffective operating procedures. It is noted that enforcement takes time to take effect, and goes hand in hand with the effectiveness of efforts to promote compliance. Communication, education and fostering stakeholder acceptance and participation are also considered management priorities for all the MPAs, and were addressed at the 2015 GNMPA Meeting through a series of workshops. The MPAs are all attempting to tackle stakeholder relations to varying degrees, and vary also in the effectiveness of their stakeholder partnerships.

Water quality impact mitigation is one of the more complex issues faced by the MPAs, in many cases without direct solutions. Ridge to reef approaches, incorporating watershed characteristics and land-based sources of pollution into MPA management considerations, are expensive and often require sustained human and financial resource input into a number of programs aimed at modifying social as well as ecological paradigms over time. Black and grey water and sedimentation pollution as a result of the widespread yachting, accommodation and tourism development interests all require not only communications efforts and investment in solutions at the site-level but the formation of partnerships which yield effective support and compliance from stakeholders and legislators.



Increasing fish biomass is highlighted as a key management priority. Connectivity between MPAs might allow them to function more effectively as replenishment zones; however, the MPAs may be too far apart to allow connectivity and too small for effective management of the species they aim to protect. Reducing fishing mortality to allow fish populations to recover from critically low levels and an increase in the number of large fish may require review of the effectiveness of MPA boundaries, present zoning paradigms, permitted fishing practices, and enforcement and stakeholder compliance strategies.

In addition to considerable knowledge gaps on the existing indicators, there is wide scope for further and more specific scientific assessment of marine resources and management paradigms on the Grenada Bank. In many cases, however, information has been collected by external entities and is either not shared with or properly archived by local management authorities. As a result, cases emerge where useful information on coastal and marine resources exists but is either not immediately available locally or simply forgotten due to time lapse or staff turnover within management authorities. Sustainable Grenadines intends to create a repository of relevant scientific information on the Grenada Bank in order to close this gap, and make information from regional and international research and assessment efforts more accessible for management authorities and stakeholders. This repository is envisioned to include a reporting framework for each MPA which allows accurate representation of the management and monitoring profiles for reference.

### CONCLUSIONS

The pilot effort for conducting transboundary monitoring in the Grenadines was considered to be a very informative first step towards effective collaborative conservation and resource management. The GNMPA was able to set baselines for reef condition, as well as a precedent for the feasibility of collaborative transboundary monitoring. The pilot effort also allowed the GNMPA to refine a series of management support tools.

However, effecting transboundary monitoring of marine resources is not as simple as signing an agreement and putting divers in the water. Other logistics come into play, including: ecological baselines; socioeconomic and stakeholder compliance baselines; effecting continuity of monitoring and mitigation programs; harmonisation and scheduling of activities across institutional and geographic boundaries; financial, human and administrative resource allocation; garnering support within the regulatory environment; and information and data management Standard Operating Procedures.

The Grenadines Network of MPAs will have to adaptively address all the factors listed above, as they have been found to be key to attempts to link data collection to management action at the site and network scale, and to the manifestation of positive change in natural resource management paradigms.

### ACKNOWLEDGEMENTS

This project was made possible with the support and collaboration of numerous partners including: The United States National Fish and Wildlife Foundation (NFWF), The United States Agency for International Development (USAID), the National Oceanic and Atmospheric Administration (NOAA), the Gulf and Caribbean Fisheries Institute (GCFI), The Healthy Reefs Initiative, the Atlantic/Gulf Rapid Reef Assessment (AGRRA) Program, The Nature Conservancy, The Mustique Company Ltd., Wind and Sea Ltd. (Union Island) for the in kind donation of a 65-foot catamaran, Ms. Marslyn Lewis, Ms. Orisha Joseph and Ms. Kristy Shortte for logistical support, Mr. Roland Baldeo for in kind donation of meeting space and vessels for monitoring in Grenada, Mr. Steve Nimrod of St Georges University for support during initial training and monitoring, Mr. Olando Harvey, Mr. Chris Alleyne, Mr. Aaron Bartholomew, Mr. Albert Hansen, Mr. Brian Richards, Mr. Jeremy Searles (research divers), Mr. Don Carlos Jack of Dive St. Vincent, the St. Vincent and the Grenadines Fisheries Division, the Grenada Fisheries Division, and the St. Vincent and the Grenadines National Parks, Rivers and Beaches Authority.

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